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UNITED NATIONS ENVIRONMENT PROGRAMME
TERRESTRIAL ECOSYSTEMS BRANCH / SOILS UNIT
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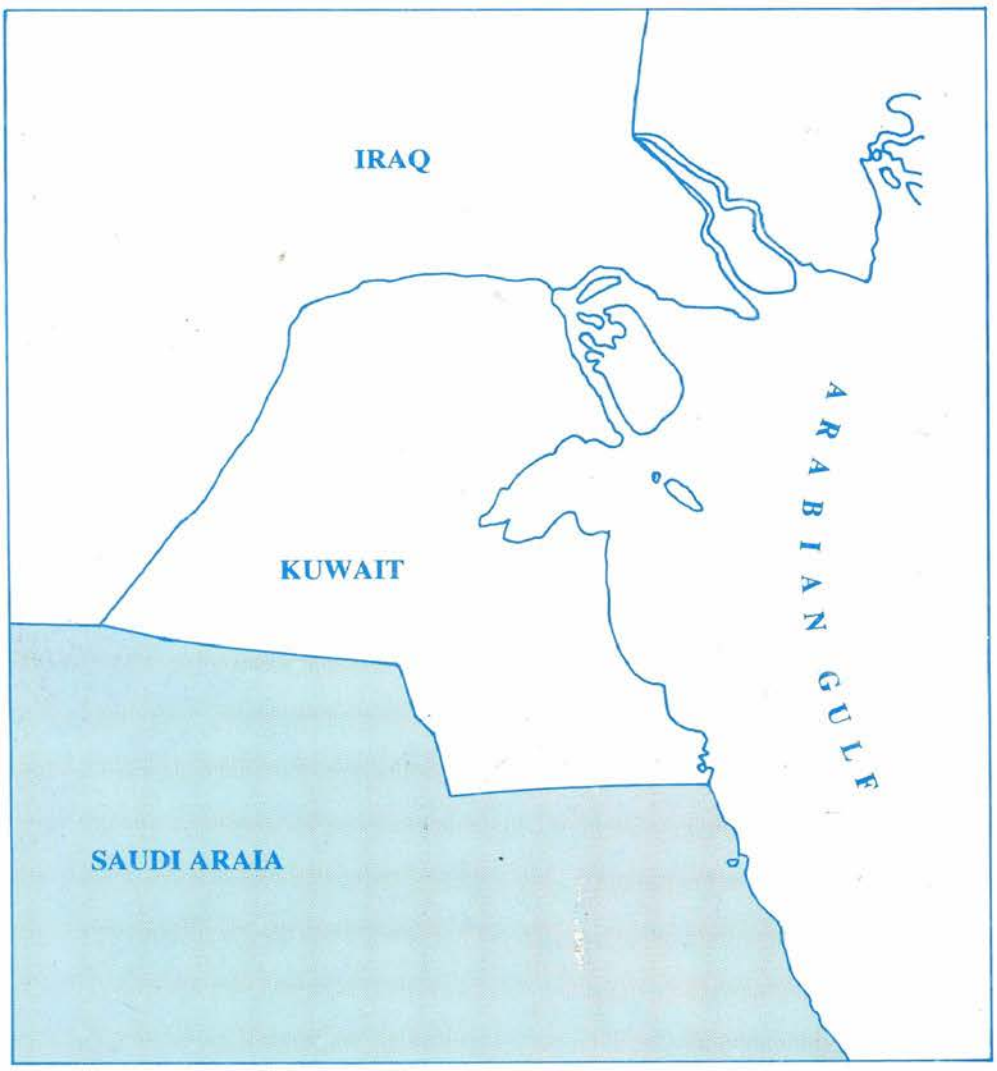

A RAPID ASSESSMENT OF THE IMPACTS OF THE IRAQ-KUWAIT CONFLICT ON TERRESTRIAL ECOSYSTEMS

PART III

SAUDI ARABIA

SEPTEMBER 1991

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PART THREE

THE KINGDOM OF SAUDI ARABIA

A Report prepared for the
United Nations Environment Programme

by

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September 1991

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A RAPID ASSESSMENT OF THE IMPACTS OF THE IRAQ-KUWAIT CONFLICT ON TERRESTRIAL ECOSYSTEMS IN THE KINGDOM OF SAUDI ARABIA

Executive Summary

This report gives an overall assessment of the effects of the Iraq - Kuwait conflict on the terrestail ecosystems in the Kindom of Saudi Arabia. It also provides a description of the state of the environment in the Kingdom before and after the war, in addition to a draft environmental rehabilitation programme which includes recommendations and measures for the mitigation, rehabilitation and protection of the environment. The assessment was carried out by a UNEP three-man team, who visited the Kingdom (28.8 - 3.9.1991), worked closely with the Meteorology and Environmental Protection Administration (MEPA), carried out extensive field trips in the eastern region - the site of war activities - and discussed preliminary observations thoroughly with Saudi Experts.

The report first dealt with the state of the environment before the Iraq-Kuwait Conflict. It described the physical factors. The area covers 224 million hectares out of which more than 120 million hectares are natural rangeland and which provide wildlife as well as livestock with biomass for feed. The vegetation is typical to the desert environment prevailing in the Arabian peninsula, where the climate is hot and subjected, for the greater part of the year, to northerly winds moving from Eastern Mediterranean towards the Gulf.

Most soils in Saudi Arabia are considered young soils (immature). About one-third of the area is sandy deserts (not stable sand dunes). Loamy shallow soils are distributed all over the country and occupy large areas. All the soils in the Kingdom are considered calcareous. Sabkhas are wide spread in the northern and eastern regions.

The eastern region is inhabited by 31 species of mammals belonging to the orders Insectivora (2), Chiroptera (2), Carnivora (12), Lagomorpha (3) and Rodentia (12). The region is also inhabited by 9 species of birds, about 3 lizard species and more than 25 species of snakes. Non of these species are extinct.

The flora of the eastern region are mainly ephemeral species (8), psammophytic plants (7 species), range plants (3 species), halophytes (3 species) and shrubby plants (4 species).

The vegetation in the eastern region is characterized by 15 plant communities. The important communities dominated by ephemeral plants include: Stipa carpensis, Horwoodia dicksonia, and Plantago boissieri (usually associated with Rhanterium epapposum).

Major land use is for natural grazing (75% of the country area). Rangeland provided in 1989 feed for 9 million sheep, 4.5 million goats and 0.61 million camels. Agricultural land use mainly irrigated, occupied 1.16 million ha in 1989. The land use in the hostility area was exclusively for range purposes.

The impact of war activities on the environment was considered in some detail. The activities that acted and impacted directly on the various components of the environment in the eastern region and studied by the team were:

(i) Off-road vehicle traffic ;
(ii) Camping and defensive construction;
(iii) Desert Combat;
(iv) Rocket shelling;
(v) Military manoeuvers;
(vi) Fallout of soot;
(vii) Oil spills.

The impacts of these war activities on fauna, flora, soil productivity, frequency of sandstorms, sand movement and food chain were assessed, presented and summarized in tabulated forms (9 Tables).

- War activities have left physical scars on the terrain surface. Movement of track and wheeled vehicles during manoeuvers and/or combat have compacted the soil and disturbed the soil surface. This along with the formation of craters and embankments have created new microhabitats for both fauna and flora. Changes of soil and water storing capacity will deprive some localities of their natural flora, seed bank and fauna. Some other localities, however, (i.e. craters) will support denser vegetation (ephemerals) and the respective fauna. The biodiversity is apt to be changed due to war activities.

- The fallout of soot, mainly hit the area falling south of Saudi/Kuwaiti borders and to the east of a line passing through Nairyah down to Dammam. Plants in the affected zone showed quite clear cover with dense soot layer. Halophytes along the coast and in the inland areas were severly affected. More than 50% of Suaeda vermiculata (Shanan) plants were dying.

The soot fallout reduced the productivity of several plants of the sand through minimizing the light, decrease of gas exchange, interference with metabolic activities as well as pollination and fertilization.

- The effect of oil spills was limited to salt marsh plants and mangrove. Within 520 km of impacted costline, more than 95% of the area was oiled.

- The area represented by Dibdiba, Summan and Dahnaa suffered severe damage of the extensive and intensive manoeuvers, off-road vehicling and military exercises. This area reputed for its value as ranglands will not be able to satisfy the needs of grazing animals. It is expected, however, that the establishment of bunkers and embankment may give chance for the regrowth of perennial Hammada plants after their complete disapearance from the area along with other perennials.

The post-war state of the environment reflected two major consequences of the war activities:

(i) Pollution of soil and biota by the soot and oil mist damaging the terrestial ecosystems in the affected area, and

(ii) Soil disturbance in large areas of the coastal belt and the northern parts of the eastern region by off-road vehicles, digging of bunkers and trenches, and raising of earthern embankments.

Animal population in the areas close to Kuwaiti borders is expected to change as regards kinds, species, numbers and activities. The fallout of soot on plants and soil forced the rodents to escape to enclosed sites.

The soot and oil mist affected the plants near Al-Khafji to a great extent. The vegetation of this affected areas may take decades to regenerate. Biomass and plant seed production were affected. The effect increased towards Kuwait and the Gulf shore.

Seed bank is expected to be reduced, due to low seed productivity.

The severe off-road vehicles left no space for perennial plants to remain. This aggravated the damaging effect of over-grazing.

The already destroyed perennials due to human activities might reappear in some bunkers and ditches.

- The pattern of land use in the area of hostilities is likely to remain unchanged, being mainly for grazing. The amounts of biomass produced are expected to decrease and if the numbers of grazing animals are not reduced, further deterioration of rangelands is expected.

Proposals for an environmental rehabilitation programme and mitigation measures were presented.

- Considering the magnitude of the impacts of the Gulf war on the coastal plains and the desert plateaux in the eastern region of Saudi Arabia, the Kingdom initiated mitigation measures. The activities carried out so far were, however, limited to monitoring and combating the devastating effects on marine ecosystems. Little has been done so far for terrestrial ones. The following additional mitigation measures are suggested:

(i) The establishment of 10 to 15 enclosures in the war-affected areas, one in each soil unit to improve the seed bank.

(ii) Encouragement of herders to transfer sizeable numbers of their animals to other areas or dispose of them to match the decreased biomass generation.

(iii) Monitoring the impact of soot and war activities on the desert ecosystems. Establishment of enclosures in the soot affected areas and in the areas where soils were drastically disturbed.

- A programme has been suggested for rehabilitation and protection of the fragile environment of the region, taking in consideration regional cooperation and action, simplicity and attraction of public support, the easy execution and the containment of built-in monitoring mechanism. The following piority areas for action were suggested:

(i) Human, animal and plant life-threatening hazards and toxic agents.

(ii) Short and long-term environment protection schemes including monitoring.

(iii) Rehabilitation of socio-economic development establishments.

(iv) Raising public awareness.

- In light of the priority areas suggested, the following actions were identifed:

(i) Survey of suspected land and demarcate dangerous areas where travelling, camping or grazing should be prohibited;

(ii) Establishment of national environmental monitoring and assessment centres;

(iii) Establish new research institutes and conduct extensive research programmes on new issues of post-war situation;

(iv) Raising public awareness;

(v) Rangeland management schemes;

(vi) Sand dune fixation programmes;

(vii) In disturbed areas regulate pastorlists cars, trucks and tankers traffic by building asphalt roads and restrict or prevent further disturbance of the soil;

(viii) Promote afforestation projects;

(ix) Establish several bioreserves;

(x) Develop recreational centres;

- Monitoring of damage to the environment and its rehabilitation has been recognized and the following topics were identified:

(i) Monitoring of the persistence of various pollutants produced as a result of the hostilities, in the atmosphere, soil, vegetation and water.

(ii) Special monitoring schemes to detect genetical or carcinogenic changes in man, animal and plant.

(iii) Monitoring habits and movements of indigenous and migratory birds.

(iv) Monitoring population dynamics of certain fauna e.g. scorpions, beetles, rodents and reptiles.

In connection with the institutional set-up, the report recommended that high priority should be given to the establishment of a National Environmental Monitoring and Assessment Centre in the Kingdom within the rehabilitation programme.

A thorough follow-up for the smooth and sound progress in the implementation of the rehabilitation programme for the Kingdom has also been recommended.

The report, in its concluding remarks, sums up observations on the execution of the mission, recalls briefly the results at country level and mentions some of the regional impacts. The report proceeds to propose how to initiate action on the rehabilitation programme and ends with a note on lessons learned - stating that the chief lesson is the belief in the strength of people in the affected region to contribute effectively in the rehabilitation programme.

INTRODUCTION

The work of this mission, which is presented in this report, was commissioned by the United Nations Environment Programme (UNEP) during the second half of July 1991. The concern of UNEP with the consequences of the war over Kuwait was immediate like a natural reflex action. UNEP Governing Council during its Special Session held on 1 - 3 August 1990 expressed its concern over the invasion of Kuwait by Iraq and the resulting destruction of the environment and disruption of social and economic structures.

The Executive Director of UNEP immediately initiated a series of actions and activities pertaining to the issue. Individuals and institutions were either urged or directly commissioned to prepare reports and assessments of the war consequences on the environment. The work of this mission is conducted within the framework of a UN Inter-agency Plan of Action to be formulated under a project entitled "Environmental Assessment of the ROPME* Sub-region and the Introduction of a Rehabilitation Programme following the War over Kuwait".

The mission was asked to assess the impact of war on terrestrial ecosystems in Kuwait, Iraq and Saudi Arabia and draft an environmental rehabilitation programme. The terms of reference appear in Appendix 1. The mission of three experts had forty days to visit the three countries and write its report.

It was readily obvious from the start that there would be a time constraint. The situation was worsened when a series of logistic problems resulted in loss of valuable time in between visits to five countries - Bahrain, Kuwait, Jordan, Iraq and Saudi Arabia. A record of the mission's travel and movements appears as Appendix 2.

In the performance of its work the mission had the benefit of four sources of information and experience from which it drew valuable data, information and wisdom which enabled them to compile this report. The four sources are:

1. The data and information generated by teams operating in the region under the UN Plan of Action.

2. Data, views and information from national counterparts and other Government officials.

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*ROPME - Regional Organization for the Protection of Marine Environment - (Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and UAE)

3. Field visits.

4. The voluminous published work by national and international sources.

This report on the impacts of the Iraq-Kuwait conflict on terrestrial ecosystems in Iraq is one out of three parts of a consolidated report prepared by the mission for Iraq, Kuwait and Saudi Arabia, which has been discussed at the ROPME meeting held in September 1991 in Kuwait and at the Ministerial meeting held in October 1991 in Kuwait.

The material in this report on Saudi Arabia is presented in seven chapters. Two of them deal with the state of the environment before and after the war; one chapter on war impacts identification and assessment, and one on monitoring and follow up. Chapter five presents a proposal for an environmental rehabilitation programme. Together with the chapter on impact identification and evaluation they constitute the centrepiece of the report. In chapter seven concluding remarks are made, including a summing up of the observations and highlighting the significance of the results, the means of applying solutions, a proposal how to start and the lessons learned.

In view of the magnitude of the catastrophe, the report proposes for a rehabilitation programme something analogous to the European Recovery Plan (ERP) better known as the Marshall Plan which saved Europe from disaster after World War Two. A framework comprising the countries involved is necessary for planning, organization and implementation of the programme. In the case of Europe, the European Economic Community was in its embryonic stage in 1947. But in the case of this war the countries involved have already got the Council of Arab Ministers Responsible for Environment.

The mission feels that a lot more could have been presented if they had more time and if the mission had more experts. Notwithstanding the complexity of the issues involved, the intricate logistic problems and the fear from subterranean bitterness and hostile feelings the mission wishes to express its profound appreciation of the abilities and potential strength felt in the region and the dormant love and kindness in the hearts of the people despite the memories of very bitter hostilities.

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Chapter I

The Assignment and Execution

1.1 Background

The outbreak of hostilities in the Kuwait Action Plan (KAP) region prompted the UNEP Governing Council to express its concern over the resulting destruction of the environment. In an effort to intensify cooperation and maximize output from the members of the UN system, the Executive Director of UNEP convened a UN Inter-agency consultation on the environmental consequences of the war in February 1991.

The outcome of that consultation and subsequent meetings of the UN Inter-agency group and of the Regional Organization for Protection of the Marine Environment (ROPME) meetings was the formulation of a project document which stipulated the following objectives:

Long-term objectives:

To assist the Governments of the KAP region in the rehabilitation and sound management of the marine, coastal and related environments of the region, through the provision of technical expertise.

Short-term objectives:

To provide Governments in the region with an assessment of the regional state of the environment as well as a draft environmental rehabilitation programme.

The project document envisaged four distinct areas of activity: the marine and coastal area, the terrestrial area, the atmosphere, and hazardous wastes. The workplan in the document included under a sub-heading 'Terrestrial' the following three activities:

(i) Agricultural areas, including food and soil, under the responsibility of FAO;

(ii) Water resources, including food safety and drinking water, under the responsibility of WHO; and

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*ROPME - Regional Organization for the Protection of Marine Environment - (Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and UAE)

(iii) Surveys and assessment of terrestrial ecosystems, under UNEP (EM/Soils) responsibility.

