MEDITERRANEAN ACTION PLAN

UNEP

UNITED NATIONS ENVIRONMENT PROGRAMME

IMPLICATIONS OF CLIMATIC CHANGES FOR THE COASTAL AREA OF FUKA-MATROUH

IMPLICATIONS DES CHANGEMENTS CLIMATIQUES POUR LA ZONE COTIERE DE FUKA-MATROUH

MAP Technical Reports Series No.102

UNEP
Athens, 1996

ISBN 92-807-1580-1

For bibliographic purposes this volume may be cited as:

UNEP: Implications of climatic changes for the coastal area of Fuka-Matrouh. MAP Technical Reports Series No. 102, UNEP, Athens, 1996.

Pour des fins bibliographiques, citer le présent volume comme suit:

PNUE: Implications des changements climatiques pour la zone côtière de Fuka-Matrouh. MAP Technical Reports Series No. 102, UNEP, Athens, 1996.

MEDITERRANEAN ACTION PLAN

UNEP

UNITED NATIONS ENVIRONMENT PROGRAMME

IMPLICATIONS OF CLIMATIC CHANGES FOR THE COASTAL AREA OF FUKA-MATROUH

IMPLICATIONS DES CHANGEMENTS CLIMATIQUES POUR LA ZONE COTIERE DE FUKA-MATROUH

MAP Technical Reports Series No.102

UNEP
Athens, 1996

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This study on the implications of climate change for the coastal area of Fuka-Matrouh was planned to cover the climatic, the geological, the hydrological, the ecosystemic and the socio-economic aspects. Accordingly, a task team of experts was formed to match these disciplines so as to carry out a study that would lead to the establishment of a sound environmental management policy for sustainable resource development and land-use of the Fuka-Matrouh area. The study allowed the following main conclusions to be drawn:

Climate Change and Sea-Level Rise

The scenarios of global climate change adopted for the present study are based on the work of Wigley and Raper (1992) who take into consideration, among others things, the effect of sulphates and stratospheric ozone depletion. In all seasons, the temperature change in the study area is more or less close to that of the global change (i.e., 1°C per °C of global change). In winter, spring and autumn, the predicted change is slightly below the global change; i.e., 0.7°C to 0.9°C per °C of global change. On the other hand, in summer, the change is indicated to be around, or slightly greater than, the global change; i.e., 1.0°C to 1.1°C per °C of global change. The operative scenarios for the time horizons 2030 and 2100 show an increase in temperature in all seasons from 0.6°C to 1.0°C and from 0.5°C to 2.8°C, respectively. In fact, the change is expected to be greater during the summer season.

The annual precipitation shows a probable decrease for the time horizons 2030 and 2100, by 0-4% and 0-10%, respectively. There would be a steady decrease in precipitation during winter amounting to 5-20% and 13-55%, respectively, for the two time horizons. However, precipitation in spring would be increased by 20-65% by the year 2100.

The rise of mean sea level in the coming century due to global warming would show a substantial increase over the local rise that has taken place during the present century along the Mediterranean coast of Egypt. Several scenarios have been proposed to predict the rate of sea-level rise in the coming decades. The best-guess scenario, used in the present study, based on the work of Wigley and Raper (1992), indicates a rise of 16cm and 48cm by 2030 and 2100, respectively.

Main Impacts of Climate Change

The present document reports the results of an investigation into the potential impacts of expected climate change, including those due to sea-level rise. The aim is to assess the impacts that climate and sea-level change may have on each domain, ecosystem and/or human activity. The possible impacts are described qualitatively and, wherever possible, quantitatively, as well.

The most important climate change would be the northward shift of winter cyclonic patterns affecting the western Mediterranean coast. There might be a decrease in cyclonic activity, more erratic rainfall, drier summers and higher evapotranspiration. Moreover, the increase in the length of the summer and the decrease in winter precipitation may lead to an extension of summer aridity.

Owing to a rise in mean sea level, the eastern part of the coast would be subject to coastal erosion and flooding of the backshore area and depressions, whereas slighter impacts are expected to take place in the western part, owing to its topography and higher elevation. The coastal ridges along some stretches of the coast would, to some degree, play an effective role in stopping flooding and damage to the coast.

Small pocket beaches and small bays would be the first to experience the impact of a gradual rise in sea level. The instability and break-up of barrier islands could become more frequent in the coming decades. Beaches in front of these barriers could be subject to accelerated erosion. Low sandy coasts have the capacity to adjust to the rising sea level by gradual landward migration.

Another consequence of rising sea level would be an increase in the occurrence of extreme events, as severe storms, waves, currents, high tides etc.

Increase in temperature is not expected to have an effect on the decomposition of organic matter in soils. Increase in air temperature would change the soil's thermal regime, reducing soil moisture, thus increasing soil erosion by wind, and soil salinity; it would also decrease soil fertility and, hence, accelerate land desertification.

The spring increase in rainfall by 2030 would be very low and have an insignificant effect on run-off. Nevertheless, winter-rainfall decrease would reduce ground-water recharge; therefore a reduction in the thickness of the fresh-water layer in the phreatic ground-water aquifers would be expected. The amount of drinking water may not, therefore, be sufficient for the human and animal populations.

Owing to the rise in the mean annual temperature and an analogous decrease in precipitation, the natural land flora may shift northwards. The flora of the present inter-dunal depressions may expand at the expense of the original endemic flora.

The decrease in precipitation and increase in temperature may also lead to shrinking vegetation cover and hence to a decrease in the food available to herbivorous mammals and in turn decrease their population and, consequently, the population of carnivorous mammals.

Global warming may alter the migration rhythm of the wintering migratory birds. The reptile community in the area may also undergo some alterations. The higher temperature may increase the probability of the appearance of jellyfish swarms and, owing also to the higher salinity, may allow Lessepsian immigrant species to inhabit the area.

Rainfall decrease and temperature increase would affect the pattern of cultivated crops. Change in rainfall and increase in evapotranspiration may lead to a reduction in the cultivated areas, and agriculture would be likely to move towards more intensive farming. A change in crop production and a decrease in soil fertility would be expected. Some tropical and sub-tropical plant diseases would move northwards and the distribution of insects and pests would be altered.

The temperature increase could have a significant impact on important fish species. Pelagic fish migration patterns and spawning areas could be changed.

Sea-grass meadows are particularly sensitive to reduced water transparency, so they may be affected by increased sediment loads in the water, owing to an expected rise in mean sea level. On the other hand, a rise in water temperature may favour sea-grass meadows.

Temperature rise would increase the energy demand for summer resort services; e.g., air-conditioning. More demand for energy would be expected for the development of established industry and for the expanding tourist industry.

Temperature increase may also favour the consumption of beverages and may encourage their production in the area.

A relatively serious problem may be the endangering of some of the historical sites in the area, owing to a rise in the water table.

Climate and subsoil water-level changes may affect the existing infrastructure of the area, which would call for upgrading.

Climate change would result in rapid corrosion of potable-water supply pipes. Increased temperature would speed up the rate of anærobic decomposition of organic matter in the sewerage system which may lead to dangerous levels of methane build-up and risk of explosion.

The change in the climatic conditions would be expected to have only a limited impact on vital behaviour of populations, and would probably have an insignificant effect on the ongoing evolution of population distribution and demographic patterns.

Measures to Eliminate, Reduce, Mitigate and/or Adapt to the Predicted Effects

The following measures are recommended to eliminate, reduce, mitigate and/or adapt to the predicted effects:

- Use of cleaner energy sources (solar, wind and wave energy) and technology to reduce emissions of CO_2 and pollutants that cause environmental problems.

- Installation of coastal protection measures in critical locations in the east. Suitable stabilisation operations (by using plants, wooden fences, spraying, etc.) should be undertaken for the coastal dunes which act as barriers against sea attack.

- Gradual landward rebuilding of some tourist developments that are located at critical sites.

- Conduct of extension programmes to upgrade water users' awareness of the scarcity of fresh-water resources and to introduce water-conservation practices.

- Selection of suitable drought-tolerant crops, shrubs and forage plants to maximise yield and minimise adverse impacts.

- Strict implementation of the laws protecting wild life.

- Increased investment in fishery and aquacultural research, which is inadequately supported at present and has to be increased to cope with the expected environmental situation. The technology of rearing fish in cages is simple and does not require much space or capital.

- Upgrading of Matrouh airport to cope with the increase in the number of tourists and investors in new developments. Local roads should be also widened and paved to facilitate the traffic in the study area. The railway line needs to be modified.

- Adoption of a new safety elevation for drainage and sewerage systems.

1. INTRODUCTION

1.1 BACKGROUND

Climate Change Studies in the Mediterranean

During its long geological history, the climate of the Earth has changed considerably under the influence of terrestrial and extraterrestrial forces. Apart from relatively sudden shifts caused by catastrophic events, the trends in these changes were gradual and, measured against the length of human life, imperceptible. Man's perceptible influence on the climate is recent. Its beginnings can be traced back to the industrial revolution, around the beginning of the 19th century, when increasing amounts of gases that have a "greenhouse" effect started to be discharged into the atmosphere. Contemporary climate modelling almost unequivocally suggests that the accumulation of these gases in the atmosphere will inevitably lead to a change in global climate at a rate not observed during the last 10,000 years.

Realising the potential threat of predicted climate change to marine and coastal systems, the Oceans and Coastal Areas Programme Activity Centre (OCAPAC) of the United Nations Environment Programme (UNEP), in co-operation with the Intergovernmental Oceanographic Commission (IOC) of UNESCO, launched, in late 1987, a systematic approach to assessing the likely impacts of climate change in geographic areas covered by the UNEP Regional Seas Programme. By early 1995, eleven task teams had been established for regions covered by the Programme (Mediterranean, Caribbean, South Pacific, East Asian Seas, South Asian Seas, South-west Pacific, West and Central Africa, East Africa, Persian/Arabian Gulf, Black Sea and Red Sea). The task of the teams was to assess the environmental, economic and social problems of coastal seas and the adjacent terrestrial areas that are likely to follow predicted climate change, and to identify suitable response measures and policy options to mitigate or avoid the negative impacts of these changes.

During the work on the Mediterranean regional study (UNEP, 1989) carried out between 1987 and 1989 by UNEP's Co-ordinating Unit for the Mediterranean Action Plan (MEDU), it was felt that, although the general effects might be similar throughout the Mediterranean region, considerable differences in the impact of climate change could be expected at different sites, and that, consequently, different response options would be required. Moreover, it became clear that, as in the case of global predictions, regional predictions may be used only for general policy guidance and that only site-specific studies could lead to practical management and policy decisions and actions relevant to each particular location.

This is particularly true when assessing the impacts of future climate change, given the influence of local geographic factors on rainfall and temperature patterns and microclimate and, in the case of sea level, where tectonic movements, sediment compaction and extraction of oil, gas and water may result in local sea-level changes which are much greater than that predicted for global mean sea-level rise.

Therefore, in the framework of the Mediterranean regional study, six site-specific case studies were prepared during 1988-1989 (deltas of the rivers Ebro, Rhone, Po and Nile; Thermaikos Gulf; and Ichkeul/Bizerte lakes). The final results of this work were published in 1992 (Jeftic *et al.*, 1992).

As a follow-up to the studies completed by 1989, a "second generation" of five Mediterranean site-specific studies was prepared in 1990-1993 for the island of Rhodes (UNEP, 1994a), Kastela Bay (UNEP, 1994b), the Syrian coast (UNEP, 1994c), Malta (UNEP, 1994d), and the Cres-Losinj archipelago (UNEP, 1994e). A "third generation" of three studies was launched for the Fuka-Matrouh area in Egypt, the Albanian coast, and the Sfax area in Tunisia; two others are to be developed, for Algeria and Morocco, in the framework of the wider Coastal Areas Management Programme (CAMP) of the UNEP Mediterranean Action Plan. In 1993, a decision was taken by the Parties to the Barcelona Convention to embark, as soon as feasible, on the preparation of three additional "fourth generation" case studies, for Israel, Lebanon and Malta, in the framework of the relevant CAMPs.

Egyptian Mediterranean Coastal Area

It became widely accepted that the increasing concentration of greenhouse gases would affect the pattern and the balance of the solar radiation in the atmosphere to the extent that a rise in the global mean surface air temperature would take place in the next century. Furthermore, the Second World Climate Conference (Geneva, 1990) highlighted the long-term implications of climate change which were considered to be major scientific, environmental, socio-economic and political challenges. The Conference consensus put the expected global warming change in a range between 2°C and 5°C over the next century, if no effective action is taken to reduce gas emissions into the atmosphere. This would lead to a mean sea level rise of 65cm ±35 cm. With such alarming figures in mind, many international and regional associations and organisations have set to work to establish an assessment of the possible impacts of climate change and to explore ways and means of facing it in good time. The UNEP Mediterranean Action Plan was one of the leading organisations to take this threat into account and has guided and encouraged the execution of several case studies within the Mediterranean basin. The present study was one of these and was of the Fuka-Matrouh area of Egypt.

The socio-economic projection for the inhabited zones in Egypt places great importance on the role the Egyptian coastal area would play in the near future, as anticipated in the country's global planning. Owing to the present fast population increase, and for certain security measures, the adopted strategy on demographic distribution calls for a balance between the heavily populated Nile valley and delta, on the one hand, and the sparsely occupied coastal area, especially along the Mediterranean, on the other.

This implies that these zones would accommodate, in the coming years, a sizeable part of the population and would have to offer adequate working opportunities, food production, housing and other infrastructural and living facilities.

In the recent past, expansion in arable-land development has led to the reclamation of almost all the suitable land lying within the lower Nile delta, including even some areas that were originally part of the northern lagoons which were already reclaimed. So, most of the future land reclamation would be on the north-western and north-eastern sides of that region.

The industry and commerce of the Mediterranean coastal area has been expanding for the last few decades, but is most concentrated around the main coastal cities, in the lower delta, and it is expected to continue thus at least for the next few decades.

The coastal touristic development, including construction of new summer resort installations on the beaches, has enjoyed a boom during the last decade, mostly to the west of Alexandria up to Matrouh, and around El-Arish, to the east. Unfortunately, this development was hasty and uncontrolled, lacking the integration of environmental and land-use principles. However, the inertia in this activity ensures that it will continue for some time unless integrated coastal-area management based on in-depth studies is brought to bear.

The area covered by the present study extends for about 72km, from Fuka (longitude 27°55'E) to Matrouh (longitude 27°10'E) and overlooks the Mediterranean; it is located in the middle of the northern part of the Matrouh Governorate. The width of the study area is about 70km southwards from the Mediterranean shoreline up to the elevated southern plateau (Fig. 1). It is considered to be a virgin area with almost no industrial activity at present, so it forms a good pilot-study area for the north-western coastal area of Egypt, an area that will soon come to the top of the country's general development agenda.

The area, being a dynamic coastal area, is subject to rapid change but also has many valuable assets and resources, which calls for reasonable development based on the concept of sustainability. Many natural environmental and managerial constraints are threatening this area, as, for example, scarcity of water, in quantity and quality, soil salinity, availability of agricultural soil, probabilities of climate change and sea-level rise due to the "greenhouse" effect, uncontrolled development and the application of hastily conceived and unintegrated management policies.

For all these reasons, this area was selected for the present study and to face these challenges.

This study was carried out in the framework of the Coastal Areas Management Programme for the coastal area of Fuka-Matrouh, starting in 1994; it comprised the following activities:

- systemic and prospective analysis, including developmental/environmental scenarios;
- study of the implications of expected climate change for the coastal area of Fuka-Matrouh;
- an integrated planning and management study for the coastal area of Fuka-Matrouh;
- training courses on the methodology of integrated planning and management in coastal areas;
- development of environmental legislation and the relevant institutional framework;
- evaluation of the application of the Land-Based Sources and Dumping Protocols;
- evaluation of the application of the Emergency Protocol and the MARPOL Convention with respect to contingency planning and port reception facilities;
- marine environmental monitoring and research;
- evaluation of the application of the Specially Protected Areas Protocol and the protection and management of historic and natural sites;
- development of environmentally sound tourism;
- evaluation of soil erosion and desertification; and
- water-resource management study.

1.2 BASIC FACTS ABOUT THE FUKA-MATROUH COASTAL AREA

The climate of the area ranges between a semi-Mediterranean one in the northern coastal plain and an arid one in the south. The average annual rainfall is around 140mm in the north, decreasing rapidly southwards. The rain falls during winter from mid-October to mid-March. The summer is warm and dry, with absolute maximum temperatures around 35°C and a mean maximum temperature of about 24°C, compared to absolute minimum and mean minimum temperatures of 5°C and 15°C, respectively, in winter. The mean temperature is 19.3°C.

The mean relative humidity encountered in the study area is about 70% during summer, sometimes reaching 90%, but decreasing to about 50% during the spring.

The area is covered mostly by sedimentary calcareous rocks and, in general terms, it may be regarded as being composed of three conspicuous geomorphological units, from north to south: the coastal plains, the northern plateau and the southern plateau. The coastal plains have a width ranging between 1km and 6km and contain the foreshore plain, the frontal plain and the piedmont plain. The foreshore plain contains some ridges running parallel to the shoreline alternating with lagoons, salt marshes and alluvial deposits. The northern plateau has a width ranging between 10km and 13km. It is an elevated rocky land 30m to 80m above sea level, with a generally northward slope. It has rocky soil patches in some places with some 35 wadis cutting through, bearing alluvial sediments. The southern plateau is about 50km wide and is characterised by its sand dunes, depressions and rocky soils. This plateau has an elevation ranging between 80m and 120m above sea level.

The present total population of the study area is about 49,000, mainly concentrated in the coastal zone, with average population density of about 10 persons per square kilometre. This density compares to a density of less than one per square kilometre in the Governorate of Matrouh as a whole, and of about 1,500 persons per square kilometre in the Nile delta and valley. The average annual growth rate, in the study area, is about 3.2% of which 10% is due to immigration.

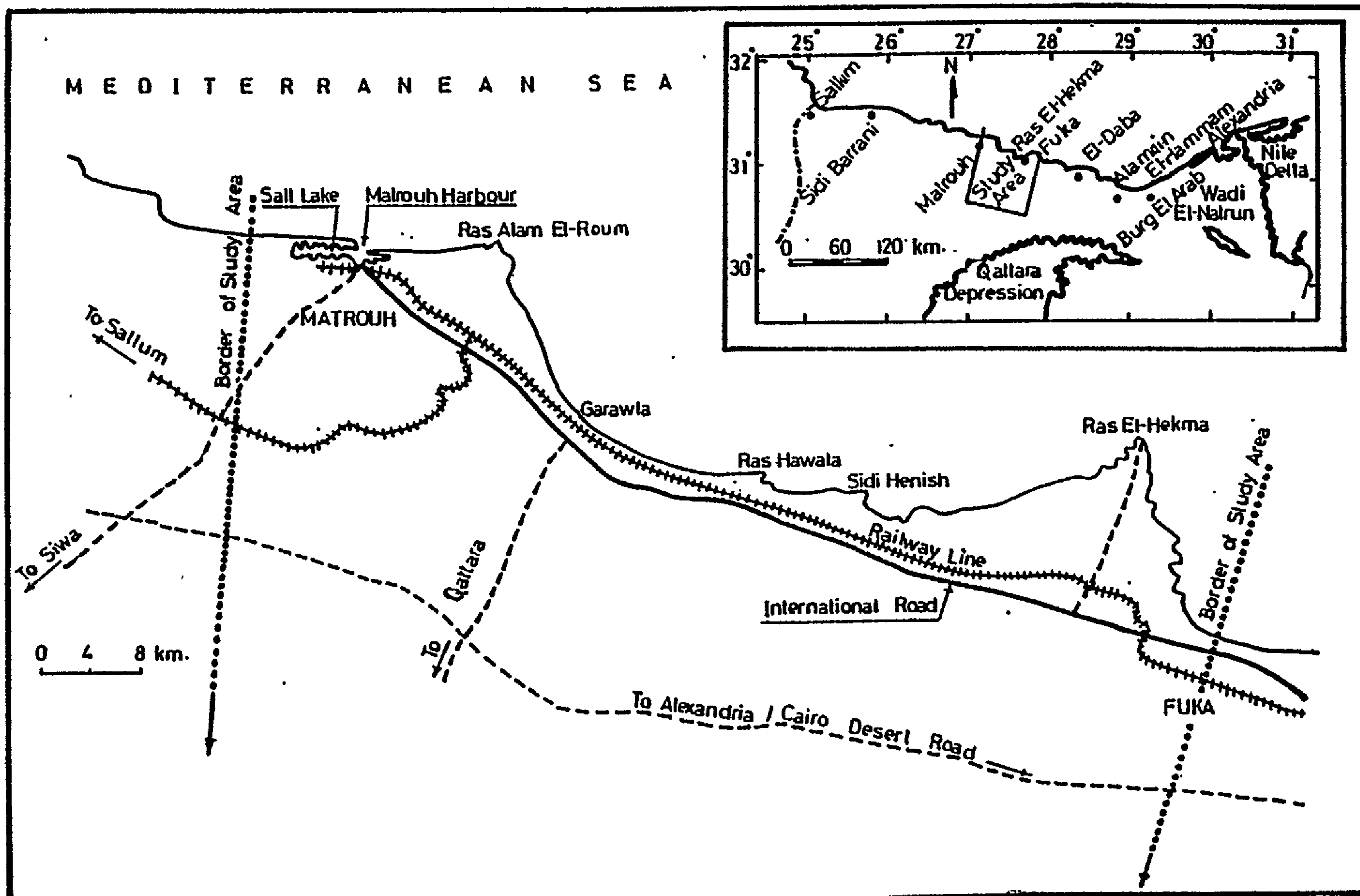


Figure 1- General location map

The area is served by reasonable transport facilities, the important ones being:

- the Alexandria-Matrouh-Sallum dual highway, which crosses the area near the coast from east to west and is part of the North African international highway;
- the railway line linking Sallum and Matrouh with Alexandria;
- the single-lane road that is located about 15km south of the international highway and which links Sallum to the Alexandria-Cairo desert road at the km-70 land-mark from Alexandria; and
- a group of unpaved roads running mostly from north to south, serving the local communities and settlements scattered throughout the area.

Grazing and cultivation are the Bedouins' main source of income. The cultivated land, which constitutes 3.2% of the total land area, is about 40,000 feddan (one feddan = 4,200m^2) and is given over to the cultivation of figs, olives, almonds, barley and wheat, as well as to range land. Agriculture depends mainly on winter rainfall, the mean amount of which is 350-400 x 10^6 m^3; this winter rainfall varies a great deal from one year to another. Of the total, 33 x 10^6m^3 is used for agriculture. This water is harvested through a system of cisterns, dykes and "sawani" constructions. However, some limited underground water is also used for human, agricultural and animal consumption, as in Fuka, Ras El-Hekma and Burbeta. Most of the orchards are located in the wadi deltas, where the fine-grained-soil cover is deep enough. Grazing used to be entirely dependent on the natural vegetation cover, but recently, some attempts are being made to grow certain types of trees for grazing purposes.

In the last few years, an unconventional economic resource has begun to develop in the area, with the emergence of summer resort tourism, with its extensive infrastructure along the coast. This new form of investment will probably expand in the coming years and eventually would play a major role in the socio-economic system and in the social structure of the local population.

1.3 EFFECT OF GREENHOUSE GASES ON THE CLIMATE

Knowledge of how the land, oceans and atmosphere interact and how they might respond to increased concentrations of greenhouse gases is incomplete. However, computer models can, to some degree, simulate these complex relationships and their effect on climate. These computer models use estimates of future greenhouse-gas levels to model possible future concentrations of these gases, global temperature, environmental conditions and climate.

Changes in the concentration of atmospheric greenhouse gases can alter the way they interact with the atmosphere, oceans and other features of the Earth's surface, and this would, in turn, have further effects on greenhouse-gas concentrations in the atmosphere. Such changes are known as greenhouse-gas feedbacks. Although these feedbacks are not yet fully understood, it is likely that, in a warmer world, feedbacks would increase rather than decrease atmospheric greenhouse-gas concentrations.

A conference on the role of carbon dioxide and other greenhouse gases in climate change, organised by the World Meteorological Organization (WMO), the International Council of Scientific Unions (ICSU) and UNEP in 1985, concluded, on the basis of the information available at that time, that current trends in the emissions of CO_2 and other greenhouse gases (NO_X, CH_4, CFCs) would lead to a warming effect equivalent to a doubling of CO_2 (in relation to pre-industrial levels) by about the year 2030 (UNEP/GEMS, 1993). This would lead to global warming of 1.5-4.5°C and a mean-sea-level rise of 20-140cm during the next century. WMO and UNEP jointly held two workshops in 1987 to examine the conclusions of the 1985 conference in the light of new scientific research, and to discuss the possible effects of climate change on the environment and society (UNEP/GEMS, 1993). The workshops produced three scenarios for future greenhouse-gas emissions and the corresponding expected temperature rises by 2050. On the basis of a large rise in greenhouse-gas emissions, the forecasts estimated a temperature increase of 0.8°C per decade. If there were no change in emission trends, the increase would be 0.3°C per decade. And if restrictions on emission were introduced, the rise would be only 0.06°C per decade. Temperature changes in these ranges were estimated to lead to a sea-level rise of between 30cm and 150cm by 2050.

In 1988, WMO and UNEP created the Intergovernmental Panel on Climate Change (IPCC), which formed three working groups to make a scientific assessment of the climate-change issue (Working Group I), to assess the impacts of climate change (Working Group II) and to formulate response strategies (Working Group III). Working Group I developed four scenarios for future greenhouse-gas emissions (IPCC, 1990). The first scenario (A) assumes that few or no steps are taken to limit emissions, and is termed "Business as Usual". The other three scenarios - referred to as scenarios B, C and D - assume that increasingly strict controls will reduce future emissions. The CO_2 level and the corresponding temperature rise projected in each of these four scenarios are shown in Figure 2. Under the "Business as Usual" scenario, mean global temperature was estimated to increase by approximately 0.3°C per decade, resulting in a temperature rise of about 1°C by 2025 and about 3°C by the end of the next century. Sea level would rise by about 65cm by 2100. Scenarios B, C and D would lead to temperature increases of about 0.2°C, a little more than 0.1°C and about 0.1°C per decade, respectively. These predictions are based on average values obtained by a number of different computer models (UNEP/GEMS, 1993).

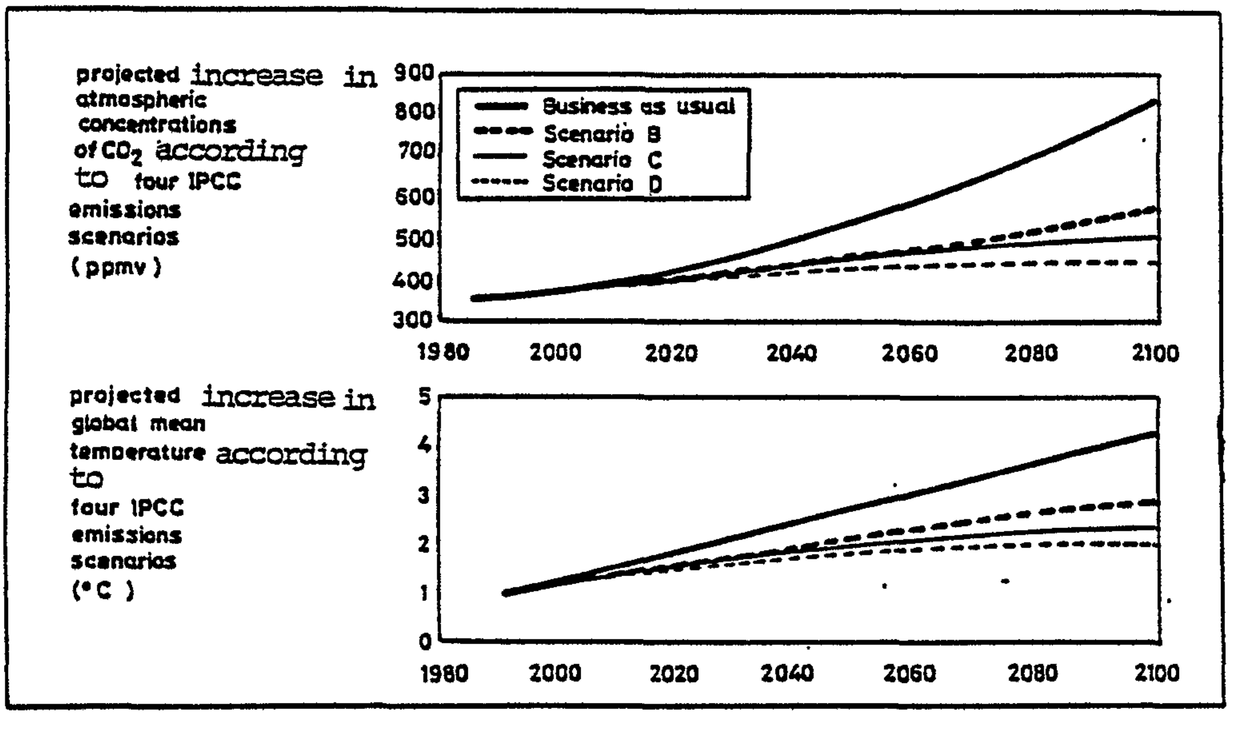


Figure 2 - Projected CO_2 concentrations and temperature change according to four IPCC emission scenarios (source: UNEP/GEMS, 1993)

Scenario A (Business as Usual)

Mainly coal-based energy generation, only modest improvements in the efficiency of energy use, deforestation continues and only partial participation in implementing the Montreal Protocol.

Scenario B

More lower-carbon fuels used in energy generation, large increases in energy efficiency, deforestation reversed and full participation in implementing the Montreal Protocol.

Scenario C

Shift towards renewable energy sources and nuclear power during 2050-2100, CFCs phased out.

Scenario D

Shift towards renewable energy sources and nuclear power during 2050-2100, CO_2 emissions reduced to half 1985 levels by 2050.

The Earth's climate is not constant: temperature and rainfall vary from year to year and fluctuate widely over much longer periods of time. Indeed, changes of only 4-5°C in the Earth's mean annual temperature brought about the onset and retreat of the Ice Ages. So, discussion of the possible effects of greenhouse-gas emissions on climate is complicated by the fact that Working Group II - the group that studied the impacts of climate change - concluded that an effective doubling of CO_2 by 2025-2050 would cause a mean global temperature increase in the range of 1.5-4.5°C (UNEP/GEMS, 1993).

Computer models indicate that warming will not take place uniformly over the planet: it will be more intense at higher than at lower latitudes, and greater in the winter than in the summer. In some areas in high northern latitudes in winter, warming could be 50-100% greater than the global mean increase. Air temperatures rise more rapidly over land than oceans, and there is likely to be a time lag between increased greenhouse-gas concentrations and increased air temperatures, particularly in areas influenced by deep-water circulation, such as that of the northern North Atlantic and the Southern (Antarctic) Ocean.

The atmosphere is a self-renewing resource. The oxygen we use is in ample supply and is continuously replaced through photosynthesis at the expense of (partly man-made) carbon dioxide. Natural processes, mainly precipitation, normally cleanse the atmosphere of undesirable gases and dust particles, but some of the gases and particles dissolve in the cloud and rain water, altering their chemical make-up and creating what has become known as acid rain. Cleansing is not always achieved before the gases and particles noticeably interact with sunlight, which causes visibility to decrease, owing to an increase in the turbidity of the atmospheric. It came to be recognised, therefore, that the environment could be seriously and dangerously impaired by steadily increasing industrial production and individual consumption.

The atmosphere and the ocean interact at the sea surface by exchanging momentum, heat, moisture, gases and salt across the air-sea interface. The oceans, moreover, play a key role in determining the Earth's climate. Indeed, any possibility of predicting the evolution of weather systems beyond a few weeks requires that ocean behaviour be taken into account.

When the atmosphere is heated, the ocean responds by storing some of the heat and by increased evaporation. Because the heat is mixed down for some metres into the water column by the wind, temperature rises much less than it does on dry land under comparable conditions. Evaporation has profound effects on the atmosphere and on climate. Water vapour released into the atmosphere *increases the greenhouse effect therein. When it recondenses (sometimes far from where it evaporated), the resultant heating of the air is a major source of energy for atmospheric motion.*

1.4 METHODS AND ASSUMPTIONS USED IN THE STUDY

This study of the implications of climate change for the Fuka-Matrouh area was planned to cover the following ten aspects: atmosphere, lithosphere, hydrosphere, natural and managed ecosystems, energy, industry, tourism, transportation, sanitation and demography. A task team of experts was formed to match these disciplines and each member of the team was assigned to one or more of these aspects (Annex I) and entrusted to carry out a full investigation of all elements of the respective aspect or aspects, with a view to establishing, with the other team members, a sound environmental management policy for sustainable resource development and land-use in the Fuka-Matrouh area in the light of the expected effects of climate change. The study took into consideration the conditions in the area under the anticipated climate change. To achieve this objective, the task team adopted an inter-disciplinary approach to the studies, to:

- identify and assess possible implications of the adopted climat-change scenario for the study area's ecosystems, populations, land- and sea-use practices and other human activities;

- determine the domains that would be most vulnerable to climate change;

- make recommendations on the planning and designing of major infrastructure systems;

- provide input to other studies related to the present subject, especially those related to further work on coastal-area management studies; and

- provide information for the public, economists and policy- and decision-makers, to enable them to take it into account in the protection of the environment and in long-term investment.

The task team comprised eight national and two international experts. The national team members held frequent bi- and multi-lateral meetings to discuss the results and to exchange information and data. Also, the national and international team members held three plenary meetings. To start the study, a preparatory meeting was held in the study area at Matrouh, 28 November-1 December 1993. The second general meeting of the team was held in Alexandria, 30 August-1 September 1994, to review the first draft of the experts' texts and to adopt an overall structure for the final report. A third general meeting was held in Alexandria, 12-14 September 1995.

Two temporal horizons are considered in the study: the years 2030 and 2100, the conditions in 1990 being taken as the baseline for comparison.

The scenarios for global climate change adopted in this study are based on the work of Wigley and Raper (1992), which takes into account, among other things, the effects of sulphates and stratospheric-ozone depletion. They estimate global warming of 0.9°C and 2.5°C in 1990-2030 and 1990-2100, respectively, which works out at 0.23°C per decade, assuming the changes are linear.

The sea-level change, according to Wigley and Raper (1992), who incorporate, besides the oceanic thermal expansion, the effects of changes in the terrestrial ice sheets and small glaciers, is estimated to be 48cm between 1990 and 2100, and 16cm between 1990 and 2030.

Based on the methods developed by Kim *et al.* (1984) and Wigley *et al.* (1990), annual and seasonal scenarios for temperature and precipitation change for the Fuka-Matrouh area have been produced by the Climatic Research Unit of the University of East Anglia (Climate Research Unit, 1993) and are presented herebelow.

For each 1°C of global warming, the changes on the coast of NW Egypt between 27°E and 28°E would be as follows:

-	Annual	Temperature Precipitation	0.8°C to 0.9°C 0% to -4%
-	Winter	Temperature Precipitation	0.7°C to 0.9°C -5% to -22%
-	Spring	Temperature Precipitation	0.7°C to 0.9°C 8% to 26%
-	Summer	Temperature Precipitation	1.0°C to 1.1°C not applicable (no rainfall in summer)
-	Autumn	Temperature Precipitation	0.7°C to 0.8°C 0% to -14%

Consequently, according to Wigley and Raper (1992), the operative scenarios for temperature, precipitation and sea-level rise by the years 2030 and 2100 for the Fuka-Matrouh area would be as follows:

		Time Horizon	
		2030	2100
Annual	Temperature Precipitation	0.7°C to 0.8°C 0% to -4%	2.0°C to 2.3°C 0% to -10%
Winter	Temperature Precipitation	0.6°C to 0.8°C -5% to -20%	1.8°C to 2.3°C -13% to -55%
Spring	Temperature Precipitation	0.6°C to 0.8°C 7% to 23%	1.8°C to 2.3°C 20% to 65%
Summer	Temperature Precipitation	0.9°C to 1.0°C not applicable	0.5°C to 2.8°C not applicable
Autumn	Temperature Precipitation	0.6°C to 0.7°C 0% to -13%	1.8°C to 2.0°C 0% to 35%
Sea-level change		16cm	48cm

2. PRESENT SITUATION AND TRENDS

2.1 CLIMATE AND ATMOSPHERE

2.1.1 Climate

2.1.1.1 Pressure Distribution

The climate prevailing along the north-western coast of Egypt is qualified as "arid Mediterranean with mild winter", characterised by subtropical temperature conditions and a typical winter rainfall pattern. This climate is basically due to the latitude and the general circulation of the atmosphere there, but it is modified by the interaction between land and sea.

The most important factors are:

- The semi-permanent pressure systems in each season: the cold Siberian anticyclone in winter, the thermal minima of Africa in spring and autumn, and the huge low-pressure area over south-east Asia in summer (these systems are air-mass source regions in their respective seasons).
- The travelling depressions and associated weather in winter and the transitional seasons.
- The Mediterranean as a source of water vapour, in addition to its being a heat source (a warm surface vis-à-vis cold polar air masses) or a heat sink (a cool surface vis-à-vis tropical air masses). In fact, the Mediterranean Sea has a pronounced influence on the region under consideration in this report.

These factors (as well as other, minor ones) are taken into consideration when discussing the situation in each season.

Winter Circulation

In winter, the Mediterranean and the western parts of the Middle East are, except for short and rare periods of extensive high-pressure systems, under the influence of Mediterranean depressions moving with the westerlies. The surface circulation over the eastern part of the Middle East is controlled for long periods in winter by the Siberian high-pressure area and dominated by north-easterly winds.

When the depression reaches the eastern Mediterranean, cold, moist north-westerly winds blow over the north of Egypt, and convective clouds appear during the daytime. When an upper cold low or steep trough exists above the depression, much cloud and rain results over the area under consideration, by day and by night. The rain is sometimes heavy and accompanied by thunder. The depression may stay an average of two or three days over the eastern Mediterranean, during which time the region experiences its worst winter weather. When the depressions are deep, the south-west winds may reach gale force and cause severe sandstorms.

Between the passage of consecutive depressions, high pressure covers the eastern Mediterranean. This situation is responsible for the flow of north-easterly winds over the coast, a condition that favours the formation of radiation fog in the early morning, dispersing a few hours after sunrise.

Spring Circulation

The main feature of this season is the southward shift of the tracks of the depressions. The centres of the depressions either move along the coastline of North Africa or farther south where they are known as desert, or "khamsin", depressions. The average frequency of these latter depressions is three or four per month, but may vary between two and six per month. Khamsin depressions can be vigorous and cause severe sandstorms. When these depressions have become upper lows, they are often associated with large amounts of high- and mid-altitude clouds as well as with thunderstorms, which can give very heavy showers of rain and hail.

In this season (spring), the Sudan trough sometimes extends northwards to cover Egypt. The hot, south-easterly air current over Arabia turns north-eastwards over Egypt and moderate or severe heat waves are then experienced. The air is hot and dry, except in the surface layers, where it picks up moisture from the Mediterranean, a feature that sometimes leads to the formation of early morning radiation fog. All record maximum temperatures are caused by this hot tropical continental air which, at the same time, corresponds to the relative humidity minima.

Summer Circulation

Summer circulation in the Middle East is dominated by the north-westerly to northerly winds between the sub-tropical high-pressure system over the Mediterranean Sea and southern Europe, on the one hand, and the low-pressure system stretching from Arabia to Pakistan, on the other. The general climate for the area in this season is hot, dry and rainless. Clear skies prevail, except for some coastal fair-weather cumulus or early morning stratus clouds which disperse a few hours after sunrise. The climate of the area being affected by the cool Mediterranean water is warm during the daytime and rather cool at night.

Autumn Circulation

The climate in this season is similar to that in spring, since it is another transitional season. Khamsin-like depressions begin to cross Egypt during late October and cause a breakdown of the settled summer regime. Early depressions in September are frequent and usually die out on arriving in Egypt from the west. The depressions at this time are much less vigorous than those in spring and are slower in their movement. On the other hand, the higher humidity in this season favours greater frequency of thunderstorms and heavier precipitation, a fact especially true of November.

2.1.1.2 Air Temperature

The air temperature in the region displays a simple annual curve and a mean annual value of 19.4°C.

The Gorszinsky coefficient of continentality, in %, based on the difference between the mean minimum of the coldest month (January) and the maximum of the hottest month (August), and corrected for latitude, has been calculated; the formula is:

$$C = \frac{1.3\,A}{\sin \omega} - 36.3$$

where **C** is the coefficient of continentality expressed in %, **A** is the mean (for the period of records) of the annual range between the maximum temperature of the hottest month and the mean minimum of the coldest month, and ϕ is the latitude.

The coefficients of continentality for Matrouh and Dabaa are 15.7 and 19.8, respectively. It is clear that the region enjoys a typical maritime climate.

Table 1 indicates the mean daily air temperature, by month, the mean monthly maximum and the mean monthly minimum air temperature, and the mean annual air temperature, for the two meteorological stations (Matrouh and Dabaa) in the region for 1961-1990.

Figures 3A and 3B have as abscissa - for the Matrouh and Dabaa stations - months of the year and, as ordinates, hours of the day. Mean monthly values for each hour were plotted and isotherms were drawn, summarising in a very compact and useful form the values, gradients and trends in air-temperature variation throughout the year.

Table 1 - Mean air temperature (°C) for the Matrouh and Dabaa stations (1961-1990)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann
Mean daily air temperature, by month													
Matrouh	12.9	13.5	15.1	17.6	20.2	23.4	25.0	25.5	24.3	21.6	17.9	14.4	19.3
Dabaa	12.8	13.7	15.0	17.8	20.6	23.6	25.4	25.8	24.5	22.0	18.2	14.4	19.5
Mean monthly maximum air temperature													
Matrouh	17.7	18.5	19.6	22.9	25.3	28.1	28.6	29.5	28.5	26.5	22.8	19.3	23.9
Dabaa	17.8	18.7	20.4	23.6	26.0	28.5	29.4	30.0	28.9	26.7	23.2	19.7	24.4
Mean monthly minimum air temperature													
Matrouh	8.7	8.9	10.4	12.5	15.1	18.6	20.7	21.2	19.9	17.2	13.5	10.4	15.2
Dabaa	7.8	8.1	9.7	12.1	14.6	18.2	20.7	21.0	19.5	16.6	13.0	9.3	14.7

The lowest temperatures were observed in January and February, for which the mean monthly minimum was around 9°C; the daily minimum seldom fell below 5°C (absolute minimum 2°C). Table 2 gives the number of days per year with a minimum air temperature below a specified threshold (5°C or 10°C) and the corresponding standard deviations.

Table 2 - Mean number of days per year (N) with a minimum air temperature below a specified temperature threshold and the related standard deviations (s.d.) at the Matrouh station (1958-1967)

Temperature thresholds				
	5°C		10°C	
Station	N	s.d.	N	s.d.
Matrouh	2.3	1.25	78.3	12.91

In the desert climate there is no danger of frost in the area, but cool nights, characterised by temperatures below 10°C, prevail from the end of December till mid-March. The maximum temperature during the winter is rather low and uniform, seldom exceeding 20°C.

Spring begins in the first two weeks of March, and there is a marked increase in the maximum daytime temperature (above 20°C), but the nights remain cool and the general trend of increasing temperature is often broken by cold spells lasting three or four days. April is characterised by frequent "khamsin" winds, bringing the maximum temperature to over 30°C or even 35°C for two or three days at a time. April nights are still cool (between 10°C and 20°C). Table 3 gives the number of days per year with a maximum air temperature above specified threshold values (between 25°C and 45°C) and the corresponding standard deviations.

The summer lasts over six months, from May till the end of October. The daytime temperature fluctuates between 25°C and 30°C. The minimum temperatures are rather high, especially in August and September (more than 20°C).

Autumn begins with the first rains. Day and night temperatures slowly decrease, dropping to about 20°C (maximum temperature) and 10°C (minimum temperature) in mid-December, the beginning of winter.

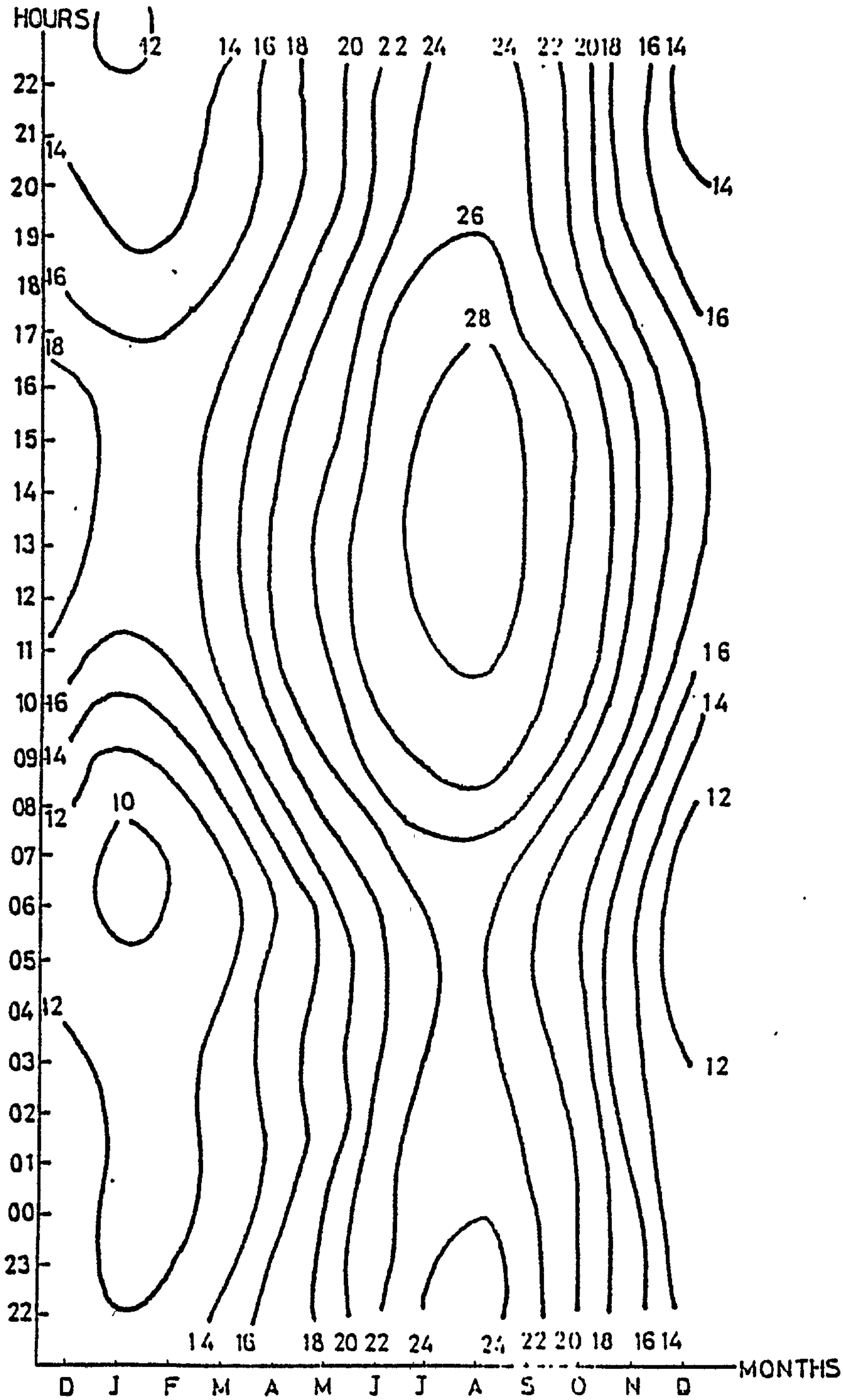


Figure 3A - Mean hourly air temperature, by month, at Matrouh

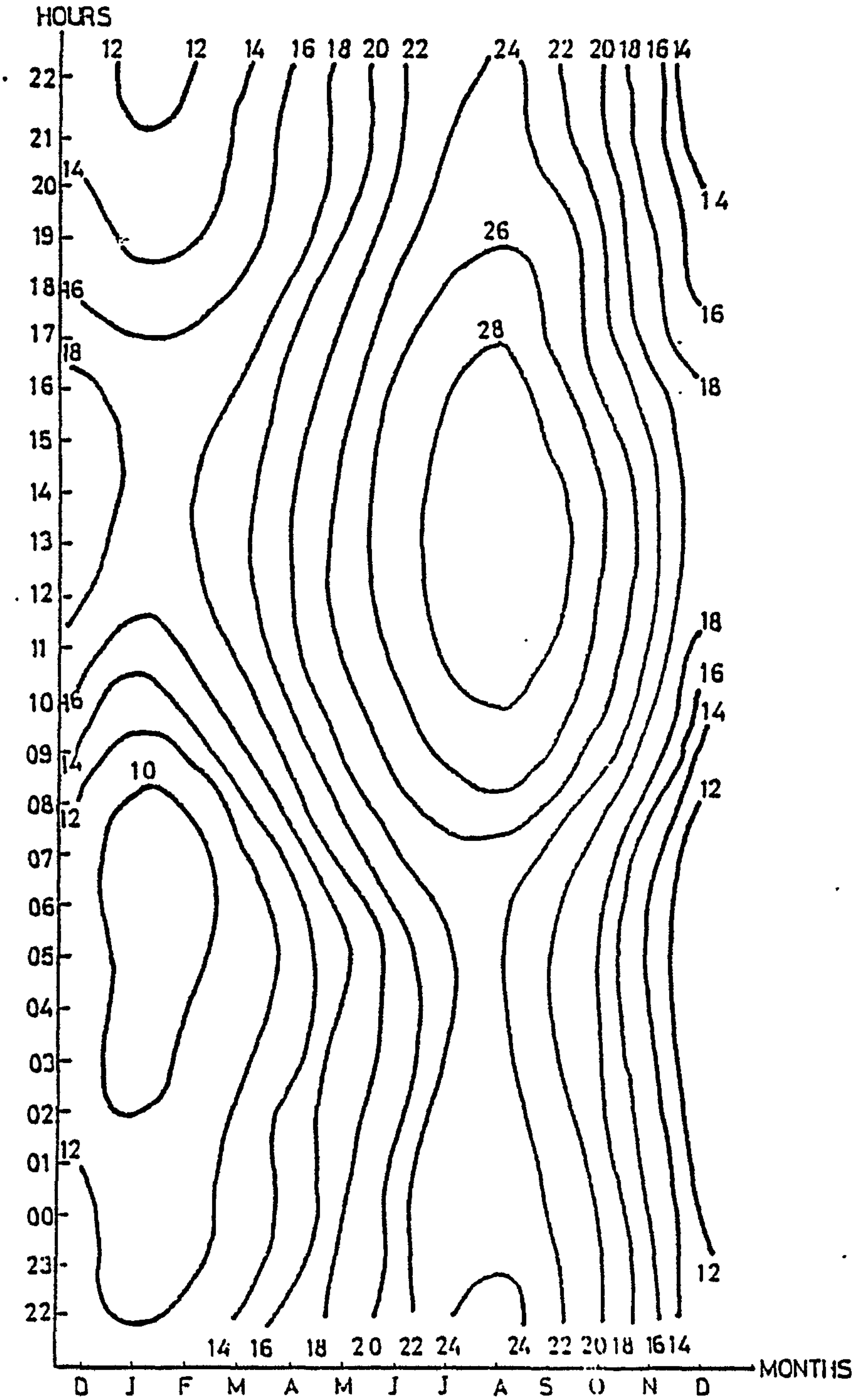


Figure 3B - Mean hourly air temperature, by month, at Dabaa

Figure 4 clearly indicates that the mean annual and seasonal values of air temperature at Matrouh have shown no trend over the period 1950-1992. Figure 5 gives the annual variation in air temperature at Matrouh.

Table 3 - Mean number of days per year (N) with a maximum air temperature greater than a specified temperature threshold and the corresponding standard deviations (s.d.) at the Matrouh station (1958-1967)

Threshold	25°C		30°C		35°C		40°C		45°C	
	N	s.d.	N	s.d.	N	s.d.	N	s.d.	N	s.d.
Matrouh	175.0	12.21	37.2	7.80	5.9	3.35	1.3	1.64	0.2	0.63

2.1.1.3 Relative Humidity

The relative humidity of the air in the region does not vary greatly throughout the year, staying between 45% and 60% at noon and between 65% and 75% in the morning and in the evening. Maximum and minimum values of relative humidity occur in July (75% at Matrouh and 69% at Dabaa) and in April (66% at Matrouh and 64% at Dabaa) with a mean annual value of 70% at Matrouh and 66% at Dabaa. Table 4 gives, by months, the mean daily relative humidity and mean relative humidity at 06, 12 and 18hr universal time, and the mean annual relative humidity. Figure 6 gives the annual variation in relative humidity at Matrouh.

Table 4 - Mean monthly and annual values of relative humidity (%) at Matrouh and at Dabaa

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean daily relative humidity													
Matrouh	71	69	68	66	73	73	75	73	71	70	68	69	70
Dabaa	67	65	67	64	66	67	69	69	66	65	64	64	66
Mean relative humidity at 06 U.T.													
Matrouh	75	72	67	65	64	64	72	72	69	70	77	72	70
Dabaa	73	72	67	64	66	68	71	72	67	69	74	73	70
Mean relative humidity at 12 U.T.													
Matrouh	50	48	46	50	54	55	61	59	56	53	55	47	53
Dabaa	48	47	46	47	51	56	58	58	56	53	55	51	52
Mean relative humidity at 18 U.T.													
Matrouh	68	68	67	71	75	75	76	73	70	71	72	66	71
Dabaa	68	67	67	68	72	77	76	75	72	70	74	70	71

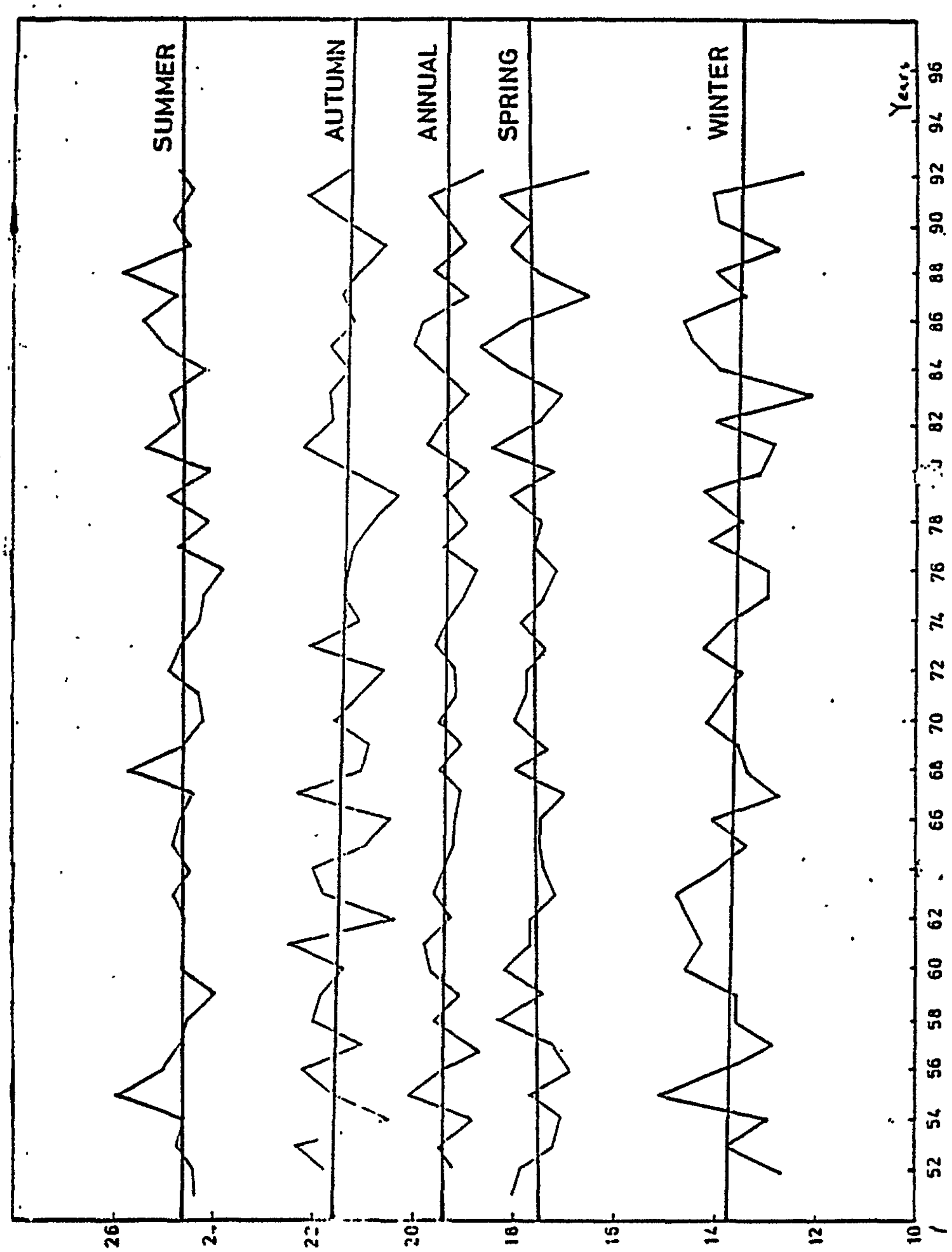


Figure 4 - Annual mean air temperature at Matrouh, by season and whole year

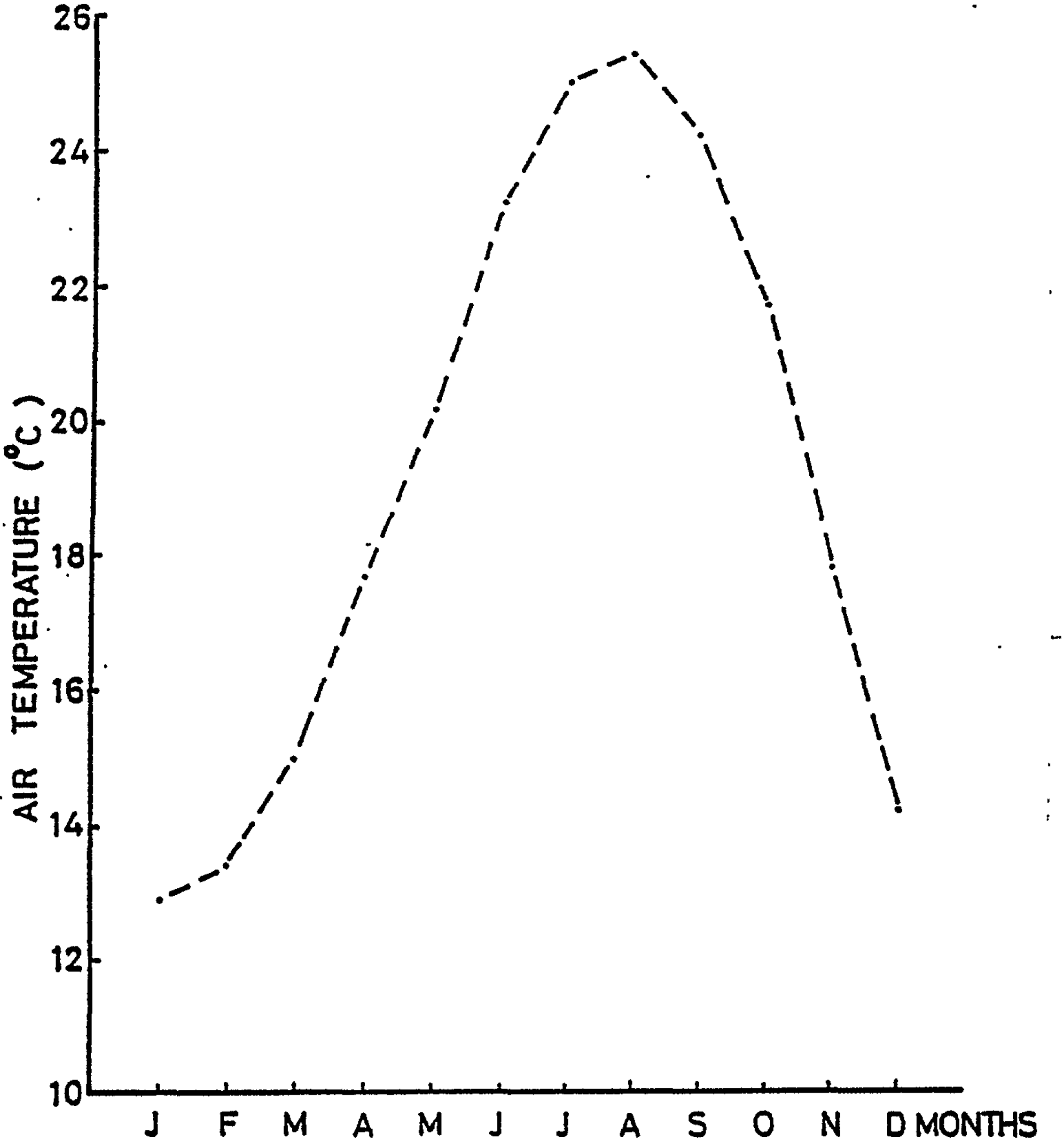


Figure 5 - Monthly mean air temperature at Matrouh

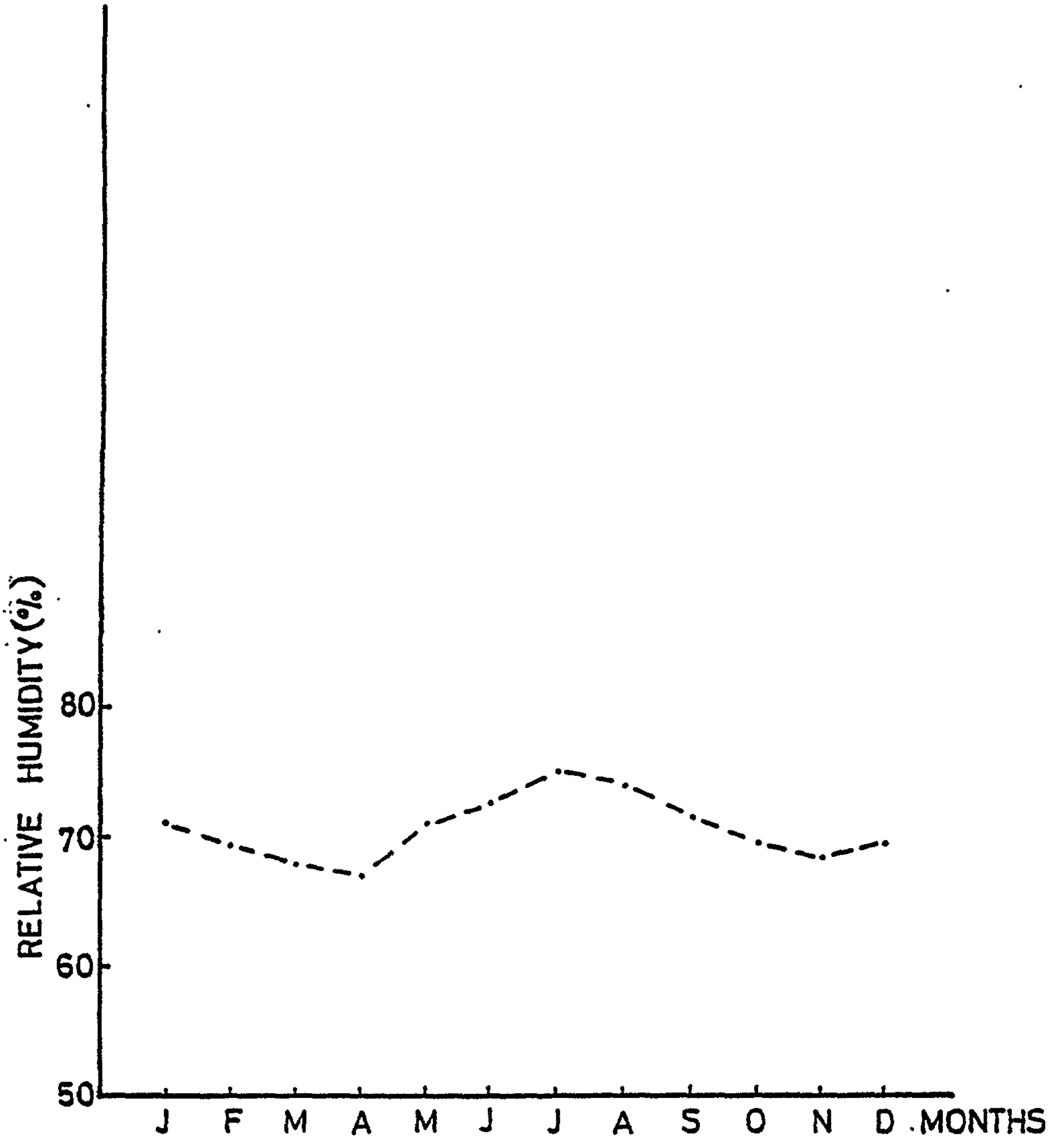


Figure 6 - Monthly mean relative humidity at Matrouh

2.1.1.4 Rainfall

Annual Rainfall Distribution

With regard to rainfall, however, there is no doubt that the region is rather homogeneous. Between October-November and April-May, the region is under the influence of the middle westerlies. The rain, which occurs in the region during these months, is mainly due to cyclones moving over the area, either from the Atlantic or after crossing the Mediterranean on a branch of the polar jet-stream in the upper troposphere.

These cyclones are of two basically different types. The first type may be connected with shallow waves moving rapidly in the upper troposphere westerlies and causing rainfall in the region. The second basic type of cyclone is connected with the cold troughs in the upper air, creating fairly stationary cyclones in particular regions. Cyprus is in one such region, where the influence of cold air often causes a cyclone to become fairly stationary. Considerable rainfall occurs over the region during winter owing to the south-westerly/north-westerly winds connected with this cyclone which moves slowly over the Near East.

During spring (March-April), another type of cyclonic rain frequently occurs in the region, but is of a quite different origin. These are the khamsin conditions. They generally cause rain in the region, as does the cyclone of the first type, but they occasionally meet a cold upper-air trough over the western part of the Middle East and consequently, in their further movement eastwards, they behave as a regenerated slow-moving cyclone with a cold upper air trough. Under the latter conditions, they may give rise to considerable amounts of rain.

During the summer, the region is under the influence of the sub-tropical high-pressure system, and winds are mainly from the north-west; practically no rain falls, except for some solitary showers.

All over the region, the autumn rainfall may be greater because of severe instability due to the upper-air depressions/trough which supply the region with cold air, while the surface may be under the effect of the monsoon low which supplies the region with north-east warm and humid air.

Some of the annual rainfall can be precipitated as hail or snow. Hail occurs over the region two or three times per decade near Matrouh. Hail could occur in association with thunderstorms. Snow is a very rare phenomenon; it fell on the western coast of Egypt six times in the last seventy years. Five of these cases occurred in February and one, in January, when the coldest air reached the western coast of Egypt via the European high-pressure area.

Amount of Annual Rainfall

The annual rainfall due to the general circulation outlined above is thus concentrated in the period October-November to April:

- At Matrouh, annual rainfall for the period 1950-1951 to 1987-1988 was 130mm; 48% of this quantity occurred in December and January, 61% occurred in December-February (winter). The lowest amount of annual rainfall recorded was 37mm in the 1950-1951 season, and the highest amount was 277mm, in the 1956-1957 season.
- At Ras El-Hekma, 50km to the east of Matrouh, mean annual rainfall for the period 1956-1957 to 1982-1983 was 129mm; 54% of this occurred in December and January, and 66% occurred in winter as a whole. The lowest amount of annual rainfall recorded was 48mm, in the 1980-1981 season, and the highest amount was 251.5mm, in the 1968-1969 season.
- At Fuka, 70km to the east of Matrouh, mean annual rainfall for the period 1948-1949 to 1963-1964 was 108mm; 50% of this occurred in December and January, and 64% of this occurred in winter as a whole. The lowest amount of annual rainfall recorded was 19mm, in

the 1950-1951 season, whereas the highest amount was 282mm, in the 1956-1957 season.

- At Dabaa, 130km to the east of Matrouh, annual rainfall for the period 1950-1951 to 1987-1988 was 127mm; 49% of this occurred in December and January, while 63% occurred in winter as a whole. The lowest amount of annual rainfall recorded was 37mm, in the 1959-1960 season, whereas the highest was 266mm, in the 1968-1969 season.

Distribution of Rainfall During the Year

Table 5 and Figure 7 give the monthly distribution of rainfall. The rainy season begins in the second half of October. Three quarters of the total amount falls between November and February. December and January are the rainiest months, with an average of 35mm per month. Some showers are still observed in March, but the spring is dry and receives only 10 % of the total.

The dry season lasts 6-7 months, without precipitation except for a few rainstorms in April, May and September. This typical winter rain regime sets severe conditions for agriculture.

The mean number of rainy days, for specified threshold minima, by month, and the mean monthly rainfall, are given in Table 5. Of the 38 rainy days per year, only a few bring enough water to moisten the soil. There were twenty-four days with a recorded rainfall greater than 1mm, and a daily rainfall of more than 5mm was observed on only 8 days per year. Rainfall of more than 10mm per day, which is of an intensity high enough to produce runoff and fill the wadis, only occurs four or five times per year, mainly in December and January. Figure 7 gives the monthly rainfall for Matrouh.

Table 5 - Mean monthly and annual values of rainfall and number of days of rainfall equal to or above a specified threshold value, at Matrouh and Dabaa

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Rainfall (mm)													
Matrouh	29.6	17.9	9.8	2.7	1.7	1.6	0.0	0.5	2.0	14.3	18.3	31.2	129.6
Dabaa	30.1	18.2	8.2	1.5	1.5	0.4	0.0	0.0	1.1	11.1	23.0	32.3	127.7
Number of days with rainfall >/= 0.1mm													
Matrouh	8.5	5.8	5.1	2.1	1.3	0.1	0.0	0.1	0.3	3.5	5.9	7.5	40.2
Dabaa	7.3	4.1	3.0	1.0	0.7	0.1	0.0	0.0	0.3	2.5	5.1	7.0	31.1
Number of days with rainfall >/= 1.0mm													
Matrouh	5.3	3.3	2.6	0.8	0.6	0.1	0.0	0.1	0.2	1.8	3.4	5.0	23.2
Dabaa	5.4	2.7	1.7	0.5	0.3	0.0	0.0	0.0	0.2	1.7	3.3	5.9	21.7
Number of days with rainfall >/= 5.0mm													
Matrouh	1.7	0.9	0.6	0.1	0.0	0.1	0.0	0.0	0.1	0.7	1.3	1.9	7.4
Dabaa	1.7	0.7	1.0	0.1	0.1	0.0	0.0	0.0	0.1	1.2	1.2	1.9	8.0
Number of days with rainfall >/= 10.0mm													
Matrouh	1.0	0.3	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.5	0.7	0.8	3.6
Dabaa	1.1	0.4	0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.5	1.1	1.3	4.8

2.1.1.5 Surface Wind

In winter, the Mediterranean depressions affect the study area directly, causing surface winds to become variable in speed and direction. Since the tracks of the depressions are north of the coastline, the prevailing directions are, as expected, south and south-westerly in front of the depressions and west or north-westerly behind them.

Winter and early spring are the seasons of strong gale-force winds in the region, usually blowing from the west. North-easterly winds become more frequent in the spring and autumn months because of the passage of the cores of the khamsin depressions south of the Mediterranean coastline.

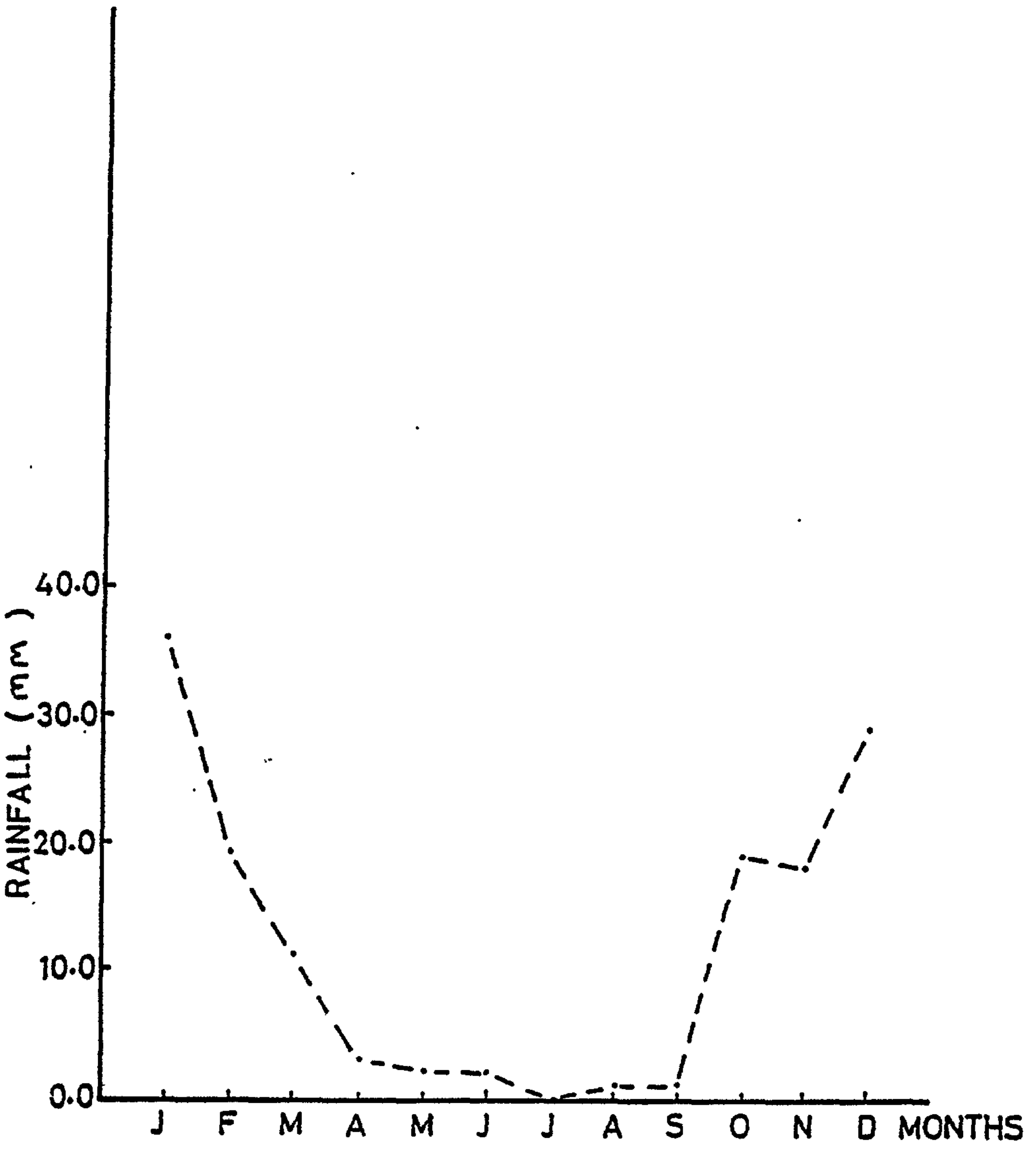


Figure 7 - Monthly mean rainfall at Matrouh

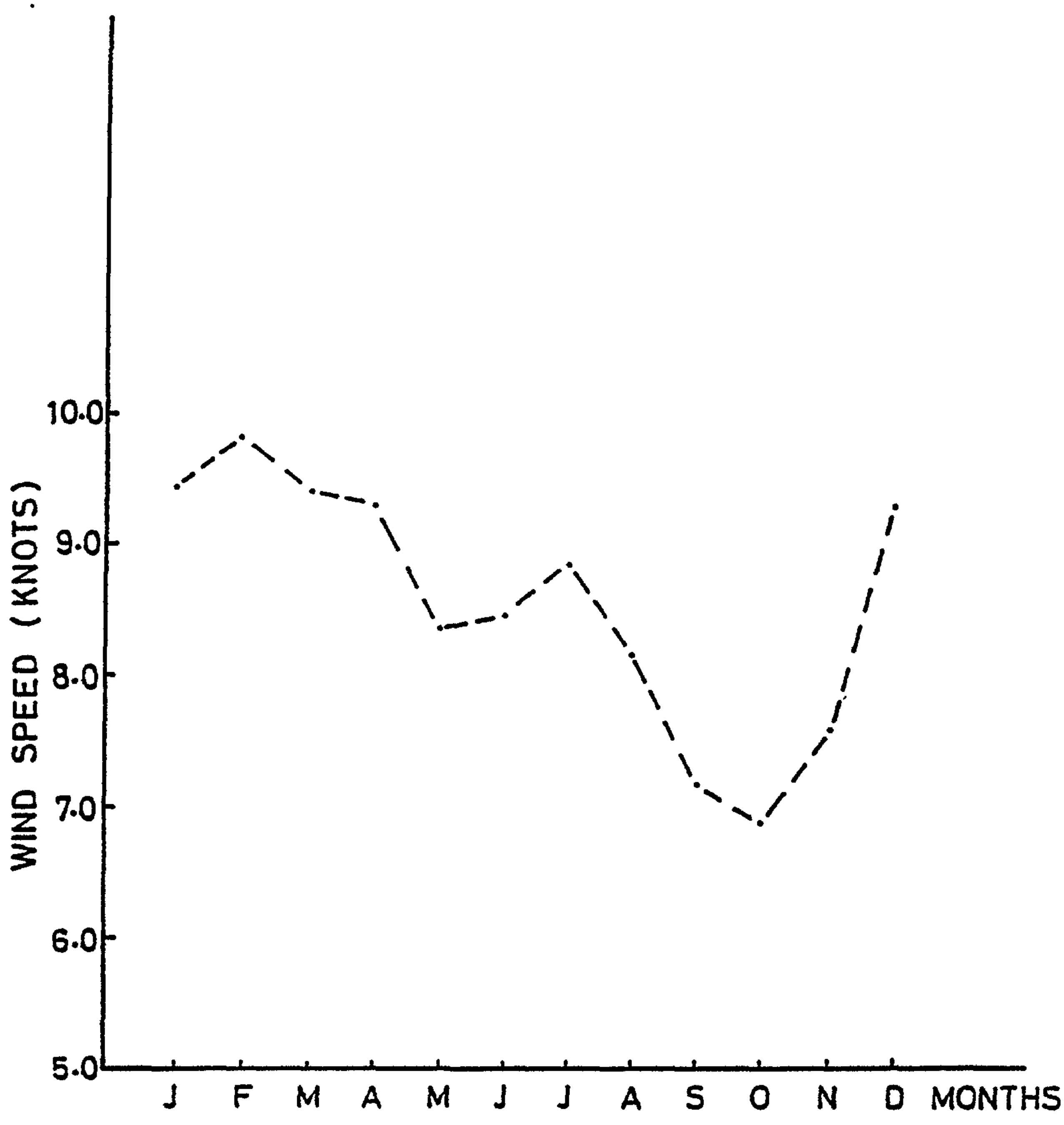


Figure 8 - Monthly mean wind speed at Matrouh

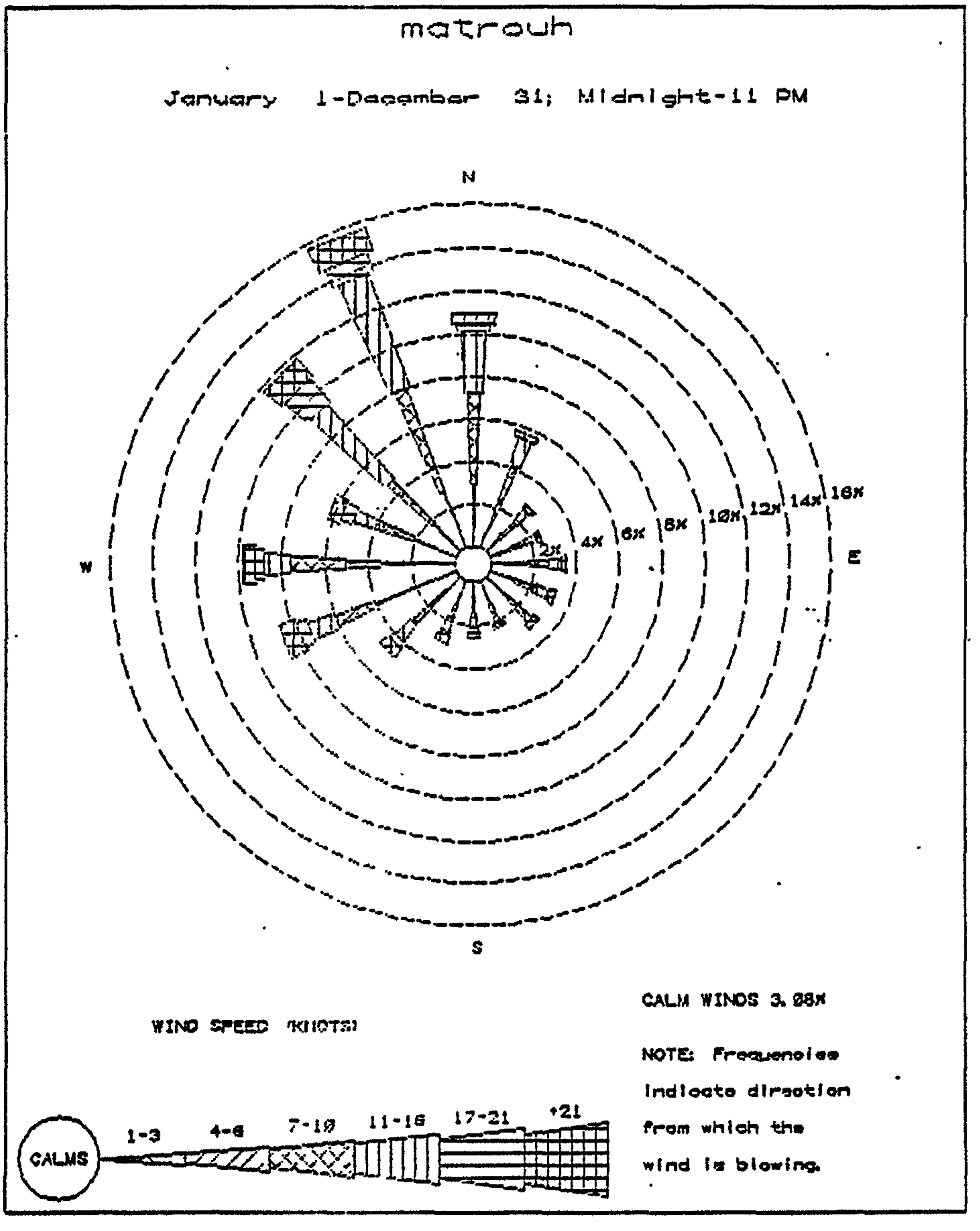


Figure 9 - Annual wind rose for Matrouh

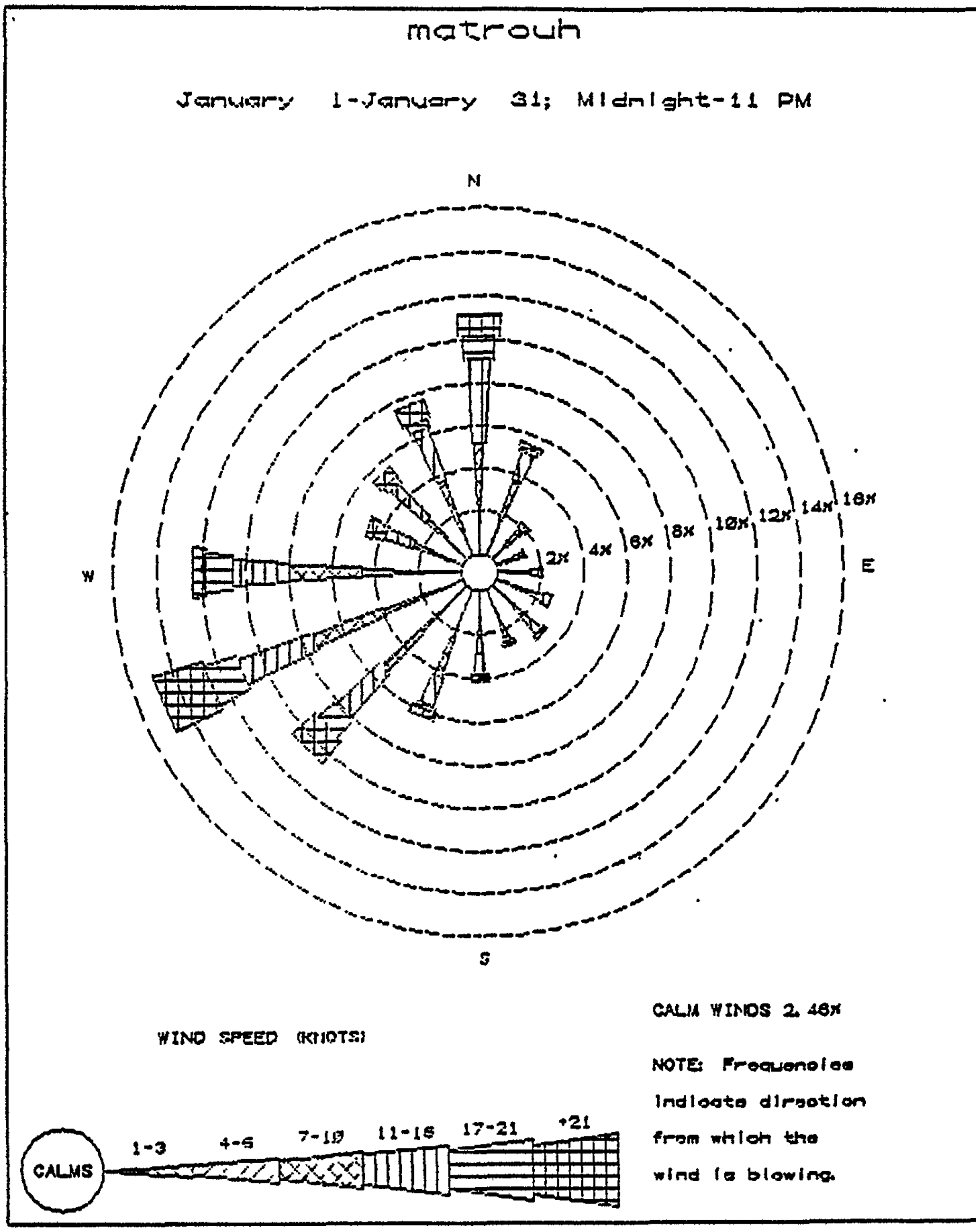


Figure 10 - January wind rose for Matrouh

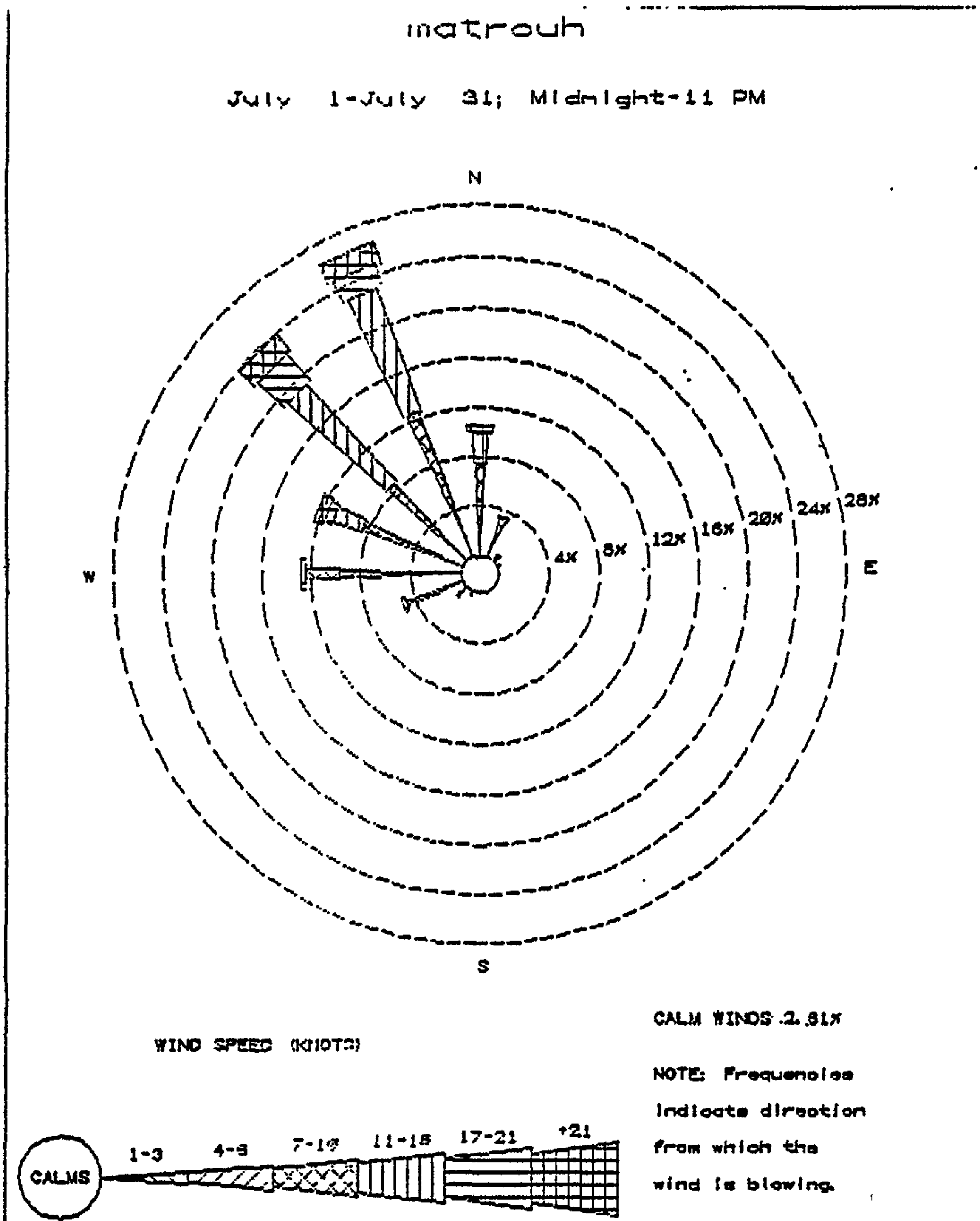


Figure 11 - July wind rose for Matrouh

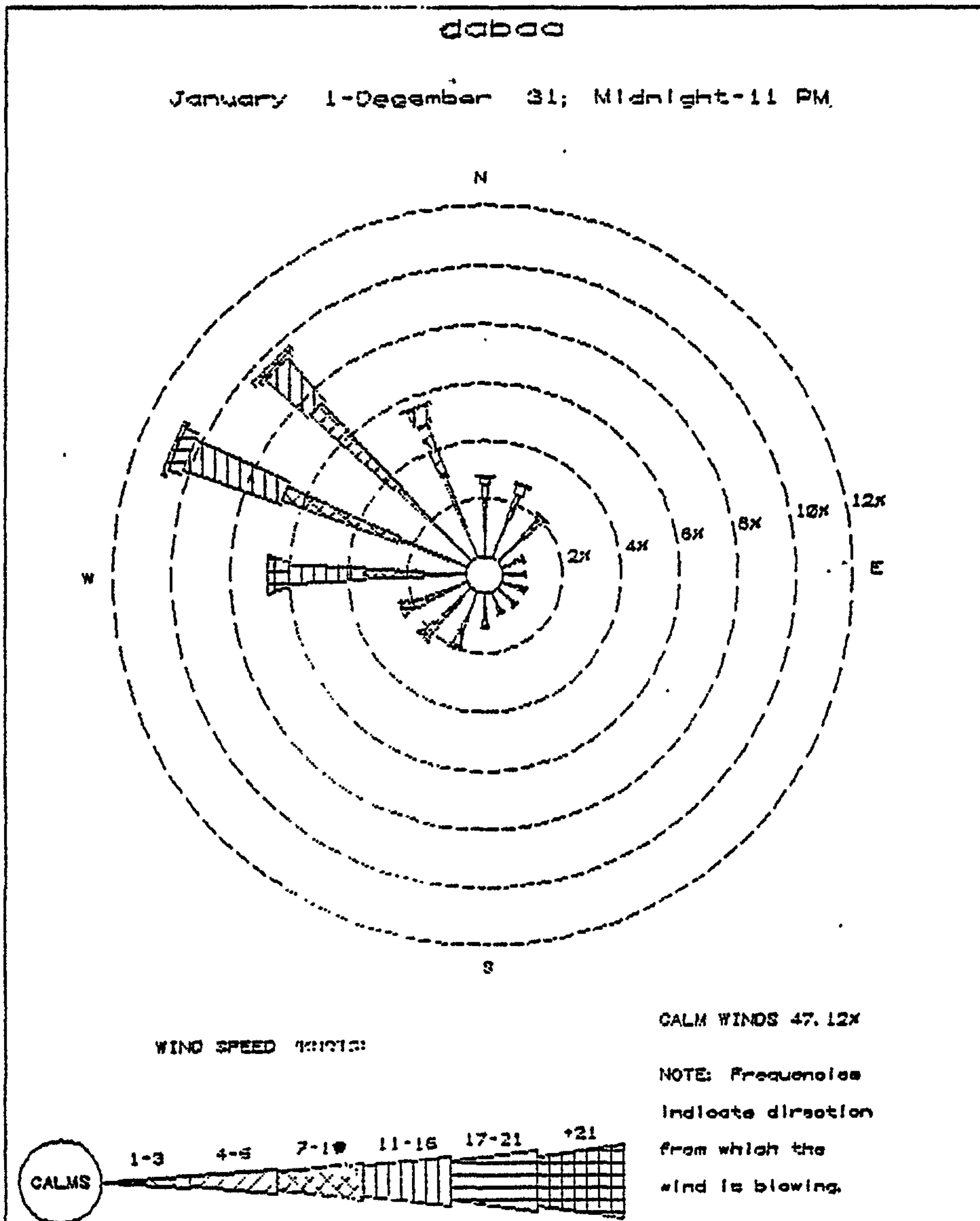


Figure 12 - Annual wind rose for Matrouh

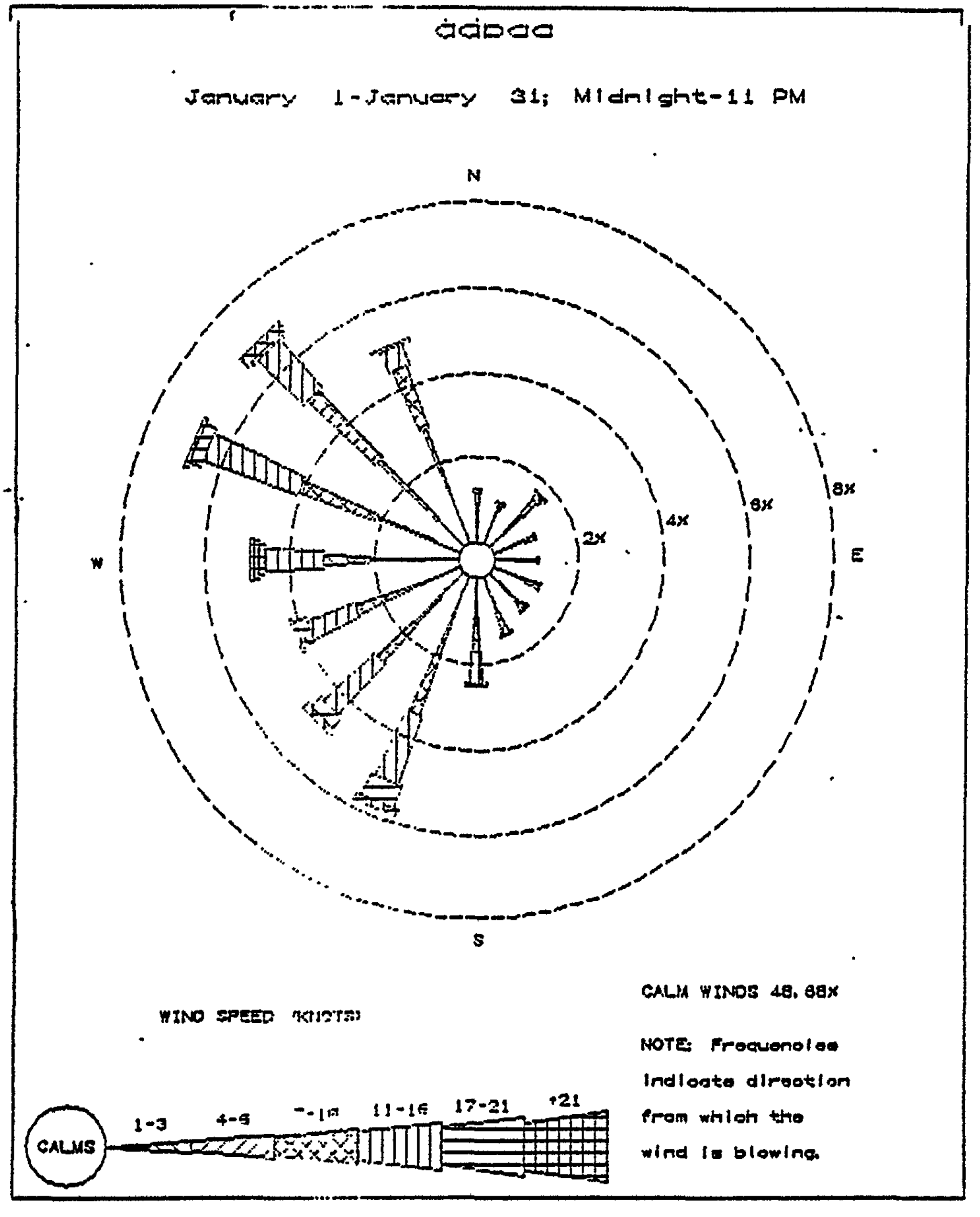


Figure 13 - January wind rose for Dabaa

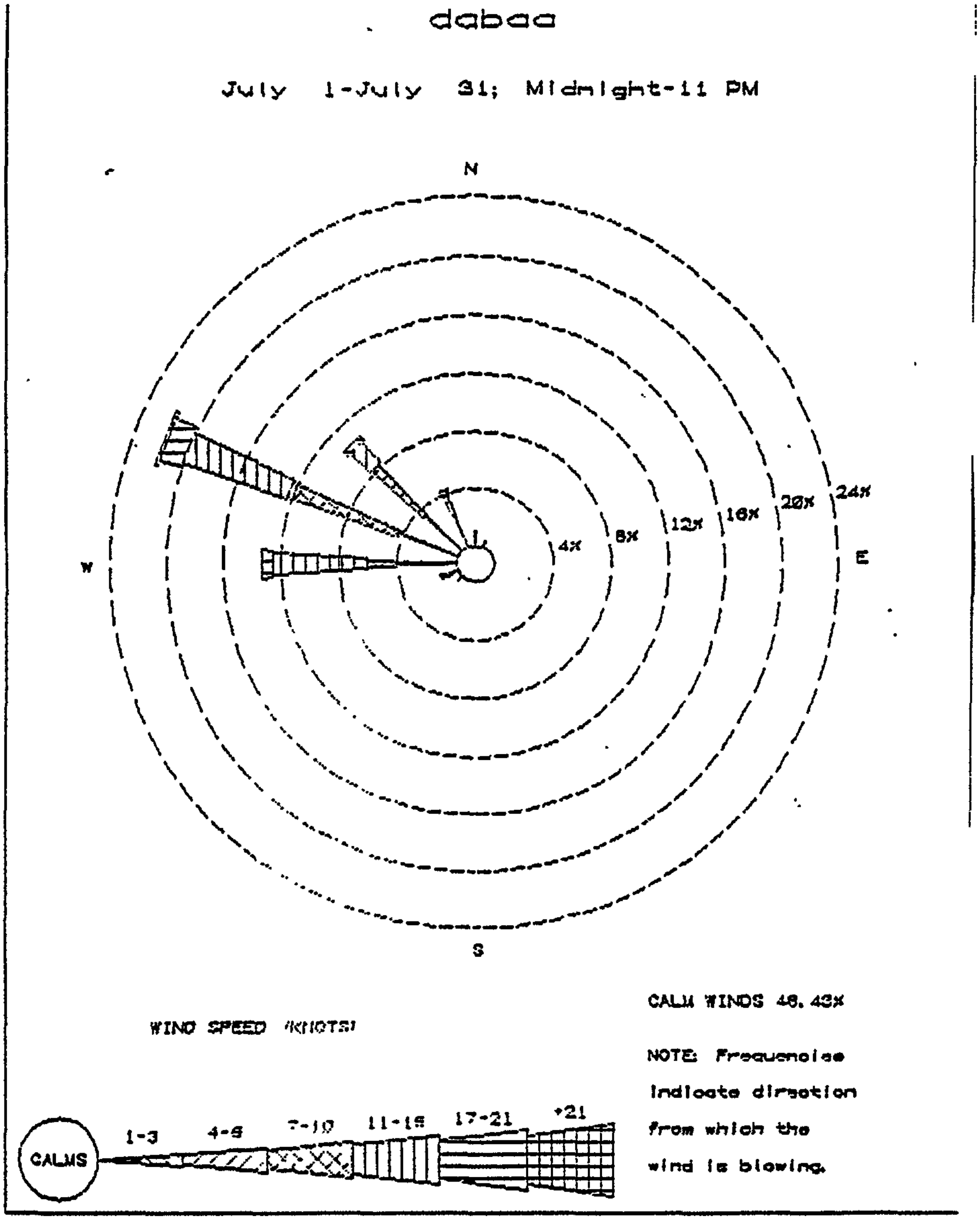


Figure 14 - July wind rose for Dabaa

This fact leads to the eastern Mediterranean becoming an area of relatively high pressure.

