SOCIALIST REPUBLIC OF VIETNAM
MINISTRY OF TRANSPORTATION AND COMMUNICATIONS
AND
BELGIAN ADMINISTRATION
FOR DEVELOPMENT COOPERATION

GENERAL STUDY OF THE ACCESS-CHANNEL OF HAI PHONG PORT, VIETNAM

CONTRACT : G.54/17142/11

PHASE 4 :
COMPARATIVE STUDY OF
ACCESS-CHANNEL ALTERNATIVES

REPORT 4.5. :
FINAL VERSION OF THE PRELIMINARY DESIGN OF THE ACCESS CHANNEL TO HAI PHONG

VAH1351
00652

HAECON
HARBOUR
and
ENGINEERING CONSULTANTS

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GENERAL STUDY OF THE ACCESS-CHANNEL TO HAI PHONG PORT

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CONTENT

1. INTRODUCTION

1.1. PROJECT BACKGROUND

In December 1994 (02-12-94), the Government of the Socialist Republic of Viet Nam and the Government of the Kingdom of Belgium signed a Specific Agreement for bilateral cooperation in the field of engineering advisory services for the General Study of the Access-Channel to Hai Phong Port.

The Terms of References (T.O.R.) of the study project and of the contribution by both signatory parties are detailed in this Specific Agreement. The Implementing Agency is the Viet Nam Ministry of Transportation (MOT) ; the study counterpart is the MOT Transport & Design Inc. (TEDI).

All reporting of the study results are due toward BADC and TEDI.

The difficult nautical access to Hai Phong Port has since long caused limitations to the maritime traffic and especially for ships with deeper draughts. These difficulties are essentially linked to the intense siltation of the maritime access-channel - the Nam Trieu Channel - crossing the offshore estuary bar between Cape Do Son and Cat Ba Island (figure 1.1. and drawing no. 34.20.101).

The study contract was awarded by BADC (Belgian Administration for Development Cooperation) to the Consulting Engineering Company HAECON N.V. (24-04-95) ; the start of the study project was set in the contract on 24-05-95 for a total duration of 16 months. This study contract aimed at "defining an optimum technical solution to improve the existing channel or selecting another channel for vessels up to 10,000 DWT (ref. Specific Agreement)". Elsewhere in the T.O.R., it is stipulated that accessibility to 30,000 DWT vessels should also be investigated (see annex 1).

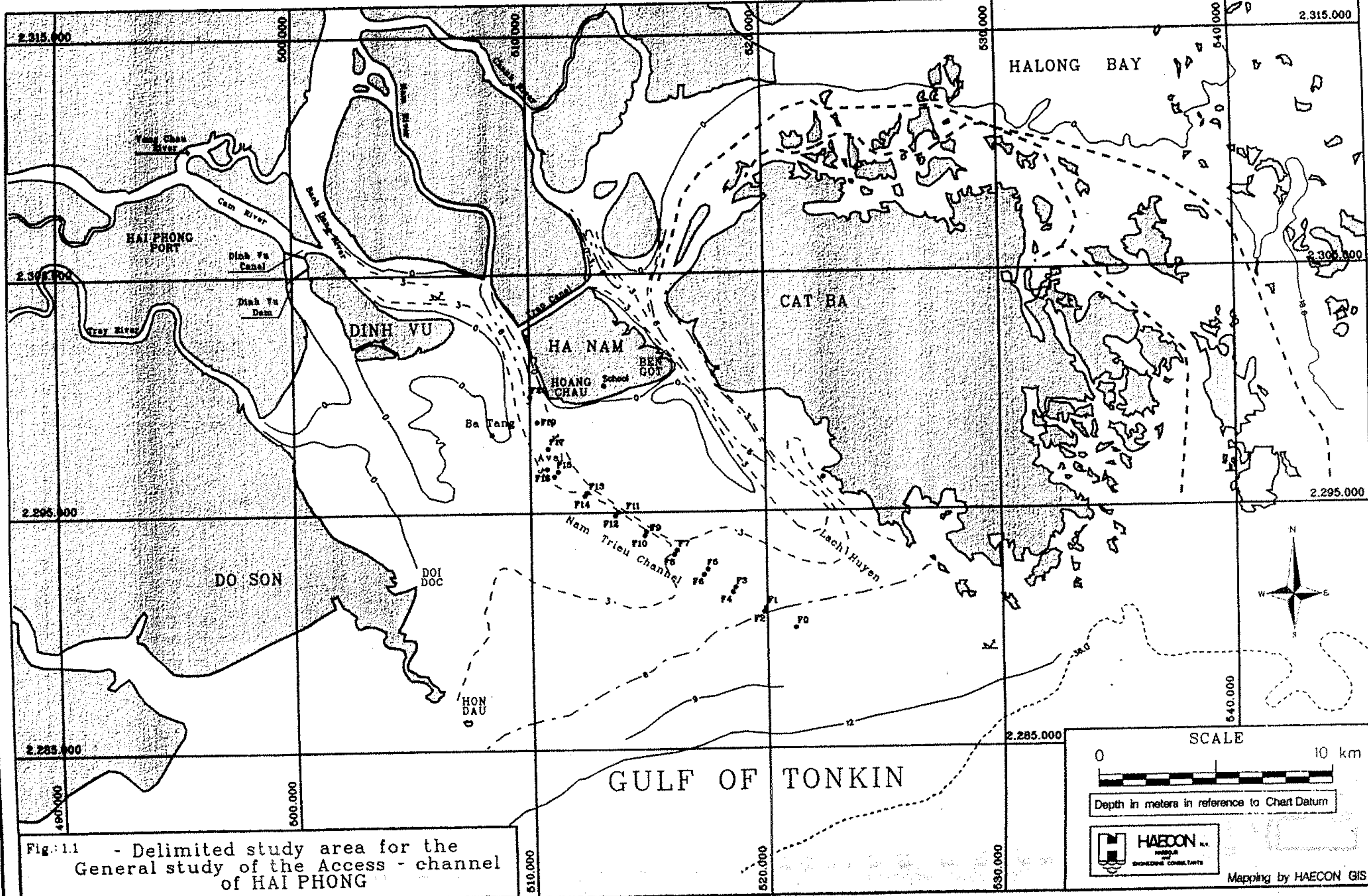
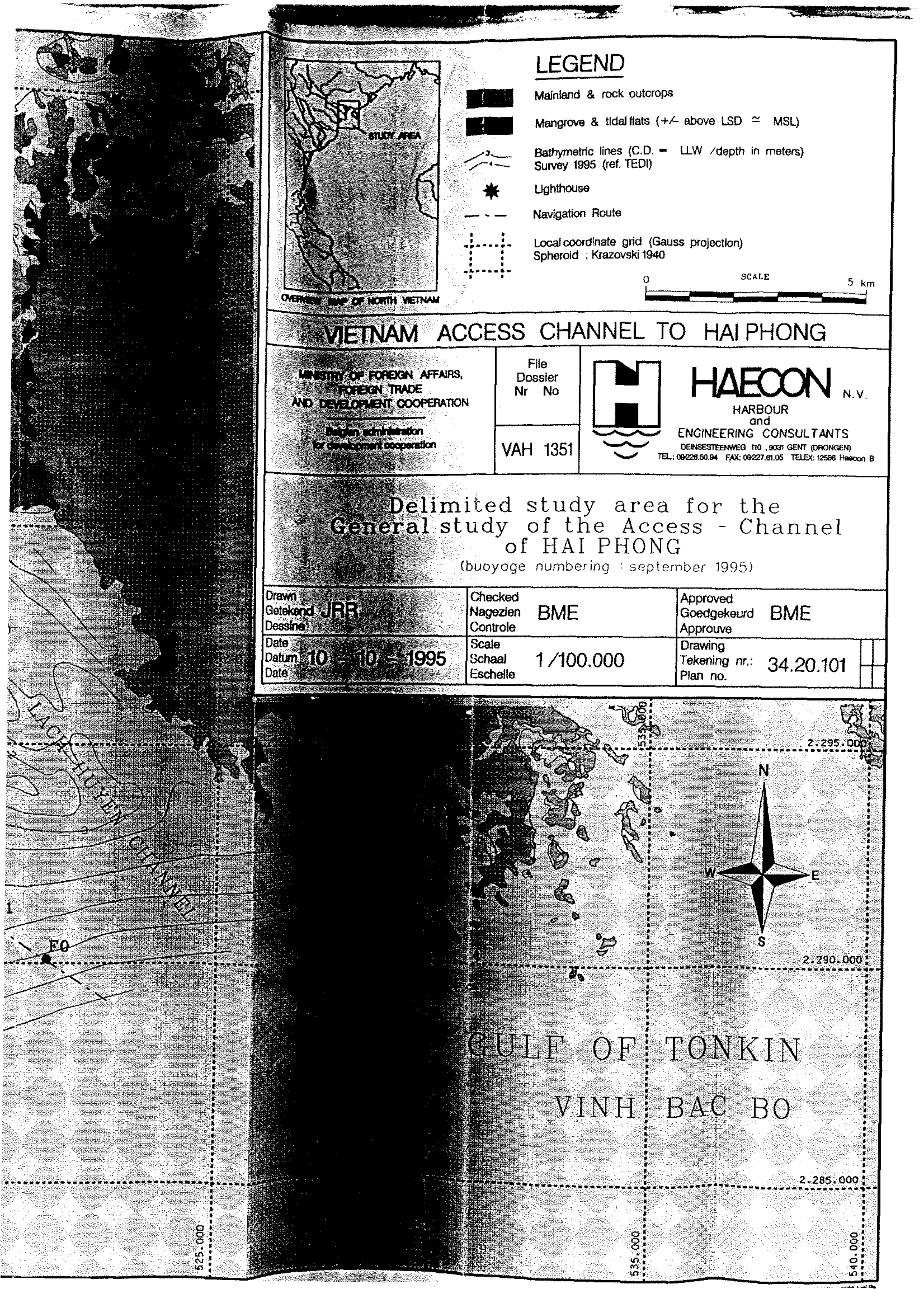


Fig. 1.1 - Delimited study area for the General study of the Access - channel of HAI PHONG


LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+/- above LSD ≃ MSL)
Bathymetric lines (C.D. = LLW /depth in meters)
Survey 1995 (ref. TEDI)
Lighthouse
Navigation Route
Local coordinate grid (Gauss projection)
Spheroid : Krazovski 1940
SCALE
0
5 km
STUDY AREA
OVERVIEW MAP OF NORTH VIETNAM
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
DEINSESTEENWEG 110 , 9031 GENT (DRONGEN)
TEL.: 09/226.50.94 FAX: 09/227.61.05 TELEX: 12586 Haecon B
Delimited study area for the General study of the Access - Channel of HAI PHONG
(buoyage numbering : september 1995)
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Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 10 - 10 - 1995
Scale Schaal Eschelle 1/100.000
Drawing Tekening nr.: Plan no. 34.20.101
LACH HUYEN CHANNEL
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GULF OF TONKIN
VINH BAC BO
525.000
535.000
540.000

The study team includes a group of experts from Viet Nam and Belgium :

1) Viet Nam :

Implementing Agency :	Ministry of Transportation (MOT)
Counterpart :	Ministry of Transportation TEDI Transport and Design Inc.
Tasks :	- provide all information to the project ; - assist to and collaborate with the Belgian Consultant Team ; - execute the field work required by the project ; - review and approve the interim study results and design ; - dispatch study results to relevant Vietnamese Authorities.

2) Belgium

Administration :	Belgian Administration for Development Cooperation (BADC)
Consultant :	N.V. HAECON
Tasks :	- execute the different study tasks specified in the T.O.R. (study, design, training ...) ; - set up the specifications of the surveys to be done by Viet Nam for the project ; - prepare and submit the study reports to BADC and TEDI ; - procure additional survey and mathematical modelling equipment.

1.2. PROJECT STATUS

At the end of April 1995, when the study project began, the Government of Viet Nam requested that the proposed time-schedule (according to contract between BADC and HAECON) be modified.

In order to link this study project to the study project for the Rehabilitation Plan of Hai Phong Port (supported by JICA), MOT requests that a first preliminary design of the access-channel be presented in November 1995. After analysing this request, HAECON estimates that this modification of the study time schedule is feasible, provided that :

a) the field survey and monitoring work is started as soon as possible and executed before the end of the 1995 rainy season ;
b) the supporting mathematical simulations of the design are executed in Belgium ;
c) training, satellite imagery, detailed design, ... activities be postponed to 1996.

This alternative project schedule was accepted by MOT and BADC during course of the first weeks of May 1995 (see par. 1.4. Time Schedule).

The project status can be described as follows (situation as of November 1995) :

1. **Data collection**

All existing and available data (excepted from the 1995 survey) have been processed and synthesised in report VAH1351/00244 "Site and Project Description".

2. **Field survey and monitoring**

- survey works were started by TEDI in early May 1995 ;
- monitoring activities have been started in June 1995 (observation of Nam Trieu, observation of pilot-channel in Lach Huyen) ;

3. Study activities

- the study activities of phase 1 "Data analysis and collection and additional survey/monitoring programme" and phase 2 "Site survey and monitoring" were executed according to schedule ; the following reports were presented :

  1. VAH1351/00134 "Additional survey and monitoring programme" (31-05-95)
  2. VAH1351/00162 "Contract documents for geotechnical survey programs" (31-05-95)
  3. VAH1351/00158 "Contract documents for dredging of pilot-channels" (02-06-95)
  4. VAH1351/00175 "Additional survey equipment and technical specifications" (30-06-95)
  5. VAH1351/00244 "Site and Project Description" (05-09-95 + rev. 1 : 09-10-95).

- the preliminary design activities of the access-channel have been started based on the available survey data and sedimentological simulations ; the outcome of this preliminary design has been published in the report VAH1351/00431 (15-11-95) and presented during the 06-12-95 Presentation Seminar held in Ha Noi with representatives of MOT, Port of Hai Phong, VINAMARINE, TEDI, BADC, ... and his Excellency the Embassador of Belgium.

- the first version of the Preliminary Design Report was updated on 22-12-95 (Report VAH1351/00513) and included a basic proposal for a new channel design for full-loaded 10.000 DWT-ships and with following characteristics :

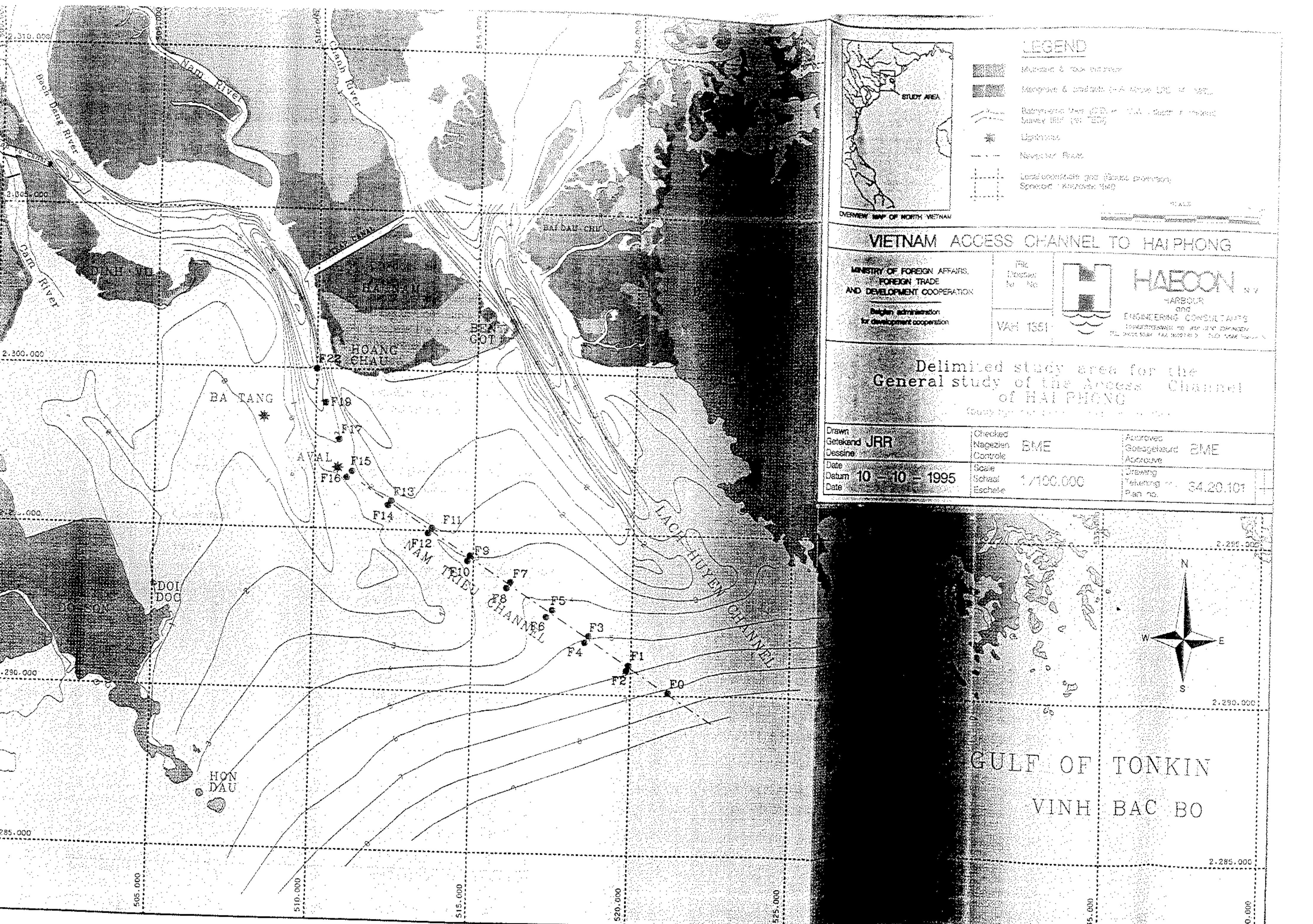
  a) alignment in the Lach Huyen + Trap Canal ;
  b) bottom width of 100 m resp. 80 m ;
  c) nautical bottom at C.D. - 8.50 m ;
  d) a tidal window set at C.D. + 1.70 m delivering a time-accessibility of ca. 65 % ;
  e) a safe keel-clearance of 1.70 m.

- due to economic constraints for capital investment Vietnamese Authorities formulated their wish to consider a phased channel development including :

  a) phase 1 : Urgent Channel Development Plan with limited accessibility (15 %), reduced capital dredging (28 % less) and design according to Vietnamese standards ;

b) phase 2 : Full Channel Development Plan with good accessibility (65 % : each day), and according to safety standards as described above.

- during the Seminar and during some work sessions with TEDI, P's C of Hai Phong Vinalines, ... comments were formulated ; these comments, together with the study activities (sedimentological, nautical and dredging study) executed since then were processed in this final version of the Preliminary Design.


LEGEND
OVERVIEW MAP OF NORTH VIETNAM
STUDY AREA
VIETNAM ACCESS CHANNEL TO HAI PHONG
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VINH BAC BO
Nam River
Chanh River
Bach Dang River
Cam River
BA TANG
AVAL
HOANG CHAU
BEN GOT
BAI DAU CHI
DOI DOC
HON DAU
LACH HUYEN CHANNEL
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   - monitoring activities have been started in June 1995 (observation of Nam Trieu, observation of pilot-channel in Lach Huyen) ;

1.3. SITUATION OF REPORT 4.5. "COMPARATIVE STUDY OF ACCESS - CHANNEL AND PRELIMINARY DESIGN"

Referring to the Terms of Reference G.54/17142/11 relative to the General Study of the Access Channel to Hai Phong Port and the bid of HAECON (VAH1351/00050) approved by BADC, a report is to be made which describes a first preliminary design of the access-channel to Hai Phong.
The purpose of this report is to generate questions and remarks especially in order to tune this channel study towards the Port Rehabilitation Plan of Hai Phong. Remarks and recommendations will be processed so as to execute the final design.

This second version of the VAH1351/00652 report was updated with new remarks from TEDI.

Partners involved in the production of this report are :

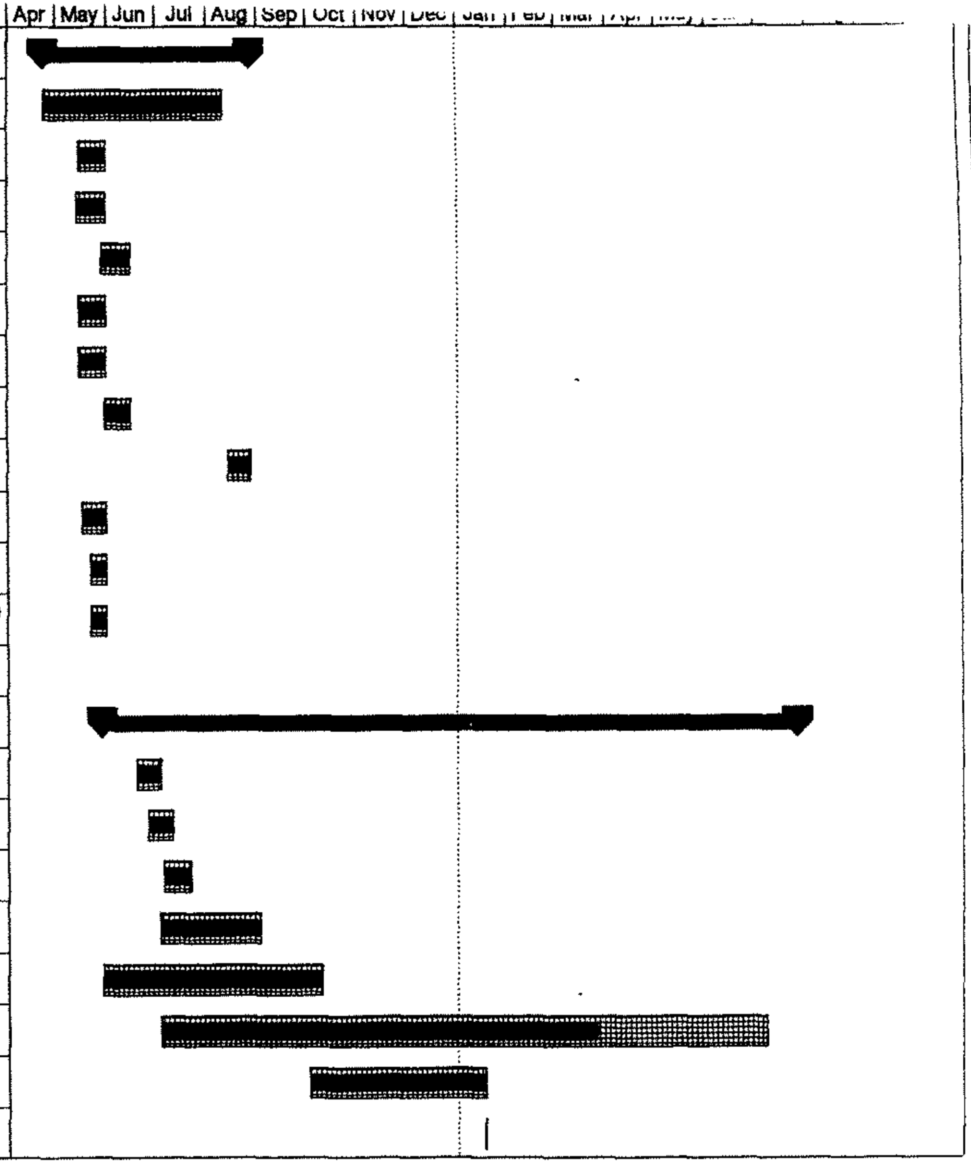
- HAECON's study team for engineering and processing of model results, survey data ;
  - Ir. B. Malherbe, Project Manager ;
  - Ing. G. De Padt, Dredging Engineer ;
  - Ing. H. Coens, Dredging Engineer ;
  - Lic. K. De Vos, Geologist.
- Hydraulics Research Ltd. to execute the mathematical hydraulic and sedimentological simulations ;
  - Dr. J. Smallman ;
  - Mr. M. Crickmore ;
  - Dr. M. Dearnaley ;
  - Dr. B. Roberts.
- TEDI's team for providing the field data, for reviewing the design elements and conclusions ;
  - Dr. La Noi ;
  - Mr. Dung ;
  - Mr. Thang ;
  - Mr. Quang.

These partners are therefore greatly acknowledged.

1.4. TIME SCHEDULE

The revised time-schedule of the study project follows, indicating the due dates of delivery of the different reports.

ID	Task Name
1	**1. PHASE 1.Data analysis and additional survey/monitoring programme**
2	1.1 Collection and analysis of existing data
3	1.2 Inventory of existing survey equipment
4	1.3 Inventory of existing modelling facilities
5	1.4 Analysis of planned port development
6	1.5 Description of additional survey programme
7	1.6 Description of required monitoring programme
8	1.7 Description of technical specifications for survey
9	1.8 Submission of report: Site and project description + approval
10	1.9 Submission of report : Additional survey and monitoring programme + approval
11	1.10 Submission of contract documents for geotechnical programme + approval
12	1.11 Submission of contract documents for dredging of pilot channel reaches + approva
13	
14	**.PHASE 2 Site survey and monitoring**
15	2.1 List of additional survey equipment
16	2.2 Technical specifications and cost estimate of additional equipment
17	2.3 Report: Additional equipment and technical specifications + approval
18	2.4 Procurement of additional equipment
19	2.5 Preparation and execution of site survey (MOTC)
20	2.6 Preparation and execution of monitoring (MOTC)
21	2.7 Preparation of interim factual report on survey and monitoring
22	2.8 Submission of interim factual report + approval



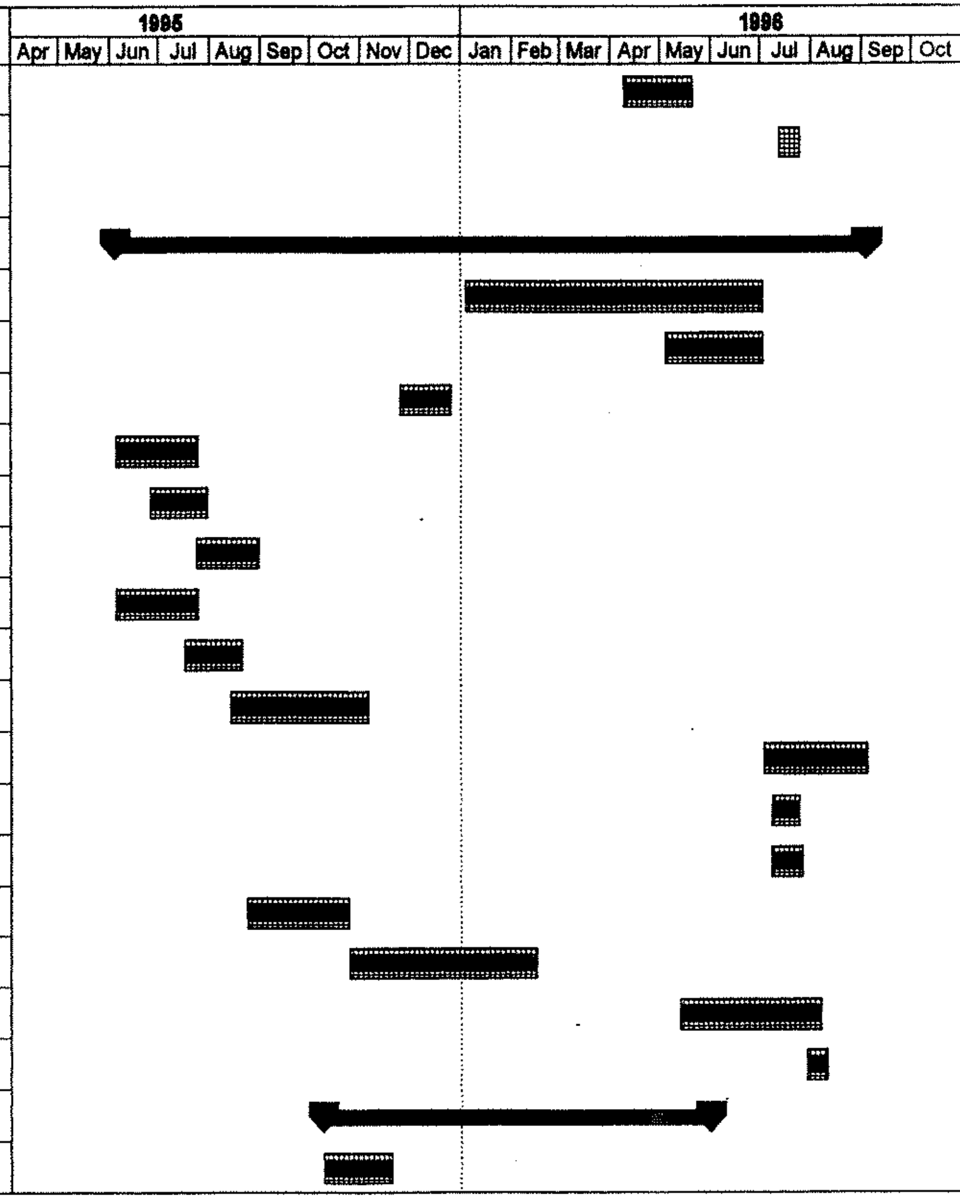
GENERAL STUDY OF THE ACCESS-CHANNEL TO
HAI PHONG PORT
TIME SCHEDULE OF THE STUDY

Task | Milestone | Progress | Summary

haecon

TIME SCHEDULE STUDY PROJECT "GENERAL STUDY OF THE ACCESS-CHANNEL TO HAI PHONG"

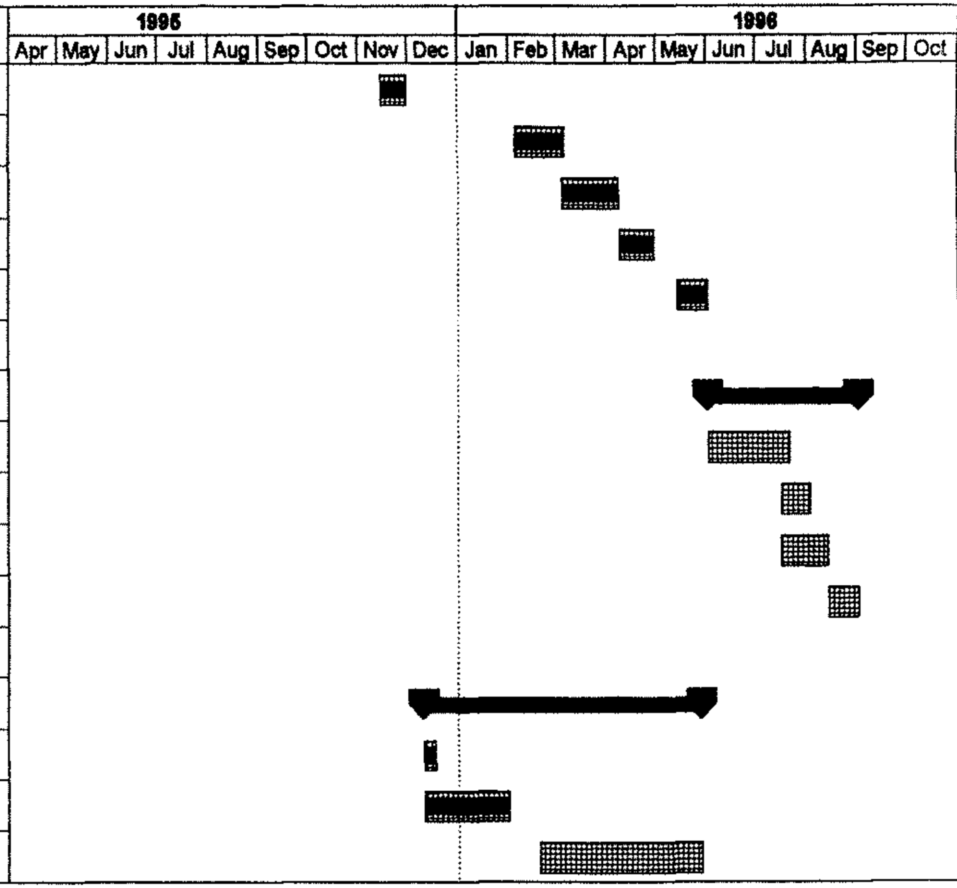
ID	Task Name
23	2.9 Preparation of final factual report on survey and monitoring
24	2.10 Submission of final factual report + approval
25	
26	**3. PHASE 3 Hydraulic and sedimentological study**
27	3.1 Procurement and processing of satellite and aerial imagery
28	3.2 Report: Satellite and aerial imagery
29	3.3 Procurement of the necessary hardware for the mathematical modelling
30	3.4 Preparation of the basic data for the hydraulic study
31	3.5 Preparation of the mathematical models for the hydraulic study + testruns
32	3.6 Modelling calculations for the hydraulic study and technical assistance
33	3.7 Preparation of the basic data for the sedimentological study
34	3.8 Preparation of the mathematical models for the sedimentological study
35	3.9 Modelling calculations for the sedimentological study and technical assistance
36	3.10 Final hydraulic and sedimentological simulations
37	3.11 Interpretation of hydraulic and sedimentological simulations HR
38	3.12 Report on mathematical investigation + approval
39	3.13 Physical testing of mud samples
40	3.14 Report on physical testing +approval
41	3.17 Preparation of report on hydraulical and sedimentological study
42	3.18 Report on hydraulic and sedimentological study + approval
43	**4. PHASE 4 Comparative study of the access channels**
44	4.1 Preliminary design of selected access channels



GENERAL STUDY OF THE ACCESS-CHANNEL TO
HAI PHONG PORT
TIME SCHEDULE OF THE STUDY

TIME SCHEDULE STUDY PROJECT "GENERAL STUDY OF THE ACCESS-CHANNEL TO HAI PHONG"

ID	Task Name
45	4.2 Presentation of interim report with preliminary design
46	4.3 Ship manoeuvering expertise
47	4.4 Preliminary design of the necessary infrastructure works
48	4.5 Multicriteria analysis of the selected channels
49	4.6 Report: comparative study of the access channels + approval
50	
51	**5. PHASE 5 Detailed design of the access channel**
52	5.1 Detailed design
53	5.2 Report: Detailed design of access-channel +approval
54	5.3 Preparation of the tender documents
55	5.4 Submission of tender documents + approval
56	
57	**6. PHASE 6 Training programme**
58	6.1 Preparation of the training programmes
59	6.2 Submission of the training programmes + approval
60	6.3 Implementation of training programmes



GENERAL STUDY OF THE ACCESS-CHANNEL TO
HAI PHONG PORT
TIME SCHEDULE OF THE STUDY

2. ACCESS-CHANNEL DESIGN ELEMENTS

2.1. GENERAL

In anticipation of the conclusions of the study project "Rehabilitation of Hai Phong Port" the basic elements for the design of the access-channel to Hai Phong can be determined by referring to the characteristics of the design ship. The channel must in fact be designed to allow safe navigation of ships of various sizes.

The major accent in the Hai Phong Port Development for the future will be oriented towards :

- improvement of nautical accessibility to 10,000 DWT (bulk carriers, general cargo, container vessels, or any of the above but lightered) ;
- increase of the port's annual throughput from actual 2.70 Mtons (1993) towards 8.4 Mtons, within 15 years ;
- improve Hai Phong's hinterland connection ;
- development of Hai Phong industrial and trading activities.

The characteristics of the design ship were defined based on actual ship traffic and traffic forecast. The JICA "Port Rehabilitation Study" will however ascertain in more detail the characteristics of future traffic and ship's size (expected datum : December 1995).

The characteristics of the channel were determined taking into account the characteristics of the design ship, considered by the Vietnamese Authorities.

Conforming to the T.O.R. and the recommendations formulated by TEDI the following design premises can be put forward for the Access-Channel to Hai Phong :

1. Traffic Lanes
   - a one-way traffic in the parts subjected to sedimentation ;
   - parts of the channel where sufficient natural widths (> 8 B) and natural depths are present, can be used as ship's crossings zones.

2. Design ship
   The design ship considered in this study is a full-loaded 10,000 DWT ship with a loaded static draft (in seawater) of 8.50 m.

3. <u>Channel design</u>
   - nautical <u>depth</u> will be determined for the design ship (10,000 DWT) and the optimised tidal level ;
   - channel <u>width</u> in the one-way traffic sections will be determined based on the beam of a 10,000 DWT ship (B = 20.00 m) ;
   - channel bending-radii will be determined based on the length (LOA) of a 10,000 DWT ship (LOA = 160 m).

4. <u>Accessibility</u>
   It is accepted that a partial accessibility of the Port is adopted. The tidal and sailing window have to be ascertained in this study ; MOT have mentioned a tidal window at C.D. + 2.5 m.

Based on the study results HAECON proposes the following channel (for 10.000 DWT-ships) :

a) a new alignement through Lach Huyen, Trap Canal, Bach Dang and Cam River ;
b) a bottom width of 100 m in the outer reaches ; a bottom width of 80 m in the inner reaches ;
c) a nautical bottom at C.D. -8.50 m ; a nautical bottom tolerance of 0.50 m ;
d) a tidal window at C.D. + 1.70 m delivering a time-accessibility of 65 % ;
e) a safe keel-clearance of 1.70 m

Moreover, is it proposed to improve aids to navigation to allow night-time navigation and to train pilots on the new channel navigation.

For more details on design, it is referred to the report VAH1351/00244 “Site and project Description”.

Because of economic constraints for capital investment Vietnamese authorities prefer to see the channel development similar to the 2 staged rehabilitation plan for Hai Phong Port - a first “Urgent Rehabilitation Plan” and a second “Port Development Plan”..
Therefore the development of the access-channel is also seen into 2 stages in order to comply with the request of Viet Nam to spread the investment :

1. **Stage 1 : Urgent Channel Rehabilitation Plan (original design)**
   - **Tidal window : C.D. + 2.5 m (and more)**
   - **Keel - clearance : g.k.c. : 1.20 m**
   - **Vessels : 10,000 DWT full-loaded**
   - **Nautical accessibility : ± 15 % of total time (waiting times up to 10 days) + navigation restriction under storm conditions**

2. **Stage 2 : Channel Development Plan (optimised design)**
   - **Tidal window : C.D. + 1.70 m (and more)**
   - **Keel - clearance : g.k.c. between 1.05 and 1.70 m**
   - **Vessels : 10,000 DWT full-loaded**
   - **Nautical accessibility : ± 65 % of total time (waiting times : maximum : 20 hours)**

The technical background of the design elements will be given hereafter.

The choice for a full channel development (stage 2) versus a partial channel development (stage 1) should be done by an economic balance of waiting times (20 hours versus 10 days), time-accessibility (65 % versus 15 %), capital investment (63 MUSD versus 45 MUSD) and port development (traffic increase). This was not the subject of this study.

2.2. DESIGN SHIP CHARACTERISTICS

For the access-channel to Hai Phong, a design ship of 10,000 DWT has been selected :

full-loaded 10,000 DWT ship	**Static Draught**	**T = 8.50 m**
	Beam	**B = 20.00 m**
	Length	**LOA = 160 m**

In the Terms of Reference (T.O.R.) of the study it is mentioned that the comparative study of access-channels (phase 4) should also address the "quality with regard to possible future deepening of the access-channel for vessels up to 30,000 DWT". This is regarded as an option in this study and is described in more detail in Annex 1 to this Preliminary Design Report.

2.3. CHANNEL DEPTH

Once the design static ship's draught (in seawater) is known the nominal nautical bottom (or nominal channel bed level : this is the theoretical minimum channel bed level related to C.D.) can be determined.

The Underkeel Clearance (k.c.) will allow the accurate definition of the nautical bottom taking 3 different types of factors into account :
1. factors related to the water level fluctuations ;
2. factors related to the ship herself and variations ;
3. factors related to the variations of the bottom.

This reasoning is further explained with figure 2.1. (ref. PIANC [1] 1985)

The Underkeel Clearance defined is applicable to the standard designed channel and w.r.t. the environmental conditions which prevail in the concerned area.

The mean channel dredged level lies in general well below the actual bed level for reasons explained below.

This important nautical principle is also illustrated on figure 2.2.

[1] PIANC : Permanent International Association of Navigation Congresses

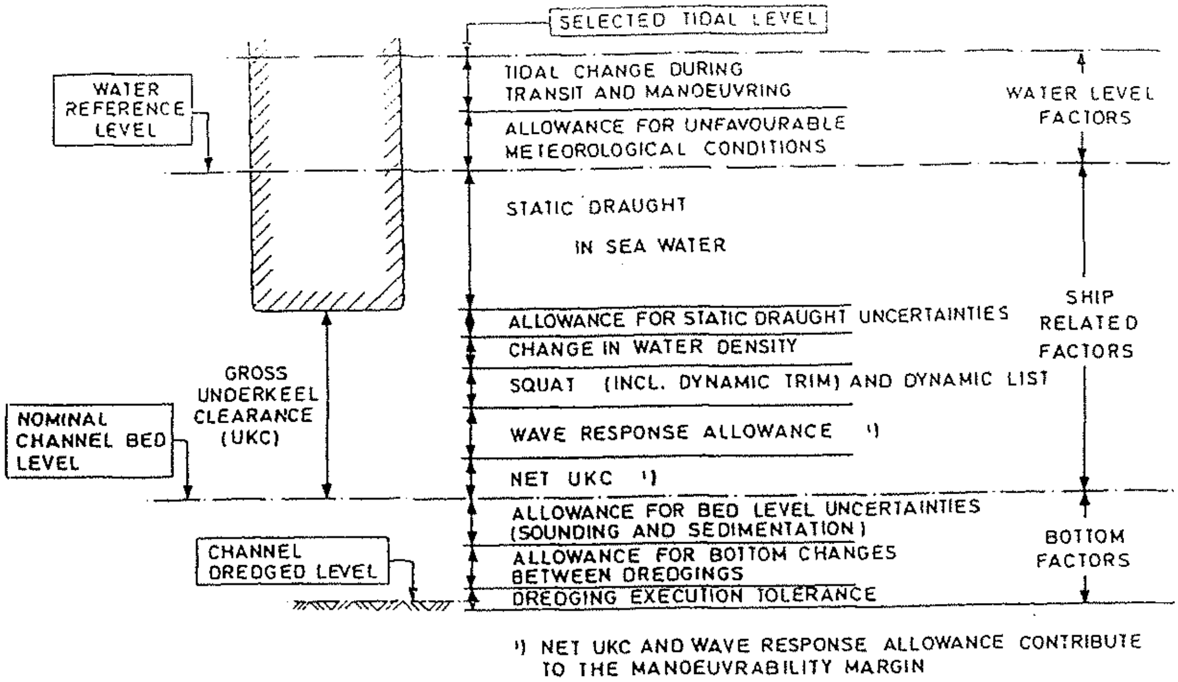


Figure 2.1.
Factors determining the required Underkeel Clearance (k.c.)

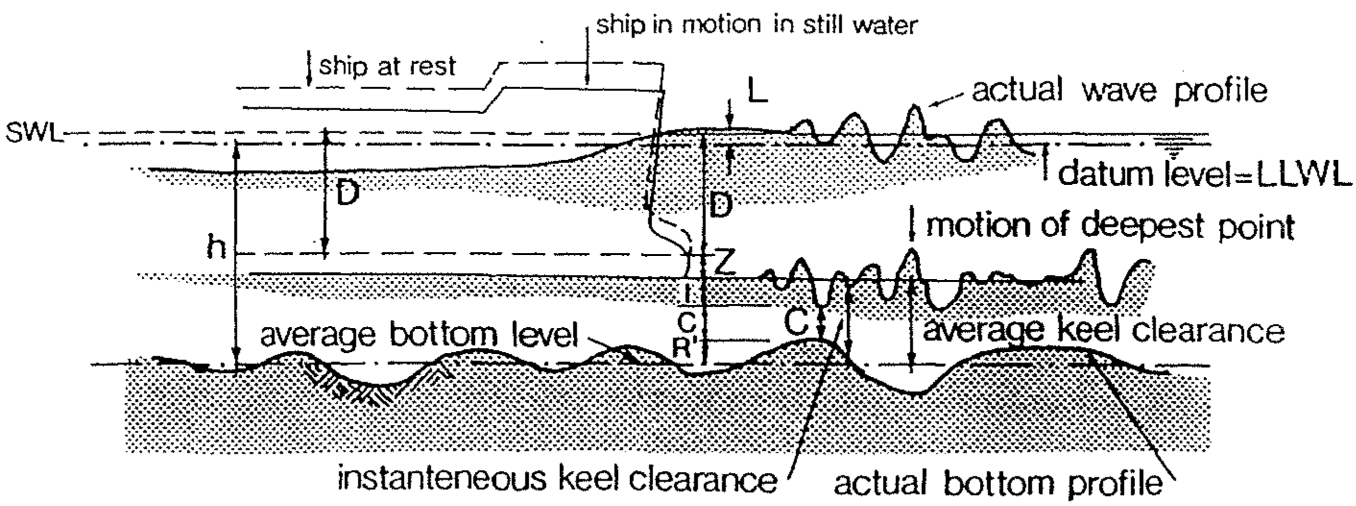


Figure 2.2.
Required depth of a navigation channel (ref. T.U. Delft 1989)

In figure 2.2., the required depth of an access-channel is derived as follows :

$$N.D. = T + L + Z + I + R + k.c. + U.c. \qquad (1)$$

in which :

N.D.	=	channel depth in relation to C.D.
T	=	static draught in still water
L	=	the deviation above chart datum of the hydrographic chart
Z	=	squat and trim
I	=	amplitude of vertical ship movement
R	=	bottom roughness
k.c.	=	keel clearance
U.c.	=	inaccuracy of water-level measurement and sounding

The formulation of k.c. by PIANC (1985) is most accurate and will be adopted in this study. Moreover, due to the lack of long series for statistics, it is preferred to use a deterministic approach of the different k.c.-factors.
The different factors determining the Nautical Bottom and the Underkeel Clearance will now be screened.

2.3.1. Gross underkeel-clearance (g.k.c.) : water level and ship related factors

2.3.1.1. Stage 1 : Urgent Channel Rehabilitation Plan

Based on the Vietnamese standard computation method for the gross underkeel-clearance a g.k.c. of 1.20 m is recommended by TEDI for full-loaded 10,000 DWT ships, and is calculated as follows : .

1. allowance for sea bed geological condition :
   $Z1 = 0.04T = 0.04 \times 8.5 \text{ m} = 0.34 \text{ m}$

2. squat due to navigational speed :
   $Z2 = 0.6 \text{ m}$

3. allowance for wave action :
   $Z3 = 0.3\ H_{3\%} - Z1 = 0.3 \times 2 - 0.34 = 0.26 \text{ m}$

g.k.c. = $Z1 + Z2 + Z3 = 1.20$ m

HAECON can accept this gross-underkeel clearance of 1.20 m according to Vietnamese standard computation method in the first stage of the channel development with the explicit restriction of navigation under rough wave conditions ($H_s > 1.0$ m). Indeed, 10,000 DWT ships are quite heave sensitive in the case of Hai Phong (see par. 2.3.1.2.4) and no net underkeel clearance is taken ; consequently absolutely no margin of safety is given under these circumstances.

2.3.1.2. Stage 2 : Channel Development Plan

Based on the deterministic calculation (PIANC), the gross underkeel-clearance for the full Channel Development Plan and according to international accepted navigation safety, standards has been evaluated for the design ship.

The different factors determining the underkeel-clearance will now be screened.

2.3.1.2.1. Static draught in sea water

This is the maximum underwater depth of the ship at any place of the ship's bottom, thus including the static trim (difference before/after) and static list (difference starboard/portside). It is defined in sea water with a specific mass of 1,025 kg/m³ for a zero ship speed (relative to the water).

In the deterministic approach this factor is a representative maximum value, taking into account the uncertainty in the draught measurement and/or calculations.

In the case of the Hai Phong access-channel the static draught is equal to - 8.50 m for the 10,000 DWT-ship and - 11.30 m for the 30,000 DWT-ship.

The maximum draught including the static trim and list will have to be determined for each ship before entering the channel.

2.3.1.2.2. Change in water density

The effect of uncertainties in the water density on the ships sinkage (due to uncertainties in the salinity and temperature of the water) is treated as a variance in the probabilistic approach. In the deterministic approach the uncertainty is incorporated in the "representative maximum" value of the factor.

Especially in the case of high fresh water discharge a double layer system can occur in the landward part of the channel.

The fixed station profilings survey results showed the occurrence of a top fresh water layer up to 3 m with salinity differences between top and bottom of 20 g/l in the outer reaches of the access-channel. (see report VAH1351/00244). With these salinity difference the extra sinkage have been calculated for a 10,000 DWT-ship.

In Bach Dang and Cam Rivers water becomes fresh over the whole water depth depending upon tide and season. A maximum extra sinkage of 0.20 m has been taken into account.

2.3.1.2.3. Squat and dynamic trim

Squat and dynamic trim include the effects of the dynamic trim due to the speed and the dynamic list due to beam winds. Uncertainties arise from the limited accuracy of the squat prediction models and the uncertainties in the exact ship speed (relative to the water), wind speed, wind direction, underkeel-clearance, beam currents, etc.

Squat is defined as the supplementary sinkage of a ship, relative to the original undisturbed water-level, which is caused by its movement at a given speed. It includes the vertical sinkage of the ship as a whole and the sailing trim.

Squat can be calculated by e.g. the formula of Barrass (1985)

$$Z = \frac{C_B}{30} \cdot \left(\frac{S}{1-S}\right)^{2/3} . V^{2.08} \qquad (2)$$

in which :

Z	=	squat (m)
V	=	vessel's speed (knots)
C_B	=	block coefficient of the ship
	=	$\frac{Dis}{LOA.B.T}$
Dis	=	Displacement (m^3)
LOA	=	Length of ship between perpendicular (m)
B	=	Ship's beam
T	=	Static draught
$\frac{S}{1-S}$	=	Channel confinement factor
S	=	Blockage factor of waterway
	=	Am/Ac
Am	=	Midship section (m^2)
	=	± B.T.
Ac	=	Channel cross-section (m^2)

The squat was calculated for a ship with the following dimensions :

LOA =	160.00 m
B =	20.00 m
T =	8.50 m
CB =	0.80 m
V =	10 knots

For the Lach Huyen/Nam Trieu sections the formula of Barrass leads to a bow squat value of 0.70 m. For the other sections the values can be slightly decreased, because of the lower vessel's speed.

Other reliable estimation methods lead to bow squat values between 0.53 m and 0.90 m for the Lach Huyen/Nam Trieu section :

Icorels (1980)	Z = 0.68 m
Millward (1990)	Z = 0.90 m
Millward (1992)	Z = 0.90 m
Dand (1975)	Z = 0.90 m
Barrass (1979)	Z = 0.70 m
Eryuzlu & Hausser (1978)	Z = 0.71 m
Eryuzlu et all (1994)	Z = 0.53 m

2.3.1.2.4. Wave response allowance

In the deterministic approach, a representative maximum value is determined of the wave response, within the operational limits. This implies that the most unfavourable wave condition in which the transit of the ship is still justified is the basis for the calculations. In the probabilistic approach a probability is calculated that the wave-induced vertical ship motion exceeds the wave response allowance.

Uncertainties occur in the wave climate, due to inaccuracies in wave observation/measurement, limited accuracy of the description of the wave spectrum (often described by only one or a few parameters), changes in the predicted wave climate during ship transit. They may have a large impact on the required wave response allowance. Models are available for the treatment of these uncertainties and the uncertainty in the response of the ship to the wave.

In order to evaluate the wave response allowance regular wave response characteristics were calculated by means of a method based on strip theory. The method was applied to a ship with following dimensions :

LOA =	160.00 m
B =	20.00 m
T =	8.50 m

in a waterdepth h = 13 m.

The response of a ship to regular waves depends on :

- wave periode ;
- wave length (related to the latter if depth is given) ;
- direction of wave propagation ;
- ship speed.

