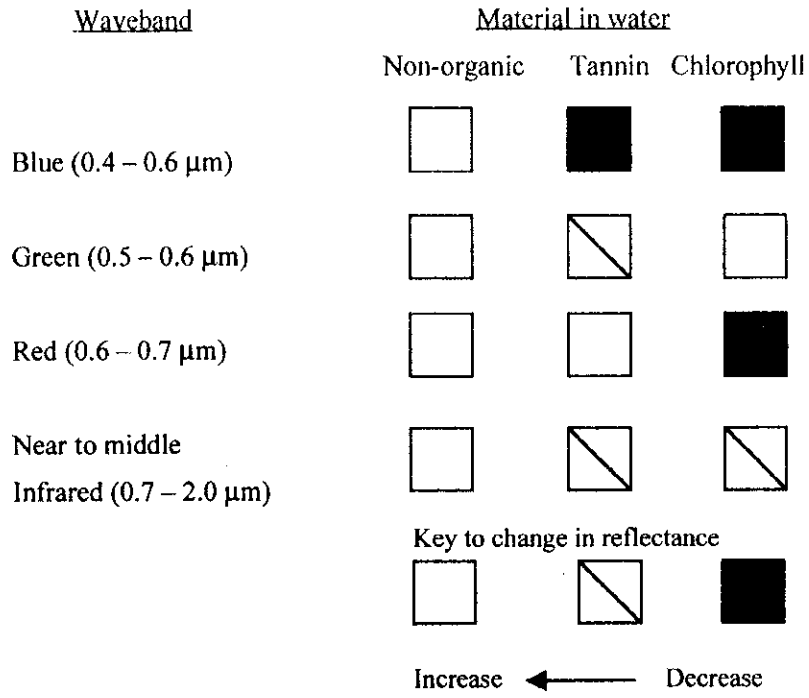


Figure 3.1.3 The relationship between the presence of materials within a water body and its reflectance in blue, green, red and near to middle infrared wavebands.

3.1.6 Water Quality *VS.* LANDSAT Data – Literature Reviewed

1) Introduction

Water quality degradation is caused by organic waste, industrial discharge or oil spills. Sunlight entering a water body is subjected to change because of absorption, scattering and reflection, and the upwelling light carries information about water quality. For instance, the spectral nature of the light just above the surface of water body where chlorophyll concentration is high will be different from that reflected by suspended sediment with little sediment. Multispectral Scanner (MSS) and TM from the LANDSAT series of satellites have shown great potential in water resources assessment.

2) Suspended Solids

LANDSAT images provide a synoptic view of the coastal region and are ideal for mapping turbidity or suspended sediment distribution pattern. The satellite image from the ocean, in the visible bands, has its characteristics determined by the properties of light interaction with water and with its suspended and dissolved constituents.

An example of the wavelength relationship with the reflectance characteristics of the suspended solids is shown in Figure 4.2.4 (Ritchie et al. 1976). One can see that reflected solar radiation between 0.45 – 0.90 μm (micrometer) increased as the concentration of suspended sediment increased. The peak of reflected solar radiation shifted from 0.55 μm at low sediment concentration to above 0.60 μm at higher sediment concentrations. This kind of study indicates the feasibility of using LANDSAT data (Lo, 1986).

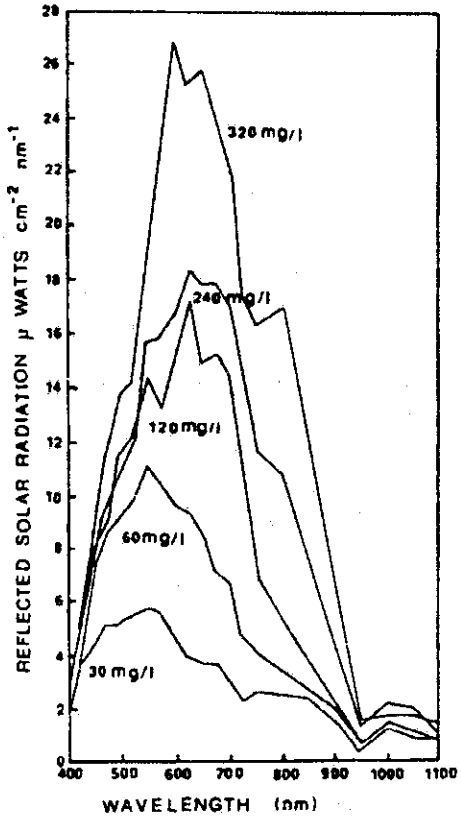


Figure 3.1.4 Reflectance characteristics at varying wavelength.

Since the launching of MSS of LANDSAT and Coastal Zone Color Scanner (CZCS) of NIMBUS Satellite in the '70s, many empirical studies have related water quality parameters and remote sensing data. For example, Klemas et al. (1974) related spectral responses of MSS Band 5 (red region, 0.60 – 0.70 μm), 80m resolution, with total suspended solids (TSS) and water circulation patterns. Saitoh et al. (1979) and Muralikrishna (1983) also used the MSS, Bands 4 (green region, 0.50 – 0.60 μm) and 5 to estimate suspended solids. Tassan (1981), working between radiance in the 0.59 μm and 0.68 μm bands to determine sediment concentrations

The remote sensing literature also shows a strong disparity between tests to identify the most appropriate bands or combinations of bands to study the same water quality parameters for different places with different satellite overpasses (Braga, 1990). This suggests the need for more field data acquired simultaneously with satellite imagery to assess the actual potential of remote sensing in water quality studies. Braga et al. (1993) conducted the principal component analysis (a method of digital data compression) of TM Bands 1-4 and reported the greatest amount of spectral information related to suspended sediments in Guanabara Bay, Brazil.

3) Chlorophyll *a*

Chlorophyll *a* is regarded as an important environmental parameter indicative of the water quality, nutrient contents and pollution effects in coastal zones, not simply as an indicator of water productivity. Changes in the color of the sea level patterns indicate the concentration of phytoplankton and sediment in the surface layer. Each phytoplankton pigment presents its typical reflectance curve. The pigment composition varies according to the phytoplankton species. A case study of the reflectance pattern of the phytoplankton is shown in Figure 3.2.5. For a given concentration of the yellow substance, sand and humus, five different values for the extinction coefficient of phytoplankton were plotted to show changes in reflectance for different chlorophyll concentrations. The values near 0.5 μm acts like a hinge; lower reflectance is observed in the blue, with increasing reflectance toward the green and red bands (Manual of Remote Sensing, 1983).

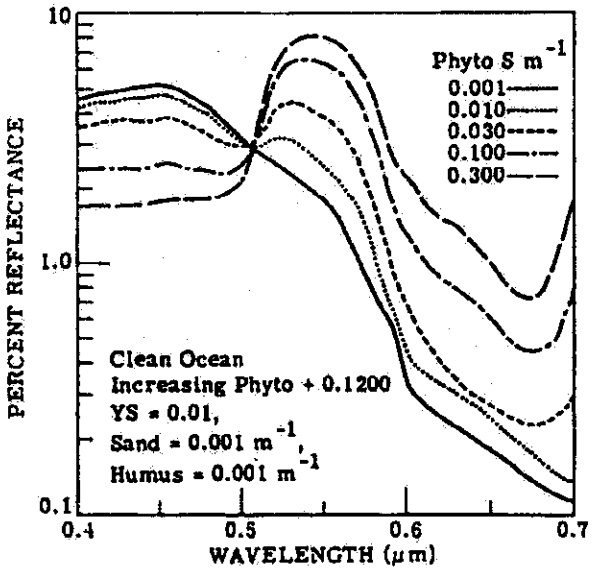


Figure 3.1.5 Reflectance characteristics of phytoplankton.

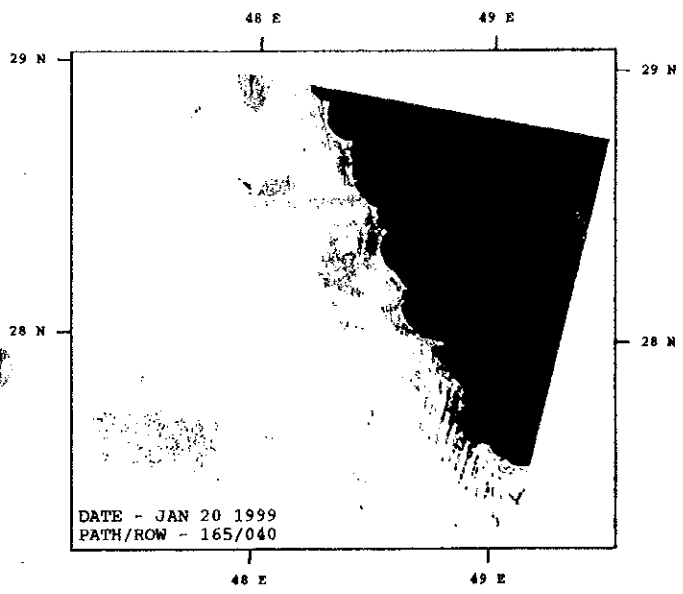
Numerous studies have been published mapping chlorophyll distributions, estimating chlorophyll concentrations and identifying algal species composition through the utilization of remote sensing. In 1972, with the LANDSAT program, there was an increase in the use of remote sensing data for estimating chlorophyll concentration. LANDSAT/TM data started to be considered for chlorophyll model development from 1986 (Grunwald et al., 1986; Ekstrand, 1991). Mizuo et al. (1993) observed chlorophyll *a* relationship with TM band 4 and other band combinations. Yacobi et al. (1995) applied a regression model to detect chlorophyll concentrations using high-spectral-resolution radiometer and LANDSAT/TM. Schooley (1996) utilized TM imagery combined with ground-truth data to model water quality in Barnegat Bay, USA and maps were produced for chlorophyll *a*, salinity and temperature. Allee and Johnson (1999) reported that TM band could explain a substantial proportion of variance within the measured chlorophyll *a* concentrations at the time of satellite flyby.

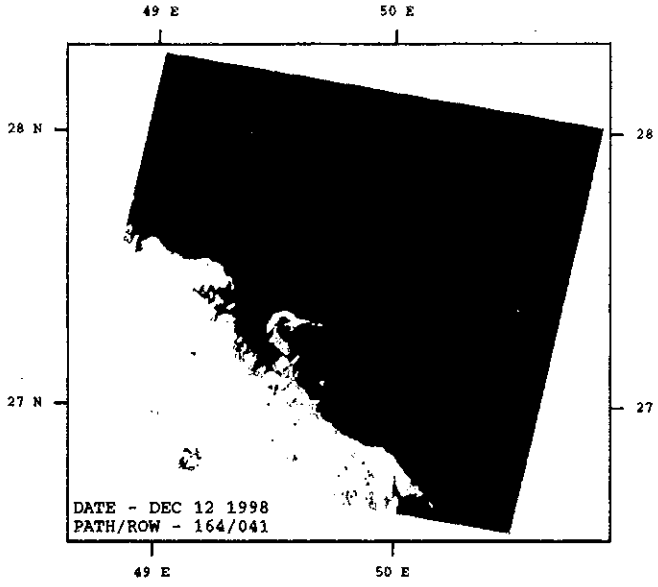
4) Oil Pollution

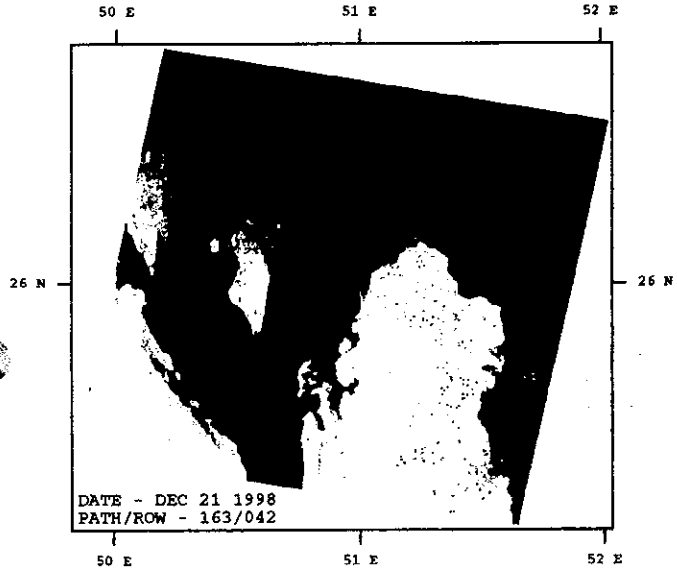
Oil spill monitoring is very important aspect considering the environmental sensitivity of the potential areas of impact. Multispectral data is widely used to map oil slicks that occur offshore due to leaks from oil-drilling platforms, pipelines, or accidental ship discharges. Satellites have shown the capability of monitoring large oil spills in marine waters. Studies have shown that oil-detection in general, several bands are useful but the ultraviolet and the thermal infrared regions consistently provide best contrast between oil and seawater.

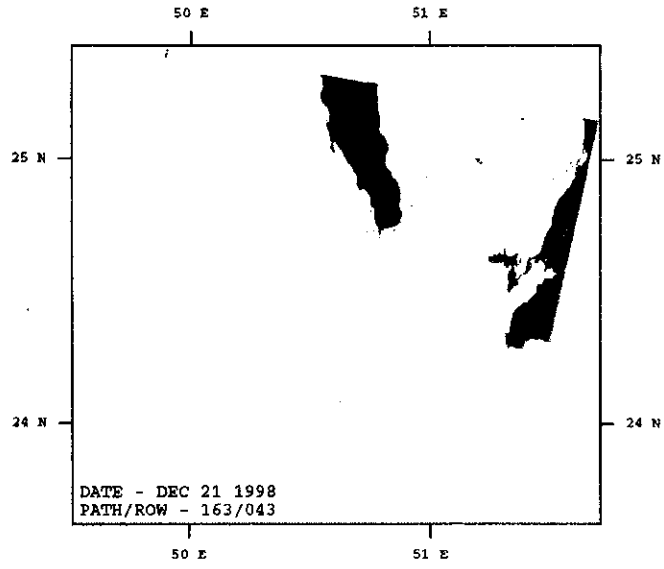
The use of satellite remote sensing for oil pollution has been attempted several times. The slick from the 1978 IXTOC-I well blowout in Mexico was detected using Geostationary Operational Environmental Satellite (GOES) and also by NOAA and the LANDSAT satellite. A blowout in the Persian Gulf was subsequently detected. In both cases, the data was studied for several days to identify features associated with the known spill site. Several workers were able to detect the Arabian Gulf War Spill in 1991 (Fingas et al. 1998). The oil spill along the eastern coast of Saudi Arabia was detected and monitored during the early part of 1991 utilizing the mid infrared (1.55 – 2.35 μm) bands combined with the visible (0.45 – 0.6 μm) bands of TM sensors (Ibrahim et al. 1992).

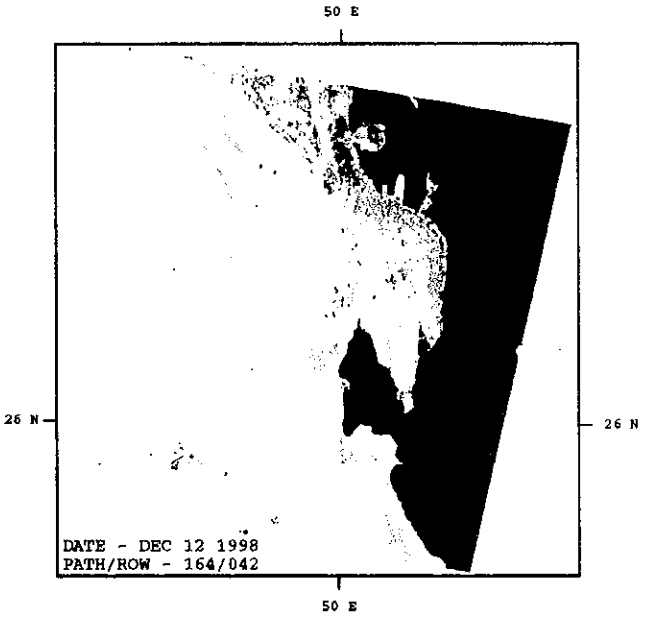
False Color Composite Images - Arabian Gulf, Saudi Arabia











LANDSAT/TM Images
Bands - R:G:B :: 4:3:2

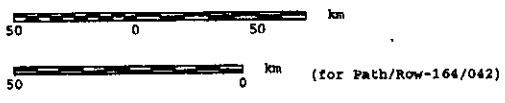


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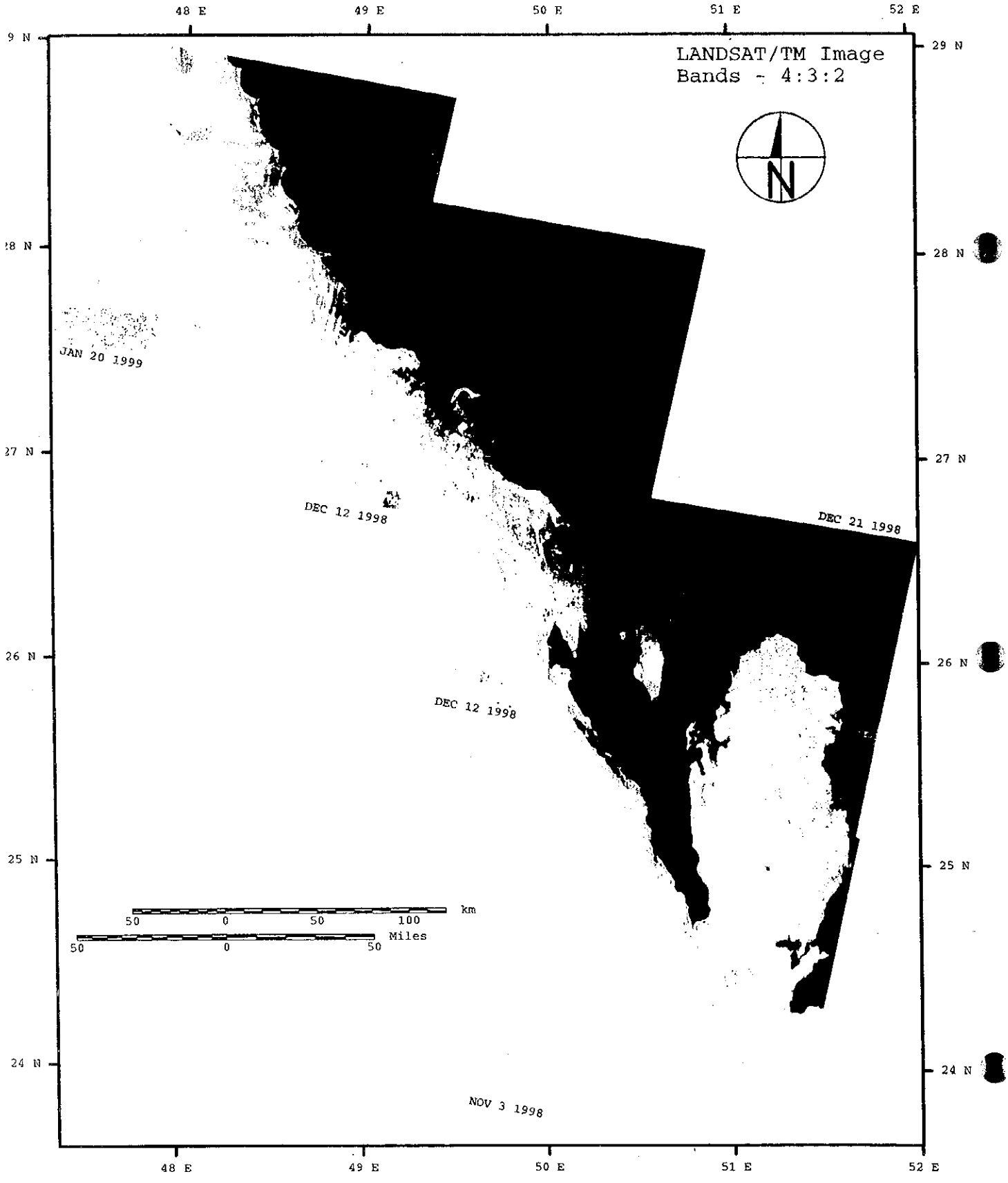
PLATE 1

False Color Composite Image - Arabian Gulf, Saudi Arabia



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CHIYODA-DAMES & MOORE CO., LTD.

PLATE 2


49 E
50 E
27 N
27 N
26 N
26 N
50 E

3.1.7 Analysis of the TM Data for the Present Study (Third Work Stage)

(1) Suspended Solids Distribution Map

1) Methodology

The Principal Component Analysis (PCA) was conducted for total suspended solids (TSS) distribution. PCA is often used as a method of data compression. It allows redundant data to be compacted into fewer bands, i.e., the dimensionality of the data is reduced. The bands of PCA data are non-correlated and independent, and are often more interpretable than the source data (Jensen 1996). The TM bands 1, 2, 3 & 4 were subset for the PCA after the land had been separated by generation of mask derived from water classification on TM 4. Thus, the PCA was applied to TM bands 1, 2, 3, and 4 on the seawater only. The PCA Band 2 (PCAB2) was chose following the method of Braga et al., 1993. The resultant images were mosaiced for preparing the Suspended Solids Distribution Map at 1:500,000 scale (Plate 4). The subsequent quantitative analysis could not be performed due to lack of *in situ* measurements and laboratory analysis of water samples for the satellite data acquisition dates.