In summer, steady northerly winds prevail. Gales do not occur during this season.

Autumn, especially October, is the time of lowest wind speed.

Mean annual values of wind speed are homogeneous throughout the region with a slight increasing trend from west to east. Annual mean wind speeds are 10.3, 10.4 and 10.5 knots (or 19.1, 19.3 and 19.4+ kilometres per hour) for Matrouh, Ras El-Hekma and Dabaa, respectively. Figure 8 gives the annual variation in wind speed at Matrouh. Figures 9-14 give the wind rose for the whole year (Fig. 9), January (Fig. 10) and July (Fig. 11) at Matrouh, and, likewise, at Dabaa (Figs. 12, 13 and 14, respectively).

2.1.1.6 Human Bioclimate

The mean monthly values of the cooling power of the air, **C_p**, in kcal/hr/m^2, and the effective temperature, **ET** (in °C), were calculated.

$$C_p = 0.57\ U^{0.42}\ (36.5 - T) \times 36$$

where **C_p** is as defined above, **T** is air temperature in °C and **U** is wind speed in m/sec.

This equation combines wind and temperature conditions, without including a humidity term. Furthermore, the emphasis is on the cooling power of the surrounding atmospheric conditions (Garnier, 1992).

Classification of the cooling power of the air is as follows:

from	396	to	540kcal/hr/m^2	cool
from	541	to	790kcal/hr/m^2	very cool
from	791	to	999kcal/hr/m^2	cold
from	1000	to	1199kcal/hr/m^2	very cold
from	1200	to	1439kcal/hr/m^2	biting cold
over	1440		kcal/hr/m^2	exposed skin freezes quickly

The effective temperature, **ET**, was determined by using the chart for **ET** devised by Ellis *et al.* (1972). Table 6 and Figures 15 and 16 give the values of **C_p** and **ET**.

<u>Table 6 - Mean monthly values of the cooling power and the effective temperature of the air at Matrouh</u>

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
C_p (kcal/hr/m^2)	968	951	878	781	629	510	440	404	448	542	690	892
ET (°C)	14.0	14.0	15.5	17.2	19.5	22.0	23.5	23.7	22.7	20.5	17.8	15.0

According to this classification (C_p data), Matrouh is cold from December to the end of March, very cool in April, May, October and November, and cool in June-September.

Sham (1977) demonstrated the difficulty in defining a range of effective temperature with which the majority of individuals from hot countries would be content and able to work at maximum efficiency, as follows:

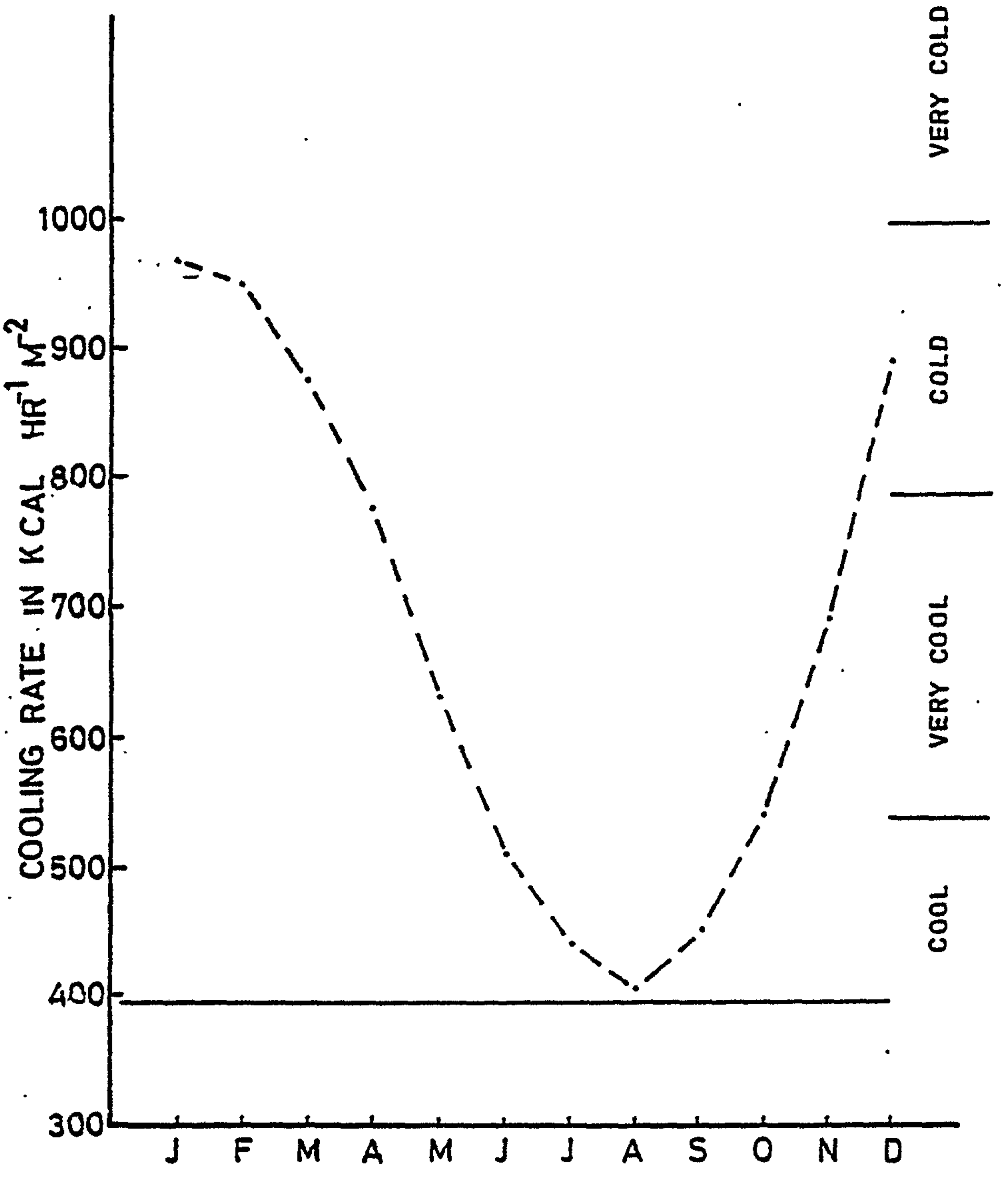


Figure 15 - Thermal-comfort classes for Matrouh

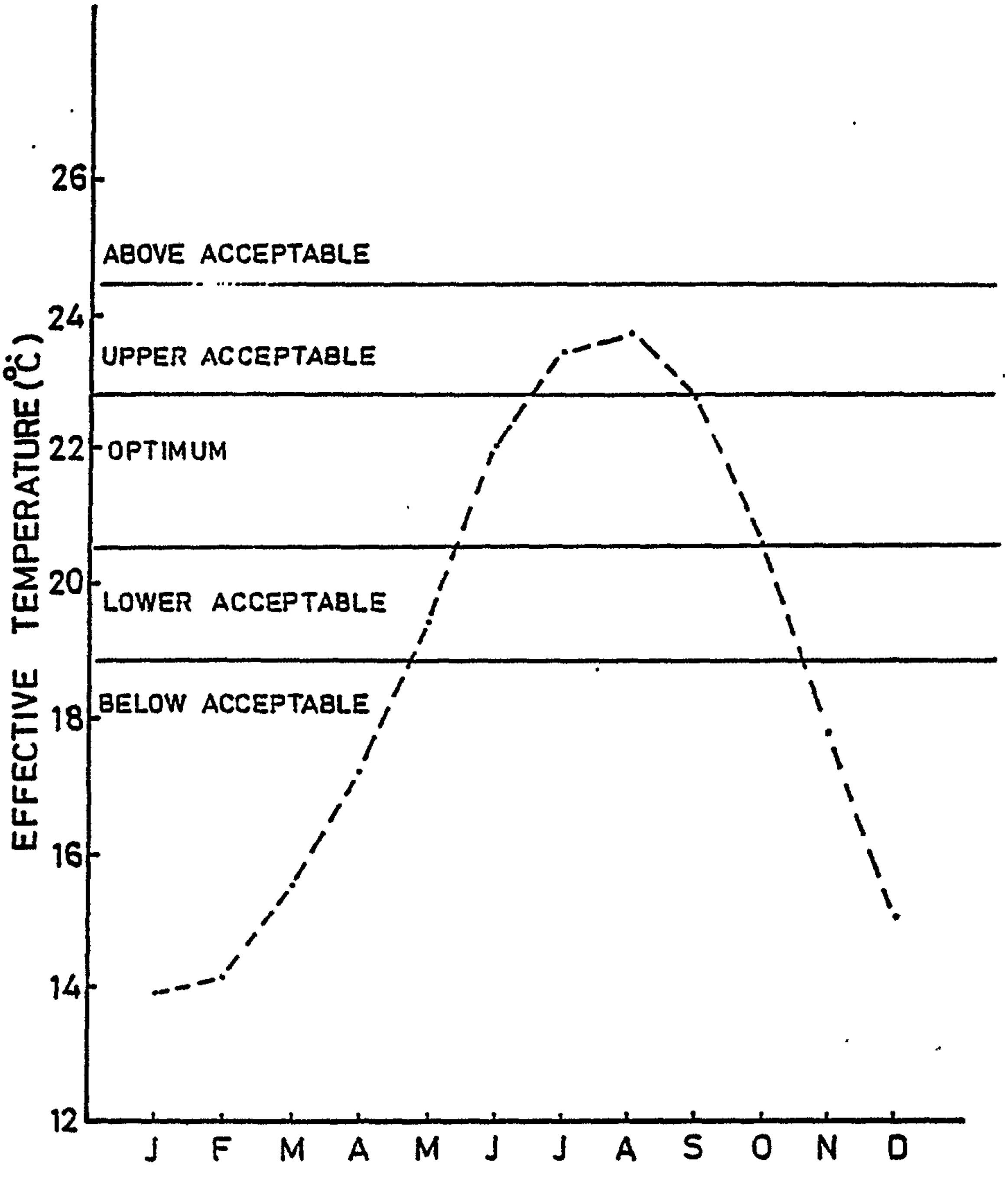


Figure 16 - Effective temperature classes Mersa-Matrouh

Comfort Range	Effective Temperature
not acceptable	above 24.5°C
upper limit of acceptability	22.8-24.5°C
optimum	20.6-22.8°C
lower limit of acceptability	18.9-20.6°C
not acceptable	below 18.9°C

According to the effective temperature (ET data in Table 6), the indoor environment lies in the upper-limit-of-acceptability range during July and August, in the optimum range during June and September, in the lower-limit-of-acceptability range during May and October, and in the not- acceptable range from November to April.

The residents have introduced their own moderating methods to reduce discomfort by either having light clothing together with a considerable use of fans to produce comfortable conditions during July and August, or by having heavy clothing and warming means in winter. Figure 15 gives thermal-comfort classes and Figure 16 gives effective-temperature classes, for Matrouh.

2.1.1.7 Extreme Events and Other Meteorological Phenomena

Table 7 gives the monthly extreme values of temperature and rainfall, and the frequency of certain unusual meteorological events; frost and snow are, of course, extremely rare phenomena in the region.

Table 7 - Extreme events and other meteorological phenomena

Month / Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Absolute maximum temperature (°C)												
Matrouh	30.0	31 8	37.5	34.4	45.2	45.4	37.3	44.2	40.4	39.3	34.4	28.8
El-Hekma	26.2	32.3	37.0	40.4	37.0	43.0	38.8	38.4	38.8	35.2	31.3	26.7
Dabaa	28.6	30.9	38.2	43.2	47.1	46.8	39.0	41.8	40.0	37.7	32.6	28.3
Absolute minimum temperature (°C)												
Matrouh	1.4	4.8	5.0	6.3	7.9	12.0	16.2	16.0	14.5	11.0	7.9	4.5
El-Hekma	2.3	5.0	4.8	6.5	9.5	14.0	16.2	16.5	13.9	11.6	6.5	5.4
Dabaa	0.9	2.8	3.1	5.6	8.4	11.6	14.5	15.6	13.7	11.4	7.4	1.8
Absolute maximum rainfall in 24 hours (in mm)												
Matrouh	35.1	26.2	12.2	8.0	20.1	47.2	0.0	15.0	9.0	55.5	75.5	53.5
El-Hekma	52.9	31.2	21.7	19.0	3.9	1.2	0.0	0.0	19.8	45.4	52.5	72.4
Dabaa	49.0	34.7	32.0	7.6	23.3	0.3	0.0	0.0	26.2	36.3	41.0	30.2
Number of days of occurrence of thunderstorms												
Matrouh	0.6	0.4	0.4	0.3	0.3	0.0	0.0	0.0	0.1	0.5	0.8	0.7
Number of days of occurrence of gales												
Matrouh	1.1	1.8	0.9	1.0	0.3	0.0	0.0	0.0	0.0	0.1	0.4	1.0
Number of days of occurrence of hail												
Matrouh	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0

2.1.2 *Atmospheric Interactions*

2.1.2.1 Global Climate and the Greenhouse Effect

Global climate patterns are produced by a complex interaction between the Sun and the Earth's atmosphere, oceans, ice and land surface. Changes in any of these can upset the established equilibrium and may affect global climate.

The Earth's climate is influenced by the average global temperature and is sensitive to changes in temperature. The Earth has a natural temperature-control system that keeps the planet warm enough to sustain life, yet prevents it from overheating. Certain atmospheric gases, the greenhouse gases, are critical to this temperature control system.

Greenhouse gases warm the Earth and its atmosphere just as glass, in effect, warms the air inside a greenhouse. Glass allows most wavelengths of the Sun's radiation to pass through it into the greenhouse, where it warms the soil and plants. The contents of the greenhouse, like all bodies, then radiate infra-red energy back into the atmosphere. However, the glass in the greenhouse allows only about 10 % of the radiation at infra-red wavelengths to pass through it and escape into the atmosphere; the remainder, about 90 % of the infra-red radiation, is trapped in the greenhouse. The temperature of the greenhouse therefore stabilises at a higher level than that of the outside air.

A similar, but more complex, interaction occurs between solar radiation, the Earth and the greenhouse gases that surround the Earth. The Earth's temperature remains fairly constant because the level of solar radiation that enters the atmosphere is similar to that radiated back into space by the Earth and its atmosphere. However, temperatures on Earth are 33°C higher than those in space because greenhouse gases absorb, hence trap, some of the radiation emitted by the Earth. This trapped radiation warms the Earth's atmosphere and, by creating a warm blanket of air around the Earth, also warms the planet's surface. This is known as the greenhouse effect.

2.1.2.2 Human Influence on Climate

Over the past few hundred years, human activity has significantly altered the Earth's surface and the composition of its atmosphere. These changes may be causing or contributing to the rise in global temperature observed over the past 150 years.

Greenhouse gases, such as water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) exist naturally in the atmosphere, but are also released into the atmosphere in great quantities when fossil fuels are burned and/or as a result of industrial and agricultural activities. The increasing concentrations of these gases in the atmosphere are likely to intensify the greenhouse effect and raise global temperature.

Concentrations of atmospheric gases were not significantly altered by human activity until the industrial revolution. Since about 1750, however, atmospheric levels of greenhouse gases have increased significantly.

Atmospheric CO_2 concentrations have increased by 26% since pre-industrial times. The main cause is the widespread and large-scale combustion of fossil fuels (coal, oil and gas) during which CO_2 is released into the atmosphere.

Deforestation, which alters the reflectivity of the Earth's surface and reduces the amount of CO_2 absorbed and conserved naturally by trees, is a secondary cause.

Methane concentrations have more than doubled over the same period because of increased rice production, cattle raising and biomass burning - all of which produce methane. Nitrous oxide concentrations have increased by about 8% since 1750; agriculture is a probable contributor.

Some greenhouse gases, such as the chlorofluorocarbons (CFCs), result only from human activity, notably from industrial processes, and have been building up in the atmosphere since first used commercially in the 1930s. Most countries are reducing CFC production and consumption to comply with the Montreal Protocol, which came into force in 1989.

Carbon dioxide, CFCs and nitrous oxide remain in the atmosphere for many years. Even if emissions were reduced, it would be decades or even centuries before atmospheric concentrations of these gases reflected these lower emission levels. If all the emissions of CO_2 that result from human activity had stopped in 1990, about half the atmospheric burden of CO_2 due to human activity would still be present in 2100. In the short-term, at least, increasing levels of atmospheric greenhouse gases are therefore unavoidable, irrespective of any future reduction in emissions.

2.1.3 Summary

The climate of the region is of the Mediterranean type, though strongly influenced by the sea.

The region has a winter rainfall (Mediterranean region), the rainy season extending from November to April, though mainly concentrated in December and January, with average rainfall of 120-140mm. The lowest annual rainfall recorded was 37mm, whereas the highest amount was 277mm.

The lowest temperatures are observed in January and February, for which the mean monthly minimum is about 9°C. The highest mean maximum temperature occurs in July or August; the extreme maximum temperature exceeds 40°C. The average temperature between November and April is 15.2°C and that between May and October is 23.4°C.

Average daily relative humidity for winter is 69% whereas that for summer is 72%.

Average daily cloud cover (in oktas) for winter is 3.4, whereas that for summer is 1.8.

Average daily wind speed (m/s) for winter is 5.0, whereas that for summer is 4.2.

Average daily number of hours of sunshine for winter is 7.5, whereas that for summer is 10.7.

2.2 LITHOSPHERE

2.2.1 Geology

2.2.1.1 Introduction

Geologically, the northern coast of Egypt may be subdivided into two units. The first unit extends eastwards from Alexandria towards Sinai. This unit consists mainly of a quartz-sand-beach-dune belt which forms the seaward edge of the deltaic coastal plain. It has developed by the redistribution of the sediments of the River Nile. The coastal strip is bordered by the Nile flood plain. The other unit extends westwards. This north-western coastal plain of the Mediterranean Sea is located between Alexandria and the frontier with Libya, over a distance of about 500km. The coastal zone has a minimum width in the west where the sea attacks the Miocene limestone which forms a wave-cut cliff, up to several tens of kilometres long in the east, where a wide coastal plain and a narrower piedmont plain can be differentiated. The coastal plain is composed mainly of oolitic and biotic calcareous sand forming the coastal beach/dune ridges, and encloses a coastal sabkha. Parallel to the coastal ridges and lying farther inland, there are series of older indurated calcareous beach/dune ridges separated by depressions filled with lagoonal-sabkha deposits.

Prior to 1960, the north-western coastal region was relatively isolated from the main stream of development in Egypt. The reason may be attributed to low rainfall, the topography, soil and climatic conditions that permit dry agriculture. Since then, the government has steadily increased its development efforts, with particular emphasis on tourism, agriculture and industry. The evaluation of coastal land is an essential tool in land-use planning. It is assigned the indispensable task of translating the data on land resources into categories that can be used in land improvement. Any coastal-area management plan for the north-west coast has to take into consideration the climate changes and sea-level rise in the coming decades and their implications for coastal geomorphology.

The Fuka-Matrouh area is one of the representative areas of the north-west coastal region (Fig. 1). Its extension along the Mediterranean coast and its width southwards to the limits of the Western Desert reflect different physiographic features. The objectives of the present study, with respect to the geology of the study area, are to:

- describe the present geology and the sediment resources;
- assess landscape variability;
- estimate the sediment drift rate in the coastal environment;
- evaluate the impact of sea-level rise on the coastal area.

2.2.1.2 Quaternary Coastal Plain

The Quaternary coastal plain occupies the area between the tableland to the south and the present shoreline of the Mediterranean Sea to the north. It has a variable width, being only a few hundred metres or less to the west, where the edge of the homoclinal plateau reaches the sea; whereas, to the east, where the plateau lies farther inland, it varies in width between 10km and 40km.

The Quaternary coastal plain is bordered to the south and to the west by the outcropping of Middle-Miocene Marmarican limestone which forms a tableland. The latter is topographically higher than the former and occupies the northern end of the great homoclinal plateau that extends southwards to the Qattara depression (Fig. 17). The boundary between the sediments of the Quaternary coastal plain and the Miocene sediments that succeed them landwards, in the west, and the Quaternary deltaic plain sediments, to the east, lies over a fault system (Hassouba, 1980). This system lies along a notional line running from 50°N-60°W to 50°S-60°E and is downthrust to the east. Hence, the Pleistocene gravels of the Nile delta are in juxtaposition to the calcareous Miocene-Quaternary sediments to the west (El-Shazly *et al.*, 1975).

The great homoclinal plateau which is, in its highest part, a hundred metres or more above present sea level, slopes gently northwards towards the Mediterranean Sea and eastwards to the Nile delta. The northern edge of the homoclinal plateau of Marmarican limestone reaches the Mediterranean coast in north-west Egypt to form a low cliff. Hence, the Quaternary coastal plain becomes narrower in a north-westerly direction.

The exposed rocks of the coastal area - Qattara depression are exclusively of sedimentary origin and date back to the Miocene-Holocene, with a maximum thickness of about 200m. The stratigraphic sequence may be outlined as follows:

A. Quaternary period:

1. *Holocene epoch:*
   - oolitic calcareous sand
   - wadi filling
   - loamy deposits
2. Pleistocene epoch:
   - oolitic limestone of consolidated ridges
   - cardium limestone
   - pink limestone

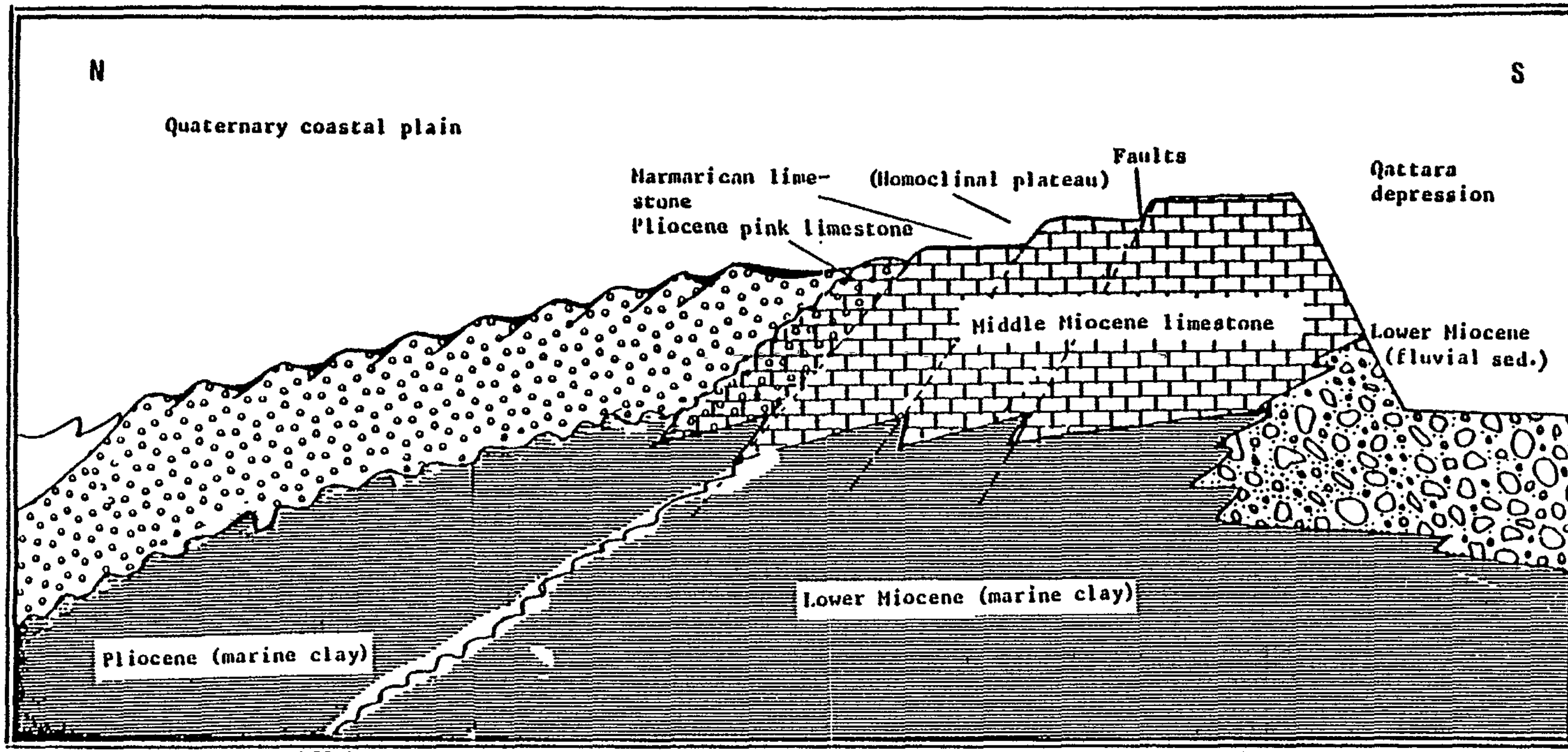


Figure 17 - Schematic N-S cross section to show the structure of the Quaternary coastal plain (source: Hassouba, 1980)

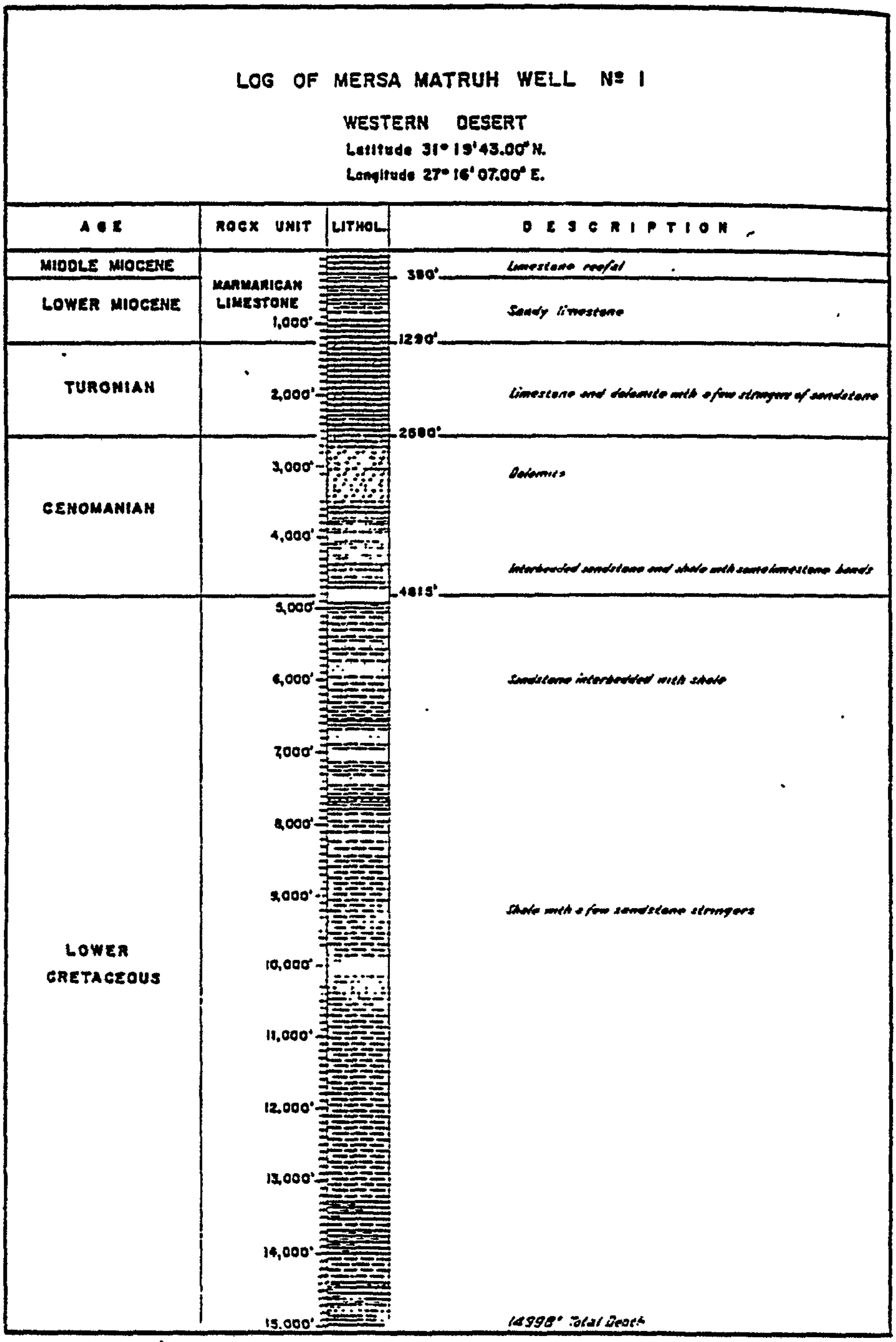


Figure 18 - Log of Matrouh well no. 1 (source: Said, 1962)

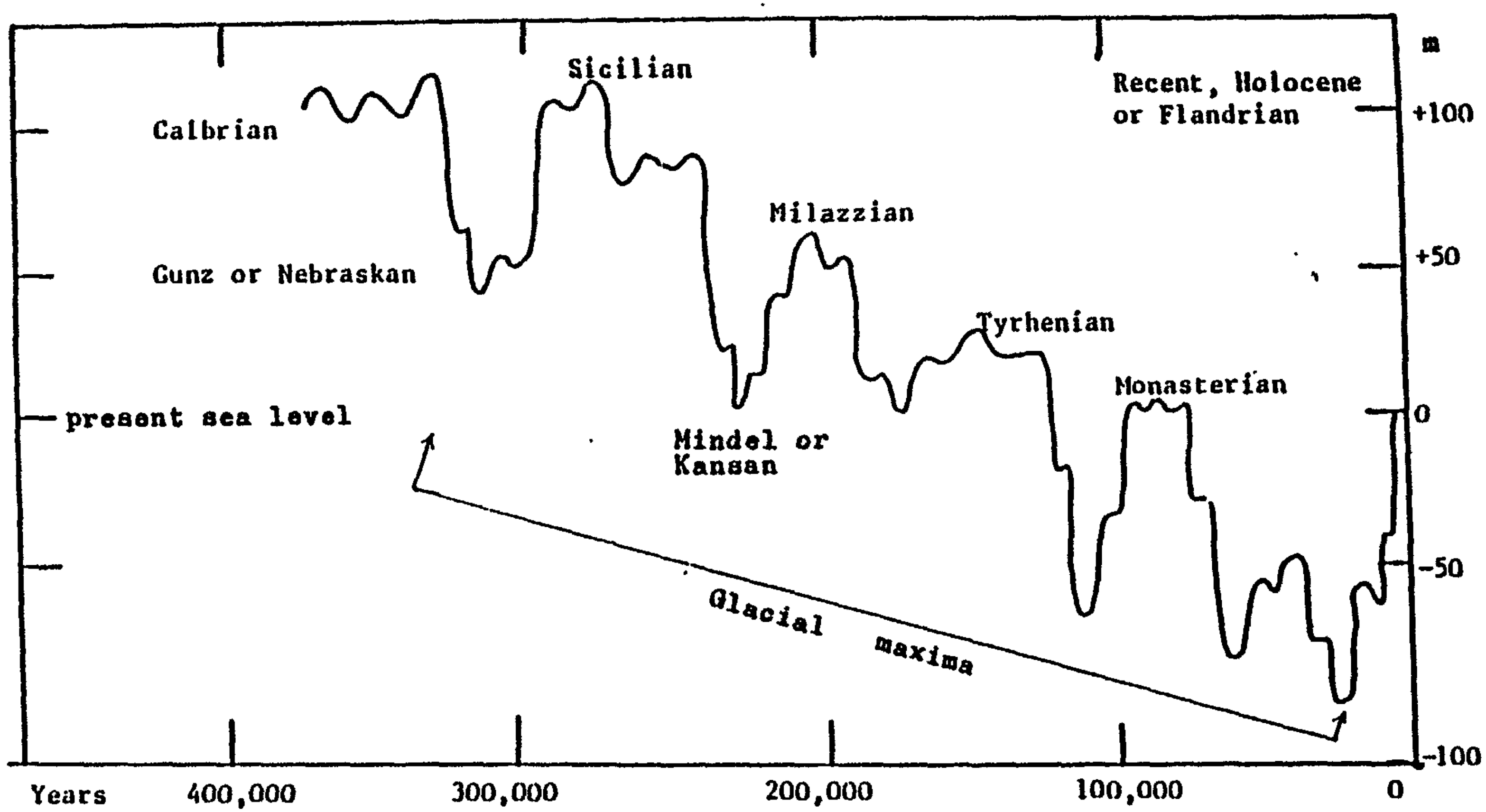


Figure 19 - Eustatic changes in mean sea level (*source*: Fairbridge, 1961)

B. Tertiary period:

1. Pliocene epoch:
   - creamy limestone, upper series
   - brown limestone, lower series
2. Miocene epoch:
   - alternation of limestone and marl of upper horizon of middle Miocene
   - fossiliferous limestone and marl of lower horizon of lower Miocene

Fig. 18 shows a log at Matrouh well (source: Said, 1962)

2.2.1.3 Geological Evolution of the Quaternary Coastal Plain

The Quaternary coastal plain of the north-western region, with its beach ridges enclosing depressions filled with lagoonal-sabkha deposits, is geologically similar to those coasts of the southern and eastern Mediterranean and other coasts around the world. The evolution of this coast can be related to the eustatic changes in sea level during the Quaternary and the formation of barrier islands. Fairbridge (1961) has summarised the hypotheses that have been proposed with respect to such phenomena; these are:

- Tectono-eustasy hypothesis

  This deals with the changes, either positive or negative, in sea level due to tectonic events that have taken place in the oceanic basins.

- Volcano-sedimento-eustasy hypothesis

  This deals with the rise in sea level due to the deposition of sediments or volcanic products in an ocean and a subsequent reduction in its capacity.

- Geodetic hypothesis

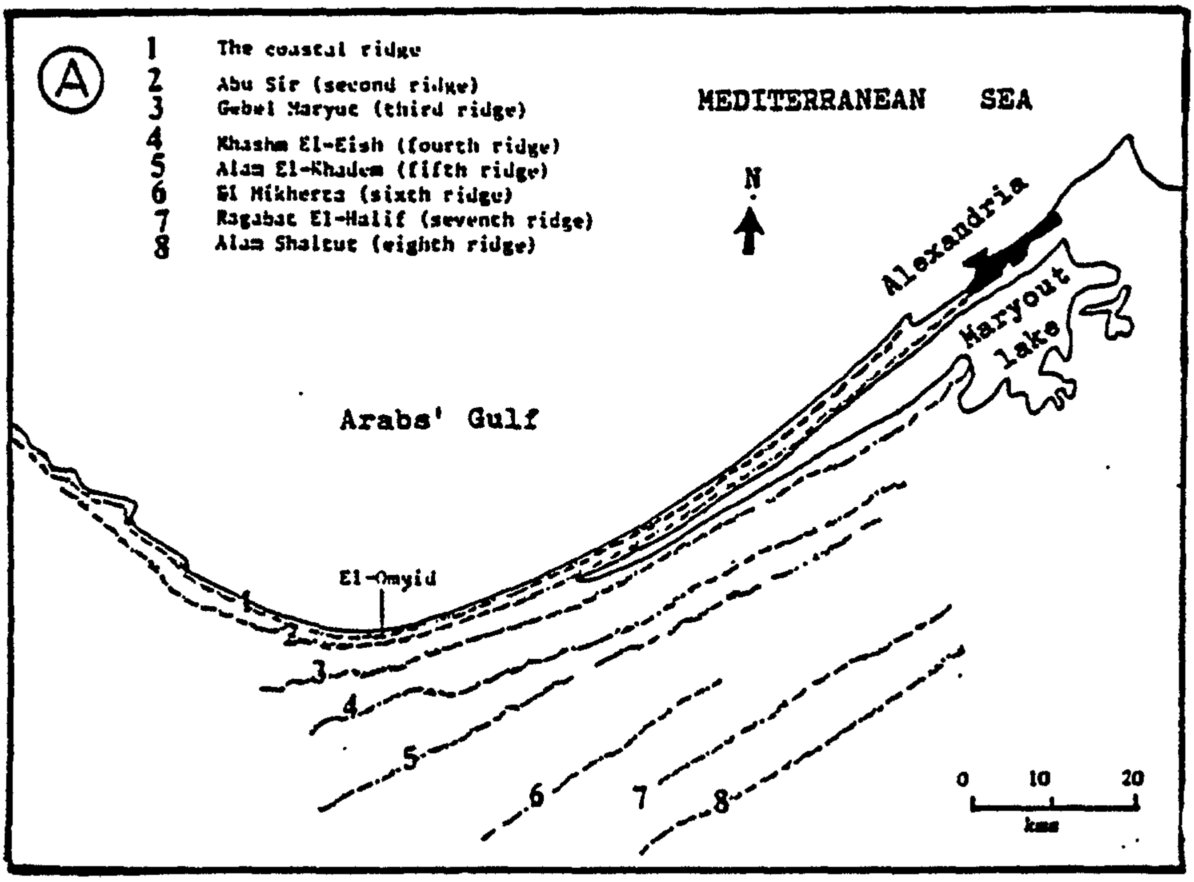
  The acceleration in the Earth's angular velocity would cause a rise in the mean sea level in the equatorial belt and a lowering at the poles.

- Glacio-eustasy hypothesis

  This is considered the most important factor in changes in sea level. Glacio-eustasy is related to the change in the volume of the ice sheets that accompanied the climate changes that have taken place in the Quaternary period, notably the four or five successive major glacial and interglacial periods, marked by the growth and melting of the ice sheets (Fig. 19). The eustatic curve helps to understand the stratigraphy of the Quaternary period on the north-western coast and shows the past fluctuations in sea level and the fall of about 100m between the early Pleistocene and the Holocene (near its present level). It indicates also the exposure of continental shelves several times during the glacial periods and then their submergence during the related interglacial periods.

  In fact, it appears that the coastal ridges of the western region have a complex origin. The investigators related their origin to:

- successive sea-level rise and fall during glacial and interglacial periods;
- offshore or marine origin;
- æolian origin;
- successive earth movements.



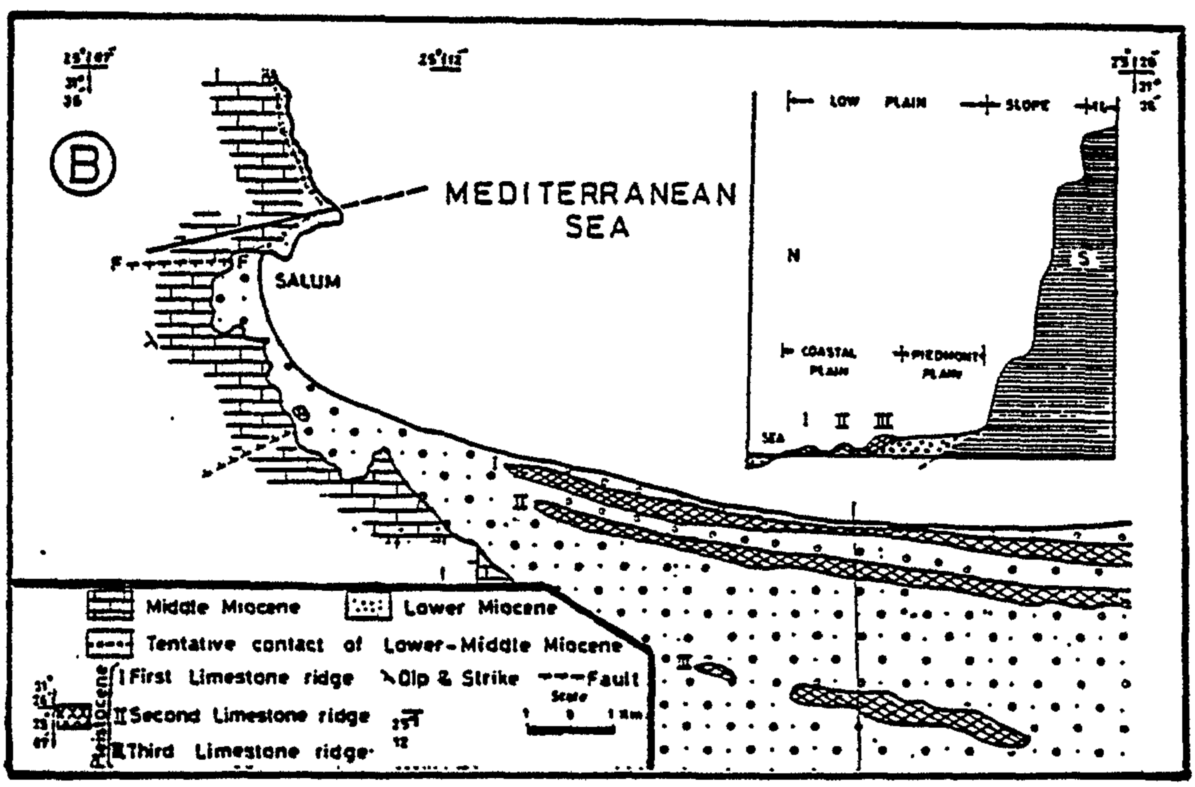


Figure 20 - Coastal and inland ridges along the north-western coast between Alexandria (A) and Sallum (B) (source: Selim, 1974)

2.2.1.4 Geomorphology and Microfacies of the Ridges

The coastal plain of the north-western region is characterised by a series of eight elongated beach/dune ridges (Fig. 20). The most inland of the ridges is the highest and has an altitude of about 110m above sea level, whereas the coastal ridge, which borders the present coast, is only about 10m above sea level. These ridges are mainly composed of oolitic and bioclastic sand and have formed as a series of coastal beach/dune ridges which developed along the receding Quaternary shorelines (Shukri *et al.*, 1955). Seawards and to the north of the coastal ridge is a ridge that is, for most of its length, submerged, but parts of it are exposed to form a series of isolated islands.

The following are the names that have been given to the ridges (Shukri *et al.*, 1955), with a very brief description of the geomorphology and microfacies, starting from the youngest, seawardmost ridge to the oldest, landwardmost ridge:

Ridge 1 The coastal ridge (Late Monasterian), 10m. This ridge is composed of friable limestone mainly consisting of oolitic grains together with organic components (e.g., calcareous algæ, pelecypods, gastropods and a few foraminifera).

Ridge 2 Abu Sir ridge (Main Monasterian), 25m. There is a similarity between ridges 1 and 2. Caliche layer is a product of recrystallisation due to the effect of rain water or the high humidity of the region. The ooliths in this layer have gradually lost their shape and have become smaller until obliterated.

Ridge 3 Gebel Maryut ridge (Tyrrhenian), 35m. In this ridge, the appearance of quartz and heavy minerals and an increase in amount of calcareous algæ is noted. The faunal content of this ridge is mainly of Mediterranean type (different from the more seaward ridges).

Ridge 4 Khashm El-Eish ridge (Milazzian), 60m. An abundance of Indo-Pacific foraminiferan species is observed in this ridge, which suggests a connection between the Red Sea and the Mediterranean Sea at the time of its development. These species show evidence of a warmer climate which accompanied the higher sea levels in the interglacial period.

Ridge 5 Alam El-Khadem ridge (Sicilian), 60m.

Ridge 6 Mikherta ridge (Sicilian) 80m.

Ridge 7 Raqabat El-Halif ridge (Sicilian), 90m.

Ridge 8 Alam Shaltut ridge (Sicilian), 110m.

Ridges 5 to 8 are the most inland and are similar in composition and micro-organic content. The conglomeratic appearance of the top layers of these ridges may be due to deeper recrystallisation and increase in quartz content. The organic remains consist of calcareous algæ, foraminifera, pelecypods, gastropods and echinoid (sea urchin) spines.

The cemented carbonate ridges (ridges 2-8) are capped by caliche deposits which form a distinctive superficial, indurated, brownish to pinkish carbonate crust. The thickness of this crust varies between 1cm and 50cm and appears to become thicker landwards as the ridges become older and higher. These crusts are sometimes laminated and superficially resemble algal-stromatolites. When fractured and brecciated, they show a conglomeratic appearance. Similar crusts may be found buried under the loessic sediment of the carbonate ridges.

In the Dabaa area, four well formed beach ridges are correlated with the beach ridges to the west of Alexandria. A well developed coastal ridge is recorded along the Fuka coast and to the west

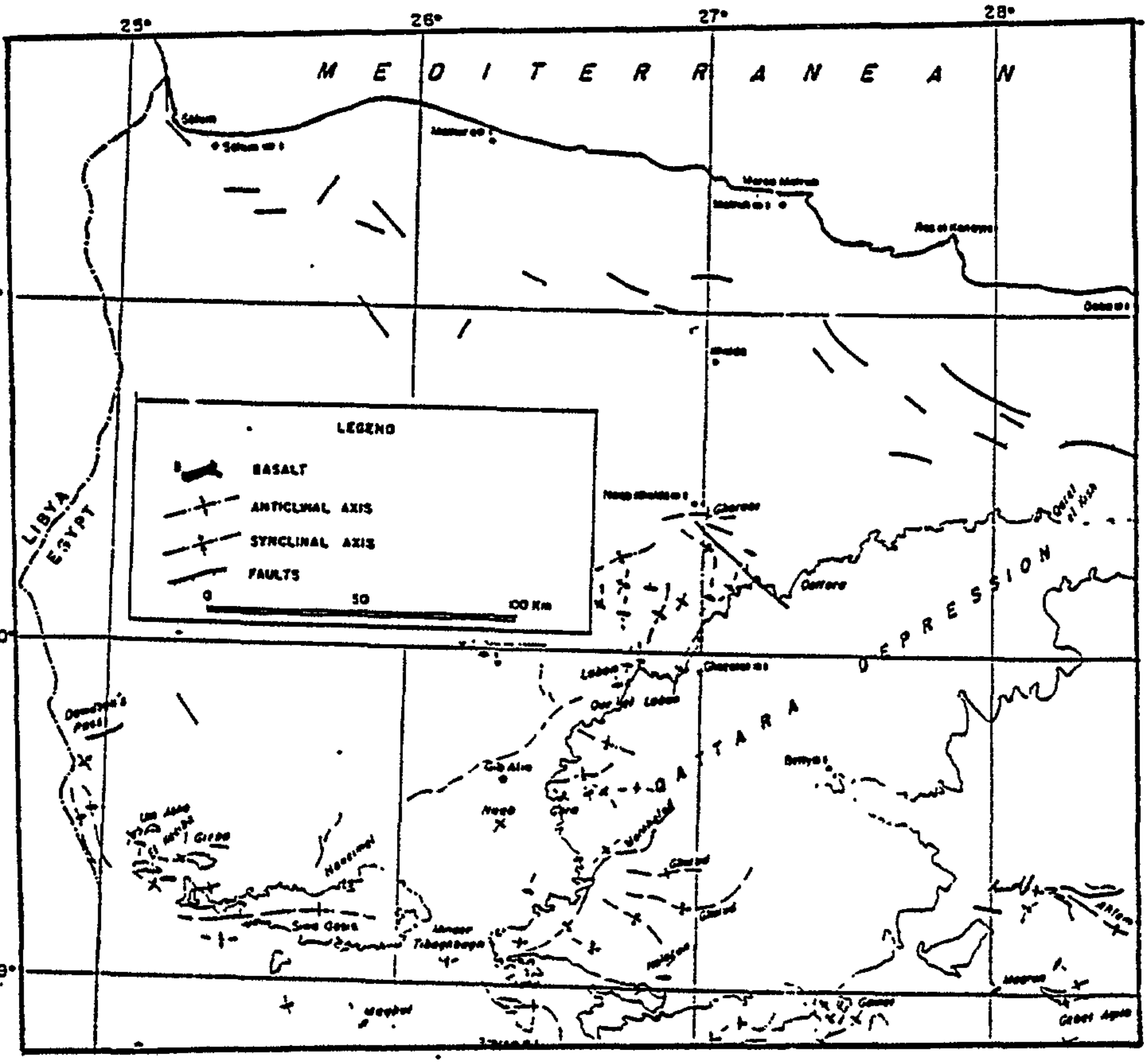


Figure 21 - Map showing surface structures along the north-western coast
(source: Said, 1962)

of Ras El-Hekma. The Matrouh area is formed by a series of ridges which range in age from Late Monasterian (the most seaward ridge), which is equivalent to the coastal ridge west of Alexandria, to the Milazzian, the most inland ridge. In fact, the coastal plain of Matrouh is covered by Quaternary deposits represented by only three elongated ridges separated from one another by three longitudinal depressions. The three successive ridges are:

- the foreshore ridge (10m);
- the Matrouh ridge (25m);
- the South Matrouh ridge (45m).

There is also a fourth ridge which runs parallel to the escarpment that forms the northern boundary of the homoclinal plateau.

To the west of Matrouh, the calcareous ridges with two intervening lagoonal depressions that run parallel to the sea represent the Quaternary deposits in the Sallum district (Selim, 1974). Some ridges are present to the west along the entire coast of the Gulf of Sirte (Libya) and extend for a distance of about 5km inland.

Therefore, the north-western beach ridges seem to continue, but may absent in some places, from Alexandria to Dabaa, Fuka, Matrouh, Sallum and towards Libya. They form a continuous and well marked chain. On the other hand, the outermost chains of ridges lying further inland are less regularly arranged.

2.2.1.5 Tectonic Movement and Subsidence

From the tectonic standpoint (Said, 1962), no major true structural displacement (faulting or folding) is recognised along the north-western coast (Fig. 21). Nevertheless, a few exceptions are found, represented by fracturing and jointing, epeirogenic movement and/or mild post-Miocene tensional forces (Abdallah, 1966). It is, however, reasonable to assume that only the eastern parts of the ridges, those close to the Nile delta, have suffered some displacement as a result of subsidence of the deltaic body, whereas, to the west, the ridges may have been only slightly affected. Evidence for continued subsidence during the last 2000 years can be seen in Alexandria and the western part of the Nile delta coast, where Ptolemaic and Roman settlements are now found at depths below sea level. The subsidence rate along the delta coast shows wide variations. The eastern coast indicated a subsidence rate of 0.5mm per year over the last 20,000 years and a rate of 0.05mm per year only during the last 2000 years. Stanley (1988) estimated a rate of subsidence of 0.5-5.0mm per year gradually decreasing from the western part of the delta coast to the east.

It is important to mention that the elevations of the ridges decrease eastwards. There may be two reasons: the bending of the ridges under the load, and the subsidence of the delta sediments; and the greater accretion of wind-borne material to their tops in the west.

2.2.1.6 Topography and Physiographic Zones

The studied area is characterised by a certain topography and physiography. The sediments are derived from highly calcareous parent material. The study of the physiographical zones of the area was based on the examination of ærial photographs, topographic maps, slope maps and field observations.

The topography between Fuka and Matrouh shows that the elevation contours run parallel to each other (Fig. 22). These contours are closer to each other near the coast, becoming more widely separated southwards. Detailed elevations at Ras El-Hekma are shown in Figure 23. The majority of the Fuka-Matrouh area has a slope of <4%; the escarpment has a slope of >8% (Fig. 24).

The area can be subdivided into three main zones:

Recent Coastal Zone

This includes coastal plains that consist of different strips ranging between 1km and 6km wide and up to 60m above sea level. The southern coastal zone consists of plains dissected by 45 wadis. The following strips, with their respective elevations, are recognised:

- beach and drifting sediments;
- cemented oolitic sand dunes up to 20m high;
- high rocky dunes at the peak of the area, 40-60m;
- complex area of different texture, composed of rock (10-20m high) and deep soil of loamy sand, 10m high;
- rocky ridge with some drifted areas, 20-30m;
- depression with deep soils of different textures ranging between sandy loam and clay loam, 10-20m.

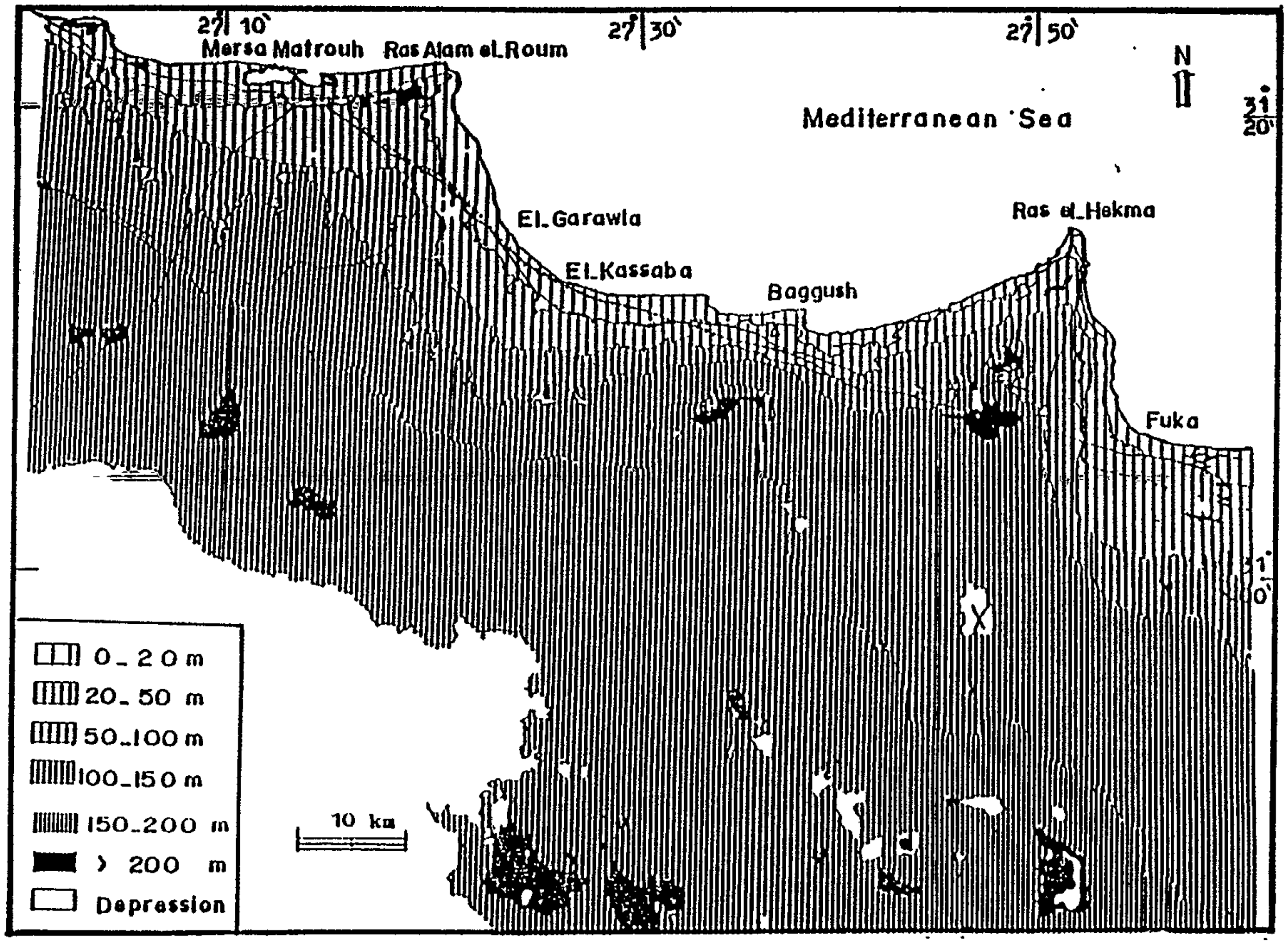


Figure 22 - Topographic map showing the elevations between Fuka and Matrouh

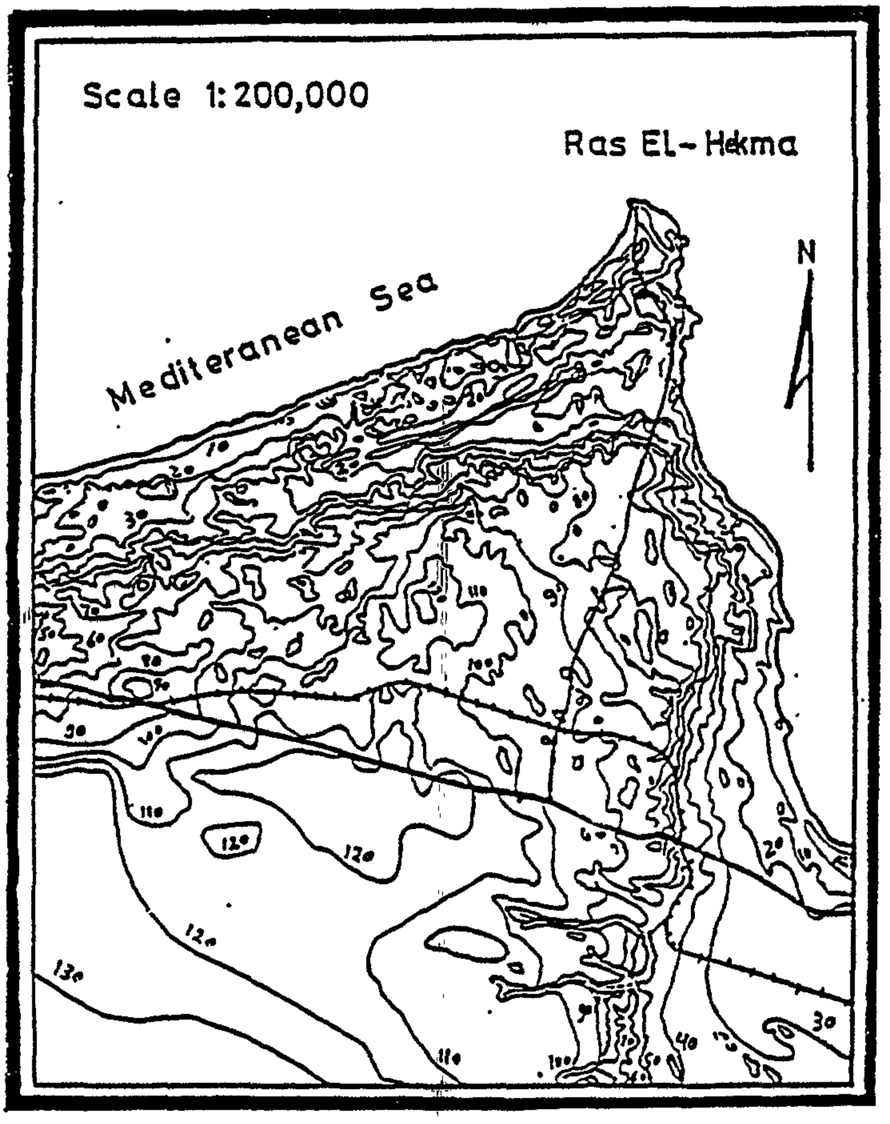


Figure 23 - Contour map of Ras El-Hekma (contours in metres above sea level)

Northern Plateau

The northern plateau is gently sloped with shallow wadis and alluvial sediments. It is a strip 10-13km wide and 30-80m in height. This zone is characterised by a dissected slope system of the old third ridge. Different textures can be recognised:

- gullied;
- without gullies;
- alluvial fans at the foot slopes, with soils limited in depth by caliche or rock.

Southern Plateau

The southern plateau extends 60km southwards, with elevations between 80m and 120m. *It is characterised by complex areas and depressions, comprising:*

- complex areas of rock and soils of different depths and textures (loam, sandy loam and sand), limited by caliche and rock or slab;
- isolated areas of outwash plains of deep soils different in texture (sandy loam, sandy clay loam and loam);
- denuded-rock land with gentle relief.

Figure 25 shows the main zones at Ras El-Hekma

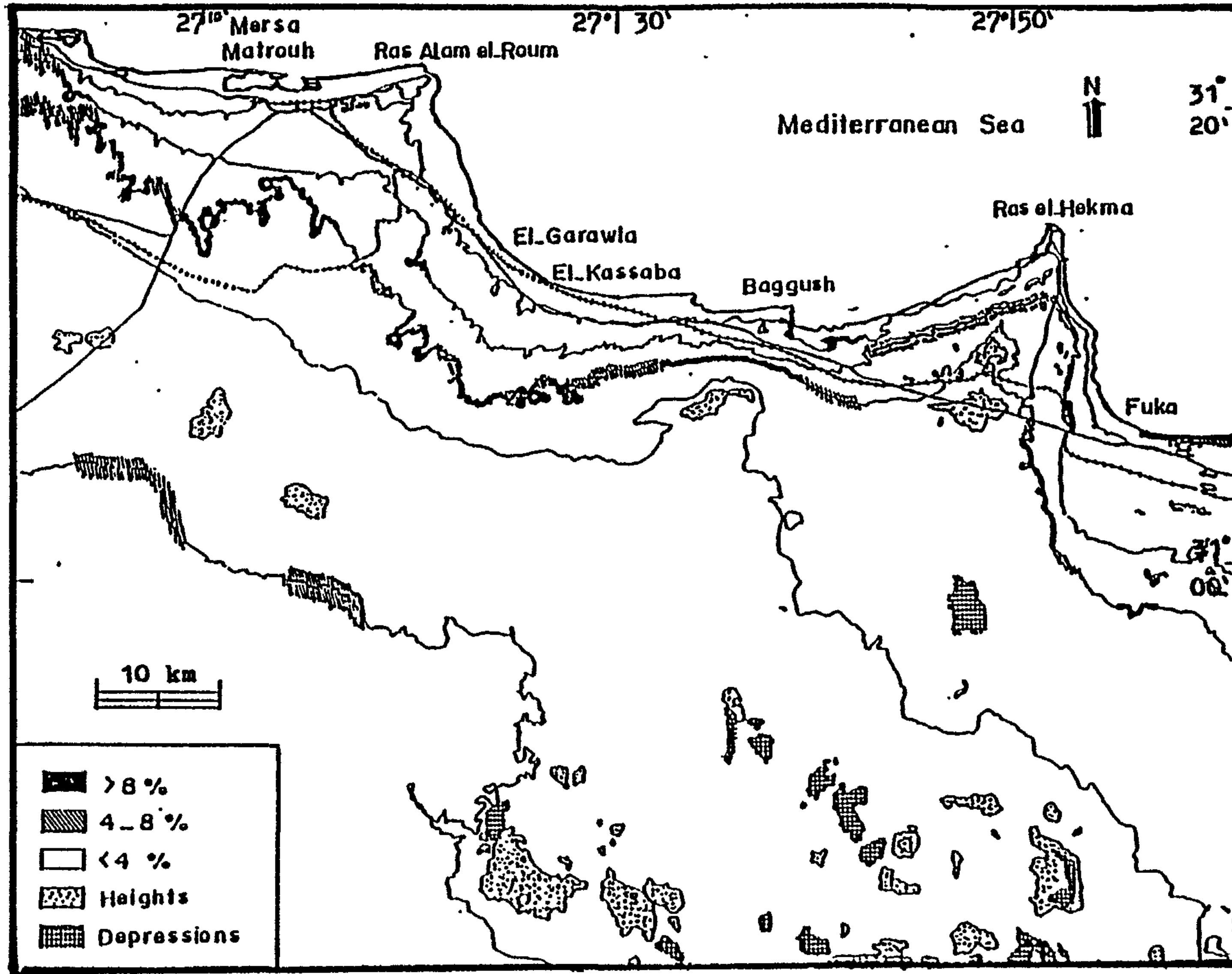


Figure 24 - Slope classes in coastal and inland areas between Fuka and Matrouh

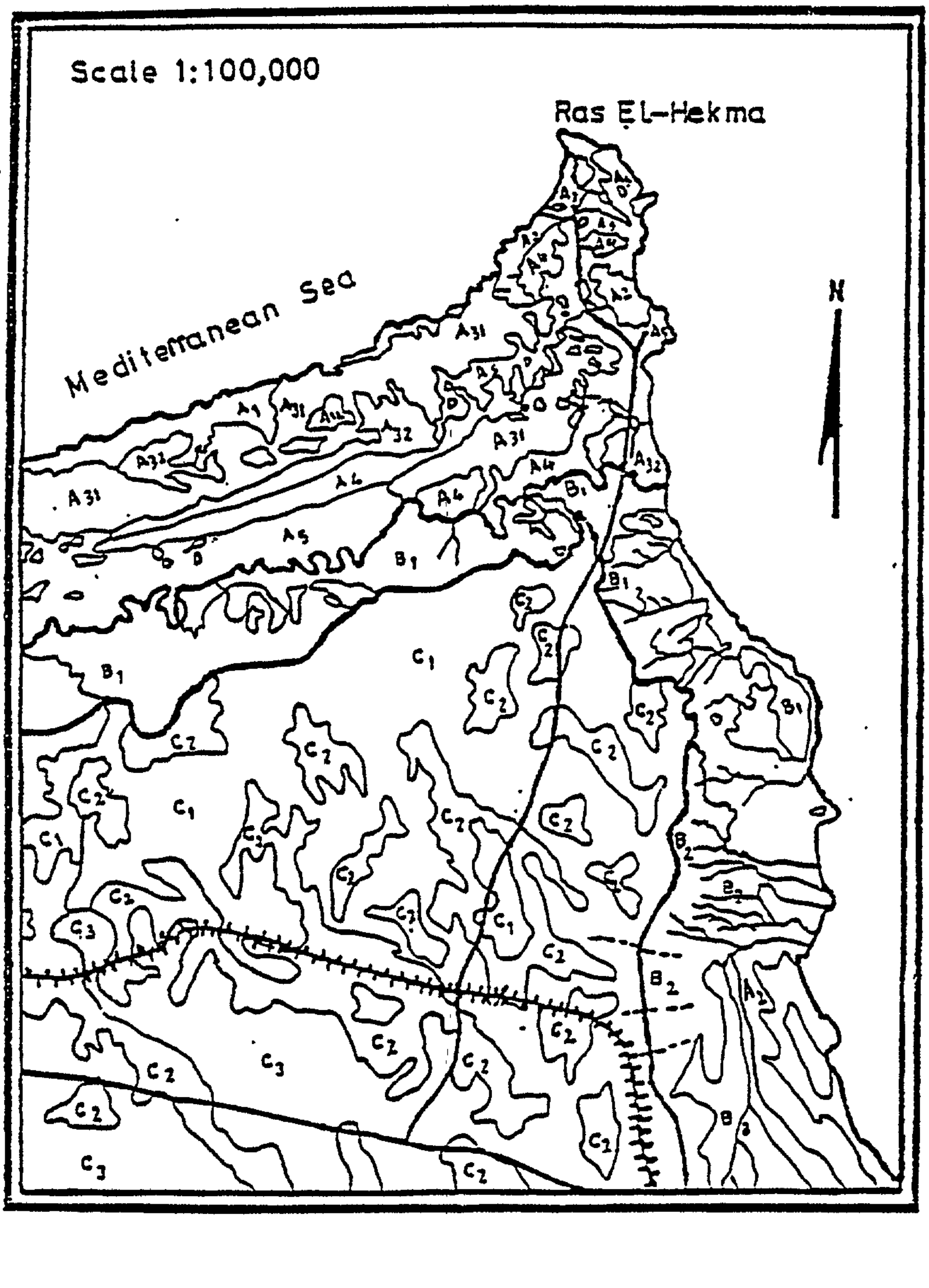


Figure 25 - Physiographic zones in the vicinity of Ras El-Hekma
A - recent coastal zone
B - northern plateau
C - southern plateau

2.2.1.7 Sediment Resources

Regarding the origin of the carbonate sediments of the north-western coastal area, the precipitation of carbonate is the first step in the formation of all limestones. Usually, the calcium carbonate in sediments can be divided into two types: primary or secondary. The primary calcium carbonate almost always occurs as calcareous parent sediments and shows influence as a sediment-forming factor. The secondary calcium carbonate is a product of diagenesis, which depends upon environmental conditions. The chemical precipitation of calcium carbonates *in situ* during evaporation of strong calcium-bicarbonate solutions has also been proposed. The limiting factors in the depth of carbonate accumulations are the parent sediments, permeability, texture, structure and climatic conditions.

Lime accumulation displays different forms, such as concretions, threads, indurated nodules, patches, pebbles and boulders of different shapes and sizes. Lime may also exist as coating on sediment grains or may bind them together by acting as a cementing material.

In addition, wind-blown dust and sand from the surrounding desert may also have settled in the coastal regions and contributed to such deposits.

The shallow depressions that separate the ridges from one another show a successive lowering in surface elevation towards the Mediterranean Sea. These depressions are filled with lagoonal-sabkha deposits consisting of alternating layers of gypsum and fossiliferous, gypseous marl and are covered with loessic sediment. Gypsum is being extracted from some old lagoonal-sabkha depressions. Much of the area of the depression between the second and third ridges is occupied by Lake Maryout (west of Alexandria). The outer sabkha forms an almost wet flat area that has an elevation of about 1m above present mean sea level. The surface sediments of the sabkha consist of loessic sediment rich in calcium carbonate, particularly near the carbonate ridges from which it receives a supply of wind-blown carbonate grains.

2.2.1.8 Loessic Sediments

Loessic sediment is defined as silt of a very special character. It is unconsolidated, porous and commonly buff in colour (locally yellow to brown). The most characteristic feature is the lack of stratification and a remarkable ability to stand in a vertical slope. It is generally highly calcareous. The loess is found to be thick in the depressions between older ridges and near the flanks of the ridges. It is also found on the top of the ridges and interfingers with the carbonate sediment of the ridges. Loessic sediment is also found to separate the various units of the cemented æolian limestone. It appears that the loess has been deposited by dust storms which blew from the adjacent deserts to the south. The source of the sediment may be composite (Hassouba, 1980); it is probably mainly derived from the alluvial plain of the Nile delta to the south-west. Intermixed with this material is surface wash from the carbonate ridges and the remains of pulverised terrestrial snails which live on the surface of the ridges and depressions. The sediment beneath the loess is very rich in gypsum which appears to have been deposited by the evaporation of water from the adjacent sea.

2.2.1.9 Wadi Sediments

The northern plateau represents one of the major topographic features of the region. The northern edge of the plateau, or tableland, is of Miocene limestone and forms an escarpment running mainly east to west and rising 50-75m above the piedmont plain (Pleistocene and recent sediments). The plateau is dissected by consequent streams that flow northwards to the sea. These streams are mostly dry at the present time. About 35 wadis are located within a strip of about 4-6km from the shoreline.

Wadi sediments south and south-east of Matrouh have been investigated (Table 8). The Nagamish, Garawla, Kasaba and Hashim wadis represent alluvial fans at the foot of the plateau. Their sediments are friable and mainly composed of clay, silt, limestone and shales. Boulders, alternating with clay strata, are found in some wadis. The mean grain size of wadi sediment ranges between 0.11mm and 0.17mm. These sediments are fine, very fine and poorly sorted. The calcium carbonate content is fairly uniform and ranges between 10 and 24%. A decreasing trend in the oolite content, from the coastal ridge to the inland ones, has been recorded and may be attributed to leaching, recrystallisation and diagenesis.

Table 8 - Mean grain size and carbonate content of some samples from the Fuka-Matrouh plain

Sample no.	Location	Mean Size ϕ	Mean Size mm	Carbonate %	Sorting Θ
1	Wadi Nagamish (a)	3.15	0.110	10	0.95
2	Wadi Nagamish (b)	8.00	0.004	-	1.80
3	Wadi Garawla	3.10	0.120	15	1.53
4	Wadi Kasaba	2.60	0.170	24	1.25
5	Wadi Hashim	3.05	0.120	21	1.31
6	Beach, Baqqush	1.60	0.330	95	1.14
7	Backshore, Baqqush	1.85	0.280	95	0.52
8	Dune, Baqqush	1.70	0.310	96	0.50
9	Beach, Matrouh	1.95	0.260	77	0.51
10	Beach, Ageba	1.70	0.310	98	0.50
11	Dune, Fuka	1.32	0.400	96	0.60
12	Dune, east Fuka	1.55	0.340	98	0.54
13	Dune, south Fuka	2.70	0.155	97	0.43

ϕ is grain size expressed as $-\log_2$(grain size in mm); the sorting factor, Θ, is based on the diameters 5ϕ, 16ϕ, 84ϕ and 95ϕ in the cumulative frequency surve of the grain size distribution expressed in terms of the standard deviation, in ϕ units, and is calculated as:

$$\Theta = 0.25\{\phi 84 - \phi 16\} + \{\phi 95 - \phi 5\}/6.6$$

2.2.1.10 Offshore and Coastal Environments

The coastal plain extends from the shoreline southwards as far as the piedmont plain, or as the plateau, when the piedmont plain is absent. Its width is narrow to the west and wide to the east. The coast includes a number of open bays: Kanayis Gulf (Ras El-Hekma Gulf) along the eastern side of Ras El-Hekma and Abu Hashaifa Bay on the eastern side of Matrouh, with numerous bays separated by points in between (Figs. 26 and 27). The headlands and bays seem to be related to some regional structural pattern. The bays are underlain by synclinical areas, resulting in a wide coastal plain, and the headlands, by monoclines where the plain is narrow.