The analysis in Table 2.T.1. is based on a ship speed V = 10 knots. Following wave directions off stern are considered : 0°, 25°, 45°, 135°, 155°, 180°. For each wave period range, the maximum ratio between the amplitude of vertical motion of the bow and the wave amplitude is given.

		wave period (S)							
		0-5	5-7	7-9	9-11	11-13	13-15	15-17	17-19
wave direction off stern	0°	0.03	0.17	0.39	0.27	0.67	1.04	1.43	1.53
	25°	0.04	0.29	0.40	0.37	0.91	1.22	1.43	1.49
	45°	0.24	0.42	0.51	0.99	1.35	1.48	1.53	1.52
	135°	0.02	0.13	0.47	2.25	2.86	2.57	2.25	1.95
	155°	0.02	0.05	0.24	0.64	2.31	2.39	2.30	2.12
	180°	0.01	0.05	0.30	0.30	1.83	2.19	2.21	2.13

Table 2.T.1.
Maximum ratio between the amplitude of vertical motion of the bow and the wave amplitude (pitch)

The ship considered is very sensitive to waves with periods larger than 9 seconds, especially with direction 135° off stern.

The maximum vertical response to each of the period/height combinations for the ship is given in Table 2.T.2. Percentages of occurence less than 0.1 % are not mentioned.

		wave period (S)				
		0-5	5-7	7-9	9-11	11-19
wave height band (m)	0.0 - 0.5	0.06 37.6 %	0.11 1.2 %	0.11 0.1 %		
	0.5 - 1.0	0.12 27.1 %	0.21 2.7 %	0.21 0.4 %	1.13 0.14%	
	1.0 - 1.5	0.18 15.1 %	0.32 3.7 %	0.32 0.6 %	1.69 0.14 %	
	1.5 - 2.0	0.24 2.7 %	0.42 1.8 %	0.42 0.5 %		
	2.0 - 2.5	0.30 1.1 %	0.53 1.2 %	0.53 0.5 %	2.81 0.12 %	
	2.5 - 3.0	0.36 0.3 %	0.63 0.6 %	0.63 0.4 %		
	3.0 - 4.0	0.48 0.2 %	0.84 0.3 %	0.84 0.4 %	4.50 0.15 %	
	4.0 - 5.0			1.05 0.1 %		
	5.0 - 8.0					

Table 2.T.2.
Maximal vertical response (m) - Percentages of occurance

From the various simulations on wave response executed in this study, it appeared that the 10,000 DWT-ship (LOA = 160 m) is a quite wave sensitive ship in the case of the Hai Phong Access-Channel because of the close proximity of wave lengths and the wave response resonance wave length of this type of ships. Ships with a larger LOA would have smaller wave responses.

In 95 % of the cases (waves lower than 2.0 m), the maximal vertical response is less than 0.50 m. Therefore it is recommended to take into account an overall wave response allowance of 0.50 m.

2.3.1.2.5. Net underkeel-clearance (n.k.c.)

"Net underkeel-clearance" is in the conventional (deterministic) approach the minimum margin remaining between the nominal channel bed level, and the keel of the vessel in the most unfavourable position under conditions of the design criteria.
If all the other factors that determine the required gross Underkeel Clearance, are assessed as representative maximum values - the usual way - net Underkeel Clearance can be considered as an additional safety margin against the bottom.
The n.k.c. provides - especially in narrow and shallow channels - for appropriate water return flow under the hull without too much induced friction forces.
For the access-channel to Hai Phong a net underkeel-clearance of 0.30 m is proposed.

2.3.1.2.6. Computation of gross underkeel-clearance

Based on the above mentioned deterministic approach, the gross underkeel-clearance has been evaluated for the design ship in Table 2.T.3.

Design Ship 10,000 DWT

	Nam Trieu Lach Huyen (Open Sea)	**Nam Trieu (Protected water)**	**Trap Ha Nam (Canal)**	**Bach Dang + Cam (River)**
<u>Keel-clearance components</u>				
1. Allowance for static draught uncertainties	0.10	0.10	0.10	0.10
2. Change in water density	0.00	0.20	0.20	0.20
3. Squat (dynamic trim + list)	0.70	0.55	0.45	0.35
4. Wave response allowance	0.50	0.30	0.00	0.00
5. Wind response allowance	0.10	0.10	0.20	0.10
6. Netto Keel-Clearance	0.30	0.30	0.30	0.30
Gross Underkeel-Clearance (m)	**1.70**	**1.55**	**1.25**	**1.05**

Table 2.T.3.
Gross underkeel-clearance computation for a 10,000 DWT ship

2.3.2. Channel Dredged Level : Bottom Related Factors

Apart from the underkeel-clearance, the bottom related factors have to be taken into account to calculate the channel dredged level, and are described hereafter.

2.3.2.1. Bed level uncertainties

This factor takes into account the inaccuracies and uncertainties in the sounding equipment, in the recorded water level and in possible vertical motions of the survey vessel during the depth measurement, but also undiscovered shoals or objects on the bed, and unexpected/unpredictable sediment deposits between sounding surveys, e.g. caused by storms. It is treated as a margin (det. approach). In the case of the Nam Trieu Channel experience shows that siltation can be very rapid.

The OMS (Office of Maritime Safety) executes a bathymetric survey of the Nam Trieu shallow parts approx. 8 times/year.

A shallowing of 0.20 to 0.30 m/month is a generally accepted figure in the Nam Trieu Channel in the dry season. In the wet season this shallowing can go to 1.0 - 1.5 m in 1 month (figure 4.2.23 and figure 4.3.2).

A major bed level uncertainty can occur in access-channels where loose mud deposits occur, making it quite difficult to define the exact nautical bottom. HAECON has done a lot of efforts on this research and focused the definition of nautical bottom on a shear-strength criterion.

Unfortunately, the surveys undertaken hereto in the Nam Trieu Channel seem to indicate that mud deposits are quite consolidated or that loose mud deposits are limited to some 1 or 2 feet (see report VAH1351/00244), making the use of this concept not applicable in keel-clearance optimisation : taking into account the estimated shear strength properties and the density profiles of the mud a maximum extra depth of 0.30 m due to loose mud can be estimated (on the places where loose mud deposits occur !). This extra depth due to loose mud is negligible compared to the bed level uncertainties due to sedimentation.

2.3.2.2. Bottom changes between 2 dredgings

In a deterministic approach this is the maximum accepted sediment deposit between two dredging campaigns. In the case of the Nam Trieu Channel and with the current practice it appears that the channel is allowed to complete siltation (this is 2 to 3 m) after each of the 2 annual dredging campaigns). In order to introduce the concept of maintaining a safe nautical depth, it will be advised to program the maintenance dredging procedure in order not to allow a channel bottom level variation between 2 dredging of more than 0.25 m.
This brings the nautical bottom tolerance to a total value of 0,50 m in the outer sea channel (see further).

2.3.2.3. Dredging execution tolerance

Dredging execution tolerance is due to the inability of dredgers to guarantee the envisaged bottom level exactly on cm-accuracy.

For Trailing Suction Hopper Dredgers (TSHD) - like used for the maintenance of the Nam Trieu Channel - in silty deposits, a vertical tolerance of 0.30 m is generally accepted.

2.3.2.4. Summary of bottom-related keel-clearance factors

From this it follows that apart from the underkeel-clearance, bottom related factors have to be taken into account to calculate the channel dredged level. The following allowance has been taken into account :

1.	allowance for bed level uncertainties	:	0.10 m
2a.	allowance for nautical bottom changes between two dredgings in Nam Trieu / Lach Huyen	:	0.25 m
2b.	allowance for nautical bottom changes between two dredgings in the river system	:	0.05 m
3.	dredging execution tolerance : 50% of 0.30 m	:	0.15 m

Thus the total assumed allowance for <u>bottom related keel-clearance factors</u> varies between **0.30 m** (river system/canal) and **0.50 m** (Nam Trieu / Lach Huyen).

2.3.3. Selection of tidal level for nautical accessibility

The accessibility to Hai Phong Port is tide-bound. On figure 2.3. a typical tide recording (Hon Dau station) is illustrated.

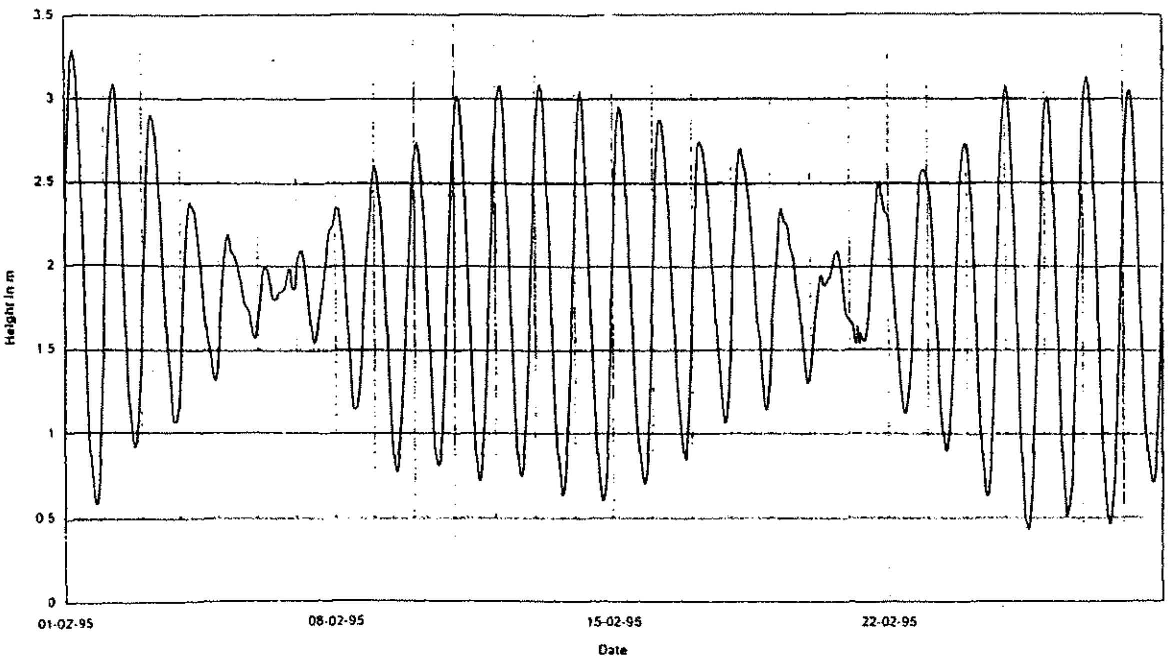


Figure 2.3.
Tidal level recording at Hon Dau showing the diurnal tide and strong influence of moon cycle (difference spring/neap)

On 365 days/year ca. 347 High Waters will occur in the access-channel to Hai Phong. From these 347 High Waters (HW), the HW's have to be selected which are occurring

a. with a minimum of 3 hours above C.D. + 2.5 m (sailing time) ;
b. during day-light (no limited night traffic because of insufficient lightning of channel buoys).

In one single moon cycle (29,53 days) 28.1 tides will occur. From these tides approx. 14 tides have a H.W. above C.D. + 2.5 m (mean duration of water level at C.D. + 2.5 m : 6 hr 20 min. This means that if the day/night proportion is taken into account (172/365 = 47 % = 50 %) that in one moon cycle 14 x 0.50 = 7 H.W. can be used for nautical access to Hai Phong (or ca. 45 hours navigation time/moon cycle). On year basis 12.36 moon cycles x 7 H.W./moon cycle = 86.5 H.W.'s can be used for nautical accessibility to Hai Phong Port (DWT = 10,000 ton ; tidal elev. = 2.5 m + C.D.) which means that only 25 % of the occurring H.W.'s can be utilised.

The water-reference level corresponds to the hydrographic chart-datum C.D. being the level of the Lowest registered Low Waters.

In order to optimise the nautical accessibility even without a detailed cost analysis, one can look at the accessibility graph of 10,000 DWT ship as a function of the tidal level cumulative distribution. This is represented on figure 2.8 where the accessibility (in % of total time) to Hai Phong is expressed as a function of Nautical depth (w.r.t. C.D.) and for different ship's sizes.

The typical " S "-shaped curves show how the nautical depth can be optimised : in the nearly horizontal (parallel to abscis) part of the curves a maximum increase in accessibility can be obtained for a minimal increase in nautical depth. For a 10,000 DWT ship the accessibility will increase from 15 % towards ± 65 % for a nautical depth increase of merely 0.80 m. It is assumed hereby that night navigation which will become possible in the future by appropriate aids-to-navigation.

Therefore, the tidal level under which navigation to and from Hai Phong Port will be considered in the 2 stages, mentioned before :
Stage 1 : Urgent Channel Rehabilitation Plan
Stage 2 : Channel Development Plan

2.3.3.1. Stage 1 : Urgent Channel Rehabilitation Plan

Previous studies (ref. 7, 8, 11) indicate a initial tidal level of C.D. + 2.5 m as appropriate for the access-channel to Hai Phong. Despite the very restricted time-accessibility linked to this C.D. + 2.5 m value, this is acceptable to the Port of Hai Phong, TEDI and VINAMARINE.

It was asked by TEDI if the selected tidal level could not be optimized by taking into account :

a. The capital dredging costs corresponding to various tidal levels and associated nautical depths ;
b. The costs linked to the waiting time for ships anchored offshore.

By decreasing the tidal level it is obvious that the channel dredged level will increase and consequently the capital dredging costs.

Regarding waiting times a statistic analysis of sailing time between buoy nr. 0 and Hai Phong Port for 1993 is done, based on the statistics of ship's traffic to Hai Phong in 1993.

On figure 2.4. the distribution histogram is given indicating that the bulk sailing time is between 2 and 6 hour, with a median value of 5 hours. However, more than 85 % of all ships nowadays have an average upsailing time of less than 24 hours. This can be deduced from the cumulative distribution graph of the sailing times illustrated on figure 2.5.

Sailing times vary between 2 hours and 750 hours with more than 50 % being less than 5 hours.

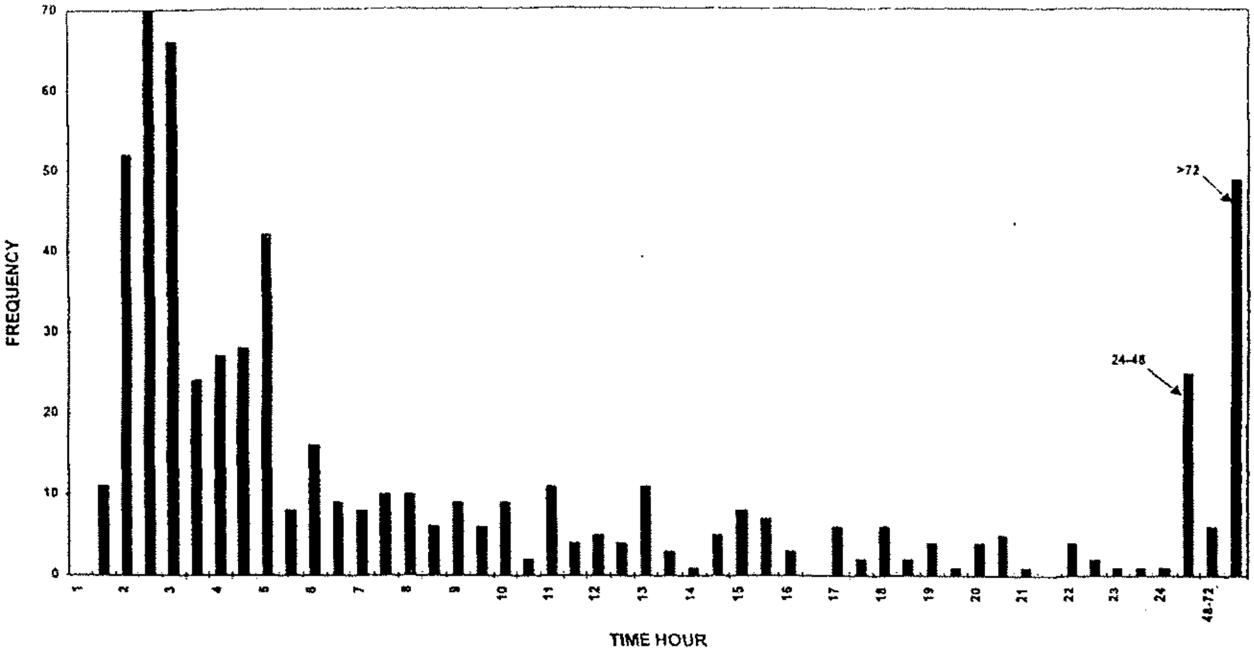


Figure 2.4.
Distribution histogram of sailing times of vessels to Hai Phong in 1993

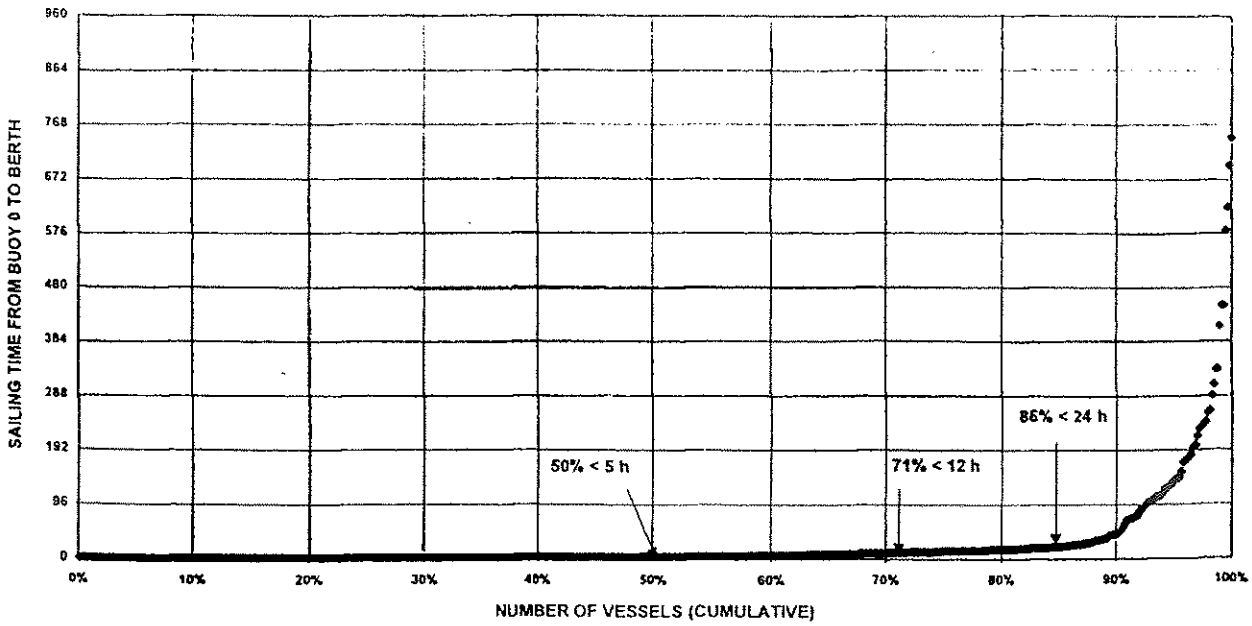


Figure 2.5.
Cumulative distribution of sailing times to Hai Phong (1993)

When a relationship is looked for between the entering draft and the total sailing time (figure 2.6.) no distinct relation seems to occur the 5-7 m draft vessels appear to present a wide variation of sailing times between 2 and 240 hours with the bulk being less than 10 hours however.

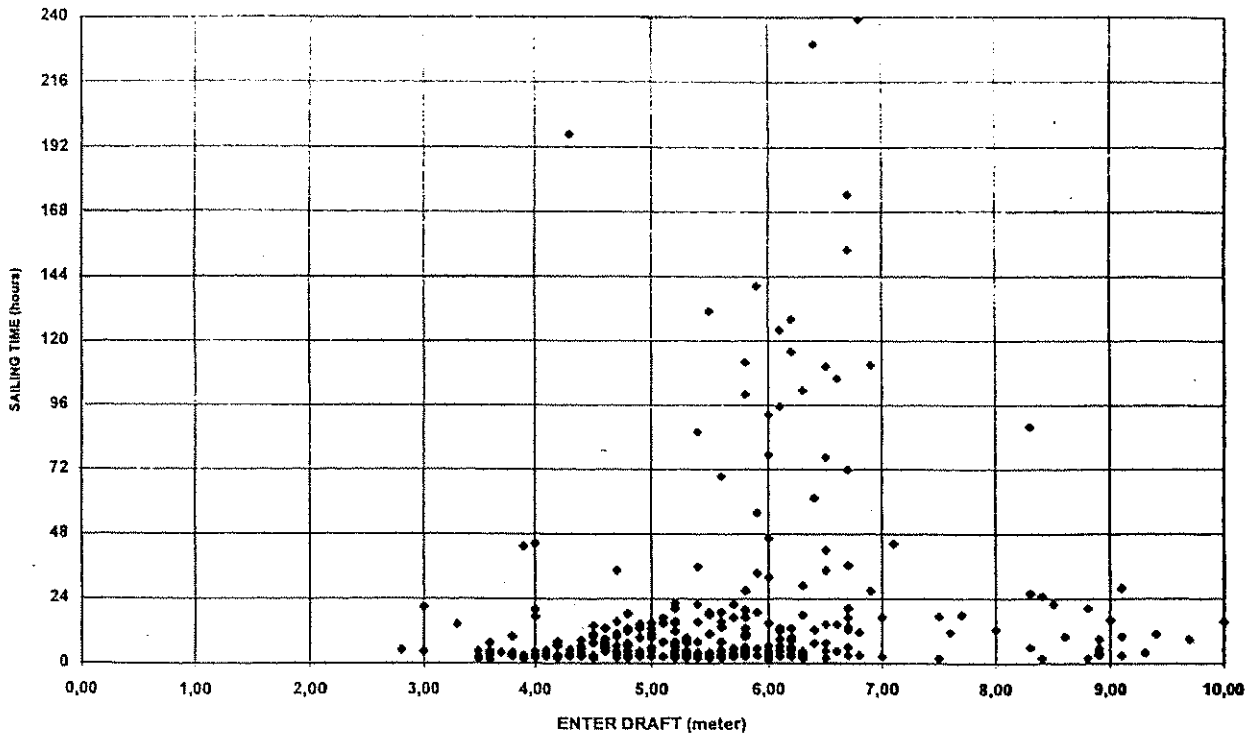


Figure 2.6.
Relationship between enter draft of vessels and sailing time to Hai Phong (1993)

It is quite impossible to find a relationship between DWT or Draft and the Sailing time.
Based on the tidal curve at Hai Phong it is possible to predict minimum and maximum waiting times for different tidal levels. It is impossible to predict the exact arrival of the ship at Buoy n° 0 w.r.t. to the tide ; therefore a minimum waiting time of one hour (boarding of pilot) and a maximum waiting time (between arrival at Buoy n° 0 and next tidal level) has been calculated.

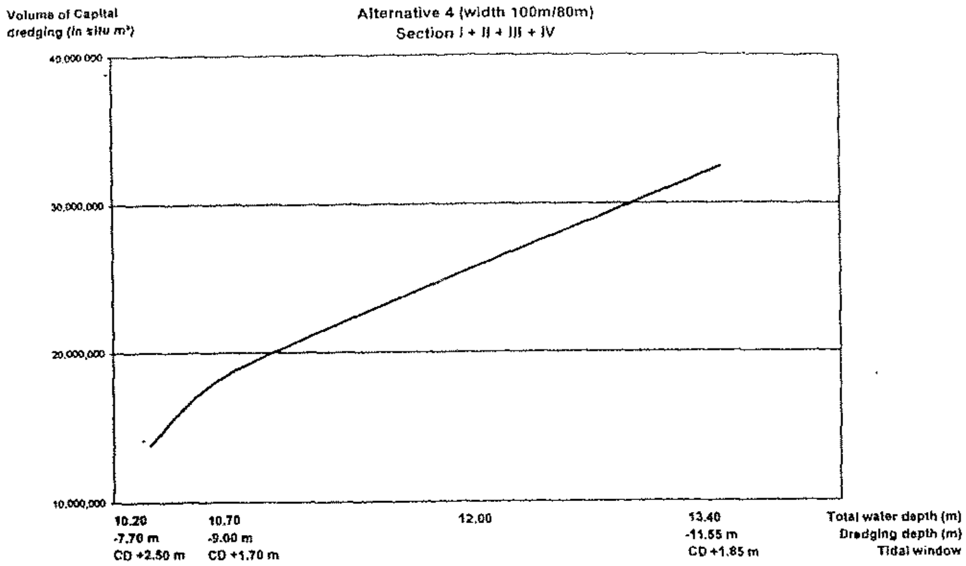


Figure 2.7.
Volume of capital dredging in function of water depth
(Alternative 4 : Trap Canal - Lach Huyen)

Tidal level	Waiting Time	
C.D. +	Minimum (hrs)	Maximum (hrs)
1.50	1	12
1.70	1	20
1.86	1	48
2.00	1	72
2.50	1	240
3.00	1	600

Table 2.T.4.
Minimum and maximum waiting times for different tidal levels in Hai Phong

Taking into account the average freight costs for different vessel sizes (ref. 9) it is obvious that it is not possible to define exactly the economic optimum w.r.t. waiting time costs because of the too large range of uncertainty. This uncertainty is closely linked to the particular tide wave occurring in this part of the world.

Vessel size (DWT)	Freight costs USD / 24 hrs	Tidal level C.D. + m	Waiting time costs (USD)	
			Minimum (USD)	Maximum (USD)
10,000	8,500	1.86	355	8,500
		2.00	355	25,560
		2.50	355	85,200
		3.00	355	213,000
20,000	12,640	1.86	530	12,640
		2.00	530	38,160
		2.50	530	127,200
		3.00	530	318,000
30,000	15,900	1.86	660	15,900
		2.00	660	47,520
		2.50	660	158,400
		3.00	660	396,000

Table 2.T.5.
Waiting time costs of freight in function of vessel size and tidal level

Therefore, it is proposed to keep the selected tidal level, for Stage 1 : Urgent Rehabilitation Plan at C.D. + 2.5 m as originally proposed by MOT.

2.3.3.2. Stage 2 : Full Channel Development Plan : Optimisation of Selected Tidal Level.

The optimisation of the tidal window can only be done after balancing the costs for further deepening and the benefits due to extra deep draught traffic. This balancing analysis is to be based on different traffic-forecasts and economic impact assessments about ship's size on the port's turnover. Because these aspects are not covered by the T.O.R. of this study another approach for the optimisation of the tidal window has been presented.

The following approach for the optimisation of the selected tidal level has been adopted :

1. the accessibility (in % of total time) to Hai Phong is analysed for the design ship and in function of the nautical depth ; the accessibility graph is represented in figure 2.8. ;

2. the relationship shows that in order to improve the accessibility for a 10,000 DWT ship from 15 % to 65 % only a slight increase in nautical depth is necessary.

It is highly recommended that the design of the access-channel to Hai Phong should be done keeping in mind the modern trend in maritime trade. There is a worldwide trend to reduce the waiting times to a strict minimum ; waiting times of more than 2 days are generally not accepted anymore because of productivity reasons. Therefore it is recommended to consider at least a 50 % time-accessibility which means that the design ship (10,000 DWT full-loaded) can sail to or from Hai Phong each day. By analysing the time-accessibility graph it can be seen that there is only a slight increase (3 %) in nautical depth necessary to increase the time-accessibility from 50 % to 65 %.

Consequently, in order to increase the nautical accessibility to 65 % of the total time, the tidal window for the full developed access-channel to Hai Phong Port is proposed at C.D. + 1.70 m for 10,000 DWT ship.

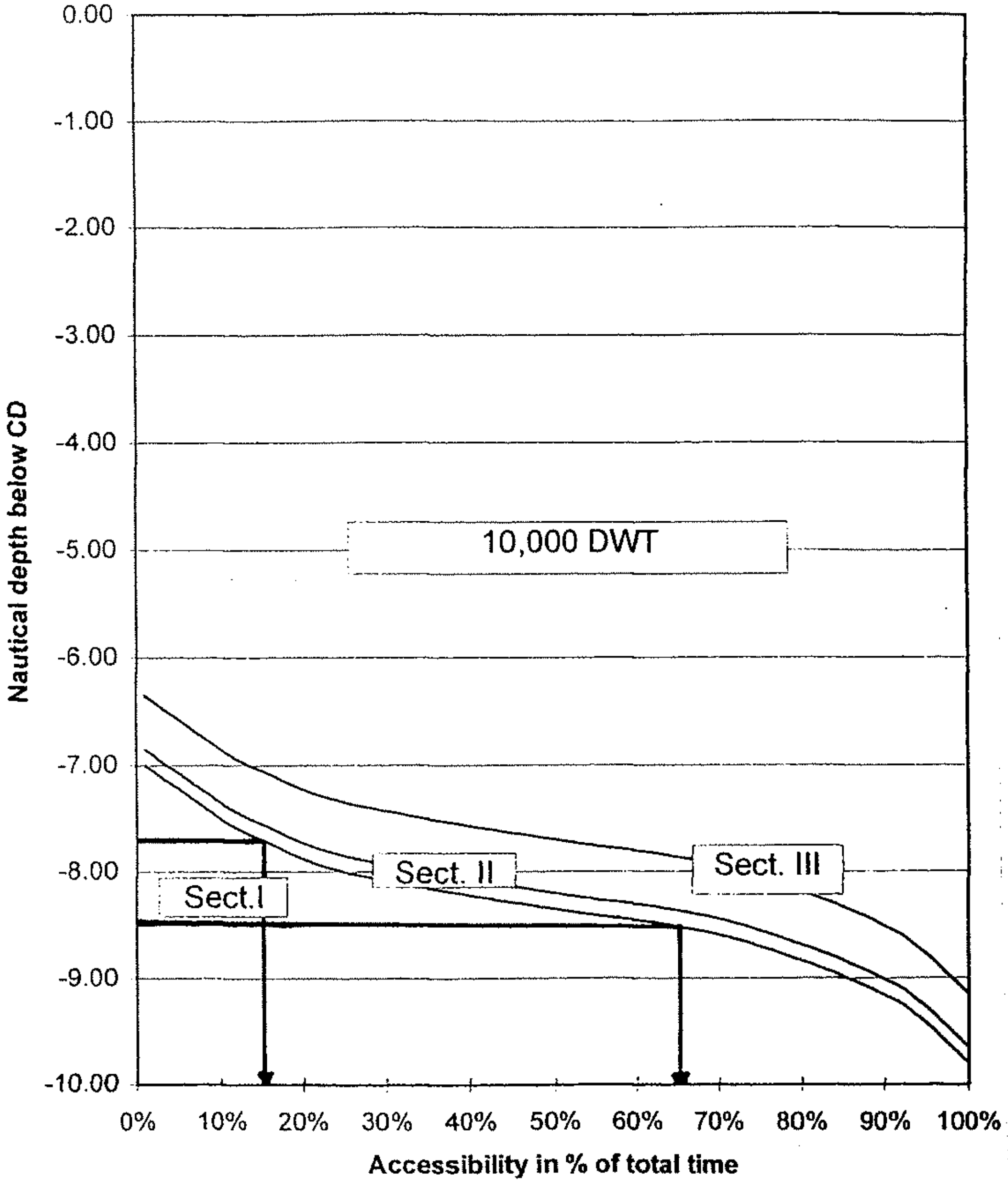


Figure 2.8.
Nautical accessibility graph to Hai Phong as a function of nautical depth

2.3.3.3. Tidal window and sailing window

Present day experience shows that the Nam Trieu Channel from Buoy Nr. 0 to Hai Phong Port is upsailed in approx. 3 hours (see also statistics in par. 2.3.3.1).

The tidal window for the full channel development and for 10,000 DWT-ships is set at C.D. + 1.70 m (see par. 2.3.3.2).

From the UNDP tidal recordings and the tidal recordings done in this study the tidal wave propagation can be computed through the buoy up till Hai Phong Port. When comparing tidal wave propagation and ship's sailing speeds (upsailing and down-sailing) it becomes possible to calculate sailing windows.

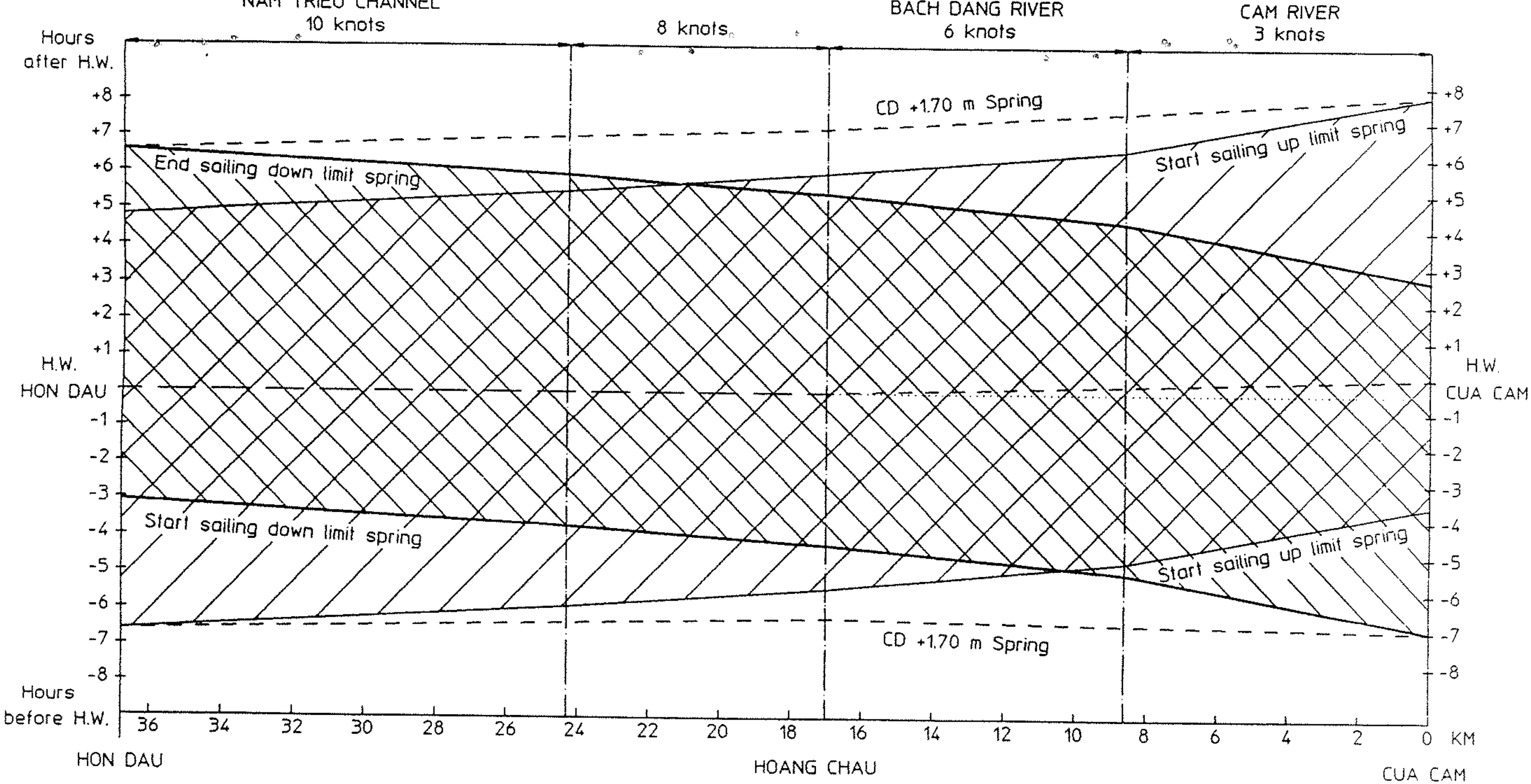
This has been done and represented in :

1. figure 2.9. Tidal and sailing window at Spring Tide (max. range) for 10,000 DWT ships (C.D. + 1.70 m) in Nam Trieu (Alt 1) (Data from 9/10-01-93)
2. figure 2.10. Tidal and sailing window at Spring Tide (max. range) for 10,000 DWT ships (C.D. + 1.70 m) in <u>Lach Huyen</u> (Alt. 4) (Data from 11/12-07-95)

From these graphs and computations the following conclusions can be drawn :

- The upsailing window ranges from approx. - 6 hrs 40'/H.W. Hon Dau up to + 4 hrs 50'/H.W. Hon Dau (tidal window set at C.D. + 1.70 m) (see figure 2.2.)
- The down-sailing window ranges from - 7 hrs/H.W. Thai Binh (Cua Cam) to + 2 hr 40'/HW Thai Binh.

Of course, this kind of analysis is very much dependent upon sailing speeds and channel options. In Hai Phong it is - according to the JICA 1993 study report - acceptable and safe, that ship's time itervals are set at approximately 30 minutes ; this means that at maximum 24 design ships can sail up in 1 single tide or that a maximum 20 design ships can sail down under the above-mentioned conditions and configuration.
No time-lag for the boarding/unboarding of pilots has been taken into account for these sailing window computations (only 1 pilot from buoy nr. 0 up to Hai Phong).



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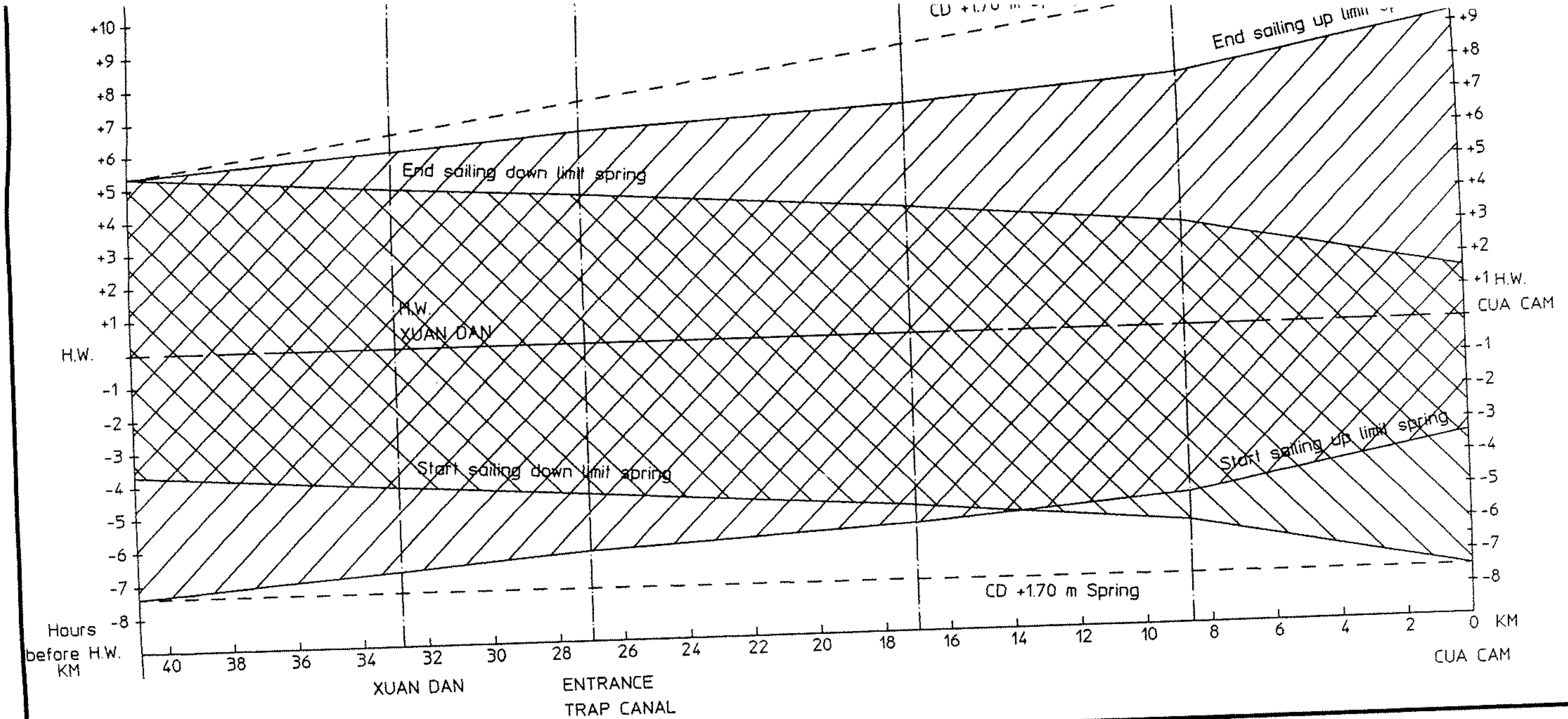
Access - Channel to Hai Phong
Alternative 1 : Nam Trieu
Tidal window and sailing window
at Spring Tide (09/10-01-93)
10,000 DWT ships

GETEK: GDP	GEZ.: BME	VAH1351 Figure 2.9



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Access - Channel to Hai Phong
Alternative 4 : Lach Huyen
Tidal window and sailing window
at Spring Tide (11/12-07/95)
10,000 DWT ships

GETEK: GDP	GEZ: BME	VAH1351 Figure 2.10

It must also be stressed that tidal window sailing implies that at berth locations in Hai Phong (at present 12 equiped berths) nautical depths must be available equalling the ships draught + approx. 10 %.

2.3.4. Conclusions and summary about determination of nautical bottom depth and channel dredged level

2.3.4.1. Channel depth for Stage 1 : Urgent Channel Rehabilitation Plan

Based on the Vietnamese standard for the gross underkeel-clearance and with a tidal window of C.D. + 2.50 m, nautical depth and dredging depths are calculated as follows :

	Nam Trieu Lach Huyen Channel	Trap Ha Nam Canal	Bach Dang Cam River
Static draught	8.50 m	8.50 m	8.50 m
Gross keel-clearance	1.20 m	1.20 m	1.20 m
Required water depth	9.70 m	9.70 m	9.70 m
Tidal window CD	+ 2.50 m	+ 2.50 m	+ 2.50 m
Nautical depth	- 7.20 m	- 7.20 m	- 7.20 m
Channel dredged level	- 7.70 m	- 7.50 m	- 7.50 m
Accessibility for 10,000 DWT ships (% of the total time)	± 15 %	± 15 %	± 15 %

Table 2.T.6.

Computation of nautical and dredging depths for a 10,000 DWT ship with an accessibility of 15 %

Stage 1 : Urgent Rehabilitation Plan

2.3.4.2. Channel depth for Stage 2 : Full Channel Development Plan

Based on the deterministic calculation for the gross underkeel-clearance with a time-accessibility of ± 65 % for a 10,000 DWT ship, nautical depths and dredged depths are calculated as follows :

Design ship 10,000 DWT

	Nam Trieu Lach Huyen (Open sea)	Nam Trieu (Protected water)	Trap Ha Nam (Canal)	Bach Dang Cam (River)
Static draught	8.50 m	8.50 m	8.50 m	8.50 m
Gross keel-clearance (deterministic)	1.70 m	1.55 m	1.25 m	1.05 m
Required water depth	10.20 m	10.05 m	9.75 m	9.55 m
Tidal window CD	+ 1.70 m	+ 1.70 m	+ 1.70 m	+ 1.70 m
Nautical depth	- 8.50 m	- 8.35 m	- 8.05 m	- 7.85 m
Channel dredged level	- 9.00 m	- 8.85 m	- 8.35 m	- 8.15 m
Accessibility (% of the total time)	± 65	± 65	± 65	± 65

Table 2.T.7.
Computation of nautical and dredging depths for a 10,000 DWT-ship with an accessibility of 65%.
Stage 2 : Final Channel Development Plan

The access-channel to Hai Phong Port should be designed in order to allow access for the design ship each day : this means the use of the daily H.W. irrespective of day or night. Appropriate aids to navigation at night will therefore become necessary.

2.4. CHANNEL WIDTH DESIGN

2.4.1. Channel width design according to PIANC - IAPH [2]

The bottom width W of the waterway with a straight alignment is given for a one way channel by formula 3 :

$$w = w_{BM} + \sum_{i=1}^{n} w_i + w_{Br} + w_{Bg} \qquad (3)$$

and for a two-way channel by :

$$w = 2w_{BM} + 2\sum_{i=1}^{n} w_i + w_{Br} + w_{Bg} + w_p$$

where, as shown in figure 2.11. w_{Br} and w_{Bg} are the bank clearances on the bank clearances on the "red" and "green" sides of the channel, w_p is the passing distance and the w_i are given in table 2.T.9.

The basic manoeuvring width w_{BM}, as a multiple of the beam B of the design ship, is given in table 2.T.8. This basic manoeuvring width is required by the design ship to sail safely in very favourable environmental and operational conditions.

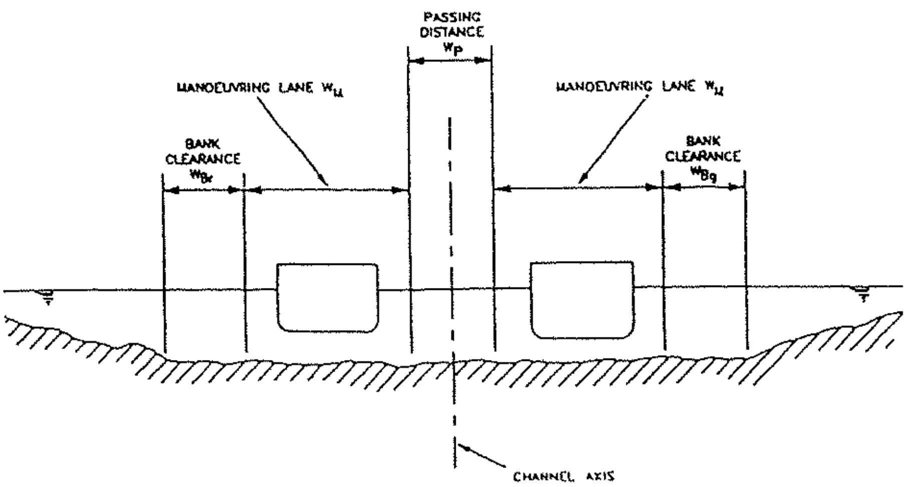


Figure 2.11.
Elements of Channel Width for a two-way channel

[2] IAPH : International Association of Ports and Harbours

To the basic manoeuvring lane width w_{BM} are added additional widths (to allow for the effects or wind, current, etc.) which gives the manoeuvring lane WM. The additional widths are given in table 2.T.10.

Ship Manoeuvrability	good	moderate	poor
Basic Manoeuvring Lane, w_{BM}	1.3 B	1.5 B	1.8 B

Table 2.T.8.
Basic manoeuvring lane in function of ship's manoeuvrability

WIDTH w_i	Outer Channel (exposed to open water)	Inner Channel (protected water)
(a) **Vessel speed (knots)**		
- fast > 12	0.1 B	0.1 B
- moderate > 8 - 12	0.0	0.0
- slow 5 - 8	0.0	0.0

WIDTH w_i	Vessel Speed	Outer Channel (exposed to open water)	Inner Channel (protected water)
(b) **Prevailing cross wind (knots)**			
- mild ≤ 15 (≤ Beaufort 4)	all	0.0	0.0
- moderate > 15-33 (> Beaufort 4 - Beaufort 7)	fast	0.3 B	-
	mod	0.4 B	0.4 B
	slow	0.5 B	0.5 B
- severe > 33-48 (> Beaufort 7- Beaufort 9)	fast	0.6 B	-
	mod	0.8 B	0.8 B
	slow	1.0 B	1.0 B
(c) **Prevailing cross current (knots)**			
- negligible < 0.2	all	0.0	0.0
- low 0.2 - 0.5	fast	0.1 B	-
	mod	0.2 B	0.1 B
	slow	0.3 B	0.2 B

- moderate > 0.5 - 1.5	fast	0.5 B	-
	mod	0.7 B	0.5 B
	slow	1.0 B	0.8 B
- strong > 1.5 - 2.0	fast	0.7 B	-
	mod	1.0 B	-
	slow	1.3 B	-
(d) Prevailing longitudinal current (knots)			
- low ≤ 1.5	all	0.0	0.0
- moderate > 1.5 - 3	fast	0.0	-
	mod	0.1 B	0.1 B
	slow	0.2 B	0.2 B
- strong > 3	fast	0.1 B	-
	mod	0.2 B	0.2 B
	slow	0.4 B	0.4 B
(e) Significant wave height H_S and length λ (m)			
- $H_S \leq 1$ and $\lambda \leq L$	all	0.0	0.0
- $3 > H_S > 1$ and $\lambda \approx L$	fast	$\approx$ 2.0 B	
	mod	$\approx$ 1.0 B	
	slow	$\approx$ 0.5 B	
- $H_S > 3$ and $\lambda > L$	fast	$\approx$ 3.0 B	
	mod	$\approx$ 2.2 B	
	slow	$\approx$ 1.5 B	

WIDTH w_i	**Outer Channel (exposed to open water)**	**Inner Channel (protected water)**
(f) Aids to Navigation		
- excellent with shore traffic control	0.0	0.0
- good	0.1 B	0.1 B
- average, visual and ship board, infrequent poor visibility	0.2 B	0.2 B
- average, visual and ship board, frequent poor visibility	≥ 0.5 B	≥ 0.5 B

(g) Bottom surface		
- if depth ≥ 1.5 T	0.0	0.0
- if depth < 1.5 T then		
- smooth and soft	0.1 B	0.1 B
- smooth or sloping and hard	0.1 B	0.1 B
- rough and hard	0.2 B	0.2 B
(h) Depth of waterway		
- ≥ 1.5 T	0.0	≥ 1.5 T 0.0
- 1.5 T - 1.25 T	0.1 B	< 1.5 T - 1.15 T 0.2 B
- < 1.25 T	0.2 B	< 1.15 T 0.4 B
(i) Cargo hazard level		
- low	0.0	0.0
- medium	≥ 0.5 B	≥ 0.4 B
- high	≥ 1.0 B	≥ 0.8 B

Table 2.T.9.
Additional widths for straight channel alignments

WIDTH for BANK CLEARANCE (w_{Br} or w_{Bg})	**Vessel Speed**	**Outer Channel (exposed to open water)**	**Inner Channel (protected water)**
Sloping channel edges and shoals :			
	fast	0.7 B	-
	moderate	0.5 B	0.5 B
	slow	0.3 B	0.3 B
Steep and hard embankments, structures :			
	fast	1.3 B	-
	moderate	1.0 B	1.0 B
	slow	0.5 B	0.5 B

Table 2.T.10.
Additional widths for bank clearance

2.4.2. Channel width design according to UN or other ports

According to the Port Development Handbook by the United Nations, it is recommendable that a minimum value for the width of a one-way channel (width at full depth) would be 5 times the beam width (B) of the biggest vessel (with limited cross-currents).

This code is based on research and experience ; actual one-way channel width in existing ports varies between 4 to 5 B.

2.4.3. Calculation of channel width

The channel width of the maritime access-channel to the Hai Phong Port has been determined based on the PIANC/IAPH guidelines, see Table 2.T.12. Some of the figures might be subject to comment.

2.4.3.1. Addition for cross current

For the Nam Trieu channel, an addition of 0.5 B accounts for cross current, which implies that the prevailing cross current is considered as moderate (0.5 - 1.5 knots).

For the Lach Huyen channel, current vectors are practically parallel to the channel, so that the component perpendicular to the channel is always less than 0.5 knots. So an addition of 0.2 B for cross currents seems reasonable for the Lach Huyen channel (low cross current, moderate vessel speed, outer channel exposed to open water).

2.4.3.2. Addition for longitudinal current

In the Cam River section, strong longitudinal currents occur (> 3 knots), so an additional width of 0.4 B is justified.
Anyway, time of passing through the Cam River and Bach Dang River sections should be arranged so as to avoid strong tidal currents. Especially for ships sailing out, it appears practically impossible to sail at a speed of 3 - 4 knots in currents of 3 knots from the stern.

