TABLES

Table 6.1.1 Environmental Laws and Regulations

No.	Title	Passed Issued Date
Decree No. 22/CP	Tasks, Power and Organization of MOSTE	May 22, 1993
Order No. 29-L/CTN	Law on Environmental protection	January 19, 1994
Decree No. 175/CP	Guidance for Implementation of the Law on Environmental Protection	October 18, 1994
Decree No. 42/CP	Issuing Regulation of Construction and Investment Management	July 16, 1996
Decree No. 12/CP	Details of Foreign Investment in Vietnam Law Implementation	February 18, 1997
Decision No. 845/TTg	Biodiversity Action Plan for Vietnam	December 22, 1995
Order No. 199/TTg	Measurements in Solid Waste Management in Town & Industrial Areas	April 3, 1997
Information Circular No. 2262-TT/MTg	Guidelines in Case of Oil Spill	-
Letter No. 2592/MTg	Control of Marine Pollution From Ships	November 12, 1996
Information Circular. No. 2891-TT/KCM	Regulation on Ha Long Bay	December 19, 1996
Decision No. 2920-QD/MTg	Application of Vietnam Environmental Standards	December 21, 1996
Decree No. 195/HDBT	Law on Marine Source Protection & Development	June 2, 1990
Decree No. 26/CP	Punishment for Administratively Violating Environmental Protection Legislation	April 26, 1996
Directive No. 200/Ttg	Ensuring the Clean Water and Environmental Hygiene for Rural Areas	April 29, 1994
Directive No. 406/Ttg	Prohibition of Production, Trading, and Firing of Firecrackers	August 8h, 1994
Interministerial Circular No. 155/TTLB	Temporary Regulation on Environmental Planning	April 11, 1994
Interministerial Circular No. 12/TTLB	Guidelines on Implementation of Directive 406TTg of Prime Minister	October 28, 1994
Interministerial Circular No. 1485/TTLB	Guidelines on Organization, Authority and Scope Activities of the Inspection of Environmental Protection	December 12, 1994
Interministerial Circular No. 142/Mtg	Guidelines on Environmental Impact Assessment of Operating Establishments	November 26, 1994
Circular No. 715/Mtg	Guidelines of Establishment of Foreign Direct Investment Projects	April 3, 1995
Circular No. 3370/TT-MTg	Temporary Guidelines of Remedy of Environmental Incidents Caused by Oil Fires and Explosions	December 22, 1995
Circular No. 2262/TT-MTg	Guidelines on the Remedy of Oil Spill Incidents	December 29, 1995
Circular No. 2433/TT-KCM	Guidelines for Implementation of Regulation of Punishment for Administratively Violating Environmental Protection Legislation	October 9, 1996
MOSTE Circular No. 1350 TT/KCM	Guidance on Implementing the Governmental Resolution No. 02/CP on the business of potential toxic chemicals, radioactive substances, metal wastes and by-products and hazardous chemicals containing wastes in domestic markets	August 2, 1995
-	National Action Plan of Biodiversity	December 22, 1995
MOSTE Circular No. 2781/TT-KCM	Guidance on Procedures of Environmental Performance Certificate Issuance and its Valid Extension for Industries	December 12, 1996
MOSTE Circular No. 2880/KCM-TM	Temporary Regulation on Imports of by-Products	-
MOSTE Circular No. 2891/TT-KCM	Guidance on Ha Long Bay Environmental Protection	December 19, 1996
MOSTE Circular No. 01 TT-CN-KCM	Guidance on Implementing the Government Decree on the Ban of Dodecyl Benezene Sulphonic Acid (DESA) Manufacturing and Application in the Synthetic Detergent Industry	February 28, 1997
Circular No. 276/TT-MTg	Guidance on the On-site Pollution Control in Enterprises upon Issuing Decisions on Approval of EIA Reports	March 6, 1997
Prime Minister's Instruction No. 199/TTg	Urgent Measures of Solid Waste Management in Urban Centres and Industrial Areas	April 3, 1997
MOSTE Minister's Directive No. 513/VP	Nation-wide Extensive Environmental Inspections	May 6, 1997
MOSTE Minister's Circular No. 1076/TT-MTg	Guidance on State of Environment Reporting Annually by line ministries, ministerial level agencies, and administrations under direct control of People's committees of provinces and centrally controlled cities	-
Circular No. 1100/TT-MTg	Guidance on Setting up and Reviewing the Report on EIA for investment projects	August 20, 1997
Circular No. 490/1998/TT-BKNHCNMT	Guidance on Setting Up and Appraising the Environmental Impact Assessment Report for Investments Project	April 29, 1998

Source: MOSTE, 1998

Table 6.1.2 Authority of Various Agencies

Agency	Authority to Apply Punishment
Environmental Inspector of DOSTE	• warnings • fines up to VND 100,000
Chief Inspector of DOSTE	• warnings • fines up to VND 2,000,000 • revoke permit granted by DOSTE • confiscate means and tools up to VND10,000,000
Inspector of NEA	• warnings • fines up to VND 500,000 • revoke permit
Director, Deputy Director, Chief Inspector of NEA	• all forms of punishments and other administrative measures
Chairman of People's Committee at commune, ward, district town level	• fines up to VND 500,000
Chairman of People's Committee at district level	• fines up to VND 2,000,000
Chairman of People's Committee at provincial level and city under central authority	• all forms of punishments and other administrative measures, except revoking a permit granted by the NEA

Source: MOSTE, 1998

Table 6.1.3 Vietnamese Water Standards

Standard	Application
TCVN 5294 - 1995	Principle for choice and quality assessment of water sources for drinking and household water supply
TCVN 5295 - 1995	General requirements for protection of surface and underground water from pollution cause by oil and oil products
TCVN 5296 - 1995	Principle for water protection from pollution caused by oil and oil products transported through pipelines
TCVN 5298 - 1995	Requirements for use of waste waters and their sludge for watering and fertilizing purposes
TCVN 5524 - 1995	General requirements for protecting surface water against pollution
TCVN 5525 - 1995	General requirements for protecting underground water
TCVN 5942 - 1995	Surface Water Quality Standard
TCVN 5943 - 1995	Coastal water quality standard
TCVN 5944 - 1995	Groundwater quality standard
TCVN 5945 - 1995	Industrial wastewater discharge standards
TCVN 5998 - 1995	Guidance on sampling on marine waters (ISO 5667-9: 1992)
TCVN 5999 - 1995	Guidance on sampling of wastewater (ISO 5667-10: 1992)

Source: MOSTE, 1995

Table 6.2.1 Public Responsibilities of Environmental Protection

Responsibility	MOSTE/NEA	Other Ministries	People's Committees/DOSTE	Businesses or Production Institutions
1) Development of policy, strategy, plans and overall direction	- primary role in formation of national strategy and policy - lead role in coordination of long term planning - monitoring implementation of laws and regulations	- within their sector and in conformance with national strategies - cooperation with MOSTE within their sector	- local policy, strategy, plans, and guidance - co-operating with national agencies in examination, inspection and settlement of breaches of the law	-
2) Environmental Monitoring Systems	- responsible for National monitoring system	- responsible for monitoring of effects of their activities	- within their locality - with assistance of DOSTE	- responsible for monitoring of effects their of activities
3) State of Environment Reporting	- responsible for national state of environment reporting	- cooperation with MOSTE within their competence	- within their locality - with assistance of DOSTE	- environmental reporting of environmental status in the locality of the operation
4) Environmental Complaints and Dispute Resolution	- at the national level	- within their competence as stipulated by law	- receiving and handling all disputes and complaints	-
5) Inspection	- national level	- within their sector with assistance of provincial departments	- local level with the assistance of the DOSTE	-
6) Research and Development	- lead role in research and development	- cooperation with MOSTE within their sector	- local level	-
7) Evaluation of environmental impact assessment reports and management of EIA process	- projects of certain size or social, economic or environmental importance are handled at national level; other projects may be assigned to DOSTE	- cooperation with MOSTE and other agencies in EIA process	- within their locality - with assistance of DOSTE	- assessment of environmental impact
8) Environmental Standards	- development of national standards for environmental quality	- compliance with standards	- within their locality - with assistance of DOSTE	- compliance with standards
9) Education and Training	- national level	- within their sector	- within their locality with the assistance of the DOSTE	- conducting propaganda and education programs to enhance understanding of management and staff
10) Licensing	- national level	- environmental conditions in licenses	- local level	
11) Pollution Control and Management	- policy and guidelines	- proper pollution control and management of activities in their sector	- local policy and guidelines	- proper pollution control and management of their activities
12) Supervision of Collection of Pollution Charges	- policy and guidelines	-	-	-
13) Solid and Hazardous Waste Management	- policy and guidelines	- proper environmental management of transport and facilities	- local policy and guidelines	- proper environmental management of transport and facilities
14) Protect Area Management	-	- creation of protected areas - management of protected areas	- local policy and guidelines	-
15) Wetland and sensitive ecological area management	-	- management of ecological areas	- local policy and guidelines	-

Source: Government Decree 175/CP, October 18, 1994 regarding Guidance on the implementation of the Law on Environmental Protection.

Table 6.2.2 Division of Responsibilities for Management and Conservation of Living Aquatic Resources

Responsibility	Council of Ministers	Ministry of Fisheries	People's Committee
1) Strategy and Planning for protection and development of living aquatic resources	- decides the content and approves strategy and plans for entire country	- prepares strategies and plans for Council of Ministers approval - implementation through agencies under its direct control	- prepare and approve strategies and plans within their locality and administrative responsibility
2) Regulations on Closing Fisheries	- decides on closure of fisheries closures during critical life stages of aquatic species	-	-
3) Quotas of allowable catch	-	- sets allowable catches of certain stocks	-
4) Licensing and Gear Restriction and Zone Demarcation	-	- may decide to ban or limit gear types - establish fishing zones - license fishing boat, gears and equipment	-
5) Research and Surveys	-	- undertakes research and surveys	-
6) State Inspection	- defines agencies organisation, rights, and obligation of inspection and responsibilities	- implement nation wide inspection on protection of key waters	-
7) Protection of Species	-	- publish of species that need to be protected and proscribe any special measure to protect them	-
8) Introduction of Exotic Species	-	- deciding on the introduction of exotic species into Vietnam - applying and introducing preventive measures against disease	-
9) Complaints and Dispute Resolution	- final arbitrator if a dispute can not be settled at other levels	- handles complaints and disputes among central branches of government or provinces	- handle complaints and disputes within their locality
10) Habitat Protection	- responsibility for habitat protection needs to be clarified	-	-

Source: Law on Conservation and Management of Living Aquatic Resources, 1989.

CHAPTER 7

CHAPTER 7 CURRENT ENVIRONMENTAL MONITORING CONDITIONS

The existing evaluation reports pointed out constraints to be improved for a sufficient environmental monitoring execution in Vietnam, including shortage of finances, technology, equipment, and skilled personnel. More basically, the environmental management framework has also been indicated to be insufficient in many aspects, namely strategies, legislation, regulations, education, training, awareness raising, research, and experimentation.

7.1 Legal and Institutional Aspect

7.1.1 Environmental Monitoring System in Vietnam

Natural disasters, rapid demographic growth, and the impacts of human activity have resulted in serious environmental problems in Vietnam. The most significant environmental issues include deforestation, degradation of soil and freshwater, deterioration of the coastal environment and wetlands, over-exploitation of biological resources and loss of biodiversity, increasing environmental pollution, and long-term environmental effects of war.

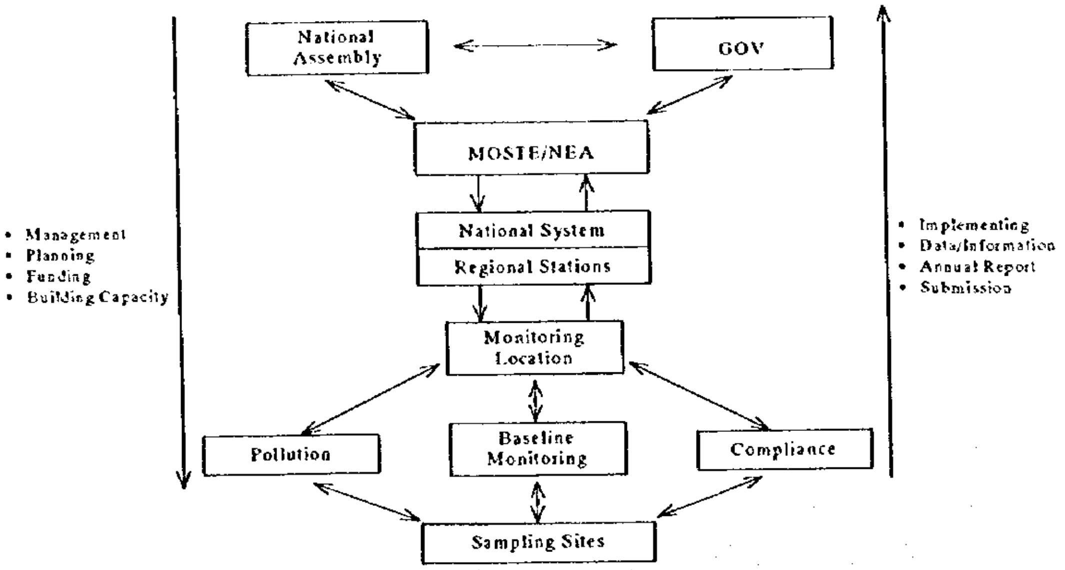
In 1981, the Ministry for Higher Education and the State Committee for Sciences and Technology (now MOSTE) received a proposal from Vietnamese scientists and launched it as the national "Resources and Environment Research Program" (RERP). Through the implementation of eighteen research projects integrated in RERP, with technical assistance from IUCN, "National Conservation Strategy" (NCS) for Vietnam was prepared in 1985.

An international conference on environment and sustainable development held in Hanoi in December 1990 in cooperation with UNDP, SIDA, and IUCN accelerated the provision of "National Plan for Environment and Sustainable Development 1991-2000" (NPESD), taking the issues raised in NCS as its foundation. NPESD was officially approved in 1992. This gave an actual starting point to the systematic environmental monitoring in Vietnam, because the framework of NPESD involved a wide variety of components including the environmental monitoring.

In implementing the national plan, the government prepared "Law on Environmental Protection" (LEP), that was then enacted in December 1993. In LEP, the environmental monitoring is addressed as a necessary activity in order to manage the environment effectively and ensure a healthy environment for human life (Item Four, Article 37, Chapter IV of the LEP). Environmental inspection is also required to MOSTE by LEP in Article 40.

7.1.2 MOSTE/NEA (National Environmental Agency)

MOSTE/NEA has a responsibility to establish a national system on coastal/marine environment monitoring, named "coastal pollution monitoring system". This monitoring system has functioned since 1995 in the northern part of Vietnam and its scope was expanded to include the whole coast and offshore waters in 1996. This monitoring system is a result of a cooperation between MOSTE/NEA and other sectors/institutes such as Natural Centre for National Science and Technology (Institute of Oceanology), Ministry of Fisheries (Institute of Sea - Product Research) and NAVY (Department of Chemistry). The coordination mechanism of the system is presented below:



Source: Coastal Pollution Monitoring in Vietnam/Ha long Bay Case Study 1997, HIO

Figure 7.1.1 Coastal Pollution Monitoring System

The monitoring system is categorized into several types, including hypothesis testing, impact assessment, and trends analysis.

7.1.3 DOSTE in Quang Ninh Province

LEP also refers to the responsibilities of the Provincial People's Committees regarding the protection of the environment in each province. This responsibility has actually been handed over to DOSTE of the province. MOSTE/NEA are responsible for offering DOSTE technical guidance and providing training for DOSTE staff.

DOSTE of Quang Ninh province has been enhanced with environmental monitoring because of the need to conserve Ha Long bay as a World Natural Heritage and the threat of coal mining activities. However, despite an eager appeal by DOSTE, no periodic monitoring station has been set up mainly due to budget constraint of the province.

7.2 Human Resource Aspect

DOSTE has 4 divisions and only 19 staff in total, as of 1999, and most of the administrative budget is given by QNPC while the Ha Long Bay Management Board (HLMB) has many staff for the care of caves and grottos in the World Heritage area as shown in the next tables. Other provincial organizations such as DOT and DOF have very poor numbers of staff for environmental conservation activity.

Human Resource of DOSTE

Division		Staff No.
a)	Environmental Management Division (EMD)	5
b)	Inspection and Control Division (ID)	2
c)	Standard, Metrology, and Quality Division (STAMQ)	3
d)	Science Technology Administrative Division (STAD)	9
Total		19

Source: DOSTE, 1998

Human Resource of HLMB

Section/Unit	Staff No.
Management Section	
- Administration and Personnel Unit	4
- Profession and Research Unit	4
- Patrol Team	4
- Accounting Unit	3
Profession Activity Section	
- Cave an Grotto Management Unit	76
- Tourists an Guidance Unit (to be established soon)	-
Total	91

Source: HLMB, 1999

7.3 Technical Aspect

7.3.1 General Technical Aspect

Literature studies and interviews with relevant organizations suggest the following problems with environmental monitoring in Vietnam:

a) National laboratories on marine environmental monitoring are being developed with newly added equipment, but the staff of these laboratories have not yet been skilled enough,

b) Quality assurance and quality control (QA/AC) procedures are often inappropriately applied in the steps of the monitoring program,

c) Linkage between marine pollution monitoring and management strategy is hardly highlighted, and

d) Experience in designing of monitoring programs is limited.

Local observation on the actual practice and report preparation concerned with the study area has further clarified these deficiencies. Some instances of the past environmental analysis reports submitted by Vietnamese organizations indicate an inadequate technical level for chemical analyses, data processing, and data checking. Extraordinary values sometimes appeared in water/sediment-quality data, which would be never found in the usual natural environment. These must have resulted from some false techniques during sampling, storage, data-check, and analysis practices. Well-educated personnel on sea/fresh water quality have not been employed for data-quality control.

More basically, biological data have included errors frequently, such as mistakes of taxonomic names, disorder of taxonomic group list and wrong summing-up of data. This may be attributed to lack of reliable taxonomic literature for species identification and careless data processing.

7.3.2 Equipment

Equipment provided by separate UNDP and World Bank projects is listed in Table 7.3.1. A component of the technical transfer and capacity development in environmental monitoring is assistance with the development of a field laboratory facility in which basic analyses can be conducted. DOSTE has provided space in an adjacent building in which it plans to develop a basic laboratory, and where field equipment can be stored.

For development of the laboratory facilities and preparation for the technical training courses, some of the procured field equipment was calibrated. The multi-parameter meter, the pH meter, and the turbidity meter were calibrated for operation. The Van Dorn water sampler, the Ekman Grab, and the plankton tow were rigged with graduated lines and required weights.

7.3.3 Technical Training by JICA Study Team

In order to assist with the ultimate implementation of the EMP, basic skills in environmental sampling and analysis are required. The technical transfer of skills in water and sediment sampling forms one element of the technical transfer component of the Study. The program was designed to maximize practical "hands-on" experience with the equipment and to integrate as much local expertise in environmental sampling and analysis as possible. During the Study the following technical training activities in water quality sampling and analysis were completed:

a) introductory principles of environmental monitoring program design,
b) delivery of classroom and field training on environmental sampling, field sampling equipment use, and

c) delivery of classroom and field training on water quality and hydrographic sampling as part of the Field Survey.

(1) Field Sampling and Introductory Principles of Monitoring Program Design

A three day classroom and field course on environmental sampling and monitoring was delivered to CP/T and staff of other provincial departments on June 10-12, 1998 in Ha Long city by the JICA study team. The course focused on instruction on use of the sampling equipment, and on basic principles of environmental monitoring design.

(2) Training Seminar on Sampling for Field Survey

Scientists from HIO, who implemented the Field Survey, delivered a pre-Field Survey seminar to CP/T on the sampling techniques and protocols that they subsequently undertook during the Field Survey. This day long seminar introduced to CP/T training activities that would take place as part of the Field Survey. The seminar detailed theoretical and practical considerations of the Field Survey, which included demonstrations of scuba diving equipment, water and sediment samplers, and techniques for sampling coral reefs, benthos, and mangroves.

(3) Training During Field Survey

During the implementation of the Field Survey, CP/T participated in the data collection activities. They worked alongside HIO staff to practice the sampling skills they acquired during previous training courses and seminars. Activities included collection and preservation of water samples, collection and processing of sediment and benthic invertebrate samples, and the collection of plankton samples.

(4) Training Program for Development of Monitoring Plan

A classroom training program for development of monitoring plan was conducted by the JICA study team to CP/T and staff of other provincial departments on

March 4, 1999. The program focused on a basic skill of development of monitoring plans such as monitoring framework, monitoring points and items selection, and establishment of monitoring organization.

7.4 Implemented Environmental Monitoring

7.4.1 Coastal Pollution Monitoring System

(1) Outline of Coastal Pollution Monitoring

The coastal/marine environment monitoring system started to carry out its task in 1995 in the northern part of Vietnam and its scope was continuously expanded throughout the coast and offshore waters in 1996.

The purpose of the coastal/marine environment monitoring system is to collect up-to-date information about coastal/marine environment quality, including three components, namely seawater, bottom sediment, and biological component. This partly meets the needs for data on some oceanographical and hydrochemical conditions, as well as on contaminants in coastal waters. These data are also accorded for coastal management and historical purpose.

The monitoring system consists of 13 monitoring locations in and near the main estuarine areas or socioeconomic centres, as well as 6 locations in and around the oil/gas platform area or some inshore islands (Figure 7.4.1).

The marine environment monitoring stations (MEMS) at Do Son and Nha Trang periodically gather information of monitoring results. From the central MEMS, coastal/marine environmental quality information is available to the users. The results contribute to the assessment of the annual state of marine environment in Vietnam. These are submitted to the GOV/MOSTE in conformity with LEP. The monitoring data are presented in the form of quarterly data report and annual report.

The coastal/marine environment information provided by the national system includes data on:

- Seawater levels and current
- Nutrients

- Contaminants in water, sediment and biota
- Plankton

The overview of the parameters at each monitoring location is presented in the Table 7.4.1.

(2) Sampling Strategy and Analyses

At each monitoring location, the measuring sites or transects line are arranged crossing the river-backish-saline water masses or parallel with current directions. Sampling frequency is four times/year in March, June, September, and December. These samples are collected during the highest and lowest tides for every site and at two layers of water column (surface and bottom). The field sampling is carried out by a motorboat/ship with GPS.

The collected samples are preserved by different survey manuals for coastal/marine resources, for example:

- DO sample: Collected into oxygen bottles and fixed by *manganese chloride* ($MnCl_2$) and *potassium iodide* in *sodium hydroxide* solutions
- Oil sample: In Teflon bottles with *sulfuric acid* added as preservative
- Heavy metal sample: In Teflon bottles with *hydrochloric acid* (HCl) 6N added
- Nutrient sample: *Mercurie chloride* solution
- Plankton: With 5% *formalin*/70 percent *alcohol*
- Coliform sample: Put in clean bottles and kept at 4°C in thermally – insulated box (ice box)

These samples are also analyzed by different methods such as:

- Water temperature: Thermometer with accuracy of ±0.5°C
- pH: Paliese standard colorimetry with cresol red indicator or digital pH meter
- Salinity: Mork-Knudxen method or by refractometer/digital salinity meter
- DO and BOD: Winkler method or water quality checker/digital BOD and DO meter
- Transparency: Secchi disc

- Nutrient contents (NO_3^-, PO_4^{3-}, SiO_3^{2-}) and total phosphorus: Chlorimeter and UV-V spectrophotometer
- Oil content: Partition-gravimetric method or infrared spectrophotometer
- Coliform: Vincent culture method
- Pesticide residues: Gas-chromatograph
- Heavy metals: Atomic absorption spectrophotometer

(3) Main Results

Data on the concentration of main contaminants in the coastal water in Vietnam were collected at MEMS in 1996 as follows:

1) Oil content

The oil content in the coastal water has been recorded at 0.62 mg/ℓ on average. In Northern coast, it was 0.1-0.72 mg/ℓ and average was 0.36 mg/ℓ. In central coast, the value was lower (0.07-0.67 mg/ℓ), average 0.21 mg/ℓ. In the coastal water in Southern coast where oil/gas mines have been exploited, the oil content was highest 0.54-2.05 and average was 1.29 mg/ℓ.

It shows that the coastal water near large ports, oil storages and oil/gas platforms has been polluted by oil. Its content exceeded the allowable concentration level of Vietnam standard (TCVN 5943-1995) by 2-4 times. Some oil spills were also recorded at MEMS in 1996, where the oil content was 20 times higher than allowable standard of Vietnam.

2) Pesticides

The pesticide residues in the coastal water were in the range of 0.09-1.17 µg/ℓ with the average value of 0.32 µg/ℓ which was lower than the allowable standard. The pesticide residues were concentrated in south coast by eight times higher than other regions as shown below. This was mainly because the amount of used pesticide per hectare in the southern areas was two times higher than in the northern areas.

Pesticide Residue Value in Different Coast in Vietnam (1996)

(Unit: μg/ℓ)

Region	Range	Average
Northern Coast	0.09 - 0.24	0.11
Central	0.09 - 1.17	0.53
Southern	0.82 - 0.85	0.84

Source: Coastal Pollution Monitoring in Vietnam, 1997, HIO

The common compounds of organochlorined pesticide residues also appeared at various levels as shown below:

(Unit: mg/ℓ)

Compounds	Range
Lindane	trace - 0.178
HCB	trace - 0.015
DDE	0.001 - 0.538
DDD	trace - 0.989
DDT	0.133 - 5.478
Others	trace

Source: Coastal Pollution Monitoring in Vietnam, 1997, HIO

3) Heavy metals

The heavy metals monitored in the coastal water in 1996 were lead (Pb), cadmium (Cd), arsenic (As), copper (Cu), zinc (Zn) and iron (Fe). Their contents in different regions are introduced in the next table.

Heavy Metals in Coastal Waters of Vietnam (1996)

(Unit: μg/ℓ)

Region	Heavy Metals (Range/Average)					
	Pb	Cd	As	Cu	Zn	Fe
Northern	9.2 - 30.4/ 16.4	0.2 - 0.3/ 0.3	-	4.4 – 11.5/ 7.4	1.3 - 104/ 22	-
Central	0.2 – 80/ 42	0.1 -0.2/ 0.2	2.3 - 5.0/ 4.3	3.3 – 7.8/ 5.8	23 - 324/ 168	4.2 - 625/ 544
Southern	0.7 - 1.0/ 0.9	<0.5/ 0.3	7.2 - 16.2/ 12.9	5.4 - 25/ 14	19 - 35/ 26	147 - 2,404/ 600
Total	0.2 - 30.4/ 7.2	0.1 - 0.5/ 0.3	2.3 - 16.2/ 8.6	3.3 - 25/ 9	1.3 - 324/ 72	4.2 - 2,404/ 572

Source: Coastal Pollution Monitoring in Vietnam, 1997, HIO

The heavy metals at some locations exceeded the allowable standard, while Pb and Cd were lower than the standard. Apart from this, Zn in the coastal water exceeded the standard: 2 times (north), over 10 times (central) and 6 times (south). Fe in central and southern coastal waters exceeded the standard by 5 times, Cu and As in southern coastal water were 1.3 times higher than the standard.

4) Coliform

The samples of coliform were collected at some locations in the coastal waters near coastal/beach tourism resorts. The mean total of coliform was in wide range (0 - 6,166 MPN/100 mℓ) with its annual average value of 1,976 MPN/100 mℓ.

(Unit: MPN/100 mℓ)

Region	Range	Average
Northern Coast	564 - 1,987	928
Central	0 - 5,640	1,205
Southern	85 - 6,116	3,796
Total	0 - 6,116	1,976

Source: Coastal Pollution Monitoring in Vietnam, 1997, HIO

The monitoring results also show that in summer season, the coliform value was usually higher than the other one. This issue relates to direct discharge of the non-treated wastewater/domestic wastes into the coastal waters.

7.4.2 Case Study in Ha Long Bay

(1) Monitoring Strategy

1) Sampling network

Sampling was carried out by modified triangular grid (Figure 7.4.2). Almost all the transect lines pass across the Cua Luc strait. The sampling network has reflected the possible sources of pollution which are predicted from diagnostic review results conducted by rapid appraisal. Total 15 sampling sites were designed on these transects, among them there were 3 sites (number 4, 6, 12) with 24 hours operation, and remain 12 sites were the spatial sites.