Matrouh inlet is completely sheltered by reefs. A fishing harbour is situated at the eastern end of the inlet. East of Matrouh, the coast is rocky and fronted by reefs that form closed chains of salt

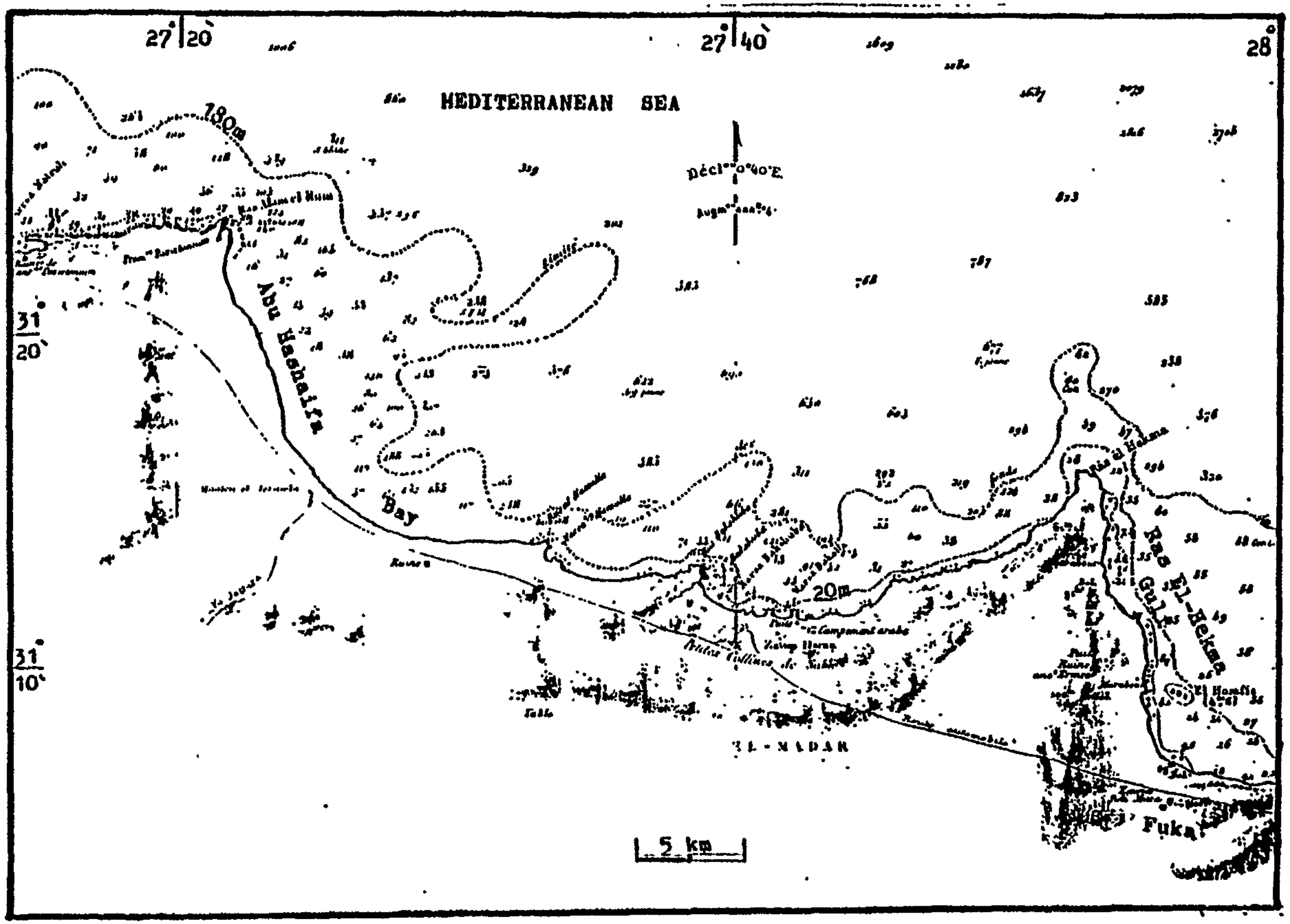
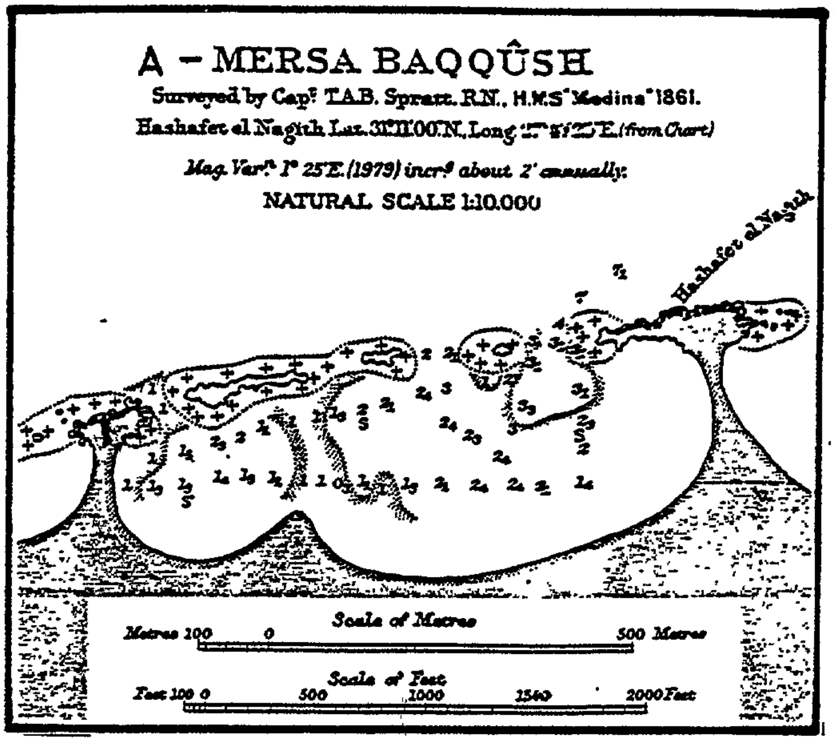


Figure 26 - Shoreline features and bathymetry of the Fuka-Matrouh area



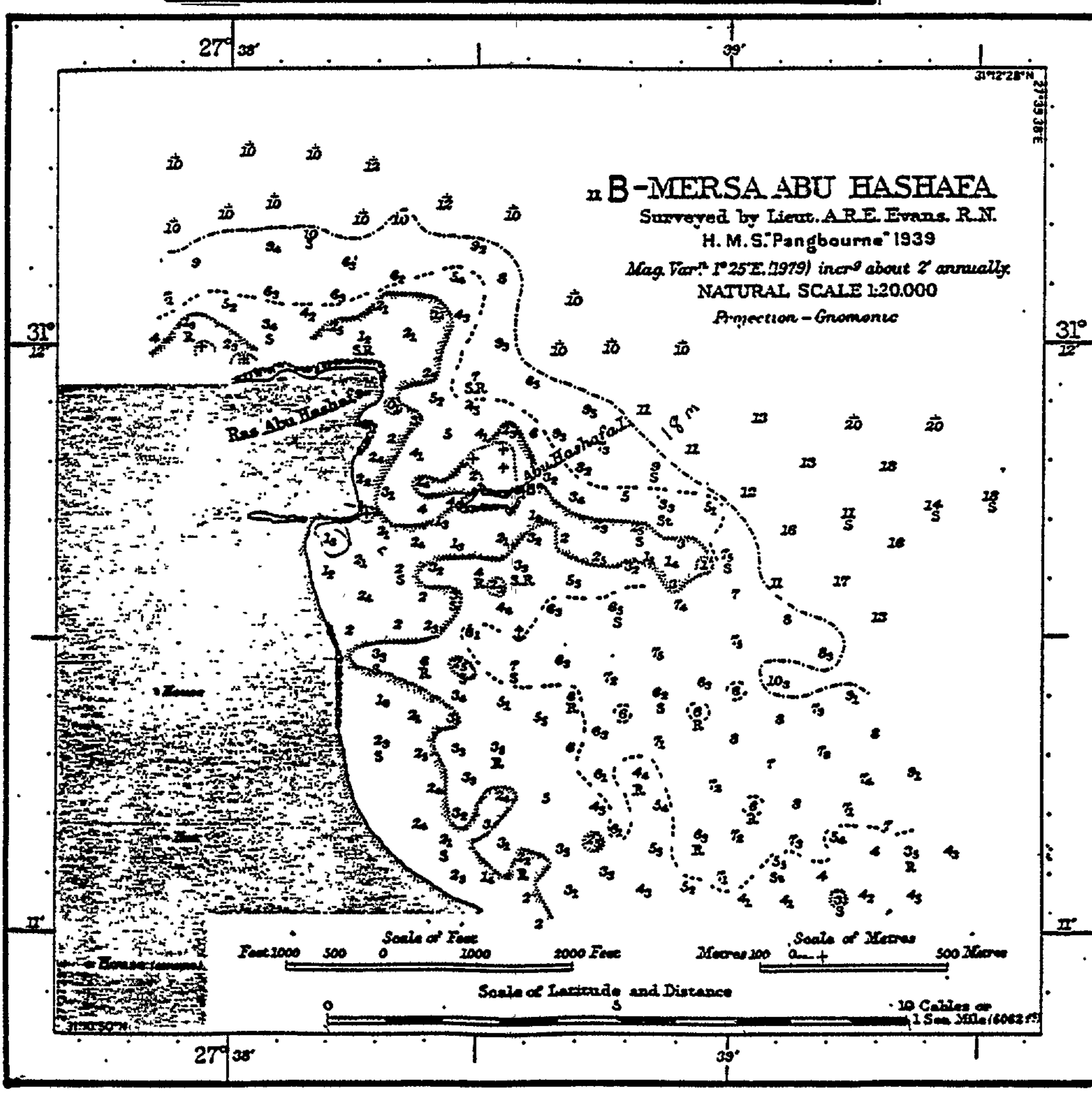


Figure 27 - Mersa Baqqush beach (A) and Mersa Bakshuba (B) (depth values are in fathoms(feet))

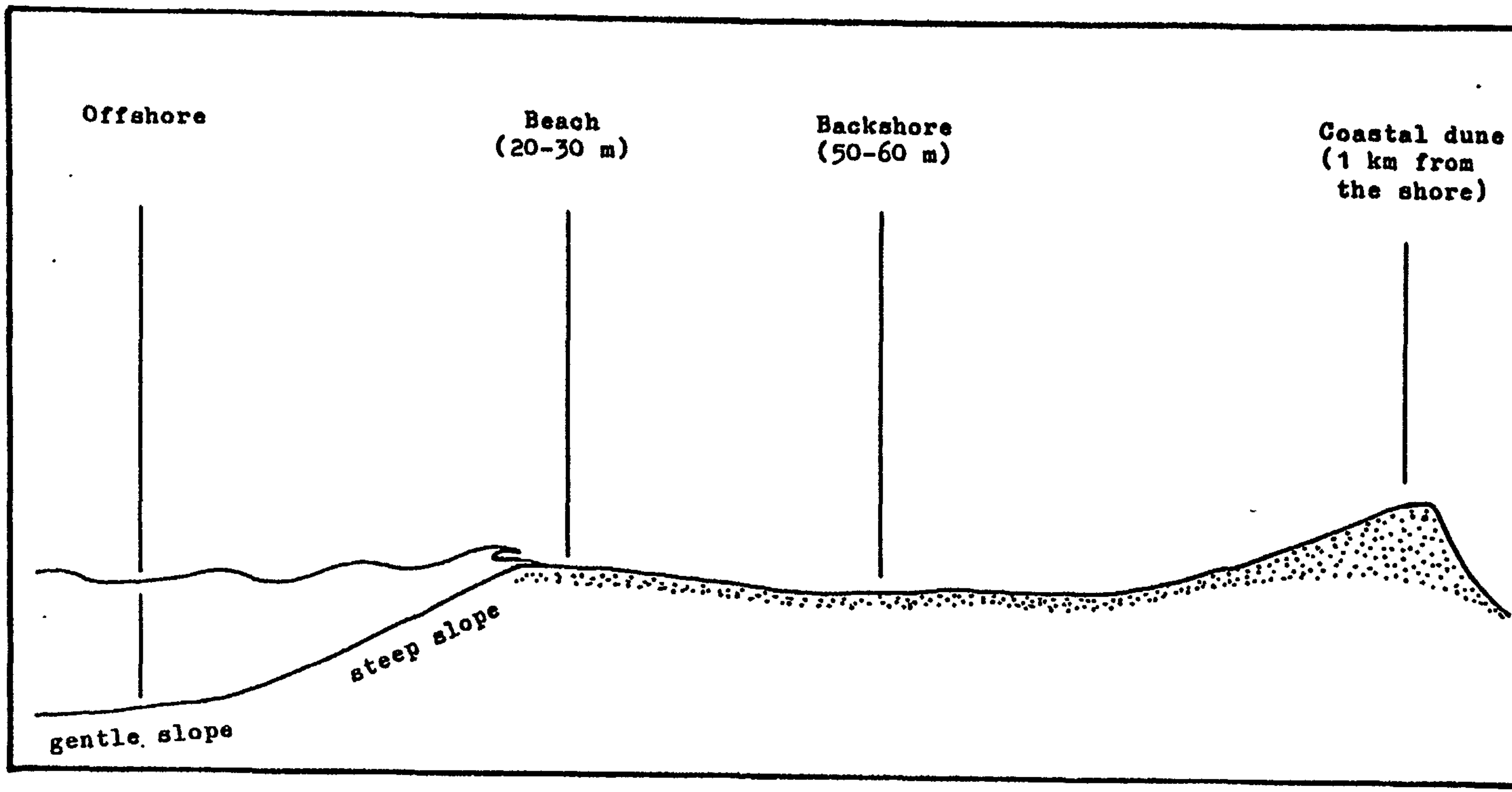


Figure 28 - Schematic diagram showing the coastal environments in the Baqqush area

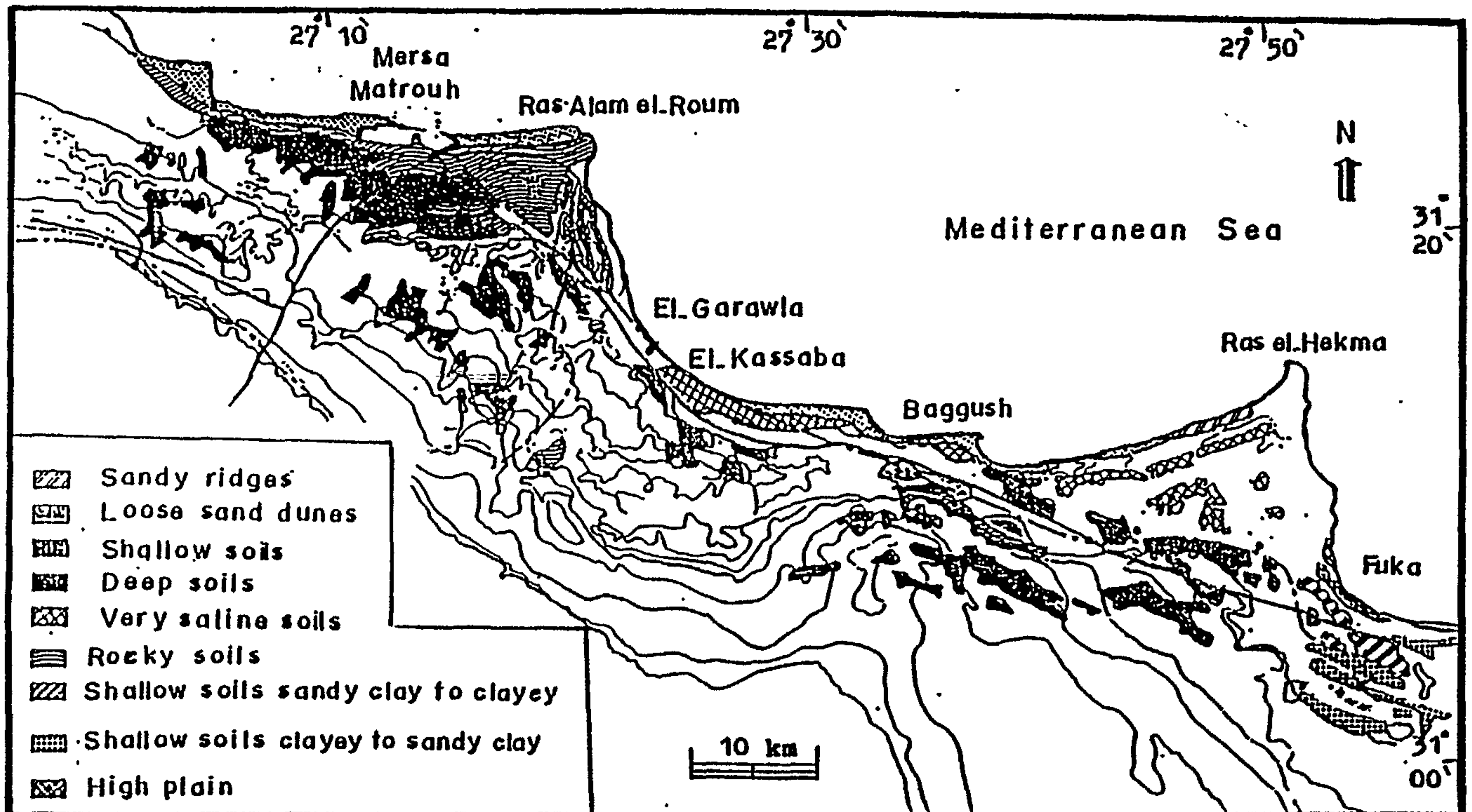


Figure 29 - Coastal and inland zones in the Fuka-Matrouh area

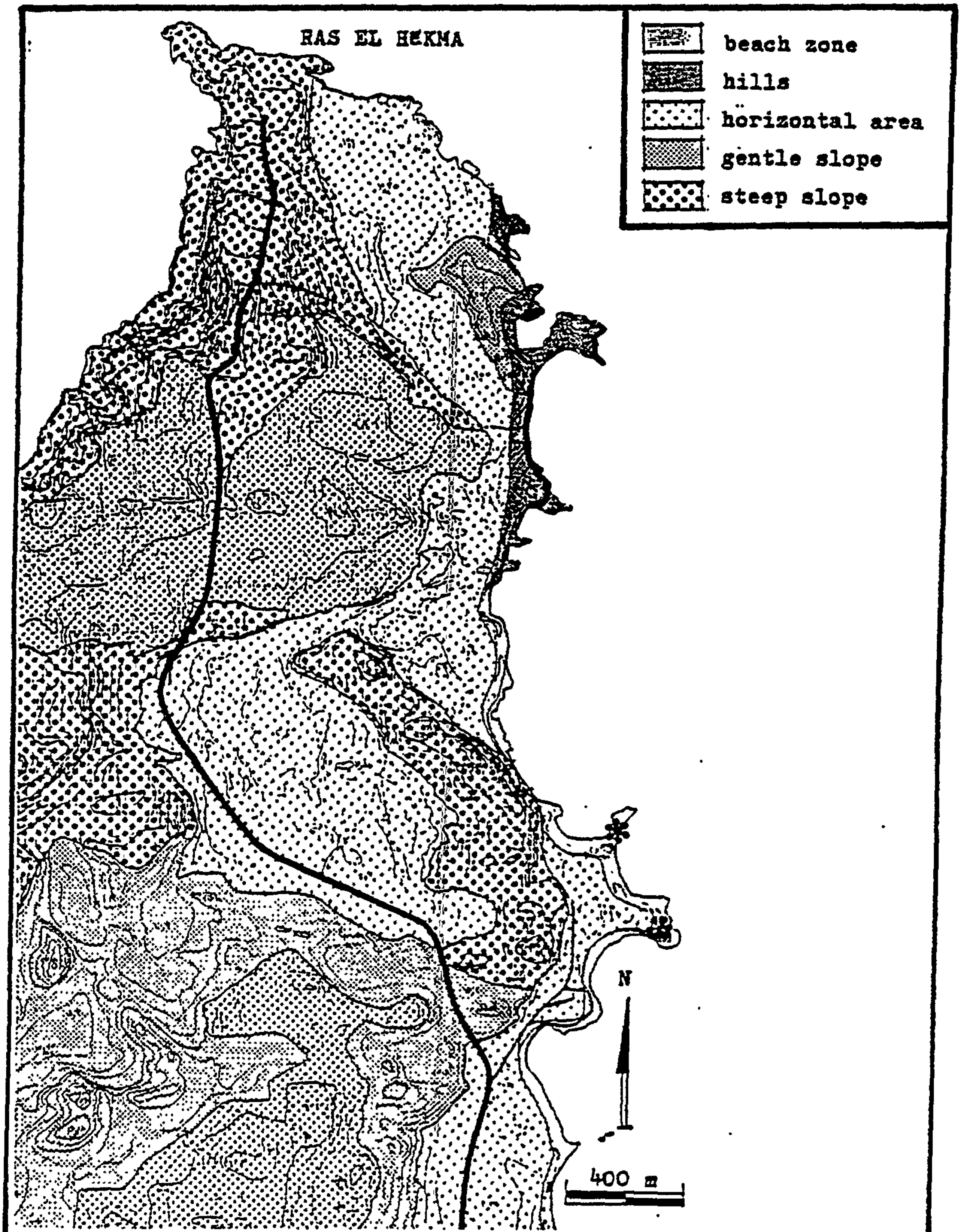


Figure 30 - Coastal environments in the Ras El-Hekma area

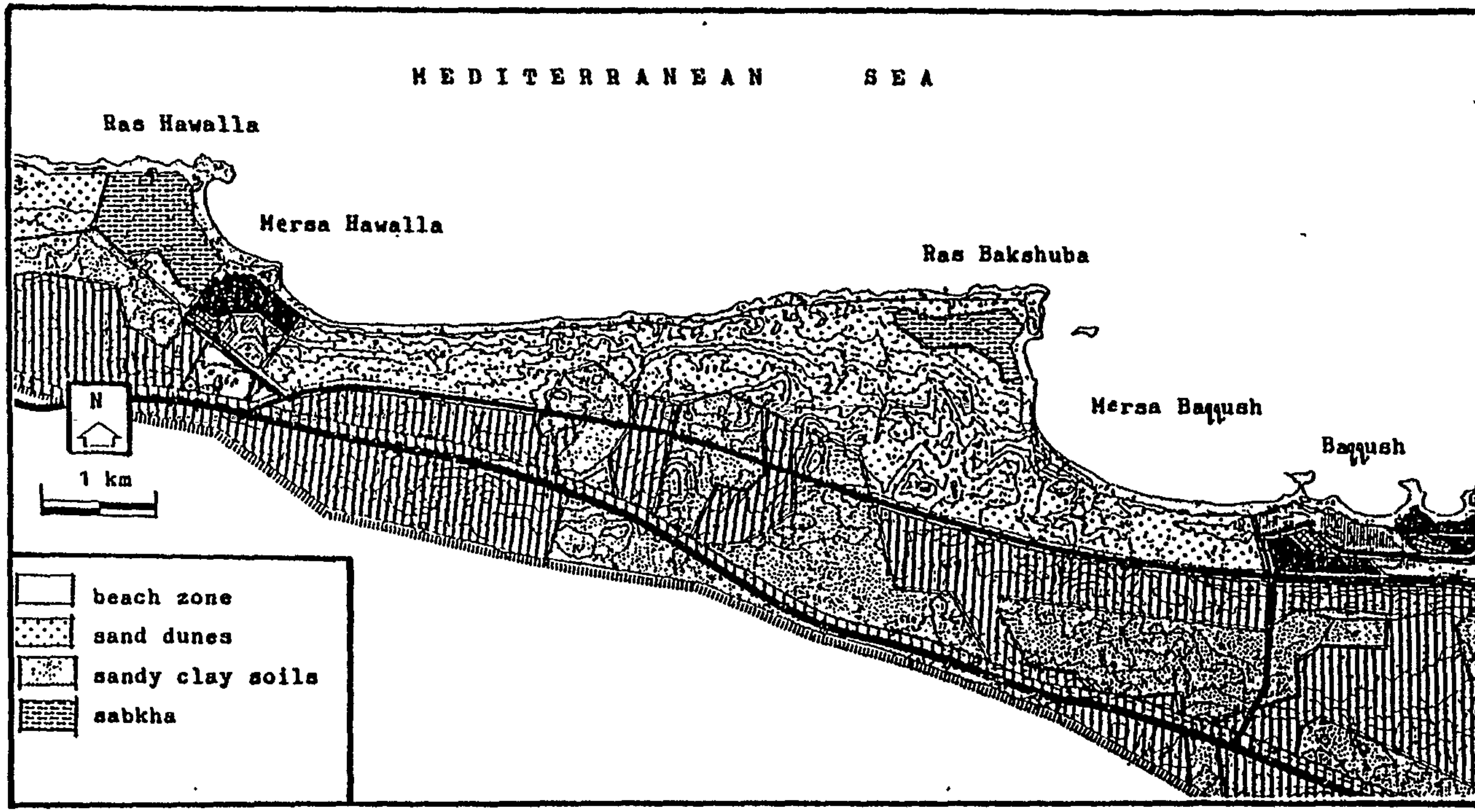


Figure 31 - Coastal plain at Ras El-Hawalla, Ras Bakshuba and Baqqush

lagoons. Between Ras Alam El-Roum and Ras El-Hekma, the coast is indented by several sandy bays bounded inland by sand dunes.

The coastal plain could be subdivided into five environments according to the geomorphology and the nature of sediments (Figs. 28 and 29, Table 8). Generally, all the coastal environments are normally sharply distinguished and extend in a strip up and down the length of the coast, with change in width. In fact, the loss of some environments in some places would disturb such a system. The Baqqush area is an ideal example; here, all coastal environments are well developed. Figures 30-31 show the nature of the coastal environments along the coasts of Ras El-Hekma and Baqqush.

Coastal Dunes

The recent coastal dunes (white dunes) are located at the far end of the backshore flat and surrounding the beach. Most of these dunes are of the barchan type with elevations up to 5m above their base level. The distance between these dunes and the shoreline may exceed 100m. They are observed to develop well, without vegetation, along the Baqqush coast within a strip of about 1km width. The coastal dune sediments are friable and mainly composed of oolitic limestone grains (96% carbonate content). They are characterised by a mean grain size of 0.31mm and the grains are well sorted (Table 8). The sediments at the top of the coastal dunes are finer and better sorted than those at the foot of the dunes.

Landwards, the old coastal æolian sediments are cemented oolitic-skeletal grainstone with rounded and well sorted grains. They occur as horizons that are lense-shaped and separated from one another by 2m-thick layers of loesses which increase in thickness towards the flanks of the dunes. Sedimentary structures in these cemented deposits range between gently dipping, cross bedding and planar stratifications, which helps confirm their æolian origin.

Backshore

The back of the beach is a 50-60m-wide strip of flat area, referred to as the backshore. It may be absent in some places. This zone is influenced by wind action. On it, there are occasional areas of low foredunes with heights less than 1m. Low parts of the backshore are flooded during winter storms and may therefore tend to subside slightly. The sediments of the backshore are of medium grain size (0 28mm) and well sorted by wind action. Carbonate constitutes the main part (95 %) of the backshore sediments.

Beach

The beach is the zone of unconsolidated sediments that extends from the low-water level to the place where there is a change in physiographic form and grain size. It is normally exposed to the action of waves and littoral currents. The beach is flat and averages about 20-30m in width on the Baqqush coast. Some beaches along the coast may be entirely submerged during heavy storms. On the western coasts, the beach is closely bordered by a wave-cut cliff about 100m high. Beach face slopes vary greatly, between a few degrees and 15 degrees.

The shoreline has two types of beaches:

- Erosional beaches

  Beaches subjected to erosion are mostly associated with the headlands and points that lie in an approximately north-south direction. In these cases, the beach may be very narrow or missing and the beach zone is characterised by wave-cut platforms and cliffs. The steep slope of the beach face causes waves to break close to the beach, which results in hazardous conditions. Therefore, the beach face slope of erosional beaches is relatively steep. Erosion at Beausite Hotel, Matrouh, and at Sidi Abdel-Rahman indicates one of the coastal problems mainly due to Man's interference in the coastal zone.

- Accretional beaches

  Accretion beaches characterise the sheltered parts of the shoreline lying in an approximately east-west direction; i.e., away from the effect of the prevailing wind and wave action. The foreshore averages 5-15m in width. Beach cusps (the wavy shoreline) are developed; the microcusps have an average length (crest to crest) of 10-100m and an amplitude (height of the crest above the trough) of 5-25cm. Megacusps are observed but they are fewer. Most cusps are usually asymmetrical, with underwater bar extensions. These cusps tend to move laterally eastwards with a mean longshore movement of about 15cm per day. Matrouh beach may be considered to be a cuspate beach with an average cusp length and amplitude of 10m and 5cm, respectively. Inside Matrouh, the velocity of the littoral current affecting the coast ranges between 16cm/s and 20cm/s.

The Alexandria coasts show minor erosion, of 20cm per year in the long term. The north-western coast is considered to be in equilibrium when there is a balance between loss and gain of material; when this balance is established, the coast is said to be a stable coast.

The beach sediments are made of white oolitic, pseudo-oolitic calcareous grains and biotic debris without any contamination by mineral typical of the recent Nile (Hilmy, 1951). They are derived mostly from the Pleistocene oolitic inland ridges bordering the coast. Aragonite and, to a lesser extent, magnesium-calcite are the constituent minerals of these carbonate grains. The carbonate content of beach sediments ranges between 77 and 98%. The selective addition of terrigenous materials such as wind-blown quartz grains from the western desert may play a role in producing the variations in carbonate content along the coast.

The mean grain size of beach sediments ranges between 0.26mm and 0.33mm (Table 8). Most of the beach grains vary in diameter between 0.063mm and 1.00mm. The beach sediments tend to be well sorted. The Matrouh beach has finer grains than the Baqqush beach. The mean grain size of beach sediments on the Matrouh coast was compared for two series of samples collected in 1951 and 1993. A mean size of 0.26mm for each of the series was found, whereas the carbonate content decreased slightly between the two reference years.

Old storm-beach deposits are found on the æolinite unit on the northern side of the coastal ridges (Hassouba, 1980). These deposits consist of piles of beach boulders with different heights (13 to 15m). Each boulder is in the form of a triaxial ellipsoid which has a long axis of 50-150cm and a short axis of 10-30cm. These boulders are composed of cemented, bored and oolitic-skeletal grainstone.

Barrier Islands

Barrier islands occur on some parts of the coasts of Fuka, Ras El-Hekma and Matrouh. They are usually narrow strips of detrital sediments which form beach/dune complexes rising above sea level and extending for a considerable distance parallel to the coast. These barriers may be isolated or separated from the coast by a lagoon. Most of the Holocene barrier islands bordering the present coasts are thought to have been formed during the Flandarian transgression. The origin of such islands may be related to:

- Submerged offshore bars which, when the sea retreats, emerge and a lagoon develops behind them which becomes cut off from the sea.

- Drowning of beach ridges; the topographic ridge is formed along the upper edge of the beach by wind or wave action or by a combination of them. Successive ridges could have formed during regression of the sea to form a series of beach ridges. In the succeeding stages of marine transgression, the area landward of the ridges would be flooded to form a lagoon behind the drowned ridges, which would then become a barrier island.

Offshore

The part of the beach profile that extends seawards is comparatively flat and may extend for about 10km from the shore, depending on its slope. The nearshore and beach face slope are relatively steep. On the western coast, the beach face and offshore slopes are found to be 1:3-1:10 and 1:20-1:90, respectively. The bathymetry of the Fuka-Matrouh area (Fig. 26) indicates that the offshore slope in front of Ras El-Hekma is steeper than that around Ras Alam El-Roum. Comparison of the different surveys shows that erosion starts in deep water and then approaches the shoreline. Such a type of erosion may be due to temporary seasonal conditions.

Most of the oolitic grains in the offshore sediments vary in diameter from 0.063mm to 1.19mm with a mean grain size of 0.30mm. In general, values of mean size tend to decrease seawards. The coastal area is characterised by the absence of a surf zone which can be confirmed by the disappearance of a breaker zone (coarse-grained sand parallel to the shoreline). The offshore sediments west of Alexandria show a tendency to be slightly coarser, the mean grain size ranging from 0.14mm to 0.71mm, with an average of 0.33mm.

The distribution of offshore sediments in Arab's Bay, east of Fuka, is very complicated (Anwar *et al.*, 1984). The finest fractions on the beach lie inshore of the coarser grains of the offshore sediments, as observed on the eastern and western sides of the bay. On the other hand, the finest fractions of the central part of the bay are found landwards of the coarsest fractions of the beach.

The adjacent beach sediments along the Fuka-Matrouh coastline are better sorted than those offshore. This may be attributed to the sorting by waves and currents affecting the beach. The winds, especially in winter, may also have a role in sorting of beach sediments. Hence, the occurrence of a higher content of coarse sand grains and biotic fractions in offshore sediments means that they are less well sorted than the beach sediments.

The carbonate content of the offshore sediments is extremely high, ranging between 90 and 98% Other non-carbonate components, such as quartz, are found in small amounts, constituting 2-10%. The higher content of true oolites in the beach and offshore sediments relative to that of the Pleistocene coastal ridges may indicate that the beach and offshore oolitic sediments are not only reworked from the coastal ridges but also that there are oolitic grains on the top of the continental shelf. These oolitic grains are younger in age, probably of early Holocene age, and have had the opportunity to be more and better developed than those derived from the inland ridges.

2.2.1.11 Dynamic Forces Affecting the Coast

The dynamic forces that affect the processes that shape the coastal ridges and dunes of the north-west coast are the winds, whereas those affecting the beach and offshore area are the waves and currents and, to a lesser extent, those factors due to winds, tides, salinity and temperature. These primary agents cause transportation and deposition of the coastal sediments, hence change in the coastal processes. Tides and their seasonal variations are also essential in any investigation of the dynamic forces and coastal processes affecting the coast. These forces may be summarised as follows:

Waves

The height and direction of the waves are affected by refraction, dissipation of energy and breaking during their propagation into shallow water near the coast. The effect depends highly on the local bathymetry which may allow only a limited window of directions to reach a certain location. The

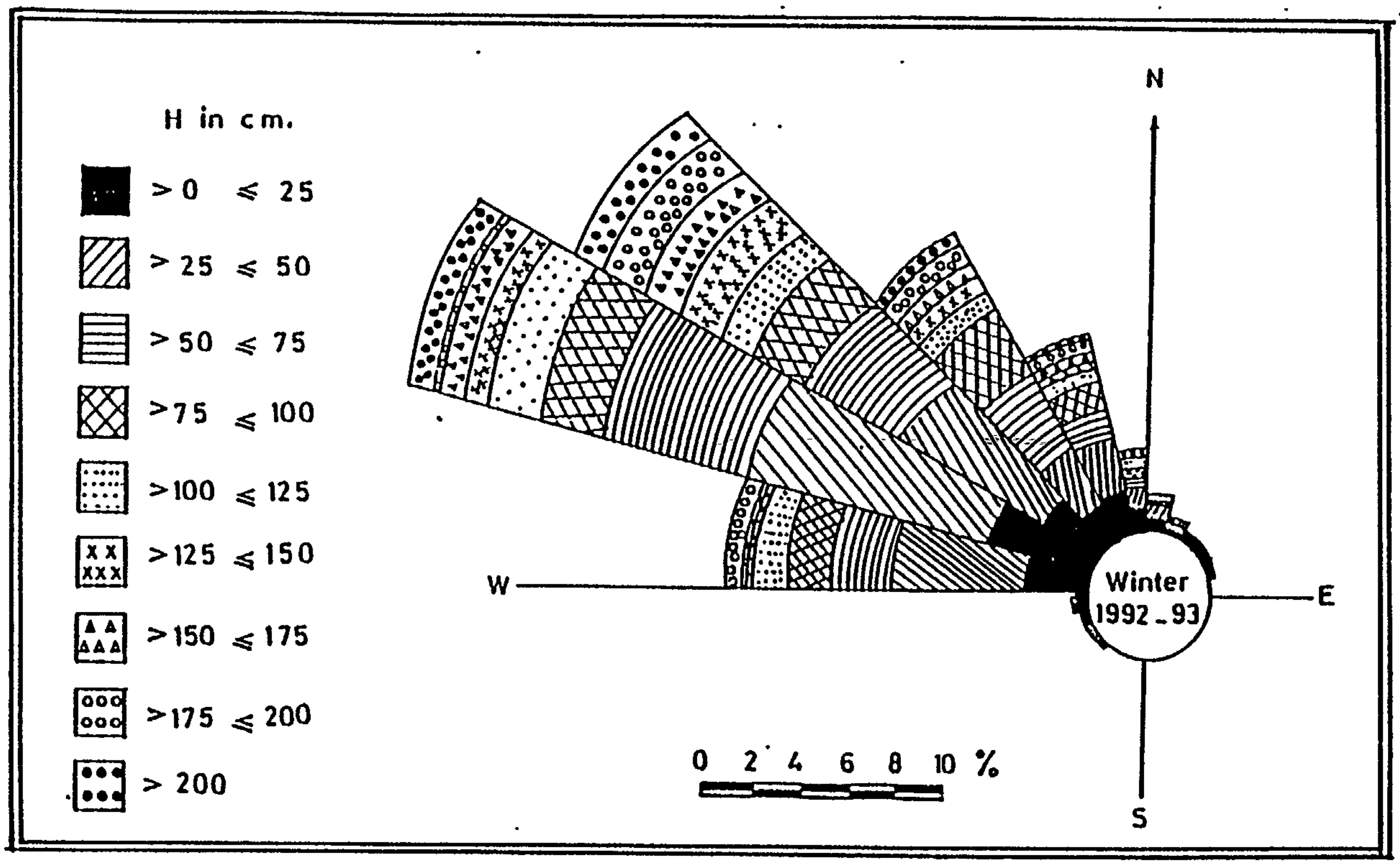


Figure 32 - Wave rose for the area outside El-Dikheila harbour, west of Alexandria
(source: Institute of Coastal Research, 1993)

directional distribution of the wave energy along the coast generally leads to a clockwise rotation of the local dominant wave direction. This causes a resultant eastward longshore direction in the propagation of the wave energy along the coasts.

Available data from the west of Alexandria (Fig. 32) show that the predominant waves approach from the north-west (Institute of Coastal Research, 1993). The following summarizes the wave characteristics:

- maximum wave height :250cm
- average wave height :74cm
- average wave period :6.8sLittoral Currents

Littoral Currents

Littoral currents play an effective role in sediment transport along the coast. The gradient current dominates the surface circulation along the north-western coast and not the drift current, as might be expected (Gerges, 1976). The computed velocity of the total surface current off the Fuka-Matrouh coast ranges between 11cm/s and 15cm/s eastwards. On the other hand, the bottom current velocity decreases noticeably down to 100m depth, to values of 3-5cm/s westwards. A rip current usually occurs along the western coast. At Arab's Bay, there is a predominant eastward current which is disrupted by a rip current (Wobber, 1967). Along the coast west of Alexandria, westward and eastward currents were recorded with an average velocity of 27-31cm/s.

There are three main factors affecting water movement in the Mediterranean Sea:

- the horizontal gradient determined by the difference in level between the Mediterranean Sea and the Atlantic Ocean; this fact accounts for the entry of Atlantic water into the Mediterranean in the upper layer, resulting in a stable eastward current which can be clearly traced along the northern shoreline of Africa, including that of Egypt;

- the horizontal pressure gradient due to the water density difference between the eastern and western basins of the Mediterranean results in a discharge of Mediterranean water into the Atlantic Ocean at depth;

- the tangential tension due to the wind; the prevalence of north-westerly winds over the Mediterranean Sea during the greater part of the year enhances the constant eastward water movement (Al-Kholy and El-Wakeel, 1975).

The estimated surface-current velocity in the Fuka-Matrouh area ranges from 9.26cm/s to 13.5cm/s in the summer, declining to 4.45cm/s in the autumn, sharply increasing in winter, owing to the strong wind, to 23.14cm/s, declining again in the spring, owing to the calm weather, to 8.4cm/s (Anon., 1983a).

The surface current in the Mediterranean Sea is cyclonic, owing to the effect of the Coriolis force (Al-Kholy and El-Wakeel, 1975). In the Fuka-Matrouh area, a coastward surface current of 9.26cm/s, in summer, and 23.14cm/s, in winter, prevails (Anon., 1983a).

There are several gyres in the Mediterranean Sea, one being located in the south-eastern part. During the warm season of the year, the water movement in the area of this gyre is cyclonic, the bearings of the central part being 25-27°E (i.e., adjacent to Matrouh). In winter, the currents change to the opposite direction and the speeds increase. The centre of the anticyclonic gyre is displaced eastwards to 30°E (i.e., eastwards to Fuka; Ovchinnikov, 1965 and 1966 in Al-Kholy and El-Wakeel, 1975). Between the shore and the said gyres there is an eastward water movement.

Tides

Tidal variations have a pronounced role in delineating the shoreline and in determining wave characteristics and breaking point, currents and bar formation. To a limited extent, the tides influence the sediment movement along the coast by shifting the level of attack of the wave action and by governing the flow in lagoons.

Tide-gauge records from Alexandria, covering a long period, are available. Analysis of the tidal records indicates that the tides are semi-diurnal, with two high- and two low-water levels in a tidal cycle, with comparatively little diurnal inequality.

Long-term analysis of tidal variations indicates that the curves of the monthly mean sea level have two minima and two maxima. The major maximum occurs in August (60cm), whereas the minor maximum occurs in December (54cm). The major minimum occurs in April (37cm) whereas the minor minimum occurs in October (46cm). The tidal range, 26cm, is considered to be small.

Storm surges during winter and swell action during summer (Manohar, 1976) may increase the water level considerably and hence accelerate erosion along the coasts (El-Fishawi and Khafagy, 1991).

2.2.1.12 *Measurement of Sediment Transport*

To analyse change in beach geometry, to study coastal accretion and erosion, and to develop predictive models, precise measurement of the sediment transport rate is required. Fluorescent sand-tracer tracking, littoral-current measurements, and the use of traps, as methods of estimating drift rate, have been applied in some parts of the western coast.

Fluorescent tracers with the desired characteristics, such as a particular grain size, were used in tracer experiments along the coast west of Alexandria. The tracer techniques give an average total drift rate for a given geographical area. The Ingle (1966) technique depends on the rate at which the tracer grains leave the relevant sample grid. Thus, it is able to compute the sediment drift rate according to the equations (1) to (4):

- $t_{50} = \frac{1}{2}G/D_e$ (1)
- $U_g = l/t_{50}$ (2)
- $V = K.W.B.$ (3)
- $Q_l = V.U_g.1440$ (4)

where: t_{50} = time (minutes) required for one half of the tracer grains to leave the sample grid, G = number of tracer grains released, D_e = average depletion rate (grain loss per minute), U_g = average grain velocity (m/min), l = distance (m) travelled by a tracer grain, V = unit volume (m^3), K = constant beach length of 1m, W = width (m) of the foreshore-backshore zone, B = thickness (m) of the mobile bed layer, Q_l = sediment drift rate (m^3 per day)..

The results of the tracer-sand experiments indicate that the sediment-grain velocity ranged between 0.4m/min and 1.2m/min, with an average velocity of 0.90m/min. Thus, the mean grain velocity was approximately 1/22 of the mean littoral current velocity (33cm/s) measured during the experiments. In fact, these velocities did not reflect the actual maximum velocities of some individual grains (which may exceed 55cm/s). It is likely that the bulk of the sediment load travels along the western coast at a much slower rate. The relatively low grain velocities suggest that most grains are travelling in traction, within the mobile bed layer, rather than in suspension. The thickness of this bed layer ranged between 1.0cm and 2.1cm. Along the western coast of Alexandria, the sediment drift rate was estimated to be 10,000-25,000m^3 per month. In Arab's Bay, the drift rate was found to be 4,200-8,300m^3 per month (Danish International Development Agency, 1991). The dispersion of sediments is directed eastwards, westwards and offshore, owing to the effect of the rip currents. As a comparison, the estimated drift rates along the western coast of Alexandria and Arab's Bay are relatively much lower than those along the Nile delta coast (50,000-300,000m^3 per month).

The sediment drift rate off the Fuka-Matrouh coast was computed from measured longshore currents and waves (Fig. 33). In ordinary conditions, the current velocity ranges between 11cm/s and 15cm/s, with an average wave height of 30cm. On the other hand, vigorous sea states reflect faster current velocities, which may reach 50cm/s, and wave heights of 70cm. Thus, by applying the empirical equation of Komar (1990), the littoral drift rate is obtained from equation (5):

- $Q_s = 0.026\ (Hb)^2\ V$ (5)

where: Q_s = littoral drift rate, Hb = wave height, and V = longshore current velocity.

The resultant eastward littoral drift between Matrouh and Fuka was predicted to be 700-900m^3 per month in ordinary conditions and 17,000m^3 per month in vigorous conditions. These rates are still much lower than those found along the coast west of Alexandria. Therefore, the main conclusion is that the sediment drift rate increases slightly from the Matrouh-Fuka coastal area to the coast west of Alexandria and attains its maximum value on the Nile delta coast. Such a phenomenon may help to explain the relative stability of the north-western coast.

Sediment transport by wind was determined by using sand traps on the backshore side of Marakia coast, which extends westwards of Alexandria (Institute of Coastal Research, 1993). The net accumulated volume of wind-blown sediments was predicted to be 340m^3 per month. The wind is very effective in the Fuka area, usually causing movement and migration of sand dunes. Accumulations of wind-blown sand are found covering the railway and roads, thus disturbing transportation.

2.2.2 Soils

The soils in the area are almost all alluvial soils (here, for the sake of convenience, rock-land is not considered to be soil). They are mainly sedimented by water action (alluvial material of the fans and out-wash plains) but, in some areas, by wind (coastal dunes and inland dunes). Probably, sub-surface, layers of the limited deep alluvial fans on the Miocene plateau are formed *in situ* and therefore are partly derived directly from the limestone bedrock. Water-flow zones are illustrated in Figure 34.

The absence of gravel and sand layers in the alluvial deposits throughout the area is striking. Even the alluvial fans at the mouth of the big wadis do not contain considerable quantities of coarse material. Because alluvial soil in the area is directly or indirectly derived from limestone, it is rich in calcium carbonate. The three main geomorphic units in the north-south direction (the coastal plain, the piedmont-like plain and the structural plateau) are usually associated with distinct soil types (Fig. 35) as follows:

- coastal plain: this includes soil of the lower and upper coastal plain ridges, inland dunes, rocky ridges and depressions between plain and ridges;
- piedmont-like plain: this is the tableland plateau and transitional zone and includes soils of wadis and fans and wash plains;
- structural plateau: this consists of the southern rocky tableland and its escarpment.

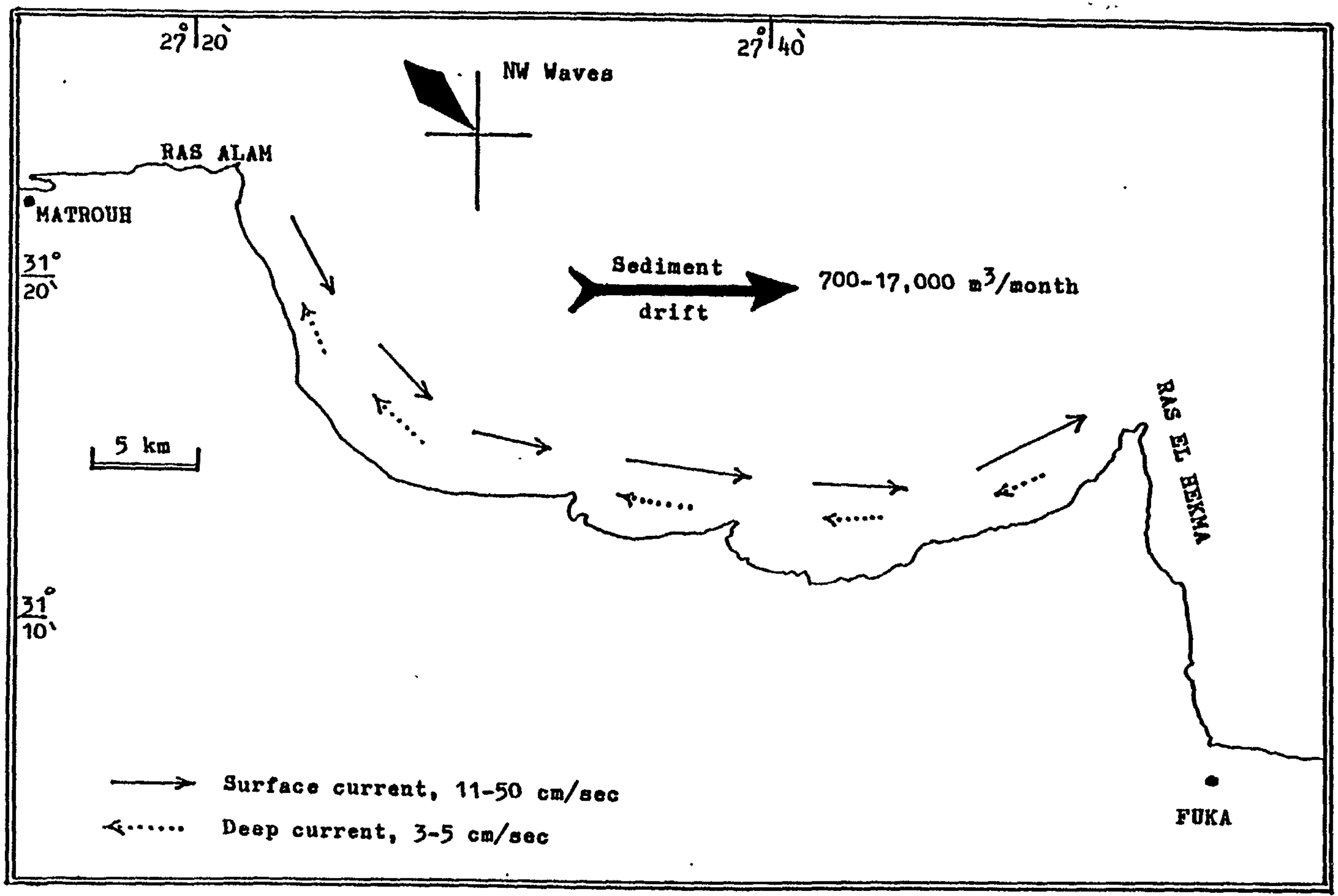


Figure 33 - Dynamic forces and resultant sediment drift rate along the Fuka-Matrouh coast

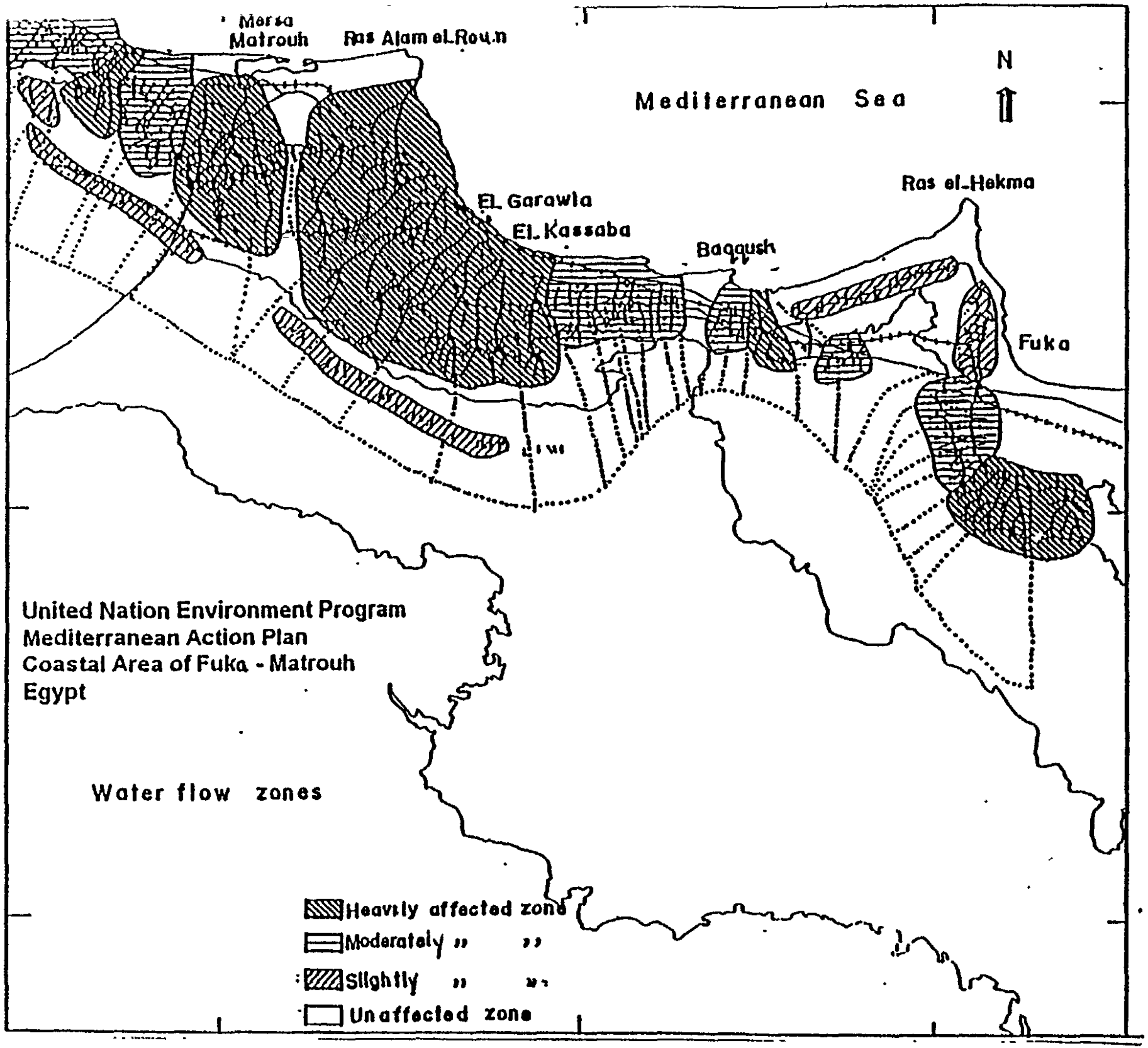


Figure 34 - Water-flow zones in the Fuka-Matrouh area

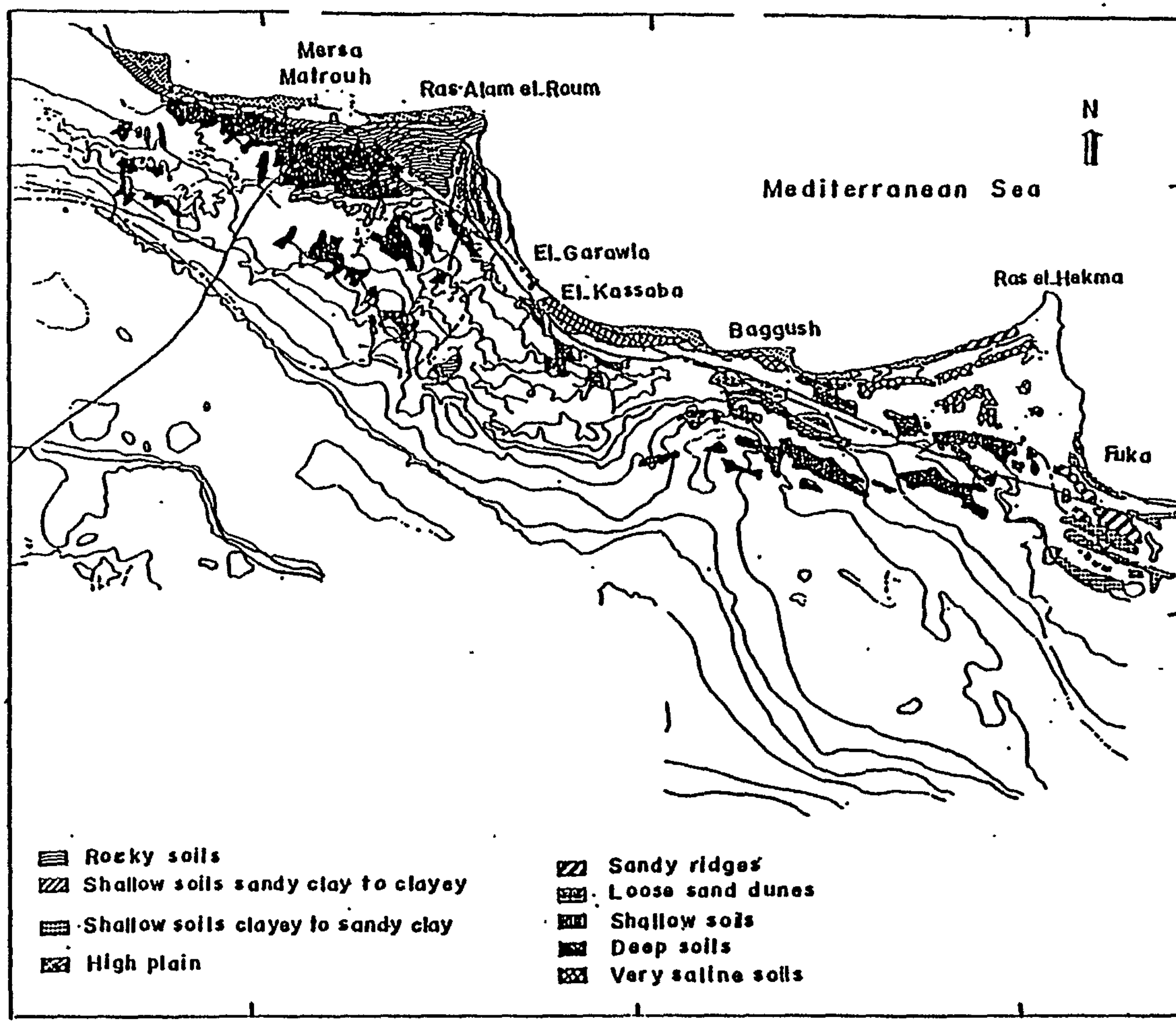


Figure 35 - Soil types in the Fuka-Matrouh area

According to the supplement to the 7th approximation of the American system of soil classification, the mapping units of reconnaissance maps (FAO, 1970, sheets III, IV) of the area can be classified to the sub-group level, as follows:

Do coastal dunes:
- Do1 Typic Torripsamment
- Do2 Typic Torripsamment
- Do4 Typic Torripsamment

DS inland dunes:
- DS1 Typic Torripsamment
- DS4 Calsy Torripsamment
- DS5 Calsy Torripsamment
- DS6 Typic Torripsamment

B soils in the former beach plain and dune depressions:
- B1 Typic Torriorthent
- B3 Typic Calci/paleorthid
- B4 Typic Calci/paleorthid
- Bp Typic Salorthid

F soils of the alluvial fans and out-wash plains:
- F1 Typic Torriorthent
- F3 Typic Torriorthent
- F4 Typic Calci/paleorthid

W soils of the wadis:
- Wb Typic Torriorthent
- Ww Typic Torriorthent

Main Characteristics of the Mapping Units Present in the Study Area and Their Suitability

Table 9 summarises the main characteristics of the mapping units that are present in the area and their agricultural potentiality. The distribution of potentiality classes for different map units is illustrated in Table 10. Figure 36 gives a soil-suitability map. The suitability for agriculture and the distribution of different potentiality classes are presented in Table 11. Some physical and chemical properties of soils distinguished in the studied area are presented in Table 12.

Table 9 - Summary of main characteristics of the mapping units of the reconnaissance survey

Mapping unit	Depth of soil in cm	Main texture	Permeability	Topography	Agricultural potential	Remarks
Do_1	-	Oolitic sand	Moderately rapid to rapid	Irregular	Locally suitable only for figs	Shifting dunes
Do_2	-	Cemented and colitic sand	Slow	Irregular	Not suitable	Cemented dunes
Do_4	> 50	ls to l in depressions	Moderate in the soils	Irregular	Not suitable and moderately suitable	Cemented dunes with depressions
Ds_1	-	s to ls	Moderately rapid to moderate	Irregular	Not suitable	Low dunes
Ds_4	-	s to sl	Moderately rapid to moderately slow	Rather level	Not suitable	Shallow over rock
Ds_5	ca 60	ls to sl	Moderate to moderately slow	Level	Suitable for vegetables, field crops and moderately deep-rooted crops	
Ds_6	-	s	Rapid to moderately rapid	Rather level	Not suitable	Shallow over rock
B_1	> 90	sl to l or cl	Moderate to moderately slow	Level	Suitable for all crops	Locally in depressions surrounded by rockland
B_3	30-90	sl to l or cl	Moderate to moderately slow	Level to nearly level	Suitable for moderately deep-rooted crops, locally for shallow-rooted crops only	
B_4	30-90	ls to slightly ls	Moderate to moderately rapid	Sloping and gullied	Suitable for moderately deep-rooted crops, locally for shallow-rooted crops only	
F_1	30-60	sl to l	Moderate	Nearly level to slightly sloping	Suitable for vegetables, field crops and other shallow-rooted crops	Locally with gravels
F_4	30-90	sl to l	Moderate	Slightly sloping to gently sloping	Predominantly not suitable	Most soils are saline; locally gravels
Wb	> 90	sl to l	Moderate	Slightly sloping	Suitable for all crops	Terracing is needed; risk of damage by run-off water
Ww	> 90	sl to l	Moderate	Nearly level to slightly sloping	Suitable for all crops	

N.B. All mapping units of the miscellaneous land types consist of rockland with less than 30 cm soil. They are not suitable for agriculture but have value as range land.

Table 10 - Summary of the potentiality classes of the reconnaissance maps and the mapping units in each class

Potentiality class		Mapping units	
Code	Brief description	Sheet III	Sheet IV
I	Suitable for all crops	B_1, F_3, Wb, Ww	B_1, B_2, P_1, F_3, Wb
IIa	Suitable for moderately deep-rooted crops		F_2
IIb	Like IIa, but locally suitable only for shallow-rooted crops	B_3, F_4	
III	Suitable only for shallow-rooted crops	Ds_5, F_1	F_1, F_4
IVa	Locally suitable only for figs	Do_1	Do_1
IVb	Locally suitable only for shallow-rooted crops		Fie
Va	Not suitable - rocky	Do_2, Ds_4, Rp, Rh, Rr, Rs, Rf, Rd, Rdg, Rde, Rt	Do_2, Do_3, Rp, Rh, Rr, Rs, Rg, Rf, Rd
Vb	Not suitable - very saline	Bp	Bp, Pp
Vc	Not suitable - inland dunes	Ds_1	Ds_1
Va/I	Complex of class Va and class I	C_2	C_2
Va/IIa	Complex of Va/IIa		Do_4
Va/IIb	Complex of class Va and class IIb	C_1	
Va/Vc	Complex of class Va and class Vc		C_3

Table 11 - Summary of the potentiality classes of the reconnaissance maps, their areas and a rough estimation of the saline soils in each class

Potentiality class		Sheet III		Sheet IV	
Code	Brief description	Feddan	%	Feddan	%
I	Suitable for all crops	67.600	13.07	11.675	1.82
IIa	Suitable for moderately deep- rooted crops			2.200	0.34
IIb	Like IIa, but locally suitable only for shallow-rooted crops	6.425	1.24		
III	Suitable for only shallow- rooted crops	15.350	2 97	67.125	10.45
IVa	Locally suitable only for figs	1.425	0.28	2.850	0.44
IVb	Locally suitable only for shallow-rooted crops			6.025	0.94
Va	Not suitable - rocky	400.675	77.47	529.850	82.47
Vb	Not suitable - very saline	1.200	0.23	6.475	1.01
Vc	Not suitable - inland dunes	2.975	0.58	600	0.09
Va/I	Complex of class Va and class I	11.775	2.28	5.450	0.93
Va/IIb	Complex of class Va and class IIb	9.750	1.89		
Va/III/IIa	Complex of class Va, class III and class IIa			9.225	1.44
Va/Vc	Complex of class Va and Vc			475	0.07
	TOTAL *	517.175	100.01	641.950	100.00

* water excluded

Table 12 - Physical and chemical properties of soils distinguished on the reconnaissance soil map

No.	Area	Mapping unit	Depth (cm)	Physical properties		Mechanical composition			Texture	EC mm Hos/cm	$CaCO_3$ %	pH	Chemical analysis						
													Cations				Anions		
				% cm/hour	field capacity	clay	silt	sand					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}
1	Matrouh	Do_1	0-30							1.0	86.9								
			30-60							1.7	98.8								
			60-120							1.9	97 9								
2	Matrouh	Do_2	surface	5.7	19.5	0 5	0.5	99.0	s.	2.7	80.4		4.8	5.7	15 0	0.7	12.6	0.3	5.6
13	Fuka	B_1	0-25	5 7	12	9	21	70	s.l.	2.7	11.2		7.7	6.2	12	0.8	22	4.0	1.9
			25-60	6.6	12 5	16	18	66	s.l.	1.4	23.1		7.9	10.2	3	1.1	7.5	2.7	2.8
			60-90	3.2	13.5	28	28	44	l.	2.4	21		10.7	10.7	9	1.0	19	2.2	10.0
			90-120	1.2	14	34	24	42	c.l.	0.7	21.4		3.0	3.4	24	0.4	6	2.1	1.7
?	Fuka	Bp	0-40	-	17.0	21	30	49	l.	60	32.3		215.0	244	492	1.5	946.2	3.5	1.2
			40-80	-	19.5	29	36	35	cl.l	64	27.9		198.3	293.3	360	1.2	1031.0	2.7	-
			80-120	-	19.5	32	34	34	cl.l	69	20 2		202 0	198 9	440	1.2	1075.8	2.7	-
20	?	F_2	0-20	1 6	13.5	11	24	65	s.l.	0.8	16		4.2	2 6	3.5	0.3	6.1	0.2	4.3
			20-60	2.9	14.5	14	33	63	s.l.	1.0	24		3.5	1.5	6.5	0.3	8.1	0.2	3.5
			60-??	0 9	18.0	24	45	31	l.	21	26		5.0	4.4	12.1	0.7	18.2	0.2	3.8
21	Baqqush	F_3	0-15	2 9	16	11	26	62	s.l.	11.25	24.9		9.8	11.8	29.7	4.5	140.7	0.3	13.1
			15-30	4.8	15.5	9	??	54	s.l.	21.5	26.2		14.9	10.5	72.5	6.5	179.7	0.3	24.3
			30-100	1.1	16	10	??	49	l.	0.9	42.2		3.8	0.3	4.4	0.5	6.7	0.3	1.9
			100-130	2.0	17.5	9	53	38	sil	11.0	40.1		25.8	16.9	57.5	1.1	86.6	0.2	14.5
22	Baqqush	Wb	0-20	7 4	13.2	6	15	79	l.s.	0.6	34		5.5	1.3	2.3	0.8	2.0	4.3	3.5
			20-60	3 4	12.5	8	13	79	l.s.	0.8	28		4.3	4.7	3.4	5.1	4.9	4.1	5.1
			60-120	2.8	13.5	23	26	51	s.cl	0.7	18		3.2	3.5	3.4	6.7	3.1	3.7	4.1
23	Fuka	Ww	0-30		13 5	20	41	39	l.	1.4	26.8		6.9	4.6	4.9	1.2	13.5	0.3	2.3
			30-60		17.5	21	43	36	s.l.	1.6	36.8		7.1	3.9	5.7	0.9	10.6	0.3	6.5

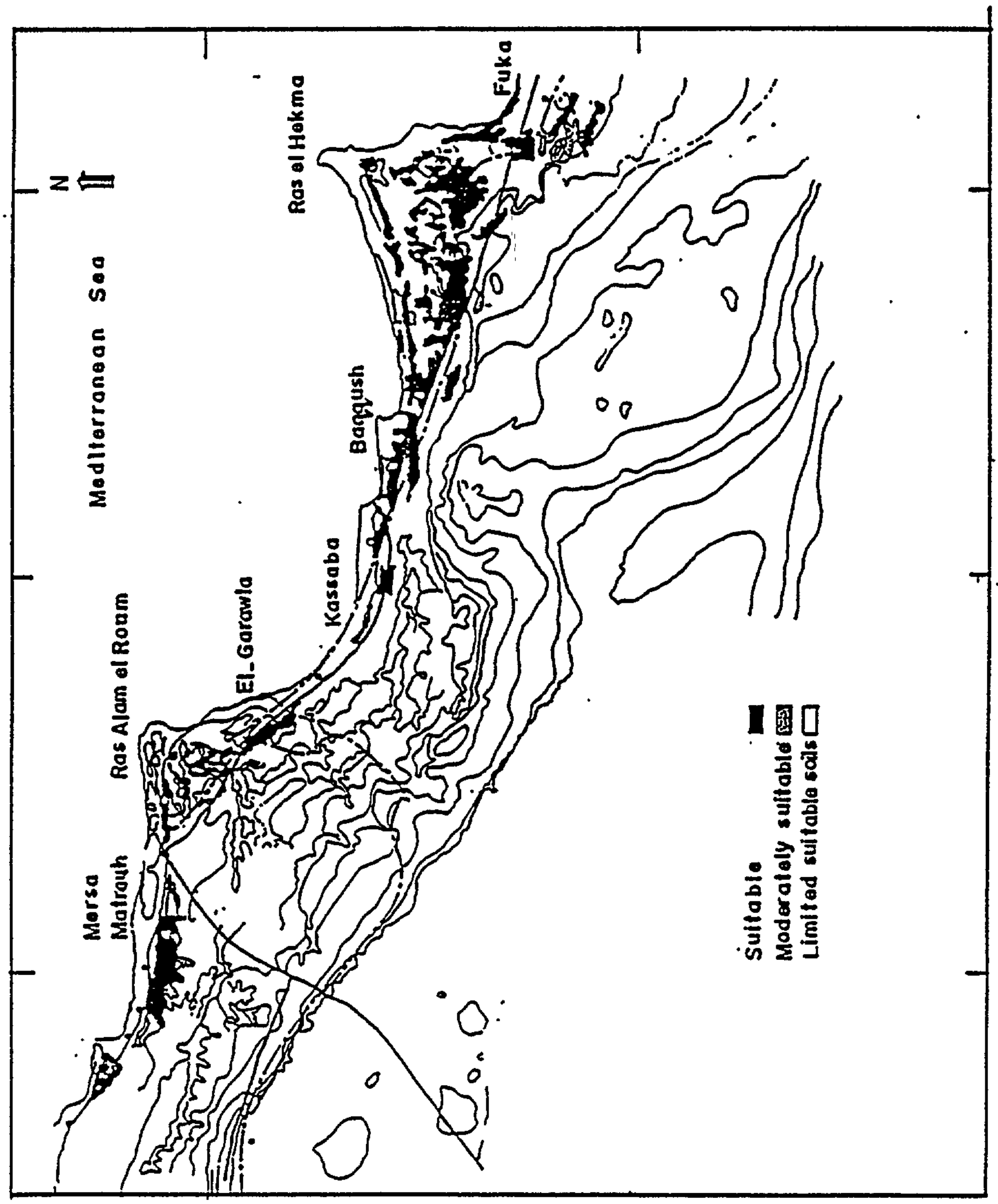


Figure 36 - Soil suitability in the Fuka-Matrouh area

2.3 HYDROSPHERE

2.3.1 Introduction

The hydrology of the study area is determined by climatic conditions, geography and geology. Rainfall is the main source of fresh water in the area. Normally, rainfall in the area is relatively higher than in other areas in Egypt. The mean monthly and annual rainfall, as well as the maximum recorded amount in one storm, are given in Tables 13 and 14.

Table 13 - Mean monthly and annual rainfall (mm)

Station	J	F	M	A	M	J	J	A	S	O	N	D	Total
Ras El-Hekma	42.9	9.8	11.6	5.7	0.9	0.1	-	-	3.3	14.8	20.8	37	147
Matrouh	33.2	15.1	12	2.8	2.6	2.0	-	0.6	1.1	15.6	22.5	30.2	138

Table 14 - Maximum rainfall recorded in one day

Station	Period of records	Maximum rainfall (mm/day)
Ras El-Hekma	1962-1975	72.4 (10/12/1964)
Matrouh	1947-1975	75.5 (22/11/1947)

Most of the rain falls during winter (mid-October to mid-March) and decreases southwards. The hydrography of the study area is characterised by a considerable number of wadis (35) in a hydrographic network (Fig. 37). Some of these wadis are important and highly ramified in this area (Wadi Nagamish, Wadi Zarga and Wadi Kassaba). Since the annual rainfall is low, these wadis carry less water than those west of Matrouh. The high cliff of Baqqush, which rises sharply some 4-5km inland has been intersected by a certain number of wadis, four of which reach the Baqqush plain. Wadis of the area between Ras El-Hekma and Fuka are of medium size and run from west to east. Some of them are well ramified but carry very little water, since the area receives, in general, less rainfall. The zones that may be affected by overland flow in the study area are illustrated in Figure 34. The main components in the water balance of the study area are rainfall, as the only input, and evaporation, run-off (sheet run-off and wadi run-off), recharging of ground water and change in soil moisture storage, as outputs. Ground water is limited in the study area. Some is exploited in some places, as Fuka, Burbeta and Ras El-Hekma.

2.3.2 Surface Water

As mentioned in the pre-investment study of the north-western coast of Egypt (FAO, 1970) and in the Land Master Plan (1986), the hydrological survey indicated that 35 wadis of different sizes of catchment area are present in the study area (Table 15).

Wadi kilo 9 is one of the wadis in the study area. Table 16 shows the results of the hydrological investigation that was carried out on this wadi in the pre-investment study of Egypt (FAO, 1970).

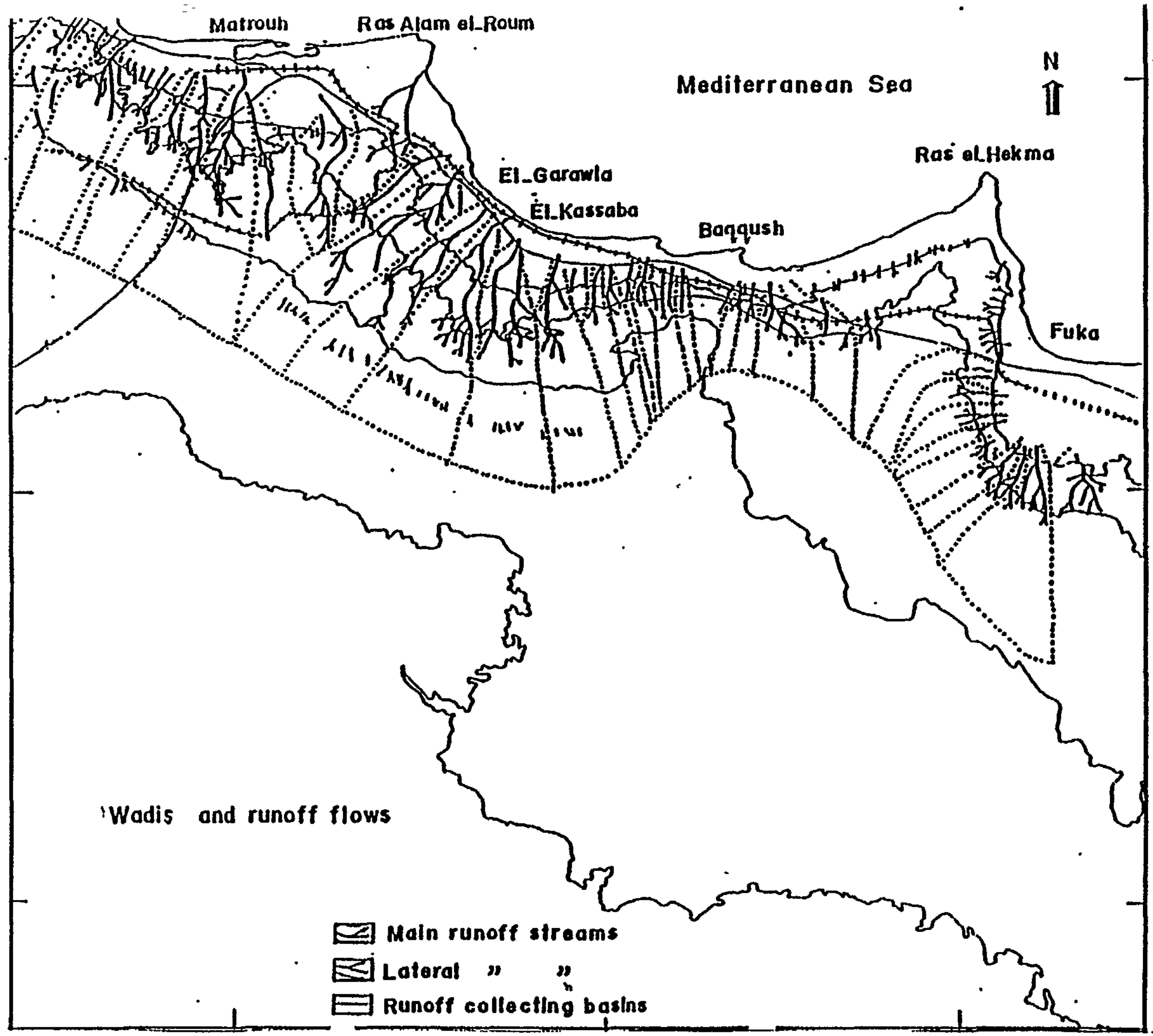


Figure 37 - Wadis and run-off channels in the Fuka-Matrouh area

Table 15 - Size, number and distribution of wadis in the study area

Location	Size of catchment area (km^2)								
	5	5-10	10-20	20-30	30-40	40-60	50-100	100	No. of wadis
East of Matrouh/Ras El-Hekma	3	1	7	4	3	1	2	3	24
Ras El-Hekma/Fuka	2	-	2	4	1	-	-	2	11
Total	5	1	9	8	4	1	2	5	35

Table 16 - Data on a representative wadi

Name of wadi	kilo 9
Location	Ras El-Hekma
Size of catchment area (km^2)	4.25
Average slope	0.035
Total length (km)	2.0
Total annual run-off (m^3)	
(a) Freq. 0.5	15,000
(b) Freq. 0.6-0.7	10,000
Specific run-off (m^3/km^2)	
(a) Freq. 0.5	3,500
(b) Freq. 0.6-0.7	2,300

The records in Table 16 are based on rainfall-runoff correlations in a representative wadi. Surface water, as sheet run-off or wadi run-off, is the main source of water in the area for irrigation and drinking water for animals and people. It is exploited by storage sheet run-off in underground reservoirs (cisterns), either Roman cisterns or recently excavated cisterns/reservoirs. They are generally excavated in rock and are lined with cement, and water can flow into them from the surrounding area. In the study area, there are 2,749 cisterns with a capacity of 778,382m^3 to collect run-off water for domestic use and the irrigation of an area of 6,768 feddan. There are numerous earth, stone and cemented dykes in the study area to distribute and use wadi run-off water. Thirty two million cubic metres per year of sheet run-off and about 1.5 million cubic metres per year of wadi run-off could be used; at present, 2.8 million cubic metres per year are intercepted and stored in the study area. According to the records of the North-West Coastal Zone Authority for Development and Rehabilitation, 432 cemented dykes, with a total capacity of 53,448m^3, were built to collect and distribute water for the irrigation of 1,188 feddan of orchard; 22 earth dykes, with a total capacity of 321,184m^3, were built to collect and distribute water for the irrigation of 2,361 feddan; and 2,692 stone dykes, with a total capacity of 218,807m^3, were built to irrigate 4,862 feddan of orchard.

2.3.3 Ground Water

2.3 3.1 Introduction

Ground water in the study area occurs in the primary openings of the dune deposits, in alluvial material and older limestone, and in the secondary openings in the limestone and consolidated dune deposits. Ground water exists in the above-mentioned water-bearing formations under a free water table and semi-confined conditions. Suitable ground water for agricultural and domestic uses *occurs in relatively shallow non-artesian aquifers or in small shallow, semi-confined aquifers with a low* artesian pressure. The ground water in rocks belongs to the Cretaceous-to-Miocene age and is in relatively large quantities of non-usable quality, from brackish to highly saline. The free ground water in the coastal plain occurs in Miocene, Pliocene, Pleistocene and recent deposits which outcrop from the land surface and which are recharged directly by rainfall and by the infiltration of surface run-off. These non-artesian ground waters in the coastal plain can be found in the main water table, the coastal-dune water table and the semi-confined water table of the Fuka synclinal basin.

2.3.3.2 Main Water Table

The main-water-table aquifer is composed of alluvial silt and sand. The surface of the water table is only about 1m above sea level (12km south of the coastline). The relatively low water-table gradient implies a very slow movement of ground water towards the sea. Recharge of the main water table is through direct infiltration of rain water and of surface run-off; and, near the coast, ground water is recharged through water ponds formed after heavy rains. The maximum thickness is about 10m and safe yields are therefore low. The quality of water is, however, generally good (1,000ppm TDS). The fresher water floats on more-saline water and its thickness is related to the level of recharge of the aquifer and to the height of the water-table level above mean sea level. Near the coast, the fresh-water layer is generally thicker because the water table is near the surface and receives substantial amounts of recharge water. Yields of wells tapping the main water table are generally adequate to justify a windmill, if water quality is satisfactory. Excessive pumping causes rapid deterioration in the water quality. According to the last survey of wells in the area, which was carried out in December 1993 by the North-West Coastal Zone Authority for Development and Rehabilitation, the number is 243 wells, drawing water with a maximum salinity of 5.87 and a minimum of 3.20.

2.3.3.3 Coastal-Dune Ground Water

This free-ground-water aquifer is found in beach sediments. In the study area, the dunes are prominent and very well developed to about 40km west of Matrouh. Recharge occurs through infiltration of rainfall, through lateral seepage of surface run-off behind the dunes, through seepage of ponded surface water (often salt marshes) and through sub-surface drainage. Where the dunes are well developed and receive substantial recharge, the water quality is very good (1,000 ppm TDS). The position of the water table in the dunes is related to the balance between recharge and discharge, to the topography and to the hydraulic properties of the dunes. The ground water is a fresh-water lens floating above saline (marine) water. In the areas where there is less recharge or more discharge, the water level may be only a few centimetres above sea level. Discharge of water from the dunes occurs through collection galleries and wells.

Extensive gallery systems were developed during World War II in the Baqqush-Burberta area. These galleries were reported to have produced 290m^3 per day, without overpumping. Unfortunately, these gallery systems have been allowed to deteriorate.

As mentioned in the general summary prepared by the North-West Coastal Zone Authority for Development and Rehabilitation, the length of the galleries in the study area is 1,960m. The ground water in this system is used to irrigate an area of 196 feddan.

2.3.3.4 Semi-confined Synclinal-Basin Ground Water

In Fuka, the Mid-Miocene interbedded limestone and clay have been folded into a gently synclinal basin. The succession in the intrusion consists of the following beds:

- an upper clay bed	16-18m thick
- an upper limestone bed	12-20m thick
- a lower clay bed	5-8m thick
- a lower limestone bed	6m thick (base not reached)

The ground water is in the upper limestone bed. The lower clay bed separates this water from the underlying main water table at sea level. The base of the upper limestone bed contacts the top of the underlying clay bed at a level between -1.8m and +3m relative to mean sea level. The water is less saline (2.00) and the water table is between 13m and 14m below the ground surface. ELACO (1976) suggested that 2,000m^3 per day could be continuously withdrawn without seriously depleting the aquifer storage. Six pumping wells are in operation in the area (Fuka) for domestic and agricultural purposes.

2.3.4 Other Water Resources

2.3.4.1 Introduction

The other water resources are mainly for domestic use (Fig. 38). These resources are the pipelines carrying fresh drinking water to Matrouh and to different villages (Bedouin and tourist) along the coast, and the fresh water from desalination stations, and treated sewage water.

2.3.4.2 Pipelines

Two pipelines carry fresh drinking water from Alexandria to Matrouh. The old pipeline of 300mm diameter was the old fresh-water supply, with a capacity of 5,000m^3 per day, but now, because of the establishment of a number of distributive branches along the northern coast, the amount of water reaching Matrouh is only about 500m^3 per day. The other pipeline, of 700mm diameter, is the main source of drinking water. The water is pumped by 12 booster pumping stations. The capacity of this line is 50,000m^3 per day. The pipeline branches at El-Hammam city and at El-Dabaa city. It is planned to extend it to Sallum.

2.3.4.3 Desalination Stations

There are four desalination plants, one of which is located within the study area at Matrouh. The station desalinates sea water with a salinity of 36.00. The capacity of the station is 500m^3 per day.

2.3.4.4 Sewage-Water Treatment Plant

A sewage-water treatment plant is now under construction eight kilometres east of Matrouh and is designed to produce 47,000m^3 of treated water per day in a first stage, for the irrigation of 1,000 feddan.

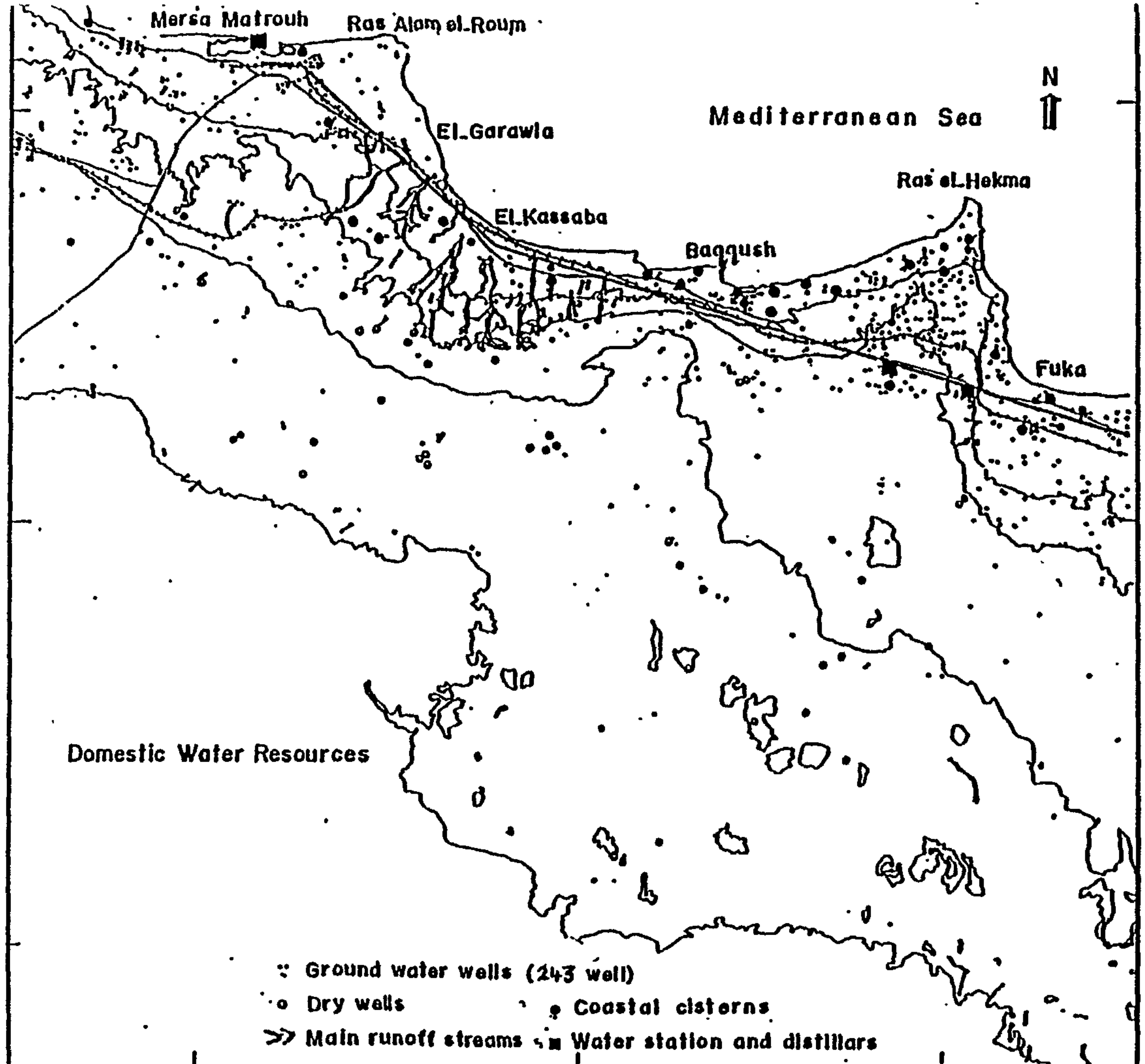


Figure 38 - Domestic water resources of the Fuka-Matrouh area

2.4 NATURAL ECOSYSTEMS

2.4.1 Terrestrial Ecosystems

There are two main terrestrial ecosystems in the study area: the sand dunes and the coastal lagoons.

The coastal limestone formation with overlying sand dunes is a unique feature of the Mediterranean. This formation extends from Alexandria to some kilometres before El-Sallum; i.e., over almost the whole study area. Many parts of the sand dunes are still unspoiled (Kasparek, 1993).

There is a small lagoon at the tip of Ras Hawala and a large lagoon at Matrouh.

2.4.1.1 Natural Flora

The north coast of Egypt has one of the highest rainfalls of any desert area in the country. This rainfall and moisture nurture the rich natural vegetation of the north coast which is floristically the richest of all the phytogeographical regions of Egypt (Ayyad, 1992). Of all the species recorded in the country, nearly 50% (about 1,000 species) occur in the western Mediterranean region (Ayyad, 1992). The areas that exhibit the greatest diversity of plant species are the coastal dunes, the rocky ridges and the inland plateau (Ayyad, 1992).

The plants of the sand dunes can be classified into nine groups: annuals, perennial grasses, perennial herbs, evergreen succulent perennial sub-shrubs, evergreen non-succulent perennial sub-shrubs, partially deciduous perennial sub-shrubs, evergreen succulent perennial shrubs, evergreen non-succulent perennial shrubs and deciduous perennial shrubs. Annuals form the highest percentage of the total flora, followed by evergreen non-succulent perennial sub-shrubs and the perennial herbs (Kasparek, 1993).

In addition to the inland flora, Bartels (undated) has defined five phytogeographical zones for the El Qasr coastal basin (the area adjacent to Matrouh). The species dominant in each zone are listed in *Table 17*.

2.4.1.2 Fauna

<u>Mammals</u>

There is a relatively high number of mammals that occur in the coastal belt between Alexandria and El-Sallum. Osborn and Helmy (1980) listed records of 27 species (Table 18, cf Kasparek, 1993).

The dorcus gazelle, *Gazella dorcas*, listed in the "IUCN Red Data Book, 1990" (IUCN, 1990) as "vulnerable", was formerly known from various locations close to the coast in the western desert and north Sinai, but is presumed to have become locally extinct during the last two decades.

<u>Birds</u>

The ornithological knowledge of the coast between Alexandria and El-Sallum is very poor. The area between Alexandria and Matrouh has hardly been visited by bird watchers and the area between Matrouh and El-Sallum may never have been visited by birdwatchers (Goodman and Meininger, 1989).

From Goodman and Meininger (1989) and Kasparek (1993), it can be concluded that the ornithological list for the Fuka-Matrouh area comprises 43 species (Table 19) Kasparek (1993) notes that the most surprising result of his survey is the regular presence of the greater sand plover, *Charadrius leschenaultii*, on beaches with flat beach rocks. There is no positive documentation of breeding of the greater sand plover in Egypt, but there is a record that it had bred at Matrouh in the 1940s (Goodman and Meininger, 1989). The flat salt lakes between the coastal ridge and Abu Sir Ridge (in the area between Alexandria and Matrouh) provide an excellent habitat for the greater sand plover. There is no reason to doubt that it actually breeds there and comes to the sea shore after breeding is finished (Kasparek, 1993). This would represent the western-most breeding area of the greater sand plover and the only one in Africa (Kasparek, 1993).

The houbara, *Chlamydotis undulata*, listed in the "IUCN Red Data Book, 1990" as "vulnerable", was a formerly common breeding resident of the Mediterranean coastal desert between Sallum and Alexandria (Goodman and Meininger, 1989). The area between Matrouh and Sallum was thought to be one of the last remaining strongholds of the houbara in Egypt; however, the present status of this species is unknown.

Reptiles

Thirty-seven reptile species (Table 20) were recorded by Marx (1968) from north-western Egypt (cf Kasparek, 1993). In his survey, Kasparek found five of these species in the Fuka-Matrouh area.

The Egyptian tortoise is classified in the "IUCN Red Data Book, 1990" as "vulnerable" and is protected under international conventions. The world distribution of the Egyptian tortoise is restricted to arid and semi-arid lands fringing the Mediterranean coasts of Libya, Egypt, the Gaza Strip and Israel. There is little recent information about the status of the population of the Egyptian tortoise in Egypt. The local population is thought to have been completely depleted by the collection of this species for the pet trade and by habitat degradation, although a small population could still exist on the north coast and in north Sinai (Baha El-Din, undated).

Table 17 - Dominant natural vegetation species in the various phytogeographical zones in the El Qasr area (the adjacent area to the west of Matrouh) (source: Bartels, undated)

COASTAL BASIN	INLAND
	Achillea santolina
1. **Active coastal dunes:**	*Anabasis articulata*
Ammophila arenaria	*Asphodelus microcarpus*
Euphorbia paralias	*Atriplex halimus*
Lotus polyphyllos	*Avena fatua*
Lygos rætam	*Chrysanthemum coronarium*
2. **Interdunal plain:**	*Convolvulus arvensis*
Chrysanthemum coronarium	*Enarthrocarpus strangulatus*
Achillea santolina	*Hamada scopparia*
Convolvulus arvensis	*Lycium arabicum*
Enarthrocarpus strangulatus	*Saliva lanigera*
Avena fatua	*Salsola tetragonum*
3. **Older dune ridges:**	*Salsola tetrandra*
Karduus sp.	*Salsola vermiculata*
Thymelea hirsuta	*Suæda pruinosa*
4. **Interdunal depression:**	*Thymelæa hirsuta*
Halocnemon strobilaceum	
Arthrocnemon glaucum	
Salicornia fruticosa	
Æluropus massarensis	
5 **Alluvial plain:**	
Suæda pruinosa	
Salsola tet	
Frankania revoluta	
Polygonium equicetiforme	
Atriplex halimus	
Limoniastrum micro	

Table 18 - Mammals recorded in the coastal belt between Alexandria and El-Sallum (source: Osborn and Helmy, 1980)

Hemichinus auritus libycus (Ehrenberg, 1833)
Paræchinus deserti deserti (Loche, 1858)
Croidura suaveolens matruhensis Setzer, 1960

This subspecies is endemic to the west Egyptian coast. Matrouh is so far the only locality where it has been found. It therefore bears the name of Matrouh (Kasparek, 1993).

Lepus capensis rothschildi (De Winton, 1902)
Gerbillus perpallidus Setzer, 1958

This species is endemic to Egypt's north-western desert (Baha El-Din, undated)

Gerbillus andersoni inflatus (Ranck, 1968)
Gerbillus gerbillus gerbillus (Olivier, 1801)
Dipodillus campestris wassifi (Setzer, 1958)
Dipodillus simoni kaiseri (Setzer, 1958)
Dipodillus amoenus amoenus De Winton, 1902
Dipodillus henleyi henleyi De Winton, 1903
Meriones shawi isis (Thomas, 1919)
Pachyuromys dupra natronensis De Winton, 1903
Psammomys obesus obesus Cretzschmar, 1828
Spalax ehrenbergi ægyptiacus (Nehring, 1898)
Rattus rattus (Linnæus, 1758)
Mus musculus prætextus (Brants, 1827)
Eliomys quercinus cyrenaicus (Festa, 1921)
Allacata tetradactylus (Lichtenstein, 1823)
Jaculus orientalis orientalis Erleben, 1777
Jaculus jaculus flavillus Setzer, 1955
Canis aureus lupaster (Hemprich and Ehrenberg, 1833)
Vulpes vulpes ægyptiaca (Sonnini, 1816)

Foxes were recorded in the sand dunes and limestone ridges several times and fox tracks were seen at a number of localities (Kasparek, 1993)

Poecilictis libyca libyca (Hemprich and Ehrenberg, 1833)
Herpestes ichneumon ichneumon (Linnæus, 1758)
Felis chaus nilotica De Winton, 1898
Acinonyx jubatus (Schreber, 1776)

The most recent record is from 1964 (Kasparek, 1993).

Table 19 - Birds recorded in the area between Fuka and Matrouh and their status within Egypt (source: Goodman and Meininger, 1989)

Falco tinnunculus	RB PV WV +
Falco biarmicus	RB WV *
Alectoris barbara	RB *
Chlamydotis undulata	RB WV *
Burbinus oedicnemus	RB PV WV *
Cursorius cursor	RB PV WV +
Charadrius alexandrinus	RB PV WV +
Charadrius leschenaultii	PV WV CB?
Charadrius morinellus	WV
Calidris alba	PV WV
Limosa lapponica	PV WV
Numenius tenuirostris	(PV)(WV)
Numenius arquata	PV WV
Tringa totanus	PV WV
Tringa ochropus	PV WV
Tringa glareola	PV WV
Actitis hypoleucos	PV WV
Arenaria interpres	PV WV
Stercorarius pomarinus	PV WV
Stercorarius parasiticus	PV WV
Larus fuscus	PV WV
Larus cachinnans	RB WV
Sterna caspia	RB PV WV
Sterna hirundo	PV
Sterna albifrons	MB PV
Pterocles coronatus	RB
Columba livia livia	RB *
Tyto alba	RB
Athene moctus	RB + *
Asio flammeus	PV WV
Apus pallidus	RB MB PV *
Alcedo atthis	CB? WV
Coracias garrulus	PV
Ammommanes cincturus	RB *
Alæmon alaudipes	RB + * O
Chersophilus duponti	RB
Melanocorypha calandra	WV
Calandrella rufescens	RB WV O
Galerida cristata	RB + *
Lullula arborea	WV
Eremophila bilopha	RB
Anthus campestris	PV WV
Motacilla flava pygmæa	RB WV O
Prunella modularis	WV
Cercotrichas galactotes	MB PV (WV) *
Erithacus rubecula	WV

Table 19 (continued)

Luscinia svecica	PV WV
Phoenicurus ochruros	PV WV
Phoenicurus phoenicurus	PV (WV)
Saxicola torquata	PV WV
Oenanthe isabellina	PV WV
Oenanthe oenanthe	PV (WV)
Oenanthe hispanica	PV (WV) MB?
Oenanthe deserti	RB PV WV
Oenanthe moesta	RB
Oenanthe lugens	RB (WV) O
Turdus philomelos	WV
Sylvia nisoria	PV
Sylvia communis	PV
Phylloscopus sibilatrix	PV
Phylloscopus collybita	PV WV
Muscicapa striata	PV (WV)
Ficedula parva	PV (WV)
Lanius collurio	PV (WV)
Lanius excubitor	RB WV *
Corvus corax	RB +
Sturnus vulgaris	WV
Passer domesticus	RB +
Fringilla coelebs	WV
Serinus serinus	RB? WV
Carduelis chloris	RB WV
Carduelis carduelis	RB WV

Abbreviations:

CB casual breeder
MB migrant breeder
RB resident breeder
PV passage visitor
WV winter visitor
( )abbreviation in parenthesis is used to indicate that the status is variable or irregular; e.g., (PV) means "irregular passage visitor"
? status uncertain; e.g., RB? means "doubtful resident breeder"
O possible breeding in the Fuka-Matrouh area
* probable breeding in the Fuka-Matrouh area
+ definite breeding in the Fuka-Matrouh area

Amphibians

Two amphibian species were recorded in the area (Kasparek, 1993):

Bufo regularis (Reuss, 1834)
Bufo viridis (Laurenti, 1768)

Table 20 - Reptiles recorded by Marx (1968) in north-west of Egypt (+ = species occurring in north-western Egypt, but not yet recorded for the coastal area; * = species recorded by Kasparek (1993) in the coastal area of Fuka-Matrouh (source: Kasparek, 1993)

Hemidactylus turcicus (Linnæus, 1758)
Ptychodactylus hasselquisti (Donndorff, 1798) +
Stenodactylus petrii Anderson, 1896 +
Stenodactylus stenodactylus (Lichtenstein, 1823)
Tarentola annularis (Geoffroy, 1823) +
Tarentola mauritanica (Linnæus, 1758)
Agama agama spinose Gray, 1931
Agama mutabilis (Merrem, 1820) *
Laudakia stellio (Linnæus, 1758)
Acanthodactylus boskianus (Daudin, 1802) *
Acanthodactylus pardalis (Lichtenstein, 1823)
Acanthodactylus scutellatus (Audouin, 1829)
Mesalina guttulata (Lichtenstein, 1823)
Eremias rubropunctatus (Lichtenstein, 1823)
Ophisops elegans (Menetries, 1832)
Varanus griseus (Daudin, 1803)
Chalcides ocellatus (Forskal, 1775)
Chalcides sepsoides (Audouin, 1827)
Eumeces schneideri (Daudin, 1802) *
Mabuya quinquetæniata (Lichtenstein, 1823)
Scincus scincus (Linnæus, 1758)
Chamæleo chamæleon Linnæus, 1758 *
Eryx colubrinus (Linnæus, 1758)
Eryx jaculus (Linnæus, 1758)
Coluber florulentus Geoffroy, 1827 +
Coluber rogersi (Anderson, 1893)
Lytorhynchus diadema (Dumeril and Bibron, 1854)
Macroprotodon cucullatus (Geoffroy, 1827)
Malpolon moilensis Reuss, 1834
Malpolon monspessulanus (Geoffroy, 1827)
Psammophis schokari (Forskal, 1775)
Psammophis sibilans (Linnæus, 1758) +
Spalerosophis diadema (Schlegel, 1837)
Naja haje (Linnæus, 1758)
Cerastes cerastes (Linnæus, 1758) +
Cerastes vipera (Linnæus, 1758)
Testudo kleinmanni (Lortet, 1883) *

Soil Fauna

Besides the problems of excessive heat and drought that desert soil fauna have to cope with, there is the problem of availability and quality of plant litter from the sparse vegetation, the basis of their food resources. This litter varies as a function of plant phenology and wind action which tends to accumulate this litter in depressions or, more often, under shrubs. Plant phenology is linked directly or indirectly to seasonality and rainfall thresholds for growth of perennials or ephemerals (Ayyad, 1978 in Ghabbour *et al.*, 1984). The summer population of soil mesofauna associated with major shrubs in the littoral sand dunes of the north-western coast are listed in Ghabbour *et al.* (1977) (Table 21).