1.2 The Work Assignment for the Mission

One of the many steps taken by UNEP in the course of implementation of the above project was the recruitment of a three-man mission composed of Dr. Gaafar Karrar; Dr. Kamal Batanouny and Mr. Muhammad Alim Mian. The work assignment contracted to the members of the mission reads as follows:

"1. Assess and study the effects of desert combat, bombing, shelling and explosion of mines on the desert fauna and flora;

"2. Assess the effects of the above and other military activities on severity and frequency of dust storms and sand movements;

"3. Assess possible damages to land resources as the result of releases of massive quantitites of oil from attacked wells, pipelines and storage structures, and by soot and air-borne pollutant gases and oily smoke resulting from burning oil wells with particular attention to:

- fauna, flora and desert food-chain;
- soil productivity.

"4. After the necessary field visits, discussions with national counterparts, and officials in Iraq, Kuwait and Saudi Arabia the team will prepare:

- a report on the detailed assessment of the present state of the environment;

- a draft environmental rehabilitation programme, including recommendations and measures for the mitigation, rehabilitation and protection of the environment.

"5. In fulfilling the above task, the team will make full use of the available data and information already generated by teams operating in the region under the UN Plan of Action."

1.3 Execution of the Assignment:

The mission members assembled in Bahrain on 1.8.1991. They discussed the scope of their work, drafted an outline of the contents of their report and agreed on a tentative itinerary with Dr. Orabi, Acting Director of UNEP Regional Office for West Asia.

The mission foresaw the realization of its target through:

- the use of available data and information, particularly that generated by other UN teams;
- consideration of the views, experience and information supplied by national counterparts;
- field trips; and
- a study of the wealth of literature available on the several components of the assignment.

The mission commenced on 1.8.1991 and ended on 10.9.1991. Within this period, the mission visited the Kingdom of Saudi Arabia from 27 August to 3 September 1991. The mission worked with the Meteorology and Environmental Protection Administration (MEPA) which provided three counterparts from its headquarters in Jeddah. The mission spent all its time in the eastern region.

The itinerary of the movements of the mission appears as Appendix 3 and a list of persons met by the mission appears as Appendix 4.

Chapter II

The State of the Environment before the Iraq-Kuwait Conflict

2.1 General

The Iraq-Kuwait conflict left a grave adverse impact on the environment of the war-affected area located in the north-eastern corner of the Kingdom. Nearly all components of the environment were damaged. It may be stated that this study is primarily concerned with terrestrial ecosystems, whereas other components of the environment e.g. atmosphere and water, would constitute the subjects of study by other missions.

Keeping this in mind, this chapter has been included in the report. It gives a special presentation mostly of qualitative nature of the state of certain environmental components before the war, which would provide base line data for subsequent chapters on the war impact, impact evaluation and mitigation measures as well as rehabilitation of the environment in its terrestrial ecosystems. Except for sections on location and physiography the rest of the sections concentrate on the Eastern region which was the site of the war activities.

2.2 Physical Factors

2.2.1 Location

The kingdom of Saudi Arabia is situated in the south-western part of Asia. The country is bounded by Iraq to the north, Jordan to the north-west, Kuwait to the north-east, the Gulf to the east, Qatar and United Arab Emirates to the east, Oman to the south-east, Yemen to the south and Red Sea to the west. The surface area of the country is 2.25 million km^2. It lies between 16°00' and 32°16' N. latitudes and between 34°36' and 65°00' E. longitudes. In addition to the mainland, the kingdom includes a number of islands in both the Gulf and the Red Sea.

2.2.2 Topography and Physiographic Regions

The Kingdom can be divided into the following physiographic regions, based on the topographic and other physical features of the landscape (Fig. 1).

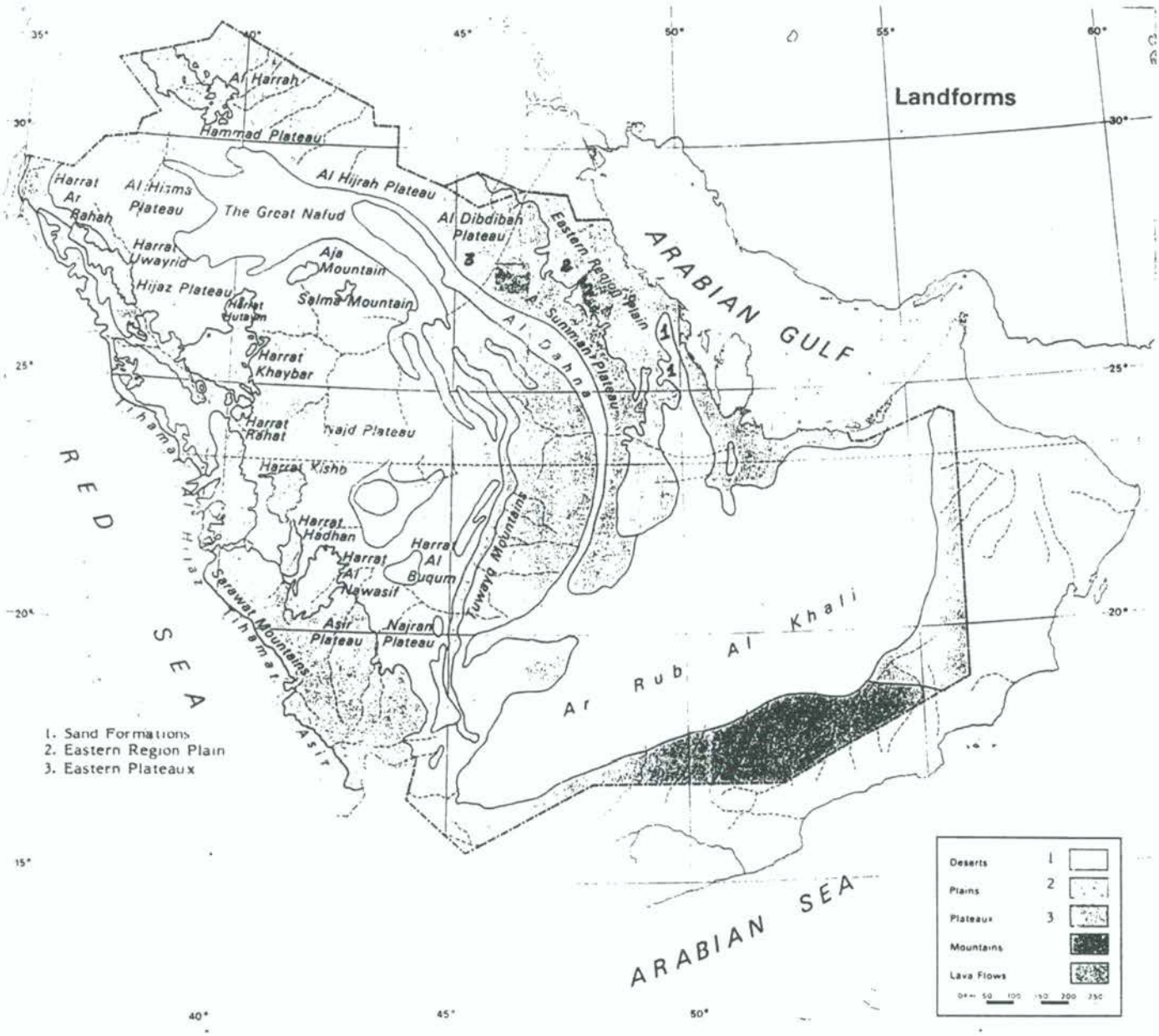

Fig. (1) Physiographic Regions in the Eastern Province, Kingdom of Saudi Arabia.

2.2.2.1 Tihama Plain

The Tihama Plain is a strip of land along the western coast. It is about 1800 km long; narrow in the north with increasing width towards the south. The average width increases from 25 km in its middle to about 40 km near Jizan in the south. It is bounded by the Red Sea in the west and by the Western Heights in the east. The Tihama Plain is traversed by a number of wadis which rise in the Western Heights and discharge into the Red Sea.

2.2.2.2 Western Heights

The western heights lie east of the Tihma and run in the north-south direction. They are narrow in the north and broaden as one goes to the south. They comprise igneous and metamorphic rock formations, which are covered in some parts with basaltic lava flows. The average elevation is around 1200 m and it increases towards Asir in the south reaching 3000 m above sea level. The heights slope abruptly towards the Red Sea, whereas the eastern slopes are gradual towards the plateau regions.

2.2.2.3 The Western Plateaux

The western plateaux are located to the east of the western heights. The important plateaux from the north to the south are: Hassmi plateau, Hijaz plateau, Al-Harrat plateau, Rukba plateau, Asir plateau and Najran plateau. The elevations range from 800 m in the north to 1500 m in the south.

2.2.2.4 Najd Plateau

The Najd plateau is the largest in the Kingdom. It is bounded by the Great Nafud desert in the north, Ar Rub Al Khali desert in the south, the western plateaux on the west and Dahnaa desert in the east. The western part of this plateau forms a part of the Arabian Shield, whereas its eastern part is a part of the sedimentary Arabian shelf. The plateau slopes very gently towards the east. The elevations range from 800 to 1200 m.

2.2.2.5 Eastern Plateaux

The Eastern plateaux, also called As Samman Plateaux, are located between the Dahnaa Desert to the west, the Gulf to the east, the Baatin wadi to the north-west, and Ar Rub Al Khali to the south. The plateaux are nearly level in the western part and are very gently sloping towards the east. The elevations increase from east to west where they reach 400 m above sea level.

2.2.2.6 Eastern Region Plain

It is a low gently undulating plain with increasing elevations westwards to the Dibdibah plateau. The plain is about 500 km long and its width is about 60 km. Some parts are covered by sand dunes. Sabkhas are common in this plain.

2.2.2.7 Northern Plateaux

The northern plateaux are considered as an extension of the Badiya Ash Shimalia plateau, lying mainly across the Iraq-Saudi and Jordan-Saudi borders. The northern plateaux are bounded on the south by the Great Nafud desert. The general slope is towards north-east and the elevations range from 400 to 900 m.

2.2.2.8 Sand Formations

The sand formations cover about one-third of the country area. Ar Rub Al Khali which is the largest expanse of sand formation in the country, occupies an area of about 640 thousand km^2. The Nafud desert covers an area of 56 thousand km^2 and is connected to Al Rub Al Khali desert through the Dahnaa desert. Dahnaa is about 1200 km long and is crescent shaped. The sand formations occur as dunes of variable sizes and different types.

The areas exposed to the impacts of the Iraq-Kuwait conflict fall in three physiographic regions as illustrated in Fig. (1) i.e. the Eastern Region Plain, the Eastern Plateaux and the northern tip of Ar Rub Al Khali.

2.2.3 Climate

2.2.3.1 General

The Arabian Peninsula is characterized by a hot climate subject, for the greater part of the year, to northerly winds moving from the Eastern Mediterranean towards the Gulf. Saudi Arabia was divided by Alzeid et al (1988) into 13 agro-climatic areas as shown in Fig. (2) and Table (1). The climatic parameters i.e. mean temperatures (max. and min.), rainfall, windspeed, annual evapotranspiration and the characteristics for the different climatic areas are given in Table (2).

The average altitude for areas 1 and 2 is less than 500 meters; for areas 3 to 10 is between 500 and 1000 meters and for areas 11 to 13 is between 100 to 2600 meters. On the basis of the analysis of the climatological data for the 1976 to 1982 period, the effect of different altitudes on

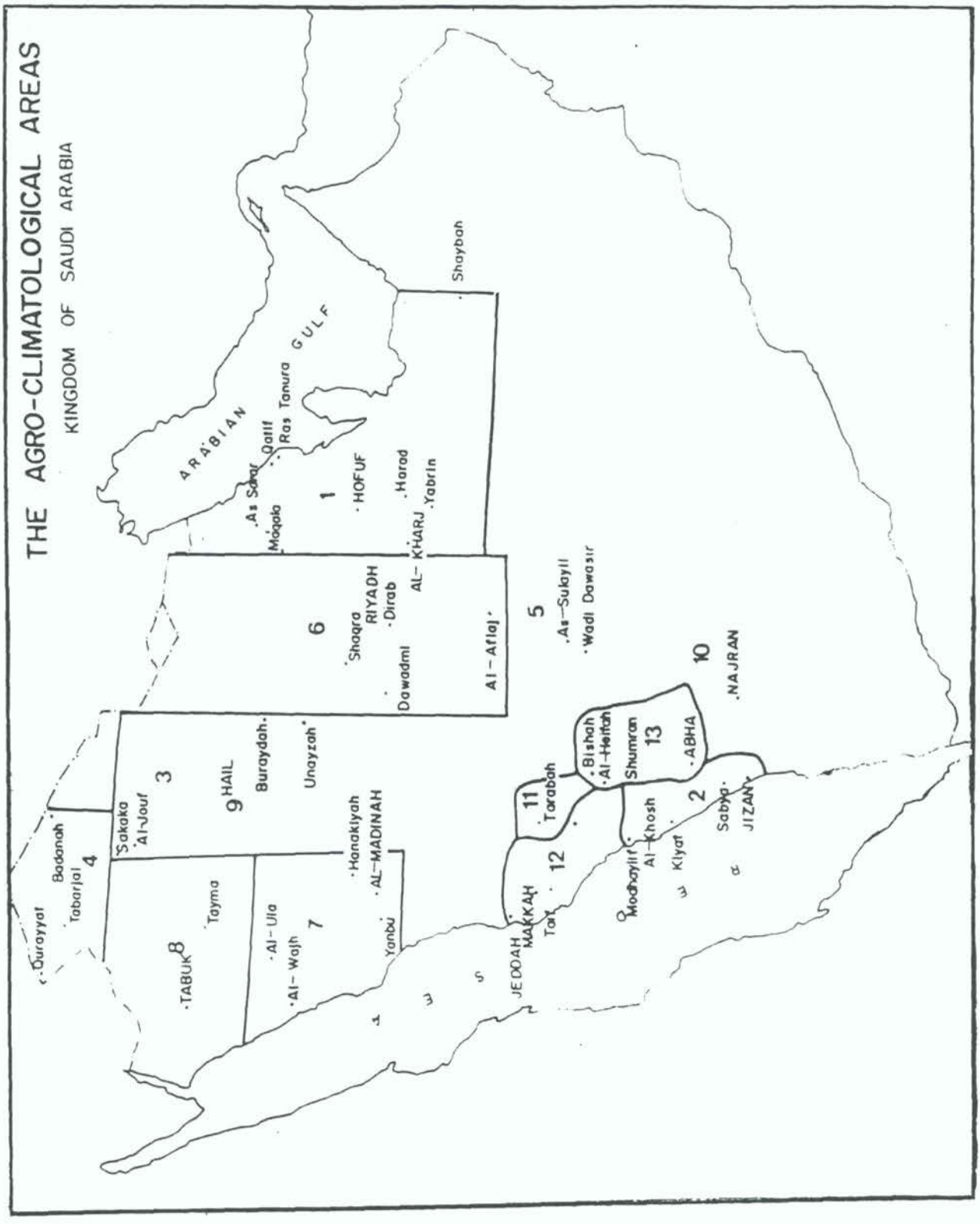

Figure (2): Map of Agro-climatic Areas in Saudi Arabia.
Source: Al-Zeid et al (1988).

