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METEOROLOGY AND ENVIRONMENTAL
PROTECTION ADMINISTRATION (MEPA)

THE STUDY ON
AN ENVIRONMENTAL ASSESSMENT AND MONITORING
OF ARABIAN GULF
IN THE KINGDOM OF SAUDI ARABIA

DATA BOOK

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Chapter 1 Environmental Condition of the Gulf

1.1. Meteorology

Table 1.1.1 indicates the summary of meteorological data observed at Dhahran in KSA from AD 1980 to 1998.

Table 1.1.1 Meteorological Data in Dhahran from AD 1980 to 1998

	TEMP ℃			R.H %			RAIN IN (MM)
MONTH	MAX	MIN	AVE	MAX	MIN	AVE	AVE
JANUARY	29.2	01.8	15.0	100	15	69	17.4
FEBRUARY	34.6	03.2	16.7	100	15	67	16.8
MARCH	37.8	05.6	19.9	100	09	63	39.0
APRIL	43.6	10.0	25.4	100	07	49	04.1
MAY	49.5	16.8	31.2	100	05	39	01.6
JUNE	48.4	21.0	34.3	100	05	33	00.0
JULY	49.0	23.0	35.7	100	05	35	00.0
AUGUST	48.7	22.8	34.8	100	05	43	00.0
SEPTEMBER	45.0	19.4	32.2	100	06	52	00.0
OCTOBER	44.5	14.6	28.1	100	07	59	00.2
NOVEMBER	37.5	08.8	22.6	100	13	64	15.3
DECEMBER	31.0	03.5	17.3	100	17	68	19.9

Attachment I shows the monthly data from AD 1980 to 1998.

The extremely arid nature of the region, high temperatures and constant and intense sunshine, especially along coastal areas, gives the overall impression of a lack of seasonal variability.

Following are the meteorological comparison of minimum/maximum values during 19 years from 1980 in Dhahran.

Items	Minimum	Maximum
Monthly average of daily mean temperature in ℃	12.5℃ in Jan. 1992	36.7℃ in Jul. 1983 and Aug. 1998
Yearly rainfall	8.3 min in 1990	329.8 in 1981

1.1.1 Seasonal atmospheric cycles

Although some characteristics such as rainfall remain constantly low with only rare exceptions, the region lies at the edge of two or more global weather systems which subject these seas to major changes in direction and force of wind and ocean current. This results in some of the most remarkable effects on marine conditions seen in tropical waters. In the Gulf, northerly winds in winter blow over the shallow water and cause water temperatures to fall to values more usually associated with temperate oceans, sometimes causing massive mortality of the tropical biota. Elsewhere, seasonally reversing winds induce upwelling in the Arabian Sea, which causes the remarkable, low sea temperatures off southeast Arabia in the hottest summer months. This has led to the existence of an enclave of southern hemisphere kelp forest along the littoral.

1) The main Indian Ocean climatic cycles

The Arabian region is affected by the Asian weather system that causes two main Indian Ocean monsoons, though they are modified by intrusions from weather systems in the Mediterranean or North Africa.

The broad cycle is basically simple. In low latitudes of the western Indian Ocean, trade winds north of the equator blow essentially from the northeast, while south of the equator they blow from the southeast. The winds are drawn in to meet at a belt of low pressure called the Inter-Tropical Convergence Zone (ITCZ). The Indian Ocean monsoonal patterns, and the seasonal migration of the ITCZ, dominate weather affecting Arabia and its marine climate.

Table 1.1.2 Seasonal Pattern of Meteorology

WINTER PATTERN	SUMMER PATTERNS
In the first quarter of each year the Northeast Monsoon is fully developed and the ITCZ lies far from Arabia, south of the equator. High pressure exists over Asia and over northern Africa. In central Africa there is low pressure, projections of which encompass the Red Sea, especially its central part. Winds along Arabian Coast near Damman are usually blowing from North and/or WNW, and usually remain below 5 m/sec.	The second quarter is the period when the Southwest Monsoon builds up, which in the third quarter holds away from the Arabian Sea to Southeast Asia. The line of the ITCZ migrates northwards, until it touches southern India, passes along the southeast coastline of Arabia, passes up the Gulf of Aden almost into the Red Sea, and then crosses into central or northern Africa. Behind it, the rise in temperature in the northern hemisphere causes strong winds to build up in the Arabian Sea. In the Arabian Sea, now south of the ITCZ, winds are strong and clockwise. Winds over the Arabian Peninsula, which is always north of the ITCZ, are variable in strength, but are anti-clockwise, revolving around a low located over Iran and northern India.

2) Local wind systems

In several parts of the region, greater effects on the marine biota derive from smaller scale wind systems, notably the sea breezes, sometimes called thermionic winds, and from related winds derived from severe temperature differences. The former are diurnal wind changes resulting from differential heating and cooling of the desert and sea, and they are of considerable significance in the Gulf. Winds along Arabian Coast near Damman are blowing from North with the velocity of about 5m/s. Other thermally forced winds may last for several days, especially in winter where one locally called the Shamal has major biological effect.

Table 1.1.3 Local Wind Characteristic

SEA BREEZES	Sea breezes in the main body of the Gulf in summer build up strongly during the afternoon. They are not perpendicular to shore but strike the coast obliquely due to the influence of the prevailing winds. And offshore coral reefs may experience rough conditions. These probably have a generally beneficial effect due to mixing and removing water stratification that causes increased stress in summer months; strong winds also keep shallow areas such as reef flats well flushed. Along mainland shores, however, which are shallow and muddy, the effects are important but more complex. Other thermal winds which have adverse effects on shallow marine life derive from land, and generally occur at night. These are infrequent winds but are intense, and have a powerful desiccating effect on coastal vegitation and, although not investigated, probably on any shallow marine life exposed at low tide as well.
THE "SHAMAL" (=COLD WINTER WINDS)	In the Gulf in winter, local effects include the Shamal, which is a cold northerly wind flowing down from the mountains of Iran, bringing severe chilling. Some of experiences show the very cold wind of around 0 degree, of which wind velocity was observed more than 30 m/sec (58 knots). Extremely high waves of more than 6 meters were used to be built by this wind. Low temperatures appear to occur almost extensive death to fish in the Gulf seemed to have been reported in the past. Mangrove distribution in the Gulf is also limited by cold winter conditions. One possibly significant effect of these winds is the transfer of large quantities of airborne sand and dust. It appears likely that the recent Gulf War will have increased particulate fall-out substantially, especially from burning oil wells. The importance of dust may not be evaluated yet unfortunately. The effects on sea surface temperature of local wind systems may be at least as severe as effects brought by the major systems, especially to intertidal and supratidal marine components such as mangroves which are at their environmental limit. Indeed, a large part of the area is scarcely affected by the major atmospheric cycles. Some of the effects of the air patterns are, of course, transferred to marine biota via induced currents and other hydrographic effects.

1.2 Oceanography

The main, broad scale circulation in the Gulf, or the residual current (current remaining after tidal currents are removed) is an anti-clockwise rotation, affected to some degree by the projection of the Qatar peninsula.

Figure 1.2.1 indicates the schematic of surface currents and circulation processes in the Gulf. Following are explanation of this figure related to the Saudi Arabian Coast by Reynolds (1993).

- The figure indicates the mean winter time surface current pattern which is the most widely known current pattern.
- The flow is predominantly density driven with surface flow inward from the Straight of Hormuz and adjacent to the Iranian coast.
- A southward coastal flow is present along the entire southern coast of the gulf.
- The northern gulf circulation is predominantly wind driven, with the surface flow along both coasts in a southerly direction.
- Outflow from the Shatt Al-Arab is carried by the counter-clockwise circulation in a westerly direction and down the Kuwait and Saudi Arabian coast.

Table 1.2.1 Summary of the Oceanography in the Gulf

The main Gulf circulation	In the Gulf, evaporation exceeds combined rainfall and fresh water input, and even though there is a substantial flow into the Gulf from the Shatt al Arab delta, there is annually a net input of water from the Gulf of Oman. The slope of the floor of the Gulf is a gradual descent to a trough in the north, which runs roughly parallel to the Iranian coast. Most evaporation in both summer and winter occurs in two extensive and mostly very shallow southern embayments along the Saudi Arabian and UAE coasts. Water enters the Gulf through the Strait of Hormuz at a salinity of 36.5 to 37ppt. Some parts in the Gulf, the surface salinity increases to over 40 ppt in open water in both summer and winter (though to much greater values in the semi-enclosed coastal embayments,), and this is about 2 ppt greater than values of normal. There must be a tendency, therefore, for the denser water formed in the southern and southwestern bays of the Gulf to sink towards the northern trough and towards the Strait of Hormuz which is the deepest part of the Gulf. Surface temperatures in the Gulf show greater extremes than those in the Gulf of Oman, being lower in winter and higher in summer. Figures 1.2.2 and 1.2.3 indicate the surface distribution of temperature and salinity for both winter and summer. Difference of temperature between winter and summer is considered to be about 10 degrees. On the other hand, salinity does not be different between two of these seasons.

	The traditional model of water exchange in the Gulf is that denser water flows outward beneath inflowing shallow water. The water enters not only along the upper part of the entrance into the Gulf but principally along the Iranian side, continuing northwest to the end of the Gulf at the Shatt al Arab. After some dilution, it passes southeast, becoming denser and sinking deeper along the bottom as it does so. It exists the Gulf beneath the flowing water, but particularly along the southern side of the Straits. In the narrowest part of the Gulf the exact stratification is unknown, but may follow the same pattern. The surface water flowing into the Gulf has a velocity of 0.1 - 0.2 m/sec. This movement is against the prevailing wind which is thus shown to have a less important controlling effect than the changes in density due to evaporation, though it undoubtedly has a retarding effect on the flow. The resulting turnover time of water in the Gulf due to the circulation, defined as the time needed for all Gulf water to come within the influence of the open sea boundary, is estimated by Hunter to be about 2.4 years. The actual flushing time is estimated to be about 3 to 5.5 years, and is longer because of the effects of vertical mixing and other turbulent processes.
Circulation in the southern embayments	The shallow southern and southwestern Gulf coasts including Arabian Coast are the principal sites of evaporation which is important because this drives the main Gulf circulation. The bays themselves are indented and include large areas with very restricted circulation, and these increase evaporation further. For this reason, the above estimates of water flushing and turnover can only be averages, and water in the Gulf of Salwah, for example, is likely to be retained for much greater periods. These embayments are important sites biologically for two reasons, firstly because they are highly productive in terms of carbon and nitrogen fixation, and secondly because their conditions of high environmental stress lead to several local extinction of marine biota.
Wave energy and tidal patterns	In the Gulf, two amphidromic points where tidal range is zero occur off northern Saudi Arabia and off the UAE coast. The tidal regime in the central part and Bahrain is complex and basically semi diurnal. Over most of the Gulf away from shore, tidal range is less than 0.6 m, but it rises to 1 - 2 m near land, especially in the far north and just outside the Strait of Hormuz. Off Kuwait at the northern tip of the Gulf, spring tidal range reaches 2 m in the south and up to 4 m in the north, while off Bahrain range is 2 m at extreme springs. To some degree the diurnal pattern in both of these locations ameliorates the conditions for shallow and intertidal biota; in summer, high tides cover the shallow reefs in daytime and expose them at night, thus affording some protection in normal conditions. Hence the conditions noted for Kuwait and Bahrain are different from several other parts of the Gulf; in the central region of Qatar, Saudi Arabia and the UAE, low tides commonly expose the gradually sloping intertidal region during daytime in summer. Because of barrier effect from a huge shallow reef complex of Fasht Azm between Bahrain and Qatar, water in the large Gulf of Salwah which is located between Qatar and Saudi Arabia is more restricted than the width of its entrance suggests. Tidal ranges which reach 1.2 m to the north of Bahrain are reduced to about 0.5 m in the south of the Gulf of Salwah, and its phase lags considerably. Flushing is reduced and total water retention time increased. Similar constrictions occur near the mainland shore of the UAE where

	extensive shallows and ponds occur on the particularly gentle transition from land to sea. Tidal streams passing through constrictions caused by reefs, current-formed sand bars, and low islands commonly exceed 1 - 2 m/sec. They are important mechanisms of water and nutrient movements even where water exchange with the main part of the Gulf is limited. Tidal streams are important in providing the water movement necessary for vigorous benthic biota, even in areas where there is little tide or water exchange other than oscillation of locally confined water.
Dissolved oxygen and nutrients	Some sources state that the Gulf is thought to be one of the most productive bodies of water in the world, though there has been confusion between benthic and pelagic production in this shallow body of water, and this statement should really apply only to the total, or benthic production. In the shallow water of the Gulf, even though there is unlikely to be any limitation by light levels, there is evidence of nutrient limitation, with a consequent reduction in true pelagic productivity. Primary productivity is greater in mixed central waters and in shallow bays, especially in the influence of the Shatt al Arab estuarine conditions. Jones reports chlorophyll a values in the Gulf of 0.2 - 0.86 mg/m^3, but as he also notes, this is less than that recorded in the Arabian Sea where upwelling raises concentrations by one or two orders of magnitude.