2.4.3.3. Addition for waves

No additional width for waves is considered, which accounts for a significant wave height $H_s < 1$ m and a wave length λ in the order of magnitude of the ship length ($\lambda \approx L$).

Table 2.T.11 shows clearly that the condition (1 m $< H_s <$ 3 m and $\lambda \approx L$) has an occurrance of only 0.33 % (1 day per year). The condition ($H_s < 1$ m and $\lambda \leq L$) occurs 69.30 % of the time, and can therefore be considered as the prevailing wave condition. It should be emphasized that Table 2.T.11 is based on data concerning offshore wave climate. The occurrence of condition ($H_s < 1$ m and $\lambda \leq L$) nearshore can be estimated at about 80 %.

		wave length (period)			
		$\lambda < L$ (T < 11 s)	$\lambda \approx L$ (11 s < T < 17 s)	$\lambda > L$ (T > 17 s)	Total
wave height	< 1 m	69.30 %	0.17 %	0.00 %	69.47 %
	1 - 3 m	28.74 %	0.33 %	0.01 %	29.08 %
	> 3 m	1.32 %	0.12 %	0.00 %	1.45 %
	Total	99.36 %	0.63 %	0.01 %	100.00 %

Table 2.T.11.
Annual offshore wave climate - wave height against wave period

2.4.3.4. Conclusions and summary about channel width

The navigable width of the maritime access-channel to the Hai Phong Port has been evaluated as follows :

	Nam Trieu	Lach Huyen	Cam River Bach Dang River Trap Canal
Basic manoeuvring lane (W_{BM})	**1.5 B**	**1.5 B**	**1.5 B**
Addition for speed	**0.0 B**	**0.0 B**	**0.0 B**
Addition for cross wind	**0.4 B**	**0.4 B**	**0.4 B**
Addition for cross current	**0.5 B**	**0.2 B**	**0.0 B**
Addition for long. current	**0.1 B**	**0.1 B**	**0.4 B**
Addition for waves	**0.0 B**	**0.0 B**	**0.0 B**
Addition for aids to navigation	**0.2 B**	**0.2 B**	**0.2 B**
Addition for bottom surface	**0.1 B**	**0.1 B**	**0.1 B**
Addition for waterway depth	**0.2 B**	**0.2 B**	**0.4 B**
Addition for cargo hazard	**0.0 B**	**0.0 B**	**0.0 B**
Bank clearance (w_{br} + w_{bg})	**1.0 B**	**1.0 B**	**1.0 B**
Total	**4.0 B**	**3.7 B**	**4.0 B**
Channel width (B = 20.0 m) =	**80 m**	**74 m**	**80 m**

Table 2.T.12.
Access Channel width design (B = beam of design ship ; 20.0 m)

For a design ship with beam B = 20.0 m, the channel would need a theoretical width of 80 m (Nam Trieu) or 74 m (Lach Huyen). Taking account of the actual width of the existing navigation channel (Nam Trieu), which is 100 m, a reduction to 80 m or 74 m in order to receive larger ships would be very different compared to the actual nautical practice.

This is not in accordance with overall nautical safety guidelines, where it is common practice not to restrict channel widths (acquaintance of pilots, helmsmen, ...). Therefore, it is recommended by this study to maintain a design bottom width of 100 m.

2.5. BENDS

In this report, it is assumed that ships navigate in the channel without tug-assistance. Therefore, any bend connecting straight legs of a channel must take into account the turning ability of a ship.

In calm water with no wind, a hard-over turn may be accomplished by a ship having average-to-good manoeuvrability with a radius of about 1.8 to 2.0 LOA in deep water increasing to perhaps 2.8 LOA at a water depth/draught ratio of 1.10.

The ship "side-slips" as it turns it sweeps out a path which is wider than its beam. This excess can vary from about 0.40 B at a water depth/draught ratio of 1.10 to 1.60 B in deep water (ref. 14 depending on the depth of water).

Therefore, the way a ship turns, depends very much on the water depth/draught ratio. This affects both the radius of turn and the width of the swept track, showing that, at the lowest water depth/draught ratios, the radius will be at its greatest and the additional width needed at its smallest.

For concept design, it is suggested by PIANC-IAPH that turning radii and swept track width of the design ship are calculated with a rudder of 15° to 20° in a bend. Greater values give too little margin for safety and lesser values making turning difficult due to the length of the track and the handling problems of keeping ship accurately on track in a bend.

The PIANC guideline further recommends bending radius to be within 5 LOA and 10 LOA.

To take a margin of safety with respect to cross-currents, (especially for entering and exit the Trap Canal or Ha Nam Canal), a turning radius of approx. 12 x LOA (R = 2000 m) is proposed.

The width in the bends is also set at 4 B, but additional width is recommended for entering and leaving the New Ha Nam Canal (Alternative 3) or the Trap canal (Alternative 4) in order to allow for the cross current : 6 B (entering) or 5 B (leaving) m at the bottom in the bend as opposed to 4 B m in the straight sections.
According to PIANC guidelines additional width is preferably placed on the inside bank rather than on the outside bank of the bend.

2.6. GENERAL CONSIDERATIONS AND CONCLUSIONS ABOUT CHANNEL DESIGN

The Port of Hai Phong expects to increase its overall annual throughput towards approximately 8.5 Mtons for 2010. This means that the ship's traffic in the access-channel will be modified in the coming years and that the new access-channel must take these modifications into account. The traffic charges can roughly be summarized as follows :

1) From a nowadays observed decrease in average ship's size, future trends are expected to show an increase in average ship's size.

2) Traffic density will increase ; it is expected that future annual number of ship movements will be approximately 4,000 to 5,000 which corresponds to approximately 15 per day.

3) Requirements for short ship handling and waiting times (especially if container traffic will increase).

The design of the access-channel to Hai Phong leads to the following scheme :

1) a channel bottom width of 100 m ;

2) a staged channel development in order to allow traffic, port development and port economics to improve progressively :

   Stage 1 : Urgent Channel Development Plan

   - nautical depth : C.D. -7.20 m ;
   - gross keel-clearance : 1.20 m ;
   - tidal window : C.D. +2.50 m ;
   - nautical accessibility : max. 15 % (with additional restrictions during rough weather and particular caution with deep draught vessels).

   Stage 2 : Full Channel Development Plan

   - nautical depth : C.D. - 8.50 m to C.D. -7.85 m ;
   - gross keel-clearance : 1.70 m to 1.05 m;
   - tidal window : C.D. +1.70 m ;
   - nautical accessibility : 65 %.

The proposed full developed access-channel (Stage 2) with a width of 100 m and a nautical bottom at C.D. - 8.50 m is able to fulfill all the above-mentioned future expected traffic requirements.

It is assumed in this Access-Channel study that the following items are handled by the Vietnamese Authorities :

1) Provide turning circles and ship's manoeuvring areas in front of the berths of Hai Phong Port ;

2) Maintain a sufficient ship's berthing depth in front of the quay walls, jetties, ... (ship's measured draft + variations of water density + allowance for siltation) ;

3) Provide appropriate pilotage and aids-to-navigation facilities, allowing also night navigation ;

4) Provide the appropriate ship handling and berthing facilities (nowadays only 12 berths are available ; this is expected to be too low for handling 8.5 Mtons) ;

5) Take the access-channel design elements into account (geotechnical stability) when planning or executing works on the river banks (groynes, jetties, quay walls, ...) ;

6) Assure a proper and regular monitoring of the available nautical depth ;

7) Assure a proper and regular maintenance dredging.

Perspective View of the Access Channel's Morphology

3. ACCESS-CHANNEL ALTERNATIVES

3.1. GENERAL

Based on the technical sessions with MOT and TEDI, a number of possible Access-Channel alternatives have been selected for further preliminary design. The channel-alternatives to be studied in this "General Study for the Access-Channel to Hai Phong" have been defined as follows :

1. Alternative 1 :
   Deepening and widening the existing channel

2. Alternative 2 :
   New Nam Trieu Channel (where a direct route south of Aval is designed)

3. Alternative 3 :
   New alignment in Lach Huyen through (new) Ha Nam Canal

4. Alternative 4 :
   New alignment in Lach Huyen through (existing) Trap Canal

The other alternatives mentioned by the consultant such as the alignment following the old Cam bedding and the route through Trap Canal/North of Cat Ba were not to be considered according to TEDI.

For the purpose of describing the different channel alternatives, the channel is divided in four sections from I to IV :

Section IV :	Cam River
Section III :	Bach Dang River upstream
Section II :	1. Bạch Dang River Downstream
	2. Trap or Ha Nam Canal
Section I :	1. Nam Trieu Channel
	2. Lach Huyen Channel

The sections III and IV (resp. Bach Dang River upstream and Cam River) are the same for all alternatives.

3.2. CAM RIVER AND BACH DANG RIVER

3.2.1. Cam River (Section IV)

a) **Lay-out**

Coming from the sea, the Port of Hai Phong is at present accessible through the Nam Trieu Channel, the Bach Dang River, the Dinh Vu Canal and the Cam River. The Cam River section is approximately 8.6 km long and flows out in the Bach Dang River through the Dinh Vu Canal (see Figure 3.1. and drawings no 34.20.105, 106, 107).

Particular attention is to be given to the existing infrastructures on both banks of the Cam River :

- quays ;
- groynes ;
- wharves.

Therefore, the maximum width of the access-channel is to be restricted to 80 m.

b) **Soil conditions**

The water of the Cam River is quite turbid with clay and silt in suspension. Part of these sediments are presumed to be eroded from the river bed and river banks ; the vast majority of sediment supply comes by advection from the Song Hong and Song Duong river system.

c) **Hydrodynamic conditions**

Relevant hydrodynamic conditions are mainly related to fluvial flow and currents. Very high fluvial flow may occur, especially during the wet season.

d) **Longitudinal profile**

Figure 3.3. shows the longitudinal profile of the bottom along the axis of the Cam River (KM 0 to KM 8.6).

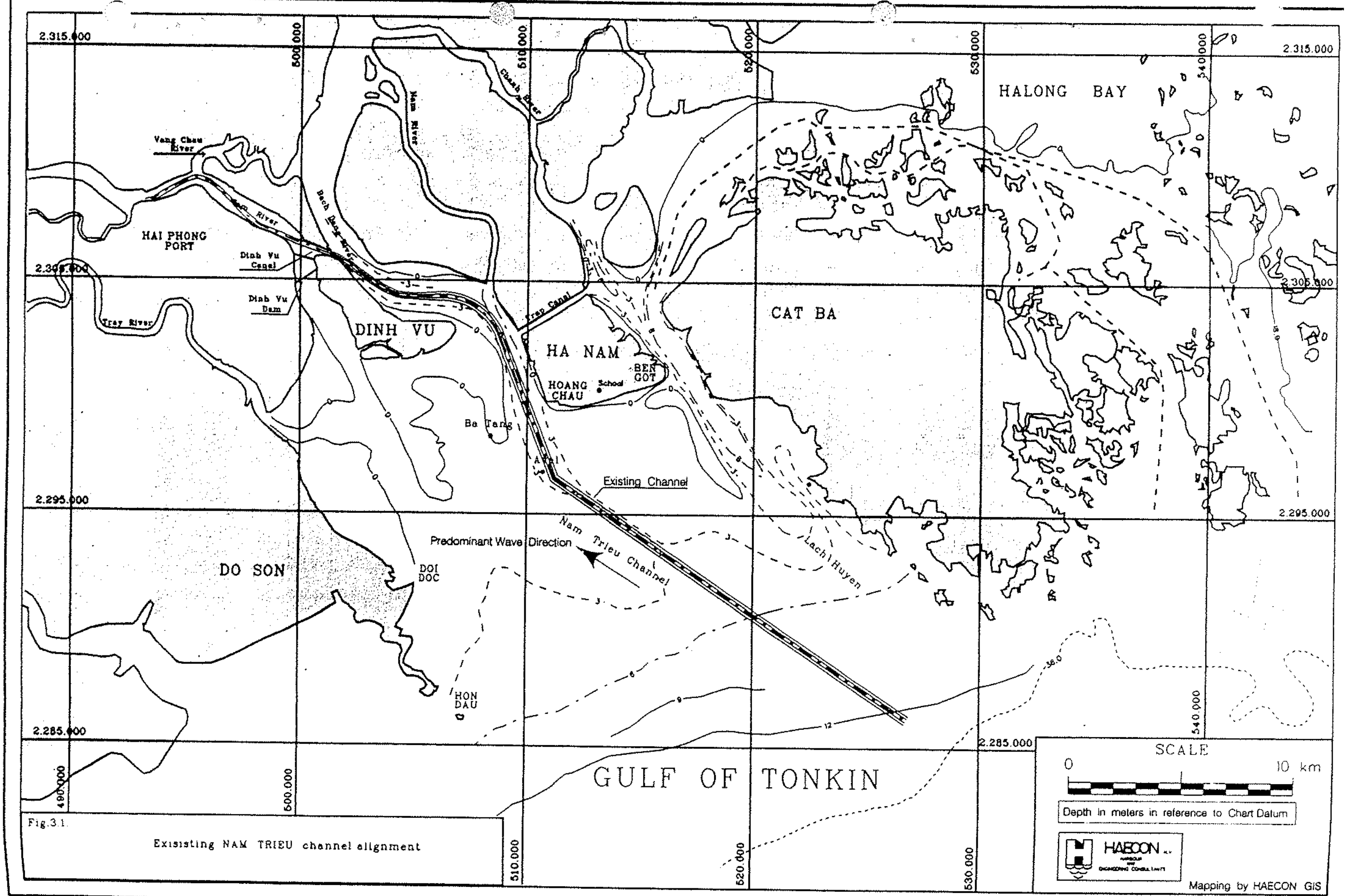


Fig.3.1.
Exisisting NAM TRIEU channel alignment

e) **Navigation aids**

The shipping channel follows at present respectively a bearing of 293°, 315° and 299°. The channel is delimited by ten red and green buoys.

f) **Design profile**

The selected design profile is a trapezoidal with the following main characteristics :

- Bottom width	80 m at C.D. - 8.15 m
- Nautical depth	C.D. - 7.85 m
- Dredging depth	C.D. - 8.15 m
- Slope gradient	1/7
- Possible navigation lane	a 80 m wide central lane along the axis for a one way sea vessel traffic of 10,000 DWT.

3.2.2. Bach Dang River (section III)

a) **Lay out**

The Nam Trieu and the Dinh Vu Canal are linked by a section of the Bach Dang River approx. 8 km long. This section of the Bach Dang River exhibits 2 bends. The bend connecting the Nam Trieu Channel and the Bach Dang River is 2,200 m long (KM 16.50 - KM 14.30) with a radius of 2,000 m. The second bend is 2000 m long (KM 12.50 - KM 10.50) with a radius averaging 2,800 m.

b) **Soil conditions**

Soil conditions in the Bach Dang River are expected to be essentially muddy sediments.

c) **Hydrodynamic conditions**

Relevant hydrodynamic conditions are mainly related to fluvial flow and current. The discharge of the Bach Dang River appears to be only a fraction of the discharge of the Cam River. Since the Dinh Vu dam closure, the discharge of the Bach Dang River is highly influenced by the discharge of the Cam River.

d) Longitudinal profile

Figure 3.3. shows the longitudinal profile of the bottom along the axis of the Bach Dang River (KM 8.6 to KM 16.5).

e) Navigation aids

The channel is delimited by three (3) red buoys n° 22, 24,26 and three (3) green buoys n° 27, 29, 31.
The PVB Leading Light (331°) helps the navigation in this section of Bach Dang.

f) Design profile (fig. 3.2.)

	10,000 DWT Section III
KM	16.50 - 8.60
Nautical depth	CD - 7.85 m
Dredging depth	CD - 8.15 m
Width at bottom	80 m at CD - 8.15 m
Slope gradient	1/7

Table 3.T.1.
Design profile for Bach Dang River

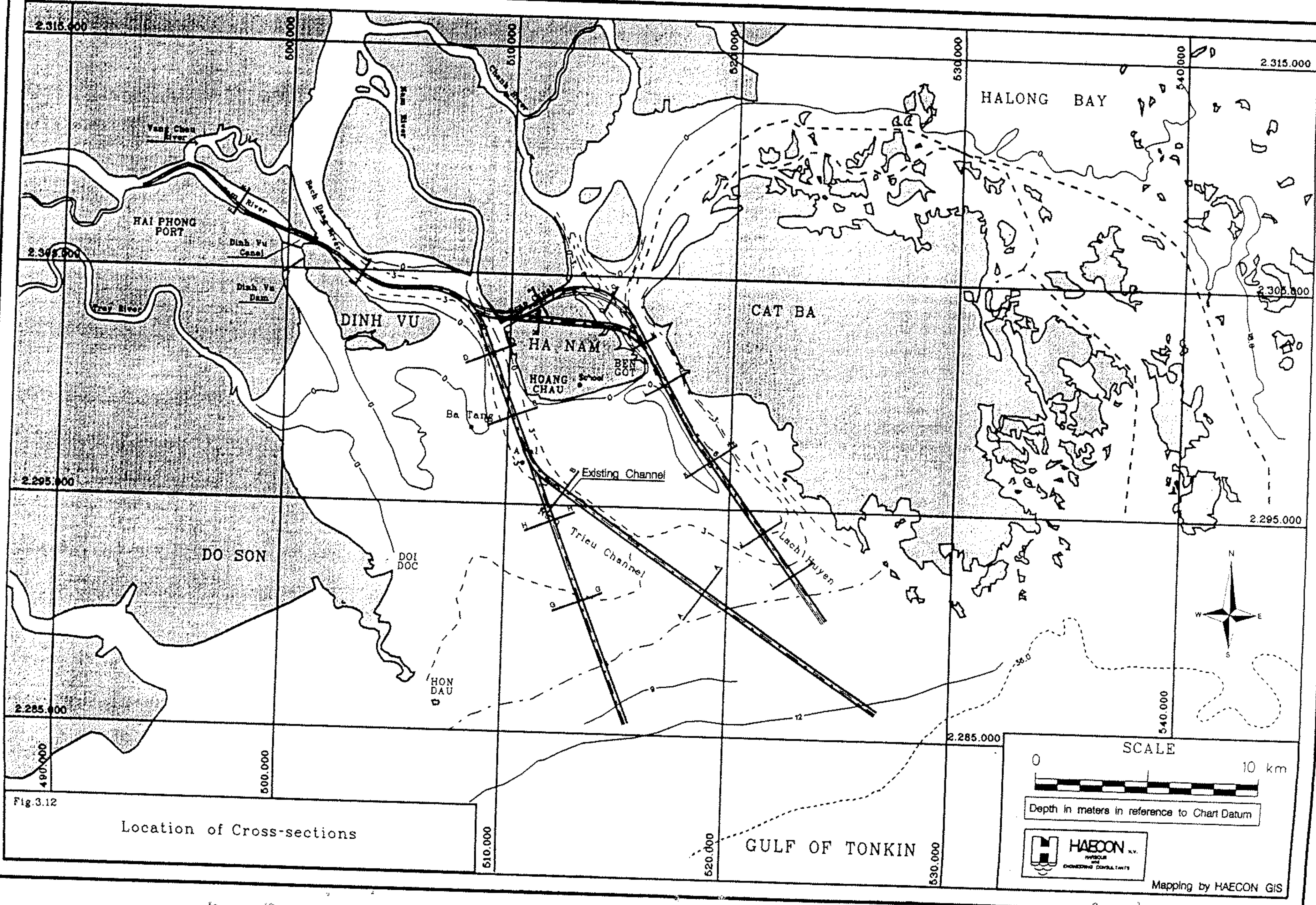
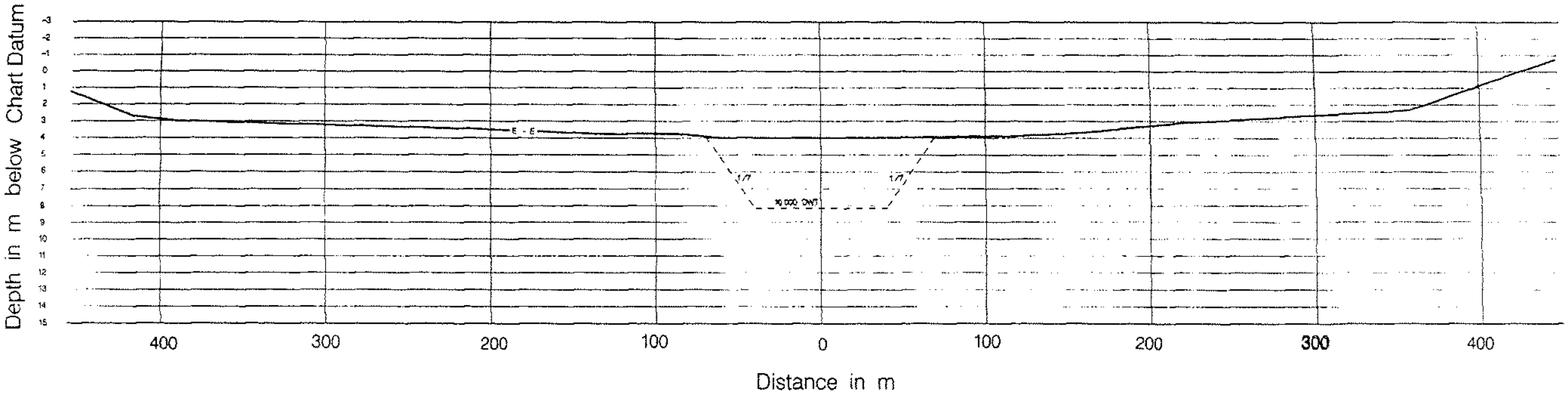
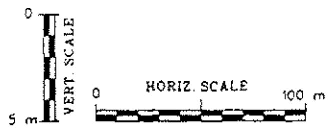


Fig.3.12

Location of Cross-sections



bathymetric data : 1995

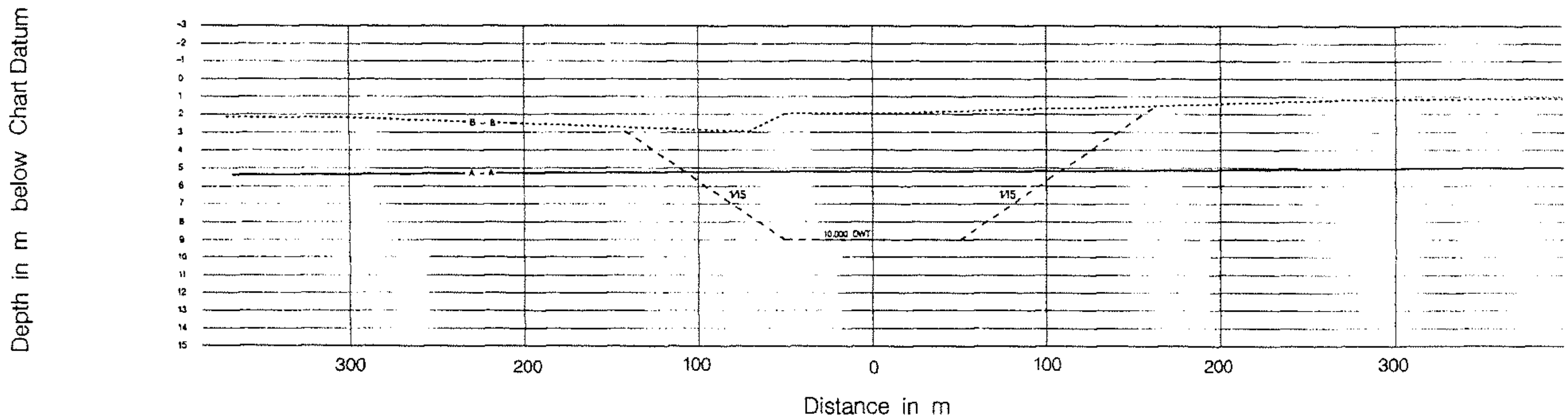


VIETNAM ACCESS CHANNEL TO HAI PHONG

HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS

DESIGN PROFILE AND
CROSS SECTION OF THE
BACH DANG RIVER

DRA.: JRR | APP.: BLE | VAH1351 | Fig. 3.7



bathymetric data : 1995

VERT SCALE 0 – 5 m

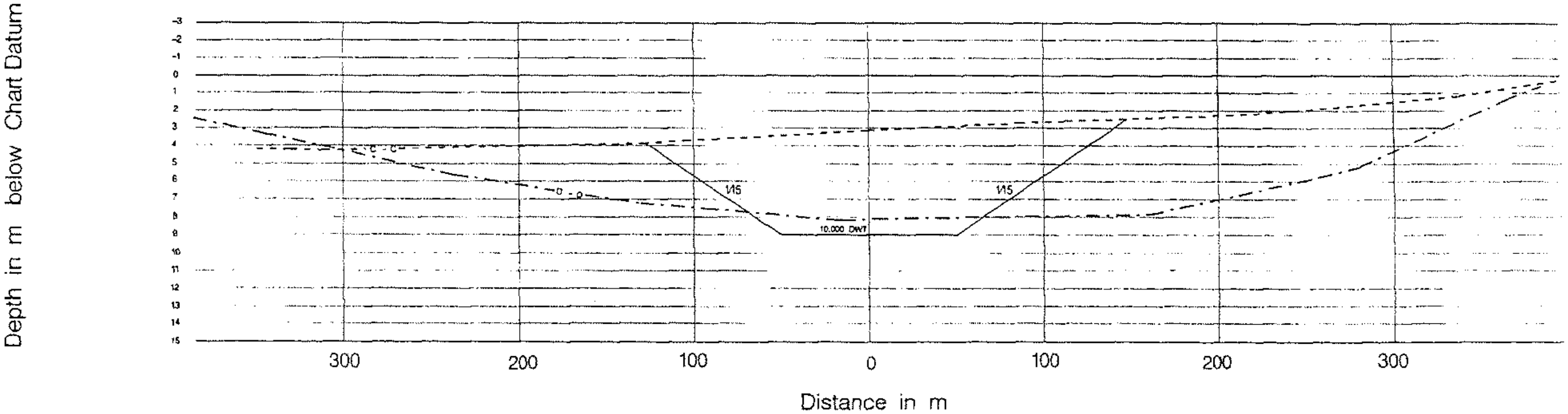
HORIZ. SCALE 0 – 100 m

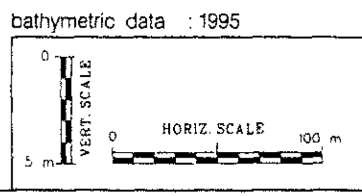
VIETNAM ACCESS CHANNEL TO HAI PHONG

HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS

DESIGN PROFILE AND
CROSS SECTIONS OF THE
EXISTING NAM TRIEU CHANNEL ALIGNMENT

DRA. JRR	APP BLE	VAH35/1	Fig. 3.4 A





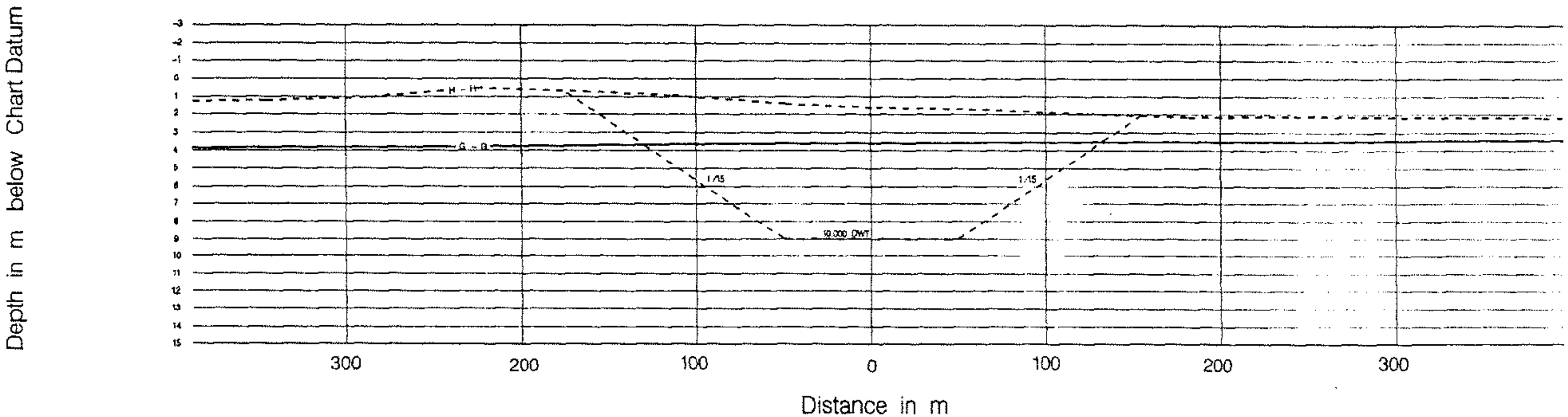
VIETNAM ACCESS CHANNEL TO HAI PHONG

HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS

DESIGN PROFILES AND CROSS SECTIONS OF THE EXISTING NAM TRIEU CHANNEL ALIGNMENT

DRA.: JRR	APP.: BLE	VAH335/	Fig. 3.5

/usr3/projects/vah335/report/fig.3.5_95.dgn



bathymetric data : 1995

VERT. SCALE 0 5 m

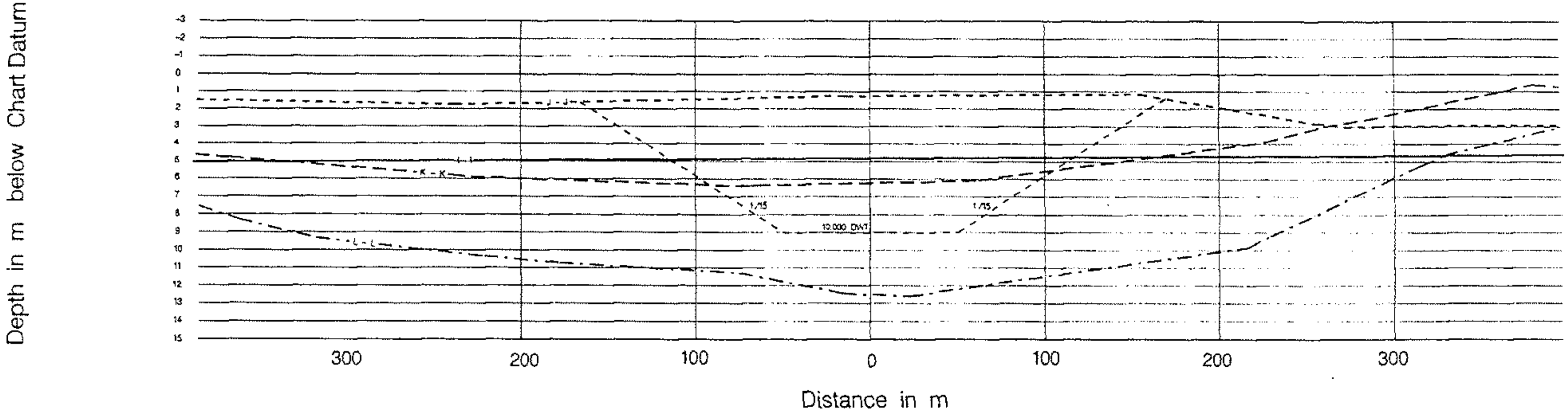
HORIZ. SCALE 0 100 m

VIETNAM ACCESS CHANNEL TO HAI PHONG

HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS

DESIGN PROFILE AND CROSS SECTIONS OF THE NEW NAM TRIEU CHANNEL ALIGNMENT

DRA : JRR	APP : BLI	VAH155/7	Fig. 3.7. A



bathymetric data : 1995

VERT. SCALE 0 5 m

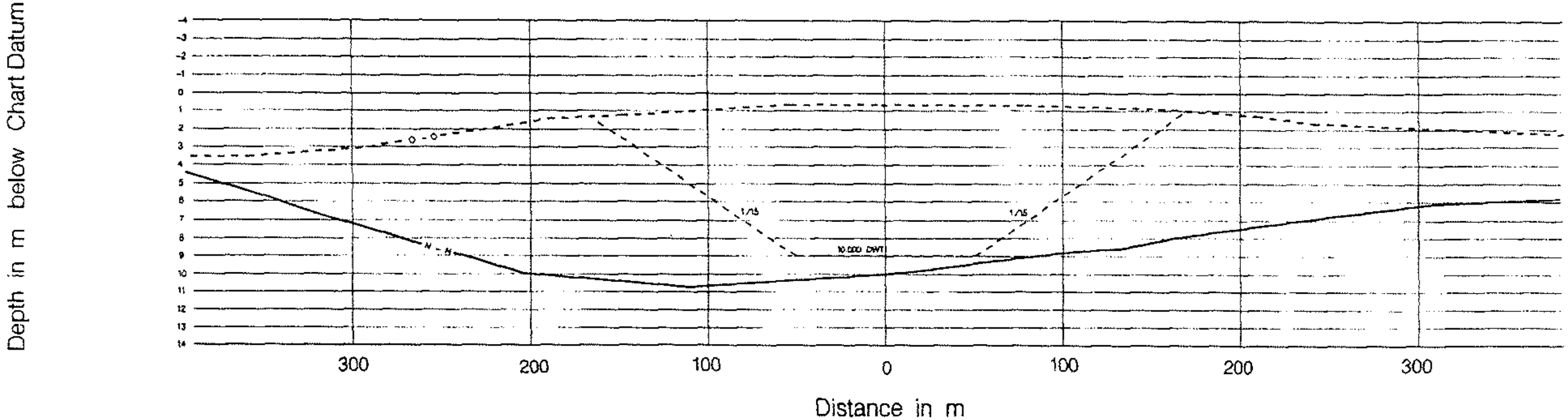
HORIZ. SCALE 0 100 m

VIETNAM ACCESS CHANNEL TO HAIPHONG

HAECON N.V. HARBOUR and ENGINEERING CONSULTANTS

DESIGN PROFILE AND
CROSS SECTIONS OF THE NEW SHIPPING CHANNEL
HAI PHONG - HA NAM - LACH HUYEN

DRA: JRR	APP: BII	VAI/351	Fig 3.9 A



bathymetric data : 1995

VIETNAM ACCESS CHANNEL TO HAI PHONG			
HAECON N.V HARBOUR and ENGINEERING CONSULTANTS	DESIGN PROFILE AND CROSS SECTIONS OF THE NEW SHIPPING CHANNEL HAI PHONG - TRAP CANAL - LACH HUYEN		
DRA. JRR	APP. BLE	VAH'35V	Fig. 3 11

3.3. DESCRIPTION OF CHANNEL ALTERNATIVES (Section I & II) AND OPTIONS

Following channel options have been selected for further evaluation :

ALTERNATIVE 1 : Existing NAM TRIEU channel alignment

- Ship traffic
  10,000 DWT

- Options for infrastructure
  * option 1 : improvement with upgraded dredging programme
  * option 2 : improvement with sedimentation basin
  * option 3 : improvement with training walls

ALTERNATIVE 2 : New NAM TRIEU channel

- Ship traffic
  10,000 DWT

- Options for infrastructure
  * option 1 : new alignment with basic dimensions
  * option 2 : improvement with sedimentation basin
  * option 3 : improvement with training wall

ALTERNATIVE 3 : New alignment of shipping channel in LACH HUYEN through new Ha Nam Canal

- Ship traffic
  10,000 DWT

- Options for infrastructure
  * option 1 : new alignment with basic dimensions
  * option 2 : improvement with training wall
  * option 3 : improvement with use of natural spit

ALTERNATIVE 4 : New alignment of shipping channel in LACH HUYEN through Trap Canal

- Ship traffic
  10,000 DWT

- Options for infrastructure
  * option 1 : new alignment with basic dimensions
  * option 2 : improvement with training wall
  * option 3 : improvement with use of natural spit

Parallel to these works, MOT plans to build a number of hydraulic infrastructures or to carry out interventions which will probably influence or interfere with the above-mentioned options :

1. the sequential removal of the Dinh Vu dam combined with the dredging of a channel in the old Cam River ;
2. the construction of 4 groynes on Bach Dang Left bank ;
3. the construction of 9 groynes in the Cam River.

3.3.1. Existing channel alignment

a) **Lay-out** (Drawing no. 34.20.110)

Coming from the open sea, the Port of Hai Phong is at present accessible through a approx. 19-24 km long existing channel, known as the "Nam Trieu Channel".

The channel can be subdivided into three (3) homogenous geometrical sections :
- 2 straight sections : L1, L2 ;
- 1 bend : B1.

The channel entrance begins with an initial straight section (L1) (KM 36.80 - KM 24.07), according to the alignment of the leading lights at Aval and Ba Tang.
This straight section L1 is followed by a second straight section (L2) over 6.4 km (KM 22.89 - KM 16.50).
The connection between the two (2) straight sections L1 and L2 is ensured by a 1,180 m long bend with a radius averaging 2,000 m.
The straight section (L2) is connected with the Bach Dang River by a 2,200 m long bend B2 (KM 16.50 - KM 14.30) with a radius of 2,000 m.

b) Soil conditions

Available data on soil characteristics show a consolidated mud layer resting on top of silt/clay layers alternating with sand layers locally (e.g. buoys 7/8).

c) Hydrodynamic conditions

The predominant wave direction is SE, almost parallel to the direction of the maritime part of the access-channel ; rolling of ships is expected to be limited while heave is accentuated under strong wave conditions. The dominant tidal currents induce a drift angle of 20° to 30° ; the max. cross current is 0.11 m/sec.

Cross wind of 7.4 m/sec for L1 and 9.3 m/s for L2 have to be taken into account ; however, this values remain quite low and are not expected to influence adversely the navigation.

d) Longitudinal profile

Figure 3.3. shows the longitudinal profile of the sea bottom along the axis of the existing channel (KM 16.50 to KM 36.80). The existing Nam Trieu channel crosses an approx. 14 km long offshore bar. This offshore bar crossing is annually dredged to an effective nautical bottom level of C.D. - 4.10 m to C.D. - 5.00 m.

e) Navigation aids

In the Nam Trieu Channel, the marker buoy system comprises :
- floating marks along the channel (17 buoys) ;
- two fixed leading lights (Aval and Ba Tang).

f) **Design profile for Alternative 1 (fig. 3.4. and 3.5.)**

	10,000 DWT	
	Section I	Section II
KM	36.80 - 22.89	22.89 - 14.30
Nautical depth	CD - 8.50 m	CD - 8.35 m
Dredging depth	CD - 9.00 m	CD - 8.85 m
Width at bottom	100 m at CD - 9.00 m	100 m at CD - 8.85 m
Slope gradient	1/15	1/15

Table 3.T.2.
Design profile for alternative 1

g) **Options**

A possibility to minimise the siltation in the Nam Trieu Channel is to dredge a sedimentation basin in the upstream part. Another possibility to improve alternative 1 is building a training wall parallel to the axis of the channel to avoid lateral inflow of sediments in the channel.
The lay-out of these improvements is described in the report : "Site and project description" (VAH1351/00244).

3.3.2. New Nam Trieu channel alignment

a) <u>Lay-out</u> (Drawing no. 34.20.111)

A possible upgraded alignment of the Nam Trieu Channel, which is described hereafter, has been defined in the light of the following topics :

- shorter navigation distance, with a shorter crossing of the offshore bar ;
- avoid the ship being exposed to cross currents to ensure better ship's navigation.

The selected improved alignment follows a NNW - SSE axis.

b) Soil conditions

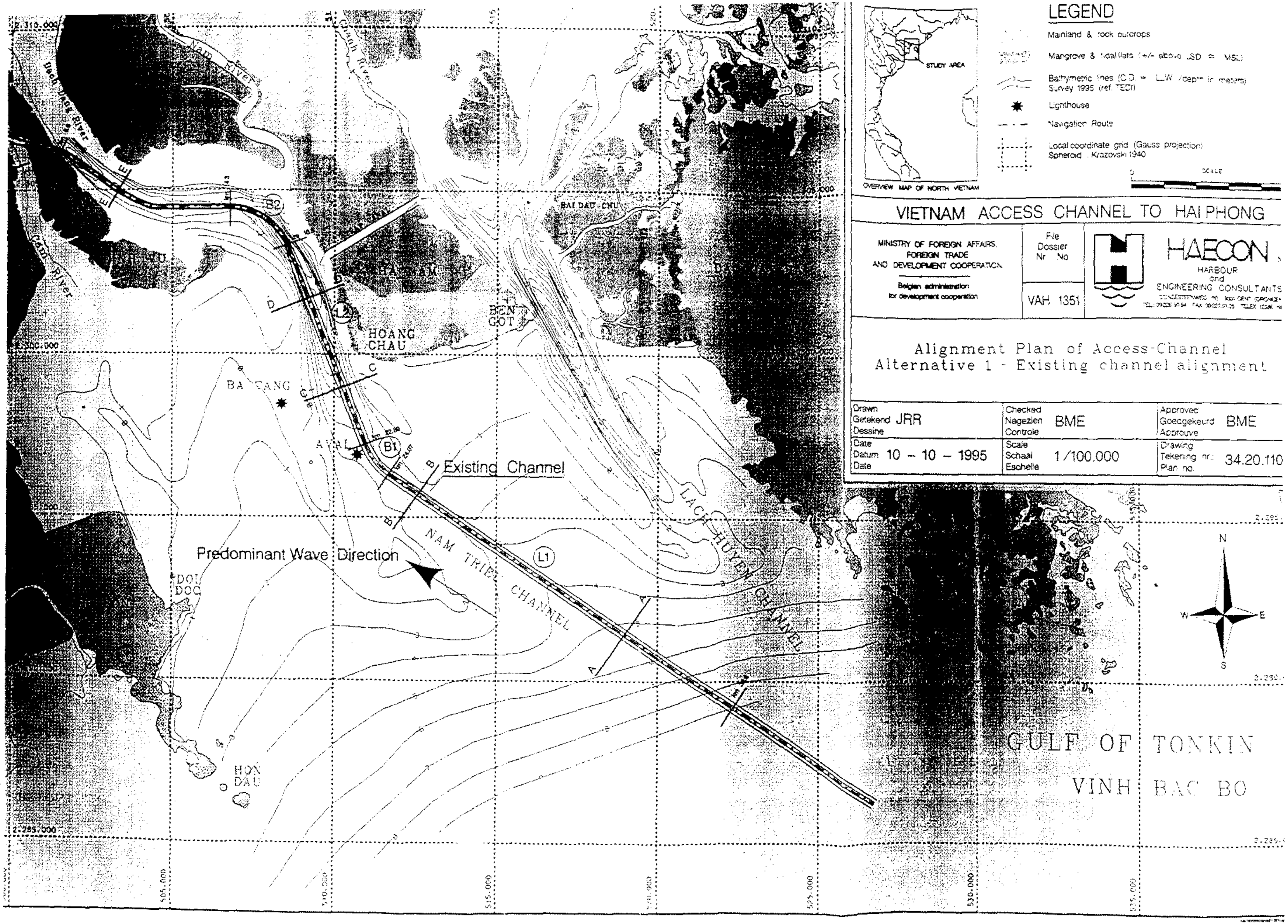
In the maritime part of the proposed access-channel, the soil is expected to be slightly more sandy in the upper meters of the seabed ; this corresponds greatly to the crossing of the submerged sand spit.

c) Hydrodynamic conditions

The predominant wave direction is SE and with a consequent angle of attack of ca. 20° - 30° with the channel. Cross currents are expected to be very low because this alignment is chosen to be parallel to the dominant tidal currents. Cross wind of 9.3 m/sec. has to be taken into account ; this value remains quite low.

d) Longitudinal profile

Figure 3.6. shows the longitudinal profile of the sea bottom along the axis of the proposed new Nam Trieu Channel (KM 16.5 - KM 34.5).



LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+/- above LSD ≈ MSL)
Bathymetric lines (C.D. ≈ LLW / depth in meters)
Survey 1995 (ref. TECI)
Lighthouse
Navigation Route
Local coordinate grid (Gauss projection)
Spheroid : Krazovski 1940
SCALE
STUDY AREA
OVERVIEW MAP OF NORTH VIETNAM
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON
HARBOUR and ENGINEERING CONSULTANTS
Alignment Plan of Access-Channel
Alternative 1 - Existing channel alignment
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 10 - 10 - 1995
Scale Schaal Eschelle 1/100.000
Drawing Tekening nr. Plan no. 34.20.110
Nam River
Bach Dang River
Da Bac River
Gianh River
Cam River
BAI DAU CHU
HOANG CHAU
BEN GOT
BA CANG
AVAL
Existing Channel
NAM TRIEU CHANNEL
LACH HUYEN CHANNEL
Predominant Wave Direction
DOI DOC
HON DAU
GULF OF TONKIN
VINH BAC BO
B2
L2
B1
L1
N
E
S
W
2.310.000
2.300.000
2.285.000
505.000
510.000
515.000
525.000
530.000
535.000

e) <u>Navigation aids</u>

The buoys located north of Aval will remain in place. The buoys located south of Aval must be removed and shifted to the west in accordance with the proposed alignment.

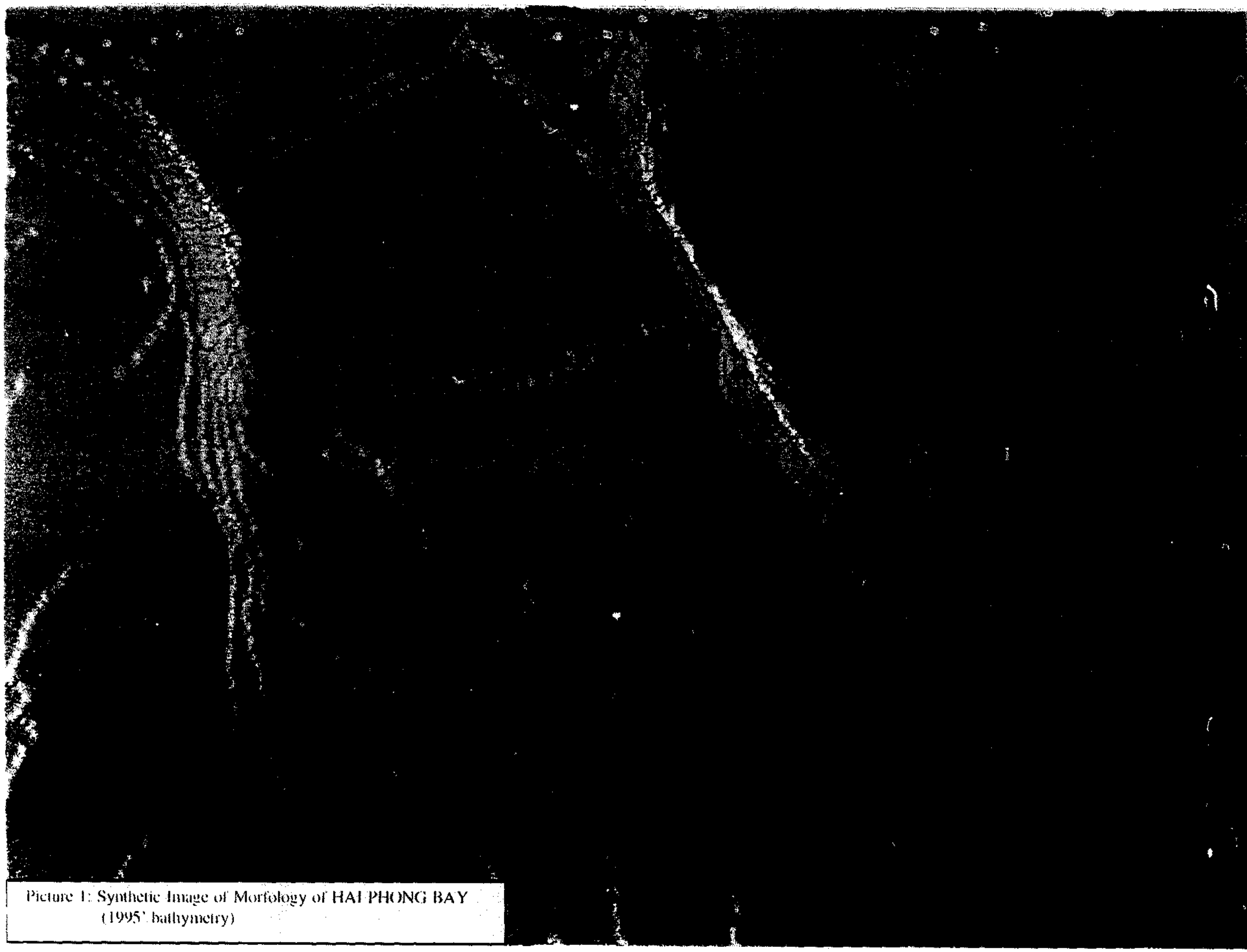
f) **<u>Design profile for Alternative 2</u> (fig. 3.7.)**

	10,000 DWT	
	Section I	Section II
KM	34.5 - 22.89	22.89 - 16.50
Nautical depth	CD - 8.50 m	CD - 8.35 m
Dredging depth	CD - 9.00 m	CD - 8.85 m
Width at bottom	100 m at CD - 9.00 m	100 m at CD - 8.85 m
Slope gradient	1/15	1/15

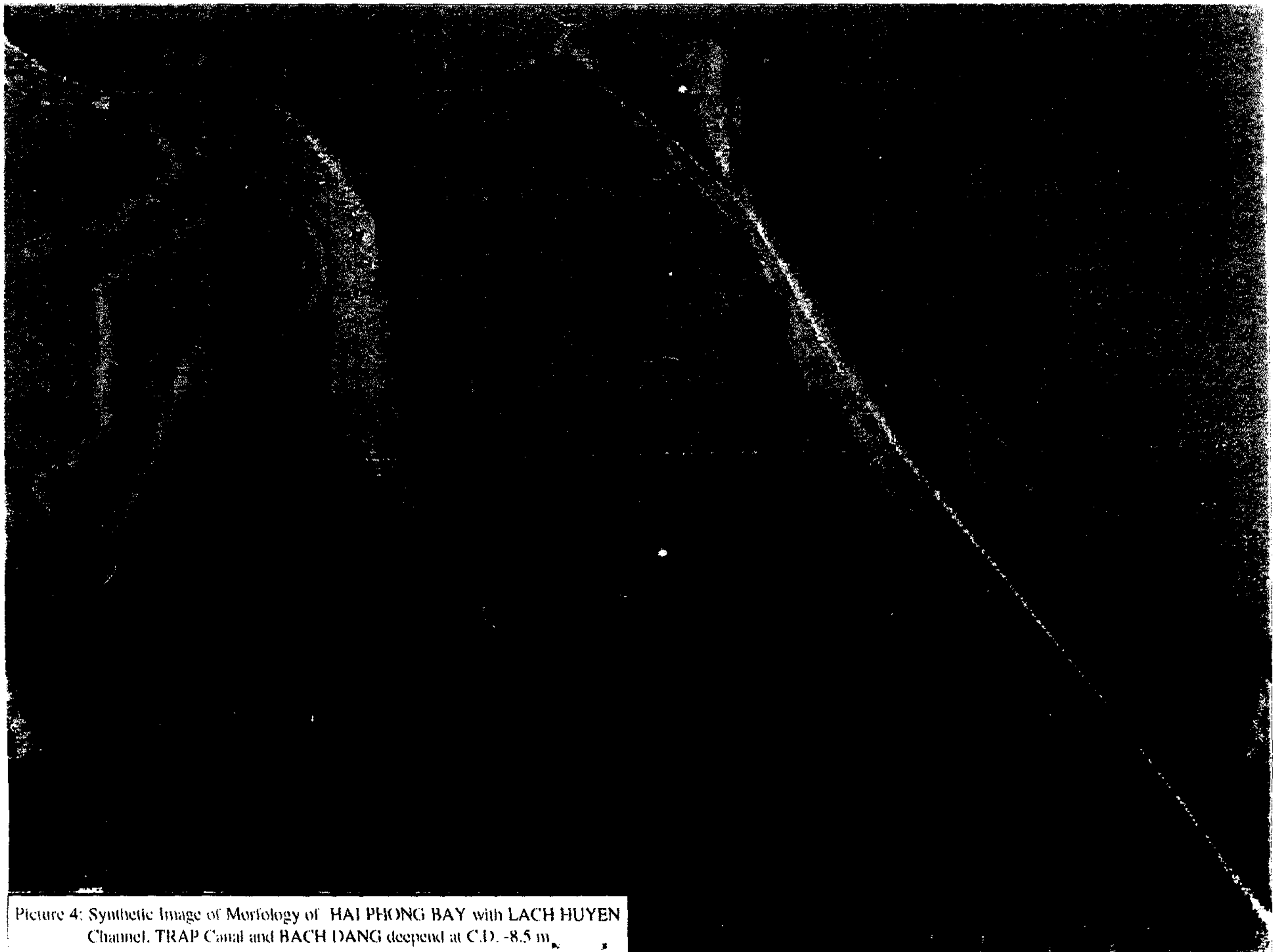
<u>Table 3.T.3.</u>
Design profile for alternative 2

g) **<u>Options</u>**

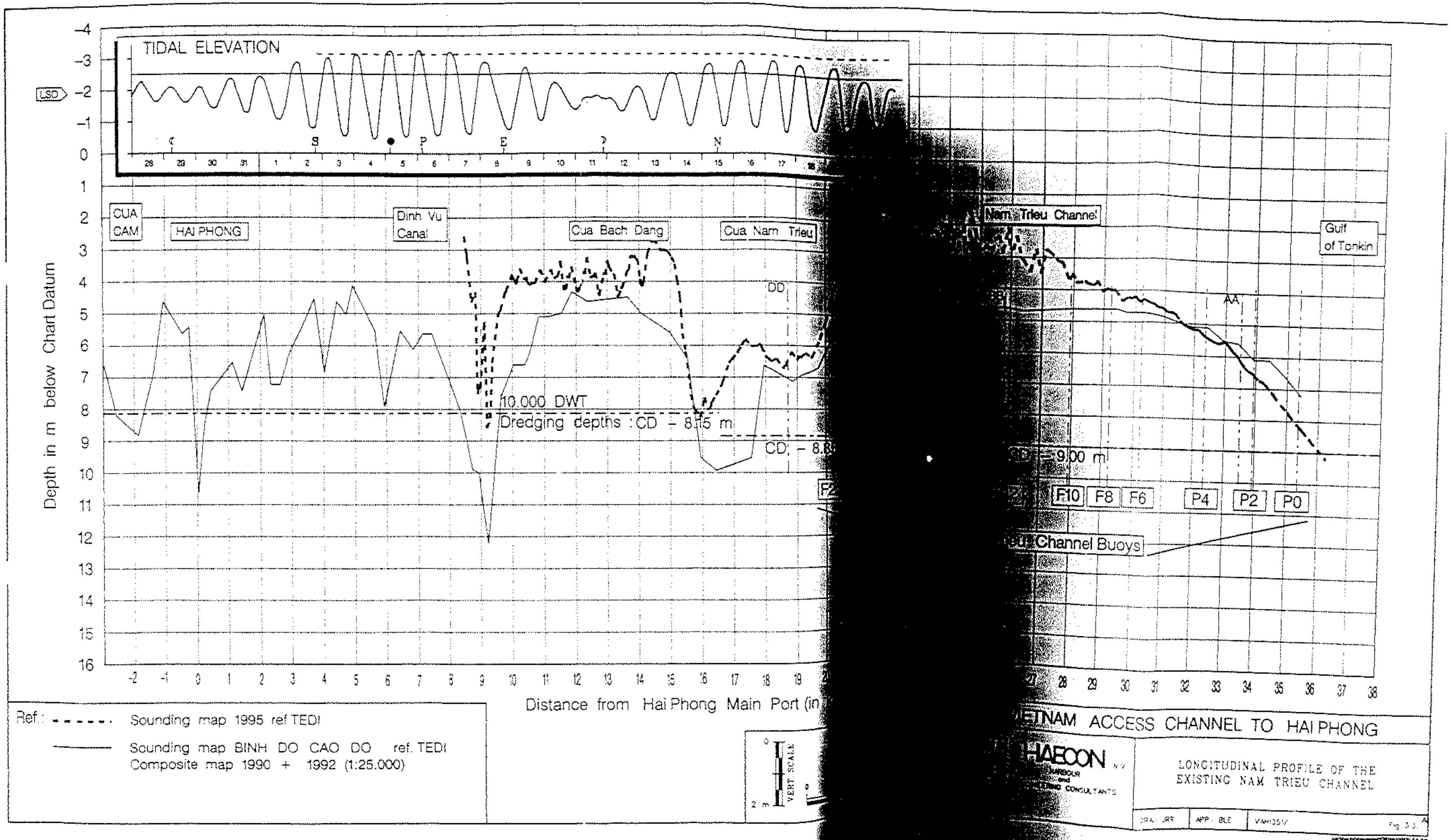
Two possibilities to improve the new Nam Trieu channel are to either dredge a sedimentation basin or to built a training wall parallel to the axis of the channel (reference 15).



