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Oil spill in the Saudi Arabian maritime environment

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OIL SPILL IN THE SAUDI ARABIAN MARINE ENVIRONMENT

BY

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I certify that all material in this dissertation which is not my own work has been identified and that no material is included for which a degree has been previously conferred upon me.

The contents of this dissertation reflect my personal views and are not necessarily endorsed by the University.

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INTRODUCTION

OIL SPILL CONTROL IN THE SAUDI ARABIAN MARINE ENVIRONMENT

Saudi Arabia has the largest offshore oilfield (Safaniya) and exporting terminal (Ras-ul-Tanura) in the world. It is, therefore, natural to assume that Saudi Arabian's Marine Environment has been one of the highest risk areas of oil pollution since the Arabian American Oil Company (ARAMCO) started producing and exporting oil in 1938.

To recognize the risk, one has merely to look at the statistics showing production and export of oil from Saudi Arabia. Appendix 1 shows these figures from 1973 to 1981. An average of 9.9 million barrel of oil per day was pro-duced in 1980, about 30% were from offshore oil fields. A total of 3,340 tankers were loaded at the Saudi terminals during the same year (which was the highest production of oil up to the present moment).

During the past two decades there have been a steady growth worries of concern for, the environment and problems of oil pollution in Saudi Arabia. The oil companies developed an internal capability to deal with the local spillage during the routine operations. In 1972, however, the Gulf Area Oil Companies Mutual Aid Organization (GAOCMAO) expanded this problem into a plan for regional cooperative capability.

In 1976 the Arab League Educational, Scientific and Cultural Organization (ALESCO), consisting of the countries bordering the Red Sea, and the UN Environmental Program (UNEP) started to develop a regional marine environmental program. The International Union for Conservation of Nature (IUCN) also has, in connection with the above pro-gramme, established a network or marine reserves throughout the region to preserve the critical marine habitants.

In 1978, under supervision of the UNEP, the countries bordering the Gulf implemented the Kuwait Action Plan (KAP) for protection and development of the marine environment and coastal areas. In 1983, based on a regional trust fund established earlier, the Marine Emergencies Mutual Aid Center was established. The UNEP, together with other UN organizations, advise the regional governments in matters concerning marine environment of the region.

In 1981, the Meteorology and Environmental Protection Administration (MEPA) was designated the responsibility for protection of the Kingdom's environment and control of oil pollution, by a Royal Decree. MEPA formulates and coordinates policies to resolve problems of oil pollution. Based on the information obtained by MEPA and through its efforts, the Environment Protection Coordinating Committee (EPCOM) passed some important resolutions on protecting the coastal environment in its first meeting in 1984. EPCOM has a powerful role in coordinating the activities of the various government organizations concerned with protection of the environment.

The Gulf War had another impact on the environment in this area which is worth mentioning in order to point out the extent of pollution in this area. The pollution caused by this war is to be dealt with in a special manner.

THE IMPACT OF THE GULF WAR ON THE AREAS' ENVIRONMENT

More than 500 oil wells were systematically set on fire by Iraq and spewed poison aloft. At the Arabian Peninsula of the Gulf, the largest oil spill ever known covered 600 square miles of the sea surface and blackened 300 miles of coastline and much of the wildlife supported by it. The Iraqis spilled about 6 million barrels of Iraqi and Kuwaiti crude oil into the sea by blasting pipelines and storage facilities and emptying the loaded tankers. Only intensive medical and scientific monitoring can ultimately assess the true cost of the war's environmental impact.

The oil fires in Kuwait burntabout 5 million barrels of oil daily, generating more than half a million tons daily of aerial pollutants, including sulfur dioxide, the key component of acid rain. The winds took the pollution far beyond Kuwait: Black rains fell in Saudi Arabia and Iran, and black snow fell in Kashmir more than 1500 miles east-ward.

The extent of the impact on human health will probably never be known with true certainty. Respiratory ailments have increased sharply and carcinogens may also exist in the air.

It took two months to bring a hundred of the easiest wells under control. It will take several years before the gro-wing lakes of oil that submerged could be in control.

Smoked related problems exist throughout the region. Arab agriculture relies heavily on greenhouses which shelter the plants from heat and cold. Greenhouse cultivation requires 80% light in order to grow. The smoke and falling soot may deprive the greenhouses of the necessary light. The chemicals from the fire will enter the milk of the dairy cattle through respiration and food. Reduced sunshine and falling soot can also cause vitamin D and E deficiencies. (The Saudi Research and Marketing Company).

Where the dynamited wellheads had not caught fire, crude oil squirted out thus creating unwanted puddles of oil lakes. These could find their ways down to the Gulf, and the Gulf needs no more oil, as it is, between 4 - 6 millions of barrels of oil have already been released into the sea by Iraq.

The shallow waters of the Gulf make a vital ecosystem for nature's wildlife. In this ecosystem, oil which should not be there is a familiar sight. Based on the experties from MEPA, an estimation of a quarter of a million barrels of oil per year routinely spills. Most of the Gulf nations possess limited cleanup capabilities. Nevertheless, the enormous slicks that crept from the Kuwaiti oil wells were unprecedented. Luckily, the unseasonably soft winds blowing from the southeast for two weeks held the slick at bay and gave valuable time to prepare. Quick action came from ARAMCO which laid down 25 miles of oil boom and mobilized a fleet of 21 oil-recovery vessels and activated its arsenal of cleanup devices. The Royal Commission for Jubayl and Yanbu, headed by HRH Prince Abdullah ibn al-Faisal ibn al-Turki, moved also decisively to deploy unwanted booms and to remove encroaching oil.

The undeveloped domain which belongs to The Gulf's wildlife is underjurisdiction of MEPA which was ill prepared and found itself overwhelmed by the enormous spill. However, international organizations like the United States Coast Guard, the US National Oceanic and Atmospheric Administration (NOAA), the US fish and Wildlife Service and others from Europe, Australia and Japan helped by sending equipment and experts.

As winds shifted, the slick moved southward to Saudi Arabian coast and with every tide the oil floated in and out of embayments and left little untouched. At the south of Al Khafji the slick first came aground and oil blackened the broad tidal zone, often half a mile wide. The shores of Al Musallamiyah Bay were so stained as if charred by fire. The intertidal zone was a black bank a mile wide and pools of oil waited for the next tide to smear it on more wildlife habitat. The oil thinned out seaward as about 40 -50% had evaporated, a lot had gone ashore, some had sunk weighted down by sand from shore or sand blown onto the sea by the winds, and due to the cleanup efforts.

The oil piled at Ad Dafi Bay was the thickest and at Gurmah Island countless trees lining the tidal channel had been killed. At Abu Ali Island, the north shore wore the ugly grime of oil but the water along the southern shore was clear. The island served as a natural block, holding back the black tide from industrial Al Jubayl, Tarut Bay and its fleet of fishing dhows, and the great industrial port of Ad Dammam.

The Al Masallamiay Bay which is a favored habitat for migrant wading birds, the inmpact of the oil on the beach was too much to clean all of it. According to the IMO, only two or three sections which were manageable and important for wildlife would be saved. The IMO, set up a multi- million dollar cleanup fund.

With the help of the British Royal Air Force, the islands which served as the maternity wards for the Gulf's imperiled turtles were cleaned up just as the egg-laying season started. At Gurmah Island 1100 feet of protective boom had been laid by the US Fish and Wildlife volunteers to protect the mangroves. Foreign and Saudi Arabian volunteers manned a bird rehabilitation center in Al Jubayl who had received 1,200 birds by that time. Several hundreds had been cleaned and released in the wild. These centers could do nothing for the grebes who tend to swallow the oily sand that got stuck to their feathers which forms a lethal stone in their gizzards. The number of birds treated at the center were small, but these centers have served to raise public awareness. The estimated number of birds killed as a result of the recent oil pollution is at least 20,000.

Opinions vary as to the extent of the harm caused by the fires and the oil slick. Some experts expect its effects to be less dire than first feared due to the Gulf's history of adaptation to spills. There are sites that had been hit hard in past years and recovered.

Juvenile fish and shrimp will die because of the destruction of nursery habitat and other sea life along the shore will be killed directly.

The Gulf shallows are its primary energy source and the effcts of oil invading these shallows will be felt for generations. The oil surrounding wells that were dynamited but not fired could seep into Kuwait's groundwater and taint it. Disruption of nature's "desert shield", the armor of pebbles over naturally compact sand, will lead to formation of shifting dunes that could block roads and airports and engulf farms. There is also the risk to ancestral grasses that may hold genes important to cereals like wheat.

As far as the impact on human health is concerned, the major worry is the toxic metals released by the slick, combustion of oil and the explosives detonated in the war. Seawater samples from the northern Gulf showed levels of metals ten times higher than normal. These metals can contaminate both soil and vegetation. Sheep,goats and camels grazing on contaminated land will accumulate the metals which may enter the food chain. Many are carcinogens which could cause brain damages and cardiovascular disorders. When tested downwind air of the fires, it revealed a high concentration of particulates which are major causes of lung-related diseases.

OBJECTIVE

The objective of this study is to look into the problem of marine oil pollution in Saudi Arabia and the measures to be taken in order to control oil spills, thus helping to protect the Kingdom's marine environment from pollution by preventing it to the highest possible extent, to approach this, it is necessary to introduce to the Saudi Arabian Marine Environment and to give statistical analysis in oil spill in Saudi Arabia which the early 80's are founded the best to be accountable and taken into consideration because of the high protection of oil. Then whatever the effects are of oil pollution in the Saudi Marine Environment, also in the National and International Legislation concerning this matter, is finally, to give effective recommendations on curbing the oil spills for oil spill response equipment and supply.

APPENDIX 1 - SAUDI ARABIA'S OIL PRODUCTION FROM 1973 TO 1981

Year and Quarter	Production Level * (millions of barrels/day)
1973	7.6
1974	8.5
1975	7.1
1976	8.6
1977: I	9.3
1977: II	9.4
1977: III	9.0
1977: IV	9.0
1978: I	8.0
1978: II	7.6
1978: III	7.7
1978: IV	10.0
1979: I	9.8
1979: II	8.8
1979: III	9.8
1979: IV	9.8
1980: I	9.8
1980: II	9.8
1980: III	9.8
1980: IV	10.3
1981: I	10.3
1981: II	10.3
1981: III	10.0

Source: Middle East Oil, Exxon Background Series, 2nd ed. (New York), Middle East Econoic Digest (London), and Middle East Econoic Survey (Nicosia); and U.S. Department of Energy, Energy Information Administration, Monthly Energy Review, DOE/EIA.

* Included Saudi share of Neutral Zone oil, about 275,000 barrels per day.

CHAPTER ONE

THE SAUDI ARABIAN MARINE ENVIRONMENT

The Saudi Arabian marine environment is an area with high potential for oil spills and pollution. Marine oil pollution does not involve only specific areas and the consequences of its occurrence in any area around the globe concerns the whole world. However, this chapter deals with the region around the Red Sea and the Gulf in general, and the Saudi Arabian marine environment in particular and points out how pollution could be harmful to the biology of marine environment and how it could destroy a good source of our income by polluting the marine environment and destroying the sea life.

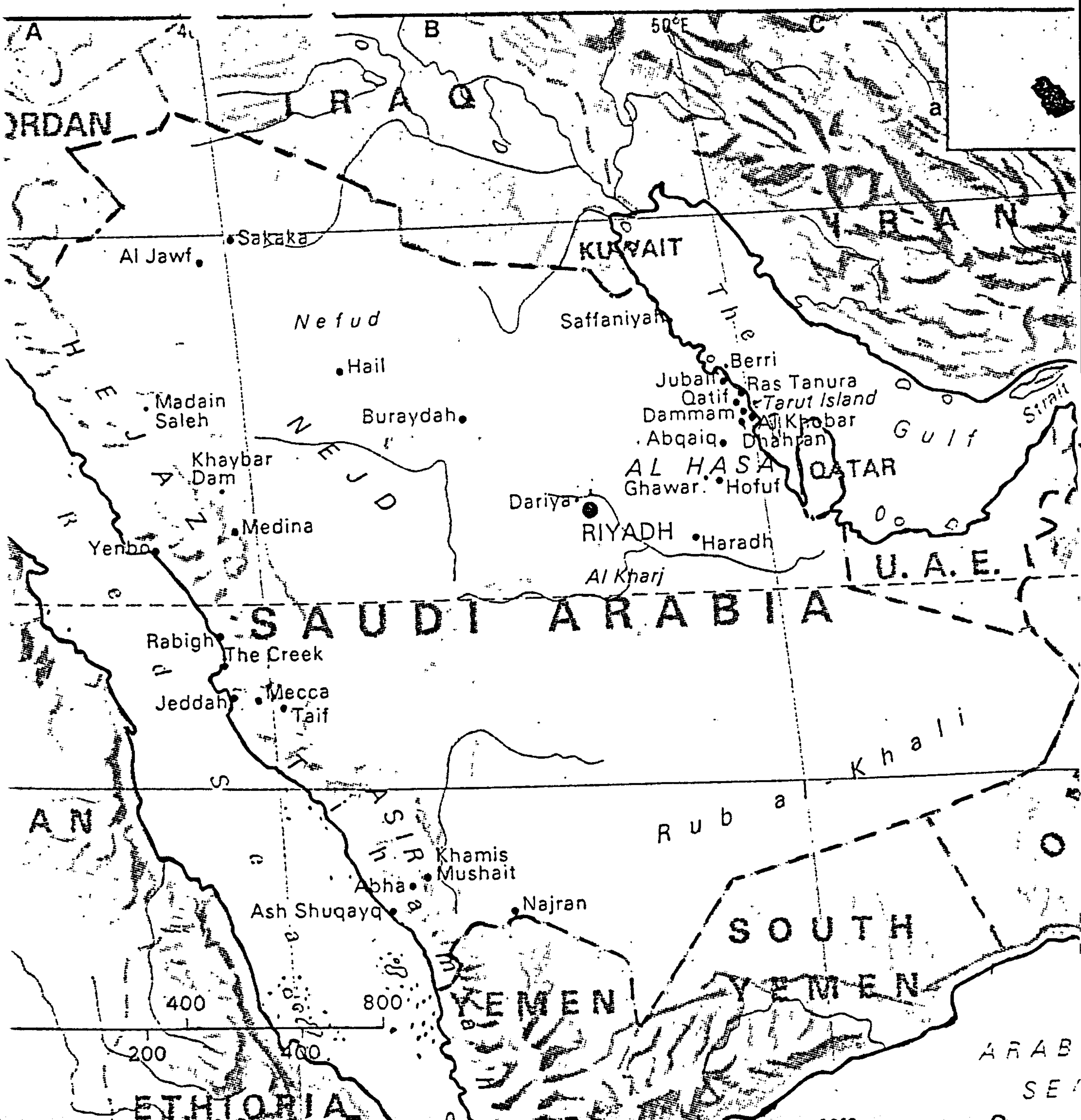
1. GEOGRAPHICAL DATA

The Kingdom of Saudi Arabia, with an area of 2,240,000 km, comprises about 80% of the Arabian peninsula. It is bordered by the Red Sea on the west; Yemen on the south; the Gulf on the east and Jordan and Iraq on the north. Its coastline is approximately 2,250 km consisting of about 1,800 km along the Red Sea on the west and 450 km along the Gulf on the east side. (See Appendix 2)

The 1,900 km of the Red Sea connect the Gulf of Suez, Gulf of Aqaba and Strait of Bab-al-Mandab and also joins the Indian Ocean via the Gulf of Aden. There is no permanent river flowing into the Red Sea and the rainfall in the northern part of it is very little. The central channel of the Red Sea extends from the East African Rift Valley in the south to the Jordan Valley in the north. The water in its central channel is very warm and salty and contains a high density of varoius metals, especially iron and manganese.

Concentration of salt in the Red Sea is high (41 parts per thousand comapred to 35 parts per thousand in the open

APPENDIX 2 - MAP OF SAUDI ARABIA



oceans). The reason for this high density is non-existence of rivers to add fresh water to the sea and the hot climate. The tides at the northern and southern ends are approximately 0.5 meter and occur on a daily basis, but in the center there is almost no daily tide.

The trade winds in the Red Sea are normally north-north-western, but this reverses in winter in the south. The monsoon winds change direction with the seasons; in winter they blow toward the ocean and in summer they draw the breezes towards the land. The spring high tides are caused by the northwestern monsoons which push water into the Red Sea through the Straits of Bab-al Mandab, but the southwestern monsoons draw water out of the Red Sea. The high temperature is responsible for the high evaporation rate in summer, therefore in winter the sea level can be from 0.5 to 1 meter higher than in summer. Due to its narrowness (it is 306 km wide) and its irregular coast-line, the currents of the Red Sea are easily influenced by local winds.

2. GENERAL BIOLOGY OF THE RED SEA

The water from the surface to 100 meters in the Red Sea is poor as far as nutrients are concerned and the plant and animal life in this region is relatively low. The probable causes are that there is not much fresh water flowing into the sea bringing the nutrition from the rich soil and that there is no nutrient rich upwelling in the Red Sea. The number of animals that an open sea can normally sustain, i.e. fish, turtles, mammals, are therefore limited in the Red Sea, the reason being that these animals depend on the food contained in shallow waters for their living.

Most of the living creatures of the Red Sea can leave the Red Sea through Bab-al Mandab with the currents caused by the monsoon winds. This could be one reason for the scarcity of the plant and animal life as you go farther up the Red Sea and away from the influence of the Indian Ocean.

Along the Saudi Arabian Red Sea several open soft-bottom habitats have been identified. Open soft-bottom habitats are those where water circulation is not restricted. They consist of:

1. Wide ranges of sand/silt hillocks which may support shrimp/gopy holes.

2. Regions supporting sea grasses.

3. Regions of fine sand supporting micro-algae which may support grazing populations of mullusces, characterized by olive shells and sand dollars.

Except for the sea grass regions, these areas appear to be unproductive and are, therefore, often overlooked.

Enclosed soft-bottom habitats, which are those with a restricted water circulation, are subject to higher temperatures, salinities and oxygen than the open soft-bottom habitats. Since the enclosed soft-bottom habitats are formed in sheltered waters, the substrate size is, therefore, less than those at the equivalent depths in open water soft- bottom habitats.

Bays, sharms and mersas, which may have been formed through erosions by rivers or wadis, represent the enclosed soft-bottom habitats of the Red Sea. Sharms and mersas are shallow bays which are partly or completely enclosed in coral reefs. Typical characteristics of sharms and mersas are an entrance of 0.2 to 1 km and a length of upto 10 km extending inland, remaining narrow and winding throughout or widening out into lakes. Examples of these are Sharm Obhur, Sharm Suleiman or Mersa Serraj in Jeddah.

Enclosed soft-bottom habitats in Saudi Arabia are very limited in number and are often surrounded by flatlands which are flooded during the rainy seasons and grow micro-algae during this period. A number of sharms and mersas along the Red Sea coast of Saudi Arabia have been destroyed due to coastal developments.

A. Fisheries

Due to uneven bottom conditions and diversity of the fish in the Saudi Arabian Red Sea, fishery in this part is not much developed. More than half of fishing boats are dug-out or planked canoes and most of the rest consist of 10-15 meter sambuks.

The three major fisheries are supplied by fish caught at and around Farasan bank by trolling, gillnetting or handlining. The coral reefs dominating many areas of the Red Sea coasts in Saudi Arabia limit the use of modern fishing equipment like trawls and purse-seines.

The monsoons with their diverse seasonal patterns in winds and currents causes hazardous weather conditions for small fishing boats. Variation of fish species on seasonal basis due to these winds is another hindrance for development of fisheries.

In 1983, a joint government/privately owned fishing company was establsihed and commercial trawling in the Saudi Arabian Red Sea waters started. The Saudi Arabian government is planning to construct new fishing harbours and develop fish farms for highly marketable fish like rabbitfish and mullets.

Shrimps are mostly caught on the Gulf Coast. Turtles, which nest mostly in the islands of the northern Saudi Arabian Red Sea and Farasan Bank, are not significant.

B. Birds

The sea birds of the Red Sea are of three various types: The tropical species which are widespread; northern Indian Ocean species which include white-eyed and sooty gulls, white-cheeked and saunders terns, brown noddy and crab plover; and temperate and tropical latitudes species of which Caspian tern is a good example.

White-eyed and Sooty gulls are native to the coasts of north-east Africa and parts of Arabia. The Sooty gull in particular seems to be breeding in the Al Hala island in the Farsan Bank.

The Sooty falcon winters in south-east Africa and Madagascar, but its breeding grounds are is restricted to the Middle East. The African collared dove and brown booty also breed in this region as do a number of other species.

Large numbers of resident and migrant waders exist on the wetlands along the Red Sea. The Sooty falcon and other birds of prey pass through the Red Sea and Gulf of Aden in their annual migration. Among the birds breeding, roosting or sheltering in the mangroves along the Red Sea are pinkbacked pelican, brown noddy, brown booby and bridled tern, some of which are natives to the region and have international conservational significance.

Although the sea birds of this region do not have much commercial value, resident doves and some migrant birds are used for food and certain species of migrating birds passing through the region can be caught and sold for falconry training. However, the value of the sea birds is in their being an indicator of the environmental condition of the region.

C. Coral Reefs

Coral reefs are normally formed in shallow waters and the maximum depths at which corals can live depends on the clarity of the water; the reason being that the algae associated with corals must have sufficient light for conversion of carbon dioxide and water into food substances.

There are more than 150 species of corals in the northern and central parts of Red Sea. Several types of coral communities exist which are:

1. Fringing reefs, which are adjacent to the shores on most of the coastline.

2. Patch/platform reefs, which are formed about 13-15 km offshore in a barrier system. The reefs at the Wejh bank and Farasan bank are of this type.

3. Pillar reefs/atolls, which can be seen in the northern part of Farasan bank and are formed about 15-20 km offshore in deeper water.

Due to the shallow bathymetry and high turbidity of the southern Red Sea, the quality of the reefs around the Farasan islands is relatively low. However, these may not be the only reasons for the low quality.