Tabel (1) Agro-Climatological Areas in Saudi Arabia

Area	Altitude	Latitude	Longitude	Agricultural Areas
1	5-450	23.3-28.4	48.1-50.1	Hofuf, Shaybah, Yabrin, Uthmaniyah, Haradh, Qatif, Ras Tanurah, As-Sarar, Rafha, Qaysomah, Ras Safaniyah, Ras Al-Khafji, Maqala, Dhahran
2	20-350	17.0-19.5	41.0-42.9	Jizan, Malaki, Sabya, Kuyat, Al-Khoush, Mudhaylip
3	574-724	26.1-30.0	40.2-44.0	Sakakah, Al-Jouf, Unayzah, Buraydah
4	549-566	30.5-31.3	37.0-41	Tabarjal, Badanah, Qurayyat
5	550-600	20.5	45.6	As-Sulayyil, Wadi Dawasir, Khamasin
6	430-930	22.2	44.4-47,4	Al-Kharj, Aflaj, Dirab, Dawadmi, Riyadh, Khurais, Zilfi, Shaqra, Hutat-Sudair
7	590-820	24.5-26.6	37.8-40.5	Al-Madina, Yanbu, Hanakiyah, Al-Ula, Al-Wajh
8	771-820	27.6-28.4	36.6-38.5	Tabuk, Tayma
9	744-988	25.8-27.5	41.6-42.2	Hail, Uqlat Suqoor
10	1200-1300	17.5	44.2	Najran
11	1020-2400	19.9-21.2	41.7-42.6	Tarabah
12	1500-1530	21.3-21.6	40.4-40.5	Taif, Wadi Aradah, Hema-Saysid, Jeddah, Sayl Al-Kabir
13.	2100-2600	18.2-20.1	41.3-42.6	Shomran, Bishah, Al-Heifa, Al Mindak, Serat-Ubida, Abha, Sirlasan

* source : Al-Zeid et al (1988)

Table (2) Climatic Conditions in Different Areas in Saudi Arabia, 1976 to 1982

Areas	Mean Temperature Max. C°	Mean Temperature Min. C°	Rainfall MM/Year	Relative Humidity	Wind Speed km/day	Annual ETO*mm	Characteristics
1	27.6	23.3	87.8	44.6	182	2472	desert
2	31.5	27.2	213.0	56.4	166	2445	inland, hot moist
3	25.8	11.2	57.4	34.6	175	2489	inland, hot, dry
4	21.8	18.8	37.0	36.3	244	2466	inland, hot, dry
5	20.2	16.7	26.2	27.5	219	2517	cool, moist
6	27.0	22.6	87.4	32.8	159	2445	inland, hot, dry
7	28.2	24.3	23.6	31.0	307	3190	coastal mountainous, hot, moist
8	22.7	19.0	33.9	38.6	194	2308	inland, hot, dry
9	25.0	21.3	101.9	35.0	195	2499	inland, hot, dry
10	24.4	21.9	77.6	35.0	97	2083	mountainous cool, dry
11	25.7	23.1	93.7	36.6	136	2257	mountainous cool, dry
12	23.5	21.2	101.0	43.4	237	2480	inland, cool dry
13	19.0	16.2	272.0	54.0	169	1811	inland, mountainous cool, dry

* Source: Al-Zeid et al (1988)

* ETO - Reference crop evapotranspiration

air temperatures were marked. The highest temperatures were registered at lower elevations and vice versa. This trend was, however, slightly altered with the secondary effects of latitude, relative humidity and windspeed.

The integrated effects of temperature, humidity, windspeed and sunshine hours are reflected on the calculated reference crop Evapotranspiration (ETO).

The area affected with the hostilities is within the north-eastern part of the country i.e. within area No. 1 and part of area No. 6 exhibited in the above-mentioned Agroclimatic map (Fig. 2).

2.2.3.2 Climate of the region of hostilities

The climate of the region has wide extremes of air temperatures ranging from absolute minimum of -4°C to absolute maximum of 49.8°C. The average monthly means range from 12.4°C in January to 39.3°C in July. The climatic data obtained from Dhahran and Qaisumah represent the climatic conditions prevailing in the region (Fig. 3).

The rainfall in the region could be described in terms used by the native Bedouins (Batanouny 1991). They distinguish between two seasons of rainfall: Shita and Saif. Shita is an Arabic word for winter and it denotes the rain during the period November to Mid-March. Saif is an Arabic word for summer and is used to refer to the rain during the period from mid-March to May. This division is quite true and could be evidenced from the study of the rainfall at Qaisumah (Fig. 3).

Rainfall in the region exhibits considerable irregularity from year to year. It ranged from 67.7mm to 190.6mm at Qaisumah. The monthly rainfall may reach high values in some years, e.g. in April 1986, the rainfall at Qaisumah amounted to 82.0 mm. Occurrence of considerable amounts of rainfall on one day is not infrequent; an amount of 49.5 mm fell on April 17, 1986 at Qaisumah.

The climatic diagrams of two stations in the region, namely Qaisumah and Dhahran show that the climate of the area is of the arid type (Fig. 3). One should not forget the role of run-off due to topographic irregularities. The irregular topography helps in redistributing the rain water, low parts regards local topography receive runoff water and soil sediments. Hence, these sites support vegetation which might be relatively denser than slightly elevated sites.

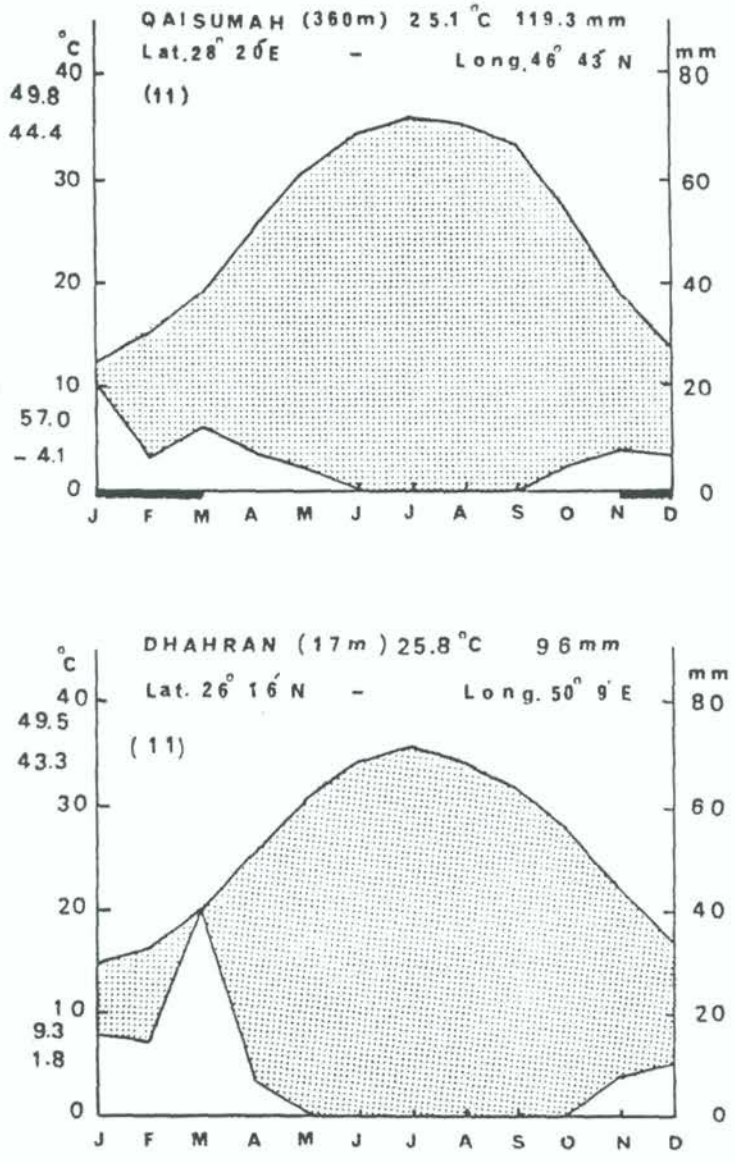

Fig. (3) Climate diagrams of Qaisumah and Dhahran

2.2.4 Soils

Most soils in Saudi Arabia (Ashraf, 1991) have not had much development due to dearth of moisture. In that sense they could be considered immature or young soils. Wind-blown soluble salts, gypsum and calcium carbonate are still being added to the soils faster than they are removed.

About one-third of the area is sandy deserts consisting of high sand dunes, which are not stable and are kept on the move by strong winds. Although small isolated areas of these soils (Torripsamments) could be found in most regions, their large extents are in Ar Rub Al Khali and Nafud deserts. Narrow strips of beaches on both eastern and western coasts also have sandy soils (Udipsamments) that remain wet and have high water-table.

Bulk of the soils, distributed all over the Kingdom, are loamy and are shallow to deep over bedrock (Torriorthents). They are non-saline to strongly saline and occur on gentle to steep slopes, which are actively eroding.

In narrow plains representing wadis or alluvial plains of intermittent streams, the soils are stratified with layers of varied materials deposited by water in different floods. They are deep and are dominantly sandy loams (Torrifluvents). Some are gravelly sands.

In a small area (Al Hasa plain) there are deep, non-saline, homogenized loamy soils (Eutrochrepts) in a low plain watered by many fresh-water springs. Some patches have high water-table, and there the soils are wet (Haplaquepts).

All the soils in the Kingdom are calcareous because there is not enough rainfall to leach out the carbonates. However, in some soils there has been partial redistribution of lime, resulting in its concentration in some layers. The soils (Calciorthids) having such layers are mostly loamy or sandy and are deep to moderately deep. They are well drained and slightly to strongly saline. Their content of carbonates is generally 10 to 15 per cent in sandy soils and 15 to 40 per cent in loamy soils.

Considerable area, locally in vast plains, has soils (Gypsiorthids) with high contents of crystalline gypsum. In some of them there is a hard gypsum pan that cannot be penetrated by plant roots.

Mostly in northern and eastern parts of the country there are many closed basins (sabkhas) which receive run-off from adjacent lands but do not have any drainage outlet. Here, the water-table is high and the soils are severely saline (Salorthids) and have a salt crust on the surface.

In terms of major environmental hazards, about 40 per cent of the land is affected by soil salinity; in about two-thirds area there is a hazard of deflation (wind erosion) or deposition of wind-blown sands, and almost all the sloping lands are subject to erosion by water. Only small areas at high altitudes in Asir mountains are terraced for cultivation.

As to the soils' suitability for farming, nearly half of the land is arable. Only a part of it, having water available for irrigation, is actually usable for cultivation.

Soil Mapping Units

A generalized soil map of Saudi Arabia at 1:1 million scale was prepared by the Kingdom of Saudi Arabia, Ministry of Agriculture and Water, Land Management Department. This was a project executed under the United States - Saudi Arabian joint Commission on Economic Cooperation, 1985. The soils were described and classified at the Great Group level according to the United States System of soil classification. The soil map comprises several sheets. A total of 49 mapping units were recognised. Of these, only 11 important mapping units cover those parts of the Eastern Province where the soils were subjected to war activities. They are briefly described in Appendix 5.

2.3 Biota

2.3.1 Fauna

Saudi Arabia is a wide country with various biogeographical regions. The concerned zone, i.e. the eastern region, is inhabited by numerous animal species. It is not easy to give a list of the species recorded only in this region. Generally, the "Mammals of the Arabian Gulf" written by Harrison (1981) gave descriptions of some mammals recorded in all Gulf countries including the eastern zone. The same author (1964, 1968 and 1972) records the mammals of the Kingdom of Saudi Arabia. Since 1979, 8 volumes of the "Fauna of Saudi Arabia" appeared so far. They comprise numerous articles on the various animal groups in the Kingdom. However, the main concern of these volumes are the insects, with some articles on reptiles, birds, rodents and other mammals.

A complete review of the literature dealing with the fauna of the country is beyond the terms of this study. However, mammals are among the groups affected by the war activities and could be endangered. Following is a group of

animals which the records of mammals in the eastern region of Saudi Arabia show:

Order Insectivora
- Suncus murinus (Indian house shrew)
- Paraechinus aethiopicus (Ethiopian Hedghog)

Order: Chiroptera (Bats)
- Rhinolopus clivosus (Arabian horseshoe bat)
- Pipistrellus kuhli (Kuhl's pipistrelle)

Order: Carnivora
- Mellivora capensis (Honey badger)
- Canis lupus (Wolf)
- C. aureus (Asiatic jackal)
- Herpestes edwardsi (Indian grey mongoose)
- Hyaena hyaena (Striped hyaena)
- Acinoryx jubatus (Cheetah)
- Vulpes vulpes (Red fox)
- V. ruepelli (Ruepell's fox)
- Fennecus zerda (Fennec fox)
- Felis silvestris (Wild cat)
- F. margarita (Sand cat)
- F. caracal (Caracal)

Order: Lagomorpha
- Gazella gazella cora (Mountain gazelle)
- Gazella subgutturosa marica (Arabian sand Gazelle)
- Lepus capensis (Cape hare)

Order: Rodentia
- Hystrix indica (Indian crested porcupine)
- Jaculus jaculus (Lesser jerboa)
- Acomys russatus (Golden spiny mouse)
- Nesokia indica (Short-tailed bandicoot rat)
- Ratus norvegicus (Brown rat; Norway rat)
- R. rattus (House rat; Black rat)
- Mus musculus (House mouse)
- Meriones crassus (Sundevell's jird)
- M. libycus (Libyan jird)
- Psammomys obesus (Fat jird)
- Gerbillus cheesmani (Cheesman's gerbil)
- G. nanus (Baluchistan gerbil)

For the whole country, the World Conservation Monitoring Centre has recently stated (WCMC, 1991) that their data base lists 60 mammalian species from Saudi Arabia. Among the extinct species recorded in the eastern region is the Asiatic cheetah (Acinoryx jubatus venaricus).

The birds recorded in east Saudi Arabia and given by the report of the same organization (WCMC, 1991) are:

Marmaronetta angustirostris	(Marbled Teal)
Haliaeetus albicilla	(White-tailed Eagle)
H. leucoryphus	(Pallas's Fish Eagle)
Aegypius monachus	(Black vulture)
Aquilla heliaca	(Imperial Eagle)
Falco naumanni	(Lesser Kestrel)
Chlamydotis undulata	(Houbara Bustard)
Crex crex	(Corncrake)
Chettusia gregaria	(Sociable Plover)

The reptile fauna of the country is rich. Around 65 lizard species and more than 25 snakes occur in the country.

Three lizards (Stenodactylis khobarensis, Acanthodactylis haasi and A. gongrorhynchatus) are largely restricted to the north-east of the Arabian peninsula; the Stenodactylus occurs mainly on coastal mudflats.

2.3.2 Flora

The flora of the country has been attracting the attention of many scientists since the Danish Expedition in 1762. Since the publication of "Flora aegyptiaco-arabica" written by Forsskal and published by Niebuhr in 1775, a tremendous number of publications on the flora of the country appeared (Batanouny 1978, 1987 and 1990). An illustrated Flora of Saudi Arabia was written by Migahid (1990). Recently, Mandaville's Flora of the eastern province appeared with coloured photos and good keys (Mandaville, 1990).

It is interesting to state that the flora of the eastern province, where the war activities took place, is characterized by the lack of trees. Only a few shrubby plants occur in this region: These are Leptadenia pyrotechnica (Markh) Ziziphus nummularia (Sidr), Tamarix spp. (Athl) and Lycium shawii (Awsaj). Human activities have affected these shrubs drastically, either due to grazing or cutting of these plants for firewood.

The region is famous for its rangelands and range plants. In the Summan, the common Rhanterium epapposum forms a widespread community.

Panicum turgidum is a common sand-binder palatable grass. The plant has been eradicated from many places. This is caused by overgrazing and the change of proper habitat conditions for its growth. The plant occurs in many sites in the concerned region.

Artemisia herba-alba is a perennial plant reputed for its value as a grazing plant. It has been deteriorating and its habitats destroyed.

Hammada elegans is a succulent chenopod which flourishes in late summer and early autumn. It is eaten by camels.

An important group in the area is the succulent chenopods, usually known by the Arabs as "Hamdh". Some of these represent good fodder for camels e.g. Seidlitzia rosmarinus on the coastal dunes.

In addition to this halophyte, there is another halophytic grass, Aeluropus littoralis (Ikrish). This grass is palatable to camels. It grows on the saline mud flats along the coast of the Gulf.

Ephemeral species represent the major group of plants in the desert flora. The common ephemerals in the region include Stipa capensis (Sama'a), Plantago boissieri (Reblah), Schismus barbatus, Neurada procumbens (Sa'adan) and some Medicago spp.

An interesting plant which appears in summer in the region is Chrozophora plicata. It is flourishing and flowering in late summer. It is non-palatable and occurs in some sites of the Stipa capensis community.

The Dahnaa has its particular flora, mainly of psammophytic plants. these include the following:

Calligonum comosum	(Arta)
Stipagrostis scoparia	
S. plumosa	(Nassi)
Artemisia monosperma	(Aa'der)
Scrophularia hypericifolia	
Pituranthus triradistus	(Gazzooh)
Cyperus conglomeratus	(Thandah)

One of the interesting ephemerals in the area, especially in Summan is the sweet-scented Horwoodia dicksoniae. The plant is eaten by camels, sheep and goats.

2.3.3 Vegetation

Studies on the vegetation in Saudi Arabia are mainly of reconnaissance type and are far from complete. Studies in the eastern region include the works of Giacomini and De Marco (1975) and Batanouny (1990 and 1991).

The following plant communities could be recognised in the area, each is given the name of the dominant species.

1. Seidlitzia rosmarinus: coastal dunes.
2. Leptadenia pyrotechnica: non-saline coastal dunes.
3. Hamada elegans: on degraded land.
4. Rhanterium epapposum: on sandy soils.
5. Artemisia herba-alba: on sandy calcareous soils in the Summan.
6. Ziziphus nummularia: in depressions with fine sediments in the Summan.
7. Calligonum comosum: on the Dahnaa sand dunes.
8. Scrophularia hypericifolia: on the Dahnaa sand dunes.
9. Artemisia monosperma: on the Dahnaa sand dunes.
10. Stipagrostis plumosa: in sandy plains.
11. Cyperus conglomeratus: on coastal and inland dunes
12. Avicennia marina: a mangrove community along the coast.
13. Aeluropus littoralis: a salt marsh coastal community.
14. Tamarix spp: in saline depressions.
15. Haloxylon ammodendron: on deep sands.