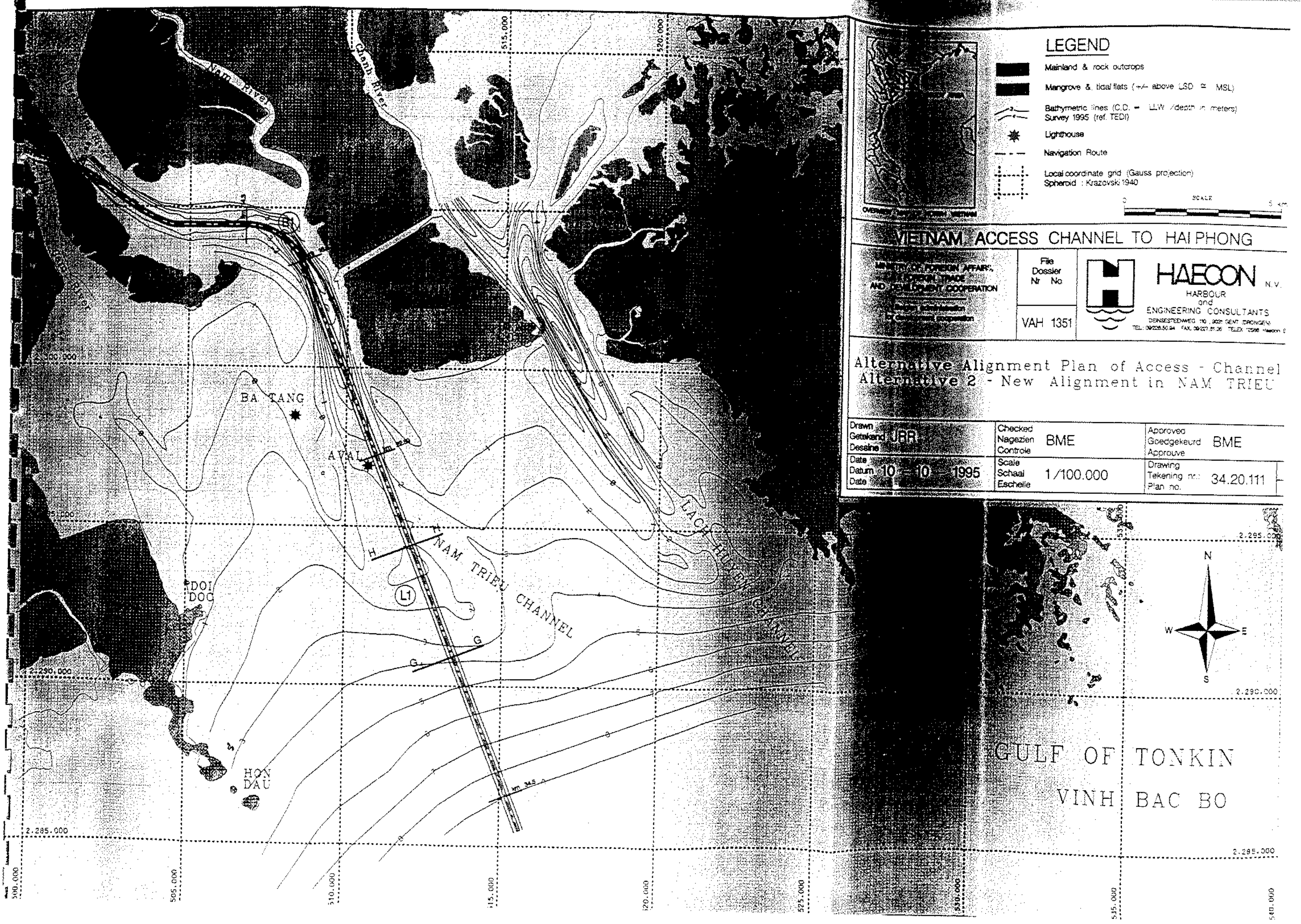
Picture 1: Synthetic Image of Morfology of HAI PHONG BAY
(1995' bathymetry)

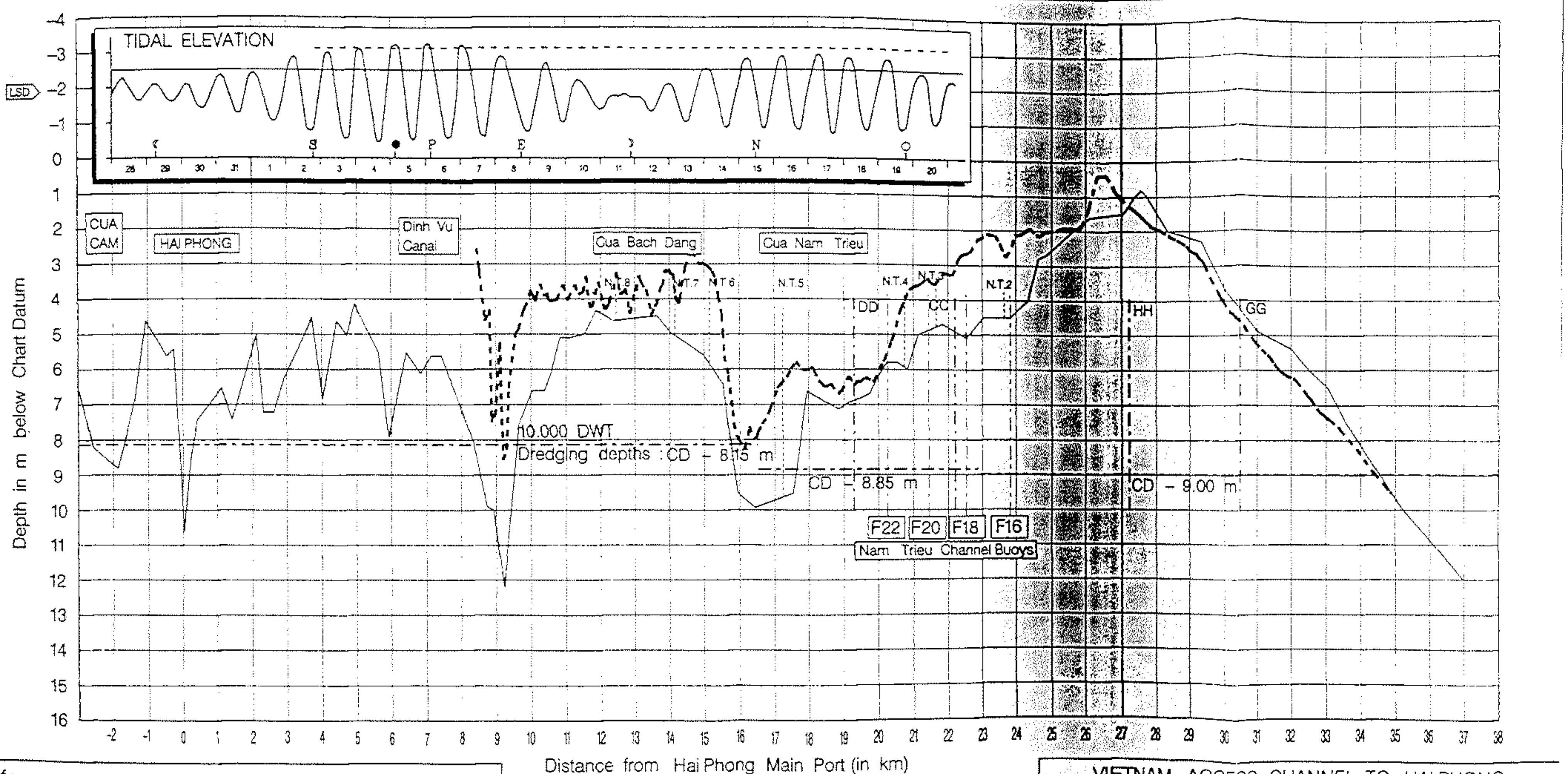


Picture 4: Synthetic Image of Morfology of HAI PHONG BAY with LACH HUYEN Channel, TRAP Canal and BACH DANG deepend at C.D. -8.5 m.



TIDAL ELEVATION
LSD
Depth in m below Chart Datum
CUA CAM
HAI PHONG
Dinh Vu Canal
Cua Bach Dang
Cua Nam Trieu
Nam Trieu Channel
Gulf of Tonkin
DD
AA
10.000 DWT
Dredging depths : CD – 8.15 m
CD – 8.8
CD – 9.00 m
F10
F8
F6
P4
P2
P0
Channel Buoys
Distance from Hai Phong Main Port (in
Ref.: Sounding map 1995 ref TEDI
Sounding map BINH DO CAO DO ref. TEDI
Composite map 1990 + 1992 (1:25.000)
VERT. SCALE
VIETNAM ACCESS CHANNEL TO HAI PHONG
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
LONGITUDINAL PROFILE OF THE EXISTING NAM TRIEU CHANNEL


LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+/- above LSD ≃ MSL)
Bathymetric lines (C.D. = LLW / depth in meters)
Survey 1995 (ref. TEDI)
Lighthouse
Navigation Route
Local coordinate grid (Gauss projection)
Spheroid : Krazovski 1940
SCALE
VIETNAM ACCESS CHANNEL TO HAI PHONG
File
Dossier
Nr No
VAH 1351
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
Alternative Alignment Plan of Access - Channel
Alternative 2 - New Alignment in NAM TRIEU
Drawn
Getekend JBR
Dessine
Checked
Nagezien BME
Controle
Approved
Goedgekeurd BME
Approuve
Date
Datum 10 - 10 - 1995
Date
Scale
Schaal 1/100.000
Eschelle
Drawing
Tekening nr. 34.20.111
Plan no.
Nam River
Chanh River
BA TANG
AVAL
NAM TRIEU CHANNEL
LACH HUYEN CHANNEL
DOI DOC
HON DAU
GULF OF TONKIN
VINH BAC BO
N
W
E
S
2.295.000
2.290.000
2.285.000
500.000
505.000
510.000
515.000
520.000
525.000
530.000
535.000
540.000



Ref.: Sounding map 1995 ref. TEDI
Sounding map BINH DO CAO DO ref. TEDI
Composite map 1990 (1:25.000)

VERT. SCALE 0 – 2 m
HORIZ. SCALE 0 – 5 km

VIETNAM ACCESS CHANNEL TO HAI PHONG

HAECON HARBOUR and ENGINEERING CONSULTANTS

LONGITUDINAL PROFILE OF THE NEW NAM TRIEU CHANNEL

Fig. 3.6.

3.3.3. New alignment in Lach Huyen through Ha Nam Canal

a) **Lay-out** (Drawing no. 34.20.112)

A possible alternative route with respect to the existing Nam Trieu Channel, is the routing of the channel in the natural deep and wide Lach Huyen. Moreover, this route is expected to deliver other advantages :

- the offshore bar is here quite narrow ; consequently the maintenance dredging is expected to be lower than in the Nam Trieu alternatives ;
- the natural channel is (of course) well aligned with the dominant tidal currents ; consequently, no significant cross-currents are expected here for navigation.

The connection between Lach Huyen and the Bach Dang River is planned to take place through a new canal crossing Ha Nam Island.
The channel can be divided into three (3) homogeneous geometrical sections :

- 3 straight sections (L1, L2, L3) ;
- 1 bend : B1.

The channel entrance in Lach Huyen begins with two straight sections L1 (KM 38.70 - KM 28.50) and L2 (KM 28.50 - KM 24.00).
These straight sections are followed by a third straight section (L3) across Ha Nam over approx. 5.0 km (KM 22.20 - KM 17.00).
The connection between the straight sections L2 and L3 is ensured by a 1.80 km long bend B1 (KM 24.00 - KM 22.20) whose radius averages 2,000 m.
The straight section L3 is connected with the Bach Dang River by a 1.46 km long bend B2(KM 17.00 - KM 15.54) with a radius of 2,000 m. This bend is followed by a bend B3, with a 2,000 m radius between KM 15.54 - KM 14.00.
An additional width is recommended on the inside of the bend for entering and leaving the Ha Nam Canal in order to allow for the cross current action. The bottom width in the bend B1 is set at 120 m and in B2 at 100 m(dredged level) over a length of ± 2 km (see drawing 34.20.112).

b) **Soil conditions**

Available data on soil characteristics show :

- superficial sand layers (1 to 2 m) on the offshore bar overlying consolidated mud deposits ;
- consolidated mud on the deeper parts of the channel.

Soil conditions in Ha Nam are quite similar to these in the Trap Canal, i.e. consolidated mud over the first 10-15 m.

c) Hydrodynamic conditions

The predominant wave direction is quite parallel with the channel in the marine sequent. Cross currents in this area are also expected to be very low.

d) Longitudinal profile

Figure 3.8. shows the longitudinal profile of the sea bottom along the axis of the proposed channel.

e) Navigation aids

Since the proposed channel runs according to a new alignment along the whole length, a new marker buoy system (+ leading lights) has to be installed.

f) Design profile for Alternative 3

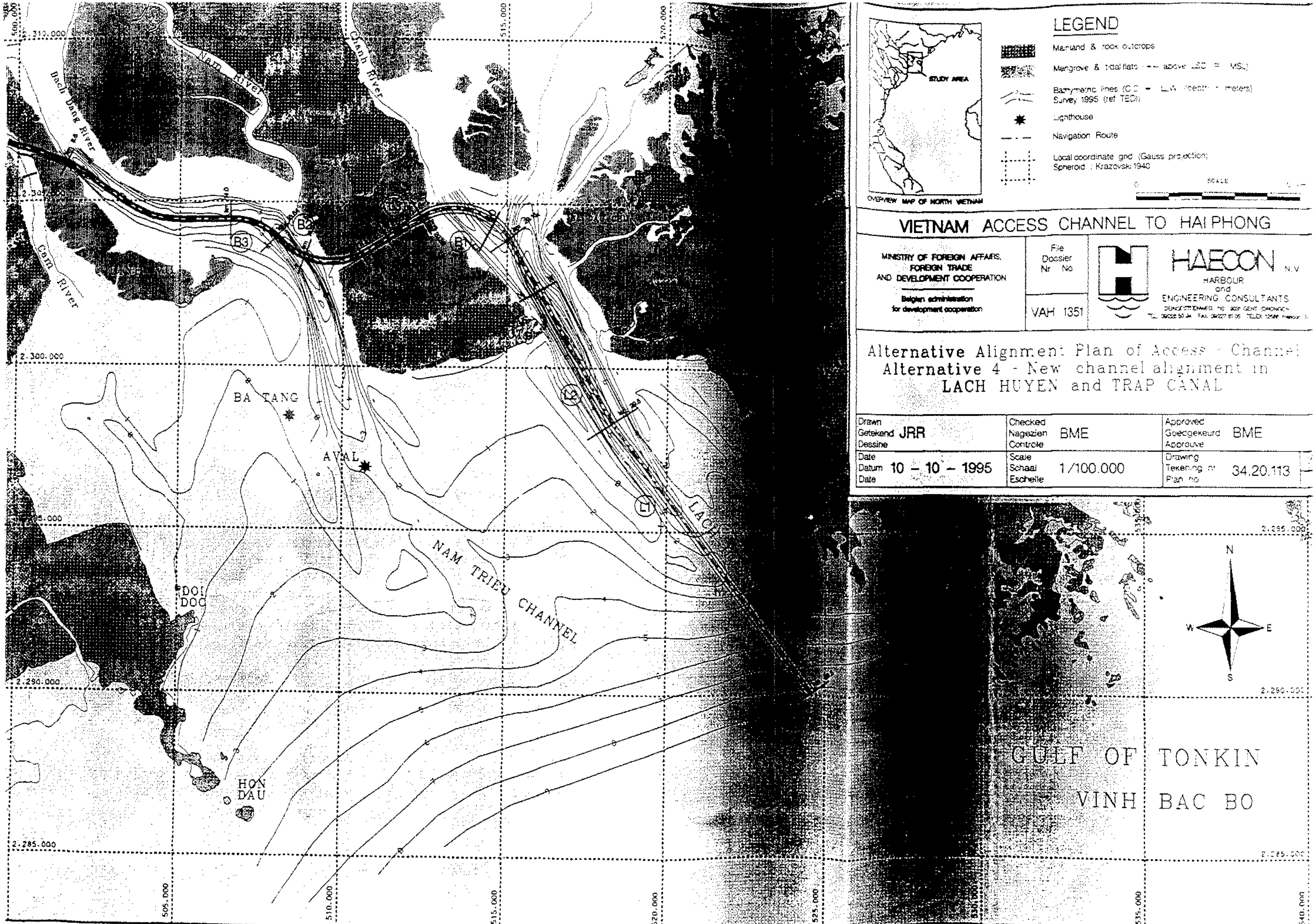
	10,000 DWT	
	Section I	Section II
KM	38.70 - 22.20	22.20- 16.50
Nautical depth	CD - 8.50 m	CD - 8.05 m
Dredging depth	CD - 9.00 m	CD - 8.35 m
Width at bottom	100 m at CD - 9.00 m	80 m at CD - 8.35 m
Slope gradient	1/15	1/5

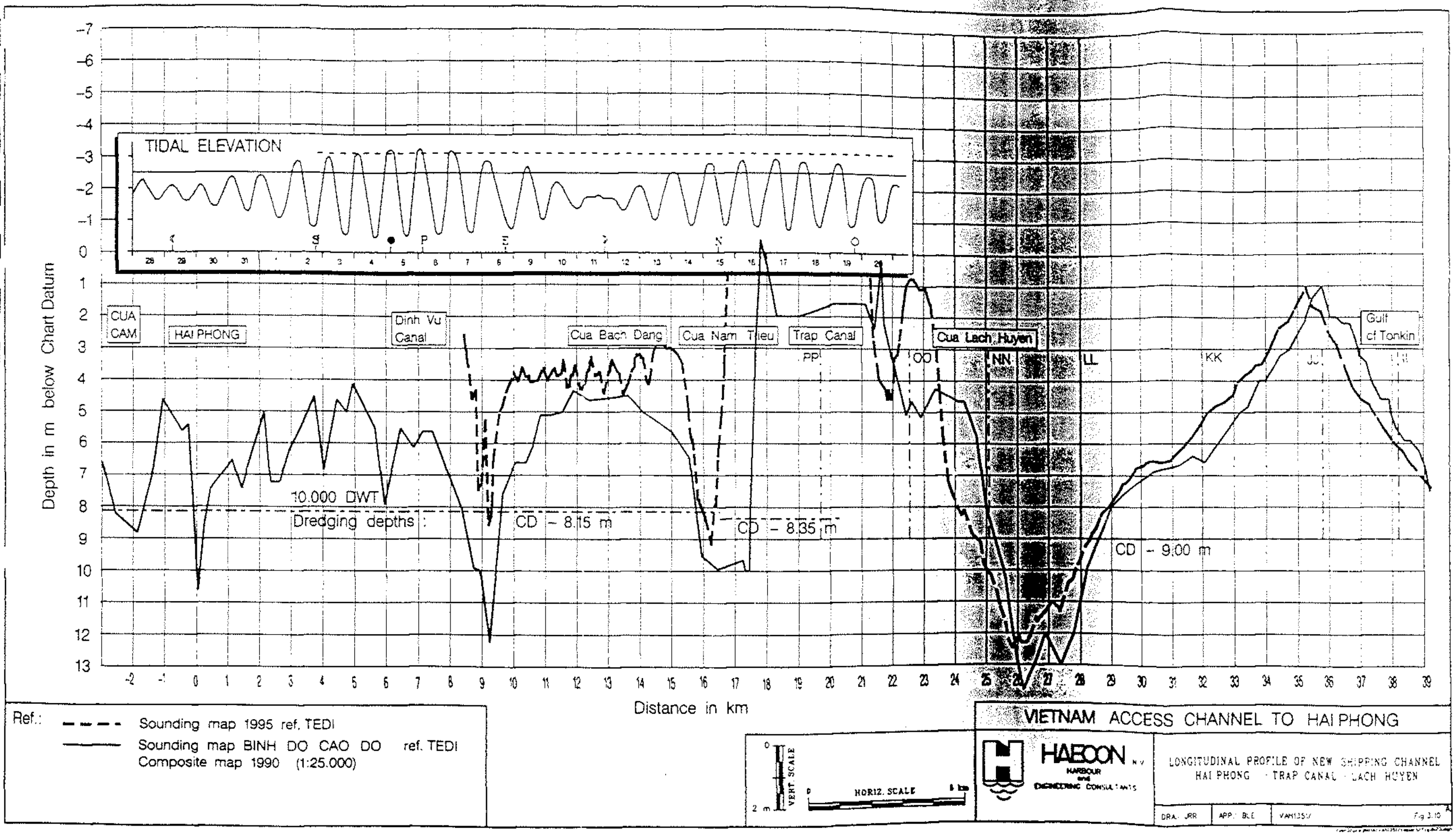
Table 3.T.4.
Design profile for alternative 3

g) Options

The Lach Huyen channel is naturally deep (more than C.D. - 6 m and down to C.D. - 13 m) and wide (500 m) and very little sediment supply occurs from the upstream parts. Moreover, the Lach Huyen is flanked to the West by a submerged spit of more than 5 km length offering natural protection against lateral sediment inflow.
Options for this alternative 3 in order to minimise future maintenance dredging are therefore considered as follows (ref. 15) :

- use and maintenance of the natural spit ;
- improvement of the natural spit by heightening the crest (supply of stones sand).


LEGEND
Mainland & rock outcrops
Mangrove & tidal flats
Bathymetric lines
Survey 1995 (ref TEDI)
Lighthouse
Navigation Route
Local coordinate grid (Gauss projection)
Spheroid : Krazovski 1940
OVERVIEW MAP OF NORTH VIETNAM
STUDY AREA
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V
HARBOUR and ENGINEERING CONSULTANTS
Alternative Alignment Plan of Access - Channel
Alternative 4 - New channel alignment in
LACH HUYEN and TRAP CANAL
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 10 - 10 - 1995
Scale Schaal Echelle 1/100.000
34.20.113
Nam River
Chanh River
Bach Dang River
Cam River
BA TANG
AVAL
NAM TRIEU CHANNEL
DOI DOC
HON DAU
GULF OF TONKIN
VINH BAC BO
N
E
S
W
2.300.000
2.295.000
2.290.000
2.285.000
505.000
510.000
515.000
520.000
525.000
535.000
540.000


TIDAL ELEVATION
Depth in m below Chart Datum
Distance in km
CUA CAM
HAI PHONG
Dinh Vu Canal
Cua Bach Dang
Cua Nam Trieu
Trap Canal
Cua Lach Huyen
Gulf of Tonkin
PP
OO
NN
LL
KK
JJ
10.000 DWT
Dredging depths :
CD - 8.15 m
CD - 8.35 m
CD - 9.00 m
Ref.:
Sounding map 1995 ref. TEDI
Sounding map BINH DO CAO DO ref. TEDI
Composite map 1990 (1:25.000)
VERT. SCALE
HORIZ. SCALE
VIETNAM ACCESS CHANNEL TO HAI PHONG
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
LONGITUDINAL PROFILE OF NEW SHIPPING CHANNEL
HAI PHONG - TRAP CANAL - LACH HUYEN
Fig 3.10

3.3.4. New alignment in Lach Huyen through the Trap Canal

a) Lay-out (Drawing no. 34.20.113)

The major advantages of the Lach Huyen route described as alternative 3 (see par. 3.3.3.) could even be further improved by designing the crossing of Ha Nam Island through the existing Trap Canal. Indeed, this alternative will avoid the possible channelization of the Cam and Bach Dang Rivers water and sediment flows into the Lach Huyen.

The entrance of the new alignment proposed is the same as the one for Alternative 3.
The connection between Lach Huyen and the Bach Dang River is planned through the Trap Canal. The channel can be devided into three (3) homogeneous geometrical sections :
- 3 straight sections : L1, L2, L3 ;
- 1 bend : B1.

The channel entrance in Lach Huyen begins with two straight sections L1 (KM 39.80 - KM 29.50) and L2 (KM 29.50 - Km 23.15), followed by a third straight section (L3) through the Trap Canal (KM 20.38 - KM 18.28).
The connection between the straight sections L2 and L3 is ensured by a 2.77 km long bend B1 (KM 23.15 - KM 20.38) with a radius which averages 2,000 m.
The straight section L3 is connected with the Bach Dang River by a 2.74 km long bend B2 (KM 18.28 - KM 15.54) with a radius of 2,000 m. This bend is followed by a bend B3 with a 2,000 m radius between KM 15.54 - KM 14.00.
An additional width is recommended on the inside of the bend for entering and leaving the Trap Canal in order to allow for the cross current action. The bottom width in the bend B1 is set at 120 m and in B2 at 100 m (dredged level) over a length of ± 2.0 km (see drawing n° 34.20.113).

b) Soil conditions

Available data on soil conditions in the Trap Canal show a top layer of soft sandy silt and soft clay.

Available data on soil characteristics show :
- superficial sand layers (1 to 2 m) on the offshore bar overlying consolidated mud deposits ;
- consolidated mud on the deeper parts of the channel.

c) Hydrodynamic conditions

The hydrodynamic conditions are expected to be the same as these of alternative 3 (new alignment in Lach Huyen through Ha Nam).

d) Longitudinal profile

Figure 3.10. shows the longitudinal profile of the sea bottom along the axis of the proposed channel in Lach Huyen. It crosses an approx. 6 km long offshore bar : the Gulf of Tonkin.

e) Navigation aids

The proposed channel runs according to a new alignment in Lach Huyen. A new marker buoy system has therefore to be installed.

f) Design profile for Alternative 4

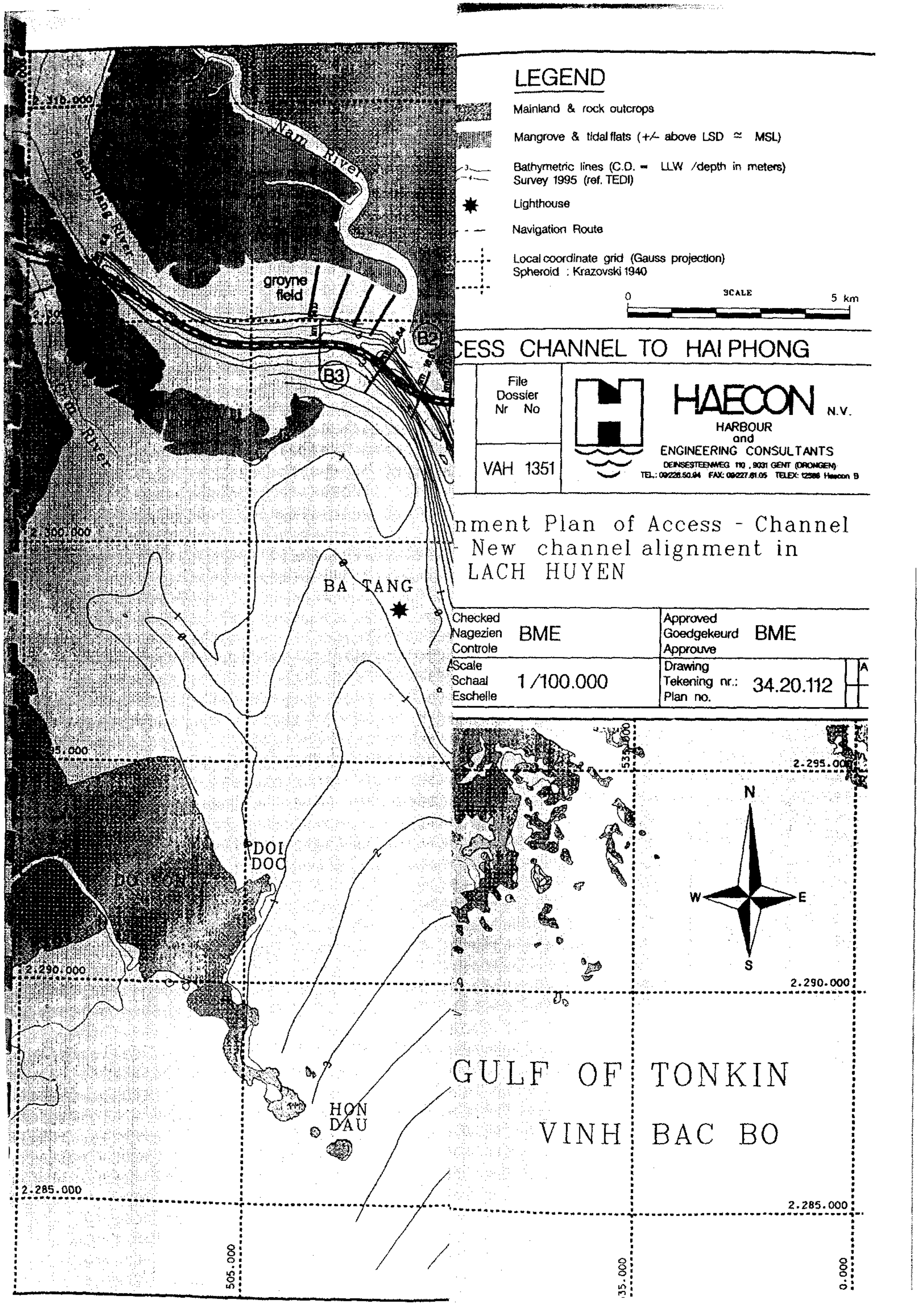
	10,000 DWT	
	Section I	Section II
KM	39.80 - 20.38	20.38- 16.50
Nautical depth	CD - 8.50 m	CD - 8.05 m
Dredging depth	CD - 9.00 m	CD - 8.35 m
Width at bottom	100 m at CD - 9.00 m	80 m at CD - 8.35 m
Slope gradient	1/15	1/5

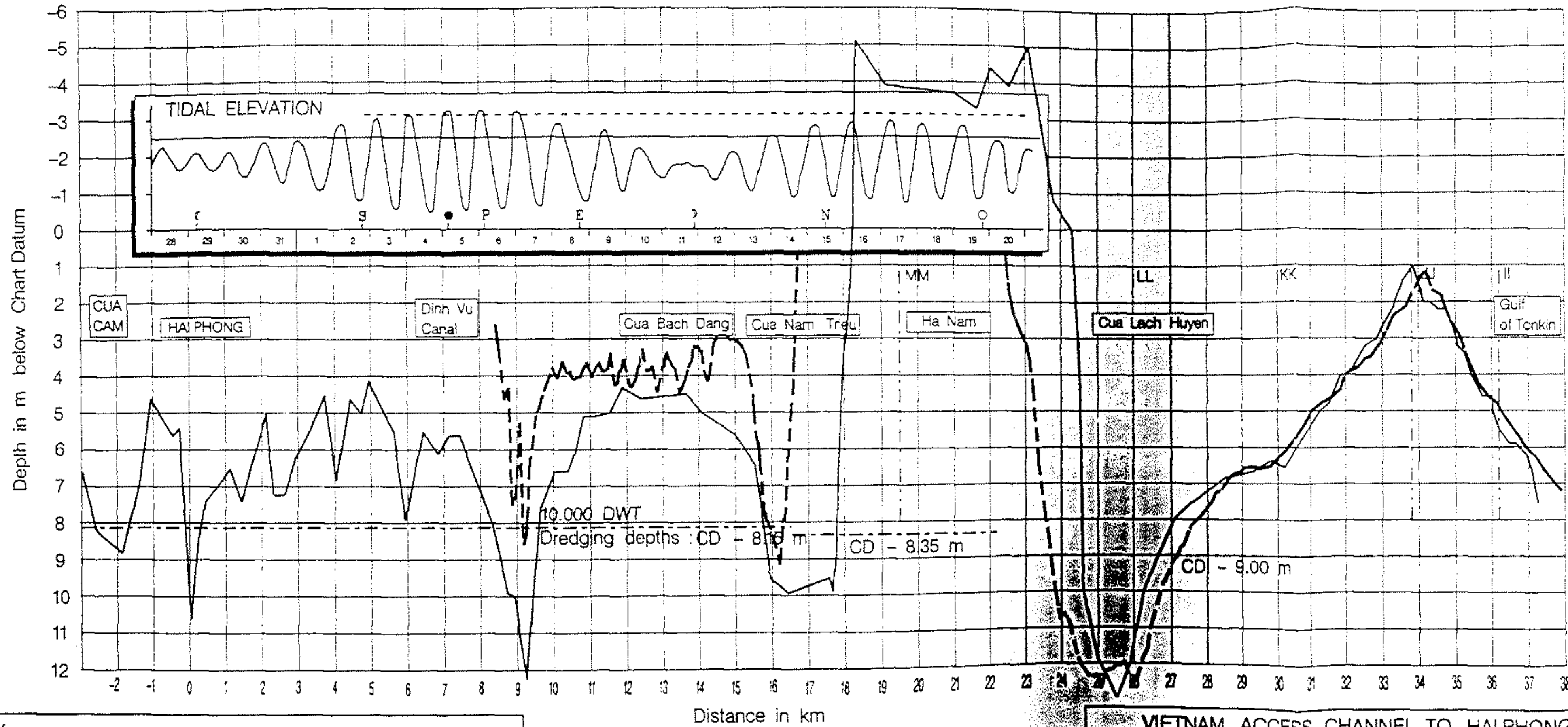
Table 3.T.5.
Design profiles for alternative 4

g) Options

The Lach Huyen channel is naturally deep (more than C.D. - 6 m and down to C.D. 13 m) and wide (500 m) and apparentely very little sediment supply occurs from the upstream parts. Moreover, the Lach Huyen is flanked to the West by a submerged spit of more than 5 km length offering natural protection against lateral sediment inflow.

Options for this alternative 4 in order to minimise future maintenance dredging are therefore considered as follows (ref. 15) :
- use and maintenance of the natural spit ;
- improvement of the natural spit by heightening the crest (supply of stones : see Training Wall).


LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+/- above LSD ≈ MSL)
Bathymetric lines (C.D. = LLW /depth in meters)
Survey 1995 (ref. TEDI)
Lighthouse
Navigation Route
Local coordinate grid (Gauss projection)
Spheroid : Krazovski 1940
SCALE
0
5 km
CESS CHANNEL TO HAI PHONG
File
Dossier
Nr No
VAH 1351
HAECON N.V.
HARBOUR
and
ENGINEERING CONSULTANTS
DEINSESTEENWEG 110, 9031 GENT (DRONGEN)
nment Plan of Access - Channel
- New channel alignment in
LACH HUYEN
Checked
Nagezien
Controle
BME
Approved
Goedgekeurd
Approuve
BME
Scale
Schaal
Eschelle
1/100.000
Drawing
Tekening nr.:
Plan no.
34.20.112
Nam River
Bach Dang River
groyne field
B2
B3
Cam River
BA TANG
DOI DOC
HON DAU
GULF OF TONKIN
VINH BAC BO
N
W
E
S
2.310.000
2.300.000
2.295.000
2.290.000
2.285.000
505.000



Ref.:

- - - - Sounding map 1995 ref. TEDI

—— Sounding map BINH DO CAO DO ref. TEDI
Composite map 1990 (1:25.000)

VERT. SCALE 0 – 2 m

HORIZ. SCALE 0 – 6 km

VIETNAM ACCESS CHANNEL TO HAI PHONG

HAECON N.V. HARBOUR and ENGINEERING CONSULTANTS

LONGITUDINAL PROFILE OF NEW SHIPPING CHANNEL
HAI PHONG - HA NAM - LACH HUYEN

DRA. JRR | APP. BLE | VAH1351/1 | Fig. 3.8

3.4. DISPOSAL AND DUMPING OF CAPITAL DREDGED MATERIAL

The planned channel improvement works involve essentially the excavation of large quantities of sediments - essentially muddy sediments - during the capital dredging (initial excavation) and the subsequent maintenance dredging (yearly operation). In order to design the planned works in an appropriate way it is essential to also design the disposal of the dredged material in such a way that :

a. recirculation of dumped material back to the dredging area is avoided by all means ;
b. maximal beneficial use of dredged material is made possible (e.g. landfilling, ...) ;
c. environmental impacts are minimised.

All above-mentioned topics are strongly related to the type of soil excavated during the dredgings. The soil investigation is not yet terminated and therefore these aspects will be based on the existing knowledge and assumptions.

One can envisage 3 types of disposal of the capital dredging volumes :

1. intertidal flat disposal by thin spreading on mangrove-areas ;
2. landfilling subtidal flats like the ones south of Dinh Vu or Cat Hai ;
3. aquatic dumping.

For maintenance dredging it is expected that the bulk of the material is mud and that upland and intertidal disposal capacity is too limited. Therefore it is proposed that maintenance dredging volumes are disposed by aquatic dumping at waterdepths exceeding C.D. - 10.00 m.

3.4.1. Intertidal flat disposal by thin-spreading

The mangrove areas on the left bank of Bach Dang and on Ha Nam are natural mud sedimentation areas. Even non-flocculated mud can sediment here in between the roots of the mangrove flora.

Because of the particular adaptation of mangrove flora to varying salinities, mud sedimentation and anoxic conditions, intertidal mangroves areas could be envisaged for the thin spreading of a mud layer. It has been assumed that this mud layer may not exceed 0.40 m thickness.

However because of the great environmental importance of mangrove areas a pilot disposal test is highly recommended. It is proposed to execute as soon as possible a thin spreading disposal of ca. 4,000 m³ over a 100 m x 100 m mangrove area and to observe the reaction of the ecosystem over 1 year.

If the results of a pilot-test are positive, a total disposal capacity on intertidal mangroves can be evaluated as follows (see drawing VAH1351/34.20.114).

1. Left Bank Bach Dang :
   - Surface : ± 10.5 Mm²
   - Geometrical Disposal Capacity : ± 4.2 Mm³

2. Ha Nam :
   - Surface : ± 6.5 Mm²
   - Geometrical Disposal Capacity : ± 2.6 Mm³

3.4.2. Landfilling of subtidal flats

South of Dinh Vu and Cat Hai there are large subtidal flats which can be potentially landfilled, provided that the landfill-material has a sufficient sand content or that the soil can be consolidated in a later stage. The landfilling will also require the construction of retaining dikes.

Especially the subtidal flat, south of Dinh Vu seems to be appropriated because of the close presence of the future Dinh Vu Economic Zone and the integration possibilities in the Port's Development Plan.

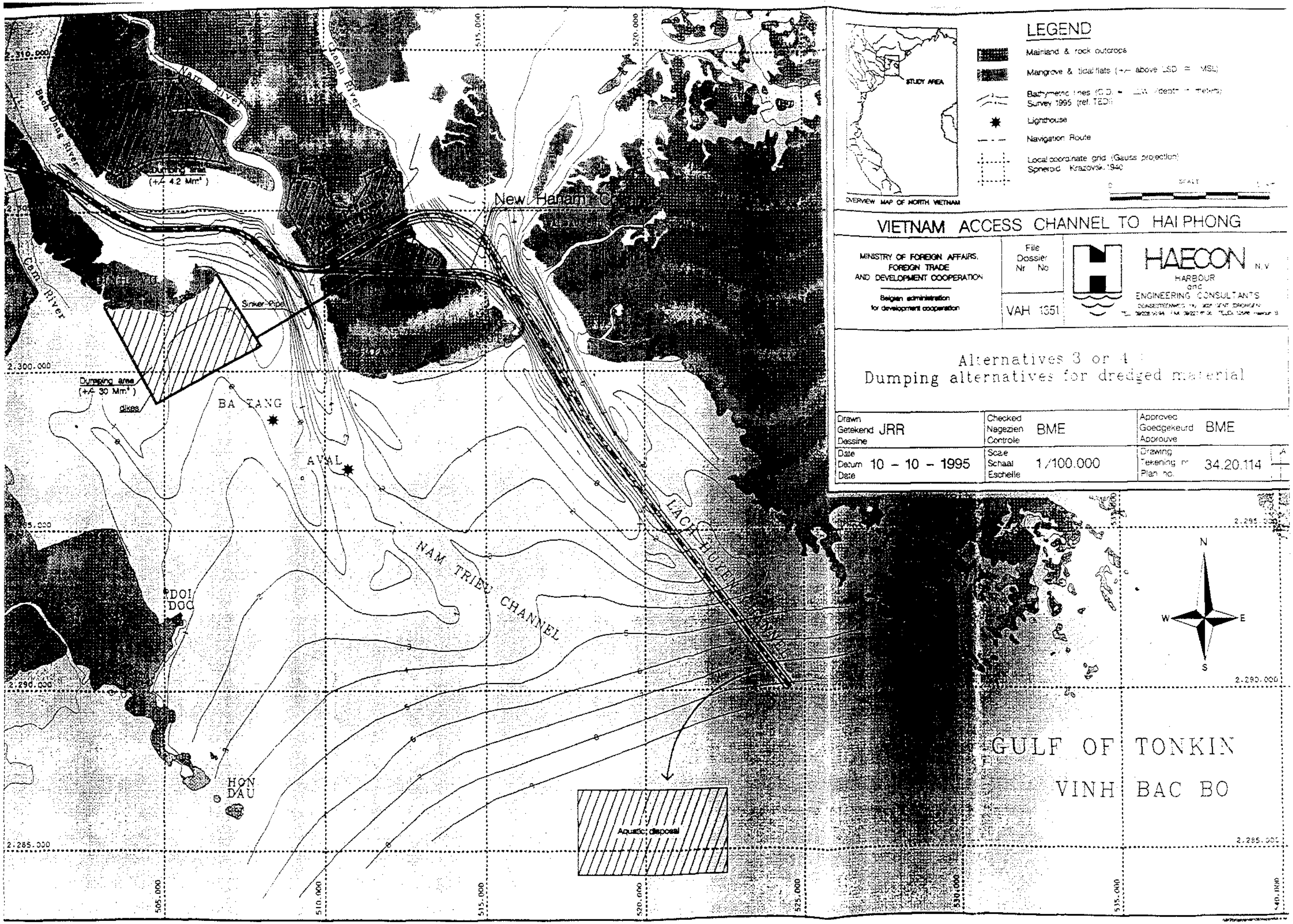
These landfilling works will first require the construction of a soil retaining dike (crest approx. C.D. + 5.50 m) as a rubble-mound breakwater. On drawing VAH1351/34.20.114 a plan view of such a possible landfill disposal facility is illustrated. Total geometric disposal capacity is estimated at ± 30 Mm³.

3.4.3. Aquatic dumping

The most obvious way of disposal the large quantities of muddy dredged material from both capital and maintenance dredgings is the mere aquatic dumping in the Gulf of Ton Kin.

The capacity of this solution is almost unlimited and the environmental impact is estimated to be negligible because the natural fore-delta seabed consists mainly of mud sediments yet.

Regarding recirculation of fine-grained dump-losses back to the dredging area, the residual transport pathways have been computed by Sediment Trend Analysis. Essentially, the very mobile mud-fractions must be looked at in close detail ; from figure 34.20.008, it appears that mud is likely to migrate from offshore to land and on the shallows from the East to the West. It can be assumed consequently that sailing distances from dredging area (Lach Huyen Bar) to dumping area are at minimum 5 km and that natural water depths should be in excess of C.D. - 12.00 m ; moreover must the dumping site be placed to the West of the dredging area in the offshore bar crossing.


LEGEND
Mainland & rock outcrops
Lighthouse
Navigation Route
Survey 1995 (ref. TEDI)
Local coordinate grid (Gauss projection)
STUDY AREA
OVERVIEW MAP OF NORTH VIETNAM
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
Alternatives 3 or 4 :
Dumping alternatives for dredged material
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 10 - 10 - 1995
Scale Schaal Eschelle 1/100.000
Drawing Tekening nr Plan no. 34.20.114
Nam River
Bach Dang River
Chanh River
Cam River
Dumping area (+/- 4.2 Mm³)
Dumping area (+/- 30 Mm³)
Sinker Pipe
dikes
New Hanam Channel
BA TANG
AVAL
NAM TRIEU CHANNEL
LACH HUYEN CHANNEL
DOI DOC
HON DAU
Aquatic disposal
GULF OF TONKIN
VINH BAC BO
N
S
W
E
2.310.000
2.300.000
2.295.000
2.290.000
2.285.000
505.000
510.000
515.000
520.000
525.000
530.000
535.000
540.000

4. SELECTION CRITERIA OF THE CHANNEL

Based on the existing knowledge of the project and the study area, the following criteria have been used versus the channel alternatives in order to perform an objective selection :

1. the volume of capital dredging affecting the capital investment ;
2. the hydraulic and sedimentological impact regarding the modified flow and sediment-transport ;
3. the expected volume of yearly maintenance dredging ;
4. the vertical, horizontal and slope stability of the proposed channel ;
5. the expected social impacts on local land-use, transportation, fishing activities, ... ;
6. the expected environmental impacts especially on mangrove and aquatic ecosystems ;
7. the nautical accessibility of the proposed channel.

Apart from this the possibility/opportunity to implement countermeasures to reduce maintenance dredging will be investigated.

The different criteria will be overviewed now for the 4 channel alternatives.

4.1. CAPITAL DREDGING

4.1.1. Volumes of capital dredging

To make a preliminary comparison of the four (4) alternatives selected, the characteristics of the proposed lay-out and the volumes of capital dredging are given for a 10,000 DWT ship in table 4.T.2.

Area	Section	Method of dredging	Estimated unit cost USD/m³ in situ
- Open water		TSHD	4
- Nam Trieu	I, II	SB	2
- Lach Huyen	I		
- Sheltered areas		CSD	2,5
- Trap Canal	II		
- Ha Nam Canal	II		
- Bach Dang	III		
- Cam River	IV		

Table 4.T.1.
Estimated unit costs for capital dredging

N.B. : TSHD : Trailer Suction hopper Dredger
CSD : Cutter Suction Dredger with 8000 m discharge pipeline
SB : Sweep Beam (bottom levelling)

Table 4.T.1. gives the estimate of the overall unit-cost for capital dredging with discharge or dumping over 8 km distance. It has been assumed in this cost-estimate that local equipment could be used. In case of international bid demand for the capital and/or maintenance dredging works additional cost-items will have to be considered such as :

- mobilisation/demobilisation of equipment ;
  a. mob/demob of a seagoing CSD + gear : ± 2,5 MUSD
  b. mob/demob of a 3000 m³ TSHD : ± 1,5 MUSD
  c. mob/demob of a 7000 m³ TSHD : ± 2,5 MUSD

- down-time and stand-by (weather, traffic, ...) ; for a CSD the following rough figures could apply :
  a. wet season : 35 % down-time
  b. dry season : 10 % down-time

No costs for infrastructure of the upland or tidal flat discharge areas - such as the construction of dikes, weirs, etc... - have yet been foreseen and will have to be designed after decision of the right channel alternative.

Moreover, it has been assumed that capital dredging is to be done in soft soils without wrecks, mines, or any other object likely to impede on normal dredging works. It is absolutely essential to execute a geophysical soil investigation in order to detect the eventual presence of subsoil rock outcrops, likely to affect the dredging methodology and the costs.