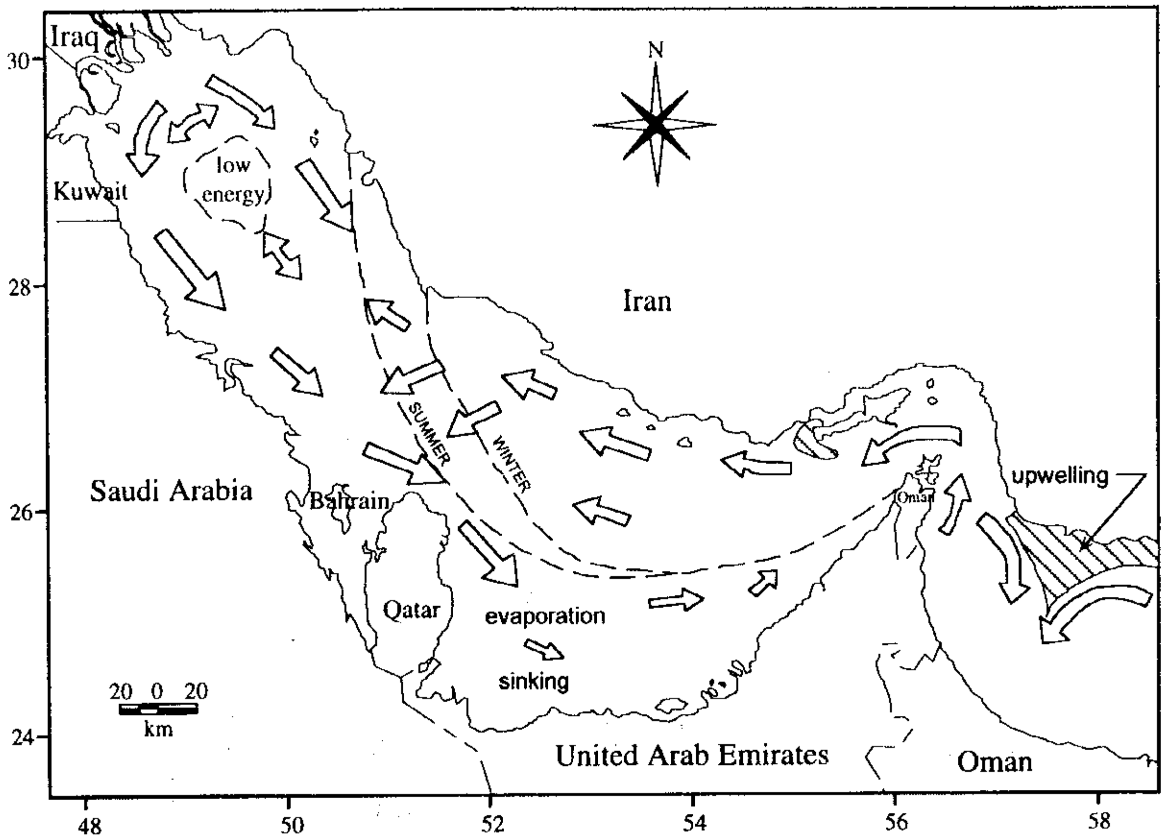

Figure 1.2.1 Schematic of surface currents and circulation processes (Michael Reynolds, 1993)

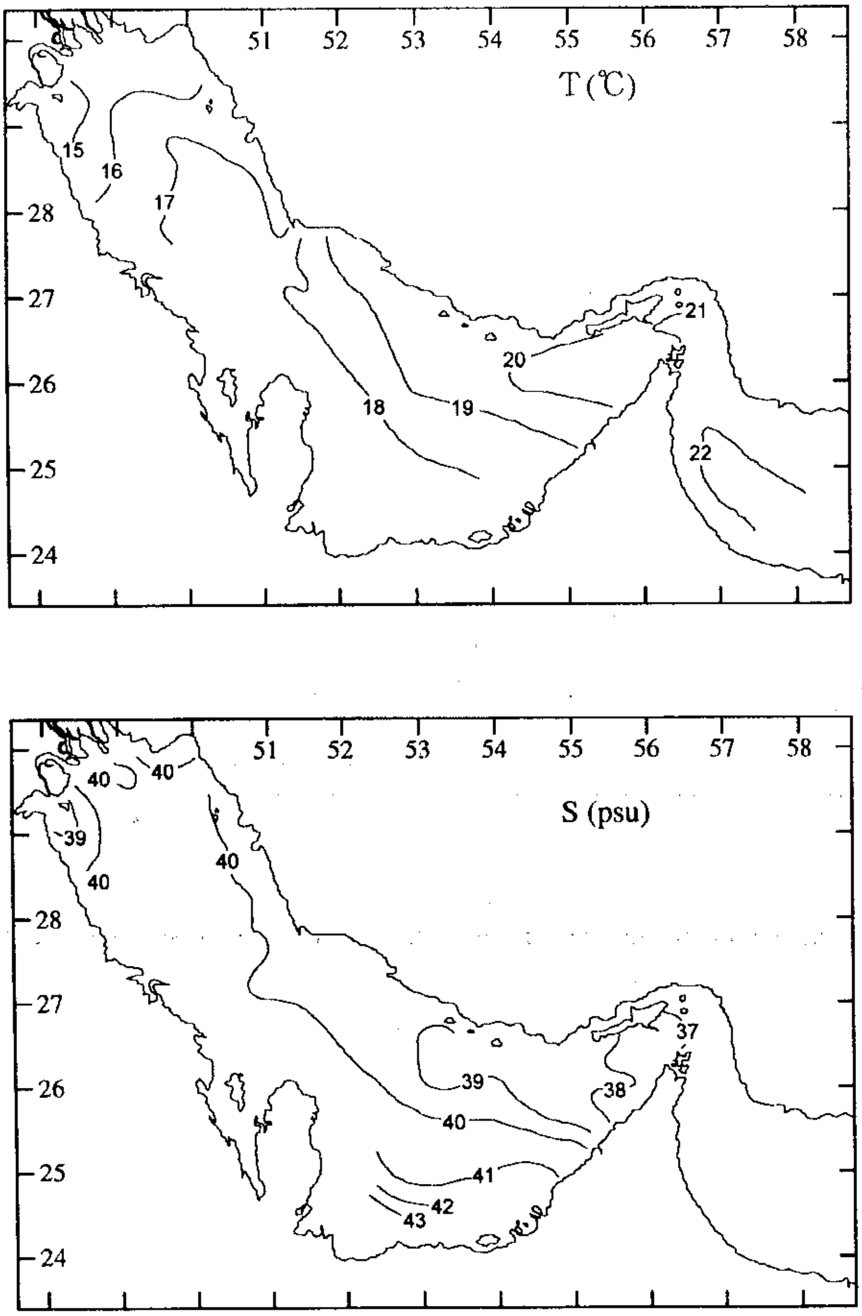

Figure1.2.2 Maps of surface temperature and salinity for winter (By Reynolds, 1993)

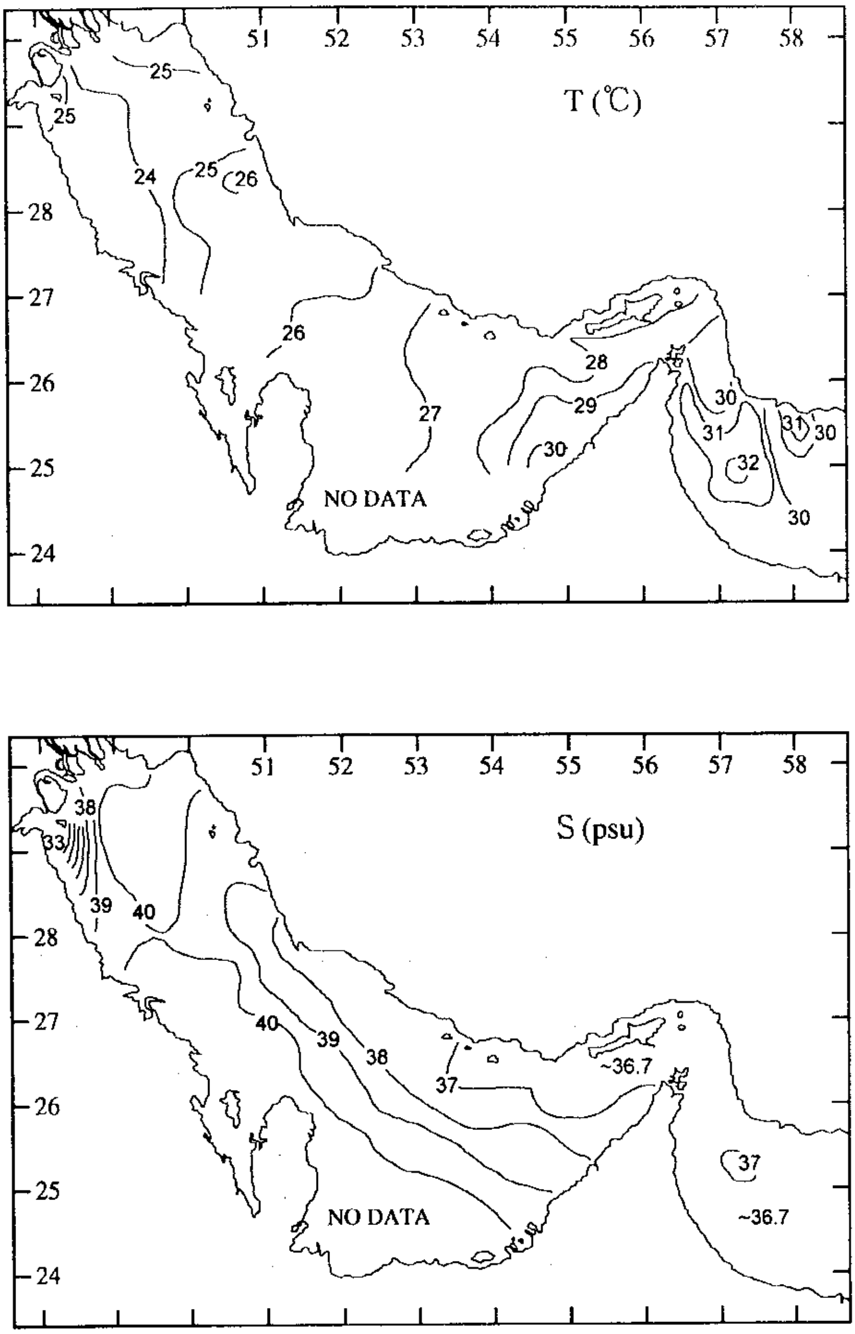

Figure1.2.3 Maps of surface temperature and salinity for early summer (By Reynalds, 1993)

1.3 Economical condition / Industrial Structure

1.3.1 Economy in General

The government of Kingdom of Saudi Arabia (KSA) has been exerting its effort to diversify the economy in the past three decades from the crude oil industry and has achieved a successful diversification. As the result, the oil sector in the GDP comparably decreased its ratio to 34.8% in 1998 from 58.9% in 1970. (WEIS Report, Sept.1999) The above achievements have been carried out through the Five Year Plans which commenced in 1970 and currently entered into the 6th plan.

Table 1.3.1 Five Year Plans of the KSA

Plan	Key Issues
The first Five-Year Development Plan (1970~1975)	Increasing of the role of the non-oil sector on the economy.
The second development plan (1975~1980)	Attainment of high economic growth rate. Decreasing of the dependence on oil. Human resources development. Raising of the standard of living. Physical infrastructure development.
The third development plan (1980~1950)	Growth in agriculture, industry, and mining. Saudi human resources training and development. Continuous efforts on the goals of the second development plan.
The fourth development plan (1985~1990)	Increasing of productivity and efficiency of the economy. Promotion and execution of economic and social integration within the GCC countries. Reduction of dependence on expatriate labor. Underlined the significance of the role which the private sector had to play in the overall economy of the country.
The fifth development plan (1990~1995)	Continuation of the long term objectives of the previous plan. Growth and industrialization of private sector. Creation of job opportunities for the Saudi work force. Local production to replace foreign imports. Increase export and improve the balance of payment.
The sixth development plan (1995~2000)	Privatization of public sector companies such as those for telecommunication, aviation, SABIC group etc. Replacement of expatriate labor force for Saudi nationals and training of Saudis.

Source: Top 1000 Saudi Companies 5th Edition 1997~98

1.3.2 Economic Structure

The GDP of Saudi Arabia as of 1998 is approximately 128.9 billion US dollars (World Bank database July, 2000). The principal sector is oil, natural gas and minerals for 38%. The second is the public services for 18 %. Thirdly manufacturing including oil and petrochemical products for 10%, likewise construction 8%, agriculture 6%, commerce and services 6%, transportation, ware-housing and communication 6%, finance, insurance and real estate services 5 % and others 3%.

In 1998, Saudi Monetary Agency estimates the oil sector shares 34.8% of GDP and non-oil sector 65.2% out of which 40.1% attributes to the private sector, and 25.1% to the public sector respectively. The non-oil sector attained an annual average growth rate at 6.3% since 1970 (For detail, refer to Table 1.3.2).

Table 1.3.2 GDP. Structure as of 1997

Unit: 100 million US Dollars (exchange rate: 3.74 Riyals/US$)

	1994	1995	1996	1997 (%)
Crude Oil Gas etc.	39,863	42,606	49,516	54,425 (38)
Industry	10,554	11,412	12,741	13,967 (10)
Oil Products	(4,195)	(4,512)	(5,223)	(5,803)
Others	(6,359)	(6,900)	(7,518)	(3,164)
Construction	11,425	11,630	11,884	12,383 (8)
Agricul./Fishery	8,323	8,449	8,599	8,857 (6)
Commerce, Hotel	8,818	8,862	9,160	9,389 (6)
Transport etc.,	8,143	8,266	8,424	8,719 (6)
Finance etc.,	5,371	7,347	7,487	7,751 (5)
Public Services	21,417	23,060	24,172	25,998 (18)
Others	6,413	4,224	4,737	4,878 (3)
Total	120,327	125,856	136,720	146,367 (100)

Source: WEIS ARC Report

1.3.3 Current Status of Export and Import

The total amount of export in 1997 was 60,731 million US dollars, while the import was

26,370 million dollars. The export exceeded the import by 34,361million dollars. However in 1998, the export is estimated to have fallen sharply to 38,822 million dollars, 36% down compared with the previous year, due to the low price of crude oil and the surplus went down to 11,287 million dollars which caused much deficiency in the national revenue of Saudi Arabia. In the middle of 1999, the oil price started increasing again and recovered the surplus to 22,765 million dollars and the current year of 2000 continued to increase and even reached to the level of the time of the Gulf War in 1990. This would improve the cash position of Saudi Arabia dramatically in 2000. (International Financial Statistics,Aug.2000)

The major export items based on 1997 data are minerals including crude oil and gas which undertake 88% of total Saudi export. Chemical products come to the second position with 4.9%, and thirdly plastics with 2.5 %. Steel and metal products are now becoming one of export items to take 1.3%

The import items are electrical appliances 19.8%, foods 17.4%, vehicles 15.5%, steel 9%, gold and precious metals 7.7%, and clothes 6.6% (by WEIS ARC Report, Sept. 1999).

1.3.4 Balance of Payment

Although Saudi Arabia exports a tremendous amount of oil, its service balance is always in the red. Taking the sample from the figures in 1998, the trade balance (export-import) was surplus by 11,280 million dollars (67% down from the previous year), but the service balance showed deficit by 15,152 million dollars.

In addition, Saudi Arabia has been paying a huge amount (US$15,053 million in 1998), as transfer, to the foreign countries mostly through remittance by the expatriate workers. Therefore the total balance of payment tends to be deficit (US$16,149 million in 1998) since 1983 except for 1996 and 97. The imbalance made the Government of KSA spend half of the foreign reserves which it ever had accumulated at a peak time (140 billion dollars) (For detail, refer to Table 1.3.3).