Generally, the coral reefs in the Red Sea are well preserved. Nevertheless, due to the coastal developments on the Saudi Arabian coast, the coral reefs around Jeddah, Yanbu and Rabigh are deteriorating.

Appendix 3 shows the major coral reef areas in the Red Sea.

D. Coastal Vegetation

1. Mangroves

Mangroves are plants that flourish in salty environments and live at intertidal fringes of tropical shallow waters.

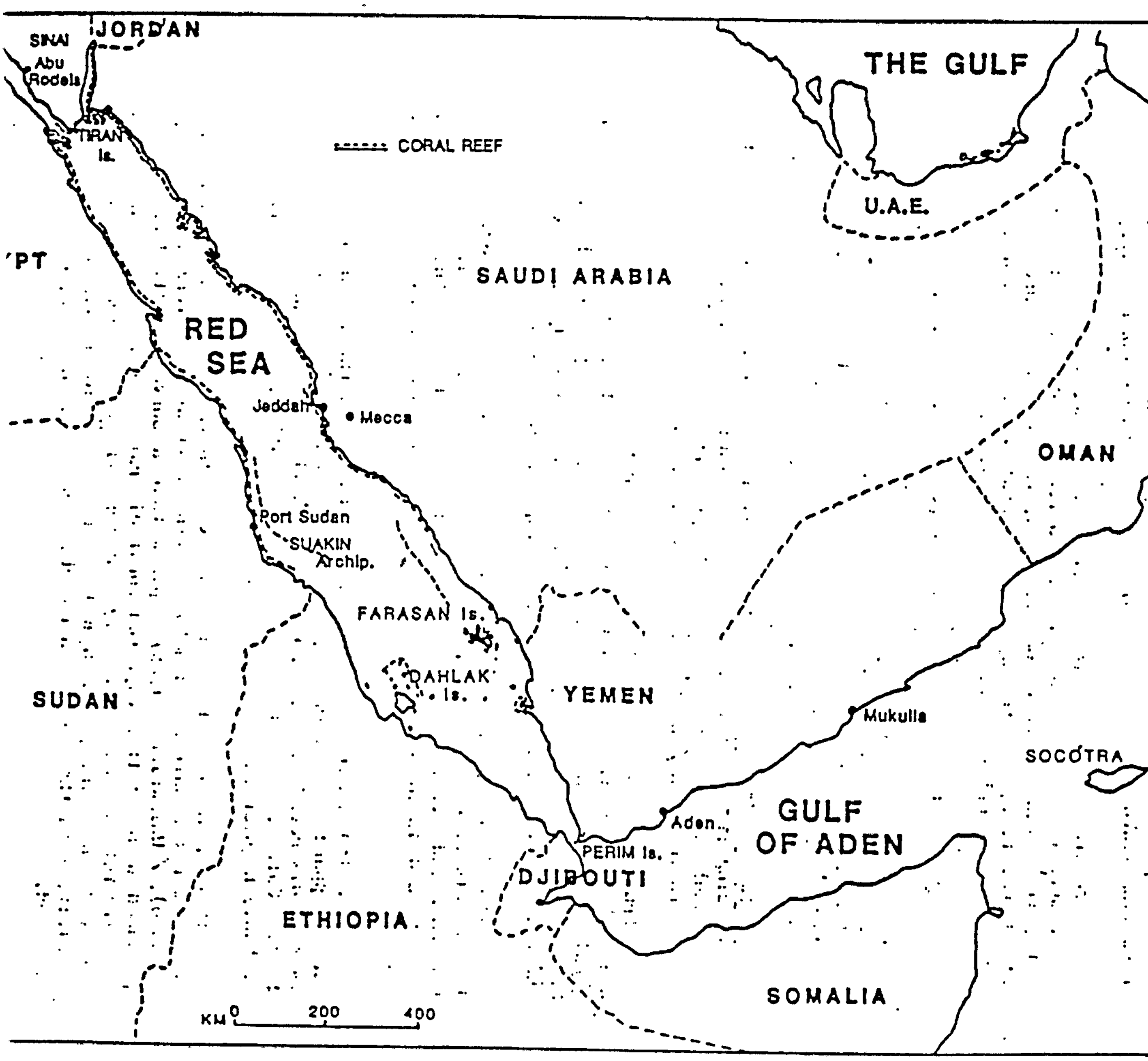
There are two tpes of mangroves in the Saudi Arabia Red Sea: Avicennia Marina and Rhizophora Mucronata. The latter covers only an area of less than 20 hectares at five restricted areas in the Saudi Arabian Red Sea and is always associated with Avicennia Marina.

Most mangroves are in the southern part of Red Sea where the tidal range is higher than the central parts. Most of the mangroves in the central Red Sea, i.e. Birema Island on the Wejh bank, are associated with the reef rock structures where there is a higher tidal range.

Mangroves can control coastal erosion and flooding and are also used for making net stands, shacks and bird traps, and heating. They are also used for grazing animals, especially camels. Avicennia Marina type mangroves at Yanbu-al-Sinaieyah may be significant as filter bed for sewage since everybody in that part has access to the coastal zone and they are not necessarily very particular.

Due to their high productivity, mangroves are often an essential element which provides a basis for

APPENDIX 3 - MAJOR CORAL REEF AREAS IN THE RED SEA



Distribution of major coral reef areas in the Red Sea. (Dashed lines near-shore indicate fringing reefs and associated patch reefs. Dashed lines off-shore indicate offshore complexes of islands, patch reefs, atolls, etc.) (Source: UNEP, 1985) marine fisheries. In an area where there is not much greenery, mangroves are significant for the landscape. They also serve as breading areas for birds.

Appendix 4 shows mangrove areas in the Red Sea.

2. Seagrasses

The importance of seagrass lies within its capability to draw mineral nutrients from within the sea bed due to its special characteristics, i.e. extensive roots and rhizoma system.

There are 10 species of seagrass between Yanbu and Shu'aiba on the Saudi Arabian coasts in the soft bottom substrates in the shallow waters of the Red Sea. However, two of the species exist in depths of 20 meters.

Seagrass is important for the following reasons:

a. It is highly productive and supports turtles, dugong, fish and invertebrates.

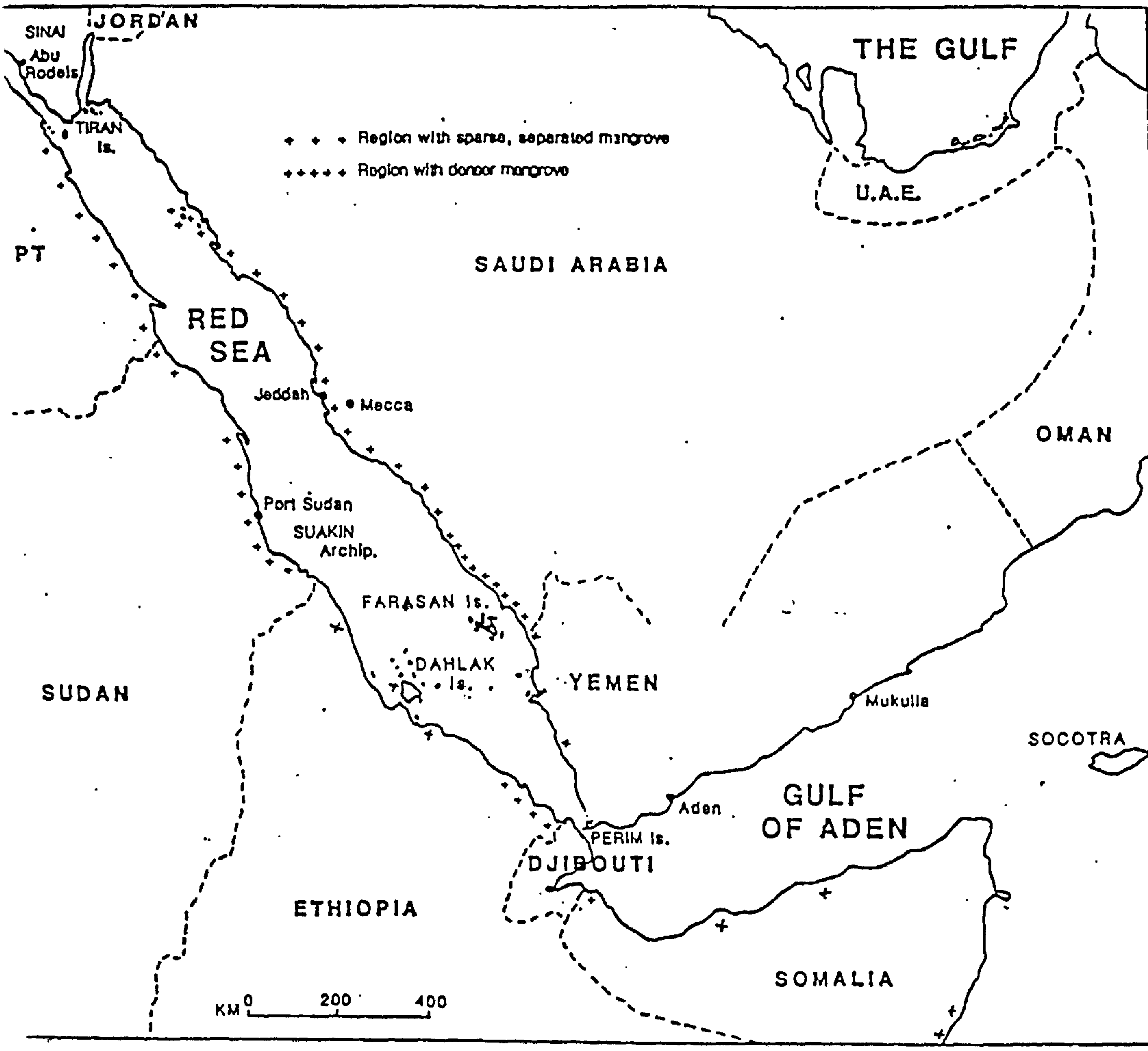
b. It shelters fish and invertebrates some of which have commercial significance.

c. It serves as a base for various epiphytic flora and fauna.

d. It recycles nutrients.

Contrary to the situation in the Gulf, the level of damage to the seagrass beds in the Red Sea is low. Much damage, however, has been done around Jeddah due to dredging and the alteration, or blocking, of water circulation.

APPENDIX 4 - MANGROVE AREAS IN THE RED SEA



Distribution of known mangrove stands in the Red Sea and Gulf of Aden region. (Note that for some countries of the region, e.g. Somalia, Djibouti, Yemen and Ethiopia, information is incomplete.

Source: UNEP

3. GEOGRAPHY AND OCEANOGRAPHY OF THE GULF

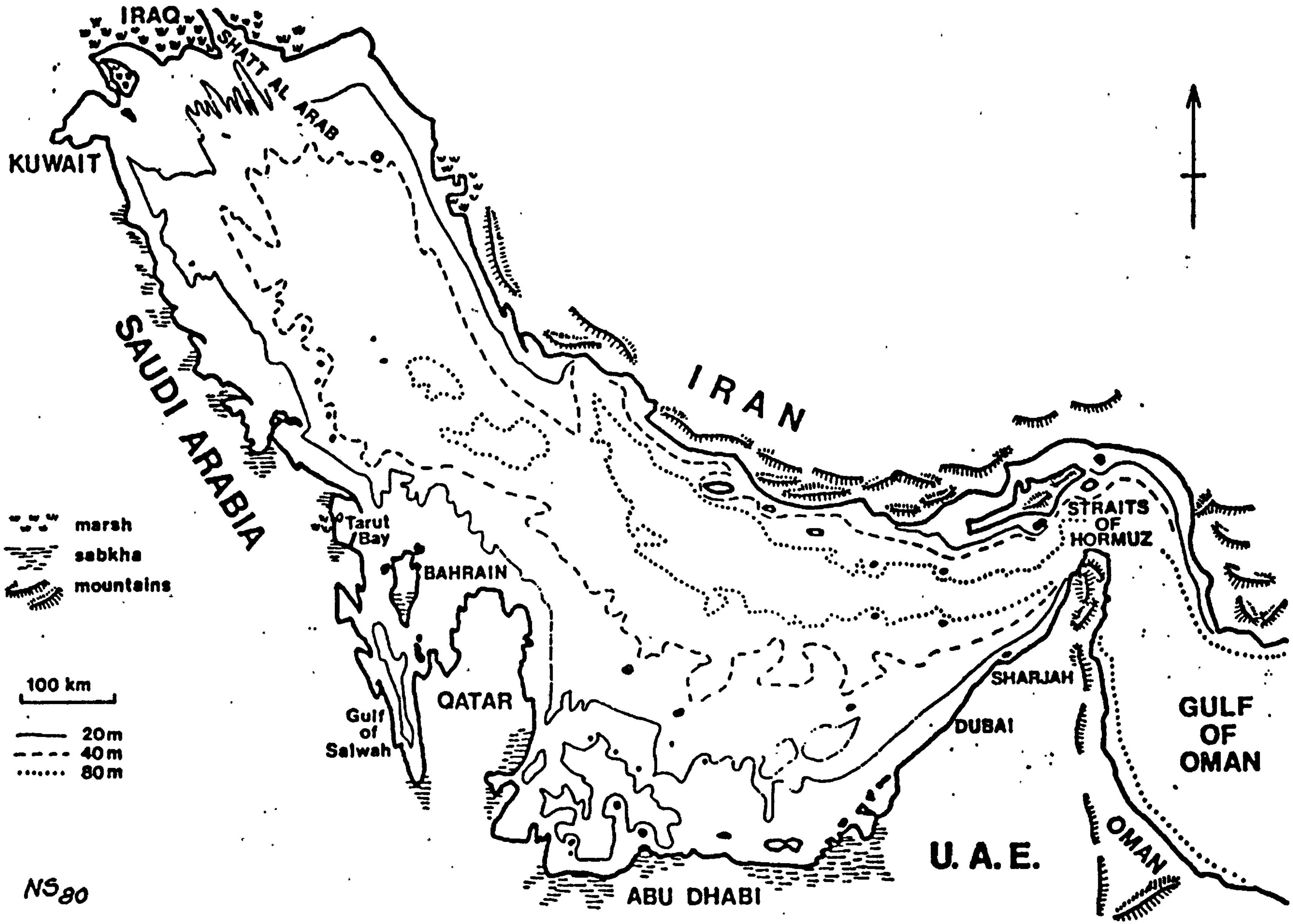
The Gulf is a shallow but large island sea of approximately 1000 km long and 200-300 km wide and an average of 35 meters deep. Except for the part parallel to the Zagros Mountains, nowhere in the Gulf is water more than 100 meters deep. The water temperature, therefore, changes rapidly on a daily basis or seasonally due to its extreme shallowness. Its only opening is through the narrow Strait of Hormuz into the Indian Ocean. (See Appendix 5)

The land surrounding the Gulf is arid and the rate of evaporation exceeds the water input. This results in highly saline waters with a rate of 34 to 41 parts per thousand in the northwestern parts and 53 to 66 parts per thousand in the eastern parts. The water in the Gulf of Salwah, between Saudi Arabia and Qatar in the Gulf, exceeds 100 parts per thousand in its shallow lagoons.

The outflow of the high-saline water along the Strait of Hormuz is balanced by the inflow of the Indian Ocean along the east coast. This results in a counter clockwise circulation. The tidal heights range from 0.5 meter in the middle to about 3 meters towards the head and the mouth. The tides result in uncovering vast areas of sand and mud at low water and flooding of sabkhas (salt-flats) at high water. The tidal waves, however, are strong only where the two-directional ends.

The direction of the wind is predominately from the north and most strongly from north-west which is called "shamal". This results in extended sandspits in the headlands along the western coast in the inner part of the Red Sea, in the NW-SE direction. The largest sandspit is in the south-east where, due to stronger waves, the bottom sediments are of coarse sand. In other parts, particularly in deeper water, they are

APPENDIX 5 - THE GULF



of fine sand or mud. The euphotic (the upper layer of the body of the water into which sufficient light penetrates to permit growth of green plants) zone is about 20-30 meters deep and includes a large area along the western side. The waters of the inner sea are generally more turbid than in the Red Sea or Indian Ocean.

The Saudi Arabian coast in the Gulf stretches about 450 km between the Kuwait border in the northernmost part, through Ras-ul-Tanura and across Bahrain and Qatar, to the southernmost part of Dammam. It curves in a southerly direction almost parallel to the prevailing winds. The coastline along the Gulf of Salweh is protected from tidal waves by a stretch of shallow water between Saudi Arabia and Bahrain. The Tarut Bay between Dammam and Ras-ul-Tanura contains vast tidal flats and grassbeds which provide the major shrimp nursery in the Gulf.

4. MARINE RESOURCES OF THE GULF

A. General Biology

Despite the high salinity, high and fluctuating temperature and other restricting factors, the marine biota of the Gulf is quite diverse and rich. The following list taken from "Biotopes of the Western Arabian Gulf" (Basson, Burchard, Hardy & Price - 1977) depicts the number of various types of species in particular habitats along the western coast of the Gulf.

Rocky shores	131 +
Intertidal rocks	314 +
Sublittoral rocks	194 +
Coral Reefs	543 +
Artificial structures	178 +
Sandy beaches	218 +
Intertidal sandflats	191 +

Sublittoral sand	638 +
Intertidal mudflats	109 +
Sublittoral mud	610 +
Seagrass beds	530 +
tidal creeks	33 +
Plankton	355 +
Open water	83 +

The research resulting in the above mentioned publication proved the existence of more than 167 different species of polychaete, 125 species of gastropod mulluscus and 73 different bivalves, over 39 different amphipod crustaceans and 66 species of decapods i.e. shrimps, crabs etc. in the sublittoral bottoms.

Due to aridity and sterility of the land surrounding the Gulf, nutrients can enter only through Shatt-al Arab or Strait of Hormuz. Nevertheless, the intertidal micro-algae, seagrass beds, mangroves and other halophytes around the sheltered bays supply enough nutrients to result in a relatively high productivity marine life.

Although the plankton has not yet been fully studied, it seems to be best stocked in the lower part of the Gulf, through contribution from Indian Ocean, and densities in the productive bays and lagoons appear to be quite high. The zooplankton contains a high amount of the larvae of benthic inverterbrates to include crabs and smaller crustaceans which are significant as adults in scavenging detritus and turning over surface sediments. Polychaete worms perform the same function. The rocks at low water can become heavily encrusted with bivalves and tubeworms and intertidal flats may support large numbers of gastropod snails.

B. Fisheries

The fishing methods used in the Gulf are the century old traditional methods, i.e. nets and lines from small boats. In shallow waters, however, e.g. Tarut Bay, fixed traps or fish weirs may also be used.

There are approximately 135 species of edible fish in the Gulf. These include pelagic species, i.e. sardines, mackerel, tuna and barracuda, whose fishery is in south-east of Saudi Arabia and is used by Iran to supply a cannery at Bandar Abbas. In the parts with a flat sea bed and shallow water trawling can be used for demersal (bottom living) species e.g. bream, jack, snapper, grouper or various flat fish. The potential yield is estimated to be between 200,000 to 600,000 tonns per year, an amount five to ten times greater than the present catch.

Modern trawling in the Gulf began in 1963. Since then the most important fishery is the one for the large pink shrimp (Penaeus Semisulcatus) which makes the largest amount of commercial landings in Saudi Arabia and other Gulf states. The major stocks of this species seem to be in the north where they are caught by Iran, Saudi Arabia and Kuwait. The stocks in the south are caught by Saudi Arabia, Bahrain and Qatar. The estimated yield for Saudi Arabia from both these stocks is approximately 2,500 tonnes per year.

Various means of improving the shrimp fisheries have been suggested. These include protection of the natural breading grounds, early release of the artificially reared young ones to boost "wild" stocks and a Japanese style culture of mature shrimps in tanks.

Turtles are not much caught in the Gulf. The known species include green turtles, hawksbill, leatherback, logerhead and Ridley's. 80% of them are in Karan island off the Saudi Arabian coast, where several thousand breading pairs, which represent a significant proportion of the world population exist. Due to their dislike of any form of disturbance, it is doubtful if these turtles use any mainland beach, no matter how isolated, for their habitat.

The fishery for pearl-oysters in the southern part of the Gulf, used mainly by Kuwait and the Emirates, does not exist any more. This is due to emergence of the cultured pearls. However, the conditions for farming of oysters and other bivalves for food is still favourable.

There are at least six species of sea snakes in the Gulf, but, due to scarcity of dense mangroves which are their favorite habitat, dugongs are rearly seen. There exist, however, several species of porpoise, dolphin and killer whales in the Gulf and larger whales regularly visit it.

C. Birds

Typical marine species, i.e. cormorants, sea-ducks, gulls, terns and the types usually associated with the water edge areas, e.g. herons, egrete, wanders and kingfishers exist in the Gulf. Ospreys and kites also feed along the coast. The islands offshore are significant breading sites for three different species of terns, and turtles. They also serve as resting places for migrating birds passing across the Gulf on their spring and autumn migrations.

D. Coral Reefs

There are no reef-building corals in the northern part of the Gulf. Numerous reefs, however, are formed in the shallow waters of the south-west towards the Strait of Hormuz and around the Gulf of Oman and other offshore islands.

According to Basson et al (1977) 43 species of scleractinians (stony corals) in 28 genera and 2 species of soft corals exist on the Saudi coast alone, compared to approximately 30 species existing in the northern part of the Red Sea. In the northern part of Red Sea although at the extreme edge of their geographical range, offer a more stable environmental condition.

In shallower parts of the Saudi coast there exist coral reefs with widely different sizes and characteristics. On the open coast coral reefs grow to the low-tide mark and have a smaller variety than the ones in the open sea. In offshore waters, due to the turbidity of the water, they grow to depths of 10 meters or less, even though the usual limit for continuous coral cover in offshore waters is 15 meters. Patch or platform reefs are typical for the Gulf area. Formation of sandbars on the leeward side of the larger platform reefs result in formation of coral islands, increasing the types of habitats and, subsequently, the number of species. Coral growth, even around single coral heads, is ringlike, which is a prominant feature of the coral flats around the coral islands in the Gulf. There is no real distinction between platform and fringing reefs in this area.