Important communities dominated by ephemeral plants include:

1. Stipa capensis: on level degraded land as Dibdiba, and Hafr El Batin area. It covers extensive areas north of the road from Nairyah to Hafr El Batin till the Kuwaiti frontiers. It extends in Kuwait.
2. Horwoodia dicksonia: in depression in the Summan.
3. Plantago boissieri: on deep sandy soils, usually associated with Rhanterium epapposum.

2.4 Socio-economic Indicators

Saudi Arabia is considered as one of the rich countries. With its population of 11.542 million in the year 1985 (AOAD, 1987) and 2.24 million square kilometer area is a well-balanced combination of land, population and natural resources. The performance of the economy showed during the last five year plan (1405 - 1410 H, 1985 - 1990)

large developments, especially in the agricultural sector. Self sufficiency in wheat, table eggs and milk was achieved.

The Gross Domestic Product (GDP) is estimated to be 99,618 million US$ in the year 1985 (AOAD, 1987) and the GDP per capita share is 8,631 US$ annually. Recent figures are, however, not available. But a large increase in GDP is expected as the oil production has more than doubled recently and the agricultural developments are performing well.

2.5 Land use

The area of Saudi Arabia covers 2.24 million square kilometer or 224 million hectares (AOAD, 1987). The major land use is for natural grazing. The area of rangeland represents about 75 percent of the total land area (Ministry of Agriculture, 1988) and is estimated to be about 120 million hectares (Al-Hassan, 1991).

The vegetation in this area provides major feed source for livestock raised in Saudi Arabia. The latest statistical figures (Al-Mutairi, 1991) indicate that in 1989, 9.01 million sheep, 4.45 million goats and 604.8 thousand camels depend mainly on these rangeland. Cows (197.7 thousands) depend partially on the rangeland and poultry (215.8 million) are fed on cultivated and imported feed.

Cultivation of different crops utilized in 1989 (Al-Mutairi, 1991) 1.162 million hectares of irrigated and rainfed agricultural land. Cereal crops represented the major commodity cultivated, occupying 0.84 million hectares, out of which 0.72 million hectares were cultivated to wheat. Forage crops were second to the cereals being 0.137 million hectares. Vegetable crops and fruit trees followed with 100.8 and 84.5 thousand hectares respectively. Forests and woodlands occupy 225 thousand hectares (AOAD, 1987).

The land use in the hostility area is exclusively for range purposes, as intensive agricultural activities are very limited in this region.

2.6 Institutional Set-up

2.6.1 Policy relating to protection of the environment

The Meteorology and Environmental Protection Administration (MEPA) was established by Royal Decree 7/M/8903 in 1401 H to serve as the national environmental agency of the Kingdom of Saudi Arabia. Since its creation, the agency has been active in expanding the Kingdom's environmental infrastructure and in creating a national

awareness of environmental matters. Emphasis has been placed on creation of institutional infrastructure to insure inclusion of environmental management into the national development process. These accomplishments are most clearly demonstrated in the expansion of activities carried out by the agency under the guidance of the Environmental Protection Coordinating Committee, and the Ministerial Committee on Environment.

2.6.2 Implementing Institutions

Implementation of environmental protection functions is the responsibility of the Meteorological and Environmental Protection Administration (MEPA). The agency is composed of three general directorates, the National Meteorological and Environmental Centre (NMEC), the Environmental Protection General Directorate (EPGD) and the General Directorate for Administration.

Chapter III

War Impact Identification and Evaluation

3.1 War Activities

3.1.1 General

The war activities in Saudi Arabia were mostly limited to the Eastern Region except for a few scud missiles which caused some damage in Riyadh. The activities which acted and impacted directly on the various components of the environment in this region include:

(i) Off-road vehicle traffic;
(ii) Camping and defensive constructions;
(iii) Desert Combat;
(iv) Limited rocket shelling;
(v) military manoeuvers.

Apart from these five types of activities, the terrestrial ecosystems were affected, some seriously, by the results of war activities outside the Saudi Arabia boundaries. These include the results of destruction of oil wells and oil storage or refinery facilities in Kuwait and Iraq. Smoke clouds from oil well fires with its soot content and oil spills to the shores of the country were the most damaging agents.

The consequences of war activities on the vegetation include direct and indirect effects. The direct effects are mainly represented by the mechanical removal of the plants. The indirect effects are tremendous and may last for decades. They act on the plant life through their direct and indirect impact on the soil attributes. The different activities have left physical scars on the terrain surface. The tremendous number of track and wheeled vehicles have disturbed the soil surface which could be seen as ruts and trails criss-crossing the desert. Bunkers, ditches and tunnels have caused the disturbance of the soil creating craters and embankments. The surface of the country is stippled with innumerable craters, embankments, scars and ruts. This has disturbed the soil to a considerable measure. It created new microhabitats. Deep ruts may channel water. Such a change in soil condition and water resources inevitably leads to the appearance of some species with greater density and the disappearance of others or at least the decrease of their abundance. Craters would support denser vegetation, especially of the ephemerals in the coming wet season.

In some sites, the war hostilities might create a diversity of neighbouring microhabitats. This leads to the

appearance of different species in these habitats. This might be the case with craters, trenches and ditches. It has been observed that the sand and deposits removed to dig these ditches have been inhabited by a dense growth of ephemerals in the last wet season.

However, in other sites, the manoeuvers and off-road vehicles caused severe compaction or loosening of the surface soil. The soil has been subjected to severe erosion. Hence, there will be no chance for the growth of plants either in compacted habitats or in eroded ones.

The biodiversity is apt to be changed due to the war activities. Some species might gain prominence, while others will be drastically damaged. Such changes in the biodiversity will continue by the the continuation of the different impacts on the environment. Creation of new habitats with different species composition, will be changed to other habitats by the processes of mine clearing.

One of the major components of the desert ecosystem is the natural seed content of the soil, the so-called seed bank. These seeds represent the assets from which the future vegetative cover comes. It is enriched, usually every year by the seed rain which is not constant due to the irregularity of the rainfall. The disturbance which happened to the surface deposits, which supports the seed bank, will lead to the burial of numerous seeds. This inevitably leads to the decrease in the number of emerging seedlings in the next season. In other sites, the disturbance of the soil surface might expose seeds to shallower depths which enhance their germination. It is expected that the potentiality of the seed bank will be changed, either to the positive or to the negative side. This depends on the local topography, soil type and the activities. Changes in the rates of runoff resulting from the changes in soil attributes and the microrelief, will cause a considerable change in the redistribution of plant growth in the different newly created microsites.

3.1.2 Off-road track-vehicles, tanks, military manoeuvers and other activities

Field observations, both on land and from air, showed that the whole region has been adversely affected by the off-road vehicles, tanks, military excercises, manoeuvers and other activities. Bunkers and digging trenches and establishment of earthen embankment are tremendous in the area, especially to the west and the north. It is hardly possible to find an area 100x100 m without dissection of the trails of vehicles and tanks or any other activity.

It is to be noted that the area before war has been subjected to severe grazing and its concommitant results.

The off-road vehicles used for transportation of animals, food and water were also common in the area. These have had drastic effects on the soil, plant and animal lives (cf Batanouny 1991). However, the unprecedented military activities in such a limited area aggravated the previous effects and added to them more damaging processes.

Digging the soil for trenches, bunkers and embankments has disturbed the soil in extensive areas. This activity was performed before the war also for getting building materials and quarrying. The new war activities damaged the soil and the desert biota in vast areas.

3.1.3 Shelling, bombing and mines

These kinds of war activities were limited in number and intensity in the eastern region of Saudi Arabia. Consequently the impact has not been very extensive.

3.1.4 Fallout of soot

Field observations showed that the area strongly affected by soot could be demarcated as follows: The area falling south of Saudi/Kuwaiti borders and to the east of a line passing through Nairyah down to Dammam and parallel to the Gulf coast. The effect is more conspicuous as one proceeds northwards towards the Saudi/Kuwaiti borders. To the west of the line given above the soot effect is probably decreasing. It shows a gradual decrease as one proceeds to the west. The black and blackish tainting of the plants, animals and the soil faints as one goes westwards.

The chart forecasting smoke concentration at 1000 ft. height for September 1-3, 1991, Fig. (4) shows that the highest smoke concentrations lie within the area near the Gulf coast and decreases westwards and southwards. Of course, this might not be the case on other days depending on the wind direction. However, the prevailing wind direction in the region is N and NW. In other words the soot fallout will be mainly occuring near the Gulf. Areas far away to the west or south might be affected, but to a lesser degree than the area defined east of the line passing through Nairyah. This would help in concentrating studies and monitoring of the soot effect within this area. Of course, areas in Kuwait around Wafra receive considerable amounts of soot also.

3.1.5 Oil Spill on Coastal Sebkhas

"National Report on oil and air pollution" (MEPA, 1991) stated that a significant amount of oil was released into the waters of the ROPME Sea area. It has been estimated that at least 6 milion barrels of oil were released. Until late

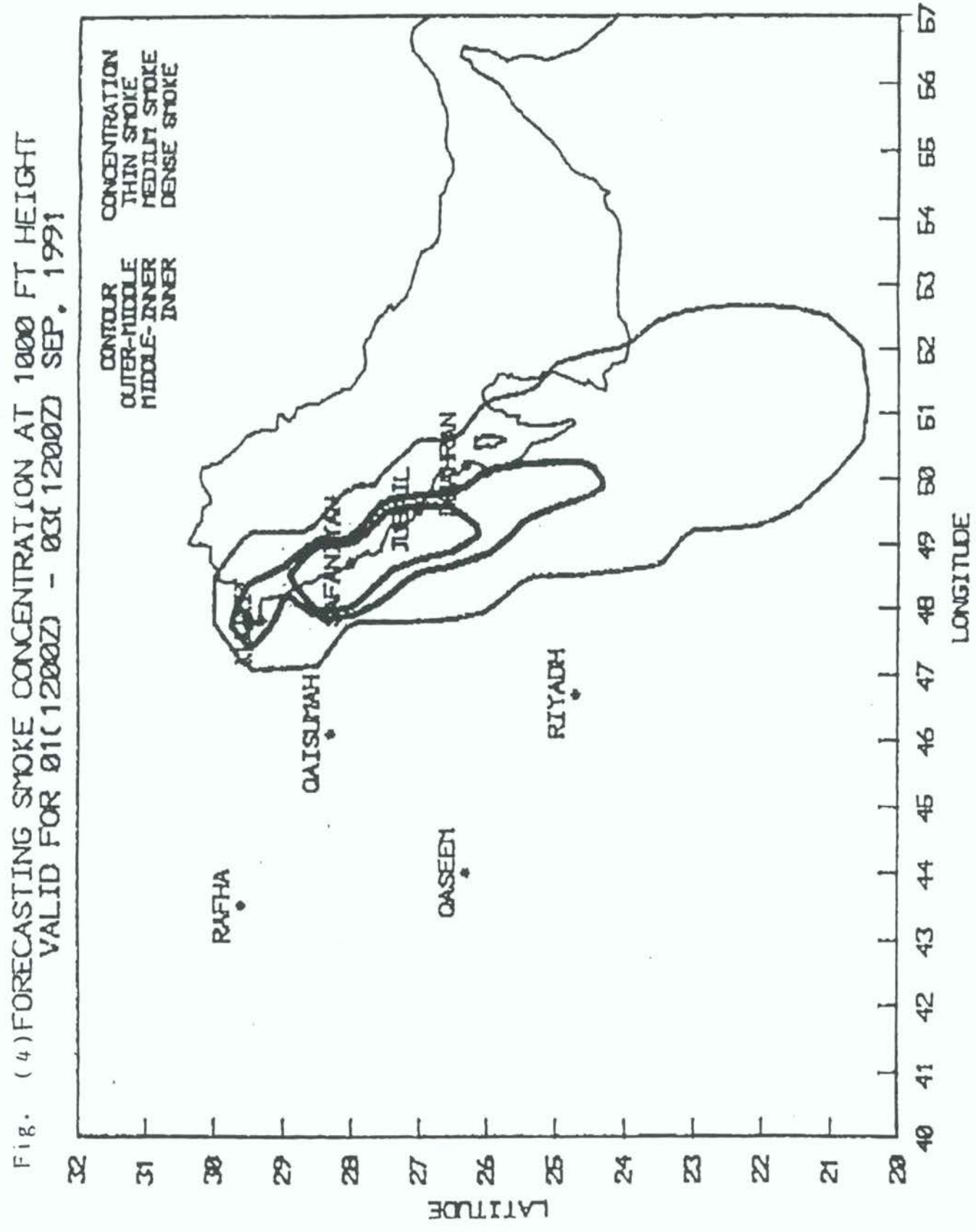
(4)FORECASTING SMOKE CONCENTRATION AT 1000 FT HEIGHT
VALID FOR 01(12000Z) - 03(12000Z) SEP. 1991
CONTOUR
OUTER-MIDDLE
MIDDLE-INNER
INNER
CONCENTRATION
THIN SMOKE
MEDIUM SMOKE
DENSE SMOKE
QAISUMAH
RIYADH
QASEEM
RAFHA
LATITUDE
LONGITUDE

Fig.

April, the report states that an estimated additional 3000 barrels of oil continued to be spilled daily.

The released oil adversely affected the shoreline. The inter-tidal and supra-littoral (above normal tide heights) zones have been very heavily impacted. The MEPA report shows that oil has been driven by wind and high tides into the most distant reaches of the salt marshes.

3.2 Environmental Components and kinds of Impacts

For the sake of clarity and simplicity, impact identification has been stipulated in a series of 9 tables (3 - 11). This will facilitate observation of the nature of impact as well as an assessment of its damage. This assessment has been added in these tables to avoid repetition and enable a complete comprehension of the act. With the exception of very few, the nature of these impacts are all negative.

3.3 Qualitative Judgement on Nature, Level and Duration of Impact Results

3.3.1 Impact on Plants

Effect of Soot

As previously mentioned, the severely affected area by soot is that lying between the Gulf and a line parallel to the Gulf coast and passing through Nairyah. The plants in this area are represented by the following groups:

Halophytes (Salt-marsh plants) occupying the saline habitats along the coast as well as salinized inland areas. Among these plants one mentions:

Aeluropus littoralis (Ikrish): a grass palatable to camels. The effect of soot is quite clear. However, this plant is able to regenerate due to its underground perennating rhizomes. Being covered with dense soot layer, its palatability is reduced.

Suaeda vermiculata (Shnan): a succulent palatable plant. It is severly affected, especially on the coastal dunes of Al-Khafji. More than 50% of the individual plant was dying due to the effect of soot. The leaves became dark and wrinkled.

Binertia cycloptera is flourishing during this season. However, the soot covers the leaves and affects their vitality.

Plants on the sand

These include different groups of plants including psammophytes. Among the plants observed in the area one mentions:

Rhanterium epapposum (Arfaj). It is a perennial undershrub. The majority of the plants seen are overgrazed. In some sites near Kuwait borders, the plants are densely covered with soot and they have lost their vitality. They have fragile dry branches. When falling of soot stops, it is expected that the perennating rootstocks of this plant would regenerate. Being one of the plants dominating a plant community with considerable range potentialities, the continuation of the soot effect will inevitably diminute its range capacity.

Hammada elegans (Rimth): a succulent chenopod palatable to the camels. Despite the season of flourishing and flowering of this plant, there is no evidence of these activities in the area affected by soot. In many sites, the plant is overgrazed and covered with soot and is unable to regenerate. Individuals of this species in the western sector of the region are performing quite well; they are not affected with soot.

Cenchrus setigerus, a grass which has been affected drastically by the soot. The seed productivity seems to be reduced. It is expected that the vitality of the produced grains will be lowered.

Lycium shawii (Awsaj); this shrub shed its leaves as a result of soot fallout. Naturally, this affects its productivity and its ability to flower and give fruits. The red small fruits of this plant are edible by the houbara bustard and even by man. The fruits are known as Mossa'a in Arabic.

Plantago boissieri (Rablah). This is a very common plant in the area. Its distribution extends from Iraq to Saudi Arabia, through Kuwait. It is a good fodder for animals and grows usually associated with the community dominated by Rhanterium. The plant exhibits a dense growth with considerable plant cover. However, the leaves and spikes of the plants are covered with soot. The degree of the soot effect exhibits a gradual decrease as one proceeds to the west from the Gulf and to the south from the Kuwaiti borders. This has been quite evident by observation and by testing seed productivity. The plants near Khafji produced no seeds. The number and the size of the seeds increase as one goes away from this severely affected area near Khafji. Even to the west, away from the effect of dense soot, some Plantago individuals have some green leaves. It might be

expected that the soot interferes with the pollination and/or fertilization processes.

In general, the soot fallout reduces the productivity of plants as a result of many factors, including minimizing the light reaching the chloroplasts in the assimilating organs, decrease of gaseous exchange, interference with matabolic activities as well as pollination and fertilization (Table 3).