2) Results and Discussion for Suspended Solids Distribution

PCAB2 analysis showed the spectral information related to the water quality in the Arabian Gulf. The distribution was categorized to six levels. The red color indicates the highest and dark blue the minimum or negligible distribution level (red>orange>yellow>green>cyan>blue). The effects of clouds on the distribution can be also seen in the images (in NE for path/row – 165/049, NW for path/row – 164/041, Plate 4). The result shows the greatest amounts of suspended solids were concentrated near the coastal region. The shallow coastal depths have also reflected the high sediment concentrations.

High SS concentration was obtained as 12 mg/L for T7 site (conducted by the Study Team in October – November 1999, see section 4.3) and the TM analyzed results have also indicated the Red color. The SS was 2 mg/L for the control site J1 and the color is indicated as Cyan. For T4 the measured SS was 9 mg/L and image shows Orange color distribution. Other sampling points have also shown agreeable results. We can observe the analyzed TM images in accordance to the measured *in situ* data although the sampling dates and the TM data acquisition dates are wide apart.

(2) Chlorophyll Distribution Map

1) Methodology

In the present project the chlorophyll distribution map was prepared by utilizing the TM 4. The TM Band 4 lies in near infrared region (0.76 – 0.90 μm), has the features of complete absorption by water, high land water contrasts and very strong vegetation reflectance. The TM band 4 was subset out of the TM's 7 bands and level slice was performed for each image. Level slicing is an image enhancement technique whereby digital numbers distributed along the x-axis of an image histogram are divided into a series of analyst-specified intervals or "slices" (Lillesand and Kiefer, 1994). The TM 4 data have been level sliced into multiple levels for determining the chlorophyll distribution for each images and finally five categories were established and mosaicked for preparing the chlorophyll distribution map at 1:500,000 scale. The red color indicates the highest and dark blue the lowest distribution (red>yellow>green>cyan>blue). Subsequent quantitative analysis could not be carried out due to lack of *in situ* measurements and laboratory analysis of water samples for the satellite data acquisition dates.

2) Results and Discussion for Chlorophyll Distribution

The distribution was categorized to five levels. The red color indicates the highest and dark blue the least distribution level (red>yellow>green>cyan>blue). The effects of clouds on the distribution can be also seen in the images (in NE for path/row – 165/049, NW for path/row – 164/041, Plate 5). The chlorophyll distribution was observed to concentrate along the nearest coastal areas. Less distribution of the chlorophyll can be attributed due to presence of higher concentration of the suspended solids, especially when both materials are spatially associated (Alfoldi, 1982). The *in situ* sampling (conducting during October – November, 1999) analysis results showed very less chlorophyll *a* detection for J4, J6, J7 and other areas. The TM analyzed images also show similar results (Cyan color distribution, Plate 5) although the date of satellite flyby was wide apart.

(3) Oil Pollution Distribution Map

1) Methodology

The TM Band 5 was considered for this analysis. The TM band 5 ranges from 1.55 - 1.75 μm (intermediate infrared wavelength region). The TM Band 5 was subset out of the 7 bands and was density sliced into 4 classes (red>yellow>cyan>blue) to obtain the variation of the digital values that indicate the possible oil pollution distribution in the study area (NASDA/EORC, 1997). Images were mosaicked (Plate 6) and map at 1:500,000 scale was prepared. The subsequent quantitative analysis could not be performed due to lack of *in situ* measurements and laboratory analysis of water samples for the satellite data acquisition dates.

2) Results and Discussions for Oil Pollution Distribution

The distribution map shows minor oily surface water micro-layers variations. If there is an apparent oil spill in the ocean, the pollution can be easily detected on the TM images. It seems that there was no oil spill on the date of TM data acquisition and therefore no apparent variation was observed for the analyzed TM images. The results of the *in situ* water quality sampling conducted during October – November 1999 did not show the presence of oil and grease for majority of the sampling sites in the Intensive study area, showing the agreement with the analyzed TM imageries. It should always be remembered however, that the oil spills are unique and often idiosyncratic, and therefore some spills will be far more amenable to detection by TM than others.

Suspended Solids Distribution - Arabian Gulf, Saudi Arabia

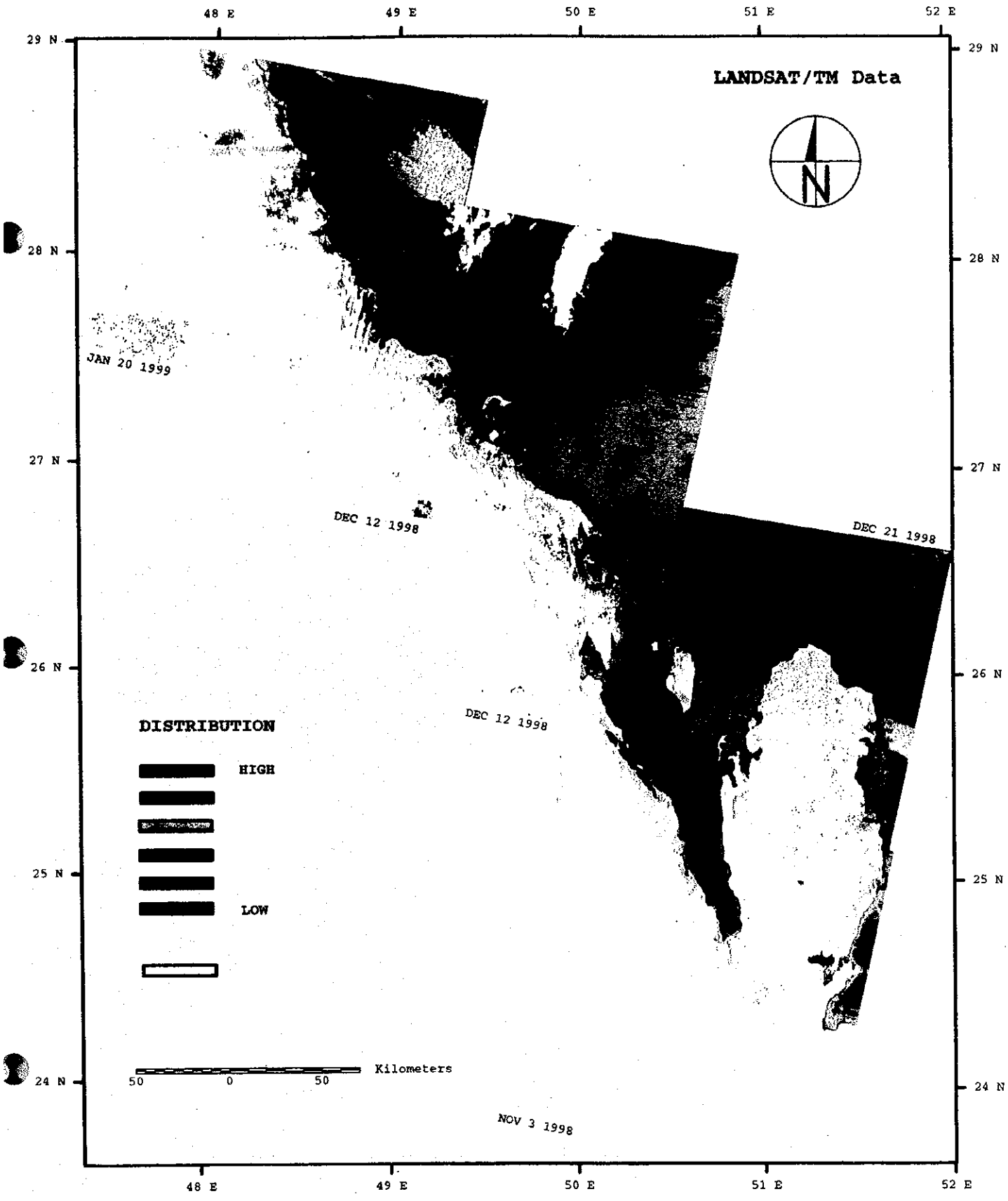

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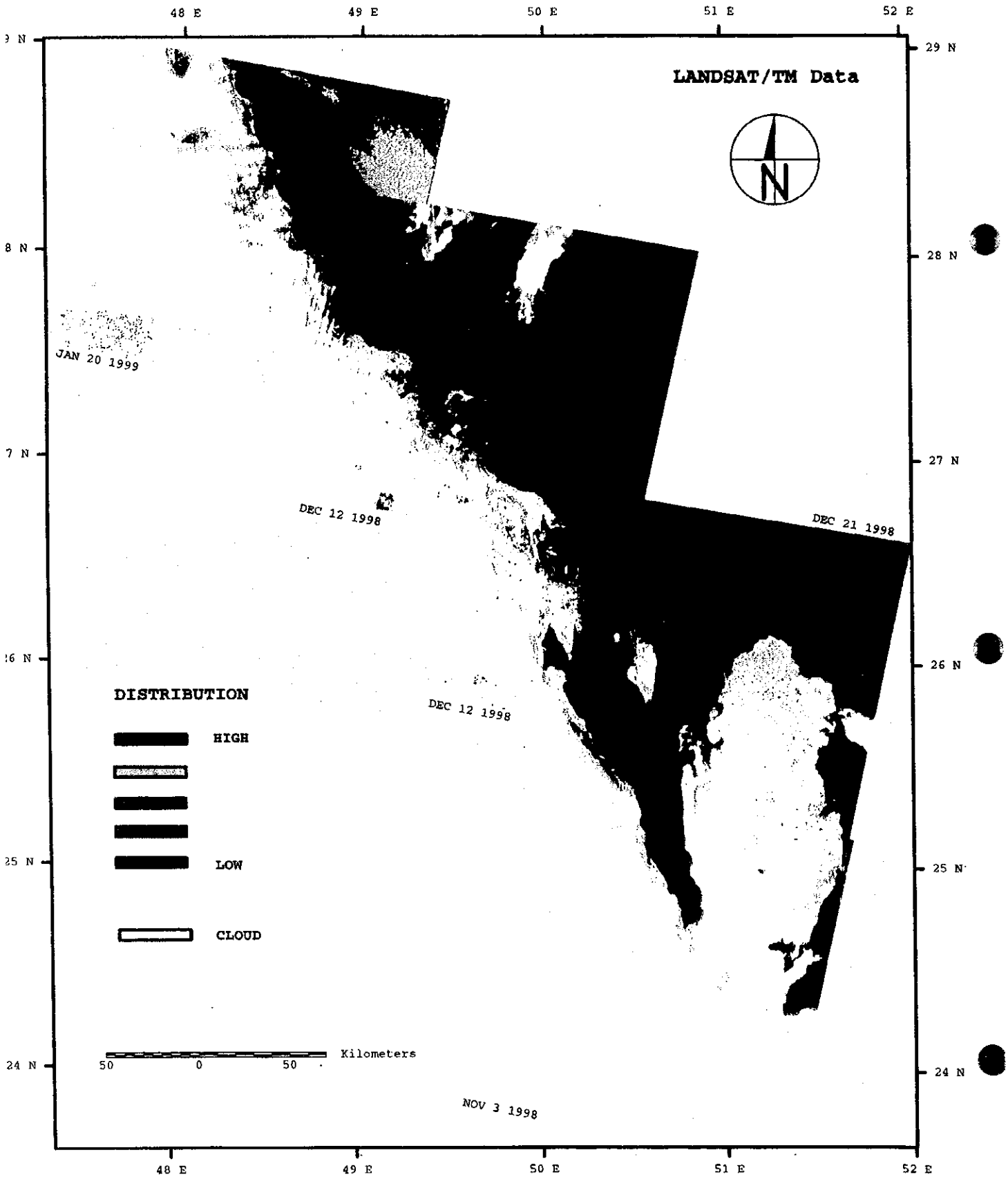
PLATE 4

Chlorophyll Distribution - Arabian Gulf, Saudi Arabia



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CHIYODA-DAMES & MOORE CO., LTD.

PLATE 5

Oil Pollution Distributio - Arabian Gulf, Saudi Arabia

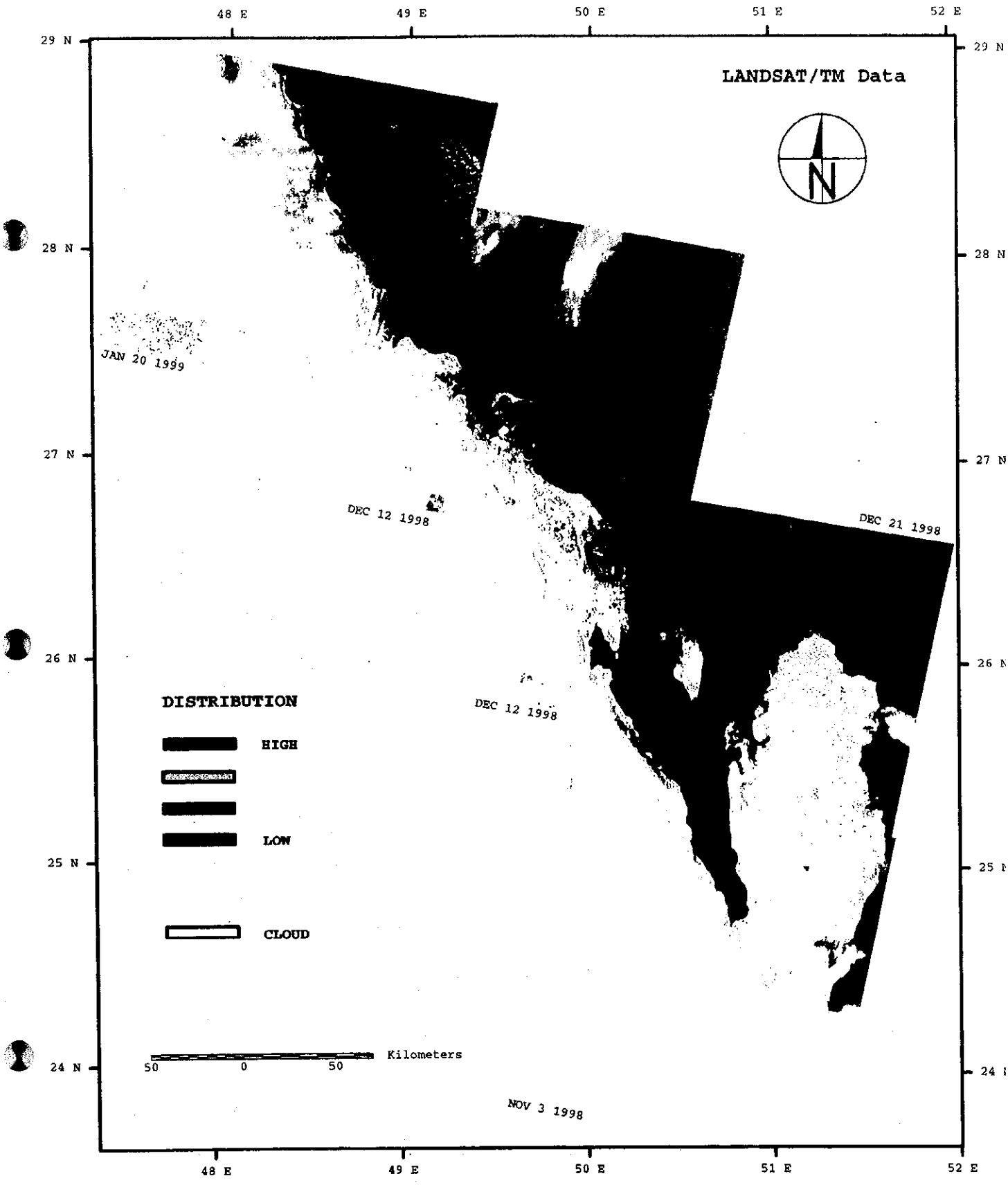

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PLATE 6

3.1.8 Analysis of the TM Data for the Present Study (Fourth Work Stage)

(1) Thermal Distribution

Monitoring of sea surface temperature is one of the most common applications of satellite remote sensing. The temperature distribution was performed for the first time in the present project utilizing appropriate TM's information.

1) Methodology

Sea surface temperature distribution was carried out by utilizing TM Band 6 (wavelength 10.4 to 12.5 micrometer, thermal infrared region) for the study area. Band 6 was a subset of the TM's 7 bands and image slicing was performed for each image. The Digital Numbers (DNs) of Band 6 are related to the thermal radiation. The DNs and corresponding temperatures were established (referring the conversion chart of the Remote Sensing Technology Center, Tokyo) for the temperature distribution of the intensive study area. Five categories for the temperature distribution were created for individual images. The images Path/Row 164/041 and 164/043 were mosaicked as both belonged to the same acquisition date, i.e., 12 October 1999. Image slicing, color-coding, recoding, mosaicking and statistical filtering were performed for the final map preparation. Plate 7 illustrates the thermal distribution coverage for the intensive study area.

2) Results and discussions

The temperature distribution for Path/Row164/041-042 ranged from a minimum of 23.5°C to a maximum of 30.6°C. For Path/Row 153/042 the range varied from 23.5 to 26.9°C. The overall temperature range of 26.5 to 27.5°C was observed from northeast (NE) to southern regions. Small patches of higher temperatures were distributed particularly in shallow areas and along the vicinities of the coastal regions where more industrial and residential activities are located (e.g., Jubail shared outfalls, SAFCO outfall etc.).

(2) Suspended Solids Distribution

1) Methodology

The laboratory analysis results of the seawater sampling, conducted during the period October 16 to November 8 1999, were utilized for the quantitative analysis of the suspended solids distribution. The digital values were extracted from TM Band 3 (0.63 to 0.69 micrometer wavelength range) for the satellite flyby sampling points of the intensive

study area, by referring to the Global Positioning System (GPS) observations. Total suspended solid (TSS) values were correlated with the DNs (r = 0.82, standard error of estimate = 1.389; some outlying points were dropped to achieve this value) and distributions were applied for the whole area. Image slicing, color coding, recoding, mosaicking and statistical filtering were performed for the final map preparation.

2) Results and discussions

The distribution range for the TSS varied from 0.45 to 6.77 mg/l for the TM image of 12 October 1999. The results showed higher distribution values along the coastal regions (e.g., the 3.16 to 4.51 mg/l was most common in the shallow water inshore areas; Plate 8). TSS range of 1.36 to 3.15 mg/l was widely distributed in mostly the offshore area. Although there was a time lag between the TM images and sample collection for a few days, a satisfactory distribution was observed for the region.

(3) Chlorophyll Distribution

1) Methodology

The TM Band 4 (0.76 to 0.90 micrometer range, near infrared region) was image sliced and distribution values were determined. Laboratory analyzed results for the chlorophyll distributions were utilized by referring the GPS locations and selecting the DNs for the Band 4. Ten sample sites were selected for generating the correlation between chlorophyll concentrations and DNs, a significant relationship was showed (r = 0.87 and standard error of estimate = 0.6113), and this calibration was applied for the whole data. Color coding, recoding, mosaicking and statistical filtering were performed for the preparation of the final distribution map.

2) Results and discussions

The distribution was divided into five categories ranging from 0.00 to 1.52 microgram/l for Path/Row 164/041-042 and 0.00 to 1.24 microgram/l for Path/Row 163/043 TM data, respectively. The quantitative analysis showed good correlation between the parameters. Generally low chlorophyll concentration were found for most of the whole intensive study area (Plate 9). Higher concentrations were present very close to the coastal sites, such as the northeast of Tarut Bay, the northeast side of Tarut Island, and Al Azaziz. Medium range (0.47 to 0.64 microgram/l) was observed in the NE parts of the image.

(4) Coastal Area Distribution

Coastal area distribution map was generated to depict the existing situation of the nearshore regions of the intensive study area. This was done for the first time as far as the present study is concerned by utilizing the TM data.

1) Methodology

TM Bands 1 to 4 (visible to near-infrared wavelengths) were utilized to classify the coastal areas. Unsupervised (automatic) classification was performed and initial 40 classes were generated for the coastal regions of the intensive study area. Interpretation was done and existing habitat maps (Executive Summary, Saudi Aramco Sustaining Research Project: Environmental Studies, Phase II, 1994) were referenced for finalizing and reducing the number of the classes. Fifteen classes were established. The present analysis shows the latest (October 1999) situation of the coastal region of the intensive study area. However, this classification still requires more detailed ground information for improving the classification accuracy and to reduce the spectrall confusions among some of the classes. P

2) Results and discussions

The classified image (Plate 10) shows that the largest distribution was the general "shallow water" followed by "very shallow" and "muddy/silty" areas. Most of the coastal areas (more than 50%) comprise modified habitats. The present classification shows the existing situation for the coastal areas, e.g., land fills, built-up areas, dredgged channels etc. Mangroves and coral reef occupied very small areas.