E. Coastal Vegetation

Vast mats of blue-green algae in the sheltered intertidal flats contribute as much to productivity of the Gulf as salt-marsh vegetation do in temperate seas. Unlike other tropical areas, mangroves are not much developed and exist only in patches along the southern and western shoreline. The thickest mangrove areas exist along each side of the Strait of Hormuz. Smaller halophytes are widespread in bays and creeks and cover the intertidal flats above the level of algae or mangroves and merge with reedbeds in the areas where there is a fresh water seepage, i.e. Tarut Bay, Saudi Arabia.

Seagrass beds below tidal marks probably bring in nutrients more important than the blue-green algae. They stabilize large areas of soft sediments and support or shelter many species from protozoans to reptiles. (ARAMCO)

CHAPTER TWO

STATISTICAL ANALYSIS AND STAGES OF OIL SPILLS IN THE SAUDI ARABIAN MARINE ENVIRONMENT

The Saudi Arabian marine environment is a high risk area as far as the potential for oil spills is concerned. This is due to the great amount of present and projected petroleum operations and the associated marine traffic in the area.

Oil spills occur during the routine transfer operations, i.e. loading and deballasting of oil tankers to prepare them for loading; offshore drilling activities; and from refineries operations and other varied sources along the coast. This chapter deals with identification of the major sources of oil pollution and estimating the amount of pollution from each source.

In order to fully appreciate the problems involved with oil pollution, one must know the basic ingredients of oils derived from petroleum, their behavior and where they end up in the marine environment. A brief review of this subject is thus given in this chapter.

1. METHODOLOGY USED FOR SPILL ESTIMATES

A. The method used to calculate the amount of annual oil spills in the Saudi Arabian marine environment are the ones developed by the following:

1. Golob and Brus, which was used to estimate the oil pollution in the Kuwait Action Plan (KAP) region based on the National Academy of Sciences (NAS) data.

2. Beyer and Painter paper.

3. Research Planning Institute (RPI) of Columbia, South Carolina, USA.

B. The data used are from the following sources:

1. Statistical Bulletin (1983), Ministry of Petroleum and Mineral Resources, Saudi Arabia (for statistics on oil production, consumption, refining and export in Saudi Arabia).

2. Offshore Magazine, British Petroleum Co. and the US Department of Energy (for statistics on oil production, consumption, refining and export in individual countries).

3. The UN Census (for worldwide population figures).

4. The Times Atlas of the World (for geographical (data).

2. TERMINOLOGY AND ASSUMPTIONS

A. The Saudi Arabian marine environment implies the marine environment and coastal areas of Saudi Arabia, both in the Red Sea and the Gulf.**(the highest oil production)**

B. The statistical data used for the calculations throughout this chapter are for 1982, reflecting the average production and export statistics of the decade between 1972 and 1982.

C. All final amounts have been converted into metric tonnes with a conversion rate of 7.3 barrels per tonne for crude oil and 7.3 barrels per tonne for all exports including crude oil and products.

D. Spill estimates have been calculated to the nearest tonne.

3. ESTIMATING THE AMOUNT OF OIL POLLUTION/OIL SPILL FROM DIFFERENT SOURCES

A. Natural Seeps

According to Wilson et al (1974), the world's continental margins are divided into three regions of low, moderate and high seepage potential, with a seepage average of 0.1, 3 and 1000 barrels per day per 1000 square miles respectively (1 square mile equals 2.59 square km). The sea area of the Gulf has a moderate seepage potential.

The offshore oil fields of Saudi Arabia are mainly in the Gulf, totalling an area of 64,200 sq. km. (24,788 sq. miles) (see Appendix 6). Based on the above data and the following formula, the annual amount of oil entering the Saudi Arabian marine environment from natural seeps is 3711 tonnes per year.

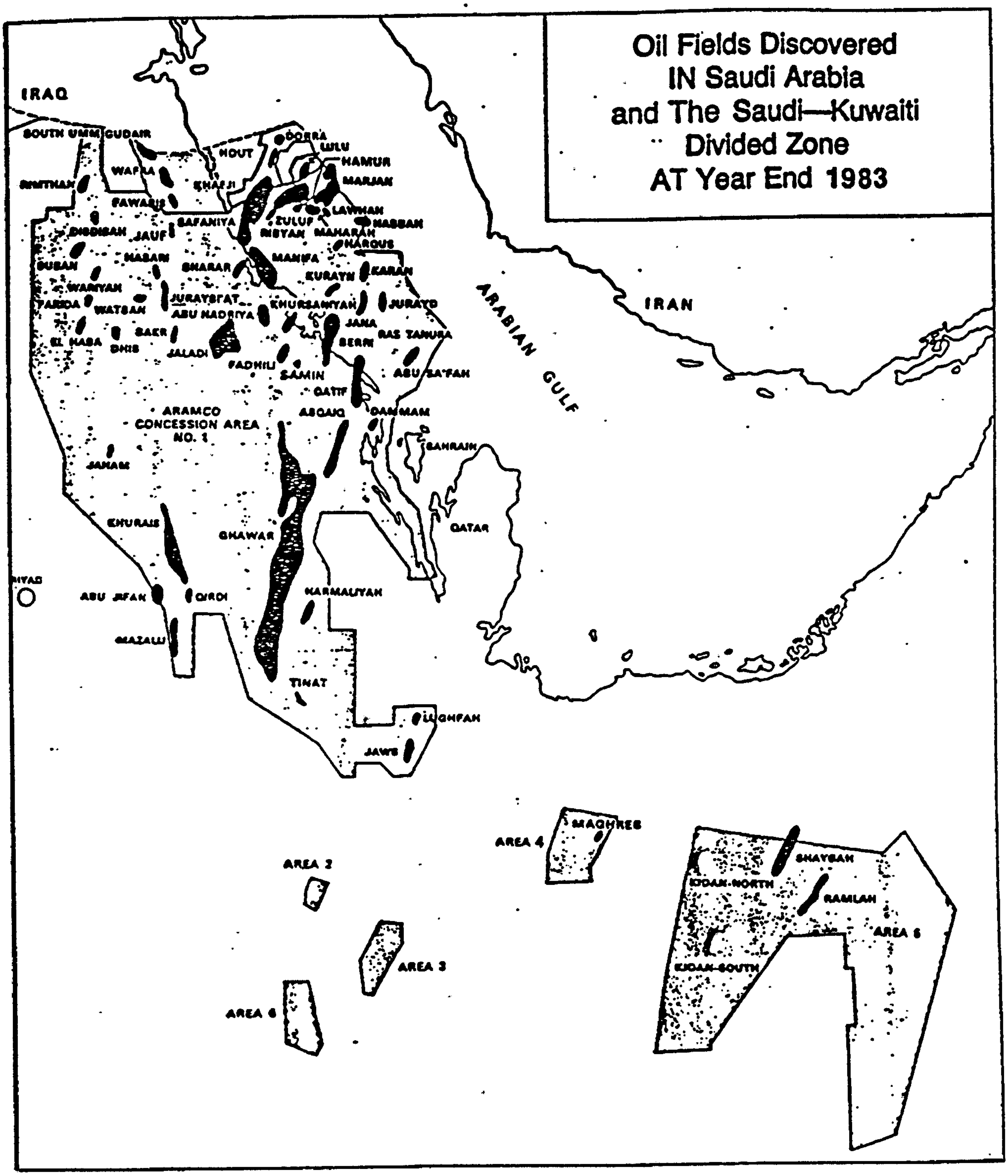
365 days per year x 3 bbls per day per 1000 sq. miles x 24,788,000 sq. miles : 7.314 bbls per tonne = 3711 tonnes per year.

B. From Offshore Production

The Saudi Arabian offshore oil production is concentrated in the Gulf (see Appendix 6). The following three methods have been used to estimate the amount of oil entering the Kingdom's marine environment from offshore platforms and pipelines in this area.

1. Devanny and Stewart
2. NAS
3. Beyer and Painter

APPENDIX 6 - CONCENTRATION OF THE SAUDI ARABIAN OIL FIELDS IN THE GULF



Source: Ministry of Petroleum & Mineral Resources Statistical Bulletin.

The statistics used for this purpose are the 1982 production figures. According to the Offshore Magazine, Saudi Arabia's offshore production in 1982 was 2,392,000 barrels per day or 119,370,069 tonnes per year.

Devanny and Stewart estimate the amount of oil spilled to be 60 tonnes per million produced from the offshore platforms and 110 tonnes per million produced from the offshore pipelines. Based on the 1982 figures, the total spillage from the Saudi Arabian offshore platforms and pipelines comes to 20293 tonnes per year.

According to the NAS method the amount of oil loss caused by minor spills (less than 50 barrels) and briny discharges varies between 8.6 and 32 tonnes per million tonnes produced; in this study I have used the average of these two figures. For larger spilled (more than 50 barrels) this amount is about 140 tonnes per million tonnes produced. Using the 1982 production figures, the spillage in the Saudi Arabian marine environment comes to an average of 2424 tonnes per million tonnes produced (from briny discharges and less than 50 barrels spillage) and 16712 tonnes per million tonnes produced (for spillages more than 50 barrels). The total spillage, therefore, is 19136 tonnes per year.

Beyer and Painter's method estimates the average spillage at 72 tonnes per million tonnes produced. Based on this method and the 1982 production figures, the amount of oil spilled in the Kingdom's marine environment from offshore oil production comes to 8595 tonnes per year.

Due to the widely varied estimates according to each method, for the purpose of this paper, we use the average of the three amounts. Thus, the annual oil spillage from the offshore productions in the Saudi Arabian marine environment is 16008 tonnes per year, as calculated below:

(20293 tonnes (Devanny & Stewart) + 19136 tonnes (NAS) + 8595 tonnes (Beyer & Painter)) : 3 (No. of methods) = 16008 tonnes per year.

C. Tanker Related Spillage

According to the Petroleum Statistical Bulletin of the Saudi Arabian Ministry of Petroleum and Mineral Resources (1983), Saudi Arabia exported 2,058,392,000 barrels (281,431,775 tonnes) of crude oil and 195,095,000 barrels (26,392,722 tonnes) of refined products in 1982. The total amount exported in 1982 is, therefore, 307,824,497 tonnes. This is the amount used in calculating the estimates in this paper.

Appendix 7 exhibits the major oil movements at sea in 1979.

1. Casualties

Based on the casualty rate during the past two decades, the following data were used by Beyer and Painter to estimate the amount of oil spilled due to tanker accidents within 80 km of the shore:

- amount of oil transported
- number of port calls

Using the above data, Beyer and Painter estimated the spillage caused by tanker casualties to be 87 tonnes per million transported. Assuming that the tankers carrying Saudi Arabian oil and involved in the accidents were within the 80 km of the Saudi Arabian shore all the time, and based on the 1982 export figures, the amount of oil spillage would be 26780 tonnes per year. However, tankers pass within 80 km of the Saudi Arabian shore during their voyage only while:

APPENDIX 7 - MAJOR OIL MOVEMENT AT SEA

The width of the arrows represents the relative volume of oil.

- transiting along the Saudi Arabian coast nearby their point of origin
- on an intermediate port call
- approaching point of destination

Assuming that nearshore casualties occur in equal numbers on each of the above three occasions, the amount of oil spillage within the 80 km zone of the Saudi Arabian shore will be on third of the total amount of 26,780 tonnes per year, which means 8,927 tonnes per year (26780 : 3 = 8,927).

Based on the world's casualty data for the past two decades, Beyer and Painter estimated the average spill rate to be 0.92 per 1000 port calls, with an average amount of 7,124 barrels per spill. In 1982, according to the Petroleum Statistical Bulletin (1983), 4353 tankers called at the various Saudi Arabian ports. Using the Beyer and Painter's method, the annual tanker accident related spillage in the Saudi Arabian marine environment comes to 3860 tonnes.

Due to the wide variations in estimates between the two methods, for the purpose of this study, the amount of 6394 tonnes, the average of the two amounts, is considered as the estimated annual tanker accident related spillage, i.e. (8,927 tonnes + 3,860 tonnes) : 2 = 6394 tonnes.

2. Cleaning and Ballasting

According to the NAS, tankers discharge about 0.35% of their carrying capacity during their ballast voyage. However, using Load On Top (LOT) procedures reduces this amount by 90%, bringing the total amount of discharge to 0.035 of the carrying capacity. LOT procedures enable the tankers to retain their tank washings and ballast waters on board to further separate the oil from water and using the separated oil in the next shipment. During 1970's about 80% of tankers used LOT procedures while the remaining 20% discharged their tank washings and ballast water directly into the ocean.

Based on the 1982 export figures (307,825,497 tonnes), the amount of oil discharge by 80% of the tankers using LOT procedures will be 86,190 tonnes. The amount discharged from the rest (20% of the tankers) amounts to 215,477 tonnes, bringing the total of 301,667 tonnes per year. Tankers carrying oil to North America, Europe and Asia spend about 5 to 10% of their voyage in the Saudi Arabian waters, therefore the total spillage into the Saudi Arabian nearshore would be 5 to 10% of the above total. Assuming that ballast waters are most probably released away from the land to avoid the close scrutiny by national and international maritime authorities, the amount of discharge into the Saudi Arabian nearshore is estimated at 5%. This results in a total discharge of 15,083 tonnes per year (5% of 301,667 tonnes).

3. <u>Terminal Operations</u>

Brummage (1973) determined that during 9 years of operations, the average oil loss at the tanker terminal at Milford Haven, UK, was 1.1 tonnes per million tonnes throughput. The rate for Portland, Maine in the USA was 2.2 tonnes per million tonnes throughput.

Due to the less strict environmental laws in Saudi Arabia, the historical data of the past decade reveal oil spillage as large as 5,000 tonnes in certain terminals. Assuming a spillage rate of 1.5 times more for Saudi Arabia than the rate for Portland, i.e. 3.3 tonnes spilled per million tonnes throughput; and considering the 1982 export figures of 307,825,497 tonnes (or 307.8245 million tonnes) as throughput, the total oil spillage resulting from terminal operations in Saudi Arabia would be 1,016 tonnes per year.

The total annual tanker related oil spillages into the Saudi Arabian marine environment would thus be 22,493 tonnes per year calculated as follows:

6,394 tonnes (tanker casualties) + 15,083 (tanker cleaning and ballasting) + 1,016 (terminal operations) = 22,493 (total annual spillage).

C. Non-Tanker Related Spillage and Their Sources

According to the NAS, approximately 100,000 tonnes of oil enter the world-wide marine environment annually. The estimates of non-tanker related oil spillages in Saudi Arabia, in this study, are based on the amount of industrial development in the whole Kingdom (coastal and non-coastal), and the assumption that the levels of industrial activities and oil consumption are directly related to each other.

The Statistical Bulletin (1983) published by the Saudi Arabian Ministry of Petroleum and Mineral Resources, indicates that the total consumption of oil and natural gas products in Saudi Arabia in 1982 was 327,817,000 barrels or about 44,347,538 tonnes. Since, according to BP (1984), the worldwide consumption in 1982 was 2,824.9 million tonnes, it can be calculated that 1,570 tonnes of the 100,000 tonnes worldwide spillage occurred in Saudi Arabia. The calculation follows:

(44.348 million tonnes consumed in Saudi Arabia: 2,824.9 million tonnes consumed worldwide) x 100,000 tonnes spilled worldwide = 1,570 tonnes spilled in Saudi Arabia

E. Spillage from Coastal Refineries

Based on the NAS reports, the oil contents of refinery discharges where refineries use gravity separation/dissolved air floatation systems is about 20 parts per million (PPM). According to the 1982 statistics published in the Statistical Bulletin (1983) of the Saudi Arabian Ministry of Petroleum and Mineral Resources, the throughput to the coastal refineries in Saudi Arabia was 432,633,000 barrels or about 58.5272 million tonnes. Assuming that the Saudi Arabian refineries use the above mentioned system, and considering the discharge rate of 20 PPM, the oil discharge from the Saudi Arabian coastal refineries into the environment will be 1171 tonnes per year.

F. Pollution as a Result of Atmospheric Fall-Out

The pollution from atmospheric fall-out for 1973, according to NAS, was 600,000 tonnes. This amount remained the same for the early 1980's although the worldwide oil consumption had increased by 20%. The reason is that implementation of strict hydrocarbon emission standards in the industrialized countries balances out the pollution which may be caused by the increase in petroleum consumption.

In this study, to estimate the 1982 atmospheric fall out in Saudi Arabia, similar assumptions have been made.

According to the Times Atlas of the World, the total surface area of the world's marine environment is

361,719,030 sq. km and the Saudi Arabian marine environment is 186,200 sq. km or 0.052% of the above total.

Using the above data, and assuming that the 600,000 tonnes of atmospheric fall-out were distributed evenly over the world's marine surface, the resulted pollution over the Saudi Arabian would be about 312 tonnes per year, i.e. 0.052% of the total.

G. Pollution Resulting from Other and Non-Refinery Related Sources

According to the NAS estimates, coastal municipal and non-refinery industrial wastes resulted in an approximate input, into the US marine environment, of 8 gramms of petroleum per day per person living in the coastal zone.

The US consumption of oil in 1982 was 705.5 million tonnes. With a population of 232.057 million, this means a consumption rate of 3.04 tonnes per person. The Saudi Arabian population in 1982, according to the United Nation estimates, was 9.684 million people. The oil consumption amounted to 44.4 million tonnes in the same year, resulting in a per capita consumption rate of 4.58 tonnes or 150.66% of the amount used in the USA in the same year.

Assuming that the coastal municipal and non-refinery related wastes are directly related to the per capita consumption of oil, the amount of pollution contributed to the Saudi Arabian environment would be 12.05 gramms per person per day. Since about 25% of the Saudi Arabian population live in the coastal zones, i.e. 2.421 million people, this results in an annual pollution input of 10,650 tonnes, calculated as follows:

(12.05 gramms per person per day x 365 days per year x 2.421 million coastal population) : 1 million gramms per tonne = 10,650 tonnes per year.

H. Pollution Resulting from the Urban Run-Off

Based on the NAS estimates the pollution resulted from the urban run-off amounts to about 50% of the pollution caused by the coastal municipal and non-refinery related wastes. According to this estimate, therefore, the amount of pollution in the marine environment of Saudi Arabia would be 50% of the 10,650 tonnes calculated above, i.e. 5,325 tonnes per year.

The total amount of oil spilled into the Saudi Arabian marine environment from the major sources explained above, based on the 1982 statistics, is 61,240 tonnes per year. (See Appendix 8)

This amount represents 2.1% of the NAS estimates of the worldwide oil pollution from the same sources (excluding pollution caused through river run-off since this does not apply to Saudi Arabia). (See Appendix 9)

3. MAJOR OIL SPILLS IN THE SAUDI ARABIAN MARINE ENVIRONMENT

It must be borne in mind that the estimated 61,240 tonnes of oil spilled annually into the Saudi Arabian marine environment are due to normal activities/accidents. However, exceptions occur.

The fracture in the Tarut Bay pipelines in 1970 and the blow-out in Hasbah-6 well in October 1980 resulted in an estimated spillage of 14,000 tonnes oil each. This amount equals the total annual spillage from offshore operations.

APPENDIX 8 - TOTAL ESTIMATE OF OIL POLLUTION IN THE SAUDI ARABIAN ARINE ENVIRONENT IN 1982

Source	Estiate in Tonnes	% of Total
Natural Seeps	3,711	6.1
Offshore Production	16,008	26.1
Tanker Transport	22,493	36.1
Non-tanker Accidents	1,570	2.6
Coastal Refineries	1,171	1.9
Atmospheric Fall-out	312	0.5
Coastal Municipal Wastes (Coastal Non-refinery Wastes)	10,650	17.4
Urban Run-off	5,323	8.7
River Run-off	N/A	N/A
TOTAL	61,240	100%

APPENDIX 9 - NSA ESTIMATED INPUTS OF PETROLEUM HYDROCARBONS IN THE WORLD MARINE ENVIRONMENT DURING THE EARLY 1980'S

Source	Estiate in Tonnes	% of Total
Natural Seeps	600,000	20.2
Offshore Production	200,000	6.7
Tanker Transport	700,000	23.6
Non-tanker Accidents	100,000	3.4
Coastal Refineries	20,000	0.7
Atmospheric Fall-out	600,000	20.2
Coastal Municipal Wastes (Coastal Non-refinery Wastes)	450,000	15.2
Urban Run-off	300,000	10.1
River Run-off	Excluded	N/A
TOTAL	2,970,000	100%

The terminal spillage from Mina Saud amounted to more than 5,000 tonnes of crude oil spillage which is almost five times the annual amount of 1,016 tonnes spilled due to terminal operations.

In August 1980, a 25 sq. km oil slick in north and west coast of Bahrain was washed ashore along 65 km of coastline. This resulted in death of about 1,000 birds, ended a large amount of intertidal marine life, contaminated the beaches and limited the fishing. It damaged fishing traps, nets, tackles and boats.

The degree of the oil pollution as a result of the Gulf War is still to be determined.

4. STAGES OF OIL SPILL IN THE MARINE ENVIRONMENT

Crude oil from different sources have different characteristics, depending on which part of the world they come from. The behavior of the oil spilled in the environment and the subsequent clean-up operations depend heavily on these differences. Oil spills in the seas involve the following steps:

A. Spreading

Spreading is the first stage after a spill. Oil spreads into a slick over the water surface unless it is of a higher specific gravity than the water (e.g. residual fuel oils) in which case it solidifies or sinks.

Absence of wind or currents do not limit the spreading of oil. Oil spreads quicker immediately after the spill and large spills spread faster than the small ones. However, after a few hours spreading rate slows down. Typically oil spreads to form a thin lens on top of the water with the inner portion being thicker than the edges.

Although rate of spreading depends on the type of oil, as a rough estimate, most crude oils spread to a thickness of about 3 mm in one hour and 0.3 mm in 10 hours. In absence of other factors having an impact on the oil spread, it will continue until a monomolecular layer of about 0.5 micrometers in thickness is formed on the surface of the sea, giving the appearance of a slight slivery sheen. In these circumstances natural dissipation of oil is rapid.