Table 21 - Systematic list of soil mesofauna associated with major shrubs in the littoral sand dunes (source: *Ghabbour et al., 1977*)

Isopoda, Oniscoidea:	*Agabiformes lentus* (B.L.) *Procellio albinus* (B.L.)
Dictyoptera, Blattoidea, Polyphagidæ:	*Heterogamia syriaca* Saus.
Rhynchota, Heteroptera, Cydnidæ:	*Sehirus melanopterus* H.S. *Macroscytus brunneus* F.
Myodochidae (Lygæidæ):	*Emblethis verbasci* F.
Neuroptera, Myrmeleonidæ (Nymphs):	*Cueta* sp.
Coleoptera, Carabidæ:	*Bradycellus lusitanicus* Dej.? *Cymindis suturalis* Dej. var
Scarabæidæ:	*Psammobius porcicollis* Ill.
Melolonthini (larvæ)	
Cetonini (larvæ)	
Tenebrionidæ:	*Crypticus murinus* All. *Dendarus piceus* Ol. *Machlopsis crenatocostata* Pioch. *Pimelia* sp. (larvæ) *Psammoica lucida* Sol. *Stenosis torre-tassoi* Koch.
Helopini (larvæ)	
Antichidæ:	*Hylophilus*?
Curculionidæ:	*Otiorhynchus* sp.
Hymenoptera, Formicidæ:	*Camponotus maculatus* F. *Messor barbarus* F. *Messor barbarus* var. *ægyptiacus* *Messor semirufus*
Diptera, Ceratopogonidæ (larvæ)	
Therevidæ (larvæ)	
Bibionidæ (larvæ)	
Arachnoidea, Opiliones:	*Phalangium savignyi*
Araneæ, Agelenidæ	
Dysderidæ	
Gnaphosidæ, Laronieæ	
Salticidæ	
Acari, Prostigmata, Trombidiidæ	
Pseudoscorpiones:	*Olpium kochi* Simon
Myriapoda, Chilopoda, Geophilomorpha	*Geophilius* sp.

2.4.2 Freshwater Ecosystem

Rain is the main source of fresh water in the area. The annual average rainfall is around 140mm, most of which falls during winter (mid-October to mid-March), decreasing southwards. This water is harvested through cisterns and dykes to be used for agricultural as well as animal and human purposes (see section 2.3). The natural flora and its associated soil fauna, as well as amphibians, depend to a great extent on this rainfall (see sections 2.4.1.1 and 2.4.1.2.). Some limited underground *water is exploited in some places, as Fuka, Burbeta and Ras El-Hekma.*

2.4.3 Marine Ecosystems

See 2.2.1.11 for waves, currents and tides.

2.4.3.1 Temperature, Salinity and Density

During a four-season survey conducted in 1977, the hydrographic variables of the sea water off Fuka and Matrouh at different depths, from the surface down to 100m depth (stations 24, 25 and 26, off Fuka, and stations 27, 28 and 29, off Matrouh; Figures 39-47) were measured. The distribution of temperature and salinity are given in Figures 39-44 which illustrate the following seasonal hydrographic features off Fuka and Matrouh (Anon., 1983a).

Fuka

In winter: the temperature and salinity distributions indicated the intrusion of a water mass with a temperature range of 18.00-18.10°C and a salinity range of 38.90-39.00. This water appeared as a tongue of relatively lower salinity moving towards the coast at a depth between 10m and 30m, with a corresponding density anomaly, $_{\sigma t}$ of 28.40. At the same time, there was a flow of water of higher temperature and higher salinity moving seawards over the shelf. However, this latter flow did not move very far down the slope, since it was met by the intruding water mass (with a temperature of 18.0°C and a salinity of 39.0) moving up the slope as described above.

In spring: a weak stratification in the temperature and salinity distributions was observed, with a corresponding density stratification. There was a tendency for temperature and salinity to decrease with depth, but the vertical gradients were rather small, apparently owing to some vertical mixing in earlier months.

In summer and autumn: although a distinct seasonal thermocline was clearly observed, the halocline had practically disappeared. However, the temperature stratification revealed a reasonable degree of density stratification. This density stratification may have developed in the shelf area in summer, but could hardly be permanent because of the shallowness of the shelf (depth about 75m) and the relatively strong winds that were frequently encountered in the coastal area during the succeeding seasons; i.e., during late autumn/early winter.

Matrouh

In winter: the water was relatively isothermal except at the outermost station, where a *thermocline was observed between 50m and 75m depth, with a corresponding halocline. The intrusion* of the relatively colder and less-saline water mass, with a $_{\sigma}$ of 28.6, was also observed, but at a greater *depth than that observed in the Fuka section described above.*

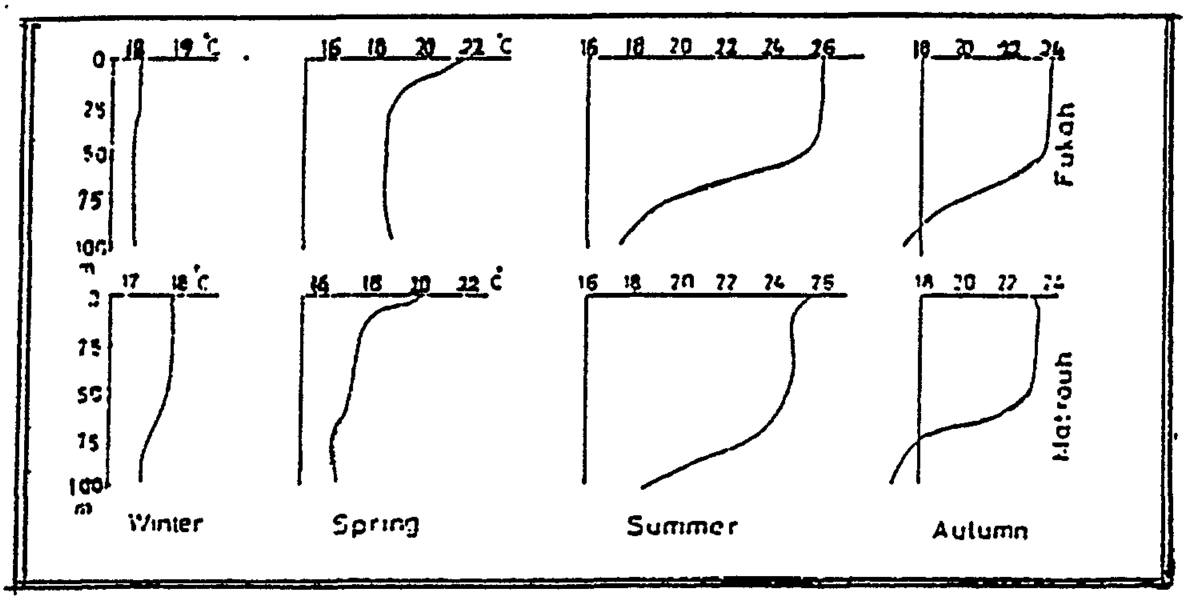


Figure 39 - Vertical profiles of sea-water temperature off Fuka and Matrouh (after Anon., 1979a)

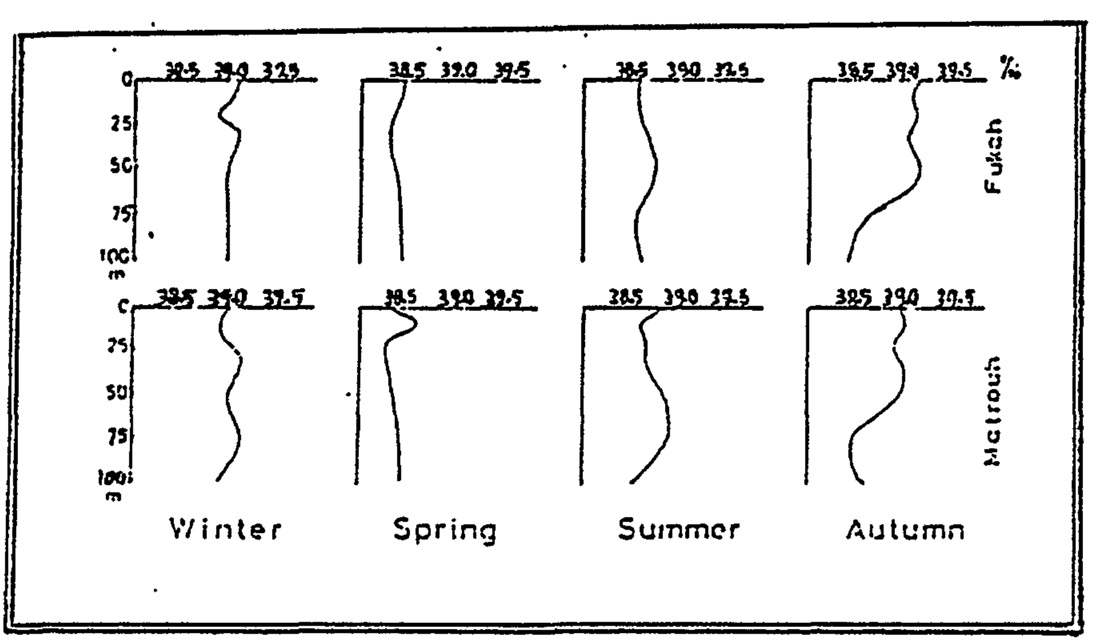


Figure 40 - Vertical profiles of salinity off Fuka and Matrouh (after Anon., 1979a)

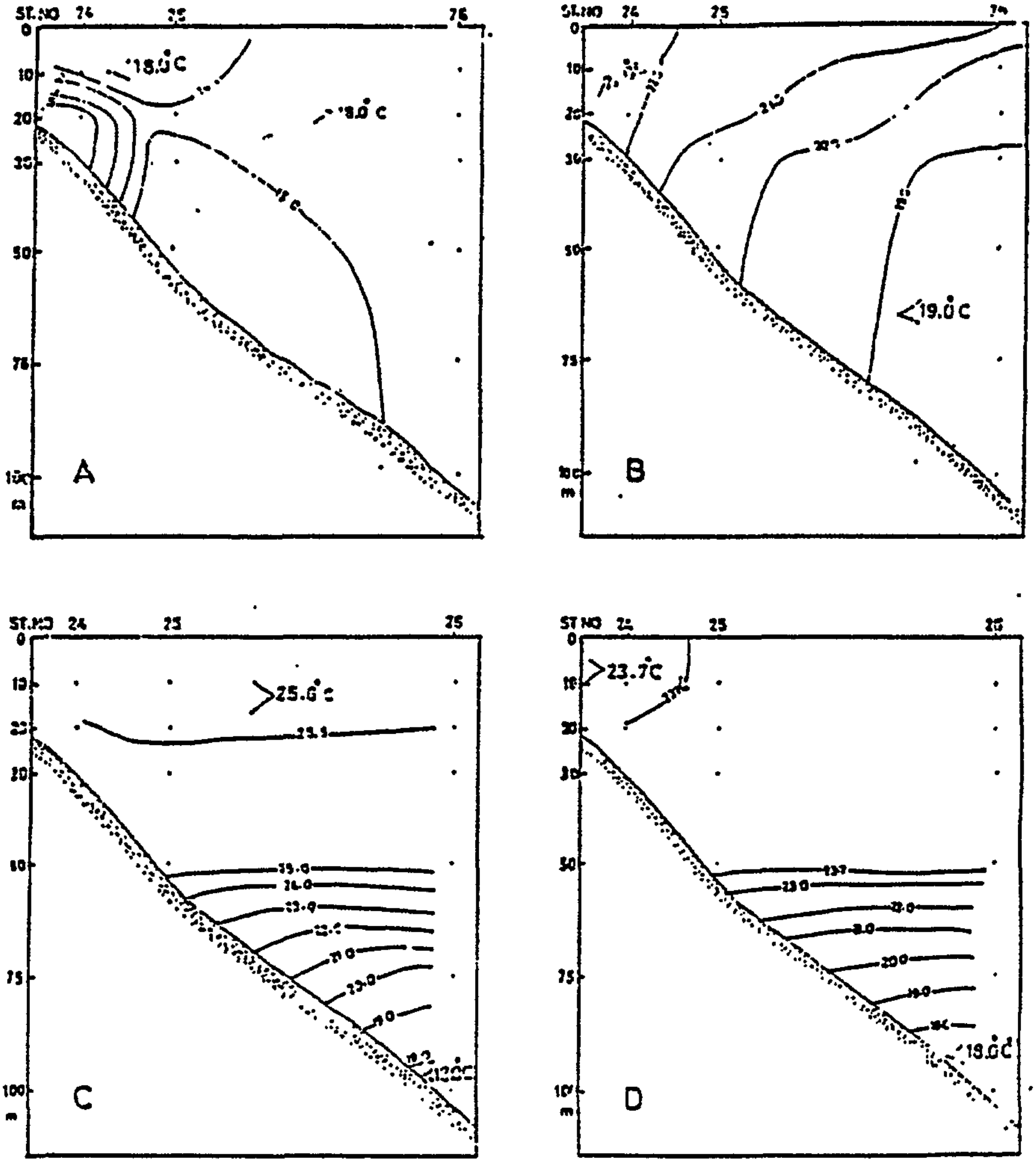


Figure 41 - Vertical distribution of sea-water temperature off Fuka in: (A) winter, (B) spring, (C) summer and (D) autumn (after Anon., 1979a)

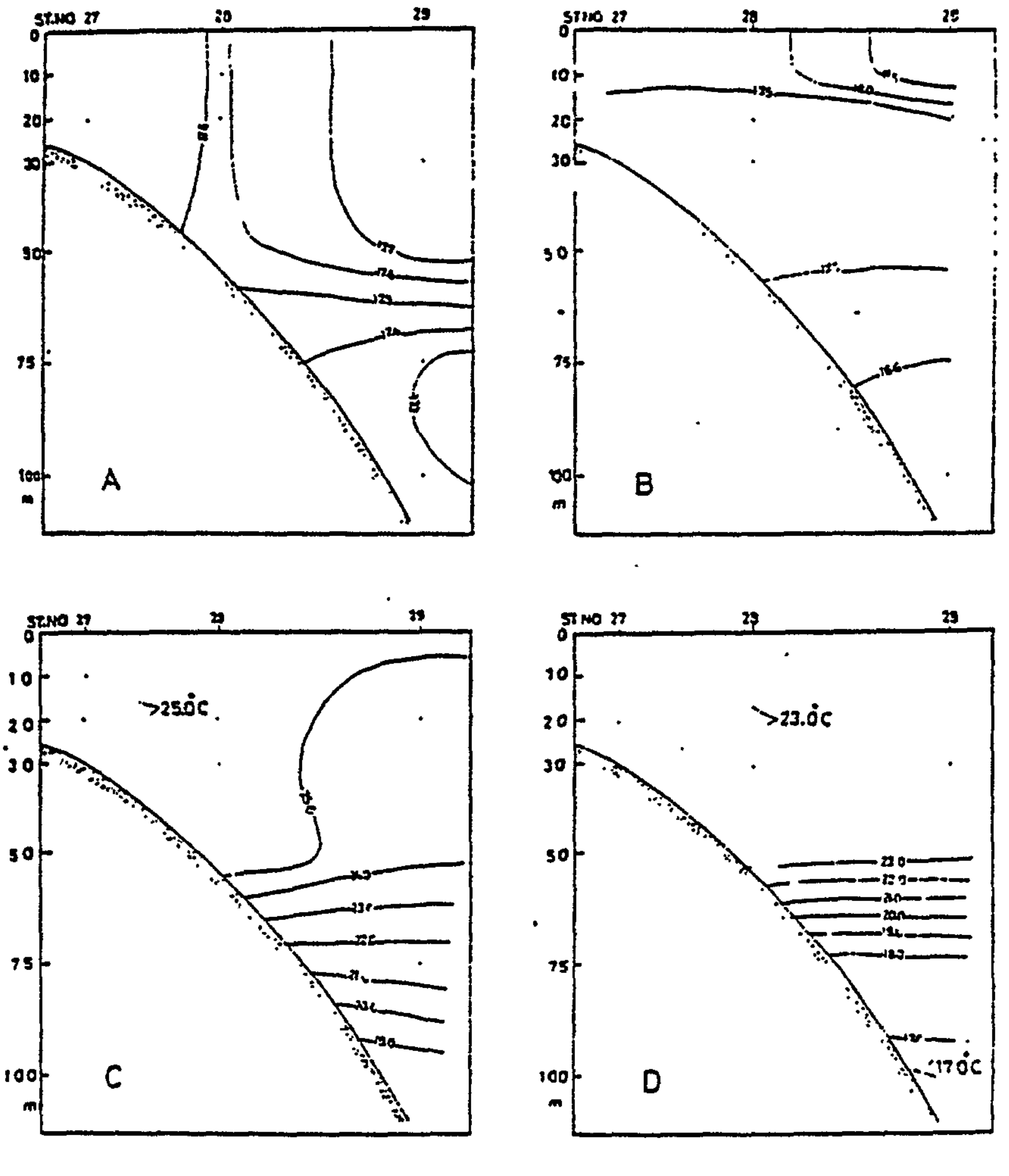


Figure 42 - Vertical distribution of sea-water temperature off Matrouh in: (A) winter, (B) spring, (C) summer and (D) autumn (source: Anon., 1979a)

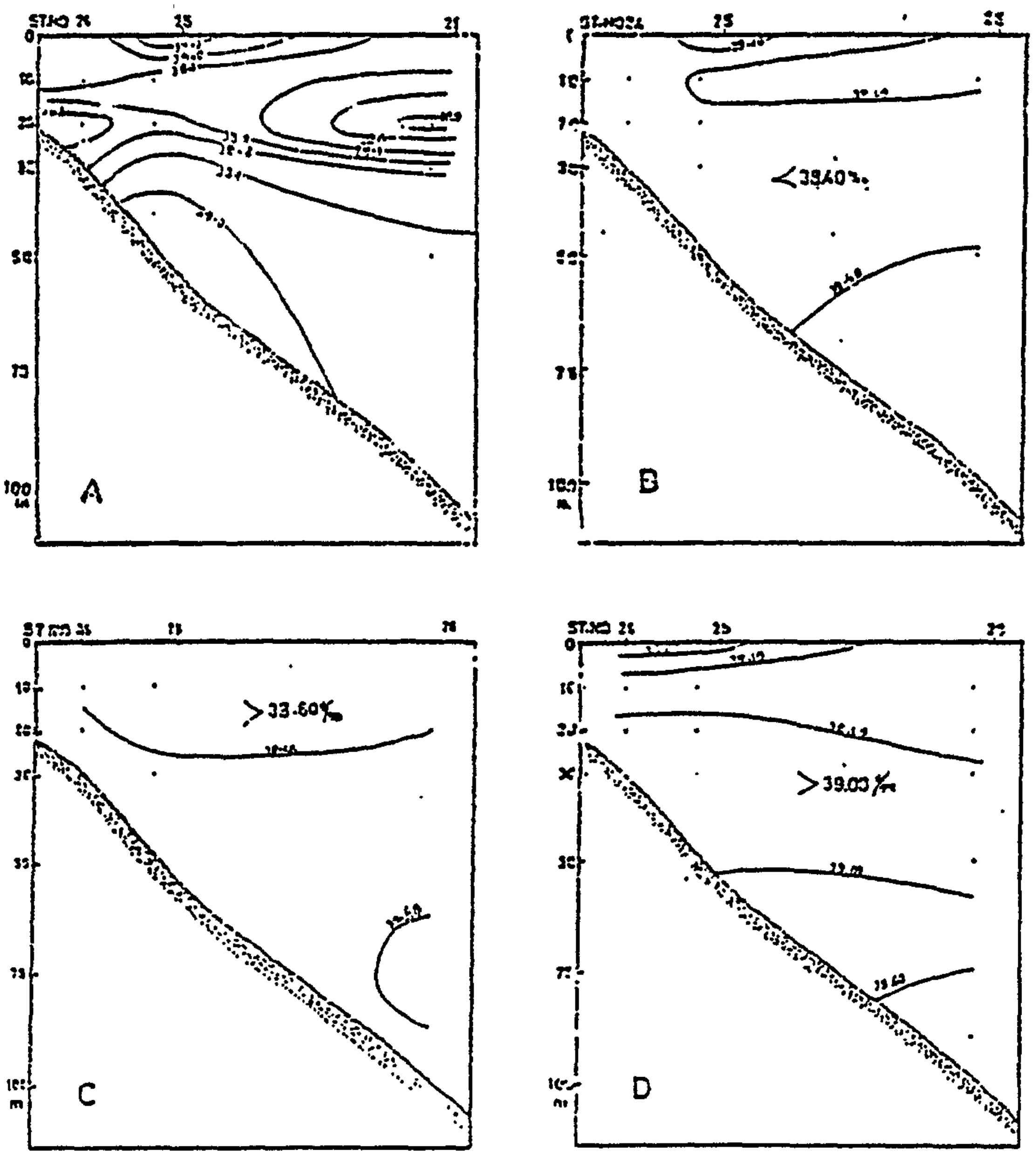


Figure 43 - Vertical distribution of sea-water salinity off Fuka in: (A) winter, (B) spring, (C) summer and (D) autumn (source: Anon., 1979a)

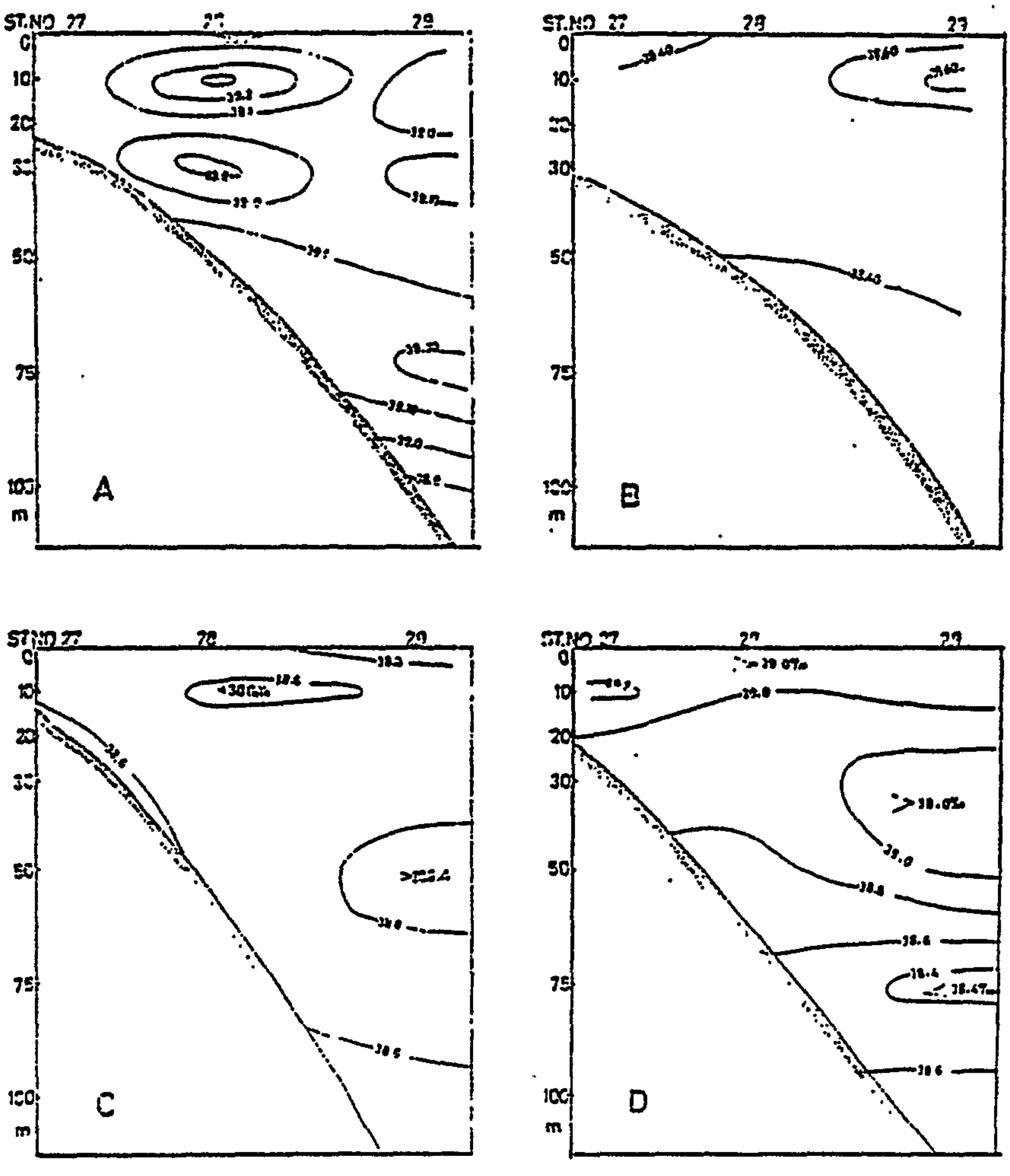


Figure 44 - Vertical distribution of sea-water salinity off Matrouh in: (A) winter, (B) spring, (C) summer and (D) autumn (source: Anon., 1979a)

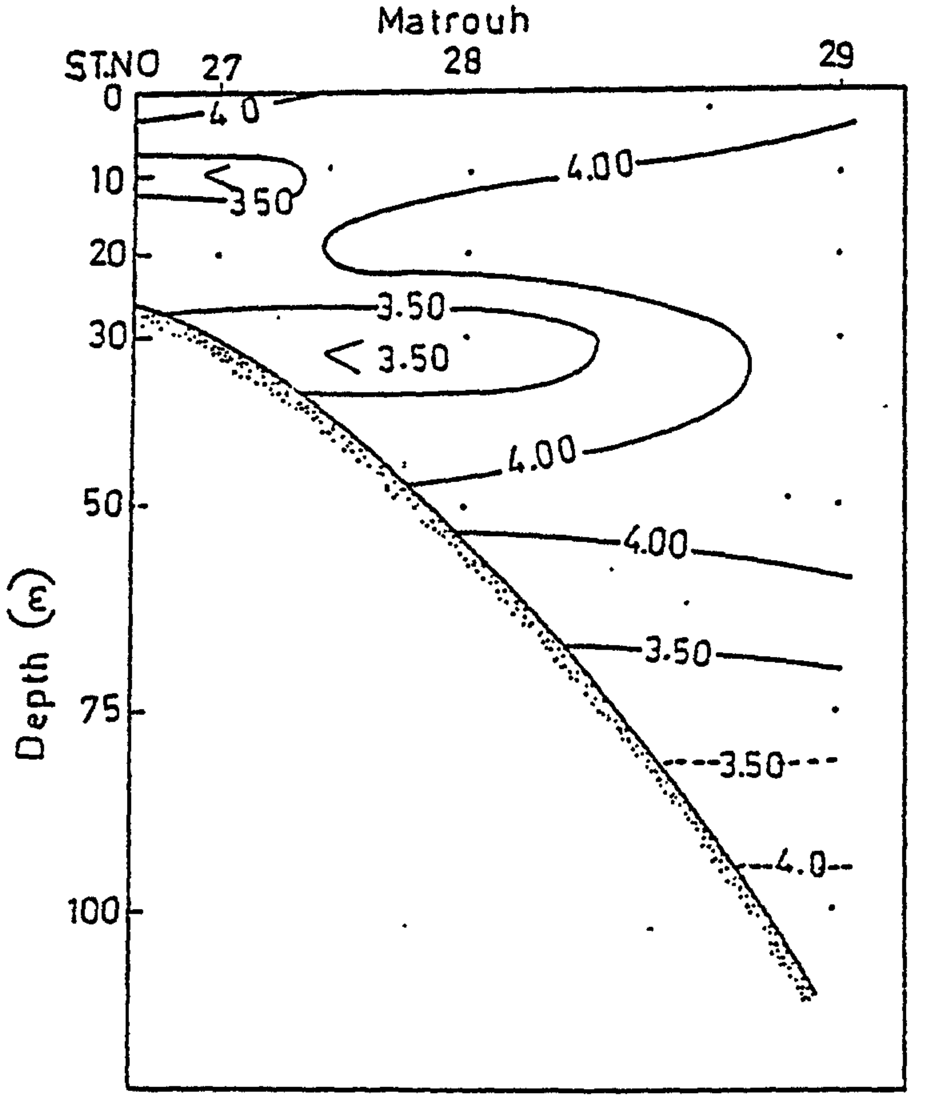


Figure 45 - Vertical distribution of dissolved oxygen (ml/l) off Matrouh in January 1977

In spring: the coastal water was still more or less homogeneous. However, at the outermost station, a thermocline and a halocline were developed in the upper layer of the water between the surface and 20m depth.

In summer and autumn: a distinct seasonal thermocline was observed at 50-80m depth, but without a corresponding halocline. The sharpest gradients of temperature along the bottom occurred over the slope, where the change in depth in this particular section is rather rapid. This is generally a characteristic feature of the western part of the Egyptian continental shelf. There was still an

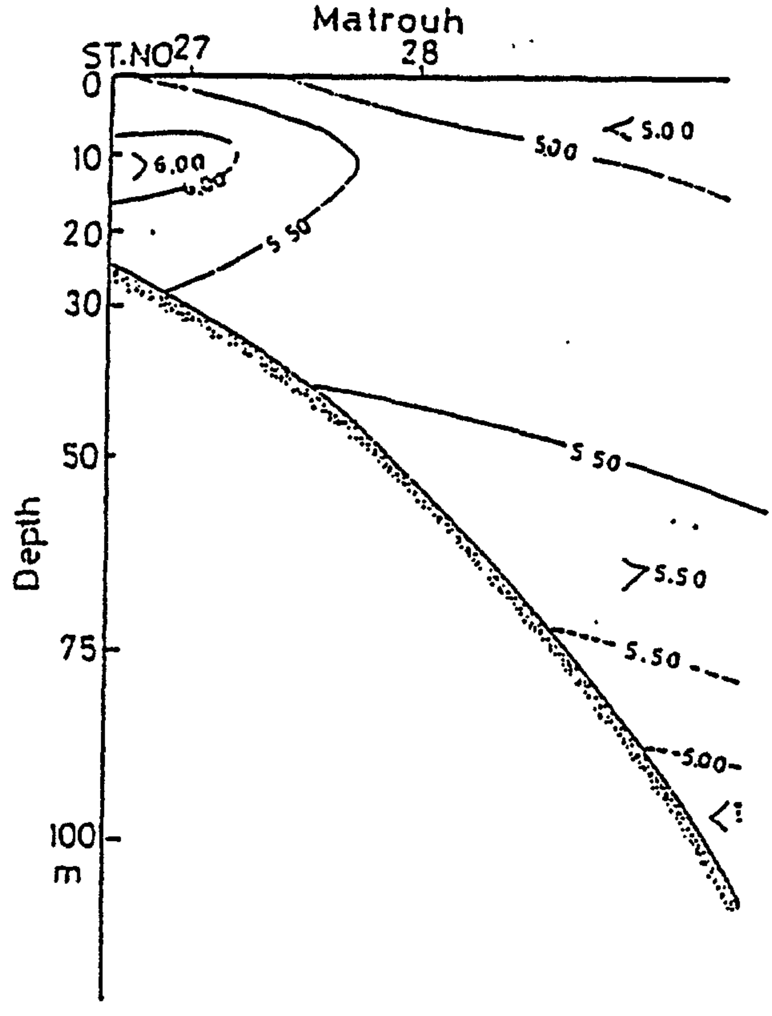


Figure 46 - Vertical distribution of dissolved oxygen (ml/l) at Matrouh in February 1977
(source: Anon.,1983a)

indication of an intrusion of open-sea water towards the coast. An interesting feature was also observed in the density distribution: an intermediate layer with a ς less than 27.0 between water of greater density above and below it. This reduction in density of a particular layer may occur at any time of the year near the shore, owing either to an increase in local run-off or an intrusion of low-salinity water from the open sea. The latter was, of course, the reason in this case. This was confirmed by the existence of a tongue of water of low salinity (less than 38.40) as revealed by the vertical salinity distribution in the autumn.

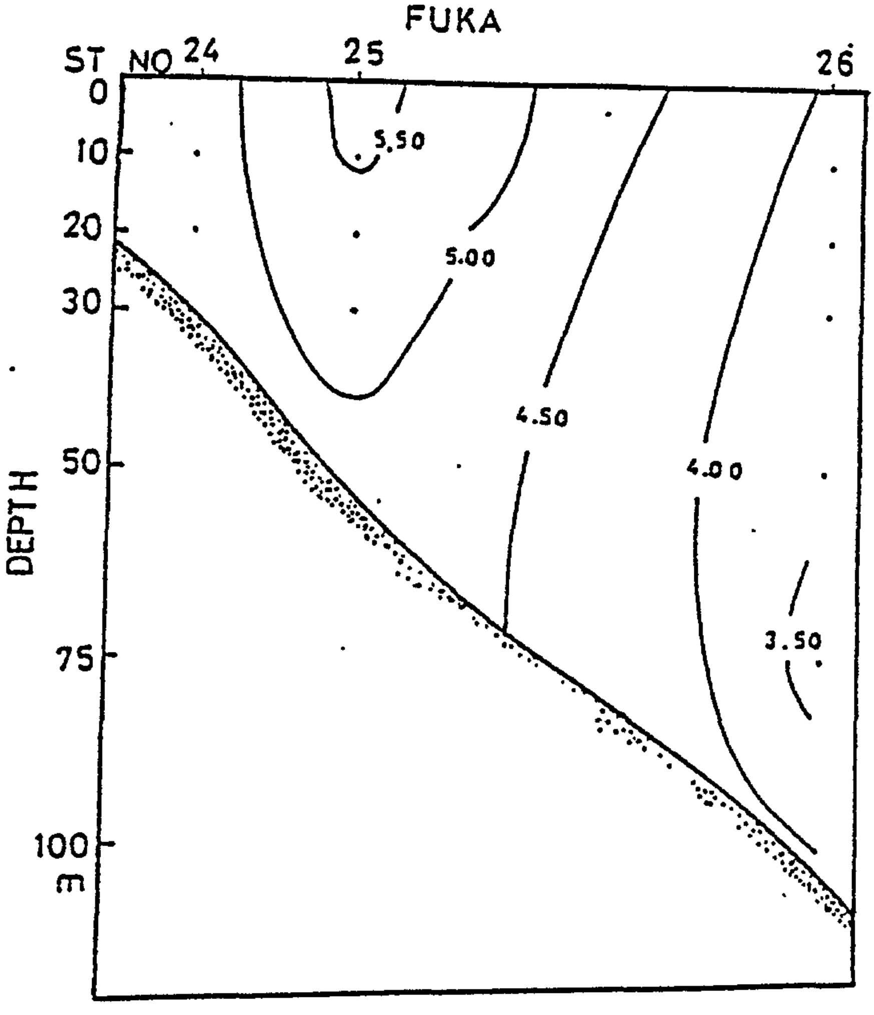


Figure 47 - Vertical distribution of dissolved oxygen (ml/l) at Fuka in October 1977
(source: Anon., 1983a)

2.4.3.2 Oxygen

According to Anon. (1983a), the dissolved-oxygen content of the surface sea water off Matrouh showed a high value during winter (6.0ml/l) and there is a slight decrease seawards. During spring and summer, the dissolved-oxygen content was slightly lower than that in winter. During autumn the oxygen content was around 4.5ml/l. This value was less than that observed during summer

Compared with January 1977, a remarkable increase in dissolved-oxygen content at 20-50m depth occurred in the spring (April, 1977). The same phenomenon of subsurface high dissolved-oxygen content was previously recorded in 1966 (Emara, 1969 and Emara *et al.*, 1973) and in 1975 (Al-Kholy and El-Wakeel, 1975).

During summer and autumn, this subsurface highly oxygenated layer disappeared and the distribution showed a water body of low dissolved-oxygen content coming from offshore in autumn and mixing with the inshore water off Fuka (Fig. 47).

Contrary to the observations of 1966 and 1971 (Emara *et al.*, 1973), the seasonal variations in dissolved-oxygen content during 1977 were not well defined (Anon., 1983a).

2.4.3.3 Nutrient Salts

In general, the eastern Mediterranean is considered to be an oligotrophic area (poor in nutrient salts, which are necessary for phytoplankton growth). The Fuka-Matrouh area is one of the most oligotrophic areas in the eastern Mediterranean.

In 1977, the nutrient salts of the Mediterranean waters off Egypt, from Rosetta to Matrouh, were determined. The following are the results of that survey of the sea off Fuka-Matrouh which were summarized by Anon. (1983a).

Inorganic Phosphate

In winter, the concentration of phosphate in the surface layer of the sea off Matrouh-Rosetta was uniform and very low (0.30-0.60μg/l in January and 0.30-0.90μg/l in February) and the vertical distribution indicated a vertical mixing characteristic of winter convection.

In spring, the surface phosphate off Matrouh-Rosetta was 0.30-5.58μg/l and, as in the winter, the vertical distribution showed no stratification.

In summer, higher phosphate values (1.24-1.86μg/l) were observed off Matrouh. Little variation with depth was observed.

In autumn, the phosphate concentration off Matrouh-Rosetta did not exceed 1.15μg/l. Off Fuka and Matrouh, inorganic phosphate was completely depleted in the water column.

Nitrite and Nitrate

As indicated in Figures 36 and 37 in Al-Kholy and El-Wakeel (1975), the nitrite in the surface water off Fuka-Matrouh did not exceed 0.7μg/l and the area was depleted of nitrate.

Reactive Silicate

In winter, the silicate was depleted from the surface down to 100m depth.

In spring, the silicate in the surface water off Matrouh ranged between 308μg/l offshore and 364μg/l inshore.

In summer, the silicate concentration was 224μg/l in the inshore surface water off Matrouh, increasing seawards and with depth.

In autumn, the concentration of silicate in the surface water off Fuka was about 84μg/l.

Table 22 summarises the chemical properties of the Egyptian Mediterranean sea water at the surface and at 100m depth.

Table 22 - Concentration of dissolved oxygen and nutrient salts at the surface and at 100m depth in 1966, 1971 and 1976 (source: Anon., 1983a)

Parameters	Depth in metres	Units used	Concentration in 1966	Concentration in 1971	Concentration in 1976
Oxygen	0 100	ml/l ml/l	4.42-5.96 5.12-6.37	4.45-6.35 about 5.50	2.20-6.29 3.28-5.92
Phosphate	0 100	µg/l µg/l	0.6-6.8 0.6-8.3	0.00-6.8 0.00-5.2	0.3-5.5 0.3-3.0
Nitrite	0 100	µg/l µg/l	- -	0.00-2.5 0.00-1.12	0.00-0.84 0.00-0.84
Nitrate	0 100	µg/l µg/l	- -	0.00-4.3 0.00-7.28	0.00-23.2 0.00-5.6
Silicate	0 100	µg/l µg/l	- -	0.00-445.2 5.6-501.2	0.00-504 0.00-364

2.4.3.4 Phytoplankton

The phytoplankton of the area was investigated during the four seasons of 1977. The results were published in Anon. (1979b, 1983b) and Abdalla *et al.* (1992). As shown in Table 23, the phytoplankton standing crop off Matrouh (1,792 cells/l) was slightly higher than that off Fuka. It was obvious that the area was oligotrophic. The production increased offshore from Matrouh, but the opposite occurred off Fuka (Table 23).

Table 23 - Phytoplankton production (cells/l) during the four seasons of 1977 inshore and offshore from Fuka and Matrouh (adapted from *Abdalla et al.*, 1992)

	Inshore					Offshore					Total
	winter	spring	summer	autumn	av.	winter	spring	summer	autumn	av.	av.
Fuka	4226	2761	238	240	1866	4568	1242	200	280	1572	1719
Matrouh	4725	599	301	332	1489	6732	1070	400	175	2094	1792

The characteristics of the phytoplankton in the area during the different seasons can be summarised as follows:

Fuka

Inshore and offshore, the winter was the season of high phytoplankton abundance, followed by a decline in production during spring and a drastic decrease during summer and autumn (Table 23).

The dominant species were *Cyclotella kutzingiana*, in winter, *C. kutzingiana, Melosira crucipunctata* and *Leptocylindrus danicus*, in spring, *L. danicus* and *M. crucipunctata*, in summer and *Rhizosolenia calcaroavi, L. danicus* and *Chætoceros affinis*, in autumn.

Matrouh

As in Fuka, the winter was the high season for the phytoplankton, the standing crop sharply declining during the other seasons of 1977.

The phytoplankton community was dominated by *Cyclotella kutzingiana*, in winter and spring, *Melosira crucipunctata* and *C. kutzingiana*, in summer, and *Bacteriastrum elongatum, C. afinis* and *L. danicus*, in autumn.

2.4.3.5 Zooplankton

The only available literature on the zooplankton of the Fuka-Matrouh area is that of Anon. (1979b) and Anon. (1983b), who report on a survey performed throughout the four seasons of 1977. The seasonal distribution of the zooplankton inshore and offshore of the area is indicated in Table 24 and illustrated by Figure 48.

Table 24 - Distribution of the total zooplankton (organisms/m^3), by season, inshore and offshore from Fuka and Matrouh (adapted from Anon., 1983b)

	Inshore					Offshore					Total Av.
	winter	spring	summer	autumn	av.	winter	spring	summer	autumn	av.	
Fuka	1262	1583	1176	1962	1496	883	947	1121	2931	1470	1483
Matrouh	863	1801	3042	2721	2107	642	1165	1603	1399	1202	1654

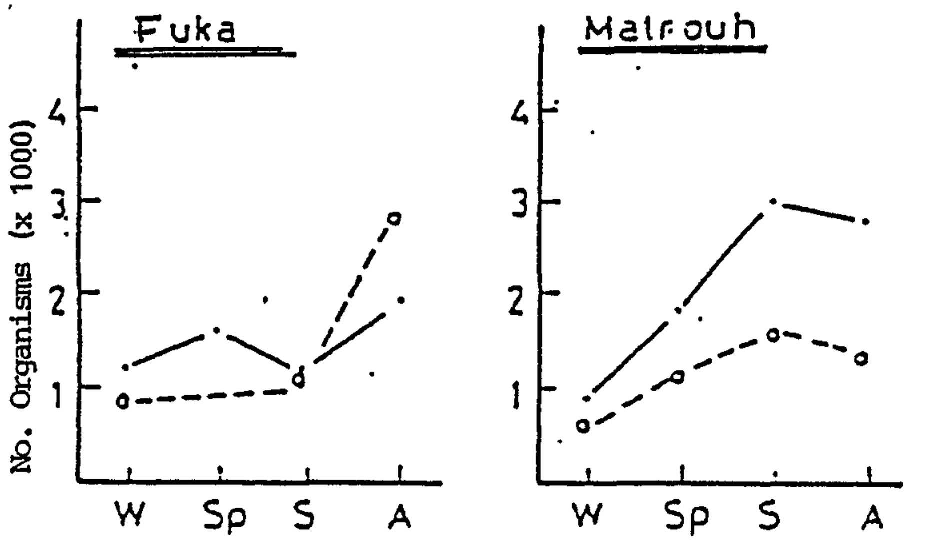


Figure 48 - Seasonal variations in the zooplankton standing crop (organisms/m^3 x 1000) recorded inshore (——) and offshore (o——o) off Fuka and Matrouh (source: Anon., 1983b)

The zooplankton distribution can be summarised as follows:

Fuka

The average population density of zooplankton off Fuka in winter was 1,072orgs/m^3. The copepods *Paracalanus* and *Oithona* were the dominant plankters and crustacean eggs, tintinnids, chætognaths (*Sagitta*) and pteropods were frequent.

In spring, the density increased slightly to 1,265orgs/m^3. The copepods, particularly *Paracalanus* and *Oithona*, remained the dominant plankters. Other groups, including tintinnids, *Oikopleura*, gastropod veligers and *Sagitta* were frequent.

In summer, the standing crop was slightly less than that of spring. The copepods *Paracalanus* and *Oithona* still dominated the zooplankton community.

Autumn was the most productive season, with a density of 2,446orgs/m^3. Unlike the other seasons of the year, the zooplankton standing crop increased seawards. As in summer, the dominant plankters were *Oithona* sp., *Paracalanus* sp. and nauplii (crustacean larvæ).

Matrouh

The zooplankton standing crop off Matrouh (752orgs/m^3) was lowest in winter. It decreased seawards. The dominant plankters were *Paracalanus*, *Oithona* and *Clausocalanus*; other common plankters were crustacean eggs, *Oikopleura* and tintinnids.

In spring, the standing crop (1,483orgs/m^3) was about double that of winter and decreased seawards; *Paracalanus* and *Oithona* were the dominant plankters. The tintinnids, echinoderm larvæ, gastropod veligers, *Fritillaria* and *Oikopleura* were common. Fish larvæ were recorded inshore.

In summer, the average standing crop increased to 2,322orgs/m^3. The highest level was inshore; this was due to the excessive number of copepod nauplii and gastropod veligers. *Paracalanus*, *Oithona* and *Centropages* were the dominant plankters. Gastropod veligers, polychæte larvæ, tintinnids and lamellibranch veligers were also common.

In autumn, the zooplankton standing crop decreased slightly to 2,060orgs/m^3. The highest level was inshore in the surface water. *Oithona* and *Paracalanus* spp. were dominant. Tintinnids, polychæte larvæ, foraminifera and lamellibranch veligers were common.

2.4.3.6 Benthic Biota

Nature of Sea Bed

The sea bed in the Fuka-Matrouh area is rocky, with fine and coarse sand and mud inshore (down to 50m depth), silty sand with pebbles and rocks offshore from Fuka and silty with gravels and rocks offshore from Matrouh (50-100m depth).

Bottom Flora

The inshore area is inhabited by green algæ such as *Caulerpa prolifera* Lam., *Codium bursa* Ag., *Halemida tuna* (Ell. and Sol.) Lam. and *Udotea petiolata* (Turra). Strands of brown algæ, mainly represented by *Sargassum* spp., are commonly found and there are beds of sea grass (*Posidonia* sp. and *Zostera* sp.) in the area (Ramadan, 1977; Farag, 1981).

The offshore area is characterised by high vegetation of red calcareous algæ, such as *Lithothamnium* spp. and *Lithophyllum* spp. (Ramadan, 1977; Farag, 1981).

Spring and summer were the main seasons of algal growth.

Bottom Fauna

Other than the works of Paget (1921-1923), El-Beshbeeshy (1983), Kheirallah *et al.* (1989) and Ramadan *et al.* (1989), which were concerned with sponges, no results of studies of the benthos of the Fuka-Matrouh area were available, except those of the survey carried out in 1977 and published in Anon. (1979b, 1983b) and Farag (1981).

The sponges in the area were represented by 11 species, five of which were commercial and six were non-commercial (Ramadan *et al.*, 1989). For the sponge fisheries, see section 2.5 3.

The other macrobenthic invertebrates were mainly represented by species of Polychæta, Sipunculidæ, Crustacea, Mollusca, Brachiopoda, Echinodermata and Ascidia. The number of species representing each group in the inshore and offshore areas off Fuka and Matrouh are given in Table 25. The macrobenthic invertebrate production (in terms of population density, expressed as number of organisms per 80m^2 per year, and biomass, expressed as grams per 80m^2 per year) is compared, in Table 26, with phytoplankton and zooplankton standing crops (expressed, respectively, as number of cells per litre and number of organisms per cubic metre) inshore and offshore from Fuka and Matrouh.

Table 25 - Number of macrobenthic species in seven taxonomic groups recorded off Fuka-Matrouh in 1977 (adapted from Farag, 1981)

	Inshore		Offshore	
	Fuka	Matrouh	Fuka	Matrouh
Polychæta	9	12	7	8
Sipunculidæ	-	-	1	1
Crustacea	5	7	5	4
Mollusca	12	8	3	9
Brachipoda	-	-	1	1
Echinodermata	4	1	3	4
Ascidia	1	1	1	1
Total	**32**	**29**	**21**	**28**

Table 26 - Average population density (PD) of benthic macroinvertebrates (orgs/80m^2 per year) and their biomass (B) (as gm/80 m^2 per year) compared with phytoplankton standing crop (cells/l) and zooplankton standing crop (orgs/m^3) inshore and offshore from Fuka and Matrouh in 1977 (adapted from Farag, 1981)

	Fuka				Matrouh			
	PD	B	cells/l	orgs/m^3	PD	B	cell/l	orgs/m^3
Inshore	9	32.3	1945	1496	11	9.3	2022	2107
Offshore	31	15.1	1268	1470	41	14.7	1900	1202

According to Anon. (1983b), the seasonal variation in the production of macrobenthic invertebrates is as follows:

Fuka

The winter population inshore from Fuka reached 5 orgs/haul (haul = 80m^2) and comprised molluscs, echinoderms and polychætes. This value increased during the spring and the summer to 11 orgs/haul, when polychætes were more dominant in the spring and molluscs were dominant in the summer.

In autumn, the standing crop declined to 6 orgs/haul (Fig. 49A).

The offshore stations were very rich and they sustained an average of 31 orgs/haul. The counts of benthic organisms amounted to 34 and 33 orgs/haul during the spring and summer, respectively, and consisted mostly of polychætes and brachiopods. This value dropped to 17 orgs/haul in the autumn, when polychætes remained the main component.

Unlike the numerical abundance of benthic organisms, the average biomasses were much higher inshore (32.3g fresh weight per haul) than offshore (15.1g f.w. per haul). This is particularly due to the higher biomasses of molluscs and echinoderms in the former stations (Fig. 49B).

Matrouh

The average number of benthic organisms recorded inshore reached 14 orgs/haul in winter. Polychætes were more abundant than other groups. The total fauna decreased to 8 orgs/haul in the spring and this was accompanied by a reduction in polychætes. The benthic fauna increased again to 12 orgs/haul with the appearance of crustaceans. This was followed by a sharp drop to 3 orgs/haul in the autumn, comprising only polychætes (Fig. 50A).

The offshore stations were numerically more productive during the four seasons. Thus, their density attained 52 orgs/haul in winter and was dominated by polychætes, although echinoderms and ascidians were also frequent. The number of benthic organisms showed a further increase to 65 orgs/haul in the spring and this was accompanied by a pronounced increase in the number of echinoderms. The density dropped again to 12 orgs/haul in the summer and this was followed by an increase to 39 orgs/haul in the autumn.

The average annual benthic biomass reached 9.3 and 14.7g per haul inshore and offshore, respectively. The peaks were observed inshore in winter and offshore in spring when echinoderms formed the bulk of the benthos (Fig. 50B).

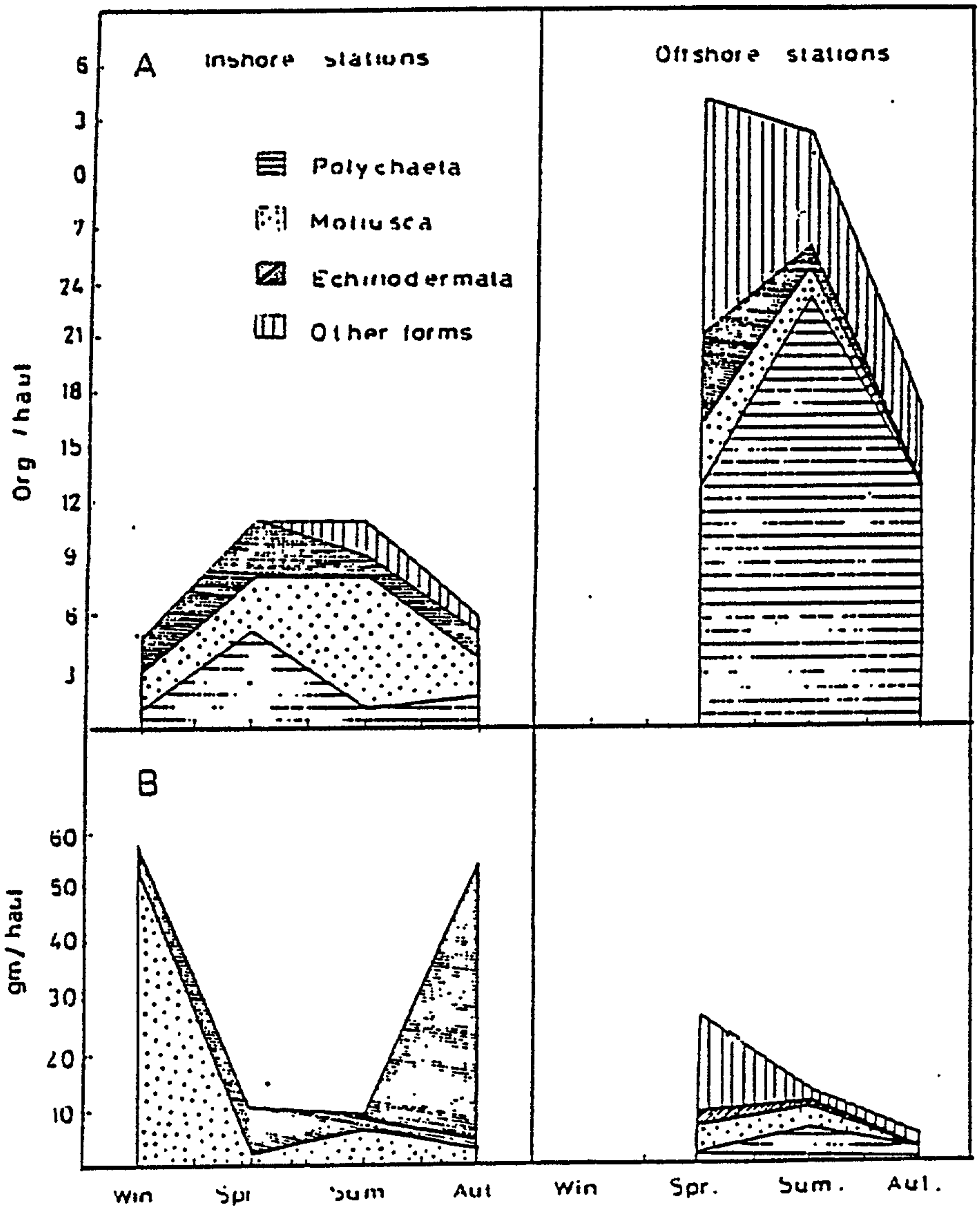


Figure 49 - Seasonal variations in the total benthic fauna along the Fuka coast, inshore and offshore
A - organisms per haul ($80m^2$)
B - grams fresh weight per haul ($80m^2$)
(source: Anon., 1983b)

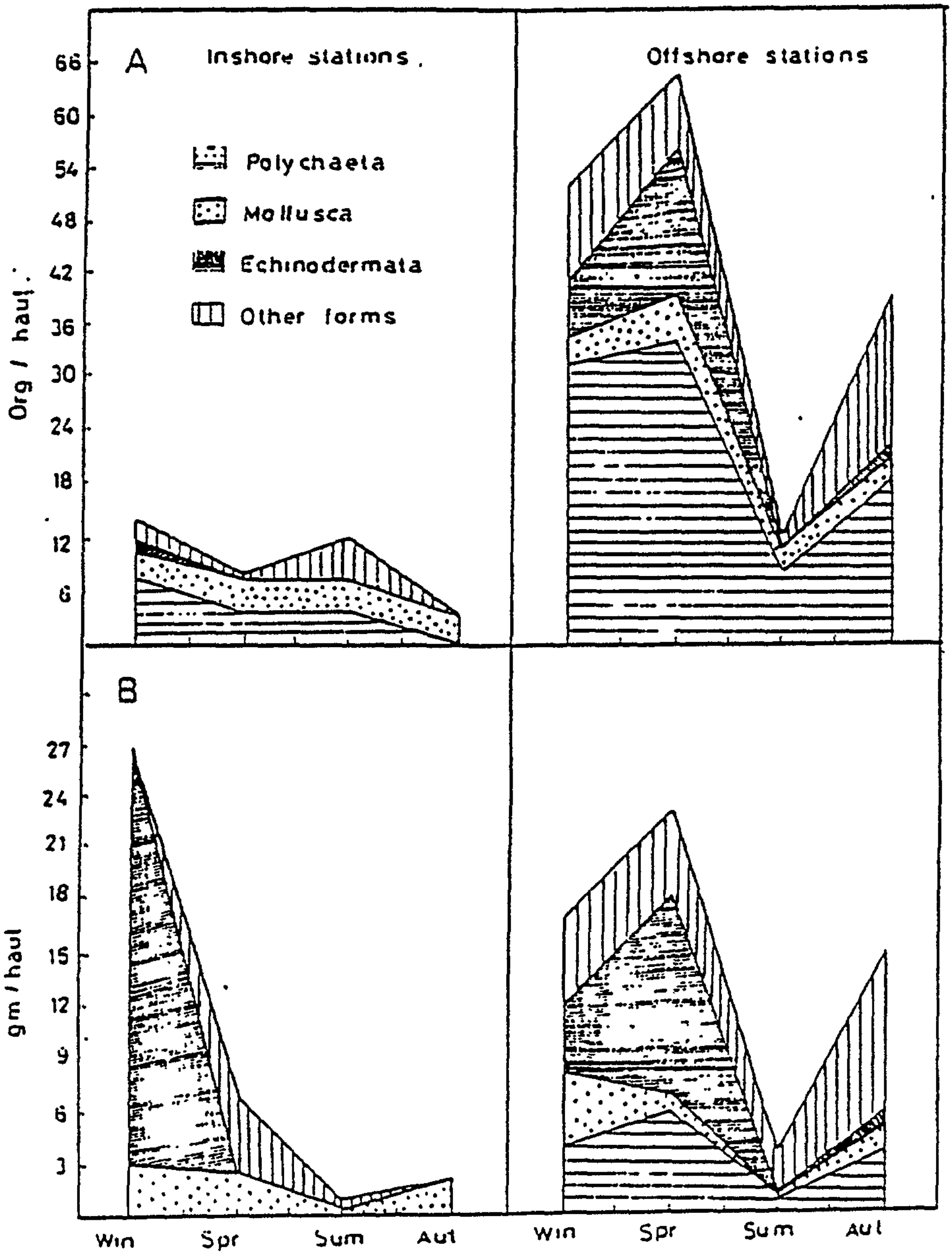


Figure 50 - *Seasonal variations in the total benthic fauna off Matrouh,*
inshore and offshore
A - organisms per haul ($80m^2$)
B - grams fresh weight per haul ($80m^2$)
(source: Anon., 1983b)

2.4.3.7 Marine Turtles

Information available on the marine turtles of the Egyptian Mediterranean Sea is very scarce. Nevertheless, there are three species of marine turtles known from the area. The commonest is the loggerhead turtle, *Caretta c. caretta*, the second, the green turtle, *Chelonia m. mydas*. The leatherback turtle, *Dermochelys c. coriacea*, is the rarest and is only known from a handful of records (Marx, 1968; Frazier and Salas, 1984, in Delft Hydraulics, 1992).

Through a survey of the north-western coast of Egypt, Kasparek (1993) found marine turtle tracks on the beaches of Arab's Bay, west of Matrouh, and of Sallum Bay. All tracks of emerging nesting turtles were identified as tracks of the loggerhead turtle. The dead turtles that were found washed ashore and those found in fish markets and elsewhere were also identified as loggerhead turtles.

In spite of the fact that all the marine turtles are listed as endangered species throughout their range and they are protected by law, the Egyptian official statistics (CAPMAS) show that the turtle landings increased from 100 tons in 1989 to 418 tons in 1990.

2.4.3.8 Marine Mammals

The study area does not provide suitable habitats for the monk seal (*Monachus monachus*). Rocks are rather flat at most locations and no coastal caves are present (Kasparek, 1993).

2.4.4 Summary

The coastal limestone formation with overlying sand dunes extends over almost the whole study area which includes two lagoons.

The coastal dunes, rocky ridges and inland plateau exhibit the greatest diversity of plant species. The plants of sand dunes can be classified into nine forms, of which the annuals form the highest percentage of the total flora.

Between Alexandria and El-Sallum, 27 mammalian species were recorded, of which *Croidura suaueolens matruhensis* and *Gerbillus perpallidus* are endemic to the west Egyptian coast. The dorcus gazelle is presumed to have become locally extinct.

The ornithological list of the area contains 43 species. The supposed breeding of the greater sand plovers in the flat salt lakes between the coastal ridge and Abu Sir ridge would represent the westernmost breeding area of this bird and the only one in Africa. The present status of the houbara, *Chlamydotis undulata*, (listed as a vulnerable species) in Egypt is unknown.

Thirty-seven reptile species were recorded from the north-western coast of Egypt. The presence of five of these in the Fuka-Matrouh area was recently confirmed.

The Egyptian tortoise is classified as vulnerable. There is little recent information about the status of its population in Egypt, but its local population is thought to have been eliminated by the pet trade and habitat degradation, although a small population could still exist on the north-western coast and in north Sinai.

The Amphibia are represented by two species.

The soil fauna in the area have to cope with the problems of excessive heat and drought, as well as the problem of availability and quality of plant litter from the sparse vegetation.

The natural flora and its associated fauna, as well as amphibians, depend to a great extent on the rainfall.

The results of the most recent (available) oceanographic survey of the area, carried out in 1977, show that:

- in winter, off Fuka and Matrouh, the intrusion of a water mass with relatively low salinity (39) and temperature (18°C) was observed to move coastwards. This water mass was balanced by a flow of water of higher salinity and temperature moving seawards;

- in spring, while a weak stratification in temperature and salinity was observed in Fuka, the coastal water in Matrouh was still relatively isothermal;

- in summer and autumn, a distinct seasonal thermocline was observed off Fuka and Matrouh;

- the dissolved-oxygen content of the surface sea water off Matrouh had a high value in winter and decreased during spring and summer and through to autumn;

- in general, the eastern Mediterranean is considered to be oligotrophic, hence poor in the nutrient salts that are necessary for phytoplankton growth;

- the Fuka-Matrouh area is one of the most oligotrophic in the eastern Mediterranean;

- the phytoplankton standing crop off Matrouh was slightly higher than that off Fuka; the population increased seawards from Matrouh, but the opposite occurred off Fuka;

- while the lowest population density of zooplankton was recorded in winter, off Fuka and Matrouh, autumn and summer were the high-growth seasons off Fuka and Matrouh, respectively;

- spring and summer were the high-growth seasons for the benthic flora;

- the highest population densities of the bottom fauna were recorded in spring and summer, inshore and offshore from Fuka, in winter and summer inshore from Matrouh, and in spring offshore from Matrouh.

The sponges were represented in the area by eleven species, five of which are commercial.

There are three species of marine turtles known from the Egyptian Mediterranean Sea; all tracks of emerging nesting turtles in the Fuka-Matrouh area were identified as tracks of the loggerhead turtle.

Although all the marine turtles are listed as endangered throughout their range and they are protected by law, the official statistics show the increase of the Egyptian turtle landings to 418 tons in 1990.

The study area does not provide suitable habitats for the monk seal.

2.5 MANAGED ECOSYSTEMS

2.5.1 Agriculture

As shown in Figure 36 and Table 27, the area of soils suitable for agriculture in the study area is about 88,000 feddan. The deep soils represent 16% of this area. The shallow soils suitable for shallow-root crops represent 80% of these suitable soils. The rest of the area is occupied by the sand-dune soils at Ras El-Hekma

Table 27 - Distribution of soils suitable for agriculture in the study area

Soil type	Area (x 1000 feddan)	%
Deep soils	14.1	16.02
Shallow soils	70.9	80.57
Sand dunes	3.0	3.41
Total	88.0	100.00

In the study area, the main source of fresh water is rainfall (100-150mm per year). This water is stored as soil moisture, surface water intercepted by dykes or stored in Roman cisterns and new cisterns. Thirty-two million cubic metres per year could be used as sheet run-off and about 1.5 million cubic metres per year as wadi run-off; and at present, in the study area, 2.8 million cubic metres per year are intercepted and stored. The other source is ground water.

Agriculture in the study area consists of crop production, range and animal production and fisheries. The limiting factors in agricultural production are ecological, such as availability of soil for agriculture, and availability of water resources. According to the ecological conditions, the study area may be subdivided into several different zones, as shown in Figure 51. These zones are: the agricultural, intensive range, mixed agricultural and range, uncultivated and low range capacity. Within these zones a more detailed classification is feasible.

As shown in Figure 52, the study area is subdivisible into areas of: intensive cultivation, moderate cultivation, low cultivation, no cultivation, intensive range, moderate range, no range, marginal range with high intensity, marginal range with moderate intensity, marginal range with low intensity.

The total area of soils available for agriculture in the Matrouh Governorate is about 372,000 feddan, 88,000 feddan of which are located in the study area. These areas represent 23% of the total area. The area actually used for agriculture is about 125,000 feddan in the whole area, whereas, in the study area, only 20,000 feddan are utilised, which represents only 16%.

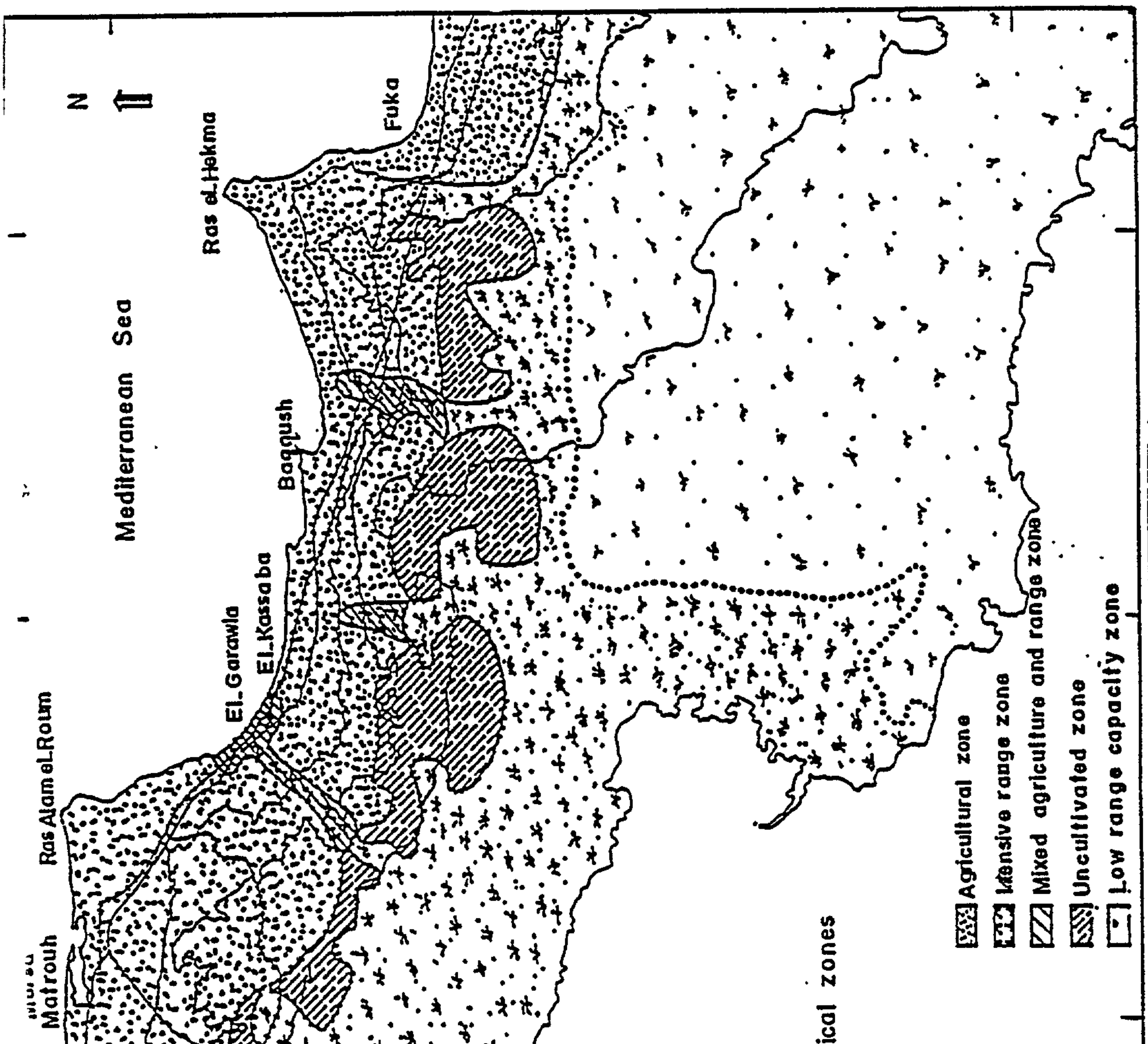


Figure 51 - Ecological zones in the Fuka-Matrouh area

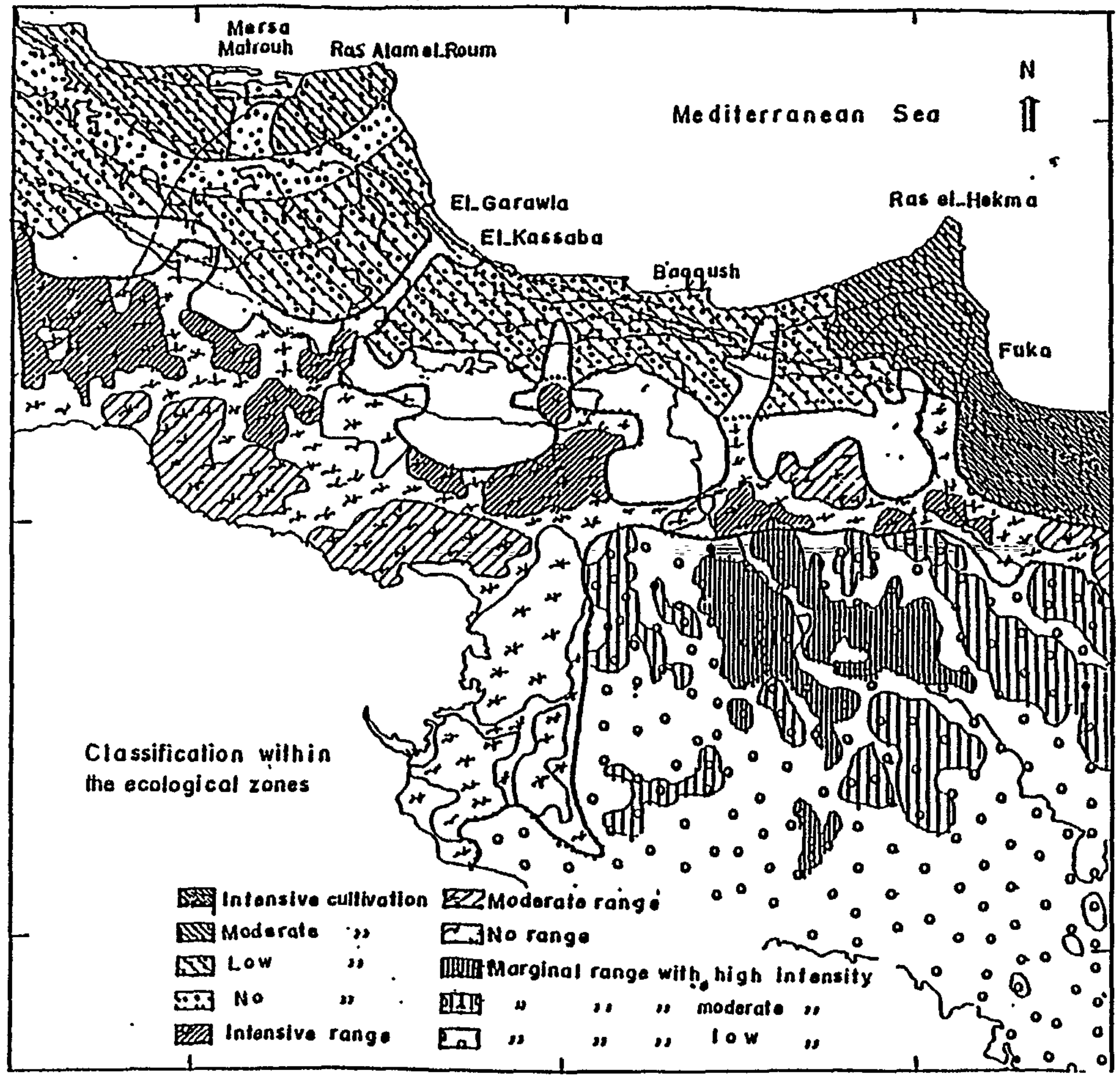


Figure 52 - Subdivision of the ecological zones in the Fuka-Matrouh area

Table 28 - Cropped area (feddan) within the study area and within the Matrouh Governorate

Crop	Governorate		Study area	
	Area	%	Area	%
Annuals: grains (wheat and barley)	99 000	80	6 900	34
Perennials: orchards (fig and olive)	26 000	20	13 100	66
Total	125 000	100	20 000	100

These data indicate that agriculture in the study area is not the limiting factor in the local economy, nor is it the main factor in the economic development. Agriculture represents only 22% of the economy of the study area. Data in Table 28 show the crop area in the whole governorate and in the study area.

The distribution of the cropped area is given in Figure 53. As shown in Table 28, the area used for growing barley and wheat in the study area represents only 34%; fruit is the main agricultural product in the area and generally represents 66%. Range and animal production has the same importance as crop production. According to a 1989 survey, the number of sheep in the whole governorate was 451,500, while in the study area it was 152,700. Figure 54 shows the range carrying capacity in the study area. A measurable deterioration was observed in range land and range capacity, which requires a programme of range improvement to stop this deterioration and develop the range lands in the study area.

2.5.2 Fisheries and the Fishery Potential of the Western Egyptian Mediterranean Waters

Past Trend and Present Situation

The Egyptian Mediterranean waters constitute the largest fishing area in the national fishery. However, the available statistical data on the commercial catch show that, on an annual basis, it is too low, having reached about 32,435 tons per year in 1988-90, which represent about 11% of the total fish catch and aquaculture yield of the country.

The Egyptian Mediterranean coast is about 1000km long, extending from El-Sallum in the west to El-Arish in the east. The fishing grounds along this coast can be divided into two distinct zones:

- the western zone, extending from Alexandria to El-Sallum, with a coast length of about 550km;
- the eastern zone, extending from Alexandria to El-Arish, with a coast length of about 450km.

However, fishing has been concentrated entirely along the coast of the eastern zone, where the continental shelf (to 200m depth) is very wide and flat, reaching a maximum width of about 70km off the Nile delta, while the western zone is practically not used for fishery, for various reasons.

Factors Affecting the Exploitation of the Western Egyptian Mediterranean Waters

The Matrouh Governorate has special peculiarities that make it different from the other provinces of the country As far as the fishery sector is concerned, there are some features that seriously affect fishing in the Matrouh Governorate.

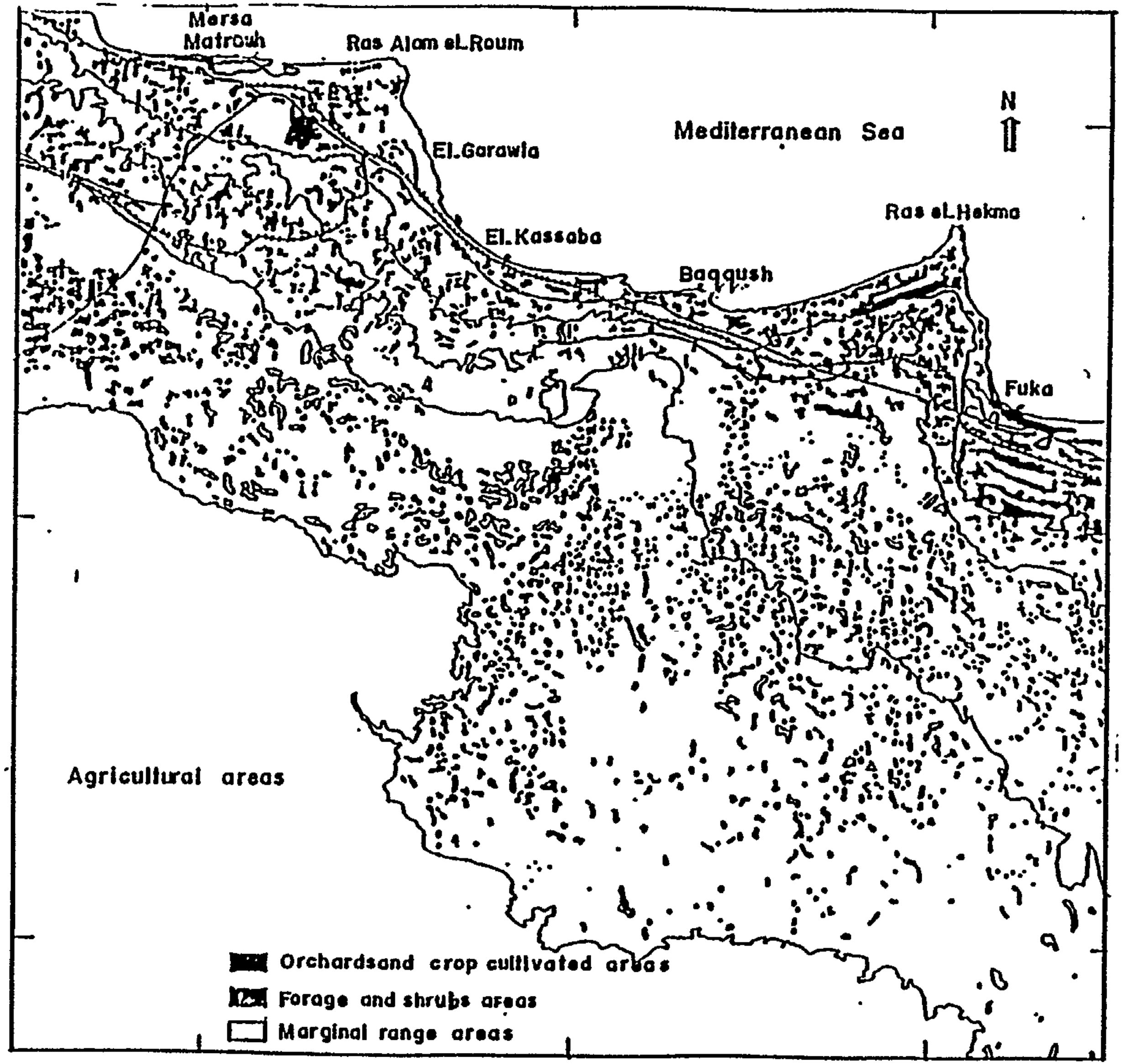


Figure 53 - Agricultural zones in the Fuka-Matrouh area

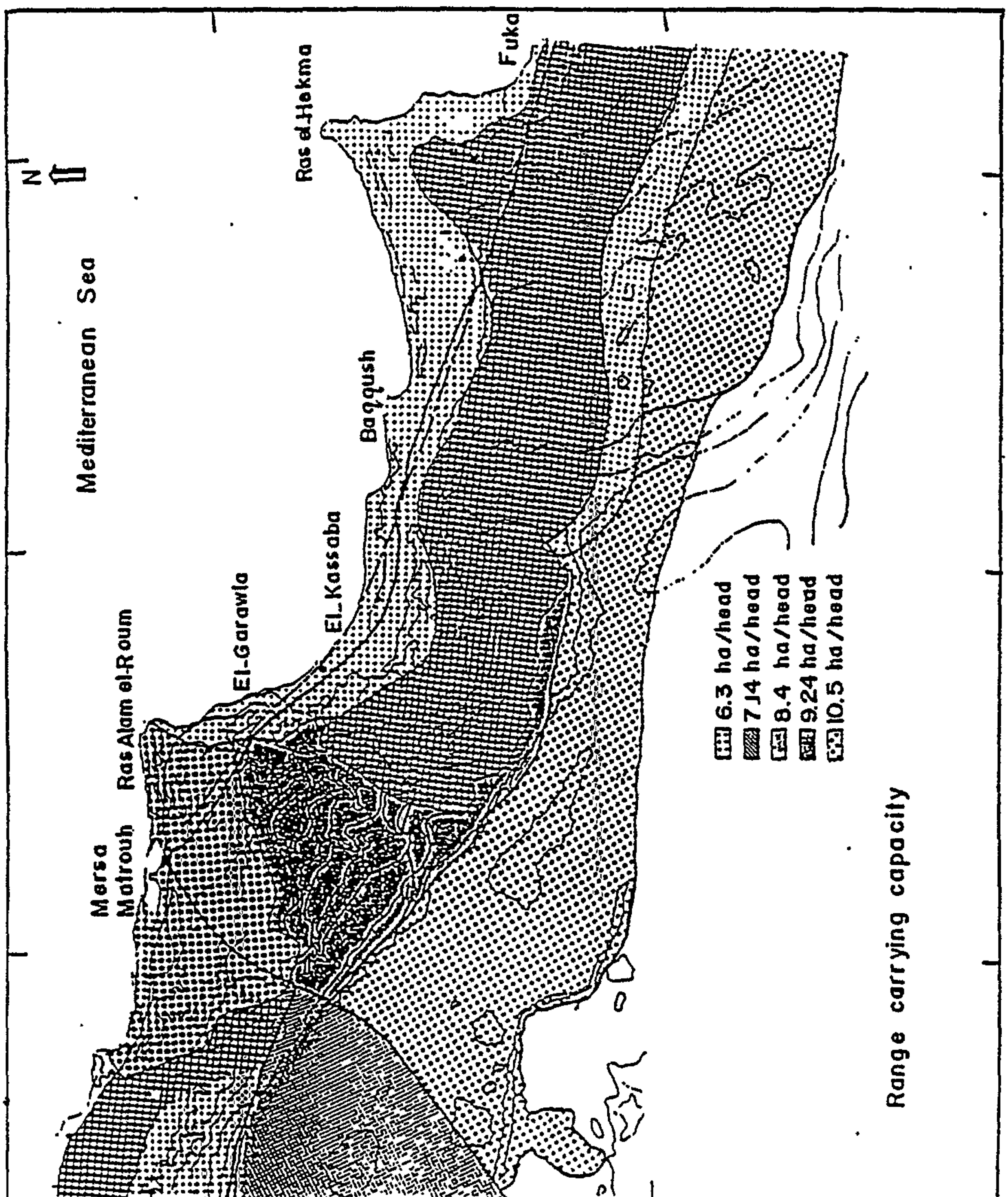


Figure 54 - Range carrying capacity in the Fuka-Matrouh area

- The sea bed in the Matrouh Governorate is rocky and the continental shelf is very narrow (bathymetric chart, Fig. 55). To the east of Matrouh towards Ras El-Hekma, the bottom becomes steadily deeper, the depth varying considerably and at short intervals. Only one nautical mile from the coast, the depth reaches 150 fathoms (≈274m) and in many places the depth was greater than the echo-sounder's range of 275 fathoms (≈503m). However, in a very few, separate areas, the bottom seems to be flat (Anon., 1959).

  A thorough acoustic survey of Ras El-Hekma Bay was carried out by the Russian RV ICHTHIOLOG (1970-71). The survey showed that the El-Kanayes Bay is not suitable for trawling because of the rough bottom and reef formations. Nor does the area between Fuka and Matrouh offer any favourable possibilities for trawling. Either the bottom falls off too steeply to great depths near the shore, or it is so rocky and uneven that it is absolutely impossible to use trawl nets (Al-Koly and El-Wakeel, 1975).

- The western coast is exposed to more or less persistent north and north-west winds. Storms are frequent during autumn and winter. From the beginning of October to the end of March, there are about 16 "nawat" with strong stormy weather, occurring on 60-70 days during that period (i.e., 60-70 days out of 180 days). At the same time, between Fuka and Matrouh, there are no havens for boats in stormy weather, except Matrouh harbour and, to some extent, the bays of Abu-Hashaifa and Ras El-Hekma.

- Most of the inhabitants of the Matrouh Governorate are Bedouins, who have their special social characteristics: they are not willing to work at sea or even to eat fish; therefore, no resident fishing communities are found along the Matrouh coast. Also, the great distance to the centres of fish consumption (Cairo and Alexandria), and the seasonal variation in local fish consumption in Matrouh (maximum fish consumption in summer and next to nothing in winter) adversely affects the development of coastal fisheries in the Matrouh area.

  All these factors, together with some others, greatly affect the fishery exploitation in the area.

Quantitative Estimation of Fish Catch at Matrouh

In the past, there were no official fishery statistical data for Matrouh. Nor are there, in the technical literature, estimates of fish stocks in the Matrouh area. Furthermore, the biological data necessary for the assessment of stocks of commercially important fishes are also incomplete. This is because little scientific work has been done in this area.

However, for the time being, given the present under-exploitation of the fishery resources of the western Egyptian coast, together with the lack of official statistical data on fish landings and fishing effort, it is only possible to give a primitive picture of the fishery situation in the Matrouh area (Hashem, 1990).

In 1982, the Matrouh Governorate started a fishing enterprise. It bought two fishing boats (each 12m long and with a 45hp engine); it then built another two similar fishing boats. In 1983, the Governorate built four smaller fishing boats (each 9m long and with a 30hp engine). Many difficulties faced the enterprise, among which was the fact that the experience and capability of the work force were not adequate to the achievement of the enterprise's objectives. The revenue was enough to cover the running costs of the enterprise, but not enough to cover the fixed costs of the boats. In 1986, the Matrouh Governorate was obliged to close the enterprise and sell the boats (Anon., 1982-1986).

Although the data of the fishing enterprise were mostly to do with the economic parameters rather than the biological ones, it was possible to estimate the average catch-per-unit-of-effort for the Matrouh area at 56kg/boat/day (Table 29).

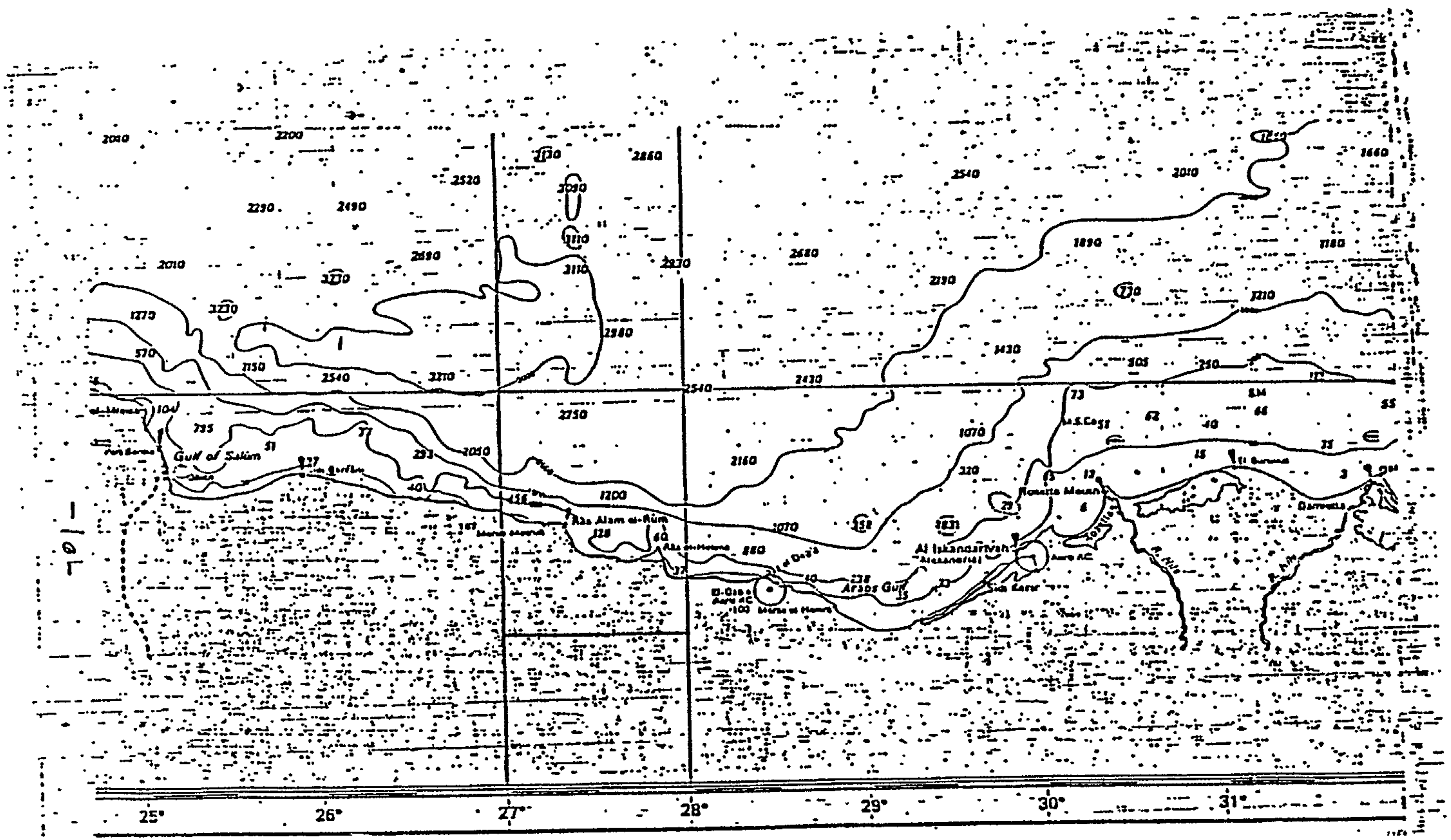


Figure 55 - Bathymetric chart of the Egyptian territorial waters off Matrouh
(depth values in metres)

Table 29 - Fish catch and sale income of one fishing boat (the Ras El-Hekma, 45 hp) of the Matrouh Fishing Enterprise during 1984-85

Month and date	No. of fishing days	Fish landed (in kg)						Sales income (E£)
		Large	Medium	Small	Others	Total	Kg/day	
1984								
April 11-29	9	61	317	233	40	651	72.3	1071
May 8-29	10	101	652	223	27	1003	100.3	1774
June 4-18	12	109	176	184	-	469	39.1	808
July 3-18	8	222	79	148	-	449	56.1	1248
Aug 2-28	10	176	182	390	-	748	74.8	1588
Sept 11-23	10	252	126	250	-	628	62.8	1446
Oct 2-23	6	293	49	28	40	410	68.3	1318
Total	65	1214	1581	1456	107	4358	67.0	9253
1985								
4/5-18/6	18	945	-	200	100	1245	69.1	3047
26/6-4/7	8	146	24	84	5	259	32.4	682
15/7-23/7	6	139	35	111	5	290	48.2	658
7/8-19/8	9	107	81	71	4	263	29.1	646
2/10-31/10	10	-	190	35	-	225	22.5	455
1/11-4/11	3	12	69	29	-	110	36.5	183
Total	54	1349	399	530	114	2392	44.3	5671

Note: Average catch-per-unit-of-effort = about 56kg/boat/day

A coastguard office on the eastern side of Matrouh harbour records the movement of all sailing units, the number of fishing boats working in the area, their names and the number of fishing trips per day and month. From this information and on the basis of the assumed catch-per-unit-of-effort for the Matrouh Fishing Enterprise during 1984-85 (56kg/boat/day), a fishing boat can land 150kg per (2-3 day) trip on average during the warm months (May-October) and 90kg per (1-2 day) trip during the other months (November-April) (Table 30). Then the amount of fish landed each month can be calculated. The monthly fish landings were estimated to be about 20 tons per month during June-September (the summer season). Table 30 also shows that, during May-October, the amount of fish landed was about 13.5 tons per month, and during the other months (November-April), the amount of fish landed was about 5 tons per month. Hence the annual yield from May 1985 to April 1986 would be about 140 tons of fish during that year (Table 30).