Temperature Distribution - Arabian Gulf, Saudi Arabia

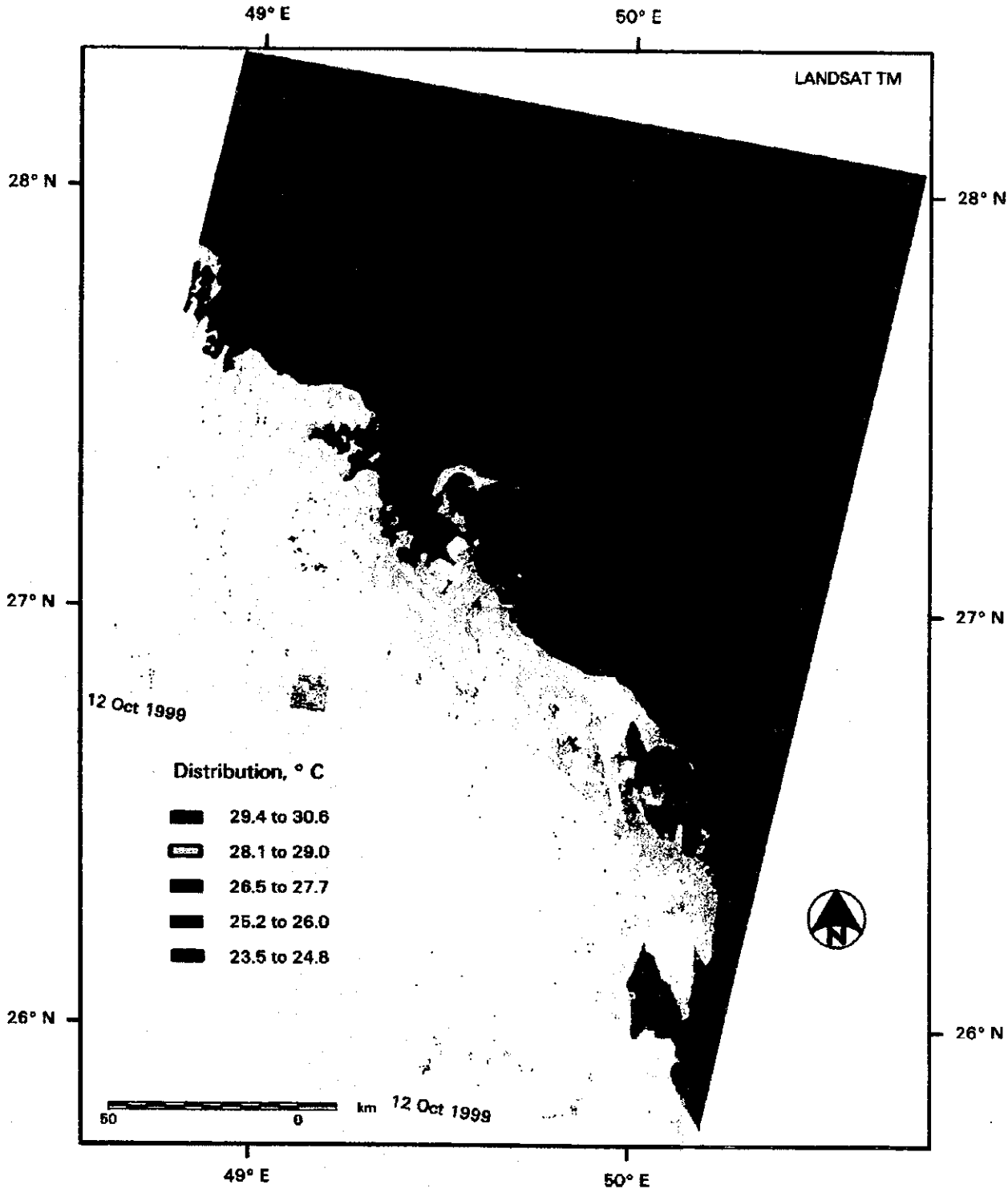

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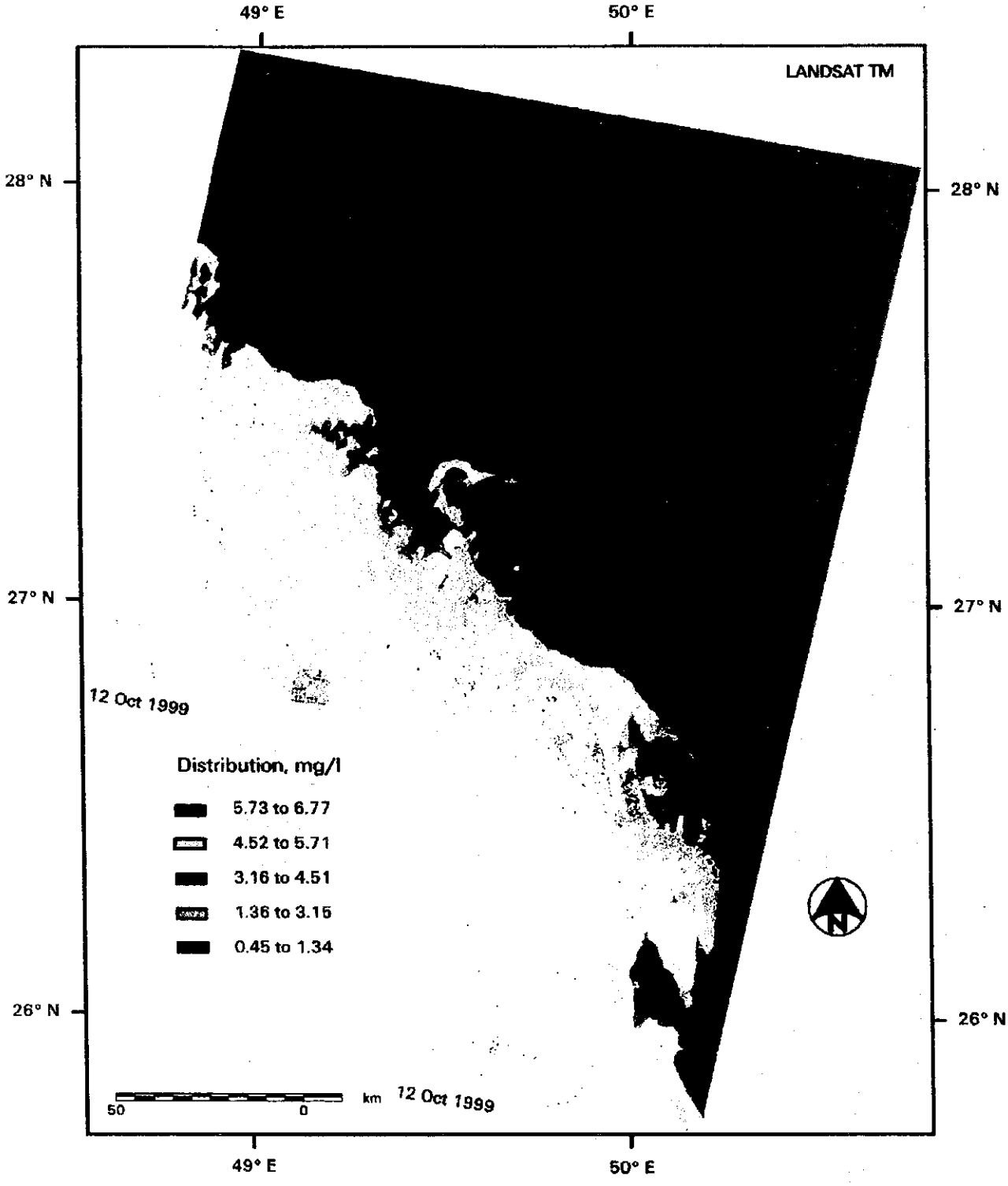
PLATE 7

Suspended Solids Distribution - Arabian Gulf, Saudi Arabia



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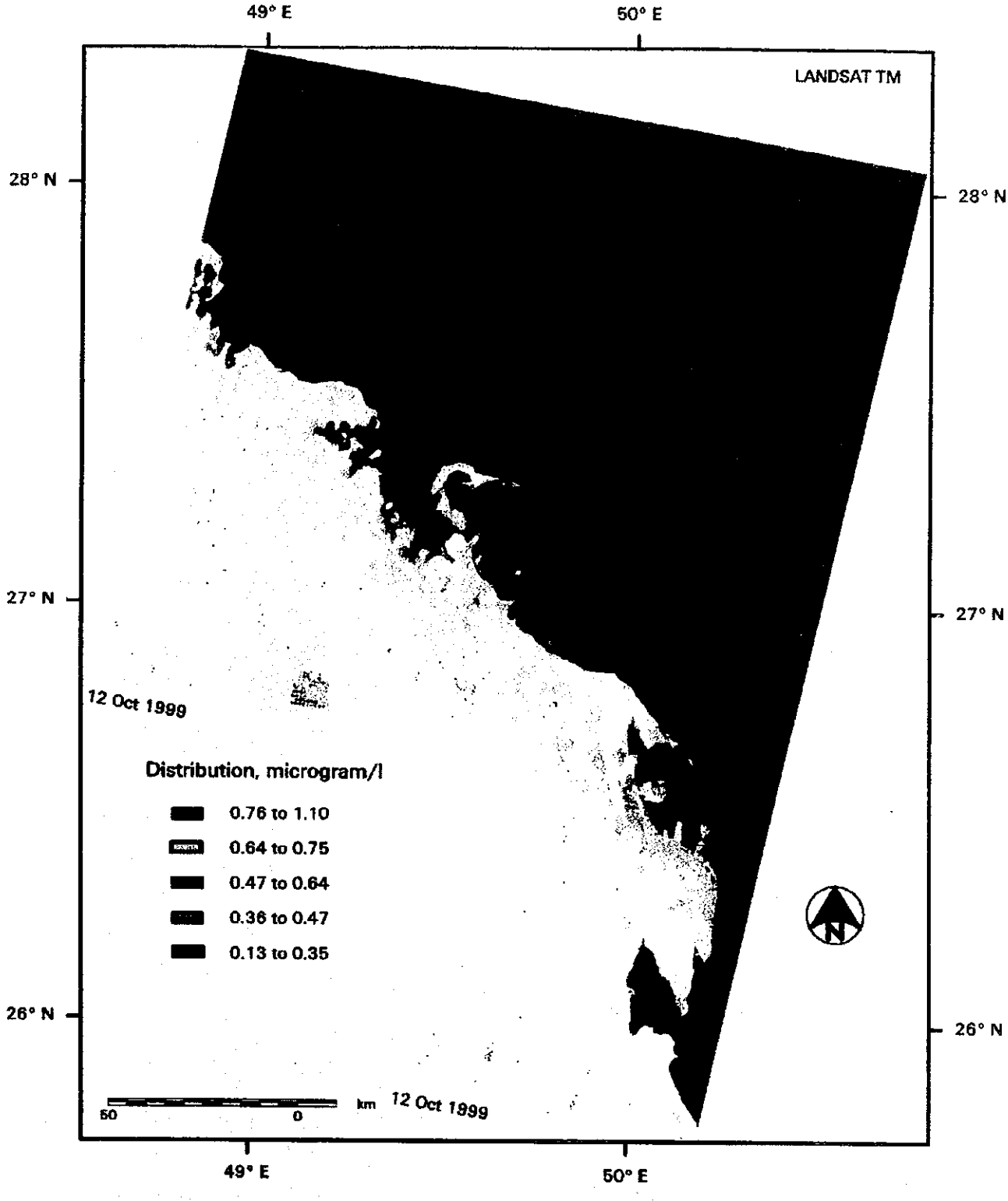
METEOROLOGY AND ENVIRONMENTAL PROTECTION ADMINISTRATION (MEPA)

PLATE 8

Chlorophyll Distribution - Arabian Gulf, Saudi Arabia



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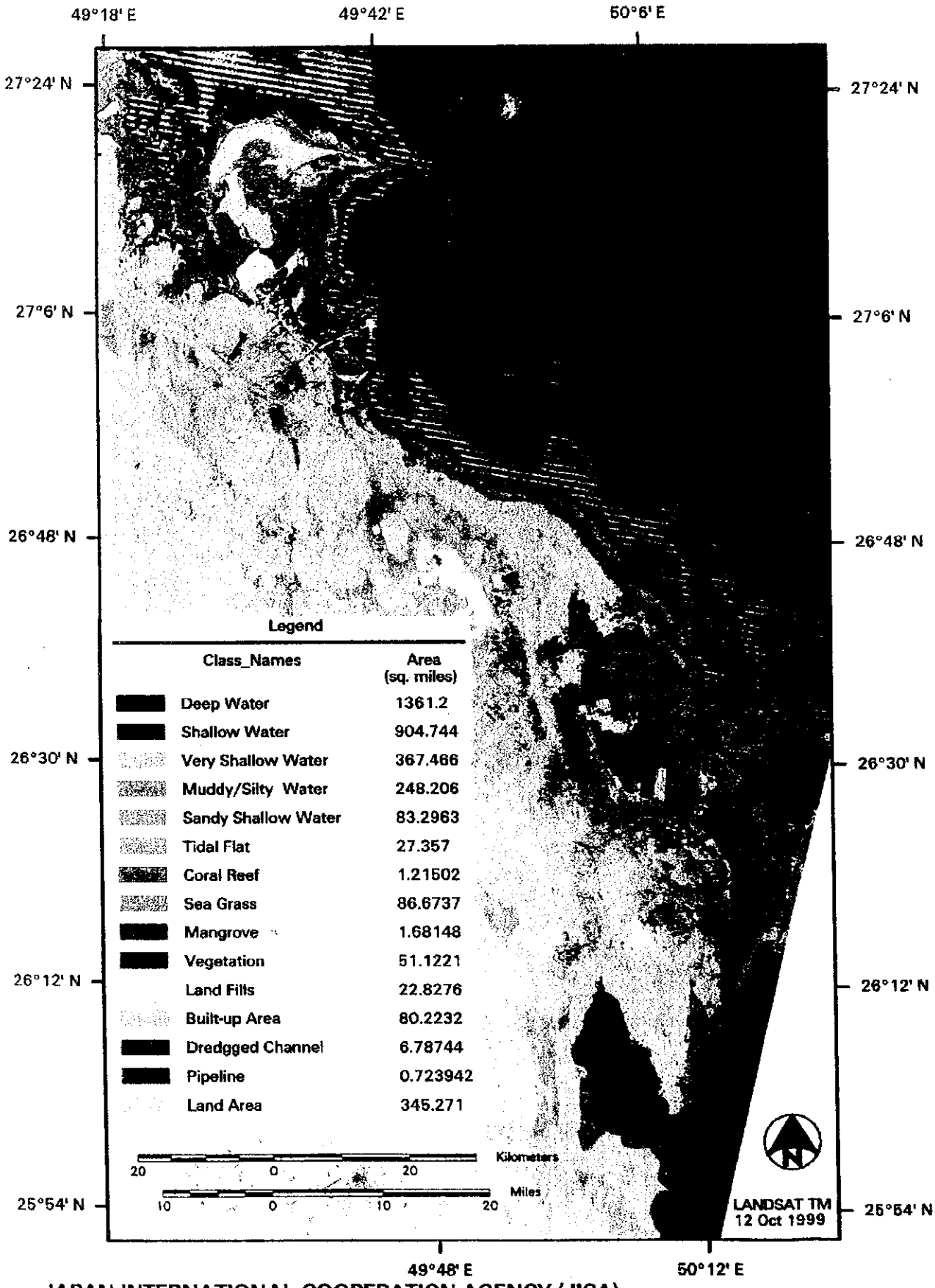
METEOROLOGY AND ENVIRONMENTAL PROTECTION ADMINISTRATION (MEPA)

PLATE 9

Coastal Mapping - Intensive Study Area, Arabian Gulf, Saudi Arabia



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METEOROLOGY AND ENVIRONMENTAL PROTECTION ADMINISTRATION (MEPA)

PLATE 10

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3.2 Preparative Field Inspection

In order to understand the general characteristics of the environmental condition of the Intensive Study Area and to collect information for monitoring plan preparation, field inspections were conducted.

For the purposes of both technology transfer and sampling location characterization, a total of 37 water/sediment samples were collected.

3.2.1 Objectives

The main objectives of the field inspection undertaken during the Second Stage (June-July 1999) were as follows.

Study area familiarization and site inspections within the Intensive Study Area.

Identify range of suitable sampling sites for the future water quality monitoring at potential future sampling stations.

Check operational logistics, requirements, navigation constrains, boat characteristics and performance, facilities, communications and liaison / coordination requirements with the Coastguard vessels and their crews.

3.2.2. Sites and Schedule

Field inspections and water samplings were conducted during the period June 13 to June 27. Laboratory analysis was conducted during he period June 19 to 28, 1999. Total of 38 sites that represented the main characteristics of the Intensive Study Area was inspected. The location of each site is shown in Figure 3.2.1 and schedule of inspection survey is shown in Table 3.2.1.