B. Movement

Wind and water current influence the movement of the spilled oil. Current alone has a direct effect on the movement in that the oil slick moves in the same direction and at the same speed as the current. Wind alone results in a speed of 3% that of its own velocity when moving an oil slick, i.e. a 60 km/h wind moves the oil slick downwind with a speed of 2 km/h. Wind speeds of more than 16 km/h cause the slick to break into streaks or windrows. when both current and wind are strong, their effect on the movement depends on the variation of the wind and current.

Lehr and Cekirge of University of Petroleum and Minerals, Dharan, Saudi Arabia, have developed a method for estimating the movement of the oil spills in various locations in the Gulf, based on the seasonal climate of this area. This method can be used by oil spill detective agencies to forecast the spill path based on minimal information available. It could help organizations concerned to assess capabilities for the clean-up operations, taking preventive measures if the spill is likely to reach the shores and control any damage which may result.

According to Lehr and Cekirge, the southern Saudi Arabian coasts have a high risk of getting the oil drifts in summer and fall, while the northern region has the highest risk in spring. This may be a determining factor in stationing the Saudi Arabian oil spill task force in the north during the spring and in the south during the summer and fall seasons.

C. Weathering

While spreading and moving, the oil undergoes a process of changing its physical and chemical characteristics. This process is called weathering. Type of oil and climate influence the weathering process. Rate of weathering process, which varies throughout the duration of the spill, may be greatest in the first few hours.

Weathering process involves evaporation which is significant in its initial stages. The lighter components of the oil evaporate quickly in the first few hours after which the rate decreases and the remainder of the spilled oil forms a residue with a higher specific gravity than the original. Factors influencing the evaporation rate include air and water temperatures, sea conditions, wind and rate of spreading. The type of components which exist in the oil will also greatly influence the extent of evaporation.

Another important weathering process is dispersion. wIn the dispersion process small particles of oil, with a diameter of 5 micrometers to several millimeters, are incorporated into the water column. The rate of dispersion depends on the condition of the sea and type of oil. In moderate conditions (climate, wind, etc.) a thin film of liquid oil disperses rapidly on the surface of the sea, enhancing the other weathering processes i.e. dissolution and biodegradation.

CHAPTER THREE

THE EFFECTS OF OIL POLLUTION ON THE SAUDI ARABIAN MARINE ENVIRONMENT

Many inhabitants in the Saudi Arabian marine environment must adapt themselves to its demanding conditions. The few species tolerant of the conditions are in abundance, although the diversity is low. Such an ecosystem always has the risk of not being able to adapt to changing circumstances. Therefore, because this system does not absorb the changes imposed upon its naturally demanding conditions as readily as a less stressed system, oil spills can have a profound impact on such a system.

Oil spills are destructive to the marine environment because hydrocarbon particles harm the organisms in the water and its surroundings. The oil slicks on the surface of water can destroy aquatic birds which alight on the slick. The oil settled at the bottom of the sea can hurt the organisms in that part by getting in their system. If washed up on the beach it can destroy the beach flora and marsh areas. The fish and shellfish living in the effected area can absorb oil components in their bodies thus becoming a health hazard for higher life forms in the food chain, including human. the contaminated species are involved.

The effect of oil pollution depends on the type of oil, rate of spreading, movement, weathering and clean-up process. The weather condition at the time of spill can significantly influence the severity of the impact of the pollution.

This chapter deals with the potential impact of an oil spill in the Saudi Arabian marine environment and protective measures to be taken.

1. TOXICITY OF OIL COMPOUNDS

Crude oil and refined products have water-soluble compounds that are toxic to a large variety of marine life. Larvae, eggs and young forms are normally more sensitive to this toxicity. It may also result in early death of fish and other animals by causing abnormalities in their developmental process.

Aromatic and middle-molecular weight compounds are more toxic than aliphatics and light-molecular weight types. Low melocular weight compounds are quickly lost in the atmosphere, therefore do not much affect the environment. A diesel fuel spill with a highly aromatic content is more harmful than bunker fuel and weathered oil with low aromatic content. Except for posing a serious fire hazard, the spillage of petrol and other white spirit has little other effect on the marine environment.

Due to the existence of several thousand compounds in the oil and the rapid changes in the compounds from the time that the oil is extracted and throughout the spillage period, precise toxicity and its impacts in various organisms cannot be specified. However, the degree of damage caused by the toxicity of the oil spilled depends also on the susceptibility of the marine life exposed to such toxicity. The susceptibility of the marine life, on the other hand, depends on their age, maturity, time of year and certain other factors. Nevertheless, long term effects of the toxics, e.g. the impact of the toxics on eggs and the young life in the long run, may be of more concern than immediate damage.

2. IMPACT OF THE MARINE COMMUNITIES

Whether caused by single spills or continuous discharges, oil pollution has a dramatic effect on the organisms in the environment. The less resistant species may die at the initial stages of the pollution. The clean up process may take any time between a few weeks (e.g. in rocky shores) to several years in areas where the oil may stay longer (e.g. soft bottom or marsh areas). While not causing sudden or obvious changes in the community, continuous low contamination may result in gradual and more lasting population changes in the contaminated area.

A. Impact of Fisheries

Due to the commercial value of fish, the effect of oil pollution on fisheries is of prime importance.

Fish deaths due to oil pollution have occurred, but the numbers have not usually been significant. This could be due to the ability of fish to avoid the polluted areas. There has been little or no reduction in the number of fish in areas exposed to continuous oil, e.g. around the oil production platforms. The biggest risk, however, is posed on the fish living in the depths where, in case of a spill, high concentration of toxic elements in oil exists; and spawning areas where the fish, in their larvae stages, are more sensitive to oil contamination.

Although no massive death may occur, various types of fish exposed to oil pollution may become contaminated by the oil components. It has not been determined conclusively that consumption of contaminated fish is hazardous to humans.

The Tarut Bay oil spill in 1980 disrupted the fishing activities, but its low impact on the mortality of plants and animals in the environment allowed a rapid recovery in the area. The damaged caused by the Bahrain oil slick in 1980, however, was substantial because it destroyed the fishing equipment and resulted in loss of catch as fishing could not be performed while oil was still floating on the water.

The oil spill from Nowruz oil field in the Iranian waters between 1983-1985 entered the Saudi Arabian waters in three forms: rafts of oil mats, sheens and tarballs of various sizes.

According to the Saudi Arabian Meteorological and Environmental Protection Administration (MEPA), this spill resulted in widespread mortality of marine life along the Saudi Arabian coast. The affected areas included Abu Ali, Dawhat Zalum, Arbiyah and Qiran islands. The number of animals killed during this spill period, by end of April 1983, was as follows:

- Fish (pelagic, reefal, benthic)	600
- Sea Snakes	1500
- Turtles (hawksbill, green)	56
- Birds	200
- Dugongs	36
- Porpoises	33

The examination of the dead animals revealed extreme irritations of the skin in reptiles (redness in turtle skins and shedding in snake skins), and of oral memberanes, lungs and gills in the vertebrate types. Air breathing species gasped for breath at the water surface before going to beach and dying.

Although these deaths coincided with the entry of the oil sheens and tarballs into the Saudi Arabian waters, there is no proof that they happened as a result of the Nowruz oil spill. No deaths were reported during May-June when the intrusion of the spill into the Saudi Arabian waters was at its peak. The distribution of coral reef fish, according to the September survey by MEPA, was normal. The examination of fresh fish and shrimps did not reveal any significant symptoms to distinguish them from the normal population. Although short term damages may have been high in this area, no long term adverse effects due to oil spills have been reported on the fish stock.

The population of dugongs and hawksbill turtles have, however, been severely affected. A survey in 1979 estimated the population of dugongs in the Saudi Arabian coasts to be 50-60. 34 of dugongs killed during the Nowruz oil spill, about 50% of which were juveniles, were from the Saudi Arabian coast. If the 1979 estimates are correct, this number of deaths may well eventually result in the extinction of dugongs in the Salwah area.

To prevent the dugongs and turtles from becoming extinct, MEPA has implemented a program to replenish the fauna where these animals live.

B. Effects on Humans

The 1985 preliminary report on "The Impact of Carcinogenic Substances on Marine Organisms and Implications Concerning Public Health" by GESAMP concluded that, if not metabolized or destroyed by cooking, the carcinogens in the marine organisms consumed by humans can induce cancer. The extent of the risk is assumed to be dependent on the type and density of the components present in the organism and the amount consumed. Only a high presence of these factors can have hazardous effects.

The Gulf waters are a valuable source of food for the Saudi Arabian population and supply various fisheries. The contamination and destruction of fishing gear and environment due to oil spills may cause hardships to the human population supported by the affected fishing areas.

The Nowruz oil spill resulted in a Royal decree to ban fishing in the Gulf waters due to the potential hazard to public health.

The 1983 MEPA study concluded that the presence of pollutants in various types of fish caught in commercial fishing, e.g. Hamour, Shaeri, Shirwi, Shrimp, Hamra, Safi, Baagha, were insignificant and below the permissible levels, therefore they posed no threat to the humans consuming them. As a result of this study, MEPA recommended lifting the ban on fishing and reopening of the fisheries.

C. <u>Effect on Birds</u>

Oil pollution results in matting of the waterproof plumage of the birds, causing the air trapped between the feathers and skin to be displaced by water, thus reducing the birds buoyancy. Contamination of plumage can also cause wetting resulting in reduced insulation.

If not sunk or drowned, the affected birds require an increased metabolism of their food reserves to withstand the heat loss. Their inability to forage in such circumstances and rapid consumption of their fat reserves and muscular energy usually results in iniminent death. Inhalation of vapors from freshly spilled oil can cause internal irritations.

In 1980 the Bahrain oil spill resulted in the death of about 1000 birds, particularly on the island of Umm Nasan and Muhammadi area. The types most affected were common and socotra cormorants. However, the number of cormorants killed is not large enough to cause any long term adverse effect on the population of cormorants in the Bahrain coastal area.

Nowruz oil spill in 1983, according to MEPA observations in the March-July period, had little effect on bird life. In April, a considerable number of dead birds, including 45 cormorants, were reported on the Gulf of Salwah. Although some oiled birds were observed among them, the cause of their death is not known.

A total of 47 and 89 oiled, flgihtless birds (mostly terns) were observed on Qiran and Jana islands respectively. Due to their inability to continue active feeding and loss of insulation most of these birds died. The breeding population of terns observed by MEPA during the middle to end of breeding season in August/September, is estimated at 5000 at Qiran and 6000 at Jana islands which is decreased over normal.

D. Effect on Coral Reefs

Corals can be coated with oil and severely damaged. The chronic exposure of the shallow water corals to the Iranian crude oil in the Gulf of Aqaba in the Red Sea has resulted in a significant decrease in the number of female gonads in 75% of the polluted colonies of corals. There is, however, little evidence of significant destruction of coral colonies due to oil pollution in the Red Sea.

Although the reefs in the Red Sea support a limited amount of coral growth in the intertidal, compared to the ones in areas with a higher tidal range this growth is not significant. Intertidal corals smothered by oil spills will be destroyed, but sulittoral coral growth may not be affected unless the oil spill is massive or the coral is growing in an area with limited water circulation and the oil is not blown or carried away.

Surprisingly, the greatest hazard to coral reefs is not from the oil spill, but from the dispersants which if applied can cause the oil to sink into the reef damaging the coral growth or polluting the water columns through their own toxic elements, thus destroying the corals growing in that column.

Despite chronic exposure to oil pollution from the Ras-ul Tanura oil terminal, there is a healthy coral growth in the 2.5-4.5 meters depth of the water in Tarut Bay.

The Nowruz oil spill damaged the corals at Qiran islands and destroyed the grazing organisms and macroalgal species, e.g. colpomenia. However, soon after, the coral reefs in Qiran islands established their typical growth of sea urchins and grazer populations although without the earlier bloom of colpomenia macroalgae.

The continuous exposure of the reefs and islands to oil spills, due to the war in the 1980s and other sources of oil pollution, has made the task of monitoring and assessing of the impact a continuous program.

E. Effects on Coastal Vegetation

Salt marshes and mangroves are ecosystems situated between the land and the sea. Their existence is significant in controlling coastal erosions, providing shelter for the marine organisms in the early stages of their life and being a source of organic elements transferred to the sea. Resembling mud-banks, they tend to trap the oil spilled in their area which harms the plants which are the basis for their existence.

The impact of the oil pollution on the vegetation depends on the season and the stages the plants are in: when in budding phase, flowering becomes limited; in full bloom, seeds may not be produced; and when seeding, germination is damaged. The annual population thus destroyed may take two or three seasons to recover by reseeding from outside the area.

The reaction of the plants to oil pollution also varies. Shallow rooted plants with nor or little food reserve, i.e. sueda maritime or salicornia, are destroyed at once. Others may survive a single spill while the ones with large food reserves, i.e. taproots, may tolerate repeated pollutions. Although the foliage may be reduced, the decomposing oil serves as a nutrient in salt marshes enabling them to renew their growth rapidly. Oil pollutions of this kind are less damaging to salt marshes than the clean up process. Mangroves live in anoxic muds and carry the oxygen taken up by their lenticles to the submerged part of the plant through their air spaces. Clogging of the lenticles by oil can drop the oxygen level in their root air space to 1-2% of the normal amount within two days, thus harming the plant. There is not enough evidence to assess their vulnerability to oil pollutions and the mangroves and seagrass beds in the Red Sea coast of Saudi Arabia do not appear to have suffered from oil pollutions. The impact of the Nowruz oil spill on the seagrasses and soft-bottom communities has not been assessed in detail, but no abnormal change in growth or mortality rate has been observed. Nevertheless, oil pollution in shallow/intertidal waters can have a significant impact on the seagrassbeds in these areas.

F. Effect on the Beaches

A dark film of oil covering animals, plants, rocks and sands on the beaches and shorelines is the most obvious evidence of oil pollution.

A polluted beach is unsightly and the smell of the polluted area adds insult to injury. However, the most severe impact of the oil pollution on the beaches is to their beauty adversely affecting the scenic element. Studies suggest that the cleaning procedures do more biological harm on the beaches than the pollutants. This has created a controversy between the desire to save the beauty of the beach on one hand and the ecosystem on the other. This controversy has been resolved by adoption of shore classification systems such as "vulnerability index" which enables the planners to protect the coastal environments most vulnerable to the damages caused by oil pollution.

Nowruz oil spill polluted the intertidal zones of most of the coastlines and sandy beaches in the area. However, the pollution subsided later in the year. Minimal clean up operations were carried out on some amenity beaches and the Qiran islands.

G. Effects on Industry

Oil pollution can adversely affect the industries relying on sea water for their operation. It may result in complete shut down of power stations close to the coast which use the sea water for cooling purposes, until clean up of the polluted area has been completed. This could in turn result in shut down of other industries relying on the power from such power stations. Other plants affected by oil pollution in the sea are desalination plants whose shut down may reduce supply of water to the communities depending on them for water. Sea transportation can be disrupted as a result of oil spill in harbours, mooring lines and jetties. Movements can be suspended until the area has been cleaned up.

Another risk involved in oil spills is the possibility of explosion and fire in case of spillage of crude oil and light refined products. This could suspend activities in ship building and repair, loading and unloading of vessels, sea traffic or any other activity which may cause a spark or flame.

Nowruz oil spill resulted in limited shut down at Al Khobar desalination plant during utilization of when some large underwater mats of oil were detected near the Ghasal power plant. Other facilities and industries in the area were minimally affected, but Jubail desalination plant maintained production throughout the spill period. A combination of booms and mechanical collection equipment were used to protect the Saline Water Conversion Corporation (SWCC) plant, Aramco and port facilities.

Consideration is being given to installing underwater remote sensing equipment in the area for early detection of oil pollution near the industrial sites.

3. VULNERABILITY INDEX

The coastline along the Saudi Arabian side of the Gulf varies from mangrove marshes to rocky beaches, resulting in different vulnerability rate in each area as far as oil spills are concerned.

The Environmental Protection Agency (EPA) of USA has developed a system for classifying the shorelines. According to EPA's Manual of Practice for Protection and Clean up of Shorelines, there are ten types of shorelines. These are: sheltered tidal flats, exposed tidal flats, sand beaches, mixed sand and gravel beaches, cobble beaches, rock headlands, and exposed wave-cut platforms.

The degree of vulnerability of each type has been identified. This identification can save time and expense by doing away with the need to survey the polluted site to identify its type each time an oil spill happens. It can also help the clean up authorities to allocate their resources to each area as required.

In 1980, Aramco conducted a survey of the entire shorelines of the gulf to prepare a vulnerability index for its operation area. Due to particular coastal characteristics of the area, the classification is somewhat different from that of the EPA. However, the types, in descending order of vulnerability are:

A. Mangroves/Salt Marshes

Like sheltered tidal flats, these are highly productive areas. Due to growth of industry and urban development, many of these areas have diminished as habitats. The remainder must, therefore be protected.

B. Offshore Islands

Surrounded by coral reefs sensitive to the environment, these are breeding grounds for birds, turtles and fish; therefore important to the ecology of the Gulf.

C. Mud Flats

These tidal flats are highly productive habitats with low water exchange which are not common in the area and must be protected.

D. Coral Reefs

Due to high salinity and low water exchange in the western area of the Gulf, these are not commonly found and must, therefore, be protected.

E. Muddy Sand

These are exposed tidal flats more commonly found in the area than mangroves and mud flats. They are moderately productive and can support the mechanized equipment used for clean up operations.

F. Rocky Beaches

Not commonly found in the area, these are moderate to low productive habitats which are usually difficult to clean when polluted. Oil spills have to be left there to weather naturally.

G. Sand Beaches

With a low biological productivity, this is the most common type of shoreline in Saudi Arabia. Heavily polluted sand need to be removed by mechanical devices. However, if the beach is not publicly used, small amounts of oil can be left to weather naturally.

Having the above classification and the information regarding location of the key industrial water intakes, can help the authorities in their contingency planning, determining the priorities in shoreline protection and allocating the clean up equipment accordingly.

The International Union of Conservation of Nature and Natural Resources (IUCN) is conducting a study for such classification as part of the "Conservation and Management of the Saudi Arabian Red Sea Coastal Areas" program. This study is sponsored by MEPA.

4. EFFECTS OF CLEAN UP MATERIALS ON THE MARINE ENVIRONMENT

The chemicals used for clean up operations can have their own adverse effects on the environment. They can either affect the sea or shore animals and plants on their own or modify the effect of the oil pollution for better or worse, or interact with the oil components to produce other elements which could have more or less harming effects. However, their presence as emulsions or solutions increases the amount of oil in the water column, adding to the risks resulting from this type of pollution.

Used on shore, the dispersants can cause the oil to go deep thus harming the animal living in burrows or crevices which would otherwise have avoided the oil. Concentrated amounts of oil and dispersant can run into shallow water and effect sublittoral organisms. Soft sediments like sand and mud can be deeply penetrated, thus causing more prolonged biological damage.

Where dispersants have more adverse effect on the environment than the spilled oil, their use must be limited. The following types of habitats along the Saudi Arabian coast are of this kind:

- Shallow coral reefs (less than 3 meters deep).
- Tidal mud flats.
- Lagoons with low water exchange.

Care must be taken to avoid or limit use of dispersants at water intakes, especially the ones used for desalination plants in the area.

CHAPTER FOUR

LEGISLATIONS CONCERNING OIL POLLUTION AND ITS PREVENTION IN SAUDI ARABIA

There are different means and ways of dealing with oil pollution after it has occurred. It can be dispersed by chemicals or left to do so naturally; it can be rerouted to less sensitive areas or it can be recovered; and better still, it can be prevented from happening.

The environmental laws relating to prevention of oil pollution from ships progress rapidly. It should be borne in mind, however, that although shipping is an important source of pollution, it is by no means the main contributor of pollution in the marine environment.

Because shipping is essentially an international affair, the laws and regulations relating to maritime safety and prevention of pollution must be discussed, agreed upon and implemented at international level. The Intergovernmental Maritime Consultation Organization (IMO) was founded in 1958 to serve as a specialized agency of the United Nations in this respect. Since its formation about 30 treaties concerning maritime safety and prevention of pollution have been adopted.

The conventions and recommendations adopted by the IMO have been instrumental in dealing with the problem of marine pollution. For example, by introducing anti pollution measures into the design, equipment and operations of the ships, the operational pollution has been prevented. Introduction of strict navigational standards and procedures on a worldwide basis has resulted in safer shipping and reduction of accidents, consequently less pollution caused by accidents. The IMO conventions also designed measures to reduce the amount of pollution in case of accidents, provided compensation for damages and helped implement the recommendations agreed upon.

Proper local legislation must exist to implement the international laws and regulations for protecting the marine environment. To be effective, these local legislations must be in harmony with the nation's beliefs and culture. Since Islam is the dominant factor in the Saudi Arabian life and culture, the Islamic religion must be considered when making any national legislation to any effect. In connection with protection of marine environment, we will review the Islamic principles, some international conventions, local legislations and ARAMCO's oil pollution prevention program.

1. PROTECTION AND CONSERVATION OF MARINE ENVIRONMENT BASED ON ISLAMIC PRINCIPLES

Saudi Arabia is founded on Islam and the Holy Quran, the Moslem's holy book, forms its States Constitution. All legislation, therefore, is based on the Islamic principles some of which are mentioned below.

According to Islam, God "made from water every living thing" and all living things, i.e. man, animal and plants, depend on water for their livelihood whether it is used in its basic function or as a means of business and commerce or a source of food or income. Its conservation and preservation is, therefore, vital for the survival of vegetations, animals and human beings. Anything to spoil or pollute this element will therefore mar its basic functions as the source of life for various beings and "what leads to the forbidden is itself forbidden".

Islam considers all animals and plants as living communities, just like mankind, and emphasizes all the measures for their survival and performing of the functions assigned to them. These creatures are there as an evidence of God's omnipotence and wisdom and to serve man for his benefit and developing of this world.

2. PROTECTION OF MAN AND ENVIRONMENT BASED ON ISLAM

Islam is as interested in protecting man and environment as it is keen on protecting the elements. Any damage in any form is therefore forbidden. Preventing damage is better than cure after it has happened and, according to the juristic rules, the "elimination of mischief and corruption (is) placed before the aquisition or production of goods and advantage". This means all attempts to benefit mankind and satisfy human needs, developing agriculture, industry, etc. must be carried out without causing damage, injury or corruption of any kind. Hence, when planning or implementing any program, necessary precautions should be taken to avoid causing damages, injuries or corruption as much as possible.