Table 1.3.3 Balance of Payment (Million U.S Dollars)

	1995	1996	1997	1998	1999
Trade Balance	24,391	35,370	34,361	11,287	22,765
Export	50,041	60,729	60,731	38,822	48,482
Import	25,650	25,358	26,370	27,535	25,717
Service Balance	△15,603	△21,523	△21,706	△15,152	△13,702
Investment	2,803	2,446	2,785	2,769	3,311
Transfer	△16,916	△15,613	△15,134	△15,053	△14,076
Total Balance	△5,324	681	306	△16,149	△1,702

Source: IMF

1.3.5 Labor Force

According to World Bank's database, July 2000, total population of Saudi Arabia in 1999 is estimated to be 21.4 million. In 1992 the national census showed the population as 16,929,294. The figures include the number of Saudis (72.7%) and expatriates (28.3%). The increase of 4.5 million in 7 years can be explained by the fact that the population growth rate is as high as 3.3~3.4% per annum. The percentage of expatriates is almost for pure labor force which means the expatriates occupy job positions more than the Saudi nationals.

The kingdom faces a delicate problem that the Saudi economy has long needed foreign labor force to attain the dynamic development, while the increasing number of young Saudis demand their jobs. However the quick replacement of expatriates for Saudis is not an easy issue, because of the gap between the actually required position and what the young Saudis want to take. The government of KSA has been exerting its effort to enhance the capability and efficiency to cope with the market needs with an extensive program of educations for the young Saudi nationals. The opportunity for high education to the level of university is given equally to male and female students and the number of enrolment in 1997 reached 223,802 in total, with male students of 113,774 and female 110,058 . The total number in 1997 increased 50% from that in 1993 (For detail, refer to Table 1.3.4).

Table 1.3.4 Number of University Students (Enrolment)

1417/1418H* (1997)			1416H (1996)			1416/1415H (1995)		
Total	Male	Female	Total	Male	Female	Total	Male	Female
223,802	113,774	110,058	163,585	86,468	77,117	148,425	78,636	69,789

Source: Saudi Ministry of Planning

*Note: 1418H (May 7 '97~Apr.26 '98)

1.3.6 Roles of Public Organization

The fast diversification of Saudi economy was successfully achieved. This would not be possible without the strong governmental leadership in line with the five–year plans. Specifically the following public entities among others have contributed to the development of Saudi economy and still are pursuing their goals in the individual area.

Table 1.3.5 Public Organizations

Organization	Established Company	Description
Saudi Arabian Oil Company (Saudi ARAMCO):	Saudi Aramco Mobil Refinery Co., Saudi Aramco Shell Refinery Co., Petromin Lubricating Oil Refining Co., Petromin Lubricating Oil Co.	Owned100 % by Saudi Government and responsible for all of the Kingdom's petroleum activities.
Saudi Basic Industries Corporation (SABIC)	Steel Rolling Co. Saudi Iron and Steel Co. Saudi MethPuanol Co. Al-Jubail Fertilizer Co. Saudi Yanbu Petrochemical Co. Al-Jubail Petrochemical Co. Saudi Petrochemical Co. National Methanol Co. Arabian Petrochemical Co. Eastern Petrochemical Co., Saudi Arabian Fertilizer Co. National Plastic Co. National Gases Co. Saudi European Petrochemical Co. Arabian Industrial Fibers Co., etc.	Responsible for Kingdom's industrial development utilizing the local resources of hydrocarbons and minerals as raw materials.
General Petroleum and minerals Organization (PETROMIN)	Saudi Arabian Mining Co. Arabian Drilling Co. Arabian Geophysical and Survey Co. Saudi Precious Metals Co.	Responsible for implementing and managing the mineral and petroleum projects.
Royal Commission of Jubail and Yanbu	-	Responsible for supply and management of all kinds of infra-structural services for both of the industrial cities in Jubail and Yanbu.
Saudi Consulting House (SCH)	-	Responsible for technical and consultancy services.
Grain Silos & Flour Mills Organization (GSFMO)	-	Responsible for development of agriculture and animal husbandry.

1.3.7 Industries in Eastern Province

1) Industries

Since 1938 when a large quantity of oil was discovered in Dammman, the Eastern Province has been the center of attractions for the government of KSA as well as for the world. The principal industries in the Eastern Province are listed in Table 1.3.6:

Table 1.3.6 Principal Industries in the Eastern Province

Refinery and NLG Plant	Aramco refinery/NLG complex including a terminal of oil/ LNG, Ras Tanura. Saudi Aramco/Shell Refinery Co., Al-Jubail
Petrochemical Plant	Al Jubail Petrochemical Co., Eastern Petrochemical Co., Al Jubail Arabian Petrochemical Co., Al Jubail National Methanol Co., Al Jubail
Metal/Steel Plant	Saudi Iron and Steel Co., Al Jubail Zamil Steel Buildings Co. Ltd., Damman
Chemical Fertilizer Plant	Al Jubail Fertilizer Co., Al Jubail Saudi Arabian Fertilizer Co., Dahran
Water Desalination and Power Generation Plant	Saline Water Conversion Corporation, Al Jubail Saudi Consolidated Electric Co., in the Eastern Province, Damman General Electricity Corporation
Plastic Products Factory	National Plastic Co., Al Jubail Saudi Plastic Products Co Ltd., Damman
Cement Plant	Eastern Province Cement Co., Damman Saudi Cement Co., Damman
Others	National Paper Products Company-Damman, Damman Saudi Fisheries Co., Damman Arabian Geophysical and Survey Co., Al Khobar

2) Industrial Features in Eastern Province

The Manufacturing sector, especially extraction of crude oil and oil refineries is dominant in terms of economic size (turnover) which is almost equivalent to 90% of total economy in the region. On the other hand, in terms of job creation, the other sector (construction, commerce and service) undertakes almost 60% of total employment, while the manufacturing sector takes 40%. In this sense, construction and service companies can be regarded as a most reliable source to offer job opportunities to the young Saudi people, particularly because those types of jobs are currently taken extensively by the expatriates. It is indicated that diversification of economy will expand possibility of saudization of human resources which is also one of important goals of KSA. (For detail, refer to Table 1.3.7)

Table 1.3.7 Ratio of Manufacturing Companies to All Companies

	Number of Companies	Number of Employee	Turnover (SR)
Manufacturing	88	96,859	175,136,843,051
All Company	247	245,323	200,544,716,185
Ratio (%)	36%	39%	87%

Source: Top 1000 Saudi Companies

3) Industrial Impact on Environment

Al-Jubail, Damman, Daharan, and Al-Khobar, which make up the core center of Saudi industrialization, are located in within a 200km zone on the eastern coast. Major Manufacturing Companies exist in this area are shown in Table 1.3.8. Also, possible sources of pollutants in those cities are assumed and listed in Table 1.3.9.

Table 1.3.8 Major Manufacturing Companies in Saudi EP

Group No.	Kind of Manufacturing	Number of Companies	Ratio (%)	Number of Employee	Ratio (%)	Turnover (SR)	Ratio (%)
12	Food	6	6.82%	6,998	7.22%	4,160,500,000	2.38%
13	Beverage/Fodder/ Cigarette	1	1.14%	61	0.06%	22,831,719	0.01%
14	Textile (Excluding Fabrics)	1	1.14%	66	0.07%	25,000,000	0.01%
17	Furniture	2	2.27%	392	0.40%	75,000,000	0.04%
18	Pulp/Paper	5	5.68%	1,120	1.16%	575,279,000	0.33%
20	Chemicals	16	18.18%	4,879	5.04%	4,903,132,000	2.80%
21	Oil and Coal Products	2	2.27%	59,000	60.91%	157,580,000,000	89.98%
22	Plastic	9	10.23%	2,878	2.97%	775,500,000	0.44%
25	Ceramic/Soil and Stone Products	11	12.50%	6,208	6.41%	1,886,917,691	1.08%
26	Steel	2	2.27%	396	0.41%	238,646,000	0.14%
27	Metal excluding Steel	1	1.14%	35	0.04%	21,000,000	0.01%
28	Metal Products	17	19.32%	8,336	8.61%	2,636,036,641	1.51%
29	Machine	5	5.68%	3,320	3.43%	794,000,000	0.45%
30	Electrical Machine	7	7.95%	1,960	2.02%	658,000,000	0.38%
34	Other Products (Jewellery, Music Instruments, etc.)	1	1.14%	50	0.05%	25,000,000	0.01%
37	Gas	2	2.27%	1,160	1.20%	760,000,000	0.43%
Total		88	-	96,859	-	175,136,843,051	-

Source: Top 1000 Saudi Comp

Table 1.3.9 Major Possible Pollutants from Manufacturing Industry in Saudi EP

Group No.	Kind of Manufacturing	Location	Possible Pollutants	
12	Food	Dammam Daharan Alkhobar	Organic Substance Residual Chlorine	Oil & Grease
13	Beverage/ Fodder/ Cigarette	Dammam	Organic Substance Nitrogen	Oil & Grease Phosphorus
14	Textile (Excluding Fabrics)	Dammam	Organic Substance Nitrogen Residual Chlorine	Oil & Grease Phosphorus Metals (Cr)
17	Furniture	Dammam Alkhobar	Organic Substance Organic Solvent	Oil & Grease
18	Pulp/Paper	Dammam Alkhobar	Residual Chlorine	Oil & Grease
20	Chemicals	Dammam Jubail Alkhobar	Metals(Mn, Cr, Pb, Cd, Hg, Fe, Na, As) Organic Substance Oil&Grease Organic solvents (BTEX) Nitrogen (NH_4-N, NO_3-N)	Cyanide (CN) Phenols Phosphorus SS LAS
21	Oil and Coal Products	Daharan Khafji	Phenols Sulphide Organic Solvents (BTEX)	Nitrogen (NH_4-N) Cyanide (CN) Oil &Grease
22	Plastic	Dammam Alkhobar	Organic Solvents (BTEX)	Phosphorus
25	Ceramic/Soil and Stone Products	Dammam Jubail Daharan Alkhobar	Metals (Ca, Pb, Fe, Cd) Organic Solvents (BTEX)	SS Oil &Grease
26	Steel	Daharan Alkhobar	Metals (Fe, Cr, Pb, As, Fe, Hg) Cyanide (CN)	Oil &Grease SS
27	Metal excluding Steel	Jubail	Metals (Pb, As, Cu, Zn, Cd, Co, Fe, Al) Organic solvents	Oil &Grease
28	Metal Products	Dammam Jubail Daharan Alkhobar Sayhat	Metals(Cr, Mn, Zn, Fe, Ni, Pb, Cu, Sn) Organic solvents (BTEX)	Cyanide (CN) Nitrogen (NH_4-N)
29	Machine	Dammam Alkhobar	Organic Solvents	
30	Electrical Machine	Dammam Daharan Alkhobar	Metals(Hg, Pb, Cd, Ni, Hg, Sn, Zn) Organic Solvents (BTEX) Nitrogen (NH_4-N, NO_3-N)	Phosphorus (PO_4-P) Cyanide (CN)
34	Other Products (Jewellery, Music Instruments, etc.)	Dammam	Organic Solvents	
37	Gas	Dammam Alkhobar	Metals	Residual Chlorine

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1.4 Coastal and Marine Uses

Oil, domestic, urban and industrial pollutants are a problem in several parts of the Gulf, although effects on ecosystem structure and function are generally not well known. The coastal zone is also fact becoming the repository for solid wastes. Major ecological problems have arisen from loss/degradation of production coastal habitats, caused by coastal landfill, dredging and sedimentation.

The distributions of main pollution sources are shown in Figure 1.4.1 and 1.4.2. The outlines of these main pollution sources are described below.

1.4.1 Oil Pollution

Linden et al. (1990) suggested that whereas in the Gulf most inputs of oil to the marine environment originate from tanker and ship traffic.

Input from tanker and ship traffic originate primarily from discharge of dirty ballast water and other oily water, which during 1986 ranged from 400,000 to 750,000 tones in 1986 in the Gulf (Linden et al. 1990). The entire Arabian Gulf is a major oil tanker and commercial shipping area. Large industrial ports along the Arabian Gulf coast are located at Tanaquib, Saffaniya, Jubayl, Ju'aymah, Ras Tanura and Damman.

The rest of the marine oil pollution originates principally from refining, industrial and urban sources. Well blowouts during drilling and as a consequence of war activities, can also be a source of oil pollution.

Major oil refineries and related facilities such as gas plant, tank farm etc. are in Zuluf field, Marjan field, Saffaniya field, Tanaquib, Manifah, Abu Ali, Al-Jubayl, Berri, Ras Tanura, Al Juaymah, Dhahran and Ras al Qulayah.

1.4.2 Wastewater Pollution

Numerous sources contribute to wastewater pollution in the coastal area of the Gulf.
Of domestic and urban sources, untreated sewage and abattoir wastes are discharged at several localities. For instance, in the Saudi Arabian towns of Al-Khobar, Al-Hasa and Al-Qatif daily inputs of the sewage into the Gulf may be as high as 40,000m^3, equivalent to

production by 175,000persons (IUCN 1987). Effects include unsightly solids and grease mats, local eutrophication, increasing biological oxygen demand (BOD) and algal blooms. Sewage treatment plants are helping to alleviate some of these problems. Domestic wastes and pollution are becoming an increasing problem in Oman (Salm et al. 1988).

Industrial facility is also possibly to be significant pollution sources. Industrial facilities are concentrated around Jubayl, Saffaniya, Ju'aymah, all around Tarut Bay including Ras Tanura, Qatif, dammam, and Al Khubar. Industrial developments in these areas include refineries, petrochemical plants, power plants, desalination plants, waste water treatment plants, and other primary and secondary industries.

Among the industrial wastewater from fertilizer plants and refinery and other industrial effluents may contain heavy metals. Elevated concentrations of lead, mercury and copper in ivalves and fish have been reported around some ports and industrial areas. High levels of cadmium, zinc and vanadium have been found in sediments (Linden et al. 1990). However, a recent study revealed that copper and vanadium levels, although comparable to values elsewhere in the Gulf, were an order of magnitude lower than heavily polluted areas in some other part of the world (Coles and McCain1990).

High concentration of heavy metals are reported near some industrial areas of the Red Sea, such as desalination plants (Dicks 1987, UNEP 1987), whose effluents also are normally above ambient temperature (+5°C) and salinity (+3ppt: Linden et al. 1990). Chlorine is also used as an ecological effect of effluents may be considerable locally, but probably only minor over larger areas, at least in the Gulf (Linden et al. 1990). Power plants also possibly discharge chlorine and/or high temperature effluent. Major waste sewage treatment plant is in Jubayl, Quatif, Dammam and Khubar and major Power plants are in Saffaniyah, Jubayl, Ghazlen, Ras Tanura, Dammam, and Khubar.

1.4.3 Commercial and Residential Development

On both coasts, commercial and residential developments are clustered around urban areas. Such developments need transportation systems, water, electricity, sewage and solid waste disposal, and other services, with the cumulative effects causing significant pressure on coastal areas. Moreover, the residents of the coast have an increasing need for recreation facilities, particularly near these urban areas.