Table 30 - Estimation of fish landings at Matrouh during one year (May 1985-April 1986)

Month and year	No. of fishing boats			No. of fishing trips	Calculated	
	Governmental	Private	Total		Catch/trip	Landed catch
May 1985	6	7	13	92	150kg	13800
June	6	8	14	138	per (2-3 day)	20700
July	6	10	16	152	fishing	22800
August	5	14	19	115	trip	17250
September	4	13	17	114		21600
October	5	8	13	88		13200
November	3	3	6	52	90kg per	4680
December	2	3	5	42	(1-2 day)	3780
January 1986	1	3	4	43	fishing	3870
February	2	6	8	49	trip	4410
March	2	8	10	85		7650
April	2	7	9	60		5400
Total	44	90	134	1030		139140

Note: Average catch-per-unit-of-effort = 56kg/boat/day (see Table 29)

The data obtained from the fishing activity of the boats previously working in the Matrouh Fishing Enterprise during 1982-86, together with some data from near-shore experimental fishing with "sinnar" (hooks) and "kanar" (trammel nets) off Fuka-Matrouh (Youssef, 1980-85), can be used as a simple measure of the near-shore fishery potential of the Fuka-Matrouh area; they show it as the most promising fishing area in Matrouh Governorate, as follows:

- For "sinnar" (hooks), the catch per boat per day generally varied from 20kg to 200kg, with an average of about 70kg/boat/day.

- For "kanar" (trammel nets), the catch per boat per day also varied between 20kg and 200kg, with an average of about 50kg/boat/day.

- For "kaddameya" (gill nets), the catch per boat per day varied from 10kg to 120kg, with an average of about 30kg/boat/day.

- The previously stated average catch-per-unit-of-effort could be increased by using more effective fishing techniques.

Some data were previously obtained from a fishing survey of sardine and other pelagic fishes along the Mediterranean coast from Rashid to El-Sallum during 1974-79. This survey revealed that, for purse seines ("shanshoulla"), the catch per unit of effort in the Matrouh area varied from 200kg to 800kg per boat per night of fishing, with an average of about 400kg/boat/night during the summer months (Anon., 1979a).

An illegal and dangerous fishing method, using dynamite, is frequently used by the Bedouins and some members of the military forces along the coast of Fuka-Matrouh.

The western lagoon of Matrouh has an area of 2 x 5 = 10km^2 and is connected to Matrouh harbour by an opening (inlet) about 200m wide. The lagoon is relatively deep (more than 10m) and there is a well established quay of more than one kilometre in length for the Navy.

In this western lagoon, there is some fishing by small rowing and sailing boats. There are more than 10 boats working mostly with "kanar" and sometimes with "sinnar" The fish catch is composed of small fishes, *Lithognathus mormyrus* and *Diplodus annulari* (10-15cm in length) and

Serranus scriba (10-20cm in length), together with crabs.

The average catch of a rowing boat in the lagoon does not exceed 5kg/day. The semi-enclosed nature of the lagoon, in addition to the use of dynamite, may be responsible for the small catch per unit of effort in the lagoon (Hashem, 1990).

Official Statistical Fish Yield at Matrouh

In the past, there were no official statistical data on fish catch in Matrouh, since there was no regular daily fish landing in Matrouh harbour, but only occasional landings.

After the political statement of President Moubarak at the First Meeting of the People's Assembly and the Shura Council in 1984, that the national fish production should be increased within 18 months, so that the country could become self-sufficient in this respect, the General Authority for Aquatic Resource Development (GAARD) and the Central Agency for Public Mobilisation and Statistics (CAPMAS) started, in 1985, to record any fish landing at Matrouh fishing harbour. Table 31 shows the official statistical data on fish yield, either from marine fishing or from aquaculture at Matrouh during the last ten years (GAARD, 1983-1992).

The clearest indicator of the level of fishing activity in Matrouh is the number of fishing boats licensed there.

In 1990, the number of fishing boats registered in Matrouh was 5 (12m long and 45hp engine) and 2 small boats (of 10-20hp engine), together with some fishing boats licensed in Alexandria but which came to work in the Matrouh area; the number varied from 3 to 14 boats monthly (Table 30).

During 1991-92, there were 12 small motorized "sinnar" fishing boats licensed at Matrouh. However, the majority of these fishing units were not working or, if working at all, only occasionally.

Table 31 - Official statistical data on fish yield in the Matrouh Governorate during the last few years (- = no data) (GAARD, 1983-1992)

Year	Total fish yield (tons)	Aquaculture (tons)	Marine fishing (tons)
1983	-	-	-
1984	-	-	-
1985	304	304	-
1986	355	355	-
1987	304	304	-
1988	626	304	322
1989	211	75	136
1990	758	287	471
1991	497	238	260
1992	335	-	335

Qualitative Description of the Catch

Given the sea currents and the unsuitable bottom topography of the continental shelf of the western coast, it follows that the pelagic fishes off Matrouh do not thrive in great quantities or, if they do, only occasionally, since there are no factors favouring a quick and prolific development of plankton, which is the basic food of small pelagic fish species (Anon., 1959).

The most commonly caught pelagic fish in the Fuka-Matrouh area are the following:

Scientific name	English name	Local name
Sardinella spp.	sardine	sardine
Trachurus spp.	horse mackerel	shakhoura
Seriola dumerili	amberjack	inch
Sphyræna sp.	sea pike	magazel
Boops boops	bogue	moza

On the other hand, the rocky bottom off Matrouh is suitable for a relatively rich demersal fish fauna. This provides a good possibility for a profitable coastal fishery. The most important demersal fishery resources are the following:

Bony fishes

Scientific name	English name	Local name
Epinephelus spp.	grouper	wakar
Serranus spp.	sea bass	korfoussa
Pagrus spp.	common sea bream	morgan
Pagellus spp.	red sea bream	ghozailla
Lithognathus spp.	striped sea bream	marmar
Diplodus spp.	two banded bream	shargoush
Sparus aurata	gilt-head bream	denis
Dentex dentex	dentex	addad
Mæna smaris	picarel	*mozat-gar*
Synodus spp.	lizard fish	halaf
Mullus spp.	goat fish	barbonni
Merluccius spp.	hake	nazelli
Umbrina sirosa	croaker	shefsh

Cartilaginous fishes

Myliobatis spp.	eagle ray	wetwaat
Raia spp.	ray .	bakara

Mollusca

Sepia spp.	cuttlefish	sobbeit
Octopus spp.	octopus	akhtaboot

The rocky coast is usually a suitable habitat for a relatively rich fauna of coastal fishes. The presence of these fishes and molluscs presents an excellent possibility for small coastal fisheries, but there is no chance for developing industrial fisheries.

Also, the majority of demersal fish caught by "*sinnar*" (*hooks*) *and* "*kanar*" (*trammel net*) *off* Fuka-Matrouh are of good quality and are sold at high prices. The small coastal fishery, although it does not provide a basis for an intensive industrial fishery, is needed to satisfy the demands of the consumers for a very high quality of fish.

One of the highly valued fish that represents a majority in the "sinnar" catch is the grouper, *Epinephelus* spp. Rafail *et al.* (1969), Mikhail (1980), Ezzat *et al.* (1981) and Wadie *et al.* (1981) studied the age and growth of the three species present off Matrouh and found the following:

- *Epinephelus alexandrinus*: locally known as "soudaya", length range 18-55cm, average size 25cm

Age group (year)	1	2	3	4	5
Calculated length (cm)	17	25	32	38	42
Calculated weight (g)	66	198	396	644	924

- *Epinephelus gigas*: locally known as "orfosa", length range 18-50cm, average size 30cm

Age group (year)	1	2	3	4	5	6	7
Calculated length (cm)	17	24	28	35	40	44	48
Calculated weight (g)	77	217	438	730	1086	1489	1925

- *Epinephelus æneus*: locally known as "waker", length range 20-100cm, average size 50cm

Age group (year)	1	2	3	4	5	6	7	8
Calculated length (cm)	18	33	48	61	72	82	95	95
Calculated weight (g)	68	42	1299	2571	4262	6089	9722	9722

Species Composition of the Shanshoulla Catch

Experimental fishing with "shanshoulla" in the area from El-Alamain to Matrouh in April and May 1977 (Anon., 1979a) showed the following:

- In April 1977, the catch per boat per night was 105kg to the east of El-Dabaa, while the catch per hour under lighting reached 49kg. *Trachurus mediterraneus* dominated the catch (63.3%) followed by *Sardinella aurita* (18.1%), *Boops boops* (9.5%) and *Sardina pilchardus* (9.1%).

- In May 1977, the catch per boat per night varied between 216kg off Sidi-Abdel-Rahman and 563kg off Ras El-Hekma, while the catch per hour under lighting was 11kg off Sidi-Abdel-Rahman and 32kg off Ras El-Hekma. The average catch per hour under lighting was estimated to be 231kg for the two places. *S. aurita* dominated the catch (61.5%) followed by *T. mediterraneus* (23.3%), *B. boops* (13.3%) and *S. pilchardus* (1.9%).

- During the two months, the body lengths of *S. aurita* ranged between 11cm and 25cm (average length = 15.9cm and average weight = 38.7g); for *B. boops*, between 14cm and 24cm (average length = 18.3cm and average weight = 61.6g); and for *T. mediterraneus*, between 9cm and 26cm (average length = 20.6cm and average weight = 77.6g).

Analysis of the few bottom-trawl catches during 1985-86 (Faltas, 1993) showed that the majority of the catch off Matrouh was composed of *Boops boops* (37%), *Pagrus* and *Pagellus* species (14%), skates and rays (10%), lizard fish (9%), *Mullus* spp. (8%) and *Trigla* spp. (8%), as well as *Synodus saurus*, although *Saurida undosquamis*, a Lessepsian migrant, was absent from the Matrouh catch.

2 5 3 Sponge Fisheries

Past Trend and Present Situation

In Egypt, sponges have so far been little studied. Of the earliest reports dealing with sponges in the Egyptian Mediterranean waters, the work of Paget (1921-1923) is of great interest. Paget investigated sponge beds west of Matrouh to the Libyan border, as well as those in Port Said and on the western coast from El-Agami to El-Sallum; he also made a survey of sponge beds along the Egyptian Mediterranean coast from El-Agami to El-Sallum. He denominated the three commercial sponges: Turkey Cup, Honeycomb and Zimocca. He also made a comparative study of the different methods of sponge fishing (scaphander, skin-diving and fernez - a diving apparatus in which compressed air, supplied by the sponge-fishing boat, passes into a bottle carried on the diver's belt, thence to his mouth by a breathing tube).

No studies were made on the Egyptian commercial sponges between 1936 and 1983, although yearly statistical records of the catch were kept. In 1983, El-Beshbeeshy obtained his M.Sc. degree on the sponges west of Alexandria. In this work, four regions (El-Hammam, El-Alamain, Fuka and Matrouh) were chosen for sampling sponges on the continental shelf. The last two sites lie 2-5km from the sea shore (Fig. 56).

The Egyptian sponges are considered to be the best in the world, because of the favourable environment along the west coast of Alexandria through Matrouh to El-Sallum. This area is characterised by suitable water temperatures and the abundance of solid substrate which favour the growth of sponges.

Two main types of solid substrate are necessary for sponge settling: rocky substratum or consolidated substratum. The consolidated substratum is constructed by living organisms. Each substratum is covered with the sea grasses (*Zostera* sp. or *Posidonia* sp.), in addition to the green alga *Caulerpa prolifera*, Lamouraux, and this is typical of all the commercial sponge beds all along the western Egyptian coast.

The Egyptian commercial sponges are the following:

Scientific name:	English Name:	Local Name:
Spongia officinalis	Turkey Cup	Banati
Spongia agaracina	Elephant ear	
Hippospongia communis	Honeycomb	Kapadika
Spongia zimocca	Leather sponge	Zimocca

The Egyptian commercial sponges are characterised by their smooth texture, high ability to absorb liquids and resistance to high compression. Because of these characteristics, the Egyptian commercial sponges have invaded all foreign markets (i.e., all the catch goes into international trade).

The study of the abundance of the commercial sponges (El-Beshbeeshy, 1983) revealed that the mean numbers of the three sponge types was 99.5 individuals/km^2, in the region of El-Hammam, 35.6 individuals/km^2, in the region of El-Alamain, 52.4 individuals/km^2, in the region of Fuka, and 64.5 individuals/km^2, in the region of Matrouh (Table 32 and Fig. 57).

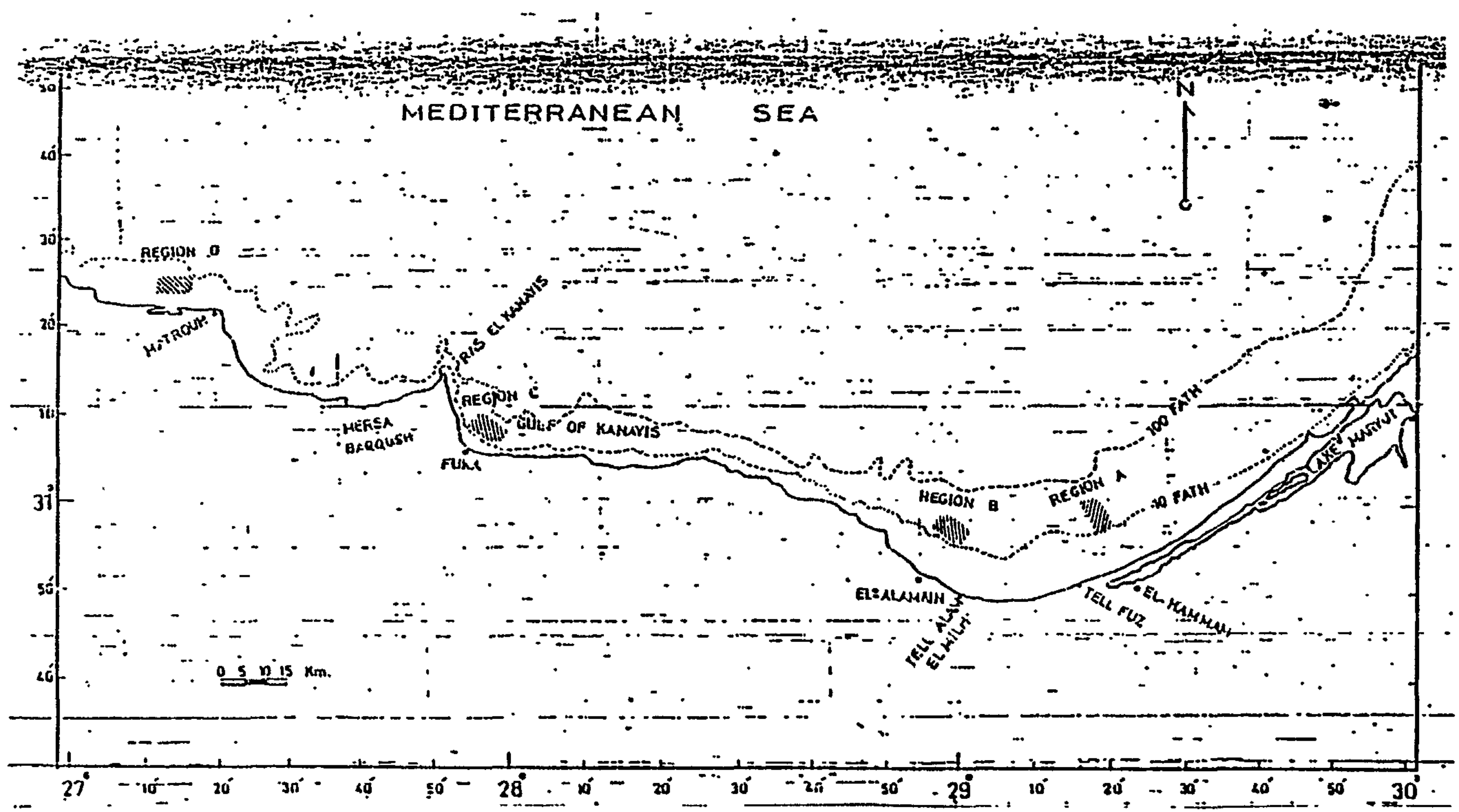


Figure 56 - The area of sponge investigations and the four regions sampled during 1981

Table 32 - Population density (number per km^2) of the three commercial sponges in each region, with standard errors (±), number of samples (in round brackets), and the depth range (in metres, below) (source: El-Beshbeeshy, 1983)

Area	Date of sample	Mean population density		
		Turkey Cup	Honeycomb	Zimocca
El-Hammam	18/6/81-21/6/81	55 7 ± 3.5 (17) 30 - 56	26 5 ± 4.4 (17) 11 - 54	17.3 ± 3.4 (17) 9 - 23
El- Alamain	8/8/91-11/8/81	20.1 ± 2.1 (14) 8 - 30	10.1 ± 0.9 (14) 5 - 16	5.4 ± 0.8 (14) 1 - 8
Fuka	18/9/81-21/9/81	21.9 ± 1.1 (33) 10 - 32	18 2 ± 1.0 (33) 9 - 35	12.4 ± 1.8 (33) 5 - 30
Matrouh	20/10/81- 24/10/81	15 6 ± 1.4 (14) 9 - 27	31.2 ± 2.3 (14) 16 - 41	14.7 ± 2.0 (14) 6 - 25

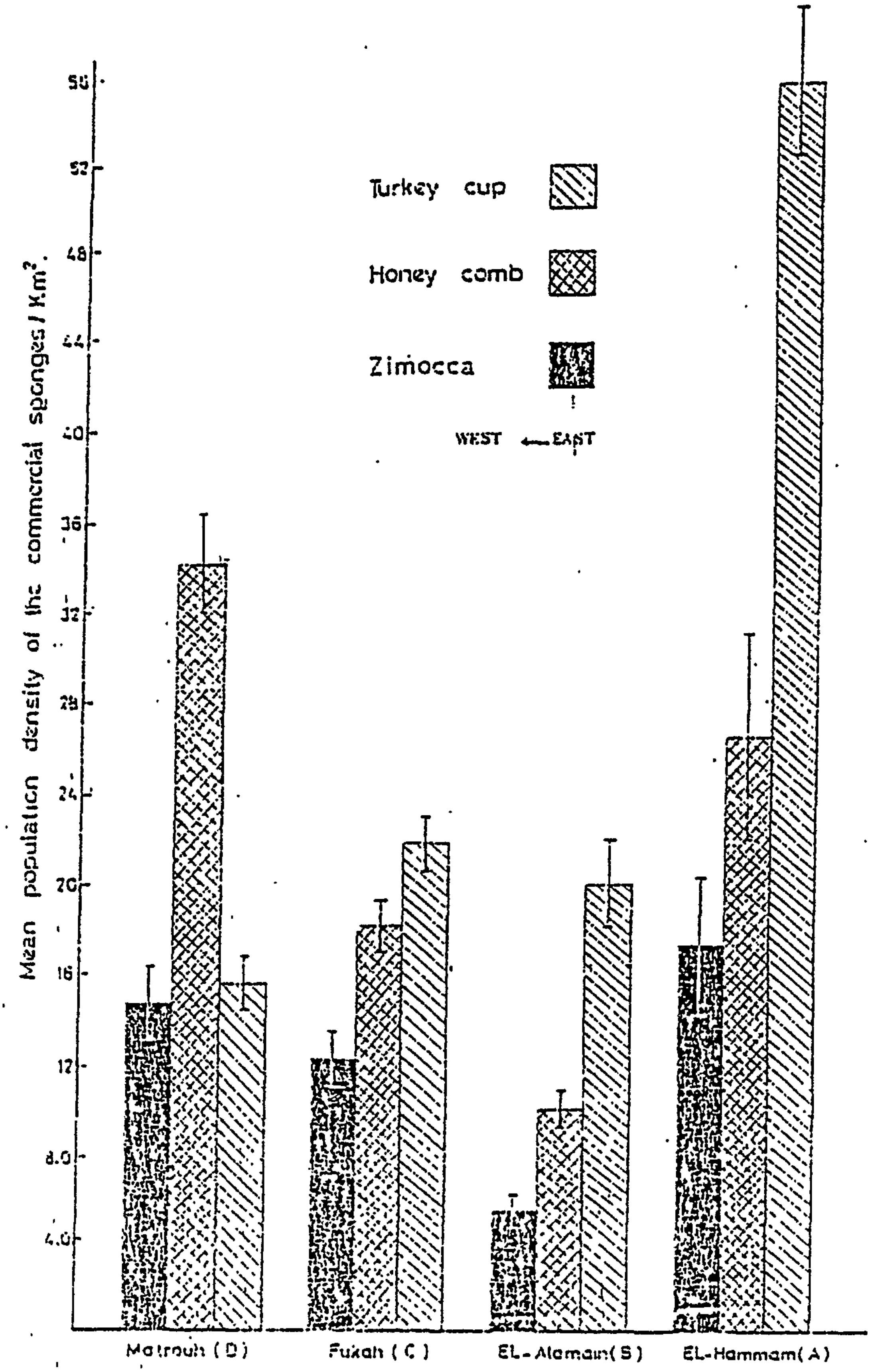


Figure 57 - The mean population density (number per km^2) of the three commercial sponges in each region. Vertical lines indicate the standard errors of the means (source: El-Beshbeeshy, 1983)

The mean numbers of each commercial sponge species in each area were as follows:

- Turkey Cup: 55.7 individuals/km^2 (El-Hammam), 20.1 individuals/km^2 (El-Alamain), 21.9 individuals/km^2 (Fuka) and 15.6 individuals/km^2 (Matrouh); likewise
  Honeycomb: 26.5 individuals/km^2, 10.1 individuals/km^2, 18.2 individuals/km^2 and 34.2 individuals/km^2, respectively; and
  Zimocca: 17.3 individuals/km^2, 5.4 individuals/km^2, 12.4 individuals/km^2 and 14.7 individuals/km^2, also respectively.

The Egyptian Company for Fishing and Fish Gears has been the responsible authority for fishing and marketing the sponges. Personal communications with the responsible people of the company revealed that a well trained diver, with a fernez apparatus, can collect 150-200kg of sponges per season, in the Matrouh area, and a sponge-fishing boat with six divers can produce one ton per season (usually May to October). This amount is usually sold for about E£100,000 in foreign currency.

Trained divers usually collect the sponges from different depths, ranging from 10m down to 50m, and the renewal of sponge beds usually takes 3-4 years to reach commercial size.

The annual statistical data on the Egyptian sponge catch and the annual export during the last few years (1980-1991) is given in Table 33 (CAPMAS, 1980-91).

Table 33 - Egyptian sponge catch (kg) and annual export, from 1980 to 1991
(source: CAPMAS, 1980-1991)

Year	Sponge species (Kg)			Total		No. of fishing boats	Av. catch per boat (kg)	Export	
	Turkey Cup	Honey Comb	Zimocca	Amount (kg)	Value (E£)			Amount (kg)	Value (E£)
1980	1277	2415	1371	5063	134863	7	723.3	6199	158170
1981	2492	1996	613	5101	198021	7	728.7	4846	200762
1982	1012	2469	686	4174	162035	8	521.8	4738	177202
1983	2633	2037	693	5363	288957	8	670.4	4638	198153
1984	1034	2189	823	4046	351710	7	578.0	7529	263524
1985	2017	2689	964	5670	75786	10	567.0	3616	145410
1986	2016	2678	969	5663	75787	9	629.2	5361	396152
1987	284	703	100	1087	14566	9	120.8	3007	302477
1988	222	387	122	731	21999	5	146.2	991	31392
1989	54	412	226	692	269430	5	38.4	666	258870
1990	291	257	574	1122	364738	6	187.0	400	155600
1991	35	450	302	787	318604	5	157.0	-	-

NB Where amount exported exceeds amount caught in any one year, this may be due to the accumulation of unsold sponge in the previous year

The Table indicates a sharp decrease in the annual catch of sponges in 1987. About 5,663kg were harvested in 1986, there was a sudden drop to about 1,087kg in 1987 and again to 200kg in 1992.

In the last few years, the state of the Egyptian commercial sponge beds between Alexandria and El-Sallum has been very bad. The symptoms the divers all over the area have observed indicate a fungal infection of the sponges. The shape, size and amount of all the commercial sponge species are greatly affected by the fungal infection (water mould).

2.5.4 Aquaculture

Past Trend and Present Situation

Previous experiments conducted in many parts of the world have shown that many marine fishes are able to grow at high densities on artificial feeds; some studies have shown a higher growth rate and food-conversion efficiency in many fishes under such conditions.

Pens and cage culture have been recently started in Egypt. This type of fish farming succeeded in fresh water, but in the sea it is still in the experimental stage.

The technology of rearing fish in pens or cages is simple and does not require much space or capital; the main requirements are as follows:

- suitable site for laying out the pens or cages;
- quality and quantity of fingerlings to be farmed;
- suitable artificial feeding, which should be economically feasible; and
- continuous daily meticulous inspection of the cages.

All these requirements could be easily met for such a new and beneficial activity to individual fishermen or fishery co-operatives in the Fuka-Matrouh sector. Nevertheless, in the Fuka-Matrouh area, storms are frequent during the autumn and winter months and there are no sheltered places suitable for laying out fish pens or cages, in case of stormy weather, except the western lagoon of Matrouh and the bays of Ras El-Hekma and Abu-Hashaifa.

It is essential to secure the necessary fish fry and fingerlings in amounts that will meet the requirements of cage farming. In Egypt, the most suitable fish for marine aquaculture are sea bream, sea bass and grey mullet. There are about eight centres along the Mediterranean coast (from Alexandria to Port Said) for collecting the fry and fingerlings of the above-mentioned species.

The cage is made up of knotless nylon netting on a rigid frame. The cage is installed in water and held in place by various types of anchors and floats. The life expectancy of such a cage is 4-5 years. The size of a cage may vary according to one's choice, needs or capability. A fish farmer with small capital may start with cages measuring 6 x 6 x 6 metres. For large-scale production, the ideal cage size is 150-200m^2 with a 6-8m depth.

Stocking rates vary according to the size and species of fish to be farmed. It may reach 50-100 fish per cubic metre. The growing period may be 8-10 months. Artificial feeding is essential in mariculture. The daily amount of food supplied is 3-5% of the fish weight, and is delivered twice or three times daily.

The main means of increasing the economic viability of cage culture is to reduce feed costs, which account for the largest part of the costs. Local sources of feed are important. The use of cheaper, lower-protein-quality feeds (20% protein) without sacrificing fish growth rates is the aim.

The fish farm should have adequate security measures against poaching. A guardhouse should be located on the spot to allow for immediate detection of intruders. Meticulous inspection of the cages should be a daily activity. Nets could be slashed and, if undetected, will result in the loss of stock.

Partial harvesting may be carried out before the scheduled harvest, if the market price allows good profit, even if the fish have not reached the projected or expected size. Sometimes, the fish population is deliberately reduced by partial harvesting to induce better growth of the remaining fish.

Unsuccessful field trials of floating fish cages were carried out in 1990 by the Egyptian Company for Fishing and Fish Gears in the western lagoon of Matrouh to determine growth rates and food conversion efficiencies of sea bream and sea bass fed on a high-protein, commercial, pelleted feed three times daily (personal communication).

2.5.5 Sylviculture

There are no forests in the study area. Only some Accacia shrubs are cultivated to fix sand dunes or as forage crop.

2.6 ENERGY AND INDUSTRY

2.6.1 General

This section revie ·s the energy supply, consumption patterns and available power resources in the area and the suppli ·s of the new energy needed for new development. It also briefly describes the industries common in the area and their future plans.

2.6 2 Energy

2.6.2.1 Traditional Energy

Electricity is considered to be the prime energy resource on which development largely depends. *Previous studies (Pacer/Egypteam Consultants, 1986a) showed that there is no high-voltage line from the main national electricity grid to the Fuka-Matrouh area, the high-voltage lines ending at Burg El-Arab city about 170km to the east of Fuka.*

So the study area mostly depends on a local thermo-electric station and diesel generators, of limited outputs, to meet its power needs. Table 34 gives the different sources of energy in the Fuka-Matrouh area.

Table 34 - Sources of electricity in the study area

Place	Source of energy	No. of units	Power
Matrouh City	thermo-electric station	1	3 megawatt-hours
	thermo-electric station	1	5 megawatt-hours
	steam-electric station	1	30 megawatt-hours
Sidi Henish	diesel generator unit	1	50 kilowatt-hours
Baqqush	diesel generator unit	1	50 kilowatt-hours
	diesel generator unit	1	80 kilowatt-hours
Ras El-Hekma	diesel generator unit	2	105 kilowatt-hours
	diesel generator unit	1	240 kilowatt-hours

These sources are in addition to some private generators providing electricity in some of the scattered villages and/or settlements The energy produced is used for households, governmental offices and motive power in the local industries.

Figure 58 gives the breakdown of electricity consumption by sector in the Governorate of Matrouh in 1992. Households are the major consumers of electricity (72.2%), whereas motive power is the minor one (9.9%)

Kerosine is becoming an increasingly important and commonly used fuel in the area (El-Miniawy et al, 1992) It is used to provide light and fuel for cooking. Although shrubs are still being used for cooking and heating, they are gradually being replaced by kerosine. Shrubs and kerosine are usually used in the villages and settlements far away from the main roads. The furnaces producing bread use fuel oil as an energy source. Benzine and kerosine are used to run cars, motorcycles and other vehicles

2.6.2.2 Wind Energy

The wind on the north-west coast is one of the highest in the entire country. Wind energy has therefore been used in the study area for pumping water since the early 1960s; the inhabitants of Fuka-Matrouh area have been encouraged to use it. This experiment did not work as successfully as anticipated, however, for lack of continuous maintenance of the fans and other mechanical parts which were readily degraded by the frequent sand storms.

The use of this method seems, nevertheless, to be appropriate for pumping ground water, although over-pumping - if by mechanical means - will exhaust the non-saline water and produce saline water, which is harmful to the crops that do not tolerate high salinity. The proposed industrial development in the area and the establishment of an electro-mechanical maintenance centre will encourage people to use these wind pumps to obtain water for irrigation and cultivation of the land. Wind energy is clean and non-polluting.

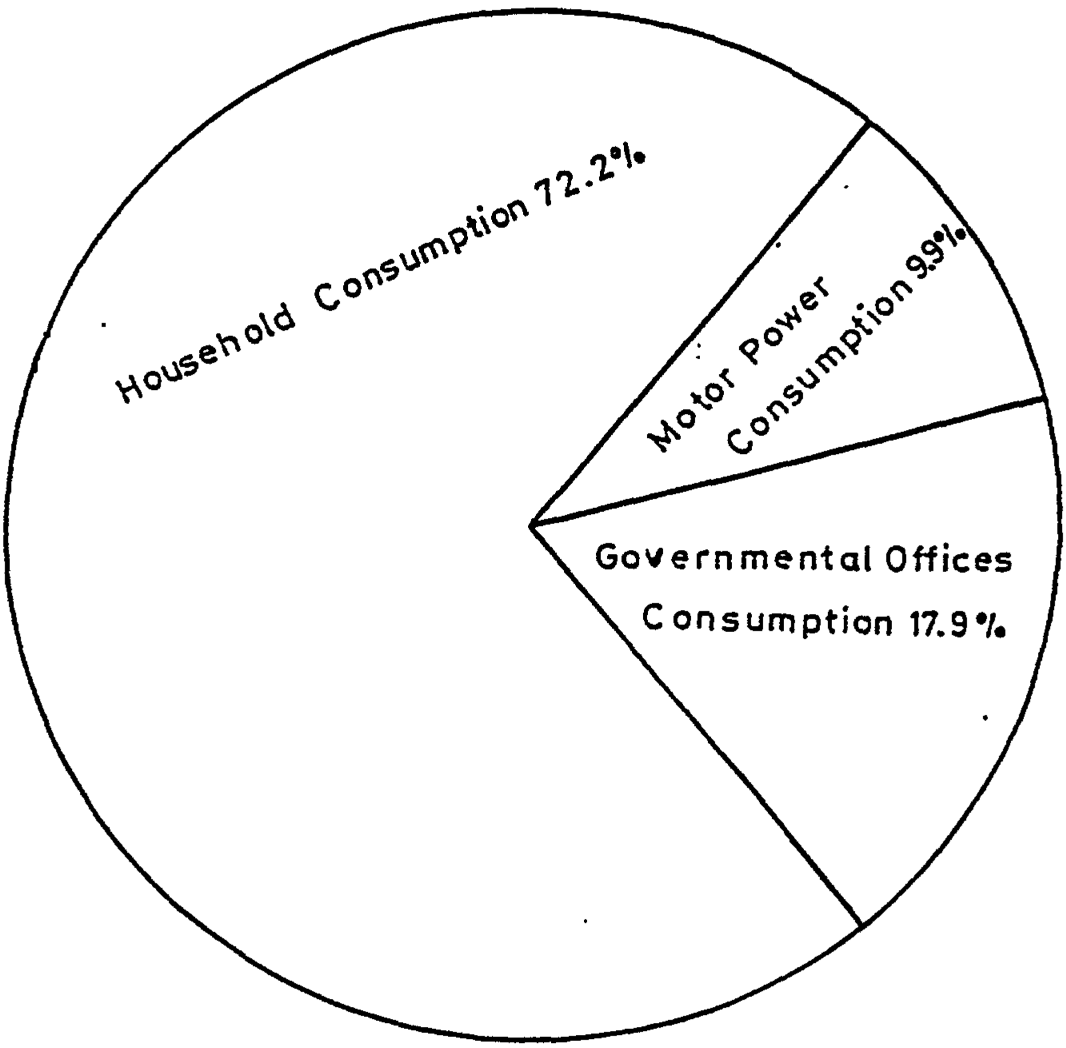


Figure 58 - Breakdown of electricity consumption by sectors

2.6.2.3 New Energy

There are many new energy sources on which the development project can depend. The following is a brief summary of these resources:

<u>Dabaa Nuclear Station</u>

Nuclear energy is one of the inevitable solutions to the problem of economical energy supply required to carry out the development plans for the study area. This station was already scheduled to provide 2,000 megawatts by the end of the first stage and to reach 8,000 megawatts by the end of the year 2000.

The decision to set up the first and second units of the giant Dabaa nuclear station, with a starting capacity of almost 2000MW, was taken in 1986, but so far this decision has not been implemented.

Hydro-Power (Qattara Project)

The Moghra-Qattara project for generating hydro-power is still under consideration. The capacity of the proposed generator is 1,800 megawatts, which could provide 1,525 megawatts at peak consumption during the eight hours required to fill the lake, daily. Electricity should be transmitted through a double high-voltage line of 500 kilovolts to the station at Haram (Pacer/Egypteam Consultants, 1986a).

Solar Energy

The study area is notable for the high number of hours of sunshine throughout the year, reaching 3,500 hours on average. The intensity of the solar radiation is, on average, 3,500-5,000 kilocalories per square metre and could be used in some applications such as:

- heating water to meet domestic and industrial requirements;
- drying crops and agricultural products;
- deep freezing by solar freezers (used in fish-freezing); and
- generation of mechanical power by the thermal units that are used in water pumping.

Wave Energy

Wave records on the north-west coast show that the waves are high in the winter and moderate in the summer, and the energy is high enough to cause many of the problems encountered along the coast. Nowadays, there are many methods to utilise this energy to generate electricity and distill water, at the same time protecting the coast from erosion/accretion problems. The products can be utilised in the new coastal development because this energy source is non-polluting.

2.6.3 Industry

Statistical analysis of employment in economic activity (Pacer/Egypteam Consultants, 1986b) shows the relative importance of the following sectors in the study area (see Fig. 59):

- agriculture, grazing and fishing	= 71.3%
- distribution sectors (trade, storage, transport and communities)	= 17 6%
- construction and building	= 5.2%
- service sector (personnel and social services etc., including non-classified activities)	= 5.0%
- manufacturing industries, mining and electricity generation	= 0.9%

Agriculture and grazing are clearly of prime importance compared to the other economic sectors and industry plays only a minor role in absorbing labour in the area. This may be due to the insufficient supply of energy and water in the area, and the traditional life of the Bedouins who migrate in search of water and pastures and therefore have only weak connections with permanent settlements.

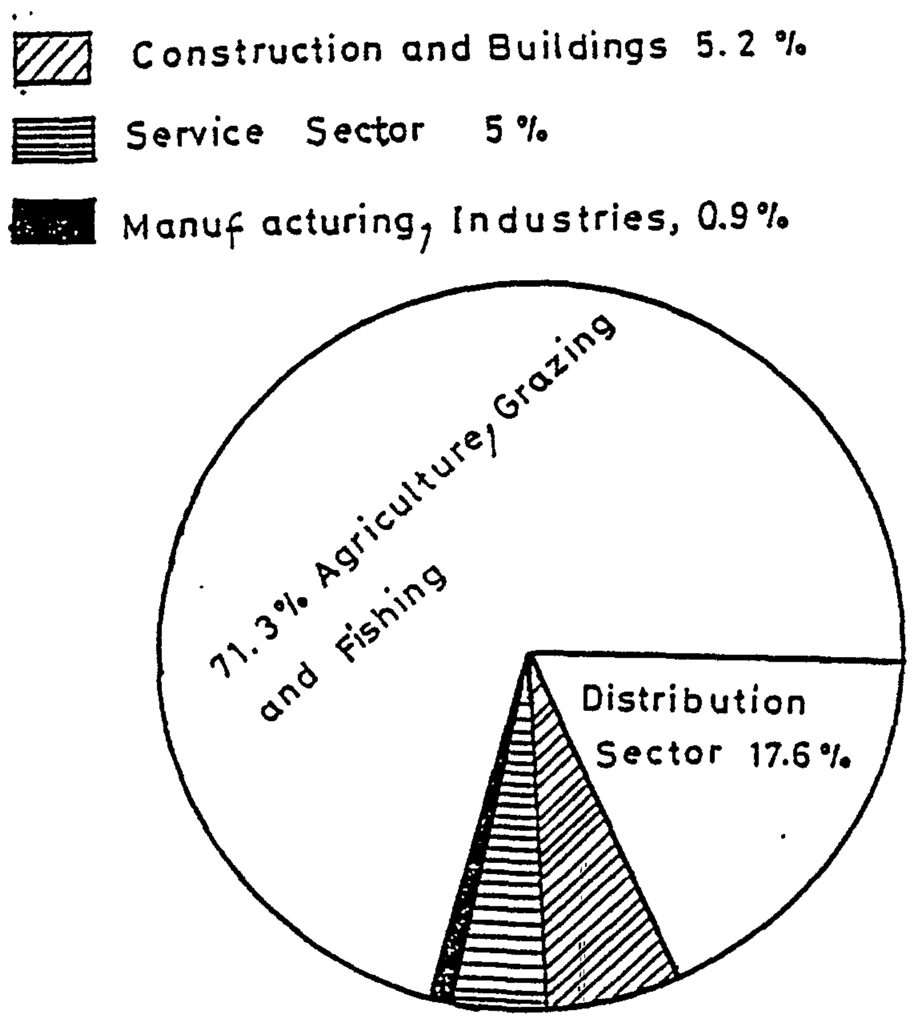


Figure 59 - Breakdown of employment by economic sector

The industries in the region comprise agro-products such as pickled olives, olive oil, dry figs, dry mint, jam, dairy products (e.g., fresh milk, butter and cheese), handicrafts (e.g., blankets, carpet-wool spinning, pillow cases, necklaces and tents), meat products (e.g., traditional kadid, pemmican and pasterma), and leather products (e.g., shoes and handbags, etc.). Most of these products are for domestic use, although leather products are used in trade.

There are also some small private workshops for carpentry, vehicle maintenance, electro-mechanical repair of agricultural equipment, plumbing and blacksmithing. The majority of these workshops are to be found in the big cities, such as Matrouh.

<u>Future Plans</u>

The targets of the development plan include four industrial groups that will conform with the possibilities of the area and its future development. They are:

<u>A Central Industrial Plant</u>

It is proposed to establish it on an area of 805 feddan south of the Matrouh/Alexandria international road between kilometres 26 and 28.5 from Matrouh; the width of the area is 1.5km and is near the city of Garawla. The plant includes the following:

- workshops for:
  - heavy industries, such as manufacturing of vehicles, agricultural machinery and equipment for new reclamation areas;
  - medium industries, such as marble-cutting and building materials; and

  - light industries, such as blacksmithing, carpentry, repair and maintenance of vehicles and windmills.
- exhibitions for investors, and administrative offices.

- services, including:
  - water stations, electricity stations, fuel stations and waste-treatment plants;
  - banks, telephone and post offices, integrated hospitals, fire station and security;
  - residential area for workers; and
  - green area occupying up to 40-45% of the industrial zone.

Agro-Industrial Projects

These projects include the construction of olive presses in the olive cultivation areas. It is expected that one ton of olives will yield 230kg of oil. The programme also includes a dairy-product processing factory integrated with animal production projects with a capacity of 70 tons of milk per day.

Handicrafts and Household Industries

Within the scope of these projects, the programme recommends the construction of a training centre for the crafts that can be exercised by someone working alone, so that his income could sustain the worker and his family, thus encouraging him to settle in the area, as well as encouraging co-operation amongst craftsmen so as to assist them to develop traditional schemes and modernise their carpet-making ("kleems").

Fishery Projects

The project aims at taking advantage of the natural characteristics of the area to increase fish production to meet the expected future consumption of the resident population and tourists. The plan includes projects to cultivate fish in floating cages, fish and shrimps together in earth basins and fenced areas. It also proposes the construction of these fish-culture centres on the coast at Ras El-Hekma, Fuka and Garawla.

2.6.4 Summary

Energy demands in the study area are satisfied mainly by electricity generated from local thermo-electric stations and diesel generators. Kerosine is becoming an important and common source of fuel in the villages and settlements far away from the main roads. Wind energy is used for pumping water for cultivation but it is suffering from a lack of maintenance facilities. The study area could be supplied by new energy sources from Dabaa nuclear stations and from hydro-power (Qattara project) when they become operational. Solar energy is also recommended, as well as wave energy for the coastal areas. These energies are non-polluting.

Industry is presently limited to agriculture, grazing and fishing. Plans for new industry are under development for heavy, medium and light industries (vehicles, agriculture machinery, blacksmithing, carpentry, repair and maintenance workshops), and for improving existing agro-industrial projects, handicraft and household industries.

2.7 TOURISM

2 7 1 General

This section describes how the tourist industry is developing in Egypt, in Alexandria and along the western coast. It shows the advantages of specific zones in the Fuka-Matrouh area, such as the triangle formed by Matrouh city and its neighbourhood, the Hawala/Baqqush coastal strip and Ras El-Hekma. This part also illustrates the present and expected tourist industry in the area.

2.7.2 Introduction

Estimates have shown that the resident population in the Mediterranean, of about 130 million people, becomes doubled during the peak summer months (UNEP, 1994a). By the end of the 1980s, over 120 million tourists had visited the countries of the Mediterranean, which is about 36% of all tourists throughout the world. By the year 2025, if the present holiday patterns are maintained, there will be between 35 million and 52 million additional tourists who will visit the Mediterranean region over the three-month summer tourist peak between June and August. By 2025, it is estimated that 400 million tourists will visit the Mediterranean annually.

2.7.3 International Tourism in Egypt

In Egypt, as one of the Mediterranean countries, tourism development is related to the development of global international tourism. Table 35 shows that the Egyptian share of international tourism has increased during 1974-1984 from 0.34% to 0.60%.

Statistical data show that there is a continuous increase in the number of tourists visiting Egypt as a result of the new open-investment policy that Egypt has adopted. Figure 60A shows that the number of tourists that visited Egypt in 1971 was 428 thousand; this number increased to 3.207 million in 1992 and was 2.508 million in 1993. The number of tourist-nights spent in Egypt increased from 5.990 million in 1971 to 21.836 million in 1992 and was 15.089 million in 1993 (Figure 60B). In spite of the increase in the number of tourist-nights and the number of tourist arrivals in Egypt, the average length of stay decreased from 14 nights in 1971 to 6.8 nights in 1992 (Figure 61A). This is because of the increase in the number of businessmen and tourist groups who always stay for short periods (one or two days). Figure 61B shows the number of tourist arrivals by nationality, which indicates that the number of Arab tourists has increased in recent years.

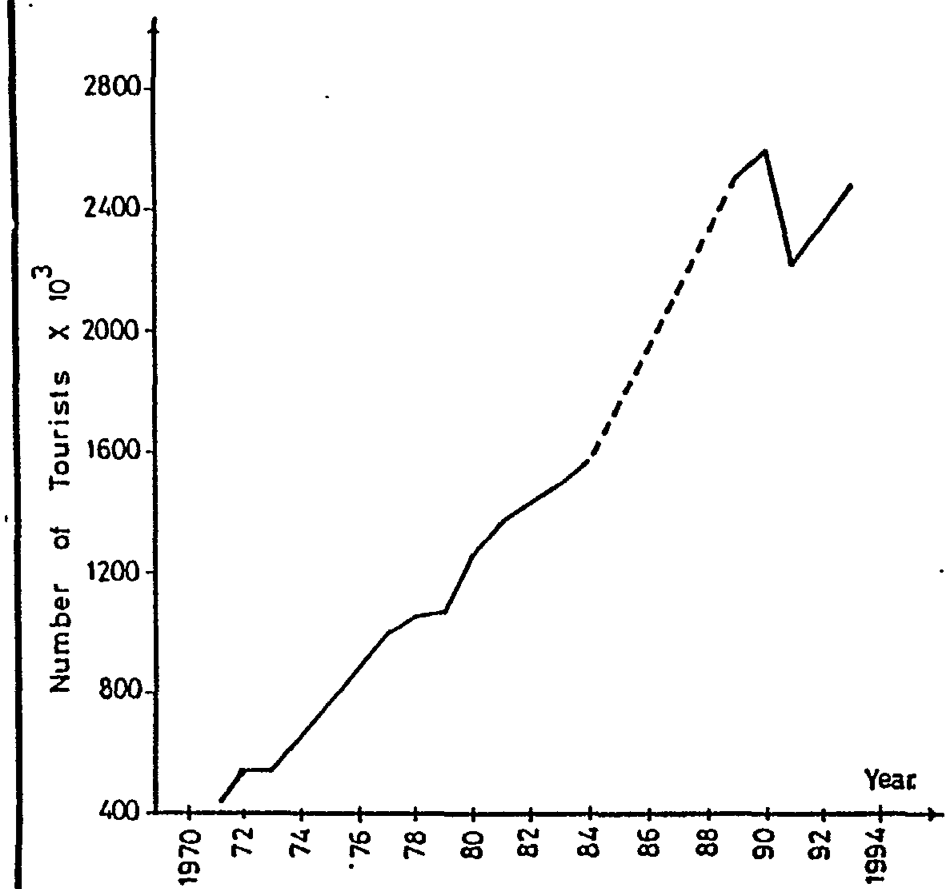


Figure 60A - Number of tourist arrivals in Egypt

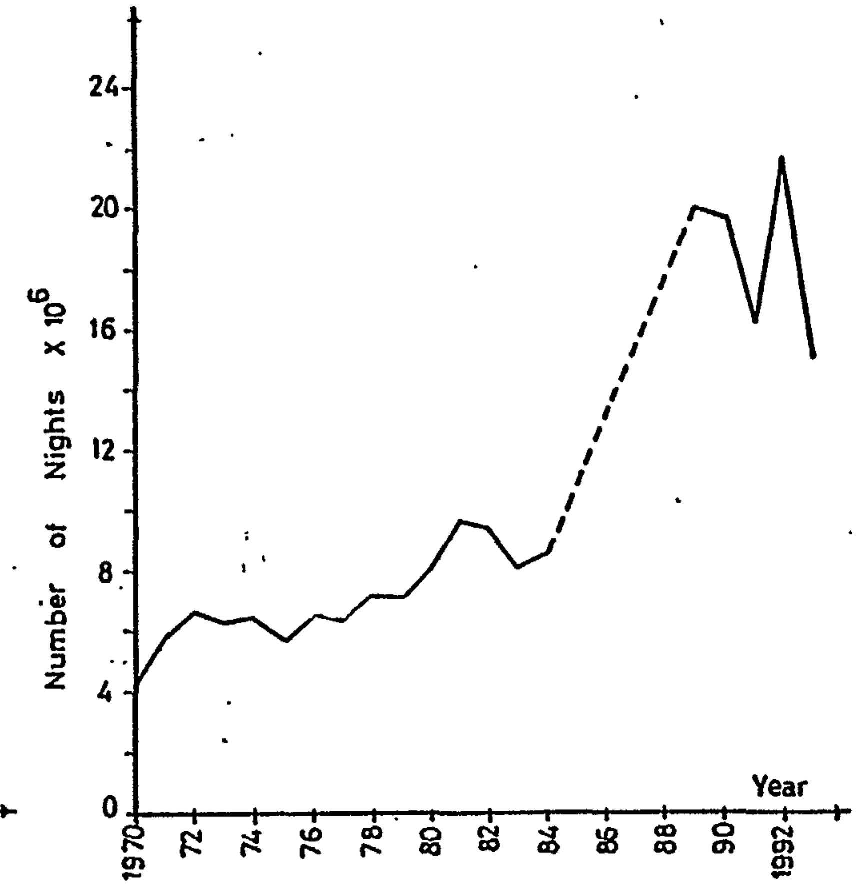


Figure 60B - Number of tourist-nights in Egypt

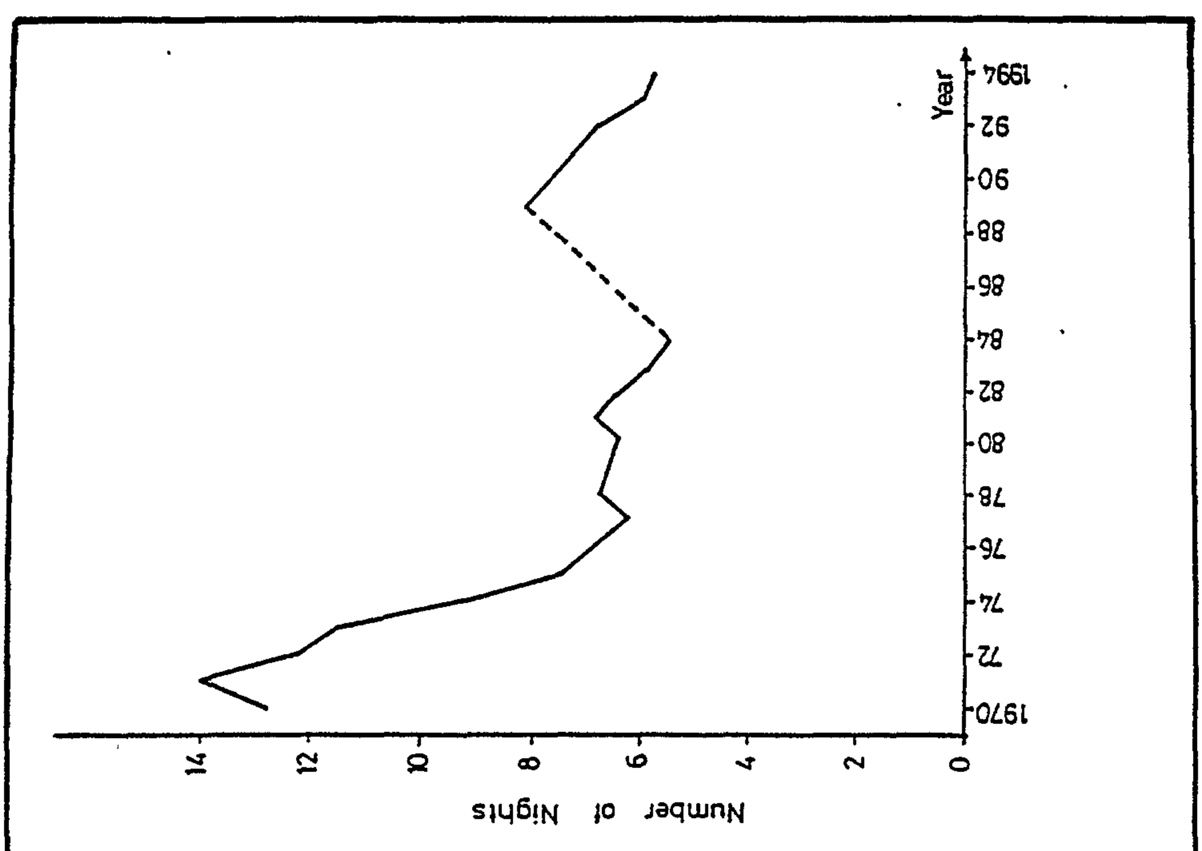


Figure 61A - Average length of overnight stays

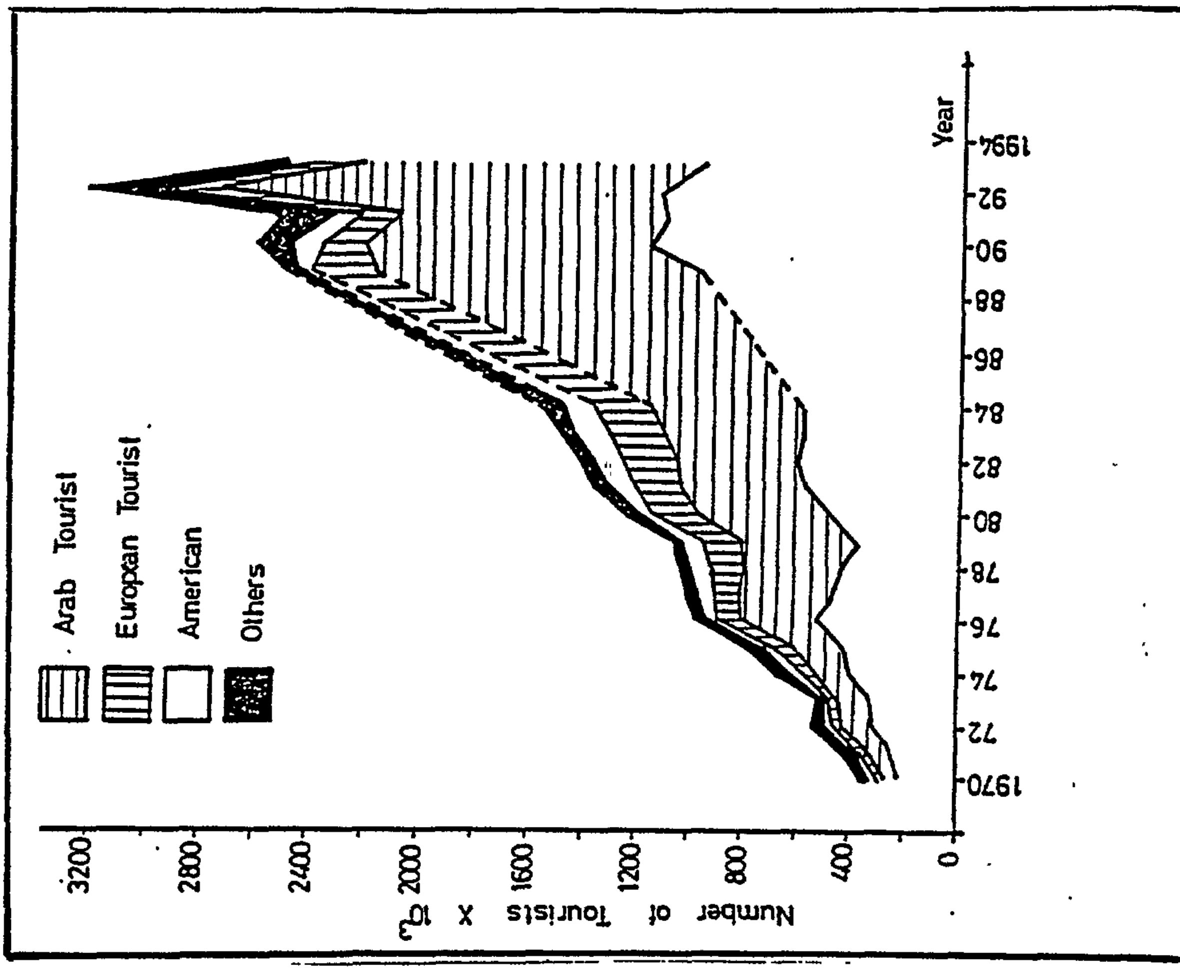


Figure 61B - Number of tourist arrivals, by nationality

Table 35 - Egypt's share of international tourism

Year	Total number of international tourists ($x\ 10^6$)	Number of tourists who visited Egypt ($x\ 10^3$)	Percentage
1974	197	676	0.14
1975	207	792	0.38
1976	227	984	0.43
1977	244	1004	0.41
1978	260	1051	0.40
1979	270	1064	0.39
1980	285	1253	0.44
1981	288	1376	0.48
1982	285	1423	0.50
1983	287	1500	0.52
1984	293	1598	0.55

The International Authority for Tourism (Pacer/Egypteam, 1986c) showed that international tourism could be classified as:

- Recreational tourism (50-75%)
- Business and/or trade tourism (25%)
- Recuperation-and-rest tourism (25%)

Figure 62 gives the distribution of arrivals by month for 1981, 1992, 1993 and 1994, and the total number of arrivals during each of these years.

The available data show that the largest number of tourists is in the summer (Table 36) and especially in August (Figure 62). Statistical analysis of 24 tourist companies showed that 75% of the total tourism is cultural and historical tourism (to visit Cairo, Luxor and Aswan), 20% is for other purposes, and 5% is recreational (swimming, sunbathing etc.).

Table 36 - Seasonal tourist arrivals

Year	Number of tourists ($x\ 10^3$)				
	winter	spring	summer	autumn	Total
1981	304.2	355.1	436.9	279.8	1376.0
1992	709.1	776.5	975.2	746.1	3206.9
1993	592.0	605.8	743.6	566.4	2507.8

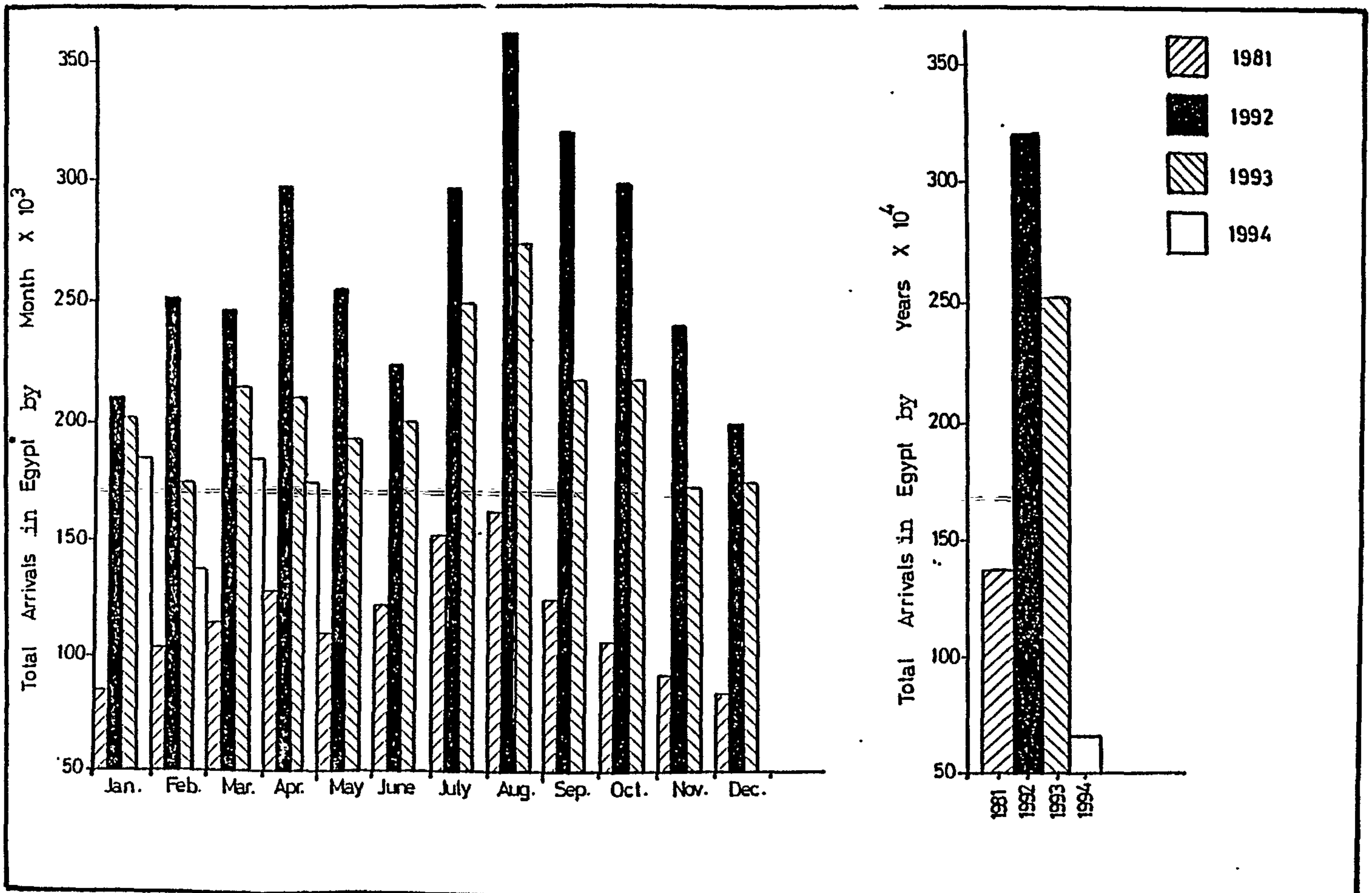


Figure 62 - Distribution of tourist arrivals in Egypt, by month and year

2.7.4 Internal or National Tourism

The above-mentioned section covered foreign tourism in Egypt, but there is also internal or national tourism which depends on the following sources:

- resident Egyptians;
- Egyptians working outside Egypt; and
- foreigners residing in Egypt, such as those working in embassies, petroleum companies etc.

This type of tourism is directed mainly towards the seashores, especially in summer.

Table 37 shows the recorded (up to 1995) and expected (up to 2010) number of tourists, spending their holidays on Egyptian shores (Pacer/Egypteam Consultants, 1986c). It shows that internal tourism is about 90% of the total Egyptian tourism. Also, with the new development of the beaches, the number of arrivals at the seaside is expected to increase by 11% up to the year 2010.

Table 37 - Recorded and expected number of tourists to Egyptian seashores

Year	International tourism (x 10^3)				National tourism (x 10^3)		
	Arabs	Western	Others	Total	Egyptian	Foreign	Total
1985	80	30	15	125	1840	75	1915
1990	100	55	25	180	2240	83	2323
1995	150	105	30	285	2860	92	2952
2000	215	215	35	465	3830	100	3930
2005	340	390	40	770	5370	110	5480
2010	465	540	45	1050	7890	121	8011

2.7.5 Tourism to the Beaches of Alexandria and the Western Coast

The statistical data of the Ministry of Tourism (Pacer/Egypteam Consultants, 1986c) show that, on average, 60% of the internal tourists and 90% of the Arab tourists go to Alexandria and the western coast of Egypt (Table 38).

Alexandria has become a very busy city all year round. The beaches are not sufficient for the large number of people who want to spend the summer season there. Also, its further development has become very difficult and may now be impossible, which is why most people have directed their sights towards the western coast where land is still available and undeveloped, and the improvement of tourist services and related development are still possible. Table 39 shows the estimated tourist demand for the west coast beaches up to the year 2010. It is clear from this Table that internal tourism is likely to form 85% of the total demand in 2010.

Table 38 - Tourist demand for Alexandria and the western coast of Egypt

Year	Tourist demand (number of persons x 10^3)							
	International tourism				Internal tourism			Total
	Arab countries	Western countries	Other countries	Total (1)	Egyptian	Foreign residents in Egypt	Total (2)	(1 + 2)
**	90%	40%	80%		60%	40%		
1985	72	12	12	96	1104	30	1134	1230
1990	90	22	20	132	1344	33	1377	1509
1995	135	42	24	201	1716	37	1753	1954
2000	194	86	28	308	2298	40	2338	2646
2005	276	110	32	418	3222	44	3266	3684
2010	389	156	36	581	4434	48	4482	5063

** The figures on this line are the percentage tourist demand for Alexandria and western coast of Egypt relative to the total tourist demand for the Egyptian sea shores

Table 39 - Tourist demand for the western coast of Egypt

Year	Tourist demand (number of persons x 10^3)							
	Arab countries		Other countries		International tourists		Total	
	No. *	% **	No	%	No	%	No	%
1985	14	20	12	50	237	20	263	21
1990	23	25	23	55	344	25	390	26
1995	40	30	40	60	526	30	606	31
2000	78	40	80	70	818	35	976	37
2005	124	45	107	75	1306	40	1537	42
2010	195	50	154	85	2017	45	2366	47

* number in thousands

** percentage relative to the total tourist demand given in Table 38

Note: These numbers do not include day-trippers.

2.7.6 Tourism in the Study Area

The study area, which extends from Fuka to Matrouh, is 72km long; it is attractive to national and international summer tourists. This area is generally characterised by: its mild summer climate, white sand beaches, clear blue water, its calmness, its long distance from noisy and busy places, such as Alexandria, its distinctive coastal areas, especially Obaid and Agiba, and its unpolluted clear sea. Winter tourism, including game-hunting trips to oases such as Siwa, outside the study area, as well as historic sites (Cleopatra's Baths, the Rommel Museum, in the eastern harbour of Matrouh, and the traditional museum in the main building of the Matrouh Governorate) could be developed.

This area may be divided into the three touristic zones, from west to east (Fig. 63).

2.7.6.1 Zone No. 1

This consists of the city of Matrouh and its neighbourhood. It includes the following tourist attractions:

- the Rommel Museum in the eastern harbour of Matrouh;
- the Tradition Museum in the main building of the Matrouh Governorate;
- the Rommel, Lido, Gharam, Beau Site, Maon and TV beaches;
- the Cleopatra Baths, which lie 12km to the west of Matrouh and can be reached by car;
- Obayyed beach, which is 20km to the west of Matrouh and can be reached by car;
- Ageeba beach, which is 35km to the west of Matrouh and can be reached by car, and Ramses Temple at Ageeba;
- Ras Alam El-Roum, which is 10km to the east of Matrouh; the beach of this zone is naturally protected, as shown in Figure 63; and
- many recreational places, such as the Matrouh Summer Cinema, the Culture Directorate Cinema, the open theatre at Cornish and Bedouin Tent, a TV area and public gardens.

Matrouh includes most of the hotels (Table 40) and tourist villages, camps and youth hostels (Table 41) (Matrouh Government, 1992).

Table 40 - Number of hotels, rooms and beds

Type of Hotel	Number of:		
	hotels	rooms	beds
One-star	1	32	64
Two-star	6	309	576
Three-star	11	1196	2424
Four-star	2	377	754
Five-star	1	15	30
Unclassified	52	1226	2884
Total	73	3155	6732

Table 41 - Number of tourist villages, camps and youth hostels

Type	Number of:		
	each type	rooms	beds
Tourist villages	14	328	980
Camps and youth hostels	29	989	3840
Total	43	1317	4820

2 7 6 2 Zone No 2

This zone lies 45km to the east of Matrouh and includes the Hawala-Baqqush coastal stretch (Fig 64). This zone is considered the best of all the underdeveloped zones of the study area, because of the following:

- extended flat, sand beach 16.5km long by 40m wide;
- mild climate,
- white sand and clear water free from pollution;
- distinctive views and bays;
- good, wide and virgin land suitable for touristic purposes, extending southwards about two kilometres on average;

- naturally protected beaches; and
- easy connection to Matrouh, with especially good possibilities to use the Matrouh airport for the transportation of tourists.

Figure 64 shows the analysis of the natural facilities of this zone. Eight tourist villages are under construction in this zone but there is no other information available on it. Also, this zone could be considered as a natural extension to the city of Matrouh.

2.7.6.3 Zone No. 3

This zone (Figure 65), which is still under development, lies about 65km to the east of Matrouh and about 20km to the east of zone No. 2, and is known as the Ras El-Hekma triangle. Its northern end is situated at a distance of about 15km from the international road between El-Sallum and Rafah. This zone is considered as one of the most important tourist zones in the study area, because of the following:

- distinctive viewpoints from the high sites near the shore;
- mild climate;
- protected bays and beaches suitable for various sports; and
- flat areas for horse riding and golf.

This zone will include some elite features, as swimming pools, golf courses, horse riding, sauna baths and diving. There are some camps and tourist villages in this zone, but little information is presently available.

The increase in the number of tourists and tourist-nights in the study area during 1990-1992 is given in Table 42 which shows that the number of tourists increased in 1991 and then decreased in 1992, even though the number of hotels continued to increase. Also, the average overnight stay increased, especially from Matrouh to the west of Ageeba and Obayyed beaches about 20km away. Day trippers could be directed towards the Hawala-Baqqush area 45km from Matrouh and may be to Ras El-Hekma. There were some 700 day-trippers per day by the year 1990 and this number is expected to increase to approximately 2,500 per day by the year 2010.

Although tourism is still at a relatively low level, it is likely that it will become important in the future and will attract capital investment.

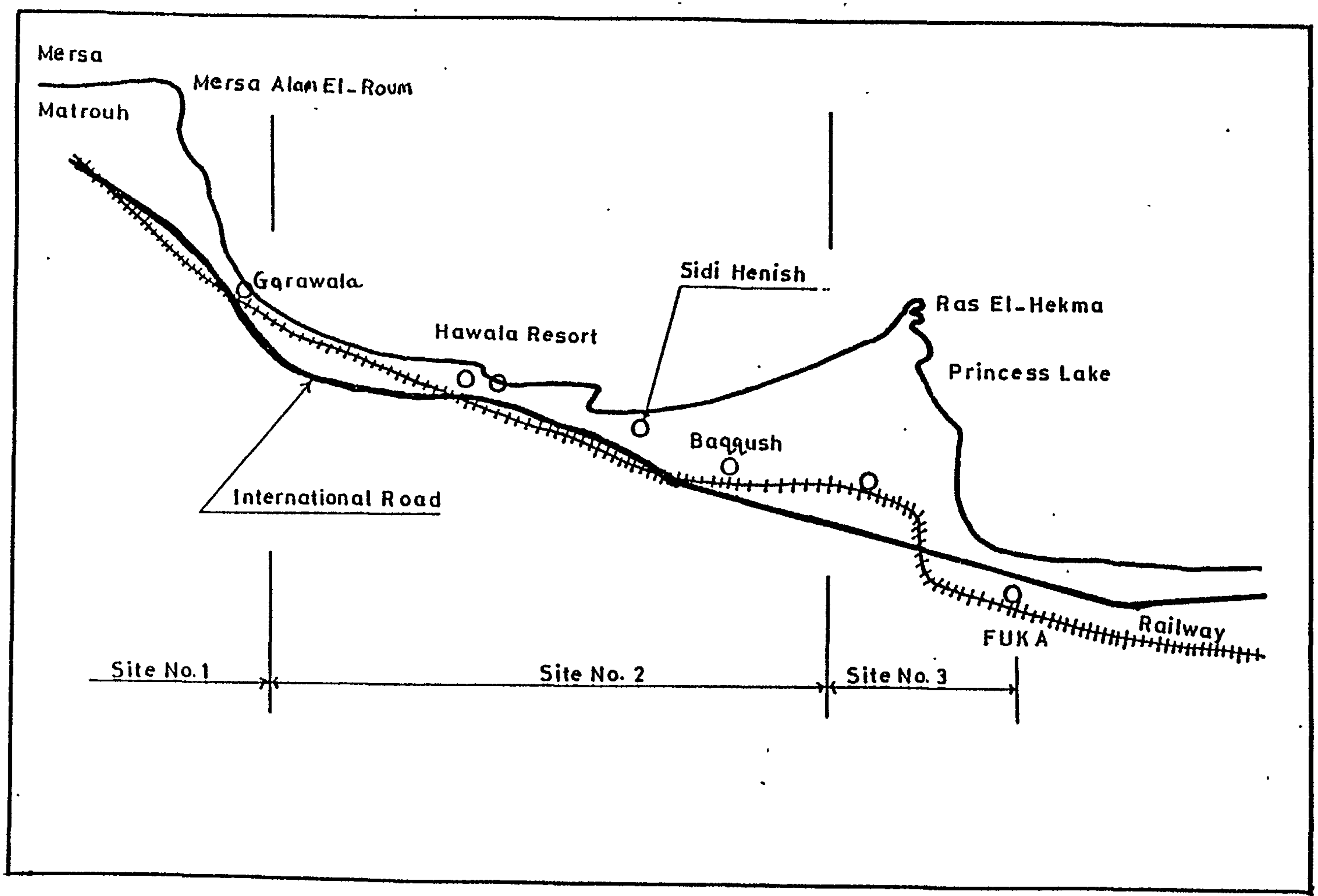


Figure 63 - Touristic zones in the study area

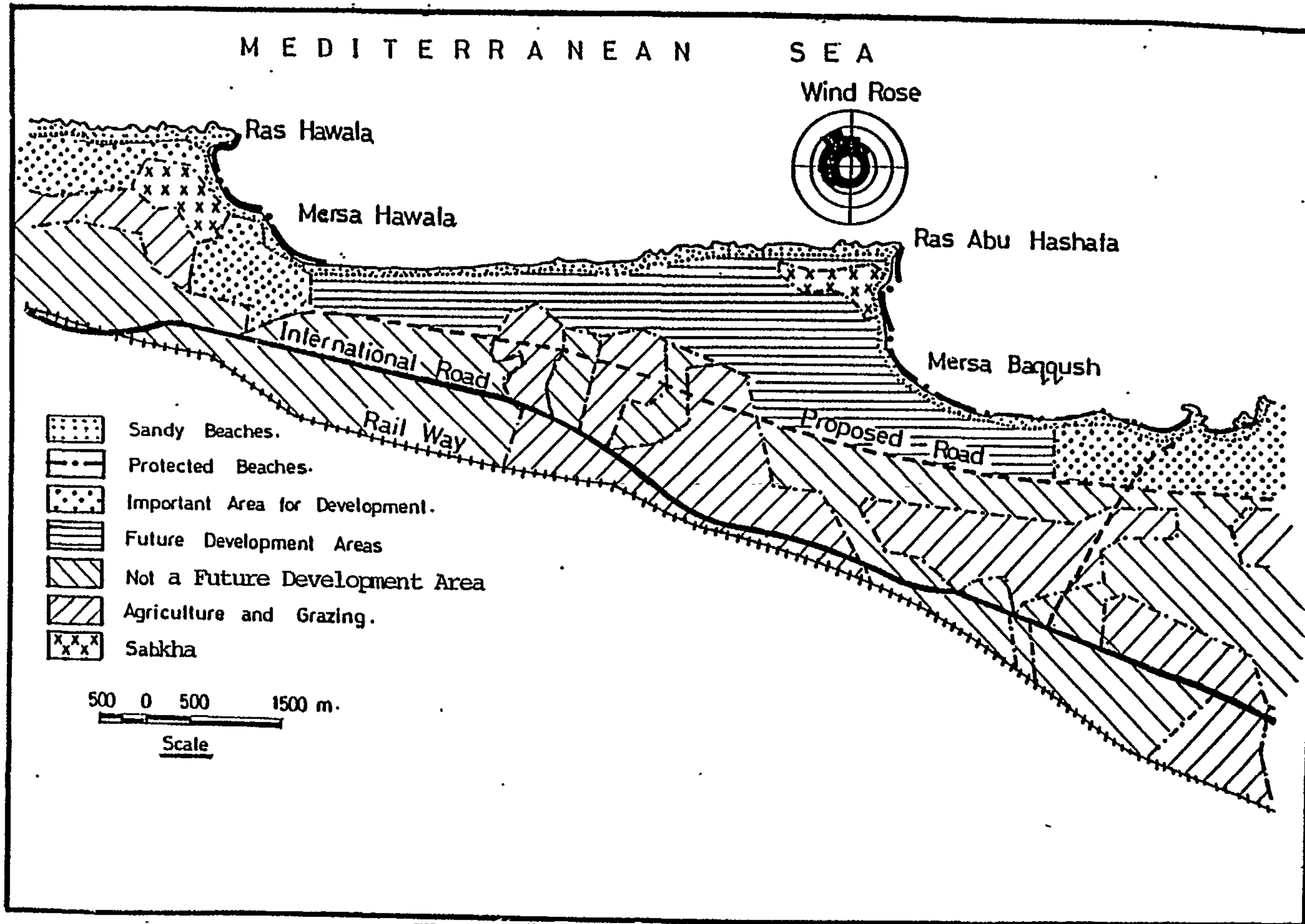


Figure 64 - The Ras Hawala-Baqqush tourist area

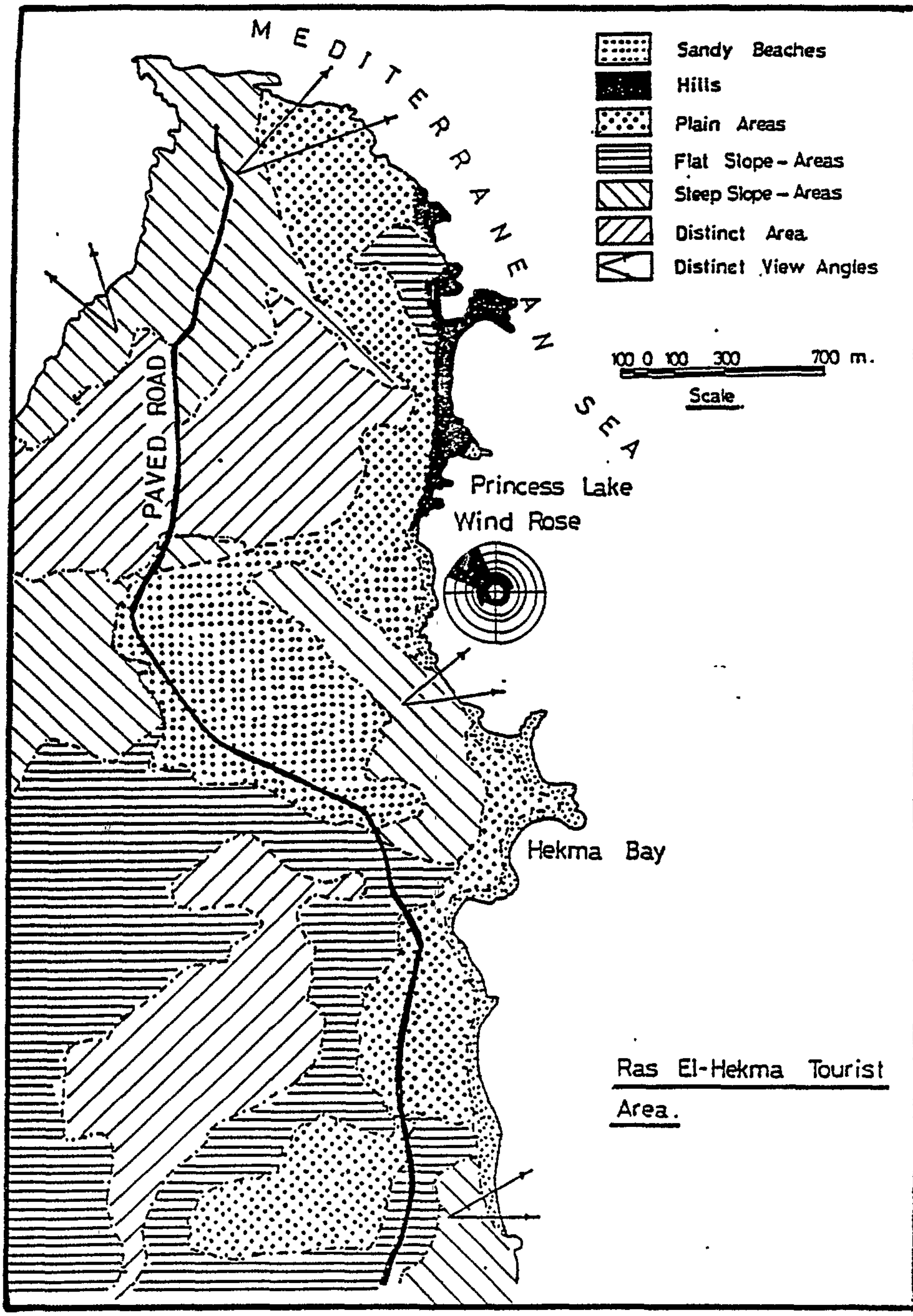


Figure 65 - Ras El-Hekma tourist area

Table 42 - Number of tourists and tourist-nights

Year	Number of arrivals				No. of tourist-nights	No. of hotels	Average overnight stay
	Egyptians	Arabs	Others	Total			
1990	119506	20800	7937	148243	173307	54	1.17
1991	165890	49745	5030	220665	338818	56	1.54
1992	92727	18839	4772	116338	205916	72	1.77

The studies carried out by Pacer/Egypteam Consultants (1986) indicated that the accommodation capacity (number of beds) in the year 2010 will be as follows:

- for Matrouh, Ras Alam El-Roum, Obayyed: 52,000 beds;
- for the Hawala-Baqqush area: 22,500 beds; and
- for the Ras El-Hekma area: 5,000 beds.

Between the afore-mentioned areas there are superb locations that may allow the construction of smaller resorts (between 500 and 1,000 beds each), such as Fuka village on the eastern border of the study area.

This would be in addition to a new tourist village under construction in the Ras Alam El-Roum area near Matrouh, at a total cost of a million Egyptian pounds, and would allow 8,000 new jobs to be created in the area.

2.7.7 *Summary*

The statistical data show that the number of tourists visiting Egypt has increased from 428,000 in 1971 to 3,207,000 in 1992, as a result of the new open-investment policy. In 1993, this number decreased to 2,508,000, owing to an adverse political situation. International tourism may be broken down into: recreational tourism (50%), business and/or trade tourism (25%) and recuperation-and-rest tourism (25%).

Alexandria is now a very busy city, year round, and its beaches are not sufficient to meet the demand. The tourist demand for the west coast of Egypt was 390,000 in 1990 and is expected to be 976,000 by the year 2000 and 2,366,000 by the year 2010.

The study area, with its mild climate, white sand beaches and clear blue water, has attracted national and international tourists. This area may be divided into three zones: the city of Mersa-Matrouh and its neighbourhood, the Hawala-Baqqush beach area (about 45km to the east of Matrouh) and the Ras El-Hekma triangle about 65km to the east of Matrouh. This is in addition to some locations that may allow for the construction of smaller resorts, such as Fuka village.

2.8 TRANSPORT AND SERVICES

2.8.1 General

The area is served by a reasonable transportation network comprising paved roads, local tracks, a railway line, airport, harbour, as well as by means of conveyance such as buses, trains, aeroplanes, boats and ships.

2.8.2 Transportation Network

The basic road and transportation network in the region links Alexandria and Sallum along the north coast. Links from Matrouh to the western desert oases and from the oases to Giza/Cairo complete the transportation grid tying Cairo and Alexandria to the western desert (Figure 66). Also, Matrouh is linked to the Qattara depression by a secondary road from the Maatin El-Garawla station.

The network is financed by the national authorities.

2.8.2.1 Main Roads

The international coastal road from El-Sallum to Rafah extends for 1000km and is 22m wide; it is an important development factor, especially since it was widened into a four-lane highway 72km long, running from Fuka to Matrouh, and thus passing through the study area. It serves as a development corridor in which tourist activities and accommodation are concentrated. It also provides a marketing/transportation link from the study area (Fuka, Ras El-Hekma, Sidi Henish, Hawala and Garawla) to the Nile delta and valley via Alexandria. The western part of this road joining Matrouh to Sallum is a 2-lane highway some 200km long. This road could, in the future, serve as an axis for more intensive exchanges with Libya and as a transit from North Africa to Mecca via Egypt, especially once it is widened to four lanes.

There is a second paved road parallel to the coast which passes through the southern plateau and is 6m wide. Although this is a military road, private and public transportation vehicles are permitted to travel on it. This road is an important transportation link between the Cairo-Alexandria desert road and Sallum, directly through the desert. It also serves the southern part of the study area.

The north-south axis perpendicular to the coastal and Sallum roads extends from Matrouh to Siwa for some 300km. It has been recently paved and widened to 7.5m with 3m levelled shoulders on each side. It is often used by oil-prospecting companies, travellers from Siwa to Matrouh and some international tourists going to or coming from Siwa via Matrouh.

2.8.2.2 Secondary Roads

There are some paved tracks that link the international coastal road to the shore at the following locations:

- at Fuka	3km long and 6m wide
- at Ras El-Hekma	15km long and 6m wide
- at Sidi Henish	3km long and 6m wide
- at Garawla	2km long and 6m wide
- a tourist road linking Alam El-Roum with Matrouh	17km long, two-lane.

The track between the international and military roads to Sallum is levelled and has a base layer. It is about 13km long and is wide enough for one car to pass at a time.

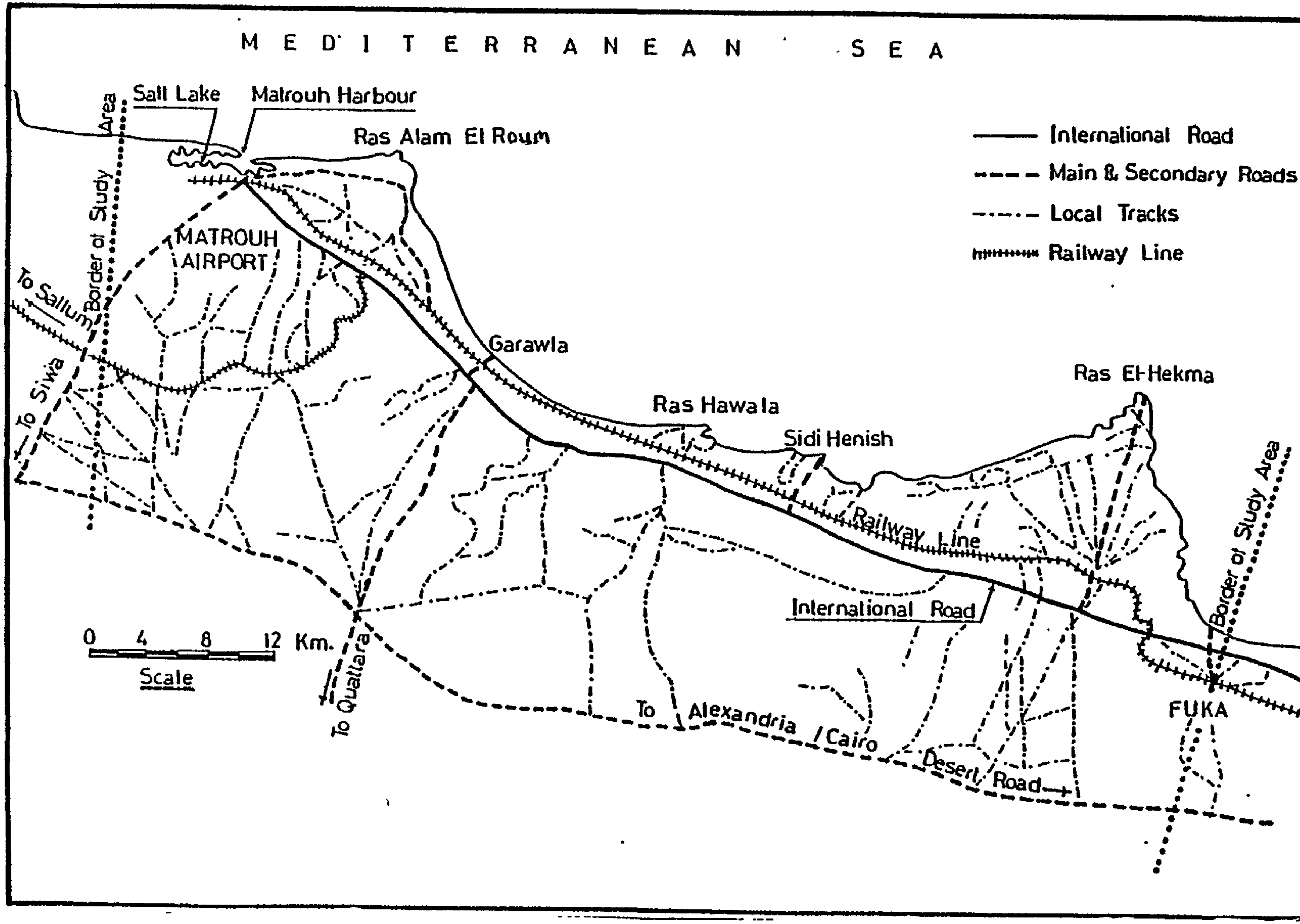


Figure 66 - Network of transport facilities

2.8.2.3 Local Tracks

There is also a large number of small tracks linking the roads extending through the desert. While most of them are just unpaved tracks, they serve in linking settlements and groups of houses throughout the southern zone of the study area. Furthermore, they will serve as a basis for developing the road network within the Fuka-Matrouh area in the future.

2.8.2.4 Railway

The national railway line from Cairo to Alexandria, Matrouh, then Sallum passes through the study area and stops at: Fuka, Ras El-Hekma, Atrouh, Sidi Henish, Hawala, Garawla and Matrouh. It is a single line adjacent or near to the international road to Matrouh and could be used as an important development corridor in the study area. It also carries passengers in the summer. In winter, it is mostly used by teachers. Nowadays, de luxe trains with sleeper facilities are used on this line to encourage tourism.

2.8.2.5 Airport

The airport serves as an important link for rapid transport to the rest of the nation. In the summer months, it is an important tourist destination. It is located in the south-western part of Matrouh, 2km from its centre. Although this airport belongs to the military forces, the National Authority for Civil Aviation leases landing rights for civilian use from June to October. In addition to this airport, there is a place for landing and take-off in Fuka, but it is used only in an emergency.

2.8.2.6 Harbour

In the study area, there is only one harbour: at Matrouh. It consists of a large water basin parallel to the shore and is protected by two rock breakwaters with an opening 100m wide; the water depth is 6m. This harbour could serve as a significant element in the transportation network, especially for transport of tourists and goods. Also it encourages car and yacht tourism.

2.8.3 Means of Transportation

The following daily transportation services are provided in the study area:

<u>Buses</u>

- First-class bus, Matrouh-Cairo	4 times
- First-class bus, Matrouh-Alexandria	2 times
- Second-class bus, Matrouh-Cairo	4 times
- Second-class bus, Matrouh-Alexandria	11 times
- Second-class bus, Matrouh-Sallum	5 times
- Second-class bus, Matrouh-Siwa	3 times

Trains

- Second-class train, Matrouh/Cairo — 2 times
- First-class train with sleeper facilities — 2 times

Aeroplanes

- Aeroplane, Matrouh-Cairo — 3 times

Taxi

- Taxi service, Matrouh-Cairo and Matrouh-Alexandria, from the taxi station near the bus station — continuous

This is in addition to the famous means of transport in Matrouh, known as the "karetta" which is drawn by a donkey; the price is one pound per person.

Table 43 shows the number of transport units and persons transported during 1993.

Table 43 - Transportation in the study area

Means of transport	Number of units		Number of passengers		Remarks
	Summer	Winter	Summer	Winter	
Trains	4	2	10000	15000	
Buses	15	13	6000	1000	
Private Cars	4000	2000	750000	200000	
Lorries	1000	800	-	-	to transport
Lorries with trailer	350	300	-	-	goods
Pick-up trucks	5000	3000	50000	25000	

2.8.4 Summary

Fuka/Matrouh area is connected internally and externally by a good transport network. This area is connected to Alexandria, Cairo, El-Sallum, Siwa and the Qattara depression by aeroplane, rail, superjet bus, ordinary bus and taxi.