2) Sampling strategy

At the sites with 24 hours operation (4, 6, 12), the parameters such as salinity, pH, COD, BOD_5, DO, NO_3-N, NO_2-N, NH_4-N, PO_4-P, T-P, SiO_3^{2-}, turbidity, and temperature were collected or measured in both surfacial and bottom layers, while pesticide, coliform, and oil only in surfacial layer. Oil and heavy metals were collected at low and high tides. Plankton sampling was conducted in two layers and every 4 hours. The sediment and benthos samples were collected by petersen grab. At the spatial sites these parameters were collected only in the two layers, and one time.

It is noticed that the coliform samples were collected only at the sampling sites where near the coast and in the Cua Luc embayment. The bedform of the bay was controlled on 5 transects by an echo-sounder. The current was also measured at 3 sites with 24 hours.

3) Monitoring site documentation

Documentation for each station included:

- identification of site number,
- latitude and longitude coordinates,
- general description of the site conditions,
- depth of water,
- distance from nearest mainland,
- local pollution sources, if any,
- any observable pollution, and,
- making sample number.

The sample types include seawater bottom sediment, some organisms, and suspended matter. Double sampling and repeat analysis were also applied to check analyzed methods.

4) Sampling time

Seasonal sampling (in January/February and July/August) was applied. The sampling equipments used and methods are mentioned in conformity with the Manual on Sampling and Analysis of Monitoring the Marine Environment and the Environment Monitoring Workbook.

(2) Maine Results

1) Organic pollution

In the Cua Luc embayment, DO was on average 4.4 mg/ℓ in the surface layer, and 4.1 mg/ℓ in the bottom layer. DO in the sites far from the coastline was higher than in the Cua Luc embayment. The average value of DO in surface layer was 5.2 mg/ℓ and in bottom one was 4.8 mg/ℓ. In water of the Cua Luc embayment, COD value was highest of Ha Long bay, on average 4.2 mg/ℓ. At the remaining sites, COD value was rather low, in range of 2.0-3.6 mg/ℓ. The average BOD value for both water layers was low, 0.1-2.2 mg/ℓ.

2) Oil

Oil content in Ha Long bay was in range of 0.02-0.70 mg/ℓ. Some 80% of total analyzed samples have contained oil with the content of 0.05 mg/ℓ. In the Cua Luc embayment and near navigation channels, the oil content was relatively high with 0.16-0.49 mg/ℓ. Thus, the high oil content is considered to be related to shipping and tourism activities. The bays' waters have been polluted by oil in comparison with the allowable standard.

3) Pesticide residue

The 11 water samples of surface layer in Ha Long bay were analyzed in term of pesticide. The main recorded substances of pesticide were Lindane and DDT.

Lindane content in surface layer of the bays was rather low with 0.0003 mg/ℓ on average. The value was lower in comparison with the allowable standard. DDT content was also very low (average 0.0003 mg/ℓ). At the sites in the Cua Luc embayment where is near agricultural/forestry actives, DDT content was relatively high with about 0.003 mg/ℓ, but still most time lower than the allowable standard.

4) Heavy meals

Cu content in Ha Long bay was in range of 4.7-57.0 μg/ℓ with 11.4 μg/ℓ on average. This was highest of the whole heavy metals. Its content in the bottom water layer was 16.3 μg/ℓ on average, about 2-3 times higher than in the surface layer (6.4 μg/ℓ on average). Lead content was relatively low with about 2.15 μg/ℓ on average. Its average value in the bottom layer (2.9 μg/ℓ) was also 2 times higher than in the surface layer (1.4 μg/ℓ). Cd content was very low, in range of 0.1-0.4 μg/ℓ and 0.2 μg/ℓ on average. Similar to Cu and Pb, Cd in the bottom layer was also higher than the surface one. Among 4 studied heavy metals, mercury (Hg) was relatively low, often under 0.1 µg/ℓ.

7.5 Relevant International Assistance

7.5.1 Vietnam-Canada Environmental Project (VCEP)

VCEP declared a goal to enhance the protection of the environment in Vietnam. Its purpose is to strengthen the capabilities of national and local environmental institutions in Vietnam. It focused on four regions, in the areas of environmental monitoring, industrial and urban pollution management, EIA, and environmental planning and information management. Though Quang Ninh province was not selected as a priority area, VCEP should be a forerunning example for the formation of an environmental monitoring system in Vietnam. The key outputs of the planning work on the environmental monitoring are:

a) to develop operational frameworks for environmental monitoring,
b) to establish environmental monitoring units and to let them function properly,
c) to train technical and managerial personnel and to utilize their expertise effectively,
d) to prepare and enact policies, regulations, and operational documents,
e) to implement demonstration programs, and
f) to develop university curricula on environmental monitoring and to start the course.

7.5.2 Biodiversity Monitoring Program

"Biodiversity Action Plan" (BAP) for Vietnam in 1994 proposed a monitoring program consisting of the following seven components:

a) monitoring of habitats,
b) monitoring of ground conditions,
c) monitoring of indicator species,
d) data monitoring,
e) monitoring of management,
f) monitoring of fishery stocks, and

g) monitoring of physical parameters.

Among these, monitoring of habitats has already commenced, while the others are still waiting to be promoted. BAP's monitoring of physical parameter requires MOSTE to coordinate a nationwide program to monitor climate, air quality and water quality.

7.5.3 Ha Long City Water Supply and Sanitation Project

The Feasibility Study (1998) on the Ha Long City Water Supply and Sanitation Project (HWSSP) emphasized the need of an environmental monitoring system for efficient environmental control in the sanitary landfill. This project recommended the implementation of monitoring on air quality, water quality, and soil quality with practical instructions. It also pointed out the importance of monitoring on the heavy metal content of fish and crustaceans in local ponds.

7.5.4 Cai Lan Port Expansion Project

The Feasibility Study on Cai Lan Port Expansion Project (JICA, 1995) recommended to prepare detailed design of the environmental monitoring plan as a part of the environmental management plan. It pointed out some key factors to be monitored, such as water quality, dust, noise, and mangrove ecosystem including fish and shellfish. As for the water quality, it is proposed monitoring on a six-month basis (summer and winter), targeting various parameters including DO, organic matters, nutrient salts, SS, oil contents, and heavy metals.

This project has been transferred to the detailed design stage. The plan of monitoring method was revised adding environmental consideration on channel dredging and the social aspect. The established monitoring plan during the detailed design stage is shown in Table 7.5.1.

7.5.5 Environmental Management Practice in Open Pit Coal Mining in Quang Ninh Province

In 1997, UNDP evaluated the environmental management practice in open-pit coal mining in the province, and recommended to introduce technical training on establishing an environmental management system. In environmental management system, environmental monitoring, environmental inspection, and waste/ environmental audits are addressed as indispensable components. At present, inspections are conducted by the Department of Industry and DOSTE.

7.5.6 Other Aid Projects and Programs Concerning Environmental Monitoring

The following projects and programs are on-going or planned at present:

a) Strengthening National Capacities to Integrate the Environment into Investment and Public Policy (UNDP),
b) Environmental Consideration for Coal Mining Industry (UNIDO),
c) Coastal and Marine Environmental Management in the South China Sea (ADB),
d) Environmental Assessment and Sustainable Development of Coal Mining Sector in Vietnam (CIDA),
e) Vietnam Coastal Area Sensitivity Mapping Project (SIDA), and
f) Strengthening Environmental Management Authority, with a purpose to implement a pollution control inspection survey (IUCN).

7.6 Inspection Activity

Some organizations are conducting inspection individually at present, without mutual coordination. QN Port Authority conducts the inspection of cargo boats and the Board of Tourist Ferry Dock carries out the inspection of tourist boats. Although DOSTE has the authority to inspect mines and industries, MOSTE holds the authority to inspect some of them depending on their scale. MOI is also related to the huge state owned company such as VINACOAL. Therefore, DOSTE does not cover all of the information related to the inspection. The inspection tends to be the reaction after the serious environmental problems because DOSTE has only two inspectors.

TABLES

Table 7.3.1 Equipment Provided to DOSTE by UNDP and World Bank

UNDP Project (VIE 94-03)

<Laboratory>

1) Oven
2) Muffle furnace
3) Digital balance
4) Refrigerator
5) Fume hood
6) Hi Vol air sampler
7) Air monitoring station
8) SS measuring equipment

<Field/Portable>

1) Laser dust Analyzer
2) Dust gauges
3) Radioactivity meters
4) Sound meters
5) Vibration meters
6) Gas meters
7) Kemmer water bottle
8) Grab water sampler
9) Sediment sampler
10) Multi-parameter
11) Soil chemistry kit
12) Soil moisture probe
13) Water quality meter
14) Flow meter
15) BOD meter
16) Conductivity meter
17) pH meter
18) Dissolved oxygen meter
19) Turbidity meter
20) Secchi disk
21) Soil auger

World Bank Pollution Study (1998)

<Field/Portable>

1) Dissolved oxygen meter
2) Coliform Laboratory

Source: DOSTE, 1998

Table 7.4.1 Overview of the Parameters at Each Monitoring Location

Location	Main Monitoring Parameters										
	Current	Temp-erature	pH	Turbidity	BOD/COD	Nutrients	Plankton	Coliform	Oil Content	Pesticide	Heavy Metal
Ha Long	x	x	x	x	x	x	x	x	x	x	x
Do Son	x	x	x	x	x	x	x	x	x	x	x
Ba Lat	x	x	x		x	x	x	x	x	x	x
Sam Son	x	x	x	x	x	x	x	x	x	x	x
Cua Lo	x	x	x	x	x	x	x	x	x	x	x
Deo Ngang	x	x	x	x	x	x				x	x
Da Nang	x	x	x	x	x	x		x	x	x	x
Dung Quat	x			x		x		x	x		x
Qui Nhon	x			x	x	x		x	x		x
Nha Trang	x	x	x	x	x	x		x	x	x	x
Vung Tau	x	x	x	x	x	x	x	x	x	x	x
Dinh An	x	x	x		x	x	x	x	x	x	x
Rach Gia	x	x	x		x	x			x	x	
Bach Ho	x	x	x	x			x		x		
Dai Hung	x	x	x	x			x		x		
Bach Long Vy	x	x	x	x		x	x		x	x	x
Con Co	x	x	x	x		x	x		x	x	x
Phu Quy	x	x	x	x		x	x		x	x	x

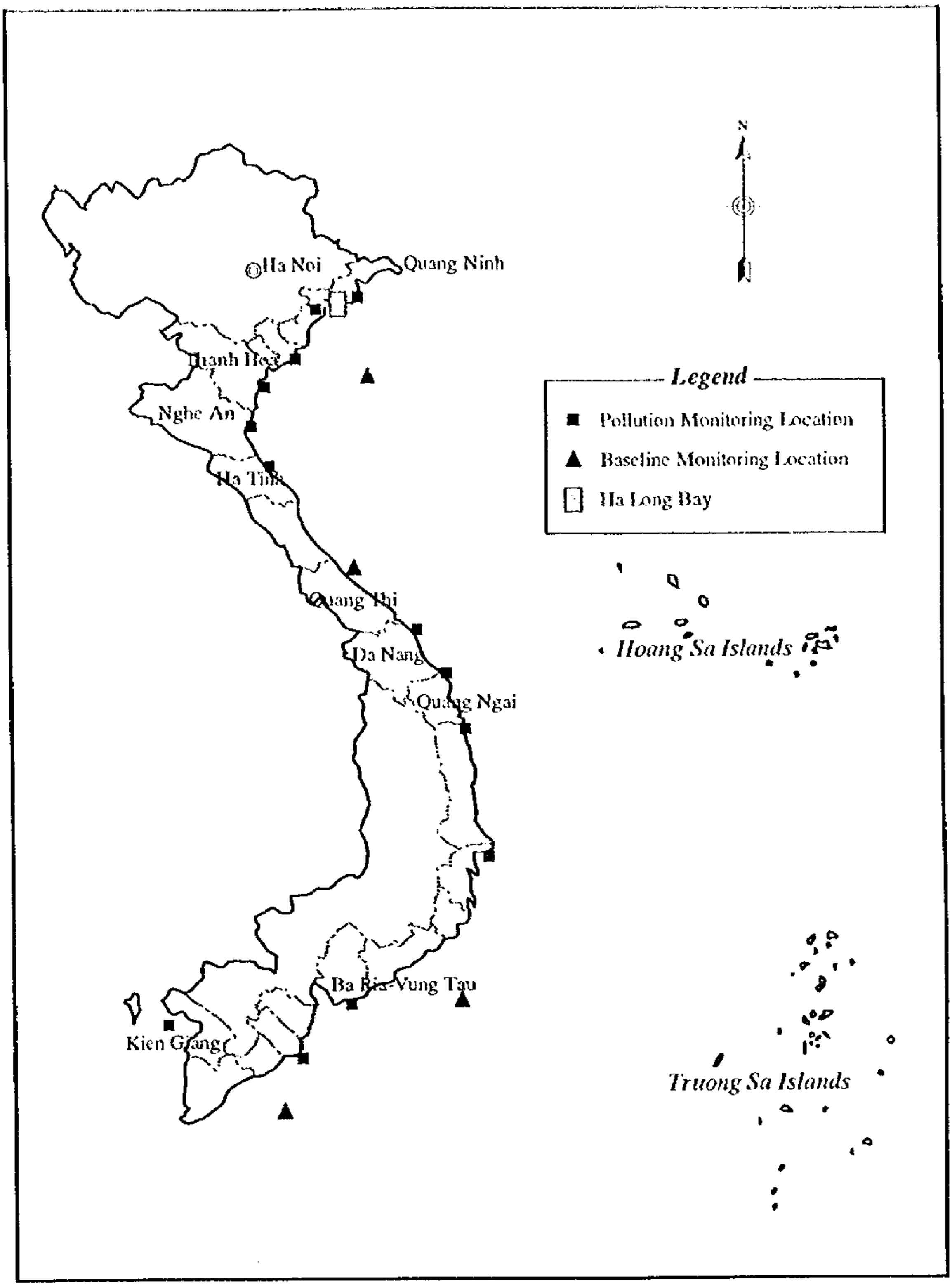
Source: Coastal Pollution Monitoring in Vietnam, 1997, HIO

Table 7.5.1 Summary of Proposed Environmental Monitoring

Anticipated Impacts	Phase	Monitoring Method
Physical Environment		
• Soil source sites	Construction	Site engineering records
• Solid and hazardous waste	Construction & Operation	Site disposal records and spot monitoring
Air Quality	Construction & Operation	Weather and air quality station
Water Quality	Construction & Operation	Water quality station at port and JICA funded stations
• Dredging	Construction	Change in water quality
• Waste water discharges	Operation	Change in water quality
- Domestic wastewater		
- Ship waste water		
- Bilge water		
- Storm water		
• Ballast Water	Operation	Change in water quality
• Accidental Spills	Operation	Change in water quality
Biological Impacts		
• Terrestrial communities	Construction	None
• Mangroves at port site	Construction	None
• Mangroves near port	Operation	Periodic sampling
• Wetlands at port site	Construction	None
• Wetlands near port	Operation	Periodic sampling
• Benthic communities	Construction & Operation	Periodic sampling
• Fish populations	Construction & Operation	Periodic sampling
• Coral Reefs	Construction	Periodic sampling
Social and Cultural Impacts		
• Affected buildings	Construction	Financial records and community interviews
• Affected populations	Construction	Financial records and community interviews
• Loss of agricultural lands	Construction	Financial records and community interviews
• Loss of small business	Construction	Financial records and interview
• Loss of access to water point	Construction	None
• Community impacts	Construction & Operation	Project records and periodic interviews
• Aesthetics	Construction	None
• Tourism	Construction & Operation	Periodic sampling
• Occupational health and safety	Construction & Operation	Project records and periodic interviews

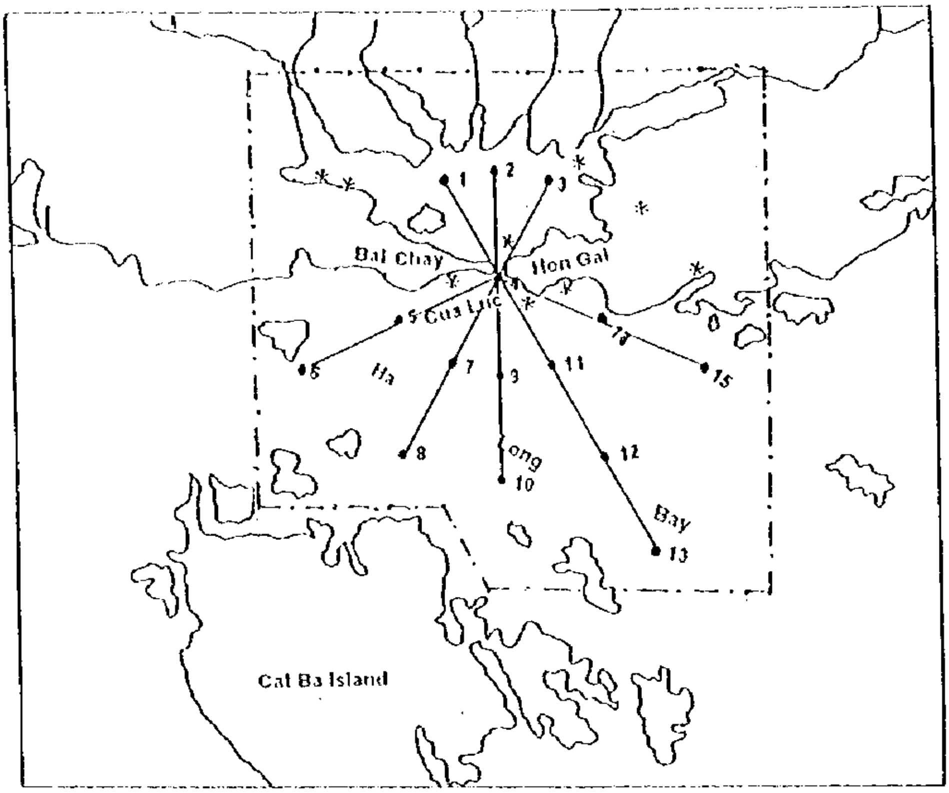
Source: Environmental Impact Assessment of Cai Lan Port Expansion Project, September 1998.

FIGURES



Source: Coastal Pollution Monitoring in Vietnam, 1997, HO

Figure 7.4.1 National System of Marine Environment Monitoring



Legend

—·—·—·–	Study Area Boundary
——●——	Sampling Sites
*	Priority Pollution Sources
1:300,000	Scale

Source: Coastal Pollution Monitoring in Vietnam, 1997, HIO

Figure 7.4.2 Proposed Field Sampling Strategy

CHAPTER 8

PART III WATER POLLUTION MECHANISM AND SIMULATION MODEL DEVELOPMENT

CHAPTER 8 OCEANOGRAPHIC CONDITIONS

8.1 Coast and Sea Bed Topography

(1) Geomorphology

Ha Long bay is delimited by the Hong Gai estuary in the north and the outer bay which extends out to Cat Ba island. Bai Tu Long bay is located west of Ha Long bay. Ha Long – Bai Tu Long bay ranges from 20° 44'to 12° 00' North latitude and 106° 58' to 107° 10' East longitude. It is characterized by over 3,000 limestone outcrops and islands along the coastline for over 100 km from Quang Ninh province to the northern border of China.

The sea bed in the bays is relatively flat and shallow, and it is typically only a few meters in depth in Bai Chay bay and near Hong Gai quarter and Cam Pha town. The average depth is only 1.0-1.5m adjacent to the coastline, sloping gently toward the southeast (0.001-0.006°), extending 2 m deep on average. However, there are narrow depressions or rivulets in the seabed up to 30 m deep (Lach Van), which allow the large vessels such as coal transport ships and cargo ships to approach the coastline.

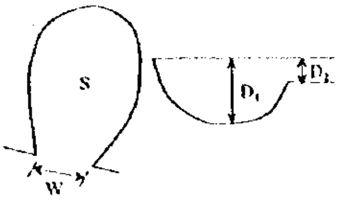
(2) Geometrical Index of Closed Water Area

The physical conditions of the bays are contributing to advection and diffusion. The currents and water exchange in the bays are controlled not only by tides but also by its topography.

The Environment Agency of Japan has a geometrical index for indicating a closed level of sea area, which is a ratio of water volume of bay and area of bay mouth. This index is being used for establishment of pollution control measures such as an area wide total pollution load control or setting seawater quality standard. The index consists of area of water surface, maximum depths of bay and bay mouth, and width of bay mouth. The index is calculated by the following formula ;

$$I = (\sqrt{S}\, D_1) / (W\, D_2)$$

where, S : area of water surface (km^2)
D_1 : maximum depth of bay (m)
D_2 : maximum depth of bay mouth (m)
W : width of bay mouth (km)



Applying this formula, the indexes are 4.9 for Bai Chay bay and 0.8 for Ha Long bay. Normally, the index of more than 1.0 indicates a highly closed water area whose water tends to have a stagnant condition. The water body in such an area has a high potential of eutrophication. Therefore, Bai Chay bay could have a high possibility of eutrophication from a geometrical viewpoint.

(3) Distribution of Tidal Flat

Tidal flat can be defined as an emergence which is submerged in high tide and exposed in ebb tide. The tidal flat in the Ha Long bay area covers the whole Cua Luc embayment with the area about 210 km^2. The extensive tidal flat being covered by mangrove is found around the estuary of the Mip river with about 8.7 km^2 and in Bai Chay bay with 4.7 km^2. Tidal flat has a water purification function as well as preservation of biodiversity and nursery ground of fishery resources. Main factors for purification are filtration by filter feeding habit shells such as bivalves and by deposit feeders such as lugworm and crabs. According to the data obtained in Japan, the water purification ratio is about 150 g COD_{Mn}/m^2/year (Figure 8.1.1).

(4) Land Reclamation Activities

Land reclamation works have been carried out in many places along the shoreline, and it changes hydrological conditions. Dike constructions in the sea have been also affecting water quality of the bays. Chronological change of reclaimed land is examined by the satellite images. According to the analysis result in 1988 and 1996, the mangrove area in Bai Chay bay has decreased about 350 ha. In Cam Pha, about 150 ha of tidal flat was reclaimed by coal mining activities such as solid wastes or coal shipping ports.

The biggest land reclamation so far was carried near Hung Thang for tourism development with about 30 ha. In the future, about 200 ha is planned to be reclaimed. A causeway having two bridges is being constructed between Hung Thang and Tuan Chau island.

8.2 Seabed Sediments

(1) General Conditions

The sediment in the bays shows a typical grading shoreline with coarser-grained sediments near shore and finer-grained sediment offshore. Bottom sediments in the bays are dominated by mud, silt, and clay, but those of Bai Chay bay contain sand, gravel and even cobbles as well as organic maters and settled detritus. Sands mainly from pieces of quarts with gravel, cobbles, boulders, and solid wastes (pieces of ceramic, bricks, and bottles) are found in the Bai Chay beach. Fine sediments near the Hong Gai, Cam Pha, and Cua Ong coal ports are black in color mainly due to fine coal and organic matters.

The area of the extensive tidal flat and sallow sub-tidal area (0-6m depth) is about 33,000 ha in total. The sediments of tidal flat surrounding limestone islands contain many pieces of shells, but those of tidal flats or deltas are composed of mud with sand and gravel and organic matters especially in Bai Chay bay.

Bottom sediments in Ha Long bay are characterized by clay, silt, sand and gravel which contain carbonate from pieces of shells. This content increases toward the south and is higher than that of nearby islands.

(2) Turbidity by Tidal Activity and Navigation

Normally, the critical tractive force of bottom sediment has a close relationship with it's water content as shown in Figure 8.2.1. Water contents of bottom sediments in the study area range from 28% to 60%. These in Bai Chay and Ha Long bays are higher than in Bai Tu Long bay. Small grain size sediments are stirred up easily by turbulence of current. As the results of field reconnaissance and satellite images analysis, high turbidity by tidal activity is found routes in the shallow water area. These phenomena indicate that bottom sediments have relatively high water content.

8.3 Tides and Tidal Currents

8.3.1 General Feature of Tides and Tidal Currents

(1) Tides

The coastal area of Quang Ninh province has the highest tide in the North Vietnam. In the Ha Long bay area, high water tide occurs once a day for most of the days, occasionally twice a day in a month. Tides have been observed at Hong Gai station. The average tidal amplitude is about 2 m and maximum is 4.7 m in spring tide. At high tide, seawater intrudes the rivers and drainage channels.

In general, a tide is categorized by 4 main component tides such as M2, S2, K1, and O1. M2 and S2 show semi-diurnal tides mainly produced by universal gravitation of the moon and the sun. K1 and O1 show diurnal tides mainly produced by universal gravitation of the moon and the sun, and the moon only, respectively. Actual tides are driven by the mixture of these components. According to the harmonic analysis of wave at the Hong Gai station, frequency, amplitude, and phase of each component tide are as follows. The values of amplitude show that semi-diurnal tides are predominant in this area.

Component of tides	Frequency (degree/hr.)	Amplitude (cm)	Phase (degree)
M2	29	7.5	114.6
S2	30	4.1	127.6
K1	15	73.3	89.5
O1	14	82.1	28.4

Source: EIA Report on Quang Ninh BOT Thermal Power Plant, Raytheon Engineers & Constructors, 1997

Figure 8.3.1 presents a fortnightly tidal harmonic oscillation diagram for summer and winter tides at Hong Gai station. There is no significant difference between tides in summer and winter.

(2) Tidal Currents

In the Feasibility Study (F/S) of Cai Lan Port Expansion Project (JICA, 1995), the tidal current measurement was carried out over one month from January to February 1994 at three different depths around the Cua Luc strait. The currents recorded are 0.20 - 0.68 m/s, and the currents in ebb tide are faster than in flood tide.

According to above data, the spring flood tide current direction in Cua Luc strait was either north or tending towards the west. During the spring ebb tide, the current direction towards the east, then swung towards the south and finally the southwest over a three hour period. The neap tides show the same direction but have less velocity.

As for the other area in Ha Long bay, current data is available in "Ha Long Bay Environmental Pollution Study, 1998". The current data measured in this study, however, was taken only 2 days. Considering ebb and low tides, it is difficult to represent the actual tidal currents. Therefore, the Field Survey for tidal current was implemented by the JICA study team. The Survey was implemented 15 days continuously at 3 points for 2 layers. The results of the survey are discussed in Section 8.3.3.

8.3.2 Tidal Currents by Satellite Images

The current tendency was analyzed from temperature distribution portraits based on LANDSAT TM data. The current directions recorded in the different date are shown with arrows in Figures 8.3.2 ~ 8.3.4.

(1) Current Tendency on November 4, 1988

The noticeable current direction was wholly toward the north from the open sea in the south of Ha Long bay. It was also identified that some part flew westward along the northern coastline of Cat Ba island while another water directed toward Cam Pha's coastal area.

Water running from the Mip river flows eastward along the Bai Chay coast. Seawater movement between Bai Chay and Ha Long bays cannot be clearly recognized. The coastal current from the northeast and water from the inland seem to flow into the bottom side of the open sea current, since their temperatures are generally lower.

(2) Current Tendency on December 1, 1992

The general tendency was similar to that on November 4, 1988. Open seawater approached the coastal line, hindering land water from moving into Ha Long bay and open sea. Open seawater generally flows from west to east, but its part is directed northward along the west coast of Cat Ba island. Compared with the November's tendency, much water tends to be closer to the coastal area and to flow toward Cam Pha.

(3) Current Tendency on June 6, 1997

In June in the rainy season, temperatures of coastal water from the inland and open seawater are almost identical. The open sea and coastal waters generally flow in different patterns so that they are not mixed up in the Ha Long bay area which is located in the middle.

The open seawater flows from southwest to east and meanders in some places. Water from the Mip river tends to stay around its estuary, and the whole water in the Bai Chay bay is likely to stay within the bay. Water along the Cam Pha coast also looks to stay or whirls around.

(4) Tidal Currents Tendency

As the results of above analysis, it could be concluded that the water body nearshore does not flow out to open sea. That is, the water body in Ha Long bay is stagnant especially in the rainy season. This condition is important for considering the water quality in the study area.

8.3.3 Field Survey by the JICA Study Team

(1) Objective and Methodology

The current measurement was conducted by the Haiphong Institute of Oceanology (HIO) under the contract with the JICA study team in July 1998. The main objective of the measurement was to provide 15-day continuous data series necessary for harmonic analysis at three stations for upper and lower layers. The JICA study team processed the data including harmonic analysis and their results were described in this section with some related information reported by HIO. The harmonic constants obtained by the analysis will be used for the validation of the hydrodynamic model in Chapter 12 through the comparison with the simulated results.