On the Arabian Gulf coast, the developments around Jubayl and further south around Tarut Bay/Dammam/Al Khubar are responsible for a great deal of the coastal land development.

1.4.4 Fishing and Aquaculture

The fishing industries in the Arabian Gulf account for some coastal land uses. However, these uses generally do not create significant disturbances to the environment. Numerous small fishing villages are scattered along both coasts and the industrial fishing ports and processing facilities are clustered near the urban areas.
On Tarut Island, there are number of small artisanal fishing villages including Darin Sanabis and Zur. Near Qatif, there are also two smaller artisanal fishing villages: Saihat and Safwa.

Anchor damage to coral reefs is now a problem on Jurayd island and possibly elsewhere. In addition to fishing, hunting of bird eggs is intensive in some areas. Agriculture appears not to be causing major coastal environmental problems, but further studies are needed.

1.4.5 Coastal Reclamation

Together with dredging, coastal reclamation probably represents one of the most significant impacts on the coastal and marine environment of the Arabian Gulf. Reclamation has been undertaken for residential development, ports, bridges, causeways, cornishe roads and other purposes. Favored areas often have included intertidal flats often with mangroves, shallow embayments and other biologically productive areas, whose true bioeconomic value is seldom recognized by developers. Coastal development and in filling has been far greater along the Gulf coast than in the Red Sea or other par of the Arabian region, where its occurrence is more localized (IUCN 1987). Approximately 40% of the Saudi Arabian Gulf coast has been developed (IUCN 1987), involving extensive infilling and reclamation. Only an estimated 4km^2 of mangroves now remain along these shores (Price et al. 1987a).

Apart from the direct and permanent loss of habitat, landfill usually increases sedimentation. This may directly smother habitats, or may limit photosynthesis of communities such as algal mats, seagrasses and coral reefs (IUCN/UNEP 1985a). Whether this has had measurable effects on the fisheries is not known, but nevertheless has caused concern (IUCN/UNEP 1985a).

1.4.6 Dredging

Dredging provides much of the infill material needed for coastal reclamation hence the two activities often occur simultaneously. The former also takes place to deepen shipping channels and harbors. Like landfill, dredging has taken place most extensively in the Gulf. As a result of projects in Jubayl and Dammam, an estimated 46.5km^2 of coastal habitats have been dredged; and for landfill the residential and industrial areas of modern Jubayl City, more than 200million m^3 of sediments adjacent to the development site (IUCN 1987) were removed. During construction of the Saudi-Bahrain causeway, nearly 60 million m^3 of mud and sand were dredged (Linden et al. 1990).

The ecological effects of dredging are similar to those described above for coastal reclamation, and include both direct habitat loss and various secondary effects. In parts of the Gulf, sedimentation stimulated by dredging has created the soft substrate feeding areas for some species such as waders (IUCN 1987). Some fauna (e.g. birds) may have benefited from new habitats created by sedimentation, for instance in Tarut Bay (IUCN 1987). In general, however, ecological effects are undoubtedly more adverse than beneficial.

1.4.7 Solid Waste Pollution

Throughout much of the region the coastal zone has become a repository for large quantities of industrial, commercial and residential trash and other solid waste (IUCN1987). Often this takes the form of plastics, metal containers, wood, tires and even entire scrapped automobiles at some localities (IUCN 1982,1987). A survey in Eastern Province shows the percentage of waste in Table 1.4.1 (JICA Country Profile on Environmet).

Table 1.4.1 Percentage of waste by material

City	Paper	Glass	Metals	Plastic	Food	Wood	Other
Dammam	1.4	4.92	6.46	7.31	61.38	1.03	4.63
Khobar	16.34	7.07	6.71	9.86	56.79	1.00	2.14
Dhahran	24.86	10.43	9.00	18.14	26.00	0.43	11.14

In the Gulf, oil sludge constitutes the most important type, in terms of quantity, of solid waste (Linden et al. 1990). Much of the lighter debris has become spread along widespread tracts of shoreline through wind and water movements. During a recent survey, solid waste was encountered at 87% of 53% sites inspected along the Gulf coast (Price et al. 1987b, Price 1990). In recreational areas, solid waste can have ecological as well as aesthetic consequences. In areas containing extensive metal and industrial debris, the potential exists for toxic substances to leach into the marine environment. Wooden pallets and driftwood may form a physical barricade to female turtles crawling up beaches to nest. Further, if such debris becomes impacted by an oil slick, the problem becomes compounded, and also increases dramatically the cost of any future oil clean-up operations. For this reason, several offshore coral islands in the Gulf, where turtles and birds nest in high densities, were cleared of debris shortly after the 1991 war.

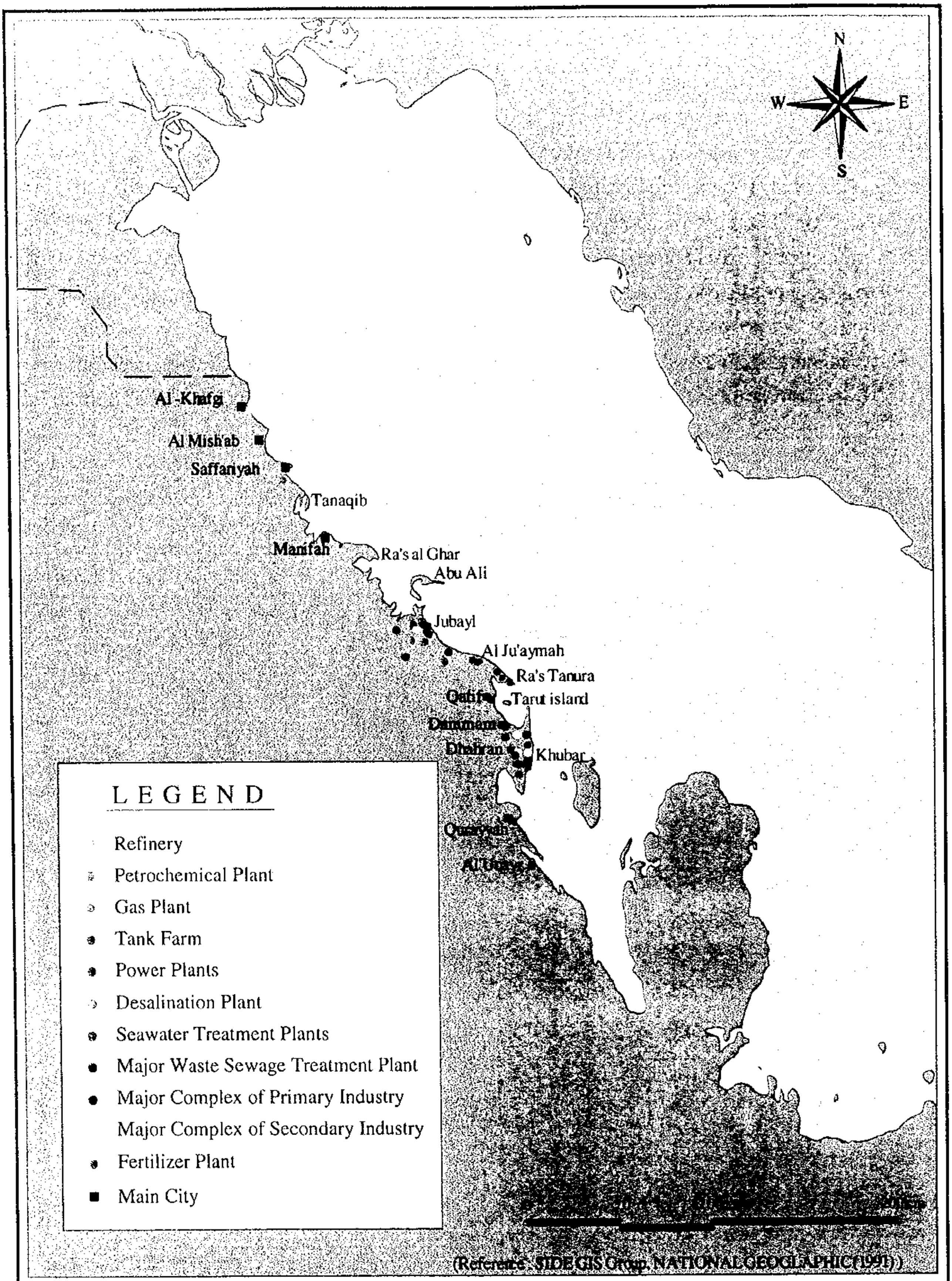

Figure 1.4.1 Distribution of Main Pollution Sources

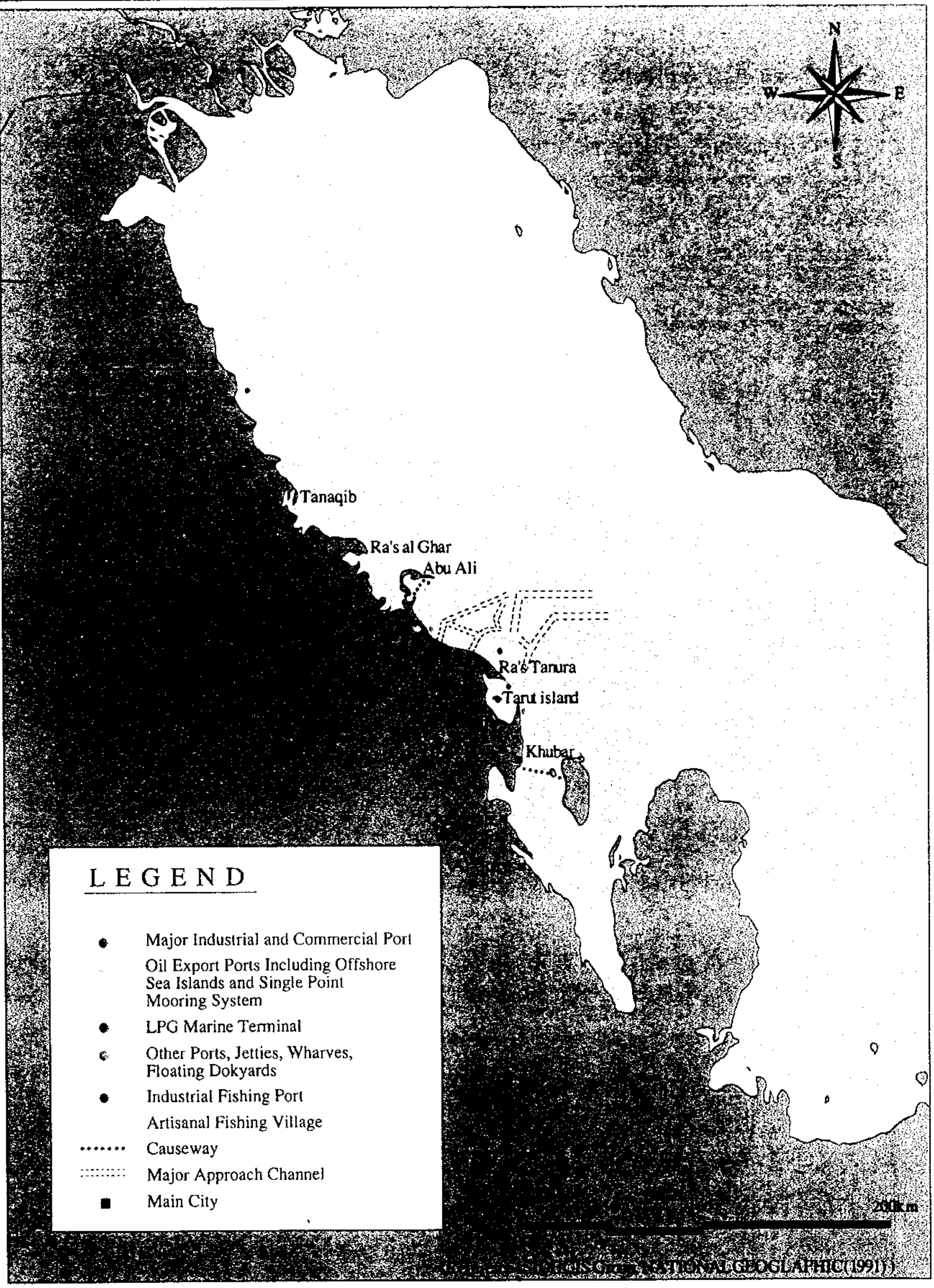

Figure 1.4.2 Distribution of Main Ports and Harbours

1.5 Ecological Condition

1.5.1 Coastal and Marine Habitats

According to the IUCN/MEPA's report (1988), the principal habitats of the Arabian Gulf have been identified as follows;

The details of these habitats are described as bellows.

1) Coastal Wetlands

Because much of the shoreline of the Gulf is low lying, its intertidal zone commonly hundreds of meters wide. This large intertidal area has ecologically important habitats such as mangroves, salt marsh and sabkhah.

Table 1.5.1 Ecologically Important Habitats in the Coastal Area

- Mangrove	Mangrove is recognized critical and ecologically significant marine habitats. Their fallen leaves and sticks make appreciable contributions to inshore and estuarine productivity. Mangrove ecosystems are also associated with the maintenance of biota, thereby assuming importance as a genetic reservoir. The major nursery function of mangrove roots (e.g., for shrimp and fish) highlights this, and is a feature often exploited by artisanal fishermen and aquaculturists. Mangroves also provide a refuge and breeding area for birds and other marine and terrestrial wildlife (Shepard et al. 1992). Mangroves occur in the Gulf along the upper intertidal zone in bays, although they tend to be poorly developed and patchily distributed. Only one mangrove species, Avicennia Marina is occurs in the Alabian Gulf, perhaps due to their unusual tolerance for high salinity (about 40 to 50%) and low temperatures (until about 12C°; Hutchings and Saenger 1987). The northernmost stands of mangroves occur about 27°N for naturally occurring mangroves on the Gulf coast (IUCN 1987) and in Saudi Arabia, their stands are mostly limited in Tarut Bay, Al Qurayyah, south of Dhahran and between Ra's al Ghar and Abu Ali (Taylor 1991). However, in recent years, artificially planted mangroves have been grown on the northern Saudi Arabian Gulf at Ras al Khafji at about 28°30N(Kogo 1986).
- Sabkha	The term sabkha is used to denote hypersaline wetland that is seasonally inundated. They cover some 1,000km^2 in Saudi Arabia, mainly in Tarut Bay, Musharihah and Mssallamiyah (Taylor 1991). Sabkha forms very flat plains in the coastal area, commonly with periodically filled pools, crusts of sodium chloride and gypsum, with "algal mats" a few centimeters thick beneath which is black reducing layer with a clear sulfide -odor.