As soon as the mid-part of the international road between Rosetta and Damietta is completed, the study area will have an easy access to the Nile delta, as well as to Saini. The traffic density will be increased tremendously as a result of the new development in the area.

2.9 SANITATION AND HEALTH ASPECTS

2.9.1 General

In this chapter, a brief description is given of the water supply for domestic purposes, liquid-waste system, solid-waste system, and the types of diseases that may be widespread in the area.

2.9.2 Sanitation

In this section, a brief description is given of the domestic water-supply system and the sewerage system.

2.9.2.1 Domestic Water Supply System

Since the Fuka-Matrouh area is arid, there is a great shortage of water for domestic purposes.

The main sources are:

- Water from a group of shallow surface wells distributed along the northern coast and in the Fuka plain. This water is not of drinking quality, but it is commonly used for domestic purposes and agriculture.
- In addition to the old 300mm water pipeline, a 700mm diameter water pipeline exists between Alexandria and Matrouh. Its capacity is 50,000 cubic metres per day. However, repeated legal and illegal tapping along the length of the pipeline greatly diminishes the amount of water reaching the study area. A new pipeline from Alexandria to Matrouh is being constructed. At present, this line extends from Alexandria to El-Alamain.
- There are four desalination stations in the Matrouh area, with a capacity of 500 cubic metres per day, each intended to serve the tourist area. These units are, however, currently out of operation.

Water is also transported in water tanks carried by rail. A new water network for Matrouh is under construction; it consists of a main pipe network 236km long and three high-level storage tanks with 120 x 10^3m^3 water capacity. The total cost of the new water supply system in the Matrouh area is E£75 million.

Another network is proposed to distribute water to tourist villages, settlements and other areas, under sufficient pressure for domestic, touristic, industrial and commercial purposes. This network may comprise:

- a tree system suitable for small communities;
- a circle system suitable for medium-sized communities; and
- a grid system suitable for crowded communities.

The water consumption in the area is expected to increase, especially with the increase of the population and the temperature.

2.9.2.2 Sewerage System

The sources of liquid wastes are as follows:

- Domestic liquid wastes: these waste waters come from the residential communities, hotels, tourist villages, hospitals, schools, offices etc. Generally, these wastes were originally pure fresh water that became polluted as a result of its use, together with human wastes. They usually contain a small percentage of solids which may be in suspension and/or deposited on the bottom;
- Industrial liquid wastes: these come from factories (existing and/or planned) in the study area. These wastes are usually more concentrated than the domestic wastes and their concentration depends on the type of industry; and
- Storm waste water: a maximum daily rainfall of 75mm contributes three to six times as much wastes to the sewerage system as domestic wastes. Storm waste water reaches the sewerage system from the paved roads and the roofs of residential settlements.

2.9.2.3 Types of Sewers

The study area is characterised by a low population density, which ranges between 70 and 110 persons per hectare (Pacer/Egypteam Consultants, 1986d), except in Matrouh, where the density is much higher in summer. This is why primitive methods are used to get rid of the wastes in the area between Fuka and Matrouh. These methods are: septic privy, pit privy, septic tanks and manholes. This approach, if not very carefully monitored, could lead to the pollution of the water layer under the sand dunes which are the most reliable source of water in the coastal area. An integrated waste-water network is under construction for the city of Matrouh and the adjacent tourist areas. This system is composed of the indoor sanitation connected to a network of sloping PVC pipes leading to three pumping stations which pump the wastes to the treatment plant which has a capacity of $100,000m^3$ per day capacity. Two waste-water mains connect the stations with the treatment plant currently under construction: one main is 8.5km long and the other is 3km long. The total cost of this system is E£90 million.

Currently, large tourist projects on the coast depend on septic tanks for sewage disposal. Bedouin communities, however, have no waste-water or solid-waste disposal system.

It is planned that the tourist resorts at Fuka, Ras El-Hekma, Baqqush, Sidi Henish, Hawala and Garawla will, between now and the year 2000, have their own integrated waste-water network; no plans exist to integrate Bedouin communities into this network before the year 2000.

2.9.2.4 Solid Wastes

The solid wastes in the study area come from houses, hotels, tourist villages and industry, especially agro-industry. It was found that the people get rid of these wastes by dumping them anywhere, on empty sites or beside houses. The solid wastes from hospitals and clinics are burned, causing atmospheric pollution.

With the increase in the population and new development of industries, new communities, new tourist villages and hotels, etc., the quantity of the solid wastes will increase tremendously. They will consist of the following:

- organic and inorganic wastes from houses, hotels, hospitals, etc., including the remains of food, vegetables, fruits, papers, wood pieces, plastic bags and covers, etc;
- industrial wastes, which vary according to the type of industry;
- inorganic bulk solid wastes from the remains of construction material, maintenance and repair operations; and
- street wastes, mainly comprising dust, papers and tree branches.

The quantity of these wastes varies according to the environment, the habits of the people and from one season to another. From studies of similar areas (Pacer/Egypteam Consultants, 1986d), it was found that the quantity of solid wastes, excluding industrial ones, is about 0.8 kg/person/day, with a density of 200-300kg per cubic metres). The industrial wastes are estimated to be 50% (by weight) of the foregoing values.

There are many methods to treat and/or get rid of these wastes, such as:

- Land fill: for each residential community, the wastes are collected, buried and covered by dust at the end of each day to prevent bad smells and the growth of flies and harmful insects. These wastes are left for a period of time to be decomposed, after which, these areas can be used as public gardens, playgrounds, etc. This method is considered to be an economical means of getting rid of the wastes from houses, hotels, etc., when empty and cheap fill sites are available.

- Biological decomposition method: the wastes are converted to organic fertiliser for agricultural use, but the cost of this method is relatively high.

- Incineration: the collected solid wastes are burned in special furnaces; the resultant material after burning is very small but it causes air pollution.

2.9.3 Health

Egypt, with its favourable climate, has been considered an ideal place for the convalescence of invalids. Because of the lack of data and information, this section will give only a very brief summary of the common diseases in the coastal area and the desert:

- diseases of the respiratory organs, as bronchial asthma;
- eye diseases, such as cataract, eye infections, terracoma;
- epidemics of intestinal disorders, such as typhoid and para-typhoid fever; and
- skin diseases, such as sunburn and skin cancer.

2.9.4 Summary

In the study area, there are different sources of water for domestic use, such as the pipe-line from Alexandria, shallow surface wells and desalination stations. Also, water is transported in tanks carried by rail. A new water-supply network for Matrouh City and its neighbourhood of 120×10^3 m^3 water capacity is under execution; it will have a capacity of 120 million cubic metres. The consumption of water in the area is expected to increase, owing to population increase and new development.

Because of the low population density in the study area and specifically for tourist projects, primitive methods, such as septic tanks, are used to get rid of wastes. Bedouin communities have no waste-water or solid-waste disposal system. The solid wastes from houses, industry and tourist villages are collected and dumped anywhere. The solid wastes from hospitals and clinics are burned, causing air pollution.

Diseases that are widespread in the area are: eye diseases, skin diseases, respiratory diseases and intestinal-disease epidemics.

2.10 POPULATION AND SETTLEMENTS

2.10.1 Past Trend and Present Situation

The study area is a semi-desert, sparsely populated area that is part of the north-west Mediterranean coast of Egypt. The inhabitants of the region are Bedouin (nomads). Before 1960, the Bedouin used to migrate all over the desert seeking grazing areas. They settled in the area at the beginning of the 1960s. Because of the lack of reliable figures on the population size before the 1976 census[1], only the figures of 1976 and 1981 are considered to represent population growth (Table 44).

Table 44 - Population size and growth rate between 1976 and 1986
(source: CAPMAS, 1976 and 1986)

	1976	1986
Size of population	27608	40112
Percentage of NWCZ* population	24	25
Annual growth rate (%)	-	3.2
Average annual national population growth (%)	-	2.5

* north-west coastal zone of Egypt

As shown in Table 44, the population in the study area represents about 25% of the population of the Matrouh Governorate. During 1976-1986, the region's population grew from approximately 27,000 to 40,000, an average annual growth rate of 3.2%. This rate is higher than Egypt's average population growth (2.5%). The urban population is 76% of the total population, and the rural is therefore 24%. The rapid increase in population can be attributed to several factors: first, the stability of the Bedouin in settlements, cultivating land with perennial trees, such as fig and olive; second, the considerable increase in per caput income in the last two decades; and third, the Bedouin custom of having more than one wife.

A formal questionnaire exercise has been carried out in the study area to determine its main demographic characteristics.

Table 45 shows that the average number of people living in a household is 12. This average is higher than that for the Governorate of Matrouh, which is approximately 7 persons per household, according to the 1986 census. The age distribution shows that about 70% of the population is in the 6-65 year age class, and about 52% are less than 15 years old. The Table also indicates that 65% of

[1] The Matrouh Governorate information system estimated the area population to be 16,000 in 1960, and 25,000 in 1970.

the population over the age of 10 is illiterate. This is a relatively high percentage compared to illiteracy in Egypt as a whole, which is approximately 49%.

Population Distribution

The bulk of the population of the region is concentrated in the coastal area, as a consequence of the favourable natural conditions, the existence of services and infrastructure, urbanisation and governmental development policies. The region can be divided into three zones: the coastal zone in the north, in which about 72% of the population lives; the middle zone, in which about 25% lives; and the southern zone, in which only 3% of the population lives. The population density of the three zones are: 72 people/km^2, 12 people/km^2 and 2 people/km^2, respectively.

Settlements

The residential area of the region is estimated at 40km^2. Public land is estimated at 10,000km^2 The technical infrastructure occupies about 2km^2, whereas the tourist area occupies about 20km^2. There are two types of residential architecture: the first is the Bedouin settlements, which consist of flat buildings normally far from the seashore; the second is the tourist villages, which are normally close to the seashore. The buildings of such villages usually have more than one floor.

Table 45 - Main demographic characteristics of the population in the study area

Family characteristics	Unit	
Average household size	no.	12
Male	%	50.5
Female	%	49.5
More than one wife/husband	%	53
Age distribution		
1-5 years	%	27
6-14 years	%	25.2
15-65 years	%	45.1
65 and above	%	2.7
Educational status (10 years or older)		
Illiterate	%	65.4
Only reads and writes	%	20.3
Primary	%	7.2
Preparatory	%	4.5
Secondary	%	2.4
College	%	0.2

2.10.2 An Outline of the Population Growth

The objective of this section is to provide a projection of the population of Fuka-Matrouh region to the year 2030. Because of the lack of historical data (annual data) on population in the study area, it is not possible to provide a projection based on trend extrapolation. The method used here depends on three common formulas normally utilised in population projections. These formulas are the exponential, the geometric and the numerical.

$P_t = P_0\, e^{rt}$
$P_t = P_0\, (1+r)^t$
$P_t = P_0\, AI$

where: P_t is the population number in projected year
P_0 is the population number in base year
r is the rate of increase
t is the number of years between P_0 and P_t
AI is the average absolute increase.

In the first formula (exponential form) and in the second formula (geometric form), the yearly increase is not constant. In the third (numerical) form, the yearly increase is constant. Because the growth rate in the region (3.2%) and the fertility rate (5 children per mother) are relatively high, the first and second formulas seems to be more convenient, since they add the varying yearly increase to the population number in the base year. Table 46 shows the population projection to the year 2030.

Table 46 - Population projection to the year 2030

Population growth model	1986	2001	2015	2025	2030
Exponential	40112	64889	108927	157698	189764
Geometric	40112	64327	106979	153826	184494
Arithmetical	40112	56362	73862	86362	92612

Since the annual growth rate of the population in the study area is 3.2%, which is higher than that of the national population (as shown in Table 44), the trends given by the exponential and geometric formulæ (as shown in Table 46) would be more representative of the expected population growth than the arithmetical formula.

3. POTENTIAL IMPACTS OF EXPECTED CHANGES ON NATURAL SYSTEMS AND SOCIO-ECONOMIC ACTIVITIES

3.1 CLIMATE AND ATMOSPHERE

3.1.1 Predicting Future Climate Change

The Earth's climate in the next fifty to a hundred years will depend on ongoing natural variations combined with global warming forced by man-made modifications of the atmospheric concentrations of greenhouse gases. Natural variations on a relatively short time-scale of decades to a century will be due to the internal dynamics of the Earth's climate system. The warming trend, on the other hand, will be induced by the steady increase in the greenhouse effect in the atmosphere. Actual warming is being delayed by the thermal inertia of the world ocean, but it will continue long after the composition of the atmosphere has been stabilised. No matter how drastic the actions taken to control the emission of greenhouse gases into the atmosphere, the global warming will be clearly observable in the next fifty to a hundred years: global environmental change is inevitable.

3.1.2 Major Expected Changes and Their Impacts

A study of the climate in the study area necessarily implies a study of those parameters that determine the climate of the Mediterranean region. Consequently, all the available meteorological data from the Matrouh airport meteorological station were analysed with the aim of finding trends over the past decades. However, the instruments used to make the measurements and the recording of data were subject to change, and the methods of calculating the mean values were not always the same, so there was some non-homogeneity in the calculations. Data on atmospheric pressure, air temperature, relative humidity and rainfall used for analysis covered the period 1961-1993 (33 years), whereas the data on wind speed, cloud cover, hours of sunshine, days of fog, days of mist and days of haze were for the period 1973-1993 (21 years). The objective of the analysis was to detect trends, but since the data time-series were short (21 or 33 years), no moving mean was computed; the original data were used. The analysis showed:

- a positive trend in mean atmospheric pressure of 0.044hPa per year, which implies an increase in anticyclonic conditions (Fig. 67);
- a negative trend in mean maximum temperature of 0.14°C per decade (Fig. 68);
- a positive trend in mean minimum temperature of 0.15°C per decade (Fig. 69);
- a positive trend in annual mean air temperature of 0.075°C per decade (Fig. 70), which is 0.25°C per °C of global change, compared with 0.8-0.9°C proposed by the Climate Research Unit of the University of East Anglia;
- a positive trend in total annual rainfall of 1.938mm per year (+1.3% per year) (Fig. 71);
- a positive trend in annual mean relative humidity of the air of 0.15% per year (Fig. 72);
- a negative trend in annual mean wind speed of 0.055 knots per year (Fig. 73);
- a small positive trend in annual mean cloud cover of 0.009 oktas per year (Fig. 74);
- a negative trend in sunshine of 0.012 hours per year (Fig. 75);
- a positive trend in the occurrence of mist of 0.14 days per year (Fig. 76); and
- a positive trend in the occurrence of haze of 0.787 days per year (Fig. 77).

The atmospheric-pressure curve indicates an increase in atmospheric pressure over the region which, in turn, indicates the invasion by the mid-latitude pressure belt from a cooler region; this would also explain the decrease in the mean maximum temperature, especially in autumn and winter. The area - as well as the marginal lands on the high-latitude side - borders the Mediterranean climate, but with winter rainfall associated with the temperate-latitude westerlies and varying with the fluctuations in the temperate-latitude winter circulation. During its passage over the Mediterranean, the air mass picks up more moisture, which increases relative humidity and, to some extent, cloud cover.

The rainfall time-series shows an increasing trend in annual rainfall of 1.938mm per year (1.346%); winter rainfall shows an increasing trend of 2.44mm per year (2.7%), whereas autumn and

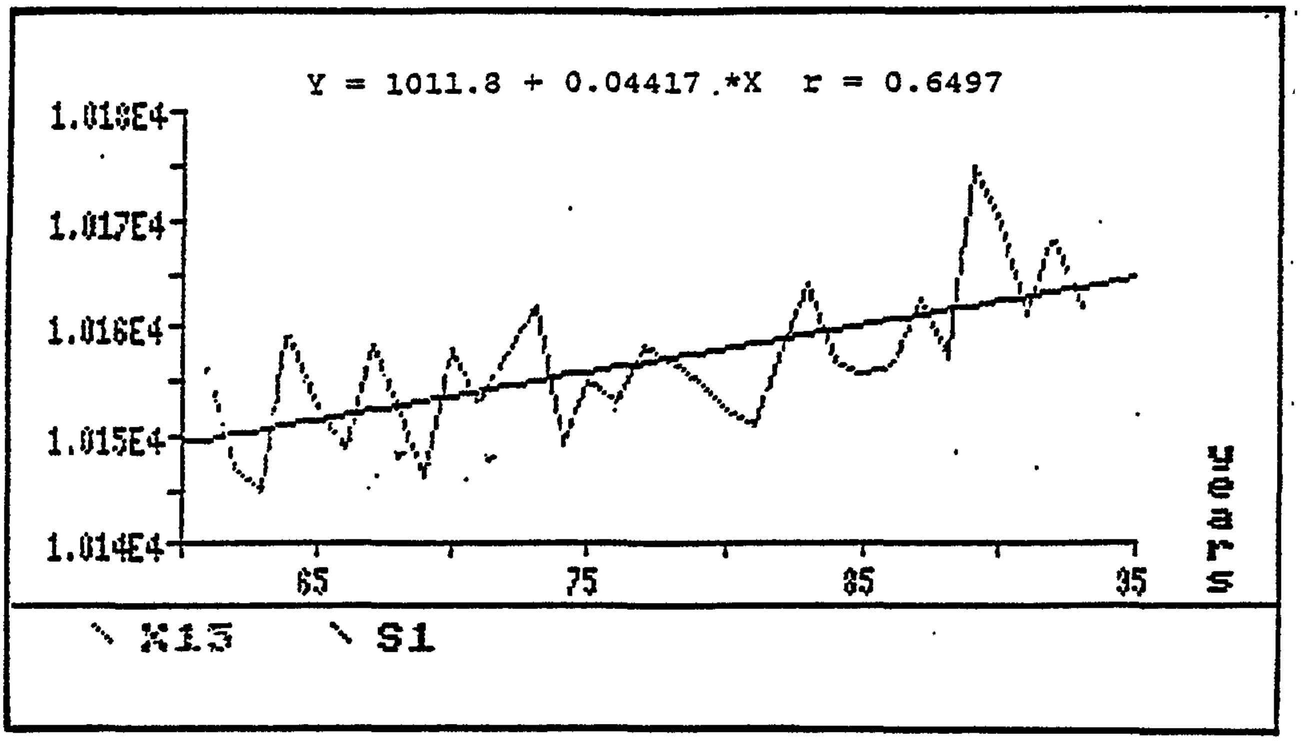


Figure 67 - Trend in annual mean atmospheric pressure (hPa) at Matrouh

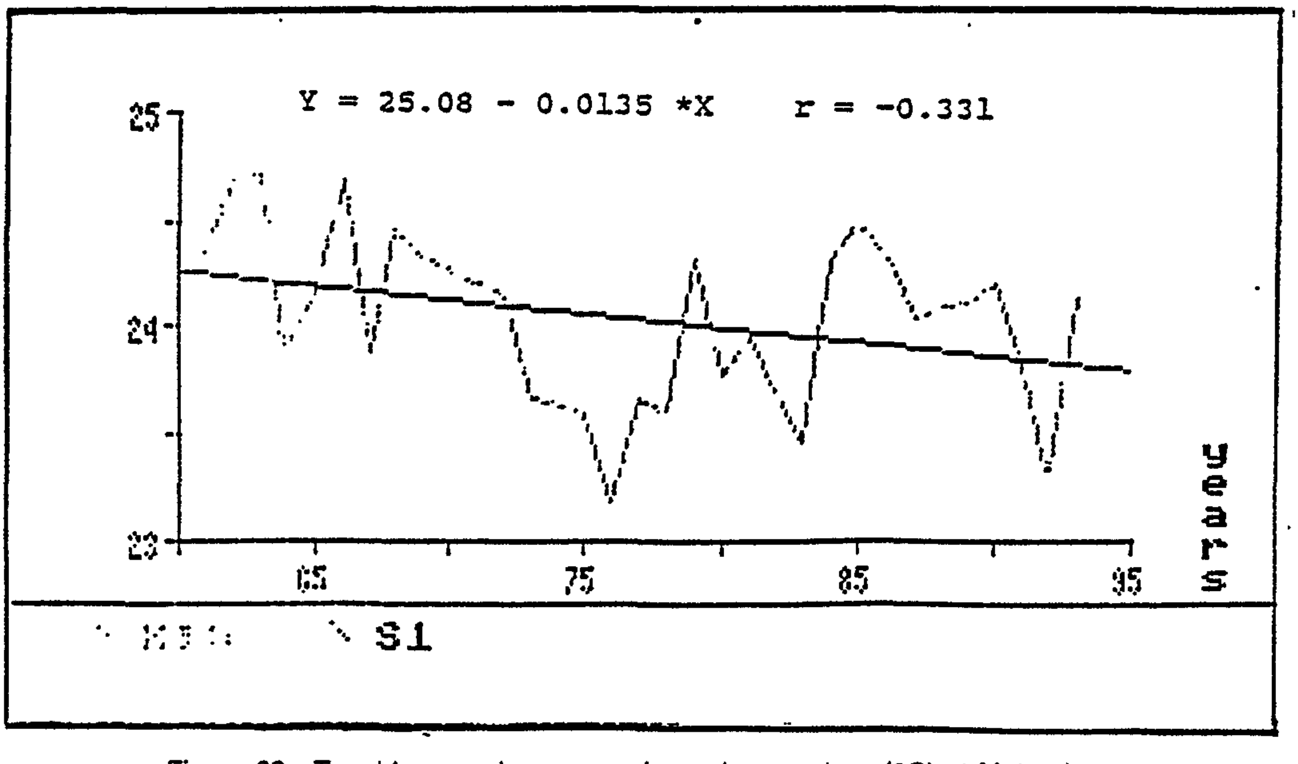


Figure 68 - Trend in annual mean maximum temperature (°C) at Matrouh

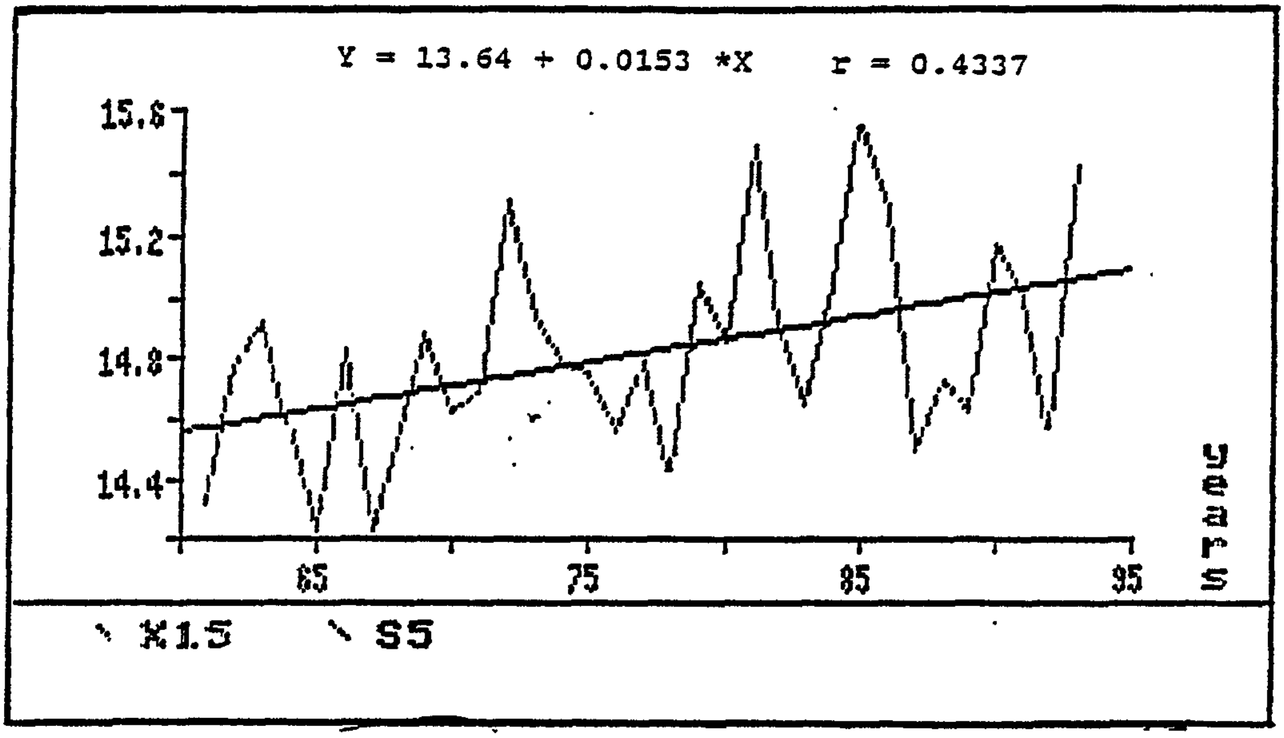


Figure 69 - Trend in annual mean minimum temperature (°C) at Matrouh

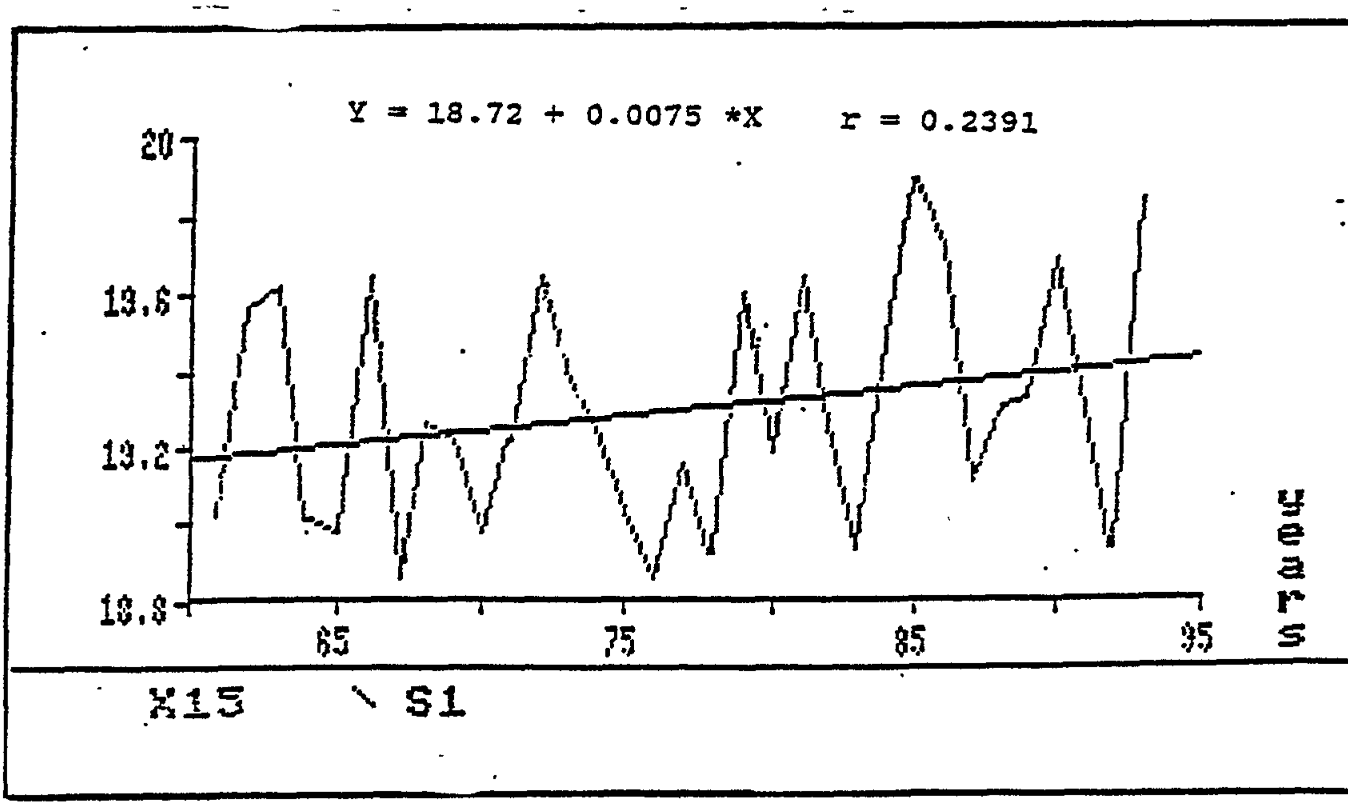


Figure 70 - Trend in annual mean air temperature (°C) at Matrouh

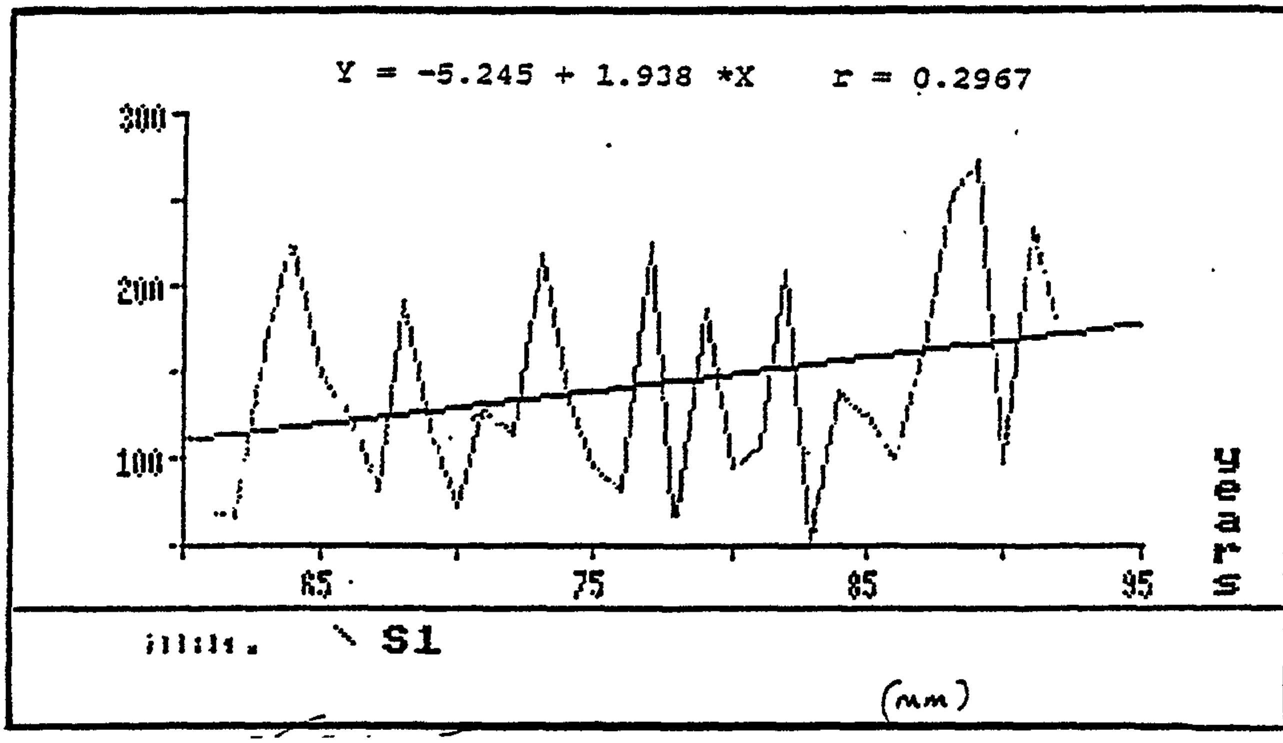


Figure 71 - Trend in annual rainfall (mm) at Matrouh

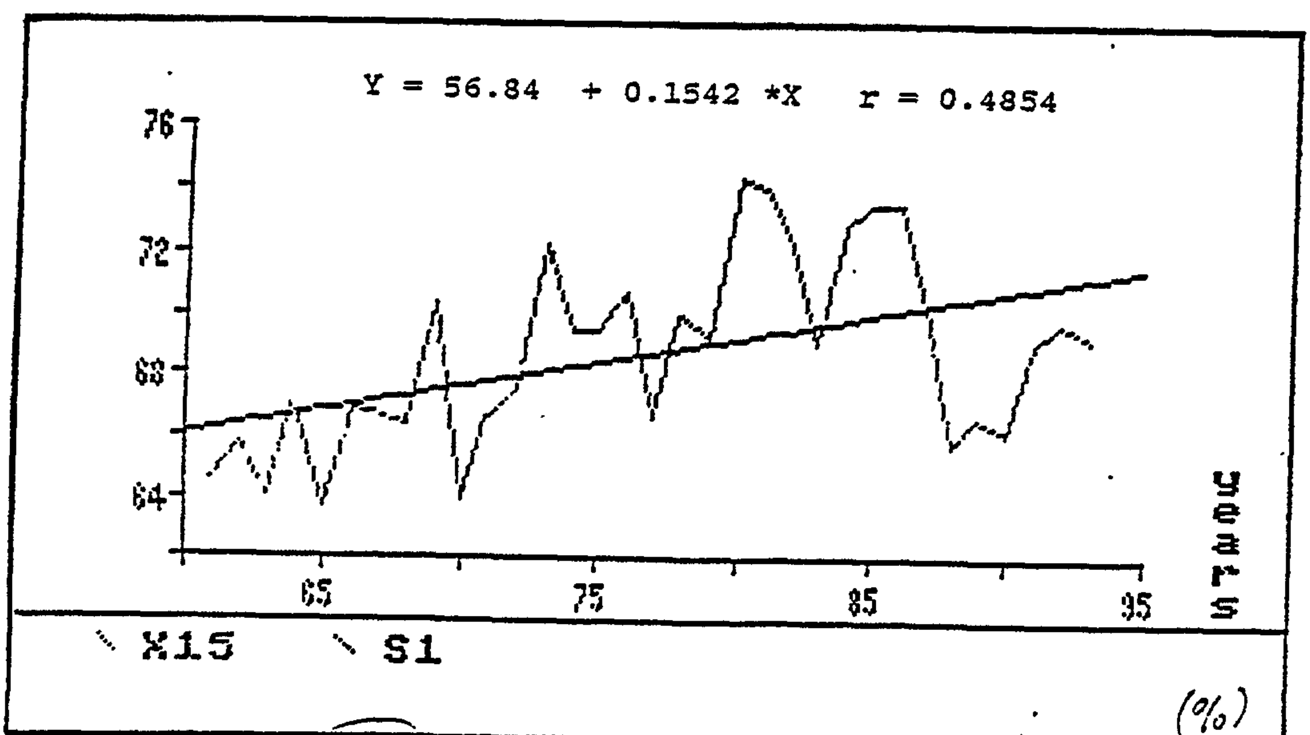


Figure 72 - Trend in annual relative air humidity (%) at Matrouh

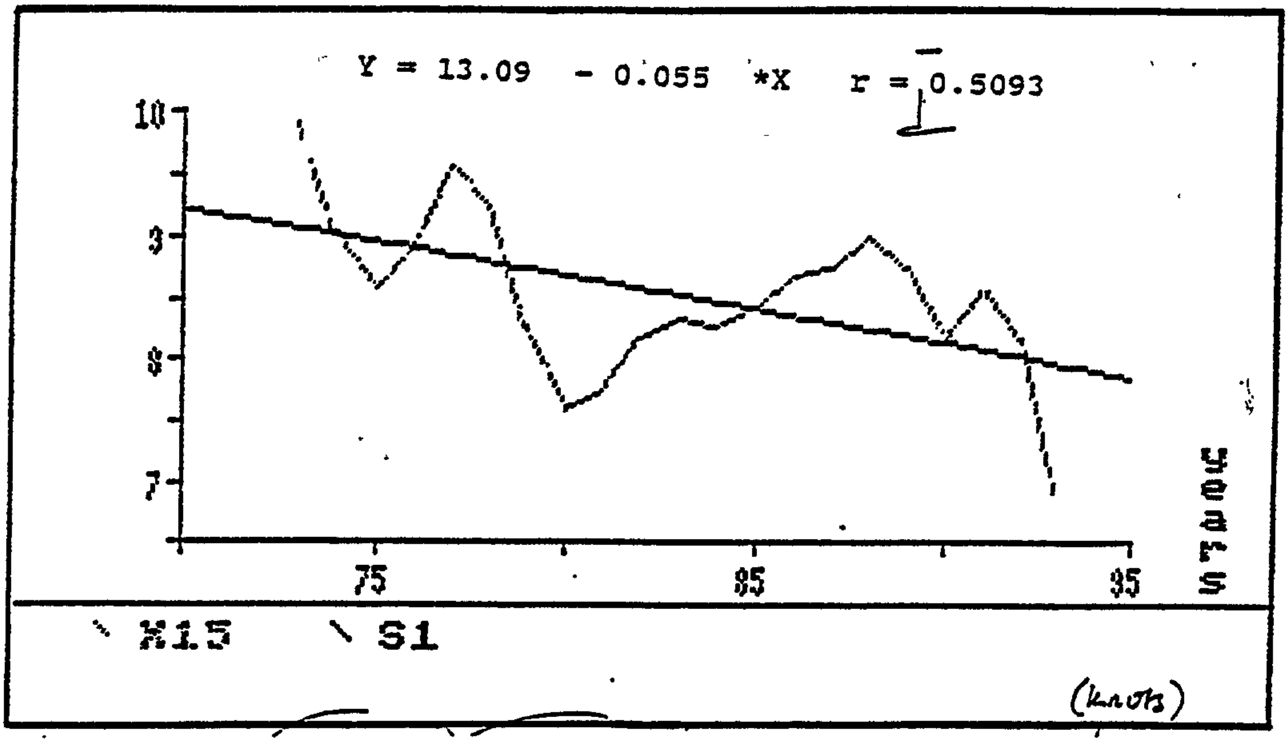


Figure 73 - Trend in annual mean wind speed (knots) at Matrouh

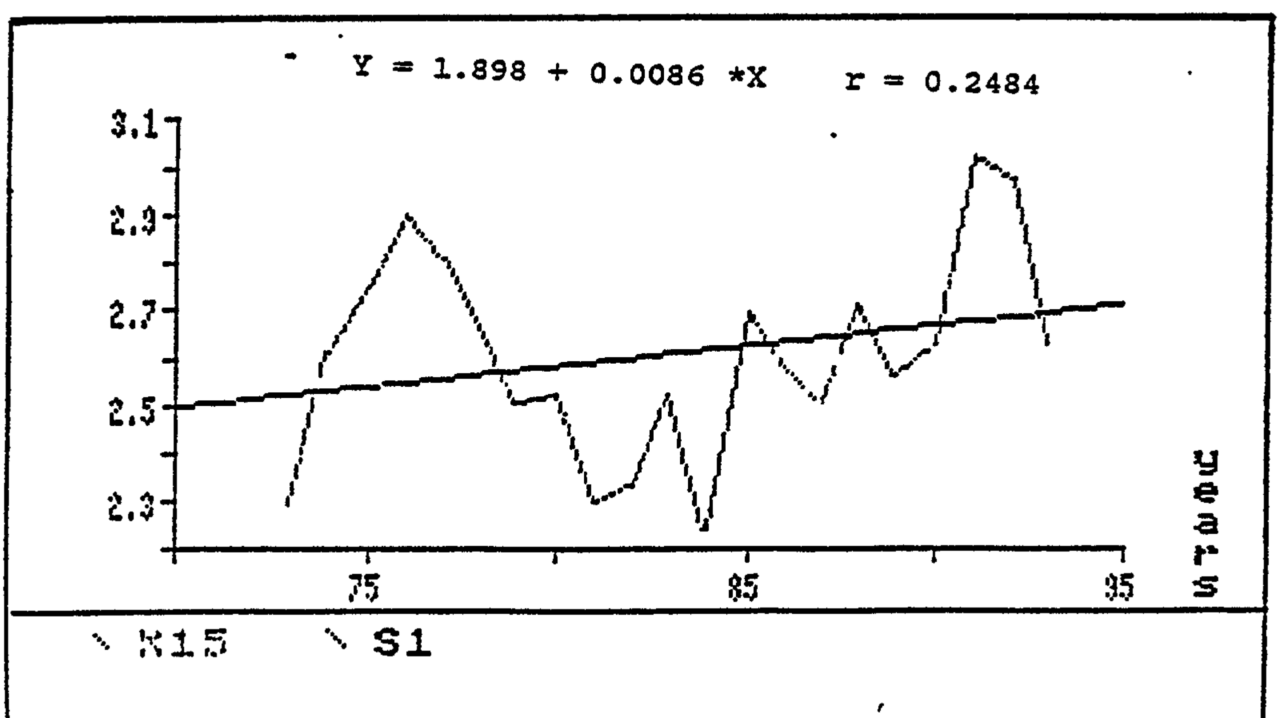


Figure 74 - Trend in annual mean cloud cover (oktas) at Matrouh

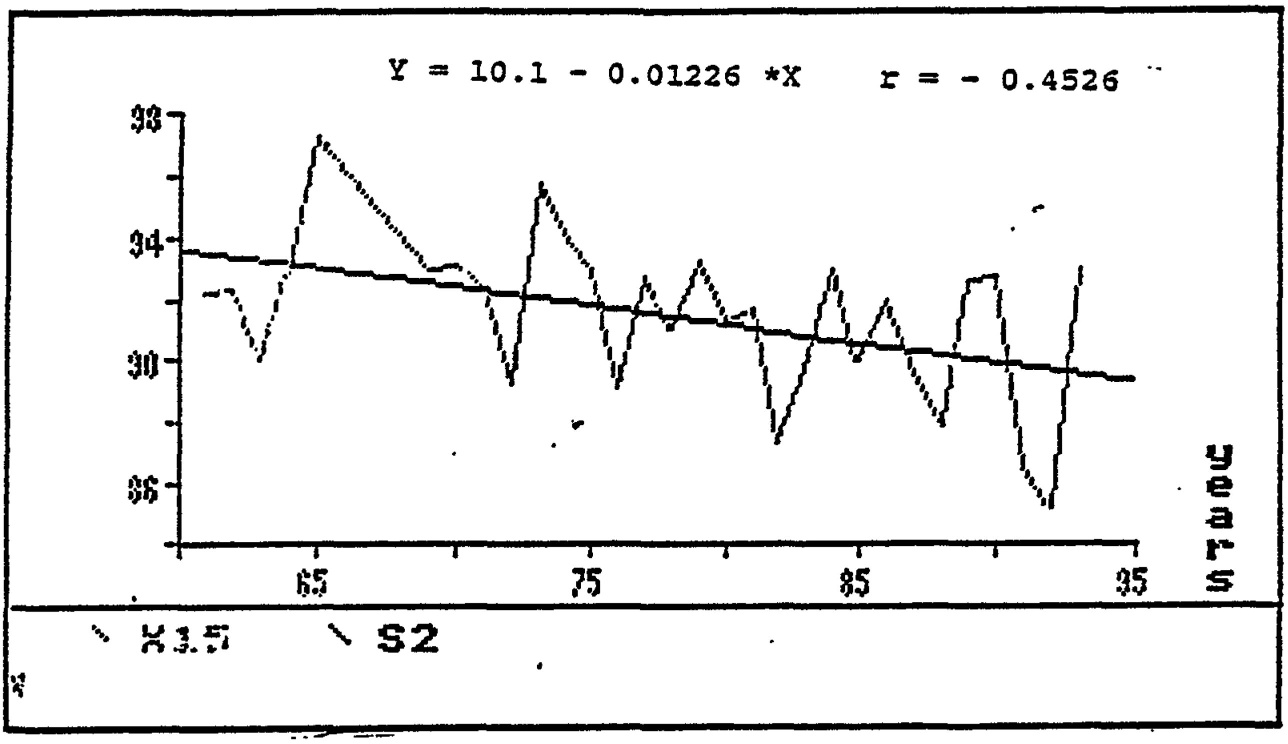


Figure 75 - Trend in annual sunshine (hours) at Matrouh

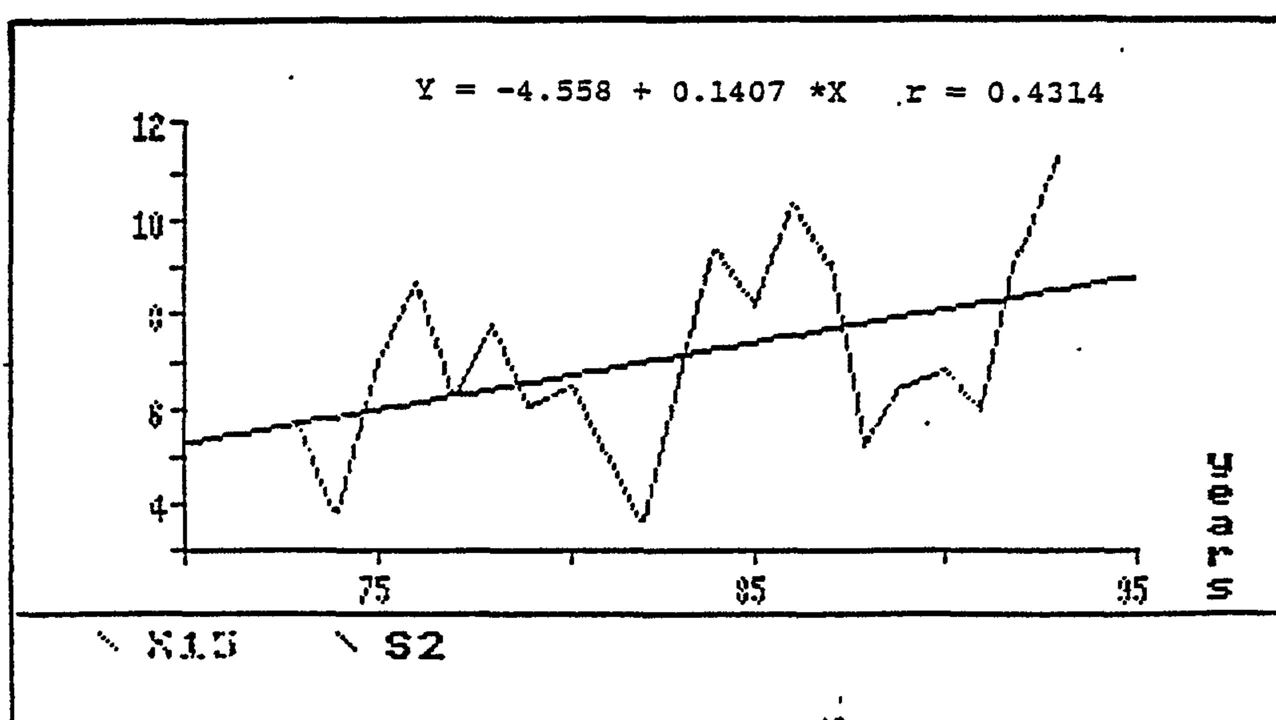


Figure 76 - Trend in annual number of misty days at Matrouh

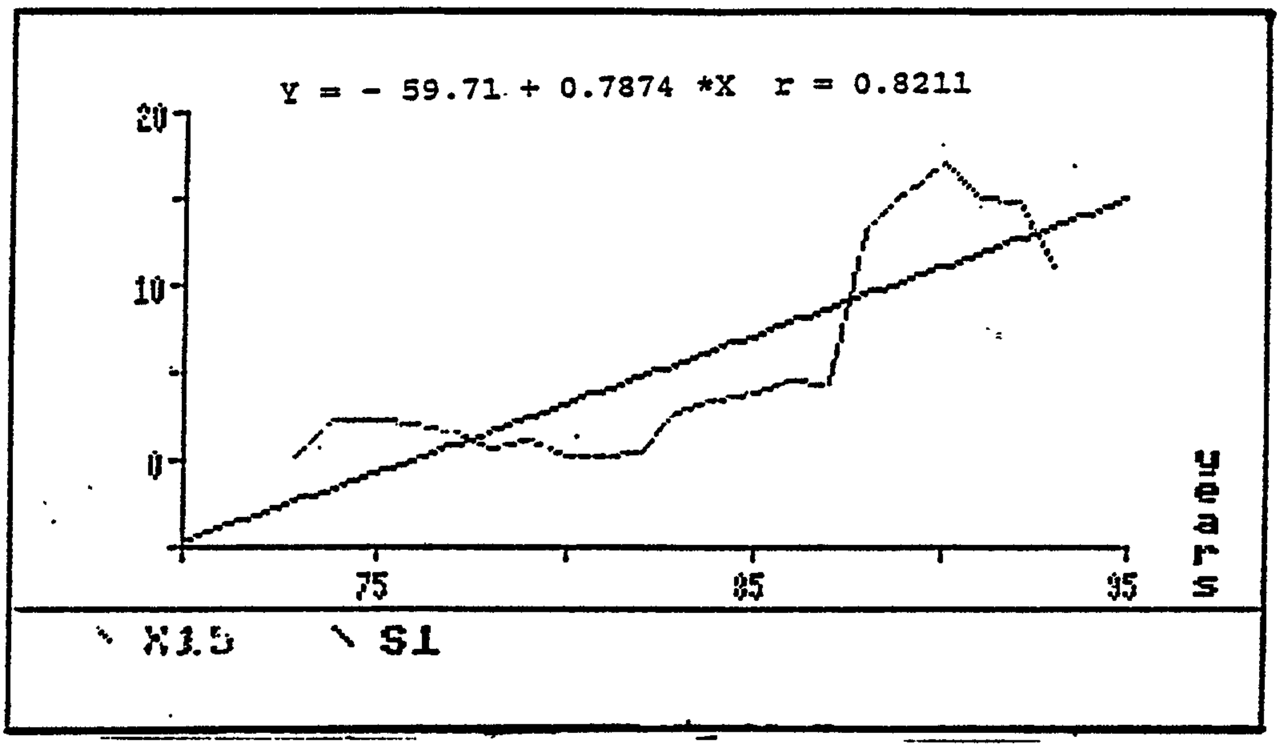


Figure 77 - Trend in annual number of hazy days at Matrouh

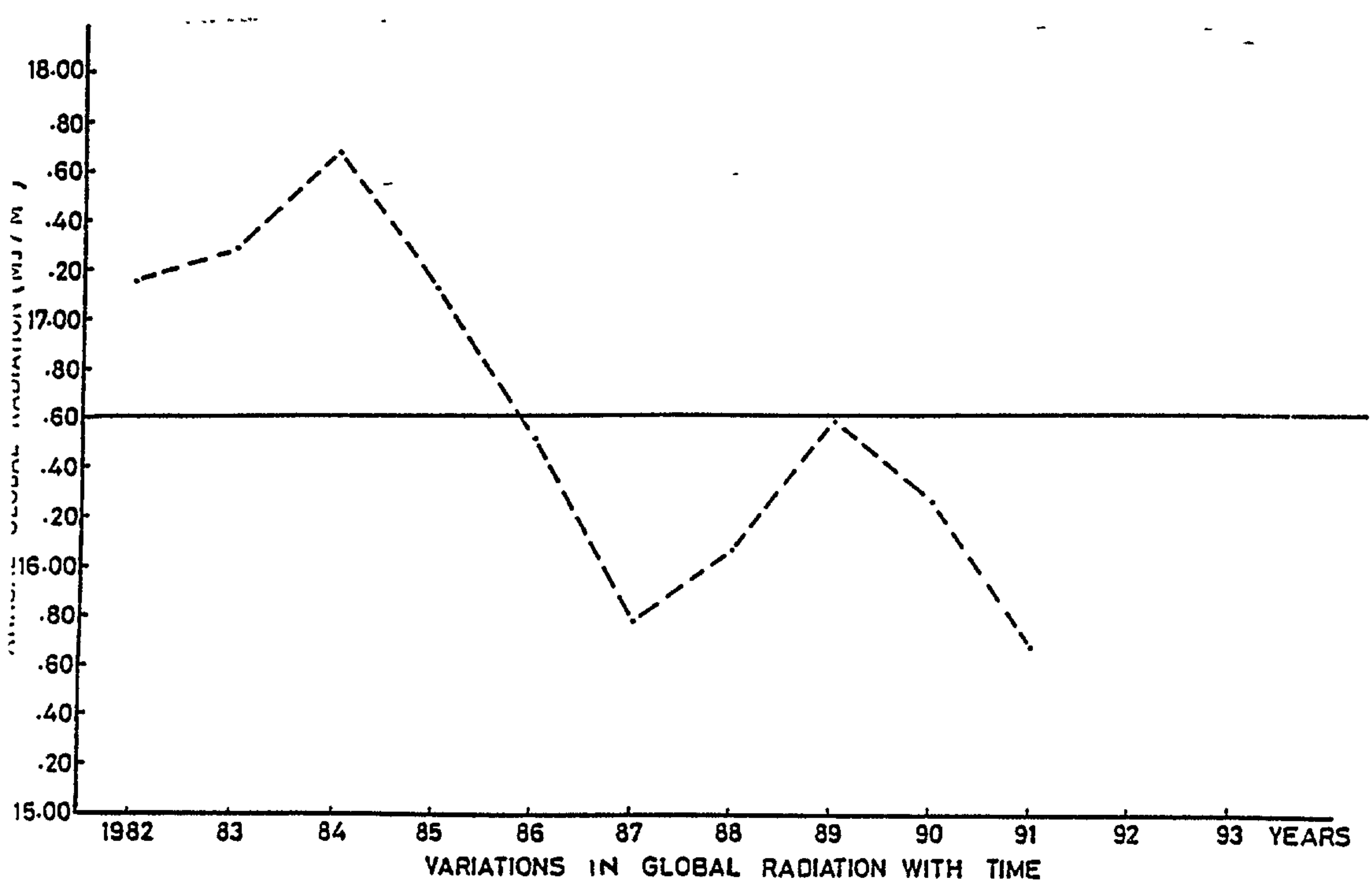


Figure 78 - Annual variation in global radiation at Matrouh

spring rainfall show decreasing trends (0.0241mm and 0.168mm per year, or 0.065% and 1.15%, respectively). The 5- and 10-year moving averages for total annual rainfall show increasing trends.

An increase in atmospheric pressure would diminish frontal activity and increase anticyclonic motion which, in turn, implies more low-level inversions. These inversions trap the atmospheric pollutants which are not dispersed by the wind because of the slack pressure gradient associated with anticyclonic conditions. This would necessarily increase the number of hazy days and the number of misty days, since mean wind speed would have decreased by 0.055 knots per year (13.3%), the occurrence of haze would have increased by 0.787 days per year (14.1%), and the occurrence of mist would have increased by 0.14 days per year (2.24%).

The variation in annual global radiation recorded at Matrouh since 1982 (Fig. 78) shows a considerable negative trend in global radiation, which may imply an increase in ærosol concentration.

Moreover, the variation in annual atmospheric turbidity measured at Sidi-Barrani, 140km to the west of Matrouh, since 1980, but with the same climate conditions as Matrouh (Fig. 79), shows a considerable increase in atmospheric turbidity which, in turn, means an increase in ærosols.

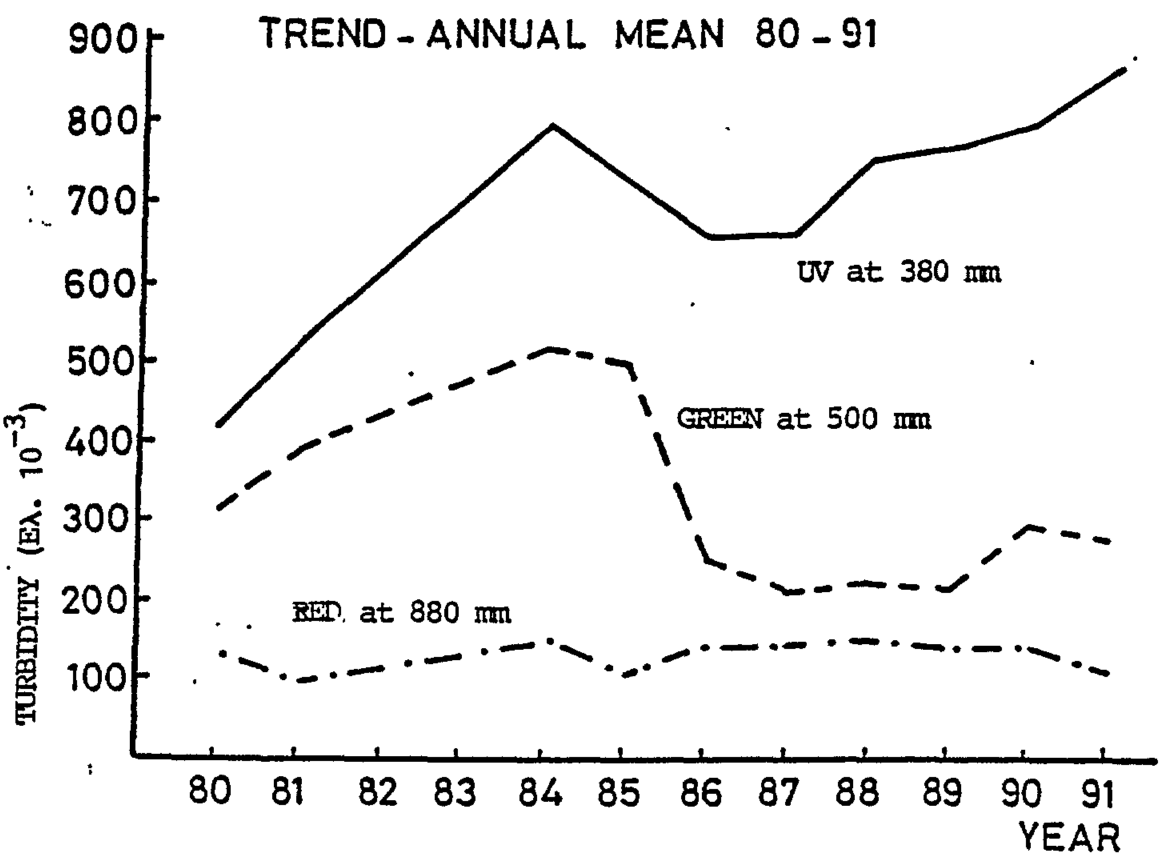


Figure 79 - Annual variation in atmospheric turbidity at Matrouh
$E\lambda = E0\lambda. \times e\text{-}\Delta\text{-}\lambda.m$ where $E\lambda$ denotes transmission of natural atmosphere, $E0.\lambda$ denotes transmission of the "ideal" atmosphere, and m denotes air mass; e is the base of the natural logarithms

According to studies of the western coast of Egypt by Mehanna (1992), based on the assumption of an annual temperature increase of 1.5°C, evapotranspiration would increase by about 10%. This would lead to a decrease of 10% in run-off, even with a decrease in precipitation. With a decrease of about 10% in precipitation, a conservative estimate of run-off would go down even further. Since potential evapotranspiration is calculated to increase by as much as 12%, the amount of water available for irrigation in the area would diminish at the same time as demand increased.

Given the expected microclimate and water balance in the region, an increase in evapotranspiration could be expected.

3.1.3 The Local Scenario for Climate Change

For this report, the best available regional-scale climate scenario for northern Egypt has been used. The Climatic Research Unit (CRU) of the University of East Anglia, UK, has specifically developed for UNEP a computer simulation of a general atmospheric circulation for northern Egypt based on meteorological data from long-term (1951-1988) records of temperature and precipitation collected at local stations (Annex II).

The output provides a valuable information base on the spectrum of possible regional climate change in temperature and, with a lower degree of confidence, in precipitation.

According to this model, the temperature changes for the Egyptian coastline west of Alexandria are expected to be less than the global change; i.e., in the range 0.7-0.8°C per °C global change. Broadly, the same pattern is seen in each season. Only in summer does the warming in the Fuka-Matrouh area approach the global level (with changes in the range 0.9-1.1°C per °C global change).

The scenarios for precipitation indicate drier conditions at the annual level, with a change in rainfall in the range of -4% to 0% per °C global warming. This relatively small change is accounted for by decreases in winter and autumn, whereas conditions in spring and summer are shown to be wetter as a result of global warming. In winter, the greatest change is seen in the west, towards the border with Libya, with a reduction in rainfall of over 10% per °C global warming. In autumn, the changes are between 0% and -14% per °C global warming. The increase in rainfall in spring is over 8% per °C global warming over the whole of the Egyptian coastline west of Alexandria. In summer, rainfall is non-existent.

The problem associated with the construction of regional scenarios for climate change due to the enhanced greenhouse effect are discussed at length by Palutikof *et al.* (1992), in their report to UNEP on the construction of climate change scenarios for the whole Mediterranean region. The confidence that can be placed in sub-grid-scale scenarios for precipitation is particularly low. These scenarios should be considered only as indicators of changes that might occur.

3.1.4 Impact of Climate Change

From the viewpoint of general atmospheric circulation, the study area, as well as the area between 23°N and 30°N, are more or less under the influence of the so-called subtropical high-pressure system, in which the air is almost permanently convecting downwards, thereby preventing rain mechanisms from operating. In areas marginal to the deserts, such mechanisms do occasionally operate and semi-arid conditions are thereby created. It is important, however, to separate the rain mechanisms operating on the high-latitude margins of the arid regions from those operating in low-latitude marginal lands. The marginal lands on the high-latitude side border the Mediterranean climate, with winter rainfall associated with the temperate-latitude westerlies and varying with the fluctuations in the temperate-latitude winter circulation. In semi-arid lands marginal to the deserts on the low-latitude side, rain mechanisms are connected instead with the meanders of the intertropical convergence zone (ITCZ), or the monsoon circulation. Rainfall is therefore mostly a summer phenomenon in those regions.

It is obvious that agriculture in semi-arid regions is already marginal and is extremely vulnerable to fluctuations in climatic conditions. Global warming must therefore be expected to be of

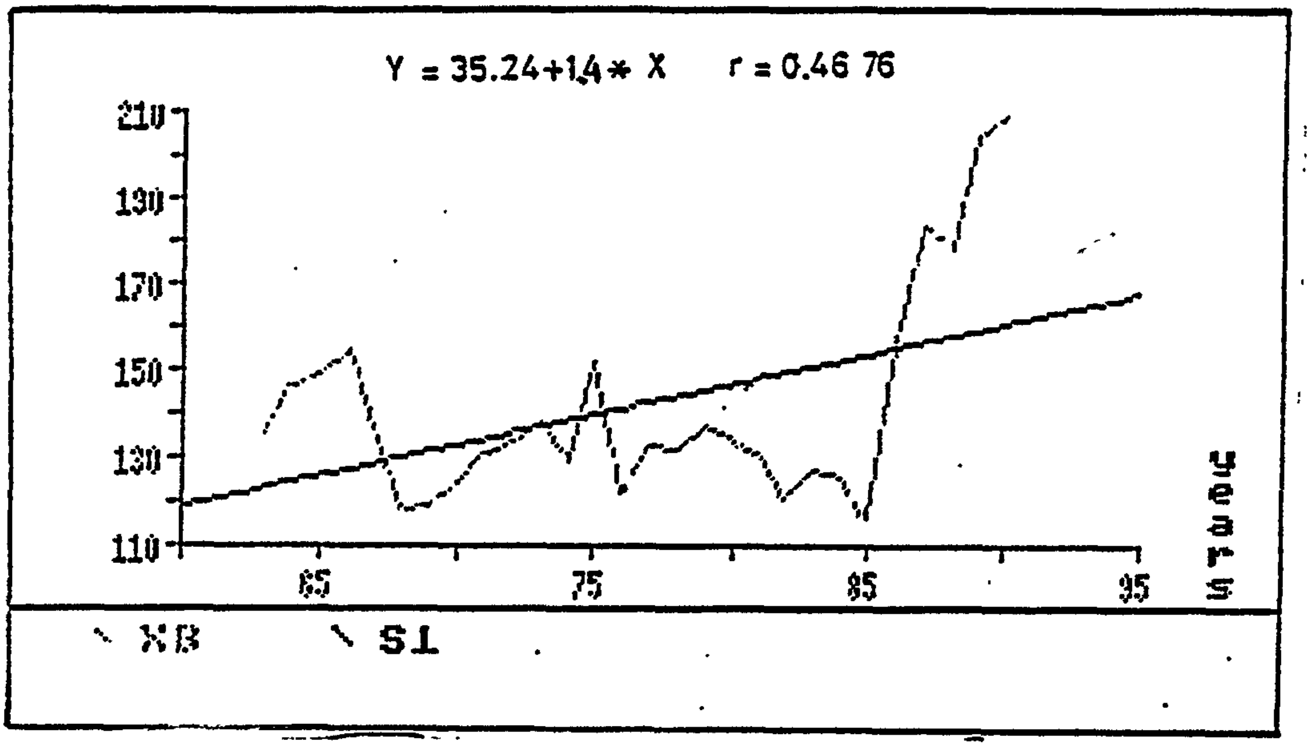


Figure 80 - Trend (5-year moving average) in annual rainfall (mm) at Matrouh

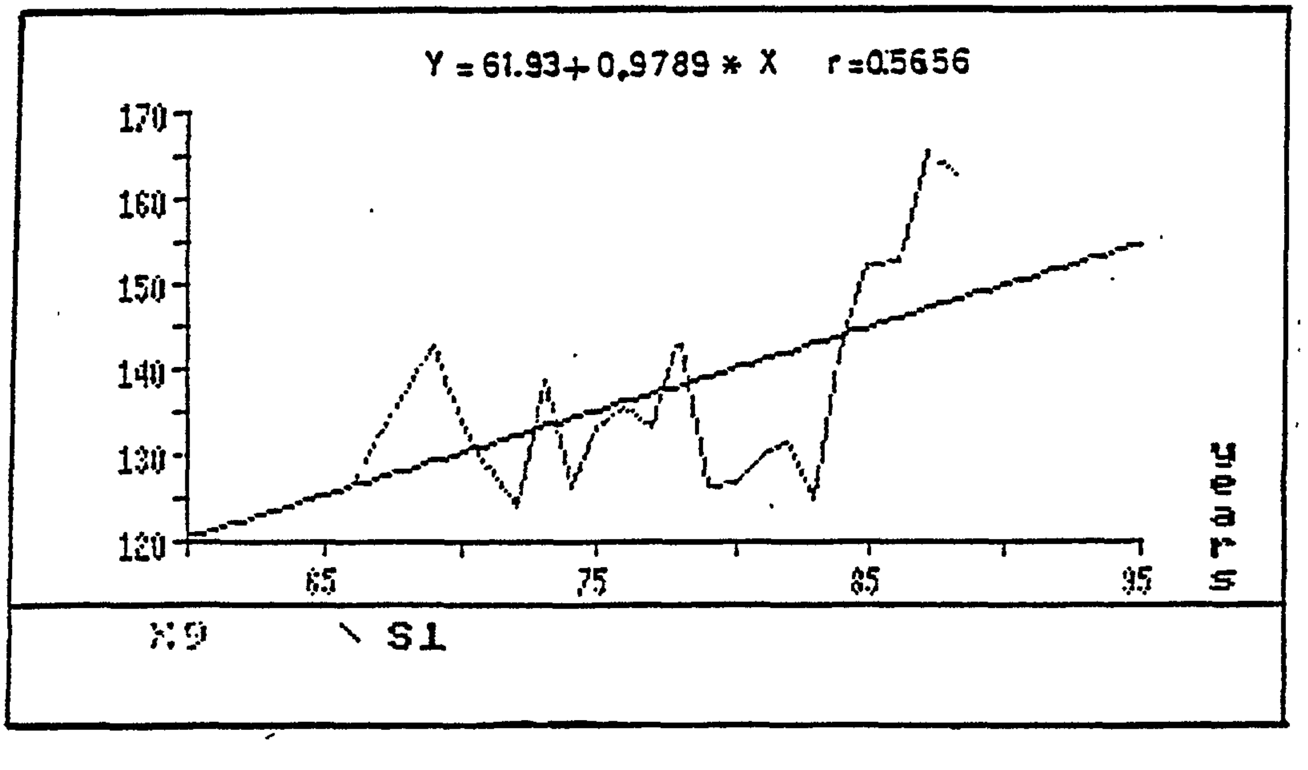


Figure 81 - Trend (10-year moving average) in annual rainfall (mm) at Matrouh

particular significance in such regions. On the other hand, since these already experience extremely variable climate conditions (particularly with respect to rainfall), it is also true that the agriculture there is often more adaptable to climatic change than in many other areas. As with Mediterranean climates, it is quite possible that semi-arid areas might become drier if the subtropical high-pressure systems, which help to create the deserts they border, move northwards in the winter season.

With respect to the study area, the present data are insufficient to determine whether these changes constitute a real trend or are just a reflection of longer-term variability.

The predicted decrease in rainfall forecast by the Climate Research Unit (CRU), or the increase in rainfall revealed by the time-series analysis (Figures 80 and 81), is smaller than the present spatial and inter-annual variations; therefore, changes in this parameter are not expected to have significant overall effects. Moreover, Hassan *et al.* (1991), in their study "On Computation of Climatological Power Spectra", indicate a significant increase in rainfall at least into the next decade.

If emissions of greenhouse gases follow the IPCC "Business as Usual" Scenario (A), the average rate of increase of global mean temperature during the next century is estimated at about 0.3°C per decade (with an uncertainty range of 0.2°C to 0.5°C). This would probably result in an increase in global mean temperature of about 1.5°C above the present value by the year 2030, and of 3-5°C above before the end of the next century.

Regarding rainfall, the most important climate change would be the northward shift of winter cyclonic patterns affecting the western and central Mediterranean in winter. There might be a deceleration of cyclonic activity and more erratic rainfall, drier summers and higher evapotranspiration. Climate zones may shift northwards, thus increasing the length of summer at the expense of the other seasons. Increased variability and patchiness of rainfall might extend summer aridity.

Relatively small changes in the mean values of rainfall and temperature could have a marked effect on the frequency of extreme levels of warmth and moisture. For example, the number of very hot days, which can cause damaging heat stress to temperate crops, could increase significantly as a result of a 1°C or 2°C increase in the mean annual temperature. Similarly, a reduction in the average level of soil moisture, as a result of higher rates of evapotranspiration, could increase substantially the number of days with a minimum threshold of water availability for given crops. In addition, relatively small decreases in rainfall or increases in evapotranspiration could markedly increase the risk and the intensity of drought in currently drought-prone regions.

An important additional effect of warming is likely to be the reduction of winter chilling (vernalisation). Many temperate crops require a period of low temperatures in winter, either to initiate or to accelerate flowering. Low vernalisation results in low flower-bud initiation and, ultimately, in reduced yields. A 1°C warming would reduce effective winter chilling by between 10% and 30%, thus contributing to a poleward shift of temperate crops.

The expected rise of 1°C in mean temperature is likely to increase personal discomfort, but it would also shorten the season of indoor heating, which would save a certain amount of energy. Ordinarily, the heating season in the study area lasts from the beginning of December to mid-April. A temperature rise would increase the energy demand for air-conditioning in summer.

The increase in air-conditioning energy demand would be considerably lower than that in heat-energy demand, which means that the total energy demand would be reduced.

3.2 LITHOSPHERE

3.2.1 General

The coastal area of the north-western region is sandy-rocky, with rock outcrops, fine sandy beaches and clear blue water, perpetually washed by the incoming Atlantic Ocean current, via the Strait of Gibraltar; these conditions make the area very suitable for tourism. A remarkable feature of the western coastal area of Egypt is the sequence of bays along its shores. Abu Hashaifa bay begins at Ras Alam El-Roum and extends eastwards. This is succeeded by Ras El-Hekma bay from the Ras El-Hekma headland to the east. The intervening coastal capes are formed by rocky projections, often as a result of local diagonal breaks, decreasing in dimension eastwards.

The Fuka-Matrouh coastal area consists of several small sandy bays which are protected by rocky headlands and, as such, constitute separate littoral transport units. The maximum eastward sediment transport is thought to be about 17,000m^3 per month.

No significant changes in the Fuka-Matrouh shoreline are currently taking place; however, a seasonal shoreline migration has been noticed and ascribed to high wave action. Sand dunes surrounding some beaches are stable and subject only to wind action and movement.

3.2.2 Erosion and Man-Made Structures

Expected climate change would cause an increase in mean sea level which, in turn, would accelerate erosion along most parts of the Nile delta coast. At the same time, more unstable conditions could be expected at the outlets of the Egyptian Mediterranean coastal lagoons. Also, most of the existing shore-protection measures, as well as those now under construction along the Nile delta coast, would prove inadequate because liable to more frequent overtopping. Therefore, most of these measures would have to be modified to meet this expected change. The shore-protection master plan currently being implemented would have to be upgraded to meet the new, expected situation.

3.2.3 Impacts of a Future Rise in Mean Sea Level

Long time-series data on mean sea level in the Mediterranean indicate that this level is spatially and temporally variable, owing to tidal, meteorological and geological factors. Tide-gauge data suggest a sea-level rise between 0.3mm and 5.0mm per year (Pirazzoli, 1989).

Studies using all the tide-gauge measurements along the Nile delta coast reveal a continuing rise in sea level, with rates ranging between 1mm and 3mm per year. El-Fishawi (1993) indicates a sea-level rise of 1.2mm to 1.3mm per year (Fig. 82).

The relative sea-level rise is, however, attributable to eustatic sea-level rise, natural subsidence and aquifer dewatering. Land subsidence, in particular, plays an effective part in increasing sea level. The rate of subsidence may reach 5mm per year in the eastern Mediterranean (Stanley, 1988).

The development of the north-western coastal area during the last decade has increased dramatically, making it more sensitive to change due to the physical processes that affect the coastal area. The following primary aspects are primarily associated with sea-level rise:

- shoreline changes due to erosion;
- changes in the frequency and depth of coastal flooding by storm surges;
- changes in alongshore sediment transport rate and sediment balance;
- changes in the dynamic forces (winds, waves etc.) acting on the coast;
- changes in offshore bathymetry and sediment texture; and
- salt-water intrusion into coastal soils and surface fresh water (shallow aquifers and wetlands).

The rise in the mean sea level in the coming century due to global warming would represent a substantial increase over the local rise that has taken place on the Mediterranean coast of Egypt. El-Fishawi and Fanos (1989) estimated a sea-level rise of 45cm at Port Said by the year 2100, from the baseline year of 1944 (Fig. 83). Several scenarios have been suggested to estimate the sea-level rise in the coming decades. The best guesses, proposed by Wigley and Raper (1992), appear to be:

- 16cm rise in mean sea level between 1990 and 2030
- 48cm rise in mean sea level between 1990 and 2100.

One aim of the present study is to estimate the impact a rising sea level might have on coastal morphology, community development, investment in tourist villages, and on the choice and implementation of protective measures.

The geomorphological impacts could be considered as a starting point in the assessment of these impacts. Further analysis would be required, however, to evaluate the importance of these physical impacts for the economy and society. An understanding of the potential economic and societal impacts of sea-level rise might improve the private and public decisions aimed at avoiding losses due to sea-level rise.

An assessment of the impacts of sea-level rise would require an estimate of the coastal area at risk, the human popluation at risk, and the capital values along the coast. Low-lying coastal areas are expected to be vulnerable to flooding due to accelerated sea-level rise. Coastal areas at a sufficient altitude above sea level would not be susceptible to flooding. Therefore, in any flood-risk analysis of the Fuka-Matrouh coast, the factors discussed in the following three sub-sections would have to be considered (Delft Hydraulics, 1992).

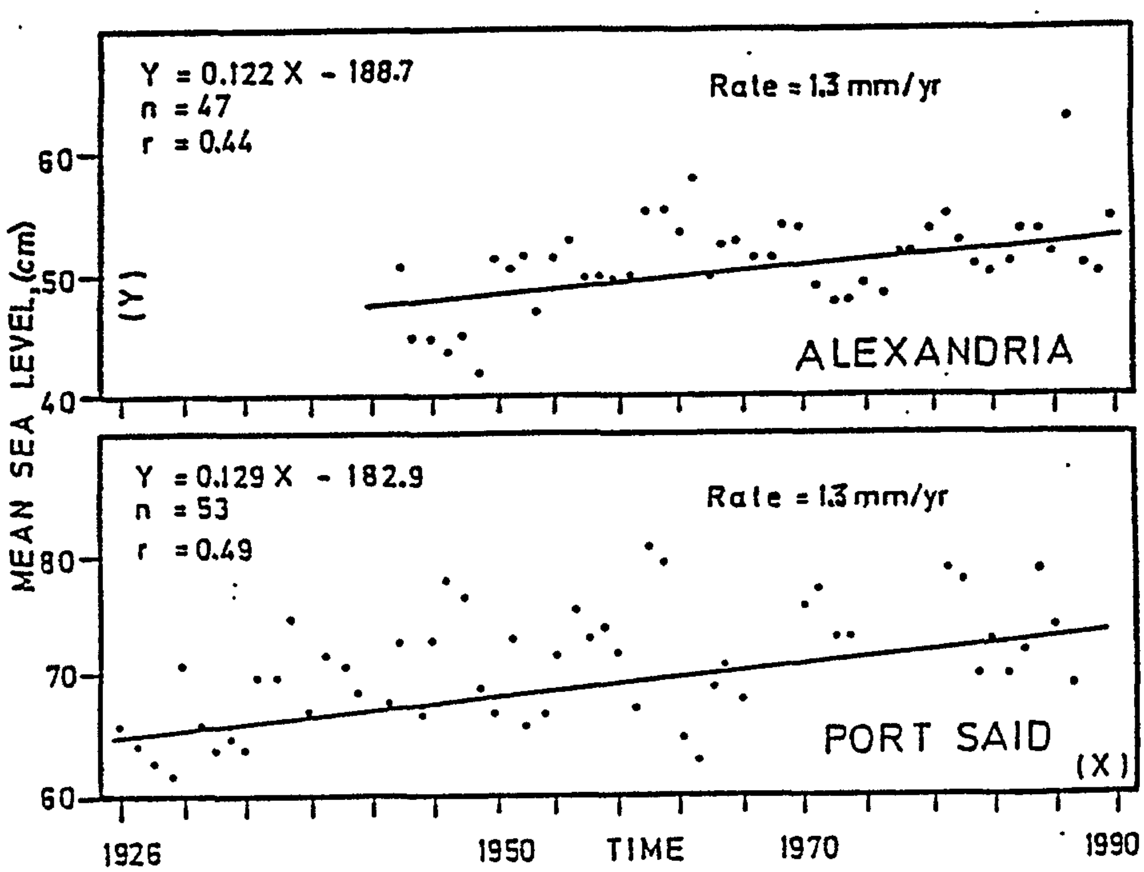


Figure 82 - Sea-level rise at Alexandria (1942-1990) and Port Said (1926-1990)
(source: El-Fishawi, 1993)

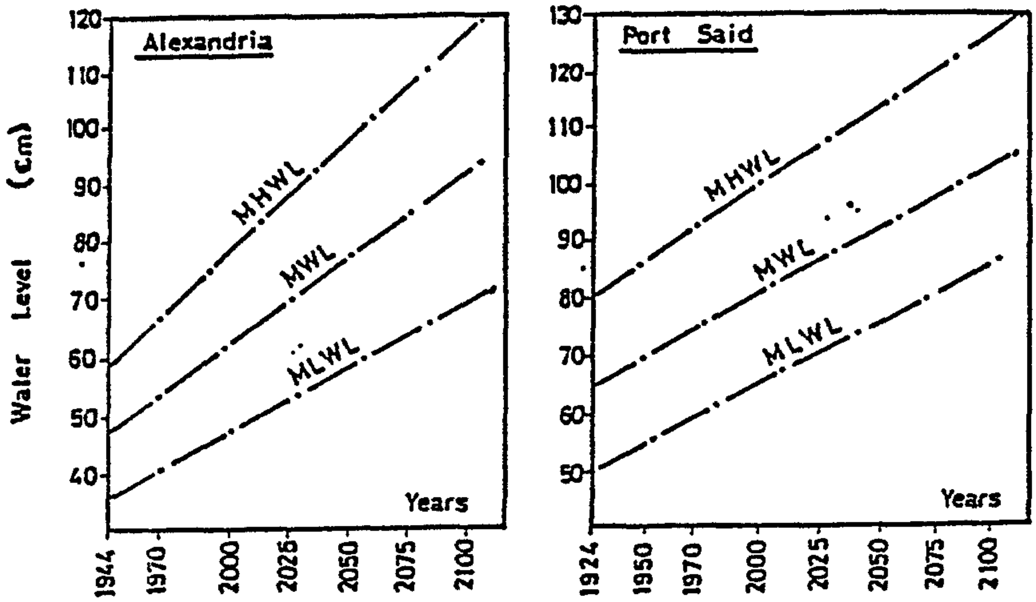


Figure 83 - Estimated sea-level rise at Alexandria and Port Said by 2100
MHWL = mean high-water level; MWL = mean water level; MLWL = mean low-water level
(source: El-Fishawi and Fanos, 1989)

3.2.3.1 Hydraulic-Condition Zone

This is a coastal zone to which a specific set of hydraulic conditions applies. Assessment of these conditions provides quantitative information on the potential flooding situation for such a zone (Delft Hydraulics, 1992). Since the south Mediterranean coast of Egypt can be characterised as a low-energy coast with little variation in wave energy and storm-surge levels along the coast, the hydraulic conditions along the Fuka-Matrouh coast constitute a single system. For each hydraulic-condition zone along the Mediterranean coast of Egypt, a unique Initial Water-Level Exceedance Frequency Curve (IEFC) applies which describes the exceedance frequency of tidal and storm-surge levels (Delft Hydraulics, 1992).

Generally, coastal areas are vulnerable to flooding and the flood level is determined by a number of factors:

Global hydraulic factors - The factor taken into account in the present study is the accelerated sea-level rise proposed by Wigley and Raper (1992), of 16cm by 2030 and 48cm by 2100.

Regional geophysical factors - Subsidence and tectonic uplift have to be taken into account. Only subsidence is applicable on some Nile delta coasts and in the Alexandria region; Stanley (1988) proposed 0.5-5.0mm per year. The rate of subsidence along the stable north-western coast is considered to be minimal, however.

Local hydraulic factors - These factors include tides and storm surges.

An Initial Water-Level Exceedance Frequency Curve (IEFC) can be determined for the Fuka-Matrouh coast by the following formula:

IEFC = $MHW + SURGE_{(f)} + SUBS + SLR$

where MHW = mean high water (0.3m at Alexandria)

$SURGE_{(f)}$	= water level for a specific storm-surge frequency (f) and a duration of 2-3 d (f > 1/1000 years)
SUBS	= subsidence rate of >0.5 mm per year
SLR	= sea-level rise of 16cm over the 40-year period 1990-2030 and 48cm over the 110-year period 1990-2100.

3.2.3.2 Coastal Impact Zone

This zone is based on land elevation, which should be subdivided into elevation zones; e.g., up to 1m, 1-2m and 2-3m. Coastal impact zones can be considered homogeneous with respect to risk (flooding) Based on the expected future hydraulic conditions of the Egyptian Mediterranean coast, including an accelerated sea-level rise, the 3m elevation forms the upper boundary of the low-lying coastal zone. This 3m elevation is an estimate based upon direct effects of accelerated sea-level rise and storm surges, and upon indirect effects such as increased salt-water intrusion into soils and fresh surface water. It may also be expected that this impact zone (up to 3m elevation) would be in some way or another affected by an increase in the sea level.

3.2.3.3 Protection Systems

These are coastal defence systems with a uniform protection status; they may be artificial or natural defence systems.

In an artificial defence system, the protection status is based on the mean wave crest height in combination with the local water-level exceedance frequency curve for the tide, storm surges and wave run-up. The actual safety height of the system determines whether or not the structure will fail, depending on the local hydraulic conditions. In fact, the north-western coast has very limited protective works. These works are based on inadequate assessment of their effectiveness and it may be expected that they would face greater hazards from future rise in sea level.

In a natural defence system (coastal ridges and dunes), the failure mechanism is based on the lowest point in the ridge or dune crest. Inundation of the hinterland will occur if these lowest points are overtopped by the sea.

It may be safely assumed that the areas at risk, such as cities and tourist villages, would have some kind of basic protection. A rough inventory of the lowest points in the coastal ridge and dune areas along Fuka-Matrouh coast, based on topographic maps and cross sections, leads to the conclusion that these coastal structures are able to withstand the present hydraulic conditions. The ridges and coastal dunes along the coast could partly stop flooding and damage to these coasts. The average elevation of the lowest point is assumed to be between 1m and 3m above sea level.

3.2.4 Impact on Erosion

Shore retreat has become common all over the world, particularly in the last several decades and the populations concerned are therefore much threatened. Sea-level rise has been identified as the principal forcing function in shoreline erosion. However, the relationship between sea-level rise and shore retreat is rarely one-to-one and must be tempered by a consideration of local factors. Along the Fuka-Matrouh coast, acceleration in beach erosion can be related to the nature of the beach, the topography, foreshore and offshore slopes, sediment supply, the nature of the coastal sediments and the relevant dynamic forces. In fact, the rate of erosion along the north-western coast is still slow; it is estimated to be 1-3m per year. This rate is expected to increase to 2-5m per year along the Matrouh stretch by 2020-2090 (Delft Hydraulics, 1992).

One of the serious impacts of rising sea level is accelerated beach erosion. The destructive effects on the shoreline are mainly due to erosion of the beach sediment itself, erosion of the protective coastal ridges and dunes, and the destruction of many beach houses.

The nature of the beach plays an effective part in the rate of erosion. A wide beach which prevents the waves reaching the coastal dune and ridges will form an effective protection to the coast and hence will minimise the erosion rate. If the beach is narrow enough to be removed by storm waves, the coastal dunes can be attacked by these waves which are the only ones capable of effective erosion. Therefore, the greater foreshore-to-backshore length and slope of some Fuka-Matrouh beaches would afford relative protection to these coasts. At the same time, the character and liability of coasts to erosion varies greatly. Where the shoreline of the study area is irregular, the attack due to the rising sea level will tend to be concentrated on the headlands (Ras El-Hekma, Ras Bakshuba and Ras Alam El-Roum). This is partly due to the concentration of wave energy on the headlands by the refraction.

Rocky coasts vary in their degree of lithification and structure and therefore also show varying response to erosion. The local characteristics, including wave climate and rock type and structure, are the controlling variables. The only broad statement worth making is that rocky shorelines are likely to retreat less quickly than sandy ones for the same set of dynamic forces affecting the coast. The carbonate rocky ridges of the study-area coast play an important part in controlling erosion during sea level rise.

Beach protective works (very rare, sometimes jetties) have been executed, but not all of them have been rationally planned and designed. These structures will interfere with the movement of sediments and hence erosion will occur on the down-drift side.

The offshore relief is important in any consideration of coastal erosion. The effect of offshore relief on wave refraction may explain the concentration of wave energy at particular places, with subsequent variation in erosion along the coast. The wide deep continental shelf of the study area will render waves more erosive than where the water is shallow close offshore. Changes in offshore relief near the beach may be important in determining which areas are likely to suffer from erosion.

A rising sea level will deepen the water offshore, allowing waves to break closer to the shore. It will increase their erosive capacity, hence lead to an acceleration of coastal erosion in areas already affected, and perhaps starting it in areas previously immune.

The movement of sediments alongshore is partly responsible for coastal erosion. Coastal erosion is most likely to take place where more sediment is moved alongshore out of the stretch of coast than is being moved into it from the up-drift direction. A coast with a smooth shoreline is also liable to erosion because there is no obstruction to hold up the movement of sediments along the beach.

With rising sea level, there will be a general tendency for the fine-grained coastal sediments to move offshore, leaving the coarser grains on the beach. In contrast, the eroded beaches of the central part of the Nile delta coast are finer-grained and better sorted than the accreted ones. These accreted beaches indicate a transport of coarser grains from some outside sources (El-Fishawi, 1977).

Sea-level rise will bring a decrease in wave height, owing to increased water depth. As a result, the waves will relatively be steeper. These steeper waves are normally destructive, lowering the level of the foreshore surface and transporting sediments seawards. The larger the waves are, the greater will be their energy and hence the removal of sediments from the beach. Destructive waves are normally associated with storms and high wind velocities. Strong winds, blowing onshore near the coast, generate steep waves. The wind itself has a marked effect on the destructive nature of the wave attack. A strong onshore wind may also assist the destructive tendency of the waves by raising the water level above its normal height, and the sea can therefore attack zones normally beyond its reach. Strong winds and the rapid changes in the atmospheric pressure associated with them can generate surges on some coasts.

3.2.5 Impact on Flooding

Coastal flooding due to future rise in sea level is expected to increase. Furthermore, flooding from storm surge is likely to increase, because the base level on which the surge would build would be higher. Sea-level rise could increase the risk of flooding in the following ways:

- there would be a higher base upon which storm surges would build, and surges would penetrate farther inland;
- beaches and sand dunes, which are currently protected in many areas from direct wave attack, would become more vulnerable to flooding and erosion due to sea-level rise if these protective barriers were removed;
- wetlands and sabkhas along some coasts slow the penetration of flood water by blocking the waves, so losses of these wetlands would increase coastal flooding and salinity;
- sea-level rise could also increase flooding from rain storms.

Along the Fuka-Matrouh coast, low-lying lands, wetlands and sabkhas in some places (up to 1m elevation) are expected to experience increased flooding due to sea-level rise and storm surges.

Storm frequency and magnitude are important because the bulk of flooding and erosion would take place during storm events, following a local increase in sea level. Therefore, a shoreline that experiences more and heavier storms will adjust to the new sea level more rapidly than another with less frequent storms. In the latter case, there may be a longer lag-time between sea-level rise and shoreline retreat, and the rate of erosion may therefore be less (EPA, 1983).

3.2.6 Impact on Sediment Transport

Shoreline development can be determined as a function of time for any given sea-level rise. It is expressed in metres of shoreline retreat or advance, square metres of beach area, and cubic metres of sediment lost or gained, for any given stretch.

The following sediment transport rates across the boundary of the Fuka-Matrouh stretch may be defined as follows:

T_{in} = rate of longshore transport into the stretch
T_{out} = rate of longshore transport out of the stretch
T_w = rate of wind transport out of the stretch
T_{off} = rate of transport out of the stretch to the offshore deep
T_n = rate of artificial beach replenishment in the stretch

Combining all sediment transport into and out of the stretch, yields the sediment balance (Delft Hydraulics, 1992) which determines the rate of recession of the stretch:

$$E = (T_{out} - T_{in} - T_w - T_{off} - T_n + WsL) / LH$$

where E = rate of recession
Ws = geomorphologically active width
L = length of the stretch
H = geomorphologically active height

Integration since the beginning of the period considered ($t = 0$) leads to the total recession of the coast (F) at the end of period (t) as follows:

$$F = \int_0^t E dt$$

The longshore transport rate along the Fuka-Matrouh coast is predicted to be small under ordinary conditions ($8,400 m^3$ per year) and not to exceed $204,000 m^3$ per year for vigorous conditions. On the other hand, the longshore transport rate is very high along unstable stretches of the Nile delta coast where it ranges between 0.6 and $3.6 \times 10^6 m^3$ per year. Sediment transport by wind action on the western coast of Alexandria does not exceed $4,100 m^3$ per year. Taking into consideration the source of the coastal sediments from the western cliffs and the wind-blown sand gained from the desert, it can be assumed that the sediment balance of the Fuka-Matrouh coast could be in equilibrium with future rise in sea level.

3.2.7 Impact on Offshore Bathymetry and Sediments

Because of a rising sea level, the increased sea-water depth would alter the hydrodynamic forces affecting the sea bottom and possibly have structural implications. Changes in offshore bathymetry due to sea-level rise could alter wave refraction patterns and the direction and magnitude of bottom currents.

Elevation in sea level by a given amount creates a "gap" at the sediment surface which represents a disturbance in the profile of the dynamic equilibrium established by the previous sea level. The "gap" has to be filled, and this will take place by removal of sediment from the foreshore to the offshore area, resulting in shore face retreat and landward advance of the water line (Fig. 84). Additionally, overtopping of the beach during storms, which are additive to the higher base level due to sea-level rise, transfers sediment in the landward direction, adding to the migration of the shoreline.