The locations of the stations are shown in Figure 8.3.5 and their coordinates and depths referred to the Chart Datum are given below. The locations of water level measuring stations by Bai Chay hydro-meteorological station are also shown in Figure 8.3.5:

Station	Location	Depth (m)
Cua Luc	E107°03'03", N20°57'24"*	16.0
Cam Pha – Cua Ong	E107°08'03", N20°49'21"	11.5
Cua Dua	E107°20'55", N20°58'25"	15.4

Note: * The coordinate should be verified because it corresponds to the land point on marine charts instead of Cua Luc shown in Figure 8.3.5.
Source: HIO, 1998

The current meters for the lower layer were fixed at the depth of 2 m above the bottom. For the upper layer, they were hung at 0.8 m below the water surface at Cua Luc and Cam Pha – Cua Ong stations. At Cua Dua station, it was fixed at the depth of 3.5 m below the water surface in order to avoid the effects of sea wave.

The measurement started on 14 July 1998 and ended on 30 July 1998 with the recording interval of 15 minutes. During the survey period, wind speed and direction were recorded every three hours at the height of 3 m above the water surface for the physical boundary conditions of the hydrodynamic model on the sea surface.

The output of the data processing included current velocities, running mean currents, current roses, harmonic constants, tidal current ellipses, auto-correlation, power spectra, and diffusion coefficients.

(2) Results

The obtained data series of the lower layer at Cua Dua included continuous records of 0 cm/s for more than half of the survey period. The current meter could be stacked by objects such as algae, seaweed, and garbage in spite of the cleaning effort by the survey team (HIO, 1998). Therefore, the data series were not enough for full data processing and only current velocities and current roses were shown for this data series, while all output were shown for other data series.

1) Current velocities

The time series of current velocities at the three stations were shown by northward and eastward component in Figures 8.3.6 to 8.3.8. The current vectors given by these components were also shown in Figures 8.3.9 to 8.3.11. The northward component of the velocity dominated at Cua Luc and Cua Dua. The eastward component of the velocity dominated in Cam Pha – Cua Ong. The velocities of the upper layer were higher than those of the lower layer especially at Cua Luc.

2) Running mean currents

Running mean of the current vector over 25 hours filtered out short term variations of the velocity such as tide within a day. The running mean currents at the three stations were shown in Figures 8.3.12 to 8.3.14. The southward currents dominated in the upper layer at Cua Luc and Cua Dua. At Cam Pha – Cua Ong, the currents varied between eastward and southward. The currents of the upper layer were clearly stronger than those of the lower layer at all three stations. This strong vertical shear of the running mean currents suggested that long term driving forces such as fresh water from rivers affected the upper layer mainly.

3) Current roses

The current roses were drawn by HIO (1998) as shown in Figures 8.3.15 to 8.3.20. Two opposite directions dominated in all figures. Therefore, it was suggested that the tide is the major driving force of the currents at three stations.

4) Harmonic constants and tidal current ellipses

The harmonic constants of tidal currents were obtained by the method of least squares as shown in Table 8.3.1. The constants will be used for the validation of the hydrodynamic model in Chapter 12. The tidal current ellipses were drawn from these constants as shown in Figures 8.3.21 to 8.3.25. The diurnal constituents such as K_1 and O_1 dominated in most data series. The semi-diurnal constituents such as M_2 and S_2 dominated secondarily.

5) Auto-correlation and power spectra

The changes of auto-correlation coefficients of velocity components by time lag were shown in Figures 8.3.26 to 8.3.28. Peaks of the coefficients around 24-hour lag showed diurnal periodicity at three stations. The power spectra of velocity components were obtained by Blackman-Tukey method (Blackman and Tukey, 1958) as shown in Figures 8.3.29 to 8.3.31. Peaks of the spectra on 24 hours and 12 hours showed diurnal and semi-diurnal periodicity at three stations.

6) Diffusion coefficients

The diffusion coefficients were obtained from three types of data series such as raw data series, those periodic components above 12 hours were removed, and those periodic components above 24 hours were removed as shown in Table 8.3.2. The values varied in the range of 10^4 to 10^7 cm^2/s and will be referenced by the hydrodynamic model in Chapter 12.

7) Wind roses

The wind speed and direction on the sea surface were recorded during the current measurement for the physical boundary conditions of the hydrodynamic model. The wind roses were drawn by HIO (1998) as shown in Figure 8.3.32 to 8.3.34. The direction with the highest frequency of occurrence was south composed of 51.9% at Cua Luc, 71.9% at Cam Pha – Cua Ong, and 65.1% at Cua Dua (HIO, 1998). To use the wind data as one of the boundary conditions for the hydrodynamic model in Chapter 12, the vector-averaged winds were obtained as below.

Station	Direction (°)	Speed (m/s)
Cua Luc	348	3.1
Cam Pha – Cua Ong	352	3.7
Cua Dua	0	3.9
Average	345	3.4

Note: *Direction is measured by clockwise degree from north for the downstream. SSE is expressed as 345°.

8) Water levels

HIO (1998) collected the measured seawater levels in July for Bai Chay and Cua Ong stations shown in Figure 8.3.5 from the Bai Chay Hydro-meteorological

Station. The measured water levels were illustrated with the tidal levels from Tidal Tables 1998 (Marine Hydrological Center, 1997) as shown in Figures 8.3.35 and 8.3.36. These values will be referenced in Chapter 12 for the hydrodynamic model.

(3) Summary

The results were summarized as below:

- The velocities of the upper layer were higher than those of the lower layer especially at Cua Luc,
- The long term driving forces such as fresh water from rivers affected the upper layer mainly,
- The tide is the major driving forces for the currents,
- The diurnal constituents such as K_1 and O_1 dominated,
- The current velocities during the spring tide were far higher than those during the neap tide,
- Although the southern wind dominated during the Survey, the averaged currents of the upper layer at Cua Luc clearly showed southward. These suggested that the freshwater from rivers to Bai Chay bay would be transported mainly in the upper layer.

8.3.4 Dry Season Field Survey by DOSTE

(1) Oceanographic Conditions

The current measurement for the dry season was conducted for 24 hours during the spring tide at Cua Luc and Cam Pha – Cua Ong in November 1998. The Cua Dua station was missing from the field survey in the dry season. Only the current velocities, current vectors, and the average velocities were obtained from the data because the measurement period of 24 hours is not enough to conduct harmonic analysis.

1) Current velocities

The time series of the current velocities were shown by northward and eastward component in Figures 8.3.37 and 8.3.38. The current vectors given by these components were also shown in Figures 8.3.39 and 8.3.40. The northward component of the velocity dominated Cua Luc and the eastward component dominated in Cam Pha – Cua Ong. These were the same characteristics as the rainy season. On the other hand, the different characteristics were that the velocities of the lower layer at Cua Luc were higher than the velocities in the rainy season. The results of the hydrodynamic model would have better met with the measured data if the velocities of the lower layer in the rainy season had been close to those in the dry season.

2) Winds during the current measurement

The wind speed and direction on the sea surface were recorded every 3 hours during the current measurement. The vector-averaged winds were obtained as below for the discussion on the average velocities of the currents. The average wind was the northern wind, which was reverse direction of the average wind in the rainy season.

Station	Direction (°)	Speed (m/s)
Cua Luc	184	2.4
Cam Pha – Cua Ong	226	3.2

Note: Direction is measured by clockwise degree from north for the downstream. N is expressed as 180°.

3) Average velocities

The vector-averaged velocities obtained from the records are shown below. Although the northern wind dominated at Cua Luc during the survey period, the southward component of the upper layer, 2.7 cm/s was lower than 13.1 cm/s in the rainy season. This suggested that the major cause of the southward currents of the upper layer at Cua Luc was not the wind but the freshwater inflow to Bai Chay bay.

Station	Layer	Eastward	Northward	Major axis	
		Amp. cm/s	Amp. cm/s	Dir. Deg.	Amp. cm/s
Cua Luc	Upper	-1.7	-2.7	212	3.2
	Lower	2.8	5.7	26	6.4
Cam Pha – Cua Ong	Upper	-1.0	0.5	297	1.1
	Lower	5.5	4.2	53	6.9

8.4 Water Mass Structure

(1) Schematic Structure

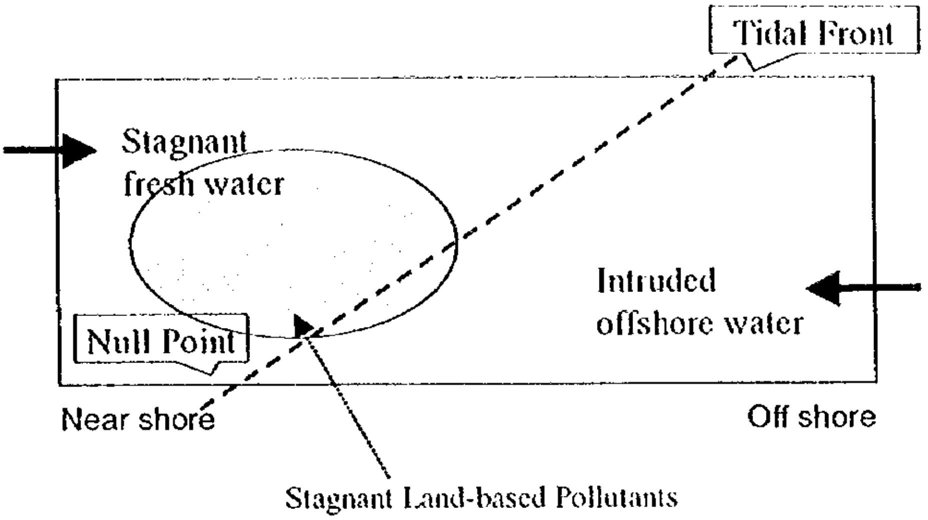
Water flow in the bays is driven by tides (tidal current), wind on the sea (drift current), inflow of river water (density current), and precipitation on the bays. Tidal current occurs in high and ebb tides periodically, and drift current and density current occur irregularly. From the viewpoint of exchange of water and advection of substances in the bays, the constant current is playing an important role. The constant current is defined as constant of harmonic analysis of measured current, i.e. average current caused by a tide-induced residual current. The tidal current is a round trip or oscillating one, while the constant current is one way.

There are many small islands in the center of Ha Long and Bai Tu Long bays, which separate the bays from the outer ocean. Recognizing a drastic change of water color during the field reconnaissance, it could be concluded that there is a "tidal front" (tide-rips) in this area. This means there are two kinds of water bodies facing each other. The constant current is weak near the tidal front, and water body between coast and tidal front is regarded as a stagnant-water area. This tidal front lies about 15-20 km from the shoreline.

(2) Stratification

As the result of the Field Survey, relatively lower values of salinity with 12-17 ‰ which indicate the existence of fresh water body were identified in the upper layer of Bai Chay and Ha Long bays (Figure 8.4.1). This existence of two kinds of values of salinity indicates that the water in Bai Chay and Ha Long bays was stratified. Considering the distribution of salinity values, the fresh water comes form the catchment area especially through the Cua Luc strait fans out and stays there, and the offshore water intrudes in wedge-wise into the bays (Figure 8.4.2~3).

The front of salt wedge is called a "null point" where the constant current in the lower layer is almost zero. Normally, land base pollutants such as SS settles easily around this area. Thus, this stratification affects the bays' water quality as shown below:



Schematic Structure of the Stratification in the Bays

(3) Water Volume in the Bays

The average depth of Ha Long and Bai Tu Long bays is about 5 m based on the existing chart, and Bai Chay bay is about 2 m. The area of Ha Long and Bai Tu Long bays is about 1,260 km^2, and Bai Chay bay is about 30 km^2. Thus, volumes of water of the bays are estimated about 6,300 × 10^6 m^3 and 60 × 10^6 m^3, respectively.

8.5 Water Exchange in the Bay

Water volume flowing into the bays is the sum of the water from the rivers in the catchment area, wastewater directly flowing into the bays from pollution sources, precipitation, and offshore water flowing through the bay's mouth.

The estimation results of the discharge in the rivers are used as the river water volume. The amount of wastewater from pollution sources is negligible. The amount of rain water on the bays is determined from the meteorological observation data at the Hong Gai station. Offshore water flowing into the bays is determined based on the tidal current observation.

The bay water outflow takes place through evaporation and the flow out to the outer seas. Evaporation is calculated by the mean annual evaporation of 23 mm/day. The method used to calculate water inflow in the bays is also used to determine bay water outflow.

Assuming that the exchange of the bays' water is caused only by the river flows and precipitation on the sea, the retention time of the bays' water is about 1 month for Bai Chay bay, and more than 6 years for Ha long bay including Bai Tu Long bay as shown below.

Bays	(a) Volume of bay water ($x10^6 m^3$)	(b) Water inflow ($x10^6 m^3$/year)	(c) Retention time (a/b)
Bai Chay bay	60	572	0.1
Ha Long and Bai Tu Long bays	6,300	981	6.4

Note: Water inflow includes precipitation on the sea.

TABLES

Table 8.3.1(1) Harmonic Constants of the Tidal Currents

Station: Cua Luc Depth: 0.8 m below the surface
Location: Long. 107.03.03 Lat. 20.57.27 Period: 1998 7/15/00:00 ~ 1998 7/30/00:00

Constituent	Eastward		Northward		Major axis			Minor axis		
	Amp. cm/s	Phase degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree
K1	14.7	6	26.6	5	29	30.4	5	119	0.2	95
O1	12.5	315	24.0	314	27	27.1	314	117	0.1	44
P1	4.9	6	8.9	5	29	10.1	5	119	0.1	95
Q1	4.6	210	8.1	234	29	9.2	229	119	1.7	139
M2	6.5	98	10.4	122	31	12.0	115	121	2.3	25
S2	4.1	112	8.1	119	27	9.1	117	117	0.5	27
N2	3.9	56	5.2	83	36	6.3	74	126	1.5	344
K2	1.1	112	2.2	119	27	2.5	117	117	0.1	27
M4	1.0	62	1.9	89	25	2.1	84	115	0.4	354
MS4	0.6	76	1.4	42	22	1.5	47	112	0.3	137
C	-3.9		-13.1		196	13.7				

Station: Cua Luc Depth: 2 m above the bottom
Location: Long. 107.03.03 Lat. 20.57.27 Period: 1998 7/15/00:00 ~ 1998 7/30/00:00

Constituent	Eastward		Northward		Major axis			Minor axis		
	Amp. cm/s	Phase degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree
K1	0.7	71	3.5	254	348	3.5	254	78	0.1	344
O1	1.4	79	5.4	166	1	5.4	166	91	1.4	76
P1	0.3	71	1.2	254	348	1.2	254	78	0.0	344
Q1	2.5	282	5.9	300	23	6.4	298	113	0.7	208
M2	0.3	304	2.1	296	7	2.1	296	97	0.0	26
S2	0.9	39	0.2	22	78	1.0	38	168	0.1	128
N2	1.3	37	3.4	70	18	3.6	66	108	0.7	336
K2	0.3	39	0.1	22	78	0.3	38	168	0.0	128
M4	0.3	216	0.5	127	1	0.5	127	91	0.3	217
MS4	0.4	194	0.2	191	64	0.4	194	154	0.0	284
C	1.2		-1.2		135	1.6				

Station: Cam Pha - Cua Ong Depth: 0.8 m below the surface
Location: Long. 107.20.55 Lat. 20.58.25 Period: 1998 7/15/00:00 ~ 1998 7/30/00:00

Constituent	Eastward		Northward		Major axis			Minor axis		
	Amp. cm/s	Phase degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree
K1	24.3	350	11.9	351	64	27.1	350	154	0.2	260
O1	22.9	298	10.3	287	66	25.0	297	156	1.8	27
P1	8.1	350	4.0	351	64	9.0	350	154	0.1	260
Q1	6.3	266	2.7	254	67	6.8	264	157	0.5	354
M2	24.5	75	8.9	69	70	26.0	74	160	1.0	164
S2	4.9	135	2.8	167	63	5.5	142	153	1.3	52
N2	6.7	64	4.1	75	59	7.8	67	149	0.7	337
K2	1.3	135	0.8	167	63	1.5	142	153	0.4	52
M4	3.1	324	0.6	33	86	3.1	325	176	0.6	235
MS4	0.9	331	1.4	292	29	1.6	302	119	0.5	32
C	7.6		-2.2		106	7.9				

Table 8.3.1(2) Harmonic Constants of the Tidal Currents

Station: Cam Pha - Cua Ong Depth: 2 m above the bottom
Location: Long. 107.20.55 Lat. 20.58.25 Period: 1998 7/15/00:00 ~ 1998 7/30/00:00

Constituent	Eastward		Northward		Major axis			Minor axis		
	Amp. cm/s	Phase degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree
K1	12.3	347	6.7	342	62	14.0	346	152	0.5	76
O1	12.0	295	6.1	291	63	13.5	294	153	0.4	24
P1	4.1	347	2.2	342	62	4.6	346	152	0.2	76
Q1	4.0	260	3.2	261	51	5.2	260	141	0.0	170
M2	13.1	63	7.0	63	62	14.8	63	152	0.0	153
S2	2.4	134	0.5	67	85	2.4	133	175	0.4	223
N2	5.7	52	2.4	57	67	6.2	53	157	0.2	323
K2	0.6	134	0.1	67	85	0.6	133	175	0.1	223
M4	0.2	152	0.4	142	25	0.5	144	115	0.0	234
MS4	0.6	139	0.8	79	35	0.9	100	125	0.5	190
C	3.4		1.1		73	3.5				

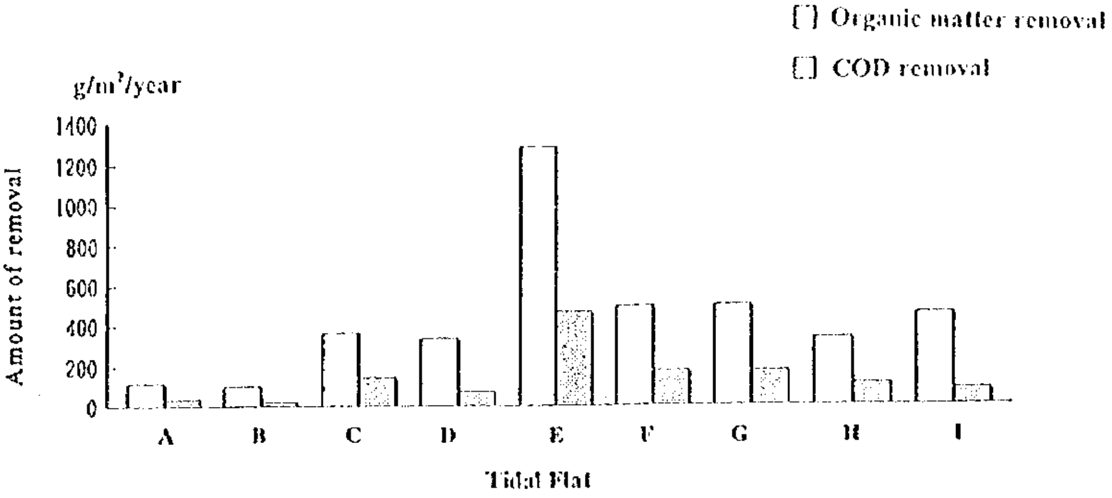
Station: Cua Dua Depth: 0.8 m below the surface
Location: Long. 107.08.03 Lat. 20.49.21 Period: 1998 7/15/15:15 ~ 1998 7/30/15:15

Constituent	Eastward		Northward		Major axis			Minor axis		
	Amp. cm/s	Phase degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree	Dir. degree	Amp. cm/s	Phase degree
K1	6.8	224	14.5	357	340	15.3	3	70	4.7	273
O1	8.3	169	12.5	298	332	13.8	311	62	5.8	221
P1	2.3	224	4.8	357	340	5.1	3	70	1.6	273
Q1	0.8	195	5.8	281	1	5.8	281	91	0.8	191
M2	2.1	342	9.0	66	2	9.0	65	92	2.1	335
S2	0.4	339	2.4	84	357	2.4	85	87	0.4	355
N2	0.9	35	3.0	100	8	3.0	98	98	0.8	8
K2	0.1	339	0.7	84	357	0.7	85	87	0.1	355
M4	1.8	32	1.7	266	311	2.2	235	41	1.1	325
MS4	1.1	67	1.1	310	312	1.3	276	42	0.8	6
C	2.2		-7.4		164	7.7				

Table 8.3.2 Diffusion Coefficients

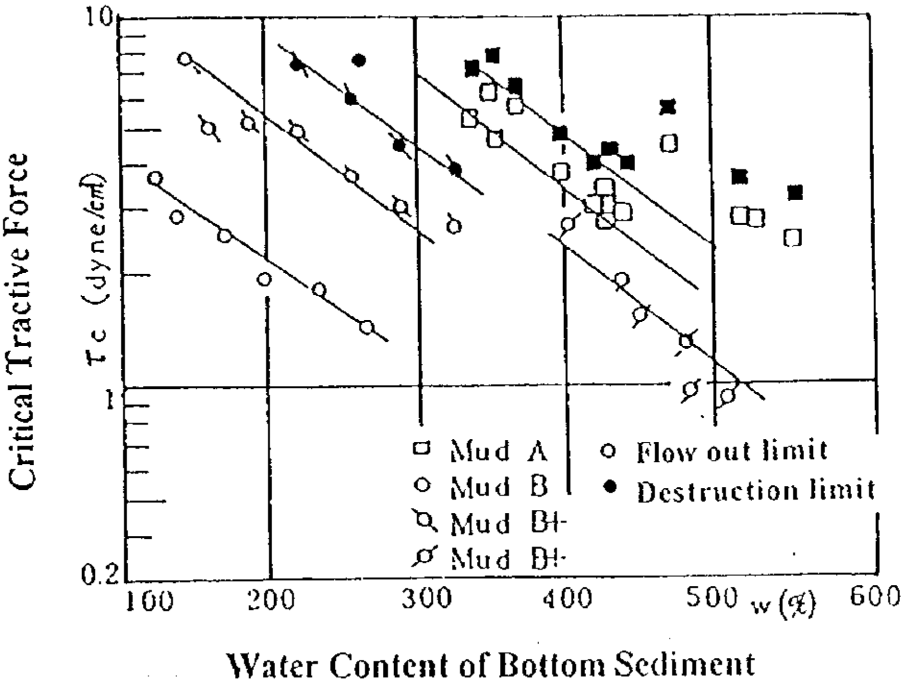
Period	1998/7/15/00.00 ~ 1998 7/30/00.00								1998 7/15/15:15 ~1998 7/30/15:15	
Station	Cua Luc				Cam Pha - Cua Ong				Cua Dua	
Location	Long. 107°03'03" Lat. 20°57'27"				Long. 107°20'55" Lat. 20°58'25"				Long. 107°08'03" Lat. 20°49'21"	
Depth	0.8 m below the surface		2 m above the bottom		0.8 m below the surface		2 m above the bottom		0.8 m below the surface	
Data series	N-S comp	E-W comp.	N-S comp.	E-W comp.	N-S comp.	E-W comp.	N-S comp.	E-W comp.	N-S comp.	E-W comp.
Raw data	1.3×10^7	3.8×10^5	7.0×10^5	1.5×10^5	2.1×10^6	1.0×10^7	8.1×10^5	2.8×10^6	3.1×10^6	7.7×10^5
Removed data above 12 hours	6.1×10^5	1.5×10^5	6.2×10^4	3.0×10^4	9.2×10^4	1.0×10^5	2.0×10^4	4.4×10^4	1.3×10^5	9.9×10^4
Removed data above 24 hours	1.6×10^6	5.5×10^5	2.8×10^5	4.9×10^4	5.3×10^5	3.3×10^6	2.7×10^5	1.1×10^6	5.6×10^5	1.4×10^5

FIGURES



Source: Ministry of Transportation, Japan

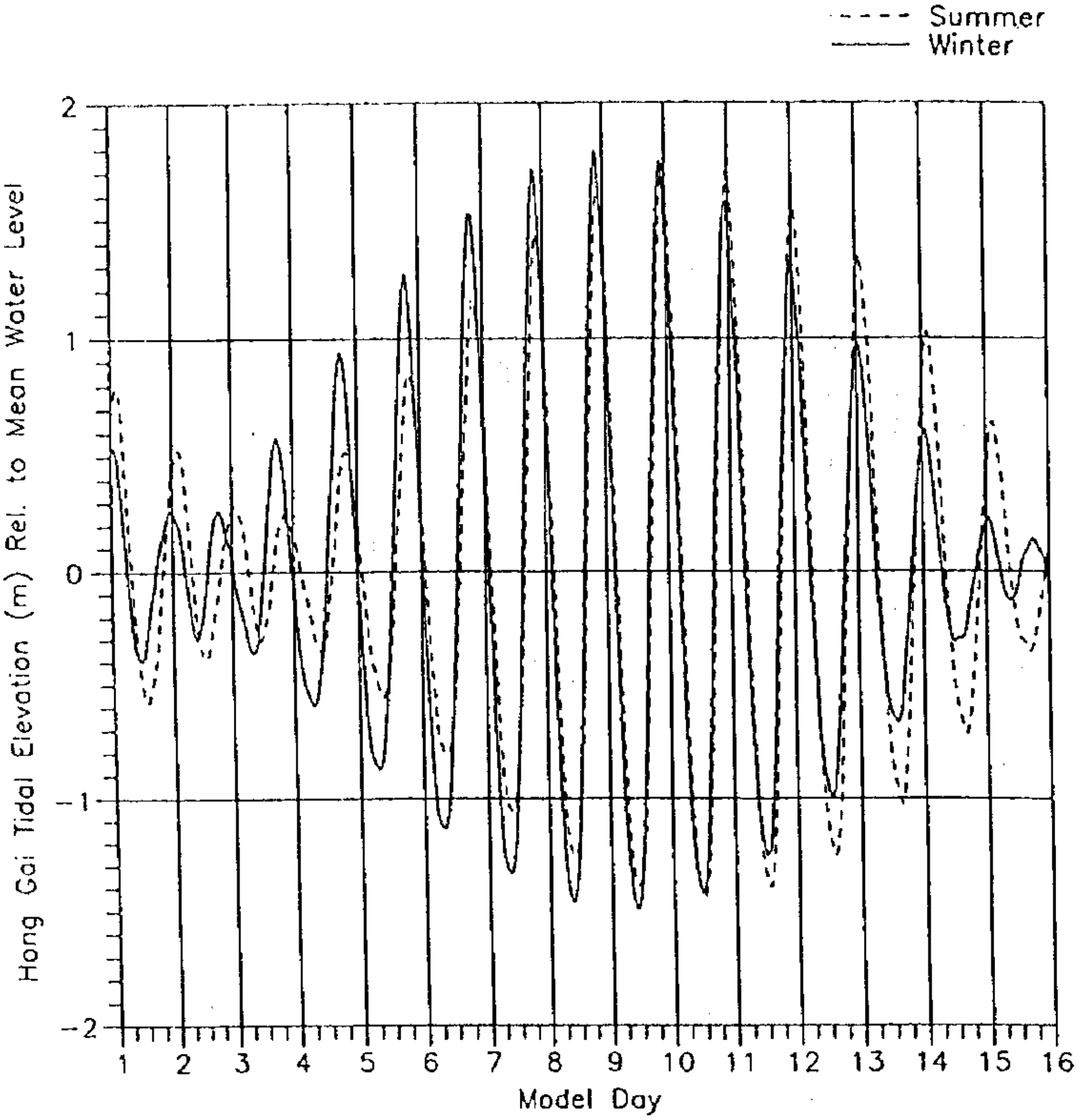
Figure 8.1.1 Water Purification at Tidal Flats