	Mats are complex associations of cyanophytes, acteria and diatoms, whose composition is determined by small difference in elevation and frequency of immersion. They remain moist from capillary action in the sediments, from the strongly hygroscopic nature of sabka salts, as well as from physiological adaptations. With increasing isolation from the sea, benthic diversity of the sabkah falls and the persistent microbial biota then forms typical mat. These are highly productive and fix nitrogen. In many examples in the Gulf, the seaward edge of the sabkha grades into seagrass beds and complex region of shallow patch reefs, mud banks and lagoons (Sheppard et al. 1992).
- Salt marsh	All natural salt marshes and their plant communities are greatly reduced or eliminated throughout the Arabian Gulf coast. However, many new march communities are appearing as a result of sewage outfalls whose fresh water derives from desalination plants. These areas also act as a focus for numerous species of birds, especially migrants.

2) Intertidal Flats

Intertidal habitats such as mudflats are particularly important because they produce a surplus of organic matter and thus provide food for coastal species.

Mud and muddy sand are the predominant marine substrates in the Arabian Gulf and are also exposed as intertidal flats. Along the Arabian Gulf coast these tidal flats are the most important types of intertidal habitat in terms of area (Basson et al. 1977). Even though quantitative data on the productivity of these tidal flats are not yet available for the Gulf, the animal biomass the flats support indicates that they are extremely rich.

Their productivity is thought to be similar to tidal flats in other parts of the world, which are known to be among the most productive of all natural ecosystems. The main sources of primary production in the Gulf are salt-marsh halophytes, mangroves, blue-green algal mats and diatoms (Jones 1985). Since a large proportion of this production is exported (e.g. by fish and birds), these habitats are of great importance of the coastal zone ecosystem as a whole.

3) Beaches

Sandy beaches are of low biological productivity and are dominated by gastropods and ghost crabs (*Ocypode spp.*) They are well distributed in all the Gulf shoreline and are a significant habitat of offshore islands. Some 350km of the Saudi shoreline comprise sandy beaches. They represent important nesting areas for marine turtles and birds (Taylor 1991).

4) Subtidal Sand / Subtidal Mud

In the Gulf, subtidal sandy ecosystems extend down to at least 30m, whereas mud occurs in depths of 6m and more and is also the principal benthic ecosystem at depths greater than 30m (Basson et al. 1977).

Morthensen and Gislen (1941) reported useful information on subtidal sand and muddy benthos in the Gulf. Species richness reported to be high (>600 species) in both subtidal sand and subtidal mud surpassing that of all other ecosystems, even coral reefs (534 species). Polychaetes followed by gastropods were the dominant fauna groups. However, other research has revealed different patterns of species richness and dominance (Coles and McCain 1990). McCain (1984b) reports a significant positive correlation ($p<0.05$) between salinity and the number of major taxonomic groups within subtidal sand. At least four or five biological communities inhabiting subtidal sand and muddy ecosystems of the Gulf have been described (Basson et al 1977). Two of these are found in mud, and have been named after the dominant fauna. One is the "*Murex/cardium*" community (dominated by two molluscs; *M. papyraecum* and *M. Kusterianus*), and the other is the "*Brissopsis/Amphioplus*" community (dominated by two exhinoderms: *B. persica and A. Seminudus*). Jones (1985) suggested that bentic biomass of the Gulf is reduced in mud, and with distance from the open ocean.

Reduced benthic biomass (and diversity) towards the north of the Gulf is also apparent from other studies (Aoki 1974, Enomoto 1971).

5) Seagrasses

Seagrasses are one of the most productive habitats. As sources of food and shelter, seagrass beds are important nurseries for juvenile fish, shrimp, and pearl oysters and are feeding areas for dugong and turtles.

Seagrass in the Arabian Gulf shows a complex distribution pattern, reflecting the heterogenous nature of the seabed and fluctuating oceanographic conditions. In Arabian Gulf waters, well-developed stands occur within a number of shallow (<10m) coastal embayments (Basson et al. 1977, IUCN/UNEP 1985a, IUCN 1987). However, the total area within these waters may constitute only a small proportion (1%) of the subtidal zone (IUCN 1987, Price et al. 1987a). There is a significant correlation between total seagrass cover and salinity, even though salinity and latitude together show strong negative correlation.

In Saudi Arabia, seagrasses are abundant in several shallow water embyments (less than 10m) along the coast. Important areas are between Saffaniya and Manifa, west and south of Abu Ali, east of Al Khobar, Taru Bay, Dawhat Zalum and the Gulf of Salwa (IUCN/MEPA, 1988).

Eleven seagrass species have been recorded from the Arabian region. Among the species, only four species have been recorded along the Arabian Gulf coast. They are "*Halodule uninervis*", "*Syringodium isoetifolium*", "*Halophila ovalis*" and " *Halophila stipulacea*" (Basson et al., 1977; IUCN/MEPA, 1988).

6) Coral Reefs

Coral reefs provide food and shelter for a multitude of plants and animals, and a refuge for several large commercial fish species.

The Gulf is at the northerly limit of coral reef distribution and because of fluctuations in temperature and salinity, it forms a highly stressful environment for corals. The reefs, therefore, are not very diverse compared to truly tropical areas.

The 1987 IUCN reported that the best reefs in the Gulf are along the Saudi coast. The most important area is probably around the islands of Karan, Kurayn, Jan, Al Jurayd, Harqus and Al Arabiyah. Coral diversity is higher here (over 50 species), but this is still low by general Indian Ocean standards. South of Ras Tanura, reef development and diversity decline because of increasing salinity and sedimentation in the Gulf of Salwah (Taylor 1991).

7) Other Hard-Bottomed Biotopes

The major species are dense brown algae dominated by kelp *Ecklonia radiata, Sargassum* *spp.*, *Padina sp.* and *Colpomenia spp.*, amongst which numerous molluscs, particularly gastropods and several bivalves. Sponge species also occur. Subtidal rocky habitats occur along much of the west gulf coast, especially in inshore waters, but are very patchy and of rather limited occurrence.

Important seaweed beds occur in Kuwait bay. In Saudi, the greatest concentrations are around Al Mish'ab, Abu Ali, Ras al Ju'aymah and Tarut, Al Khubbar and the Gulf of Bahrain. The majority of the Iranian coastline is rocky in character.

Seaweed beds have been shown to support over 650 species of animal and plant, mud bottom habitats to support over 600 species, rock bottom habitats to support some 200 species. Subtidal sand and mud habitats represent important fishing grounds (Taylor 1991). Subtidal rock habitats, rich in seaweed beds, are economically important for shrimps, pearl oysters and abalone fisheries (e.g., Kuwait Bay and Tarut Bay, Saudi Arabia).

1.5.2 Key Species

The key species (and/or important species) in the Arabian Gulf are described in Table 1.5.2.

Table 1.5.2 Key Species in the Gulf

Group	Species name		Remarks
Birds	Waders	Grey Plover, Kentish Plover, Lesser Sandplover, Ringed Plover, Eurasian Curlew, Redshank, Little Stint, Dunlin, Curlew Sandpiper and Broad-billed Sandpiper, etc.	Breed on the islands and marshes of the region.
	Gulls	Herring Gull, the Black-headed Gull ,the Slender-billed Gull.	
	Terns	Caspian Tern, Greater Crested Tern, Lesser Crested Tern, Common Tern, White-cheeked Tern, Bridled Tern, Saunders' Tern and the Little Tern. etc.	
	Grebes	Black-necked Grebe.	
	Pelicans	Dalmatian Pelican.	
	Cormorants	notably the Great Cormorant, the Socotra Cormorant and possibly the Pygmy Cormorant.	
	Herons and Egrets	Grey Heron, Western Reef Egret. White Spoonbill , Greater Flamingo,	
	Socotra Cormorant	-	Threatened species
Reptiles	Marine Turtles	Green Turtle (Chelonia mydas) and Hawksbill Turtle (Eretmochelys imbricata) Leatherback Turtle (Dermochelys coriacea), Loggerhead Turtle (Caretta caretta), Olive Ridley Turtle (Lepidochelys olivacea), etc.	Most of the population breeds on offshore islands include Karan, Kurayn, Jana, Harqus and Jurayd.
	Sea Snakes	(Hydrophiidae) Enhydrina schistosa, Hydrophis cyanocinctus, H. lapemoides, H. ornatus, H. spiralis, Lapemis curtus, L. viperina (= Praescutata viperina), Microcephalophis gracilis (= Hydrophis gracilis), Pelamis platurus, etc.	Not identified as of special conservation concern.

Marine Mammals	Dolphins	Humpbacked Dolphin (Sousa chinensis,) Bottlenose Dolphin (Tursiops truncatus) , Common Dolphin (Delphinus delphis)	It is classed by IUCN as "Not threatened" species.
	Whales	Bryde's Humpback Whales, Minke Whales, Fin Whales, Blue whales, Sperm whale, Killer whale	It is classed by IUCN as "Not threatened" species.
	Sea Cow	Dugong	Categorized as "Vulnerable" species in the 1990IUCN Red List of Threatened Animals. Most abundant in the Gulf of Salwah between Bahrain and Auatar.

1.5.3 Ecologically Sensitive Area

The Saudi Arabian Government, through its Marine Environmental Protection Agency in association with IUCN-The World Conservation Union, has drawn up an extensive list of important marine and coastal nature conservation areas in the country (IUCN/MEPA 1987). Table 1.5.3 is a list of the environmentally sensitive areas (ESAs). The distribution of these ecologically sensitive areas are shown in Figure 1.5.1

Table 1.5.3 List of the Environmentally Sensitive Areas (ESAs)

Areas	Description
Saffaniya/Manifah Bay Complex	Coral reefs, Important mangroves and seagrass beds, nesting site for gree turtles, pearling banks, and fishery resources
Harqus Island	Key sites for nesting green turtles and birds.
Arabiyah Island	Well-developed coral reefs
Karan Island	Primary nesting site for marine turtle (Green Turtle and Hawksbill Turtle), nesting site for birds.
Kuayn Island	Key sites for nesting green turtles and birds.
Jana Island	Key sites for nesting green turtles and birds.
Jurayd Island	Key sites for nesting green turtles and birds.
Abu'Ali/Dawhat Dafi/ Musallamiyah Complex	Seagrass bed, coral reefs, pearling bank, and fishery resources.
Tarut Bay Complex	Coral reefs, critical mangrove areas, well developed seagrass beds, habitat of Dugong or sea cows and sea turtles, pearling bank, fishery resources
Al'Uqayr Bay	Primary breeding area of Socotra Cormorant (threatened bird species).
South Gulf of Salwah	Seagrass bed, Habitat of Dugong or sea cows and sea turtles, fishery resources.

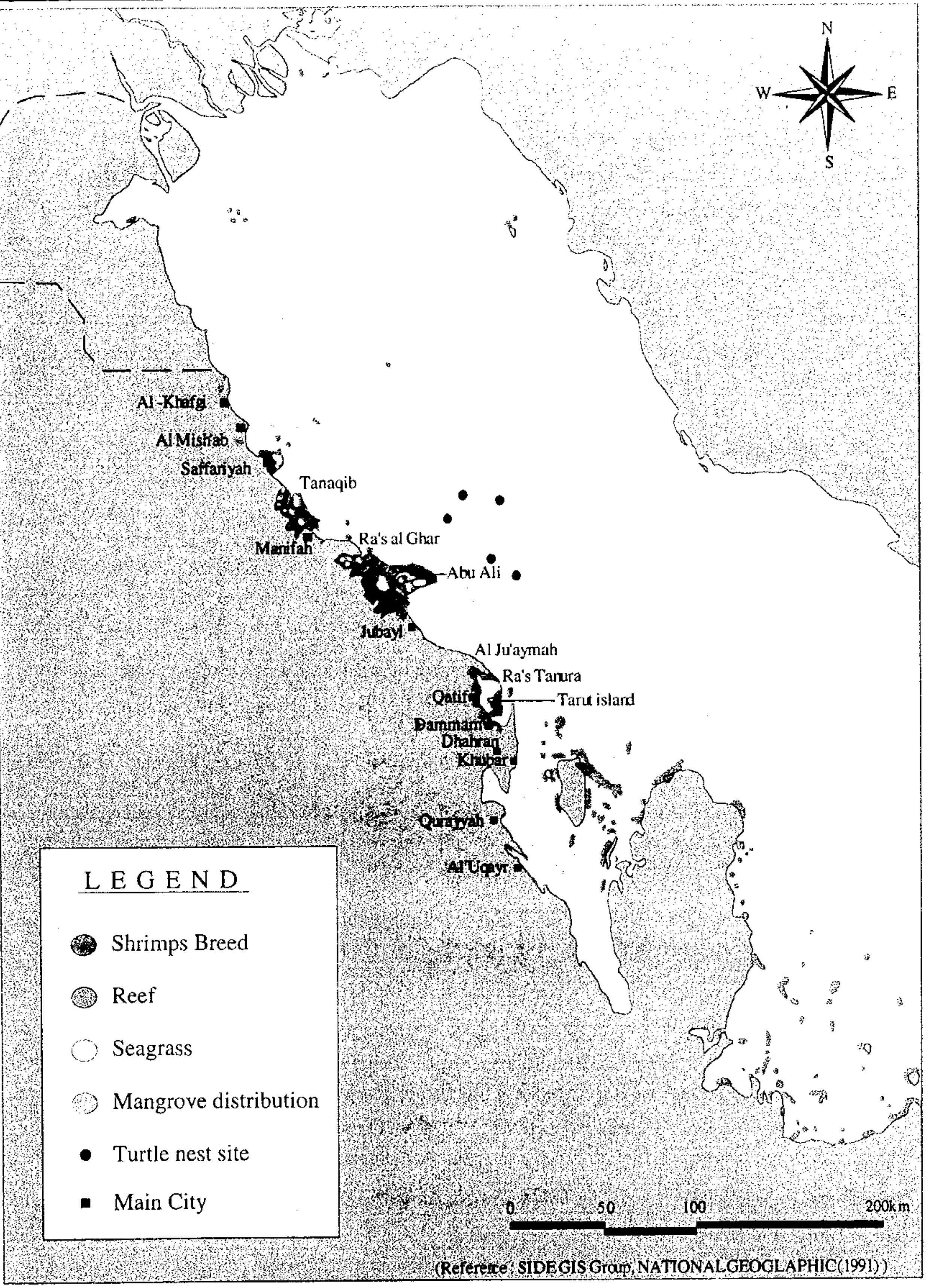

Figure 1.5.1 Distribution of Ecologically Sensitive Areas

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Chapter 2. Status of Environmental Management

2.1 General Description

The Islamic principles teach man that the Universe was created in balance by God, and that man as steward of God should manage all the created beings fairly and equally to enhance the universal common good of them not only for the current generation but also next generations. Based on the Islamic taught, the people of the Kingdom of Saudi Arabia had lived on the benefits of the nature, paying due attentions to the natural environment.