3.3.2 Impact of Oil Spills

Salt marsh plants and mangroves are the two groups of plants affected by the oil spills. The MEPA report (May 1991) states that within 520 km of impacted coastline, only two patches of salt marsh (representing less than 5% of the salt marshes) have remained un-oiled. The report stated that all the mangroves (Avicennia marina, Girm) have been oiled. The same report stated that the oil has permeated into the sediment on the beach to a depth of 2-30 cm and in many areas clean windblown sand has been deposited naturally on top of the oiled area. This is the reason that many exposed beaches do not appear from the air to have been oiled.

The smothering of plants covered with oil will lead to their death. However, shallow oil might not be detrimental to some plants, especially those with perennating underground organs. It is expected that the pneumatophores of Avicennia will be severely affected and exchange of gases through lenticels clogged with oil will be stopped.

3.3.3 Impact of on-land Military Activities

The impact of off-road track-vehicles, military excercises etc. on plant life is usually indirect apart from the direct damage of the plants due to their impact on the soil physical properties (texture, structure, depth)and the soil-water relationships (water holding capacity, the amount of water in the soil profile, moisture equivalent etc.). The attributes will evidently affect the seed germination, the availability of water to the plants and the root extension and consequently the productivity of the plant (Table 4).

Soil erosion (wind and/or water) enhanced by the military activities resulted in the disappearance of the perennial plant cover in many areas. In the Dibdiba and Summan, the perennial plants are disappearing in many sites. The land supports in many cases only growth of Stipa cepensis (Sama'ah). Even the ephemeral growth of Stipa exhibits discontinuous patchy growth. This is due to the severe disturbance of the soil and the growth of Stipa is confined to sites with thin veneer of fine deposits. Such

TABLE (3) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE FLORA IN SAUDI ARABIA 32

Serial No.	Activities/ and Factors	Nature of the Impact on Plants	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.g	Soot, air-borne pollutants	Change of metabolic activity. Decrease of productivity and seed production. Affect the pollination and fertilization	x	x	x	x *	x	x *

* Only in cases of excessive deposition of soot and air-borne pollutants.

TABLE (4) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE FLORA IN SAUDI ARABIA 33

Serial No.	Activities/ and Factors	Nature of the Impact on Plants	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.b	Desert combat, bombing, shelling and explosion of mines	Change of habitat conditions, disturbance of seed bank.	x	x	x		x	
		Direct killing	x			x		x
3.2.a	Bunkers, ditches, trenches and embankments	Direct destruction, change of habitat conditions, creation of new niches and disappearance of others.	x	x	x		x	
3.2.b	Off-road vehicles and manoeuvers	Compaction of soil in some areas, removal of it from others leading to changes in vegetation and the floristic composition		x	x		x	
3.2.c	Camping	Compaction of soil, change of runoff. Changes in the floristic composition. Chance for appearance of ruderal plants.		x	x		x	
3.2.d	Wrecks (cars, trucks, tanks etc.)	Creation of niches for some particular plants, enhancing runnoff and change habitat conditions, shading of some sites		x	x		x	
3.2.e	Mines and live munitions	Protect the plants from grazing.	x	x	x		x	
		Their removal destroys plants and habitats.				x		x

result would inevitably diminish the range potentiality of the land by removal of perennial plant growth and the mosaic pattern of ephemeral growth.

The area represented by Dibdiba, Summan and Dahnaa, where extensive and intensive manoeuvers and activities took place, are reputed for their value as rangelands. During the field trips, thousands of camels and sheep were found grazing in these areas. However, the pastoralists were providing their animals with supplementary feed. The dry Stipa and Plantago can not support such big numbers of animals.

In the Summan, where depressions support a growth of Ziziphus nummularia , there has been observed a severe erosion of the soil. The mounds formed by the Ziziphus (Sidr) plants are reduced to a limited part and the spaces between the shrubs are covered by very compact clayey soil with no plant cover. Ephemerals and stunted perennials are confined to the sides of the mounds.

In the Dibdiba, due to the extensive digging of soil and sediments for building materials and road construction, the perennial plant cover disappeared. However, in low sites as regards local topography, fresh soil eroded from the neighbouring areas was carried by water to these sites. This is quite evident from the rill erosion along the margins of the dug hollows. In such sites, Hammada elegans grow. It might be expected that the establishment of bankers and embankment would give the chance for the growth of the perennial Hammada plants. This would be fulfilled if there is no overgrazing of the newly appearing seedlings.

In some sites of the Dibdiba, the plant cover increases with considerable numbers of perennial species. This is observed in runnels dissecting the plateau. It has been observed that many of these plants are non-palatable. A list of the species recorded in such a site is given below:

Chrozophora plicata - Astragalus sieberi - A. bombycinus - Anvillea garcini (nogd)- Citrullus colocynthis (Handhal)- Euphorbia granulata and dry ephemeral plants including Stipa capensis, Ifloga spicata and Filego spp.

Table (5) presents the impacts of various war activities on the fauna as well as the assessment of the damage inflicted. Table (6) identifies the effects of war activities on the frequency of dust storms in Saudi Arabia. Table (7) identifies the effects of war activities on the sand movement, Table (8) describes the effects of war activities on soil productivity. Finally, Tables (9), (10) and (11) describe the impact and presents an assessment for the damage done by soot and air-borne pollutants on the

fauna, desert food chain and on the soil productivity respectively.

TABLE (5) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE FAUNA IN SAUDI ARABIA

Serial No.	Activities/ and Factors	Nature of the Impact on animals	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.a	Desert combat, bombing, shelling & explosion of mines	Disturbance of habitat. Destruction of nests, burrows and tunnels. Change of habitat conditions. Disturbance in productivity.	x	x	x		x	
		Direct killing.	x			x		x
3.2.a	Bunkers, ditches, trenches and embankments	Disturbance of habitat. Creation of niches for particular animals and disappearance of some habitats.		x	x		x	
3.2.b	Off-road vehicles and manoeuvers	Disturbance, deprive many animals from their suitable habitats. Noise affect the activity of animals	x	x	x		x	
3.2.c	Camping	Destruction of habitats, creation of new conditions. Possible increase of rodents, scorpions.		x	x		x	
3.2.d	Wrecks (tanks, cars, etc.)	Create habitat conditions suitable for some animals, give shade for others and protect other groups.		x	x		x	
3.2.e	Mines and live munition	Keep small animals away from human impact. Removal disturbs the habitats.		x	x		x	

TABLE (6) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE FREQUENCY OF DUSTSTORMS IN SAUDI ARABIA

Serial No.	Activities/ and Factors	Nature of the Impact	Assessment of the Damage/Impact				
			Direct	Indirect	Temporary.	Permanent	Reversible	Irreversible
3.1.c	Desert combats; bombing, shelling and explosion of mines	Shattering and displacement of soil making it vulnerable to wind erosion. Increase of dust-load in duststorms. May increase the frequency of duststorms after the disappearance of the plume.	x	x		x		
3.2.a	Bunkers, ditches, trenches and embankments	Same as above	x	x		x		
3.2.b	Off-road vehicles and manoeuvers	Pulverisation of surface soil adding to dust-load of duststorms. May increase the frequency of dust-storms after the disappearance of plume.	x	x		x		
3.2.c	Camping	Soil disturbance and removal of vegetation; enhancement of dust-load of duststorms. May increase the intensity and frequency of duststorms after the disappearance of the plume.	x	x		x		
3.2.d	Wrecks (tanks, cars, etc.)							
3.2.e	Mines and live munition	Removal of mines would disturb soil and add to the dust-load of duststorms.	x	x		x		

TABLE (7) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE SAND MOVEMENT IN SAUDI ARABIA

Serial No.	Activities/ and Factors	Nature of the Impact	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.d	Desert combat, bombing, shelling and explosion of mines	Shattering and displacement of soil, susceptibility to wind erosion resulting in sand movement and blowing away of fine soil fraction.	x	x		x		
3.2.a	Bunkers, ditches, trenches and embankments.	Loosening and displacement of soil, vulnerability to increased wind erosion resulting in increased sand movement.	x	x		x		
3.2.b	Off-road vehicle movements and manoeuvers	Pulverisation and soil displacement leading to increased wind erosion and sand movement.	x	x		x		
3.2.c	Camping	Soil disturbance and removal of vegetation leading to increased wind erosion and sand movements.	x	x		x		
3.2.d	Wrecks (tanks, cars, etc.)	Piling of sand on leeward side of wrecked vehicles.	x	x		x		
3.2.e	Mines and live munition	Removal of mines would cause soil disturbance and render it susceptible to wind erosion and sand movement.	x	x		x		

TABLE (8) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON SOIL PRODUCTIVITY IN SAUDI ARABIA

Serial No.	Activities/ and Factors	Nature of the Impact	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.h	Desert combat, bombing, shelling and explosion of mines	Shattering and displacement of soil, destruction of soil structure; burial of normal soil with displaced soil debris; increased vulnerability to water and wind erosion.	x	x	x (long period)			x
3.2.a	Bunkers, ditches, trenches and embankments	Soil disturbance, burial of topsoil with unproductive substratum, exposure of hardpan or bedrock. Increased water and wind erosion.	x	x	x (long period)			x
3.2.b	Off-road vehicles movement and manoeuvers	Pulverisation of surface soil leading to increased wind erosion. Soil compaction leading to reduced permeability and water holding capacity; increased susceptability to water erosion.	x	x	x (long lasting)			x
3.2.c	Camping	Soil compaction and disturbance; pollution	x	x	x			x
3.2.d	Wrecks (tanks, cars, etc.)	Piling of sand on leeward side of wrecks resulting in burial of productive soil and vegetation with unproductive sand.		x	x			x
3.2.e	Mines and live munition	Mine clearance would involve soil destabilization leading to increased soil erosion.		x	x			x

TABLE (9) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE FAUNA IN SAUDI ARABIA 40

Serial No.	Activities/ and Factors	Nature of the Impact	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.i	Soot, air-borne pollutants	Affect the feathers, fleece and the skin. Ulcers appear on the skins of camels and other animals. Some animals died.	x	x	long period	x	x	could lead to death x

TABLE (10) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE DESERT FOOD CHAIN IN SAUDI ARABIA

Serial No.	Activities/ and Factors	Nature of the Impact on Desert Food Chain	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.k	Soot and air-borne pollutants	Considerable changes of the productivity of the ecosystem. Effect on the consumers.	x		x (over long periods)		x	
		Expect deterioration in the biological productivity due to soot.	x	x	x		x	
		Affect human health, as soot inhaled and ingested by grazing animals.						

TABLE (11) IDENTIFICATION AND ASSESSMENT OF THE IMPACT OF WAR ACTIVITIES ON THE SOIL PRODUCTIVITY IN SAUDI ARABIA

Serial No.	Activities/ and Factors	Nature of the Impact	Assessment of the Damage/Impact					
			Direct	Indirect	Temporary	Permanent	Reversible	Irreversible
3.1.1	Soot and air-borne pollutants	Contamination of soil with heavy metals e.g. nickel and vanadium; reduced aeration and permeability; incrustation with acid rain may hinder seed germination; increased run-off.	x	x		x		x

Chapter IV

Post-War State of Environment

4.1 General

In Chapter II, a description regarding the qualitative nature of certain environmental components before the start of war activities, was presented. It is now intended in this chapter to present an account of various changes - temporary or permanent, reversible or irreversible, which have been produced in various components of the environment. It may be stated that all the components discussed in Chapter II have not undergone change as a result of the war. For this reason, a component may not be included here because no change in its state was recorded.

A statement on the financial resources, however, seems necessary. Of the three countries whose territories were exposed to the war activities, Saudi Arabia was the least affected by the direct impacts. However, the indirect impacts of war in its affected areas are considerable and serious, especially on the marine ecosystems. The country underwrote a major chunk of war expenses incurred on the cost of fighting the war by the Allied forces, and on armaments, ammunition, supplies etc. Despite heavy burden of the costs of war, the country's financial resources are more than adequate to undertake mitigation measures and to start work on the rehabilitation of destroyed infrastructure and damaged ecosystems, both terrestrial and marine, simultaneaously.

The two major consequences of the war activities and hostilities in Saudi Arabia as far as the terrestrial ecosystems are concerned, are:

(i) Pollution of soil and biota by the soot and oil mist coming out of the exploded and burning oil wells in Kuwait towards the coastal belt and thus damaging the terrestrial ecosystems in the affected areas.

(ii) Soil disturbance in large areas of the coastal belt and in the northern parts of the eastern region mainly by off-road military vehicles, digging of bunkers and trenches, and raising of earthen embankments.

4.2 Climate

The clouds of soot and other suspended particles reported to affect the climate in Kuwait have and still are affecting the areas in the eastern region of Saudi Arabia

close to Kuwait. The north west winds carry the clouds of soot and the suspended particulates as far as Bahrain, Qatar and United Arab Emirates. The same effect on air temperature recorded for Kuwait, namely 4 - 10°C decrease of day air temperatures has been observed in the belt along the Gulf coast in the eastern region.

The incoming solar radiation to the soil and plants has been reduced due to the presence of soot clouds.

Blackening of ground surface was observed in large areas of rangeland in the eastern region. The blackening of the ground surface would have its effect on the heat budget and temperature conditions of the soils. The evaporation rate from the soil is also affected due to the soot and oily dust cover on the ground surface.

Changes in the air temperature have their impact on the air humidity, a factor which affects life in this area.

4.3 Soils

Soils in the war affected areas were exposed to both direct and indirect impacts. The direct impacts include soil disturbance (pulverisation of surface and compaction of the subsoil) by off-road vehicle movements. These also include soil displacement by sharp turning of vehicles and scraping of soil for making protective embankments around bunkers. The latter activity has exposed the hardpan occuring within shallow depth.

The soil disturbance was observed throughout the coastal belt from Jubail in the south to the Kuwaiti border and also throughout the As Samman and Al Dibdibah plateau regions extending to the border with Kuwait and Iraq. The disturbed soil is exposed to wind erosion. The sand movement will further increase in the coastal plain where sand dunes were active in a large area even before the Gulf war. The plateau areas have been exposed to increased deflation, which will increase the intensity of dustfall in other areas. Soil compaction will reduce the water intake and storage capacity of the soils.

The indirect impact of the war comprises the deposition of soot on the soil surface in the coastal plain. The affected area has been polluted by heavy metals to some extent.

4.4 Biota

4.4.1 Fauna

It is expected that the animal population in the areas close to Kuwaiti borders would change as regards kind of species, number of individuals and activity. The fallout of soot on plants and soil led the rodents to escape to enclosure sites. Considerable occurrence of rodents and/or reptiles with burrows and tunnels in these sites are obvious. This could be due to the presence of considerable amounts of animal droppings (organic matter and forage residues).

4.4.2 Flora

The floristic composition in severely affected habitats near to the borders with Kuwait and towards the Gulf has been changed. Plants able to regenerate will persist, others will decrease in density. The endangered species, already mentioned in the state of environment before the war, might be the only ones to be affected by war consequences.

4.4.3 Vegetation

The soot and oil mist affected the plants near Al-Khafji to a great extent. The plants died. Revegetation of such areas will take decades. The productivity and the seed production by plants were affected. This effect increases as one proceeds towards Kuwait and towards the Gulf shore. West of Naiyryah, the soot effect is gradually diminishing. It is expected that due to low seed productivity as a result of soot (may be due to failure of pollination and/or fertilization), the seed bank is reduced. The severe off-road vehicles to the west left no space for perennial plants to remain. This aggravates the damaging effect of grazing. The changes in soil conditions and run-off patterns as well as erosion have severe impacts on the vegetation. The already destroyed perennials due to human activities might reappear in some bunkers and ditches. The pattern of grazing and keeping animals in enclosures, a common phenomenon in the area, created habitats devoid of plants. Oil pools along the coast affected the salt marsh plants. These are good fodder plants, hence the range potentiality is affected. The most conspicuous impact is observed on the rangeland in the area; being affected by soot or degradation of the soil. Numerous herds of sheep and camels lack necessary food supply.

4.5 Socio-Economic Indicators

The impacts of the Iraq-Kuwait conflict on Saudi Arabia, although physically and environmentally limited to the eastern region (area of hostilities), is extended to several socio-economic parameters in the whole country.

The economic activity in the eastern region, mostly of private enterprise, is adversely affected as:

- Fishing is very much reduced because of oil spills.
- Animals production is badly affected due to forced migration of livestock and increased mortality due to unknown diseases.
- Escape of foreigh labour, especially from hostility areas, and thus shortages of services.

At the national level, the Kingdom had to bear sizeable share of the war cost. Although different figures for the cost of the Iraq-Kuwait war have been quoted, it was reported that Saudi Arabia contributed $16.5 billion. The Saudi contribution to war cost along with other commitments for upgrading the defence force at the national level and at the level of the Gulf Cooperation Council (GCC) of the Arab States of the Gulf will, in addition to the above mentioned factors, represent a heavy load on the Saudi economy.