Note: Mud B is a mud treated by H_2O_2 for reducing organic matters

Source: Study Report National Public Pollution Research Institution, Japan

Figure 8.2.1 Critical Tractive Force and Water Content of Bottom Sediment



Source: Ha Long Bay Environmental Pollution Study, 1998

Figure 8.3.1 Fortnightly Cycle of Summer and Winter Tides at Hong Gai Station

Figure 8.3.2 Current Tendency on November 4, 1988

Figure 8.3.3 Current Tendency on December 1, 1992

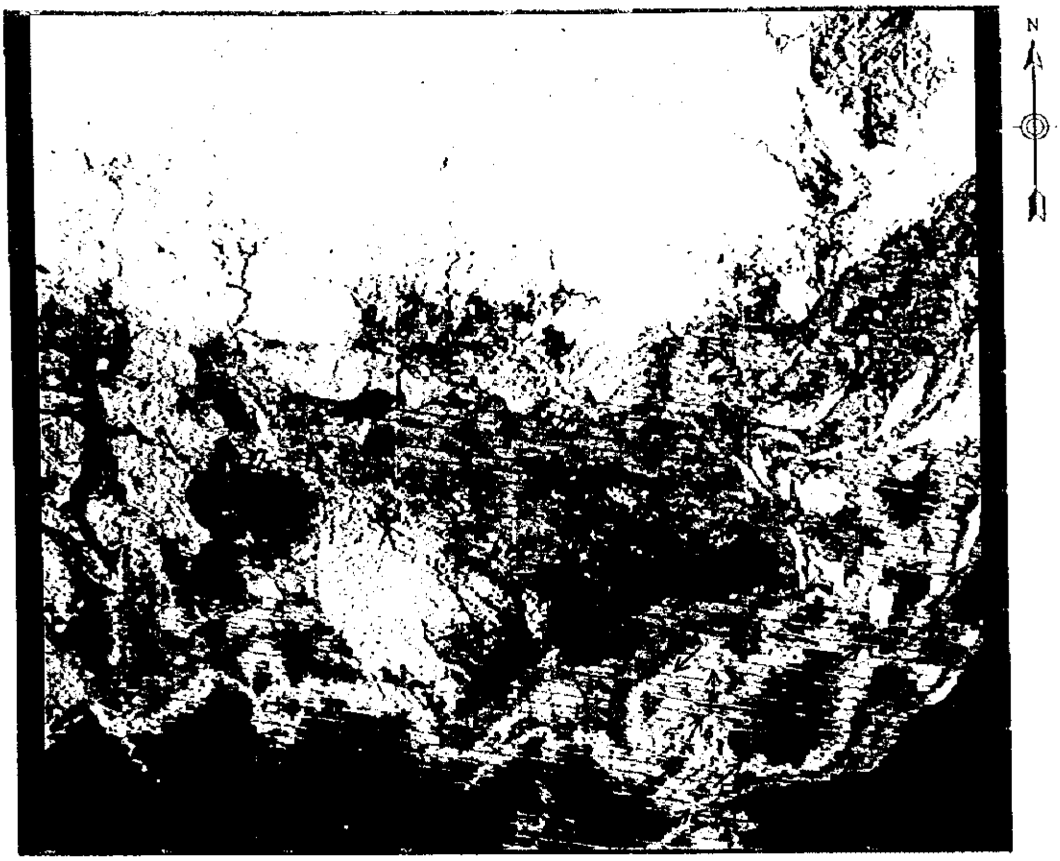


Figure 8.3.4 Current Tendency on June 6, 1997

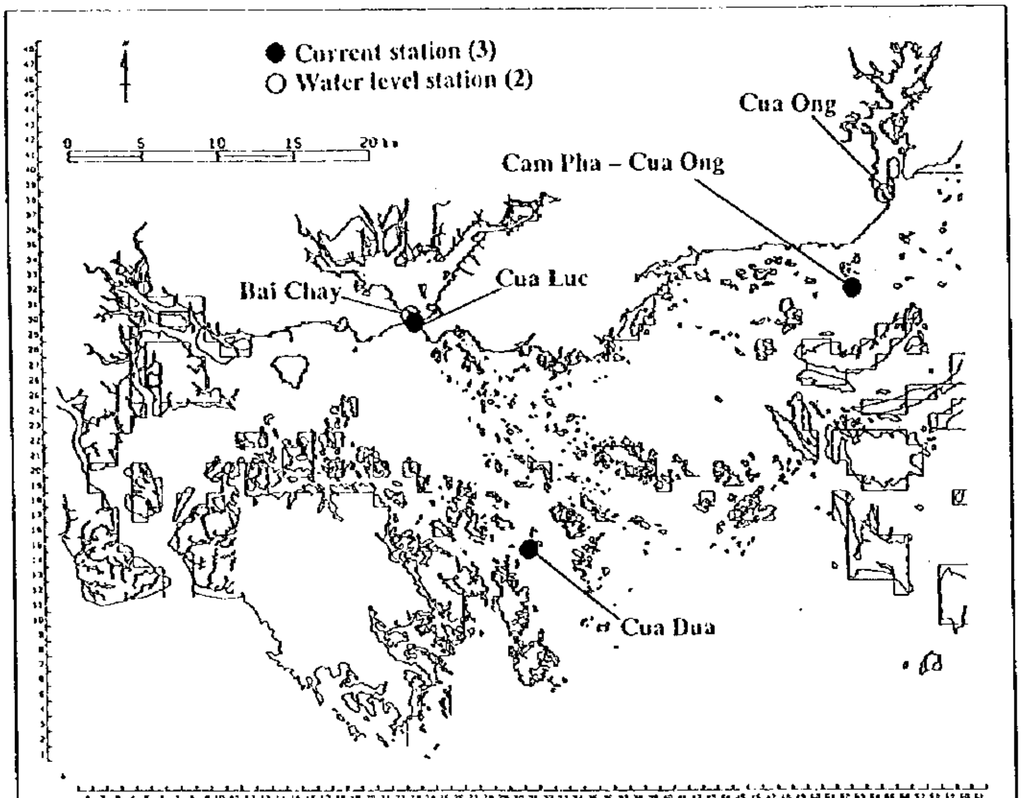


Figure 8.3.5 Locations of the Current Measuring Stations and Water Level Measuring Stations

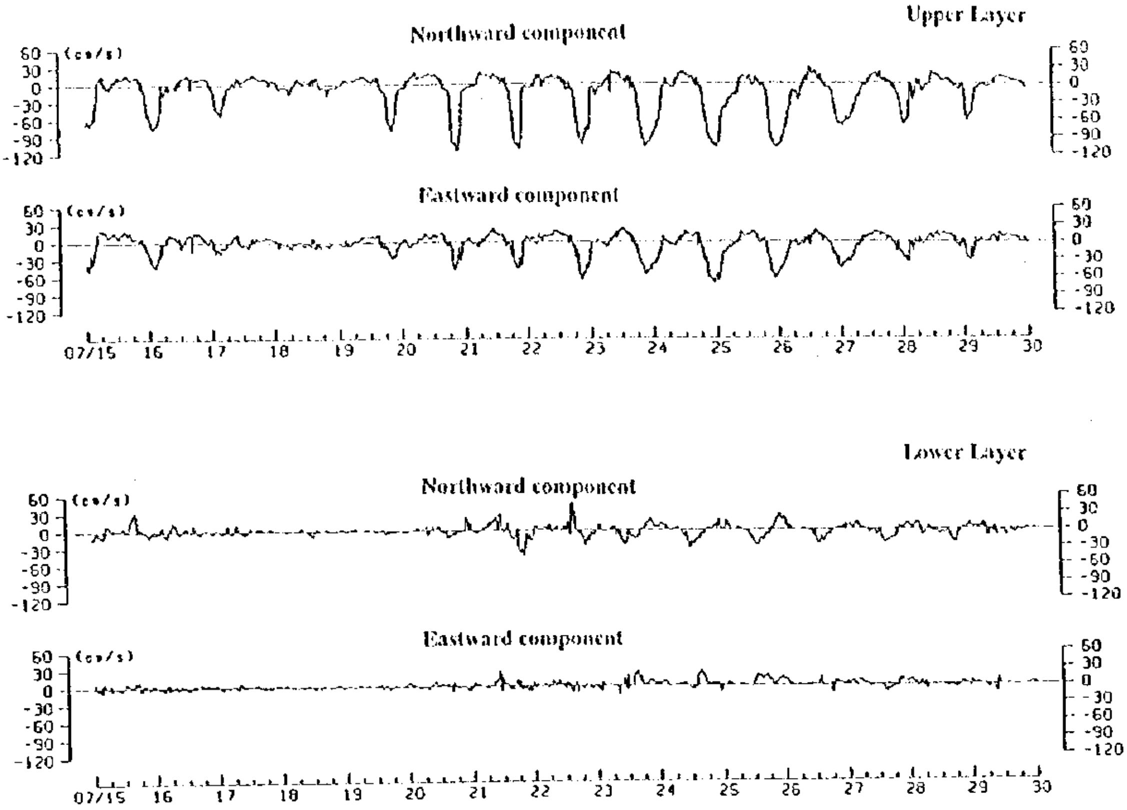


Figure 8.3.6 Current Velocity at Cua Luc

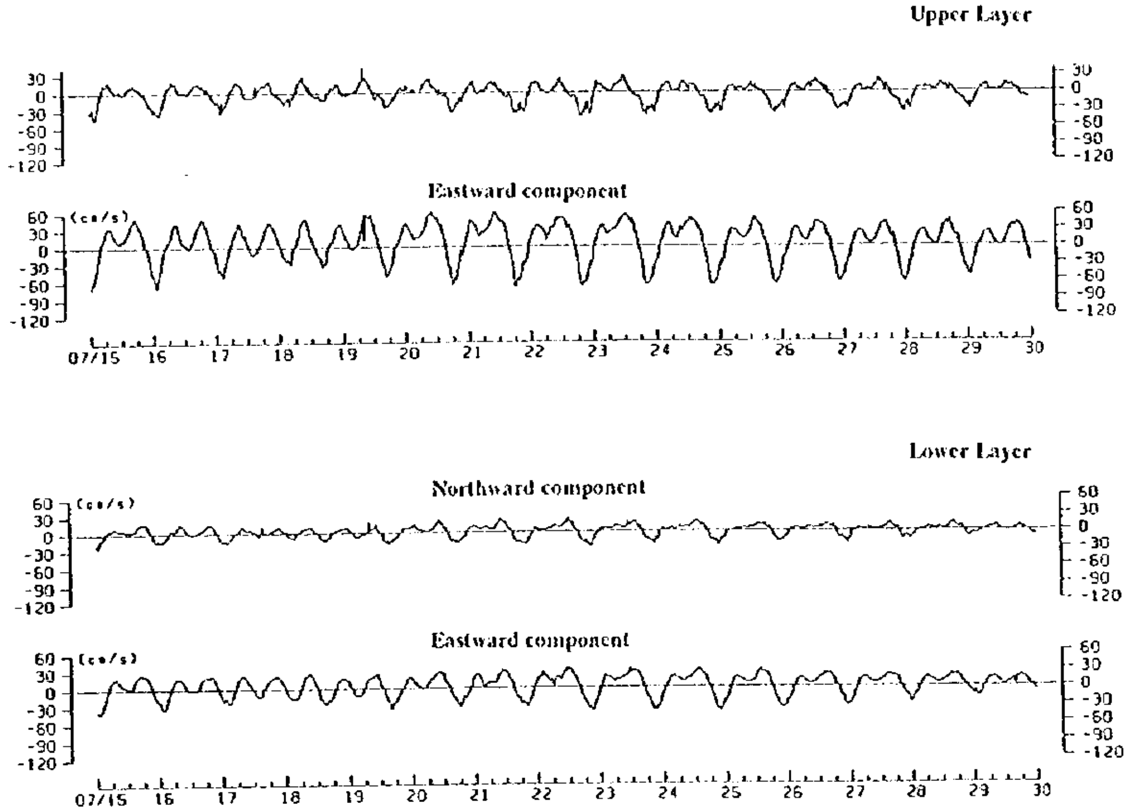


Figure 8.3.7 Current Velocity at Cam Pha – Cua Ong

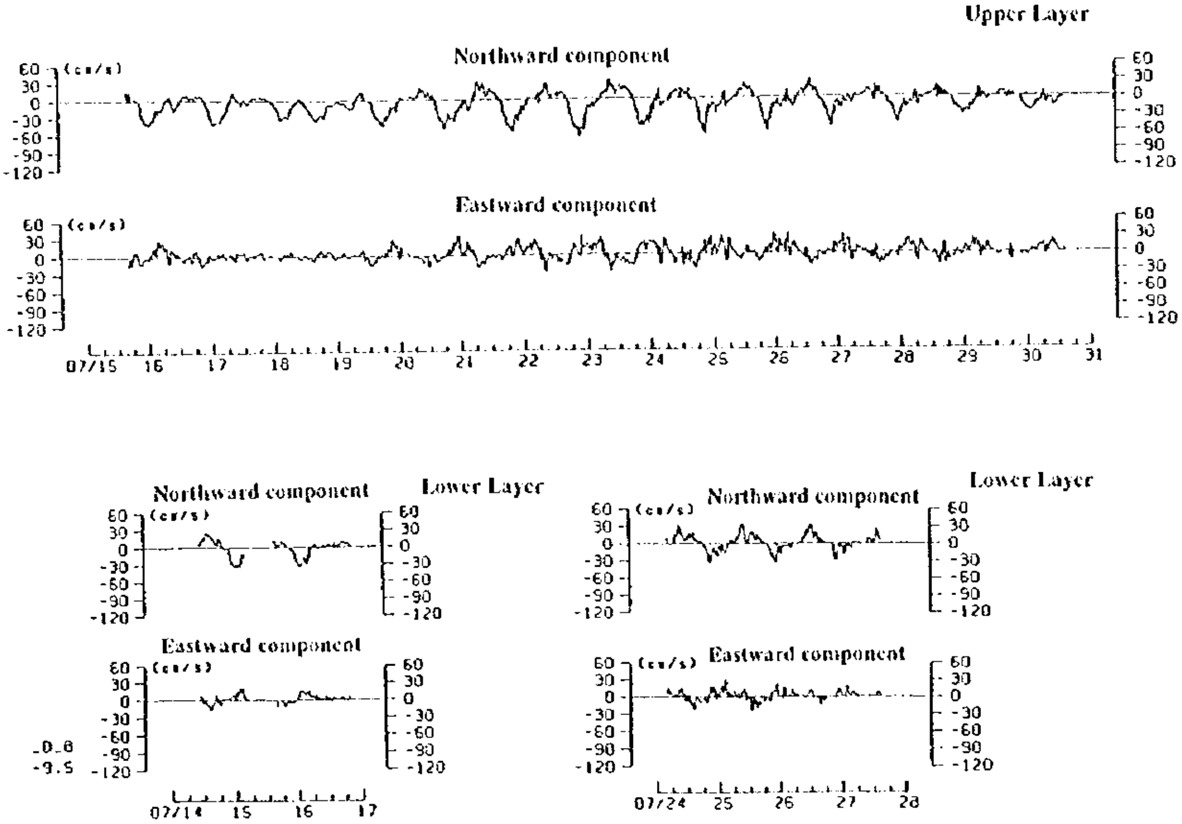


Figure 8.3.8 Current Velocity at Cua Dua

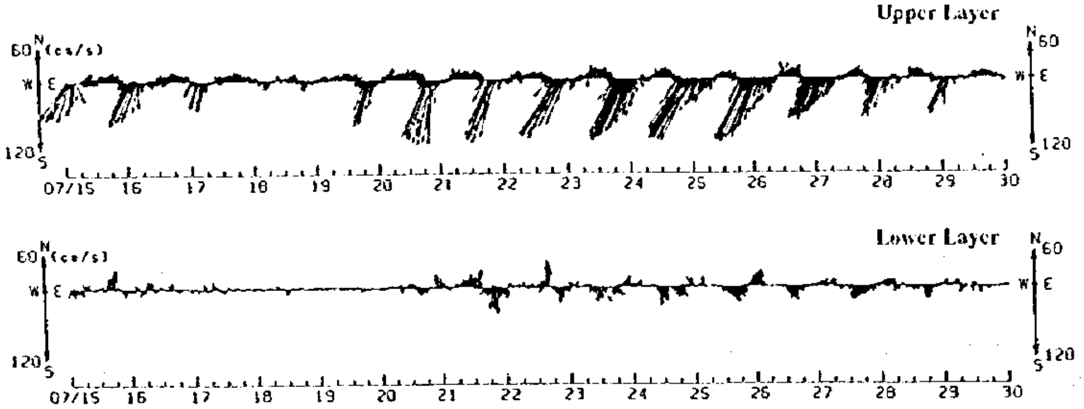


Figure 8.3.9 Current Vector at Cua Luc

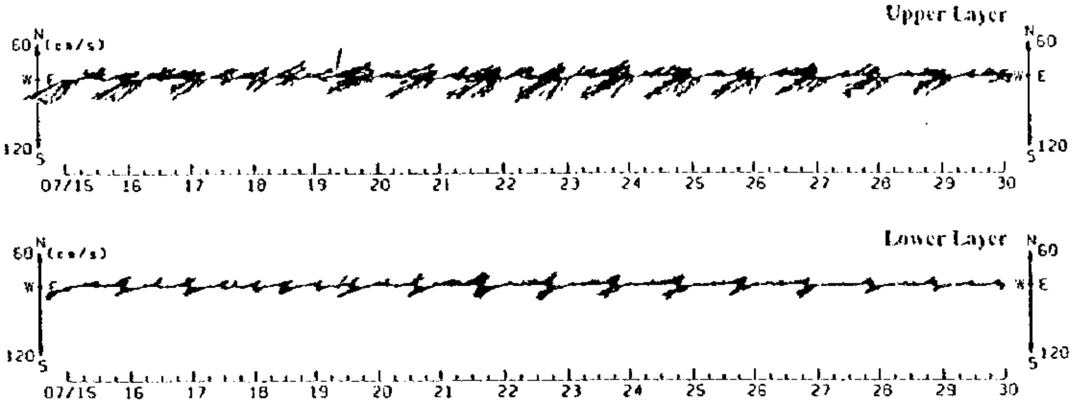


Figure 8.3.10 Current Vector at Cam Pha -- Cua Ong

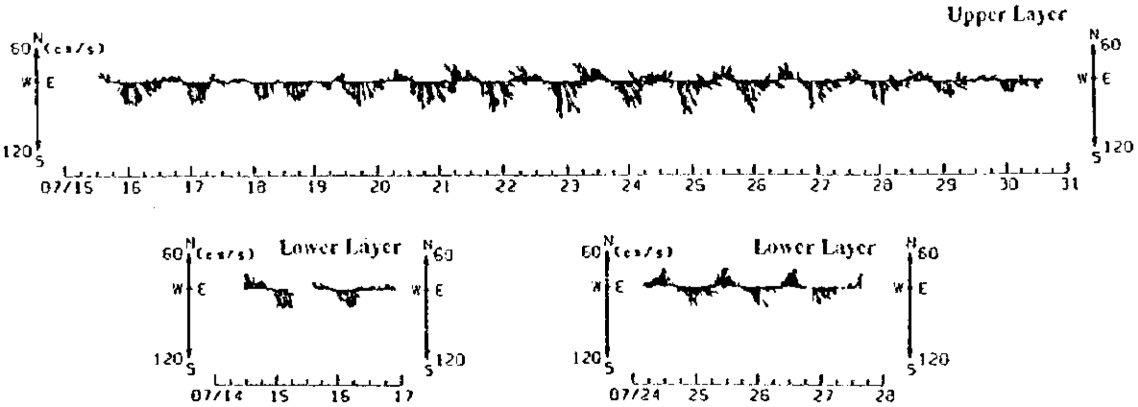


Figure 8.3.11 Current Vector at Cua Dua

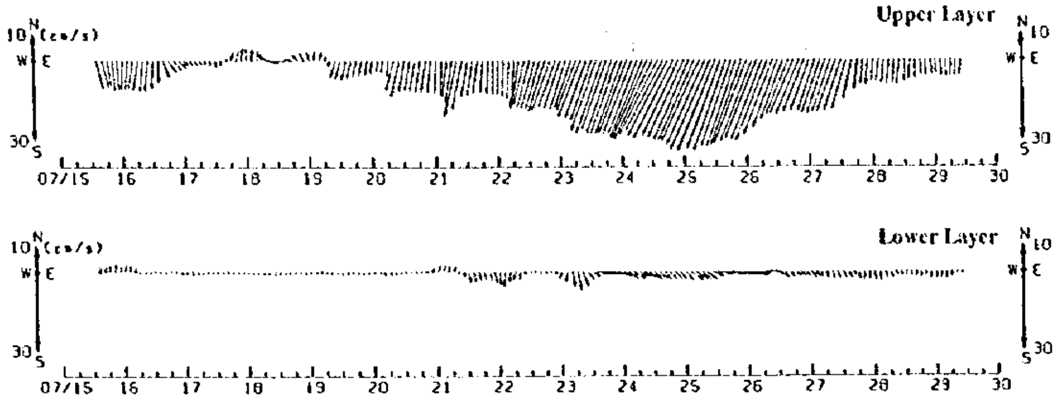


Figure 8.3.12 Running Mean of the Current Vector Over 25 Hours at Cua Luc

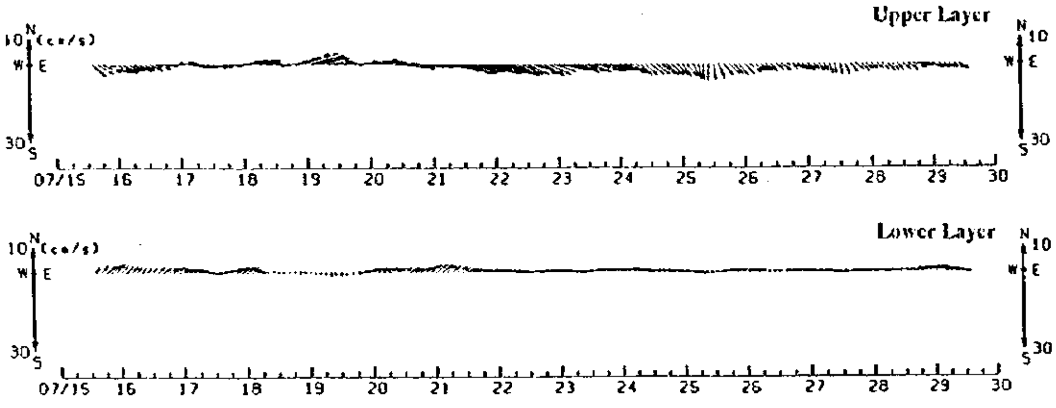


Figure 8.3.13 Running Mean of the Current Vector Over 25 Hours at Cam Pha - Cua Ong