During these decades, the Kingdom has been experiencing the most rapid economical development in line with its industrialization originated by the enormous amount of revenues from the oil industry. Through the consequent urbanization, the social structure has also undergone a considerable change from the traditional nomadic life with a subsistence economy to modern city life with a market economy accompanied by an explosive increase of population mainly on the coastal area of the Arabian Gulf and the Red Sea All these changes are incurring new types of stresses on the environment of the Kingdom. The Saudi government has established a number of administrative agencies and legal orders in order to cope with the environmental protection in the modern Kingdom, along with the resolutions of many international organizations and councils. However, there are many impending issues yet to solve.

2.2 Governmental Activity

2.2.1 National Policy

Geographically the Kingdom is flanked by the Red Sea on the west and the Arabian Gulf on the east. Both are featured as semi-closed seas, oil producing sites and busy passage of tankers and ships of around 50% of world oil tanker shipment which carry out and carry in a tremendous amount of oil and general cargoes to and from all over the world. On top of that, there were a number of conflicts and wars* between the surrounding countries which imposed serious damages to the natural environment. The Saudi Government well realizes the vulnerability of the environmental conditions of the Kingdom and emphasizes the importance of protection of its land and seas from any environmental hazards.

In 1981, the Government created Meteorology and Environment Protection Administration (MEPA) as a directly responsible entity for the environment under the Ministry of Defense and Aviation by Royal Decree No. 7/M/8903 to control pollution, protect environment and set up standards related to pollution control and environment protection and also in 1986, similarly created National Commission for Wild Life Conservation and Development (NCWCD) by Royal Decree No. M/22 specifically to protect national fauna and flora. Along with the two entities, the government established in 1981 " Environment Protection Coordination Committee" to coordinate among the ministries and governmental departments, and in 1990 "Ministerial Committee for Environment" as the highest level directorate to deal with environment affairs on the national level in the Kingdom (see Figure 2.2.1).

* Ex.: Iran-Iraq War in 1980, Gulf War in 1991.

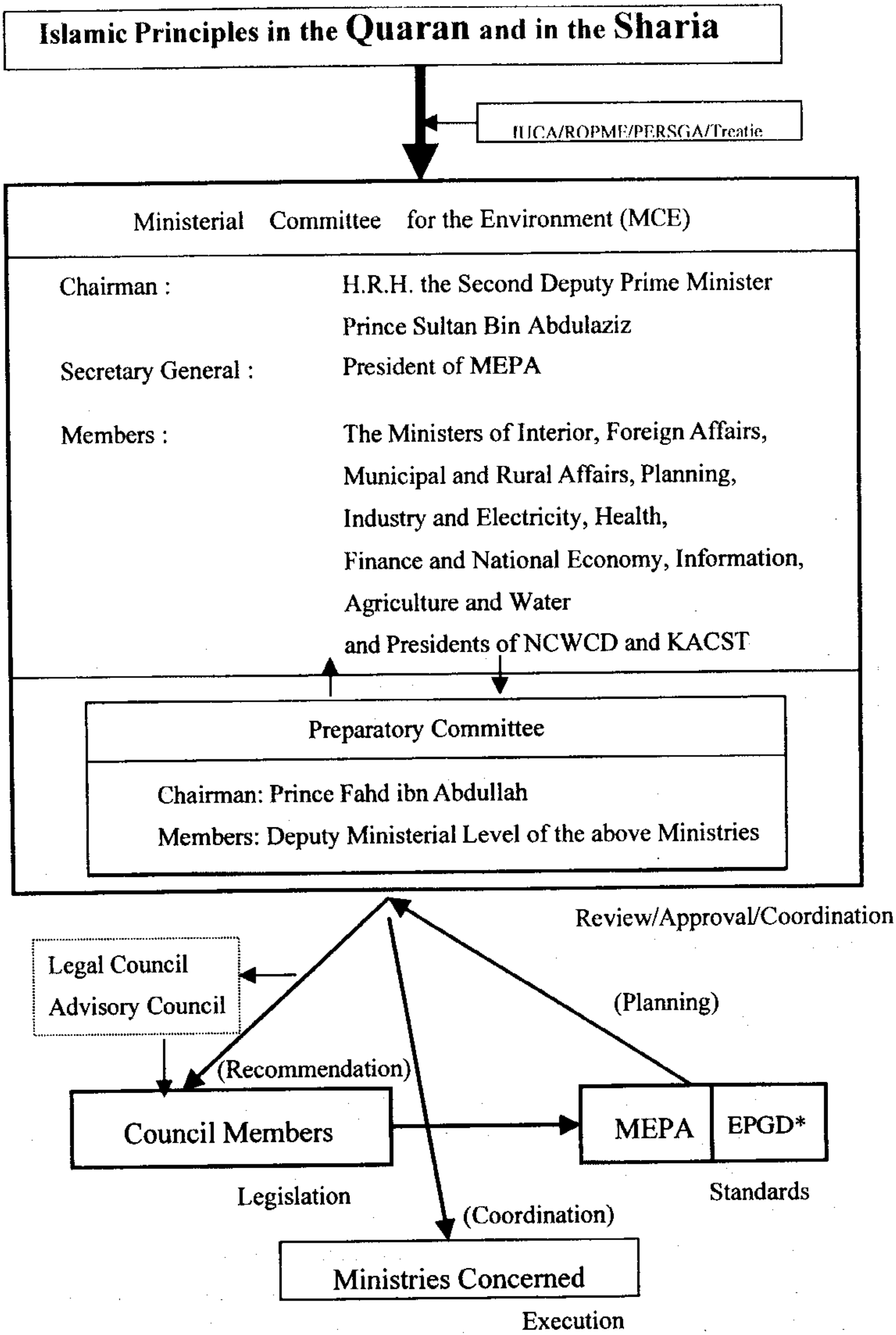

Figure 2.2.1 The Environment Protection System of Saudi Arabia

2.2.2 Environmental Laws and Standards

The Islamic principles have been philosophically effective to date over the mind of Saudi Arabian people. The Islamic rules are interpreted by MEPA and The World Conservation Union (IUCN) as guidelines of Moslems for the environment protection. Besides the Islamic principles, the Saudi Government issued a number of administrative orders in the forms of royal decrees, royal orders, ministerial resolutions, and MEPA standards as follows:

Laws and Regulations	Contents
Royal Decree No.M/22(3/5/1398H:1979G)	This Decree defines the natural range lands as land which is totally or partially covered by local plants naturally grow and usable for animal feeding. It is considered as lands owned by the government, and the MAW have the right to issue the regulations that govern its utilization and conservation.
Royal Decree No. M/26(25/5/1398H: 1979G)	This Decree regulates birds and wildlife hunting system.
MEPA No. 1401-01 Environmental Standards	Environmental standards which includes the standard for air and water quality. These standards were put into effect as of the 1 /11/ 1402(1982)
Ministerial Resolution No.271 (23/11/1404H: 1984G)	This resolution regulates for industrial activities (cement and gypsum).
Royal Order 1182/8(5/7/1405H: 1985G)	This order concerns forests. Investment and transfer of any forest land or products is not permitted.
Ministerial Resolution No. 157(20/11/1411H: 1991G)	This regulation regulates against sea pollution.
Royal Decree No.A/90(27/8/1412H:1992G)	This delegates specific roles to the governmental departments.

In addition to the above, the Kingdom has extensively participated in regional and international organizations, and/or signed several important agreements with them for cooperation in environment protection and preservation such as:

- United Nations Environment Program (UNEP)
- The World Conservation Union (IUCN)
- Intergovernmental Oceanographic Commission (IOC)
- The Arab League Decisions 1407H(1986) which adopted "the Arab Declaration on Environment and Development"
- The Advisory Committee on Protection of the Sea (ACOPS)
- Decision of the Heads of State of the Gulf Cooperation Council 1407H(1983)
- Regional Organization for the Protection of the Marine Environment (ROPME) signed by eight states on the Arabian Gulf and Oman.

- Saudi Sudanese Joint Red Sea Commission
- Regional Organizations of the Red Sea and Gulf of Aden (PERSUGA)

2.2.3 Environment Related Authorities

The governmental authorities directly involved in environmental protection management are MEPA and NCWCD namely;
MEPA: Meteorology and Environmental Protection Administration.
NCWCD: National Commission for Wildlife Conservation and Development.

In addition, the central government clearly described the responsibility of each ministry and other government departments in environmental protection by Royal Decree No.A/90 dated 27/8/1412H (1992) as follows:

Organization	Role and Responsibility
Ministry of Agriculture & Water	It implements the national plans concerning use of pasturage, forest and agricultural land and fisheries. As well, It is responsible for organizing, developing and observing the land, Water, pasturage and forests besides issuing any permits related to agricultural water resources and fishing.
Ministry of Finance and National Economy	It provides the necessary funds for the environmental projects that the governmental departments propose.
Ministry of Petroleum and Mineral Resources	It implements several environmental activities through Saudi Aramco Co. (a government company working under this Ministry) and the Arabian Oil Co. which is also working under this ministry. All the environmental activities of this Ministry are to be coordinated with MEPA.
Ministry of Health	Its responsibilities are represented in provision of Health care and control of environment and professional Health conditions
Ministry of Industry and Electricity	It issues the industrial projects licenses besides Its responsibility for electricity.
Ministry of Interior	It takes over the duties of evaluating the chemical, radioactive, military and natural hazards.
Ministry of Communication	It assumes the responsibility of transporting the dangerous wastes, besides preventing Oil spillage from ships and any sea pollutants.
Ministry of Planning	It defines the objectives of the economic, social and environmental development through the Kingdom development plans.
Ministry of Municipal and Rural Affairs	It controls the works of water and sanitary systems, besides disposal of solid wastes (industrial, medical, construction). It has a department for environment affairs taking over the public health matters.

Royal Commission for Jubail and Yanbu	According to an understanding memorandum with MEPA, the Royal Commission assumes All responsibilities related to environmental protection in the industrial cities of Jubail and Yanbu. the Royal Commission observes the environmental issues, air pollution and wastes control according to a strict system similar to MEPA systems.
Higher Committee for Riyadh City Development	Its responsibility includes Planning and implementing the development programs of Riyadh City on continual basis and in coordination with MEPA.

2.2.4 MEPA's Activity

1) History

In line with fast economic development in the Kingdom, the problem of environmental pollution was becoming an area of concern, and among others, the Iran-Iraq war (1982) made a large scale of oil spills, continuously threatening the Saudi territorial water of the Gulf. To cope with such situations, in 1981 the Government reorganized the ever existing "General Directorate of Meteorology" to "Meteorology and Environmental Protection Administration" under the Ministry of Defense and Aviation by Royal Decree No. 8903 dated 21/4/1401.

2) Organization

As historically seen above, the environment protection administration department was newly added to the meteorology administration department under the Ministry of Defense and Aviation (MDA). Although MEPA belongs to the Ministry of Defence, the personnel and function are regarded totally as civilians. The organization chart is shown in Figure 2.2.2.

3) Role and Responsibility

MEPA is assigned to undertake the following activities:

- Conduct environmental surveys to define problems and recommend environmental standards and measures.
- Recommend practical measures necessary to deal with emergency situations affecting the environment.
- Recommend protection regulations and measures dealing with environmental problems.
- Assess existing environmental pollution levels and future variations (such information to be documented for easy retrieval).

- Keep abreast with development in the field of environmental protection on the regional and international levels.
- Establish environmental standards and specifications for pollution control and environmental protection, in a definite and stable form to be considered by the appropriate authorities when issuing permits for industrial and agricultural projects which may have an environmental impact.

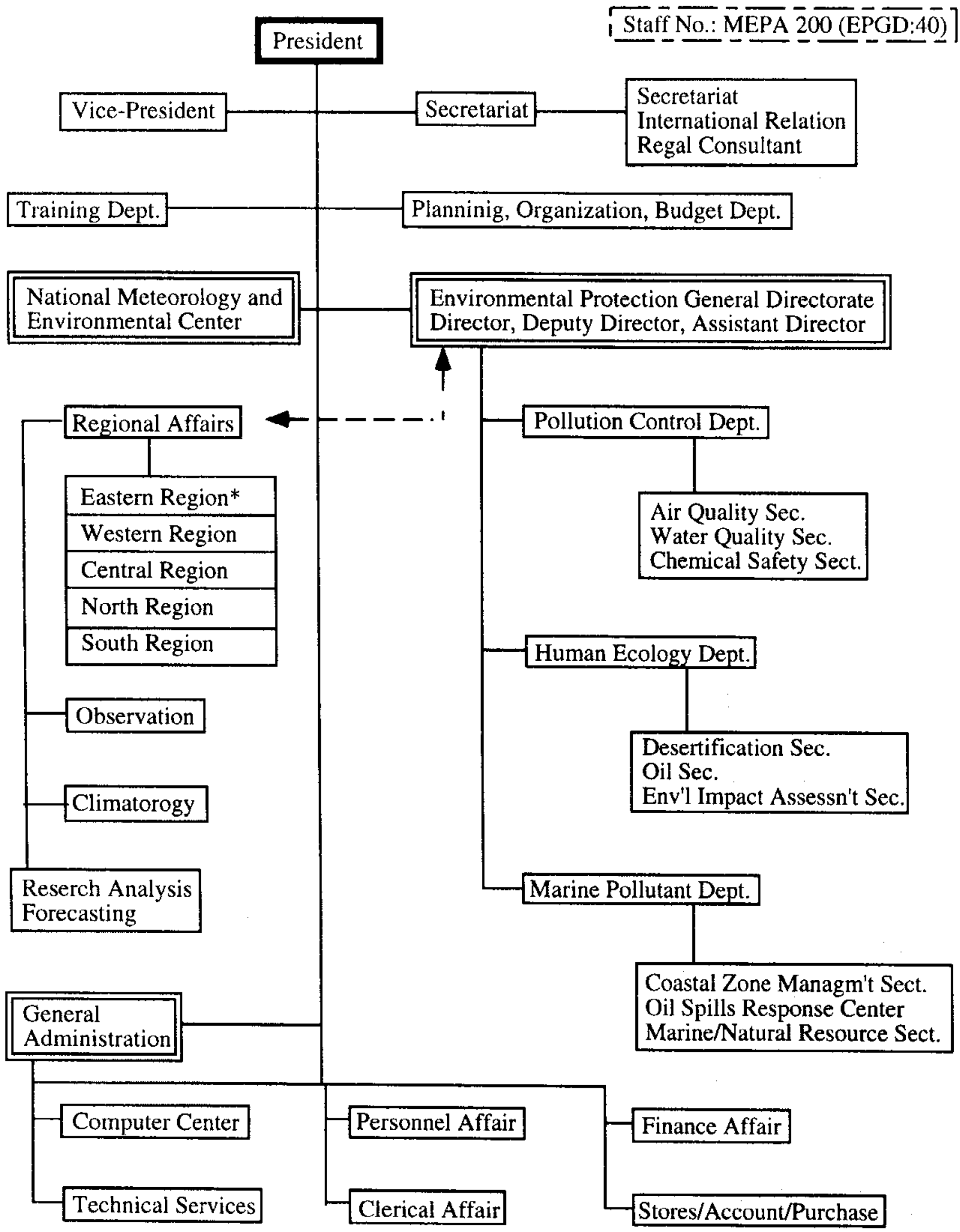

Figure 2.2.2 MEPA Head Office Organization

2.2.5 Practical Activities of MEPA's Eastern Province

1) Organization

From the MEPA head office organization, MEPA Eastern Province Office (Eastern Office) is situated under National Meteorology and Environmental Center, not under Environmental Protection General Directorate. As seen in Figure 2.2.3, the number of personnel at Meteorology Division of the Eastern Office is much more than at Environmental Protection Division.