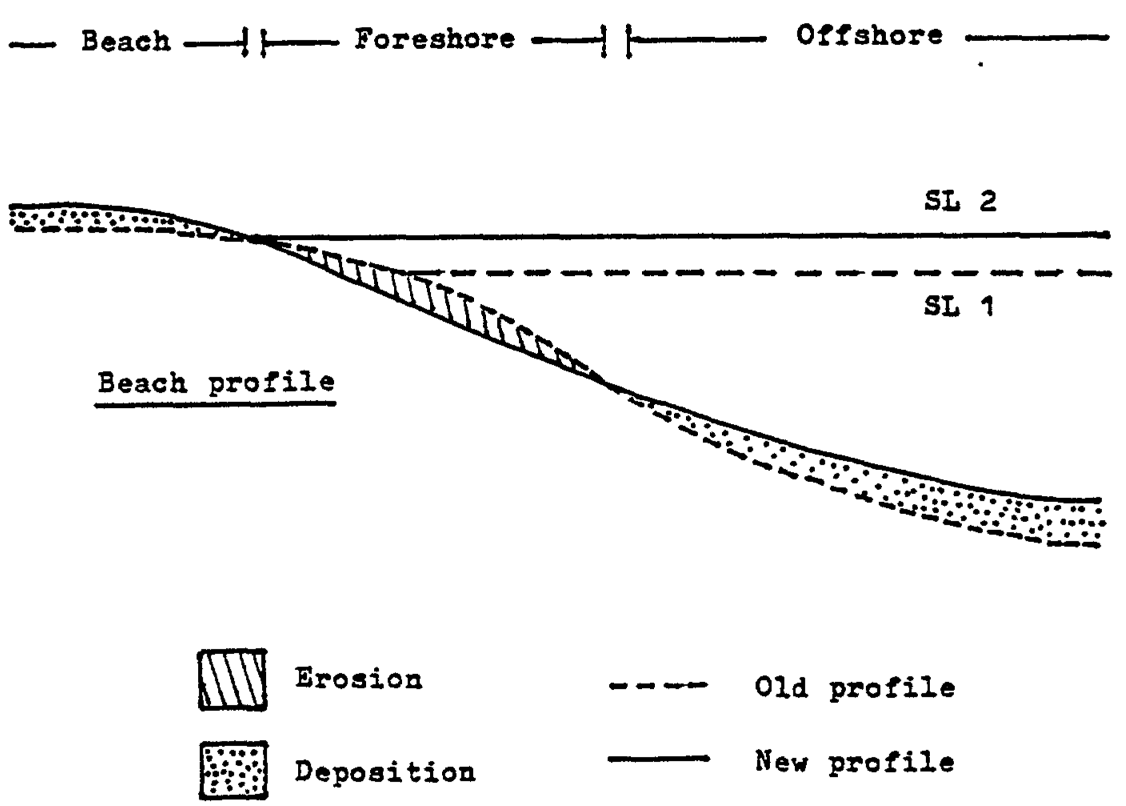


Figure 84 - The effect of sea-level rise on bottom sediments

Owing to higher wave action, as a consequence of rising sea level, the sediments of the steeper beach face, especially the fine sediments, will move downshore. As a result, there will be a major reduction in the percentage of fine-grained sediment load along the coast. The percentage of fine and very fine sediments along the Fuka-Matrouh coast ranges between 18% and 48% and it is expected to decrease in beach sediments as sea level increases, whereas coarse-grained sediments are expected to increase (>12%).

3.2.8 Impact on Dynamic Forces

Sea-level rise and climate change would have substantial impacts on the dynamic forces affecting the coast (winds, storms, waves, currents and tides). It is known that the magnitude of the wind set-up contribution to the storm surge is inversely proportioned to the water depth. Mercado (1989) gives a simple equation relating the change in maximum surge height to sea-level rise:

$$\Delta\eta\text{max} = \left(\frac{-\eta\text{max}/h_o}{1+\eta\text{max}/h_o}\right)S$$

where $\Delta\eta$ max = change in maximum surge height
h_o = depth of shelf
η max = wind stress surge
S = magnitude of sea-level rise

Mercado (1989) discussed the effect of sea-level rise on storm surges by using models. A rising sea level, hence increased depths, will result in less wave damping and higher wave energy at the shoreline. Also, wave generation is bound to be increased: given a water depth of 10m, a shelf width of 10km, a wave period of a 8s, an initial wave height of 2m, a friction coefficient of 0.01, a sea level rise of 1m would bring about a 3% increase in wave height attributable to increased water depth. Under the same conditions, wind-generated wave heights could increase by 7.5%. As a first approximation, these two increases can be linearly combined. Hence, one should expect larger wave heights near the shoreline.

The longshore current is also expected to be faster, owing to the effect of greater wave heights along the coast due to increased water depths. Wind-driven currents and wave-induced currents would predominate in the foreshore zone.

Sea-level rise could change tidal ranges by removing barriers to tidal currents and by changing the resonance frequencies of tidal basins. If the sea-level rise leads to inundation of wetlands or erosion of the ends of barrier islands, more water may flow in and out and thereby increase tidal area. A greater tidal area would increase the inundation of dry land, while increasing the area of intertidal wetlands. Tidal currents would also cause additional erosion by washing sand along the coast.

The coastal geomorphology of the Fuka-Matrouh stretch, with the presence of extremely deep water just offshore and the relatively steep slopes of the coastal land, would diminish the effect of sea-level rise on storm-surge heights, as well as the direct effects it might have because of changing depth (bathymetry).

3.2.9 Impact on the Coastal Zone and Its Morphology

The western coastal zone comprises two distinct sections: the eastern 100km section is a low area with wide sandy beaches, sand dunes and marshland farther inland in certain areas; westwards, the landscape becomes more uneven with several headlands protruding from the coast creating small coves with stable sandy beaches in between.

Therefore, with a sea-level rise, the eastern part would be subject to coastal erosion and flooding of the backshore area and depressions, whereas only slight impacts should be expected in the western part. The coastal ridges bordering the coast along certain stretches would play an effective role in stopping flooding and damage to the coast.

The retreat of the beach-dune zone of the Fuka-Matrouh coast essentially depends on the persistence of an adequate supply of sediments from cliff erosion and littoral drift from the western to the eastern area. If the littoral drift is insufficient, the dune is obliterated and sediments removed seawards. Thus, coastal erosion is accelerated and the breaching of beach-dune ridges by storm waves and the breakup of barrier islands could become more frequent. Equally, man-made structures and subsidence would worsen the often already precarious situation. Serious impact due to sea-level rise would be expected in small bays and narrow coastal plains where sediments move in a closed system with a scarce supply. The coastal lagoons and depressions would migrate landwards if the rate of sea-level rise decreased to a low level.

A consequence of rising sea level in the coming decades would also be a much increased recurrence of extreme events, such as severe storms and high tides. Therefore, an acceleration in sea-level rise would result in flooding of the coastal zones.

Small pocket beaches and small bays along the Fuka-Matrouh coast would be the first to experience the impact of a gradual rise in sea level which would reinforce erosion cycles so that the enclosed small sandy strips and bays might be gradually invaded by the sea.

Barrier islands are dominant in some parts of the Fuka-Matrouh coast. They are narrow strips of detrital sediment rising above sea level. The instability and breakup of these barriers could become more frequent in coming decades, owing to sea-level rise. Beaches in front of barrier islands could be subject to accelerated erosion if the sea water covered the barrier island so that the waves could directly attack the shore.

As a result of flooding, some inter-dunal areas and inter-ridge depressions might suffer slight subsidence with a rise in sea level.

Low sandy coasts to the west of Ras El-Hekma which are shaped by marine processes have the capacity to reform themselves after severe storms and to rise in phase with the rise in mean sea level, by gradually migrating landwards.

Calculations were made for the Fuka coastal stretch and the area to the west to show the percentage occurrence of slope classes, geological and geomorphological units (Tables 47-49). The most important zones that would be affected by a rise in sea level are those in the 0-2m slope class, and beach deposits. Slope class areas between 0 and 2m above sea level represent the largest part of the coastal zone, constituting about 91% of the elevated plain and occupying about 132km^2. Assuming the same gradient within the 0-2m slope class, estimates suggest that an additional area of about 11km^2 would be affected by a sea-level rise of 16cm, by 2030, and about 33km^2 by a sea-level rise of 50cm, by 2100. As indicated in Tables 48 and 49, beach deposits, salt marshes and some alluvial deposits would be vulnerable to a rise in sea level. Limited coastal areas could be expected to be eroded at Ras Alam El-Roum and Matrouh.

Table 47 - Slope-class areas and percentage occurrence in the Fuka coastal area (source: Ramadan, 1992)

Slope class	Percentage area	Area (km^2)
0-2m	90.97	131.95
2-4m	6.94	10.07
4-8m	1.57	2.28
8-12m	0.51	0.74

Table 48 - Areas and percentage areas of the principal geomorphological units in the Fuka area (source: Ramadan, 1992)

Age and type	Percentage area	Area (km^2)
1. Quaternary		
a. Recent:		
- beach deposits	2.52	3.70
- salt marshes	0.33	0.49
- *alluvial* deposits	62.13	91.17
b. Pleistocene:		
- consolidated limestone ridge	7.91	11.60
- consolidated limestone	7.54	11.07
2. Tertiary		
- Miocene limestone	19.56	28.70

Table 49 - Areas and percentage areas of the prinicipal geomorphological units in the Fuka coastal plain (source: Ramadan, 1992)

Coastal plain	Percentage area	Area (km^2)
Low coastal plain:		
- beach deposits	2.00	2.89
- salt marshes	0.56	0.66
- alluvial deposits	9.37	13.50
- lagoonal depressions	11.52	16.60
Elevated coastal plain:		
- rocky plain	60.20	86.70
- isolated hills	1.74	2.50
- first ridge	2.76	3.98
- dissected land	10.84	15.61
- ridge escarpment	1.11	1.60

3.2.10 Impact on Coastal Tourist Villages

Recently, the rapidly growing tourist industry has led to a more intensive use of the north-western coast. This has affected its stability and rendered it more vulnerable to changes in sea level such as those that could be induced by global warming.

Marakia, Marina, Marabella tourist villages, El-Alamain, Sidi Abdel Rahman, El-Hamra harbour, Dabaa, the entrance to the Qattara depression, Ras El-Hekma, Fuka, Baqqush, Matrouh and Sallum are the main cities and sites lying along the western coast of Egypt. The buildings of many tourist villages are located at a critical distance from the shoreline. Moreover, the coastal protective works at some of these villages are based on inadequate assessments of the effectiveness of these works, so these villages would face greater hazards in future. This serious situation has arisen during the last decade as a result of non-compliance with the existing legislation. Given an accelerated sea-level rise, damage to the shoreline buildings in many tourist villages, due to attack by sea waves, may become a serious problem.

Matrouh Bay is about 3km wide and is connected to a shallow lagoon to the west. Many tourist sites are located in the bay as well as on the sea shore 10-30km to the east and to the west. A slight erosion of the swimming beach of the Beausite Hotel has occurred recently; it has been caused by the dredging of the navigation channel inside the bay which is used by the Navy as a refuge harbour. A project is under execution to protect this area; it consists of sand nourishment with the construction of a groyne on the eastern edge.

A strip of sandy beach surrounding Matrouh city is of high touristic importance. Owing to the morphology of Matrouh (southern cliffs and low-relief beaches), the urban areas are not expected to experience significant impacts from sea-level rise.

Baqqush coast, west of Fuka, consists of sandy beaches and low coastal dunes. With a gradual sea-level rise, the shoreline would migrate landwards and the backshore zone would decrease in area, without changing the coastal-dune zone.

3.2.11 Area at Risk

To calculate the areas at risk in the various zones of coastal impact, an assumption has to be made of the correlation between the water-level exceedance frequency and the area of impact (Delft Hydraulics, 1992). Suppose that, near a zone of interest, the sea level exceeds 0.4m once every 100 years (F_{04} = 0.01/yr), and that the exceedance frequency for a level of 1.0m is once every 1000 years (F_{10} = 0.001/yr). Suppose, moreover, that, between the levels corresponding to F_3 and F_4, the area is 1000km^2. If the whole area has an elevation of approximately 0.4m, the average area at risk per year (AAR) would be $AAR_{04,10}$ = 10km^2/yr (1/100 x 1000km^2). On the other hand, if the area has an elevation of approximately 1.0m, the result would be $AAR_{04,10}$ = 1km^2/yr (1/1000 x 1000km^2). In general, the average area at risk per year will lie between these two limits.

Following the same notations as those above, it is assumed that the exceedance frequency for level h_i is given by F_i and for level h_j by F_j. The number of people living between these levels is POP_{ij}. Let POP(F) denote the total population living below the level with exceedance frequency F, so

$$POP = \int_{Fi}^{Fj} * \frac{dPOP(F)}{df}\, df$$

If POP(F), as a function of F, is known, then the average number of people at risk per year would be:

$$P_a R_{ij} = \int_{Fi}^{Fj} * \frac{dPOP(F)}{df} df$$

By inserting the values (per km^2) and the exceedance frequencies in decades for each coastal impact area and/or coastal-elevation zone, an estimate of flooding and flood risk can be calculated (Pennekamp *et al.*, 1992) by the following simple equation:

$$P_a R_{ij} = \frac{9F_i}{\log(F_j / F_i)} * POP_{ij} = 3.9\ F_j\ POP_{ij}$$

3.2.12 Cost Aspects

Assessment of the vulnerability to future sea-level rise along the Egyptian coast was carried out by Delft Hydraulics (1992). Value of lost land and cost of beach nourishment were estimated. In the present study, some stretches of the north-western coast were selected; these were: Matrouh (including Fuka), Alamain and Alexandria. The case studies comprised a combination of:

- scenario for accelerated sea-level rise of 1m/100yr;
- time horizons considered: 30 years (2020) and 100 years (2090); and
- with or without socio-economic development.

Table 50 illustrates the cost aspect of beach loss and assessment of the cost of beach nourishment resulting from a rising sea level, as simplified from Delft Hydraulics (1992). As an estimation, the shoreline of Fuka-Matrouh would retreat by between 2km^2 and 5km^2 by the years 2020 and 2090, respectively. Therefore, the capital losses due to beach retreat range between E£78 million and E£261 million without socio-economic development, and between E£454 million and E£1512 million with socio-economic development, by the years 2020 and 2090, respectively. At the same time, the cost of beach nourishment (full measures) are expected to be E£185 million and E£615 million for the same two periods.

Table 50 - Beach loss and cost assessment of beach nourishment resulting from sea-level rise (simplified from Delft Hydraulics, 1992)

A. Beach losses without socio-economic development

Stretch	Beach length (km)	Shoreline decrease (km^2)		Capital loss (beach retreat) (E£ x 10^6)	
		2020	2090	2020	2090
Matrouh	123	2	5	78	261
Alamain	93	1	3	170	568
Alexandria	63	4	12	539	1795

B. Beach losses with socio-economic development

Stretch	Beach length (km)	Shoreline decrease (km^2)		Capital loss (beach retreat) (E£ x 10^6)	
		2020	2090	2020	2090
Matrouh	123	2	5	454	1512
Alamain	93	1	3	644	2148
Alexandria	63	4	12	810	2700

C. Cost assessment of beach nourishment (full measures)

Stretch	2020 (E£ x 10^6)	2090 (E£ x 10^6)
Matrouh	185	615
Alamain	165	549
Alexandria	734	2446

3.2.13 Impact on Soil

Owing to the low organic-matter content in the different soil types in the study area, besides high calcium-carbonate content and low soil moisture, the 1-2°C increase in temperature is not expected to affect the decomposition of organic matter. Increase in air temperature will change the soil thermal regime. Soil thermal regime studies at El-Omayed and El-Gharbaneat on the northern coast showed that the Van Wijk equation could predict soil temperature if soil thermal diffusivity could be determined with good accuracy, and a quantitative evaluation could be made of the implication of increasing temperature (Mokable, 1978).

Soil erosion is expected to increase as a result of the expected climate changes. Higher temperature would reduce soil moisture content and the drier soil would be affected by wind and or water run-off. Local sedimentation is expected to increase. Soil fertility and salinity are expected to increase as a consequence of the anticipated temperature rise.

Soil in the depressions nearest to the seashore, as well as the soil of fans at the ends of wadis are expected to become saline owing to sea-level rise and increasing evaporation and evapotranspiration.

3.2.14 Summary

The western coast of Egypt is an example of a coastal plain zone still not entirely developed. Therefore, topographic and human impacts could be very slight relative to sea-level rise impacts. The reason may be related to the topographic-sedimentological conditions of the coast and to the lack of intensive occupation in parts that would be subjected to sea-level rise and extreme events. The degree of vulnerability therefore depends on the following main factors which would shape the coast during coming decades:

- Sea-level rise: A rise of about 50cm could cause the calcareous sandy beaches to migrate landwards; reclaimed lowlands west of Alexandria could become flooded; marinas, harbours and shoreline roads would require major restructuring.

- Sediment balance: The maximum sediment drift rate along the coast of Fuka-Matrouh (0.20 x $10^6 m^3/yr$) is still enough to maintain the shoreline. Generally, the sediment supply is mainly cliff erosion on the western side; the sediment balance might be slightly changed in coming

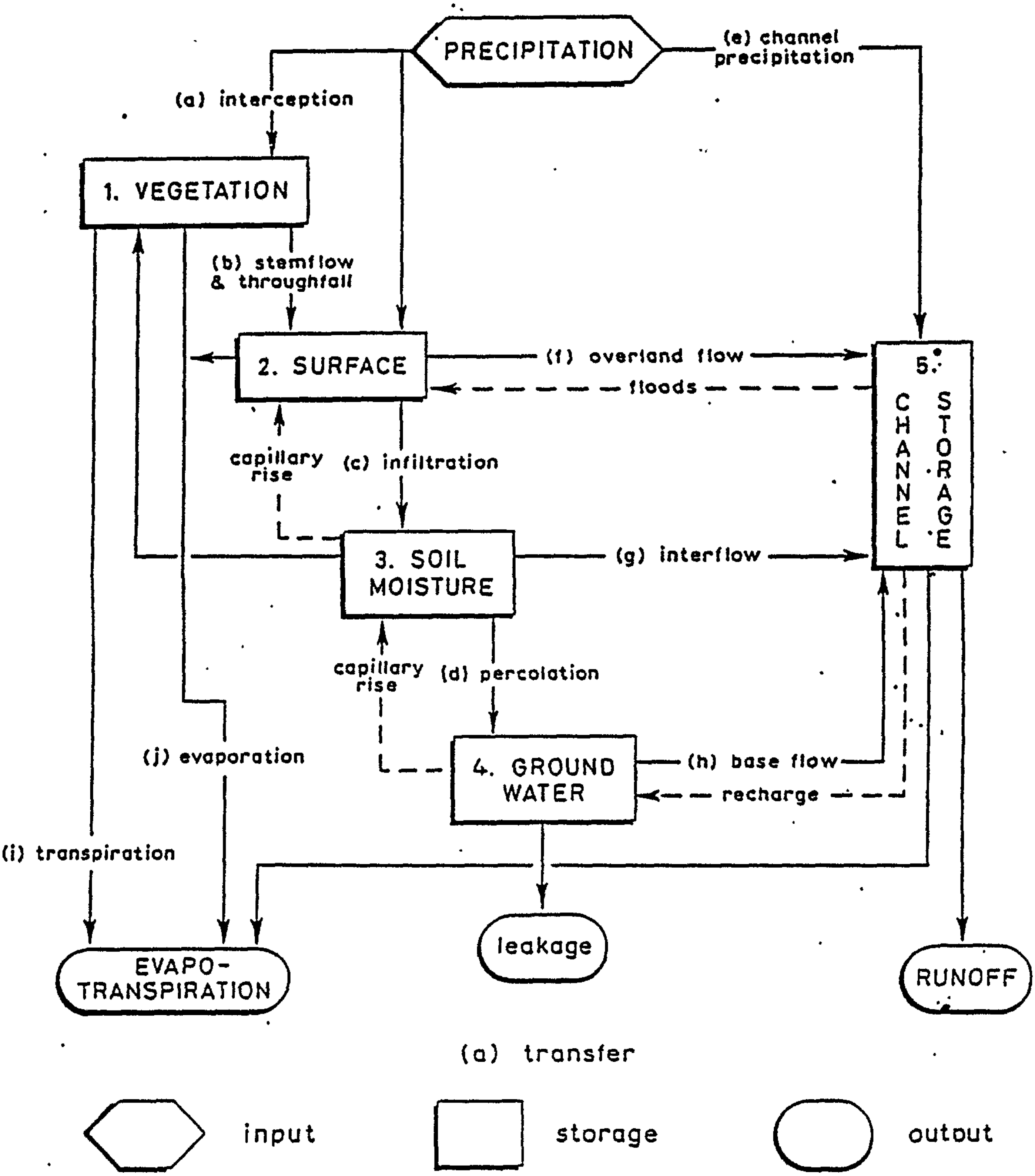


Figure 85 - Hydrological cycle on a local scale (sources: Lewin, 1975; Ward, 1975)

decades.

- <u>Subsidence and tectonic movement</u>: No major, truly tectonic, movements are recognisable along the coast. It is reasonable to assume that only the eastern part of the ridges, those close to the Nile delta, have suffered some displacement as a result of subsidence of the deltaic body. Therefore, the western coast would be only slightly affected by sea-level rise.

3.3 HYDROSPHERE

3.3.1 Expected Climate Change

The changes for the time horizons 2030 and 2100, according to UEA scenarios for the study area, are as given in item 1.3.

The parameters of climate change would have quantitative and qualitative implications for the water balance in the Fuka-Matrouh area. The water resources are stored in the hydrological system of the area. Figure 85 gives a simple diagram of the hydrological cycle in the study area (Lewin, 1975; Ward, 1975).

The expected climate change would directly and indirectly affect the input and output elements of the water budget. The need to quantify climate-change implications and hydrological processes is still more pressing in view of the fact that, in the study area, water availability is barely adequate to the basic human needs (about 100m^3 per inhabitant per year). A modified and verified simulation model to evaluate the local hydrological impacts of climate change is needed. An example of such a model is the water mass-balance equation proposed by Sokolov and Chapman (1974).

$$P = Q + E$$

where P = precipitation
Q = run-off
E = evapotranspiration

This equation can be subdivided to depict partial processes. Several water-balance models can be used to assess the consequences of the impact of global change on the hydrological system. Salt-water intrusion due to climate change could be simulated also by the so-called Hubberts formula.

$$Z = \alpha(hf - hs) - hs$$

where Z = depth of the interface below mean sea level
α = ^W/f (√s - √f) = 40
hf = fresh-water head (water-table elevation over mean sea level)
hs = salt-water head
ρ = density of fresh water = 1000kg/m^3
ρ = density of salt water = 1025kg/m^3

Gleick (1986, 1987a,b in Jeftic *et al.*, 1992, p. 92) points out that, once the region has been characterised in terms of its water balance, the effects of climate change can be evaluated in three ways:

- after having verified the accuracy of the model by using long time-series (historical) data, it should be possible to use these data to evaluate the effects of historical fluctuations in precipitation and temperature on historical run-off and soil moisture;

- after determining the sensitivity of run-off and soil moisture to theoretical changes in the *magnitude and temporal distribution of precipitation and temperature*, a wide range of .

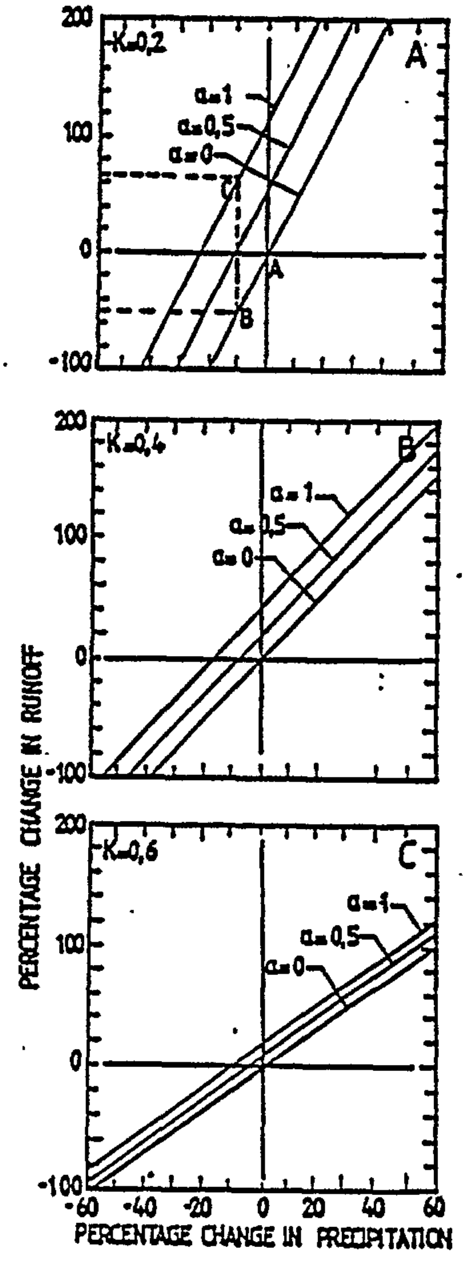


Figure 86 - Run-off changes due to changes in precipitation (P) and evapotranspiration (E)
a = 0 corresponds to no change in E
a = 1 corresponds to 30% reduction in E (maximum direct CO_2 effect)
Three values of run-off coefficient K are shown. Precipitation change alone is given by a = 0. Thus, the line AB shows the effect of a 10% reduction in P. The line BC corresponds to a range of E reduction from 0% (point B) to 30% (point C)
(source: Wigley and Jones, 1985 in Jeftic *et al.*, 1992, p.93)

hypothetical climatic changes can be assessed to evaluate the hydrological sensitivity of the water shed; and

- by incorporating even rough, regionally desegregated changes in temperature and precipitation predicted by General Circulation Models, a first estimate can be made of the impacts of future predicted climate change on regional hydrology.

The study of Wigley and Jones (1985, in Jeftic *et al.*, 1992, p.93) on the hydrological cycle's response to changes in precipitation from P_0 to P_1 due to a doubling of atmospheric CO_2 is given by

$$P_1 = aP_0$$

where a indicates change in evapotranspiration, as shown in Figure 86. The authors claim that run-off is more sensitive to precipitation changes than to evapotranspiration changes, particularly for higher values of the run-off coefficient. They also state that precipitation changes have an amplifying effect on run-off.

3.3.2 Potential Evapotranspiration

$$ETO = \frac{\Delta}{\gamma}\,[0.95\,RA\,(0.16 + 0.62\frac{n}{N}) - OT^4\,(0.56 - 0.079\,\sqrt{ed})\,(0.1 + 0.9\frac{n}{N})] + 0.26\,(ea - ed)\,(1.0 + 0.54) \,/\, \frac{\Delta}{\gamma} + 1$$

where ETO is potential evapotranspiration, in mm/day
RA is extraterrestrial radiation, in J/m²/day
N is maximum possible number of hours of sunshine
n is observed number of hours of sunshine
OT is Absolute Temperature, in kelvins
ea is saturation vapour pressure, in millibars
ed is observed vapour pressure, in millibars
γ is index of reflection
Δ is slope of saturation vapour pressure curve of air at absolute temperature, in °F

Evaporation from water surface:

$$ETO = \frac{\Delta}{\gamma}\,[0.76\,RA\,(0.16 + 0.62\frac{n}{N}) - OT^4\,(0.56 - 0.079\,\sqrt{ed})\,(0.1 + 0.9\frac{n}{N})] + 0.26\,(ea - ed)\,(0.5 + 0.54) \,/\, \frac{\Delta}{\gamma} + 1$$

Table 51 shows the changes in potential evapotranspiration due to the expected increase of 1°C in air temperature, calculated by both of the foregoing equations.

Table 51 - Changes in potential evapotranspiration (mm/day) and evaporation (mm/day) due to the expected increase of 1°C in mean air temperature in the Fuka-Matrouh area, applying the Modified Penman method to Matrouh meteorological station normals

Month	Potential evapotranspiration (mm/day)			Evaporation (mm/day)		
	Normal	Expected	Change (%)	Normal	Expected	Change (%)
January	2.01	2.26	12.44	2.32	2.54	9.48
February	2.67	2.94	10.11	3.12	3.35	7.37
March	3.57	3.85	7.84	4.15	4.42	6.51
April	4.63	4.94	6.70	5.40	5.71	5.74
May	5.27	5.57	5.69	6.36	6.64	4.40
June	6.15	6.47	5.20	7.41	7.72	4.18
July	6.40	6.71	4.84	7.77	8.05	3.60
August	5.84	6.14	5.14	7.05	7.32	3.83
September	4.99	5.24	5.01	6.00	6.21	3.50
October	3.65	3.90	6.85	4.31	4.54	5.34
November	2.54	2.77	9.06	2.98	3.18	6.71
December	2.04	2.26	10.78	2.27	2.47	8.81
Mean	4.15	4.42	7.47	4.93	5.18	5.79

3.3.3 Impact on Water Resources

Rainfall is the main source of surface and ground water. The most important climate change would be that the area of low rainfall might increase and shift northwards. The magnitude of the decrease in rainfall according to the UEA scenarios for time horizon 2030 is very low and represents only 4% of the annual average rainfall (140mm/day). This small decrease in rainfall would represent a drop of 0.56mm/year in run-off, which is insignificant. The decrease in rainfall for the time horizon 2100 might have a measurable effect on the run-off. Low rainfall also would cause reduced ground-water recharge and therefore a lesser thickness of the fresh-water layer in the ground-water aquifers in the study area. The total amount of water run-off stored in the existing cisterns would decrease and the amount of drinking water would not be sufficient for people and animals.

As shown in Table 51, potential evapotranspiration would rise by 5-12.5% if the mean temperature increases 1°C. For the time horizon 2100, evapotranspiration would rise by at least 10%. Despite an increased need for supplementary irrigation water, the average storage in the reservoirs would fall by up to 25%, owing to the decreased run-off and rainfall and the increased evapotranspiration. Reduction in the rainfall and increase in the actual evapotranspiration during the summer might cause a deficiency in soil moisture and consequently a decrease in crop production. More pumping of ground water, under conditions of low recharge due to low rainfall, would increase salinity and sea-water intrusion. Sea-level rise for the time horizons 2030 and 2100 would have a measurable impact on the ground-water aquifer through increased sea-water intrusion and would result in an advance in the brackish water front. This would be particularly intense in galleries where salination of ground water is already occurring and would appear in other wells.

3.4 NATURAL ECOSYSTEMS

The paucity of knowledge of the natural ecosystems of the area, especially in terms of a long data time-series, does not help in the synthesis of a quantitative estimation of the impact of anticipated climate change; therefore, only a qualitative estimation of the impact will be discussed.

In addition to the serious degradation of the sand dunes in the area, owing to the expanding tourist resorts and villages, the expected sea-level rise, coupled with storm surges, would adversely affect them.

The coastal lagoons at Matrouh and Ras Hawala might extend and become transformed into bays.

Owing to the expected rise in mean temperature (0.7-0.8°C by the year 2030 and 2-2.3°C by the year 2100; Guo *et al.*, 1993) and the expected decrease in annual precipitation (up to 4% by the year 2030 and up to 10% by the year 2100; Guo *et al.*, 1993), the natural flora of the hinterland may shift northwards. Owing to the expected sea-level rise, the interdunal depressions might increase and substitute a vast area of the interdunal and the alluvial plains. Consequently, the flora of the present interdunal depression might expand in these areas at the expense of the original endemic flora.

The terrestrial mammals in the area already suffer from the impact of human activities. Owing to illegal hunting, the dorcus gazelle, *Gazella dorcas*, is presumed to have become locally extinct. Increasing urbanisation also threatens the local mammals.

The expected decline in precipitation and the expected increase in temperature might lead to shrinking vegetation cover; i.e., a decrease in the food available to herbivorous mammals, in turn decreasing their population, a situation that leads to a decrease in the population of carnivorous mammals which feed on the herbivorous mammals.

The global warming might alter the migration rhythm of migratory birds which might postpone their southward wintering migration and start their northern return earlier than usual. These birds might also be affected by the changing ecosystems. For example, the wader birds, which used to feed on the bottom fauna of the shallow lagoons in Matrouh and Ras Hawala, might have to seek alternative feeding grounds, owing to the possible evolution of these shallow lagoons into rather deep bays as a result of sea-level rise.

The reptile community in the area might undergo slight changes in their behaviour as a response to the global warming. For example, the changeable agama lizard, *Agama mutabilis*, is common in the spring, up to late-May, and in autumn, from early November. In summer, they hide underground (Flower, 1933, in Kasparek, 1993). Global warming might extend the æstivation period of this reptile, which might lead to alterations in its physiological and ecological needs and, at the same time, protect it from its enemies for a longer time than usual.

Decreased precipitation and increased temperature might adversely affect the ecosystem preferred by amphibians, which are dependent on a wet substratum and vegetation.

The type and density of soil fauna depend on the plant phenology which in turn is directly or indirectly linked to the seasonality of the rainfall and its times of inception.

The available data on the marine ecosystems of the Fuka-Matrouh area are not adequate to predict the future situation attributable to climate change, nor even if there is no such change. Moreover, the possible impacts of the anticipated climate change on the marine ecosystems of the area would be consequences of the probable changes in its physico-chemical parameters. A mathematical model might assist in understanding the probability and extent of these changes. This model necessitates the establishment of a database for the area.

In the absence of such a model, however, one can only imagine that a rise in the mean sea level as well as in surface water temperature and salinity, coupled with increased spring precipitation, decreased autumn and winter precipitation and a more prolonged dry season, would all interact to increase the range of variations in the physico-chemical parameters of the area. This might lead to erosion of the coastal sand dunes, recession of the shoreline and the disappearance of the beaches in some places, which might, consequently, lead to an increase in sediment load and a decrease in the transparency of the sea water inshore, as well as to an increase in the nutrient salts inshore (due to the wash-off of land soil) and to more pronounced water stratification and oxygen depletion during warm seasons as a result of higher surface-water temperature.

The increased sediment load might lead to changes in the sea-bed profiles and to altered substrate types and changed benthic communities. Also, the dissolved-oxygen depletion during warm seasons might alter the composition of benthic communities by favouring species with higher tolerance of fluctuations in the dissolved-oxygen level.

The above-mentioned physico-chemical fluctuations might affect the primary production in the area and consequently affect secondary production and zooplankton distribution. While the increased temperature and nutrients would positively affect plant production (phytoplankton, macroalgæ and sea grasses), the decreased water transparency would negatively affect this production. On the other hand, the higher temperature might increase the probability of red tides and, over a certain limit, destroy the *Posidonia oceanica* beds (based on the physiological demand of the plant, the sea-grass beds would suffer regressive succession or would even be exterminated at temperatures over 22°C (den Hartog, 1970, in UNEP, 1992).

The higher temperature might increase the probability of the appearance of jellyfish swarms (jellyfish is the favourite food of some sea turtles) and, in addition to the higher salinity, might enable the Lessepsian immigrants (species that migrate from the Red Sea to the Mediterranean via the Suez Canal) to inhabit the area. These new immigrants could affect the Fuka-Matrouh marine community in an unpredictable way.

The sea turtles and their nesting grounds in the area are more threatened by urbanisation and fishing than they would be by the expected climate changes.

3.5 MANAGED ECOSYSTEMS

3.5.1 Agriculture

A decrease in rainfall and increases in temperature and sea level as a result of climate change would affect the cultivated crops in the area. The expected change in rainfall distribution and the increase in evapotranspiration would cause a slight shift in the agricultural zone in the area (Fig. 51). Owing to the reduction in cultivated areas, agriculture is likely to become even more intensive, with changes in crop production and yield.

A decrease in soil fertility is expected, owing to the expected increase in soil salinity. Some tropical and subtropical plant diseases would move northwards, and the distribution of insects and pests would be altered. There would be a need for new biological and/or chemical controls of pests and pathogens (Jeftic, 1992). The expected increase in mean annual evapotranspiration and decrease in rainfall would have a slight impact on natural vegetation and, consequently, range and animal production would also be affected by climate change. The present carrying capacity (Fig. 54) would be changed and a shift in range zones could be expected (Figs. 51 and 52).

3.5.2 Marine Fisheries

The impact of climate change on the commercial fish species in the study area is impossible to predict on the basis of available knowledge.

Predicted sea-level rise by the year 2030 (up to 16cm) and by the year 2100 (up to 48cm) would very probably not have an impact on commercially important fish species; the impact of temperature increase could be significant, however. A temperature increase of up to 0.9°C (by the year 2030) and up to 2.5°C (by the year 2100) would warm the sea water by at least 0.5°C and 1.5°C, respectively.

A sea-water temperature increase would very probably affect the migration of pelagic fish species, such as sardines; they might be induced to approach the coast earlier and remain longer than they now do. This would lengthen the traditional fishing season which is based on the use of nets under artificial light (on moonless nights). Their spawning area might also be changed.

It is quite probable that anticipated climate changes (temperature increase and sea-level rise) would not directly affect the demersal fish stocks before the year 2030. The extent of these changes would be insignificant, so it is quite certain that marine ecosystems would not suffer significant changes, even if fish resources were slightly changed. The biological cycle of the commercial demersal fish species is not fully known. Particularly little is known about their spawning, leaving no scope for predicting whether and to what extent the expected climate change might influence the fish stocks.

To undertake the appropriate measures, it would be necessary to obtain more information on the biology of important fish species, especially on their spawning patterns and feeding ecology. Changes in the phytoplankton population and in primary production, as well as changes in the food chain, would probably have some indirect effect.

Changes in the ecosystem expected to occur under the influence of climate change would probably have some impact on the behaviour of fish. One impact of increased water temperature might be to accelerate the spread of Lessepsian migrants from the east to the west. The presence of Lessepsian migrants in the Fuka-Matrouh area might itself affect local communities in various ways which are very difficult to define and predict. It is also difficult to assess the impact of these migrants on the fisheries. At best, they would diversify catches; at worst, they would actively compete with more desirable fish species.

3.5.3 Sponge Fisheries

Life in nearshore marine environments is mostly dependent on physico-chemical parameters, such as salinity, temperature, nutrient levels, water turbidity and bottom-substrate types. Such parameters would be affected by the predicted climate changes which are bound to influence primary productivity and the distribution of animal and plant life in nearshore coastal waters.

Kheirallah *et al.* (1989) found that the commercial sponges along the western Egyptian Mediterranean coast flourish in regions with a large surface area of rocky and consolidated substrata and high production of sea grasses and green algæ. Sea-grass meadows form extensive prairies of high productivity and support a rich community of animals, including economically important fishes, molluscs and sponges.

During bad weather in the autumn and winter, there may be significantly increased turbidity in some coastal localities, owing to increased sediment inputs. Sea-grass meadows are particularly sensitive to reduced water transparency, so that any increase in sediment inputs into the marine environment as a result of climate change could be expected to lead to changes in offshore bottom profiles as well as to altered substrate types and therefore to changes in benthic communities, including sponges.

On the other hand, a rise in water temperatures could be expected to favour sea-grass meadows, particularly those of *Posidonia*, hence also to favour sponges.

3.5.4 Aquaculture

There is considerable potential for aquaculture in coastal waters. However, there are probably several limiting factors: competition for the use of the coastal areas, limited knowledge of intensive aquaculture, lack of cheap feed for rearing fry and water pollution, which still impede the expansion of this activity.

Although different forms of aquaculture have been practised in Egypt, it is only in the last few years that research and incentives have materialised to turn aquaculture into a profitable industry. The fishes currently used in mariculture are sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*).

Sites suitable for mariculture should be selected on the basis of a thorough examination of their physical and hydrobiological properties.

The eastern lagoon of Matrouh could be used for pond culture of sea bass, sea bream and grey mullet. Other coastal wetlands in the area could also be used for such fish culture. At the same time, protected areas in Ras El-Hekma and Abu-Hashaifa bays, as well as the western lagoon of Matrouh, could be used for cage culture of sea bass and sea bream, using artificial high-protein feeds.

The expected temperature increase and sea-level rise would not significantly affect aquaculture in the Fuka-Matrouh area. However, the Egyptian Authorities have to protect the wetlands that are separated from the sea by sand dunes and a limestone ridge, since they are thought to be important breeding, resting and wintering grounds for migratory birds and are seriously threatened by current tourist development and would so be by future development of tourism in the area.

3.5.5 Summary

<u>Agriculture</u>

The expected decrease in rainfall and increase in evapotranspiration would cause a slight shift in the land area under agriculture, and these factors, together with sea-level rise, would increase soil salinity and reduce soil fertility. This would change the distribution of insects and other pests and some plant diseases would move northwards; animal ranges and production would also be affected. With the likely reduction in the cultivated area, agriculture would become even more intensive.

<u>Marine Fisheries</u>

Predicted sea-level rise up to the year 2100 would very probably not have a significant impact on the commercially important fish species in the Fuka-Matrouh area, but the increased sea-water temperature would very probably affect the commercially important fish species. Migration patterns and spawning areas of pelagic fishes could be changed. However, the expected climate changes would not directly affect the demersal fish stocks until at least the year 2030.

Changes in the ecosystem expected to occur under the influence of climate change would probably have some impact on the behaviour of fish. One impact of increased water temperature might be to accelerate the spread of Lessepsian migrants from east to west. The presence of Lessepsian migrants in the Fuka-Matrouh area might itself affect local communities in various ways, which are very difficult to define and predict from the present knowledge.

The impact of climate change on the commercially important fishes in the study area is also impossible to predict on the basis of available knowledge. The biological cycle of fish species is not fully known. It would be necessary to obtain more information, especially on the spawning patterns and feeding ecology of the commercially important fish species.

<u>Sponge Fisheries</u>

The annual Egyptian sponge harvest in 1980-1986 was more or less stable at about 5000kg. A sudden and sharp decrease in the annual catch occurred in 1987 (it fell to about 1087kg), and it declined further to 200kg in 1992.

During the last few years (1987-1992), the state of the commercial sponge beds from Alexandria to El-Sallum was very bad and remains so. The divers fishing all over the area have observed symptoms (shape and size of all the commercial sponge species) that indicate that the Egyptian sponges suffer from a fungal disease (water mould).

Water turbidity increases during bad weather in autumn and winter and since sea-grass beds are particularly sensitive to reduction in water transparency, increased sediment inputs due to the bad weather may change bottom profiles, alter substratal types and, therefore, benthic communities of animals and plants.

Aquaculture

Marine cage culture has been recently started in Egypt. Although cage culture of fish had succeeded in fresh water, in the sea it is still in the experimental stage. A number of limiting factors (competition for the use of the coastal area, limited knowledge of intensive aquaculture, lack of cheap feed for rearing, availability of the necessary fish fry and fingerlings, and water pollution) still impede the expansion of this activity in coastal waters.

The wetlands separated from the sea to the east of Matrouh city, could be used for pond culture of sea bass, sea bream and grey mullet. At the same time, protected areas in Ras El-Hekma and Abu-Hashaifa bays, as well as the western lagoon of Matrouh, could be used for cage culture of sea bass and sea bream on artificial high-protein feeds.

Overall, the expected temperature and sea-level increases would not significantly affect aquaculture in the Fuka-Matrouh area.

3.6 ENERGY AND INDUSTRY

3.6.1 Energy

Electricity generated by thermo-electric stations and diesel generators, as well as by kerosene and wind, is the main source of energy in the study area at present.

The direct and indirect impacts of the expected climate change on the area are presented only quantitatively here, owing to the lack of quantitative data. The increase in temperature, whether of 2.5°C between 1990 and 2100 or of 0.9°C between 1990 and 2030, would shorten the season of indoor heating which would spare a certain amount of energy. Ordinarily, the heating season in this area lasts from mid-October to mid-April.

A temperature rise would, however, increase the energy demand for air-conditioning in summer. Since, however, present energy demand for air-conditioning is somewhat less than that for heating, it may be assumed that the increase in air-conditioning energy demand would be considerably lower than heating-energy demand, which means that the total energy demand would be reduced, other things being equal. The increase in the tourist industry would also increase the use of electricity for air-conditioning, lighting, cooking, etc., and more energy will be required for the new industrial development.

Therefore, the total annual energy requirement would increase. Hence, other energy sources would be needed, such as solar energy, wind energy, nuclear energy, wave energy and hydro-energy. These new energy sources are recommended because they are clean; i.e., without carbon dioxide emissions, hence unlikely to contribute to global warming.

3.6.2 Industry

The industry in the study area depends mainly on the agricultural production; hence, it is all light industry. However, for future development, new heavy, medium and light industries will be established.

The increase in the temperature is not expected to have a significant effect on the operation of the present industries. It may, however, favour the consumption of soft drinks, which may, in turn, encourage their production in the study area. Sea-level change would be taken into account when constructing new factories for new industries, especially if they are established near the coastal zone.

3.7 TOURISM

The tourist industry is developing very quickly in the Fuka-Matrouh area. Many hotels and tourist villages have been constructed or are under construction. The number of tourists, especially from the Arab countries, is increasing steadily. By the year 2010, the accommodation capacity will be increased to 52,000 beds in the Matrouh area, to 22,500 beds in the Hawala/Baqqush area, and to 5000 beds in the Ras El-Hekma area.

Regarding the impact of climate change on tourism:

- A temperature rise would probably make the summer season longer. This would encourage large numbers of international or national tourists to come and stay for longer periods at the seaside because of its moderate temperature compared with those in most other parts of the country far away from the coast. The number of day-trippers, of the international tourists who come to visit Luxor and Aswan and want to enjoy the blue sea water and the white sand of the Fuka-Matrouh area, may also increase. Accordingly, a number of pressures would fall on the local population, such as the increases in water consumption and sewage disposal.

- It is generally recognised that the change in climatic conditions, and particularly the predicted sea-level rise, would not have a significant impact on the development of tourism, since it will not result in the loss of sites or land considered as suitable for tourism. This is because the majority of these sites are located on relatively high land which may be naturally protected from the maximum predicted rise (48cm) in sea level. However, it may be expected that the sea-level rise would cause the disappearance of any small, narrow, sandy beach below the new water line. A relatively serious problem would be the intrusion of salt water into ground water, and the elevation of water tables, leading to the deterioration of historical and cultural heritage sites in the area. This process will not be the product of sea-level rise alone, but it might be accelerated as a result of sea-level rise acting in conjunction with other factors in the area.

3.8 TRANSPORT AND SERVICES

The area under study is well connected to the west and the east of Egypt by highway (the international road), paved roads, a railway line, airlines and ships. Super-jet buses, ordinary buses, trains and de-luxe trains, aeroplanes, taxis and ships are all used as means of transportation.

There are no data available that would allow any quantification of the impact of climate change on transportation and related services. Therefore, only a qualitative treatment of direct and indirect impacts is possible here.

Matrouh airport would not be directly affected by the expected rise in sea level, because it is located inland far from the sea. A rise in temperature of 0.9°C and 2.5°C from 1990 to 2030 and from 1990 to 2100, respectively, would not be an important factor, although it is difficult to forecast *whether temperature and precipitation increases would cause fog or low clouds which might affect air transport.*

The railway and the international road are both well above sea level, so they would not be affected by the expected 48cm rise in the sea level in the area by 2100.

The temperature increase would necessitate a considerable financial output to air-condition all trains, buses and other means of transport. The asphalt surface of the paved roads might be melted and thus cause more accidents.

An increase in precipitation, particularly in winter, might increase the number of traffic accidents on the paved and unpaved roads and tracks.

Matrouh port is naturally protected from the sea, but its quays might need to be raised because of the sea-level rise.

3.9 SANITATION AND HEALTH ASPECTS

At present, Bedouin communities have no adequate liquid- or solid-waste disposal systems. Even the modern tourist resort areas, recently built in the study area, are using primitive sewage methods, such as septic tanks and drainage trenches. These infrastructures need to be upgraded urgently; otherwise, serious pollution events, especially those related to hygienic quality of ground and nearshore water, would certainly occur. However, a new, integrated sanitary sewerage network is now under construction in Matrouh city, but it would serve only the city and its surrounding tourist centres.

New water supplies for domestic, recreational and industrial use have to be obtained from various traditional and untraditional sources to meet the expected increase in the consumption of water due to increased ambient temperature. The demand for the water in the area is therefore expected to increase, owing to:

- *natural increase in indigenous population;*
- *improvement in the standard of living;*
- *expansion of tourism;*
- *establishment of new simple industries;*
- *establishment of more residential communities in the newly reclaimed areas; and*
- *increase in the mean water consumption per caput.*

The expected increase in temperature would speed up the rate of anærobic decomposition of the organic matter in the sewerage systems. This would lead to methane build-up in these systems and, consequently, to increased risk of explosion, if no adequate precautions were taken. Also, similar effects may occur at solid-waste disposal sites.

On the other hand, the increase in rainfall would exceed water percolation and leaching of soil, which might affect the level of pollution of ground water and coastal water.

Increased temperature would also affect the treatment of waste water in the sewage-treatment plant now under construction, with possible effects on the quality of the effluent.

Since the rate of decomposition of organic matter generally increases with the increase in temperature, a temperature rise is expected to affect the urban environment, by generally reducing the sanitation level.

The storage of food and beverages under refrigeration or freezing in households and tourist villages would become more expensive under higher temperature conditions. The storage, collection, transfer and disposal of food and organic wastes would become more tedious and costly, which means that some sanitary problems would arise and would have to be met by adequate measures, to avoid deterioration of the environment and possible health hazards.

Sea-water intrusion with a concomitant rise in the ground-water level, as a result of expected sea-level rise, would aggravate the corrosion of water supply systems and might also cause contamination in, and leakage from, the system, which could increase the risk of epidemics of enteric disorders such as typhoid. This, in particular, would be a serious problem in low-lying residential areas, especially those near the coast.

Deficient sanitation, coupled with increased temperature, might cause insect-borne diseases to become more widespread, either because the vector would be able to survive better at higher temperatures or because parasites might be able to complete their life cycle more easily.

Melanomas and non-melanotic skin disorders, due to excessive direct exposure to sunlight would be affected by climate change. Also, exposure to ultra-violet radiation might cause damage to the cornea and the lens of human eyes and increase the incidence of cataracts.

It is very difficult to predict the magnitude or the trend of these effects, since they are dependent on the climate change: the bigger the change, the greater the negative consequences.

3.10 POPULATION AND SETTLEMENTS

The changes in the climate of the Fuka-Matrouh area are expected to have only a minor impact on the vital behaviour of the local population. The time scale on which the changes are expected to occur would enable the population to adapt smoothly to them. The magnitude of the expected climate change in the Fuka-Matrouh area indicates that the area will still remain within the limits normally accepted for human habitation. The expected climate change will probably have no significant effect on the distribution of the local population, nor on its demographic structure.

By the year 2030, neither a temperature increase of 0.7-0.8°C nor a sea-level rise of 16cm would be expected to affect either the population or settlement patterns prevailing in the area. Nevertheless, by the year 2100, the indirect consequences of climate change are likely to be more important. A sea-level rise of 48cm might cause an increase in the salinity of the ground water and a rise in the water table. However, in the Fuka-Matrouh area, this would not present a serious problem for agricultural land productivity because most agricultural land is relatively high and far enough from the sea shore and so naturally protected from the expected sea-level rise.

The expected sea-level rise in the study area is bound to have an impact on the tourist villages which are directly located on the shore. An increase in temperature might lead to increased personal discomfort and alter the need for cooling units, which would increase the energy and water demand in the tourist season. On the other hand, a rise in the water table might cause sewage problems for the tourist villages. Buildings on and near the shore would be affected by sea-level rise and might increase the maintenance costs.

4. RECOMMENDATIONS

4.1 SUGGESTED ACTIONS TO AVOID OR ADAPT TO THE PREDICTED EFFECTS

4.1.1 Climate and Atmosphere

The importance of climate change lies in its potentially serious effects on the Earth, including ecosystems and human society. The current view on environmental policy is that long-term environmental goals should be based on the assessment of: ecosystem vulnerability and adaptability; the desirability and the socio-economic acceptability of corrective measures; and the feasibility of proposed measures.

To improve predictive capability, there is a need to:

- improve the systematic observation of climate-related variables such as solar radiation, evaporation and precipitation, and investigate changes that took place in the past;

- initiate and maintain integrated monitoring programmes;

- initiate and support regional, national and international research and impact-assessment programmes;

- educate resource managers and the public on the potential consequences of climate change for natural terrestrial ecosystems;

- improve our scientific understanding and prediction of critical climate factors, their impacts on natural resources and their socio-economic consequences; and

- analyse effects on key ecological indicators, ecosystems and their vulnerability.

The objectives of the proposed programme are to:

- develop and maintain a broad knowledge base for describing the state of the environment and for developing environmental forecasts in the area of climate change;

- integrate scientific knowledge of causes, distribution and effects of climate change;

- reduce scientific uncertainties about climate change and its consequences; and

- increase general awareness of the problems and improve the basis for decision-making.

4.1.2 Lithosphere

An impact-preventing approach to sea-level rise is to be preferred. The limits of such a preventive approach are governed by the level of risk set by decision-makers. The implementation of a preventive response requires:

- realistic sea-level rise scenarios and, consequently, assessment of the local extent of sea-level rise to be expected and the time-frame of its occurrence;

- determination of what a specified water level would do to the shoreline and the adjacent coastal areas beyond it; and

- assessment of the economic and social impacts of climate change and therefore of land and building values.

From the point of view of geology and geomorphology, the following proposals are made with a view to preventing, avoiding, mitigating and/or adapting to the predicted effects of future rise in sea level:

- design of coastal protection measures along vulnerable coasts;
- application of suitable stabilisation methods (using plants, wooden fences, spraying, etc) to the coastal dunes which act as barriers against sea attack;
- control of underground water exploitation to reduce the expected subsidence and salt-water intrusion in coastal areas;
- gradual landward transfer of some tourist projects presently located in vulnerable areas;
- compliance with the existing legislation, notably that requiring a distance of more than 200m between the shore and any construction;
- development of the inland areas south of the Alexandria-Sallum road; and
- application in, and adaptation to, the study area, of the up-to-date technology used in developed countries with similar climatic conditions, to mitigate the expected impacts.

The development plan for the north-western coast has to take into consideration the preparation of a coastal-area management plan, including a strategy to achieve the following aims:

- proper management of the present and future siting of development activities in the coastal area;
- stopping the encroachment of the sea on important shore areas mainly owing to interference by man-made structures;
- assessment of the effect of a higher sea level on natural processes, through the monitoring of, for example, wave climate, sediment drift, wind regime and storm frequency;
- ensuring that coastal erosion-control measures are cost efficient and socially and environmentally acceptable;
- harmonization of different development purposes in the coastal area, as, for example, tourism, swimming areas, breakwaters and fisheries; and
- determination of the costs, benefits, design and tender documents for the various coastal projects.

4.1.3 Hydrosphere

The following proposals are made with respect to the expected impact of forecast climate change:

- upgrade the awareness of decision-makers concerning the possible impacts of climate change on the whole coastal area, design plans and find means to minimise adverse impacts, and maximise possible benefits, at minimum cost;
- carry out extension programmes to upgrade the awareness of water users concerning scarcity of fresh-water resources and introduce cultural practices favouring water conservation;

- establish a long-term programme of action to manage the expected climate-change impact;

- establish monitoring stations or centres to be supervised by the NWCA (North-West Coastal Authority for Development and Rehabilitation) and scientific institutions using remote sensing and GIS techniques, and apply suitable tests to predict the impact of climate change;

- adapt a well defined scenario for land use based on expected changes in natural resources;

- select suitable drought-tolerant crops, shrubs and forage plants, so as to maximise yield and minimise adverse impacts.

4.1.4 Natural Ecosystems

The following proposals are made:

- an environmental-impact assessment has to be performed prior to any proposed activity in the area, with a view to minimising the adverse impacts of the expected climate change on the natural ecosystems;

- a considerable space should be left between the shoreline and any planned building or infrastructure in the area, so as to minimise the impacts on the coastal sand dunes and their ecosystems, and thus give the sand dunes a chance to shift landwards;

- sand dunes, which play an important role in protecting the seashore from the encroachment of the high waves, should be protected by vegetation cover, and artificial means should be adopted to enhance formation of new sand dunes, so as to minimise the adverse effect of expected sea-level rise;

- strict compliance with the laws protecting wildlife is required since, as a result of illegal hunting and the pet trade, many of the wild animals in the area will become threatened, even without climate change, which would lead to an unbalanced environment;

- wildlife in the area is already suffering from the boom in tourist-village development and urbanisation, so a number of natural protected areas should be declared, with a view to preserving certain endangered species from extinction and thus give them the chance to adapt to the expected climate change.

4.1.5 Managed Ecosystems

Agriculture, being limited mainly by the availability of suitable land and by water shortage, will have to develop to meet the growing needs of the resident and the increasing tourist populations. Climate changes expected in the coming decades, as well as other factors, will tend to reduce the availability of suitable agricultural land and of a suitable water supply; changes in rainfall and temperature patterns will force quantitative changes in agriculture.

Careful study should therefore be made of how to increase the efficiency and intensiveness of the agriculture sector, through more careful, more efficient and better adapted use of water, fertilizers, pesticides etc. and choice of crops, cattle and other animals, in the light of changing conditions and demands for agricultural products.

In the present state of our knowledge, the availability of baseline information on marine ecosystems and their environment in the Fuka-Matrouh area is, at best, incomplete and, in some cases, completely lacking. There is an urgent need to develop fully the local potential in the marine sciences, especially physical, chemical and biological oceanography.

With reference to fisheries and fish culture, the most urgent measures required are:

- investment in fishery and aquacultural research is currently inadequate and should be substantially increased, so as to provide a sound basis for fishery development;

- establishment of a fishery and fish-culture research centre in Matrouh city to ensure the optimum use of marine resources and to avoid or mitigate the negative effect of climate change on fish production;

- rearing fish in cages should be promoted, since the relevant technology is simple and does not require much space or capital, and it is suitable for individual fishermen or small fishery cooperatives in those parts of the Fuka-Matrouh area protected from wind, as well as in the western lagoon of Matrouh;

- control of all human activities that seriously damage the marine resources; and

- establishment of a proper monitoring system and the employment of appropriate measures to avoid damage to the resources arising from the negative effects of climate change on marine ecosystems.

4.1.6 Energy and Industry

The predicted effects should be taken into account in the future development of industry, which is the main energy consumer and a significant source of pollution in the study area. A reduction in emissions of carbon dioxide and other gases would be one of the measures to combat or mitigate global warming. Use of the following clean energy sources is therefore recommended:

- solar energy, given that the study area has a high number of hours of sunshine throughout the year (3500 hours on average);

- wind energy, given that the wind along the north-west coast is the highest in Egypt; and

- sea-wave energy, especially for the coastal population and for sea-water desalination.

Also, new settlements, tourist villages, beaches, new sport facilities and new development near the coast should undergo modification to adapt to sea-level rise.

4.1.7 Tourism

The climate change, and particularly sea-level rise, could be of considerable importance for the development of tourism. An increase in temperature would increase the number of national and international tourists which, in turn, would increase water and electricity consumption and increase the pressure on the sewerage system. These factors are likely to create serious problems of water shortage and increase the demand for electricity. It is necessary to be aware of their possible impact and to determine specific policies and measures that would help to avoid or mitigate the negative consequences. New networks for water distribution and for sewerage should be planned and constructed in the study area.

Tourist areas could be divided into an immediate coastal area and a wider area behind. Those in the first category would be high-capacity areas with complementary services, beaches and bathing places. These places are not, at present, under direct threat, since almost all the buildings are away from the immediate coastline. Bathing places, as well as sport and recreational areas, could, if appropriate, be nourished to minimise the effects of erosion. Tourist buildings, housing and other construction in the coastal area could, under this plan, be moved inland by applying principles of decentralised concentration, which would ensure free space of natural value between built-up settlements or tourist complexes.

4.1.8 Transport and Services

Transport would be affected by the direct impact of climate change and indirectly, as when transportation vehicles become subject to actions designed to reduce emissions of greenhouse gases.

Sea-level rise would necessitate an increase in the elevation of constructions near the seashore, especially Matrouh port structures (breakwaters, quays etc.).

Matrouh airport should be widened to handle the increase in the number of tourists and of investors in the new development. Local roads should be widened and paved to facilitate mass movement in the study area. Also, the railway line could be doubled and the speed and number of trains increased.

4.1.9 Sanitation and Health Aspects

A new sewerage system should be planned, designed and built to meet the needs of new development and the increase in the number of tourists and tourist settlements, taking into consideration the expected sea-level rise and temperature increase.

4.1.10 Population and Settlements

It is not anticipated that the expected climate change in the Fuka-Matrouh area would have any direct effect on human demography. Climate change would also not cause either large-scale movements of population or alter the general strategy for the future socio-economic development of the area. However, indirect consequences of climate change are likely to be more important. The climate change would lead to increased demand for water and energy, and would increase the maintenance costs of sewerage systems and buildings close to the shore. Certain adaptive options may have to be taken up to reduce the possible impacts of climate and sea-level change. These options can be summarised as follows:

- prevention of the establishment of new tourist villages on the seashore;
- prevention of any kind of capital investment project in the coastal area near the seashore;
- adoption of a safe elevation for drainage and sewerage systems; and
- consolidation of water- and energy-supply systems.

4.2 SUGGESTION FOR FOLLOW-UP OF THE PRESENT STUDY

4.2.1 Climate and Atmosphere

Because climate change would affect, either directly or indirectly, almost every sector of society, broad global understanding of the issue would facilitate the adoption and implementation of such response options as deemed necessary and appropriate. The following options are suggested:

- development of inventories, databases, monitoring systems, and catalogues of the resources, their use and management and their current status;
- installation of a rain-gauge network, especially for the coast, so as to facilitate study of the spatial variability of rainfall;
- a more detailed study of the long time-series of rainfall, wind, cloud cover and turbidity data;
- establishment of an appropriate monitoring system for critical pollutants, such as CO_2, CH_4, SO_2, NO_x, tropospheric ozone and ærosols; and

- research to reduce scientific and socio-economic uncertainties about climate change.

4.2.2 Lithosphere

The following follow-up options are proposed:

- construction and operation of a field station in the study area for field-data collection, surveying and data analysis;
- monitoring of sea level and land subsidence;
- long-term measurements of the dynamic forces affecting the coast;
- use of mathematical models to predict the impacts on beaches, coastal dunes and sediment balance;
- elaboration of detailed topographic maps;
- monitoring of soil conditions so as to achieve a better understanding of the effects of expected climate changes on agriculture;
- evaluation of the coastal area for different types of use;
- elaboration of an optimum coastal-protection plan;
- elaboration of an optimum coastal-area management plan; and
- preparation of detailed designs, technical specifications and tender documents for coastal-protection works.

4.2.3 Hydrosphere

Suggestions for the follow-up of the study are:

- establishment of monitoring stations and selection of representative wells and cisterns to allow the recording and follow-up of all hydrometeorological data for the Fuka-Matrouh area;
- monitoring of the water-table level as well as the quality of the ground water in the existing aquifers, and updating and upgrading of the predictive models;
- establishment of a hydrological and hydrochemical model, based on the existing data, of a representative wadi, and prediction of the hydrological and hydrochemical situation as a result of expected climate change; and
- conduct of experiments in pilot areas to simulate the expected hydrophysical and chemical conditions with respect to selected crops (drought-resistant and salt-tolerant) as a result of the increase in evapotranspiration and, consequently, in the water demand.

4.2.4 Natural Ecosystems

To overcome the scarcity of knowledge of the natural ecosystems, a monitoring programme should be started and a database of the different basic physical, chemical and biological parameters of the terrestrial and marine environments in the area should be established. These data should be fed into a geographical information system, and mathematical models should be developed.

4.2.5 Managed Ecosystems

For agriculture, the proposals for follow-up are:

- development of inventories/databases of the current agricultural resources, their use and management;

- a detailed study of the long time-series of meteorological data required by farmers and stockmen;

- establishment of an appropriate monitoring system for critical pesticides, fungicides and herbicides likely to be used in a more intensive agriculture;

- research to reduce scientific and socio-economic uncertainties about the effects of climate change on agriculture;

- monitoring of soil conditions so as to achieve a better understanding of the effects of expected climate changes on agriculture;

- conduct of experiments in pilot areas to simulate the expected hydrophysical and chemical conditions with respect to selected crops (drought-resistant and salt-tolerant) as a result of the increase in evapotranspiration and, consequently, in the water demand.

Monitoring stations should be established to follow climate change and apply suitable tests to predict its impact on:

- fish behaviour, especially the spawning pattern and feeding ecology of the economically important fish species; and

- spread of Lessepsian migrants and their effect on local communities.

4.2.6 Energy and Industry

More data on the consumption of electricity should be collected, and more studies carried out, whether for the present or a possible future situation.

It would be necessary to elaborate on the possibility of using new energy sources such as solar, wind and wave energy.

4.2.7 Tourism

The following options are suggested:

- the existing tourist villages near to the coast should be protected, either by a detached breakwater or any other protective works, in the light of the field data on the dynamic forces and sediment transport;

- more data are required on the water consumption by tourists, so as to improve prediction of water demand and hence determine the size of the sewers required, taking into consideration the sea-level rise and temperature increase.

4.2.8 Transport and Services

The following options are suggested:

- there is a need to create a database on all endangered transportation facilities; such a base would comprise all the relevant characteristics of these facilities, all the development programmes for renewal, reconstruction or adaptation;

- it is also necessary to collect all information on the past climatic conditions and especially on exceptional impacts on the transportation facilities due to such events as exceptionally high sea levels (and the conditions under which they occur), the strongest storms recorded in the open sea and in port.

4.2.9 Sanitation and Health Aspects

The following options are suggested:

- more data collection is needed on this aspect because of the present shortage of appropriate data;

- monitoring of changes in water quality and the use of appropriate water-purification methods.

4.2.10 Population and Settlements

The following options are suggested:

- identification of the buildings in tourist villages that might require protection, in the light of the available field data;

- research on the demand for water, energy and sewage treatment in the study area;

- verification and updating of demographic data.

REFERENCES

Abdallah, A.M. (1966). Stratigraphy and Structure of a Portion in the Northwestern Desert of Egypt with Reference to its Economic Potentialities. **Geol. Surv. Egypt**, Paper No. 45, 19pp.

Abdalla, R.R., Halim, Y., Gergis, W. and Assad, F.N. (1992). Phytoplankton diversity in the oligotrophic waters west of Alexandria (Egypt). **Bull. Nat. Inst. Oceanog. and Fish.** (A.R.E.), 18:73-84.

Al-Kholy, A.A. and El-Wakeel, S.K.(1975). Fisheries of the South-Eastern Mediterranean Sea along the Egyptian Coasts. Soviet-Egyptian Expedition (1970-1971). **Bull. Inst. Oceanog. and Fish.** (A.R.E.), 5:270pp.

Anon. (1959). Final Report on the Work of the Yugoslavian Fishing Boats in the Egyptian Mediterranean Waters during 1958-1959. Submitted to the Ministry of Agriculture, August 1959.

Anon. (1979a). Fisheries Investigation of the Sardine and Other Pelagic Fish along the Egyptian Mediterranean Coast from Rashid to El-Sallum. Technical Report (2/1): Physical, Chemical and Geological Investigations. National Institute of Oceanography and Fisheries, Mediterranean Branch. Academy of Scientific Research and Technology (A.R.E.). 75pp.

Anon. (1979b). Fisheries Investigation of the Sardine and Other Pelagic Fish along the Egyptian Mediterranean Coast from Rashid to El-Sallum. Technical report (2/2): Biological Investigations. National Institute of Oceanography and Fisheries, Mediterranean Branch. Academy of Scientific Research and Technology (A.R.E.).

Anon. (1982-1986). Data of the Fishing Enterprise of the Matrouh Governorate.

Anon. (1983a). Fisheries Investigation of the Sardine and Other Pelagic Fish along the Egyptian Mediterranean Coast from Rashid to El-Sallum. Final Report. Part I: Physical, Chemical and Geological Investigation. National Institute of Oceanography and Fisheries, Mediterranean Branch. Academy of Scientific Research and Technology (A.R.E.). 169pp.

Anon. (1983b). Fisheries Investigation of the Sardine and Other Pelagic Fish along the Egyptian Mediterranean Coast from Rashid to El-Sallum. Final Report. Part II: Hydrobiological Investigation. National Institute of Oceanography and Fisheries, Mediterranean Branch. Academy of Scientific Research and Technology (A.R.E.). 235pp.

Anwar, Y.M., El-Askary, M.A. and Nasr, S. (1984). Arab's Bay oolitic carbonate sediments: bathymetric, granulometric and chemical studies. **N. J. Geol. Paläont. Mh.**, 10:594-610.

Ayyad, M A. (1992). An Overview of Plant Biodiversity in the Rangelands of Mariut. Egyptian Environmental Affairs Agency (unpublished contribution to the national study of Egyptian biodiversity).

Baha El Din, M. (undated). A Biological Resource Assessment for the Egyptian Mediterranean Coast. Egyptian Environmental Affairs Agency (unpublished report).

Bartels, M. (undated). Land-use Planning for the Area of Qasr Rural Development Project. Department for Land-use Planning and Environment Monitoring, Qasr Rural Development Project. German Agency for Technical Cooperation and Egyptian Environmental Affairs Agency. 143pp.

Bretherton, F.P., Bryan, K. and Woods, J.D. (1990). Time-dependent greenhouse-gas-induced climate change. pp.173-193 in: Climate Change 1992: the Supplementary Report to the IPCC Scientific Assessment. (J.T. Houghton, B.A Callander and S.K. Varney, eds.) Cambridge University Press. pp.173-193.

CAPMAS (1976). Population Census. Central Agency for Public Mobilization and Statistics (A.R.E.).

CAPMAS (1980-1991). Statistical Yearbook. Central Agency for Public Mobilization and Statistics (A.R.E.).

CAPMAS (1986). Population Census. Central Agency for Public Mobilization and Statistics (A.R.E.).

Climatic Research Unit (1992). A Scientific Description of the ESCAPE Model. Climatic Research Unit, University of East Anglia, Norwich, UK. 126pp. (plus Appendices)

Climatic Research Unit (1993). Temperature and Precipitation Scenarios for Northern Egypt. School of Environmental Sciences, University of East Anglia, Norwich, UK. Report to the UNEP Co-ordinating Unit for the Mediterranean Action Plan.

Danish International Development Agency (1991). Master-plan for Coast Protection of the North-West and North Sinai. Copenhagen, Denmark.

Delft Hydraulics (1992). Vulnerability Assessment to Accelerated Sea-Level Rise. Case Study: Egypt. Final Report, Coastal Research Institute. Alexandria, Egypt.

ELACO (1976). Regional Plan for the Coastal Zone of the Western Desert. Vol. I: Main Report and Annex 4. Water and Land Resources, Ministry of Development, Cairo, A.R.E.

El-Beshbeeshy, M. (1983). Survey and Ecological Studies of the Sponges West of Alexandria. M. Sc. Thesis, Faculty of Sciences, Alexandria University, Egypt.

El-Fishawi, N.M. (1977). Sedimentology Studies of the Present Nile Delta Sediments on Some Accretional and Erosional Areas between Burullus and Gamasa. M.Sc. Thesis, Faculty of Sciences, Alexandria University, Egypt. 143pp.

El-Fishawi, N.M. (1993). Recent Sea Level Changes and Their Implications along the Nile Delta Coast. IV:3-11 in: International Workshop on Sea Level Changes and Their Consequences for Hydrology and Water Management. 19-23 April 1993, The Netherlands.

El-Fishawi, N.M. and Fanos, A.M. (1989). Prediction of sea level rise by 2100, Nile delta coast. **Int. Union Quat. Res.**, 11:43-47. INQUA, Spain.

El-Fishawi, N.M. and Khafagy, A.A. (1991). Sea level characteristics along the Nile delta coast. **Int. Union Quat. Res.**, 13:29-37. INQUA, Spain.

Ellis, F.P., Smith, F.E. and Waiters, J.D. (1972). Measurement of environmental warmth in SI units. **J. Ind. Med.**, 29:361-377.

El-Miniawy, H., Mark, F. and Tabeh, D. (1992). Qasr Rural Development Plan: Summary of Final Report, May 1992.

El-Shazly, E.M., Abdel-Hady, M.A., El-Ghawaby, M.A., El-Kassas, I.A., Khawasik, S.M., El-Shazly, M.M. and Sanad, S. (1975). *Geologic Interpretation of Landsat-Satellite Images from West Nile Delta Area, Egypt.* Academy of Scientific Research and Technology, Cairo. 38pp.

Emara, H.I. (1969). Distribution of Oxygen, Nutrient Salts and Organic Matter in the Mediterranean Sea off the Egyptian Coast. M.Sc. Thesis. Alexandria University, Egypt.

Emara, H.I., Halim, Y. and Morcos, S.A. (1973). Oxygen, phosphate and oxidizable organic matter in the Mediterranean water along the Egyptian coast. **Rapp. Comm. Int. Mer. Medit.**, 21(7):345-347.

EPA (1983). Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2100 and Research Needs. US Environmental Protection Agency, Washington, D.C. 121pp.

Ezzat, A.A., Wadie, W.F., Mikhail, M.Y. and Hashem, M.T. (1981). Age and growth of *Epinephelus æneus* in Egyptian Mediterranean waters. **Bull. Inst. Oceanog. and Fish.** (A.R.E.), 7(3).

Fairbridge, R.W. (1961). Eustatic Changes in Sea Level: Physics and Chemistry of the Earth. Pergamon Press, London, 4:99-185.

Faltas, S.N. (1993). Studies on the Fishery Biology of Lizardfish (Family *Synodontidæ*) in the Egyptian Mediterranean Waters. Ph.D. Thesis, Faculty of Sciences, Alexandria University, Egypt.

FAO (1970). Preinvestment Survey of the Northwestern Coastal Region, UAR. Technical Report. FAO, Rome.

Farag, M.F. (1981). Studies on Macrobenthos along the Mediterranean Coast West of Alexandria. M.Sc. Thesis. Mansoura University.

GAARD (1983-1992). Annual Statistical Reports. General Authority for Aquatic Resource Development, Egypt.

Garnier, B.J. (1992). Compendium of Lecture Notes in Climatology for Class III and Class IV Personnel. WMO. No. 726. World Meteorological Organization, Geneva.

Gates, W.L., Mitchell, J.F.B., Boer, G.J., Cubasch, U. and Meleshko, V.P. (1992). Climate modelling, climate prediction and model validation. pp.97-134 in: Climate Change 1992: Supplementary Report to the IPCC Scientific Assessment. (J.T. Houghton, B.A. Callander and S.K. Varney, eds.). Cambridge University Press.

Gerges, M.A. (1976). Preliminary results of the numerical model of circulation using the density field in the eastern Mediterranean. pp.163-176 in: Symposium on the Eastern Mediterranean Sea. 11-15 September 1973, Malta. International Biological Programme, UNESCO, Paris.

Ghabbour, S.I., Mikhail, W.Z.A. and Rizk, M.A. (1977). Ecology of soil fauna of Mediterranean desert ecosystem in Egypt. I: Summer populations of soil mesofauna associated with major shrubs in the littoral sand dunes. **Rev. Ecol. Biol. Sol.**, 14(3):429-459.

Ghabbour, S.I., Canala da Fonseca, J.P. and Mikhail, W.Z.A. (1984). The characterization of soil mesofauna at the Omayed biotope "the Maruit area, Egypt". **Bull. Soc. Bot. Fr., Actual. Bot.**, 131:329-339.

Goodman, S.M. and Meininger, P.L. (eds.) (1989). The Birds of Egypt. Oxford and New York. 551pp.

Guo, X., Palutikof, J.P. and Wigley, T.M.L. (1993). Temperature and Precipitation Scenarios for the Northeastern Mediterranean. School of Environmental Sciences, University of East Anglia, Norwich, UK. Report to the UNEP Co-ordinating Unit for the Mediterranean Action Plan. 18pp.

Hashem, M.T. (1990). Development of Coastal Fishery in "El-Qasr" Coastal Zone. Final Report for the Qasr Rural Development Project (Egyptian-German co-operation, Matrouh Governorate).

Hassan, A.A., Ibrahim, A.A. and Mehanna, A.E. (ms, 1991). Statistical Analysis of Rainfall over North Egypt for Detection of Trends. (not published)

Hassouba, A H (1980). Quaternary Sediments from the Coastal Plain of Northwestern Egypt. Ph.D. thesis, Imperial College, London. 320pp.

Hilmy, M.E. (1951). Beach sands of the Mediterranean coast of Egypt. **J. Sed. Pet.**, 21:109-120.

Ingle, J.C. 1966. The Movement of Beach Sand. Elsevier Publishing Company. 221pp.

Institute of Coastal Research (1993). Short-term Studies and Proposed Measures for Improving Nearshore Coastal Zone Conditions along Marakia Touristic Village. Technical Report, Institute of Coastal Research, Alexandria. 25pp.

IPCC (1990). Climate Change: IPCC Scientific Assessment. Intergovernmental Panel on Climate Change/WG 1. (J. Houghton, G. Jenkins and J. Ephraums, eds.). Cambridge University Press, Cambridge, UK.

IUCN (1990). 1990 IUCN Red List of Threatened Animals. IUCN Red Data Book, World Conservation Monitoring Centre (WCMC), UK.

Jeftic, L. (1992). Implications of Expected Climate Change in the Mediterranean Region.

Jeftic, L., Milliman, J.D., and Sestini, G. (1992). Climatic Change and the Mediterranean. Edward Arnold, a division of Hodder and Stoughton. 673pp.

Kasparek, M. (1993). Marine Turtles Conservation in the Mediterranean: Marine Turtles in Egypt. Phase I: Survey of the Mediterranean Coast of Egypt between Alexandria and El-Sallum. SPA/RAC-MEDASSET. National Institute of Oceanography and Fisheries, Alexandria.

Kheirallah, A.M., Badawi, H.K. and El-Beshbeeshy (1989). Ecological studies on commercial sponges west of Alexandria. **Bull. Nat. Inst. Oceanog. and Fish.** (A.R.E.), 15(2).

Kim, J.M., Chang, J.T., Baker, N.L., Wilks, D.S. and Gates, W.L. (1984). The statistical problem of climate inversion: determination of the relationship between local and large-scale climate. **Monthly Weather Review**, 112:2069-2077.

Komar, P.D. (1990). Littoral sediment transport. pp.681-715 in: Handbook of Coastal and Ocean Engineering. (J.B. Herbich, ed.), Vol. 2, Chapter 11.

Land Master Plan (1986). Final Report. Code 5.09.077. Arnhem, The Netherlands.

Leggett, J., Pepper, W.J. and Swart, R.J. (1992). Emission scenarios for IPCC: an update. pp.69-96 in. Climate Change 1992: Supplementary Report to the IPCC Scientific Assessment. (J.T. Houghton, B.A. Callander and S.K. Varney, eds.). Cambridge University Press, Cambridge, UK.

Lewin, K.L. (1975). Areal Investigation Survey of the North-western Coastal Region of the UAR. A preliminary administrative report of FAO. Alexandria, Egypt.

Manohar, M. (1976). Dynamic factors affecting the Nile delta coast. pp.104-129 in: Proceedings of a Seminar on Nile Delta Sedimentology. UNESCO, Alexandria.

Marx, H. (1968). Checklist of the Reptiles and Amphibians of Egypt. US Naval Medical Research Unit (NAMRU), Special publication, No. 3. Cairo.

Mehanna, A.E. (ms., 1992): Agroclimatology of Northwestern Coast of Egypt. M.Sc Thesis. (not published)

Mercado, A. (1989). On the impact of changed water depth (sea level rise) on storm surge and storm wave modelling for island and continental shelf locations. pp.119-124 in: Implications of Climatic Changes in the Wider Caribbean Region. (G. Maul, ed.).

Mikhail, M.Y. (1980). Some Biological Studies on *Epinephelus* Species in the Egyptian Mediterranean Waters. M.Sc. Thesis, Faculty of Sciences, Alexandria University, Egypt.

Mitchell, J.F.B, Manabe, S., Tokioka, T. and Meleshko, V. (1990). Equilibrium climate change - and its implications for the future. pp.131-172 in: Climate Change: the IPCC Scientific Assessment. (J.T. Houghton, G.J. Jenkins and J.J. Ephraums, eds.). Cambridge University Press, Cambridge, UK.

Mokable, M. (1978). Soil Thermal Regime of El-Omayed and El-Gharbarneat Area. M.Sc. Thesis. Alexandria University, Egypt.

Osborn, D.J. and Helmy, I. (1980). The contemporary land mammals of Egypt (including Sinai). **Fieldiana Zoology**, New Series, 5:1-579.

Pacer/Egypteam Consultants (1986a). Development Plan of North West Coast km100-268. New Communities and Land Reclamation, Ministry of Development. Final Report 1986.

Pacer/Egypteam Consultants (1986b): Development Plan of North West Coast km100-268. New Communities and Land Reclamation, Ministry of Development. Annex No.12: Infrastructure.

Pacer/Egypteam Consultants (1986c). Development Plan of North West Coast km100-268. New Communities and Land Reclamation, Ministry of Development. Annex No.8: Tourism.

Pacer/Egypteam Consultants (1986d). Development Plan of North West Coast km100-268. New Communities and Land Reclamation, Ministry of Development. Annex No.7: Industry.

Paget, C. W. (1921-1923). Reports on the Fisheries of Egypt for the Year 1920-1922. Government Press, Cairo. (3 volumes).

Palutikof, J.P., Guo, X., Wigley, T.M.L. and Gregory, J.M. (1992). Regional Changes in Climate in the Mediterranean Basin due to Global Greenhouse Gas Warming. MAP Technical Reports Series No.66., UNEP, Athens.

Pennekamp, H.A., Hoozemans, F.M. and Morchand, M. (1992). Sea Level Rise. A Global Vulnerability Assessment: Vulnerability Assessment for Population, Coastal Wetlands and Rice Production on a Global Scale. Delft Hydraulics, Delft, The Netherlands.

Pirazzoli, P A. (1989). Present and near-future global sea level changes. **Global Planetary Change**, 1:241-258.

Rafail, S.Z., Daoud, W.L. and Hilal, M.M. (1969). Long-Line Mediterranean Fisheries Studies, West of Alexandria. **Gen. Fish. Counc. Medit., Stud. Rev.** No. 42.

Ramadan, H.M. (1992). Land Variability and Evaluation of Dabbaa-Fuka Area, Northwestern Coast, Egypt. Ph.D. Thesis, College of Agriculture, Alexandria University. 177pp.

Ramadan, Sh.E. (1977). Personal communication.

Ramadan, M.M., Kheirallah, A.M., Badawi, H.K. and El-Beshbeeshy, M.M. (1989). A new record of sponges from the Egyptian Mediterranean waters. **Bull. Inst. Oceanog. and Fish.** (A.R.E.), 15(20):47-61.

Said, R. C. (1962). The Geology of Egypt. Elsevier Publishing Company. 377pp.

Selim, A. (1974). Origin and lithification of the Pleistocene carbonates of the Sallum area, western coastal plain of Egypt. **J. Sed. Pet.**, 44:70-78.

Sham, S. (1977): An index of comfort for Kuala Lumpur-Petaling Jaya and its environs. **Sains Malaysiana**, 6(1):65-83.

Shukri, N.M.. Phillip, G. and Said, R. (1955): The geology of the Mediterranean coast between Rosetta and Bardia. Part II: Pleistocene sediments: geomorphology and microfacies. **Bull. Inst. Egypt**, 37:395-444.

Sokolov, A.A. and Chapman, T.G. (1974). Hydrological Investigation of the North-western Coast of Egypt. Report of a consultation held at FAO, Rome. **World Soil Resources**, Series No. 49.

Stanley, D.J. (1988): Subsidence in the northern Nile delta: rapid rates, possible causes and consequences. **Science,** 240:497-500.

Matrouh Government (1992): Beaches of Dreams, Matrouh. A Report by the Tourist Department, Matrouh Government (Tourist Guide).

UNEP (1989). Implications of Expected Climate Changes in the Mediterranean Region: An Overview. MAP Technical Reports Series, No. 27. UNEP, Athens.

UNEP (1994a). Implications of Expected Climatic Changes on the Island of Rhodes. Document UNEP(OCA)/MED WG.55/2 Rev. UNEP, Athens.

UNEP (1994b). Implications of Expected Climatic Changes on Kastela Bay. Document UNEP(OCA)/-MED WG.55/4 Rev. UNEP, Athens.

UNEP (1994c). Implications of Expected Climatic Changes on the Syrian Coast. Document UNEP(OCA)/MED WG.55/6 Rev. UNEP, Athens.

UNEP (1994d). Implications of Expected Climatic Changes on Malta. Document UNEP(OCA)/MED WG.55/3 Rev. UNEP, Athens.

UNEP (1994e). Implications of Expected Climatic Changes on Cres-Losinj Islands. Document UNEP(OCA)/MED WG.55/5 Rev. UNEP, Athens.

UNEP/GEMS (1993). The Impact of Climate Change. Environment Library No. 10

Wadie, W.F., Hashem, M.T., Mikhail, M.Y. and Ezzat, A.A. (1981). Age and growth of *Epinephelus alexandrinus* in the Egyptian Mediterranean waters. **Bull. Inst. Oceanog. and Fish.**, (A.R.E.) 7(3).

Ward, C.A. (1975). Reconnaissance Hydrogeological Investigation in Arid Zone. Report of H.M. Stationery Office, London.

Wigley, T.M.L. and Raper, S.C.B. (1992). Implications for climate and sea level of revised IPCC emissions scenarios. **Nature**, 357:293-300.

Wigley, T.M.L., Jones, P.D., Briffa, K.R. and Smith, G. (1990). Obtaining sub-grid-scale information from coarse-resolution General Circulation Model output. **J. Geophys. Res.,** 95(D2):1943-1953.

Wilks, D.S. (1989). Statistical specification of local surface weather elements from large-scale information. **Theor. and Appl. Climatol.**, 40:119-134.

Wobber, F J. (1967). Space photography: a new tool for the sedimentologist. **Sedimentology**, 9:265-317.

Youssef, S.F. (1980-1985). The Inshore Fisheries of El-Sallum and Matrouh Regions: Experimental Fishing. Ph.D. degree (personal communication).

ANNEX I

MEMBERS OF THE TASK TEAM

A. NATIONAL MEMBERS

Prof. A.A. Khafagy (Tast Team Co-ordinator)
Director, Coastal Research Institute (CRI)
15 El-Pharaana Street, El-Shallalat — Tel: 203-482 1208
Alexandria, 21514 — Tfx: 203-482 9582

Prof. A.M. Fanos (Energy, Industry, Tourism, Transport, Sanitation)
Deputy Director, Coastal Research Institute (CRI)
15 El-Pharaana Street, El-Shallalat — Tel: 203-482 1208
Alexandria, 21514 — Tfx: 203-482 9592

Prof. M.T. Hashem (Fisheries, Aquaculture)
National Institute of Oceanography and Fisheries
Kayet Bey — Tel: 203-807 140
Alexandria — Tfx: 203-801 174

Prof. A.M. Fathi (Hydrosphere, Agriculture, Sylviculture)
Professor of Soil Physics and Water Management
Faculty of Agriculture — Tel: 203-597 5405
University of Alexandria — Tel: 203-577 1863
Alexandria — Tfx: 203-597 2780

Dr. A.E. Mehanna (Climatic Conditions, Atmosphere)
General Director of Research — Tel: 203-284 9858
Meteorological Authority — Tfx: 203-284 9589
Kobry el-Quobba 11784 — Tfx: 203-284 9857

Prof. G.A. El-Mallah (Population and Settlements)
Professor of Agricultural Economics
Faculty of Agriculture
University of Alexandria — Tel: 203-597 5405
Alexandria — Tfx: 203-597 2780

Prof. N.M. El-Fishawi (Geology)
Professor, Coastal Research Institute (CRI)
15 El-Pharaana Street, El-Shallalat — Tel: 203-482 1208
Alexandria, 21514 — Tfx: 203-482 9582

Prof. S.E. Ramadan (Natural Ecosystems)
National Institute of Oceanography and Fisheries
Kayet Bey — Tel: 203-807 140
Alexandria — Tfx: 203-801 174

Mr. T.A. Ghaffar (Data Collection)
North West Coastal Authority for Development
and Rehabilitation — Tel: 203-933 861
Matrouh — Tfx: 203-935 153

Mr. M.A. Mutaleb (Data Collection)
North West Coastal Authority for Development
and Rehabilitation
Matrouh
Tel: 203-933 861
Tfx: 203-935 153

B. INTERNATIONAL MEMBERS

Mr. L. Jeftic
Deputy Coordinator
Coordinating Unit for the Mediterranean Action Plan
L. Vassileos Konstantinou, 48
Athens 11635
Greece
Tel: 30-1-7 253 190-5
Tfx: 30-1-7 253 196-7

Mr. S. Keckes
21 Lodovici Brunetti
Borik
Rovinj
Croatia 52210
Tel: 385-52-811 543
Tfx: 385-52-811 543

ANNEX II

TEMPERATURE AND PRECIPITATION SCENARIOS FOR NORTHERN EGYPT

1. Introduction

Climate models, and those based on general circulation models (GCMs) in particular, are mathematical formulations of atmosphere, ocean and land surface processes based on classical physical principles. They represent a unique and potentially powerful tool for studying climate changes that may result from increased concentrations of CO_2 and other greenhouse gases in the atmosphere. Such models are the only available means of considering simultaneously the wide range of interacting physical processes that characterise the climate system, and their objective numerical solution provides an opportunity to examine the nature of past and possible future climates under a variety of conditions.

2. The Use of GCMs in Regional Scenario Development

It is generally accepted that the results from GCMs offer the best potential for the development of regional climate scenarios, since such results are the only source of detailed information from which future climate configurations can be extrapolated beyond the limits that have prevailed in the past.

GCMs are complex, computer-based models of the atmospheric circulation which have been developed by climatologists from numerical meteorological forecasting models. The standard approach is to run the model with a nominal "pre-industrial" atmospheric CO_2 concentration (the control run) and then to re-run the model with doubled, or sometimes quadrupled, CO_2 concentration (the perturbed run). In both, the models are allowed to reach equilibrium before the results are recorded. This type of model application is therefore known as an equilibrium-response prediction.

The fact that the GCMs are run in equilibrium mode must in itself be regarded as a potential source of inaccuracy in model predictions. It can be argued that the predicted regional patterns of climate change will differ from those that will occur in a real, transient-response world. Results are becoming available from transient-response predictions, where the CO_2 concentration increases gradually throughout the perturbed run and where the oceans are modelled using ocean GCMs, and which therefore should provide a more realistic estimate (Gates *et al.*, 1992). These indicate that the large-scale patterns of change are similar to those obtained from comparable equilibrium experiments, scaled down by an appropriate factor. Differences do exist, largely because equilibrium-model runs ignore important oceanic processes such as ocean current changes, differential thermal inertia effects between different parts of the oceans and between land and ocean, and changes in the oceanic thermohaline circulation. These differences are greatest in areas where the ocean thermal inertia is large, such as the North Atlantic and high southern latitudes (Mitchell *et al.*, 1990). They are relatively small in most regions (and in the Mediterranean basin in particular).

The present study is therefore restricted to the use of results from equilibrium-GCM experiments. The results from four GCMs developed for climate studies have been used to develop the scenarios used in this report. They are from the following research institutions:

UK Meteorological Office (UKMO);
Goddard Institute of Space Studies (GISS);
Geophysical Fluid Dynamics Laboratory (GFDL); and
Oregon State University (OSU).

The models vary in the way in which they handle the physical equations describing atmospheric behaviour UKMO, GISS and OSU solve these in grid-point form, whereas GFDL uses a spectral method. All models have a realistic land/ocean distribution and orography (within the constraints of model resolution); all have predicted sea, ice and snow; and clouds are calculated in each atmospheric layer in all models.

One problem with the application of GCMs to the study of climate impacts is the coarse resolution of the model grid. The grid scale of the four models listed above ranges from 4° latitude x 5° longitude (OSU) to 7.83° latitude x 10° longitude (GISS). GCMs therefore have a spatial resolution of several hundreds of kilometres, which is inadequate for regional climate-change studies, especially in areas of high relief. We present here a set of high-resolution scenarios for northern Egypt, based on the statistical relationship between grid-point GCM data and observations from surface meteorological stations.