Human and industrial wastes must be so disposed of or eliminated that no harmful effect is left on the environment. All possible measures should be taken to avoid and prevent any damage caused to the environment by the use of cleaning materials in homes, factories, farms and other private and public places. If not possible to eliminate, measures should be taken to cure the harmful impact when it happens. If damages caused by these materials prove to be more than their benefit, their use should be forbidden altogether and a search be conducted for a less damaging alternative.

3. ISLAMIC LAWS GOVERNING LEGISLATION ON PROTECTION AND CONSERVATION OF ENVIRONMENT

A. Every Moslem is responsible to God to protect himself and his community. Protection, conservation and development of the environment and natural resources are, therefore an individual religious duty as well as a common social duty undertaken by the rulers and government agencies concerned.

B. It is the basic duty of the ruling authorities to involve themselves for the good and in the interest of the people and eliminate mischief and corruption as determined by their lawful and assigned responsibilities. According to the juristic rule "the leader's actions are determined and dictated by the common good".

C. The States legitimate involvement is in case of conflicting interests. The national and community's interest have priority over individual's. Private interests can be overlooked or neglected for the good of public and community and public interest will be upheld at the expense of the individual's if the two conflict. It is basically accepting the lesser evil to avoid the greater.

D. Interests are classified into the following categories based on their importance and urgency. These categories, in descending order of priority, are: Fundamental interests, needed interests and luxury interests. Obviously fundamental interests take precedence over needed or luxury interests.

E. The degrees of actuality and urgency vary in interests. Actual or urgent interests have priority over projected or probable ones.

F. If fulfilling some interests may cause equal or more damage than the actual achievement, this action should be avoided. Since the first step in achieving and realization of the common good is to eliminate mischief, the "avoidance of mischief should be given preference and should come before the achievement of interests".

G. It is the primary duty of the ruler and his various offices to realize the interest of the individuals and do their best for improving the lives of those people and the society as a whole. This includes the environment and natural resources and it is done through prevention, in the first place, and remedy of damages.

H. In compliance with the rule that "no damage or retaliation for such damage is allowed" and the annihilate "all pretexts leading to mischief", the State has the right to impose rules and standards, set by the experts in those fields, and to take any step necessary in order to avoid, prevent or minimize any damage before it occurs. It can forbid or limit the scope of any action which may result in temporary or permanent damage to any of the basic elements, resources or environment used by the community. This includes air pollution, water pollution, etc.

I. When damage occurs, the State has the right to take the necessary steps to remedy or eliminate the ipact of the damage. Although "damage or mischief should be eliminated or removed", it "should not be removed through similar damage or mischief", therefore alternatives should be sought to repair the damage with the least possible risk to man, environment or other creatures.

The State can hold the individuals and organizations responsible for elimination/repair of damages caused by their activities or the cost of such corrective actions. It can also claim compensation or indemnity from individuals and organizations whose unlawful actions have caused irrepairable damages which could have been avoided and could hold them responsible for such actions and restrict them from further activities. It can also stop certain projects from being carried out if the welfare of the community and environment so requires. It can weigh the advantages and disadvantages of any project in this light and act accordingly.

4. INTERNATIONAL LAWS ON MARINE POLLUTION

There are about 40 international conventons and bodies which address the problem of marine pollution in this concept. Some of these bodies are directly related to shipping industry while others have a marginal interest in the problem. Nevertheless, they have all contributed to todays legal aspects of preventing marine pollution.

Up to recent years, shipping industry concentrated its efforts on those rules which had a direct effect on its operations, and even these conventions and bodies concentrated more on liability and compensation rather than prevention. This is now changing.

The 1982 UN Conventoin on the Law of the Sea attempted to reform the internatonal law. The Third UN Law of the Sea Conference (UNCLOS III), originating in 1967, resulted in establishment of the UN Seabed Committee. The shortcomings of the Geneva Law of the Sea Conferences had made the existence of the new laws inevitable and the limit of the national jurisdiction, which had not been decided in Geneva, became one of the main issues of the UNCLOS III. This had a considerable impact on shipping industry which felt uneasy about UNCLOS III, specially because the force behind its establishment had been the Third World and that there was the possibility of an extended national maritime jurisdiction in the oceans aimed at shipping in maritime areas up to 12 miles and possibly 200 miles from coasts. UNCLOS III has also been charged with making new international rules for protection of marine environment.

UNCLOS III sessions from 1973 to 1982 were not merely international conferences; they became a "law reform movement" aiming to redistribute resources and uses of the oceans. Despite the still existing problems in the area of deep seabed mining encountered by the US and some other advanced countries, these efforts have been successful and most of the 300 articles produced by this convention have been accepted. Although it may take some years before the rules of this convention are implemented, many of its provisions have already become international law and it provides "umbrella" legislation for shipping, e.g.:

a. It provides new jurisdiction for coastal states in 12-mile territorial seas; 24-mile continuous zones, 200-mile exclusive economic zones, archipelagic waters and environmentally endangered waters.

b. It gives coastal states considerable power to protect their marine environment in their new jurisdiction area, incorporating fully the Stockholm UNCHE state obligation to protect the environment.

c. It provides new provisions as to the rights and responsibilities of coastal, flag and port states concerning the vessels in ports, inland waters, territorial seas, economic zones, archipelagic waters and on the high seas.

The Convention also provides for settlement of disputes and gives technical assistance in shipping and environmental protection to the developing states.

The treaties of the International Maritime Organization (IMO), which is the designated "competent international organization", are further legitimized by the UN Convention on the Law of the Sea.

5. THE 1954 INTERNATIONAL CONVENTION FOR PREVENTION OF POLLUTION OF SEAS BY OIL (OILPOL '54)

OILPOL '54, which has been replaced by MARPOL 73/78, was the first international treaty dealing with the problem of oil pollution. It prohibited discharge of oil and oil mixtures by certain ships in certain areas of the ocean. Therefore, based on OILPOL, ballast discharges were restricted to permitted areas and all loading and discharging operations were recorded in an "oil record book" which was inspected regularly. The amendments to this convention in 1962 and 1969 narrowed these "permitted areas" for pollutant discharges.

6. THE 1969 INTERNATIONAL CONVENTION RELATING TO INTERVENTION ON THE HIGH SEAS IN CASES OF OIL POLLUTION (INTERVENTION 1969)

This convention gives coastal states limited rights to take preventive measures on the high seas against vessels which pose great and imminent danger of oil pollution to coastlines and other ocastal areas due to a maritime casualty. Granting of this right was debated considerably at the convention as the traditional international legal principles allowed no interference in the legitimate operations of vessels on the high seas. It was therefore for the first time that states other than flag states could take preventive measures against foreign vessels when there was a realistic concern that an oil pollution may cause major consequences.

This convention, which has been criticized both for allowing too much at the discretion of the coastal states and limiting the rights of these same states in taking action, has been in force since 1975 and accepted by a large number of states. Its 1973 Protocol covering substances other than oil became effective in 1983.

7. 1973 INTERNATIONAL CONVENTION FOR PREVENTION OF POLLUTION FROM SHIPS (MARPOL '73)

This convention which is one of the most important in this field, addressed, for the first time, marine pollution from other substances in addition to oil. There had already been some concern that some pollutants other than oil may be more harmful to the environemnt in some circumstances. Consisting of a Preamble of 20 articles, two Protocols and five Annexes, MARPOL '73, therefore, regulates other polluting sources e.g. sewage and garbage from ships. Its annexes deal with noxious liquid substances in bulk and harmful substances carried in packaged form or containers.

Although held in 1973, in London, under the guidance of IMCO, and attended by delegates from 77 states, MARPOL '73 took ten years to be partly enforced. The part enforced is its Annex 1, Oil Pollution Regulations. Had it not been for its provisions of 1978 Protocol allowing states to adopt the convention accepting only Annex 1, it would still have not been in effect.

The 1978 Protocol, called MARPOL 73/78, was established as a result of the shipping disasters of the winter of 1977/78. Known as the "Tanker Safety and Pollution", it also became effective in October 1983.

8. 1969 INTERNATIONAL CONVENTION ON CIVIL LIABILITY FOR OIL POLLUTION DAMAGE (CLC 1969)

The Torrey Canyon incident proved that the maritime laws concerning liability could not satisfactorily deal with oil pollution claims, therefore separate rules had to be made to meet this demand.

The purpose of the CLC 1969 is to provide uniform rules and procedures concerning liability and compensation in cases of oil pollution. It covers only oil carried in bulk as a cargo, therefore the vessels in ballast cases are not included.

According to this convention the shipowner is strictly liable for damages caused by pollution. Negligence does not have to be proved to establish liability.

To avoid liability, the shipowner has to prove existence of certain circumstances, e.g. war, natural phenomena or exceptinal nature, negligence of the victim state and failure of the authorities to provide navigational aid. Where neither such circumstances exist nor the shipowner is at fault, the liability is limited to US$ 160 per ton with a maximum ceiling of US$ 17 million per incident. Effective 1981, an amending Protocol replaced the original calculation method of using gold standards of compensation with Special Drawing Rights (SDR) of the International Monetary Fund.

To be covered under this convention, ships must carry certificates confirming that they have adequate insurance. These certificates are required by many states.

Although the flag states and the shipowners states need not be members of this convention its rules apply only to damages caused in the territories of the member states. Claims against the parties liable under this convention will be field in the state where the damage occurred and the shipowner wishing to limit liability must establish funds just as in other limitation proceedings. The court having jurisdiction over the fund will be responsible for distribution of such fund.

Due to the concern that the CLC 1969 did not fully meet the requirements of major oil pollutions, the 1984 Protocol was developed at the IMO. This protocol raises the liability limits to US$ 3.1 million in SDR funds for ships upto 5000 GRT. For larger vessels it is calculated based on their tonnage to a maximum ceiling of US$ 62 million for ships of 140,000 GRT and above. Additional compensation will be provided by the 1984 Protocol if damages exceed the shipowners liability.

9. 1971 INTERNATIONAL CONVENTION ON ESTABLISHMENT OF AN INTERNATIONAL FUND FOR COMPENSATION FOR OIL POLLUTION DAMAGE (FUND 1971)

The insurance underwriters had realized the inadequacy of the CLC limits before it was implemented in 1975. Subsequently, the supplementary convention - Fund 1971 - made provisions for extraordinary incidents.

Fund 1971 is financed by the member states from the import and export levies on oil and applies only to oil carried in bulk. To be members of Fund membership in CLC is required. In order for the shipowner to seek compensation when such need arises, the flag state of the ship must also be a member.

Fund 1971 allows a maximum amount of US$ 54 million added to any available CLC cover. This amount can be increased to US$ 72 million at the discretion of the administration. However, the 1984 Fund Protocol increased this ceiling to US$ 208 million on condition that the total amount of oil imported in three of the number states was, at minimum, 600 million tons in the previous calendar year. Liability becomes void where hostilities exist, the pollution is caused due to negligence of the claimant or it cannot be proved that the polluting oil was spilled from the vessel concerned. Claims are filed in the applicable courts of the member states. Like CLC, the convention's 1976 Protocol recommended use of the SDR for calculation of liability. However this protocol has not been implemented yet.

10. THE SAUDI ARABIAN LAWS ON MARINE POLLUTION

There is no national law in Saudi Arabia against the pollution, but the contracts with the exploration and exploitation companies stipulate articles obliging them to prevent the pollution of the marine environment by oil. The existing laws and regulations concerning the Saudi Arabian's marine environment are not specifically related to control and prevention of pollution, but contain some articles regarding this matter. An example of this is the 1974 Royal Decree No. M/27 on Seaport and Lighthouses Law which includes provisions for Non-Pollution of Seawater with Oil (Articles 311-332, Chapter 1, Section 12). This law was promulgated in compliance with the provisions of OILPOL 54/62 after ratification of the convention.

The 1981 Royal Decree No. 7/M/8903 gave the responsibility for control of pollution in the Kingdom's environment to Meteorology and Environmental Protection Administration (MEPA). This organization has established the country's Environmental Protection Standards protecting the air and water from pollution. These standards apply to all existing and planned facilities. Further standards are to be set concerning land and noise pollution, toxic and hazardous material. Implementation of these standards on the coast is necessary to maintain the protected areas and fisheries and for the long term protection of the Saudi Arabian marine environment.

Based on the Royal Decree No. 7/M/8903, the Environmental Protection Coordinating Committee (EPCCOM) coordinates the activities of varous government organizations involved in protecting the environment. The chairman of this powerful committee is HRH the Minister of Defense and Aviation and its members are at Deputy Minister level. Its function is to study MEPA rules and regulations concerning the environment and, if approved, submit them to the Council of Ministers for further processing. These rules and regulations, after concurrence of each Ministry involved and endorsement of the Council of Ministers, become national policy.

EPCCOM has tasked MEPA to ensure that the Kingdom's authorities abide by the rules set in the Kuwait Regional

Agreement for Protection of the Marine Environment, the Regional Agreement for Conservationof the Environment of the Red Sea and Gulf of Aden, and their Protocols. It has also approved the following:

A. The Regional Agreement for Conserving the Environment of the Red Sea and Gulf of Aden, and its Protocol.

B. The National Plan for Control of Pollution by Oil and Other Harmful Substances in Emergencies and the related regulations and procedures for their implementation.

C. Designating marine protectorates in the Red Sea and the Gulf area where all development is stopped pending preparation of detailed plans for conservation of the areas.

D. Prohibition of any new coastal infilling, dredging and solid waste disposal without assessing the environmental impact.

E. Delegating the responsibility of stopping prohibited activities to Coast Guard in coordination with MEPA.

F. Setting up a permanent committee consisting of the Ministry of Education, Ministry of Higher Education, Directorate General of Girls Education and MEPA to study means of promoting environmental education at all levels.

G. Setting up a permanent committee consisting of the Ministry of Information and MEPA to develop programs for environmental awareness.

H. Creating fixed positions to monitor pollution.

I. Setting up a committee to determine the overlapping jurisdiction of MEPA and the Saudi Arabian Standard Organization (SASO).

CHAPTER FIVE

SPILL RESPONSE EQUIPMENT AND SUPPLY RECOMMENDATIONS

Spill response recommendations presented in this chapter should be considered as a preliminary scoping estimate. It is anticipated that detailed contingency plans and associated risk assessment will be developed at a later date by On-Scene Coordinators for locations within the subareas identified herein. Therefore, this document presents a standard basis to judge the adequacy of future location-specific proposed response inventories, especially in the context of the total needs of each subarea and considering the potential for cooperative use of equipment and supplies.

Generally, there are not standard criteria available for specifying recommended amounts of response equipment/supplies as a function of spill size. Therefore, subjective judgments have been frequently used as a basis for providing preliminary spill-response inventory recommendations. These recommendations are generally based on considerations of the experience of Clean Atlantic and Clean Gulf (of Mexico) oil spill cooperatives, as well as U.S. Coast Guard and other worldwide experience.

1. GENERIC RECOMMENDATIONS FOR ALTERNATIVE DESIGN SPILL AMOUNTS

Equipment and supply recommendations have been developed for the Kingdom of Saudi Arabia in response to design spills of 1000, 5000, 10000, 50000 and 100000 barrels (137, 685, 1370, 6850, and 13700 metric tonnes). These recommendations provide for a multifaceted response approach based on consideration of worldwide experience. There may be situations when the use of chemical dispersants is appropriate (especially for initial response before oil weathering is significant). Other situations (e.g., spills within sensitive ecological areas) may require mechanical containment and cleanup methods (e.g., use of booms and skimmers). The recommendations provided in this section are based on the conservative assumption that for a given design spill amount the capability should be available for total response by mechanical means and by application of dispersants.

Appropriate spill response actions and associated equipment and supplies depend on the specific type of substance spilled. The emphasis for the present analysis has been on spills associated with the handling and transport of crude oil; however coastal operations at Jubail, Yanbu, and Rabigh will also involve refined products and petrochemicals, as well as other hazardous materials. Spill response methods for potential spills associated with these petroleum products are generally similar to those methods used for crude oil spills. Primary response may involve the use of booms, skimmers, or dispersant applications. Frequently, it is advisable to dilute and mechanically disperse (flush) such spills, or even take a no-response action, instead of using containment and recovery methods, because of the potential toxic flammable and explosive characteristics associated with some hazardous materials expected to be handled at Saudi Arabian ports is presented in Table 5-1. For the present analysis, it has been assumed that a well-rounded response equipment and supply inventory for crude oil spills will also be appropriate, supplemented by additional safety equipment, supplies and procedures, for many potential refinery and petrochemical production spills expected in the coastal waters of the Kingdom. However, response equipment recommendations specified in this report are based primarily on response to oil-like spills. Recommendations for hazardous substance spills involve many complex considerations which are beyond the scope of this study.

To determine design spill amounts for the present risk assessment, it was assumed that response actions (not including deployment time would need) to be completed within about one to three days of the start of the spill event.

Table 5-1
Cautionary and Corrective Response Summary

		Cautionary Response							Corrective Response		Collection Systems			Chemical & Physical Treatment Systems					Precautions										
	Operation	Restrict Access	Restrict Ignition	Evacuate	Restrict Human Use	Restrict Irrigation Use	Restrict Industrial Use	Dilute and Disperse*	Stop Discharge	Contain	Skim	Pump	Dredge	Burn	Neutralize	Absorption	Chemical Dispersants and Other Treatments	Clean Shore Line	Avoid inhalation. Vapors or dust are irritating or toxic	Avoid direct contact. Contact with skin or eyes can cause irritation or burns	No ignition hazard once material is dissolved, reacted, or covered with water.	Burning may be prohibited by anti-air pollution laws and regulations.	Poisonous gas or vapor danger. Substance is highly volatile.	Flammable or explosive gas or vapor danger. Substance is highly volatile	Highly corrosive, particularly to eyes and skin	Water reactive compound which reacts vigorously or violently. Disperse or neutralize contaminated waters after reaction subsides	Burning not recommended, fire difficult to control and/or poisonous gas is formed.	Sooty burning	Chemical shipped as gas or liquefied compressed gas, depending on atmospheric conditions, a large portion of the hazard will be dissipated with no action necessary
— Acetic acid	Petrochemical						●	●	Applies to all spills								Evaluated on Case-by-Case basis		●	●									
— Ammonia, anhydrous	Petrochemical	●		●	●			●											●	●			●						●
— Benzene	Petrochemical	●	●		●		●			●	●			●					●	●		●						●	
— Caustic soda solution	Petrochemical	●			●	●	●	●												●					●				
— Diethylene glycol	Petrochemical							●																					
— Ethyl alcohol (ethanol)	Petrochemical	●	●					●													●								
— Ethylene	Petrochemical	●	●	●										●						●		●		●					●
— Ethylene dichloride	Petrochemical	●	●		●							●	●						●	●							●		
— Ethylene glycol	Petrochemical							●																					
— Gas oil: cracked	Refinery									●	●			●		●		●		●									
— Hexane	Petrochemical	●	●	●			●			●	●			●					●	●		●						●	
— Methyl alcohol (methanol)	Petrochemical	●	●					●											●	●	●								
— Naphtha: coal tar, solvent, stoddard solvent, VM & P (75% Naphtha)	Refinery	●	●		●	●	●			●	●			●				●	●	●		●						●	
— Oils, clarified: crude, diesel	Refinery	●	●							●	●			●		●		●	●	●		●						○	
— Oils, fuel: No. 1 (kerosene), 1D, 2D, 3, 4, 5 & 6	Refinery	●	●							●	●			●		●		●		●		●						●	
— Phosphoric acid	Petrochemical	●						●							●					●					●				
— Styrene	Petrochemical	●	●		●		●			●	●							●	●	●									
— Triethylene glycol	Petrochemical							●																					
— Vinyl acetate	Petrochemical	●	●	●	●			●										●	●	●									

Source: Extract from NEPA 1991

* Dilute and disperse (i.e., by flushing) only when other corrective methods cannot be used

Spills in ports will generally require rapid deployment of spill response equipment. Although rapid response is still important before oil spreads to cover an unwieldy area and before weathering makes response more difficult, offshore spills are associated with longer spill transport periods before the shoreline is affected. Longer deployment times are therefore acceptable to some greater degree for offshore spills. Shoreline cleanup completion time is considered less critical than spill-control operations and could generally extend for several days or more without serious additional impacts.

A one- to three-day response time is generally attainable only for spills of approximately 10,000 to 20,000 barrels (2,470 metric tonnes), or less, in which the total spill amount is released almost instantaneously. Logistical problems involved in operating a fleet of response vessels and the restriction of the area close to the spill source where cleanup operations are most efficient are the primary reasons for this limitation. Spills that exceed 10,000 to 20,000 barrels or are associated with long-release durations will, of necessity, therefore require a multiday-response period. A summary of representative spill amounts and rates for various sources is provided in Table 5-2 based on worldwide and U.S. Coast Guard experience.

The effective working period (day) relevant to response activities for the purposes of design of an effective program is considered to be approximately 10 hours (not including deployment time). Daytime conditions for an actual spill are highly dependent on the season of the year and the prevailing conditions of the time. Night time response efforts are generally inefficient and dangerous for the response staff because of the significantly reduced visibility due to darkness. Therefore it has been assumed that only a 10-hour work shift per day could be reasonably expected on the average.

Table 5-2
Summary of Representative Spill Amounts and Rates

Source	Representative Maximum Spill Amount, bbl (metric tonnes)	Representative Spill Discharge Rate, bbl/hr (metric tonnes/hr)
Tanker terminals Damage to loading arms Damage to cargo hose or manifold	7,300 (1,000)	Instantaneous
Offshore loading buoys Damage to subsea hoses Damage to floating hoses	36,500 (5,000)	Instantaneous
Tankers Groundings Collisons Explosions	73,000 (10,000)	1,500 to 4,400 (200 to 600)
Subsea pipelines	73,000 (10,000)	Instantaneous
Offshore platforms and wells	182,500 (25,000)	50 to 73,00 (6 to 100)

Source: IMCO, 1977a, personal communication based on worldwide and U.S. Coast Guard experience, Adm. W. Barrow, Ret. U.S. Coast Guard, October 1983.

a. Extreme events may result in spill amounts in excess of those listed above.