2) Role and Responsibility

Since there is no written document available about designated responsibilities of the Eastern Office, only assumption can be made from the organization chart and interviews with the staff members as follows:

- Meteorological observation
- Meteorological record keeping and analysis
- Deal with marine pollution
- Deal with hazardous waste management
- Deal with air pollution
- Deal with oil spill problems
- Laboratory
- Maintenance of facility and equipment
- Any other items designated by MEPA head office

3) Laboratory condition

a. Old System

For the laboratory space, approximately 400m^2 in total are allocated in the Eastern Office building. The space is divided into several sections including manager's office, stock room and laboratories. The laboratory has tap water, sinks, and experimental stands. There was no need to expand further the space, nor modify the rooms in order to accommodate new equipment and utensils newly provided by JICA, this time. One of the major reasons was that most of the existing equipment were too old and obsolete and therefore replaced by new one.

As to equipment and consumables (chemicals), there were fairly plenty, but they were deemed not good for use. It is reported that the old equipment was brought in from Jeddah head office in 1996 and rarely utilized up to date. There was a moving laboratory which consists of an automobile and some laboratory equipment including gas chromatograph, atomic absorption spectrum etc. However the automobile is out of order with flat tires and the equipment also need to be repaired. There is no record of use for many years. The list of the already existing equipment is as per Attachment-4.

Laboratory personnel are not countable, though one Indian specialist and a couple of janitor boys are assigned for the laboratory. According to MEPA, the Indian and other personnel are contracted persons and therefore not targeted people for technology transfer from the JICA team.

b. New System

JICA provided the Eastern Office with the equipment and chemicals in order to implement the monitoring and analytical work in the laboratory. The equipment list provided by JICA is shown in Table 2.2.1 and the present layout of the laboratory that is installed with the equipment is shown in Figure 2.2.4.

4) Budget Condition

It is assumed that all expenditures of the Eastern Office are controlled by the head office. For example, the expenses accrued on routine works such as salary and maintenance cost are already determined by its head office and expenses accrued on ad-hoc basis are basically reimbursed by the head office if they are permissible within the budget of the head office. Since there is no separate budget for laboratory and laboratory management and maintenance is directly under the control of contract department of MEPA (The Planning, Organization Budget Department shown in the Figure 7). So MEPA E. P. do not have authority to maintain or to purchase any kind of chemical/spare parts or even small equipment unless it is approved by the contract department.

No. of Personnel	
Directorial	2
Meteorology	45
Maintenance	7
Environment	8
Total	62

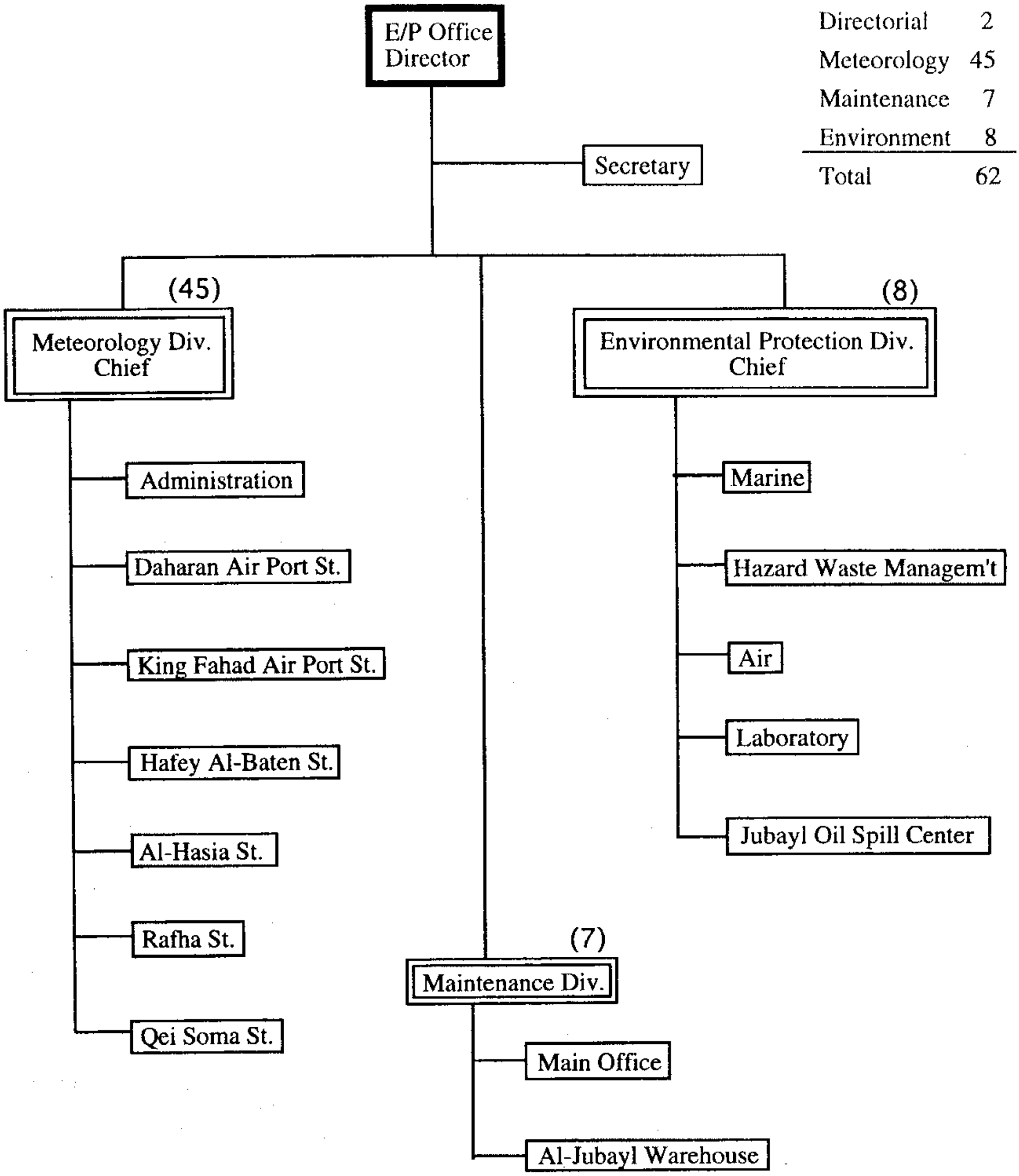

Figure 2.2.3 MEPA Eastern Province Organization

Table 2.2.1 Equipment List Provided by JICA

No	Material	Maker/Model	Q'ty	Specification requested
1	Gas Chromatograph	Shimadzu GC17A	1	FID, headspace sampler
2	Atomic Absorption Spectrometer	Varian spectra 220	1	vapor generator unit
3	Spectrometer	Shimadzu UV1240	1	UV and visible
4	Benchtop pH meter	Metrohm 744	1	
5	Benchtop EC meter	EC-CON-500/23	1	
6	TOC meter	Shimadzu 5000A	1	solid sample module
7	Oil Content meter	Horiba OCMA300	1	
8	Microbiological System	Millipore Milliflex	1	for total coliform
9	Microscope	Nikon Alphaphot 2	1	for plankton analysis
10	Multiprove meter	Hydrlab Surveyor 4	1	pH, temperature, salinity, turbidity and DO
11	ORP meter	Model 3071	1	
12	Microkjeldahl Assebly	Fisher Scientific	5	distillation flask, condenser
13	Cyanide Distill Assembly	Wilkens-Anderson	3	distillation flask, condenser and heating mantle
14	Phenol Distill Assembly	Wilkens-Anderson	3	distillation flask, condenser
15	Autoclave	ALP Japan KI 30S	1	
16	Shaker	SGM-200-010F	1	
17	Centrifuge	LIG/UK	1	3000 rpm
18	COD digestion vessel	Fisher Scientific	1	condenser and flask
19	Hotplate	SD3DI	1	
20	Ultrasonic cleaner	Neytech 19B	1	
21	Fume hood	Nuaire NU164-424G	1	acid-resistant type
22	Water Purification	Milli-Q"Academic"	1	
23	Refregrator	Thermolyne	1	500 liter
24	Desktop type	Intel Pentium II	1	Windows, CPU Pentium II 350, 15' CRT
25	Laptop type	Acer Extensa 711TE	1	Windows, CPU Pentium II 266, 13.1' TFT, CD-ROM
26	Printer	HP 895Cxi Color	1	Ink-jet type, A4 size
27	Outside memory	Jazz Drivew 2GB	1	Hard disk, 2 GB

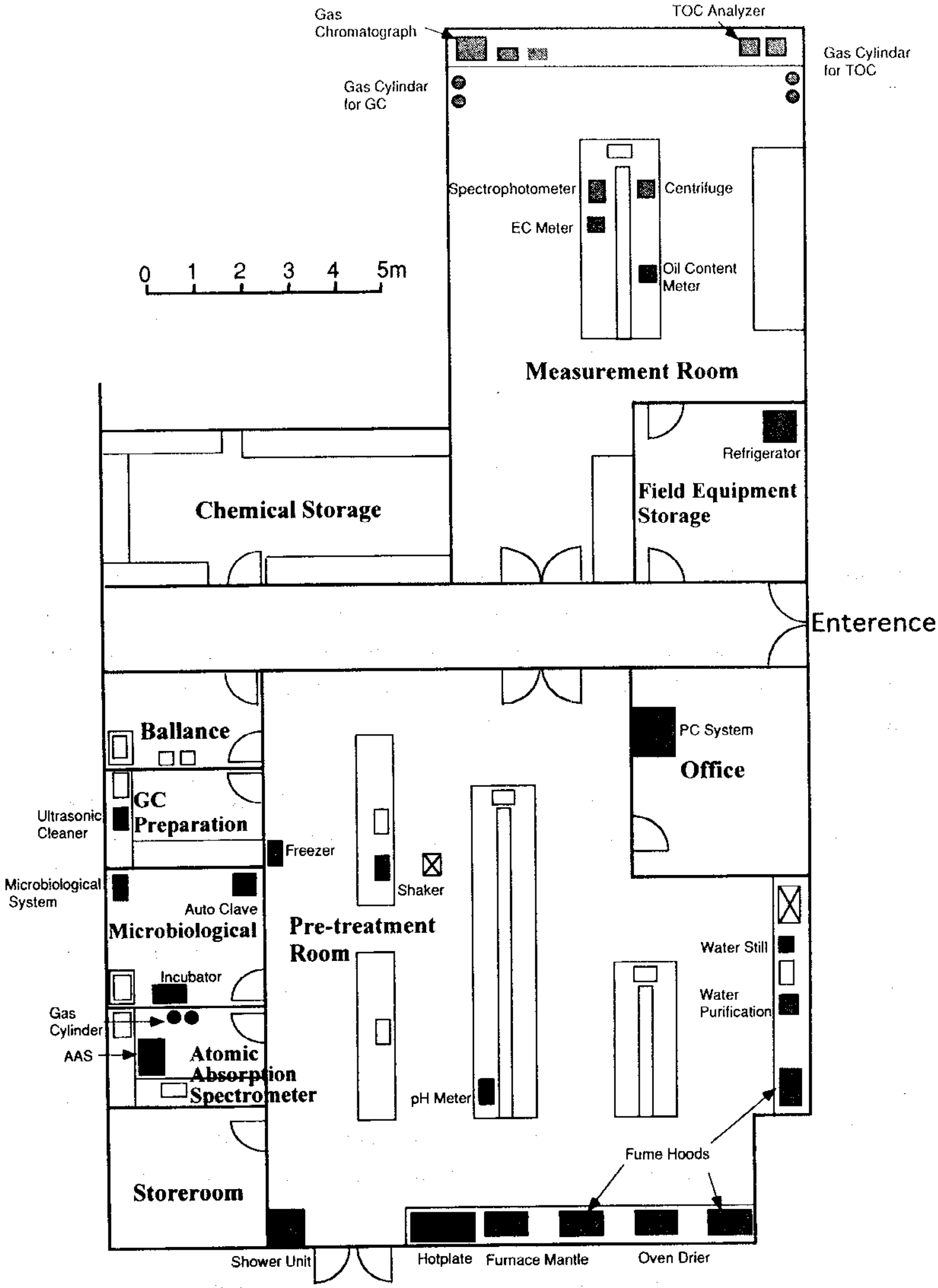

Figure 2.2.4 Present Layout of Laboratory in MEPA E.P.

2.3 Private sectors Activity

Royal Commission

Al-Jubayl is the biggest petrochemical industrial area in Saudi Arabia. They occupy huge space of Jubayl region and have many plants of petroleum, petrochemical and petroleum related industries.

Resident and recreational areas for the plant workers are also built by the industrial area. Royal Commission substantially manages the Al-Jubayl area and it is treated as a kind of self-government body. Royal Commission has the duty of conservation of the environment of this area. Al sewage and effluents, except for the seawater used for indirect-cooling-water, is completely treated and recycled for irrigation.

Royal Commission has been conducted seawater quality monitoring over a decade and they have sufficiently equipped chemical analysis laboratory and the permanent staff for laboratory operation. The Royal Commission routinely monitors the Gulf water quality in the Harbor and adjacent to the Industrial City. Ten water quality monitoring stations (see Figure 2.2.3) have been established to give a comprehensive picture of water quality. These stations allow the detection of water quality changes near the coast and off-shore. Routine monitoring gives an early indication of long-term trends, allowing action to be taken to prevent damages.