4.6 Land use

The impacts of war on land use in Saudi Arabia are limited to the areas affected by military activities and/or affected by soot. The pattern of land use, however, will remain unchanged, namely grazing. The amount of biomass produced in the affected area will decrease as a result of:

- Direct killing of plants by manoeuvers of vehicles.
- Direct killing of plants by soot.
- Disturbance, and in some cases the destruction, of seed bank in the top soil.
- Compaction of the soil which in turn will lead to increased run-off. It will reduce available moisture in the soil profile.
- Reduction of biomass production due to soot and reduced availability of moisture in the root zone.
- The quality of vegetation will also be affected.

The above-mentioned factors will lead, if the numbers of grazing animals are not reduced, to further deterioration of rangeland.

The minor land use for crops, fruits, vegetables and forage production in the areas of the eastern region is also not expected to change. Some yield decreases might occur as a direct effect of soot, spread of rodents and other secondary factors. Productivity of agricultural land is, however, expected to recover within one to two agricultural seasons.

4.7 Institutional Set-Up

The Meteorology and Environmental Protection Administration (MEPA) continues discharging its responsibilities for environmental matters after the war. The scope of work has been widened by the developments after the war and rehabilitation of the extensively degraded environment requires further strengthening of the institutions charged with the responsibility.

Saudi Arabia is a large country endowed by nature with rich oil and mineral resources. The country has progressed tremendously in the past few decades by planning and construction of huge development projects. The experience of undertaking development at a massive scale is a great asset for repairing the damages caused to her terrestrial ecosystems. The country seems to have gracefully accepted the challenge of reconstruction after the war. The concepts of a healthy environment need to be given due consideration in the post-war rehabilitation of affected areas.

Chapter V

A Proposal for an Environmental Rehabilitation Programme

5.1 The Magnitude of the Problem

The Kingdom of Saudi Arabia, a rich land in mineral and oil resources, is a desert with fragile and degraded terrestrial habitats. A large part of the coastal plains and the desert plateaux located in its Eastern Province were exposed to a devastating blow by the Gulf war activities. It all started with an invasion of Kuwait, which was immediately followed by landing of the Allied forces to secure the evactuation of invading forces from Kuwait. The Allied forces spread out and dug in with the war machinery in the affected areas, which disturbed the normal life of people and exposed all the ecosystems to abnormal conditions. Farming, grazing, hunting as well as other out-of-town activities stopped while some hundred thousand soldiers spread out in the eastern zone. The beginning of the end came with the start of "the first war of the space age" as it was described by USA Air Force Chief of Staff.

A new phase of the war came into action on 17 January when the air raids, long distance missilies and rockets came into action. This was followed by days of fear and anxiety. Many of the local population and foreign labour fled from the war area. The long-distance missiles targetted far off places e.g. Riyadh and Dahran as well, and thus disturbed the normal life almost in the entire country.

The war activities and their immediate impacts were extensively described and widely publicised over the last few months. In short, they were seen in the form of vast oil spills in the Gulf, soot and pollutant gases filling the air, destruction of buildings in the border towns, and to a lesser extent in a few other cities. The affected landscapes were, and still are, littered with bunkers and ditches, and the soil and its biota got badly trampled with the war machine.

5.2 International Experience

5.2.1 The Marshall Plan

Before proposing an environmental rehabilitation programme it seems appropriate to recall international action under similar situations. At the end of the Second

World War almost every country in Europe suffered, apart from losses in lives, serious damage in its infrastructure, services network, social fabric and economic stability. The future looked bleak. America came forward with a generous proposal for assistance to Europe. American Secretary of State, General George Marshall in a famous speech at Harvard University, on 5 June 1947, presented his idea for a 'European Recovery Programme' (ERP) based on American aid. There were three essential points in the proposal:

"1. that there must be a request for aid from Europe (the USA had no intention of giving unwanted aid);

2. that the programme must a joint American-European one and not a series of individual agreements between the USA and various European nations;

3. that the USSR and the Communist states of Eastern Europe should be invited to participate, but the programme would go forward whether or not they joined in."

An important point to be noted was the balanced and forward looking approach, Marshall advocated on whether the United States assistance should be avialable to all European countries or only to those shunning communism? He said, "Our policy is not directed against any country or doctrine, but against hunger, poverty, desparation and chaos." These are very important words to remember while pondering on what kind of a rehabilitation programme should be proposed for the beleagered region.

Representatives of 16 European countries (not including Russia and 8 East European states) met in Paris in June, 1947 and formulated a four year programme costing $15 billion in American aid. In April 1948 the Marshall Plan (as the ERP came to be known) got its appropriation $5.6 billion for the first year. The ERP rolled into action, and into Europe flowed goods vitally needed to restore the economies of the cooperating countries* - grain, coal, petroleum products, cotton and other raw materials to enable lagging industries increase future production (Barck and Blake, 1965).

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* Economic aid was granted to Great Britain, France, Italy, Belgium, The Netherlands, Luxembourg, Norway, Sweden, Denmark, Austria, Greece, Portugal, Switzerland, Turkey, Ireland, Iceland, and Nationalist China.

ERP was on the whole a distinct success. After spending some $11 billion in a matter of three years a report of the Economic Cooperation Administration stated: "Over-all industrial production in Western Europe was running 40% higher than in 1938; harvests were about 10% above their pre-war levels; economic recovery in Britain and Ireland had advanced to a point where these two nations felt able to get along without further aid" (Barck and Blake, 1965). The same source stated that the Marshall Plan, in four years (1948-52) distributed some $12 billion worth of economic aid which enabled the 16 nations (plus West Germany) to achieve a rise in their gross national products of 15 - 25 percent during this period.

This example of world experience is stated in this detail because it offers the basis for the proposal presented later in this chapter if the environment in this part of the World is to be effectively rehabilitated.

5.2.2 Saving the European Wild Buffalo - Aurochs

The Aurochs or wisent (Bison bonasus bonasus; Bovidae) was brought close to extenction during World War I. The animals were hunted for food by the German forces and their habitat was destroyed by intensive tree felling by the forces (Westing, 1980). Post-war efforts barely rescued this animal from extinction. But it was virtually wiped out again during World War II. The efforts by a group of dedicated zoologists succeeded in saving the wisent and more than 1,000 of them were roaming by 1980 in a 12,000 hectare forest reserve in Poland.

5.3 Mitigation Measures

A large expanse of the land bears the scars of war in addition to its adverse effects on marine ecosystems and some damage to civil buildings. The terrestrial ecosystems have mainly been affected by the soot and oil mist coming out of the exploded oil wells in Kuwait, and the military activities on the ground undertaken in the preparation of war. it may be stated that the impact area is used exclusively for grazing of sheep, goats and camels. As a result of excessive use through overgrazing, signs of soil erosion, both by wind and water, are seen everywhere and natural vegetation is extremely degraded. The war activities have considerably enhanced the degradation processes.

5.3.1 Action taken since the war stopped

The Kingdom of Saudi Arabia initiated mitigation measures before the ceasefire declaration. MEPA established an Oil Spill Emergency Task Force immediately after the

first oil spill into the Gulf. The duties of this task force centred on the marine and coastal area ecosystem. MEPA and King Fahd University of Petroleum and Minerals, also in collaboration with others started investigations into the pollutant gases and particulate matter carried in the smoke/soot coming from the burning oil wells in Kuwait. Similar investigations were carried out on the soil in the eastern region of the Kingdom as well.

The Kingdom welcomed several research institutions from other Governments as well as non-governmental institutions to work in the eastern region in all sorts of mitigation efforts including research and monitoring.

(i) Enclosures

It is understood that there are 20 enclosures at present (1988) scattered in the country. The information whether there is any enclosure in the impact area, was not readily available due to time constraint. There is, however, a great need to establish 10 to 15 enclosures in the war-affected area, one in each soil unit (see Appendix 5) so as to improve the seedbank not only within the enclosures, but also in outside areas.

(ii) Decreasing animal pressure on the rangelands

Despite the severely degraded condition of the rangelands, the animal population is extremely high. Without any substantial reduction in the number of animals, improvement of the rangeland habitats is not possible. Some policy measures are needed to be taken to encourage the herders to transfer a good part of their animals to other areas or dispose them off. There is a great need to reintroduce the rotational grazing (Hema system) as an important measure to improve the degraded rangelands. Similar suggestions were made by Al-Hassan (1991) for the rangeland in the Northern regions of Saudi Arabia.

(iii) Monitoring

The impact of the soot and the war acitivites on the desert ecosystems has not been systematically studied anywhere in the past. It is recommended that enclosures may be established in the soot affected areas as well as in the areas where soil has been disturbed drastically. This may be followed by researches to study the changes produced in various components of the environment, and also the rate and mode of natural rehabilitation processes, on a continuous basis. This would be a very extensive programme, taken up immediately but continuing into the future in the rehabilitation programme.

5.4 Rehabilitation and Protection of the Environment

5.4.1 General

The mission realises that its assignment covers only one area of the environment - the terrestrial ecosystems. Other teams are responsible for the atmosphere, the marine and the coastal area while another group will deal with hazardous wastes. Therefore, concern with a rehabilitation programme for the environment is rather wide and shared by many groups dealing with portions of this wide and interrelated issue. The following paragraphs are written with this understanding of our responsibility within the framework of the UN Inter-agency Plan of Action for the Mitigation and Rehabilitation of the Environment in the ROPME Region.

5.4.2 Features of a General Strategy

Rehabilitation and protection of a fragile environment, within the context of the present conditions in the ROPME Region, requires a strategy characterised by the following guiding principles:

(i) Its cornerstone is regional cooperation and action. The nature of the problem faced and types of solutions needed for them, make individual state action of little or no future effect or sustainable value. Pollution of the atmosphere or of fresh or sea waters are handy examples.

(ii) Simplicity and attraction of public support.

(iii) Easy to execute and easy to maintain.

(iv) It should have its built-in monitoring mechanism.

5.4.3 Priority Areas

Priority areas for action in an environmental rehabilitation programme are selected in full consideration of:

(i) The type and nature of war impacts on the ecosystems;

(ii) The state of the environment before and after the war.

Considering the first item, war activities and their consequences in the eastern region, were essentially the fallout of soot and the various forms of land degradation effected by military activities. There was very limited shelling and bombing and limited oil spill on coastal sebkhas. The degradation of the physical and biological environment before the war was, however, very extensive. This was made even worse by even the slightest damage from war activities.

On the basis of the above, proposed priority areas would include:

(i) Human, animal and plant life-threatening hazards and toxic agents.

(ii) Short and long-term environment protection schemes including monitoring.

(iii) Rehabilitation of socio-economic development establishments.

(iv) Raising public awareness.

5.4.4 Proposed Actions

In the light of priority areas identified in the previous paragraph, the following actions are proposed. These proposals are on the whole fairly restricted to rehabilitation of the environment in the terrestrial ecosystems. Although rehabilitation of the socio-economic development establishments is one of the priority areas, the list of proposed actions does not include many of them. They will have to be taken care of under other parts of the overall rehabilitation programme in the Kingdom.

Very brief notes are provided on each action proposed. Under each topic one or several projects may be formulated and costed. It is not possible at this stage to go beyond the level of this identification.

(i) Survey of suspected land and demarcaion of dangerous areas where travelling, camping or grazing should be prohibited;

(ii) Establishment of national environmental monitoring and assessment centres;

(iii) Establish new research institutes and conduct extensive research programmes on new issues of post-war situation.

(iv) Raising public awareness;

(v) Rangeland management schemes;

(vi) Sand dune fixation programmes;

(vii) In disturbed areas regulate pastorlists cars and trucks and tankers traffic by building asphalt roads and restrict or prevent further disturbance of the soil;

(viii) Promote afforestation projects;

(ix) Establish several bioreserves;

(x) . Develop recreational centres;

5.4.4.1 Research and Monitoring

Although very limited bombing and shelling and combat have taken place on Saudi Arabia's soil, the serious damaging effects of soot, pollutant gases, and land degradation which resulted from the war put, at least, the eastern part of the Kingdom in a prevarious situation. New issues are arising and hundreds of questions, demanding unknown answers so far, have come to the forefront. This is the rationale for stressing the scientific research and the monitoring and assessment issues.

5.4.4.2 Public Awareness

Public support and participation in programmes on environmental rehabilitation are vital for its success. Although country specific issues and methodologies are stressed, regional cooperation in this area is recommended.

5.4.4.3 Other suggested actions

The remaining suggested actions are known topics in development programmes. The Kingdom has its experience in the fields of afforestation, range management and sand stabilization.

5.5 A mechanism for achieving rehabilitation and protection of the environment in the ROPME Region Countries

5.5.1 General

Several countries in the ROPME Region have been hit hard during and after this war. To remove the damage and the very serious and long acting primary and secondary impacts, the mission looks for a regional approach, programme and mechanism. A country, however, may decide to

go it alone but the end results would be far from rehabilitation and protection of its own environment. It is in the interest of all countries of the region to cooperate in meeting the challenge.

5.5.2 The framework

In section 5.2 on international experience, the Marshall Plan was described in some length. The idea was to give the example the mission wishes to propose in order to meet the big challenge posed by the situation and conditions seen in Kuwait, Iraq and Saudi Arabia. The requirements of the situation call for nothing less than a new "Marshall Plan" to pull the region out of its present catastrophic situation. Surprisingly enough there are many similarities between the two situations - in European and in ROPME countries:

(i) Extensive damage befell both sides - the victorious and the others;

(ii) A successful rehabilitation programme should include the countries from both sides of the conflict in a cooperative effort;

(iii) The organizational structure which was in the making in the first case (Europe) is already existent in the second (Arab States);

(iv) Countries on both sides of the war fronts possess most of the potential capabilities required for a successful plan of rehabilitation.

In the case of Marshall Plan, the formation of a European economic community was in the making, but in the present case a ready vehicle exists in the form of the Council of Arab Ministers Responsible for the Environment (CAMRE) and its parent organization - the League of Arab States (LAS). If this collosal enterprise succeeds it would affirm a remarkable feat of UNEP's forsightedness in creating CAMRE only three years before hostilities began.

The LAS, after a transient shock and paralysis following the beginning of hostilities is presently fully operational with members from both sides attending its meetings in Cairo. Apparently there would seem to be no problem with a presentation of such a proposal in a LAS meeting or in a CAMRE special meeting for the purpose.

5.5.3 The Arab Economic Cooperation Administration

In the previous paragraphs an outline of a rehabilitation programme for the Iraq-Kuwait conflict area was presented (c.f. paragraph 5.5.2). The framework within which such a programme may be discussed and prepared for execution has been identified as the CAMRE and LAS Council. Of course, what is more important is the existence of a funding body or bodies bent on the issue and determined to bring about rehabilitation and protection of the environment in this area. Furthermore, there should be a competent implementing institution. This is proposed here as 'The Arab Economic Administration'. This institution would be the replica of the American ECA which was charged with responsibility for making grants and loans under the European Recovery Programme.

The three most affected countries, Kuwait, Iraq and Saudi Arabia, are oil rich countries. Together they can contribute the bulk of the capital required for a rehabilitation programme for the region. Other countries which have taken an active part in the act of the war itself may perhaps wish to play an equally active role in the funding and implementation of this programme. The industrialized countries in particular should contribute generously in the funding. The United Nations is another potential contributor. Finally an array of countries from the region and from outside the region as well as regional and International organizations may be asked to contribute. The rationale behind this is the global nature of the issue and its environmental consequences.

Chapter VI

Monitoring and Follow-Up

6.1 Monitoring

6.1.1 Scope of Monitoring

The importance of monitoring in connection with damage to the environment and its rehabilitation has been recognised from the outset of the missions work. It was, therefore, included in the first outline of the contents of its report. This position was confirmed in the final discussions with the counterparts and the following topics were identified:

(i) Monitoring of the persistence of various pollutants produced as a result of the hostilities. Many of these pollutants in the atmosphere, soil, vegetation and water have been named in the relevant reports.

(ii) Special monitoring schemes to detect genetical or carcinogenic changes in man, animal and plant.

(iii) Monitoring habits and movements of indigenous and migratory birds.

(iv) Monitoring population dynamics of certain fauna e.g. scorpions, beetles, rodents and reptiles.

6.1.2 Institutional Set-up

The report of the Executive Director of UNEP to the Governing Council session in May 1991* recommended "that national environmental monitoring and assessment centres should be set up in each country ....". This recommendation should be accorded high priority in the rehabilitation programme.

6.2 Follow-Up

In many projects undertaken to achieve certain clearly identifiable objectives, the main cause of failure was lack of follow-up on important issues and ensuring that another activity which constitutes a vital pre-requisite has been done.

A programme on environment rehabilitation, by its nature, will have a plethora of activities and inter-related actions the failure of one of them will have repercussions on several others. A thorough and meticulous follow-up for the smooth and sound progress in the implementation of the programme is an essential requirement.

Chapter VII

CONCLUDING REMARKS

7.1 Nature of the Assignment

The assignment given to the mission was to assess impacts of war activities and consequences on terrestrial ecosystems in the Kingdom of Saudi Arabia with special emphasis on desert fauna and flora; other targets of impact e.g. soil, were included. After completion of the survey and assessment the mission had to prepare (i) a report on the state of the environment and (ii) a draft rehabilitation programme. The terms of reference (Appendix 1) which came in a few lines unfolded into a very demanding task - a multidisciplinary assignment, requiring the services of several disciplines.