A summary list of recommended types of spill response equipment and supplies, as well as their associated costs, is presented in Table 5-3. A comprehensive list of vendors and specifications for commercially available spill control and cleanup products is presented in the 1983 International Directory of Oil Spill Control Products.

Generic equipment and supply recommendations for alternative design spill sizes of 1000, 5000, 10000, 50000, and 100000 barrels for a local area are presented in Table 5-4, based on Clean Atlantic/Clean Gulf (of Mexico), U. S. Coast Guard and other worldwide experience. Only dispersant supplied are directly related to spill size. As the spill size increases much beyond 20000 barrels, it becomes logistically impractical and costly to increase the amount of mechanical and supplemental support equipment, especially that for inshore response. Spill containment also becomes impractical for these large spill sizes. Therefore, for those larger spills, cleanup equipment should be primarily based on the use of offshore, high-capacity equipment, supported as necessary by additional smaller units. Response inventory recommendations summarized in Table 5-4 represent equipment and supplies that would be used in a cooperative arrangement for a local area (e.g., for a combination of port, tanker terminal, and off-shore operations). Thus, duplication of equipment would be minimized for the sake of efficiency. This approach, however, requires that all equipment be compatible (such as booms and connections).

A. Skimmers

Skimmers can be effectively used as a mechanical means for spill cleanup. They are designed to collect oil from the water surface without chemically or physically altering the oil. There are four major types of skimmers as follows:

Table 5-3
Summary Specification for Spill-Response Equipment and Supplies
(Page 1 of 3)

Type	Description	Propulsion	Additional Information	Unit Cost Estimate (SR)[a]
I. Skimmers	Offshore (weir)	Towed	350 to 600 bbl/hr (includes 150 to 200-m Class III boom)	1,000,000
	Harbor (oleophilic or submersion)	Self-propelled	70 to 200 bbl/hr	1,500,000
	Shallow-water	Towed	10 to 50 bbl/hr	100,000
II. Booms	Offshore	NA	Class III	1,500/m
	Harbor	NA	Class II	500/m
	Shallow-water	NA	Class I	200/m
	Sorbent	NA	Class I	500/m
III. Chemicals	Dispersants	NA	1 bbl treats 10 bbl oil	1,500/bbl
	Collectants	NA	1 bbl treats 50 km shoreline or slick perimeter	2,000/bbl
IV. Sorbents	Synthetic	NA	7 kg treats 1 bbl oil	40,000/tonne
V. Miscellaneous	Offshore vessel	Inboard	30 to 60-m length,	(b)
	Vessel of Opportunity System	-	250-bbl dispersant load capacity, 25-bbl/hr dispersant concentrate spray rate	

Table 5-3
Summary Specification for Spill-Response Equipment and Supplies
(Page 2 of 3)

Type	Description	Propulsion	Additional Information	Unit Cost Estimate (SR)[a]
V. Miscellaneous (continued)	Utility boat	Inboard	12 to 16-m length, 5-bbl dispersant load capacity, 5-bbl/hr dispersant concentrate spray rate	(b)
	Workboat	Outboard or inboard/ outboard	6 to 8-m length, trailer mounted, capable of deploying Class I boom	(b)
	Inflatable boat	Outboard	4-m length, shallow water use, trailer mounted	40,000
	Dracone/barge	Towed	1,000-bbl storage capacity (recovered oil)	1,000,000
	Dracone/barge	Towed	250-bbl storage capacity (recovered oil)	300,000
	Fireboat	Inboard	For flushing and foam application operations	(b)
	Van	Self-propelled	Radio equipment, capable of towing boat trailer and carrying small supplies	(b)
	Vacuum truck	Self-propelled	100-bbl/hr capacity	300,000
	Tank truck	Self-propelled	100-bbl capacity	(b)
	Aircraft	Self-propelled	For aerial spill surveillance, equipped with chemical spraying system	(b)

Table 5-3
Summary Specification for Spill-Response Equipment and Supplies

Type	Description	Propulsion	Additional Information	Unit Cost Estimate (SR)[a]
V. Miscellaneous (continued)	Oily beach cleaner	Front-end loader	100-bbl/hr oil collection rate	100,000
	Front-end loader		Bucket mounting to accommodate oily beach cleaner	(b)
	Truck		100-bbl capacity, capable of over beach travel, can be loaded from top (may be same units as tank trucks specified above	(b)
	Dredge/pump system		For response to spills of heavier-than-water substances	(b)

a. Typical costs without delivery included; however, there is a wide range of costs between manufacturers and different variations of equipment.
b. Can serve multiple purposes in addition to spill response; costs therefore not provided.

Table 5-4

Design Spill-Response Equipment and Supplies Recommendations for a Generic Local Area

Type	Description	1,000 bbl (137 tonnes) Design Inventory[a]	1,000 bbl (137 tonnes) Cost Estimate (SR)[b]	5,000 bbl (685 tonnes) Design Inventory[a]	5,000 bbl (685 tonnes) Cost Estimate (SR)[b]	10,000 bbl (1,370 tonnes) Design Inventory[a]	10,000 bbl (1,370 tonnes) Cost Estimate (SR)[b]	50,000 bbl (6,850 tonnes) Design Inventory[a]	50,000 bbl (6,850 tonnes) Cost Estimate (SR)[b]	100,000 bbl (13,700 tonnes) Design Inventory[a]	100,000 bbl (13,700 tonnes) Cost Estimate (SR)[b]
I. Skimmers	Offshore (350-600 bbl/hr)	1[c]	1,000,000	1	1,000,000	2	2,000,000	4	4,000,000	4	4,000,000
	Harbor (70-200 bbl/hr)	2	3,000,000	3	4,500,000	4	6,000,000	6	10,500,000	6	10,500,000
	Shallow-water (10-50 bbl/hr)	2	200,000	4	400,000	6	600,000	8	800,000	8	800,000
II. Booms	Offshore (Class III)	500 m	750,000	500 m	750,000	1,000 m	1,500,000	2,000 m	3,000,000	2,000 m	3,000,000
	Harbor (Class II)	1,000 m	500,000	1,500 m	750,000	2,000 m	1,000,000	3,000 m	1,500,000	4,000 m	2,000,000
	Shallow-water (Class I)	1,000 m	200,000	2,000 m	400,000	3,000 m	600,000	4,000 m	800,000	5,000 m	1,000,000
	Sorbent	1,000 m	500,000	2,000 m	1,000,000	3,000 m	1,500,000	4,000 m	2,000,000	5,000 m	2,500,000
	Exclusionary (site-specific)	-	-	-	-	-	-	-	-		
III. Chemicals	Dispersants	100 bbl	150,000	500 bbl	750,000	1,000 bbl	1,500,000	5,000 bbl	7,500,000	10,000 bbl	15,000,000
	Collectants	2 bbl	4,000	10 bbl	20,000	20 bbl	40,000	100 bbl	200,000	200 bbl	400,000
IV. Sorbents	Synthetic	1 tonnes	40,000	4 tonnes	160,000	8 tonnes	320,000	40 tonnes	1,600,000	80 tonnes	3,200,000
V. Miscellaneous	Offshore vessel[d]	3	(e)	3	(e)	6	(e)	12	(e)	12	(e)
	Utility boat	4	(e)	6	(e)	8	(e)	12	(e)	12	(e)
	Workboat	4	(e)	8	(e)	12	(e)	16	(e)	16	(e)
	Inflatable boat	4	160,000	8	320,000	12	480,000	16	640,000	16	640,000
	Dracone/barge (1,000 bbl)	1	1,000,000	5	5,000,000	10	10,000,000	20	20,000,000	20	20,000,000
	Dracone/barge (250 bbl)	2	600,000	2	600,000	2	600,000	2	600,000	2	600,000
	Fireboat	1-3	(e)	1-3	(e)	1-3	(e)	3-6	(e)	3-6	(e)
	Van	8	(e)	14	(e)	24	(e)	32	(e)	40	(e)
	Vacuum truck	1	300,000	2	600,000	4	1,200,000	6	1,800,000	8	2,400,000
	Tank truck	2	(e)	4	(e)	8	(e)	12	(e)	16	(e)
	Aircraft	1	(e)	1	(e)	1	(e)	1	(e)	2	(e)
	Oily beach cleaner	1	100,000	3	300,000	6	600,000	10	1,000,000	20	2,000,000
	Front end loader	1	(e)	3	(e)	6	(e)	10	(e)	20	(e)
	Truck	4	(e)	12	(e)	24	(e)	40	(e)	80	(e)
	Dredge/pump system	1	(e)	1	(e)	1	(e)	1	(e)	2	(e)
Total			8,504,000		16,550,000		27,940,000		55,940,000		68,040,000

a. Quantities represent the number of the total recommended fleet required to support mechanical and dispersant operations.
b. Typical costs without delivery included.
c. Lower capacity skimming units or use of dispersants, if possible, are better candidates for these small spills provided offshore sea-spill conditions permit such operations.
d. Number of vessels predicated on the towing mode selected.
e. Can serve multiple purposes in addition to spill response; costs therefore are not provided.

Source: Extract from MEPA 1991.

Weir Skimmers (including skimming barriers)
a weir is positioned near the oil-water interface to minimize the flow of water along with the oil.

Oleophilic Skimmers (including rope, disc, and belt skimmers)
an oleophilic surface is moved through the slick, and the absorbed oil is scraped or squeezed into a collection area.

Submersion Skimmer
a rotating nonabsorbent belt submerges the oil and moves it beneath the surface of the water toward a collection area in which the oil rises because of its buoyancy.

Centrifugal or Vortex Skimmers (including vessel-mounted and pump-assisted skimmers)
a vortex is formed to draw oil into the skimmer in which centrifugal forces separate the denser water from the most buoyant oil that collects at the surface.

The proposed skimmer inventory for a local area should have appropriately sized portable equipment to respond effectively to both small and large spills. The smaller units like small weir or oleophilic loop units are generally best for shallow-water applications or protected waters (such as port and harbor areas). Large recovery capacity may be provided by skimming/boom system (recovery units fitted at the apex of diversion booms) or self-propelled units with integral skimmer systems. For this study, a skimming/boom system has been recommended as the primary offshore skimmer because of its larger potential for oil recovery. Although primarily designed for offshore use, these large-capacity skimmers can be used to supplement smaller equipment for large spills within port areas; however, use may be limited to deep-water channels.

The amount of equipment specified has been based on the assumption that actual skimming capacity is less than that normally specified by the manufacturer. Manufacturer specificatons are generally for ideal recovery conditions, such as calm water, favorable weather conditions, and substances with optimum pumping characteristics. Limited tank tests and actual operation have indicated that these recovery rates do not accurately reflect "field capacity rates". For this study, it has been assumed that actual recovery rates are 50 percent of the manufacturer rates, based on consideration of U.S. Coast Guard experience.

B. Booms

Booms can be used to facilitate spill cleanup by containment or by funneling the spill to a skimmer. Booms can also be used to protect vulnerable areas. This can be accomplished by using booms to divert the spill or by closing off an area. Such as a harbor entrance. Therefore, the amount of diversionary or exclusionary boom necessary for protection of a local area is dependent on the sensitive facilities and locations to be protected.

The amount of boom needed to completely contain a spill rapidly becomes impracticably large as a function of increasing spill quantity, based on U.S. Coast Guard and other worldwide experience. For example, assuming an average spill thickness of 0.1 m, the circumference of a 1000-barrel spill is 4500 m and 45000 m for a 100,000-barrel spill. Therefore, for this assessment the amount of containment boom recommended is not directly related to spill size. Instead, a basic amount of 500 m per skimmer has been recommended for each of the three boom types (i.e., offshore, harbor, and shallow-water) for containment, diversion, or use with skimmer applications.

Table 5-5
Boom Classification Criteria

Class	Skirt Depth (m)	Freeboard (m)	Total Height (m)	Use	Maximum Conditions: Current Velocity Perpendicular to Boom (m/sec)	Maximum Conditions: Wind Velocity Perpendicular to Boom (m/sec)	Maximum Conditions: Wave Ratio Height/Length
I	0.2	0.1	0.3	Calm waters	0.5	6.8	0.08
II	0.4	0.2	0.6	Harbor (moderate waves and current)	0.8	9.0	0.08
III	0.6	0.5	0.9	Open water	1.0	11.3	0.08

Source: Byroade et al., 1981.

Note: It is recognized that all booms in currents in excess of 0.4 meter per second are subject to water entrainment. Current categories provided are indicative of the environment in which they could be used, even though containment efficiency would be reduced.

Boom amounts recommended of 500 m per skimmer provide the basis for funneling the oil spill to the skimmer unit. Excess amounts may create logistical problems. It has been assumed that cleanup operations and the use of coastal diversionary and exclusionary booms would provide the protection required to supplement the 500 m of boom per skimmer. The amount of sorbent boom (for use in shallow and ecologically sensitive areas) required has been assumed to be equal to the amount of Class I boom recommended. However, there are not firm criteria or other worldwide information available to substantiate this assumption. Local On-Scene Coordinators may vary their inventory based on a detailed assessment of local requirements.

Standard classification criteria are presented in Table 5-5 to specify boom types. These classification have been used for the boom inventory recommendations presented in this chapter.

The following are general characteristics that must be considered for boom selection:

- Sufficient buoyancy to prevent submergence under all predicted forces.

- Sufficient draft to minimize entrainment and to contain significant amounts of oil.

- Sufficient freeboard to prevent splash over.

- Tension lines that are external to the curtain or skirt sections to allow the boom to follow and maintain proper height with respect to the seas.

- Resistance to oils, abrasion, and sunlight.

- Provisions for simple, quick connection of sections.

- Built-in mooring points.

Air-inflated booms are generally cheaper and more easily stored and handled. The complication is that a high-volume, low pressure air supply must be provided and some air leakages may occur. Also deployment is much slower, decreasing the opportunity for rapid response.

Boom recommendations are based on the following:

- An average daily maximum wind speed of 10 meters per second was assumed. Although winds of up to 25 meters per second have been recorded in the Arabian Gulf region, they are infrequent. In addition, deployment of booms in winds of this magnitude would be extremely difficult, if not impossible, and the equipment would be unlikely to remain effective or undamaged at speeds of more than 10 to 12 meters per second. Selection of a higher wind speed would also substantially increase the amount of boom required. However, it is not cost-effective to develop an equipment inventory based on an extreme weather or spill event. Winds greater than ten meters per second generally occur less than five percent of the time in Saudi waters.

- Rapid deployment of containment booms would be used downwind or downcurrent, or to surround a loading tanker with booms in the event of a spill. The boom would be used to deflect the oil, and thus move it to a skimming device that could be fitted at the apex of the boom, or a skimmer could skim within the boom areas.

- Harbor basins would be protected by means of exclusionary booms placed so as to reduce the current perpendicular to the boom to approximately 0.4 meter per second. A skimming device would be incorporated in the boom system.

- Under the influence of wind, oil moves at about three to four percent of the wind speed in the same general direction of the wind, if other currents are not a major factor.

- Selected priority beach areas, and especially sensitive areas, would be protected by diversionary booming to channel oil to selected recovery sites.

- Sea-water-intake channels would be protected by exclusionary booms and skimming systems.

- For spills that occur inside the harbor basins, containment booms would be placed as near the spill sites as possible to prevent the spread of oil to the breakwater or beach areas, which would require a much more difficult cleanup.

- Approximately one-half of the boom inventory in a local area should be reel-mounted or in pollution-response vessels and ready for immediate deployment. The remainder should be stored in a secure covered area.

Environmental impacts associated with the use of booms are summarized in Table 5-6. A similar discussion is presented in Table 5-7 relevant to marsh and mangrove areas.

B. Chemicals

Chemical dispersants and collectants are frequently used to control oil spills (the petroleum industry in the Kingdom of Saudi Arabia has routinely used dispersants for offshore spills). These substances, however, have varying degrees of toxicity to marine organisms, and

Table 5-6
Environmental Impacts of Alternative Booming Techniques

Protection Technique	Description of Technique	Primary Use of Protection Technique	Environmental Effect of Use
1. Exclusion Booming	Boom is deployed across or around sensitive areas and anchored in place. Approaching oil is deflected or contained by boom.	Used across small bays, harbor entrances, inlets, river or creek mouths where currents are less than 1 kt and breaking waves are less than 25 cm in height.	Minor disturbance to substrate at shoreline anchor points.
2. Diversion Booming	Boom is deployed at an angle to the approaching slick. Oil is diverted away from the sensitive area or to a less sensitive area for recovery.	Used on inland streams where currents are greater than 1 kt; across small bays, harbor entrances, inlets, river or creek mouths where currents exceed 1 kt and breaking waves are less than 25 cm, and on straight coastline areas to protect specific sites, where breaking waves are less than 25 cm.	Minor disturbances to substrate at shoreline anchor points, cause heavy shoreline oil contamination on downstream side.
3. Containment Booming	Boom is deployed in a "U" shape in front of the oncoming slick. The ends of the boom are anchored by drogues or work boats. The oil is contained within the "U" and prevented from reaching the shore.	Used on open water to surround an approaching oil slick to protect shoreline areas where surf is present and oil slick does not cover a large area; also on inland waters where currents are less than 1 kt.	No effect on open water; minor disturbance to substrate on inland anchor point.
4. Sorbent Booming	Boom is anchored along a shoreline or used in one of the manners described above to protect sensitive areas and absorb oil.	Used on quiet waters with minor oil contamination.	Minor disturbance to shoreline at anchor points.
5. Sorbent Barriers	Barriers are constructed across a waterway and constructed of wire mesh and stakes which contain loose sorbents. The barrier allows water to flow but retains and absorbs oil on the surface.	Used in small, low velocity streams, tidal inlets or channels, or any narrow waterway with low current velocities.	Minor disturbance to stream or channel substrate.

Source: Extract from NEPA 1991

Table 5-7
Marsh/Mangrove Impacts of Alternative Booming Techniques

Skirt and fence booms	No impact	No impact	No impact
Earth and rigid barriers	Possible interruption of tidal cycle; substrate loss if marsh soil is used for barrier construction	Substrate loss if marsh soil is used for barrier construction	Possible interruption of tidal cycle; substrate loss if marsh soil is used for barrier construction
Permeable barriers	No impact	No impact	No impact
Sorbents	Possible injury to birds and other animals by nonbiodegradable remnants	Possible injury to birds and other animals by nonbiodegradable remnants	Possible injury to birds and other animals by nonbiodegradable remnants

varying degrees of effectiveness, depending on the substance spilled. Therefore, consideration of their use in shallow waters or in sensitive ecological areas, such as coral areas and shrimp nurseries, must be approached with caution. A summary of environmental considerations for dispersant use is presented in Table 5-8.

Dispersants are chemical surfactants containing molecules that have an oil-compatible segment and a water-compatible segment. This results in enveloping the oil droplets with an oil-repulsing zone that repels other droplets and prevents coagulation. Thus, the dispersants tend to break up and disperse oil spills. But the effectiveness of dispersants is limited to liquids that have oil-like properties.

Typically, dispersants are most effective on the least persistent (more volatile) oils and the least effective on the more persistent oils. In some cases, such as with nonspreading or emulsified oils, chemical treatment can be expected to have little or no effect. Dispersants can frequently reduce the fire and toxic hazards of many types of volatile spills in port areas. However, the effectiveness and applicability of dispersants varies for different commercial products and spill situations. Dispersant selection and use therefore must be evaluated on a case-by-case basic and also considered based on environmental factors.

Dispersants should be used in conjunction with decision criteria and procedures to minimize any potential environmental damage and to ensure that dispersants are used appropriately. In general, dispersants are best used for initial response to offshore spills, and mechanical cleanup is best suited for inshore and port areas. There are, however, exceptions to these general

Table 5-8
Environmental Considerations for Dispersant Use Evaluation (Lindstedt-Siva, 1982)

Area	Impact	Recommendations
Coral Reefs	Susceptible (highly variable by species) to toxic effects of dispersed oil.	Whenever an oil spill threatens a coral reef, the use of dispersants should be considered to prevent oil from reaching the reef. For spills that occur over a reef, decisions on the use of dispersants should take into account the type of reef and the location on the reef. Floating oil will have the greatest impact on emergent reefs. Dispersant use should be considered to prevent grounding of oil on such reefs. Shallow submergent reefs will be less affected by floating oil than by chemically dispersed oil. The use of dispersants over these reefs should weigh the potential impacts to the reef against impacts that might occur from allowing the oil to come ashore. Deep-water reefs are unlikely to be affected by chemically dispersed oil. The use of dispersants should be a definite consideration if the alternative is to allow the oil to impact shorelines. Oil should be prevented from entering reef habitats having low flushing rates (e.g., lagoons, atolls). The use of dispersants in such areas should have secondary priority to mechanical cleanup techniques.

Table 5-8
Environmental Considerations for Dispersant Use Evaluation (Lindstedt-Siva, 1982)
(Page 2 of 5)

Area	Impact	Recommendations
Seagrass Beds	Lack of information on the effects of dispersed oil.	Dispersant use should be considered while a slick is still offshore to prevent the oil from impacting the grass bed. Seagrass distribution ranges from the intertidal down to approximately 25 m. Dispersant use should be considered where grass beds are deeper than 10 m or where floating oil is likely to ground on intertidal grass beds. Grass beds between the intertidal zone and 10 m depth are more likely to be impacted by dispersed oil than by oil floating on the surface. Dispersant use in these areas should weigh impacts to the grass beds against the potential exposure to onshore habitats. In shallow lagoons or areas of restricted flushing rates, mechanical cleanup is preferred to dispersant usage. However, dispersant usage should remain an option to protect more sensitive shoreline environments.
Rocky Shores	Can harm intertidal biota.	Use with caution. Direct application to rocky shores normally not recommended. If required, apply in front of an advancing tide allowing sea to accomplish "wash down".
Marine Mammal Habitats	Effects of dispersed oil not well-known.	Avoid close-in use. Treat oil spill well away from such habitats.