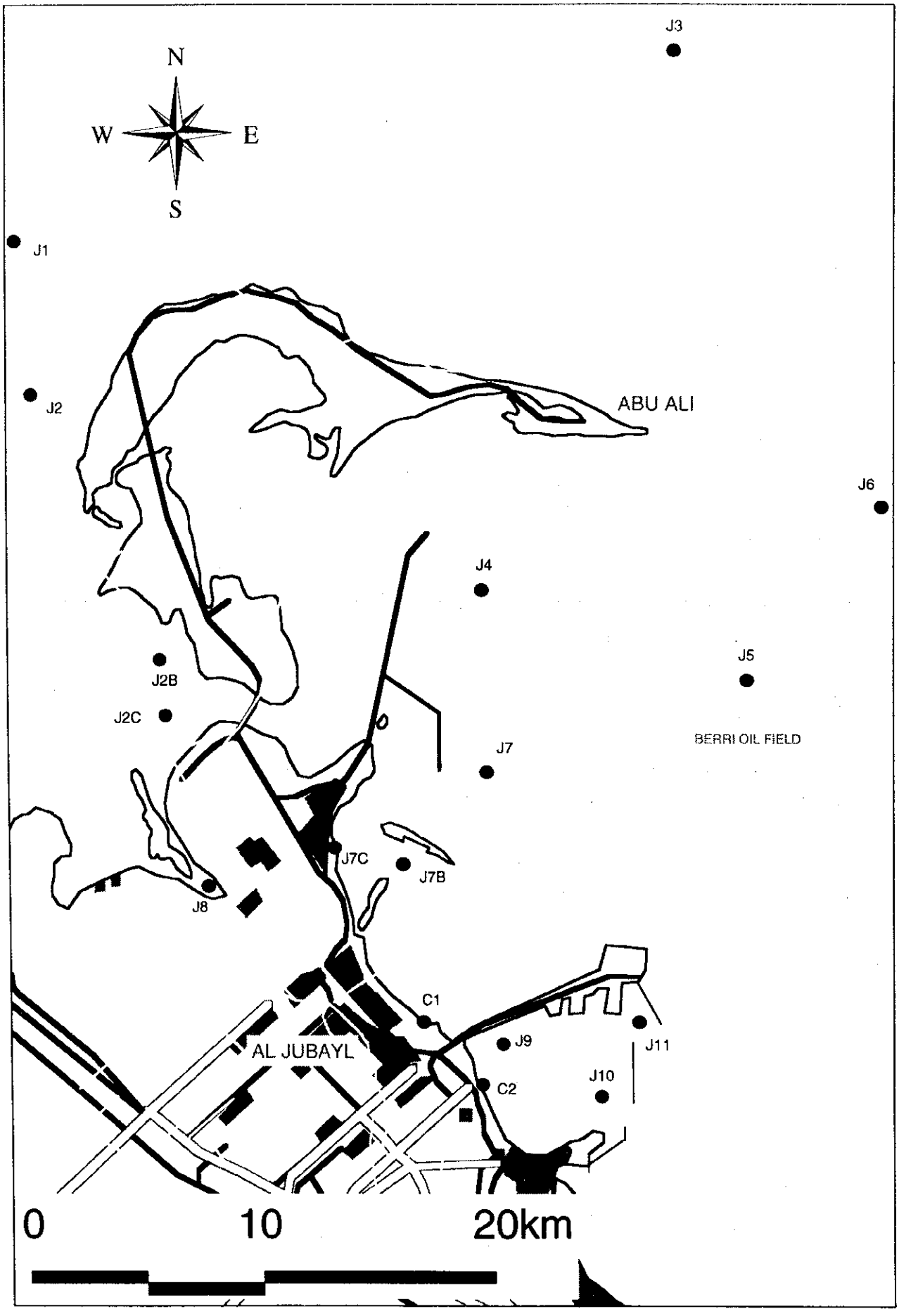


Figure 3.2.1 (1) Field Inspection Location

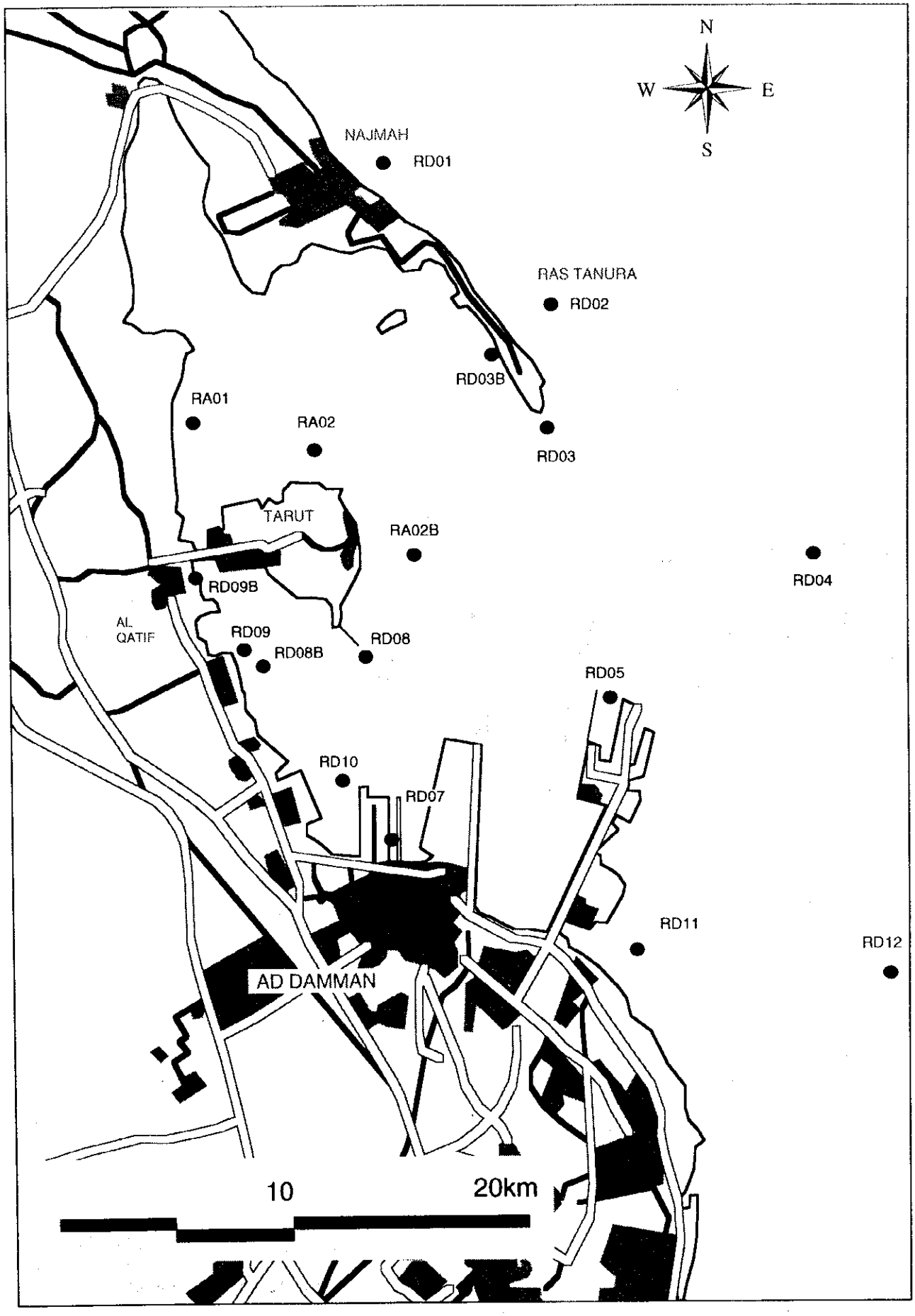


Figure 3.2.1 (2) Field Inspection Locacion

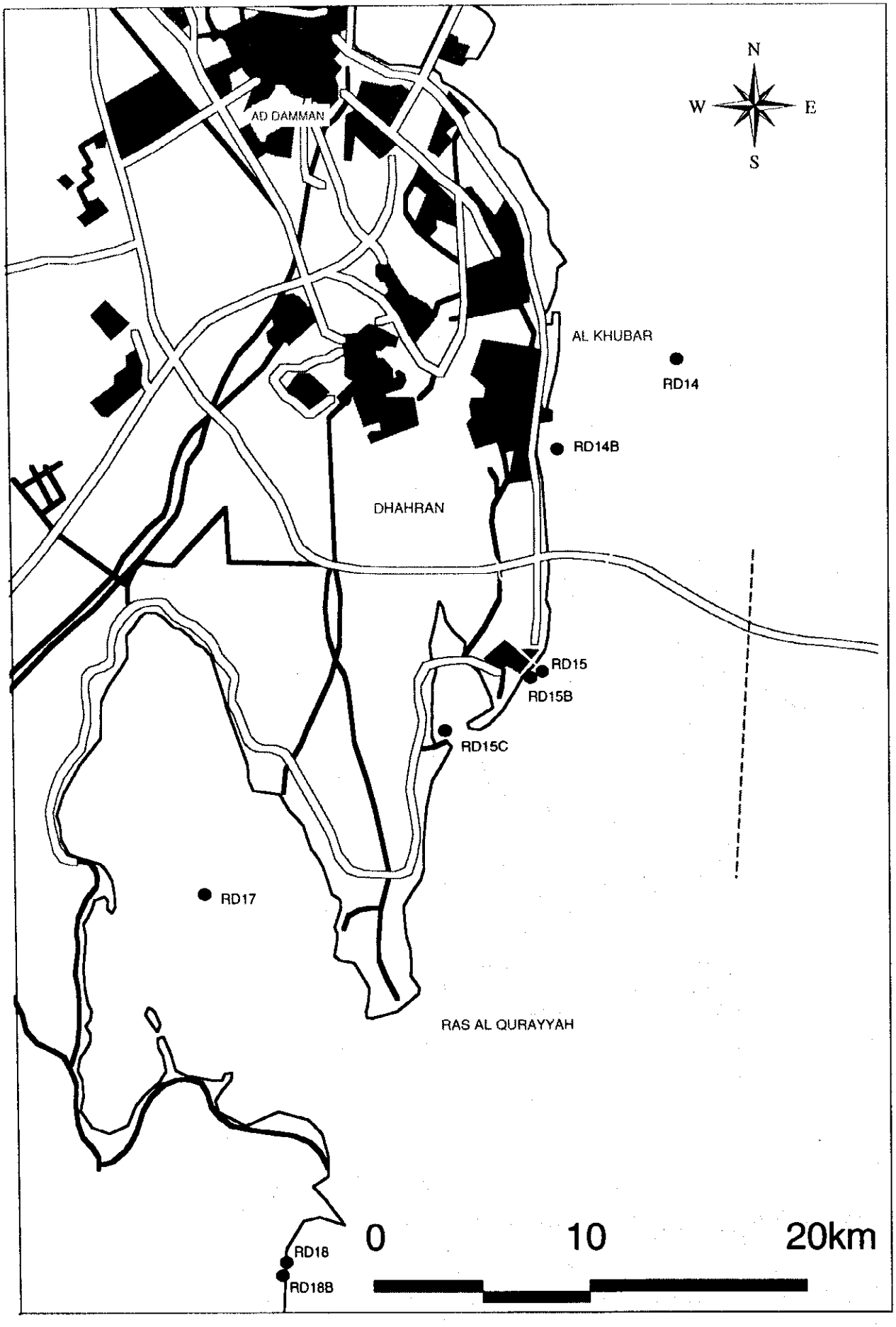


Figure 3.2.1 (3) Field Inspection Location

Table3.2.1 Site Inspection Schedule

Date	Region	Code of Inspected	Location Name
13.Jun.99	Al Jubail	J7A	ARAMCO South Terminal
	Al Jubail	J7B	Fanateera Island
	Al Jubail	J7C	Fanateera Marina
	Al Jubail	J9	Shared Industrial Outfall
	Al Jubail	J10	Jubail Harbour
14.Jun.99	Al Jubail	J11	Jubail Industrial Port Tank farm North
	Al Jubail	J3	Abu Ali North
	Al Jubail	J5	Berri Oilfield
	Al Jubail	J6	Outer Shoal
15.Jun.99	Al Jubail	J2B	Dawhat Dafi Bay
	Al Jubail	J8	Maduraigh Marina
	Al Jubail	C01	Storm outfall of Jubail Industrial City(1)
16.Jun.99	Al Jubail	C02	Storm outfall of Jubail Industrial City(2)
19.Jun.99	Ra's Tannurah	RD01	ARAMCO Oil Refinery Outfall
	Ra's Tannurah	RD02	Sea Island Termnl
	Ra's Tannurah	RD03	South Sand Spit
	Ra's Tannurah	RD03B	Platform reef (Almost dead)
	Ra's Tannurah	RD04	Marine coral reef (Najwah Island)
21.Jun.99	Tarut Bay	RA01	North side of Tarut Is
	Tarut Bay	RA02	Inshore north of Tarut
	Tarut Bay	RD8	Fishing Fleet jetty
	Tarut Bay	RD8B	South central Tarut
	Tarut Bay	RD9	Qatif Marina dredged
	Tarut Bay	RD9B	Qatif S/W drain
23.Jun.99	Dammam	RD10	Near ARAMCO Reclaim Island
	Dammam	RD11	SAFCO corner
	Dammam	RD12	Kaskus Island
	Dammam	RD4	Najwah Island
	Dammam	RD5	Dammam Harbour
	Dammam	RD7	Small boat Harbour
26.Jun.99	Al Khobar	RD14	Al Benhani Islet
	Al Khobar	RD14B	Sewage Outfall
	Al Khobar	RD15	Desalination intake
	Al Khobar	RD15B	Desalination outfall
	Al Khobar	RD15C	Residential marinas
27.Jun.99	HalfMoon Ba	RD17	Centre of HM Bay
	Al Qurayyah	RD18	Power station intake
	Al Qurayyah	RD18B	Power station outfall

3.2.3 Organization

The field inspection and the laboratory work were conducted under the leadership of Dr. Hilliard and Mr. Ohi respectively. Members of the two components were as follows:

Field Survey Team

Dr. Robert Hilliard (JICA)
Mr. Tomohiko Ike (JICA)
Mr. Yasuaki Kigushi (JICA)
Mr. Khalid Busbait (MEPA)
Mr. Khalid Al-Rasheed (MEPA)

Laboratory Team

Mr. Hiroyuki Ohi (JICA)
Mr. Mamoru Sato (JICA)
Mr. Qusai Bohlaiqah (MEPA)
Mr. Yousif H Al-Hilal (MEPA)

3.2.4. Water Quality Parameters and Methods

The following parameters were measured in the Intensive Study Area during the inspection survey:

Variable	Method
- Water depth (m)	: 20m&30m plastic tape and lead sinker
- Surface water current speed and direction	: Orange sub-surface floats and stopwatch
- pH	: Portable probe
- DO	: Portable probe
- Temperature	: Thermometer and portable probe
- Water clarity	: Secchi disc
- Water samples for MEPA laboratory training	: Vinyl bucket, 2 x 1L polyethylene sample bottles disposable sterile gloves, coolers and ice.
- Water Quality parameters	: TSS, COD_{Mn}, TS (number of samples: 37 sites)
- Seafloor inspections (for sites<5m)	:Snorkeling inspection, underwater photographs, and hand-held seafloor sediment sampler.

The water quality analyses have been practiced as follows:

Total Suspended Solids (TSS)

The TSS analyses were carried out by common filtrate-gravimetry method. Samples were filtered with pre-weighting glass-filter and rinsed with distilled water. Filtered samples were dried at 105 °C.

Chemical Oxygen Demand (CODMn)

The COD analyses were carried out by potassium permanganate method that is standardized in Japanese Industrial Standards. CODMn method is able to remove chloride ion influence. While the method provided by Standard Method or U.S. EPA, using potassium dichromate (CODCr), not enable to eliminate high chloride influence.

Total Solids (TS)

Chemical Oxygen Demand by potassium permanganate at The TS analyses was carried out by common evaporate-gravimetry method. Samples were dried at 105 °C

TS consist of TSS and TDS (Total Dissolved Solids). In seawater, TDS is much greater than TSS. Therefore the TS results can be regarded as nearly equal to TDS or salinity for the samples taken

3.2.5 Results and Study Area Characterization

Based on both the above site observations and information gathered, the characterization of the Intensive Study Area was discussed.

1) Field Measurements

The results of the field measurements are listed in Table 3.2.2. The field records provide no evidence for any gross water pollution, with Temperatures, pH, DO and Clarity values in the expected range for all areas, including most outfall mixing zones except for the Jubail Industrial and Al Khobar Sewage Treatment Plant outfalls.

2) Laboratory Analyses

Results of the laboratory analyses undertaken at the MEPA Laboratory are shown in Table 3.2.3. Total Solids (TS), Total Suspended Solids (TSS) and COD values show the natural differences between the inshore and offshore areas of the Intensive Study Area, as well as the general north-south trend of increasing salinity, as can be expected with the predominance of the southerly flowing current. Overall, the laboratory values provide a consistent picture that matched the field observations and records.

3) Seafloor Descriptions and Study Area Characterization

The descriptions made during the seafloor site inspections are listed in Table 3.2.4. Based on the survey field work, seafloor and shoreline site inspections and materials collated during June 1999 (including a biotope map of two sub-regions from Saudi Aramco and NCWCD publications), a preliminary characterization of the Intensive Study Area can be given as follows.

The Intensive Study Area (ISA) occupies a 180 km stretch of coastline from Dafi Dalwhat (north and east of Abu Ali) to Half Moon Bay (south of Al-Khobar). This region can be divided into six convenient sub-regions or 'zones' based on the coastline shape, coastal morphology and the degree of human development. The six zones are briefly described, from north to south, as follows:

Zone D: Dawhat ad-Dafi Bay.	This large and shallow bay lies within the Jubail Marine Wildlife Sanctuary, and it extends southward on the west side of Abu Ali until its southern termination at the recently developed Maguraih Marina. This shallow, evaporative and hypersaline embayment is relatively undeveloped except for reclamation works along the south-west shoreline, whilst its former entrance to Jubail Bay (south of Abu Ali) was closed off during the Aramco causeway construction in the mid 1980's. The northern parts of the bay contain extensive seagrass meadows (primarily *Halodule uninervis*). In the south, it also contains Gurnah Island. This vegetated sand island supports an extensive stand of *Avicennia* mangroves, saltmarsh halophyte shrubs and high intertidal sabkhas. All these communities were oiled during the 1991 Gulf War, and are presently under continued monitoring by the Marine Studies Section of the KF University Research Institute. The bay forms an important fish nursery area, and is also popular for commercial and recreational fishermen. At present there are no outfalls, industrial developments or significant residential developments. Therefore the potential value of this zone to the JICA/MEPA study is that it represents a reasonably unmodified area where seawater chemistry is modified by primarily by natural evaporitic events, whilst pollution is restricted to some areas which show the residual high intertidal effects from beaching of oil from the 1991 Gulf War spill. The zone also provides mangrove habitats that may be useful as a reference control for water quality and mangrove habitat conditions in the more eutrophic Tarut Bay (Zone 4).
Zone J: Jubail Bay:	This large bay extends southward from Abu Ali island, past the new Jubail harbour, the old town of Jubail and its fishing port, and terminates south of the KSA Navy base at the Gaslan power station. This area contains substantial developments and industrial activities, which include the offshore Berri oil field, the reclamation and dredging works associated with the Fanateera corniche, marina and artificial island development, the major new harbor and tank farm at Jubail, the shared Jubail industrial outfall managed by the Royal Commission of Jubail, the commercial harbor, the fishing boat harbor, and the large SWCC desalination plant located 40 kms south near the Navy base. The sensitive habitats in this region include the extensive seagrass meadows which, in water depths of 1-3 m below LAT, extend from Fanateera Island (also an important tern breeding site) to the north. Zone J provides many examples of point source discharges, the ones of key interest to the study including (a) the shared industrial outfall, (b) the Berri oil field production platforms, and (b) the SWCC outfall.

Zone R: Ras Tannura Peninsula:	This isolated and relatively exposed coastline extends southward from the Gaslan power station to the sand spit at the tip of Ras Tannura, and it includes the Saudi Aramco Sea Island Terminal and onshore refinery. The intertidal zone comprises linear sand beaches that are fronted by a sublittoral limestone pavement with variable veneers of coarse carbonate sands. These sand sheets, which are exposed to strong inshore southerly currents for much of the year support patches of seagrass that are interspersed by well developed macroalgae and sponge beds in areas where the veneer is thin or non-existent. Inshore platform coral reefs are also present near the tip of Ras Tanurra. This zone provides the best example of a major crude oil load-out terminal, refinery outfall and associated coastal infrastructure and facilities to the study.
Zone T: Tarut Bay:	This large bay extends south and west from the tip of Ras Tannura to the commercial harbor at Dammam Port in the south. The bay is divided into northern and southern halves by the road and causeway that joins Tarut Island (which contains the substantial residential town of Tarut) to the adjoining coastal town of Al Qatif. This area provides a good example of diffuse groundwater and surface water nutrient pollution from older style residential areas that are not connected to reticulated sewage treatment works. A large urban storm water drain at Qatif discharges into the mangrove area, and appears to be occasionally used for convenient disposal of urban and residential waste waters. The ecologically important habitats of Tarut Bay comprise: (a) the mangrove fringes which fringe the mainland coastline to north and south of Tarut Island; (b) the remaining offshore seagrass beds which occur in undisturbed shallow water areas to the north, south and east of Tarut Island; and (c) the coral reef at Nazwah Island. The inshore waters and coastal zone near Tarut Island and Dammam are the most heavily modified areas of the ISA, with major dredging, reclamation, corniche, harbor and marina works having being undertaken almost continuously over the past 20 years. Apart from the urban drain outfall at Qatif, an STP outfall at Ramos (north of Tarut) and a refinery outfall to the north-east (now under decommissioning), Zone T also includes a significant and historic oil and transformer pollution source in the narrow fishing boat harbor immediately north of the Port of Dammam.
Zone K: Al Khobar.	This zone extends from the south side of Dammam Port to the Qurayyah peninsula in the south. It contains the major Al-Khobar/Dhahran urban area, and the principal outfalls of the SAFCO fertiliser plant, the Al Khobar STP and the As-Azir desalination plants, all of which are important for the JICA/MEPA study. The zone also contains the new Al-Khobar corniche, the KSA-Bahrain International Causeway and the developing holiday marina and residential areas near the small embayment of As-Azir. It also contains offshore sand spits and seagrass meadows, such as those at Kascus Island, and popular fishery grounds. Further inshore, seagrass meadows extend from Dammam Port to the area offshore from the SAFCO plant.
Zone H: Half-Moon Bay and Agraiha Area:	The southernmost zone of the ISA comprises a very large, evaporative embayment with a net inflow of water due to the evaporation rate. Salinities in the northern end exceed 60 g/kg. The area is fast becoming a popular holiday and fishing playground, with several holiday residential areas being developed on both the east and west sides. The fine sediments in the center of the bay fall out of suspension due to the relatively sheltering of the bay from northerly winds, and these provide a 'sink' of suspended particulate contaminants and nutrients originating from the more northern zones. The southern end of this zone is marked by the large power station, complete with a large seawater cooling intake and outfall, at Ras al'Qurayyah.