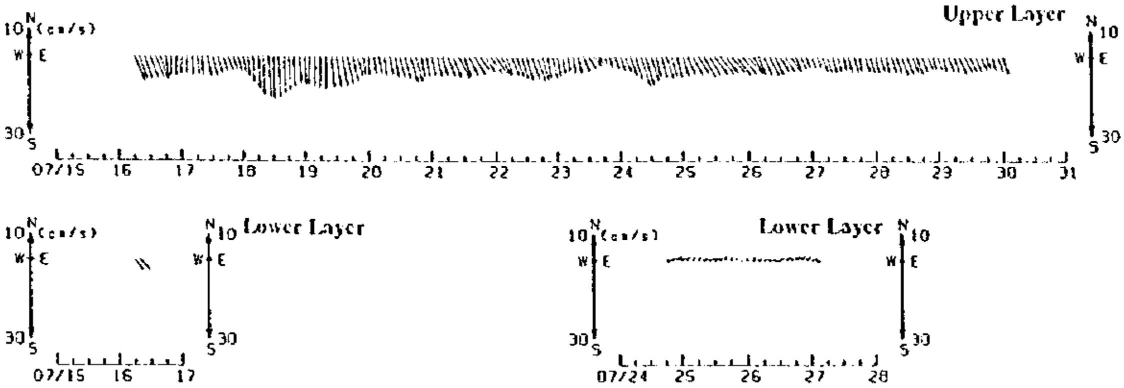


Figure 8.3.14 Running Mean of the Current Vector Over 25 Hours at Cua Dua

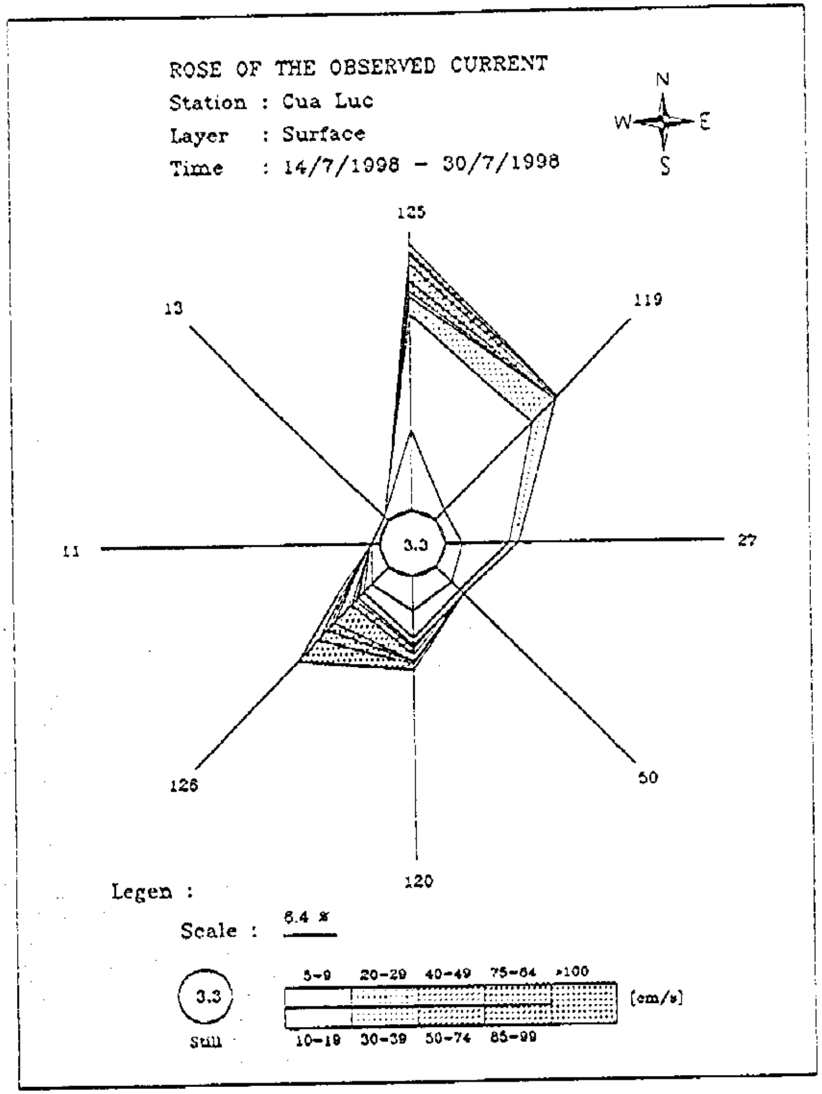


Figure 8.3.15 Current Rose of the Upper Layer at Cua Luc

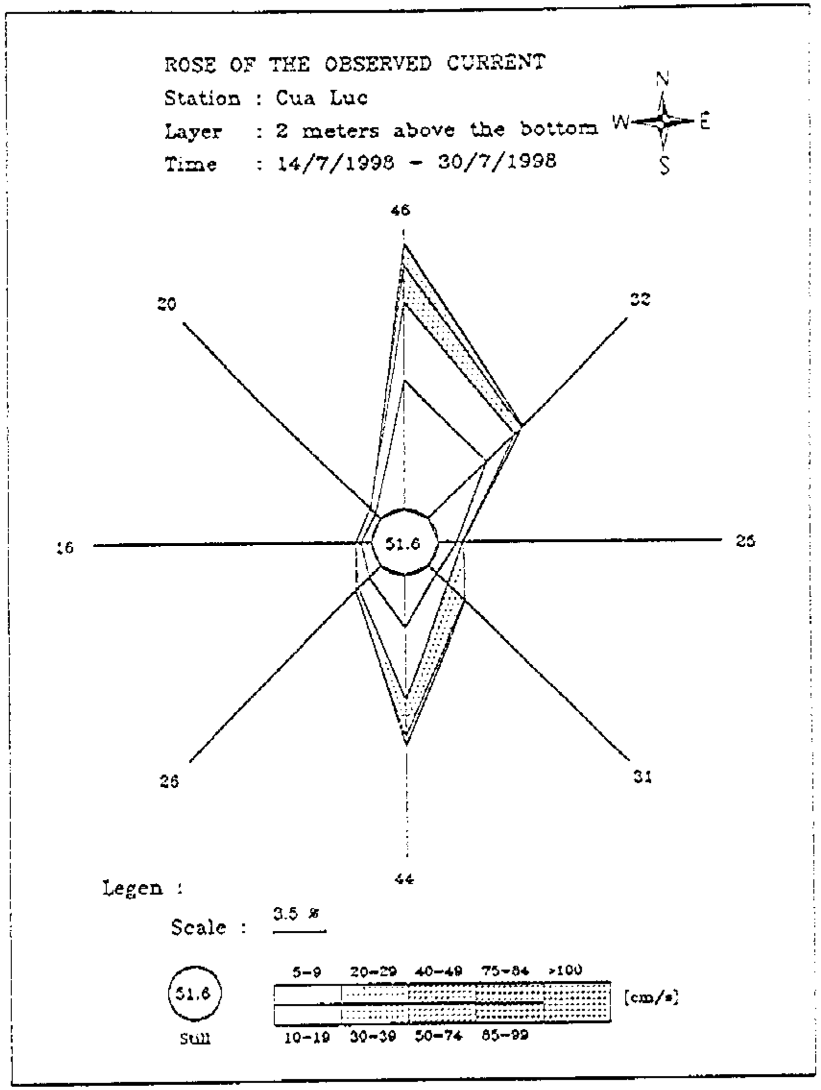


Figure 8.3.16 Current Rose of the Lower Layer at Cua Luc

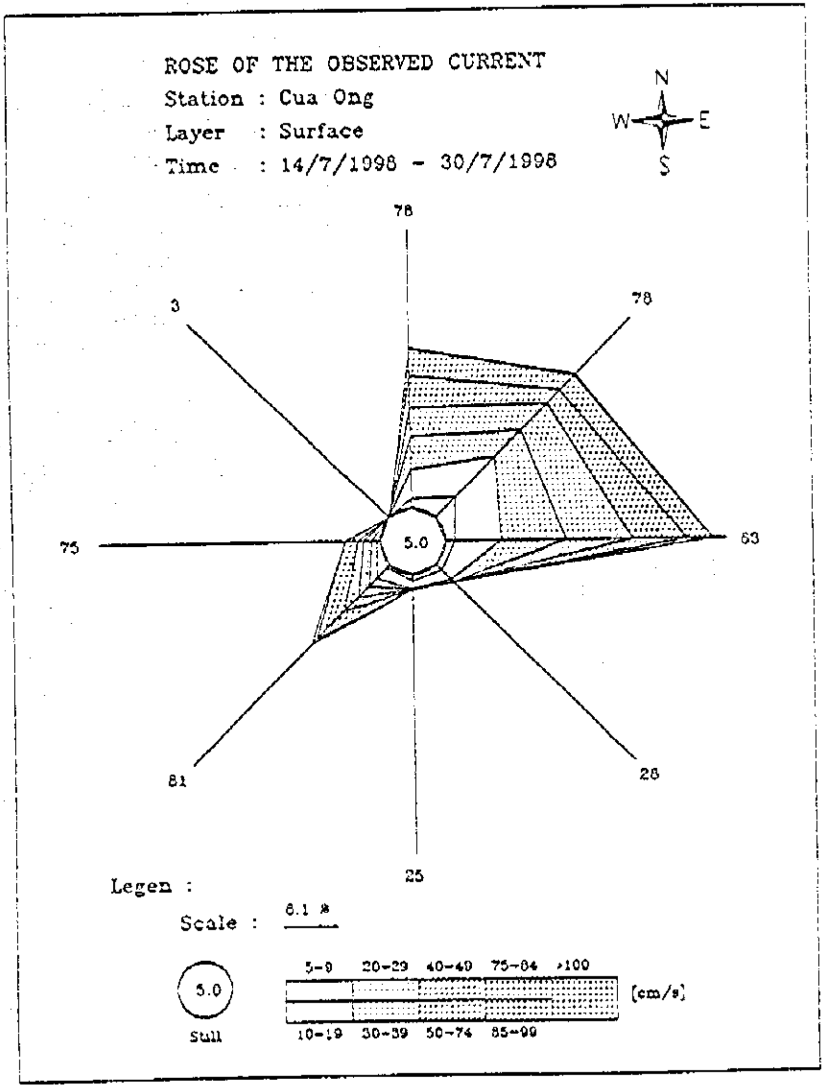


Figure 8.3.17 Current Rose of the Upper Layer at Cam Pha – Cua Ong

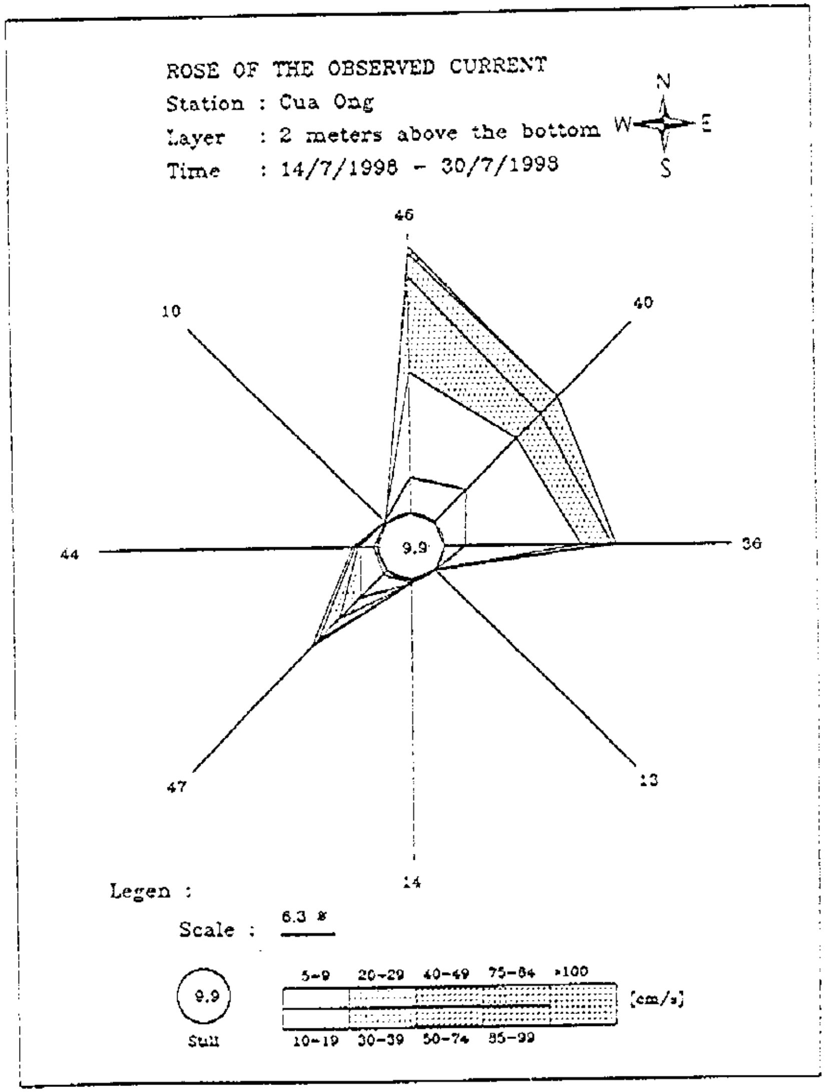


Figure 8.3.18 Current Rose of the Lower Layer at Cam Pha – Cua Ong

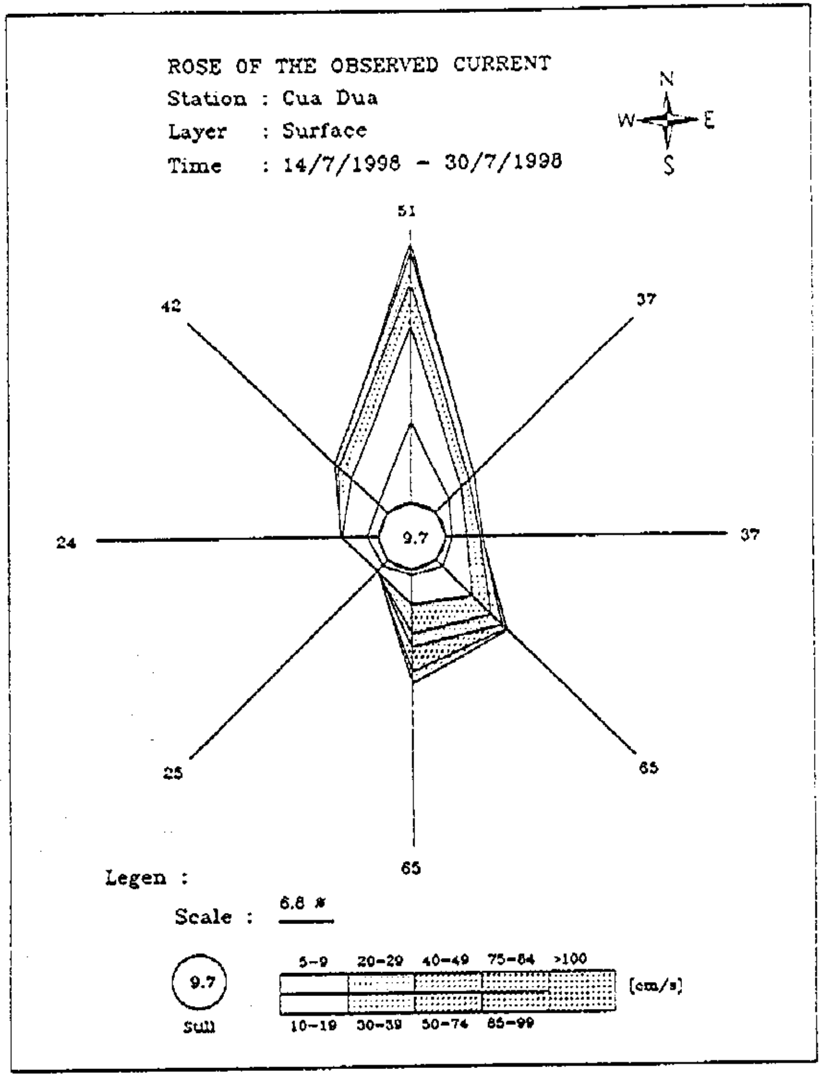


Figure 8.3.19 Current Rose of the Upper Layer at Cua Dua

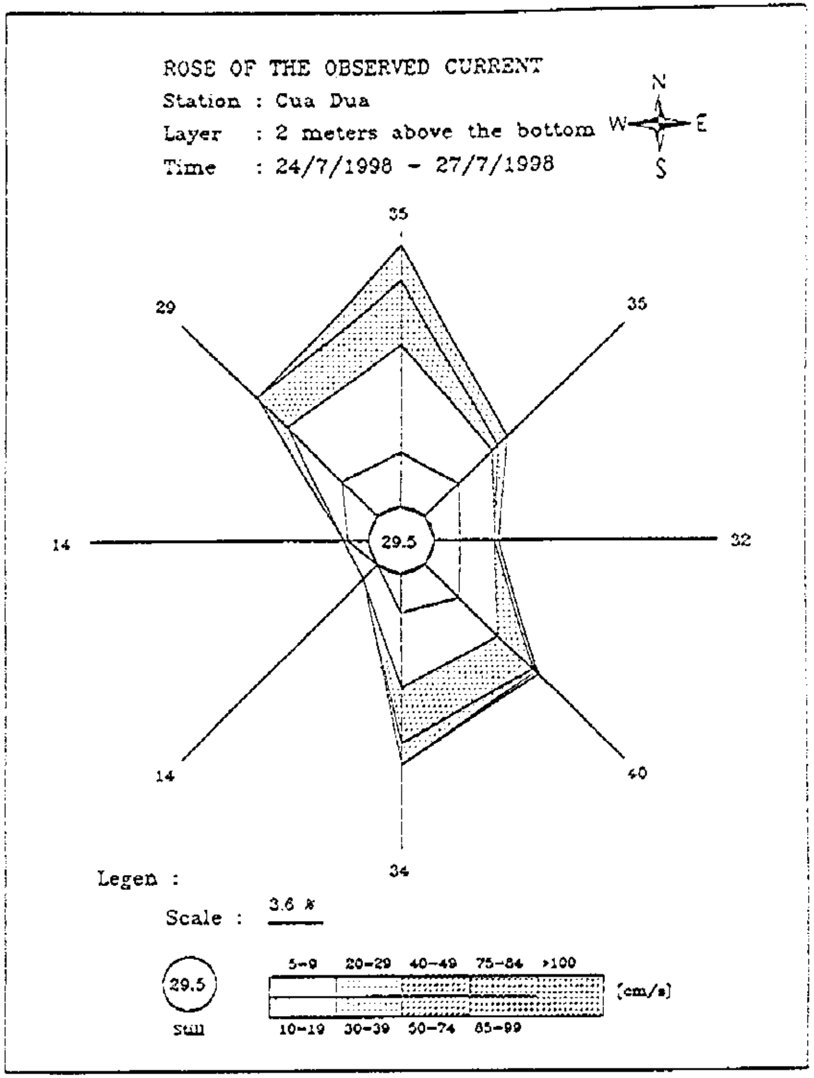


Figure 8.3.20 Current Rose of the Lower Layer at Cua Dua

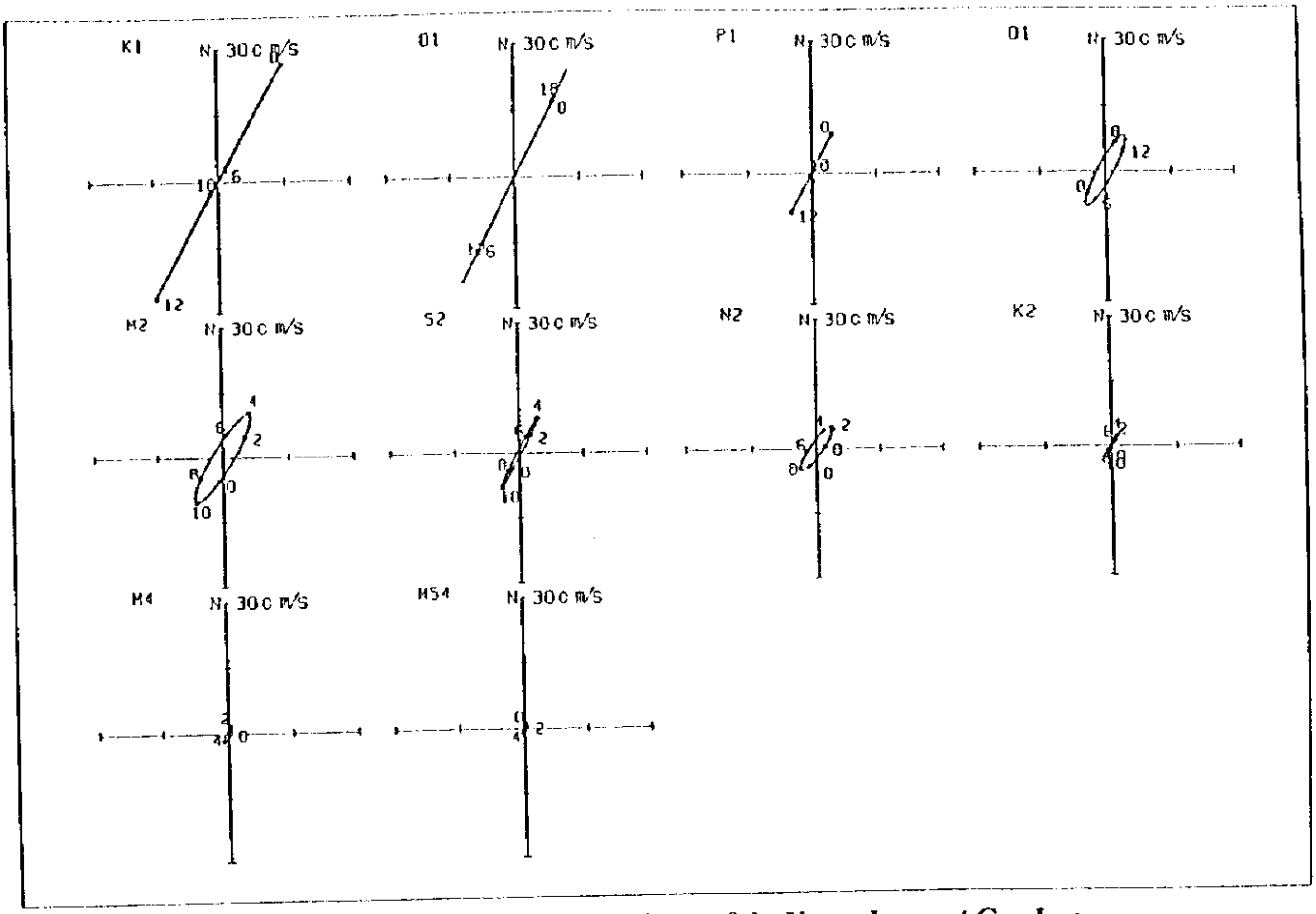


Figure 8.3.21 Tidal Current Ellipses of the Upper Layer at Cua Luc

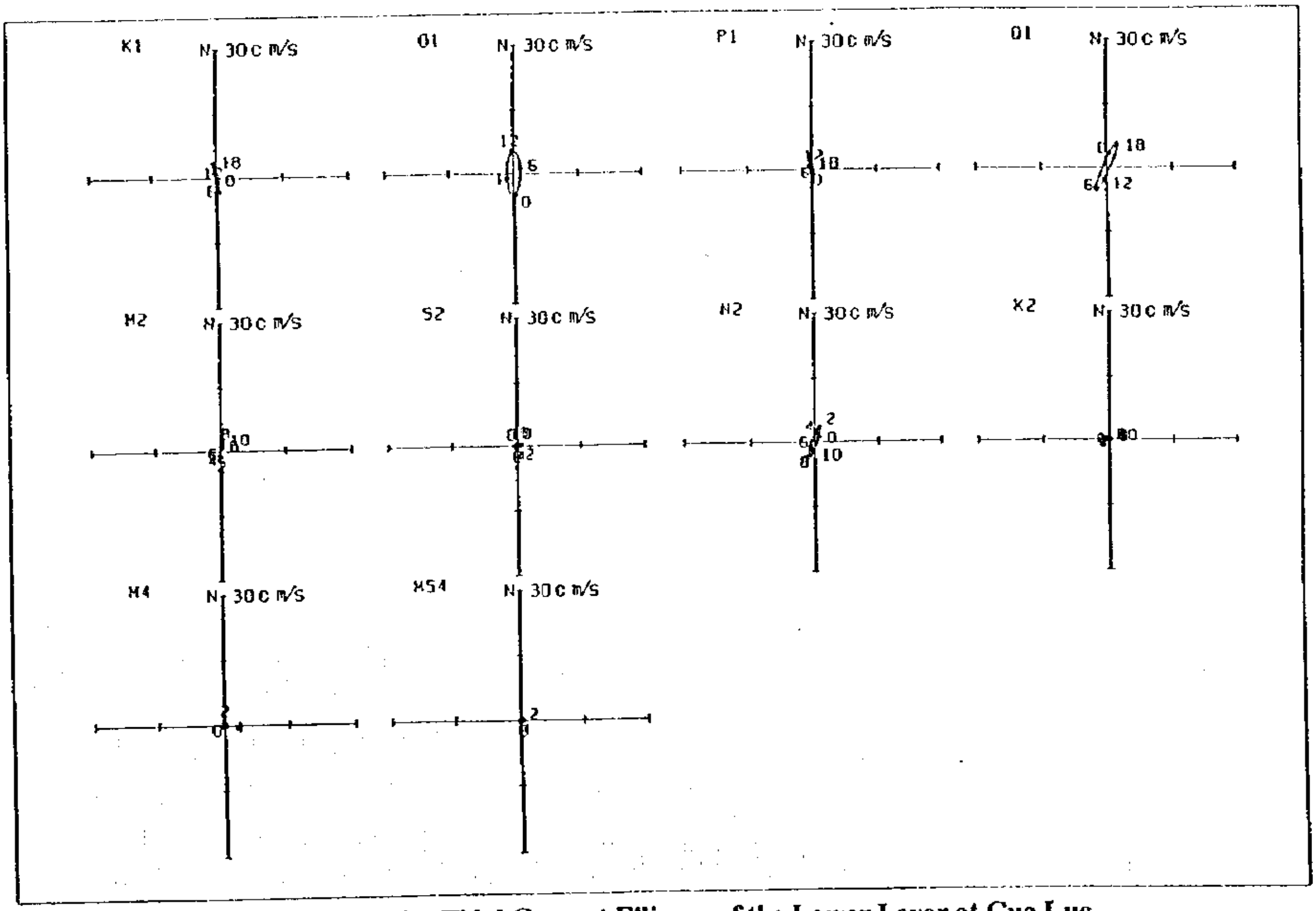


Figure 8.3.22 Tidal Current Ellipses of the Lower Layer at Cua Luc

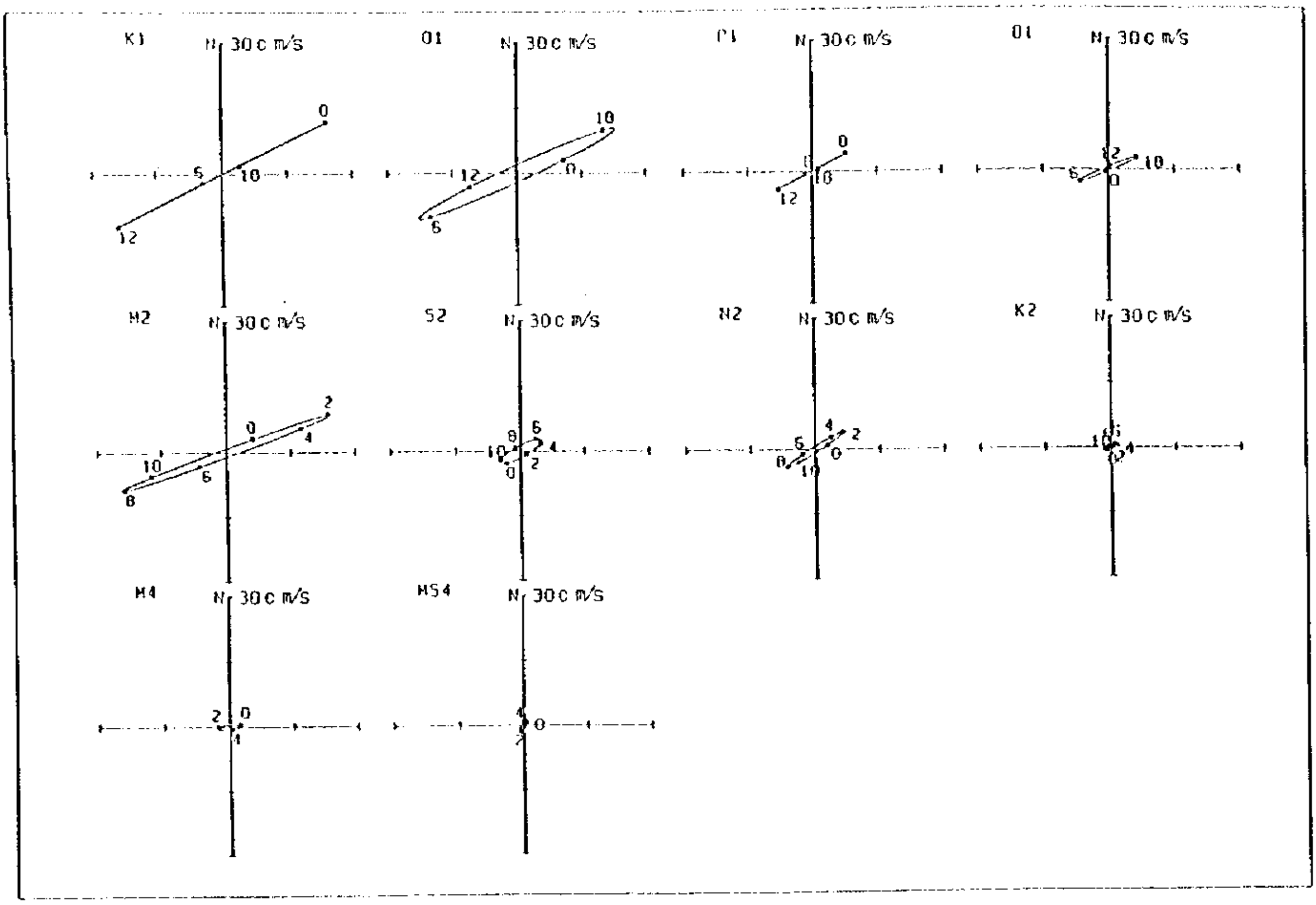


Figure 8.3.23 Tidal Current Ellipses of the Upper Layer at Cam Pha - Cua Ong

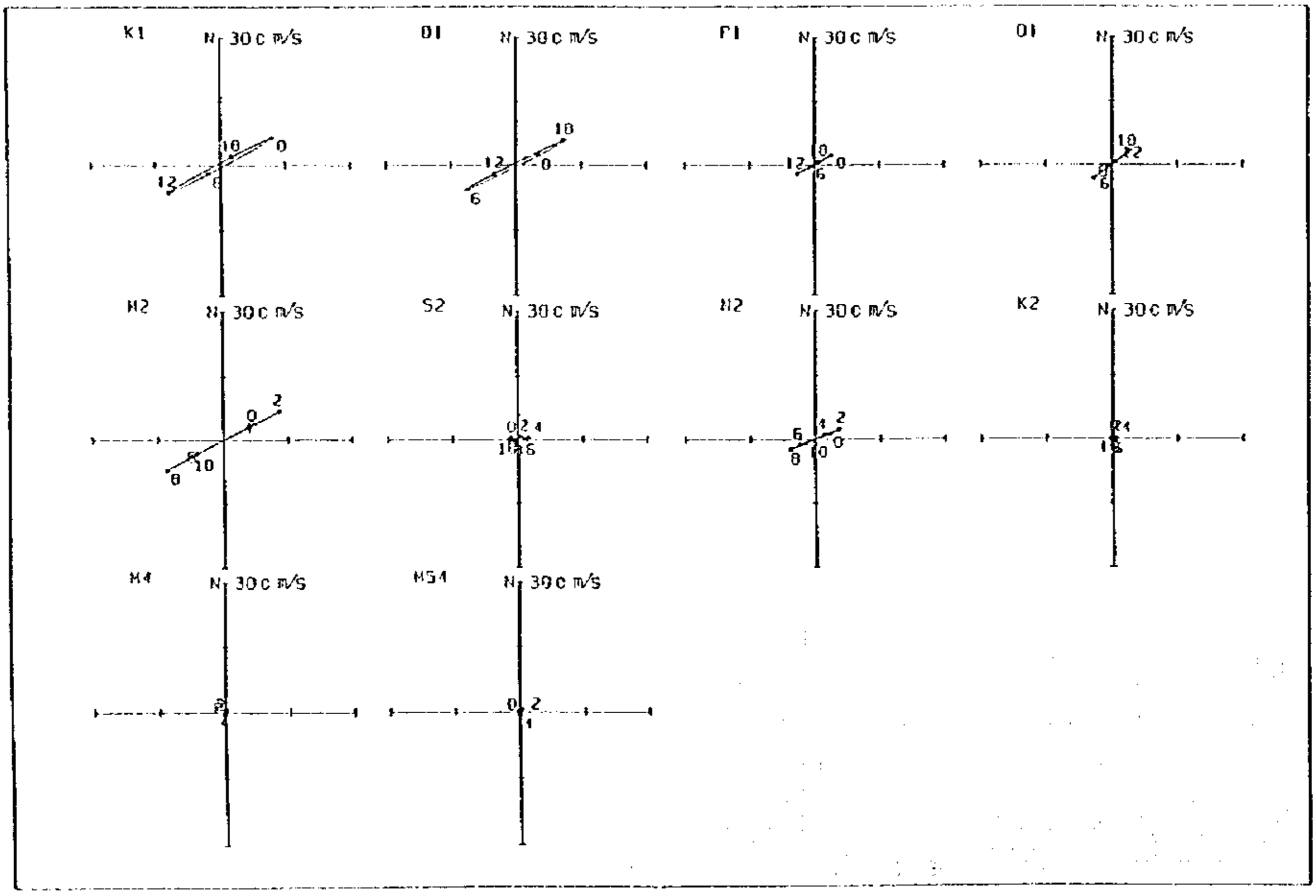


Figure 8.3.24 Tidal Current Ellipses of the Lower Layer at Cam Pha - Cua Ong

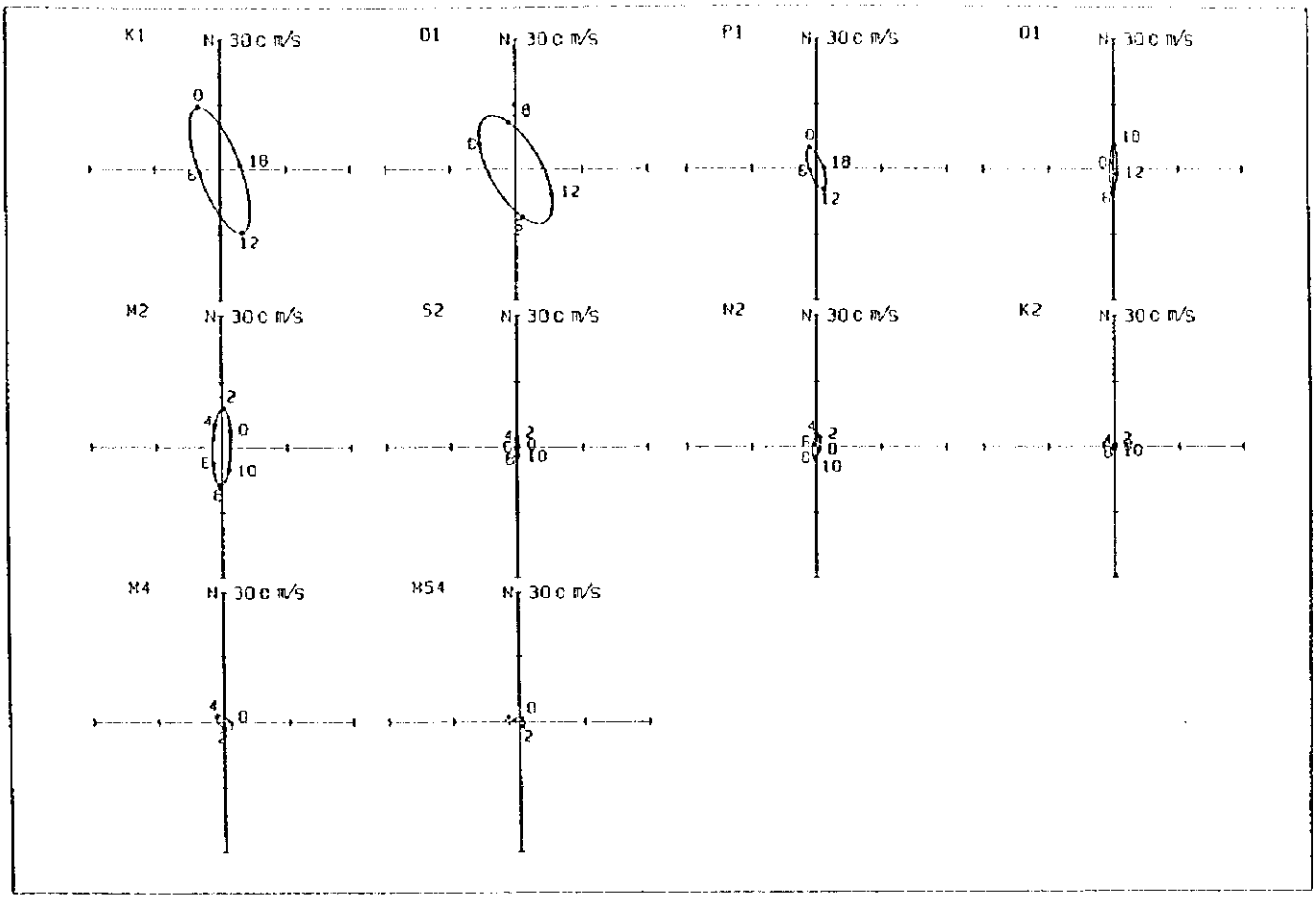


Figure 8.3.25 Tidal Current Ellipses of the Upper Layer at Cua Dua

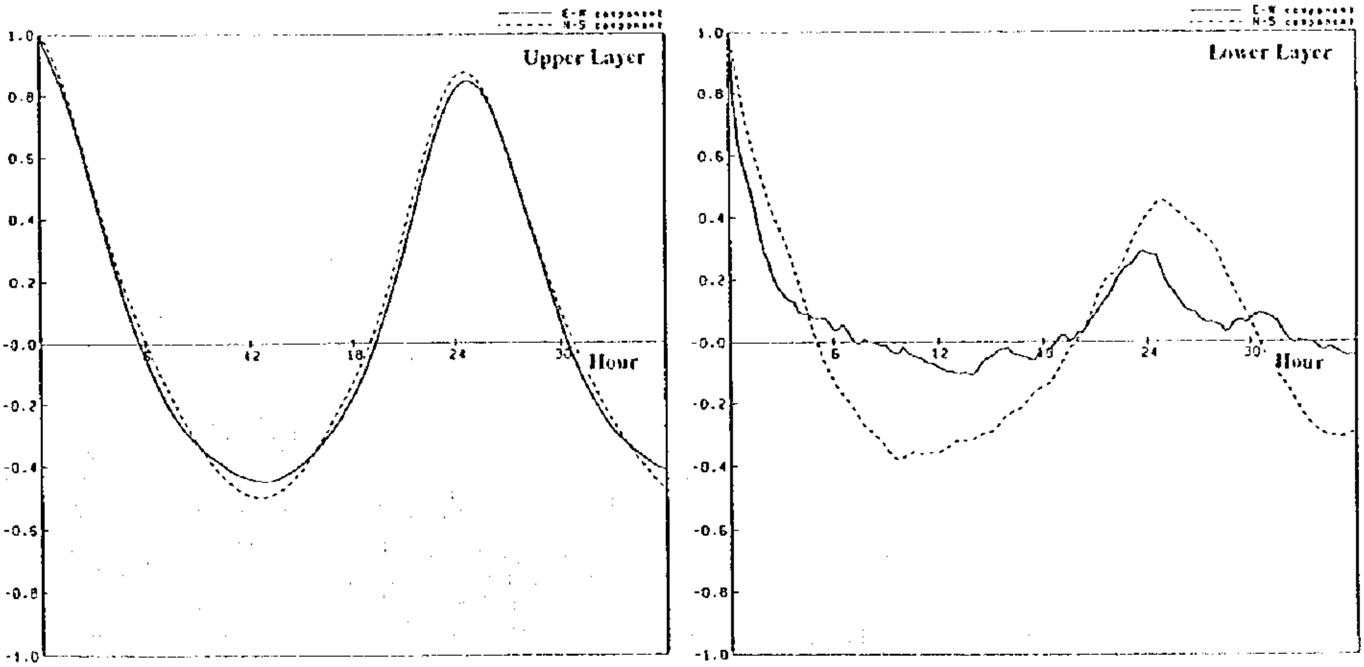


Figure 8.3.26 Auto Correlation of Velocity Components at Cua Luc