A mine hunting/sweeping operation previous to any dredging work is also highly recommended.

The volume of capital dredging has been calculated with an Intergraph Digital Terrain Model (DTM) by comparison of the designed channel dimensions with the modelled 1995 bathymetric survey data. The results of these computations are given in table 4.T.2. (Stage 1 : Urgent Channel Rehabilitation) and table 4.T.3. (Stage 2 : Channel Development Plan).

Layout	Alternative 1 Nam Trieu	Alternative 2 Nam Trieu	Alternative 3 Lach Huyen/ Ha Nam Canal	Alternative 4 Lach Huyen/ Trap Canal
Design profile				
Section I	**Nam Trieu**	**Nam Trieu**	**Lach Huyen**	**Lach Huyen**
- KM	**KM 36.80 - 22.89**	**KM 34.50 - 22.89**	**KM 38.70 - 22.20.**	**KM 39.80 - 20.38**
- nautical bottom	CD -7.20 m	CD -7.20 m	CD - 7.20 m	CD - 7.20 m
- channel dredged level	CD -7.70 m	CD -7.70 m	CD - 7.70 m	CD - 7.70 m
- bottom width	100 m at CD-7.70 m	100 m at CD-7.70 m	100 m at CD-7.70 m	100 m at CD-7.70 m
- slope gradient	1/15	1/15	1/15	1/15
Section II	**Nam Trieu**	**Nam Trieu**	**Ha Nam Canal**	**Trap Canal**
- KM	**KM 22.89 - 16.50**	**KM 22.89 - 16.50**	**KM 22.20 - 16.50**	**KM 20.38 - 16.50**
- nautical bottom	CD -7.20 m	CD -7.20 m	CD -7.20 m	CD -7.20 m
- channel dredged level	CD -7.70 m	CD -7.70 m	CD -7.50 m	CD -7.50 m
- bottom width	100 m at CD-7.70 m	100 m at CD-7.70 m	80 m at CD-7.50 m	80 m at CD-7.50 m
- slope gradient	1/15	1/15	1/5	1/5
Section III	**Bach Dang river**	**Bach Dang river**	**Bach Dang river**	**Bach Dang river**
- KM	**KM 16.50 - 8.60**	**KM 16.50 - 8.60**	**KM 16.50 - 8.60**	**KM 16.50 - 8.60**
- nautical bottom	CD - 7.20 m	CD - 7.20 m	CD - 7.20 m	CD - 7.20 m
- channel dredged level	CD - 7.50 m	CD - 7.50 m	CD - 7.50 m	CD - 7.50 m
- bottom width	80 m at CD -7.50 m	80 m at CD -7.50 m	80 m at CD -7.50 m	80 m at CD -7.50 m
- slope gradient	1/7	1/7	1/7	1/7
Section IV	**Cam river**	**Cam river**	**Cam river**	**Cam river**
- KM	**KM 8.60 - 0.00**	**KM 8.60 - 0.00**	**KM 8.60 - 0.00**	**KM 8.60 - 0.00**
- nautical bottom	CD - 7.20 m	CD - 7.20 m	CD - 7.20 m	CD - 7.20 m
- channel dredged level	CD - 7.50 m	CD - 7.50 m	CD - 7.50 m	CD - 7.50 m
bottom width	80 m at CD -7.50 m	80 m at CD -7.50 m	80 m at CD -7.50 m	80 m at CD -7.50 m
- slope gradient	1/7	1/7	1/7	1/7
Capital dredging (in situ m³)				
Section I	5,530,000	6,560,000	3,930,000	7,000,000
Section II	1,750,000	1,750,000	8,570,000	3,940,000
Section III	1,240,000	1,240,000	1,300,000	1,300,000
Section IV	1,590,000	1,590,000	1,590,000	1,590,000
Total	**10,110,000**	**11,140,000**	**15,390,000**	**13,830,000**
Costs of capital dredging (USD)	**36,195,000**	**40,315,000**	**44,370,000**	**45,075,000**

Table 4.T.2.

Comparison of channel alternatives and volumes of capital dredging for 10,000 DWT ship

Stage 1 : Urgent Channel Rehabilitation Plan

Layout	Alternative 1 Nam Trieu	Alternative 2 Nam Trieu	Alternative 3 Lach Huyen/ Ha Nam Canal	Alternative 4 Lach Huyen/ Trap Canal
Design profile				
Section I	**Nam Trieu**	**Nam Trieu**	**Lach Huyen**	**Lach Huyen**
- KM	**KM 36.80 - 22.89**	**KM 34.50 - 22.89**	**KM 38.70 - 22.20**	**KM 39.80 - 20.38**
- nautical bottom	CD -8.50 m	CD -8.50 m	CD - 8.50 m	CD - 8.50 m
- channel dredged level	CD -9.00 m	CD -9.00 m	CD - 9.00 m	CD - 9.00 m
- bottom width	100 m at CD-9.00 m	100 m at CD-9.00 m	100 m at CD-9.00 m	100 m at CD-9.00 m
- slope gradient	1/15	1/15	1/15	1/15
Section II	**Nam Trieu**	**Nam Trieu**	**Ha Nam Canal**	**Trap Canal**
- KM	**KM 22.89 - 16.50**	**KM 22.89 - 16.50**	**KM 22.20 - 16.50**	**KM 20.38 - 16.50**
- nautical bottom	CD -8.35 m	CD -8.35 m	CD -8.05 m	CD -8.05 m
- channel dredged level	CD -8.85 m	CD -8.85 m	CD -8.35 m	CD -8.35 m
- bottom width	100 m at CD-8.85 m	100 m at CD-8.85 m	80 m at CD-8.35 m	80 m at CD-8.35 m
- slope gradient	1/15	1/15	1/5	1/5
Section III	**Bach Dang river**	**Bach Dang river**	**Bach Dang river**	**Bach Dang river**
- KM	**KM 16.50 - 8.60**	**KM 16.50 - 8.60**	**KM 16.50 - 8.60**	**KM 16.50 - 8.60**
- nautical bottom	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m
- channel dredged level	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m
- bottom width	80 m at CD -8.15 m	80 m at CD -8.15 m	80 m at CD -8.15 m	80 m at CD -8.15 m
- slope gradient	1/7	1/7	1/7	1/7
Section IV	**Cam river**	**Cam river**	**Cam river**	**Cam river**
- KM	**KM 8.60 - 0**	**KM 8.60 - 0**	**KM 8.60 - 0**	**KM 8.60 - 0**
- nautical bottom	CD - 7.85 m	CD -7.85 m	CD - 7.85 m	CD - 7.85 m
- channel dredged level	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m
- bottom width	80 m at CD -8.15 m	80 m at CD -8.15m	80 m at CD -8.15m	80 m at CD -8.15 m
- slope gradient	1/7	1/7	1/7	1/7
Capital dredging (in situ m³)				
Section I	9,010,000	9,770,000	6,680,000	10,600,000
Section II	2,990,000	2,990,000	9,520,000	4,570,000
Section III	1,550,000	1,550,000	1,610,000	1,610,000
Section IV	2,160,000	2,160,000	2,160,000	2,160,000
Total	**15,710,000**	**16,470,000**	**19,970,000**	**18,940,000**
Costs of capital dredging (USD)	**57,275,000**	**60,315,000**	**59,945,000**	**63,250,000**

Table 4.T.3.

Comparison of channel alternatives and volumes of capital dredging for 10,000 DWT ships

Stage 2 : Full Channel Development Plan

4.1.2. Type of soil to be dredged

From the geotechnical soil investigation in Hai Phong bay some general conclusions can be drawn from the seabed (100) sampling and the vibrocoring (50) program (see maps VAH 1351/34.20.005, 006 and 007). The soil investigation has been focused to soft soil survey techniques because it was assumed that the vast majority of soils within reach of the potential capital dredging works (i.e. max. dredging level C.D. - 9.0 m) are Quaternary deposits. In this area of the Red River Basin these Quaternary formations consist mainly of sand and mud from both fluvial and marine origin.

However, special care should be taken regarding the possibility of presence of subsoil rock basement and especially close to Cat Ba (karstic limestone). Moreover, objects like wrecks or mines are likely to occur in these recent deposits. No dedicated survey work (geophysical survey) has been conducted up till now and is imperatively to be foreseen before any commencement of the capital dredging.

The purpose of this criterium is to analyse the feasibility of beneficial use of the capital (and maintenance) dredged material for :

- beach replenishment (Cat Hai, Do Son, ...) ;
- landfill of port development areas (industrial zones in Hai Phong, ...).

The vast majority of soils surveyed along the existing Nam Trieu Channel (see figure 4.1.1) is very soft brown clay with a high plasticity. In Cua Nam Trieu the soil consists essentially of very soft silty clay.

The Lach Huyen offshore bar (alternative 3 + 4) (submerged spit) consists of a 1.5 to 3 m fine to medium sand deposit (see map 34.20.006).

In the Trap canal itself, the soil layers consist essentially of soft dark grey sandy silt (2.5 m), and an underlaying soft clay with high plasticity.

From the maps 34.20.006 (sandlayer thickness from vibrocores) and 34.20.007 (median grain-size of surface samples) the following can be concluded :

- all the spit-like features on both sides of the Nam Trieu/Bach Dang and Lach Huyen consist mainly of very fine, fine or medium sand ;
- the sand deposits of these spit-like features are also reflected by the vibrocorings ; the layer thicknesss varies between 1.5 and 3 m.
- the vast majority of the subtidal flat and deeper deposits consist of silty clay (mud).

On figure 4.1.1. (Existing Nam Trieu) and 4.1.2 (Trap Canal + Lach Huyen) geotechnical/geologic longitudinal profiles are drawn :

- the Nam Trieu Channel bar crossing consists almost completely of silty clay (mud) in a more or less consolidation stage ;
- the Lach Huyen Channel bar crossing has a top 2 - 3 m sand layer on top of a silty/clay deposit.

The surveys executed do not allow to conclude that there are no presences of mines, wrecks and/or subsoil rock outcrops. This should be assessed with a dedicated geophysical survey.

4.1.3. Methods of execution of capital dredging

The method of execution of the capital dredging is closely linked to :

a. the workability of the area (wave action, currents, traffic) ;
b. the soil type ;
c. the disposal site.

Regarding the workability of the area the following classification can be given (see also wave climate simulations par. 4.2.3.5.) :

a. sheltered areas
   - Cam River
   - Dinh Vu Canal
   - Bach Dang upstream
   - Trap Canal
   - Ha Nam Canal
   - Lach Huyen upstream Ben Got

b. partially sheltered areas
   - Bach Dang downstream
   - Lach Huyen between Ben Got and Xuan Dan

c. open sea
   - Lach Huyen Bar
   - New Nam Trieu Bar
   - Existing Channel Nam Trieu

In sheltered areas a Bucket Wheel Dredger (BD), a Grab Dredger (GD) or a Cutter Suction Dredger (CSD with floating or sunken discharge pipe) can be operated ; of course a Trailer Suction Hopper Dredger can also be used. Preference is given to a CSD.

In partially sheltered areas a Bucket Wheel Dredger, or preferably a Trailer Suction Hopper Dredger can be operated.

The non-sheltered areas are best dredged with Trailing Suction Hopper Dredgers with high utility coefficients. In the shallow parts of the channel it is recommended to first dredge a trench with a CSD in sidecasting mode. Afterwards a shallow draught TSHD (e.g. HV = 3000 m^3) can deepen up the channel to allow operations for a larger TSHD (e.g. H.V. = 7000 m^3).

Regarding the soil type, the majority of soils are soft so all types of dredgers are suitable. Even for slopes proposed in the design a Trailing Suction Hopper Dredger can be operated. If rock outcrops are present it is expected that these formations are Carboniferous Limestone, dredgeable with a powerful Seagoing Cutter Suction Dredger. For rock dredging, also rock blasting platforms can be mobilised.

With respect to the disposal it is proposed to dispose the biggest quantity of dredgings by aquatic dumping at great waterdepths (see drawing 34.20.114). The sheltered river sections can profit from special disposal sites to be designed in a later stage. Dumping can be done by Trailer Suction Hopper Dredgers and by split-barges (filled by a Bucket Wheel Dredger, ...).

4.1.4. Conclusions about Capital Dredging

Based on the above-mentioned considerations the following preference classification for the different channel-alternatives is given :

- best : Alternative 1
- second best : Alternative 2
- medium : Alternative 4
- least : Alternative 3

4.2. HYDRAULIC AND SEDIMENTOLOGICAL IMPACT

4.2.1. Introduction

The excavation of a 9.00 m deep channel in the present day seabed will not only influence the seabed topography but will also have a tremendous impact on the local hydrodynamics. The hydraulic and sedimentological impact of the excavation of a channel is expected to be of different orders :

1. modification of flow velocities (change of wet section : slackening or increase of flow) ;
2. channelization of tidal currents and river discharge ;
3. local modification of wave field ;
4. modification of tidal wave propagation;
5. modified sediment transport system and induction of erosion or sedimentation ;
6. upstream morphological changes.

The complexity of the hydrodynamics in the bay of Hai Phong necessitates a specific approach for the prediction of these hydraulic impacts :

1. river discharge measurements (wet and dry season) ;
2. fixed station profilings ;
3. bathymetric survey ;
4. sedimentological survey ;
5. hydraulic and sedimentological mathematical modelling.

The survey activities and basic understanding of the present day situation has been described in detail in the " Site and Project Description " report VAH1351/00244 (ref. 15).

Therefore, this paragraph will present the mathematical modelling results as for today based on existing data and implemented with the 1995 bathymetry and seabed sediment characteristics. The 1992 and 1995 fixed station profilings have both been used for the setting of the boundary conditions of the model.

4.2.2. Hydrodynamic modelling set-up

In order to study the sediment transport processes in the approaches to Hai Phong Port, it was first necessary to establish a hydrodynamic flow model. In the case of Hai Phong approaches a three-dimensional flow model was necessary for the simulation of wet season conditions because of the complex vertical structure of the flow (salt-wedge), whereas for dry season conditions a two-dimensional depth averaged flow model could be used.

The model selected was the HR Wallingford TIDEFLOW 3D (3 dimensions) model that solves the 3D shallow water equations on a square grid including the effects of salinity variation.

4.2.2.1. Bathymetry data sources

The numerical flow model requires first a representation of the bathymetry of the area to be modelled. The initial model bathymetry data for the model was digitised from two sources ; first, a compilated map of different bathymetric surveys on scale 1:25,000 and executed between 1989 and 1991 and secondly a 1:25,000 chart produced from a survey undertaken in 1993 by the Transport and Engineering Design Institute, Vietnam (TEDI), it covered an area from Hon Dau to Cat Ba.
This data was supplemented from the 1:75,000 Admiralty chart number 3875 "Hai Phong to Cam Pha" (which included corrections to 1986) to produce a bathymetry data set which extended from the Southern point of Cat Ba to Hon Dau and included the major channels such as Lach Huyen, Bach Dang and the Cua Cam upstream of Hai Phong itself. From October on, the new bathymetric survey data (July - September '95) have been provided by TEDI. These new bathymetry has been used for the final simulations.
All depths were relative to Chart Datum which was considered not to vary significantly over the area represented in the model.

4.2.2.2. Model setting up procedure

The initial digitised data was interpolated onto a square grid of cell size 200 m. This grid was aligned 28° West of North to enable the two deep channels of Cua Nam Trieu and Lach Huyen to be aligned with the model grid.

The interpolation procedure first interpolates onto a grid smaller than the model grid size and then averages along the cell sides to ensure that the cross-sectional area of each cell face is correct. This cross-sectional area in turn influences the discharge through the cell face.

The resulting model bathymetry extended from Cat Ba to Hon Dau and included Lach Huyen as far as Mango Island, Bach Dang and Cua Cam stretching 3 km upstream of Hai Phong. This area was considered sufficiently large for the calculation of realistic flows in the areas of interest. The model had 122 columns and 171 rows of cells of which 9377 were active (Figure 4.2.1.).

Some checking and adjustment of the narrower channels was still necessary because of the relatively coarse representation of some of the narrower channels by the 200 m model grid.

These and other subsequent changes to the initial model set-up were the following :

- extra data was added to improve the representation of the deepest section of Lach Huyen and Cua Nam Trieu,
- the Trap Canal was deepened to 1.8 m below Chart Datum,
- the confluence of the Song Nam with Cua Cam Trieu was deepened,
- the Dinh Vu Dam was put in place,
- the Dinh Vu Canal was deepened with special care taken at its confluence's with Cua Cam and Bach Dang,
- Cua Cam was also deepened upstream of the Dinh Vu Canal.

4.2.2.3. Accuracy of model bathymetry

The model bathymetry contours were compared with the initially digitised contours by overlaying the digitised contours onto plots of the model bathymetry. The model contours produced were generally accurate to better than ± 0.3 m when compared in this way.

Maximum depths in the deepest channels were also compared in Lach Huyen, Bach Dang and Cua Cam Trieu. The model was within ± 1 m of the surveyed depths at the deepest point.

From this comparison it has been confirmed that the model represents the main features of the bathymetry adequately for the purpose of the study. The final model bathymetry is shown as Figure 4.2.1.

During the course of the study the new data from the TEDI 1995 was also used to compare with the model bathymetry.

4.2.2.4. Hydrodynamic Boundary Conditions

In order to simulate the tide in the numerical model then it is necessary to impose hydraulic boundary conditions on the open boundaries of the model. The model included five boundary segments where it was necessary to define the boundary conditions. The southern boundary of the model was set as a tidal elevation boundary and tidal discharge boundaries were imposed landward of Lach Huyen, at Bach Dang, Song Nam and Cua Cam.

The data used for these boundary conditions came from Reference 8. This report included observed velocity cross-sections at Bach Dang, Lach Huyen and Song Nam. These were used to calculate the tidal discharge through these sections and so calculate the imposed boundary velocities upstream of them. The Bach Dang section was downstream of the confluence of the Dinh Vu Canal with Bach Dang and so the discharge calculated there was distributed between Cua Cam and Bach Dang itself. The tide curve observed on the same day as the velocity cross-sections was used to define the water elevation between Hon Dau and Cat Ba.

The Admiralty Tide Tables quote the tidal harmonic constituents for Hon Dau and Apowan which is on Cat Ba at the eastern end of the model tidal elevation boundary.

At these sites the main semi-diurnal constituents (M2 and S2) are very small (0.05 m or less) and so the tidal propagation is dominated by the diurnal harmonic constituents (O1 and K1). Of these the K1 differs by only 1° of phase and 0.01 m in amplitude and the O1 differs by 0.04 m amplitude and 12° phase between Hon Dau and Apowan. The tidal elevation could therefore be assumed not to vary along the length of the seaward boundary.

4.2.2.5. Calibration and Validation

It was necessary to simulate the hydrodynamics for differing tidal and seasonal conditions at Hai Phong. To this end four representative tidal conditions were chosen and comparisons were made with observed data for each. They were spring and neap tides for both the wet and dry seasons.

All of the tides simulated were for a full diurnal period (i.e. 25 hours) because as mentioned above the diurnal component of the tide is much larger at Hai Phong than the semi-diurnal component.

The following acceptance procedure of the model has been applied :

a) the calculated flow velocities and directions were compared with the data of the fixed station profiling (see e.g. figures 4.1.3, 4.1.4, 4.1.5) ;
b) the calculated salinities were compared with the data of the fixed station profilings (figures 4.1.6, 4.1.7, 4.1.8) ;
c) the calculated suspension concentrations were compared with the data of the fixed profilings (see e.g. figures 4.1.9, 4.1.10, 4.1.11) ;
d) the calculated wave climate at Aval (and Hon Dau) was compared to the observed data (see further) ;
e) the calculated annual infill rate was compared with the observed data deduced from cross-sectional profilings in Nam Trieu since 1990 (for both Wet and Dry Season) (see figures 4.3.2 and 4.3.3) ;
f) the calculated infill rate of the Lach Huyen pilot channel was compared to the observed data deduced from the cross sectional profilings ;
g) sand transport computations have been checked against bed-load tracer tests carried out (measured sand transport rates by the Nuclear Institute of Dalat and close to Buoy 9, 10, 11, 12 are 0.4 to 0.8 $m^3/m'.day$) ;
h) calculated model points of residual transports are compared with processed reflectometry on satellite images for check of the position of turbidity maximum ;
i) calculated residual sediment transport is checked against results of sediment trend analysis.

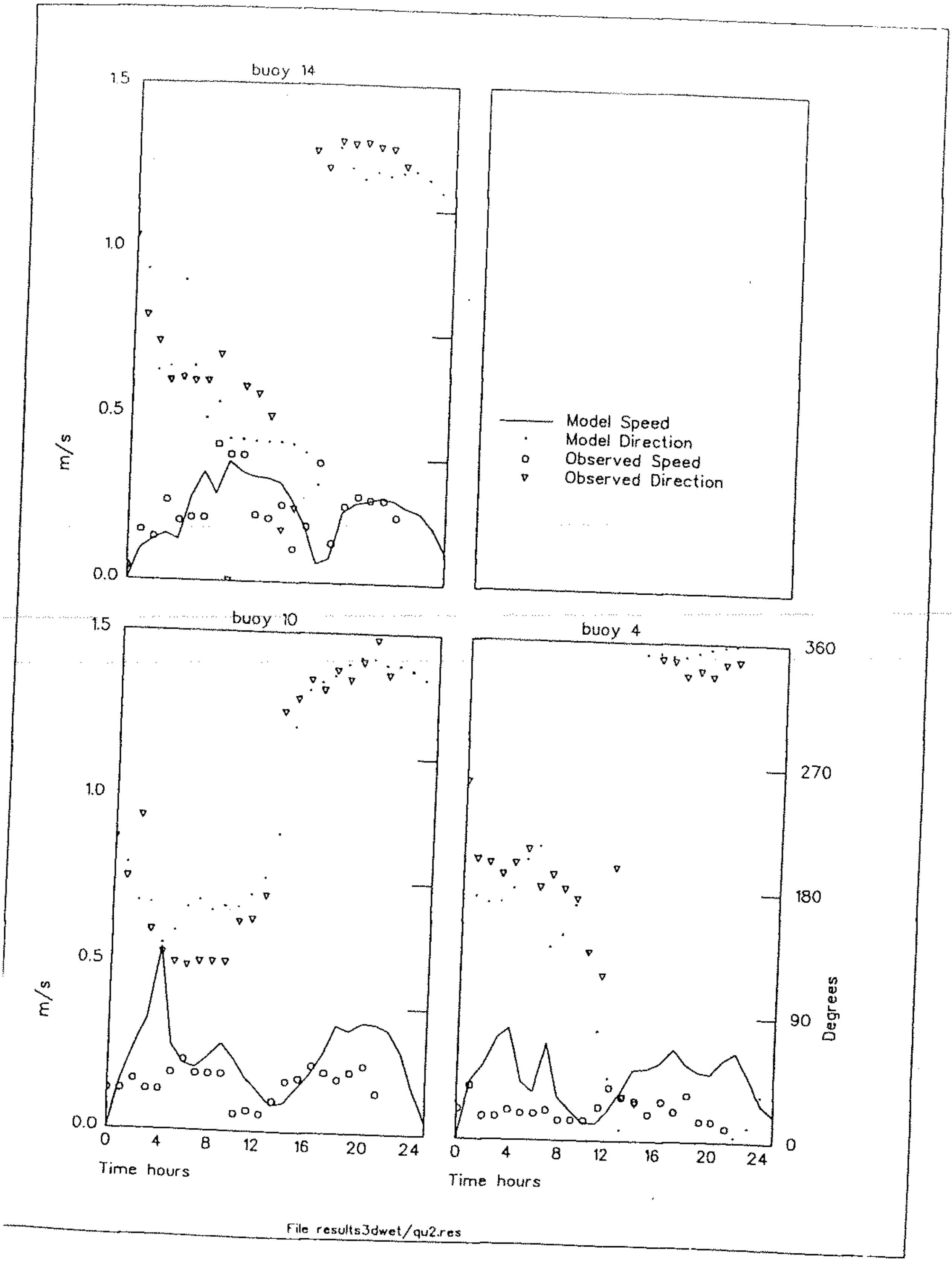


Figure 4.1.3.
Hai Phong Channel model velocity calibration
Wet season, Spring tide Bed Observations

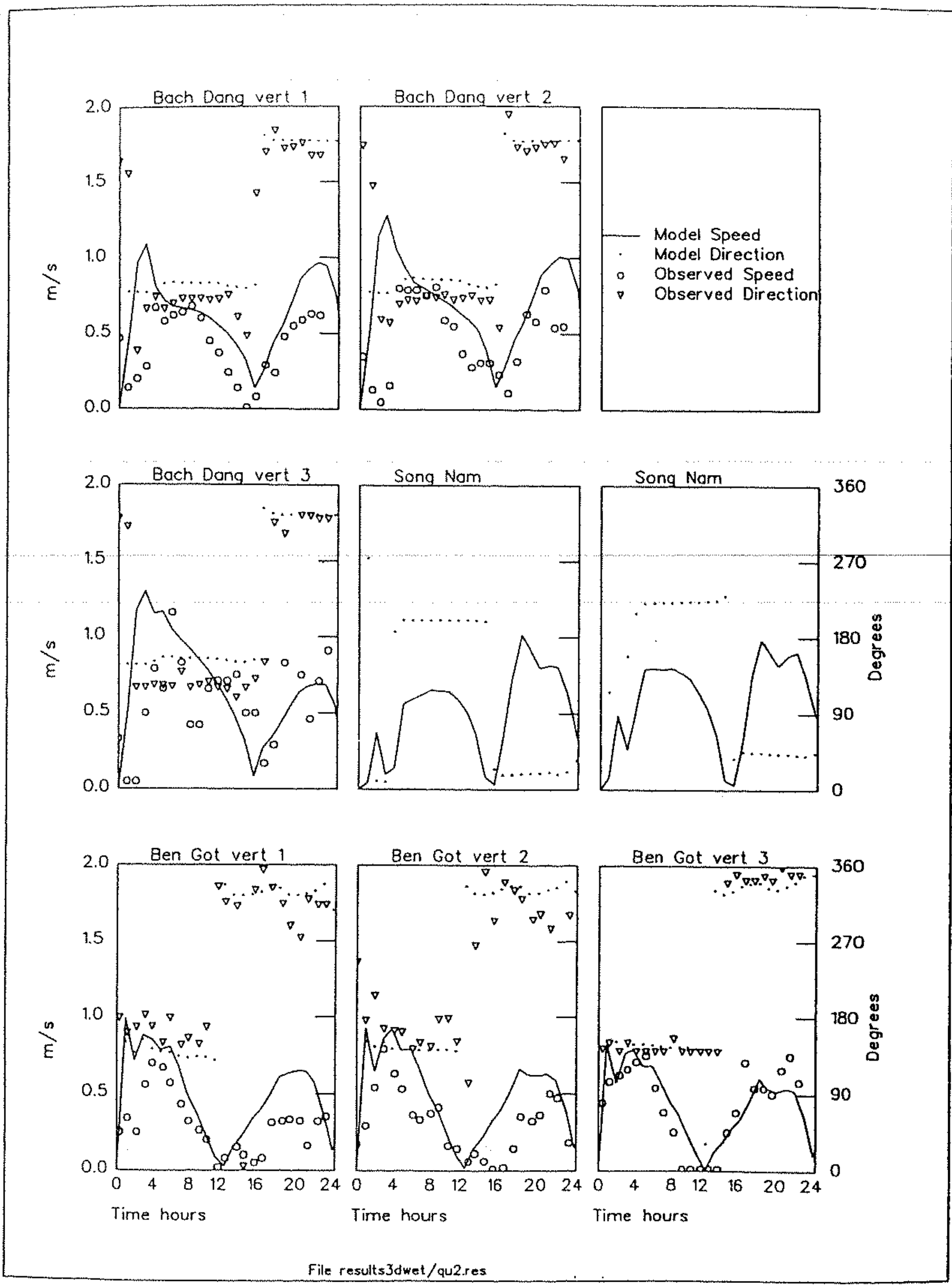


Figure 4.1.4.

Calibration results, Wet Season, Spring tide

Bed observations

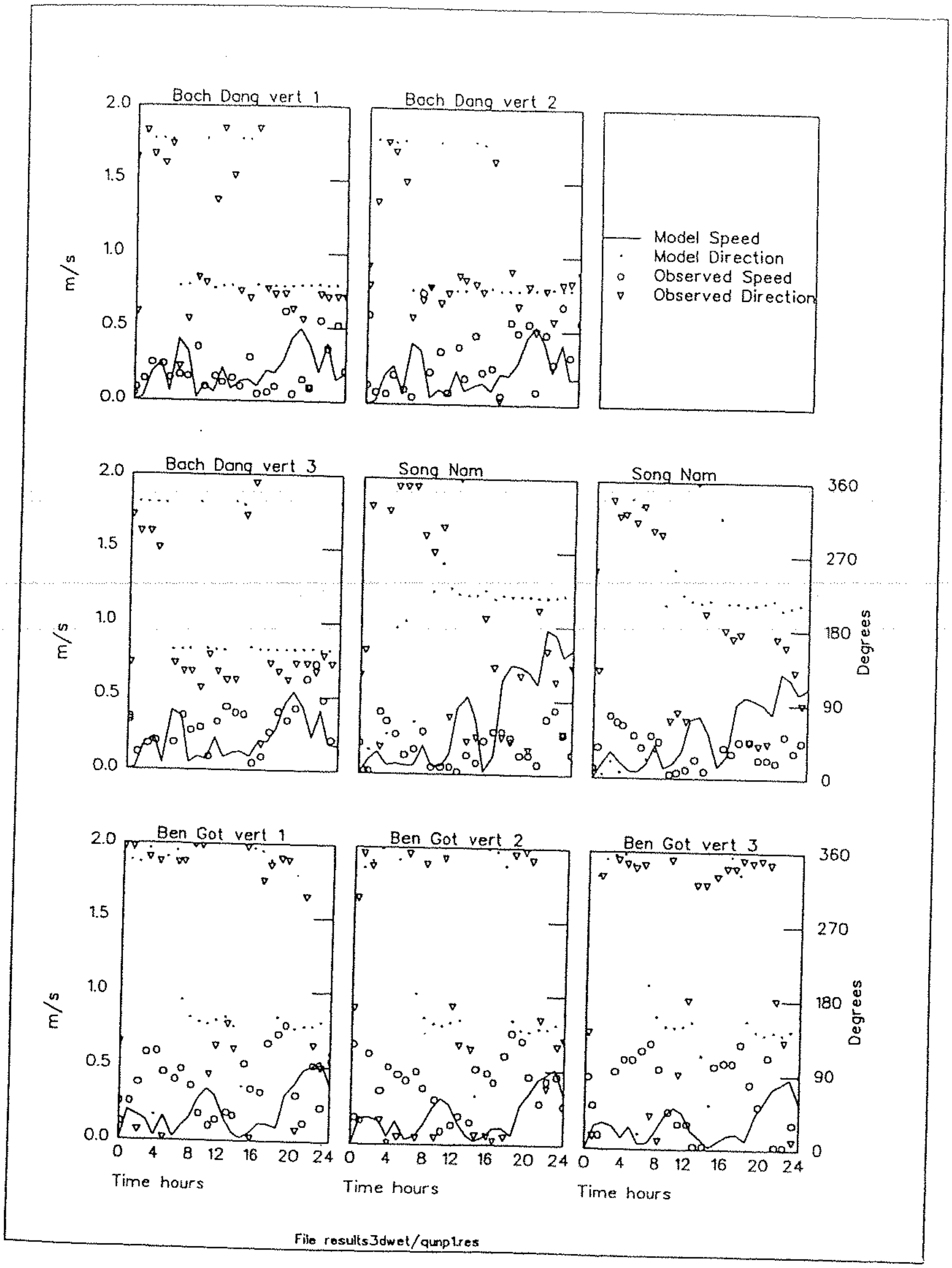


Figure 4.1.5.
Calibration results, Wet Season, Neap tide
Surface observations

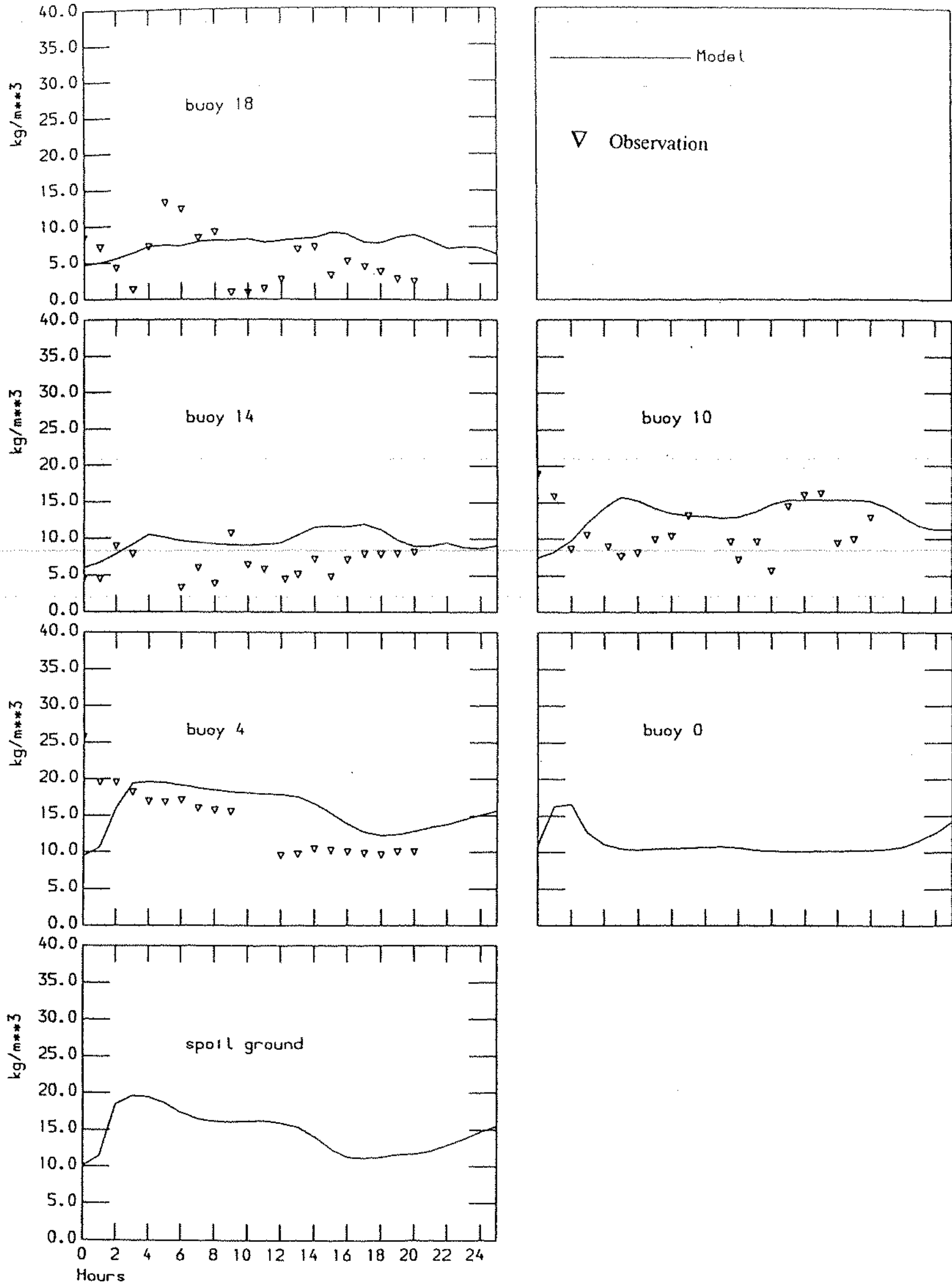


Figure 4.1.6.

Bed salinity 8-9 August, Wet Season, Neap tide (layer 1)

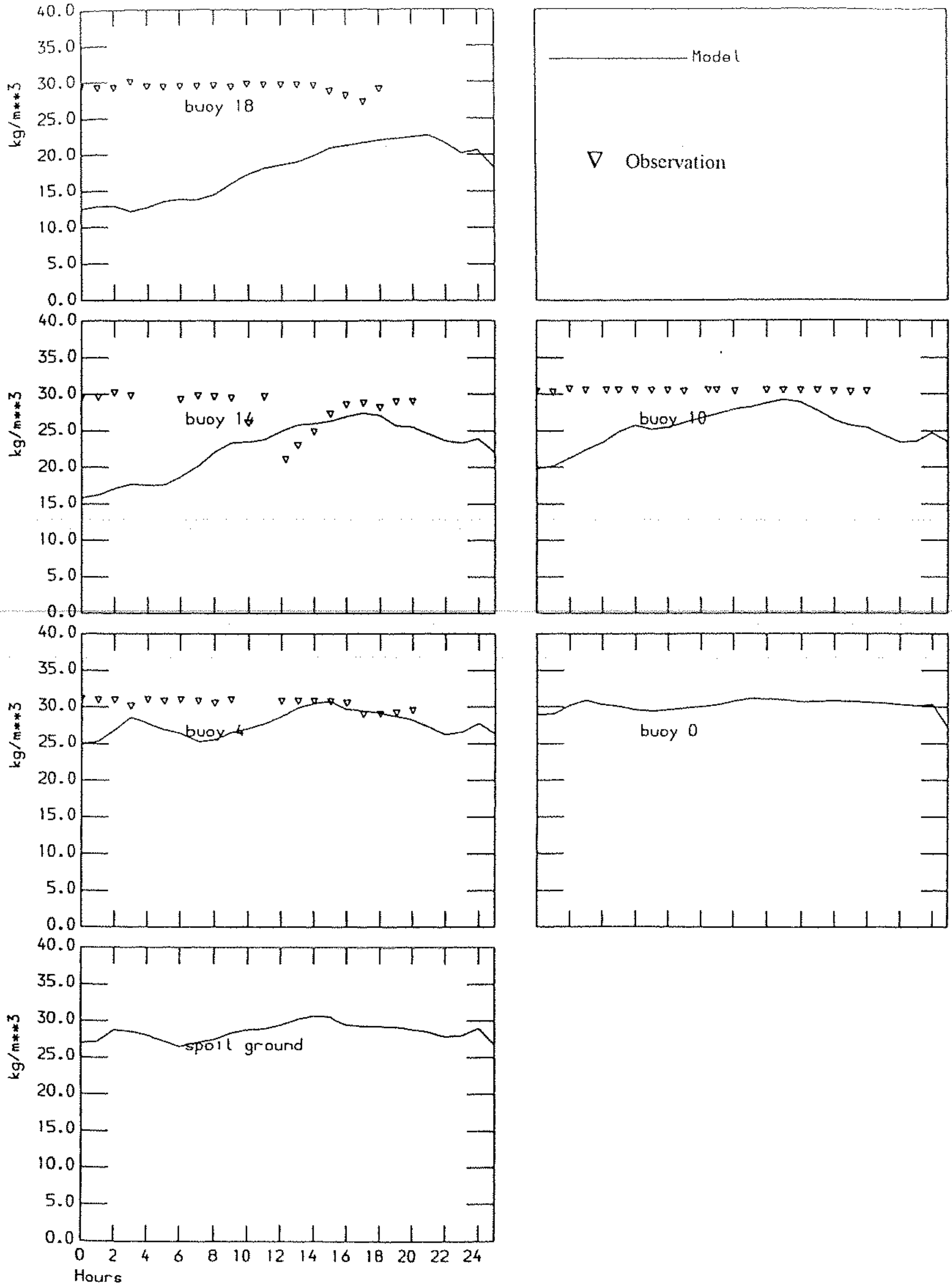


Figure 4.1.7.
Bed salinity 8-9 August, Wet Season, Neap tide
(layer 3)

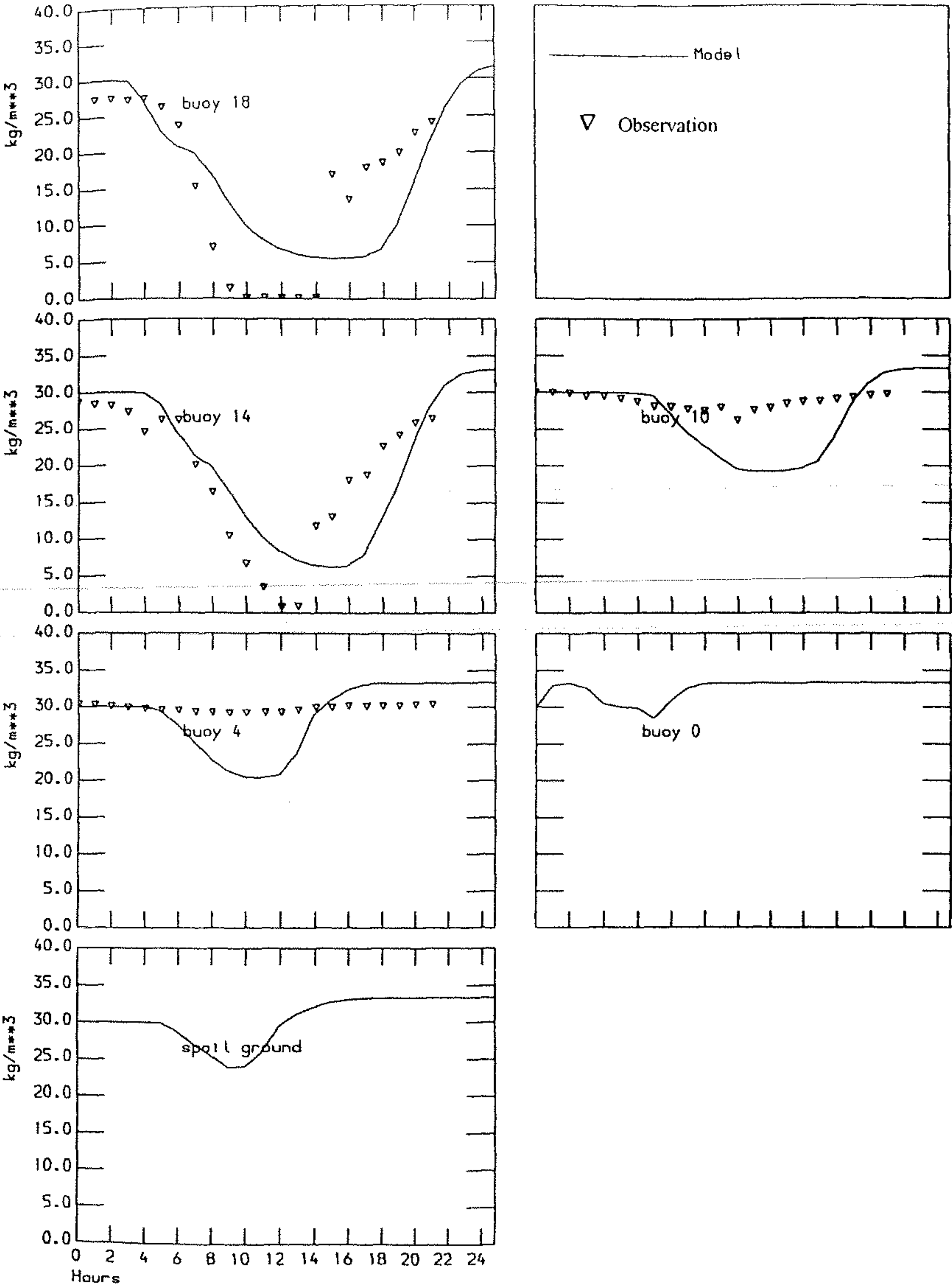


Figure 4.1.8.
Bed salinity, Wet Season, Spring tide

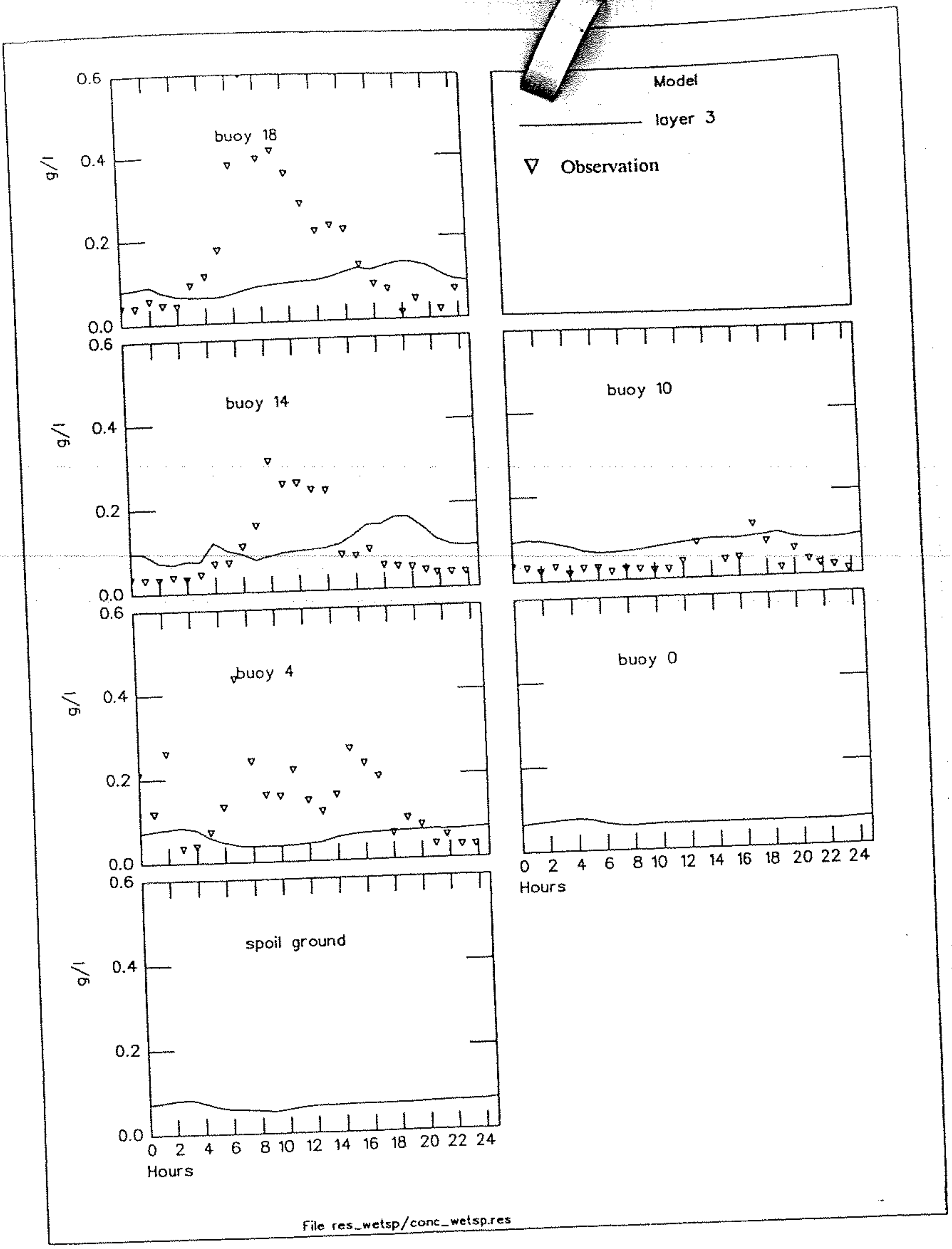


Figure 4.1.9.
Bed salinity Solids 27 August, Wet Season, Spring tide

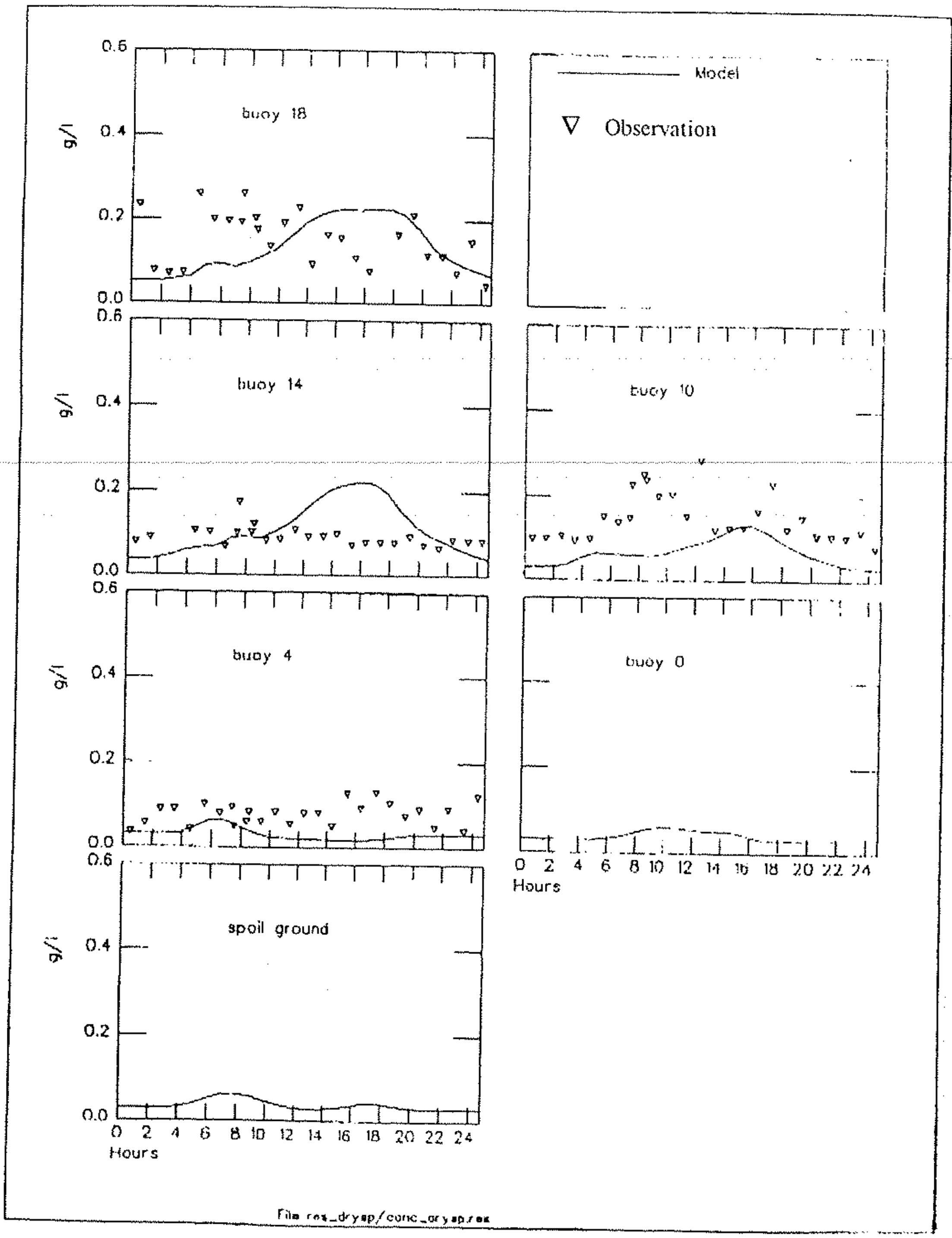


Figure 4.1.10.
Surface Suspended Solid Content 27 August, Wet Season, Spring tide

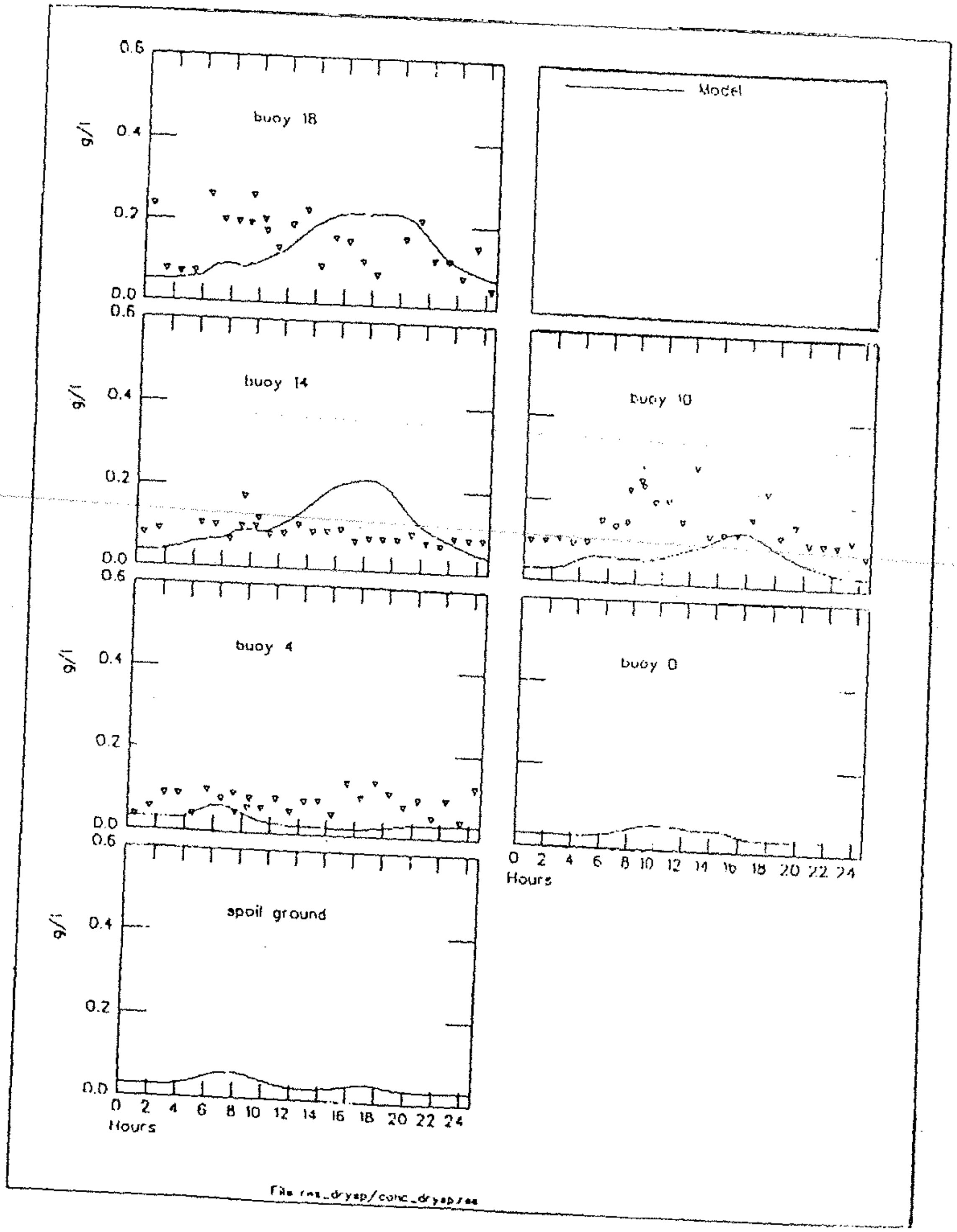


Figure 4.1.11.
Bed Suspended Solid Content 8 January, Dry Season, Spring tide

4.2.3. Hydraulic modelling results : Description of the actual situation

4.2.3.1. Dry season, Spring tide

The landward boundary conditions for the dry season spring tide run were taken from observations of velocities at the Song Nam, Bach Dang and Lach Huyen cross-sections for 4-5 February 1993 (Ref. 8). The tidal levels at Hoang Chau during that observation period were :

HW 3.32 m C.D. 0200 hrs (local time)
LW 0.45 m C.D. 1510
HW 3.32 m C.D. 0230
LW 0.34 m C.D. 1600
Range : 2.87 m

During this period, because of the low fresh water flow associated with the dry season and the large mixing effect of the high tidal range measurements show that there was no significant variation of salinity in the water column and so the tidal current could be represented by a depth averaged current. This simulation could therefore be run using a single layer model to produce a depth averaged velocity. Reference 8 quotes depth-averaged values for the observed currents at the cross-sections and also at a number of fixed station observation positions along the approach channel. The positions of these observation points are marked by the number of buoys used to mark the Nam Trieu Channel.