Table-3.2.2 Field Inspection Results

Location Name	Site Code	Date	Latitude	Longitude	Depth (m)	Temp. (C°)	pH (-)	DO (mg/l)	Clarity (m)
Jubail Region									
Dawhat Dafi Bay	J2B	15.Jun.99	27°10.0'N	48°29.2'E	2.6	31.9	8.10	6.2	1.5
Abu Ali North	J3	14.Jun.99	27°22.6'N	49°45.5'E	35.0	30.8	8.12	6.6	15.0
Berri Oilfield	J5	14.Jun.99	27°12.5'N	49°43.0'E	16.0	31.4	8.16	6.6	11.0
Outer Shoal	J6	14.Jun.99	27°13.6'N	49°48.8'E	6.9	31.0	8.20	6.5	6.9
ARAMCO South Terminal	J7A	13.Jun.99	27°08.0'N	49°37.3'E	1.9	33.7	8.27	8.3	>1.9
Fanateera Island	J7B	13.Jun.99	27°07.0'N	49°35.1'E	1.1	33.0	8.20	8.2	>1.1
Fanateera Marina	J7C	13.Jun.99	27°07.1'N	49°33.1'E	4.6	31.2	8.18	8.3	2.4
Maduraigh Marina	J8	15.Jun.99	27°07.1'N	49°30.4'E	3.4	31.7	8.15	5.4	2.7
Shared Industrial Outfall	J9	13.Jun.99	27°03.6'N	49°37.8'E	4.5	41.0	8.14	7.5	2.4
Jubail Harbour	J10	13.Jun.99	27°02.5'N	49°41.8'E	5.0	32.3	8.20	6.5	3.3
Jubail Port Tank farm North	J11	14.Jun.99	27°04.5'N	49°42.5'E	20.0	31.7	8.17	6.6	8.2
Storm outfall of Jubail Ind. City(1)	C01	15.Jun.99	27°04.5'N	49°35.2'E	<1	32.1	8.21	6.8	-
Storm outfall of Jubail Ind. City(2)	C02	16.Jun.99	27°04.5'N	49°38.2'E	<1	30.6	8.31	7.1	-
Ra's Tannurah Region									
ARAMCO Oil Refinery Outfall	RD01	19.Jun.99	26°37.8'N	50°09.9'E	6.0	31.8	8.15	6.5	3.0
Sea Island Termnl	RD02	19.Jun.99	26°39.7'N	50°11.1'E	32.0	31.8	8.18	6.2	6.0
South Sand Spit	RD03	19.Jun.99	26°42.8'N	50°08.6'E	2.7	31.6	8.11	6.7	4.9
Platform reef (Almost dead)	RD03B	19.Jun.99	26°41.8'N	50°06.6'E	-	-	-	-	-
Tarut - Dammam Region									
North side of Tarut Is	RA01	21.Jun.99	26°35.8'N	50°00.8'E	0.7	30.5	8.07	5.7	0.6
Inshore north of Tarut	RA02	21.Jun.99	26°36.1'N	50°03.5'E	0.9	32.1	8.27	6.6	>0.92
Marine coral reef(Najwah Is)	RD04	19.Jun.99	26°33.0'N	50°15.3'E	0.8	32.7	8.21	8.6	>0.8
Dammam Harbour	RD5	23.Jun.99	26°28.2'N	50°13.8'E	8.5	30.1	8.15	7.4	3.2
Small boat Harbour	RD7	23.Jun.99	26°26.9'N	50°07.7'E	1.2	32.5	8.22	6.0	0.3
Fishing Fleet jetty	RD8	21.Jun.99	26°32.5'N	50°03.5'E	3.3	31.6	8.22	5.8	0.6
South central Tarut	RD8B	21.Jun.99	26°32.4'N	50°03.6'E	3.0	31.6	8.16	6.1	0.8
Qatif Marina dredged	RD9	21.Jun.99	26°32.8'N	50°01.7'E	8.2	30.6	8.22	5.8	0.9
Qatif S/W drain	RD9B	21.Jun.99	26°38.5'N	50°05.3'E	-	-	-	-	-
Near ARAMCO Reclaim Island	RD10	23.Jun.99	26°29.5'N	50°06.7'E	1.9	32.6	8.30	6.4	1.3
SAFCO corner	RD11	23.Jun.99	26°24.5'N	50°11.9'E	0.8	32.9	8.30	7.8	0.8
Kaskus Island	RD12	23.Jun.99	26°24.8'N	50°18.1'E	1.6	33.4	8.22	6.0	>1.6
Al Khobar Region									
Al Benhani Islet	RD14	26.Jun.99	26°15.2'N	50°19.6'E	>20	33.7	8.44	6.2	6.7
Sewage Outfall	RD14B	26.Jun.99	26°14.4'N	50°13.4'E	5.3	33.8	8.40	5.9	0.3
Desalination intake	RD15	26.Jun.99	26°10.4'N	50°12.8'E	-	33.5	8.42	5.8	2.7
Desalination outfall	RD15B	26.Jun.99	26°10.6'N	50°12.7'E	6.0	39.3	8.46	7.0	2.2
Residential marinas	RD15C	26.Jun.99	26°09.6'N	50°11.8'E	-	34.6	8.41	6.9	2.6
HalfMoon Bay									
Centre of HM Bay	RD17	27.Jun.99	26°04.0'N	50°03.0'E	3.5	32.6	8.25	5.6	>3.5
Al Qurayyah									
Power station intake	RD18	27.Jun.99	25°51.6'N	50°07.3'E	4.1	35.4	8.25	7.5	2.7
Power station outfall	RD18B	27.Jun.99	25°51.1'N	50°07.6'E	-	39.0	8.14	6.9	-

Table-3.2.3 Analysis Results of Field Samples

June, 1999

No.	Sample ID	Date Sampled	Time	Container	Q'ty	Note	COD mg/L	TSS mg/L	TS %
Jubail Region									
1	J 2B	15.Jun.99	10:08	1 liter, P	1		3	18	5.5
2	J 3	14.Jun.99	12:44	1 liter, P	4	control area	2	4	4.3
3	J 5	14.Jun.99	14:54	1 liter, P	2		1	5	4.4
4	J 6	14.Jun.99	14:00	1 liter, P	2		2	7	4.5
5	J 7	13.Jun.99	15:27	1 liter, P	2	seaweeds area	2	7	4.6
6	J 7B	13.Jun.99	16:25	1 liter, P	2	Fanateer Island	2	9	4.6
7	J 7C	13.Jun.99	17:08	1 liter, P	2	harbor	2	8	4.6
8	J 8	15.Jun.99	11:30	1.5 L, PET	2	Mardumah marina	4	9	5.7
9	J 9	13.Jun.99	11:35	1 liter, P	3	polluted area	2	7	4.5
10	J 10	13.Jun.99	10:10	1 liter, P	2	polluted area	2	6	4.3
11	J 11	14.Jun.99	16:15	1 liter, P	1		2	10	-
12	C1	16.Jun.99	9:30	1.5 L, PET	1		2	10	4.6
13	C2	15.Jun.99	17:50	1 liter, P	1		3	17	4.7
Ras Tannurah Region									
14	RD1	19.Jun.99	11:05	1 liter, P	2		2	7	4.4
15	RD2	19.Jun.99	11:55	1 liter, P	2		2	5	4.4
16	RD3	19.Jun.99	12:35	1 liter, P	2		2	6	4.6
Tarut-Damman Region									
17	RD4	23.Jun.99	14:30	1 liter, P	1		1	6	4.5
18	RD5	23.Jun.99	15:10	1 liter, P	2		2	8	4.5
19	RD7	23.Jun.99	11:00	1 liter, P	2	polluted area	4	21	4.5
20	RA1	21.Jun.99	10:00	1 liter, P	2		4	11	4.9
21	RA2	21.Jun.99	10:59	1 liter, P	2	polluted area	5	10	5.2
22	RD8	21.Jun.99	11:55	1 liter, P	2		3	11	4.8
23	RD8B	21.Jun.99	12:20	1 liter, P	1		-	7	4.7
24	RD9	21.Jun.99	12:50	1 liter, P	2		4	9	4.9
25	RD10	23.Jun.99	10:30	1 liter, P	2		2	8	4.6
26	RD11	23.Jun.99	12:20	1 liter, P	2		2	8	4.6
27	RD12	23.Jun.99	14:00	1 liter, P	2		1	7	4.5
Al Khobar Region									
28	RD14	26.Jun.99	11:50	1 liter, P	2		2	6	5.0
29	RD14B	26.Jun.99	10:50	1 liter, P	2	much suspended	3	24	3.6
30	RD15A	26.Jun.99	12:50	1 liter, P	2		2	15	5.7
31	RD15B	26.Jun.99		1 liter, P	2	desalination outlet	2	12	5.9
32	RD15C	26.Jun.99	14:30	1 liter, P	2		3	13	5.6
Half Moon Bay									
33	RD17	27.Jun.99	10:00	1 liter, P	2		2	6	6.4
Al Qurayyah									
34	RD18	27.Jun.99	12:00	1 liter, P	2	Power plant intake	2	7	6.0
35	RD18B	27.Jun.99		1 liter, P	2	Power plant out fall	2	7	5.9

COD: Chemical Oxygen Demand by Permanganate Method
TSS: Total Suspended Solids dried at 105 °C
TS: Total Solids dried at 105 °C (nearly equal to TDS or Salinity for these samples)

Table 3.2.4 Seafloor description

REGION:	JUBAIL	DATES:	13-15 June 1999	REFERENCE:	KD-UW1
SITE	**DESCRIPTION**				
Site J10:	Outer Jubail Harbour: Sunday 13 June@1050. 4.8 m deep, near south end of outer breakwater. Coarse gravelly sand bottom with coral rubble. Some small colonies of yellow favid corals (5-10 cm in diameter; cf. *Goniastrea*). Black solitary sea squirts (7-10 cm high) on rubble. Bright red encrusting sponge on coral rubble (underside). Three crabs in rubble brought to surface. One fish seen. Currents in area at spring tide ebb (skipper; 1-1.5 knots). One photo.				
Site J9B:	Near outfall. 3 m deep. Burrow marks and fish feeding marks on soft fine to medium grained silty sands. Worth grab sampling for benthos. Thermocline at about 1.5 m, temp 31.8 on bottom, 39.2 on top. 3 photos. 1 shot of boat.				
Site J7A:	1.9 m deep. 800 m north-west of Aramco south breakwater coastal terminal (initially misnamed as Site 6 on water sample bottles). White sandy veneers (0.5-10 cm thick) over smooth carbonate platform, no rubble or rock. Thin veneer were colonised by green macroalgae with holdfast and bobbly stem ("Caulerpa" like but different?). No Sargassum. Bindweed (red or brown simple branching stem forming a network) was quite thick in this seaweed. Where sediment sheet was >5 cm, *Halodule uninervis* was very common. About 4 photos. South-east tip of south-east spit off Fanateer Island – boulders and rock spit, no live coral. Some reef fish.				
Site J7B:	1.1 m deep. Sand and seagrass beds (400 m diameter patch) on west edge of shallow bank, mid way between Fanateer Island and the other island to the south. Depth still shallow (1.6 m) until reaching the dredged area east of marina (7 m deep). One shot of the small boat, about four shots taken of seagrasses and seabed.				
Sites 3,5,6,11	No snorkelling at the four deepwater sites inspected on Monday 13 June.				
Site J2B:	Tuesday 14 June, 1000 am. North end of island ~8 km north of Maguraih Marina. Intertidal rocky platform on edge of steep sand slope to tidal channel (6 m deep). Sandy floor depths at the black post (1 km to the north) were 2.6 m. Six photos taken showing live barnacles, creepers, top shells and other gastropods. No sign of any coral in the intertidal or subtidal zone. Seagrass beds (*H uninervis*) relatively close because of large quantities of dead leaves washed up on the mangroves at Gurnah Island.				

REGION:	RAS TANURRA	DATE:	19 June 1999	REFERENCE:	KD-UW2
SITE	**DESCRIPTION**				
Site RD03B:	Platform coral reef, 1 km south-west off Ras Tannura spit, marked by two spit posts. Dived at south-west edge of intertidal reef. High tide. Depth 2-3 m. Old corals and coral rubble (cf. Stumps of branching *Acropora* or *Porites cylindrica* or branching type of *Montipora*?) all dead – maybe 3-5 years ago. Many long spined black sea urchins (*Diadema* sp). Sand taken for description on deck. 4 photos taken, then photo of boat. No WQ sampling.				
Site RD03A:	End of Ras Tannura spit – alongside the old spit post assembly, 30 m from beach. Shelley coarse white sands with small disc-like sandy tar balls (0.5-1.0 cm long). Description taken on deck. Large cods (Hamura) and other fish atr spit post. Depth 2-3 m. 4 photos taken of fish at spit post. Photo taken of boat from water showing spit.				
Site RD02:	Sea Island Terminal. 31 m deep. Too deep for inspection. UW photo of tanker departure operations and general scenes (3 photographs).				
Site RD01:	Ras Tannura Refinery – 200 m from refinery outfall. Water depth 2-2.5 m. Three photos taken of seafloor showing macroalgae (*Padina / Codium / Sargassum*) on carbonate plate rubble, covered with thin veneers (0.5-10 cm) of medium to coarse sands (description taken on deck). No seagrass observed (current too strong – seabed scoured to prevent sufficient sand build up). Three small crabs and *Scylla*-like crustaceans, plus 2 gastropod molluscs, and a green crunchy colonial sea squirt on underside of the rubble plates. Stored on ice ten in fridge (-4°C) before transfer to 70% methanol in the MEPA lab on Sunday a.m. (20 June 1999). Also a single coral polyp found under one rock, plus one single colony (bleached; 10 cm diameter; cf. *Cyphastrea*) seen on sand covered rubble on seafloor.				

Site RDO4:	Snorkelling inspection of coral fringing the sand spit immediately south of the Coastguard station jetty at Ras Tannura. Medium to fine white sands below coral level (~1 m below LAT), and medium to coarse sands on the rippled intertidal white sand spit above the coral level (MSL-MLW). Almost all the coral is dead – covered in fine white sediment and turfing algae – but maybe died last summer – bleaching event suspected. Very few living coral left (~25 parts of colonies just intact – all bleached or near bleached condition). No disease bands, no sedimentation event. Peculiar taste in water? (not felt by Ike-san). Possibility of minor local oil spill (there was thin tar layers from a 2-6 month old spill covering the intertidal rocks at base of sand spit). Also the reported possibility of Aramco's recent adoption to use dispersants routinely for oil spill combat (K. Al-Rasheed, pers comm). The corals were from MLW to 1 m below estimated LAT – and all were in same condition – no depth zoning. Coral colony size (0.2-0.8 typical diameter) indicated typical ages of 20-40 years. Coral types include cf. *Porites cylindrica*, thick branching Montipora spp., and several faviids (brains – *Goniastera/Plesiastrea* plus cf. *Cyphastrea*). No evidence/sign of *Acropora*. Also there were many dead clams and cup oysters – same death time. Some corals covered by caramel coloured encrusting sponge. A few medium grey branching sponges also found (10-20 cm long). Two live cone shells found. Short-spined and long-spined sea urchins (*Diadema*) plentiful everywhere. No algae or seagrass. Plenty of fish, including spotted cod and brown-banded cods (20-30 cm long), plus many blackspots and a few black damsel fish. Gastropod molluscs (cerithiid creepers) plentiful in the shallow intertidal, plus a small whelk with nobbly, ribbed shell (2-4 cm). Many empty shells – no hermit crabs or other crustaceans observed.

REGION:	TARUT	**DATE:**	21 June 1999	**REFERENCE:**	KD-UW3

SITE	**DESCRIPTION**
Site RA02:	Inshore low intertidal seafloor sampled near high tide (1030) (~1.0 m deep) about 500 m off the mangrove fringe to the north of the town of Al Qatif, and about 2.5 km north of the Tarut Island causeway. The seafloor comprised silty sands with live tube worm colonies forming 10-40 cm diameter limestone plates (10-20 cm high). The calcareous tube worm colonies (cf. Serpulid worms) provide a microhabitat for several crustacean and gastropod mollusc species, including 3-4 types of small crabs (cf. Xanthid family). Large numbers of creeper shells in the sediments (see field noes for description of molluscs). Sediment description recorded on field sheets. About 4 photos taken to show distribution of the tube worm colonies on the seafloor. Visibility was less than 2 m. Many small fishing boats in the area.
Site RA01:	Low intertidal site close to north side of Tarut Island, and immediately north-west of Zur. The site was inspected at about 1130 am, close to high tide. It was selected near an apparent STP plant on Tarut Island, based on the advice of local coastguard officers. The substrate comprised a thick multi-laminated BMC mat (1-4 cm thick) overlying sulphurous silty fine sands (dark grey). A sediment sample of the mat and sediments was taken for storage by freezing in the laboratory. The seawater was dark green, with clarity variable in the region (from very poor 500 m offshore) to about 1.5 m near the shore, a variation caused by the asymetrical displacement of turbid waters by the ingress of the clearer high tidal waters. About five photos were taken to show the edges of the BMC mat, plus many burrow marks and the tube worm colonies. The tube worm colonies were also present (in the same manner as RA03, but fewer and, on average, larger). The colour of the water (dark green hue) indicated the presence of nutrient inputs, but no outlet or outfall could be seen extending from STP, as viewed from the boats. A photo was also taken of the two boats.
Site RA01B:	This site was located in shallow subtidal waters (from LAT to 1 m below) on the east side of Tarut Island. A quick stop was made to determine the nature of the seabed. Water visibility was 2-3 m, and the area typical of the east coast. The substrate comprised coarse to medium sandy sediments with large and extensive patches of *Halodule uninervis* seagrasses, finely coated with sediment and some loosely attached epiphytic algae (colour was a milky pale brown due to sediment deposition). About 3 photos taken, followed by a surface photo of the boat. The seagrass was healthy when taken to deck (stirring action caused material to rinse off during ascent)with no signs of dieback or disease. However there was a large amount of recently detached floating seagrass wrack (still green-green/brown colour) in the whole Tarut region – probably seasonal and associated with summer temperature rise.
Site RD08A:	Tarut fishing jetty (1200-1215). Substrate was coarse to medium grey silty sands, recently dredged – no photos. Visibility (10 cm) and light low (~3 m) – no photos taken at this site.

Site RD08B:	South central side of Tarut Island, about 1 km from the shore; depth about 1.5-2 m. Inshore water normal pale green over sand, large area of outer waters show a strong yellow-brown tinge, with clear inshore demarkation line. Tide now on the ebb (1230), with surface current due south due to breeze, but near bottom current may be to the east – parallel to shore. No obvious source such as outfall. Substrate comprised bare and pale creamy colour sandy sediments – both in front of and within the west-east stained water area. May have been dredging operation in the marina to the east – but water colour or turbidity did not give obvious suggestion that suspended silt may be the cause (clarity no change??). So stained water emanating from deep dredged area? But no obvious increase in staining towards this area (but change of depth, and thermodensity may explain a bottom plume that becomes more visible in the shallower offshore areas....). See also site RA01 description. No photos taken.
Site RD03:	Beside entrance to new marina at Al Qatif (near coastguard jetty). Waters very deep (8-10 m) due to recent dredging. Drifted across marina mouth to overturned barge, and where depth shelved very rapidly to 2 m. Light and visibility was zero >5 m in the deep water area. Brown colour strong. This may well be the source of the brown stained water during the ebb tide. Substrate comprised limestone rubble and blocks due to recent dredging. Bottom of newly dredged area could not be reached (>6 m). No photos taken.
Site RD09B:	Shoreline Storm water discharge canal. Ebb tide. Visited by car on highway at about 1400. Dark green waters with weed. Current flowing at about 0.5-0.7 m per second, and enter mangrove creek on sea side of highway. No smell. No faeces, paper or other items indicating mixture with sewage discharge. However nutrient levels appear high due to dark green colouration of water (diatom or other phytoplankton bloom). No u/w photos taken.

REGION:	DAMMAM	**DATE:**	23 June 1999	**REFERENCE:**	KD-UW3

SITE	**DESCRIPTION**
Site RD10:	Aramco Reclaim sland used for Recreation – 0.8 km on east side in shallow water, seagrass beds – about 4 photos taken
Site RD07:	Dammam small boat fishing harbour and historic railway disposal site. Sediments taken (2 samples) but no photos – no light.
Site RD11:	SAFCO corner – inshore thin sediments on rock platform , with tube worm colonies. Further offshore sand sheets (with stingrays) getting thicker with seagrass beds – photos taken; Extensive seagrass beds stretching north to the Dammam Port and the refuse burning site.
Site RD12:	Kaskus Shoal; a linear ribbon sand spit, overlying a limestone platform with thick sand sheets and seagrass patches. Photos taken at sampling site. Plenty of fishing activity (including fishermen huts). Search made for coral – none found.
Site RD4:	Najwah Island – bare sand islet. Coral graveyard found on north-west corner of island. Extensive search found no live coral, all dead due to a 1-2 years old event – bleaching?? Small turf algae. No sign of significant eutrophication. Six photos taken.
Site RD5:	Inside Dammam Harbour – deep water site. No sediments or photos.

REGION:	AL-KHOBAR	**DATE:**	26 June 1999	**REFERENCE:**	KD-UW4

SITE	**DESCRIPTION**
Site RD14B:	Al Khobar sewage outfall – no sediments or photos taken due to health risks.
Site RD14:	Al Benhani Islet – a vegetated sand cay with well, on west side of the main channel passing southward to the Causeway. Seven photos taken of the 3 seagrass species and 7 algae species, plus pearl oyster bed. No corals or sign of corals nearby.
Site RD15:	Desalination Plant intake island – deepwater – no photos or sediments taken due to depth.
Site RD15B:	Desalination plant outfalls- deepwater – no photos or sediments taken due to depth.
Site RD15C:	Close inshore in the gap between the Sunrise and Sunset Marina – sediments taken – no photos taken due to depth.
Site RD16:	Site visit to this islet south of the main causeway and 6 km offshore was abandoned due to lack of

	petrol.				
REGION:	HALF-MOON	**DATE:**	27 June 1999	**REFERENCE:**	KD-UW4
SITE	**DESCRIPTION**				
Site RD17:	Centre of Half-Moon Bay – about 3.5 m deep. Less jellyfish and extensive seagrass beds comapred to northern end of bay. Mostly bare sands with small pearl shells (*Pinctada* and *Elatra*), grey sponges and occasional *Caulerpa* green macroalgae present at the sampling site. Silty sand sediments had a sulphur smell - fairly strong due to sulphate-reducing bacteria.				
Site RD17B:	Coastguard Marina at north end of Half-Moon Bay – water quality monitored and a sample taken – no photos or sediments due to time restriction.				
Site RD18:	Power station intake – no underwater photos or sediments (too dangerous to enter water). Artificial rock wall habitat.				
Site RD18B:	Power station outfall – no underwater photos or sediments (too dangerous to enter water – fast flow). Concrete raceway leading to shallow bay with local algal mat in shallows – all reachable by car.				