Table 5-8
Environmental Considerations for Dispersant Use Evaluation (Lindstedt-Siva, 1982)
(Page 3 of 5)

Area	Impact	Recommendations
Bird Habitats	Generally reduces oil spill impacts of bird habitats, but may be harmful to wetlands.	Treat offshore if possible. May be used in and near habitats for the following: o Areas with large numbers of migrating birds o Areas that support large year-round colonies o Endangered species habitat should not be used for: + Breeding colony sites + Important coastal wetlands
Sandy Beaches	May affect biota if concentration high.	Use offshore if possible. Shoreline application directly on a case-by-case basis considering local ecology and land use.
Tidal Flats	Little information of the dispersed oil into the sediments can be expected.	Treat offshore if possible; but can be used in shallow water (less than 5 m), if necessary. Do not apply to tidal flats which have already been impacted.
Nearshore Subtidal	May be harmful at high concentrations to bottom organisms.	Treat offshore if possible. In deciding whether to disperse a slick in the nearshore area, the potential exposure of bottom organisms must be weighed against the potential exposure of onshore organisms.

Table 5-8
Environmental Considerations for Dispersant Use Evaluation (Lindstedt-Siva, 1982)
(Page 4 of 5)

Area	Impact	Recommendations
Salt Marshes	May be harmful at high concentrations. Additional research needed.	Chemical dispersion should be carried out as far from the salt marsh ecosystem as is feasible. If it is necessary to apply dispersant to an oil slick near a salt marsh, the dispersant should be sprayed just ahead of a rising tide to maximize mixing and dilution of the oil, and to minimize impact of floating oil on the marsh. Direct applications of dispersants to salt marshes is not recommended. If marsh vegetation has been heavily oiled, dispersants will probably not prevent nor lessen damage, and low pressure flushing, or the "no treatment" option should be considered.
Mangrove	May have less adverse impact on organisms than untreated slick. Must be evaluated on case-by-case basis.	Because of the very high probability that an oil spill will damage mangrove trees that it impacts, the major goal of the cleanup effort should be to prevent oil from reaching mangrove forests. Chemical dispersion should be carried out as far from the mangrove forest as possible. Chemical dispersion should be considered a viable option even if some dispersed oil may enter the forest. If significant amounts of dispersed oil enters a mangrove forest in an area with little tidal range, attempts should be made to flush it out.

Table 5-8
Environmental Considerations for Dispersant Use Evaluation (Lindstedt-Siva, 1982)
(Page 5 of 5)

Area	Impact	Recommendations
Offshore	Increases hazard posed by the spill to offshore water-column organisms since they will be exposed to higher hydrocarbon concentrations than otherwise.	For spills offshore, chemical dispersants are recommended when sensitive habitats, animals, or shorelines are at risk. This is especially true when untreated oil threatens highly aggregated populations (e.g., migrating or staging populations of seabirds, breeding sites, areas of upwelling) or threatens particularly oil-sensitive coastal areas (e.g., salt marshes, mangrove swamps, seagrass beds). These oil-sensitive resources should be considered to be at risk from an untreated oil slick if they lie within several hundred kilometers of the spill site. There are two possible exceptions to this recommendation. i) When the dispersed oil threatens aggregated populations of water-column organisms (usually applies only to fish eggs and/or larvae), dispersant should be used only if it will minimize the overall environmental damage caused by the spill; ii) When trajectory data indicate that the possibility of contact between oil and oil-sensitive resources is very small under prevailing conditions, there is little justification for using dispersants.

guidelines. For this study it has been assumed that dispersant capacity should be available for treatment of the total spill amount.

The amount of chemical dispersants necessary is directly proportional to the postulated spill size, but the dosage rates for application are difficult to assess. In general, the smallest amount of dispersant that produces the desired result of adequate dispersion is appropriate and minimizes the environmental impact. Also, the use of large quantities of chemical dispersants can be quite expensive. (However, one barrel of dispersed oil is generally less expensive than one barrel of skimmed oil.) Most dispersant manufacturers supply dosage recommendations in terms of amount per acre. The dispersant application results can vary substantially, depending on wind and wave conditions, the oil type, and the effectiveness of the application process. These recommendations, therefore, should be considered as initial starting points and should be adjusted after assessment in the field on a case-by-case basis. In addition, manufacturer recommendations are frequently based on ideal conditions and there is a general lack of toxicity and effectiveness information for subtropical/tropical environments. For example, a typical manufacturer-recommended dosage rate is the equivalent of 1 barrel of dispersant to 30 - 60 barrels of oil. However, independent estimates indicate that as much as 1 part dispersant (concentrate) to 10 parts of oil may be required. For this study, the 1-to-10 ratio has been used as the basis for conservatively recommending dispersant stockpile amounts. Frequently, application of the dispersant in the concentrate form is warranted. This has been the assumption used for conservatively specifying dispersant application equipment and supplies for this study. Such an approach, however, may require special modification of standard equipment. In general, the local On-Scene Coordinator should use a 1-to-30 ratio initially.

Depending on the effectiveness of this ration, the amount of dispersant to oil treated may be varied as warranted by actual on-scene conditions. However, for conservatism, the dispersant stockpile inventory should be based on the 1-to-10 ratio.

Chemical collectants are useful in restricting the spreading of a spill during low-wind, low-current conditions. Therefore, their application is best suited for protected port areas. However, during suitable wind and wave conditions, collectants can be used at sea on the spill perimeter (such as application via helicopter spraying). They are usually applied only to the perimeters of spills and in very low dosages.

Specific criteria for determining the quantities required for different sized spills are not available. For this study, it has been assumed that one barrel of collectant will treat about 50 km of spill perimeter or shoreline. In general, collectants would be used in shore (i.e., along the shoreline or in the port).

While surface collecting agents have a measureable level of toxicity, they are typically applied in very low dosages and over limited areas (i.e., along the perimeter or leading edge of a slick). They also operate at the surface and evaporate relatively rapidly. (Agents contain carrier solvents that may be partially soluble.) It is doubtful that ocean application in accordance with manufacturers' recommendations would result in concentrations causing quantifiable effects.

Greater ecologic concern should be given to shoreline application, where direct agent: amenity contact results in higher concentrations. This may be particularly important where continual or repeated application is necessary. Surface collecting agents hold a great deal of promise for the temporary protection of wetlands and mangroves. Since their impacts on vegetation are not well-known, use probably should be limited to application where significant contamination is indicated.

A final consideration should be directed to the possible misapplication of surface collectors. If surface collectors are applied seaward of the oil and shoreline, the oil may be forced ashore greatly compounding cleanup and damage. Wind and tidal shifts can result in the generation of similar problems. Use of surface collectors inshore requires a clear understanding of their performance and nature of area to be treated.

The effectiveness of collectants is relatively short-lived and frequent reapplications may be necessary. Formal guidelines for the recommended inventory of collectants are not available in the technical literature. For this study, it has been recommended that approximately 20 barrels of collectant be stockpiled per each 1000 barrels of dispersant, similar to the inventory used by Clean Gulf in the United States.

It should be noted that the Kingdom of Saudi Arabia is currently evaluating the availability and effectiveness of using biological agents. However, such an approach is still in the experimental stage.

D. Sorbents

Sorbents are generally used to clean up spills that are too thin for efficient recoery by skimmers. Also, sorbents are frequently used in lieu of skimmers or vacuum trucks for spill cleanup in relatively inaccessible or ecologically sensitive areas (such as marshes and mangroves) that might be damaged by such equipment and people transversing the area. Sorbents can also provide effective cleanup of small spills in protected areas such as ports.

Sorbents recover oil by means of absorption or adsorption. Absorption involves the oil penetrating the solid structure of fibers or particles which then swell. Adsorption involves the oil adhering to the surface area of the recovery material. Sorbent materials can be classified as follows:

- Natural organic products - hay, peat moss, straw, or wood pulp

- Synthetic products - polyethylene, polypropylene, and polystyrene

- Mineral compounds - ash, perlite, or vermiculate

Synthetic sorbents generally provide more effective cleanup capacity per unit weight compared to natureal organic products or mineral compounds. Many synthetic sorbents can absorb greater than 20 times their weight in oil. A 1-to-20 ratio has been assumed for this study. This is roughly equivalent to assuming that 0.007 metric tonne (7 kg) of sorbent is necessary to treat one barrel of oil. Because use of sorbents are not considered a practical (because of logistical and disposal factors) primary response approach, it has also been assumed that only 10 percent of the total spill amount would be treated by the use of sorbents.

E. Miscellaneous Equipment

Vessels:

A mix of vessels and associated equipment are required to meet the needs of varied response plans. Some of these needs can be supplemented by multipurpose vessels or boats. For instance, launches, fishing vessels, or tugs may be used for towing booms and for dispersant spraying (provided they are outfitted with special fittings). None of these craft, however, is ideally suited for loading, carrying, or deploying major skimming and containment equipment offshore. They generally do not have sufficient open-deck space, and their fixed stern bulwarks impede launching and retrieving equipment.

Offshore service and supply vessels with superstructures forward and with a large open afterdeck with a removable stern rail are ideal for launching and retrieving equipment. For deploying a large open-water skimming boom system, at least 10 x 20 m of open deck is desirable, since approximately 50 m^2 of storage space may be required for 100 m of boom. Some crane loading capability is also needed.

In general, the following types of vessels are required:

- Pollution-response vessels (30 to 60 m), similar to the offshore service/supply vessels used by the petroleum industry with a large open after deck, a removable stern rail, and a crane, for offshore boom and skimmer deployment and dispersant spraying.

- Utility boats (12 to 16 m) for boom deployment and recovery and dispersant spraying in harbor areas.

- Work boats (6 to 8 m) for response support in protected and shallow waters.

- Inflatable rubber boats (4 m) for work near the shoreline in very shallow waters.

- Barges or dracones and associated pumping facilities for off-loading recovered oil.

- Fireboats for flushing or applying foam to certain hazardous spills.

The number of vessels required for response to offshore spills is dependent on spill size. It has been assumed that three vessels are required to support one skimming boom setup, similar to the approach used by Clean Atlantic/Clean Gulf (of Mexico). One vessel is located at each of the two end of the boom, and one is either at the apex where the skimmer is located (basically a trinagle configuration) or is used to tow dracones or barges of recovered oil to port recovery or disposal facilities. Each vessel is assumed to be able to carry at least 100 m of Class III boom.

The number of vessels required for dispersant applications is considerably less than needed for deployment of a skimming boom offshore. It has been assumed that each vessel that supports an offshore spill response is capable of spraying the chemical concentrate solution at a rate of 25 barrels per hour and for response to smaller spills in the harbor area, the use of utility boats with an application rate of 5 barrels per hour is recommended, commensurate with standard equipment capabilities. All of these dispersant spraying vessels can serve a dual purpose; they can also be used for mechanical recovery and other response support operations.

Based on worldwide experience, it has been assumed that for large spills occurring in the harbor area, a contingency of small vessels will be required independent of spill size. for larger spills, some of the offshore vessels and equipment recommended for offshore spills would also be placed at strategic locations as a supplemental response capability.

Shoreline Cleanup

In this line the use of equipment specifically designed for oily beach cleanup is recommended in conjunction with standards heavy equipment used by the construction industry. This approach is applicable to the sandy beaches that are quite common along the shoreline of the Kingdom. Sensitive ecological areas (such as marshes, mud flats) may require flushing using water hoses (but may harm certain habitats), or in many cases, no cleanup action is taken, which usually results in the least environmental damage. A summary of the potential ecological impact of alternative shore cleanup approaches is presented in Tables 5-9 and 5-10.

The recommended shoreline cleanup equipment (based on selection considering cleanup rates compared with alternative equipment) is listed in Table 5-11. The recommended oily beach cleaner unit is mounted on a front-end loader. The unit contains an oleophilic belt to which oil adheres as it rolls over the beach. The belt is scraped into a conveyor that loads the recovered oil into containers (barrels or bags) carried by a truck driven alongside the cleaner unit. The recovered oil can then be hauled to a disposal site.

The shoreline cleanup operations described above could clean a 24-km length of a path approximately 7 m wide during a 10-hour work day. Optimally, this may involve the collection of up to 1000 barrels of waste oil and

Table 5-9
Impacts Associated with Beach Cleanup Techniques
(Page 1 of 4)

Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
1. Motor grader/ elevating scraper	Motor grader forms windrows for pickup by elevating scraper.	Removes only upper 3 cm of beach.	Removes shallow burrowing polychaetes, bivalves, and amphipods. Recolonization likely to rapidly follow natural replenishment of the substrate.
2. Elevating scraper	Elevating scraper picks up contaminated material directly off beach.	Removes upper 3 to 10 cm of beach. Minor reduction of beach stability. Erosion and beach retreat.	Removes shallow and deeper burrowing polychaetes, bivalves, and amphipods. Restabilization of substrate probably slow; recolonization likely to follow natural replenishment of substrate; reestablishment of long-lived indigenous fauna may take several years.
3. Motor grader/ front-end loader	Motor grader forms windrows for pickup by front-end loader.	Removes only upper 3 cm of beach.	Removes shallow burrowing polychaetes, bivalves, and amphipods. Recolinization likely to rapidly follow natural replenishment of the substrate.
4. Front-end loader - rubber-tired or tracked	Front-end loader picks up material directly off beach and hauls it to unloading area.	Removes 10 to 25 cm of beach. Reduction of beach stability. Erosion and beach retreat.	Removes almost all shallow and deep burrowing organisms. Restabilization of the physical environment slow; new faunal community could develop.
5. Bulldozer/ rubber-tired front-end loader	Bulldozer pushes contaminated substrate into piles for pickup by front-end loader.	Removes 15 to 50 cm of beach. Loss of beach stability. Severe erosion and cliff or beach retreat. Inundation of backshores.	Removes all organisms. Restabilization of substrate and repopulation of indigenous fauna is extremely slow; new faunal community could develop in the interim.
6. Backhoe	Operates from top of a bank or beach to remove contaminated sediments and loads into trucks.	Removes 25 to 50 cm of beach or bank. Severe reduction of beach stability and beach retreat.	Removes all organisms. Restabilization of substrate and repopulation of organisms is extremely slow; new faunal community could develop in the interim.

Source: Extract from MEPA 1991

Table 5-9
Impacts Associated with Beach Cleanup Techniques
(Page 2 of 4)

Clean up Technique	Description	Physical Effect of Use	Biological Effect of Use
7. Dragline or clamshell	Operates from top of contaminated area to remove oiled sediments.	Removes 25 to 50 cm of beach. Severe reduction of beach stability. Erosion and beach retreat.	Removes all organisms. Restabilization of substrate and repopulation of indigenous fauna is extremely slow; new faunal community could develop in the interim.
8. High-pressure flushing (hydro-blasting)	High pressure water streams remove oil from substrate; oil is channeled to recovery area.	Can disturb surface of substrate.	Removes some organisms and shells from the substrate, damage to remaining organisms variable. Oil not recovered can be toxic to organisms downslope of cleanup activities.
9. Steam cleaning	Steam removes oil from substrate where it is channeled to recovery area.	Adds heat (> 100°C) to surface.	Removes some organisms from substrate but mortality due to the heat is more likely. Empty shells remaining may enhance repopulation. Oil not recovered can be toxic to organisms downslope of cleanup activities.
10. Sandblasting	Sand moving at high velocity removes oil from substrate.	Adds material to the environment. Potential recontamination, erosion, and deeper penetration into substrate.	Removes all organisms and shells from the substrate. Oil not recovered can be toxic to organisms downslope of cleanup activities.
11. Manual scraping	Oil is scraped from substrate manually using hand tools.	Selective removal of material. Labor-intensive activity can disturb sediments.	Removes some organisms from the substrate, crushes others. Oil not removed or recovered can be toxic to organisms repopulating the rocky substrate or inhabiting sediment downslope of cleanup activities.
12. Sump and pump/ vacuum	Oil collects in sump as it moves down the beach and is removed by pump or vacuum truck.	Requires excavation of a sump 60 to 120 cm deep on shoreline. Some oil will probably remain on beach.	Removes organisms at sump location. Potentially toxic effects from oil left on the shoreline. Recovery depends on persistence of oil at the sump.

Source: Extract from MEPA 1991

Table 5-9
Impacts Associated with Beach Cleanup Techniques

	Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
13.	Manual removal of oiled materials	Oiled sediments and debris are removed by hand, shovels, rakes, wheelbarrows, etc.	Removes 3 cm or less of beach. Selective. Sediment disturbance and erosion potential.	Removes and disturbs shallow burrowing organisms. Rapid recovery.
14.	Low-pressure flushing	Low-pressure water spray flushes oil from substrate and is channeled to recovery points.	Does not disturb surface to any great extent. Potential for recontamination.	Leaves most organisms alive and in place. Oil not recovered can be toxic to organisms down slope of cleanup.
15.	Beach cleaner	Pulled by tractor or self-propelled across beach picking up tar balls or patties.	Disturbs upper 5 to 10 cm of beach.	Disturbs shallow burrowing organisms.
16.	Manual sorbent application	Sorbents are applied manually to contaminated areas to soak up oil.	Selective removal of material. Labor intensive activity can disturb sediments.	Foot traffic may crush organisms. Possible ingestion of sorbents by birds and small mammals.
17.	Manual cutting	Oiled vegetation is cut by hand, collected, and stuffed into bags or containers for disposal.	Disturbs sediments because of extensive use of labor; can cause erosion.	Removes and crushes some organisms. Rapid recovery. Heavy foot traffic can cause root damage and subsequent slow recovery.
18.	Burning	Upwind end of contaminated area is ignited and allowed to burn to downwind.	Causes heavy air pollution; adds heat to substrate, can cause erosion if root systems due damaged.	Kills surface organisms caught in burn area. Residual matter may be somewhat toxic (heavy metals).
19.	Vacuum trucks	Truck is backed up to oil pool or recovery site where oil is picked up via vacuum hose.	Some oil may be left on shoreline or in water.	Removes some organisms. Potential for longer-term toxic effects associated with oil left on the shoreline. Recovery depends on persistence of oil left in the pools.

Source: Extract from MEPAS 1991

Table 5-9
Impacts Associated with Beach Cleanup Techniques
(Page 4 of 4)

	Cleanup Technique	Description	Physical Effect of Use	Biological Effect of Use
20.	Push contaminated substrate into surf	Bulldozer pushes contaminated substrate into surf zone to accelerate natural cleaning.	Disruption of top layer of substrate; leaves some oil in intertidal area. Potential recontamination.	Kills most of the organisms inhabiting the uncontaminated substrate. Recovery of organisms usually more rapid than with removing substrate.
21.	Break up pavement	Tractor fitted with a ripper is operated up and down beach.	Disruption of sediments. Leaves oil on beach.	Disturbs shallow and deep burrowing organisms.
22.	Disc into substrate	Tractor pulls discing equipment along contaminated area.	Leaves oil buried in sand. Disrupts surface layer of substrate.	Disturbs shallow burrowing organisms. Possible toxicity effects from buried oil.
23.	Natural recovery	No action taken. Oil left to degrade naturally.	Some oil may remain on beach and could contaminate clean areas.	Potential toxicity effects and smothering by the oil. Potential incorporation of oil into the food web. Potential elimination of habitat if organisms will not settle on residual oil.

Source: Extract from NEPA 1991

Table 5-10
Major Impacts of March Cleaning Activities

Source: Extract from MEPA 1991

Cleanup Operation	Reed-like Marsh	Succulent-like Marsh	Red and Black Mangrove Marsh
Traffic	Rhizomes may be damages; erosion potential high	Rhizomes may be damages; little erosion potential	Red mangrove - tolerant to traffic Black mangrove - pneumatophores may be damaged
Cutting	Very tolerant	Tolerant	Intolerant
	--------------Frequently involves foot traffic------------------		
Flushing	Very tolerant	Very tolerant	Very tolerant
Burning	Very tolerant	Intolerant	Intolerant
Sorbents	Very tolerant	Very tolerant	Very tolerant
	--------------Frequently involves foot traffic------------------		
Soil Removal	Plant dominance may change, or marsh plant habitat may be eliminated	Plant dominance may change or marsh plant habitat may be eliminated	Plant dominance may change or marsh plant habitat may be eliminated

Table 5-11
Shoreline Cleanup Equipment Recommendations
Source: Extract from MEPA 1991

Description	Quantity[a]	Additional Information
Oily beach cleaner	1 unit	100-bbl/hr oil-collection rate
Front-end loader	1 unit	Bucket mounting to accommodate oily beach cleaner
Trucks	4 units[b]	100-bbl capacity, capable of over-beach transit

a. Heavy equipment required to clean approximately 7-m-wide swath of 24-km length of shoreline in a 10-hour work day.
b. Based on a 4-hour round trip per truck.

small debris during a work day. Shoreline cleanup operations generally do not have to be accomplished with the same urgency as containment and protection action. Therefore, it has been assumed that shoreline cleanup operations could extend for several months if necessary.

Additional Equipment

Additional equipment supplies are recommended to supplement the primary response inventory as follows:

- Aircraft equipped with a portable dispersant-collectant spraying system also to be used for aerial surveillance.
- Pump and compressors as required to support skimmer operations.
- Radios and other communication equipment and supplies.
- Boom anchors, boat fenders, lines, shackles, swivels, and other supplies to support mechanical-recovery operations.
- Fire extinguishers, life jackets, hazardous gas monitors and alarms, protective clothing and masks, first-aid kits, and other safety-related equipment.
- Spare parts and tools for maintenance and repairs.
- Vacuum trucks and tank trucks for small spills that are accessible from the shoreline.

F. Facilities

Facilities at a waterfront location should be established at each Local Response Center for the following:

- Emergency Control Center for spill response.

- Moorings for vesels and boats.

- Covered storage facilities for maintaining response inventory.

- Mobile cranes and forklifts for loading and unloading of equipment.

- Administrative office space.

- Dispersant-pumping system for refilling storage tanks on dispersant-spraying vessels.

- Cleanup facilities for equipment used in spill response.

- Waste oil and slop tank facilities with required pumping equipment (similar facilities for hazardous spill wastes).

- Nearby airstrip.