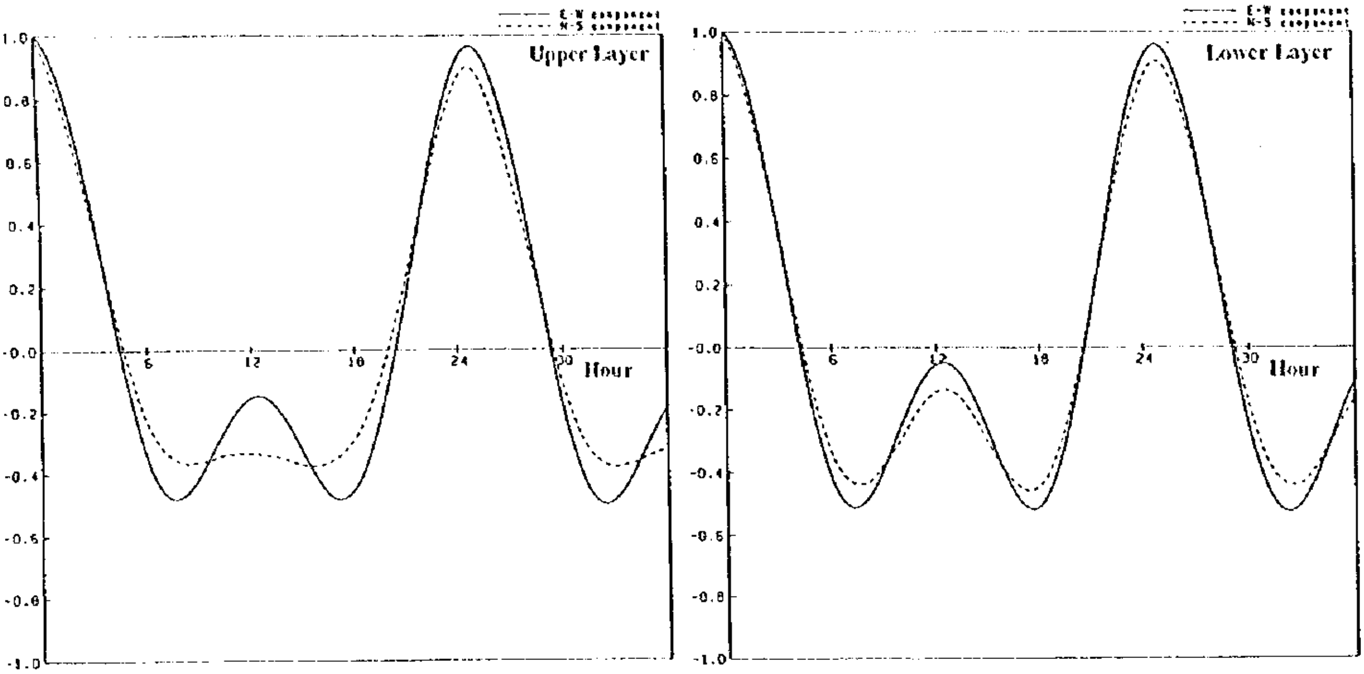


Figure 8.3.27 Auto Correlation of Velocity Components at Cam Pha - Cua Ong

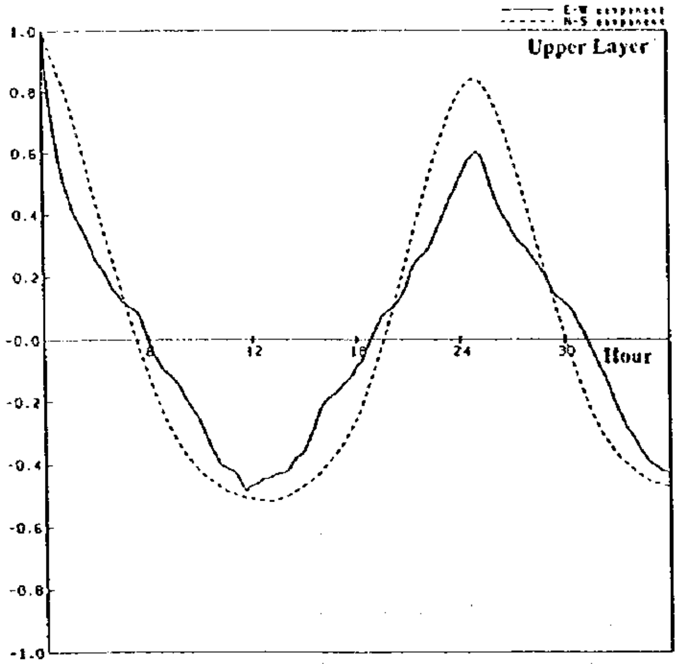


Figure 8.3.28 Auto Correlation of Velocity Components at Cua Dua

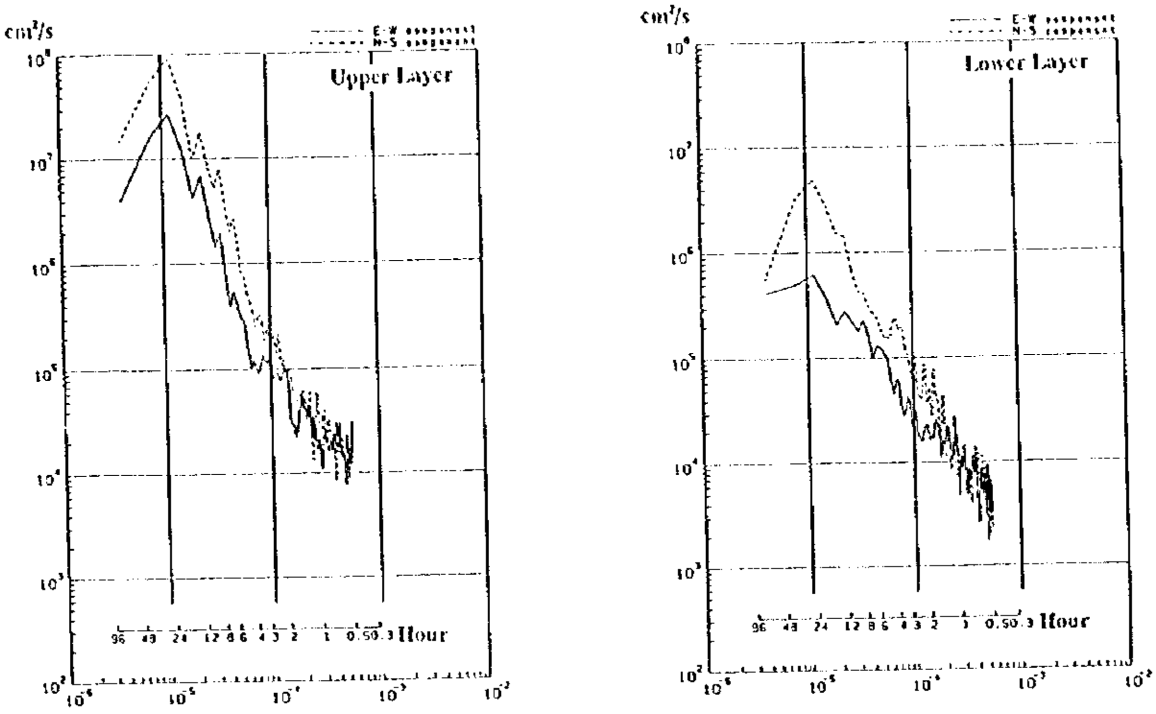


Figure 8.3.29 Power Spectra of Velocity Components at Cua Luc

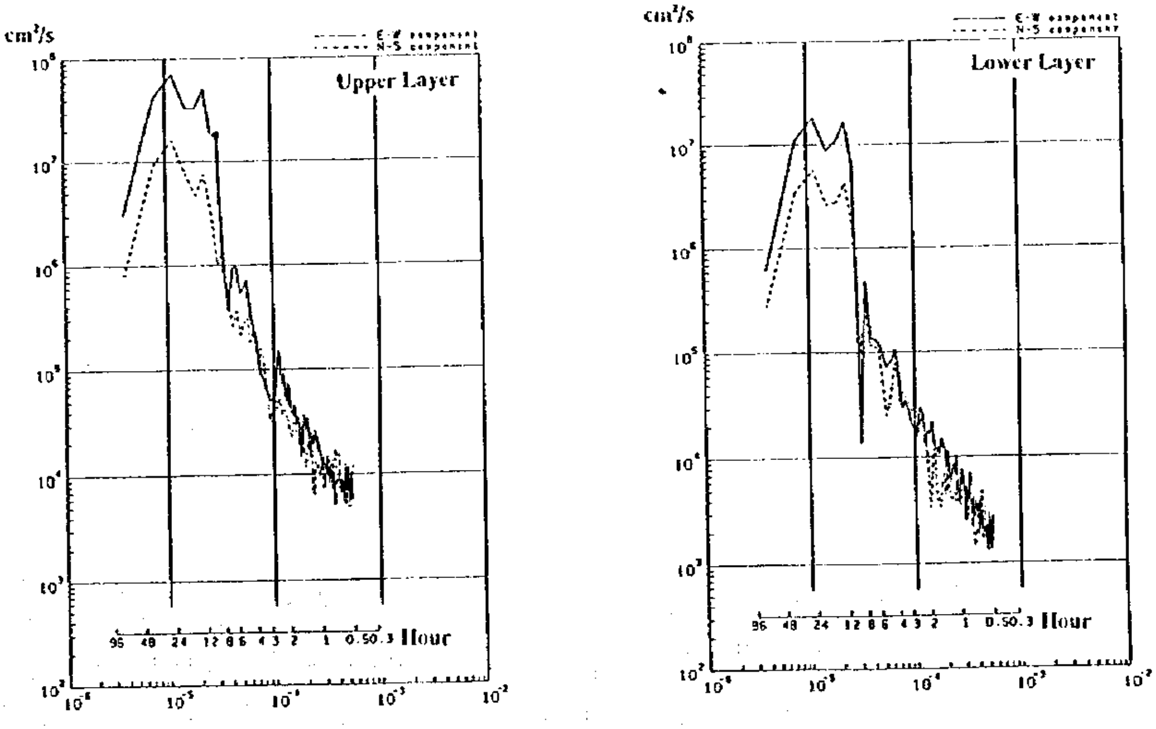


Figure 8.3.30 Power Spectra of Velocity Components at Cam Pha - Cua Ong

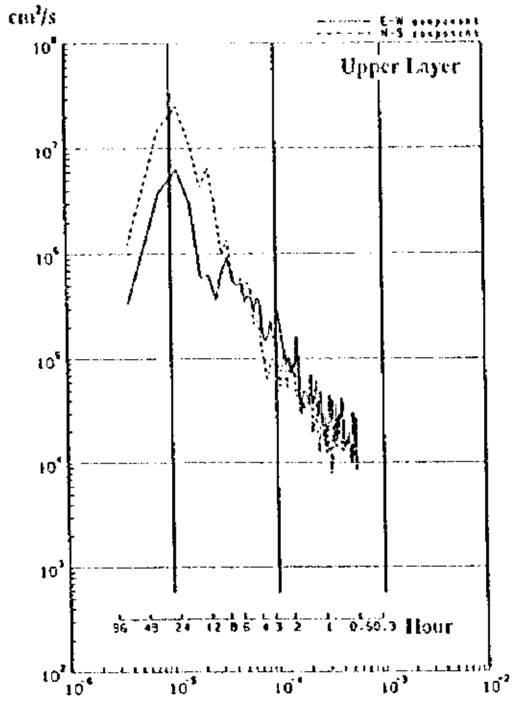


Figure 8.3.31 Power Spectra of Velocity Components at Cua Dua

Station : Cua Luc
Time : 14/07/1998 – 30/07/1998

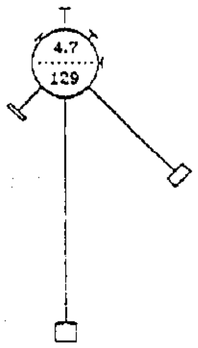


Figure 8.3.32 Wind Rose at Cua Luc

Station : Cua Ong
Time : 14/07/1998 – 30/07/1998

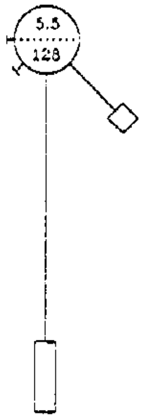


Figure 8.3.33 Wind Rose at Cam Pha - Cua Ong

Station : Cua Dua
Time : 14/07/1998 – 30/07/1998

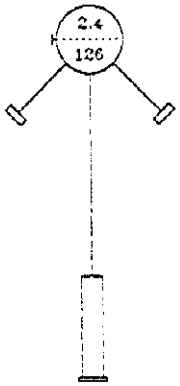
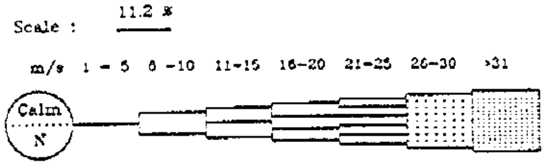
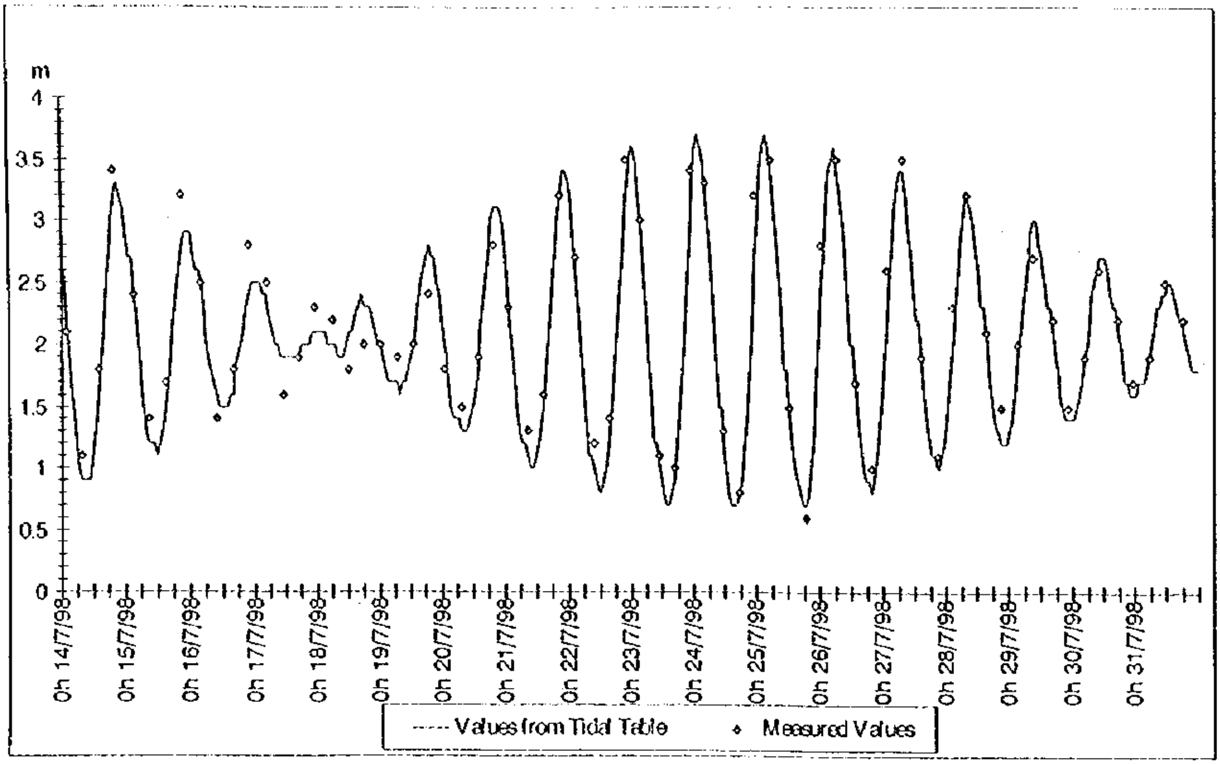


Figure 8.3.34 Wind Rose at Cua Dua

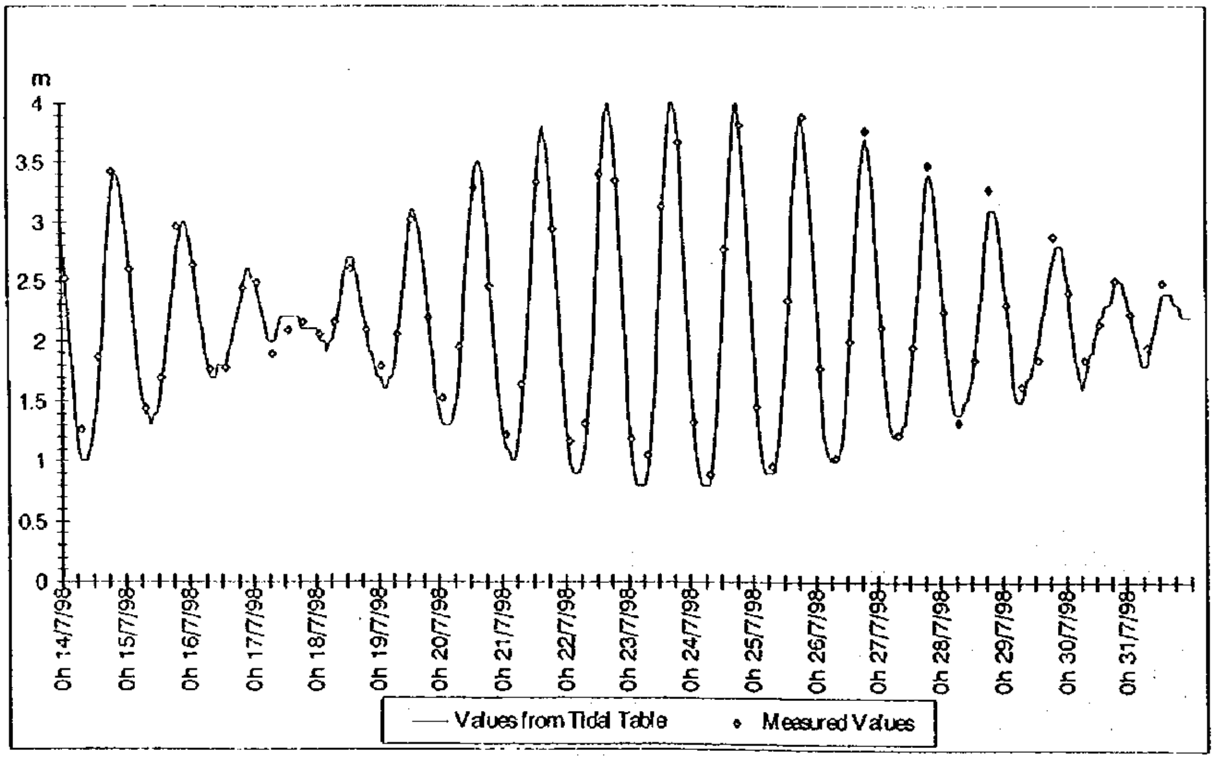
LEGEND:





Source : HIO (1998)

Figure 8.3.35 Measured Water Levels at Bai Chay Station and Tidal Levels from Tidal Tables 1998 from 14 July to 31 July 1998



Source: HIO (1998)

Figure 8.3.36 Measured Water Levels at Cua Ong Station and Tidal Levels from Tidal Tables 1998 from 14 July to 31 July 1998