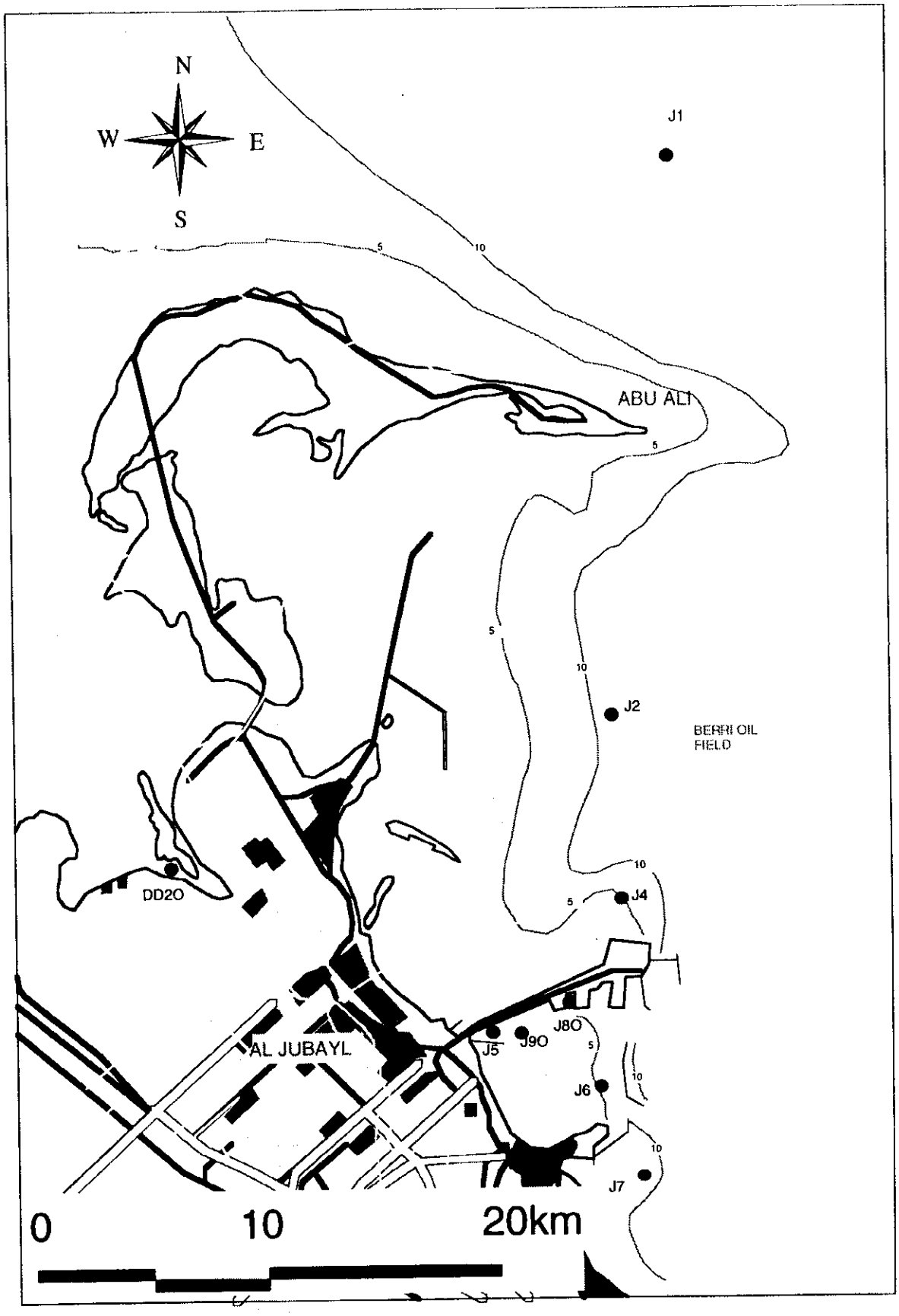
3.3 Monitoring Investigation

3.3.1 Field Work Locations and Methods

A total of 34 sampling sites were selected. The locations of the sampling sites that have been positioned to achieve these objectives are shown in Figures 3.3.1.

Details of the various sample containers, preservatives and holding times associated with individual laboratory analyses are summarized in Table 3.3.1.

Field measurement parameters and methods are summarized in Table 3.3.2.
Water and sediment quality parameters and their analytical methods are described in Table 3.3.3.



Fugure 3.3.1(1) SAMPLING LOCATIONS

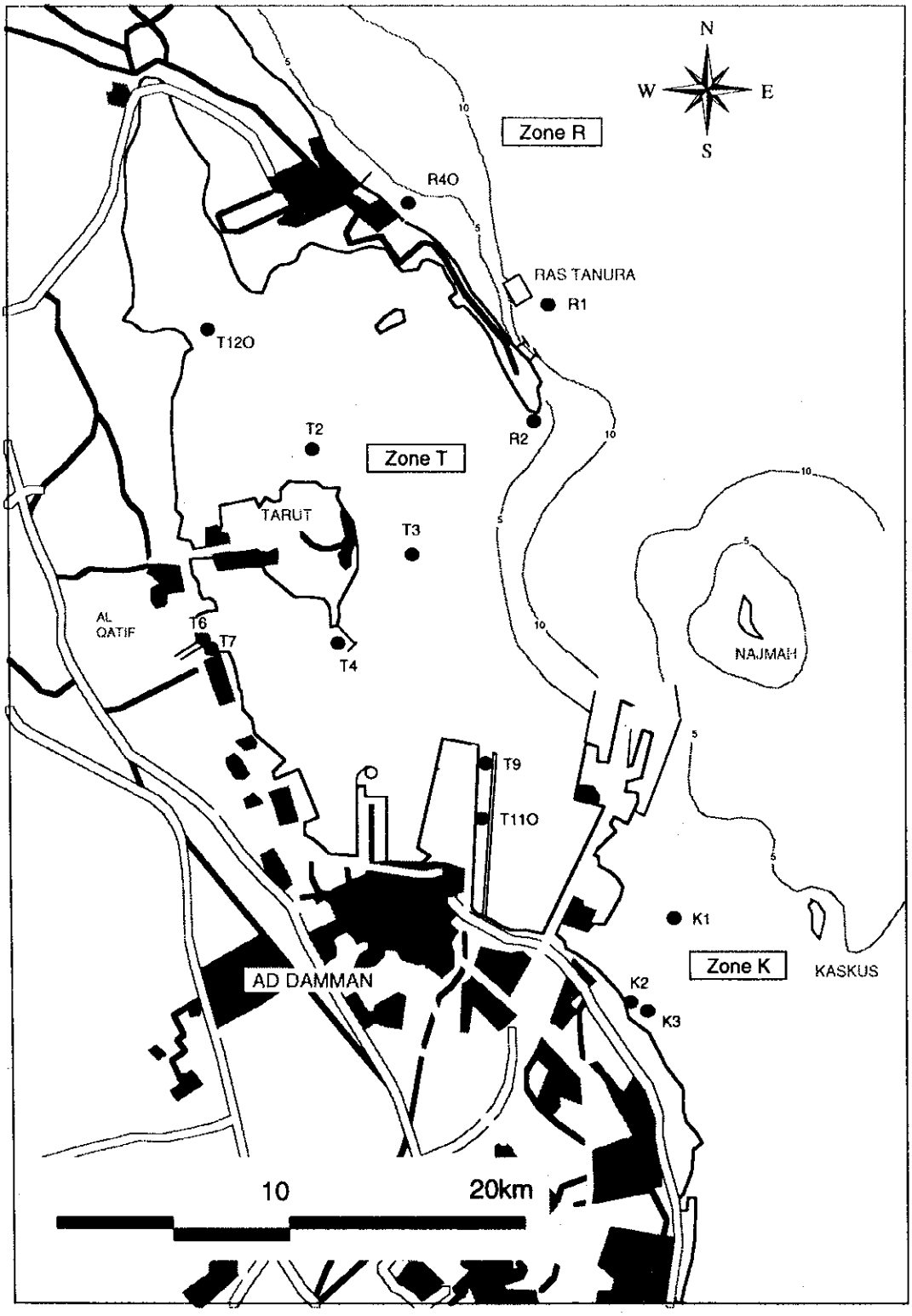


Figure 3.3.1(2) SAMPLING LOCATIONS

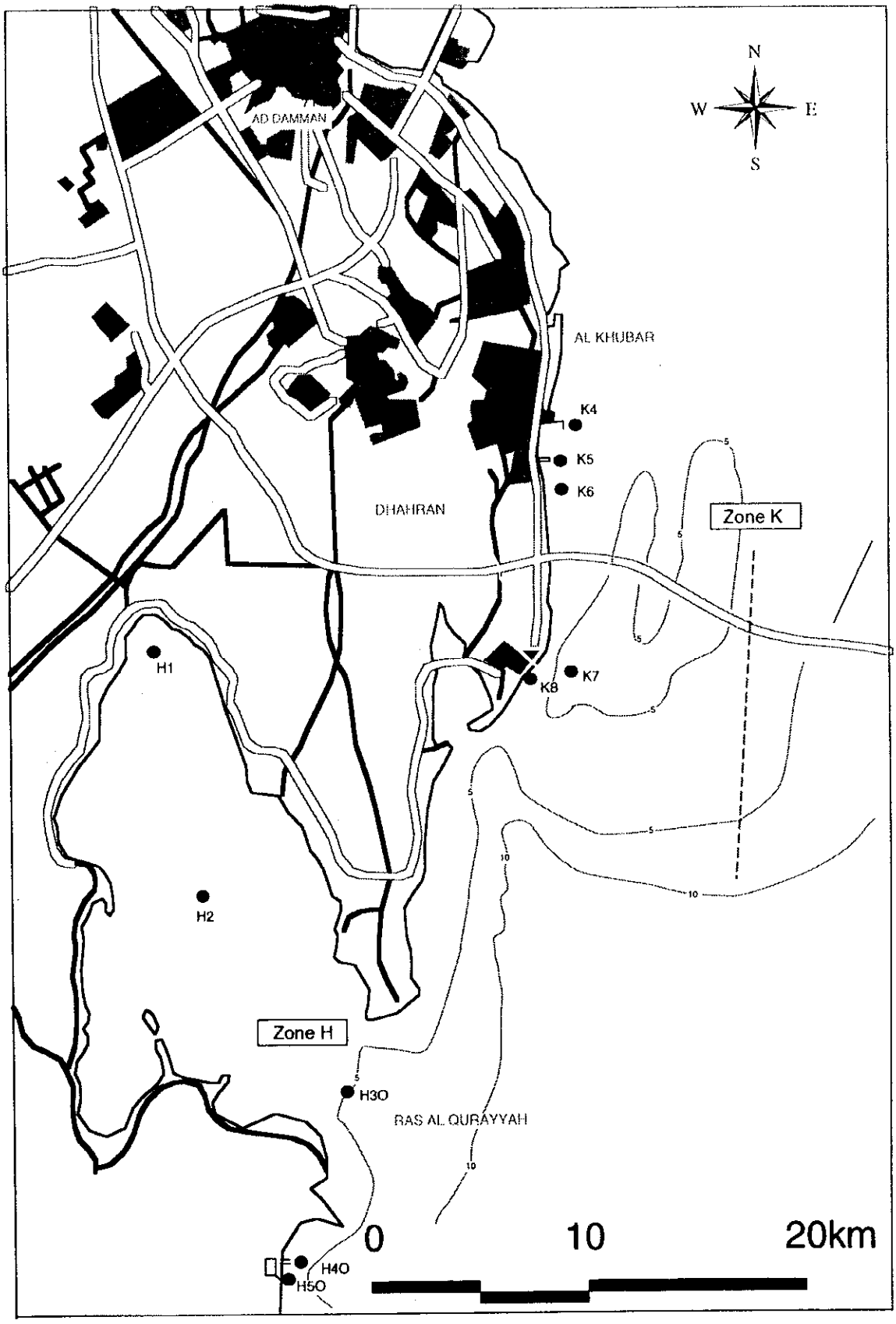


Figure 3.3.1 (3) SAMPLING LOCATIONS

Table 3.3.1 Sample Containers, Preservatives and Holding Times

Analysis Parameter	Container	Volume (ml)	Preservation	Holding Time
Total Suspended Solid	Plastic	1000	Cool, 4°C	48hrs
Residual Chlorine	Plastic	1000	Cool, 4°C	Immediately
COD / TOC Ammonia, Total Kjeidahl Nitrogen Total Phosphorus	Plastic	2000	Cool, 4°C	48hrs
Cyanogen	Plastic	500	Cool, 4°C add NaOH, pH>12	14days
Metals	Plastic	500	add HNO_3, pH<2	28days (Hg), 6 months (others)
Phenols	Glass	500	Cool, 4°C add H_2SO_4, pH<2	28days
Oil &Greese, TPH	Glass	1000	Cool, 4°C add HCl, pH<2	28days
BTEX (Benzene, Toluene, Etylbenzen, Xylene)	Glass with teflon liner cap	250	Cool, 4°C add HCl, pH<2	14days
Chloropyll	Plastic	1000	Cool, 4°C	Immediately to filtrate 28days (Frozen)
Total Coliform	Plastic (sterilized)	125	Cool, 4°C	24hours

Table 3.3.2 (1) Parameters and Measurement Methods at Field (Water)

Parameters	Measurement Methods
Water Color	Observation with naked eyes
Odor	Performed by Personal sense of smell
pH	Portable multi-probe meter
DO	Portable multi-probe meter
Chlorine	Portable Chlorine meter
Temperature	Thermometer or Portable multi-probe meter
Salinity	Portable multi-probe meter
Turbidity	Portable multi-probe meter
Water Clarity	Secchi plate
Water Depth	Sounding lead

Table 3.3.2 (2) Parameters and Measurement Methods at Field (Sediment)

Parameters	Measurement Methods
Temperature	Portable probe meter
Color	Observation with naked eyes
Odor	Performed by Personal sense of smell
Oxidation-Reduction Potential (ORP)	Portable probe meter

Table 3.3.3 List of Analysis Method

Analysis Parameter	Method Reference		Note
	pre-treatment	measurement	
Water Analysis			
Residual Chlorine	SM 4500-Cl G		using portable meter
TOC	SM 5310 B		Shimadzu TOC5000A
TSS	SM 2540 D		
NH_3	SM 4500-NH_3 B	SM 4500-NH_3 F	
TKN	SM 4500-N_{org} B	SM 4500-NH_3 F	except Ammonia removal
Total Phosphorus	SM 4500-P B	SM 4500-P E	
Cyanogen	SM 4500-CN C	SM 4500-CN E	
Magnesium	SM 3111 B		Flame AAS
Cd, Pb, Zn, Cu, Co, Ni	SM 3111 C		Flame AAS
Chromium	SM 3111 C		Flame AAS
Mercury	SM 3111 C		Cold vapor AAS
Arsenic	SM 3111 C		Hydride generation AAS
Phenols	EPA 420.1		
Oil & Grease	EPA 413.2 (Oil contents meter)		Horiba OCMA300
TPH	EPA 418.1 (Oil contents meter)		Horiba OCMA300
BTEX	Headspace-GC/FID		
Chlorophyll	SM 10200 H		
Total Coliform	SM 9222 B		Milliflex system
Sediment Analysis			
Ignition Loss	SM 2540 B	SM 2540 E	Loss on Ignition at 550 _C
TOC	MOOPAM IV.4		
Cr, Cd, Pb, Zn, Cu, Co, Ni, V	EPA 3050 B	Flame AAS	
Hg	EPA 3050 B	Cold vapor AAS	
As	EPA 7471 A	Hydride generation AAS	
TPH	EPA 3550 B	Oil contents meter	Horiba OCMA300
BTEX	EPA 5021	Headspace-GC/FID	

Note;

SM: Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WEF, 20th edition

EPA: U.S. EPA Methods;
Methods for Chemical Analysis of Water and Wastes -EPA/600/4-79-020
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846)

MOOPAM: Manual of Oceanographic Observations and Pollutant Analysis Methods, third edition
Regional Organization for the Protection of the Marine Environmet

3.3.2 Results

Third work stage

Field survey was performed during the period October 16 to November 8 1999. The survey schedule is shown in Table 3.3.4.

Results of the field measurement conducted in October 1999 is summarized in Table 3.3.5. Laboratory analyses results for water, sediments and Coliform are shown in Table 3.3.6 respectively. Plankton survey results is presented in Table 3.3.7. Results of the Particle Size Analyses (PSA) of sediment are shown in Table 3.3.8 and Figure 3.3.2.

Fourth work stage

Field survey was performed during the period June 8 to June 28 2000. The survey schedule is shown in Table 3.3.9.

Results of the field measurement conducted in June 2000 is summarized in Table 3.3.10. Laboratory analyses results for water, sediments and Coliform are shown in Table 3.3.11 respectively. Plankton survey results is presented in Table 3.3.12. Results of the Particle Size Analyses (PSA) of sediment are shown in Table 3.3.13 and Figure 3.3.3.

Table 3.3.4 Field Survey Schedule (3rd Stage)

Day	Date	Region	Sampling stations				
Saturday	16.Oct	KHOBAR	K2	-	-	-	-
Sunday	17.Oct	TARUT	T120	T6	T7	-	-
Monday	18.Oct	TARUT	T2	T3	T4	T1	-
Tuesday	19.Oct	-	-	-	-	-	-
Wednesday	20.Oct	RAS TANURA	R2	-	-	-	-
Thursday	**21.Oct**						
Friday	**22.Oct**						
Saturday	23.Oct	TARUT	T11O	T9	K1	K3	-
Sunday	24.Oct	-	-	-	-	-	-
Monday	25.Oct	HALF MOON	H50	H40	-	-	-
Tuesday	26.Oct	-	-	-	-	-	-
Wednesday	27.Oct	-	-	-	-	-	-
Thursday	**28.Oct**						
Friday	**29.Oct**						
Saturday	30.Oct	DAFI DAHWAT	DD20	-	-	-	-
Sunday	31.Oct	JUBAIL	J1	J2	J4	-	-
Monday	1.Nov	JUBAIL	J6	J7	J9O	J5	J8
Tuesday	2.Nov	-	-	-	-	-	-
Wednesday	3.Nov	-	-	-	-	-	-
Thursday	**4.Nov**						
Friday	**5.Nov**						
Saturday	6.Nov	HALF MOON	H1	H2	H3	-	-
Sunday	7.Nov	KHOBAR	K4	K5	K6	K7	K8
Monday	8.Nov	RAS TANURA	R1	R4O			

Table 3.3.5 Results of Field Measurement (3rd Stage) (1)