An inshore waste-disposal site should also be available. The recommended disposition of oily wastes (in order of priority) is as follows:

- Reclaim as much oil from the waste, and use directly as much of the oily waste itself, as possible; and

- Where air pollution standards can be met, thermally oxidize (i.e., burn, incinerate, pyrolyze, etc.) the remaining oily debris; or

- Where debris size permits, land cultivate (i.e., aerobic microbially decompose) the remaining oily debris; or

- Employ very long term anaerobic storage (such as sanitary landfill or direct burial), together with adequate groundwater quality monitoring. Since fine-grained soils (such as clays and silts) have more surface area per unit weight and more sorptive capacity than coarse-grained soils (such as sand and gravel), long term storage sites should be located, wherever possible, on fine-grained soil. Where poor soil conditions may result in hydrogeologic connection to groundwater, leachate collection and treatment shall be employed.

Alternative waste-disposal approaches are summarized in Tables 5-12 through 5-18, based on U.S. Environmental Protection Agency technical documents.

The Emergency Control Center should provide a continuously manned communications center for spill reports and for coordinating response activities. Major elements of the recommended system include the following:

- Telephone branch lines.

- Telex terminal.

- VHF/UHF base telephone radios with portable radios. It may be necessary, in view of the distances involved, to provide radio repeaters.

Other communications matters to be considered include the following:

- Assignment of sufficient radio frequencies to manage several simultaneous response activities. Three to four are needed to ensure close communications.

- Frequencies assigned should be common to all response elements, including aircraft.

Table 5-12
Land Cultivation of Oil Spill Debris: Possible Operational Problems and Solutions

Possible problem	Solution
- Inclement weather hindering site preparation and/or mixing	- Stockpile debris in prepared, diked area until weather improves
- Difficulty in scarifying soils	- Rip soils with track dozer pulling double or single ripper blades prior to rototilling
- Slow oil decomposition	- Till the oil/soil mixture more frequently
	- Add fertilizers (such as urea and phosphates) or water
- Erosion of land surface	- Regrade the surface to maintain no more than a 1% to 2% slope.
- Runoff of oily material	- Regrade the surface
	- Construct berms
	- Construct runoff catch basin downstream from the area

Source: Extract from MEPA 1991

Table 5-13
Sanitary Landfilling of Oil Spill Debris: Possible Operational Problems and Solutions

Possible Problem	Solution
- Oil not absorbed by refuse (over-saturated or under-saturated)	- More mixing with refuse until adequate mix is secured
- Ignition of oily debris/refuse	- Extinguish flame; prevent by installing spark arrestors on equipment and assuring they have mufflers above equipment
- Leaching of oil into groundwater (vertical infiltration of water from surface)	- Reduce percolation by improving cover material; slope surface to encourage runoff
- Leaching of oil into groundwater (vertical migration down through bottom)	- Dip up landfill and reseal bottom
- Leaching of oil into groundwater (groundwater flow through refuse)	- Reduce groundwater level through pumping; excavate material and install liner
- Erosion of cover soil	- Place more cover soil; use cover vegetation if feasible

Source: Extract from MEPA 1991

Table 5-14
Direct Burial of Oil Spill Debris: Possible Operational Problems and Solutions

Possible problem	Solution
- Groundwater contamination	- Define the extent of the contamination and institute the necessary corrective measures, e.g., pumping, installing groundwater interceptor trenches, excavating point-source materials
- Surface water contamination	- Determine the source (groundwater or surface waters) and institute remedial measures, i.e., if source is groundwater, use corrective measures as in "groundwater contamination," above; if surface water over the site is becoming polluted, then the area where the surface water comes into contact with debris must be defined corrected by covering the debris with soil and/or diverting surface waters
- Slumping of fill	- Placement and compaction of additional cover soils
- Erosion of cover soil	- Place more cover soil; use cover vegetation if possible

Source: Extract from MEPA 1991

Table 5-15
Summary of Oil Spill Debris Disposal Site
Selection Criteria

Factor	Criterion
Land use	Planned use of the site for debris disposal should be compatible with on-site and adjacent land use. Disposal at a sanitary landfill would meet this criterion fully. Debris disposal in a residential area may not be compatible.
Water quality	The site should not be a source of water pollution by oil. Disposal on porous soil overlying potable groundwater or in an area subject to flooding would not meet this criterion. Sites that do not overlie groundwater (or, if they do, have a clay layer in between) are likely to offer the best protection for groundwater.
Location	Sites should be situated as closely as practical to the point(s) where oil spill debris is (or might be) collected or stockpiled.
Access	Existing access roads into the site should be of all-weather construction or such roads should be constructable in an emergency situation. A site that cannot be readily accessed is of little use. Access into a muddy farm may be temporarily facilitated by placement of a gravel road or military landing mats.

Source: Extract from MEPA 1991

Table 5-16
Advantages and Disadvantages of Alternative Debris Disposal Methods

Source: Extract from MEPA 1991

Disposal method	Advantages	Disadvantages
Land cultivation	- Oil is degraded, minimizing long-term environmental threat - Land surface reusable for debris or other purposes - Soil properties may be improved	- Opportunity for oil volatilization and thus air pollution increased - Periodic soil mixing required; frequency dependent upon soil conditions - Relatively costly - Stockpiling at disposal site may be necessary - May be impractical to implement during inclement weather
Landfilling with refuse	- Minimal equipment needs - Relatively low initial cost - Minimal site preparation - Many landfills available	- Land is dedicated to disposal indefinitely - Influx of oil spill debris may overtax available equipment and personnel - Long-term pollution potential - Long-term monitoring desirable
Burial	- Oil encapsulated, minimizes volatilization - Operations completed relatively quickly - Land surface can be returned to pre-disposal appearances	- Land is dedicated to disposal indefinitely - Oil remains undegraded for long periods with consequent long-term pollution potential - Long-term monitoring desirable

Table 5-17
Applicability of Disposal Methods to Different Types of Oil Spill Debris

Disposal method	Size of solid matter	Biodegradability of debris	Oil content
Land cultivation	- Debris should be relatively small in size, less than 15 cm (six inches, e.g., oiled soils; some larger vegetation may be acceptable, such as seaweed or brush	- Predominately oils and soils are best; non-degradable sorbents or inorganic trash should not be present	- Land cultivation best suited for heavily oiled debris
Landfilling with refuse	- No limitation on size	- No limitation	- In general no limitations on debris oil content; regulatory agencies may object to disposal of heavily oiled or high water content debris in a newer landfill where relatively little refuse is present to absorb the liquids
Burial	- In general, no size limitation; bulky debris, such as poles, may pose operational problems; disposal trenches may require widening to accommodate bulky items	- No limitation on materials	- No limitation on oil content as site conditions

Source: Extract from MEPA 1991

Table 5-18
Correcting Waste Disposal Environmental Problems

Problem	Possible solutions
Infiltration of groundwater into	- Pump out groundwater to drain upstream area - Construct diversion channels - Construct peripheral subsurface drains to intercept groundwater flow - Rebuild "impermeable" walls
Surface runoff of oily materials from site	- Install impoundment dikes or berms - Improve upstream diversion channels - Recycle runoff to debris disposal area (if quantity is small enough)
Ponding of water on surface of disposal site	- Regrade surface; possibly apply more cover soil - Establish vegetation to both increase evapo-transpiration and reduce runoff velocities
Leaching of oily matter from debris mass to groundwater	- Intercept leachate with trench - Pump out excess moisture from debris mass: either recycle pumped-out water or remove for treatment at an approved facility - Rebuild "impermeable" walls
Impeded oil degradation at land cultivation site	- Rototill or disc the soil/oil mixture more frequently - Add nutrients or other amendments

If above-noted remedial actions do not solve environmental problems, be certain that debris disposal site is actually the source of contamination. If so, removal of debris to another site may be the last resort.

Source: Extract from MEPA 1991

- Mobile communicating vans would be useful.

In addition to the communications capability, the Control Center should be equipped with the following:

- The latest updated marine charts for the area and adjacent areas.

- A technical library that includes oil spill and hazardous substance information.

- Copies of the local, the area, and the national and regional contingency plans.

2. RECOMMENDATIONS FOR COASTAL SUBAREAS

The selection of a design spill size is a subjective exercise. As can be seen from Table 5-3, the costs for response equipment and supplies are high. These costs are further escalated when labor, training, facility, and maintenance costs are accounted for. Therefore, the benefits of having an extensive spill response capability must be balanced by cost considerations. For this study, it is recommended that a design spill be defined as a spill amount that would have only a 10 percent probability of being exceeded in any given year. While alternative probability levels could be subjectively selected, the specification of a spill response equipment inventory is really not very sensitive to such a choice. This is because logistical and cost factors serve to limit the actual amount of equipment that could be effectively used at any one time, as previously discussed. It has also been recommended that a maximum design spill be limited to 100,000 barrels. Larger spills can be considered as relatively rare events (Gulf war). A cost-effective approach for handling thise spills is by cooperative arrangements to use the response resources of other coastal subareas supplemented by use of international assistance and contractors. To be conservative, a minimum design spill of 1000 barrels has also been recommended for this application. However, the information presented in Tables 5-3, 5-4 and 5-20 provide a basis to specify a response inventory for design spills of less than 1000 barrels if a less conservative approach is desired.

The amount of exclusionary boom appropriate for each subarea depends on the size and configuration of each individual port complex. Because exclusionary booming is for the protection of facilities, the amount of required boom does not depend on spill size. A summary of the exclusionary boom recommendations is provided in Table 5-19. These recommendatons are based on the consideration of major ports in each subarea. The amount of boom specified in Tables 5-4 and 5-19 together should also enable exclusiionary booming to be placed at each strategic intake location within a coastal subarea.

The limitations of the use of booms to protect harbors, cooling-water intakes, marinas, and other sensitive areas must be realized. Most planning for exclusionary booming attempts unrealistically to provide for total protection from oil ingress into sensitive areas. A realistic approach, as presented in Table 5-19, provides for minimizing pollution damage by deploying booms in such a number and manner that can be properly managed and maintained.

A summary of the recommended inventory of response equipment and supplies for the design spill selected for each coastal subarea is presented in Table 5-21. Because of the intensive offshore petroleum operations in the Arabian Gulf, it is not surprising that design spills and associated recommended equipment inventories are much larger for the Gulf than for the Red Sea. These locations were selected based on considering proximity to potential spill sources. The information presented in Tables 5-20 through 5-22 present a basis for

Table 5-19
Exclusionary Boom Recommendations

Coastal Subarea	Location	Design Inventory, m (Class III)[b]
A-1	Ras Al-Klafji	
	Harbor entrance	500
A-2	Jubail Port Complex	
	North/south entrances	2,000
	Water intake channel	200
A-2	King Abdul Aziz Naval Base	
	North/south entrances	1,000
A-2	Ras Al-Ghar desalination plant	200
A-3	Ras Tanura	-
A-3	Ju'aymah	-
A-3	King Abdul Aziz Commercial Port Damman	
	Northern entrance	1,200
	Southern entrance	900
	Small boat harbor entrance	300
R-1	Commercial Port-Yanbu	1,000
R-1	King Fahd Industrial Port Yanbu	
	Water intake channel	200
	Service harbor	200
	Oil port	700
	Domestic refinery	1,100
R-2	Rabigh	1,000[c]
R-3	Jeddah Islamic Port	3,000
R-3	Commercial Port-Gizan	
	Entrance	400
	Coast Guard harbor	100

a. Recommendations do not include desalination plant or military harbors unless so noted. In general, detailed information was not available for these facilities.
b. Boom inventory recommendations based on winds of less than 20 knots (10 m/sec).
c. Estimated terminal layout design not available for this report.

Source: Extract fro

Table 5-20

Design Spill Response Equipment and Supplies Recommendations for Subareas A-1, A-2, and A-3

Type	Description	Subarea A-1 (100,000 bbl, 13,700 tonnes) Design Inventory[a]	Subarea A-1 Cost (SR)[b]	Subarea A-2 (50,000 bbl, 6,850 tonnes) Design Inventory[a]	Subarea A-2 Cost (SR)[b]	Subarea A-3 (100,000 bbl, 13,700 tonnes) Design Inventory[a]	Subarea A-3 Cost (SR)[c]
I. Skimmers	Offshore (350-600 bbl/hr)	4	4,000,000	4	4,000,000	4	4,000,000
	Harbor (70-200 bbl/hr)	6	10,500,000	6	10,500,000	6	10,500,000
	Shallow-water (10-50 bbl/hr)	8	800,000	8	800,000	8	800,000
II. Booms	Offshore	2,000 m	3,000,000	2,000 m	3,000,000	2,000 m	3,000,000
	Harbor	4,000 m	2,000,000	3,000 m	1,500,000	4,000 m	2,000,000
	Shallow-water	5,000 m	1,000,000	4,000 m	800,000	5,000 m	1,000,000
	Sorbent	5,000 m	2,500,000	4,000 m	2,000,000	5,000 m	2,500,000
	Exclusionary[d]	500 m	750,000	3,400 m	5,100,000	2,400 m	3,600,000
III. Chemicals	Dispersants	10,000 bbl	15,000,000	5,000 bbl	7,500,000	10,000 bbl	15,000,000
	Collectants	200 bbl	400,000	100 bbl	200,000	200 bbl	400,000
IV. Sorbents	Synthetic	80 tonnes	3,200,000	40 tonnes	1,600,000	80 tonnes	3,200,000
V. Miscellaneous	Offshore vessel	12	(c)	12	(c)	12	(c)
	Utility boat	12	(c)	12	(c)	12	(c)
	Workboat	16	(c)	16	(c)	16	(c)
	Inflatable boat	16	640,000	16	640,000	16	640,000
	Dracone/barge (1,000 bbl)	20	20,000,000	20	20,000,000	20	20,000,000
	Dracone/barge (250 bbl)	2	600,000	2	600,000	2	600,000
	Fireboat	3-6	(c)	3-6	(c)	3-6	(c)
	Van	40	(c)	32	(c)	40	(c)
	Vacuum truck	8	2,400,000	6	1,800,000	8	2,400,000
	Tank Truck	16	(c)	12	(c)	16	(c)
	Aircraft	2	(c)	1	(c)	2	(c)
	Oily beach cleaner	20	2,000,000	10	1,000,000	20	2,000,000
	Front-end loader	20	(c)	10	(c)	20	(c)
	Truck	80	(c)	40	(c)	80	(c)
	Dredge/pump system	2	(c)	1	(c)	2	(c)
			68,790,000		61,040,000		71,640,000

a. Quantities in parentheses represent the number of the total recommended fleet required to support dispersant operations.
b. Typical equipment and supply costs, but do not include shipping costs.
c. Can serve multiple purposes in addition to spill response; costs therefore are not provided.
d. Preliminary recommendations do not include desalination plants (except at Jubail Industrial Port) or military harbors (except for Jubail). In general, detailed information was not available for other facilities.

Source: Extract from MEPA 1991

Table 5-21

Design Spill Response Equipment and Supplies Recommendations for Subareas R-1, R-2, and R-3

Type	Description	Subarea R-1 (5,000 bbl, ~685 tonnes) Design Inventory[a]	Subarea R-1 Cost (SR)[b]	Subarea R-2 (1,000 bbl, 137 tonnes) Design Inventory[a]	Subarea R-2 Cost (SR)[b]	Subarea R-3 (1,000 bbl, 137 tonnes) Design Inventory[a]	Subarea R-3 Cost (SR)
I. Skimmers	Offshore (350-600 bbl/hr)	1	1,000,000	1	1,000,000	1	1,000,000
	Harbor (70-200 bbl/hr)	3	4,500,000	2	3,000,000	2	3,000,000
	Shallow-water (10-50 bbl/hr)	4	400,000	2	200,000	2	200,000
II. Booms	Offshore	500 m	750,000	500 m	750,000	500 m	750,000
	Harbor	1,500 m	750,000	1,000 m	500,000	1,000 m	500,000
	Shallow-water	2,500 m	400,000	1,000 m	200,000	1,000 m	200,000
	Sorbent	2,000 m	1,000,000	1,000 m	500,000	1,000 m	500,000
	Exclusionary[d]	3,200 m	4,800,000	1,000 m	1,500,000	3,500 m	5,250,000
III. Chemicals	Dispersants	500 bbl	750,000	100 bbl	150,000	100 bbl	150,000
	Collectants	10 bbl	20,000	2 bbl	4,000	2 bbl	4,000
IV. Sorbents	Synthetic	4 tonnes	160,000	1 tonnes	40,000	1 tonnes	40,000
V. Miscellaneous	Offshore vessel	3	(c)	3	(c)	3	(c)
	Utility boat	6	(c)	4	(c)	4	(c)
	Workboat	8	(c)	4	(c)	4	(c)
	Inflatable boat	8	320,000	4	160,000	4	160,000
	Dracone/barge (1,000 bbl)	5	5,000,000	1	1,000,000	1	1,000,000
	Dracone/barge (250 bbl)	2	600,000	2	600,000	2	600,000
	Fireboat	1-3	(c)	1-3	(c)	1-3	(c)
	Van	14	(c)	8	(c)	8	(c)
	Vacuum truck	2	600,000	1	300,000	1	300,000
	Tank truck	4	(c)	2	(c)	2	(c)
	Aircraft	1	(c)	1	(c)	1	(c)
	Oily beach cleaner	3	300,000	1	100,000	1	100,000
	Front-end loader	3	(c)	1	(c)	1	(c)
	Truck	12	(c)	4	(c)	4	(c)
	Dredge/pump system	1	(c)	1	(c)	1	(c)
			21,350,000		10,004,000		13,754,000

a. Quantities in parentheses represent the number of the total recommended fleet required to support dispersant operations.
b. Typical equipment and supply costs, but do not include shipping costs.
c. Can serve multiple purposes in addition to spill response; costs therefore are not provided.
d. Recommendations do not include desalination plants (except at Yanbu Industrial Port) or military harbors (except for Jeddah). In general, detailed information was not available for other facilities.

Source: Extract from MEPA 1991

Table 5-22

Recommended Spill Response Equipment Inventory Locations (Local Response Centers)

Type	Description	Coastal Subareas A-1	A-2	A-3	R-1	R-2	R-3
I. Skimmers	Offshore	Ras Al-Khafji (AOC/ARAMCO)[a]	Jubail Port Complex (JWG)[a]	Ras Tanura (ARAMCO)[a]	Yanbu Industrial Port (SPA)[a]	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
	Harbor/shallow-water	Ras Al-Khafji (AOC)	Jubail Port Complex (JWG)	Ras Tanura 50%, Damman 50%	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
II. Booms[b]	Offshore	Ras Al-Khafji (AOC/ARAMCO)	Jubail Port Complex (JWG)	Ras Tanura (ARAMCO)	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
	Harbor/shallow-water/sorbent	Ras Al-Khafji (AOC)	Jubail Port Complex (JWG)	Damman (SPA)	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
III. Chemicals	Dispersants/Collectants	Ras Al-Khafji (AOC/ARAMCO)	Jubail Port Complex (JWG)	Ras Tanura 80% Damman 20%	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
IV. Sorbents	Synthetic	Ras Al-Khafji (AOC/ARAMCO)	Jubail Port Complex (JWG)	Ras Tanura 80% Damman 20%	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
V. Miscellaneous	Offshore vessel	Ras Al-Khafji (AOC/ARAMCO)	Jubail Port Complex (JWG)	Ras Tanura (ARAMCO)	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
	Dracone/barge (1,000 bbl)	Ras Al-Khafji (AOC/ARAMCO)	Jubail Port Complex (JWG)	Ras Tanura (ARAMCO)	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
	Aircraft	Ras Al-Khafji (AOC/ARAMCO)	Jubail Port Complex (JWG)	Ras Tanura (ARAMCO)	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)
	Other	Ras Al-Khafji (AOC/ARAMCO)	Jubail Port Complex (JWG)	Damman (SPA)	Yanbu Industrial Port (SPA)	Rabigh (Petromin)	Jeddah Port Complex (Petromin/SPA)

a. AOC = Arabian Oil Company, Ltd.; JWG = Jubail Working Group; SPA = Saudi Ports Authority.
b. Exclusionary boom recommendations and locations are presented in Table 5-6.

Note: Ras Al-Khafji is the best protected harbor in Subarea A-1 and would be used as a base for offshore response equipment for both AOC and ARAMCO. However, ARAMCO may select an alternative base for their equipment closer to Safaniyah.

Source: Extract from MEPA 1991

evaluating the adequacy of present spill response capabilities for coastal subareas and to specify improvements as warranted. It should be noted that an alternative approach would be to have only one centralized response center for the Gulf coast and one for the Red Sea Coast of Saudi Arabia. Initially this might be a more manageable arrangement but would result in greater deployment/travel times.

CONCLUSION

Since its foundation, the Kingdom of Saudi Arabia has realised that oil and other mineral resources are although valuable, but of a non-renewable nature. The Kingdom has therefore, wisely issued a main policy to invest the available non-renewable resources for establishing the necessary infrastructure needed to ensure a long-life prosperity for its citizens and the future generations. Various developments have taken in this respect, which when compared with achievements even of well technologically advanced, shows a remarkably fast development.

The length of Saudi Arabian Coastline is along both the Red Sea and Arabian Gulf, approximately 1214 NM. Consequently, the country does own within its realm a treasure of Natural Resources of both renewable and non-renewable natures. Such resources can represent a considerable share in the national income of the Kingdom.

Oil, on the other hand is the Kingdom's main export to various parts of the world and its influence to strengthen the national economy should not be ignored. On the other hand, oil does have an adverse effect on some other resources, mainly fishing and sea water used in distillation plants producing potable water for human use. It may be important in this context to point out that distillation plants represent the main source of potable water for the most major part of the Kingdom. Additionally, it may be added that the Kingdom has long coast of golden sandy beaches, which will be widely utilized for tourism. The effect of having all these lovely beaches, as it is now being polluted is indeed heartbreaking and woeful.

Having taken into consideration, that the preventive measures do not stop the oil spill and there is great potential of an oil spill when transfered from tanks to tankers or by collision. Therefore, by having appropriate oil spill response action, associated equipment, supplies could make any oil spill under control at all times.

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