At each of the water quality stations, an electronic probe is used to determine the in-situ values of several water quality parameters, including temperature, salinity, dissolved oxygen (DO) and pH. Water samples from several depths are also collected for the analyses of free ammonia, turbidity, total suspended solids (TSS), oil and grease, phenol, total phosphorous, zinc, total organic carbon (TOC), and residual chlorine on a monthly basis and some additional heavy metal parameters on a quarterly basis.

At the Royal Commission Environmental Laboratory, the water samples are analyzed and the results are then entered into a computerized database to facilitate analysis. Periodical reports are generated to ensure that Royal Commission environmental criteria are met. This Laboratory is also used for hygienic check of food in the restaurant for the workers. (Water monitoring data is shown in Attachment III)

Oil concentration, temperature and salinity of the seawater are monitored at the intake of the desalination plant to find and to protect the plant from oil pollution.

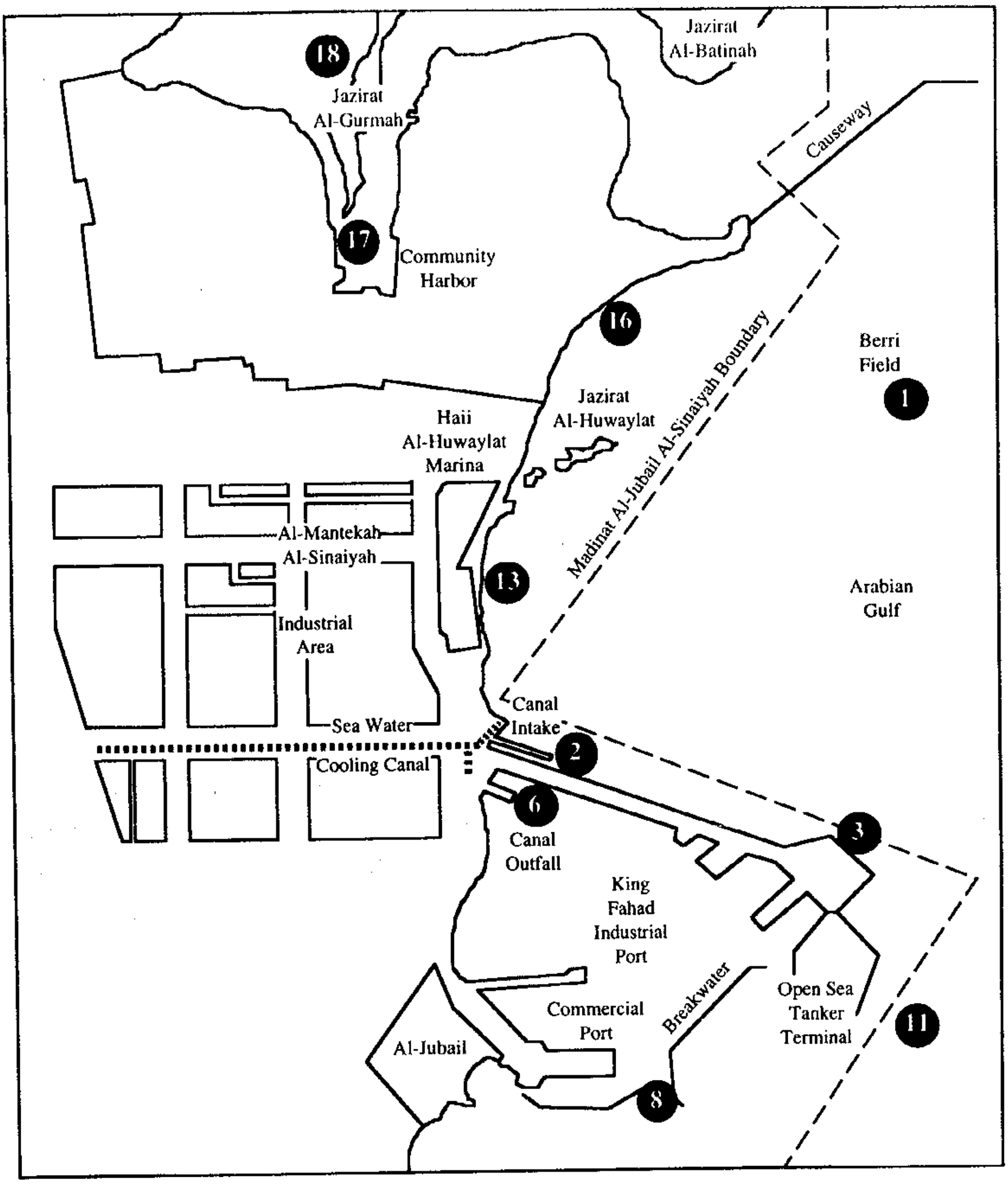

Figure 2.2.5 Location of Gulf Water Quality Monitoring Stations (quated from The Brochure of Jubail Industrial City)

3. Status of Actual Environment

3.1 Satellite Image Analysis

3.1.1 Introduction

The multispectral satellite data have the inherent properties of being able to provide synoptic observations with high observational density over relatively large areas. Satellite images have shown great potential for monitoring coastal environment. This project utilized the LANDSAT Thematic Mapper (TM) data to cover the Arabian Gulf, coastal region, of the Kingdom of Saudi Arabia (KSA) and analyzed the situation of the sea-pollution.

LANDSAT/TM Satellite

The American Satellite, LANDSAT Thematic Mapper (TM) is designed to maintain fixed orbital paths around the earth with each path covered in 16 days at a standard altitude of about 705 km. One full LANDSAT scene is covered by 170 km (north-south) by 185 km (east-west) with spatial (ground) resolution of 30 x 30 m (except thermal-infrared range, i.e., band 6, which has a pixel resolution of 120m). The satellite crosses the equator from north to south on a descending orbital node at approximately around 09:45 a.m. local time on each pass. Each orbit takes nearly 99 minutes, and spacecraft completes just over 14 orbits each per day, covering the entire Earth (poles excepted) every 16 days. TM data are available in seven narrow bands, i.e., three in the visible spectrum band [bands 1 (blue), 2 (green) and 3 (red)], three in the infrared zone (bands 4, 5 and 7) and one in thermal (emitted) infrared region (band 6). The descriptions of the seven sensors are mentioned in Table 3.1.1.

Table 3.1.1 LANDSAT's sensor description

TM Bands	Wavelength (micrometer, μm)	Resolution (m)	Coverage (km)
1	0.45 – 0.52 (blue)	30	185
2	0.52 – 0.60 (green)	30	185
3	0.63 – 0.69 (red)	30	185
4	0.76 – 0.90 (near-infrared)	30	185
5	1.55 – 1.75 (intermediate-infrared)	30	185
6	10.4 – 12.5 (thermal infrared)	120	185
7	2.08 – 2.35 (mid-infrared)	30	185

3.1.2 Study Area Coverage

The four Full Scenes and one Sub-scene of the LANDSAT TM Satellite cover the Arabian Gulf coastal region (for the present Study).

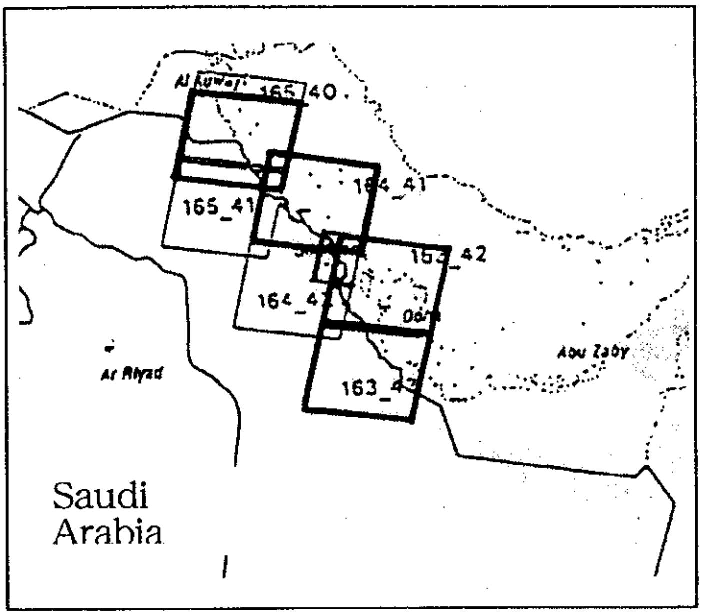

Figure 3.1.1 Study area coverage by LANDSAT/TM Satellite

Due to cloud cover and satellite recording problem the following TM's Path/Row and acquisition dates were selected and utilized to prepare the Mosaic Image and subsequent analyses in this Study.

	Path/Row	Acquisition Date	Scene
1.	165/040-041	JAN 20 1999	Full Scene (50% South shift)
2.	164/041	DEC 12 1998	Full Scene
3.	164/042	DEC 12 1998	Sub-Scene (1/4 or NE of Full Scene)
4.	163/042	DEC 21 1998	Full Scene
5.	163/043	NOV 03 1998	Full Scene

3.1.3 Analysis Procedures

The analysis procedures conducted in the present study is summarized as below:

LANDSAT/TM Data searching, selection and acquisition

⇩

Georeferencing and preparation of LANDSAT/TM Mosaic Image at 1:500,000 scale

⇩

Water Quality Analysis of the TM data and preparation of Maps at 1:500,000 scale

- Suspended Solids Distribution Map
- Chlorophyll Distribution Map
- Oil Pollution Distribution Map

⇩

Report preparation and utilization of the Maps for the monitoring plan

Utilized Software and Map production

In order to process the LANDSAT/TM satellite data, ERDAS IMAGINE ver 8.3 (ERDAS IMAGINE Field Guide, 1997) was utilized. ERDAS IMAGINE is powerful Image Processing Software that provides innumerable solutions to the various users for different application purposes. Also, ARC/INFO ver 7.2, Geographic Information System software for geographic solutions and database management, was used for map layout preparation.

Once the data were analyzed by the image processing software, the prepared image files were converted as GRID files (it is a raster image file in ARC/INFO's format) and brought into the ARC/INFO's environment for map layout preparation. The maps were prepared at 1:500,000 scale and plotted by CalComp X2020 Plotter.

3.1.4 Mosaic Image

The Mosaic Image was prepared by using bands 4, 3, and 2. TM's Band 4 (spectral range as near-infrared region, 0.76 – 0.90 μm), Band 3 (red spectral region, 0.63 – 0.69 μm) and Band 2 (green spectral region, 0.52 – 0.60 μm) were utilized to prepare the False Color Composite (FCC). TM's six bands have an improved spatial resolution of 30 x 30 m or (0.5 ha) and band 6 (thermal infrared) has a resolution of 120 x 120 m. In the present Study the ground resolution was re-sampled for 50 x 50 m during georeferencing for preparing the Image at 1:500,000 scale.

The FCC shows coverage of the Intensive Study Area and Target Marine Area for this project (Plate 2). The Intensive Study Area is covered by the TM data acquired on 12 December 1998 (Path/Row 164/041 and 164/042). The data acquisition dates are different for the remaining areas. This was due to presence of clouds and limitation of TM's data quality therefore, the best imageries of the nearest dates were acquired.

FCC Interpretation

The brightness of the processed images was enhanced to highlight the sea water surface. The shallow water depth areas along the coast can be identified from the visual interpretation. The combination of bands 4, 3 and 2, senses peak chlorophyll reflection as red. The resulting red hues are easily discriminated by human eye. Water boundaries are defined clearer. FCC shows the sea water color variation near the coastal areas. The seawater color variation can be interpreted as the variation in the reflection and refraction characteristics due to water quality degradation along the Arabian Gulf. The coastal modifications by dredging or corniche developments can be clearly observed (Plates 2 &3).

The TM bands showed scan lines as noise in the images. Occasionally, images are corrupted by "noise" that is periodic in nature. The images were spatially filtered for reducing the noise and for improving the analysis results. However, the noises were unavoidable to be removed completely from the images.

3.1.5 Interaction of Electromagnetic Radiation with Water

Unlike vegetation or soil, the majority of the radiant flux incident upon water is not reflected but is either absorbed or transmitted. Water absorbs near infrared and middle infrared wavelength strongly, (Figure 3.1.2) leaving little radiation to be either reflected or transmitted (Curran, 1985).

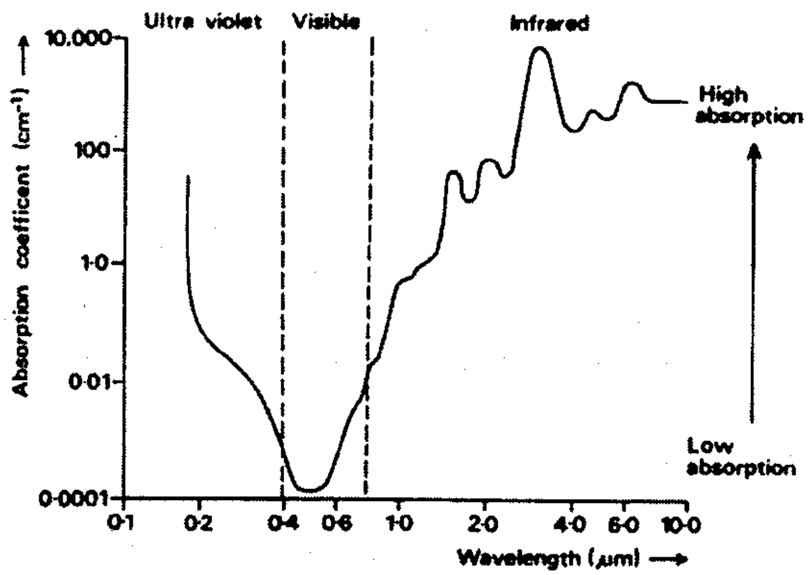

Figure 3.1.2 The absorption of electromagnetic radiation by seawater.

This results in a sharp contrast between any water and land boundaries as can be seen in a near infrared image of LANDSAT.

The factors that affect the spatial variability in the reflectance of a body of water are usually determined by the environment. The three most important factors are, the depth of water, the materials within the water and the surface roughness of the water. In shallow water some of the radiation is reflected not by the water itself but from the bottom of the waterbody. The three most common materials suspended in water are non-organic sediments, tannin and chlorophyll (< biblio >). The effect of non-organic silts and clays is to increase the scatter and reflectance, in visible wavelengths as can be seen for the coastal region. In agricultural scene the main coloring agent is tannin produced by decomposing humus; this is yellowish to brown in color and results in decreased blue and increased red reflectance. Water bodies that contain chlorophyll have reflectance properties that resemble, at least in part, those of vegetation with increases green and decreased blue and red reflectance. However, the chlorophyll content must be high before these changes can be detected. The roughness of water surface can also affect its reflectance properties.