3. Construction of Sub-grid-scale Scenarios

Kim *et al.* (1984) looked at the statistical relationship between local and large-scale regionally averaged values of two meteorological variables: temperature and precipitation. They then used these relationships, developed using principal-component analysis techniques, to look at the response of local temperature and precipitation to the predicted change at GCM grid points. The area of study was Oregon State. Although the paper contains certain statistical flaws, the underlying ideas of relating local and large-scale data statistically is sound. The methods of Kim *et al.* (1984) have been extended and refined by Wilks (1989) and Wigley *et al.* (1990).

The methods of Kim *et al.* (1984) and Wigley *et al.* (1990) have been modified for application in the Mediterranean region. In the model-validation exercise carried out for the Mediterranean region by Palutikof *et al.* (1992), it was established that no single GCM can be identified as being always the best at simulating current climate. This being the case, there is little merit in presenting scenarios based on only one model. Presentation of scenarios for each of the four models avoids the issue, since the task of deciding which model is "best", and/or of synthesising the information to obtain a best estimate, is left to the impact analyst. We have therefore combined the information from the four models into a single scenario for each variable, according to the method described below.

The problem with scenario construction based on a number of models is that the results may be biased by the different equilibrium responses of the individual models. The global warming due to 2 x CO_2 for the four GCMs ranges between 2.8°C for the OSU model and 5.2°C for the UKMO model run. We should therefore expect that the warming indicated by the UKMO GCM for the Mediterranean basin will be greater than that suggested by the OSU model, even though the sensitivity of the region to climate change when compared to the global sensitivity might be the same. The individual model perturbations have therefore been standardised by the equilibrium (global annual) temperature change for that model, prior to the calculation of the four-model average.

A generalised computer programme was needed that would be applicable throughout this geographically complex area, and that could be used with meteorological records of variable length and density. After investigating a number of approaches to the problem, we adopted the procedure summarised below (Palutikof, *et al.*, 1992).

a. Data sets of monthly mean temperature and total precipitation have been compiled for the area surrounding the Mediterranean basin. Stations used in this study of northern Egypt are listed in the Appendix to this Annex. Where possible, each record should be complete for the period 1951-88. Any station with a record length less than 20 years in the period 1951-88 for over six months out of twelve was immediately discarded.

b. Then, for every valid station, the temperature and precipitation anomalies from the long-term (1951-88) mean were calculated. For this part of the work, which is the first step in the construction of the regression equations (the calibration stage), only the data for 1951-80 were used. The 1981-88 data were retained to test the performance of the regression models (the verification stage, see Palutikof *et al.*, 1992). For the calculation of the mean monthly temperature anomaly $\mathbf{At_{ij}}$, the simple difference was used:
$At_{ij} = t_{ij} - T_j$

where $\mathbf{t_{ij}}$ is the mean temperature of month **j** in year **i**, and $\mathbf{T_j}$ is the long-term mean for month **j**. The precipitation anomaly $\mathbf{Ap_{ij}}$ was expressed as the ratio of the mean monthly anomaly to the long-term mean.

$$Ap_{ij} = (P_{ij} - P_j) / P_j$$

where P_{ij} is the monthly total precipitation in month **j** of year **i**, and P_j is the long-term mean for that month. If P_j is less than 1mm, this equation is modified to:
$Ap_{ij} = (P_{ij} - P_j) / 1$

c. The individual station anomalies are used to calculate regionally averaged anomalies. The procedures described from here to the end of point **f** are station-specific, and must be repeated for each station in the data set. A 5° latitude x 5° longitude square is centred over the station for which regression equations are to be developed (the predicted station). All the stations that fall within this square are used to calculate the regional averages. If the number of stations is less than three, for temperature, or four, for precipitation, the procedure is halted. For temperature, the anomalies from all stations in the 5° x 5° square are averaged month by month to produce an area-average time-series. For precipitation, the substantial degree of spatial variability makes it advisable to area-weight the station anomalies before calculating the regional mean for each month. To do this, the 5° x 5° region is divided into 20 x 20 smaller squares. The precipitation anomaly value assigned to a particular square is that of the station nearest to it (with the restriction that the distance separating a square from its nearest station should be no greater than 1°; where the distance is greater, the square is ignored). The area average is then the mean of the values in the 400 (or fewer, if any fail the minimum-distance criterion) squares. This method is similar to the standard Thiessen polygon method.

d. Regression analyses were performed using station temperature and precipitation anomalies as the predictands. These analyses were carried out on an annual and seasonal basis: winter (December - February), spring (March - May), summer (June - August) and autumn (September - November). By considering the monthly values as separate observations within each season, we were able to extend the number of observations and so preserve a high number of degrees of freedom. The predictor variables are the regionally averaged anomalies of temperature and precipitation.

e. To determine the perturbation due to the greenhouse effect at each station, the results from GCMs were employed. It was assumed that a GCM grid-point temperature or precipitation value is equivalent to a regionally averaged value derived from observational data. For each of the four GCMs (GFDL, GISS, OSU and UKMO), the perturbed run and control run grid-point temperature (**t**) and precipitation (**p**) values are interpolated to the station position. Then, we obtain, for temperature:

$$Atm_i = t_i(2 \times CO_2) - t_i(1 \times CO_2)$$

where **Atm** is the perturbation due to CO_2 or the "temperature anomaly" for model **i** and, for precipitation:

$$Ptm_i = [P_i(2 \times CO_2) - P_i(1 \times CO_2)] \times 100/P_i(1 \times CO_2)$$

where **Ptm** is the standardised perturbation due to CO_2 or the "precipitation anomaly".

The values for **Atm** and **Ptm** for each GCM are then substituted in the regression equations to obtain a prediction for the station perturbation of temperature (°C) and precipitation (percent) due to CO_2.

f. The predicted change in temperature and precipitation for each model is divided by the equilibrium (global mean) temperature change for that model. The results are then averaged across the four models to obtain a composite value.

g. The procedures from points **c** to **f** are repeated for each station throughout the Mediterranean. The results can then be plotted and contoured to obtain a map of the expected patterns of temperature and precipitation change due to the greenhouse effect.

To arrive at this procedure, a rigorous investigation of the validity of the method was carried out. In particular, we looked at:

- the use of other predictor variables in the regression equation;
- performance and verification of the regression equations;
- autocorrelation in the data; and
- multi-colinearity in the predictor variables.

These aspects are discussed in detail by Palutikof *et al.* (1992).

4. Climate-Change Scenarios for Northern Egypt

The sub-grid-scale scenarios, constructed according to the method outlined in section 3, are shown in Figs. 1-5. The temperature perturbations are presented as the model average change, in degrees Celsius, per °C global annual change. The precipitation perturbations are shown as the percentage change for each 1°C global annual change. This procedure is described in greater detail, and the approach justified, in section 3.

The scenarios are presented as the regional change in a particular climate variable to be expected in response to a 1°C change in mean global temperature. As such, they do not provide any information on when such changes might be expected to occur. However, such information can be extracted from scenarios presented in this form. The results from four transient-response GCMs presented in IPCC 92 (Gates *et al.*, 1992) show a constant rate of warming in recent decades, of around 0.3°C per decade. This is in line with the findings of IPCC 90, based on the "business-as-usual" CO_2-forcing scenario and an energy-balance atmospheric model coupled to an upwelling-diffusion ocean model (Bretherton *et al.*, 1990). Although the impossibility of placing calendar dates on this figure must be emphasised, it suggests that a 1°C change in mean global temperature may be achieved in a period of around thirty years.

It should be noted that the figure of 0.3°C per decade does not take into account possible opposing human influences, in particular the forcing from sulphate ærosols and stratospheric ozone depletion. Wigley and Raper (1992) made temperature projections based on IPCC 92 emission scenario IS92a (Leggett *et al.*, 1992), taking into account the ozone-depletion feedback and best-guess sulphate ærosol effects. They used their upwelling-diffusion energy-balance climate model (as used in IPCC 90, see above) and found the warming between 1990 and 2100 to be in the range 1.7-3.8°C.

The results from these time-dependent experiments can be combined with the scenarios of the magnitude of change presented in this report, and superimposed on a baseline (present day) climatology to arrive at a climate scenario for a particular future time. A recent example of the application of this approach to the development of "snapshot" scenarios for Europe is the ESCAPE project (Climatic Research Unit, 1992). This approach requires that the spatial pattern of the enhanced greenhouse signal remain constant with time, but the available model evidence suggests that this is a reasonable assumption to make (Mitchell *et al.*, 1990; Gates *et al.*, 1992).

Annual Scenarios for Climate Change

The scenarios for changes at the annual level are shown in Figure 1. The temperature change along the coast west of Alexandria (the region of interest) is indicated to be less than the global change; i.e., in the range 0.7-0.8°C per °C global change. The scenario for precipitation indicates drier conditions at the annual level, with a change in rainfall in the range of 4% to 0% per °C global warming.

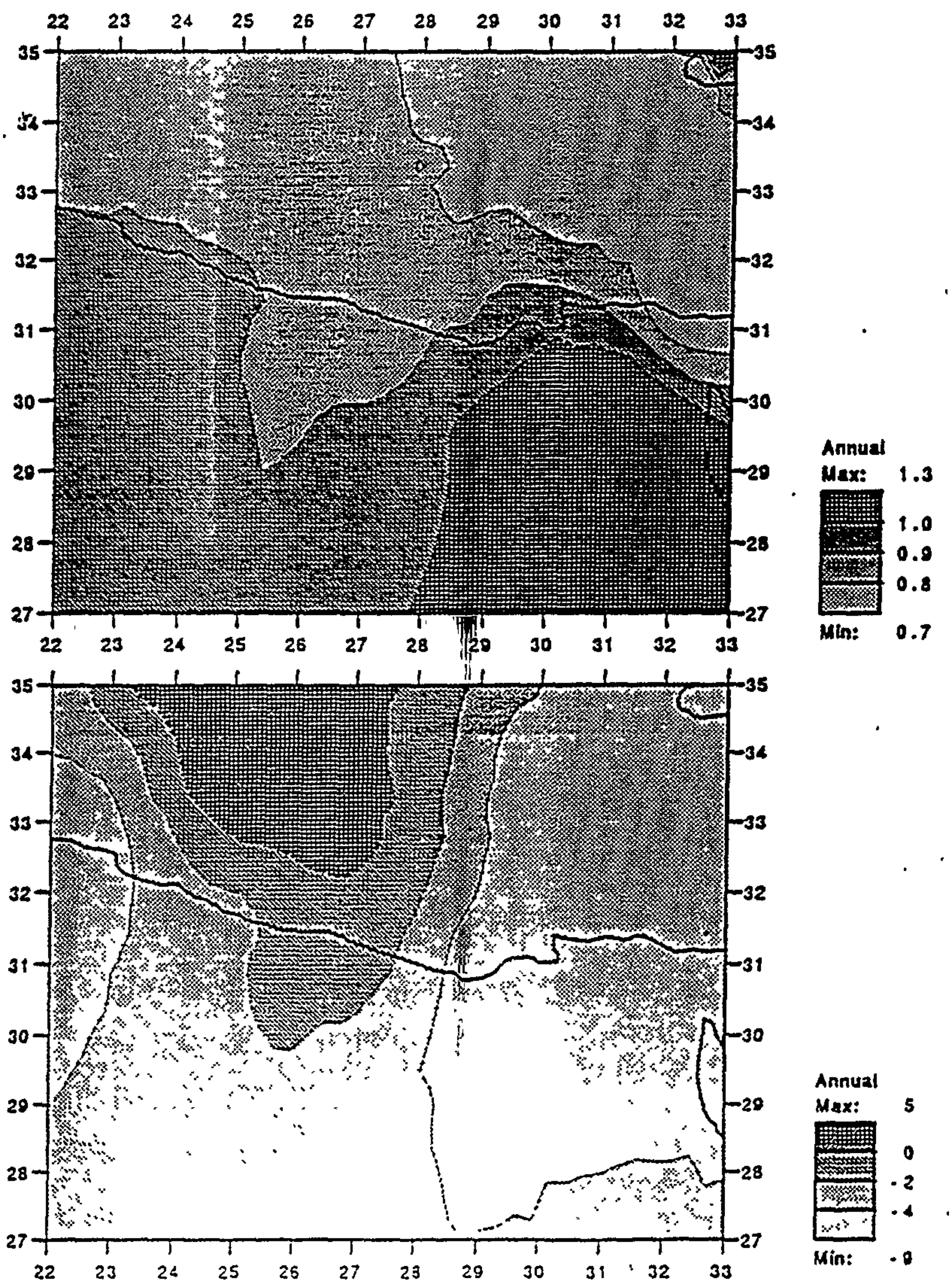


Figure 1 - Regional climate scenarios for northern Egypt: annual. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (percent per °C global change)

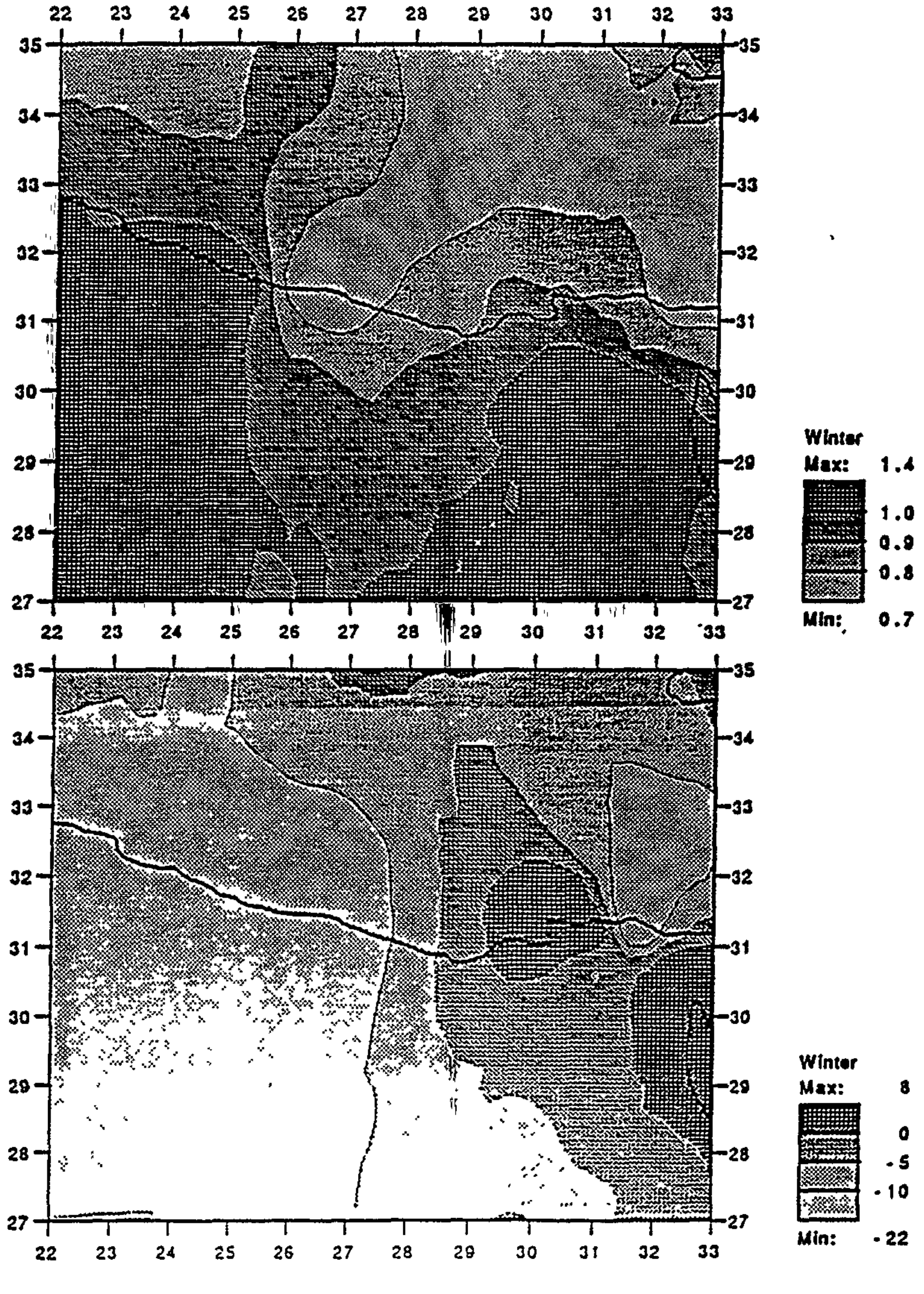


Figure 2 - Regional climate scenarios for northern Egypt: winter. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (percent per °C global change)

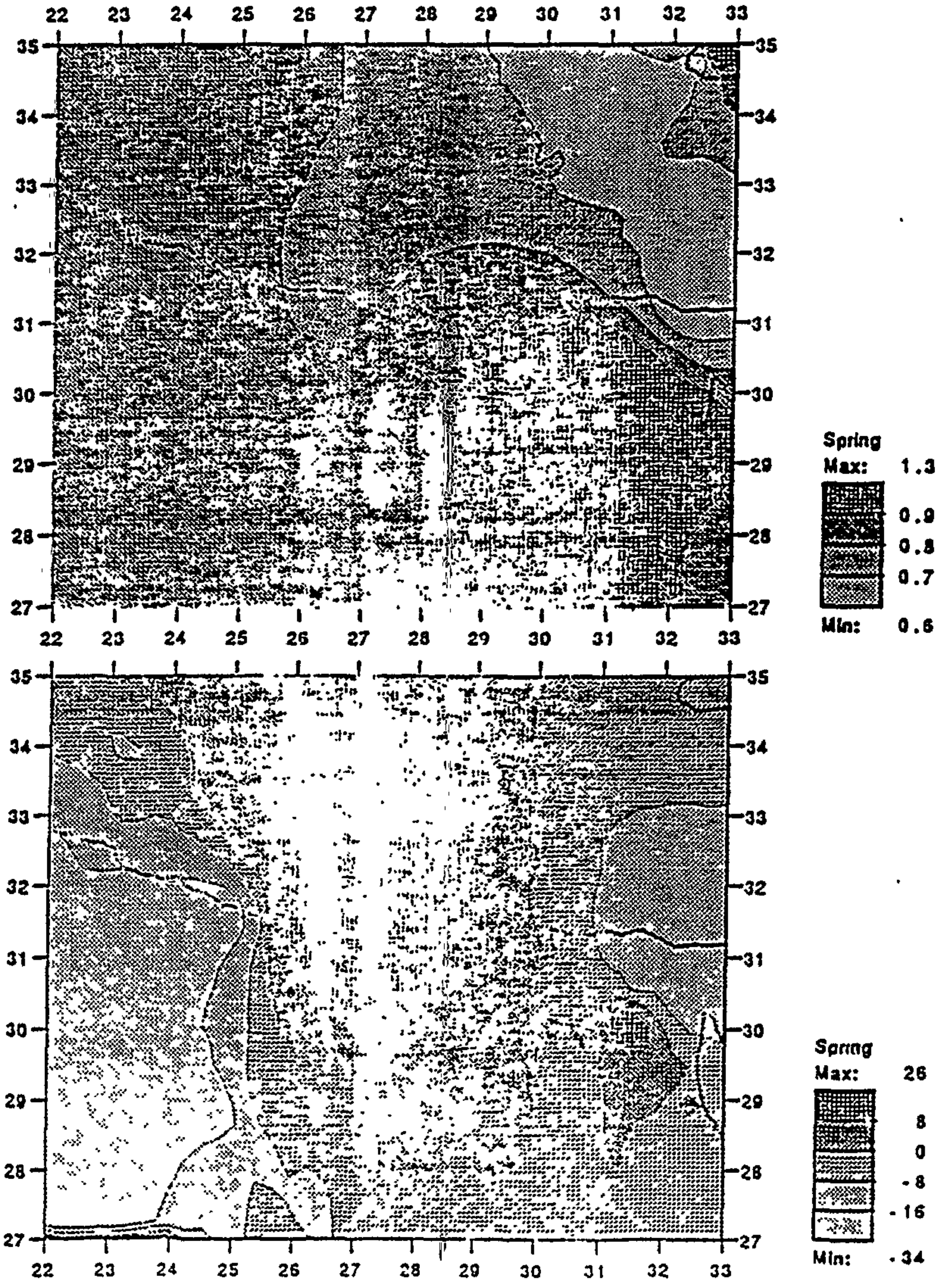


Figure 3 - Regional climate scenarios for northern Egypt: spring. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (percent per °C global change)

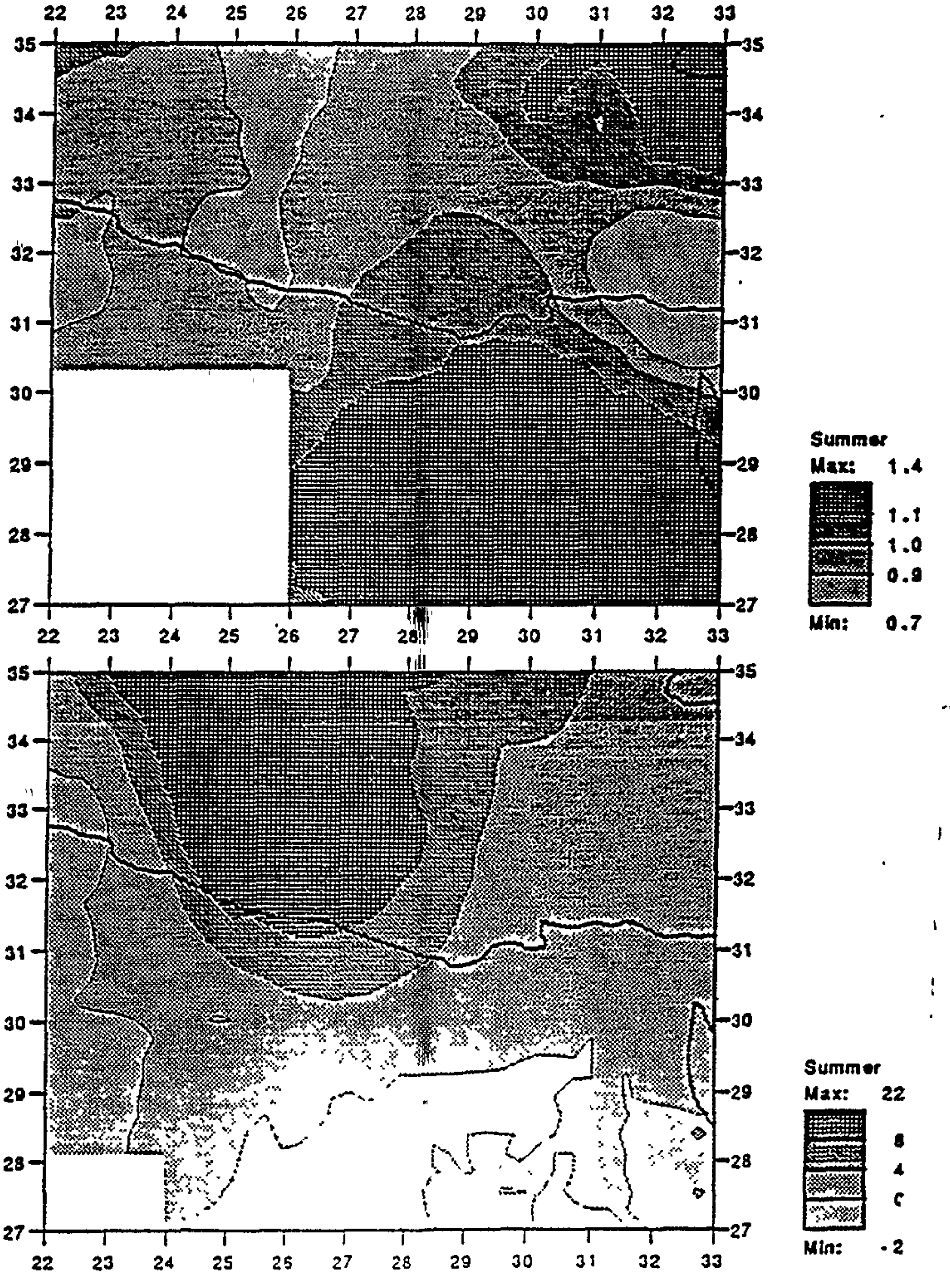


Figure 4 - Regional climate scenarios for northern Egypt: summer. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (percent per °C global change)

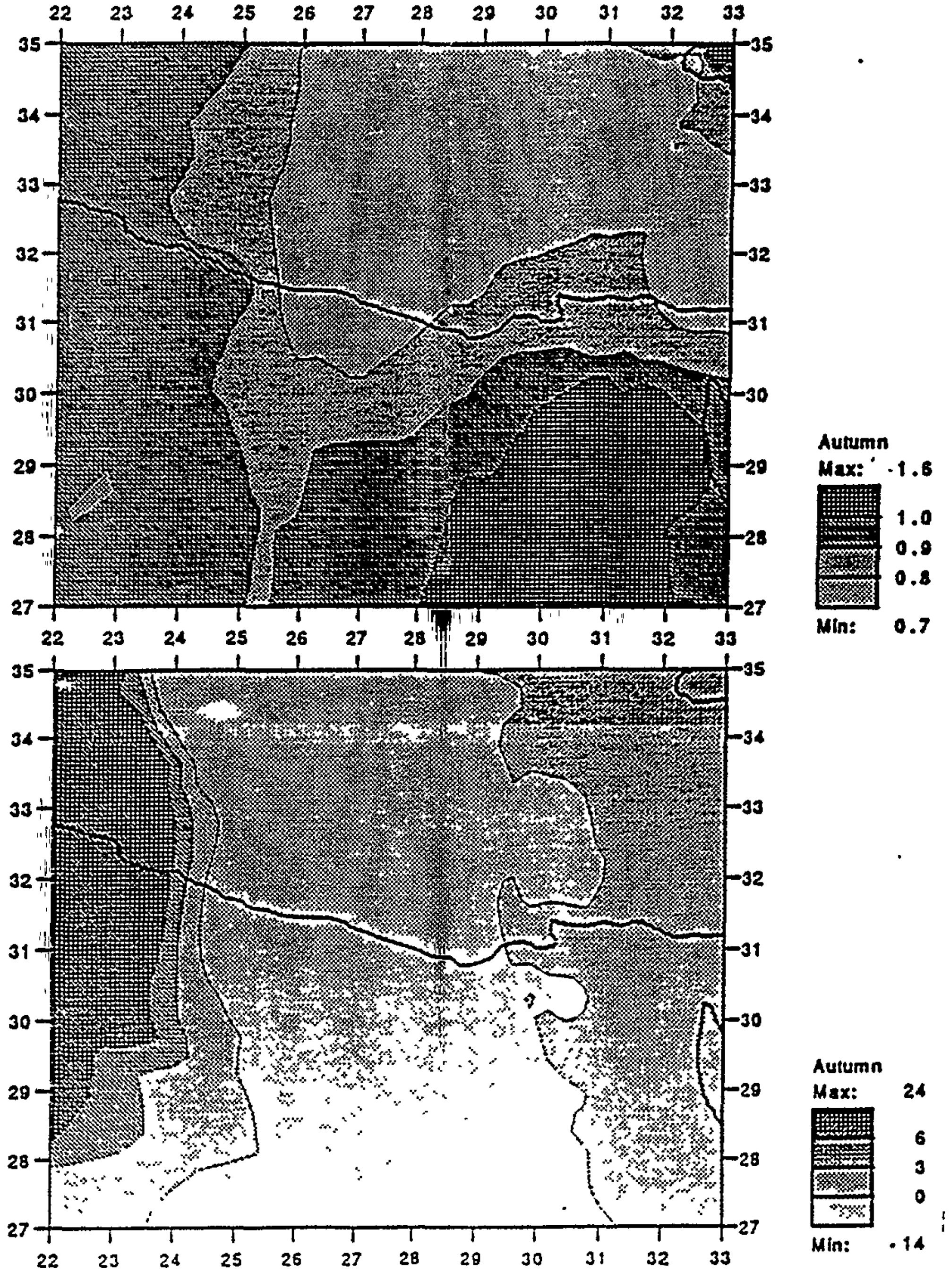


Figure 5 - Regional climate scenarios for northern Egypt: autumn. Upper map shows change in temperature (°C per °C global change) and the lower map snows change in precipitation (percent per °C global change)

Seasonal Scenarios for Climate Change

The seasonal changes in temperature in the Fuka-Matrouh area, as predicted by the four GCMs, broadly reflect the changes foreseen at the annual level. Only in the summer months of June, July and August (Fig. 4) does the temperature change approach that at the global level, with suggested increases of between 0.9°C and 1.1°C per °C global change, along the north-western coast of Egypt. In the winter months of December, January and February (Fig. 2), the predicted temperature increases are 0.7-0.8°C per °C global change; i.e., less than the global change. The smallest amount of warming in the study area is found in the spring season (Fig. 3): between 0.6°C and 0.8°C per °C global warming. In autumn (Fig. 5), the warming is between 0.7°C and 0.9°C in the Fuka-Matrouh area. The annual change in precipitation of around -4% to 0% per °C global change is made up of increased rainfall in the spring and summer seasons (lower maps, Figs. 3 and 4), and drier conditions in winter and autumn (lower maps, Figs. 2 and 5). In winter, the suggested reduction in precipitation along the coast west of Alexandria is between 0% and 22% per °C global change, with a gradient of increasing aridity from east to west. In spring, an increase of more than 8% is indicated for virtually the whole of the area of interest. Summer conditions are also shown to be wetter as a result of the enhanced greenhouse effect, with increases of between 0% and 8% per °C global change, with greatest increase in the western part of the study area. In autumn, the suggested changes are again negative, with a reduction of between 0% and 14% per °C global change. The greatest changes in this season are seen close to Alexandria.

5. Conclusions

We have applied the methods developed by Kim *et al.* (1984) and Wigley *et al.* (1990) to the construction of sub-grid-scale climate-change scenarios for northern Egypt. Regression equations were developed to predict station temperature and precipitation anomalies from regionally averaged climate anomalies. We substituted GCM "perturbed-run" minus "control-run" values of temperature and precipitation in the regression equations to obtain a prediction of the change due to the greenhouse effect at each station. The results were scaled by the equilibrium global temperature change of each of the four GCMs, and an average change per °C global change was calculated from the results for the four models. The procedure was repeated for every station in the data set, and the results contoured to produce scenarios for northern Egypt.

Annual and seasonal scenarios for temperature and precipitation change were produced. The specific region of interest is the Egyptian coastline west of Alexandria. Here, for temperature, the annual change is indicated to be less than the global change; i.e., in the range 0.7-0.8°C per °C global change. Broadly, the same pattern is seen in each season. Only in summer does the warming in the Fuka-Matrouh area approach the global level (with changes in the region 0.9-1.1°C per °C global change.

The scenarios for precipitation indicate drier conditions at the annual level, with a change in rainfall in the range of -4% to 0% per °C global warming. This relatively small change is accounted for by decreases in winter and autumn, whereas conditions in spring and summer are shown to be wetter as a result of global warming. In winter, the greatest change is seen in the west, towards the border with Libya, with a reduction in rainfall of over 10% per °C global warming. In autumn, the changes are between 0% and -14% per °C global warming. The increase in rainfall in spring is over 8% per °C global warming over the whole of the Egyptian coastline west of Alexandria. In summer, the increase is greatest in the west (over 8%), dropping to 0% to 4% per °C global warming close to Alexandria.

The problems associated with the construction of regional scenarios for climate change due to the enhanced greenhouse effect are discussed at length by Palutikof *et al.* (1992), in their report to UNEP on the construction of climate-change scenarios for the whole Mediterranean region. The confidence that we can place in sub-grid-scale scenarios of precipitation is particularly low. These scenarios should be considered only as indicators of changes that might occur.

APPENDIX

STATIONS USED IN SCENARIO CONSTRUCTION FOR NORTHERN EGYPT

Note that not all these stations will necessarily be used in the final scenario construction. They must first fulfil the criteria for acceptance laid down in Section 2 of this report, and by Palutikof *et al.* (1992).

CYPRUS

Station	E	N	HT	PRN	TEM	P%	T%
1. PAPHOS	32.4	34.8	10	1951-1989	1951-1989	100	100
2. PRODHROMOS	32.8	35.0	1380	1967-1989	1959-1989	96	99
3. LIMASSOL	33.0	34.7	10	1951-1989	1951-1989	100	98
4. NICOSIA	33.4	35.2	160	1951-1989	1951-1989	100	100
5. LARNACA	33.6	34.9	3	1951-1989	1951-1989	100	97

EGYPT

Station	E	N	HT	PRN	TEM	P%	T%
6. SALLOUM	25.2	31.5	6	1951-1987	1951-1987	99	89
7. SIDI-BARANI	26.0	31.6	23	1951-1987	1951-1987	100	99
8. MATROUH	27.2	31.3	30	1951-1988	1951-1987	99	97
9. NOUZHA	30.0	31.2	7	1951-1987	1951-1987	100	56
10. ROSETTA	30.4	31.4	3	1951-1987	-	74	0
11. DAMIETTA	31.8	31.4	5	1951-1987	-	99	0
12. PORT-SAID	32.3	31.3	6	1951-1987	1951-1987	99	98
13. SAKHA	30.9	31.1	-999	1951-1987	-	96	0
14. TANTA	30.9	30.8	8	1961-1986	1951-1986	100	100
15. ZAGAZIG	31.5	30.6	13	1961-1986	1951-1986	100	100
16. CAIRO	31.4	30.1	74	1951-1988	1951-1986	99	83
17. GIZA	31.2	30.0	22	1951-1986	1975-1986	100	100
18. HELWAN	31.3	29.9	141	1951-1988	1951-1986	99	96
19. FAYOUM	30.8	29.3	23	1961-1986	1951-1986	100	100
20. MINYA	30.7	28.1	40	1951-1987	1951-1986	100	100
21. ASSUIT	31.1	27.2	70	1951-1986	1951-1986	100	100
22. QENA	32.7	26.2	74	1951-1986	1951-1986	100	100
23. LUXOR	32.7	25.7	88	1951-1986	1951-1986	96	100
24. ASSWAN	32.8	24.0	194	1951-1988	1951-1986	95	100
25. SIWA	25.5	29.2	14	1951-1987	1951-1986	100	100
26. BAHARIA	28.9	28.3	130	1951-1986	1951-1986	100	99
27. DAKHLA	29.0	25.5	112	1951-1988	1951-1986	96	99
28. KHARGA	30.6	25.4	73	1951-1986	1951-1986	100	100
29. ISMAILIA	32.3	30.6	12	1951-1986	1951-1986	64	42
30. TOR	33.6	28.2	3	1955-1986	1956-1986	48	41
31. HURGHADA	33.8	27.3	3	1951-1986	1951-1986	99	100
32. KOSSEIR	34.2	26.2	-999	1955-1986	1961-1986	100	99

GREECE

Station	E	N	HT	PRN	TEM	P%	T%
33. KERKYRA	19.9	39.6	2	1955-1987	1951-1988	100	96
34. YANENA	20.7	39.6	-999	1956-1987	-	100	0
35. AGRINION	21.7	38.6	47	1956-1987	-	99	0
36. ARAXOS	21.4	38.2	23	1955-1987	1951-1970	100	100
37. ZAKYNTHOS	20.9	37.8	8	1956-1982	1951-1982	89	79
38. LARISSA	22.4	39.6	74	1955-1987	1951-1987	100	100
39. AGXIALO	22.8	39.0	-999	1956-1987	1956-1987	100	100
40. TRIPOLIS	22.2	37.6	660	1957-1987	1957-1987	100	100
41. KALAMATA	22.1	37.0	5	1951-1989	1951-1988	92	95
42. METHONI	21.7	36.8	34	1951-1987	1951-1987	100	99
43. TANAGRA	23.5	38.3	-999	1957-1986	1957-1986	99	99
44. ATHENS	23.7	38.0	107	1951-1986	1951-1988	100	97
45. HELLENIKON	23.7	37.9	10	1951-1989	1951-1987	97	100
46. KYTUIRA	23.0	36.2	-999	1955-1987	1955-1987	100	100
47 SKYROS	24.6	38.9	5	1955-1987	1955-1987	100	100
48. MILOS	24.5	36.7	-999	1955-1987	1955-1987	99	99
49. MITILIA	26.4	39.2	-999	1955-1987	1955-1987	100	100
50. NAXOS	25.5	37.1	9	1955-1987	1955-1987	100	100
51. SOUDA	24.1	35.6	161	1958-1986	1958-1986	97	97
52. ANOGIA	24.9	35.3	-999	1951-1985	-	96	0
53. HERAKLION	25.2	35.3	48	1955-1986	1951-1988	100	97
54. IERPETRA	25.8	35.0	-999	1956-1987	1956-1987	99	99
55. SITIA	26.1	35.2	28	1951-1985	-	87	0
56. KARPATHOS	27.2	35.5	20	1971-1988	1971-1988	95	95
57. RHODES	28.1	36.4	12	1955-1988	1955-1988	99	100

ISRAEL

Station	E	N	HT	PRN	TEM	P%	T%
58. LOD	34.9	32.0	49	1951-1989	1951-1988	93	100
59. JERUSALEM	35.2	31.8	809	1951-1989	1951-1980	97	100
60. EILAT	35.0	29.5	11	1951-1989	1951-1988	86	99

ITALY

Station	E	N	HT	PRN	TEM	P%	T%
61. CROTONE	17.1	39.0	155	-	1961-1985	0	100

JORDAN

Station	E	N	HT	PRN	TEM	P%	T%
62. IRBID	35.9	32.6	585	1955-1989	1955-1989	100	98
63. AMMAN	36.0	32.0	771	1951-1989	1951-1989	100	100
64. DEIR-ALLA	35.6	32.2	-224	1952-1989	1952-1989	98	98
65. MAAN	35.8	30.2	1069	1960-1989	1960-1989	100	100
66. WADI-YABIS	35.6	32.4	-200	1960-1989	1960-1989	95	98
67. MAFRAQ	36.3	32.4	686	1960-1989	1960-1989	100	100
68. ER-RABBAH	35.8	31.3	920	1960-1989	1961-1989	100	94
69. AQABA	35.0	29.6	51	1960-1989	1960-1989	100	100
70. JORDAN-UNIV	35.9	32.0	980	1960-1989	1961-1989	100	89
71. BEIRUT	35.5	33.9	24	1951-1985	1951-1985	80	84
72. RAYACK	36.0	33.9	921	1951-1984	1951-1985	76	80
73. TRIPOLI	36.0	34.6	10	1951-1982	1955-1980	77	76

LIBYA

Station	E	N	HT	PRN	TEM	P%	T%
74 BENINA	20.3	32.1	132	1951-1989	1951-1988	85	88
75. BENGHAZI	20.0	32.1	10	1951-1973	-	100	0
76. AGEDABIA	20.2	30.7	-999	1951-1988	1954-1988	99	58
77. SHAHAT	21.9	32.8	625	1951-1988	-	98	0
78. DERNA	22.6	32.7	9	1951-1988	1951-1988	31	56
79. TOBRUQ	24.0	32.1	14	1951-1973	-	100	0
80. ADEM	23.9	31.9	155	1951-1988	1951-1975	96	93
81. GIALO	21.6	29.0	62	1951-1988	1964-1988	98	86
82. KUFRA	23.3	24.2	382	1951-1989	1951-1988	86	79

SAUDI ARABIA

Station	E	N	HT	PRN	TEM	P%	T%
83. TABUK	36.6	28.4	774	1966-1989	1966-1989	59	48
84. WEJH	36.5	26.2	8	1966-1989	1966-1989	60	50

SYRIA

Station	E	N	HT	PRN	TEM	P%	T%
85. ALEPPO	37.2	36.2	393	1951-1989	1952-1988	97	99
86. LATTAKIA	35.8	35.6	9	1952-1989	1952-1988	90	94
87 DAMASCUS	36.2	33.5	724	1951-1989	1951-1988	97	99
88. SAFITA	36.1	34.8	-999	1959-1988	1959-1988	100	100
89. IDLEB	36.7	35.9	-999	1955-1988	1957-1988	100	100
90. HAMA	36.8	35.1	-999	1955-1988	1956-1988	100	100
91. HOMUS	36.7	34.8	-999	1955-1988	1955-1988	100	100
92. NABEK	36.7	34.0	-999	1955-1988	1959-1988	100	100
93. SUEIDA	36.6	32.7	-999	1958-1988	1958-1988	100	100
94. TELSHEHAB	36.0	32.7	-999	1958-1988	1958-1988	100	100

TURKEY

Station	E	N	HT	PRN	TEM	P%	T%
95. IZMIR	27.3	38.4	25	1929-1989	1929-1988	97	98
96. MUGLA	28.4	37.2	646	1951-1989	1951-1988	94	96
97. AFYON	30.5	38.8	1034	1951-1989	1951-1988	97	98
98. ISPARTA	30.6	37.8	1043	1951-1989	1951-1988	97	98
99. ANTALYA	30.7	36.9	43	1929-1989	1930-1988	97	98
100. ANKARA	32.9	40.0	894	1926-1989	1926-1988	98	98
101. KONYA	32.5	37.9	1022	1951-1989	1951-1988	93	98
102. KAYSERI	35.5	38.7	1070	1951-1982	1951-1988	97	91
103. ADANA	35.3	37.0	66	1929-1985	1929-1985	96	97
104. SIVAS	37.0	39.8	1285	1929-1989	1930-1980	98	100

E - longitude
N - latitude
HT - height above sea level (m)
PRN - length of precipitation record
TEM - length of temperature record
P% - percentage of precipitation record present
T% - percentage of temperature record present

ANNEX III

LIST OF ACRONYMS AND ABBREVIATIONS

AAR	Average area at risk
CAMP	Coastal Areas Management Programme (UNEP/MAP)
CAPMAS	Central Agency for Public Mobilization and Statistics (Egypt)
CFC	Chlorofluorocarbon
CRU	Climate Research Unit (UEA)
EPA	Environmental Protection Agency (USA)
FAO	Food and Agriculture Organization of the United Nations
GAARD	General Authority for Aquatic Resources Development (Egypt)
GCM	General circulation model
GEMS	Global Environment Monitoring System (UNEP)
GFDL	Geophysical Fluid Dynamics Laboratory (USA)
GIS	Geographical information system
GISS	Goddard Institute of Space Studies (USA)
ICSU	International Council of Scientific Unions
IEFC	Initial water-level exceedance frequency curve
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IPCC	Intergovernmental Panel on Climate Change (WMO/UNEP)
MARPOL	International Convention for the Prevention of Pollution from Ships
MEDU	Coordinating Unit for the Mediterranean Action Plan (UNEP)
NWCA	North-West Coastal Zone Authority for Development and Rehabilitation
OCAPAC	Oceans and Coastal Areas Programme Activity Centre (UNEP)
OSU	Oregon State University
TDS	Total dissolved solids
UEA	University of East Anglia (UK)
UKMO	United Kingdom Meteorological Office
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UT	Universal time
WMO	World Meteorological Organization

PUBLICATIONS OF THE MAP TECHNICAL REPORTS SERIES

1. UNEP/IOC/WMO: Baseline studies and monitoring of oil and petroleum hydrocarbons in marine waters (MED POL I). MAP Technical Reports Series No. 1. UNEP, Athens, 1986 (96 pages) (parts in English, French or Spanish only).

2. UNEP/FAO: Baseline studies and monitoring of metals, particularly mercury and cadmium, in marine organisms (MED POL II). MAP Technical Reports Series No. 2. UNEP, Athens, 1986 (220 pages) (parts in English, French or Spanish only).

3. UNEP/FAO: Baseline studies and monitoring of DDT, PCBs and other chlorinated hydrocarbons in marine organisms (MED POL III). MAP Technical Reports Series No. 3. UNEP, Athens, 1986 (128 pages) (parts in English, French or Spanish only).

4. UNEP/FAO: Research on the effects of pollutants on marine organisms and their populations (MED POL IV). MAP Technical Reports Series No. 4. UNEP, Athens, 1986 (118 pages) (parts in English, French or Spanish only).

5. UNEP/FAO: Research on the effects of pollutants on marine communities and ecosystems (MED POL V). MAP Technical Reports Series No. 5. UNEP, Athens, 1986 (146 pages) (parts in English or French only).

6. UNEP/IOC: Problems of coastal transport of pollutants (MED POL VI). MAP Technical Reports Series No. 6. UNEP, Athens, 1986 (100 pages) (English only).

7. UNEP/WHO: Coastal water quality control (MED POL VII). MAP Technical Reports Series No. 7. UNEP, Athens, 1986 (426 pages) (parts in English or French only).

8. UNEP/IAEA/IOC: Biogeochemical studies of selected pollutants in the open waters of the Mediterranean (MED POL VIII). MAP Technical Reports Series No. 8. UNEP, Athens, 1986 (42 pages) (parts in English or French only).

8. Add. UNEP: Biogeochemical studies of selected pollutants in the open waters of the Mediterranean MED POL VIII). Addendum, Greek Oceanographic Cruise 1980. MAP Technical Reports Series No. 8, Addendum. UNEP, Athens, 1986 (66 pages) (English only).

9. UNEP: Co-ordinated Mediterranean pollution monitoring and research programme (MED POL - PHASE I). Final report, 1975-1980. MAP Technical Reports Series No. 9. UNEP, Athens, 1986 (276 pages) (English only).

10. UNEP: Research on the toxicity, persistence, bioaccumulation, carcinogenicity and mutagenicity of selected substances (Activity G). Final reports on projects dealing with toxicity (1983-85). MAP Technical Reports Series No. 10. UNEP, Athens, 1987 (118 pages) (English only).

11. UNEP: Rehabilitation and reconstruction of Mediterranean historic settlements. Documents produced in the first stage of the Priority Action (1984-1985). MAP Technical Reports Series No. 11. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1986 (158 pages) (parts in English or French only).

12. UNEP: Water resources development of small Mediterranean islands and isolated coastal areas. Documents produced in the first stage of the Priority Action (1984-1985). MAP Technical Reports Series No. 12. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (162 pages) (parts in English or French only).

13. UNEP: Specific topics related to water resources development of large Mediterranean islands. Documents produced in the second phase of the Priority Action (1985-1986). MAP Technical Reports Series No. 13. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (162 pages) (parts in English or French only).

14. UNEP: Experience of Mediterranean historic towns in the integrated process of rehabilitation of urban and architectural heritage. Documents produced in the second phase of the Priority Action (1986). MAP Technical Reports Series No. 14. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (500 pages) (parts in English or French only).

15. UNEP: Environmental aspects of aquaculture development in the Mediterranean region. Documents produced in the period 1985-1987. MAP Technical Reports Series No. 15. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (101 pages) (English only).

16. UNEP: Promotion of soil protection as an essential component of environmental protection in Mediterranean coastal zones. Selected documents (1985-1987). MAP Technical Reports Series No. 16. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (424 pages) (parts in English or French only).

17. UNEP: Seismic risk reduction in the Mediterranean region. Selected studies and documents (1985-1987). MAP Technical Reports Series No. 17. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (247 pages) (parts in English or French only).

18. UNEP/FAO/WHO: Assessment of the state of pollution of the Mediterranean Sea by mercury and mercury compounds. MAP Technical Reports Series No. 18. UNEP, Athens, 1987 (354 pages) (English and French).

19. UNEP/IOC: Assessment of the state of pollution of the Mediterranean Sea by petroleum hydrocarbons. MAP Technical Reports Series No. 19. UNEP, Athens, 1988 (130 pages) (English and French).

20. UNEP/WHO: Epidemiological studies related to environmental quality criteria for bathing waters, shellfish-growing waters and edible marine organisms (Activity D). Final report on project on relationship between microbial quality of coastal seawater and health effects (1983-86). MAP Technical Reports Series No. 20. UNEP, Athens, 1988 (156 pages) (English only).

21. UNEP/UNESCO/FAO: Eutrophication in the Mediterranean Sea: Receiving capacity and monitoring of long-term effects. MAP Technical Reports Series No. 21. UNEP, Athens, 1988 (200 pages) (parts in English or French only).

22. UNEP/FAO: Study of ecosystem modifications in areas influenced by pollutants (Activity I). MAP Technical Reports Series No. 22. UNEP, Athens, 1988 (146 pages) (parts in English or French only).

23. UNEP: National monitoring programme of Yugoslavia, Report for 1983-1986. MAP Technical Reports Series No. 23. UNEP, Athens, 1988 (223 pages) (English only).

24. UNEP/FAO: Toxicity, persistence and bioaccumulation of selected substances to marine organisms (Activity G). MAP Technical Reports Series No. 24. UNEP, Athens, 1988 (122 pages) (parts in English or French only).

25. UNEP: The Mediterranean Action Plan in a functional perspective: A quest for law and policy. MAP Technical Reports Series No. 25. UNEP, Athens, 1988 (105 pages) (English only).

26. UNEP/IUCN: Directory of marine and coastal protected areas in the Mediterranean Region. Part I - Sites of biological and ecological value. MAP Technical Reports Series No. 26. UNEP, Athens, 1989 (196 pages) (English only).

27. UNEP: Implications of expected climate changes in the Mediterranean Region: An overview. MAP Technical Reports Series No. 27. UNEP, Athens, 1989 (52 pages) (English only).

28. UNEP: State of the Mediterranean marine environment. MAP Technical Reports Series No. 28. UNEP, Athens, 1989 (225 pages) (English only).

29. UNEP: Bibliography on effects of climatic change and related topics. MAP Technical Reports Series No. 29. UNEP, Athens, 1989 (143 pages) (English only).

30. UNEP: Meteorological and climatological data from surface and upper measurements for the assessment of atmospheric transport and deposition of pollutants in the Mediterranean Basin: A review. MAP Technical Reports Series No. 30. UNEP, Athens, 1989 (137 pages) (English only).

31. UNEP/WMO: Airborne pollution of the Mediterranean Sea. Report and proceedings of a WMO/UNEP Workshop. MAP Technical Reports Series No. 31. UNEP, Athens, 1989 (247 pages) (parts in English or French only).

32. UNEP/FAO: Biogeochemical cycles of specific pollutants (Activity K). MAP Technical Reports Series No. 32. UNEP, Athens, 1989 (139 pages) (parts in English or French only).

33. UNEP/FAO/WHO/IAEA: Assessment of organotin compounds as marine pollutants in the Mediterranean. MAP Technical Reports Series No. 33. UNEP, Athens, 1989 (185 pages) (English and French).

34. UNEP/FAO/WHO: Assessment of the state of pollution of the Mediterranean Sea by cadmium and cadmium compounds. MAP Technical Reports Series No. 34. UNEP, Athens, 1989 (175 pages) (English and French).

35. UNEP: Bibliography on marine pollution by organotin compounds. MAP Technical Reports Series No. 35. UNEP, Athens, 1989 (92 pages) (English only).

36. UNEP/IUCN: Directory of marine and coastal protected areas in the Mediterranean region. Part I - Sites of biological and ecological value. MAP Technical Reports Series No. 36. UNEP, Athens, 1990 (198 pages) (French only).

37. UNEP/FAO: Final reports on research projects dealing with eutrophication and plankton blooms (Activity H). MAP Technical Reports Series No. 37. UNEP, Athens, 1990 (74 pages) (parts in English or French only).

38. UNEP: Common measures adopted by the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against pollution. MAP Technical Reports Series No. 38. UNEP, Athens, 1990 (100 pages) (English, French, Spanish and Arabic).

39. UNEP/FAO/WHO/IAEA: Assessment of the state of pollution of the Mediterranean Sea by organohalogen compounds. MAP Technical Reports Series No. 39. UNEP, Athens, 1990 (224 pages) (English and French).

40. UNEP/FAO: Final reports on research projects (Activities H,I and J). MAP Technical Reports Series No. 40. UNEP, Athens, 1990 (125 pages) (English and French).

41. UNEP: Wastewater reuse for irrigation in the Mediterranean region. MAP Technical Reports Series No. 41. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1990 (330 pages) (English and French).

42. UNEP/IUCN: Report on the status of Mediterranean marine turtles. MAP Technical Reports Series No. 42. UNEP, Athens, 1990 (204 pages) (English and French).

43. UNEP/IUCN/GIS *Posidonia: Red Book "Gérard Vuignier", marine plants, populations and* landscapes threatened in the Mediterranean. MAP Technical Reports Series No. 43. UNEP, Athens, 1990 (250 pages) (French only).

44. UNEP: Bibliography on aquatic pollution by organophosphorus compounds. MAP Technical Reports Series No. 44. UNEP, Athens, 1990 (98 pages) (English only).

45. UNEP/IAEA: Transport of pollutants by sedimentation: Collected papers from the first Mediterranean Workshop (Villefranche-sur-Mer, France, 10-12 December 1987). MAP Technical Reports Series No. 45. UNEP, Athens, 1990 (302 pages) (English only).

46. UNEP/WHO: Epidemiological studies related to environmental quality criteria for bathing waters, shellfish-growing waters and edible marine organisms (Activity D). Final report on project on relationship between microbial quality of coastal seawater and rotarus-induced gastroenterities among bathers (1986-88). MAP Technical Reports Series No.46, UNEP, Athens, 1991 (64 pages) (English only).

47. UNEP: Jellyfish blooms in the Mediterranean. Proceedings of the II workshop on jellyfish in the Mediterranean Sea. MAP Technical Reports Series No.47. UNEP, Athens, 1991 (320 pages) (parts in English or French only).

48. UNEP/FAO: Final reports on research projects (Activity G). MAP Technical Reports Series No. 48. UNEP, Athens, 1991 (126 pages) (parts in English or French only).

49. UNEP/WHO: Biogeochemical cycles of specific pollutants. Survival of pathogens. Final reports on research projects (Activity K). MAP Technical Reports Series No. 49. UNEP, Athens, 1991 (71 pages) (parts in English or French only).

50. UNEP: Bibliography on marine litter. MAP Technical Reports Series No. 50. UNEP, Athens, 1991 (62 pages) (English only).

51. UNEP/FAO: Final reports on research projects dealing with mercury, toxicity and analytical techniques. MAP Technical Reports Series No. 51. UNEP, Athens, 1991 (166 pages) (parts in English or French only).

52. UNEP/FAO: Final reports on research projects dealing with bioaccumulation and toxicity of chemical pollutants. MAP Technical Reports Series No. 52. UNEP, Athens, 1991 (86 pages) (parts in English or French only).

53. UNEP/WHO: Epidemiological studies related to environmental quality criteria for bathing waters, shellfish-growing waters and edible marine organisms (Activity D). Final report on *epidemiological study on bathers from selected beaches in Malaga, Spain (1988-1989)*. MAP Technical Reports Series No. 53. UNEP, Athens, 1991 (127 pages) (English only).

54. UNEP/WHO: *Development and testing of sampling and analytical techniques for monitoring* of marine pollutants (Activity A): Final reports on selected microbiological projects. MAP Technical Reports Series No. 54. UNEP, Athens, 1991 (83 pages) (English only).

55. UNEP/WHO: Biogeochemical cycles of specific pollutants (Activity K): Final report on project on survival of pathogenic organisms in seawater. MAP Technical Reports Series No. 55. UNEP, Athens, 1991 (95 pages) (English only).

56. UNEP/IOC/FAO: Assessment of the state of pollution of the Mediterranean Sea by persistent synthetic materials which may float, sink or remain in suspension. MAP Technical Reports Series No. 56. UNEP, Athens, 1991 (113 pages) (English and French).

57. UNEP/WHO: Research on the toxicity, persistence, bioaccumulation, carcinogenicity and mutagenicity of selected substances (Activity G): Final reports on projects dealing with carcinogenicity and mutagenicity. MAP Technical Reports Series No. 57. UNEP, Athens, 1991 (59 pages) (English only).

58. UNEP/FAO/WHO/IAEA: Assessment of the state of pollution of the Mediterranean Sea by organophosphorus compounds. MAP Technical Reports Series No. 58. UNEP, Athens, 1991 (122 pages) (English and French).

59. UNEP/FAO/IAEA: Proceedings of the FAO/UNEP/IAEA Consultation Meeting on the Accumulation and Transformation of Chemical contaminants by Biotic and Abiotic Processes in the Marine Environment (La Spezia, Italy, 24-28 September 1990), edited by G.P. Gabrielides. MAP Technical Reports Series No. 59. UNEP, Athens, 1991 (392 pages) (English only).

60. UNEP/WHO: Development and testing of sampling and analytical techniques for monitoring of marine pollutants (Activity A): Final reports on selected microbiological projects (1987-1990). MAP Technical Reports Series No. 60. UNEP, Athens, 1991 (76 pages) (parts in English or French only).

61. UNEP: Integrated Planning and Management of the Mediterranean Coastal Zones. Documents produced in the first and second stage of the Priority Action (1985-1986). MAP Technical Reports Series No. 61. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1991 (437 pages) (parts in English or French only).

62. UNEP/IAEA: Assessment of the State of Pollution of the Mediterranean Sea by Radioactive Substances. MAP Technical Reports Series No. 62, UNEP, Athens, 1992 (133 pages) (English and French).

63. UNEP/WHO: Biogeochemical cycles of specific pollutants (Activity K) - Survival of Pathogens - Final reports on Research Projects (1989-1991). MAP Technical Reports Series No. 63, UNEP, Athens, 1992 (86 pages) (French only).

64 UNEP/WMO: Airborne Pollution of the Mediterranean Sea. Report and Proceedings of the Second WMO/UNEP Workshop. MAP Technical Reports Series No. 64, UNEP, Athens, 1992 (246 pages) (English only).

65. UNEP: Directory of Mediterranean Marine Environmental Centres. MAP Technical Reports Series No. 65, UNEP, Athens, 1992 (351 pages) (English and French).

66. UNEP/CRU: Regional Changes in Climate in the Mediterranean Basin Due to Global Greenhouse Gas Warming. MAP Technical Reports Series No. 66, UNEP, Athens, 1992 (172 pages) (English only).

67. UNEP/IOC: Applicability of Remote Sensing for Survey of Water Quality Parameters in the Mediterranean. Final Report of the Research Project. MAP Technical Reports Series No. 67, UNEP, Athens, 1992 (142 pages) (English only).

68. UNEP/FAO/IOC: Evaluation of the Training Workshops on the Statistical Treatment and Interpretation of Marine Community Data. MAP Technical Reports Series No. 68. UNEP, Athens, 1992 (221 pages) (English only).

69. UNEP/FAO/IOC: Proceedings of the FAO/UNEP/IOC Workshop on the Biological Effects of Pollutants on Marine Organisms (Malta, 10-14 September 1991), edited by G.P. Gabrielides. MAP Technical Reports Series No. 69. UNEP, Athens, 1992 (287 pages) (English only).

70. UNEP/IAEA/IOC/FAO: Organohalogen Compounds in the Marine Environment: A Review. MAP Technical Reports Series No. 70. UNEP, Athens, 1992 (49 pages) (English only).

71. UNEP/FAO/IOC: Selected techniques for monitoring biological effects of pollutants in marine organisms. MAP Technical Reports Series No. 71. UNEP, Athens, 1993 (189 pages) (English only).

72. UNEP: Costs and Benefits of Measures for the Reduction of Degradation of the Environment from Land-based Sources of Pollution in Coastal Areas. A - Case Study of the Bay of Izmir. B - Case Study of the Island of Rhodes. MAP Technical Reports Series No. 72. UNEP, Athens, 1993 (64 pages) (English only).

73. UNEP/FAO: Final Reports on Research Projects Dealing with the Effects of Pollutants on Marine Communities and Organisms. MAP Technical Reports Series No. 73. UNEP, Athens, 1993 (186 pages) (English and French).

74. UNEP/FIS. Report of the Training Workshop on Aspects of Marine Documentation in the Mediterranean. MAP Technical Reports Series No. 74. UNEP, Athens, 1993 (38 pages) (English only).

75. UNEP/WHO: Development and Testing of Sampling and Analytical Techniques for Monitoring of Marine Pollutants (Activity A). MAP Technical Reports Series No. 75. UNEP, Athens, 1993 (90 pages) (English only).

76. UNEP/WHO: Biogeochemical Cycles of Specific Pollutants (Activity K): Survival of Pathogens. MAP Technical Reports Series No. 76. UNEP, Athens, 1993 (68 pages) (English and French).

77. UNEP/FAO/IAEA: Designing of monitoring programmes and management of data concerning chemical contaminants in marine organisms. MAP Technical Reports Series No. 77. UNEP, Athens, 1993 (236 pages) (English only).

78. UNEP/FAO: Final reports on research projects dealing with eutrophication problems. MAP Technical Reports Series No. 78. UNEP, Athens, 1994 (139 pages) (English only).

79. UNEP/FAO: Final reports on research projects dealing with toxicity of pollutants on marine organisms. MAP Technical Reports Series No. 79. UNEP, Athens, 1994 (135 pages) (parts in English or French only).

80. UNEP/FAO: Final reports on research projects dealing with the effects of pollutants on marine organisms and communities. MAP Technical Reports Series No. 80. UNEP, Athens, 1994 (123 pages) (English only).

81. UNEP/IAEA: *Data quality review for MED POL: Nineteen years of progress.* MAP Technical Reports Series No. 81. UNEP, Athens, 1994 (79 pages) (English only).

82. UNEP/IUCN: Technical report on the State of Cetaceans in the Mediterranean. MAP Technical Reports Series No. 82. UNEP, Regional Activity Centre for Specially Protected Areas, Tunis, 1994 (37 pages) (English only).

83. UNEP/IUCN: Specially protected Areas in Mediterranean. Sketch of an Analytical Study of Relevant Legislation. MAP Technical Reports Series No. 83. UNEP, Regional Activity Centre for Specially Protected Areas, Tunis, 1994 (55 pages) (French only).

84. UNEP: Integrated Management Study for the Area of Izmir. MAP Technical Reports Series No. 84, UNEP, Regional Activity Centre for Priority Actions Programme, Split, 1994 (130 pages) (English only).

85. UNEP/WMO: Assessment of Airborne Pollution of the Mediterranean Sea by Sulphur and Nitrogen Compounds and Heavy Metals in 1991. MAP Technical Report Series No. 85, Athens, 1994 (304 pages) (English only).

86. UNEP: Monitoring Programme of the Eastern Adriatic Coastal Area - Report for 1983-1991. MAP Technical Report Series No. 86, Athens, 1994 (311 pages) (English only).

87. UNEP/WHO: Identification of microbiological components and measurement development and testing of methodologies of specified contaminants (Area I) - Final reports on selected microbiological projects. MAP Technical Reports Series No. 87, UNEP, Athens, 1994 (136 pages) (English only).

88. UNEP: Proceedings of the Seminar on Mediterranean Prospective. MAP Technical Reports Series No. 88, UNEP, Blue Plan Regional Activity Centre, Sophia Antipolis, 1994 (176 pages) (parts in English or French only).

89. UNEP: Iskenderun Bay Project. Volume I. Environmental Management within the Context of Environment-Development. MAP Technical Reports Series No. 89, UNEP, Blue Plan Regional Activity Centre, Sophia Antipolis, 1994 (144 pages) (English only).

90. UNEP: Iskenderun Bay Project. Volume II. Systemic and Prospective Analysis. MAP Technical Report Series No. 90, Sophia Antipolis, 1994 (142 pages) (parts in English or French only).

91. UNEP: A Contribution from Ecology to Prospective Studies. Assets and Issues. MAP Technical Reports Series No. 91, Sophia Antipolis, 1994 (162 pages) (French only).

92. UNEP/WHO: Assessment of the State of Pollution in the Mediterranean Sea by Carcinogenic, Mutagenic and Teratogenic Substances. MAP Technical Reports Series No. 92, UNEP, Athens, 1995 (238 pages) (English only).

93. UNEP/WHO: Epidemiological studies related to the environmental quality criteria for bathing waters, shellfish-growing waters and edible marine organisms. MAP Technical Reports Series No. 93, UNEP, Athens, 1995 (118 pages) (English only).

94. UNEP: Proceedings of the Workshop on Application of Integrated Approach to Development, Management and Use of Water Resources. MAP Technical Reports Series No. 94, UNEP, Athens, 1995 (214 pages) (parts in English or French only).

95. UNEP: Common measures for the control of pollution adopted by the Contracting Parties to the Convention for the Protection of the Mediterranean Sea against Pollution. MAP Technical Reports Series No 95, UNEP, Athens, 1995 (69 pages) (English and French).

96. UNEP/FAO: *Final reports of research projects on effects (Research Area III) - Pollution* effects on plankton composition and spatial distribution, near the sewage outfall of Athens (Saronikos Gulf, Greece). MAP Technical Reports Series No. 96, UNEP, Athens, 1996 (121 pages) (English only).

97. UNEP/FAO: Final reports of research projects on effects (Research Area III) - Pollution effects on marine communities. MAP Technical Reports Series No. 97, UNEP, Athens, 1996 (141 pages) (English and French).

98. UNEP: Implications of Climate Change for the Albanian Coast. MAP Technical Reports Series No. 98, UNEP, Athens, 1996 (179 pages) (English only).

99. UNEP: Implications of Climate Change for the Sfax Coastal Area (Tunisia). MAP Technical Reports Series No. 99, UNEP, Athens, 1996 (326 pages) (English and French).

100. UNEP: State of the Marine and Coastal Environment in the Mediterranean Region. MAP Technical Reports Series No. 100, UNEP, Athens, 1996 (142 pages) (English only).

101. UNEP: State of the Marine and Coastal Environment in the Mediterranean Region. MAP Technical Reports Series No. 101, UNEP, Athens, 1996 (148 pages) (French only).

PUBLICATIONS "MAP TECHNICAL REPORTS SERIES"

1. PNUE/COI/OMM: Etudes de base et surveillance continue du pétrole et des hydrocarbures contenus dans les eaux de la mer (MED POL I). MAP Technical Reports Series No. 1. UNEP, Athens, 1986 (96 pages) (parties en anglais, français ou espagnol seulement).

2. PNUE/FAO: Etudes de base et surveillance continue des métaux, notamment du mercure et du cadmium, dans les organismes marins (MED POL II). MAP Technical Reports Series No. 2. UNEP, Athens, 1986 (220 pages) (parties en anglais, français ou espagnol seulement).

3. PNUE/FAO: Etudes de base et surveillance continue du DDT, des PCB et des autres hydrocarbures chlorés contenus dans les organismes marins (MED POL III). MAP Technical Reports Series No. 3. UNEP, Athens, 1986 (128 pages) (parties en anglais, français ou espagnol seulement).

4. PNUE/FAO: Recherche sur les effets des polluants sur les organismes marins et leurs peuplements (MED POL IV). MAP Technical Reports Series No. 4. UNEP, Athens, 1986 (118 pages) (parties en anglais, français ou espagnol seulement).

5. PNUE/FAO: Recherche sur les effets des polluants sur les communautés et écosystèmes marins (MED POL V). MAP Technical Reports Series No. 5. UNEP, Athens, 1986 (146 pages) (parties en anglais ou français seulement).

6. PNUE/COI: Problèmes du transfert des polluants le long des côtes (MED POL VI). MAP Technical Reports Series No. 6. UNEP, Athens, 1986 (100 pages) (anglais seulement).

7. PNUE/OMS: Contrôle de la qualité des eaux côtières (MED POL VII). MAP Technical Reports Series No. 7. UNEP, Athens, 1986 (426 pages) (parties en anglais ou français seulement).

8. PNUE/AIEA/COI: Etudes biogéochimiques de certains polluants au large de la Méditerranée (MED POL VIII). MAP Technical Reports Series No. 8. UNEP, Athens, 1986 (42 pages) (parties en anglais ou français seulement).

8. PNUE: Etudes biogéochimiques de certains polluants au large de la Méditerranée (MED POL VIII).
Add. Addendum, Croisière Océanographique de la Grèce 1980. MAP Technical Reports Series No. 8, Addendum. UNEP, Athens, 1986 (66 pages) (anglais seulement).

9. PNUE: Programme coordonné de surveillance continue et de recherche en matière de pollution dans la Méditerranée (MED POL -PHASE I). Rapport final, 1975-1980. MAP Technical Reports Series No. 9. UNEP, Athens, 1986 (276 pages) (anglais seulement).

10. PNUE: Recherches sur la toxicité, la persistance, la bioaccumulation, la cancérogénicité et la mutagénicité de certaines substances (Activité G). Rapports finaux sur les projets ayant trait à la toxicité (1983-85). MAP Technical Reports Series No. 10. UNEP, Athens, 1987 (118 pages) (anglais seulement).

11. PNUE: Réhabilitation et reconstruction des établissements historiques méditerranéens. Textes rédigés au cours de la première phase de l'action prioritaire (1984-1985). MAP Technical Reports Series No. 11. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1986 (158 pages) (parties en anglais ou français seulement).

12. PNUE: Développement des ressources en eau des petites îles et des zones côtières isolées méditerranéennes. Textes rédigés au cours de la première phase de l'action prioritaire (1984-1985). MAP Technical Reports Series No. 12. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (162 pages) (parties en anglais ou français seulement).

13. PNUE: Thèmes spécifiques concernant le développement des ressources en eau des grandes îles méditerranéennes. Textes rédigés au cours de la deuxième phase de l'action prioritaire (1985-1986). MAP Technical Reports Series No. 13. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (162 pages) (parties en anglais ou français seulement).

14. PNUE: L'expérience des villes historiques de la Méditerranée dans le processus intégré de réhabilitation du patrimoine urbain et arcnitectural. Documents établis lors de la seconde phase de l'Action prioritaire (1986). MAP Technical Reports Series No. 14. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (500 pages) (parties en anglais ou français seulement).

15. PNUE: Aspects environnementaux du développement de l'aquaculture dans la région méditerranéenne. Documents établis pendant la période 1985-1987. MAP Technical Reports Series No. 15. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (101 pages) (anglais seulement).

16. PNUE: Promotion de la protection des sols comme élément essentiel de la protection de l'environnement dans les zones côtières méditerranéennes. Documents sélectionnés (1985-1987). MAP Technical Reports Series No. 16. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (424 pages) (parties en anglais ou français seulement).

17. PNUE: Réduction des risques sismiques dans la région méditerranéenne. Documents et études, sélectionnés (1985-1987). MAP Technical Reports Series No. 17. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1987 (247 pages) (parties en anglais ou français seulement).

18. PNUE/FAO/OMS: Evaluation de l'état de la pollution de la mer Méditerranée par le mercure et les composés mercuriels. MAP Technical Reports Series No. 18. UNEP, Athens, 1987 (354 pages) (anglais et français).

19. PNUE/COI: Evaluation de l'état de la pollution de la mer Méditerranée par les hydrocarbures de pétrole. MAP Technical Reports Series No. 19. UNEP, Athens, 1988 (130 pages) (anglais et français).

20. PNUE/OMS: Etudes épidémiologiques relatives aux critères de la qualité de l'environnement pour les eaux servant à la baignade, à la culture de coquillages et à l'élevage d'autres organismes marins comestibles (Activité D). Rapport final sur le projet sur la relation entre la qualité microbienne des eaux marines côtières et les effets sur la santé (1983-86). MAP Technical Reports Series No. 20. UNEP, Athens, 1988 (156 pages) (anglais seulement).

21. PNUE/UNESCO/FAO: Eutrophisation dans la mer Méditerranée: capacité réceptrice et surveillance continue des effets à long terme. MAP Technical Reports Series No. 21. UNEP, Athens, 1988 (200 pages) (parties en anglais ou français seulement).

22. PNUE/FAO: Etude des modifications de l'écosystème dans les zones soumises à l'influence des polluants (Activité I). MAP Technical Reports Series No. 22. UNEP, Athens, 1988 (146 pages) (parties en anglais ou français seulement).

23. PNUE: *Programme national de surveillance continue pour la Yougoslavie, Rapport pour 1983-1986.* MAP Technical Reports Series No. 23. UNEP, Athens, 1988 (223 pages) (anglais seulement).

24. PNUE/FAO: Toxicité, persistance et bioaccumulation de certaines substances vis-à-vis des organismes marins (Activité G). MAP Technical Reports Series No. 24. UNEP, Athens, 1988 (122 pages) (parties en anglais ou français seulement).

25. PNUE: Le Plan d'action pour la Méditerranée, perspective fonctionnelle; une recherche juridique et politique. MAP Technical Reports Series No. 25. UNEP, Athens, 1988 (105 pages) (anglais seulement).

26. PNUE/UICN: Répertoire des aires marines et côtières protégées de la Méditerranée. Première partie - Sites d'importance biologique et écologique. MAP Technical Reports Series No. 26. UNEP, Athens, 1989 (196 pages) (anglais seulement).

27. PNUE: Implications des modifications climatiques prévues dans la région méditerranéenne: une vue d'ensemble. MAP Technical Reports Series No. 27. UNEP, Athens, 1989 (52 pages) (anglais seulement).

28. PNUE: Etat du milieu marin en Méditerranée. MAP Technical Reports Series No. 28. UNEP, Athens, 1989 (225 pages) (anglais seulement).

29. PNUE: Bibliographie sur les effets des modifications climatiques et sujets connexes. MAP Technical Reports Series No. 29. UNEP, Athens, 1989 (143 pages) (anglais seulement).

30. PNUE: Données météorologiques et climatologiques provenant de mesures effectuées dans l'air en surface et en altitude en vue de l'évaluation du transfert et du dépôt atmosphériques des polluants dans le bassin méditerranéen: un compte rendu. MAP Technical Reports Series No. 30. UNEP, Athens, 1989 (137 pages) (anglais seulement).

31. PNUE/OMM: Pollution par voie atmosphérique de la mer Méditerranée. Rapport et actes des Journées d'étude OMM/PNUE. MAP Technical Reports Series No. 31. UNEP, Athens, 1989 (247 pages) (parties en anglais ou français seulement).

32. PNUE/FAO: Cycles biogéochimiques de polluants spécifiques (Activité K). MAP Technical Reports Series No. 32. UNEP, Athens, 1989 (139 pages) (parties en anglais ou français seulement).

33. PNUE/FAO/OMS/AIEA: *Evaluation des composés organostanniques en tant que polluants* du milieu marin en Méditerranée. MAP Technical Reports Series No. 33. UNEP, Athens, 1989 (185 pages) (anglais et français).

34. PNUE/FAO/OMS: Evaluation de l'état de la pollution de la mer Méditerranée par le cadmium et les composés de cadmium. MAP Technical Reports Seri es No. 34. UNEP, Athens, 1989 (175 pages) (anglais et français).

35. PNUE: *Bibliographie sur la pollution marine par les composés organostanniques.* MAP Technical Reports Series No. 35. UNEP, Athens, 1989 (92 pages) (anglais seulement).

36. PNUE/UICN: Répertoire des aires marines et côtières protégées de la Méditerranée. Première partie - Sites d'importance biologique et écologique. MAP Technical Reports Series No. 36. UNEP, Athens, 1990 (198 pages) (français seulement).

37. PNUE/FAO: Rapports finaux sur les projets de recherche consacrés à l'eutrophisation et aux efflorescences de plancton (Activité H). MAP Technical Reports Series No. 37. UNEP, Athens, 1990 (74 pages) (parties en anglais ou français seulement).

38. PNUE: Mesures communes adoptées par les Parties Contractantes à la Convention pour la protection de la mer Méditerranée contre la pollution. MAP Technical Reports Series No. 38. UNEP, Athens, 1990 (100 pages) (anglains, français, espagnol et arabe).

39. PNUE/FAO/OMS/AIEA: Evaluation de l'état de la pollution par les composés organohalogénés. MAP Technical Reports Series No. 39. UNEP, Athens, 1990 (224 pages) (anglais et français).

40. PNUE/FAO: Rapports finaux sur les projets de recherche (Activités H, I et J). MAP Technical Reports Series No. 40. UNEP, Athens, 1990 (125 pages) (anglais et français).

41. PNUE: Réutilisation agricole des eaux usées dans la région méditerranéenne. MAP Technical Reports Series No. 41. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1990 (330 pages) (anglais et français).

42. PNUE/UICN: Rapport sur le statut des tortues marines de Méditerranée. MAP Technical Reports Series No. 42. UNEP, Athens, 1990 (204 pages) (anglais et français).

43. PNUE/UICN/GIS Posidonie: Livre rouge "Gérard Vuignier" des végétaux, peuplements et paysages marins menacés de Méditerranée. MAP Technical Reports Series No. 43. UNEP, Athens, 1990 (250 pages) (français seulement).

44. PNUE: Bibliographie sur la pollution aquatique par les composés organophosphorés. MAP Technical Reports Series No. 44. UNEP, Athens, 1990 (98 pages) (anglais seulement).

45. PNUE/AIEA: Transfert des polluants par sédimentation: Recueil des communications présentées aux premières journées d'études méditerranéennes (Villefranche-sur- Mer, France, 10-12 décembre 1987). MAP Technical Reports Series No. 45. UNEP, Athens, 1990 (302 pages) (anglais seulement).

46. PNUE/OMS: Etudes épidémiologiques relatives aux critères de la qualité de l'environnement pour les eaux servant à la baignade, à la culture de coquillages et à l'élevage d'autres organismes marins comestibles (Activité D). Rapport final sur le projet sur la relation entre la qualité microbienne des eaux marines côtières et la gastroentérite provoquée par le rotavirus entre les baigneurs (1986-88). MAP Technical Reports Series No.46. UNEP, Athens, 1991 (64 pages) (anglais seulement).

47. PNUE: Les proliférations de méduses en Méditerannée. Actes des IIèmes journées d'étude sur les méduses en mer Méditerranée. MAP Technical Reports Series No.47. UNEP, Athens, 1991 (320 pages) (parties en anglais ou français seulement).

48. PNUE/FAO: Rapports finaux sur les projets de recherche (Activité G). MAP Technical Reports Series No. 48. UNEP, Athens, 1991 (126 pages) (parties en anglais ou français seulement).

49. PNUE/OMS: Cycles biogéochimiques de polluants spécifiques. Survie des Pathogènes. Rapports finaux sur les projets de recherche (activité K). MAP Technical Reports Series No. 49 UNEP, Athens, 1991 (71 pages) (parties en anglais ou français seulement).

50. PNUE: Bibliographie sur les déchets marins. MAP Technical Reports Series No. 50. UNEP, Athens, 1991 (62 pages) (anglais seulement).

51. PNUE/FAO: Rapports finaux sur les projets de recherche traitant du mercure, de la toxicité et des techniques analytiques. MAP Technical Reports Series No. 51. UNEP, Athens, 1991 (166 pages) (parties en anglais ou français seulement).

52. PNUE/FAO: Rapports finaux sur les projets de recherche traitant de la bioaccumulation et de la toxicité des polluants chimiques. MAP Technical Reports Series No. 52. UNEP, Athens, 1991 (86 pages) (parties en anglais ou français seulement).

53. PNUE/OMS: Etudes épidémiologiques relatives aux critères de la qualité de l'environnement pour les eaux servant à la baignade, à la culture de coquillages et à l'élevage d'autres organismes marins comestibles (Activité D). Rapport final sur l'étude épidémiologique menée parmi les baigneurs de certaines plages à Malaga, Espagne (1988-1989). MAP Technical Reports Series No. 53. UNEP, Athens, 1991 (127 pages) (anglais seulement).

54. PNUE/OMS: Mise au point et essai des techniques d'échantillonnage et d'analyse pour la surveillance continue des polluants marins (Activité A): Rapports finaux sur certains projets de nature microbiologique. MAP Technical Reports Series No. 54. UNEP, Athens, 1991 (83 pages) (anglais seulement).

55. PNUE/OMS: Cycles biogéochimiques de polluants spécifiques (Activité K): Rapport final sur le projet sur la survie des microorganismes pathogènes dans l'eau de mer. MAP Technical Reports Series No. 55. UNEP, Athens, 1991 (95 pages) (anglais seulement).

56. PNUE/COI/FAO: Evaluation de l'état de la pollution de la mer Méditerranée par les matières synthétiques persistantes qui peuvent flotter, couler ou rester en suspension. MAP Technical Reports Series No. 56. UNEP, Athens, 1991 (113 pages) (anglais et français).

57. PNUE/OMS: Recherches sur la toxicité, la persistance, la bioaccumulation, la cancérogénicité et la mutagénicité de certaines substances (Activité G). Rapports finaux sur les projets ayant trait à la cancérogénicité et la mutagénicité. MAP Technical Reports Series No. 57. UNEP, Athens, 1991 (59 pages) (anglais seulement).

58. PNUE/FAO/OMS/AIEA: Evaluation de l'état de la pollution de la mer Méditerranée par les composés organophosphorés. MAP Technical Reports Series No. 58. UNEP, Athens, 1991 (122 pages) (anglais et français).

59. PNUE/FAO/AIEA: *Actes de la réunion consultative FAO/PNUE/AIEA sur l'accumulation et* la transformation des contaminants chimiques par les processus biotiques et abiotiques dans le milieu marin (La Spezia, Italie, 24-28 septembre 1990), publié sous la direction de G.P. Gabrielides. MAP Technical Reports Series No. 59. UNEP, Athens, 1991 (392 pages) (anglais seulement).

60. PNUE/OMS: Mise au point et essai des techniques d'échantillonnage et d'analyse pour la surveillance continue des polluants marins (Activité A): Rapports finaux sur certains projets de nature microbiologique (1987-1990). MAP Technical Reports Series No. 60. UNEP, Athens, 1991 (76 pages) (parties en anglais ou français seulement).

61. PNUE: Planification intégrée et gestion des zones côtières méditerranéennes. Textes rédigés au cours de la première et de la deuxième phase de l'action prioritaire (1985-1986). MAP Technical Reports Series No. 61. UNEP, Priority Actions Programme, Regional Activity Centre, Split, 1991 (437 pages) (parties en anglais ou français seulement).

62. PNUE/AIEA: Evaluation de l'état de la pollution de la mer Méditerranée par les substances radioactives. MAP Technical Reports Series No. 62, UNEP, Athens, 1992 (133 pages) (anglais et français).

63. PNUE/OMS: Cycles biogéochimiques de polluants spécifiques (Activité K) - Survie des pathogènes - Rapports finaux sur les projets de recherche (1989-1991). MAP Technical Reports Series No. 63, UNEP, Athens, 1992 (86 pages) (français seulement).

64. PNUE/OMM: Pollution par voie atmosphérique de la mer Méditerranée. Rapport et actes des deuxièmes journées d'études OMM/PNUE. MAP Technical Reports Series No. 64, UNEP, Athens, 1992 (246 pages) (anglais seulement).

65. PNUE: Répertoire des centres relatifs au milieu marin en Méditerranée. MAP Technical Reports Series No. 65, UNEP, Athens, 1992 (351 pages) (anglais et français).

66. PNUE/CRU: Modifications régionales du climat dans le bassin méditerranéen résultant du réchauffement global dû aux gaz à effet de serre. MAP Technical Reports Series No. 66, UNEP, Athens, 1992 (172 pages) (anglais seulement).

67. PNUE/COI: Applicabilité de la télédétection à l'étude des paramètres de la qualité de l'eau en Méditerranée. Rapport final du projet de recherche. MAP Technical Reports Series No. 67, UNEP, Athens, 1992 (142 pages) (anglais seulement).

68. PNUE/FAO/COI: Evaluation des ateliers de formation sur le traitement statistique et l'interprétation des données relatives aux communautés marines. MAP Technical Reports Series No. 68. UNEP, Athens, 1992 (221 pages) (anglais seulement).

69. PNUE/FAO/COI: Actes de l'Atelier FAO/PNUE/COI sur les effets biologiques des polluants sur les organismes marins (Malte, 10-14 septembre 1991), publié sous la direction de G.P. Gabrielides. MAP Technical Reports Series No. 69. UNEP, Athens, 1992 (287 pages) (anglais seulement).

70. PNUE/AIEA/COI/FAO: Composés organohalogénés dans le milieu marin: Une synthèse. MAP Technical Reports Series No. 70. UNEP, Athens, 1992 (49 pages) (anglais seulement).

71. PNUE/FAO/COI: Techniques sélectionnées de surveillance continue des effets biologiques des polluants sur les organismes marins. MAP Technical Reports Series No. 71. UNEP, Athens, 1993 (189 pages) (anglais seulement).

72. PNUE: Coûts et bénefices des mesures pour la réduction de la dégradation de l'environnement des sources de pollution d'origine tellurique dans les zones côtières. A - Etude de cas de la baie d'Izmir. B - Etude de cas de l'île de Rhodes. MAP Technical Reports Series No. 72. UNEP, Athens, 1993 (64 pages) (anglais seulement).

73. PNUE/FAO: Rapports finaux sur les projets de recherche traitant des effets de polluants sur les communautés et les organismes marins. MAP Technical Reports Series No. 73. UNEP, Athens, 1993 (186 pages) (anglais et français).

74. PNUE/FIS: Rapport de l'Atelier de formation sur les aspects de la documentation marine en Méditerranée. MAP Technical Reports Series No. 74. UNEP, Athens, 1993 (38 pages) (anglais seulement).

75. PNUE/OMS: Mise au point et essai des techniques d'echantillonnage et d'analyse pour la surveillance continué des polluants marins (Activité A). MAP Technical Reports Series No. 75. UNEP, Athens, 1993 (90 pages) (anglais seulement).

76. PNUE/OMS: Cycles biogeochimiques de polluants spécifiques (Activité K): Survie des pathogènes. MAP Technical Reports Series No. 76. UNEP, Athens, 1993 (68 pages) (anglais et français).

77. PNUE/FAO/AIEA: Conception des programmes de surveillance continue et de gestion des données concernant les contaminants chimiques dans les organismes marins. MAP Technical Reports Series No. 77. UNEP, Athens, 1993 (236 pages) (anglais seulement).

78. PNUE/FAO: Rapports finaux sur les projets de recherche traitant des problèmes de l'eutrophisation. MAP Technical Reports Series No. 78. UNEP, Athens, 1994 (139 pages) (anglais seulement).

79. PNUE/FAO: Rapports finaux sur les projets de recherche traitant de la toxicité des polluants sur les organismes marins. MAP Technical Reports Series No. 79. UNEP, Athens, 1994 (135 pages) (parties en anglais ou français seulement).

80. PNUE/FAO: Rapports finaux sur les projets de recherche traitant des effets des polluants sur les organismes et communautés marins. MAP Technical Reports Series No. 80. UNEP, Athens, 1994 (123 pages) (anglais seulement).

81. PNUE/AIEA: Examen de la qualité des données pour le MED POL: Dix-neuf années de progrès. MAP Technical Reports Series No. 81. UNEP, Athens, 1994 (79 pages) (anglais seulement).

82. PNUE/UICN: Rapport technique sur l'état des cétacés en Méditerranée. MAP Technical Reports Series No. 82. PNUE, Centre d'activités régionales pour les aires spécialement protégées, Tunis, 1994 (37 pages) (anglais seulement).

83. PNUE/UICN: Les aires protégées en Méditerranée. Essai d'étude analytique de la législation pertinente. MAP Technical Reports Series No. 83. PNUE, Centre d'activités régionales pour les aires spécialement protégées, Tunis, 1994 (55 pages) (français seulement).

84. PNUE: Etude de gestion intégrée pour la zone d'Izmir. MAP Technical Reports Series No. 84, PNUE, Centre d'activités régionales pour le programme d'actions prioritaires, Split, 1994 (130 pages) (anglais seulement).

85. PNUE/OMM: Evaluation de la pollution transférée par voie atmosphérique en mer Méditerranée pour les composés soufrés, azotés et pour les métaux lourds en 1991. MAP Technical Reports Series No. 85, UNEP, Athens, 1994 (304 pages) (anglais seulement).

86. PNUE: Programme de surveillance continue de la zone côtière de l'Adriatique Est - Rapport pour 1983-1991. MAP Technical Reports Series No. 86, UNEP, Athens, 1994 (311 pages) (anglais seulement).

87. PNUE/OMS: Identification de constituants microbiologiques et de dosage (mise au point et essai de méthodes) de contaminants donnés (Domaine de recherche I) - Rapports finaux sur certains projets de nature microbiologique. MAP Technical Reports Series No. 87, UNEP, Athens, 1994 (136 pages) (anglais seulement).

88. PNUE: *Actes du Séminaire débat sur la prospective méditerranéenne. MAP Technical* Reports Series No. 88, UNEP, Blue Plan Regional Activity Centre, Sophia Antipolis, 1994 (176 pages) (parties en anglais ou français seulement).

89. PNUE: Projet de la Baie d'Iskenderun. Volume I. Gestion de l'environnement dans le cadre de l'environnement-développement. MAP Technical Reports Series No. 89, PNUE, Centre d'activités régionales pour le Plan Bleu, Sophia Antipolis, 1994 (144 pages) (anglais seulement).

90. PNUE: Projet de la Baie d'Iskenderun. Volume II. Analyse systémique et prospective. MAP Technical Reports Series No. 90, UNEP, Sophia Antipolis, 1994 (142 pages) (parties en anglais ou français seulement).

91. PNUE: Une contribution de l'écologie à la prospective. Problèmes et acquis. MAP Technical Reports Series No. 91, Sophia Antipolis, 1994 (162 pages) (français seulement).

92. PNUE/OMS: Evaluation de l'état de la pollution de la mer Méditerranée par les substances cancérigènes, tératogènes et mutagènes. MAP Technical Reports Series No. 92, UNEP, Athens, 1995 (238 pages) (anglais seulement).

93. PNUE/OMS: Etudes épidémiologiques relatives à la qualité de l'environnement pour les eaux servant à la baignade, à la culture des coquillages et à l'élevage d'autres organismes marins comestibles. MAP Technical Reports Series No. 93, UNEP, Athens, 1995 (118 pages) (anglais seulement).

94. PNUE: Actes de l'Atelier sur l'application d'une approche intégrée au développement, à la gestion et à l'utilisation des ressources en eau. MAP Technical Reports Series No. 94, UNEP, Athens, 1995 (214 pages) (parties en anglais ou français seulement).

95. PNUE: Mesures communes de lutte contre la pollution adoptées par les Parties contractantes à la Convention pour la protection de la mer Méditerranée contre la pollution. MAP Technical Reports Series No. 95, UNEP, Athens, 1995 (69 pages) (anglais et français).

96. PNUE/FAO: Rapports finaux des projets de recherche sur les effets (Domaine de recherche III) -Effets de la pollution sur la composition et la répartition spatiale à proximité de l'émissaire d'eaux usées d'Athènes (Golfe Saronique, Grèce). MAP Technical Reports Series No. 96, UNEP, Athens, 1996 (121 pages) (anglais seulement).

97 PNUE/FAO: Rapports finaux des projets de recherche sur les effets (Domaine de recherche III) - Effets de la pollution sur les communautés marines. MAP Technical Reports Series No. 97, UNEP, Athens, 1996 (141 pages) (anglais et français).

98. PNUE. Implications du changement climatique pour la zone côtière d'Albanie. MAP Technical Reports Series No. 98, UNEP, Athens, 1996 (179 pages) (anglais seulement).

99. PNUE: Implications des changements climatiques sur la zone côtière de Sfax. MAP Technical Reports Series No. 99, UNEP, Athens, 1996 (326 pages) (anglais et français).

100. PNUE: Etat du milieu marin et du littoral de la région méditerranéenne. MAP Technical Reports Series No. 100, UNEP, Athens, 1996 (142 pages) (anglais seulement).

101. PNUE. Etat du milieu marin et du littoral de la région méditerranéenne. MAP Technical Reports Series No. 101, UNEP, Athens, 1996 (148 pages) (français seulement).

Issued and printed by:

Mediterranean Action Plan
United Nations Environment Programme

Additional copies of this and other publications issued by the Mediterranean Action Plan of UNEP can be obtained from:

Coordinating Unit for the Mediterranean Action Plan
United Nations Environment Programme
Leoforos Vassileos Konstantinou, 48
P.O.Box 18019
11610 Athens
GREECE

Publié et imprimé par:

Plan d'action pour la Méditerranée
Programme des Nations Unies pour l'Environnement

Des exemplaires de ce document ainsi que d'autres publications du Plan d'action pour la Méditerranée du PNUE peuvent être obtenus de:

Unité de coordination du Plan d'action pour la Méditerranée
Programme des Nations Unies pour l'Environnement
Leoforos Vassileos Konstantinou, 48
B.P. 18019
11610 Athènes
GRECE