Site Code	Site Name	Location (GPS)		Sampling		MET-OCEAN CONDITIONS								FIELD WATERT PARAMETERS										
		Lat.	Long.	Date	Time	Air Temp. (°C)	Cloudiness (%)	Wind Direction (o)	Wind Speed (m/s)	Wave Height (m)	Depth (m)	Water Current Direction (°)	Water Current Speed (cm/s)	Water Temp. (°C)	Salinity (g/L)	pH	DO (mg/L)	Turbidiy (NTU)	Water Clarity (m)	Water Color	Odor	Sheen	Rubbish	Res.Cl as Total (mg/L)	Res.Cl as Free (mg/L)
DD20	Gumah Island	27° 07.92'N	49° 29.16'E	30.Oct.99	16:00	32.0	0	52.5	2-3	<0.05	5.2	52.5	14	27.5	52	8.15	5.6	-	2.25	Green	no	no	no	0.04	0.01
J1	Abul Ali North	27° 23.49'N	49° 44.59'E	31.Oct.99	11:30	33.5	40	35.4	3-4	<0.5	32	290(surf.) 310(5m)	6-9(surf.) 21(5m)	29.7	40	8.4	5.9	-	5.75	Geen	no	no	no	0.07	0
J2	Berri Oil Field	27° 10.54'N	49° 42.07'E	31.Oct.99	15:50	30.3	70	70.5	4-5	<0.5	25	-	-	29.7	40	8.22	5.4	-	11.5	Green	no	no	no	0.02	-
J4	North Jubail	27° 07.56'N	49° 41.33'E	31.Oct.99	16:15	30.5	40	123.6	4-5	<0.3	6.8	-	-	25.5	40.2	8.3	5.3	-	>6.9	Green	no	no	no	0.02	-
J5	Jubail Shared Outfall	27° 03.36'N	49° 37.22'E	1.Nov.99	12:30	35.5	0	298	5-6	<0.3	9.3	30	25	34.8	40.4	8.24	5.29	-	4.1	blue	no	no	algae	0.01	-
J6	Jubail Harbour	27° 02.54'N	49° 40.97'E	1.Nov.99	10:25	33.0	20	206	2	<0.3	6	350(surf.) 90(5m)	7(surf.) 8(5m)	28.9	40.6	8.26	5	-	>6.0	blue	no	no	little from fertalizer	0.07	0.05
J7	South Jubail	27° 00.98'N	49° 42.24'E	1.Nov.99	9:35	29.0	20	174	3	<0.3	10.3	260(surf.) 260(5m)	6(surf.) 4(5m)	29	40.4	8.23	5.2	-	9.2	blue	no	no	no	0.03	0.02
J8O	Jubail Boat Harbour	27° 05.08'N	49° 40.92'E	1.Nov.99	13:35	32.5	20	24.6	5-6	<0.1	5	-	-	29.3	40.3	8.01	5.01	-	>5.0	Geen	no	no	no	0.05	0.03
J9O	Near Jubail Outfall	27° 03.54'N	49° 37.70'E	1.Nov.99	11:30	36.3	10	350	5	<0.2	5.5	90(surface) 260(4m) 70(3m) 100(2m)	15(surf.) 4(4m) 20(3m) 6(2m)	34.22(S) 31.0(B)	40.3(S) 40.7(B)	8.27(S) 8.32(B)	4.95(S) 4.43(B)	-	3.3	Geen	no	no	little algae	0.04	0.02
H1	Half Moon Bay - North	26° 12.00'N	50° 02.24'E	6.Nov.99	11:50	29.5	0	S	5	<0.5	4.45	-	-	27	61	8.08	5.15		>4.45	Green	no	no	no	0.10	0.0
H2	Half Moon Bay - mid	26° 04.05'N	50° 04.94'E	6.Nov.99	10:35	30.0	0	225.3	1	<0.1	5.7	86(S) 233(3-4m) 227(B)	7.5(S) 6(3-4m) 3-5(B)	25.8(S) 25.7(B)	56.3(S) 59.3(B)	8.0(S) 8.1(B)	5.18(S) 4.73(B)		>5.7	Dark Green	no	no	no	0.07	0.05
H3O	Half Moon Bay - South	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1	Sea Island Terminal	26° 39.73'N	50° 11.04'E	8.Nov.99	12:35	31.0	0	159.1	6	<1	26.85	175	36	27.7(S) 27.6(B)	41.3(S) 41.4(B)	8.20(S) 8.12(B)	5.52(S) 5.69(B)		9.7	Dark Green	no	no	no	0.07	0.07
R2	Ras Tannura Spit	26° 37.60'N	50° 09.81'E	20.Oct.99	11:10	31.5	0	42.7	6	<0.5	6.7	215(S) 223(B)	45(S) 20(B)	29.8(S) 29.5(B)	40.8(S) 40.6(B)	8.15(S) 8.15(B)	5.2(S) 5.2(B)		6	Dark Green	no	no	no	0.08	0.07
R4O	Refinery Outfall	26° 41.86'N	50° 06.48'E	8.Nov.99	13:50	32.0	0	130	4	<0.5	1.9	170	11	28.5	41.2	8.13	6.85		>1.9	Pale Green	no	no	no	0.11	0.04
T1	Tarut - Zur	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T2	Tarut - Zur	26° 36.52'N	50° 04.94'E	18.Oct.99	13:21	30.5	0	51.9	4	<0.2	1.3	85	17	29.6	43.5	8	5.32	-	-	Pale Green	no	no	no	0.06	-
T3	Tarut - East	26° 33.83'N	50° 06.67'E	18.Oct.99	14:30	30.0	0	42.7	5	<0.2	1.36	120	3	29.5	43.1	8.2	8.2	-	>1.36	Pale Green	no	no	no	0.07	-
T4	Tarut - Darin	26° 32.43'N	50° 05.11'E	18.Oct.99	15:20	28.5	0	42.7	42.7	<0.2	2.76	140	3	29.1	42.4	8.15	5.65	-	-	Pale Green	no	no	no	0.06	-

Table 3.3.5 Results of Field Measurement (3rd Stage) (2)

						MET-OCEAN CONDITIONS								FIELD WATERT PARAMETERS											
Site Code	Site Name	Location (GPS)		Sampling		Air Temp.	Cloudiness	Wind Direction	Wind Speed	Wave Height	Depth (m)	Water Current Direction	Water Current Speed	Water Temp.	Salinity	pH	DO	Turbidly	Water Clarity	Water Color	Odor	Sheen	Rubbish	Res.Cl	
		Lat.	Long.	Date	Time	(°C)	(%)	(o)	(m/s)	(m)		(°)	(cm/s)	(°C)	(g/L)		(mg/L)	(NTU)	(m)					as Total (mg/L)	as Free (mg/L)
T6	Qatif/Anik urban drain	26° 30.55'N	50° 02.11'E	17.Oct.99	14:40	26.0	0	64	3	-	40-60	-	33	31.9	3.9	7.4	2.2	-	<0.3	Dark Green	weak sewage smell	no	no	0.1	-
T7	Qatif/Anik Drain Mouth	26° 30.53'N	50° 02.57'E	17.Oct.99	15:50	29.5	0	58.3	5	<0.1	0.5	-	-	30	12.5	8	9.2	-	<0.3	dark green	sewage smell	no	no	0.05	-
T9	Dammam Fishing Harbour - Entrance	26° 29.46'N	50° 08.14'E	23.Oct.99	13:05	32.5	0	30.9	5	<0.5	4	256	31	27.9	41.7	8.02	5.5	-	2.2	green	no	no	no	0.14	0.08
T11O	Dammam Fishing Harbour	26° 27.55'N	50° 08.00'E	23.Oct.99	11:55	30.0	0	26.6	5	<0.1	1.3	0	0	27.5	41.6	8.3	5.63	-	0.72	Pale Green	no	no	no	0.07	0.05
T12O	Swfwa	26° 38.95'N	50° 01.15'E	17.Oct.99	12:30	32.7	0	102.4	5	<0.2	0.5	40	2	30.4	45.3	8.1	5.3	-	>0.5	blue / green	no	no	no	0.12	-
K1	Dammam South	26° 25.14'N	05° 01.26'E	23.Oct.99	15:00	32.7	0	27.8	6	<0.4	1.7	220	18	28	42	8.08	5.74	-	>1.7	Pale Green	no	no	no	0.08	0.01
K2	SAFCO outfall	26° 24.52'N	50° 11.42'E	16.Oct.99	13:40	34.0	0	42.5	4.5	-	-	-	-	37.5	-	-	-	-	-	little milky	little smell	-	-	0.13	-
K3	SAFCO south	26° 24.47'N	50° 11.90'E	23.Oct.99	15:43	30.7	0	332.8	6	<0.5	1.2	0	0	27.2	42.7	8.2	6.31	-	>1.2	Pale Green	no	no	no	0.04	-
K4	Khobar Central	26° 14.94'N	50° 13.37'E	7.Nov.99	11:25	32.1	0	171.2	4-5	<0.1	4.1	0	25	26.7	47.3	8.04	5.73		1.3	pale green	no	no	no	0.12	0.05
K5	Khobar STP Outfall	26° 14.45'N	50° 13.41'E	7.Nov.99	12:10	30.3	0	171.8	5	<0.2	4.9	5	50	29.14	31	7.84	6.35		0.7	pale green	no	no	no	0.17	0.09
K6	Khobar South	26° 14.33'N	50° 13.50'E	7.Nov.99	10:45	31.0	0	SSE	4-5	<0.1	7.85	0	75(S) 50(B)	26.26	47.6	8.17	5.8		1.6	pale green	no	no	no	0.08	0.02
K7	Desalination intake	26° 10.40'N	50° 13.02'E	7.Nov.99	9:17	30.2	0	178.6	4-5	<0.2	6.9	10(S) 360(B)	30(S) 25(B)	26.3(S) 26.1(B)	49.0(S) 49.7(B)	8.10(S) 8.15(B)	5.90(S) 5.0(B)		1.7	pale green	no	no	no	0.09	0.02
K8	Desalination Outfall	26° 10.58'N	50° 12.70'E	7.Nov.99	9:47	30.0	0	170.9	4	<0.2	4.85	40(S) 50(B)	30(S) 24(B)	30.93(S) 27.6(B)	50	8.09	5.05(S) 5.2(B)		2.2	pale green	no	no	no	0.13	0.05
H4O	Power Station Intake	25° 51.62'N	50° 07.31'E	25.Oct.99	12:10	37.5	0	250.2	4	<0.1	4.5	-	-	29	54.1	7.98	5.7	-	>4.5	Dark Green	no	no	no	0.18	0.06
H5O	Power Station Outfall	25° 51.23'N	50° 07.57'E	25.Oct.99	12:35	37.0	0	224.2	3	-	1.9	-	-	34.3	53.6	8	4	-	-	pale green	little smell	no	no	0.13	0.12

Table 3.3.5 Results of Field Measurement (3rd Stage) (3)

Site Code	Site Name	Location (GPS)		Sampling		SEDIMENT PARAMETERS					Observation and Comment
		Lat.	Long.	Date	Time	Color	Odor	Texture	Sediment Temp. (°C)	ORP (mv)	
DD20	Gumah Island	27° 07.92'N	49° 29.16'E	30.Oct.99	16:00	glay	no	sandy	-	24	*Sediment is little oily. (Extra sample)*
J1	Abul Ali North	27° 23.49'N	49° 44.59'E	31.Oct.99	11:30	glay	little (H_2S)	muddy	27.7	-	
J2	Berri Oil Field	27° 10.54'N	49° 42.07'E	31.Oct.99	15:50	glay	no	sandy	-	-	
J4	North Jubail	27° 07.56'N	49° 41.33'E	31.Oct.99	16:15	-	-	-	-	-	Sediment sampling was impossible because sediment was rocky.
J5	Jubail Shared Outfall	27° 03.36'N	49° 37.22'E	1.Nov.99	12:30	dark glay	little (H2S)	sandy	-	-40	Water sampling point was 50-100m far from outfall, sediment point was 300m.
J6	Jubail Harbour	27° 02.54'N	49° 40.97'E	1.Nov.99	10:25	slight glay	no	sandy	-	-	
J7	South Jubail	27° 00.98'N	49° 42.24'E	1.Nov.99	9:35	clay	no	sandy	-	-	
J8O	Jubail Boat Harbour	27° 05.08'N	49° 40.92'E	1.Nov.99	13:35	glay	no	sandy	-	-34	
J9O	Near Jubail Outfall	27° 03.54'N	49° 37.70'E	1.Nov.99	11:30	-	-	-	-	-	
H1	Half Moon Bay - North	26° 12.00'N	50° 02.24'E	6.Nov.99	11:50	-	-	-	-	-	
H2	Half Moon Bay - mid	26° 04.05'N	50° 04.94'E	6.Nov.99	10:35	-	-	-	-	-	Extra water sample for H3O
H3O	Half Moon Bay - South	-	-	-	-	-	-	-	-	-	Sampling was not conducted because of petro shortage. Substitute sample was taken at H2
R1	Sea Island Terminal	26° 39.73'N	50° 11.04'E	8.Nov.99	12:35	gray	no	Sandy silt	27.5	-30	Very Small tarball was observed in the sediment.
R2	Ras Tannura Spit	26° 37.60'N	50° 09.81'E	20.Oct.99	11:10	creamy	no	Silty sand	29	84	Old tarballs was observed in the sediment.
R4O	Refinery Outfall	26° 41.86'N	50° 06.48'E	8.Nov.99	13:50	creamy	no	Sandy	28.9	-55	
T1	Tarut - Zur	-	-	-	-	-	-	-	-	-	No sample site. Just coral reef condition check
T2	Tarut - Zur	26° 36.52'N	50° 04.94'E	18.Oct.99	13:21	creamy	no	shelly coarse	-	56	Shally sediment. Hermit crab was observed.
T3	Tarut - East	26° 33.83'N	50° 06.67'E	18.Oct.99	14:30	-	-	-	-	-	
T4	Tarut - Darin	26° 32.43'N	50° 05.11'E	18.Oct.99	15:20	gray	little smell	silty sand	28.5	-56	Soft fine Sediment

Table 3.3.5 Results of Field Measurement (3rd Stage) (4)

Site Code	Site Name	Location (GPS)		Sampling		SEDIMENT PARAMETERS					Observation and Comment
		Lat.	Long.	Date	Time	Color	Odor	Texture	Sediment Temp. (°C)	ORP (mv)	
T6	Qatif/Anik urban drain	26° 30.55'N	50° 02.11'E	17.Oct.99	14:40	-	-	-	-	-	Drain channel, flesh water
T7	Qatif/Anik Drain Mouth	26° 30.53'N	50° 02.57'E	17.Oct.99	15:50	-	-	-	-	-	Near the sewage outfall
T9	Dammam Fishing Harbour - Entrance	26° 29.46'N	50° 08.14'E	23.Oct.99	13:05	dark gray	no	Silty sand	27	124	
T11O	Dammam Fishing Harbour	26° 27.55'N	50° 08.00'E	23.Oct.99	11:55	dark gray	weak smell	silty sand	27	16	
T12O	Swfwa	26° 38.95'N	50° 01.15'E	17.Oct.99	12:30	-	-	silty sand	-	-	Mongrove area. New mangrove is growing. Plenty of aminal life, fish, shrimp
K1	Dammam South	26° 25.14'N	05° 01.26'E	23.Oct.99	15:00	mediam gray	no	shilty course sand	28	16.4	Sgrass was obserbed on the bottom.
K2	SAFCO outfall	26° 24.52'N	50° 11.42'E	16.Oct.99	13:40	dark glay	little smell	sticky and clayee	-	-212	Hashim can smell ammonia clearly. Birds are drinking. Surface sediment (0-10cm) is glay, below 10cm is dark. Biology activity Is low.
K3	SAFCO south	26° 24.47'N	50° 11.90'E	23.Oct.99	15:43	mediam gray	no	silty medium sand	26	98	Bottom condition: 50% of algae mat. 30% Rock, 20% sand.
K4	Khobar Central	26° 14.94'N	50° 13.37'E	7.Nov.99	11:25	dark gray	no	silty sand	26.5	-37	
K5	Khobar STP Outfall	26° 14.45'N	50° 13.41'E	7.Nov.99	12:10	gray	no	gravelly sand	27.1	-41	Sediment:Silty coarse gravelly sand
K6	Khobar South	26° 14.33'N	50° 13.50'E	7.Nov.99	10:45	creamy	no	coarse	26.3	-51	
K7	Desalination intake	26° 10.40'N	50° 13.02'E	7.Nov.99	9:17	-	-	-	-	-	
K8	Desalination Outfall	26° 10.58'N	50° 12.70'E	7.Nov.99	9:47	dark gray	no	silty coase sand	28.5	-40	
H4O	Power Station Intake	25° 51.62'N	50° 07.31'E	25.Oct.99	12:10	-	-	-	-	-	
H5O	Power Station Outfall	25° 51.23'N	50° 07.57'E	25.Oct.99	12:35	dark gray	no	Sandy shilty course sand	30	53	

Table 3.3.6 Results of Laboratory Analysis (3rd Stage) (1)

SAMPLE DETAILS				LABORATORY RESULTS - WATER SAMPLES																							
Site Code	Site Name	Sampling		TSS	TOC	TKN	NH4	Tol P	ChLA	Mg	As	Cr	Hg	Cd	Co	Cu	Ni	Pb	Zn	Oil & Grse	TPH	Benzene	Toluene	Ethylene	Xylene	Phenol	CN	Res. Cl
		Date	Time	mg/l	ppm	mg/l	mg/l	mg/l	g/l	g/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DD20	Gumah Island	30.Oct.99	16:00	-	-	1.5	-	<0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J1	Abul Ali North	31.Oct.99	11:30	2	2	1.5	<0.2	<0.01	1.3	1.5	<0.01	<0.1	<0.005	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	-	-	-	-	-	-	-	<0.01	<0.5
J2	Berri Oil Field	31.Oct.99	15:50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.2	-	-	-	-	-	-	-	-
J4	North Jubail	31.Oct.99	16:15	1	-	1.5	-	0.01	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J5	Jubail Shared Outfall	1.Nov.99	12:30	3	2	1.5	<0.2	0.01	-	1.5		<0.1	<0.005	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	<0.2	-	-	-	-	-	-	<0.005	<0.01	<0.5
J6	Jubail Harbour	1.Nov.99	10:25	2	1	1	-	0.01	0.3	-	<0.01	<0.1	<0.005	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	-	-	-	-	-	-	-	<0.01	-
J7	South Jubail	1.Nov.99	9:35	-	1	0.8	-	0.01	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J8O	Jubail Boat Harbour	1.Nov.99	13:35	<1	-	-	-	-	-	-	<0.01	-	-	-	-	-	-	-	-	<0.2	<0.1	-	-	-	-	-	-	-
J9O	Near Jubail Outfall	1.Nov.99	11:30	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.5
R1	Sea Island Terminal	8.Nov.99	12:35	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	<0.2	<0.1	-	-	-	-	-	-	-
R4O	Refinery Outfall	8.Nov.99	13:50	1	-	-	-	-	-	-	-	-	-	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	-	<0.1	<0.01	<0.01	<0.01	<0.01	-	-	<0.5
T2	Tarut - Zur	18.Oct.99	13:21	<1	3	1	<0.2	0.02	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T3	Tarut - East	18.Oct.99	14:30	1	-	<0.1	<0.2	0.01	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T4	Tarut - Darin	18.Oct.99	15:20	9	4	1	<0.2	0.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T6	Qatif/Anik urban drain	17.Oct.99	14:40	7	12	5	4.2	0.88	54	0.17	<0.01	<0.1	<0.005	<0.01	<0.05	<0.05	<0.05	<0.1	0.03	-	-	-	-	-	-	-	-	-
T7	Qatif/Anik Drain Mouth	17.Oct.99	15:50	12	11	3.6	2.7	0.64	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
T11O	Dammam Fishing Harbour	23.Oct.99	11:55	3	5	1	<0.2	0.04	-	-	<0.01	<0.1	<0.005	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	<0.2	0.2	<0.01	<0.01	<0.01	<0.01	<0.005	-	-
T12O	Swfws	17.Oct.99	12:30	10	-	1	<0.2	0.01	3.8	1.7	<0.01	<0.1	<0.005	<0.01	<0.05	<0.05	<0.05	<0.1	0.03	-	-	-	-	-	-	-	-	-
K1	Dammam South	23.Oct.99	15:00	4	-	0.8	-	<0.01	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K2	SAFCO outfall	16.Oct.99	13:40	3	48	130	90	0.20	-	0.13	<0.01	0.2	<0.005	<0.01	<0.05	<0.05	<0.05	<0.1	0.20	0.6	-	-	-	-	-	-	<0.01	3.5
K3	SAFCO south	23.Oct.99	15:43	5	3	1.5	-	0.01	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K4	Khobar Central	7.Nov.99	11:25	3	2	1.5	<0.2	0.10	-	-	-	-	-	-	-	-	-	-	-	<0.2	-	-	-	-	-	-	-	-
K5	Khobar STP Outfall	7.Nov.99	12:10	8	5	2.5	0.4	1.03	-	-	<0.01	<0.1	-	<0.01	<0.05	<0.05	<0.05	<0.1	0.02	<0.2	-	-	-	-	-	-	-	16
K6	Khobar South	7.Nov.99	10:45	4	2	1	-	0.02	-	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K7	Desalination intake	7.Nov.99	9:17	-	-	-	-	-	-	1.8	-	-	-	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	-	-	-	-	-	-	-	-	<0.5
K8	Desalination Outfall	7.Nov.99	9:47	-	-	-	-	-	-	1.9	<0.01	<0.1	-	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	-	-	-	-	-	-	-	-	<0.5
H1	Half Moon Bay - North	6.Nov.99	11:50	1	-	1.5		<0.01	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2	Half Moon Bay - mid	6.Nov.99	10:35	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H4O	Power Station Intake	25.Oct.99	12:10	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H5O	Power Station Outfall	25.Oct.99	12:35	<1	2	-	-	-	-	-	-	-	-	<0.01	<0.05	<0.05	<0.05	<0.1	<0.01	-	-	-	-	-	-	-	-	-

Table 3.3.6 Results of Laboratory Analysis (3rd Stage) (2)