7.2 Execution

Despite some logistic difficulties the mission - of three experts - managed to visit Saudi Arabia. This was an achievement because it was very doubtful at the time of recruiting the mission members that it will happen. However, in order to end this section with a positive note, the difficulties will be first mentioned.

- Valuable time was lost in organization of travel and the journey had to start from Bahrain;

- The Kingdom of Saudi Arabia is a large country and organization of informative field visits covering the whole country was not necessary. The visits were therefore limited to the war impacted eastern region;

- There were difficulties in obtaining the information needed either for reasons of confidentiality; military restriction on type of information or because of difficulty to locate and retrieve within the time available. Sometimes it was not known if the information actually existed.

- After one year from the start of the conflict many people were found tired from continuous interrogation and demands by mission after mission.

- With all these negative aspects there were some positive sides in the experience of the mission. These included good reception and cooperation from the side of national counterparts.

- Although good coverage of the assessment area by field trips within the time allowed for the mission posed problems, there should be no doubt that the persons responsible in Saudi Arabia have done their maximum to make the field visits a success and the mission is satisfied with their efforts.

In an overall assessment here, the mission is quite satisfied with the intents and efforts of its host. The mission realizes that usually there are difficulties which can never be anticipated. In a situation of fear and mistrust developing in the wake of such devastating war, much worse than this could have happened. But this was not the case.

7.3 The Results:

The report of the mission, apart from the table of content and appendices, covered 67 pages.

The results of the survey and assessment of the impacts of war activities and their consequences are given in a narrative form and in 9 tables. The narrative form explains the physiological basis of the impact and gives information of the geographical location. Some quantitative data were also included when information was available or could be calculated from observations. Some of the impacts were of temporary nature and reversible and these mostly came under activities, e.g. bombing, off-road vehicles etc. Some impacts are reversible while others are irreversible; the latter mostly came under the effects of oil lakes or spills.

The area affected by soot lay south of the Saudi-Kuwaiti border and to the east of a line passing through Nairyah down to Al-Dammam and parallel to the Gulf coast.

- The limited oil spills on the land have their influence on the halophytes growing in the sebkhas;

- The sandy soil belt along the coast has been disturbed by military activities;

- Vehicle movements have pulverized the surface soils exposing it to severe erosion, both wind and water. In many sites the soils have been extensively compacted;

- The adverse effects described earlier have taken appreciable areas out of grazing thus increasing the gravity of overgrazing which, in addition to severe soils disturbance, has caused the disappearance of perennial plants;

- Death of Hammada elegans and other species in Al-Khafji area due to dense soot fallout and possibly oil mist. The death percentage among the vegetation decreases as we proceed away (southward) from the source;

- Vegetation seed productivity has been reduced by the soot.

All the above results are concerned with national situations. This is of course very important. But, at the same time, there is another dimension of the impacts of this war on regional and global levels. This is causing serious concern and alarm. Such impacts include the following:

- Explosion of oil wells and fire which send to the atmosphere smoke, oil particles and pollutant gases;

- Contamination of soil with heavy metals;

- Increased sand movement and dust load of storms;

- Spread of human and animal epidemic diseases;

- Fall of acid rain leading to incrustation of affected soils and blackening of snow;

- Effect of smoke clouds on sun light, lowering of temperature with some repercussions on plant and animal life.

7.4 The significance of results:

In this section the mission wishes to deal with the significance of results on the grounds that the results of this mission's work have been based partly on data and information generated by other groups who worked in the area. Another aspect of the matter is that in dealing with the environment the gravity and seriousness cannot always be apportioned between the various ecosystems.

On these bases it is concluded, as it was before in the reports of other missions (Ahtisaari, 1991; Westing, 1991; UNEP, 1991; Cave, 1991; WCMC. 1991) that a humanitarian as well as an environmental catastrophe has taken place. Some

of what has happened in the ROPME Region will revert back to its normal condition, the example in this case is the

dryness, darkening and defoliation which affected parts of prosopis trees.

Some of what has happened may revert back to its pre-war condition, but after some decades, the example in this case the land degradation due to the scars and ruts on land surface resulting from the movement of tanks and heavy machinery.

And finally some of what has happened will not revert back - it is gone forever. This group includes the dead and it includes parts of the soil which have lost forever its ability to produce. Also it includes some plants and animals which although alive have lost, forever, some of their properties. This group is of considerable importance, however small its number is.

The real significance of the results in this and other reports is that there is a possibility for rehabilitation and protection in the future, albeit with some conditions.

In Chapter V of this report the mission has proposed some mitigation measures and some actions under a proposed rehabilitation programme. On these mitigation measures and rehabilitation scheme volumes of well formulated and costed projects could be worked out for consideration. But this is neither important now, nor is this the time for it. This is perhaps the time for laying down principles, defining priorities and probing for ways of co-operation.

7.5 Means of Applying Solutions

7.5.1 The magnitude of the problem

The problem cannot be described in words better than those in the report of the mission led by the Under-Secretary-General for Administration and Management (Ahtisaari [S/22366, 1991]). It states on page 5, "It should, however, be said at once that nothing that we had seen or read had quite prepared us for the particular form of devastation which has now befallen the country. The recent conflict has wrought near-apocalyptic results upon the economic infrastructure of what had been, until January 1991, a rather highly urbanized and mechanized society. Now, most means of modern life support have been destroyed or rendered tenuous."

This applies to a certain extent to Saudi Arabia. The problem is very serious everywhere in the eastern region, of course in some places more serious or exceptionally serious than in others.

- A serious problem requires an urgent decision and action, particularly when it deals with the environment because delay is costly.

The problem faced in ROPME sub-region - with Kuwait, Iraq and Saudi Arabia as the centre of the quake eruption - is too great to be contained except through a special solution. An effort to find one has been proposed in Chapter V of this report - a programme similar to the Marshall Plan which saved Europe after World War Two from hunger, poverty, desparation and chaos.

- This special solution also requires special implementing tools. In the case of the Marshall Plan, USA established the Economic Cooperation Administration (ECA), which was charged with the responsibility of making grants and aids. In this case the mission proposes the creation of an Arab Economic Cooperation Administration.

- Furthermore application of the proposed solution requires patronage and full responsibility behind the proposal. This is essentially a funding responsibility. Apart from some proposals, the issue remains open.

The report of WCMC (1991) considers that a coordinated regional response is required to address the long-term ecological consequences of the war. Furthermore the report states, "There will no doubt be a major international commitment towards the post-war recovery of the region, and already a Middle East Bank for Reconstruction and Development has been proposed."

7.5.2 A proposal on how to start

The initiative must come from somewhere. Perhaps from the United Nations. Since this is where the world decisions on condemnation, request for withdrawal, application of sanctions and enforcement of withdrawal, it seems the UN (Security Council) would be an ideal place for initiation of action. Indeed the continuation of current affairs in Iraq and in other affected states threatens world peace and tranquility. This, perhaps, appears to be a respectable role for the UN to play.

Next to the UN, the mission believes that the states in the region should come forward to play an active role. They should take the initiative if the UN fails to do so for one reason or another.

The third in this line for shouldering responsibility are the group of countries who rallied together to defend a just cause. These were said to be 28 countries.

To be practical, if all this failed to bring an initiative into action, it will be the responsibility of the three countries involved and at the same time the most seriously affected.

7.6 Lessons Learned

There are many lessons to be learned from this heart-breaking calamity. The mission does not wish to step into this very wide and unsafe land. The mission would rather confine itslef to the limits of its own analysis and proposals and state that the main lesson to be learned is that man is resourceful and great and can pull himself out of a calamity. This has happened in Europe 40 years ago; indeed it can happen here now. In Europe, "the basis of such economic recovery was provided by the people of those nations, whose labour and organizational ability rebuilt societies devastated by years of war and Nazi exploitation. American aid provided vital psychological and material support, but it would have been little more than a massive relief programme without the European contribution." (The New Encyclopaedia Britanica, (1974).

The mission believes in the strength of people in the affected countries and has already expressed its view in the introduction of this report.

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Appendix 1

Multidisciplinary Team to Assess Impacts

of war on Terrestrial Ecosystems

in Kuwait, Iraq and Saudi Arabia

TERMS OF REFERENCE

In the framework of the UN Inter-agency Plan of Action for the ROPME Region, the mission of the above team shall perform the following tasks:

1. Assess and study the effects of desert combat, bombing, shelling and explosion of mines on the desert fauna and flora;

2. Assess the effects of the above and other military activities on severity and frequency of dust storms and sand movements;

3. Assess possible damages to land resources as the result of releases of massive quantities of oil from attacked wells, pipelines and storage structures, and by soot and air-borne pollutant gases and oily smoke resulting from burning oil wells with particular attention to:

   - fauna, flora and desert food-chain;
   - soil productivity.

4. After the necessary field visits, discussions with national counterparts and officials in Iraq, Kuwait and Saudi Arabia the team will prepare:

   - a report on the detailed assessment of the present state of the environment;

   - a draft environmental rehabilitation programme, including recommendations and measures for the mitigation, rehabilitation and protection of the environment.

5. In fulfilling the above task, the team will make full use of the available data and information already generated by teams operating in the region under the UN Plan of Action.

Appendix 2

A Record of Travel and Field Trips of the Mission 31.7 - 3.9.1991*

Date	
31.7 and 1.8.1991	Arrival of mission members in Bahrain.
1.9.1991	Meeting with Dr. A.A. Orabi, Acting Director of UNEP/ROWA.
2 - 4.8.1991	Review of literature and discussions, preparation of an annotated outline of the report.
5.8.1991	Departure to Kuwait.
12.8.1991	Return to Bahrain.
16.8.1991	Departure to Iraq via Amman (by car).
17.8.1991	Arrival in Baghdad.
24.8.1991	Departure to Bahrain via Amman (by car).
25.8.1991	Arrival in Bahrain.
28.8.1991	Departure from Bahrain to Dammam (by car).
3.9.1991	Return to Bahrain.
3.9.1991	Report writing.

* Detailed itinerary of the mission is given in Appendix 3 in each of the country reports.

Appendix 3

Itinerary of the Mission in the Kingdom of Saudi Arabia 28 August - 3 September 1991

Preparatory Steps:

- 26 and 27.8.1991 mission stayed in Bahrain to organize travel requirements including entry visas for Saudi Arabia.

28.8.1991

- Travel by car to Al Dammam, Eastern region, Saudi Arabia.

- Meeting in MEPA office with Saudi counterparts.

- Travel by car to Al-Jubayl.

29.8.1991

- The mission and the national counterparts went from Al-Jubayl by road to visit the coastal belt up to the Kuwait-Saudi Arabia border. The impact of soot and oil-mist on soils, fauna and flora was studied.

30.8.1991

- The mission travelled from Al-Jubayl to Hafar Al-Batin by road and studied the impacts of military activities on soil, sand movement, fauna and flora.

31.8 1991

- The mission visited the areas north of Al-Qaysumah up to the Kuwait border and the area south of Hafar-Al Batin in Samman for the study of the war impacts on various components of the environment.

1.9.1991

- The mission travelled by road from Hafar Al-Batin to Al-Jubayl and studied the extent of the soot affected area in the coastal belt.

- Took observations in the area lying between Al-Jubayl and Dammam.

2.9.1991

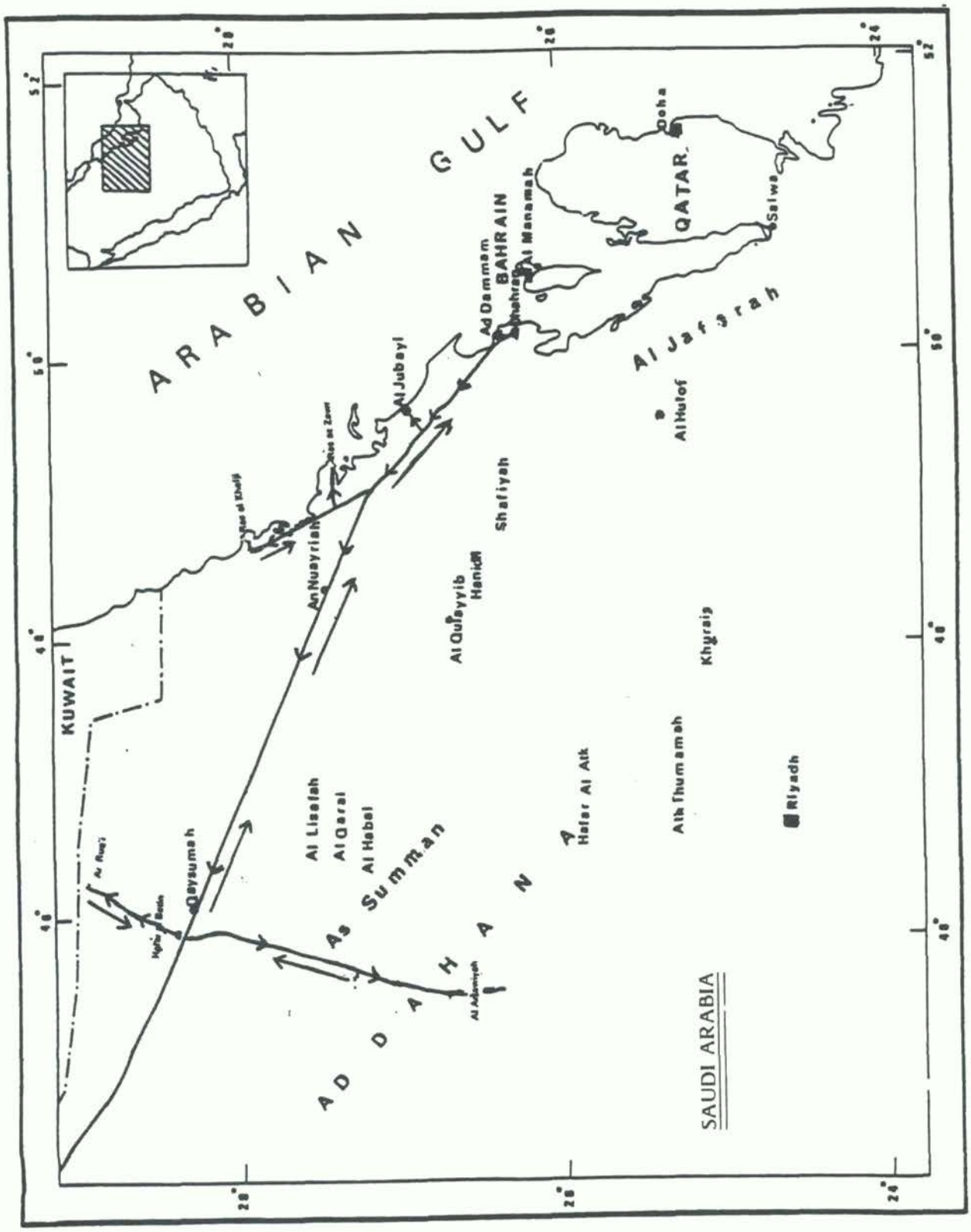
- A trip by a Civil Defence helicaopter to Al-Khafji; from there along the border between Saudi Arabia and Kuwait all the way westwards to Ar Rugi, then south to Al-Qaisumah, Al-Nairyah, Al-Qatif and Al Dammam. The flight commenced at 0800 and ended at 1630.

- The mission made observations on the effects and disturbance made by various types of military activities. The oil well fires inside Kuwait and the smoke plume emanating from them were observed from the borders.

3.9.1991

- Final meeting in MEPA offices between mission and Saudi counterparts. The meeting was chaired by Mr. Mahmoud M. EL NOWAILATY, Deputy on-site Oil Spill National Coordinator. A list of participants appears on page 4.

N.B. The routes of the field trips are shown on the map on page 3.



Map showing routes of field trips in the Kingdom of Saudi Arabia.

Final Meeting in MEPA

List of Participants

Name	Organization
Mr. Mahmoud M. Nuwailati	Meteorology & Environmental Protection Administration (MEPA)
Mr. Hosni Abdulraziq	"
Mr. Saood A. Al-Sati	"
Dr. Ahsanullah Khan	"
Mr. Adel Qasti	"
Mr. Jamal H. Ben-Manie	"
Mr. Khalid Abu Elief	"
Mr. Khalid A. Arkanji	"
Mr. Aziz Al-Omari	"
Mr. Mohamed A. Al-Ashi	"
Dr. Ibrahim A. Aalem	King Fahd University
Mr. Abdel Mohsin Al-Sunaid	ARAMCO
Mr. Tareq M. Khattab	"
Mr. Nasser Al-Saadoon	"
Mr. Bencon, R.L.	IMO
Mr. Graham, G.M.	Crowley Maritime
Mr. Don Kane	BECHTEL

UNEP Team

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Dr. Muhammad Alim Mian	Team Member UNEP Mission	43/M, Gulberg-III, Lahore, Pakistan.
Prof. Dr. Kamal H. Batanouny	Team Member UNEP Mission	Head, Botany Dept., Faculty of Science, Cairo University, Egypt.