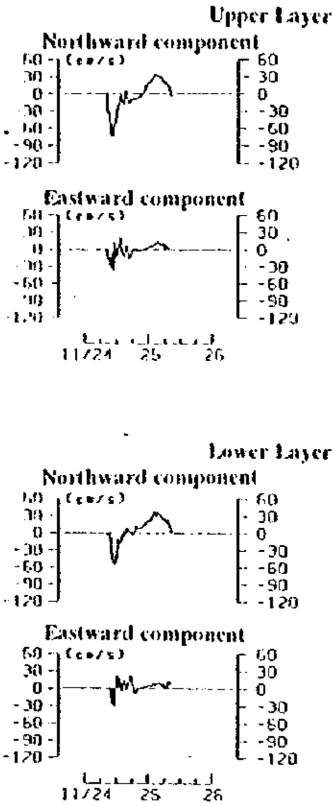


Figure 8.3.37 Current Velocity at Cua Luc

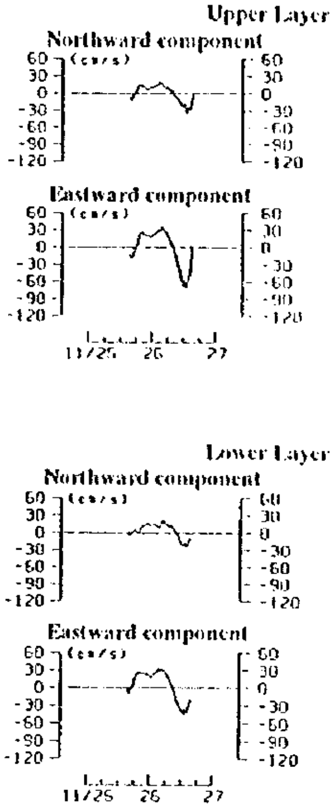


Figure 8.3.38 Current Velocity at Cam Pha-Cua Ong

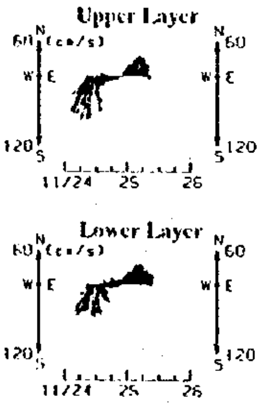


Figure 8.3.39 Current Velocity at Cua Luc

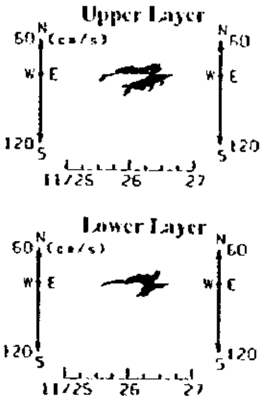


Figure 8.3.40 Current Velocity at Cam Pha-Cua Ong

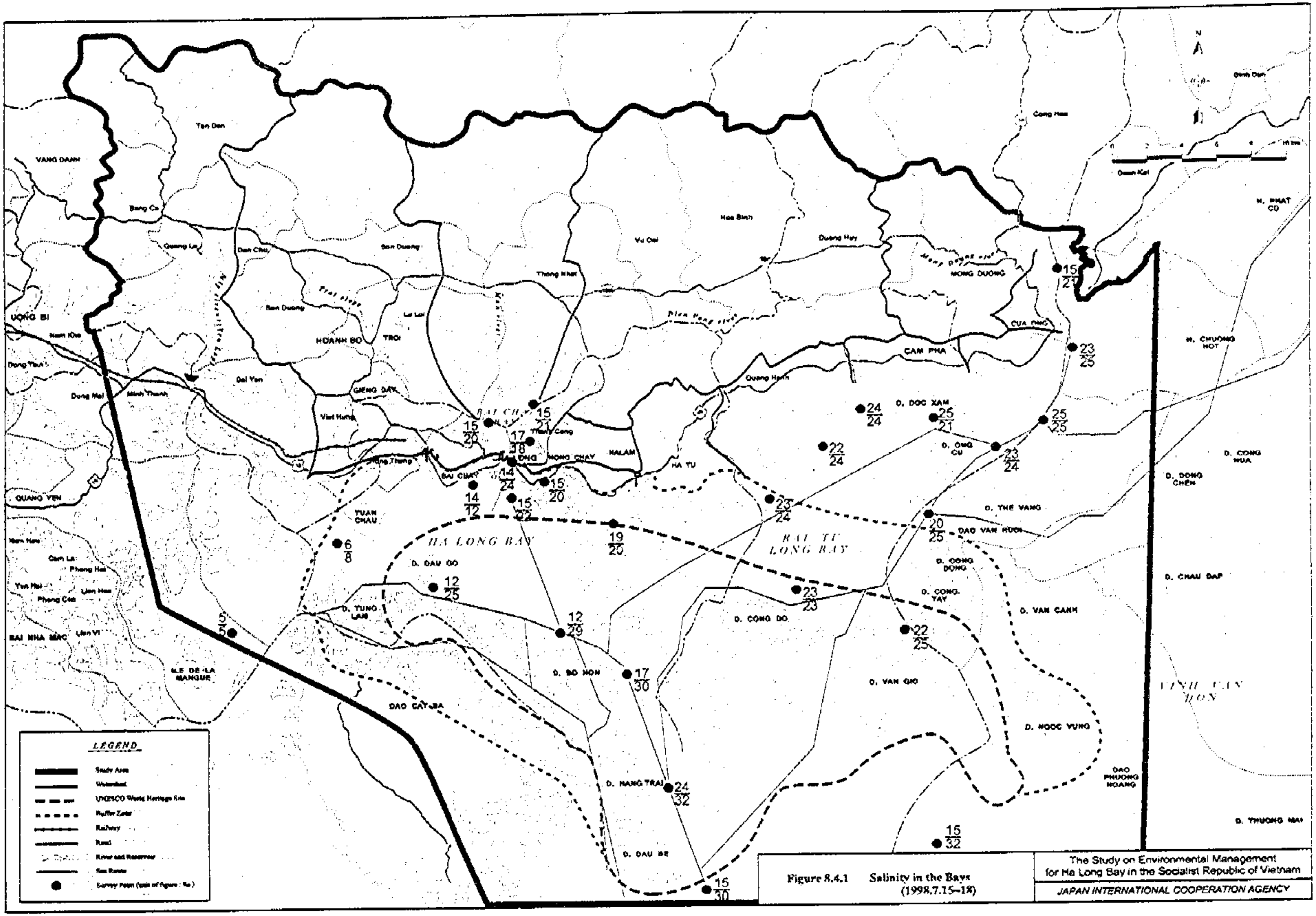


Figure 8.4.1 Salinity in the Bays (1998.7.15~18)

The Study on Environmental Management for Ha Long Bay in the Socialist Republic of Vietnam

JAPAN INTERNATIONAL COOPERATION AGENCY

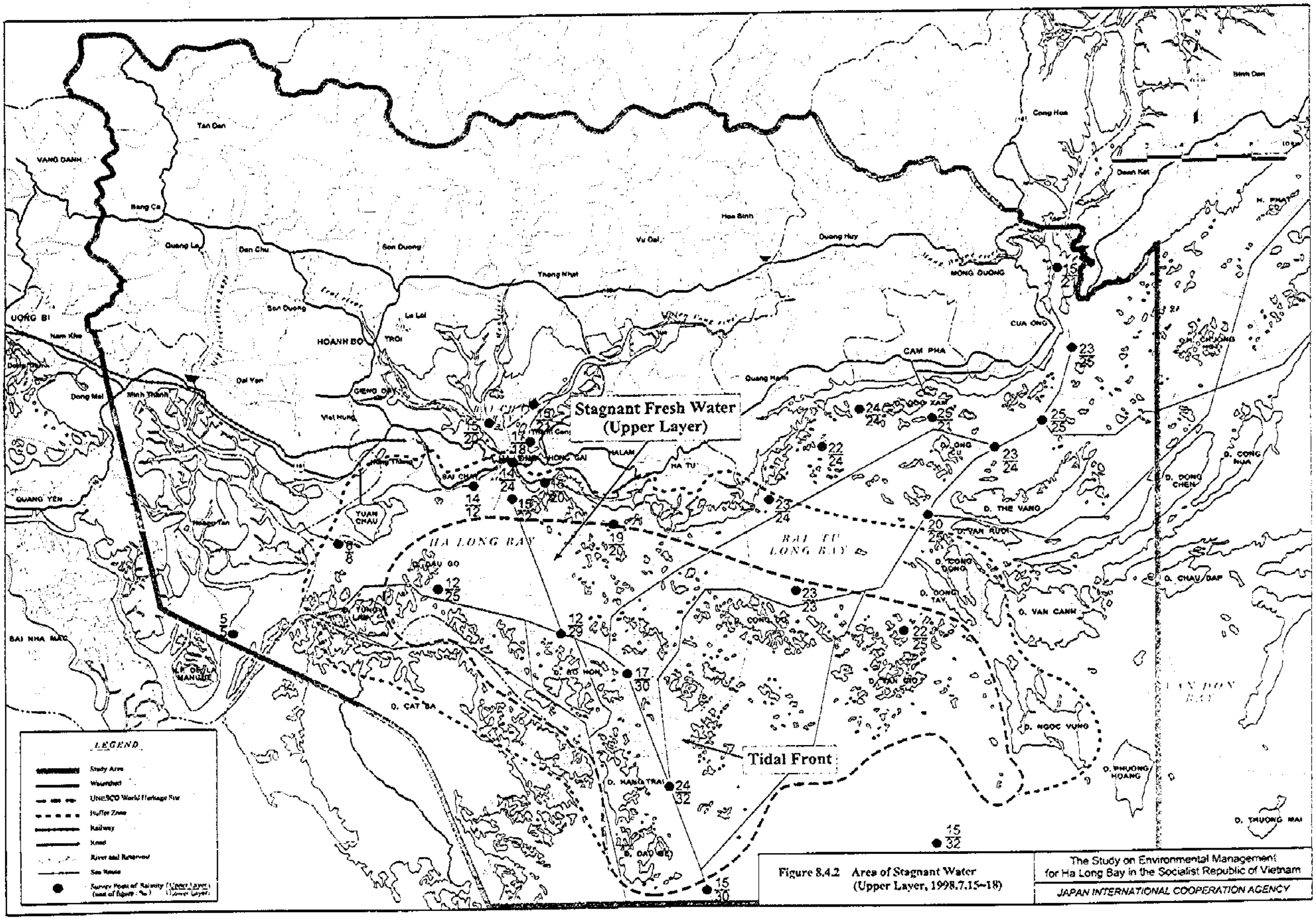


Figure 8.4.2 Area of Stagnant Water (Upper Layer, 1998.7.15~18)

The Study on Environmental Management for Ha Long Bay in the Socialist Republic of Vietnam

JAPAN INTERNATIONAL COOPERATION AGENCY

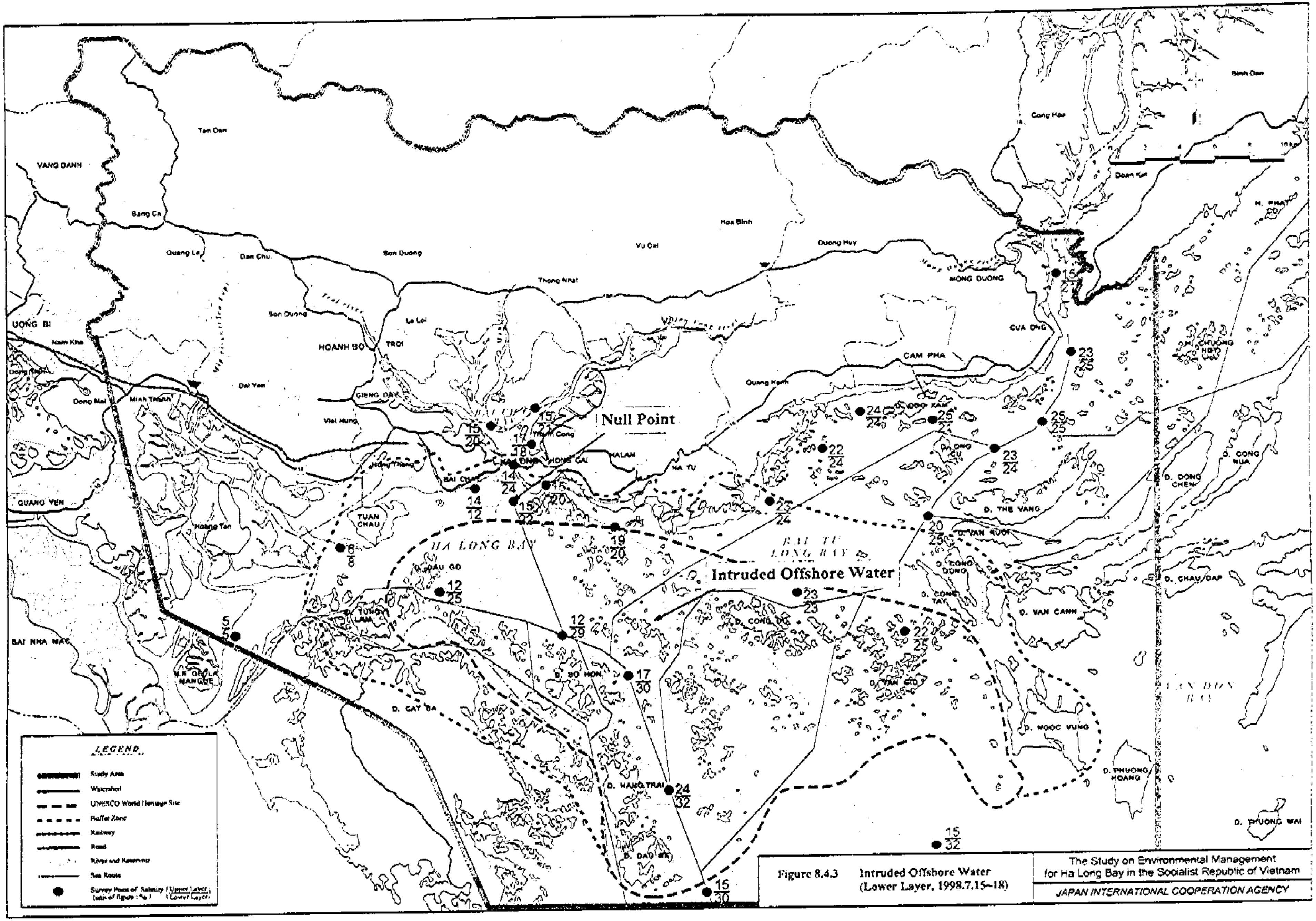


Figure 8.4.3 Intruded Offshore Water (Lower Layer, 1998.7.15~18)

The Study on Environmental Management for Ha Long Bay in the Socialist Republic of Vietnam

JAPAN INTERNATIONAL COOPERATION AGENCY

CHAPTER 9

CHAPTER 9 WATER AND SEDIMENT QUALITY

9.1 Overview of Historic Water Quality Data

9.1.1 Overview of Recent Studies

Investigations of water and sediment quality of the bays have been dominated by studies conducted since 1992. Approximately 34 water and sediment quality variables have been measured as part of the investigations. A summary of the different studies and sampled variables is provided in Tables 9.1.1 and 9.1.2. The common theme of the different studies has been water quality levels in the bays.

The studies were conducted by different agencies with different experimental designs and analytical methodologies. Most studies collected point-in-time samples at different locations in the bays either during the dry (winter) or rainy (summer) seasons. Due to the differing designs and methodologies of the previous studies, information on water quality at the different sampling sites in the bays is highly variable. Standard, rigorous field and laboratory analytical methods required to produce accurate water quality data are not fully developed at all Vietnamese institutions which resulted in the great variability of historic data. Thus, the independent results on water quality in the bays reported by these studies are not conclusive.

9.1.2 Water Quality Indicators

To overcome the great variability of existing data and to reveal general water quality conditions in the bays, key water quality indicators were summarized for four different areas of the bays. To further reduce data, variability individual data from different studies that were considered a little relation with the Study outliners were excluded from the analysis. Pollution indicators that were sampled broadly in the bays were included in the analysis.

The indicators selected from previous studies are dissolved oxygen (DO), nitrate nitrogen (NO_3-N), fecal coliform, four heavy metals (cadmium, mercury, lead, zinc), total suspended solids (TSS), and oil. DO integrates the effects of biological oxygen demand (BOD) of organic waste. The areas of the bay for which these variables were summarized are defined as Bai Chay bay, nearshore Ha Long bay, Ha Long bay - Cat Ba island, and Cat Ba island - Gulf of Tonkin (Figure 9.1.1). These water quality variables are indicative of domestic and industrial waste effluents, agricultural runoff, and waste effluents from coal mining and shipping activities.

9.1.3 Historic Water Quality Data

Figures 9.1.2 and 9.1.3 summarize these selected six water quality indicators in four areas of the bays. The data represent average levels at surface and bottom strata. The variability of the data is indicated by the vertical maximum-minimum bars. The data suggest that the water quality of Bai Chay bay is different than water quality in outer Ha Long bay as defined by Cat Ba island-Gulf of Tonkin. However, caution must be exercised when attempting definitive conclusions due to the great variability in the data within and across the four defined regions in the study area.

(1) Dissolved Oxygen (DO)

DO levels in earlier studies show a trend of increasing oxygen concentration offshore. This trend is expected given the presence of oxygen consuming pollution, such as untreated domestic sewage and industrial effluents such as food processing plant discharged along the shores of Ha Long city. DO levels did not violate the Vietnam Standard (TCVN) for coastal water quality (Table 9.1.3).

(2) Nitrate Nitrogen (NO_3-N)

The paucity and high variability of NO_3-N data makes interpretation of NO_3-N levels difficult. The average levels, however, are generally consistent with normal terrestrial inputs which include anthropogenic nutrient loads (Clark 1996). NO_3-N levels do not exceed the environmental standard for normal coastal water quality (Table 9.1.3). Unfortunately, concomitant chlorophyll-a data are not available to determine the effects of ambient nitrate levels on photosynthesis. Thus, more NO_3-N measurements in the bays are required.

(3) Total Suspended Solids (TSS)

Total suspended solids (TSS) refer to the amount of suspended matters in water that can be removed by filtration with a standard micron filter. Vietnam has adopted "suspended solids (SS)" for TCVN (Table 9.1.3), while TSS is normally reported in water quality studies conducted by Vietnamese investigators. The terms can be used interchangeably because they are derived from the same analytical methodology.

TSS appears to decrease from Bai Chay bay to offshore. This trend can be expected that major sources of TSS to Ha Long bay be believed to be land-base. Potential sources of TSS are the tributaries of Bai Chay bay that drain the basins to the north of the bay. Other potential sources of TSS are coal mining activities, urban pollution, and possibly periodic sediment upwelling events from the bottom of the bays during the strong wind conditions. The potential sources of TSS notwithstanding, the levels of TSS recorded in the bays by earlier studies are significantly higher than normally expected in a coastal estuarine environment with similar amount of urban and industrial activities.

The historic TSS data are not sufficiently reliable because of the high likelihood that a bias existed with the analytic methodologies that produced TSS levels that are too high. For example, not included in Figure 9.1.3 are TSS data collected in the bays in January 1997. The measured levels of TSS of that study averaged approximately 120 mg/ℓ, which are 10 times the levels summarized in Figure 9.1.3. It is suspected that the analytic methodologies for TSS were inconsistent among earlier studies, and that some or all previous studies did not remove the dissolved salts from the calculations of TSS. Thus, caution must be exercised with any interpretation of historic TSS data for the bays.

(4) Fecal Coliform

The presence of fecal coliform bacteria in Ha Long bay is expected given the absence of sewage treatment in Ha Long city. The measured levels summarized in Figure 9.1.2, however, can only be used to indicate the presence of enteric bacteria, and cannot be used in a quantitative analysis of levels and distribution due to the nature of this biological pollutant. The relatively short life of coliform bacteria combined with the resultant patchy distribution in ambient waters require that coliform bacteria be sampled intensively, both in space and time, in order to document concentrations comparable to environmental standards or criteria.

(5) Heavy Metals

Reported heavy metals concentrations in the bays are summarized in Figure 9.1.3. With the exception of zinc, average levels of all heavy metals did not violate the strictest TCVN for coastal water quality. Average zinc levels exceeded the standard of 0.01 mg/ℓ in all four areas (Table 9.1.3).

(6) Oil

Existing data are extremely variable as indicated by the vertical maximum and minimum bars in the oil plot in Figure 9.1.3. Averaged values of oil suggest that their levels gradually decrease offshore. The variability in reported oil concentrations is most likely a combination of the analytical difficulties with measuring oil in seawater, and the application of different analytic methodologies of different studies. The presence of oil in Ha Long bay is expected given the shipping activities such as bilge water discharge, spills from the floating gas stations and B12 oil port. However, only qualitative comparison among regions should be attempted given the variability of the data.

9.1.4 River Water Quality

Almost no water quality data exists for the rivers flowing to the bays. The exception to this are monthly discharge and suspended sediment data at the Duong Huy station (21°03'N, 107°12'E) on the upstream of Dien Vong river collected by the Hydro-meteorological Service of Vietnam from 1961 - 1974 (see chapter 3).

9.1.5 Sediment Quality in the Bays

The only extensive study of sediment quality in the bays prior to 1998 was conducted as part of the Feasibility Study on Cai Lan Port Expansion Project (1994). For that study a series of bottom sediment parameters were measured in the proposed harbor area in Bai Chay bay and just outside Cua Luc strait for inventorying ambient contaminant loads in the sediments. Average levels of sediment parameters sampled during June of 1994 are shown below:

Average Levels of Sediment Parameters in the Bays in June of 1994

Location	Variables						
	Water Content (%)	Ignition Loss (%)	COD (mg/ℓ)	Cd (mg/ℓ)	Pb (mg/ℓ)	Hg (mg/ℓ)	As (mg/ℓ)
Near shore (12 sites)	17.0	10.5	2,108	2.17	56.0	0.27	1.12
Ha Long bay (7 sites)	19.8	13.2	2,407	2.91	90.5	0.16	1.15

Source: Feasibility Study Report on Cai Lan Port Expansion Project, 1994

9.1.6 Summary of Historic Data of Bay Water Quality

Earlier studies suggest that water quality in the bays was influenced by human activities in Ha Long city, but that water quality had not been degraded on the whole. Existing data suggest that effects of untreated domestic and industrial effluents of Ha Long city be restricted to the nearshore area, with pollution conditions being located close to the effluent discharge locations. The influence of land-based pollution on offshore water quality adjacent to Cat Ba island appears to be minimal.

The nearshore water quality of the bays falls within the Eutrophic Water Classification (Table 9.1.4) of the Overseas Coastal Area Development Institute of Japan (OCDI). This classification corresponds to the mesotrophic state, which is a typical coastal estuarine environment (Clark, 1996). Mesotrophy is intermediate to oligotrophy and eutrophy, following international convention.

Mesotrophy describes a state of an aquatic ecosystem that is influenced by terrestrial inputs, which can include pollutant loads, but is not degraded. Elevated nutrient and suspended sediment levels due to land runoff are common characteristics of mesotrophic water, which can lead to increased primary production and suppressed summer DO levels due to increased BOD. Only the most sensitive marine species such as coral reefs are negatively affected by mesotrophic conditions. Human uses of coastal waters, normally are not affected by mesotrophic conditions; however, swimming and untreated water consumption can be negatively affected due to the presence of coliform bacteria, which is common in tropical coastal waters receiving untreated urban effluents.

Oligotrophic waters are pristine and unaffected by terrestrial inputs or pollution, and typify water quality requirements of coral reef ecosystems. Eutrophic waters represent the extreme opposite of the oligotrophic condition in which pollution levels (normally nutrients, metals, toxic) are very high. Eutrophic waters are associated with high turbidity, extreme primary production, regular anoxia, frequent algae blooms, that are populated by few tolerant organisms.

Reported DO and NO_3-N levels of the bays combined with the presence of fecal coliform bacteria indicate that the inshore areas of the bays are likely mesotrophic and are influenced by urban and industrial activities of Ha Long city and surrounding rural areas.

9.2 Water Quality of the Rainy Season by the Field Survey

Although several field surveys concerning water quality have been implemented in the study area, the data are not enough from scientific and objective analysis viewpoint. This is because the number of sampling points are very few, sufficient information on water quality of Bai Tu Long bay near Cam Pha and Cua Ong is missing from the historic data. Besides, survey period and frequency is at random, and the filed survey on rivers and pollution sources are rare. Therefore, the Field Survey was conducted to confirm the validity of the existing data to collect necessary information for elucidation of water pollution mechanisms, and to formulate pollution control measures.

9.2.1 Methods

(1) Methods

The Field Survey of water and sediment quality in the bays and the rivers was conducted by HIO during July and August of 1998 under the supervision of the JICA study team. In addition to the surveys, field and laboratory studies were conducted to describe the major mechanisms through which land- and water-based pollution enter and reach equilibrium in the bays.

With regards to water and sediment quality, the Field Survey sampled 38 variables at 30 and 15 sites, respectively, in Bai Chay, Ha Long, and Bai Tu Long bays which included nutrients and heavy metals. A similar set of variables was sampled from 15 sites in major tributaries of the study area (Figure 9.2.1, Table 9.2.1).

A major component of the design of the Field Survey was the articulation of Quality Assurance and Quality Control (QA/QC) protocols that were given to HIO to guide their field sampling and laboratory analyses in order to maximize data accuracy. A water quality variable of particular interest was SS due to the apparent difficulties encountered by previous studies in producing realistic SS data.

The QA/QC protocols were developed by the JICA study team primarily to serve the integrity of the Field Survey, also became part of the technical transfer program for the C/P during the hands-on training in field sampling that they received during the implementation of the Field Survey.

(2) Focal Points of Analysis of Survey Data

The historic data suggest that water quality in the bays is influenced by pollutant from the catchment, and that the Bai Chay bay and the nearshore areas of the bays could be more affected than the offshore areas. Unlike the regional summary of historic data, the Field Survey data were examined by specific sampling locations to determine in more detail the magnitude and extent of water pollution in the bays.

An underlying hypothesis of the Study is that land-based pollution discharged from the catchment, and from industrial and coal mining activities influences water quality of the bays, as governed by the hydrography of the bays. If the hypothesis is valid then gradients of water pollution indicators should exist from nearshore waters adjacent to urban area, and to offshore area. Therefore, analysis of survey data is mainly focused on the followings:

a) water quality in the rivers,
b) water or sediment quality in the bays, and
c) water pollution mechanism in the bays

(3) Water and Sediment Quality Standards

Water and sediment quality standards and guidelines are used in the Study to provide benchmarks with which to assess the effects of land-based pollution on the water quality. Because the water quality expresses the integration of land-based pollution with pollutant transport mechanisms of the bays, standards and guidelines assist with identification of required pollution remedial management action and monitoring in the bays and rivers.

More than one set of coastal water quality guidelines and standards are presented in the Study because a complete and definitive set of water and sediment standards for the bays is not available. Existing TCVN does not address all pollution variables relevant to the water quality. Thus, TCVN are supplemented with standards and guidelines from Japan, Canada, and general standards derived for many tropical coastal areas.

TCVN were developed by the National Directorate for Standards and Quality (STAMEQ, 1995), Japanese standards (Table 9.2.2) are taken from the Environment Agency of Japan, and "General Tropical Guidelines" (Table 9.2.3) represent a compilation of guidelines from different mesotrophic coastal environments (Clark, 1996). Sediment quality standards for dredged material were taken from Japanese and Canadian sources (Table 9.2.4).

9.2.2 Water Quality in the Rivers by the Field Survey

(1) Water Quality in the Rivers

Water quality indicators in the rivers sampled during dry and rainy conditions are described in Figures 9.2.2 ~ 9.2.4. Plotted data represent averages of two samples taken on different days for each weather condition.

1) DO

DO was essentially uniform across all rivers during the dry and rainy conditions, except for DO at stations 10 and 13. BOD was much more variable among the stations than DO.

2) Nutrients

Nitrogen concentrations in the rivers are similar with the exception of nitrogen levels in two tributaries near Cam Pha. No significant difference exists between nitrogen levels on rainy or dry days. Comparative analysis of T-P and phosphate (PO_4-P) concentrations shows a greater difference between rainy and dry conditions. During the rainy day, T-P concentrations were generally greater in the tributaries draining the Hong Gai quarter east to the Mong Duong river.

3) SS

There is a significant range in SS among tributaries between dry and rainy conditions. The rivers show the greatest SS concentrations form part of the Dien Vong river and rivers extend eastward of Hong Gai quarter. SS levels in the Mong Duong river were also high. By comparison the rivers forming the Troi and Man river systems that drain northern and western Bai Chay bay have low SS levels.

4) Heavy metals

Iron and zinc concentrations clearly distinguish the rivers. Iron and zinc are significantly greater in eastern rivers starting at the Dien Vong river and extending to the Mong Duong river north of Cua Ong. Concentrations of other heavy metals are comparatively uniform across all rivers. Note that the pH levels of the tributaries with high iron and zinc concentrations are generally lower than the other tributaries. Elevated metal concentrations are consistent with waters of low pH.

(2) Assessment of Water Quality in the Rivers

SS levels in the Troi and Dien Vong rivers are over TCVN for inland water quality during the dry conditions. Similarly the rivers near Cam Pha including the Mong Duong river also exceed TCVN. The high level of SS in some rivers during the dry conditions could be due to soil erosion from deforestation and agricultural activities, or from a runoff associated with coal mining activities.

Nitrate nitrogen, DO, and BOD concentrations in the rivers do not exceed TCVN, and nitrate nitrogen does not exceed the Canadian freshwater standard of approximately 0.6 mg/ℓ. Based on these standards, water quality of the rivers does not impair the aquatic life. The high concentrations of nitrogen in two rivers near Cam Pha (No. 13 and 14) are considered to be due to the influence of mining activities. Nitrogen-based explosives are commonly used in coal mining in the study area.

High concentrations of iron and zinc in the rivers draining the Hong Gai quarter and the rivers along the coast to Cua Ong coincide with the presence of coal mining activities in these areas. Iron levels in some of these rivers greatly exceed TCVN (Table 9.2.5) of 1 mg/ℓ. Zinc levels in one tributary also exceed the standard of 1 mg/ℓ. These rivers run through some large coal mining areas. The low pH in some rivers is consistent with the effects of mine drainage. Low pH acts to mobilize natural metals from geology that would be occurring from drainage basins in which coal mining occurs.

Some of the high concentrations of iron and zinc measured at inshore stations in the bays would be associated with the rivers that are discharging high concentrations of these metals. The relatively high iron concentrations in Bai Chay bay (No. 1 & 2) may be due to discharge from the tributary just north of Hong Gai (No. 10). Similarly, the relatively high iron levels at inshore bay stations east of Hong Gai to Cua Ong would be associated with iron discharged from tributaries along that shoreline.

Similar to bay nutrient concentrations, the difference between shoreline and offshore iron and zinc levels suggest that the effects of the high tributary concentrations and thus loads of these two metals do not extend far beyond the respective river mouths. There does not appear to be a relationship between metal concentrations in bay sediments and tributaries.

9.2.3 Water Quality in the Bays by the Field Survey

(1) Water Quality in Bays

Key indicators of the water quality in the bays obtained by the Field Survey are summarized in Figure 9.2.5 ~ 9.2.9 and Table 9.2.6.