The model was run for a diurnal tide period starting from a condition of flat water surface and stationary water. The results from the model run were compared with observations of water elevation and tidal current at the cross-sections for 4-5 February and tidal currents at the fixed stations which were observed on 8-9 January 1993. The tidal range for this day was 3.16 m on the ebb and 3.24 m on the flood (i.e. larger than the tide from which the boundary conditions were set).

The vectors of residual discharge are shown in figure 4.2.2.

4.2.3.2. Dry Season, Neap tide

The boundary data for the dry season neap tide run were taken from observations at the discharge cross-sections on 11-12 February 1993. The neap tide curve on this day was almost flat at 2 m above C.D. This confirms the general observation that neap tide ranges are extremely small compared to spring tides at Hai Phong. Because of the smaller diurnal component, the semi-diurnal component can be seen more readily in the neap tides.

As in the case of the dry season spring tide a depth-integrated representation was chosen for this tide simulation. In this case, although comparison of tidal currents with the observations made at the cross-sections was possible, there was not a comparable set of dry season neap tide fixed station observations. Currents were observed on 10-11 March 1993 but this tide had a range at Hoang Chau of 1.04 m on the ebb and 1.24 m on the flood compared to ebb and flood ranges of 0.49 m and 0.78 m respectively for the tide used for the boundary conditions.

Vectors of residual discharge are presented in figure 4.2.3.

4.2.3.3. Wet Season, Spring tide

Discharge boundary data for the wet season spring tide condition were taken from cross-section observations taken on 15-16 August 1993. In this case the high fresh water flow results in vertical structure of the velocities which meant a multi-layer model was necessary. Three model layers were used, their interfaces being constant at 0.1 m and 1.5 m below C.D. with the bed layer being at least 1 m thick.

Thus in shallow areas, only 1 or 2 model layers were used. This arrangement meant that the tidal variation was contained in the top layer and that all layers were present throughout the approach channel.
Boundary conditions were also set for salinity which were assumed not to vary significantly during the tide. They were 33 ppt at the seaward limit and fully fresh water (0 ppt) at the landward limits, this information matched the observations on 15-16 August 1993 at the cross-sections.

The model was run from high water with an initially flat water surface. An initial salinity value of 30 ppt was imposed from observations taken at the cross-section and also at the fixed station sites (taken on 27 - 28 August 1993).

These observations show little or no density variation at high water with stratification increasing through the ebb then returning to a well-mixed state for the following high water.

The tidal level at Bach Dang during the cross-section observations for this tide was :

HW 3.63 m C.D. 1500 hrs (local time)
LW 0.79 m C.D. 0610
HW 3.67 m C.D. 1500
Ranges 2.84 m on the ebb and 2.88 m on the flood.

From the model results it can be deduced that on the ebb the velocities in the different layers vary much more greatly than on the flood. This is due to the action of gravitational circulation that tends to make the surface current seaward and the bed current more landward. The tidal range for the period of the fixed station observations was 2.72 m on the ebb and 2.74 m on the flood. One would therefore expect slower currents on the day of the fixed station observations compared to those associated with the period of the cross-section observations

Vectors of residual discharge are shown in figure 4.2.4. for layer 1 (surface layer) and in figure 4.2.5. for layer 3 (surface layer).
[illegible]

4.2.3.4. Wet season, Neap tide

Boundary data for the wet season neap tide condition were taken from cross-section observations taken on 25 & 26 July 1993. For this condition 4 layers were used, their interfaces being constant at 0.5 m above C.D. and 0.5 m below C.D. This arrangement of the layers was used to represent the very strong vertical density gradient that prevailed on this tide - effectively a salt wedge situation as the neap tide range is very small so tidal currents weak and insufficient to cause much vertical mixing.

Again all layers were present throughout the approach channel. The water surface elevation in this case resembled much the dry season neap tide with very little variation around a mean level of about 2 m above C.D. An initial salinity distribution was chosen to represent approximately the salinity observed as it does not vary much during the tide.

In the case of this run it is found that there is a near-permanent state of seaward flow at the surface and landward at the bed. When a slight tide ebb occurs the surface ebb flow is enhanced and the bed flow is nearly stationary. Similarly during a slight flood phase the surface current comes to rest and the flood at the bed is enhanced. During all of this time there is a general surface current that is more seaward than the bed current by about 0.30 m/s at buoy 18 and less at the other buoy locations, which is reproduced in the model. The tide curve for the day when observations were made at the buoy locations is different to that for which boundary conditions were obtained so the detailed velocities at the buoy locations are not compared here.

Vectors of residual discharge are shown in figure 4.2.6. and figure 4.2.7. (resp. for layer 1 and layer 4).

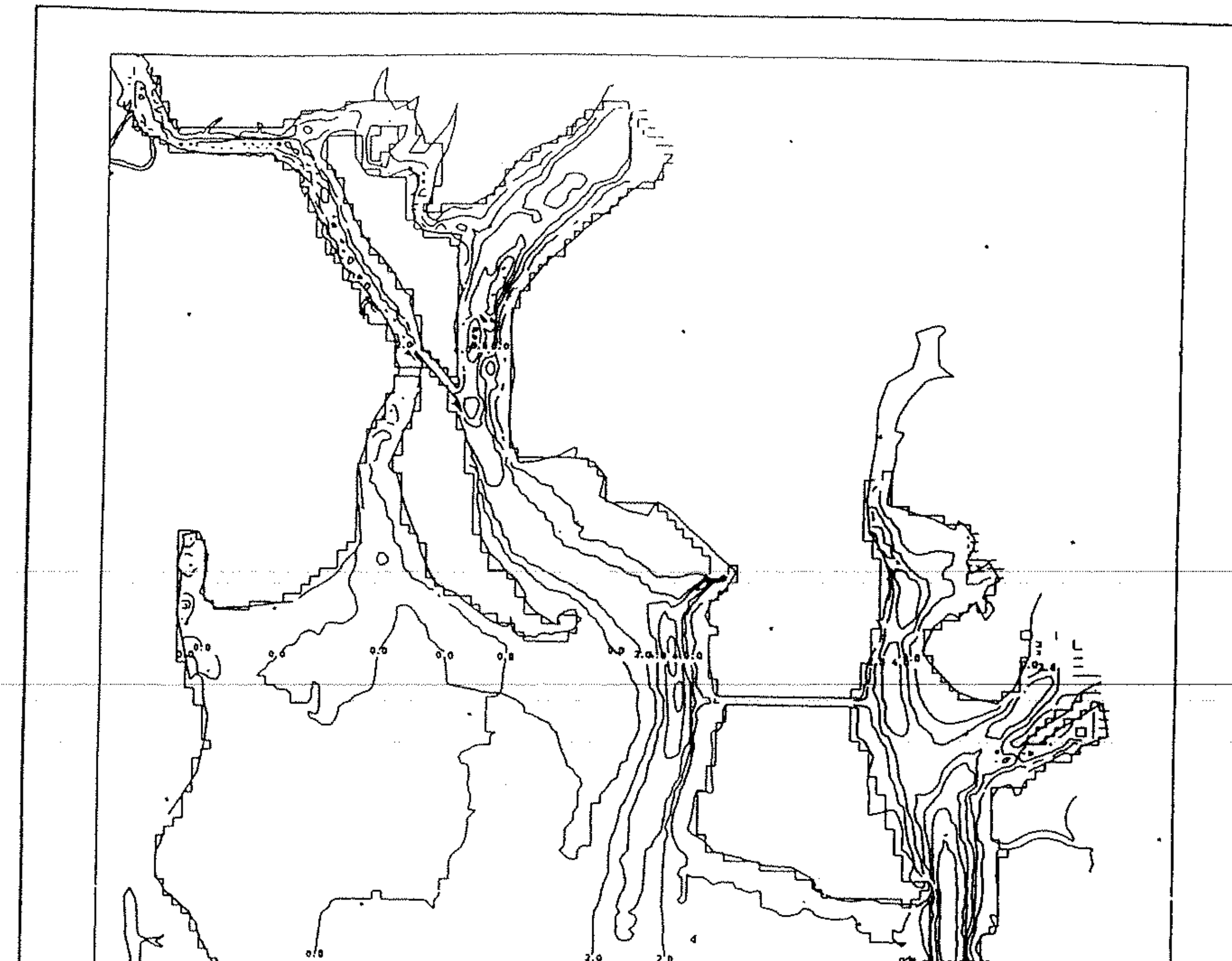


Figure 4.2.1.
Hai Phong approaches model

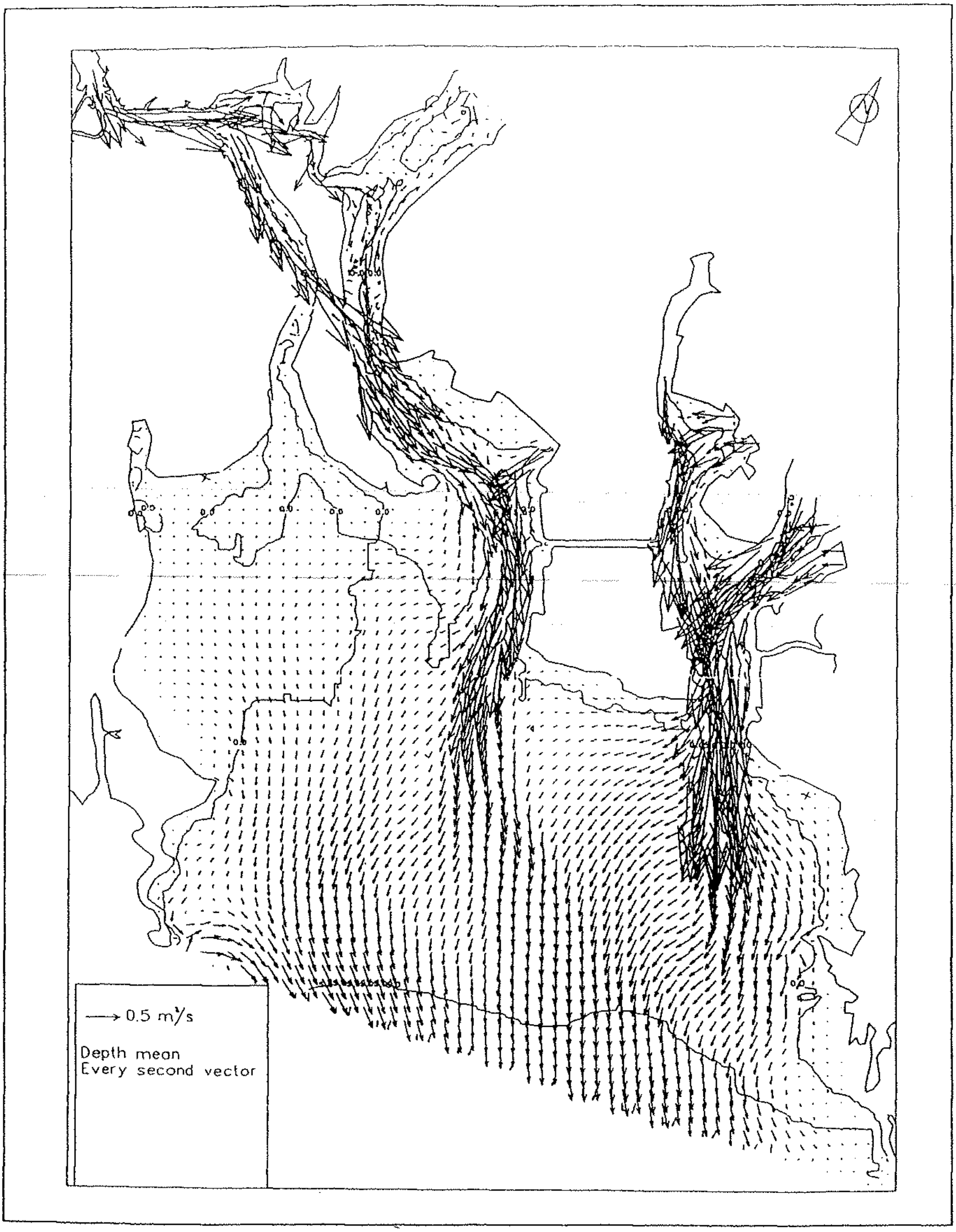


Figure 4.2.2.
Residual discharge Vectors
Dry season, Spring tide

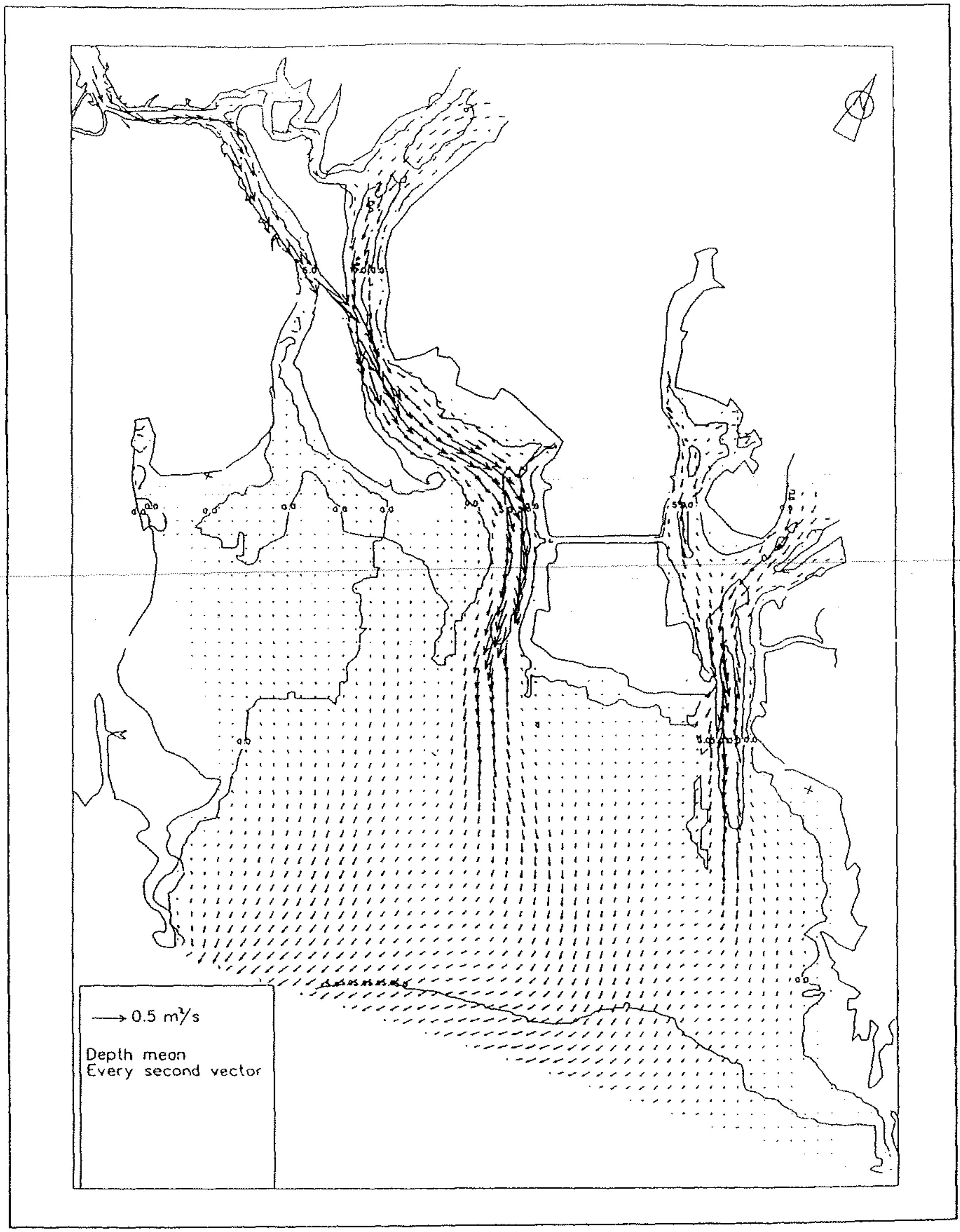


Figure 4.2.3.
Residual discharge Vectors
Dry season, Neap tide

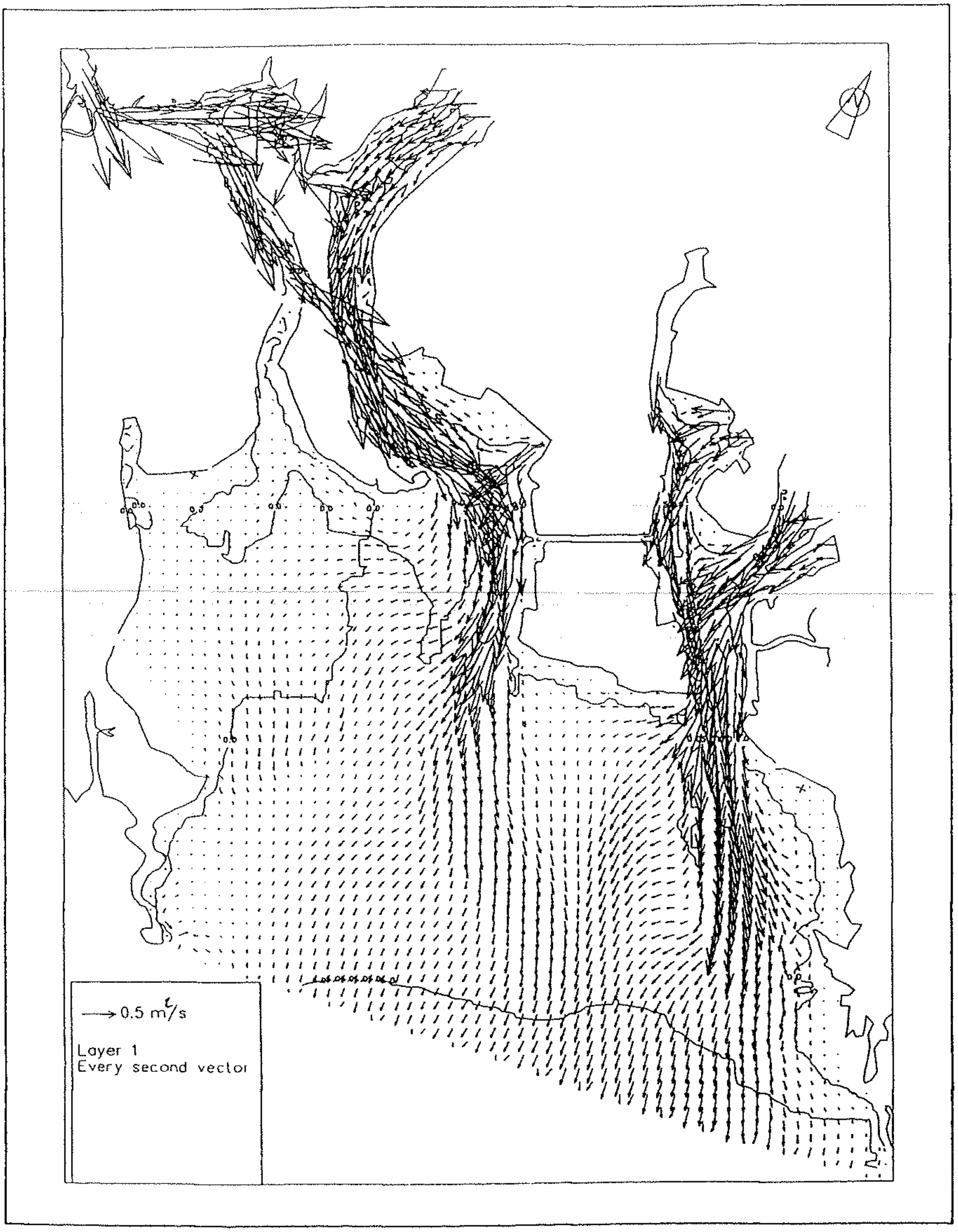


Figure 4.2.4.
Residual discharge Vectors (surface layer)
Wet season, Spring tide

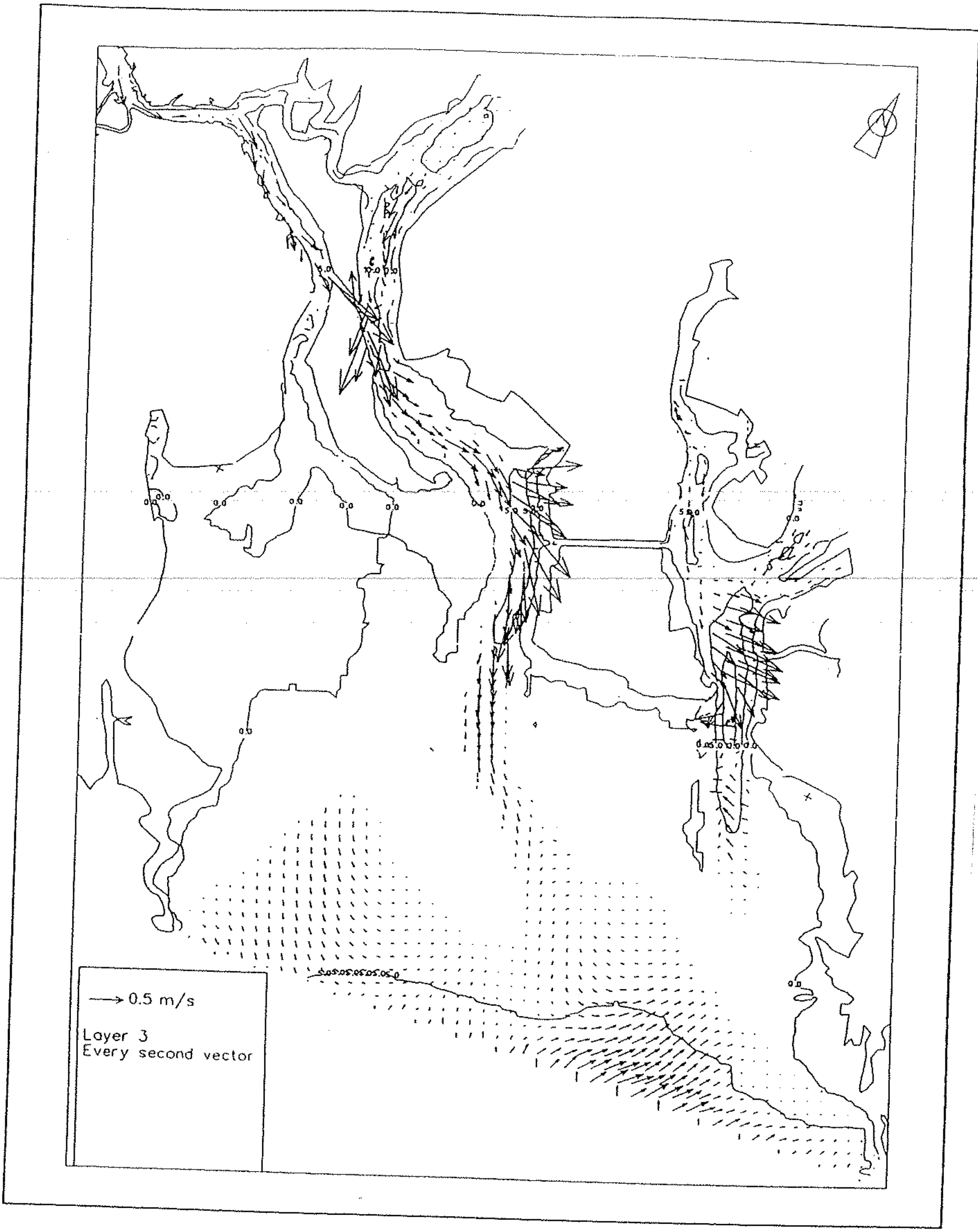


Figure 4.2.5.
Residual discharge Vectors (bed layer)
Wet season, Spring tide

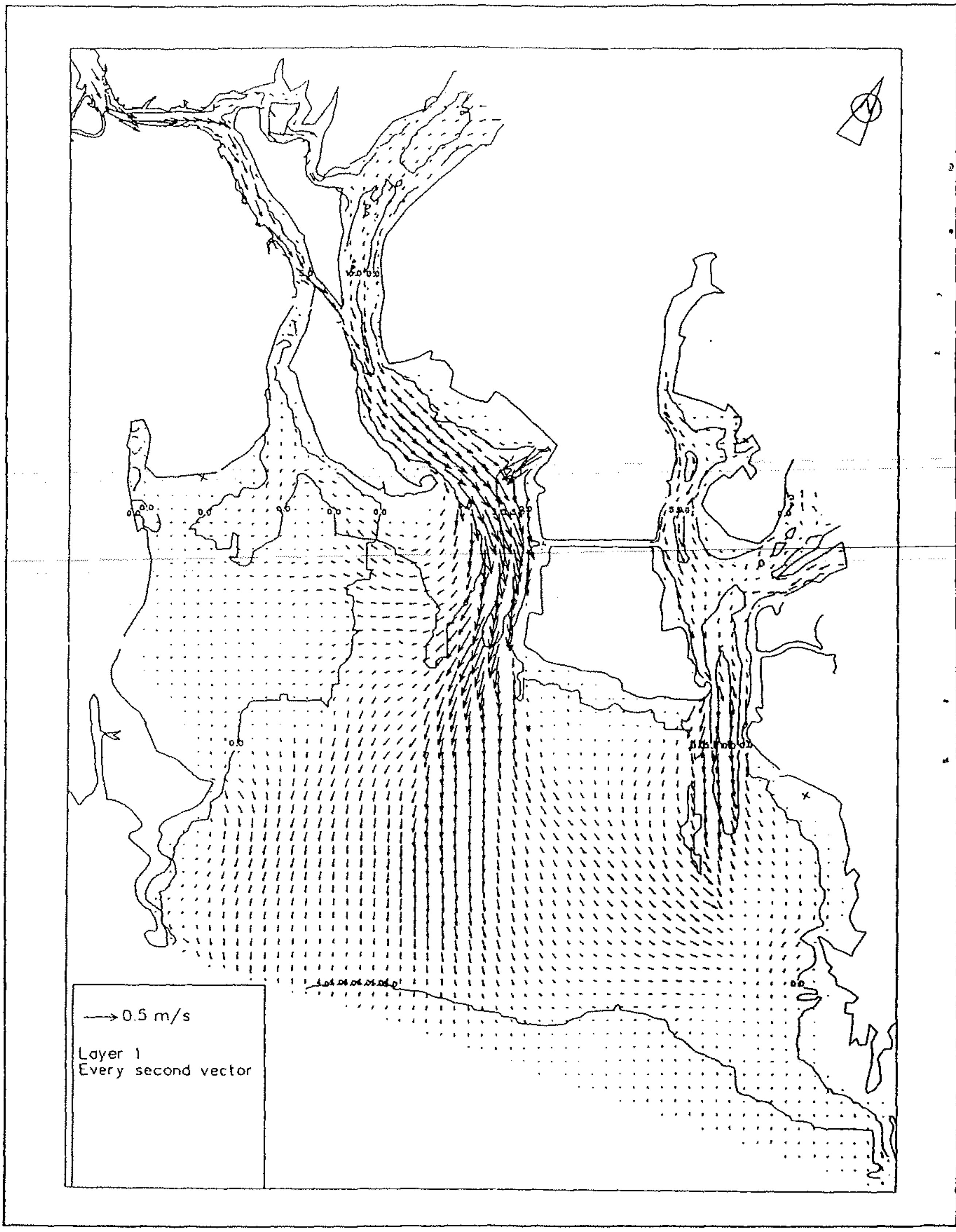


Figure 4.2.6.
Residual discharge Vectors (layer 1)
Wet season, Neap tide

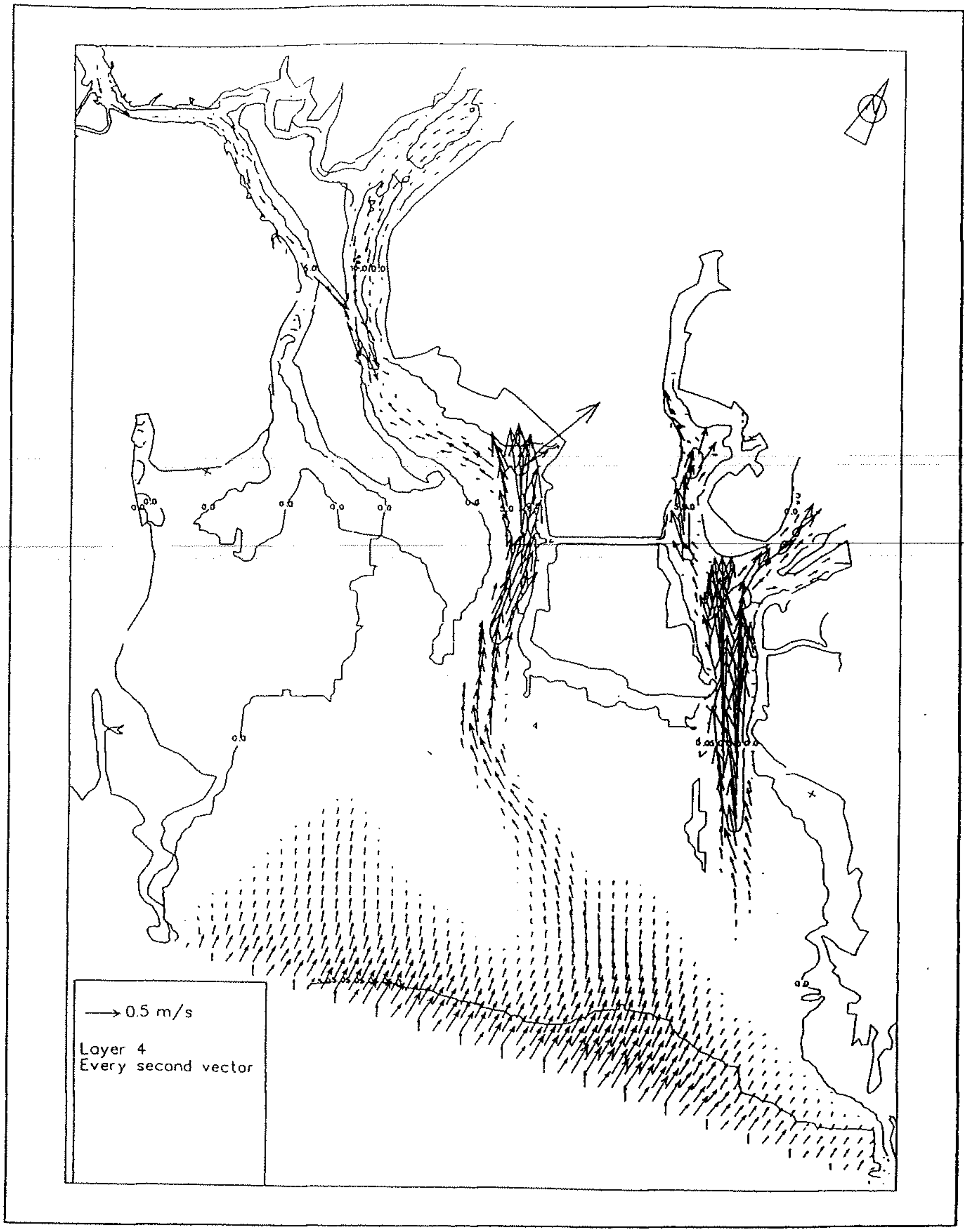


Figure 4.2.7.
Residual discharge Vectors (layer 4)
Wet season, Neap tide

4.2.3.5. Wave fields

4.2.3.5.1. Methodology

For the Hai Phong access-channel study wave conditions are required in various locations within the Bay so that the effect of waves on the transport of sediments can be determined.

Ideally, when assessing wave conditions in Hai Phong Bay, long-term recorded wave data would be used. However at the time this study was carried out, no such wave data was available. Wave climates were therefore predicted at six points in Hai Phong Bay using data obtained from the British Meteorological Office in conjunction with a computational wave transformation model. This is a technique which has been used in many previous studies, and provides a reliable method for predicting wave conditions at shallow nearshore locations.

In this paragraph, the prediction of annual and seasonal wave climates at the locations in Hai Phong Bay is considered. Annual and seasonal offshore frequency tables from VOS data were obtained from the British Meteorological Office. The HR Wallingford wave refraction model OUTRAY was then used to represent the effects of refraction and shoaling as the waves propagate inshore. The results from the wave model were analysed to provide `typical' and `storm' events which were used by the FLUIDMUDFLOW model to include the effect of waves in the siltation process (see further).

4.2.3.5.2. Assessment of offshore wave conditions from VOS data

The majority of ships of passage make regular observations of wind and wave conditions as part of their routine duties, known as Voluntary Observations of weather from Ships (VOS). This information is collected and collated world wide and is available through the British Meteorological Office. The records include date, time, location, wind speed and direction, significant wave height (H_s), mean zero crossing period (T_m) and wave direction. Although not scientifically measured, VOS records have been found to be a reliable source of data, particularly for areas including shipping lanes where a large number of observations have been made over many years.

VOS data is available in the form of monthly, seasonal and annual frequency tables of wave height and wave period in 30° directional sectors for sea areas specified in latitude and longitude limits.

When using VOS data it is important to ensure that the selected area is large enough to contain sufficient data in each sector for reliable analysis, but small enough that wave conditions are representative of the region of interest. In addition, for a VOS analysis to be valid it is necessary to ensure that the exposure of the location of interest is the same as that of the VOS area used for the direction sectors of interest.

VOS data for the Gulf of Tonkin was obtained from the British Meterological Office for this study. The VOS data obtained was for the region 18°N to 22°N and 105°E to 110°E. Over a 44 year period, 13764 observations were recorded in this area, of which 84 were of indeterminate direction. It appears that waves incident from between north north east and south south east account for over 65% of the annual waves. In general waves from these directions are less than 4.0m (Hs) in height, but there are recordings of waves up to 8.0m (Hs). 98% of all waves are less than 3.0m (Hs). The associated wave periods, shows that 90% of all wave periods are less than 7.5s (Tz). Although records up to 20s have been observed. The data are used directly as the offshore wave climate for the wave refraction model.

Equivalent seasonal climates for the periods June to September and December to March were also obtained for the same area. It is evident from these that during June to September the dominant wave directions are around south, and for December to March they are around north-east.

4.2.3.5.3. The OUTRAY wave refraction model

In this study, the HR wave refraction model, OUTRAY, was used to derive the wave climates at six points in Hai Phong Bay corresponding to given offshore climates. OUTRAY represents the physical processes of wave refraction and shoaling, caused by spatial variations in the water depth as waves propagate through shallowing water.

The OUTRAY wave refraction model predicts wave activity at coastal sites given a spectral description of offshore wave conditions. The model uses the concept of wave rays, which are lines everywhere perpendicular to the wave crest. These rays are tracked seawards from a selected inshore point to the offshore edge of the model grid system, using Snell's law to calculate changes in ray path direction due to refraction effects.

Since the ray paths are reversible, each ray then gives information on how energy travels between the seaward edge of the grid system and the nearshore point of interest.

Computations in the OUTRAY program can be split into two parts. The first stage involves considering a large number of ray paths, representing a wide range of offshore periods and directions, to generate a set of matrices known as transfer functions. These transfer functions provide a description of the transformation of wave energy between the edge of the diffraction grid and the inshore point of interest. The second stage uses these transfer functions to modify offshore spectra to a corresponding spectrum at the nearshore point of interest.

OUTRAY does not include the non linear effects of currents and energy dissipation processes such as seabed friction and wave breaking. In many cases this will not be a significant drawback and the model will give accurate predictions of wave conditions, even in shallow water. Diffraction is also not included in OUTRAY, however the seabed of Hai Phong Bay is generally smoothly varying with no sudden changes in depth and diffraction effects will not be significant.

4.2.3.5.4. The application of OUTRAY to Hai Phong Bay and comparison with field observations

To assess the effects of wave refraction and shoaling on wave conditions, the OUTRAY model requires a digital description of the seabed bathymetry in the area being modelled. The bathymetric information was obtained from Admiralty Charts 3875, 3990, 1965 and 3989. The OUTRAY grid system consists of six grids which are varied in size and spacing so as to represent the bathymetry in the area as accurately as possible. The grid system is given below (Table 4.T.4) :

Grid	Grid spacing (metres)	Number of nodes		Grid origin (model coordinates)	
		x direction	y direction	x (m)	y (m)
1	2000	123	35	0	0
2	1000	99	31	0	68000
3	1000	57	109	98000	68000
4	2000	46	55	154000	68000
5	1000	60	40	39000	98000
6	500	91	55	53000	137000

Table 4.T.4.
OUTRAY grid characteristics

The positive x axis of the grid system was orientated at 90°N and the origin of the grid system was at approximately 19°25'N and 106°10'E. The extent of the grid system was chosen so as to allow the wave transformation processes of waves generated in the approaches to Hai Phong Bay to be modelled. The outer boundary of the grid is positioned so as to be adjacent to the area covered by the VOS data set. The sizes of the inner grids are selected so as to accurately represent the bathymetry of the Bay.

The main purpose of the wave modelling was to provide wave input to the FLUIDMUDFLOW sediment transport model. This requires that wave conditions are selected so as to represent `typical' and `storm' conditions throughout the modelled area. In order to select these conditions an understanding is required of the annual and seasonal conditions at locations within the Bay. The approach which was therefore adopted was to apply the OUTRAY model to transform the offshore annual and seasonal wave climates, to a series of six inshore points at locations throughout the Bay.

OUTRAY runs for analysis points 1 and 2 were carried out using still water levels C.D. + 3.9m and C.D. + 0.0m which correspond to Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS) respectively. This was done in order to assess the sensitivity of the wave climate to changes in water level. For each water level at points 1 and 2 the annual wave climate was considered as well as two seasonal climates, December to March and June to September. These correspond to the dry and wet seasons respectively. OUTRAY runs for analysis points 3, 4, 5 and 6 were carried out using a still water level of C.D. +3.9m and the annual climate only was considered.

Wave climate at Aval deduced from refracted VOS data are summarised in the following Table 4.T.5.

Hs (m)	% exceedance	log (% exceedance)
0.5	30.57	1.49
1.0	11.24	1.05
1.5	1.51	0.18
2.0	0.34	- 0.47
2.5	0.12	- 0.92
3.0	0.07	- 1.15
3.5	0.03	- 1.52
4.0	0.01	- 2.00

Table 4.T.5.
Wave climate at Aval deduced from refracted VOS data (Annual climate)

The wave model results in an offshore wave climate based on VOS data for the period 1949 to 1993 (44 years ; 13764 observations). The offshore wave climate is transformed to an inshore point using the OUTRAY model (MHWS Still Water).

There are no long term time series for wave observations at Aval. Despite this the wave observations acquired by MOT/TEDI under this project can be compared with the above wave climate.

Hs (Aval) m	Dry Season % exceedance (02/95 - 06/95)	Wet Season % exceedance (06/95 - 07/95)
0.20	44 %	81 %
040	18 %	55 %
0.70	5 %	24 %
1.00	1,21 %	4,7 %
1.40	0,10 %	0,25 %
1.60	0 %	0 %
2.70	0 %	0 %

Table 4.T.6.
Observed wave-climate at Aval in the period 1995 - 1996

It appears that the observed wave climate is notably calmer than the one predicted from multi-annual statistics. This indeed corresponds to the overall impressions of people acknowledged with the site that the 1995 - 1996 periods were calmer.

For the simulation of the channel infill a wave climate as described in the table below was adopted (Table 4.T.7) :

Hs (Aval) m	Dry Season % exceedance	Wet Season % exceedance
0.20	70 %	70 %
0.40	40 %	41 %
0.70	20 %	21 %
1.00	10 %	11 %
1.40	5 %	6 %
1.60	2 %	3 %
2.70	0 %	1 %

Table 4.T.7.
Representative wave climate at Aval take into account for the siltation predictions

4.2.3.5.5. Discussion of results

It can be seen from the annual table that the majority of waves are from easterly directions between 15°N and 160°N. The same can be said for December to March, however during the wet season between June and September waves are incident form more southerly directions. Offshore wave heights can reach up to 6.0m, however the majority of waves are less than 2.0m offshore.

It can also be concluded that, as expected, the waves inshore have tended to align perpendicular with the bottom contours and wave energy has been re-distributed in the refraction process. At refraction points 1 and 2 the majority of waves are incident in the 30° direction sector centred on 150°N. At refraction point 1 there is a slight tendency for the wave direction to be more towards the ESE whereas at point 2 it is more south-easterly to southerly. This is consistent with the overall orientation of the sea bed contours adjacent to these two areas. For both points 1 (Aval) and 2 there is a greater reduction in wave energy between offshore and inshore at MLWS than at MHWS.

This analysis indicates that the annual inshore wave conditions at typical locations in Hai Phong Bay are relatively insensitive to change in tidal level between MHWS and MLWS.

The analysis of seasonal variability shows that during the wet season, June to September, inshore waves are predominantly from directions between South-South-east and south (135°N to 195°N). For the dry season, December to

March, the directions are more south-easterly and are between 105°N and 165°N. This is consistent with the wet season conditions being more southerly offshore than the dry season which are predominantly from the north-east.

There is very little seasonal variation in heights at the inshore locations. For both seasons at point 1 almost 95% of waves are less than 2.0m (Hs), with less than 1% being between 2.0m and 4.0m. Waves in the dry season are marginally larger with about 0.02% being between 4.0m and 4.5m. Similar comments on the seasonal variability of wave height apply at MLWS and at point 2 for both water levels.

From the results at points 1 and 2 it was noted that there was little variation in wave height either between seasons or at different water levels.

A comparison of predicted wave conditions with measured data at Aval was made and shows a reasonable similarity. Wave data at Aval has been made available to HR for the dates 10 February 1995 to 27 July 1995 excluding 6 April to 5 May. From this data it can be seen that there is a maximum wave height of 1.5m and the majority of recorded waves are less than 0.5m. The seasonal December to March wave climate for point 1 (Aval), show that less than 2.0% of waves exceed 1.5m and 71% of waves are less than 0.5m. Similarly the remaining recorded wave data compares well with predicted wave conditions. It should be noted that the comparison of the predicted and measured conditions can only be made on the basis of wave height as the wave recorder does not measure direction.

4.2.3.5.6. Selection of wave conditions for sediment transport modelling

The wave input conditions used for the FLUIDMUDFLOW model are showned in figures 4.2.7.(a) and (b) (see par. 4.2.5.).

Five (5) different wave climates were used throughout the various simulations with representative significant wave heights (Hs) at Aval of :

Description	Hs (Aval)
No waves	0.00 m
Typical waves	0.40 m
Storm waves	0.70 m
Severe Storm waves	1.60 m
Typhoon	2.72 m

Table 4.T.8.
Wave climate used in the modelling

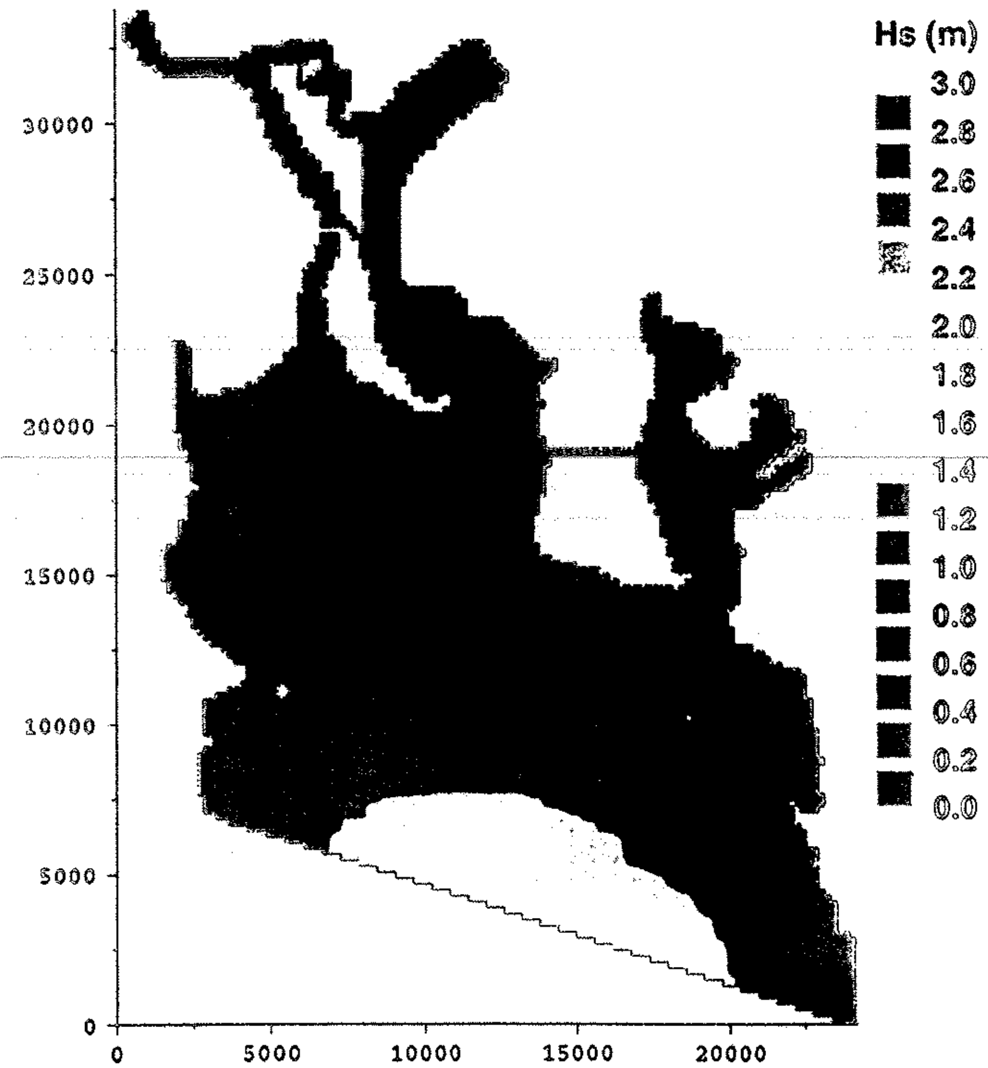


Figure 4.2.7.(a)
Wave input conditions, storm waves

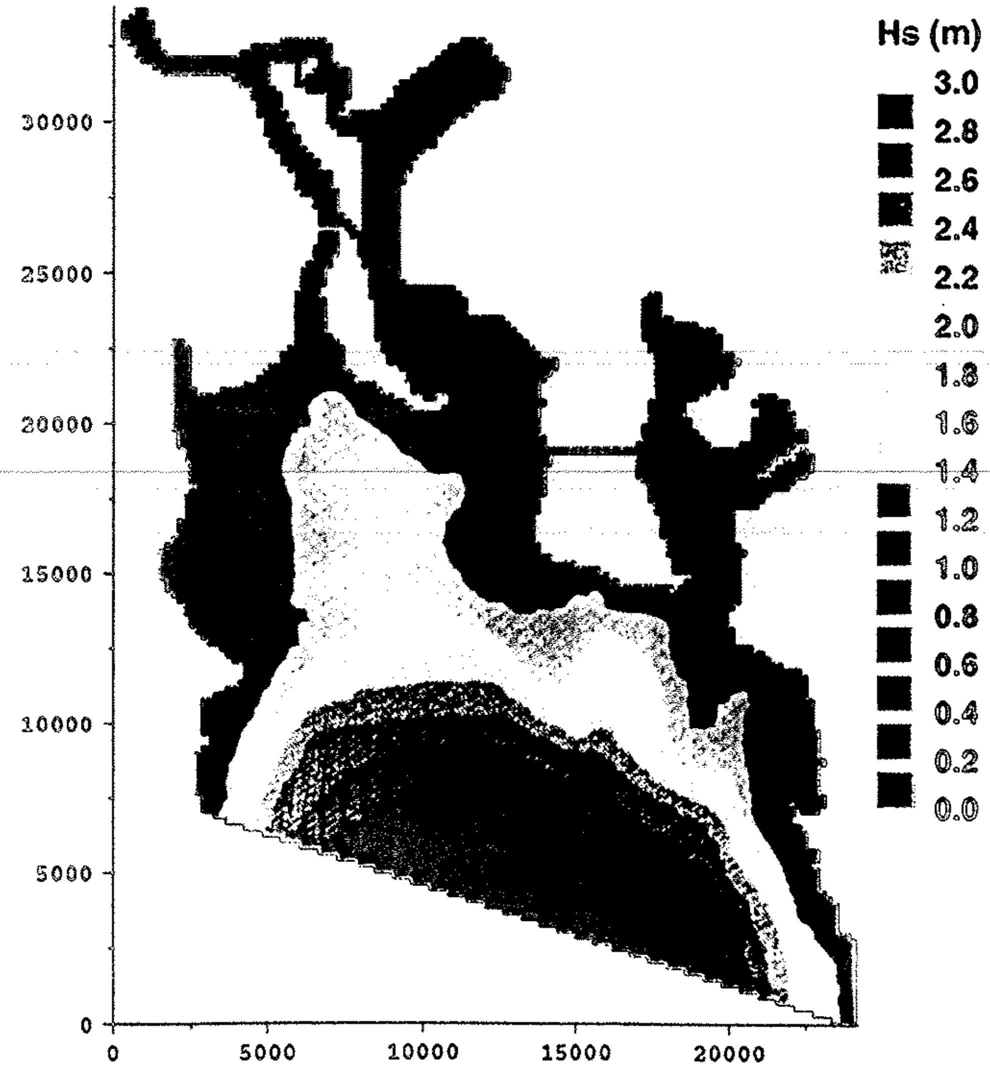


Figure 4.2.7.(b)
Wave input conditions, severe storm waves

4.2.4. Modelling results : hydraulic impact of the different alternatives

4.2.4.1. Selection of test cases

The calibrated hydrodynamic model was used to investigate the impact of different channel alternatives on the flows in Hai Phong Bay. The main purpose is to provide flows for the various alternatives which can be used in the mud transport model. The mud transport model is then used to investigate channel siltation and the consequential requirement for maintenance dredging. There are 3 possible depths for the channel alternatives and four different tide types to be considered. At an early stage in the study it was decided to model a representative selection of combinations of depth, alternative channels and tide types. This selection was made on the basis of the information required to make the siltation assessment. In addition to the different channel alternatives, model predictions were also made for the situation with the Dinh Vu Dam partially removed.