Appendix 4

List of persons met by the UNEP Mission in the Kingdom of Saudi Arabia (27.8 - 3.9.1991)

Name	Organization
Mr. Mahmoud M. Nuwailati	Meteorology & Environmental Protection Administration (MEPA)
Mr. Hosni Abdulraziq	"
Mr. Saood A. Al-Sati	"
Dr. Ahsanullah Khan	"
Mr. Adel Qasti	"
Mr. Jamal H. Ben-Manie	"
Mr. Khalid Abu Elief	"
Mr. Khalid A. Arkanji	"
Mr. Aziz Al-Omari	"
Mr. Mohamed A. Al-Ashi	"
Dr. Ibrahim A. Aalem	King Fahd University
Mr. Abdel Mohsin Al-Sunaid	ARAMCO
Mr. Tareq M. Khattab	"
Mr. Nasser Al-Saadoon	"
Mr. Bencon, R.L.	IMO
Mr. Graham, G.M.	Crowley Maritime
Mr. Don Kane	BECHTEL

Appendix 5

Description of Soil Mapping Units in the Kingdom of Saudi Arabia*

Following is the description of 11 soil mapping units which cover large areas in the Eastern province of the country. The mapping unit number as appearing on the Generalised Soil Map is indicated within brackets just after the serial number so that the reader may refer directly to the soil map.

- a (31) - Gypsiorthids: loamy soils, gypsum pan, 0 to 3 percent slopes

This map unit consists of nearly level soils on plains. The landscape is smooth. There is very little dissection by drainageways.

This map unit is about 85 percent Gypsiorthids and 15 percent minor soils and areas of rock outcrop.

The Gypsiorthids and similar soils are on plains. Slopes range from 0 to 3 percent. The Gypsiorthids are loamy, slightly saline to strongly saline soils. These soils are dominantly shallow to a layer cemented by crystalline gypsum, but they range from very shallow to moderately deep. Permeability is moderate above the gypsum pan. The water retention difference is low. In most places, the soils have a desert pavement.

Included in this map unit are deep soils and non-saline soils that have a thin sandy surface layer. These soils and the Gypsiorthids are on a similar landscape. Also included are small depressional areas where the soils have a high water table and areas of rock outcrop on knolls.

The suitability for rangeland is poor.

- b (32) - Gypsiorthids - Calciorthids: plains of loamy soils with gypsum pan and loamy, deep soils

This map unit consists of nearly level and gently sloping soils on plains. Small intermittent streams begin and generally terminate within the delineations. Drainage nets are not well developed.

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* The section on soils appears in Chapter II, Section 2.2.4.

This map unit is about 55 percent Gypsiorthids, 30 percent Calciorthids, and 15 percent minor soils and areas of rock outcrop. The Calciorthids are in small areas and are intricately mixed with Gypsiorthids.

The Gypsiorthids and similar soils are on linear and convex plains. Slopes range from 0 to 5 percent. The Gypsiorthids are loamy, slightly saline to strongly saline soils. Typically, they are moderately deep to a layer cemented by crystalline gypsum, but they range from shallow to moderately deep. Permeability is moderate above the gypsum pan. The water retention idfference is low to moderately high. In most places, the soils have a desert pavement.

The Calciorthids and similar soils typically are in small depressions on linear and concave plains throughout most delineations. Slopes range from 0 to 5 percent. The Calciorthids are deep, loamy, calcareous, slightly saline to strongly saline soils. Permeability is moderate. The water retention difference is high. In most places, the soils have a desert pavement.

The limitations are excess salt, excess gypsum, and small depth to a gypsum pan.

The suitability for rangeland is poor.

- c (33) - Gypsiorthids - Calciorthids: plains and knolls of loamy soils with gypsum pan and loamy, deep soils

This map unit consists of nearly level to steep soils on plains and knolls. Small intermittent streams begin and generally terminate within the delineations. Drainage nets are not well developed.

This map unit is about 40 percent Gypsiorthids, 35 percent Calciorthids, and 25 percent minor soils and areas of rock outcrop. The Gypsirothids and Calciorthids are intricately mixed.

The Gypsiorthids are similar soils that have slopes ranging from 0 to 8 percent are on short sideslopes of knolls. The Gypsiorthids are deep to bedrock, but in about half of the areas they are shallow and moderately deep to a layer cemented by crystalline gypsum. The Gypsiorthids are loamy, slightly saline to strongly saline soils. Permeability is moderate. The water retention difference is low to high. In some places, the soils have a desert pavement.

The Calciorthids and similar soils that have slopes ranging from 0 to 8 percent are on concave and convex plains and summits of knolls. Those that have slopes ranging from 8 to 25 percent are on short sideslopes of knolls. The Calciorthids are deep, loamy, calcareous, slightly saline to strongly saline soils. Permeability is moderate. The water retention difference is high. In some places, the soils have a desert pavement.

Included in this map unit and intermixed throughout most delineations are small areas of very gravelly soils. Also included are areas of rock outcrop and soils that are shallow and moderately deep to bedrock on steep sideslopes and summits of knolls.

The major limitations are steep slopes, excess gypsum, excess salt, and, in about half of the areas of Gypsiorthids, shallow depth to a gypsum pan..

The suitability for rangeland is poor.

- d (34) - Gypsiorthids - Calciorthids: plains and knolls of loamy, shallow and moderately deep soils

This map unit consists of nearly level to steep soils on plains and knolls. Small intermittent streams begin and generally terminate within the delineations. Drainage nets are not well developed.

This map unit is about 40 percent Gypsiorthids, 35 percent Calciorthids, and 25 percent minor soils and areas of rock outcrop. The Gypsiorthids and Calciorthids are intricately mixed.

The Gypsiorthids and similar soils that have slopes ranging from 0 to 8 percent are on convex plains and summits of knolls. Those that have slopes ranging from 8 to 25 percent are on short sideslopes of knolls. The Gypsiorthids are shallow and moderately deep to bedrock. In one-third of the areas they are shallow and moderately deep to a layer cemented by crystalline gypsum. The Gypsiorthids are loamy, slightly saline to strongly saline soils. Permeability is moderate. The water retention difference is low to moderately high. In some places, the soils have a desert pavement.

The Calciorthids and similar soils that have slopes ranging from 0 to 8 percent are on concave and convex plains and summits of knolls. Those that have slopes ranging from 8 to 25 percent are on short sideslopes of knolls. The Calciorthids are shallow and moderately deep,

loamy, calcareous, slightly saline to strongly saline soils. Permeability is moderate. The water retention difference is low to moderately high. In some places, the soils have a desert pavement.

Included in this map unit are small areas of deep soils on linear and concave plains and on footslopes of knolls. Also included are some areas on the summits of knolls where rock outcrop is mixed with very gravelly soils that are shallow to bedrock.

The limitations are moderate and shallow depth to rock, steep slopes, excess gypsyum, excess salt, and, in about one-third of the areas of the Gypsiorthids, shallow depth to a gypsum pan. These are continuing limitations and, in most places, these limitations are noncorrectable. The Torriorthents are very shallow and shallow, loamy-skeletal, nonslaine to slightly saline soils. Permeability is moderately rapid. The water retention difference is low.

Included in this map unit are small areas of sandy soils on narrow footslopes near the lee side of rocks. Soils that are moderately deep and deep to bedrock are in concave positions on upper sideslopes, footslopes and narrow valley floors.

The suitability for rangeland is poor.

- e (48) - <u>Torripsamments: sandy, deep soils, 0 to 5 percent slopes</u>

This map unit consists of nearly level and gently sloping soils on plains. There is no evident drainage pattern.

This map unit is about 90 percent Torripsamments and about 10 percent minor soils and areas of rock outcrop.

The Torripsamments and similar soils are on plains. Slopes range from 0 to 5 percent. The Torripsamments are deep, sandy, nonsaline to slightly saline soils. Permeability is rapid. The water retention difference is moderately low.

Included in this map unit are small areas of loamy soils, soils that have excess gypsum, and moderately saline and strongly saline soils, all of which are in concave areas. Also included are sandy soils on dunes and areas of rock outcrop on knolls.

About 90 percent of this map unit is suitable for large-scale irrigation farming. The limitations are droughtiness and sand blowing. Windbreaks can reduce sand blowing. Droughtiness is a continuing limitation, but it can be overcome by frequent irrigation.

About 95 percent of this map unit is suitable for small-scale irrigation farming.

The suitability for rangeland is good.

Land class IV.

- f (49) - <u>Torripsamments: plains of sandy, deep soils and dunes less than 2 meters high</u>

This map unit consists of nearly level and gently sloping soils on plains and nearly level to strongly sloping soils on dunes. The dunes are less that 2 meters high. A drainage pattern is not evident.

This map unit is about 60 percent Torripsamments on plains, 20 percent Torripsamments on dunes, and 20 percent minor soils. The areas of plains are large, and the areas of dunes are small and are scattered throughout each delineation.

The Torripsamments and similar soils on plains have slopes that range from 0 to 5 percent. Those on dunes have slopes that range from 2 to 10 percent. The Torripsamments are deep, sandy, nonsaline to slightly saline soils. Permeability is rapid. The water retention difference is moderately low.

Included in this map unit are small areas of loamy soils, soils that have excess gypsum, and moderately saline and strongly saline soils, all of which are in concave areas. Also included are sandy soils on dunes 2 to 10 meters high with slopes ranging to 60 percent on the lee side of the dunes.

About 85 percent of this map unit is suitable for large-scale irrigation farming. The limitations are droughtiness, dunes, and sand blowing. The dunes can be levelled, and sand blowing can be reduced by windbreaks. Droughtiness is a continuing limitation, but it can be overcome by frequent irrigation.

About 90 percent of this map unit is suitable for small-scale irrigation farming.

The suitability for rangeland is good.

Land class IV.

- g (51) - Torripsamments: dunes 2 to 10 meters high

This map unit consists of gently sloping to steep soils on dunes. The dunes are 2 to 10 meters high and are closely spaced throughout the map unit. There is no evident drainage pattern.

This map unit is about 80 percent Torripsamments on dunes and 20 percent minor soils and areas of rock outcrop.

The Torripsamments and similar soils are on dunes. Slopes range from 3 to 60 percent. The steeper soils are on the lee side of the dunes. The Torripsamments are deep, sandy, nonsaline to slightly saline soils. Permeability is rapid. The water retention difference is moderately low.

Included in this map unit are small areas of nearly level and gently sloping sandy soils in interdunal areas, small areas of loamy soils, soils that have excess gypsum, and moderately saline and strongly saline soils, all of which are in interdunal depressions. Also included are soils on dunes that are less than 2 meters high or more than 10 meters high and areas of rock outcrop on knolls.

This map unit is not suitable for large-scale irrigation farming. The limitations are droughtiness, the steep dunes, and sand blowing. Droughtiness is a continuing limitation, but it can be overcome by frequent irrigation. The dunes also are a continuing limitation. Because of their size and height, leveling is not practical. Sand blowing can be reduced by windbreaks.

About 15 percent of this map unit is suitable for small-scale irrigation farming.

The suitability for rangeland is poor.

Land class VI.

- h (52) - Torripsamments: dunes more than 10 meters high

This map unit consists of strongly sloping and steep soils on dunes. The dunes are more than 10 meters high and are closely spaced throughout the map unit. There is no evident drainage pattern.

This map unit is about 85 percent Torripsamments on dunes and 15 percent minor soils and areas of rock outcrop.

The Torripsamments and similar soils are on dunes. Slopes range from 10 to 60 percent. The steeper soils are on the lee side of the dunes. The Torripsamments are deep, sandy, nonsaline to slightly saline soils. Permeability is rapid. The water retention difference is moderately low.

Included in this map unit are small areas of nearly level and gently sloping sandy soils, small areas of loamy soils, soils that have excess gypsum, moderately saline and strongly saline soils, areas of rock outcrop, and soils that are shallow to bedrock, all of which are in interdunal depressions. Also included are soils on dunes that are less than 10 meters high.

This map unit is not suitable for large-scale irrigation farming. The major limitation is the steep dunes. The limitation is noncorrectable, and it is continuing.

About 10 percent of this map unit is suitable for small-scale irrigation farming.

The suitability for rangeland is poor.

Land class VI.

- i (53) - Torripsamments - Gypsiorthids: dunes and loamy soils with gypsum pan

This map unit consists of gently sloping to steep soils on dunes and nearly level and gently sloping soils on plains. The dunes are mostly less than 5 meters high. A drainage pattern is not evident.

The map unit is about 60 percent Torripsamments on dunes, 30 percent Gypsiorthids, and 10 percent minor soils. The Torripsamments and Gypsiorthids are intricately mixed.

The Torripsamments and similar soils are on dunes. About 75 percent of the dunes are 2 to 5 meters high, and 25 percent are less than 2 meters high. Slopes range from 3 to 60 percent. The steeper soils are on the lee side of the dunes. The Torripsamments are deep, sandy, nonsaline to slightly saline soils. Permeability is rapid. The water retention difference is moderately low.

The Gypsiorthids and similar soils are on plains between dunes. Slopes range from 0 to 8 percent. The Gypsiorthids are loamy, strongly saline soils. They are very shallow and shallow to a layer cemented by crystalline gypsum. Permeability is moderate above the gypsum pan. The water retention difference is low.

Included in this map unit are nearly level and gently sloping sandy soils in small scattered inter-dunal areas.

The limitations are droughtiness, steep dunes, sand blowing, excess salt, excess gypsum, and very shallow and shallow depth to a gypsum pan.

The suitability for rangeland is poor.

Land class VI.

- j (56) - Torripsamments - Salorthids: dunes and basins

This map unit consists of gently sloping to steep soils on dunes 2 to 10 meters high, and nearly level soils in interdunal depressions. A drainage pattern is not evident.

This map unit is about 50 percent Torripsamments, 30 percent Salorthids, and 20 percent minor soils. The Torripsamments and Salorthids are intricately mixed.

The Torripsamments and similar soils are on dunes and other thick eolian sand deposits. Slopes range from 3 to 60 percent. The Torripsamments are deep, sandy, slightly saline and moderately saline soils. Permeability is rapid. The water retention difference is moderately low.

The Salorthids and similar soils are in concave interdunal basins. Slopes range from 0 to 3 percent. The Salorthids are deep, sandy and loamy, strongly saline soils. In most places, the surface layer when dry has a crust. Permeability is moderate. The water retention difference is moderately low and moderate. A high water-table is at a depth of 50 to 75 centimeters for many days of each year.

Included in this map unit are small areas of slightly saline soils and soils that have excess gypsum. These soils are intermixed with the Salorthids. Small areas of sandy soils on dunes that are more than 10 meters high are intermixed with the Torripsamments.

The limitations are steep dunes, sand blowing, excess salt, wetness, and poor outlets.

The suitability for rangeland is poor.

Land class VI.

- k (58) - Udipsamments - Torripsamments: marine flats and dunes

This map unit consists of nearly level soils in concave areas and on flats and gently sloping to steep soils on dunes and other eolian sand deposits, all on coastal plains. The sand dunes are mostly more than 2 meters high. There are no evident drainage nets, other than channels that were formed by storm tides. Large intermittent streams cross some delineations.

This map unit is about 50 percent Udipsamments, 30 percent Torripsamments, and 20 percent minor soils, beaches, and water areas. The Udipsamments and Torripsamments are intricately mixed.

The Udipsamments and similar soils are in concave areas and on flats on the coastal plains near the sea. Typically, slopes are less than 1 percent, but they range from 0 to 3 percent. The Udiopsamments are deep, sandy, strongly saline soils. In most places, the surface layer when dry has a crust. Permeability is rapid. The water retention difference is moderately low. A high water table is at a depth of less than 50 centimeters for many days each year.

The Torripsamments and similar soils are on dunes, hummocks, and other thick eolian sand deposits on coastal plains. Slopes range from 3 to 60 percent. The Torripsamments are deep, sandy, slightly saline and moderately saline soils. Permeability is rapid. The water retention difference is moderately low.

Included in this map unit are small areas of loamy soils, typically on the inland side of delineations. Soils that are shallow and moderately deep to coral rock are intermixed with the Udipsamments. Also included are very gravelly soils near the seashore and in drainageways, beaches of washed and rewashed sand, and water areas.

This map unit is not suitable for large-scale irrigation farming. The limitations are steep dunes, sand blowing, excess salt, wetness, and poor outlets.

The suitability for rangeland is poor.

Land class VI.

It is evident from the description of the soils that they are invariably calcareous due to arid climate and high content of lime in the soil parent materials. Also, the country falls in the shadow of duststorms that originate in the desert regions of Iraq, Jordan and Syria. Dustfall is also an important element of climate here. The duststorms and dustfall contribute significant amounts of calcareous dust to the soils.

A large part in Al Dibdibah plateau and a considerable part in the coastal plain comprises saline soils. These soil conditions make the surface soil loose and unstable. Even minor disturbance renders them vulnerable to wind and water erosion.