(2) Distribution Analysis of Water Quality in the Bays

The sampling data were spatially stratified in three ways to permit three views of water quality in the bays. The first analysis is of nearshore water quality extending from the western most sampling station at Ile De La Mangue east to the Cua Ong estuary (excluding Bai Chay bay). The second and third analyses examine potential nearshore-offshore water quality gradients; the first from Bai Chay bay south to Cat Ba island and the second from Cam Pha south to Ile Danh Da. The sampling stations corresponding to the three analyses are listed below;

Sampling Stratification	Sampling Stations
Nearshore	5, 6, 7, 4, 9, 10, 11, 16, 18, 19, 20, 26, 27 28, 29, 30
Bai Chay bay - offshore Cat Ba island	1, 2, 3, 4, 9, 8, 12, 13, 14, 15
Cam Pha-Cua Ong - offshore Bai Tu Long	17, 21,22, 23, 24, 25,29, 30

Note: The location of sampling stations is shown in Figure 9.2.1.

1) Shoreline

Figures 9.2.10 ~ 9.2.12 show the concentrations of eleven water pollution indicators at nearshore stations in Ha Long and Bai Tu Long bays from Ile De La Mangue (No. 5) east to Cua Ong estuary (No. 27). Data from the stations sampled in Bai Chay bay were excluded because the hydrodynamics of that semi enclosed bay are significantly different than the hydrodynamics of the shoreline of Ha Long and Bai Tu Long bays.

a) Nutrients

Ammonical nitrogen (NH_4-N) and nitrate nitrogen (NO_3-N) levels were relatively high adjacent to Bai Chay and Hong Gai quarter. NO_3-N levels were also relatively high west of Bai Chay and near Ile De La Mangue. Similarly, total phosphorus (T-P) was also relatively high adjacent to Ha Long city. Note, relatively high T-P levels in Cua Ong estuary. Total nitrogen (T-N) was greatest along the Cam Pha - Cua Ong corridor.

b) Chlorophyll-a and DO

Inshore chlorophyll-a concentrations do not vary significantly from east to west in the study area. DO concentrations are uniform in inshore areas, with the exception of waters near Ile de la Mangue (No. 5) and two locations off

Cam Pha, at which DO was approximately 4.0 mg/ℓ. Dissolved oxygen correlates with BOD.

c) SS

Shoreline SS levels were comparatively high near the Mip river estuary (No. 6), off western Bai Chay, and adjacent to Cam Pha. Another area that showed high SS was just south of the Cua Luc strait that drains Bai Chay bay.

d) Fecal coliform

Fecal coliform concentrations are highest at nearshore stations adjacent to Ha Long city and Cam Pha - Cua Ong. The change in water quality from Cam Pha south to Ile Danh Da is similar to the change in water quality south from Ha Long city to Cat Ba island. With the exception of SS, similar but milder gradients in water quality indicators exist from Cam Pha to Ile Danh Da (No.23).

e) Heavy metals

Nearshore heavy metals concentrations were generally uniform throughout the bays, with the exception of mercury (Hg) which was relatively high at station 16. The only slight trend in metal concentrations in inshore waters of the bays appears to be with iron. Iron concentrations were relatively high in waters off Hong Gai east to Cam Pha -Cua Ong.

f) Oil

Due to the high variability in reported oil levels of recent studies, levels measured during the Field Survey of 1998 are expressed as an index. This allows the analysis to focus on the relative differences among sampling sites and potential source locations, and not get bogged down with differences in recorded concentrations. Trends in historic data can be directly compared to data collected in the Field Survey. Shoreline oil levels were greatest adjacent to Ha Long city and Cam Pha-Cua Ong.

2) Inshore - offshore gradients

Figures 9.2.13 ~ 9.2.15 show water pollution indicators measured in Bai Chay bay south to Cat Ba island.

a) Nutrients

NH_4-N and NO_3-N levels clearly decrease from Bai Chay bay offshore to Cat Ba island. There is also a gradient of T-P offshore but not as strong as shown for NH_4-N and NO_3-N.

b) Chlorophyll-a and DO

There is no apparent difference between inshore and offshore concentrations of chlorophyll-a. There appears to be gradients in surface and bottom DO from Bai Chay bay offshore to Cat Ba island. Surface and bottom DO decrease and increase, respectively to almost a convergence southeast of Cat Ba island (No. 15).

c) SS

SS concentrations from inshore to offshore waters do not show an apparent trend. The relatively high SS level recorded at the single station in Bai Chay bay is expected. However, the high concentrations in the shipping channel (No. 9), and the high levels recorded near Cat Ba island (No. 8 & 14) are not expected. The high shoreline SS levels at Cam Pha decrease sharply to below 5.0 mg/ℓ, similar to SS levels off Cat Ba island.

d) Fecal coliform

Fecal coliform levels are higher in Bai Chay bay and nearshore Ha Long bay than in the water near Cat Ba island.

e) Heavy metals

There is no noticeable trend in heavy metals between Bai Chay bay and offshore Cat Ba island. Concentrations of all five metals are similar inshore and offshore. These data are consistent with the historic data. Iron is the only variable that showed a slight decrease concentration offshore of Cam Pha.

f) Oil

There is a clear gradient of oil concentration from Bai Chay bay south to Cat Ba island. The gradient is expected given the density of shipping activities, the location of the oil port and floating gas stations. The decrease in oil concentration offshore is consistent with the historic data, which also show that oil concentrations decrease offshore.

(3) Characteristics of Water Quality in the Bays

1) DO

DO levels in the bays are similar to levels recorded by previous studies. DO levels at bottom strata in the nearshore zone of the bays often violate standards because concentrations exist below 80% saturation. The decrease in surface DO and the increase in bottom DO, respectively from Bai Chay bay offshore to Cat Ba island likely reflects the mixing of highly oxygenated freshwater from Bai Chay tributaries with low oxygenated saline bottom waters originating from the Gulf of Tonkin.

Oxygen is a critical water pollution variable because of the requirement of oxygen by aquatic organisms, and because it responds directly to changes in BOD loadings. The marginal levels of oxygen at bottom strata may stress sensitive benthic organisms in the bays, and pelagic fishes that require the bottom for feeding or spawning habitat.

BOD levels are consistent with other reported studies of estuarine coastal zones. The correlations between shoreline BOD and DO show nicely the link between these two water pollution variables. BOD levels in the bays correspond to the slightly polluted eutrophic water classification of OCDI and to mesotrophic coastal water.

2) Nutrients

NO_3-N concentrations measured in the Field Survey are similar to the historic data. Both data sets suggest that Ha Long city and Cam Pha town act as relatively large sources of nitrogen to the bays. The lack of strong correlation between T-N, NH_4-N and NO_3-N is likely due to differences in suspended sediment loads. Unlike T-N, and NH_4-N and NO_3-N data are derived from filtered water samples. Filtering removes nitrogen adsorbed on suspended matter, which is a highly variable form of nitrogen.

The shoreline concentrations and offshore gradients of T-N, NH_4-N, and NO_3-N from Ha Long city and from Cam Pha-Cua Ong suggest that nitrogen that enters the bays from land-based sources is assimilated in the nearshore zone resulting in the decay of waterborne nitrogen offshore. Nitrogen concentrations in the bays sediments strongly support the assertion that Ha Long city and Cam Pha-Cua Ong are potentially large sources of nitrogen. The relatively low nitrogen levels in offshore sediments support the hypothesis that nitrogen loads from land-based sources are assimilated and removed from the water column and sediment in the nearshore zone.

The range of chlorophyll-a concentrations throughout the bay exceeds levels expected in offshore oligotrophic waters. For example, the limit for the protection of coral reefs is approximately 0.6 μg/ℓ (Connell and Hawker, 1992). The uniform chlorophyll-a levels throughout the bays, however, suggest that the measured differences in nutrient concentrations between inshore and offshore areas are insignificant for primary production. While nitrogen (NO_3-N) and to a lesser degree phosphorus (PO_4-P) are limiting nutrients for algae growth in seawater, other factors in the bays, such as light, may be providing a greater influence on primary production.

3) SS

The change in SS from earlier studies does not represent a decrease in ambient conditions, but an improvement in the analytic method for measuring SS in the lab that was used in the Study. As part of the QA/QC program, the protocol for removing dissolved salts from the sample was made explicit in the analyses. Thus, SS levels measured in 1998 are not comparable to SS levels reported in earlier studies.

The steep SS gradient offshore suggests that the effects of intensive coal mining activities of Cam Pha and Cua Ong on water quality are restricted to nearshore areas. The relatively low SS levels in Bai Chay bay can be attributed to quiescent conditions.

The historic SS levels, while significantly higher than 1998 data, did not violate TCVN for coastal water. It is the judgment of the Study that the standard for SS of 50 mg/ℓ is too high. A more acceptable standard is considered to be the general international standard of 15 mg/ℓ for coastal waters. When 1998 SS levels are compared to this more conservative standard, SS exceeded the standard at 4 stations; these were the Mip river estuary, Bai Chay, and two stations adjacent to Cam Pha.

4) Fecal coliform

Fecal coliform levels measured in 1998 are consistent with historic levels measured in the bays and show high levels in nearshore waters adjacent to Ha Long city and to a lesser extent Cam Pha and Cua Ong. Fecal coliform levels violate TCVN for water used for drinking water, swimming and recreation. Bacteria levels are particularly serious for the development of tourism industry in Bai Chay area. Remedy of coliform will require sewage treatment or relocation of domestic waste discharges.

9.3 Water Quality of the Dry Season

DOSTE has conducted field survey in the dry season, December 1998. The survey was carried out by being entrusted to the Hai Phong Institute of Oceanology (HIO). The surveyed items were tidal current, water quality and plankton in the bays, and dust. As a reference of the analysis of water mass structure and pollution mechanism of the bays, the surveyed data of the dry season as well as historical data were summarized as shown below.

1) Historic dry season water quality data

A comparison of water quality data collected in dry and rainy seasons in the nearshore area of the bays by earlier studies shows that not all pollution indicators support the hypothesis of better water quality in the dry season. Average water quality in dry and rainy seasons reported by other studies are shown below:

Variable	Rainy Season (June - July)	Dry Season (Dec - Feb)
DO (mg/ℓ)	5.3	7.0
COD (mg/ℓ)	11.4	11.4
BOD (mg/ℓ)	1.1	1.2
NO_3-N (mg/ℓ)	0.01	0.06
T-P (mg/ℓ)	0.04	0.03
SS (mg/ℓ)	30.3	34.8
Oil (mg/ℓ)	0.14	0.22
salinity (ppt)	24.1	30.0
heavy metals	higher	lower
coliform. Bacteria (log #/100ml)	1.45	1.96

BOD in the bays was slightly higher in the dry season, while COD levels were the same in both seasons. This is unexpected given the positive correlation that normally exists between these variables.

NO_3-N concentrations, the only form of nitrogen measured throughout the bays prior to 1998, were consistently lower in the rainy season than in the dry season while total phosphorus (T-P) was slightly higher in the rainy season.

SS in the bays were slightly greater during the dry season. Heavy metal concentrations (Cd, Pb, Hg, Fe) in the bays were generally higher in the rainy season.

Expectedly, DO and salinity levels were greatest during the dry (winter) season. Oil and fecal coliform levels in the bays were also higher during the dry (winter) months.

2) Summary of historic dry season data

The historic data show weak trends in the differences in concentrations of pollution variables between the rainy and dry seasons that in some cases conflict with the hypothesis of pollution loading to the bays being greatest during the high river discharge and land runoff period of the rainy season. The greater SS levels reported for the dry season conflict with lower land runoff and erosion during that season. The differences between NO_3-N and T-P inconsistently support the hypothesis that water quality in the bays is better during the dry season due to decreased runoff.

The lower coliform bacteria levels during the rainy season is also not consistent with greater runoff during the rainy season. The greater dry season oil levels in the bays can be explained by the fact that the dominant source of oil is located on the bays, i.e., from ships and boats, and that the little freshwater runoff could act to concentrate the oil in the dry season. The slightly higher rainy season heavy metal concentrations support the hypothesis of the basins being the dominant source of pollution.

3) Nearshore conditions in the dry season of 1998

DOSTE commissioned an independent survey of water quality in the bays during December 1998 in order to document conditions during the dry season. The samples were taken among the inshore stations of the rainy season survey implemented by the JICA study team. Most of the same parameters as the rainy season survey were analyzed. The dry season data obtained by DOSTE was summarized and compared with the rainy season data obtained by the JICA study team.

The DOSTE survey sampled 19 inshore stations extending from Tuan Chau island east to Cua Ong estuary, which included sites in Bai Chay bay and the inshore area of Ha Long city. The 19 survey points were same ones as No.1, 3, 4, 6, 7, 8, 9, 10, 11, 16, 18, 19, 20, 24, 25, 26, 28, 29, and 30 of the rainy season. Most stations were sampled at surface and bottom layers.

As part of their analysis, DOSTE compared their dry season data to the rainy season data collected by the JICA study team. Because the nearshore area of the bays is shallow and relatively mixed, as indicated by rainy and dry season salinity and temperature data, surface and bottom water quality data were averaged for each season. The only variable that showed slight vertical stratification in the inshore area during the rainy and dry seasons is DO in Bai Chay bay.

In addition to the comparison of dry with rainy season conditions, DOSTE also assessed whether water quality differed between flood and ebb tidal conditions. They found that water quality did not differ significantly between the two tide conditions.

The water quality data of dry season by DOSTE survey are internally consistent, and supports the hypothesis that land runoff and tributary discharge from the hinterland forms the major source of organic, inorganic, and nutrient loads to the bays. Expected increases in DO and salinity, and decreases in SS from rainy to dry conditions are supported by the data.

Nearshore water quality in bays during rainy and dry seasons, 1998

Variable	Rainy Season (July)	Dry Season (December)
Temperature (°C)	31.7	24.4
Salinity (ppt)	20.7	30.2
DO (mg/ℓ)	5.5	6.2
BOD (mg/ℓ)	1.2	0.5
COD (mg/ℓ)	6.3	2.6
SS (mg/ℓ)	5.0	3.5
Turbidity (FTU)	8.8	1.7
Oil (mg/ℓ)	1.7	0.7
Chlorophyll-a (surface, mg/ℓ)	2.5	1.8
T-N (mg/ℓ)	1.7	0.98
T-P (mg/ℓ)	0.8	0.36
Coliform bacteria (MPN/100ml)	247	10

Source: 1) Rainy season: Field Survey by JICA study team
2) Dry season: DOSTE

Decreased nutrient and chlorophyll-a levels in the dry season are mutually consistent with decreased land runoff. Decreased BOD and COD flowing into the bays supports reductions in primary production.

Lower coliform levels are consistent with lower runoff. The concentrations of heavy metals (Cd, Fe, Hg, As, Cu, Pb) in inshore waters are similar in both rainy and dry seasons.

The lower oil levels in the dry season do not support a concentrating effect resulting from decreased freshwater runoff from the basins. Since the major source of oil is believed to be ships and boats on the bays, greater oil levels in the rainy season are not expected.

4) Offshore conditions in the dry season

To supplement the inshore water quality data collected by DOSTE in December 1998, the JICA study team sampled an inshore-offshore transect of 9 stations in February 1999 extending from Bai Chay bay to southern Cat Ba island. Seven stations were re-sampled from the Field Survey in July 1998. Two additional stations were added at the southern outskirts of Cat Ba island. The purpose of the survey was to determine whether water quality as well as water mass structure in whole Ha Long bay differed in the dry season. Of particular interest was the existence of different water quality at the southern outskirts of Cat Ba island as indicated by the Field Survey in July 1998.

Transparency, salinity, turbidity, COD and BOD levels in the bays from Bai Chay bay to south of Cat Ba island indicate that offshore water quality in the dry season is relatively homogenous and not heavily influenced by freshwater runoff from the basins. Salinity in Bai Chay bay (No. 2) was similar to salinity in offshore areas suggesting little freshwater input from the basins draining to the bay.

Transparency increases offshore to a maximum depth at the two stations sampled south of Cat Ba island. Surface turbidity steadily decreased offshore which supports the increase in transparency.

Station	Variable									
	Temp (°C)	Transp. (m)	Salinity (‰)		Turbidity (NTU)		COD_{Mn} (mg/ℓ)		BOD (mg/ℓ)	
	sur	bot	sur	bot	sur	bot	sur	bot	sur	bot
2	18.6	1.7	29.9	30.0	6	12	3.6	5.4	2.1	3.1
4	18.8	3.3	30.4	30.5	3	3	5.0	2.9	2.9	1.7
9	18.8	3.5	30.5	30.5	3	7	2.4	3.5	1.4	2.1
12	19.3	2.8	30.4	30.3	4	10	4.2	1.5	2.5	0.9
13	19.4	3.0	30.4	30.3	4	9	5.0	3.3	2.2	1.9
14	19.2	3.3	30.4	30.1	3	20	5.0	4.6	2.9	2.7
15	19.3	3.8	30.4	30.3	3	8	2.9	2.4	1.8	1.2
15a	19.4	3.7	30.5	30.3	3	9	3.5	3.1	1.7	1.6
15b	19.3	4.0	30.5	30.3	2	6	4.8	4.2	2.5	2.4

Note: 1) Station Nos. are same as the Field Survey in July,1998 by the JICA study team
2) Insignificant temperature difference between surface (S) and bottom (B) were averaged.

While the increase in transparency offshore in the dry season was expected, the relatively small range in transparency from Bai Chay bay to southern Cat Ba island was not expected. The range in transparency in the bays in July was greater. These data suggest that different water masses may dominate offshore areas in dry and rainy seasons by turns. The southward prevailing current in winter, as opposed to the northward current in summer, reported for western Gulf of Tonkin (Hoi et al. 1995) support this hypothesis.

9.4 Bottom Sediment Quality in the Bays

Bottom sediment quality was measured at some of the water quality sampling sites (Figure 9.2.1). Key sediment quality indicators are summarized in Table 9.4.1.

T-N concentrations in sediments adjacent to Ha Long city and Cam Pha town are relatively high compared to sediments in offshore areas. T-P levels in sediments are mostly uniform across all sampling sites. There is not a strong trend of COD in sediments in the bays. COD in offshore sediments appear to be higher than that adjacent to Cam Pha. Arsenic is the only metal that shows regional differences in concentration with the relatively high level measured in Bai Chay bay (Figure 9.4.1).

9.5 Water Quality Analyzed by Satellite Image

9.5.1 Water Temperature Distribution

(1) November 4th, 1988 (Figure 9.5.1)

Open seawater whose temperature is about 26~27°C generally flows northward from the southwestern and western coasts of Cat Ba island to Bai Chay bay through Ha Long bay. On the other hand, there are low temperature areas where water temperature is lower than 24°C, such as the Mip river estuary, tidal area in Bai Chay bay, and coastal area of Cam Pha. This low temperature water flows along the coast from the Mip river estuary to Bai Chay, and westward from Cam Pha. As a result, current rips, where open seawater and coastal current meet, exist between Bai Chay bay, Ha Long bay and Hong Gai offshore.

(2) December 1st, 1992 (Figure 9.5.2)

Water temperature in December is lower than that in November on the whole, at about 21°C on average. Open seawater from the south approaches closer to Bai Chay . On the other hand, water from the Mip river flows into the lower current layer near Bai Chay. Cam Pha area is more affected by open seawater than by the coastal current.

(3) June 6th, 1997 (Figure 9.5.3)

June is in the rainy season so that its distribution image quite differs from those in November and December. Open seawater flows toward eastward from the south coast of Cat Ba island. Coastal water tends to disappear inside of Bai Chay bay and offshore of Cam Pha. In addition, little current of low temperature flows, especially at central part of Ha Long bay.

9.5.2 Turbidity Distribution

Turbidity distribution images were prepared by taking and revising correlation with the sea-truth data, based on band 2 of the LANDSAT TM data, in the same manner as water temperature distributions.

(1) November 4th, 1988 (Figure 9.5.4)

High turbidity water flows southward from the Mip river and Bai Chay bay through the central part of Ha Long bay. Turbidity is relatively high along the coast of Hong Gai and Cam Pha, while flow from the Mong Duong river has low turbidity.

(2) December 1st, 1992 (Figure 9.5.5)

Compared to November, turbidity in December is remarkably higher. In particular, turbid water from the Mip river, Bai Chay and the coastal area of Hong Gai and Cam Pha expands offshore.

(3) June 6th, 1997 (Figure 9.5.6)

There is few influence from the open seawater, and circulation and stagnance of turbid water is remarkable within Ha Long bay. Turbidity is high at tidal area around the Mip river estuary and in Bai Chay bay, as well as coastal area of Hong Gai and Cam Pha.

9.5.3 Chlorophyll-a Distribution

Chlorophyll-a distribution images were prepared by taking and revising correlation with the sea-truth data, based on band 3 of the LANDSAT TM data, in the same manner as water temperature distributions.

(1) November 4th, 1988 (Figure 9.5.7)

Chlorophyll-a distribution is similar to the turbidity distribution, but influence by open seawater is more remarkable. High concentration areas of chlorophyll-a are at the mouth of the Mip river and the eastern part of the east islands group. Chlorophyll-a flowing from the Mip river to southern area through northern and western Cat Ba island is interrupted by open seawater flow, tending to turn toward Hong Gai. Concentration of chlorophyll-a in the Mong Duong river is low, but influencing Hong Gai area.

(2) December 1st, 1992 (Figure 9.5.8)

Compared to the distribution image in November, high concentration area of chlorophyll-a further distributes in the central part of Ha Long bay. Especially, the concentration is higher between the mouth of the Mip river, Bai Chay coast and the farther southwestern. As in November, its concentration is high in the eastern part of the eastern islands group. Some are identified to go up to the north such as Cam Pha, affected by open seawater. The concentration of chlorophyll-a is low at Cam Pha coast and western part of Bai Chay bay.

(3) June 6th, 1997 (Figure 9.5.9)

Basically high concentration areas of chlorophyll-a are at the Mip river estuary and eastern part of the eastern islands group as shown in the distribution images for November and December. Besides, unlike these two images, high concentration can be seen also at the eastern part of Cam Pha area. Although it is recognized that the distribution links between the Mip river estuary and the eastern islands group in November and December, there is no succession in June due to influence of the open seawater.

9.6 Influence of Offshore Water Body

(1) Existence of Contaminated Water Body

Relatively lower values of salinity with less than 15‰ were measured offshore area during the Field Survey in July 1998. Lower salinity indicated that this water body was influenced by fresh water and was different from that in the center of Ha Long bay.

The levels of COD, SS, and nutrients showed an unexpected change, steeply increase, along transect of five or more stations from the center of Ha Long bay to offshore. There is a sudden drop of transparency offshore area, too. These changes in water quality were supported by significantly reduced surface salinity at the two southernmost, offshore stations. Thus, it is possible to build up a hypothesis that there is a relatively contaminated water body, which is seemed to be from the large river system, in the southern outskirts of the study area at the Field Survey in July 1998.

(2) Potential Influence of Red River System

As shown in Figure 9.6.1, normally the tidal current of the Gulf of Tonkin flows from south to north during the rainy season. Considering the necessity of great amount of fresh water supply with relatively higher water temperature and direction of the tidal current, it seems reasonable to suppose that the origin of this water body would be the Red river system including its tributaries.

On the other hand, the tidal current of the Gulf of Tonkin flows from north to south in the dry season. The possibility of influence by the Red river system in the dry season is lower than it in the rainy season.

(3) Overview of Red River Water Quality

The Red river system at the delta is defined by five major tributaries; the Red river, the Thai Binh river, the Cam river, and the Bach Dang river, all of which flow into the Gulf of Tonkin just southwest of the study area. The total discharge from the Red river system is estimated at about 123 km^3/year(Hoi et al 1995). At the delta, most of the Red river tributaries are heavily laden with SS as a result of erosion from intensive agricultural activities and urbanization in its vast drainage basin. Dams on some of the large tributaries, however, have resulted in relatively clear waters downstream.

COD and NO_3-N levels of 1.1 mg/ℓ and 0.54 mg/ℓ, respectively have been recorded at the delta (CMESRC 1992). The system also transports relatively high nutrients, sometimes accompanied by pesticide load such as DDT, to the Gulf of Tonkin (HIO 1997).

It is assumed that SS from the Red river system is being carried northward in dry season by the inshore currents of the Gulf of Tonkin (Hoi et al 1995). The discharge plume emanating from the river is estimated to extend 20-25 km from the delta, which would extend northward to southern outskirts of the study area.

(4) Satellite Image Analysis

A hypothesis of the study is that the Red river system discharging into the Gulf of Tonkin southwest of the study area influences offshore water quality in the bays during the rainy season. The effect of the Red river system needs to be investigated further, such as getting a wide range of information from satellite images. The plume from the Red river system needs to be characterized in terms of both quality and spatial extent.

LANDSAT images of water temperature in June 6, 1997 and in July 11, 1998 suggest that a relatively warm, turbid water mass from the southwest influences the water in Ha Long bay. The northward prevailing currents in western Gulf of Tonkin in dry season, which are identified by the wide range LANDSAT images analysis, support the hypothesis on influence of the Red river system, especially of the Thai Binh river and the Bach Dang river (see Figure 9.6.2 to 5).

9.7 Summary of Water and Bottom Sediment Quality in the Study Area

9.7.1 General Conditions of Water Quality in the Study Area

The results of the Field Survey indicate that the bays' water, on the whole, have mesotrophic condition and little deterioration. However, the water and sediment quality inshore along Ha Long city and Cam Pha-Cua Ong areas are comparatively influenced by land-based effluent discharges. It is obvious that polluted water run-off from the catchment is limited to the inshore areas close to untreated effluent discharge points. The only pollution variable that appears to influence offshore areas is oil mainly due to the presence of shipping activities throughout the bays.

SS and iron are the only problematic variables in some rivers. The rivers experience high SS loads, which is likely a result of erosion from past and present denuded areas by urbanization, coal mining, and agricultural activities. The relatively higher iron levels in some tributaries are likely caused from mine waste in concert with low pH.

The concentrations of heavy metals in water and sediment of the bays are consistent with levels reported in previous studies. The only metals that violate coastal water and sediment quality standards are zinc and cadmium, respectively. The uniform distribution of cadmium concentrations throughout bay sediment suggests that the cadmium concentrations are natural.

9.7.2 Water Quality Distribution in the Bays

(1) Distribution of Rainy Season

As observed in the Field Survey in July 1998, land-based fresh water together with pollutants is stagnated inshore. Besides, the water in the bays is stratified wedge-wise by land-based fresh water and is intruded offshore water which shows relatively higher values of COD, SS, and nutrients than that in the center of the Ha Long bay.

Observed water quality distribution in the dry season is consistent with this water mass structure. Namely, relatively higher values of pollutants are observed inshore and offshore, while lower values in the middle of Ha Long bay. Some parameters such as SS shows the highest at the front of salt wedge, null point, where run-off pollutants tend to be settled.

(2) Distribution of Dry Season

Observed water quality distribution in the dry season was a little different from that in the rainy season. Salinity in the dry season was higher than in the rainy season due to a difference of the amount of the precipitation between the two seasons. Stratified water in the rainy season disappeared in the dry season, so that offshore water invaded into the inner part of bays. Accordingly, little differences of the water quality such as transparency was observed throughout the bays in the dry season.

9.7.3 Water Quality in Rainy and Dry Seasons

The rainy and dry seasons can be distinguished by significant differences in surface and subsurface runoff from the catchment into the bays. Considering the amount of precipitation, it is assumed that runoff ratio of generated land based pollution loads is a difference between dry and rainy seasons. Thus, the dry season water is expected to show lower pollutant levels and overall better water quality than rainy season.

The observed bays' water quality of BOD, COD, and SS is around twice as bad during the rainy season than the dry season. Transparency in the rainy season also shows around half of that in the dry season. One possibility is that land based pollution loads in the rainy season are higher than in the dry season. Another possibility is an effect of a higher primary production.

Needless to say, precipitation in the rainy season is great, accounting for more than 60% of annual rainfall. Relatively higher land based pollution loads are washed out by the precipitation in the rainy season.

In view of chlorophyll-a values of the two seasons, which shows degree of photosynthetic activity by phytoplankton, it is around twice as high during the rainy season than it in the dry season. This means that photosynthetic rate in the rainy season, namely generated organic matters by primary production, is higher than in the dry season. Normally, primary production is induced by inflow of nutrients such as phosphates and nitrogen which encourage the growth of plankton and alga. Besides, it is also depending on the water temperature and light intensity. Relatively active primary production in the rainy season could be caused by these higher land based nutrients washed by the precipitation and water temperature compared with the dry season.

The productivity rate in the dry season can be obtained from the previous survey by HIO, in January 1997. According to this survey, the productivity rate in the dry season is 6 mgC/m^3/hr. The rates in rainy season obtained by the Field Survey by the JICA study team in July 1998 are higher than that in the dry season, with 43~276 mgC/m^3/hr (see Chapter 11). These data supports these assumptions.