The situations selected for testing are shown in the following table :

Tide type		Dry Spring	Wet Neap	Wet Spring
Layout Existing		x	x	x
CD -9.0 m	Alt 1	x	x	
	Alt 2	x		x
	Alt 3	x		
	Alt 4	x	x	
CD -7.3 m	Alt 1	x	x	
CD -11.5 m	Alt 1	x		
Removal of Dinh Vu Dam		x	x	

Table 4.T.9.
Hydrodynamic model tests carried out to examine the alternative channel configurations

The test cases were set up by changes to the bed levels in cells in the 200 m grid Hai Phong model, (see par. 4.2.2.2.). As the channel bottom width is intended to be 160 m the model slightly overestimates the impact of the channel. The channel depth studied in the present work was predominantly C.D. -9.0 m, with extra tests for one of the alternatives to investigate the sensitivity of the hydrodynamics to increasing the channel depth to C.D. -11.5 m or decreasing it to C.D. -7.3 m. The side slopes for the channel were 1:20.

For the test cases the model was run in exactly the same way as the existing conditions model. The dry spring tides are first considered below followed by the wet neap and then the wet spring tide condition.

4.2.4.2. Dry season spring tides

The simulations of a dry spring tide use a 2D depth integrated flow model as calibrated for existing conditions.

4.2.4.2.1. Existing conditions

The magnitude of the simulated spring tidal current at peak ebb and flood tidal phases are shown in figs 4.2.8.(a) and (b). Outside of the channels the peak current is no more than 0.6 m/s but in the channels the current can be up to and greater than 1.0 m/s.

4.2.4.1.2. Alternative 1 : Widening and deepening the existing Nam Trieu Channel

The channel generally follows the existing channel with the bed level in the navigational channel reduced to C.D. - 9.0 m. The resulting peak ebb and flood current speeds appear to be similar to the existing conditions but some areas of speed decrease can be seen. Plots of the difference in speed at peak flood and ebb times are shown in figs 4.2.9.(a) and (b). They show generally speed decreases, some as large as 0.2 m/s or more.
In some places the flow speed in the channel is apparently unchanged but the channel being now deeper it is carrying more of the total discharge and the flow outside of the channel is correspondingly weaker.
This speed decrease is especially noticeable near to Dinh Vu island where sedimentation may be expected as a result of the channelization of the flow. Some very localised areas of speed increase can also be seen in the channel particularly at the seaward end of the channel. On the ebb the speed increases tend to be on the south slope of the channel (where the larger channel

discharge leaves the channel) and on the flood it is on the north side of the channel. The model also predicts some speed decrease in the Trap Canal relative to existing conditions at these times. Note that these peak ebb and flood times may not correspond to the times of peak flow in the Trap Canal.

The model with the channel alternative 1 has also been run with a dredged depth of C.D. - 7.3 m. The difference in peak speed compared with the existing situations are shown in figs 4.2.10.(a) and (b). The speed difference plots show the same features as for the deeper channel on route 1, only the effects are rather smaller. There are speed increases compared to the existing situation seaward of the Trap Canal and speed decreases further away. Also speed decreases just north of Dinh Vu island, but slight speed increases in the dredged channel, as with the deeper dredged channel. The flow in the Trap canal at these times again shows a slight decrease.

The model with channel alternative 1 has further been run with a channel dredged to C.D. - 11.5 m up to the Dinh Vu Channel and C.D. -7.30 m above there to Hai Phong.
The speed differences relative to the existing conditions are shown in figure 4.2.11.(a) an (b) respectively for peak ebb and peak flood.

4.2.4.1.3. Alternative 2 : New Nam Trieu Channel

Alternative 2 is generally more aligned with the flow direction in the model and unlike alternative 1 it does not follow the existing channel across the bar. The existing channel is however included in the model representation in addition to the proposed one. Clearly all but the seaward part of this channel is the same as alternative 1. The speed differences on peak ebb and flood between alternative 2 (C.D. - 9.0 m) and the existing condition are shown in figs 4.2.12.(a) and (b). Similar speed decreases can be seen as for alternative 1, e.g. at Dinh Vu, but at the seaward end where a new channel across the bar has to be dredged the speed is larger in the channel than for existing conditions and speed decreases also occur away from the new channel, especially on the ebb in the vicinity of the existing channel. Further changes in peak speed could be expected if the existing channel were to be abandoned.

Speed increases along the seaward part of the channel are again very clear here and larger than for alternative 1, perhaps because the channel is aligned more with the flow and because in alternative 1 one is considering deepening an existing channel. Outside of the channel there are slight speed decreases.

The landward part (where the two routes overlap) is the same as alternative 1, including the spread decrease at peak ebb and flood tide in the Trap Canal.

4.2.4.1.4. Alternative 3 : New alignment in Lach Huyen through Ha Nam Canal

This alternative involves making a new canal running approximately east-west from the western end of the existing Trap canal. The existing channel through the bar is kept as is the existing Trap Canal. The channel depth is again at C.D. -9.0 m and the channel above the canal is the same as earlier test cases. The currents have decreased near to Dinh Vu island as is apparent in the speed difference plots figures 4.2.13.(a) and (b) for peak ebb and flood. Speed increases in the channel dredged across the bar at Lach Huyen can be seen. The speed changes near to Dinh Vu island are the same as for alternative 1.

4.2.4.1.5. Alternative 4 : New alignment in Lach Huyen through Trap Canal

Alternative 4 passes along the Trap Canal before turning seaward. The existing channel across the bar is again retained in the model. The speed difference plots (C.D. - 9.0 m) figs 4.2.14.(a) and (b) show an increased current speed in the new seaward part of the channel, as well as a speed increase of at least 0.1 m/s through the Trap Canal, and some speed decrease in the vicinity of the existing channel as more discharge is being carried along the Trap Canal and along the new channel across the bar.

Further landward the speed differences resemble closely the ones for alternatives 1 and 2. Where the Trap Canal flood flow emerges into the channel it also causes some slowing of the flow.

4.2.4.1.6. Effect of removal of Dinh Vu Dam

The effect of the removal of the existing Dinh Vu dam has been simulated by considering a condition that differs from the existing only in the removal of the dam and the dredging of a channel at C.D. -2 m for 7 km seaward of the dam site. Peak ebb and flood currents in the channel downstream of the dam site are up to 0.8 m/s during the ebb. The peak currents in the existing channel to the east of Dinh Vu island are correspondingly reduced. The speed difference plots for peak ebb and flood compared with existing conditions (figure 4.2.15.(a) and (b)) show that the effect is mainly confined to either side of Dinh Vu island with effects not greater 0.05 m/s further away.

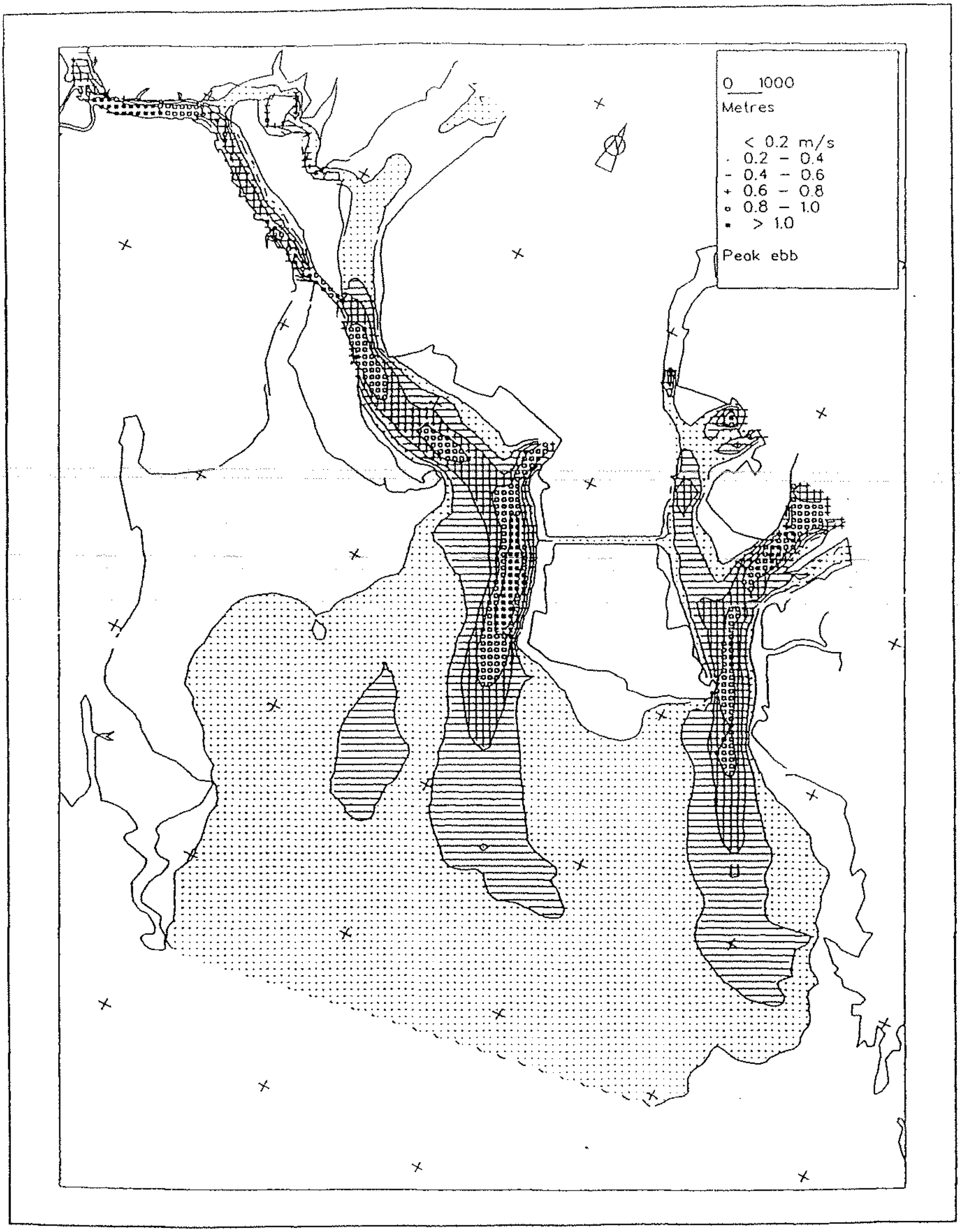


Figure 4.2.8.(a)
Hai Phong
Magnitude of speed - Peak ebb
Existing conditions

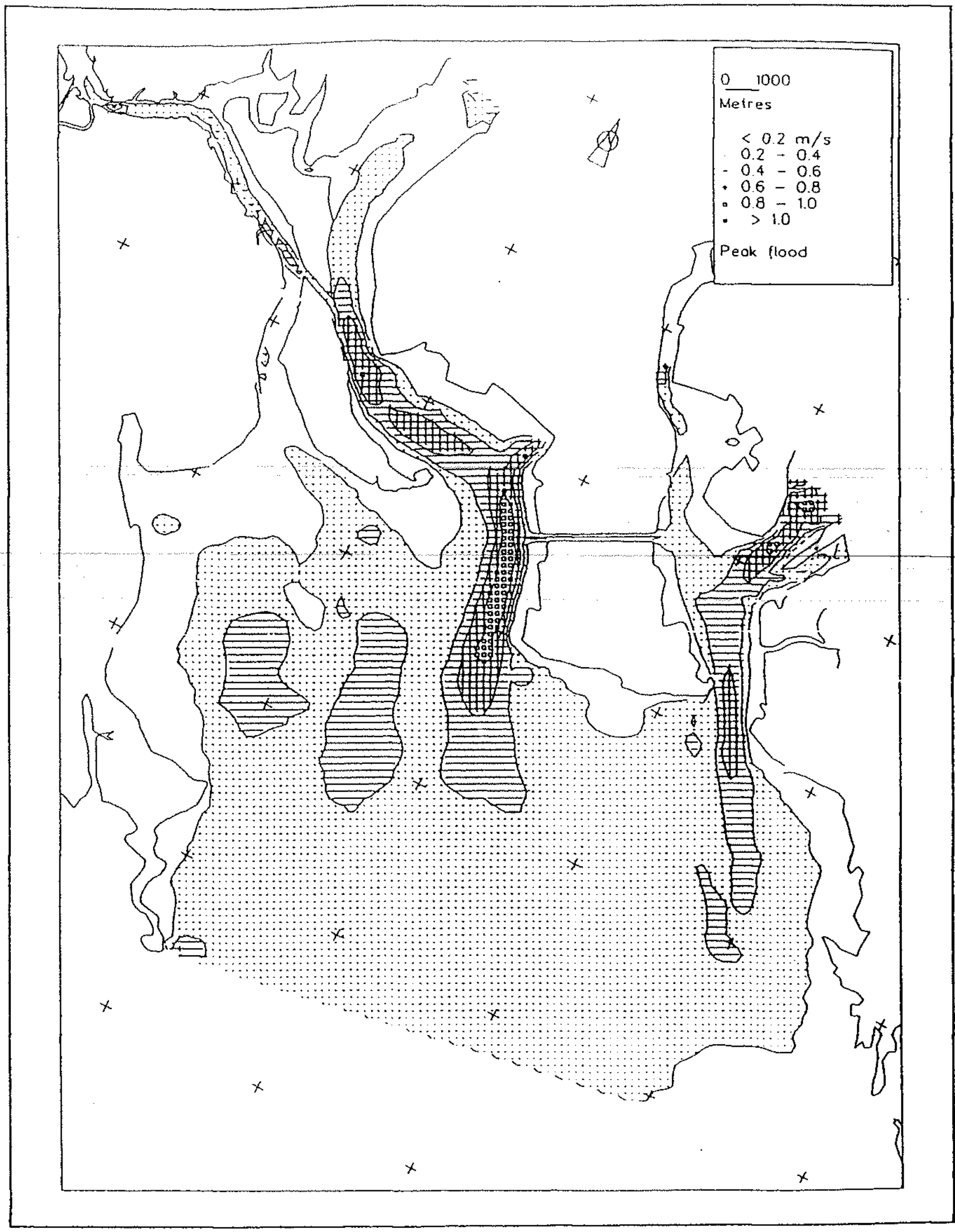


Figure 4.2.8.(b)
Hai Phong
Magnitude of speed - Peak flood
Existing conditions

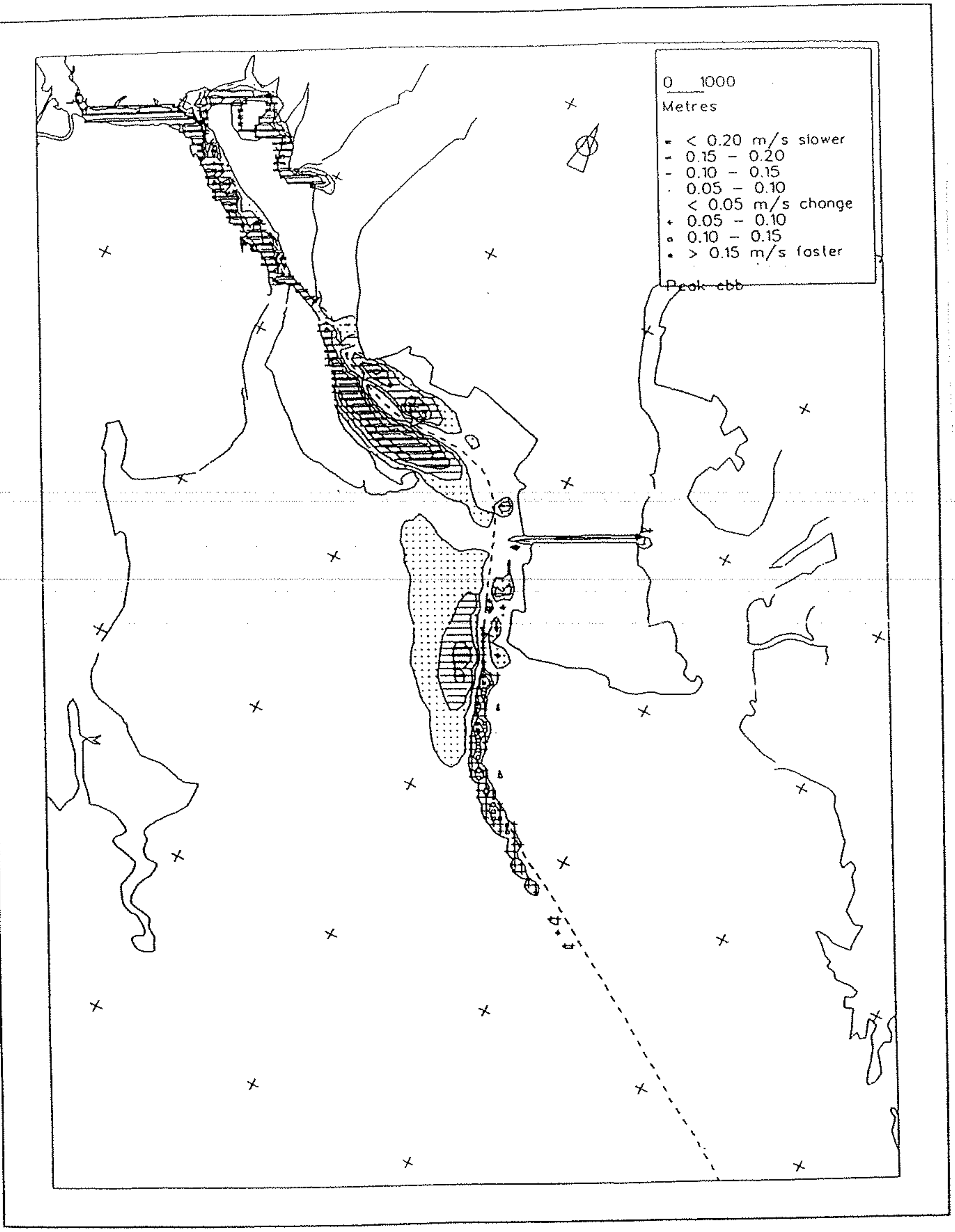


Figure 4.2.9.(a)
Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 1 : C.D. - 9.0 m channel

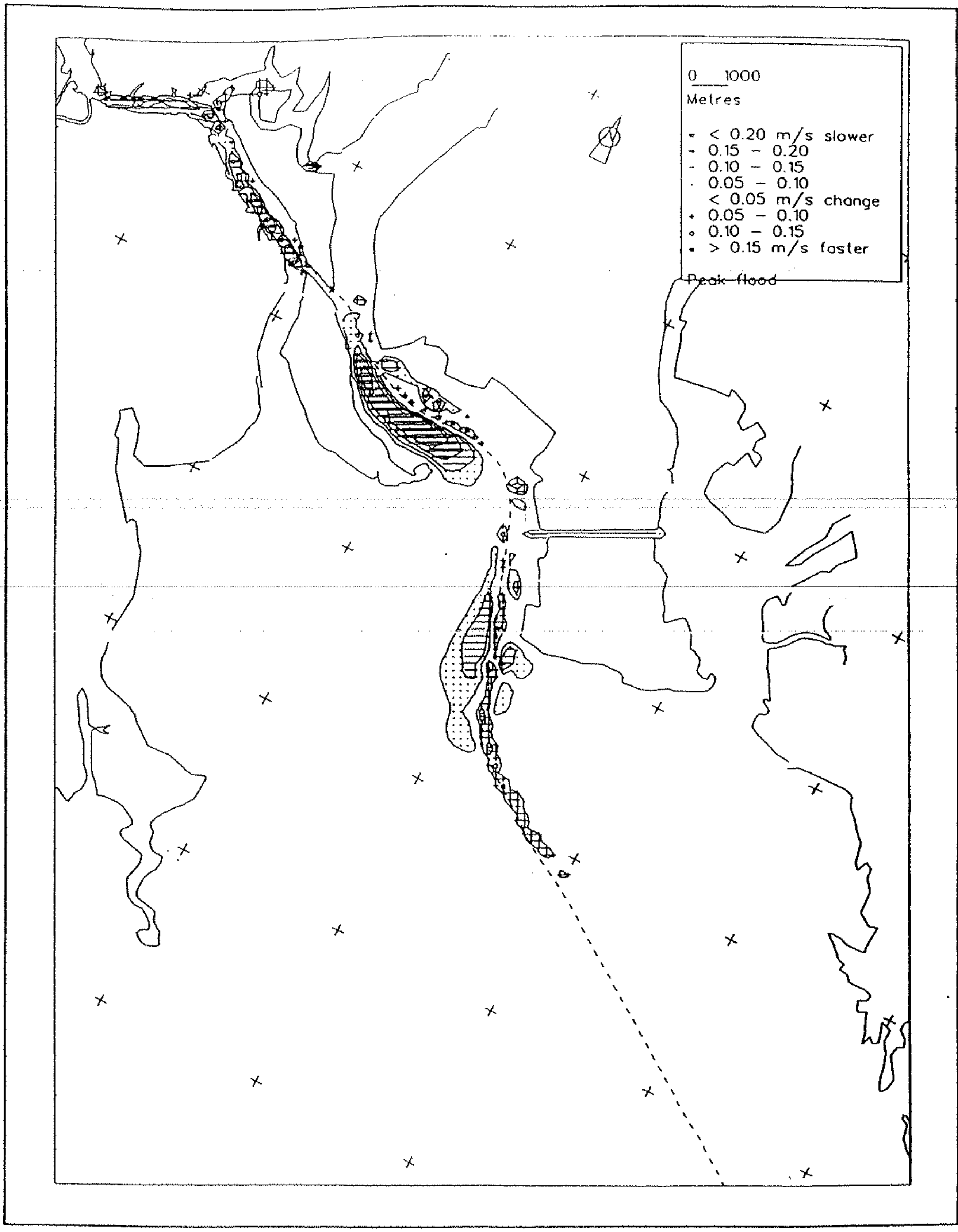


Figure 4.2.9.(b)
Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 1 : C.D. - 9.0 m channel

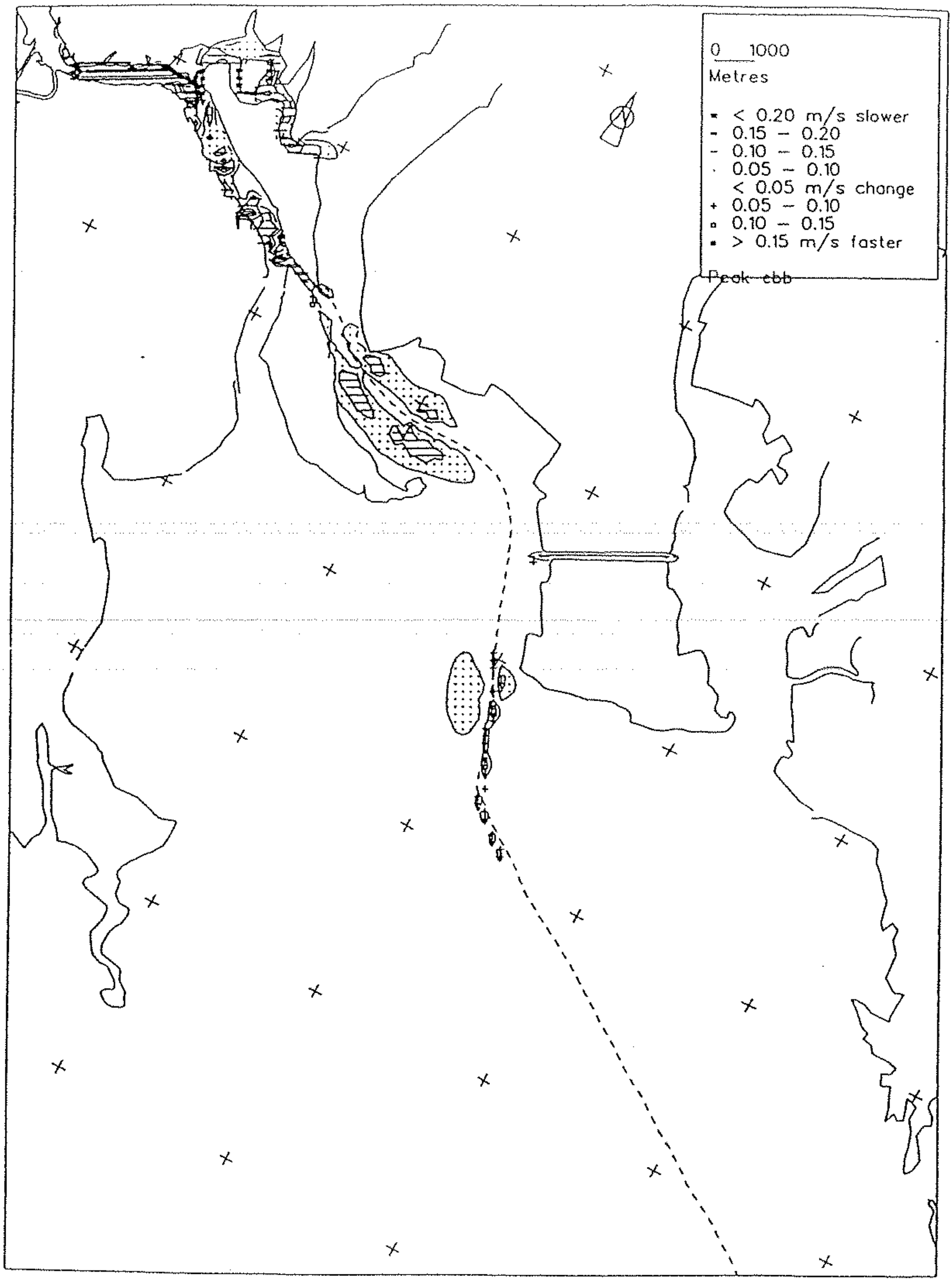


Figure 4.2.10.(a)
Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 1 : C.D. - 7.3 m channel

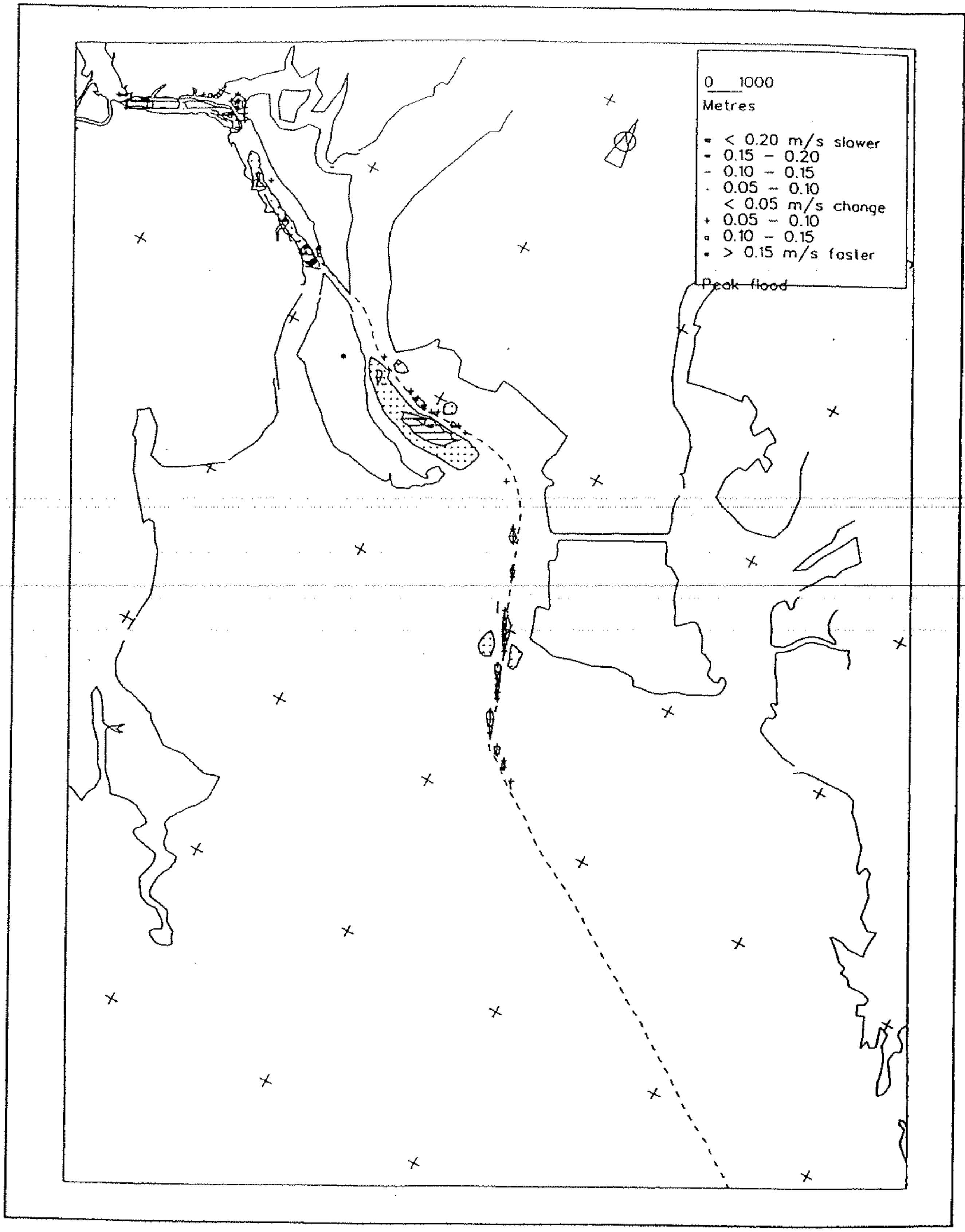


Figure 4.2.10.(b)

Hai Phong

Difference in magnitude of speed - Peak flood

Alternative 1 : C.D. - 7.3 m channel

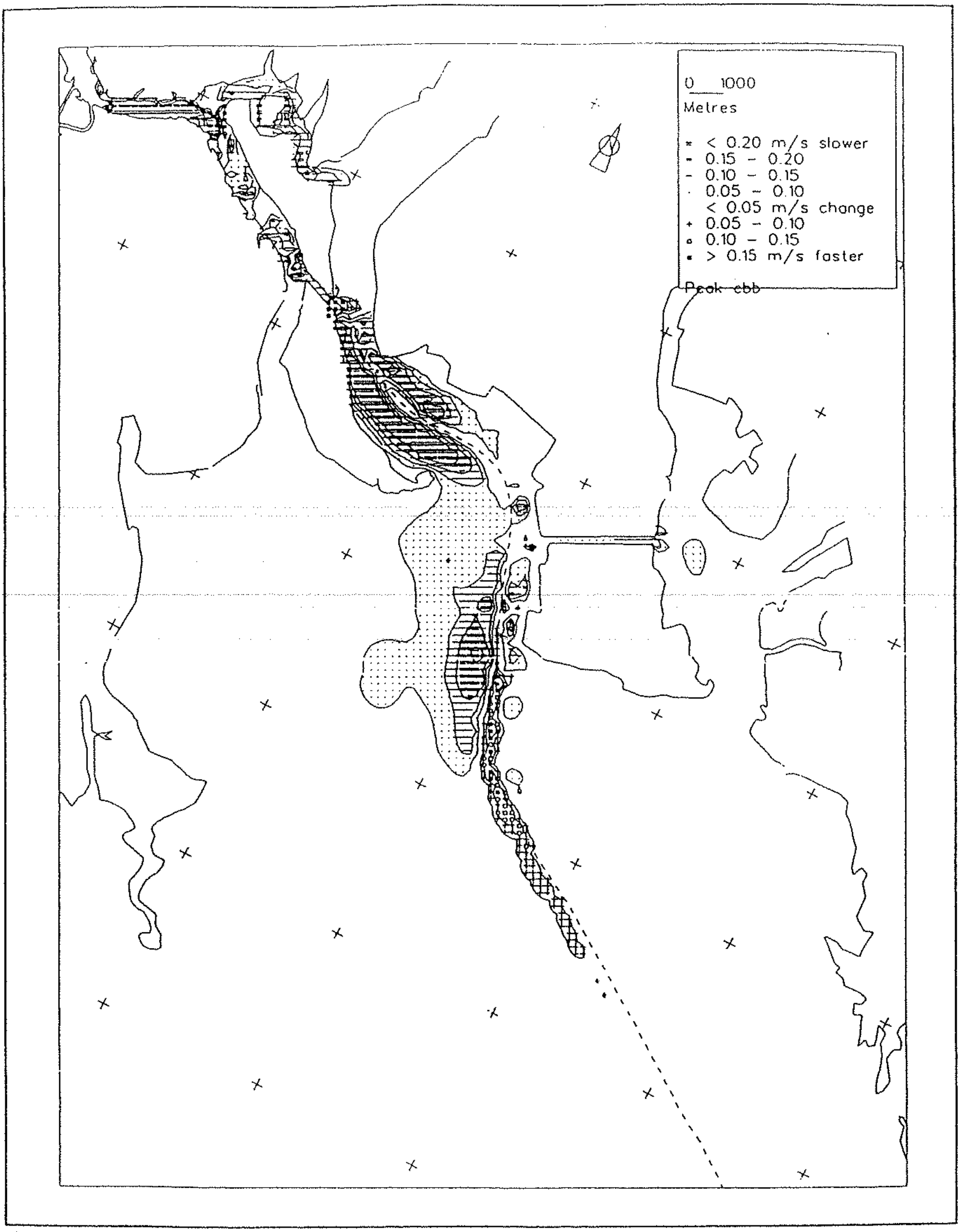


Figure 4.2.11.(a)
Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 1 : C.D. - 11.5 m channel

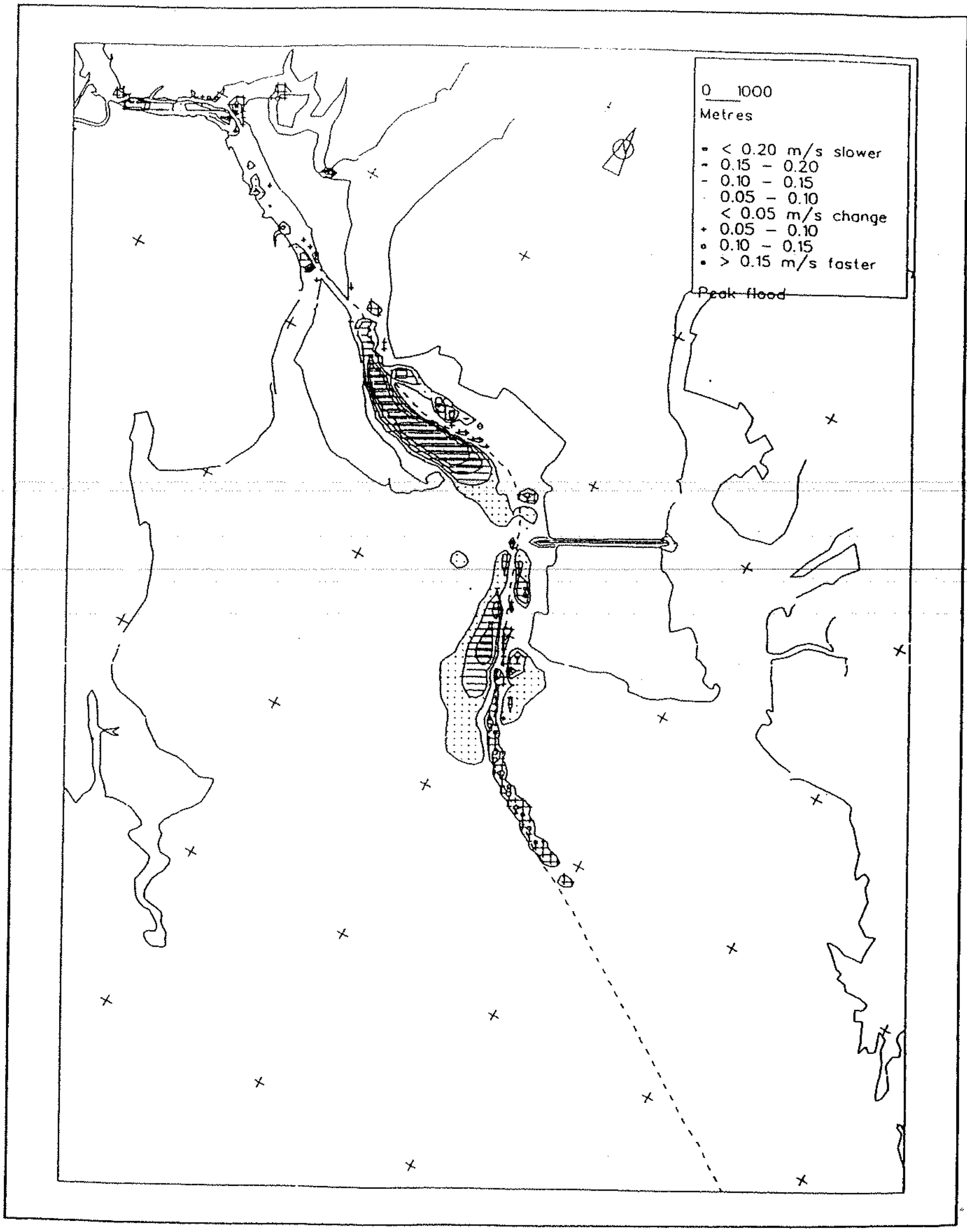


Figure 4.2.11.(b)
Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 1 : C.D. - 11.5 m channel

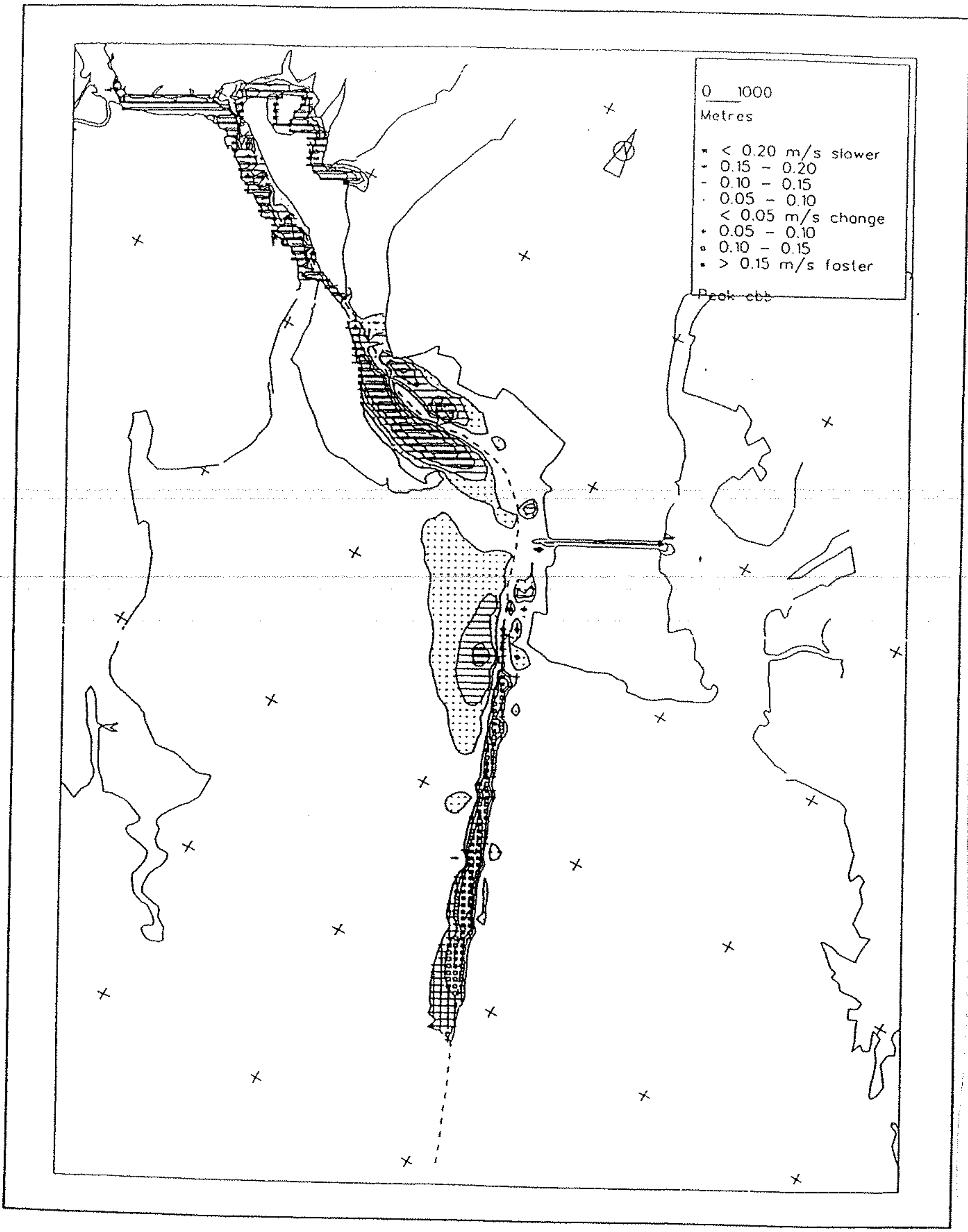


Figure 4.2.12.(a)
Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 2 : C.D. - 9.0 m channel

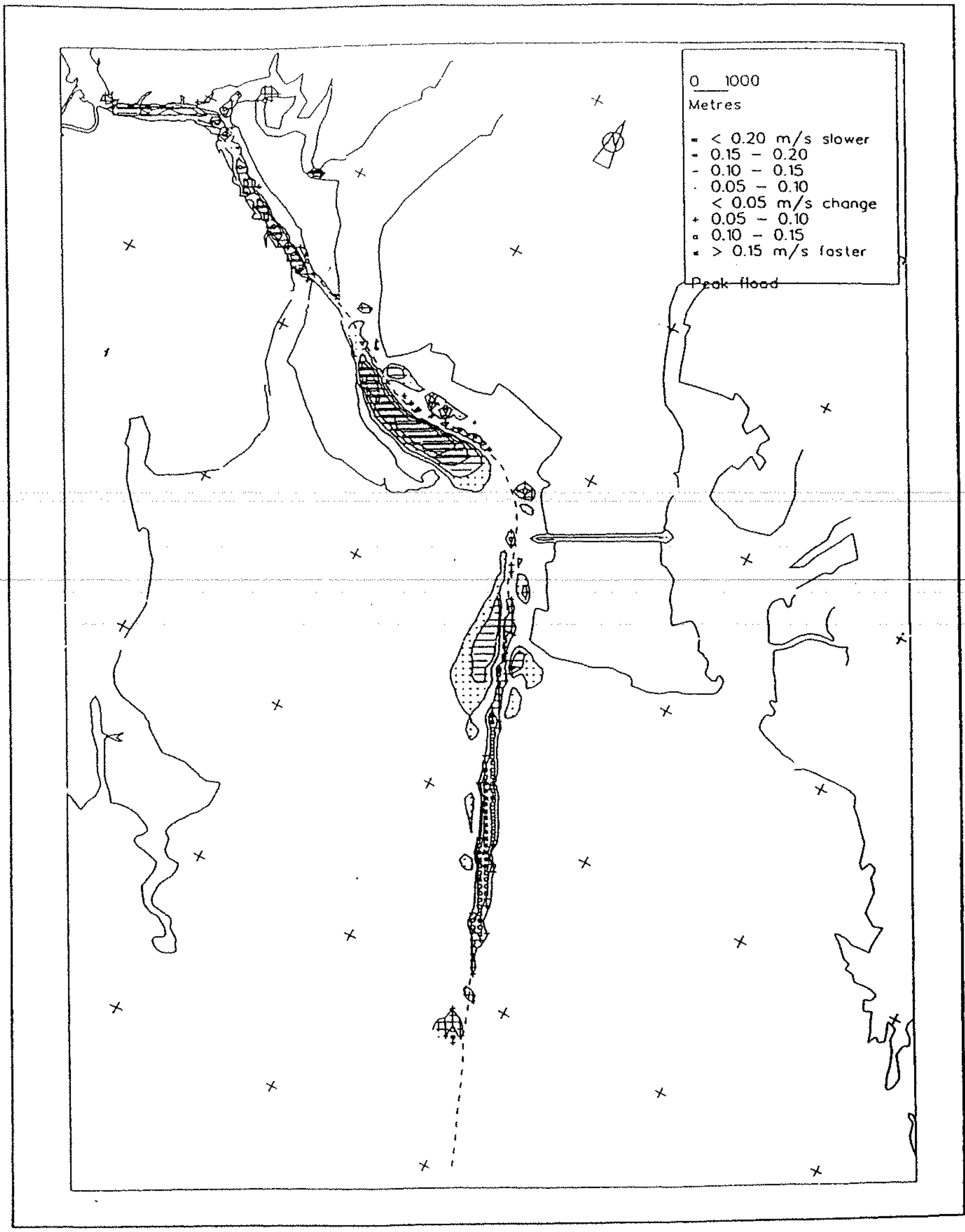


Figure 4.2.12.(b)
Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 2 : C.D. - 9.0 m channel

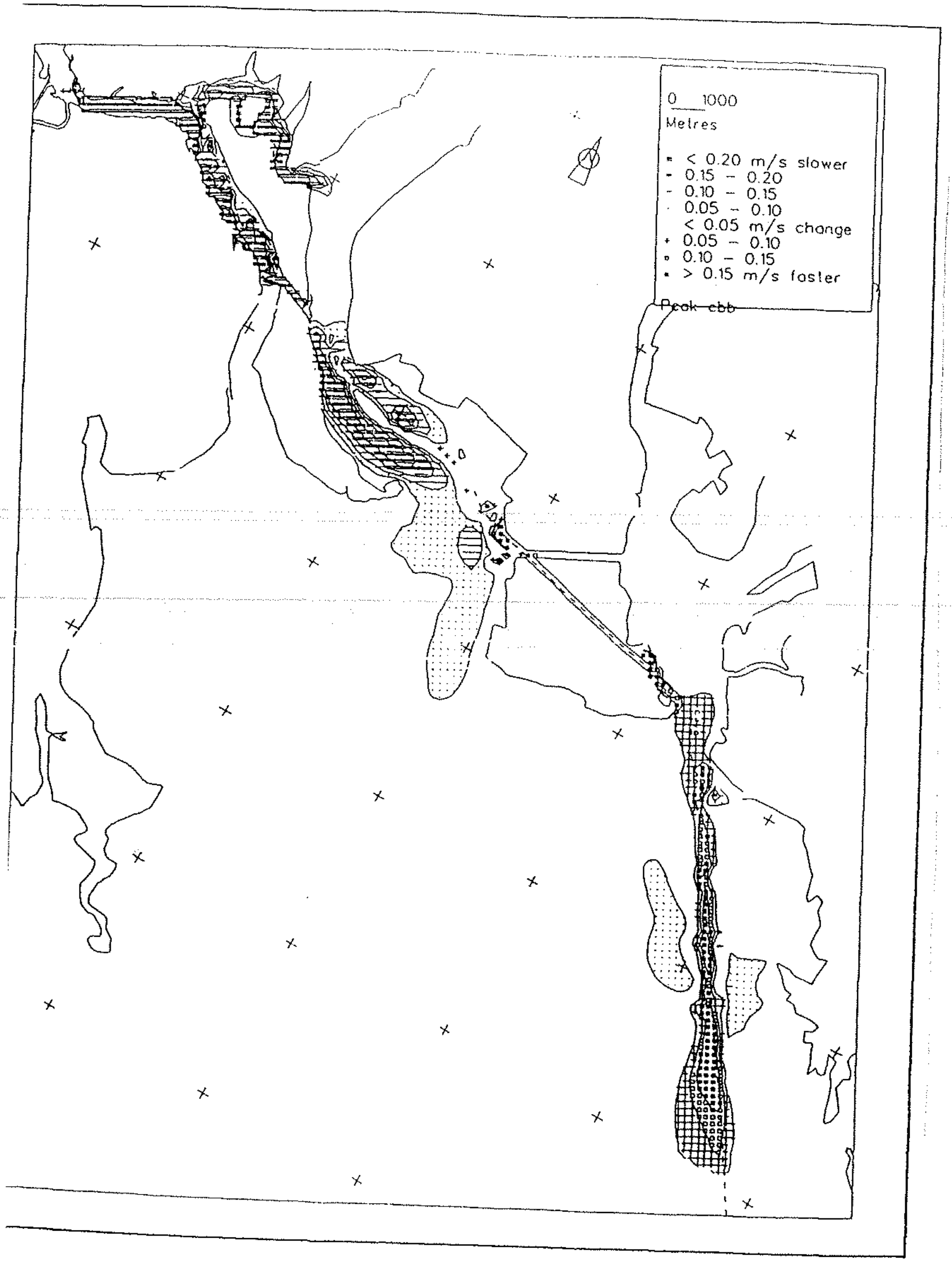


Figure 4.2.13.(a)
Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 3 : C.D. - 9.0 m channel