SAMPLE DETAILS				LABORATORY RESULTS - SEDIMENT SAMPLES															
Site Code	Site Name	Sampling		Ign. Loss	TOC	As	Cr	Hg	V	Cd	Co	Cu	Ni	Pb	Zn	TPH	Benzene	Toluene	Ethylene	Xylene
		Date	Time	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
DD20	Gumah Island	30.Oct.99	16:00	13.4	3.2	1.6	<50	-	<100	<1	19	12	31	35	16	19	-	-	-	-
J1	Abul Ali North	31.Oct.99	11:30	18.9	2.1	0.48	<50	<0.05	<100	<1	24	21	71	40	22	15	<2	<2	<2	<2
J2	Berri Oil Field	31.Oct.99	15:50	5.1	-	-	<50	-	<100	<1	20	14	28	43	11	17	-	-	-	-
J4	North Jubail	31.Oct.99	16:15			-	<50	-	<100	-	-	-	-	-	-	-	-	-	-	-
J5	Jubail Shared Outfall	1.Nov.99	12:30	2.7	0.36	-	<50	<0.05	<100	<1	11	6	25	21	13	-	-	-	-	-
J6	Jubail Harbour	1.Nov.99	10:25	4.0	1.2	1.03	<50	<0.05	<100	<1	15	9	20	31	<10	10	-	-	-	-
J7	South Jubail	1.Nov.99	9:35	3.1	-	-	-	-	-	3	16	<5	20	30	<10	-	-	-	-	-
J8O	Jubail Boat Harbour	1.Nov.99	13:35	-	-	-	<50	-	-	3	17	14	20	35	10	9	<2	<2	<2	<2
R1	Sea Island Terminal	8.Nov.99	12:35	6.7	1.5	-	-	-	<100	3	20	20	35	48	70	<5	<2	<2	<2	<2
R2	Ras Tannura Spit	20.Oct.99	11:10	2.7	-	-	<50	-	<100	<1	17	6	21	26	16	<5	-	-	-	-
R4O	Refinery Outfall	8.Nov.99	13:50	2.9	-	1.3	<50	<0.05	<100	3	17	7	21	36	<10	38	<2	<2	<2	<2
T2	Tarut - Zur	18.Oct.99	13:21	3.1	0.36	-	-	-	-	3	17	6	19	35	<10	-	-	-	-	-
T4	Tarut - Dariu	18.Oct.99	15:20	11.7	3.4	-	-	-	-	<1	22	40	51	57	110	31	-	-	-	-
T6	Qatif/Anik urban drain	17.Oct.99	14:40	2.3	0.61	0.68	<50	-	-	2	11	8	19	27	24	96	-	-	-	-
T11O	Dammam Fishing Harbour	23.Oct.99	11:55	2.7	0.15	1.1	<50	0.28	<100	<1	10	6	29	24	23	<5	<2	<2	<2	<2
K1	Dammam South	23.Oct.99	15:00	26.4	0.56	0.83	<50	-	-	3	19	7	22	39	13	-	-	-	-	-
K2	SAFCO outfall	16.Oct.99	13:40	10.7	4.1	1.1	570	0.16	<100	<1	16	41	48	56	2100	-	-	-	-	-
K3	SAFCO south	23.Oct.99	15:43	4.7	1.1	0.93	-	-	-	3	17	9	22	42	130	-	-	-	-	-
K4	Khobar Central	7.Nov.99	11:25	5.2	1.5	0.98	<50	-	-	3	18	14	28	36	19	-	-	-	-	-
K5	Khobar STP Outfall	7.Nov.99	12:10	4.3	1.2	1.01	<50	-	-	3	17	10	25	36	13		-	-	-	-
K6	Khobar South	7.Nov.99	10:45	-	0.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K8	Desalination Outfall	7.Nov.99	9:47	2.7	0.34	1.3	<50	-	-	1	9	10	23	21	11	-	-	-	-	-
H1	Half Moon Bay - North	6.Nov.99	11:50		0.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H5O	Power Station Outfall	25.Oct.99	12:35	1.2	-	-	-	-	-	<1	<5	<5	10	<20	<10	-	-	-	-	-

Table 3.3.7 (1) Results of PlanktonSurvey (3rd Stage)

Pytoplankton

Site Code	Class	Order	Family	*Speices*	No. of Individuals (/L)	Frequency
J1	Dinophyceae	Peridiniales	Ceratiaceae	*Ceratium tripos?*	9	+
	Bacillariophyceae	Centrales	Coscinodiscaceae	*Coscinodiscus asteromphalus*	1	+
	Dinophyceae	Peridiniales	Peridiniaceae	*Peridinumu depressum*	1	+
	Bacillariophyceae	Soleniineae	Rhizosoleniaceae	*Rhizonosolenia alata*	5	+
	Bacillariophyceae	Pennales	Fragilariaceae	*Thalassiothrix frauenfeldii*	517	++
	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	1,740	++++
J4	Dinophyceae	Peridiniales	Ceratiaceae	*Ceratium fusus*	11	+
	Dinophyceae	Peridiniales	Ceratiaceae	*Ceratium tripos*	26	+
	Bacillariophyceae	Pennales	Nitzchiaceae	*Nitzchia sp.*	4	+
	Dinophyceae	Peridiniales	Peridiniaceae	*Peridinum dpressum?*	4	+
	Bacillariophyceae	Pennales	Fragilariaceae	*Thalassiothrix frauenfeldii*	13,156	+++++
	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	9	+
J6	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	77,770	+++++
J7	Dinophyceae	Peridiniales	Ceratiaceae	*Ceratium tripos?*	40	+
	Bacillariophyceae	Biddulphiineae	Chaetoceraceae	*Chaetoceros affinis*	30	+
	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	55,443	+++++
K1	Bacillariophyceae	Pennales	Nitzchiaceae	*Nitzchiaceae sp.*	15	+++++
R1	Dinophyceae	Peridiniales	Ceratiaceae	*Ceratium tripos*	131	++++
	Bacillariophyceae	Biddulphiineae	Chaetoceraceae	*Chaetoceros affinis*	65	++
	Dinophyceae	Peridiniales	Peridiniaceae	*Peridinium depressum?*	7	+
T2	Bacillariophyceae	Centrales	Coscinodiscaceae	*Coscinodisus stellaris*	58	++
	Spirotricha	Titinnida	Ptychocylidae	*Epiplocylis sp.(nauplius)*	46	++
	Bacillariophyceae	Soleniineae	Rhizosoleniaceae	*Rhizosolenia alata*	232	++++
K6	Bacillariophyceae	Pennales	Nitzchiaceae	*Nitzchia sigma*	10	++
	Bacillariophyceae	Soleniineae	Rhizosoleniaceae	*Rhizosolenia alata*	6	++
	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	14	+++
K8	Bacillariophyceae	Pennales	Nitzchiaceae	*Nitzchiaceae sp.*	9	++
	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	21	++++
H1	Bacillariophyceae	Soleniineae	Rhizosoleniaceae	*Rhizonosolenia alata*	23	++
	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	105	++++
H2	Bacillariophyceae	Centrales	Coscinodiscaceae	*Coscinodisus stellaris*	13	+
	Bacillariophyceae	Pennales	Nitzchiaceae	*Nitzchia sigma*	13	+
	Bacillariophyceae	Pennales	Fragilariaceae	*Thalassiothrix frauenfeldii*	39	+++
	Cyanophceae	Oscillatoriales	Oscillatoriaceae	*Trichodeswmium eryhraem*	52	+++

Table 3.3.7 (2) Results of PlanktonSurvey (3rd Stage)

Zooplankton

Site Code	Class	Order	Family	*Speices*	No. of Individuals (/L)	Frequency
J1	Copepoda	Calanoida	Acartiidae	*Acartia erythraea*	1	+
	Copepoda	Calanoida	Paracalanus	*Acrocalanus gracilis*	1	+
	Copepoda	Calanoida	Pseudocalanidae	*Clausocalanus furcatus?*	1	+
	Crustacea	Mysidacea	Mysidae	*Neomysis sp.*	1	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp.(nauplius)*	1	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis*	2	+
	Sarcodina	Foraminifera	*Globrigorinidae*	*Orbulina universa*	12	+++
	Sarcodina	Foraminifera	*Globrigorinidae*	*Globrigorinidae sp.*	2	+
	-	-	-	*Fish egg?*	3	+
J4	Copepoda	Calanoida	Acartiidae	*Acartia erythraea*	42	++
	Copepoda	Calanoida	Calanidae	*Caranus minor?*	39	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp.(Nauplius).*	25	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis.*	30	+
	Sarcodina	Foraminifera	*Globrigorinidae*	*Globrigorinidae sp.*	106	+++
	-	-	-	*Fish egg?*	21	+
J6	Copepoda	Calanoida	Calanidae	*Calanus sp.*	15	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp. (nauplius)*	54	+++
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp.(nauplius)*	54	+++
J7	Copepoda	Calanoida	Acartiidae	*Acartia erythraea?*	40	++
	Copepoda	Calanoida	Paracalanus	*Acrocalanus gracilis?*	10	+
	Copepoda	Calanoida	Pseudocalanidae	*Clausocalanus arcuicornis?*	30	++
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis*	40	++
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp.(nauplius)*	35	++
	Sarcodina	Foraminifera	*Globigerinidae*	*Globigerinidae sp.*	50	++
R1	Copepoda	Calanoida	Acartiidae	*Acartia erythraea*	9	+
	Crustacea	Balanidae	Balanidae	*Balanus sp.(Nauplius)*	9	+
	Copepoda	Calanoida	Calanidae	*Calanus sp.*	254	+++
	Copepoda	Calanoida	Calanidae	*Calanus sp.(Nauplius)*	14	+
	Copepoda	Calanoida	Calocalanidae	*Calocalanus pavo*	42	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona furcatus*	106	++
	-	-	-	*Fish egg?*	21	+
T2	Spirotricha	Tintinnida	Ptychosylidae	*Epiplocylis sp.*	23	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp. (nauplius)*	58	++
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp.(nauplius)*	23	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis*	23	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis.*	46	++
	Copepoda	Calanoida	Temoridae	*Eurytemora sp.*	46	++
	Copepoda	Calanoida	Temoridae	*Temora sp.*	35	+
K1	Branchiopoda	Ostracoda	Halocypridae	*Archiconchoecia sp.*	15	+
	Copepoda	Calanoida	Calanidae	*Calanus sp. (a)*	31	++
	Copepoda	Calanoida	Calanidae	*Calanus sp. (b)*	38	++
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp. (nauplius)*	23	++
	Malacostraca	Decapoda	Sergestidae	*Sergia sp.(nauplius)*	15	+
	Copepoda	Calanoida	Temoridae	*Temora sp. (nauplius)*	15	+
	Copepoda	Calanoida	Temoridae	*Eurytemora sp.*	15	+
K3	Copepoda	Calanoida	Calanidae	*Calanus sp (a).*	39	+++
	Copepoda	Calanoida	Calanidae	*Calanus sp.(nauplius)*	77	++++
K6	Copepoda	Calanoida	Acartiidae	*Acartia erythraea?*	18	+
	Copepoda	Calanoida	Paracalanus	*Acrocalanus sp.*	10	+
	Copepoda	Calanoida	Augapdastilidae	*Euaugaptilus hecticus*	6	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp.(nauplius)*	57	+++
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis*	16	+
	Crustacea	Mysidacea	Mysidae	*Neomysis sp.*	4	+
	Annelida	Archiannelida	Sarcocirridae	*Sarcpcorris sp.*	6	+

Table 3.3.7 (3) Results of PlanktonSurvey (3rd Stage)

Zooplankton (Continue)

Site Code	Class	Order	Family	*Speices*	No. of Individuals (/l.)	Frequency
K7	Crustacea	Balanidae	Balanidae	*Balanus sp.(nauplius)*	11	++
	Copepoda	Calanoida	Calanidae	*Caranus sp.*	26	+++
	Copepoda	Calanoida	Calanidae	*Caranus sp.(nauplius)*	4	+
	Polychaeta	Polychaeta	Sarcocirrus	*Sarcocirrus sp.*	2	+
K8	Copepoda	Calanoida	Acartiidae	*Acartia sp.(nauplius)*	18	+
	Copepoda	Calanoida	Paracalanus	*Acrocalanus sp.*	27	++
	Crustacea	Balanidae	Balanidae	*Balanus sp.(Nauplius)*	12	+
	Sarcodina	Foraminifera	*Globrigorinidae*	*Globrigorinidae sp.*	6	+
	Crustacea	Balanidae	Balanidae	*Balanus sp.(Cypriform larva)*	18	+
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis.*	33	++
H1	Heteropoda	Pteropoda	Cavoliniidae	*Limacina inflata?*	23	+++
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp. (Nauplius)*	12	++
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis.*	23	+++
H2	Copepoda	Calanoida	Calanidae	*Calunus sp.*	17	++
	Copepoda	Cyclopoida	Oithonidae	*Oithona sp. (Nauplius)*	39	+++
	Copepoda	Cyclopoida	Oithonidae	*Oithona tenuis.*	35	+++

+	appear very rarely	(appearance rate, 10% or less)
++	appear rarely	(appearance rate, 20 to 30%)
+++	appear commonly	(appearance rate, 40 to 60%)
++++	appear frequently	(appearance rate, 70 to 80%)
+++++	appear very frequently	(appearance rate, 90% or more)

Table 3.3.8 RESULTS OF SEDIMENT PSA ANALYSIS (3rd Stage)

Sample ID	Gravel / shell >2 mm	Coarse Sands >1 mm	Medium Sands >300 um	Medium Sands >200 um	Fine sands >150um	Fine sands >75 um	Silts & Clays >75 um	Moist (% wt)
J4	85.0%	10.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%
T2	11.6%	26.6%	38.4%	18.2%	4.4%	0.4%	0.4%	23.6%
R2	46.0%	10.8%	26.4%	11.5%	3.6%	1.6%	0.2%	17.8%
J7	18.4%	10.7%	31.3%	28.0%	4.1%	4.5%	3.0%	26.7%
H1	0.0%	0.8%	12.5%	47.8%	26.4%	11.3%	1.2%	20.8%
T6	1.7%	45.5%	21.8%	9.1%	8.6%	10.0%	3.3%	39.0%
J80	3.2%	6.3%	35.6%	30.7%	10.9%	8.8%	4.5%	25.1%
K3	5.8%	4.2%	15.5%	38.1%	22.9%	6.8%	6.8%	30.3%
J6	3.5%	6.8%	33.1%	26.8%	11.8%	16.3%	1.8%	30.9%
J2	8.6%	12.7%	27.2%	17.8%	14.3%	9.7%	9.7%	24.4%
H50	27.7%	12.1%	32.8%	4.1%	0.0%	17.5%	5.8%	17.0%
K5	19.4%	6.3%	11.3%	16.2%	22.7%	14.4%	9.6%	27.4%
K1	1.8%	3.2%	13.7%	25.4%	31.6%	19.4%	4.8%	30.1%
DD20	12.3%	9.6%	16.8%	12.5%	11.9%	14.8%	22.2%	45.3%
J5	2.3%	1.7%	11.9%	23.2%	17.3%	21.7%	21.7%	22.6%
K6	8.1%	8.1%	11.8%	9.9%	15.2%	35.3%	11.8%	34.0%
K4	6.1%	7.9%	11.9%	11.4%	14.5%	24.1%	24.1%	34.6%
R40	0.0%	0.4%	3.8%	11.9%	26.3%	46.1%	11.5%	23.1%
K8	1.4%	1.7%	5.1%	16.9%	15.6%	44.4%	14.8%	20.9%
T110	0.1%	0.3%	1.8%	10.6%	21.7%	39.3%	26.2%	21.0%
K2	0.5%	1.4%	1.6%	1.6%	3.0%	9.2%	82.6%	47.6%
T4	1.5%	1.0%	0.4%	1.0%	2.1%	27.0%	67.0%	49.1%
J1	0.0%	0.5%	0.5%	0.5%	0.9%	9.8%	88.0%	55.0%

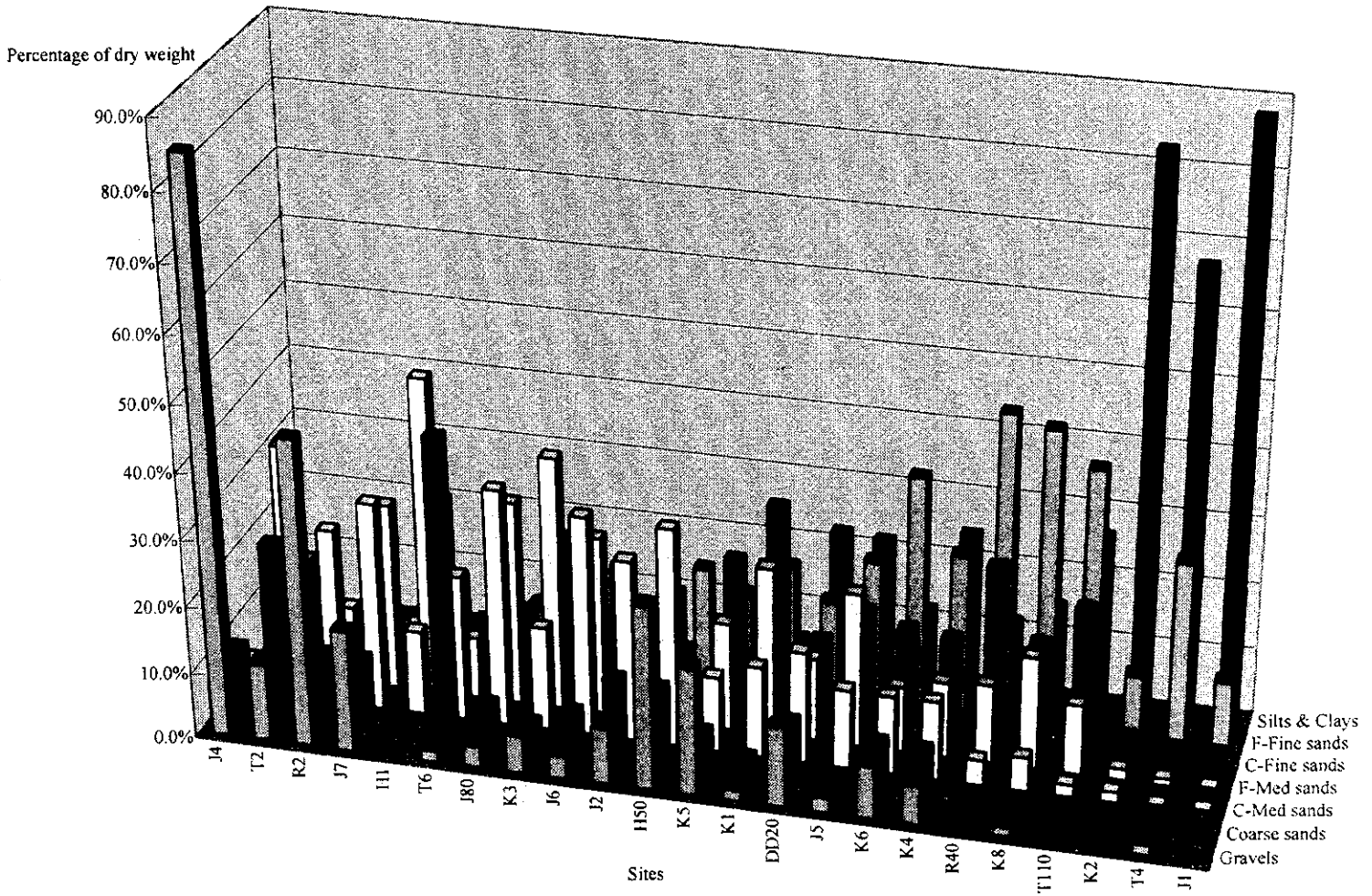


Figure 3.3.2 Results of Sediment PSA Analysis (3rd Stage)

Table 3.3.9 Field Survey Schedule (4th Stage)

Day	Date	Region	Sampling stations				
Saturday	10.Jun	HALF MOON	H4O	H5O	-	-	-
Sunday	11.Jun	TARUT, HALF MOON	H1	T6	T7	T12O	-
Monday	12.Jun	KHOBAR	K4	K5	K6	-	-
Tuesday	13.Jun	KHOBAR	K7	K8	-	-	-
Wednesday	14.Jun	KHOBAR	K1	K2	K3	-	-
Thursday	15.Jun						
Friday	16.Jun						
Saturday	17.Jun	TARUT	T11O	T9	-	-	-
Sunday	18.Jun	HALF MOON	H2	H3	-	-	-
Monday	19.Jun	TARUT	T2	T3	T4	-	-
Tuesday	20.Jun	RAS TANURA	R1	R2	R4O	-	-
Wednesday	21.Jun	-	-	-	-	-	-
Thursday	22.Jun						
Friday	23.Jun						
Saturday	24.Jun	JUBAIL, DAFI DAHWAT	J5	J6	J7	J9O	DD20
Sunday	25.Jun	JUBAIL	J1	J2	J4	J8O	-
Monday	26.Jun	-	-	-	-	-	-
Tuesday	27.Jun	-	-	-	-	-	-
Wednesday	28.Jun	KHOBAR	K2*	K5*	-	-	-

* Reconfrimation on site measurement