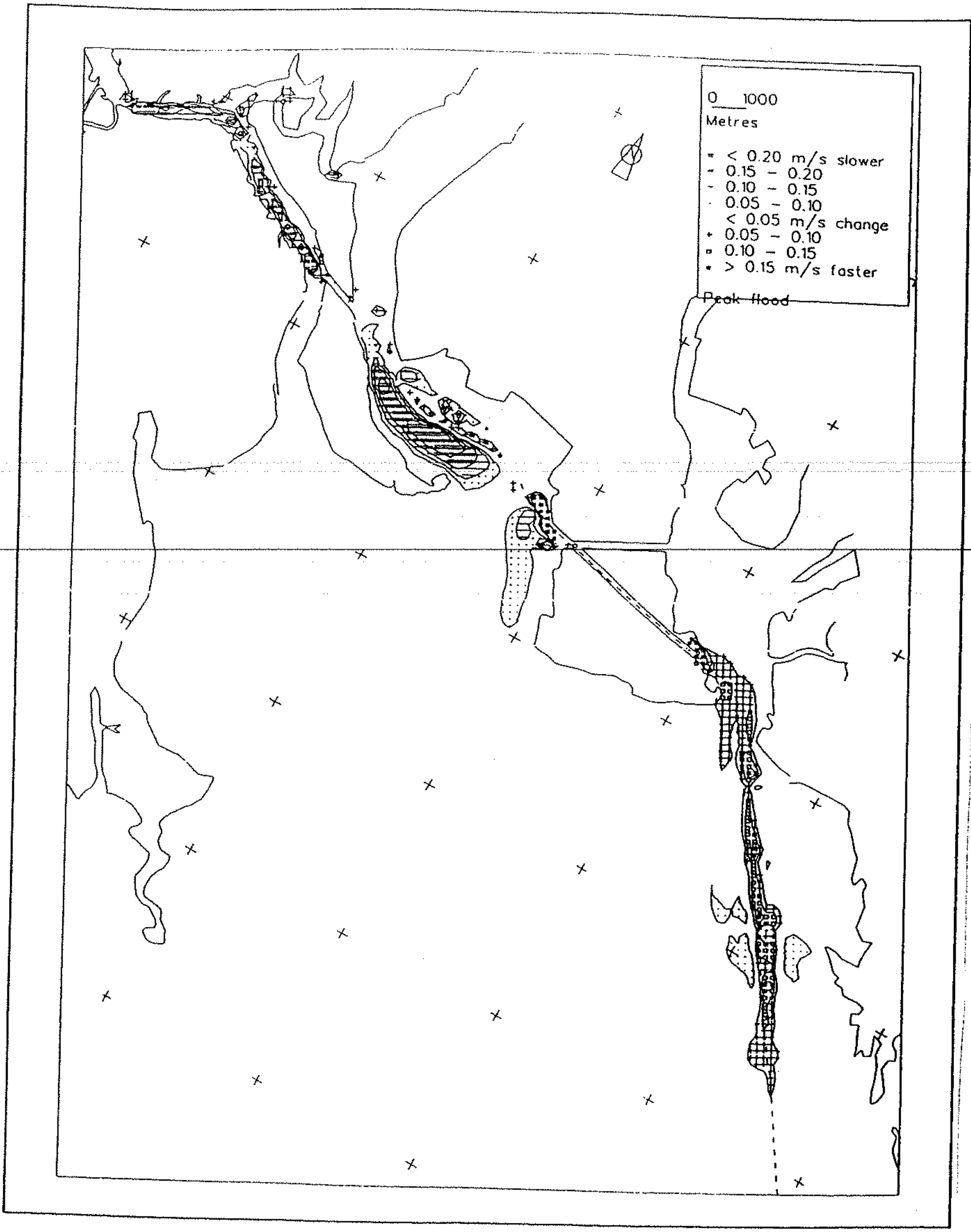


Figure 4.2.13.(b)
Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 3 : C.D. - 9.0 m channel

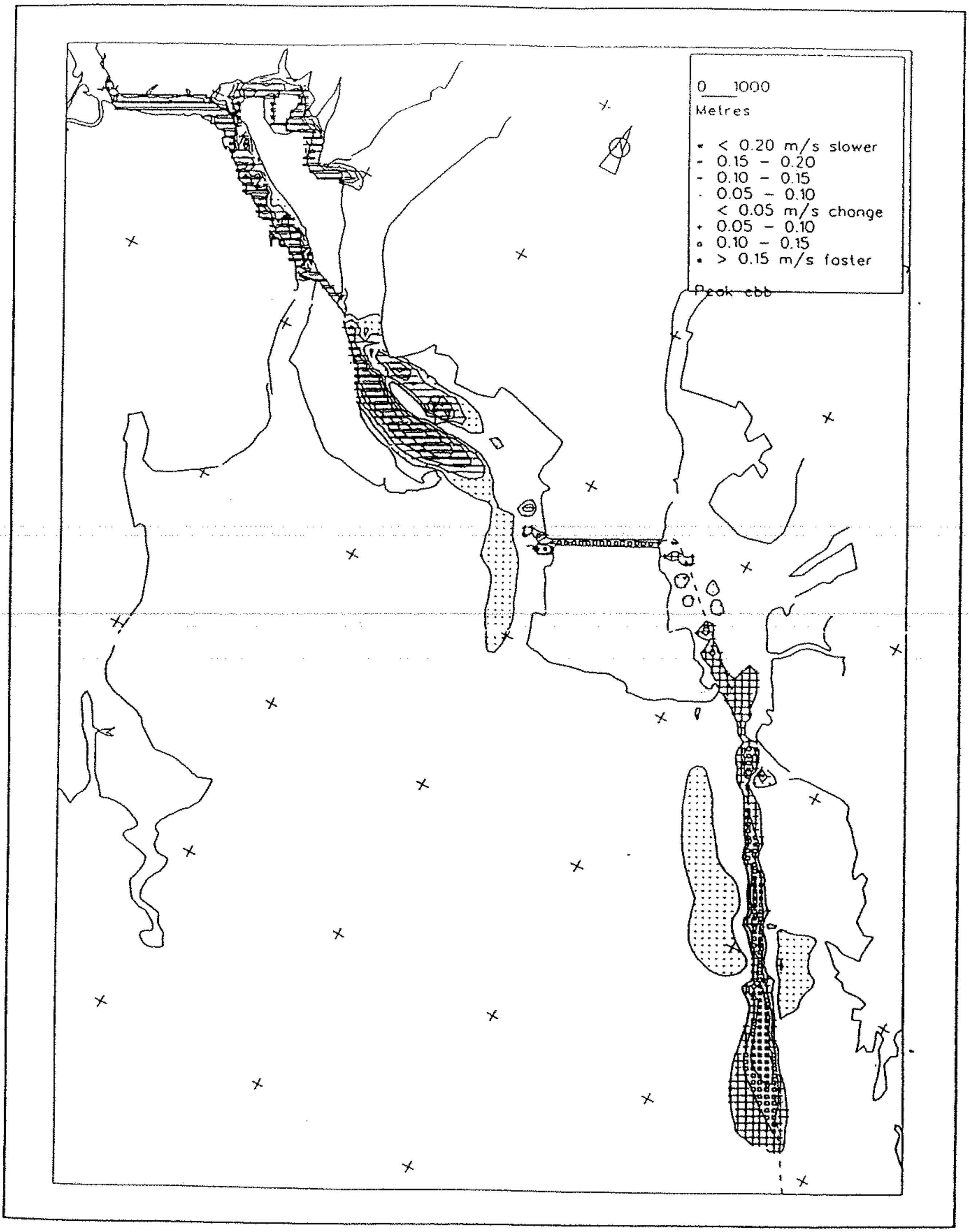


Figure 4.2.14.(a)
Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 4 : C.D.- 9.0 m channel

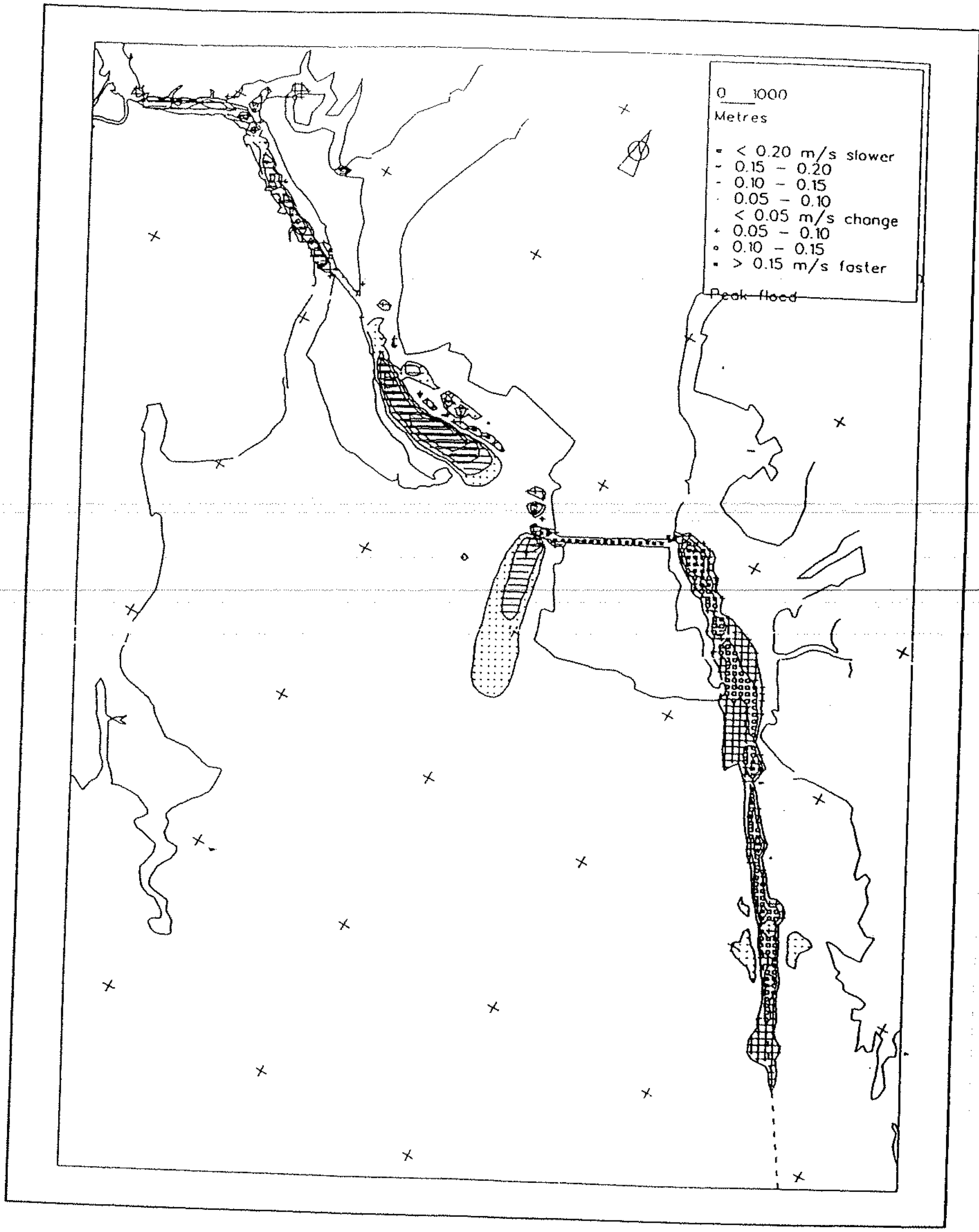


Figure 4.2.14.(b)
Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 4 : C.D. - 9.0 m channel

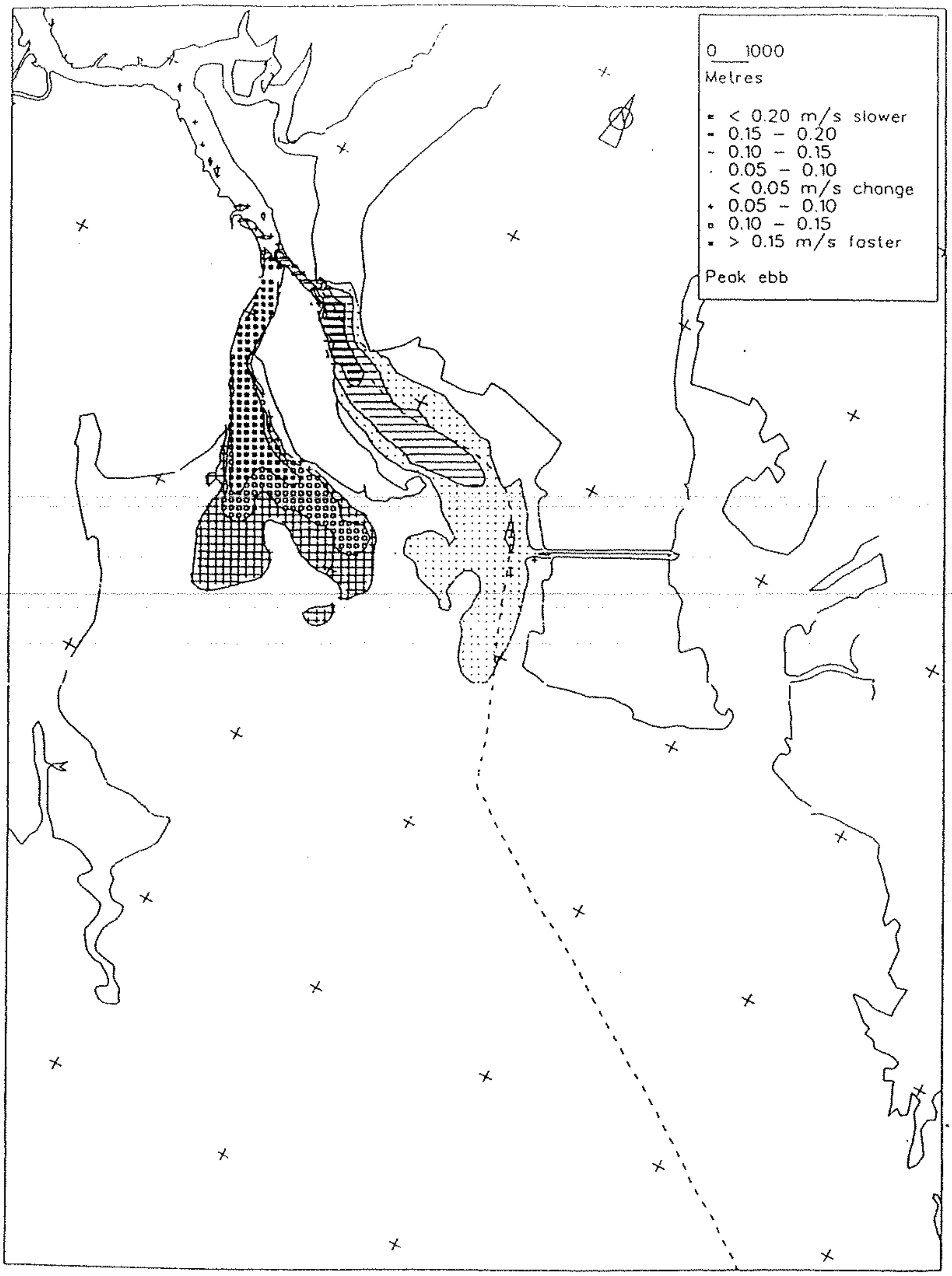


Figure 4.2.15.(a)
Hai Phong
Difference in magnitude of speed - Peak ebb
Dinh Vu dam removed : C.D. - 2 m channel

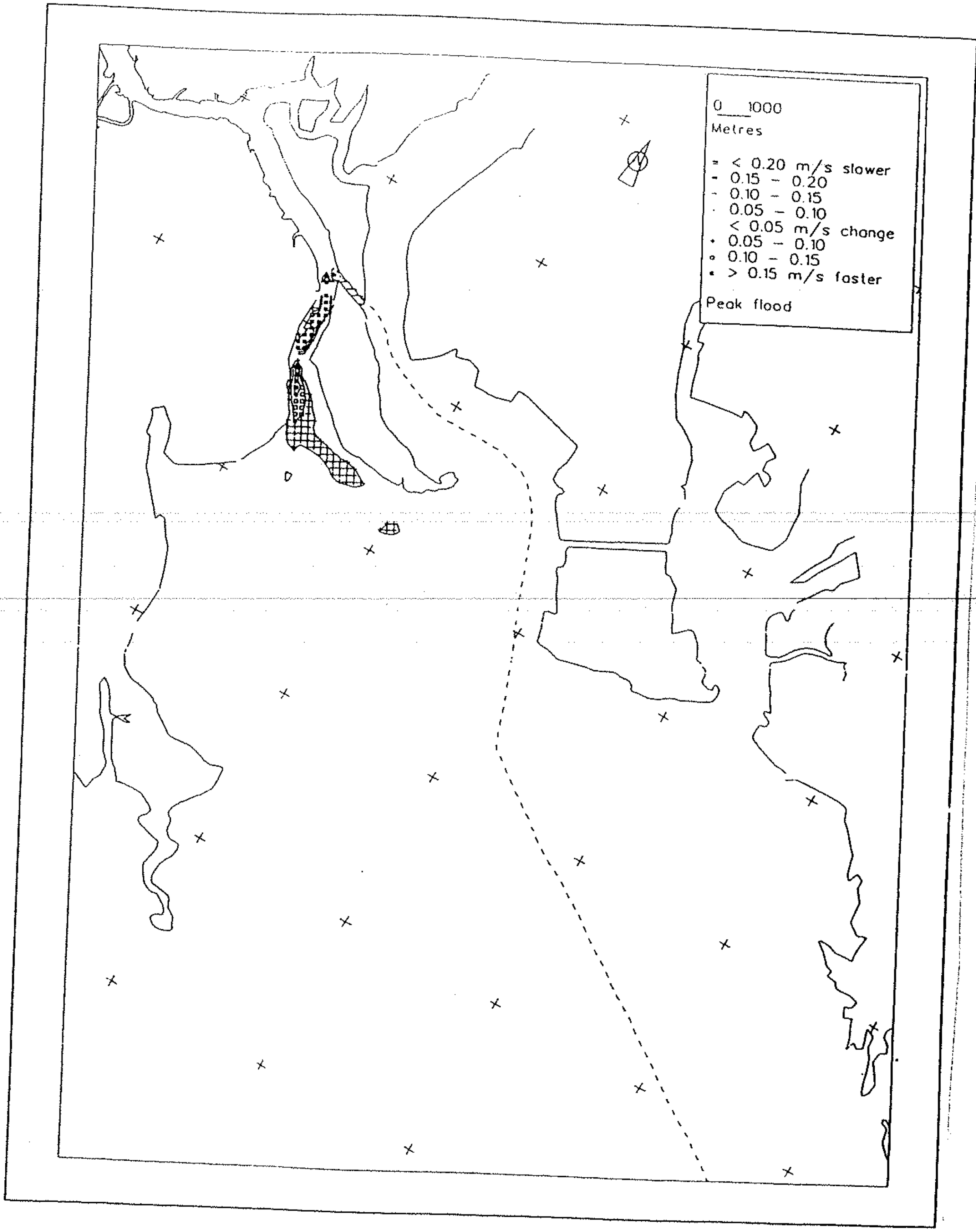


Figure 4.2.15.(b)
Hai Phong
Difference in magnitude of speed - Peak flood
Dinh Vu dam removed : C.D. - 2 m channel

4.2.4.3. Wet season, neap tides

4.2.4.3.1. Existing conditions

The wet neap simulation has been analysed to give the residual flow velocity over the tide considered. The residual velocities are shown in figs 4.2.16.(a) and (b) for the surface layer and layer 4 (the bed layer). The surface layer displays a seaward current at all locations, but the bed layer shows a landward current at the seaward limit but a seaward current further landward.

4.2.4.3.2. Alternative 1 : Deepening and widening the existing Nam Trieu Channel - Depths at C.D. - 9.0 m and C.D. - 7.3 m

The residual velocities over the tide fig 4.2.17.(a) and (b) for surface and bed show similar results for the surface current but the null point between seaward and landward current in the bed layer has moved landward by a distance of one or two kilometres.
This seems to show the possibility for deepening of the channel to produce a likely increase of saline intrusion. The salinities in the seaward part of the model, however, show little effect of the channel. The current speeds for alternative 1 show that the bed current at buoy 18 is considerably increased with the dredged channel, which as the bed layer is also deeper in this case results in a considerable increase in the salt being transported landward at this section of the estuary. This could also lead to increased possibilities of siltation landward of buoy 18 if the lower layer contains large amounts of suspended sediment.

The residual velocities with the shallower channel (C.D. -7.3 m) alternative 1, are shown in figures 4.2.18.(a) and (b) for surface and bed currents. The results are generally intermediate between the existing situation and the alternative 1 channel at C.D. - 9.0 m.

4.2.4.3.3. Alternative 4 : New alignment in Lach Huyen through Trap Canal Depth at C.D. - 9.0 m

The residual velocities over the tide are shown in figure 4.2.19.(a) and (b). While the effects of increased gravitational circulation can be seen in the Bach Dang salinities (which are zero for the existing case), they are similar in size to those for the alternative 1 channel set at C.D. - 7.3 m and less than those for a C.D. - 9.0 m channel on alternative 1.

4.2.4.3.4. Effect of removal of Dinh Vu Dam

The residual velocities over the tide (figures 4.2.20.(a) and (b)), the salinities in the Dinh vu part of the model and the velocity all show rather little effect on the gravitational circulation of the removal of Dinh Vu dam.

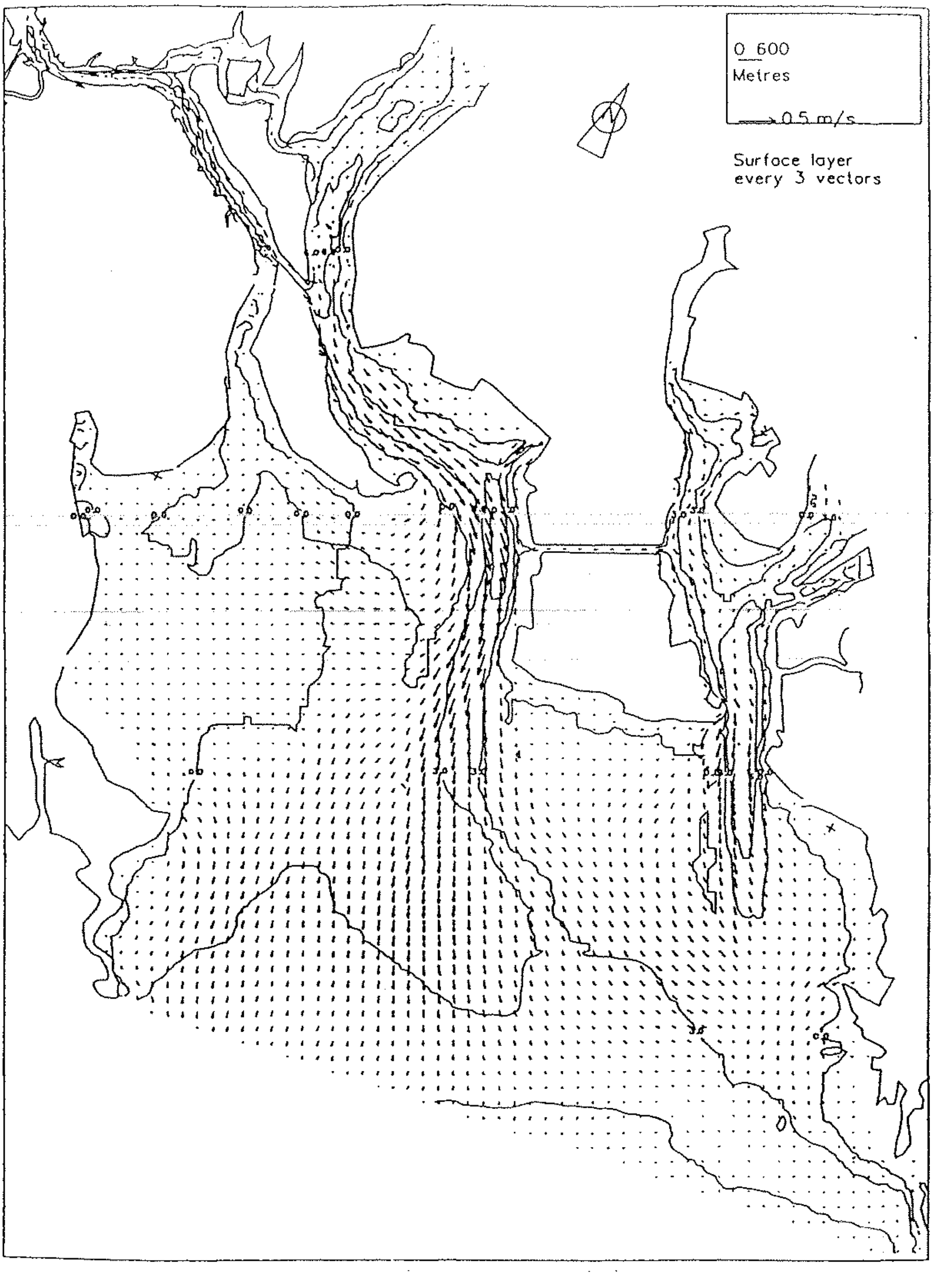


Figure 4.2.16.(a)
Residual Current Vectors - Surface layer
Wet season neap tide
Existing conditions

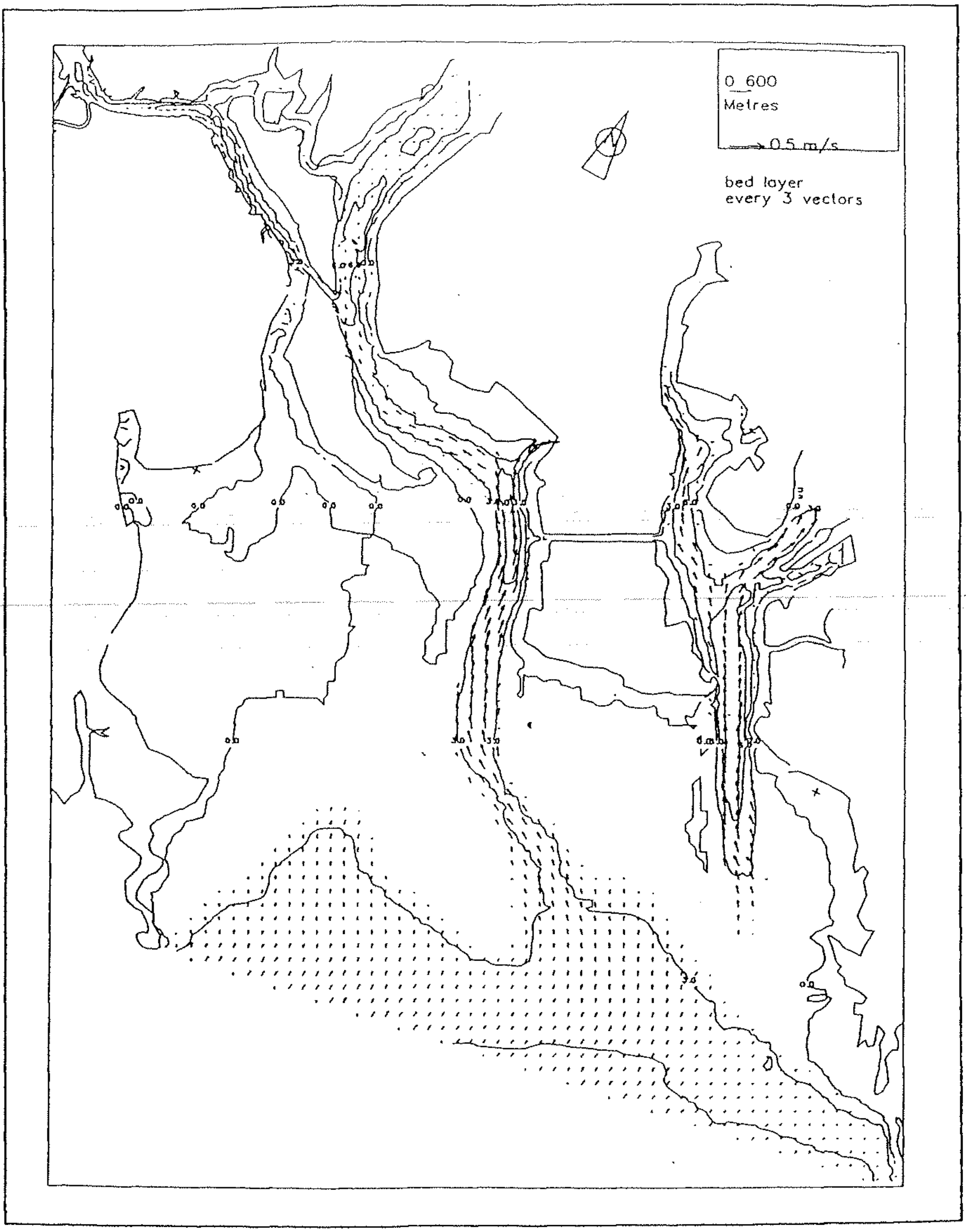


Figure 4.2.16.(b)
Residual current vectors - Bed layer
Wet season neap tide
Existing conditions

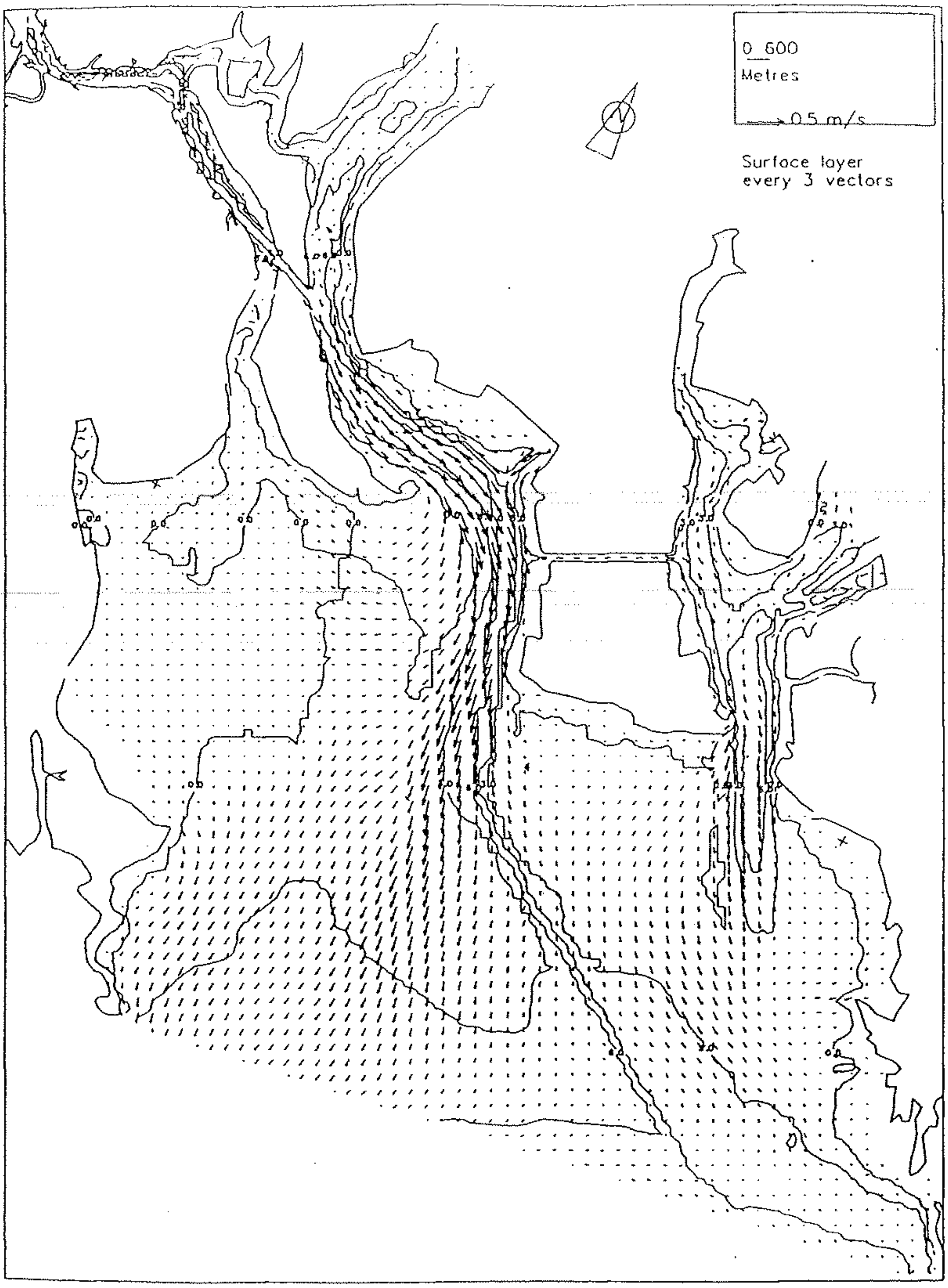


__Figure 4.2.17.(a)__
Residual Current Vectors - Surface layer
Wet season neap tide
Alternative 1 : C.D. - 9.0 m channel

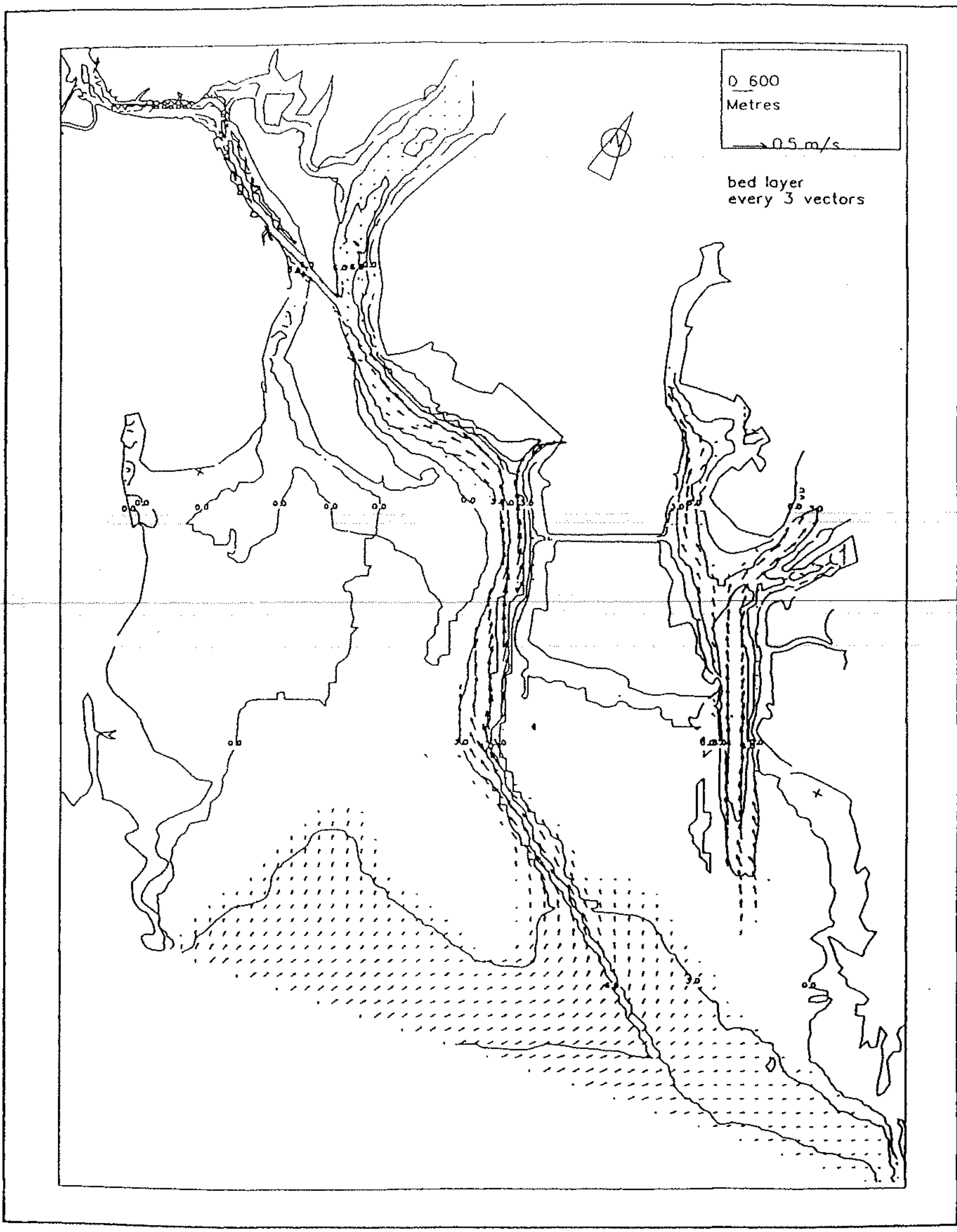


Figure 4.2.17.(b)
Residual Current Vectors - Bed layer
Wet season neap tide
Alternative 1 : C.D. - 9.0 m channel

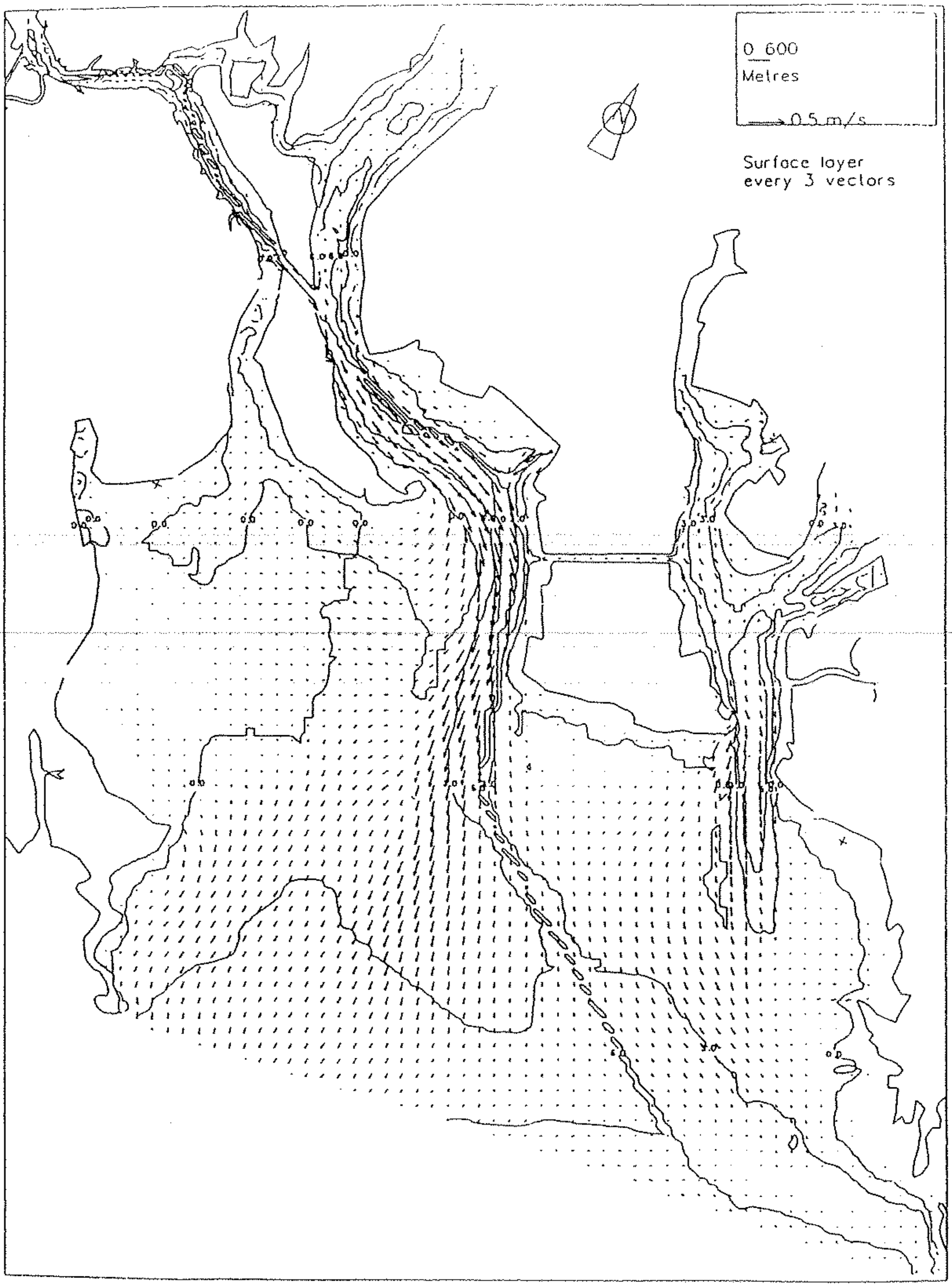


Figure 4.2.18.(a)
Residual current vectors - Surface layer
Wet season neap tide
Alternative 1 : -7.3 m

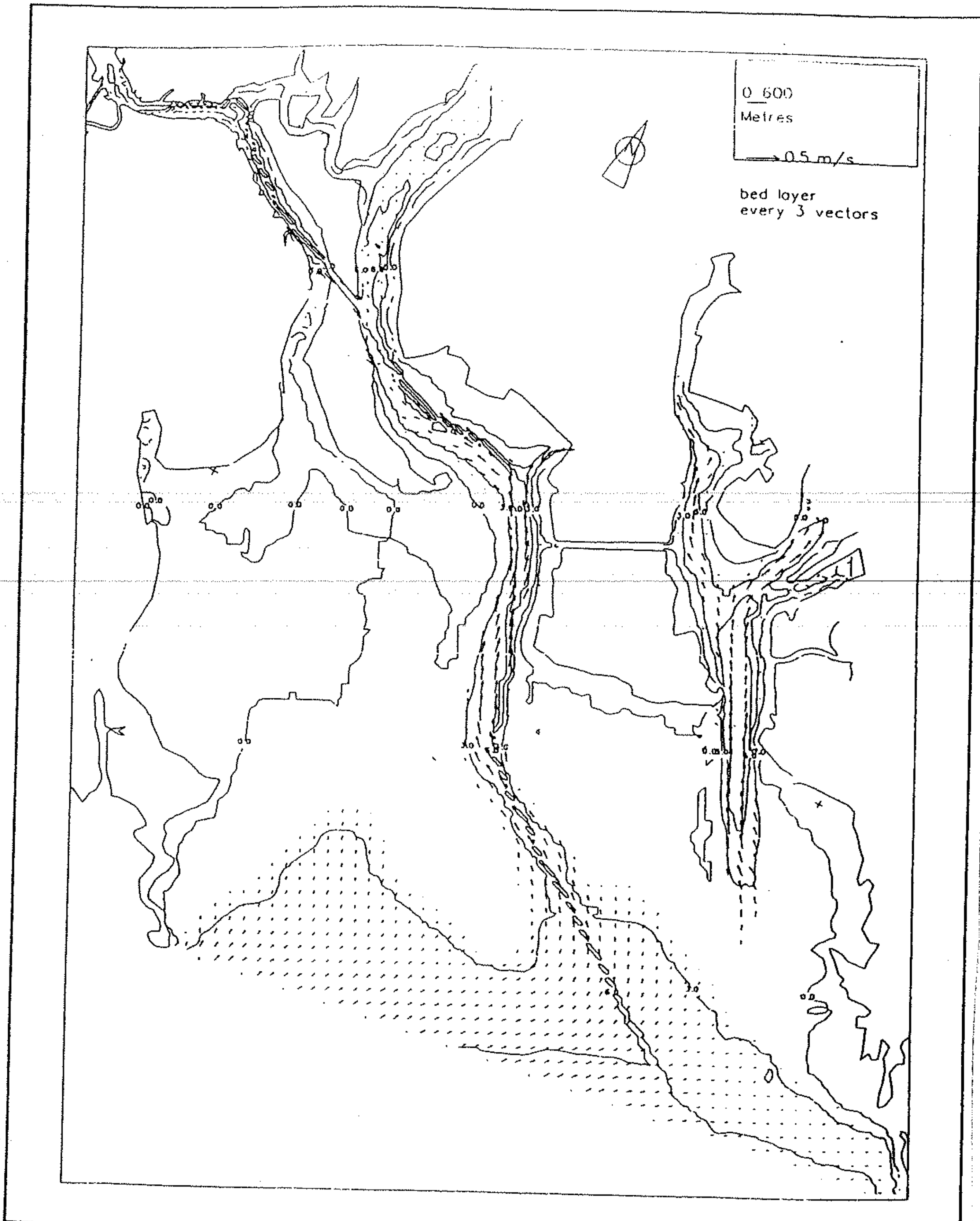


Figure 4.2.18.(b)
Residual current vectors - Bed layer
Wet season neap tide
Alternative 1 : - 7.3 m

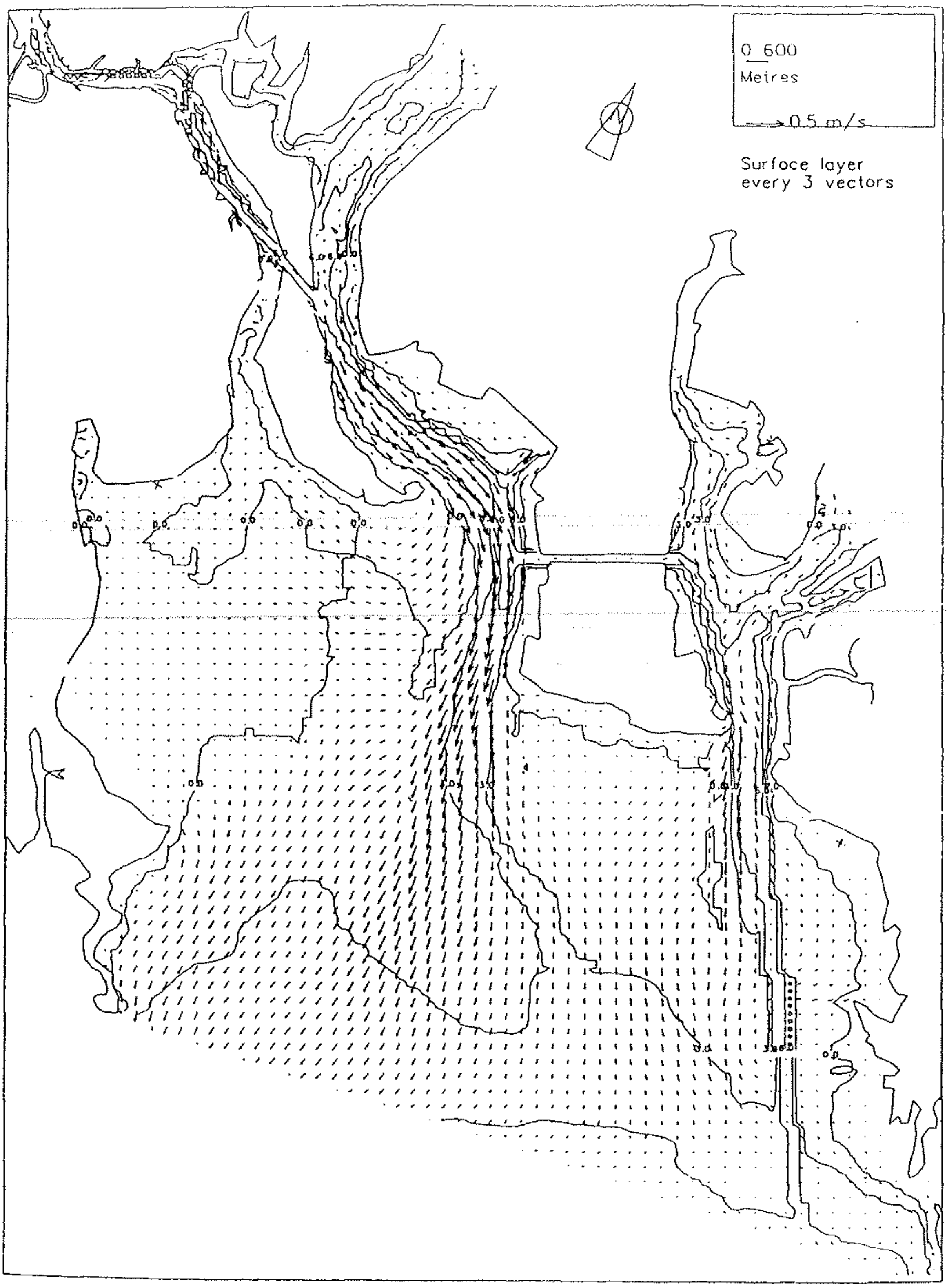


Figure 4.2.19.(a)
Residual current vectors - Surface layer
Wet season neap tide
Alternative 4 : C.D. - 9.0 m

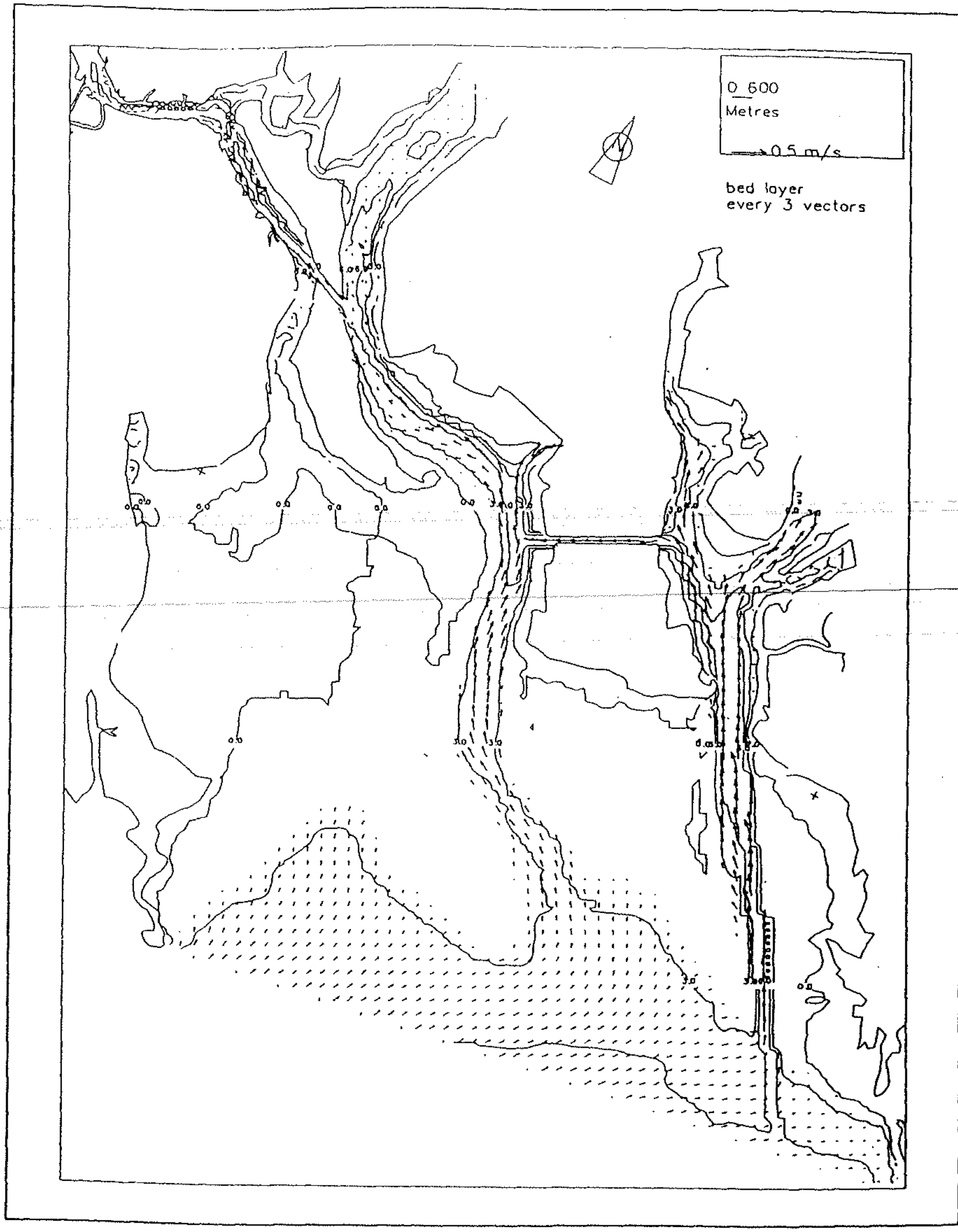


Figure 4.2.19.(b)

Residual current vectors - Bed layer
Wet season neap tide
Alternative 4 : C.D. - 9.0 m

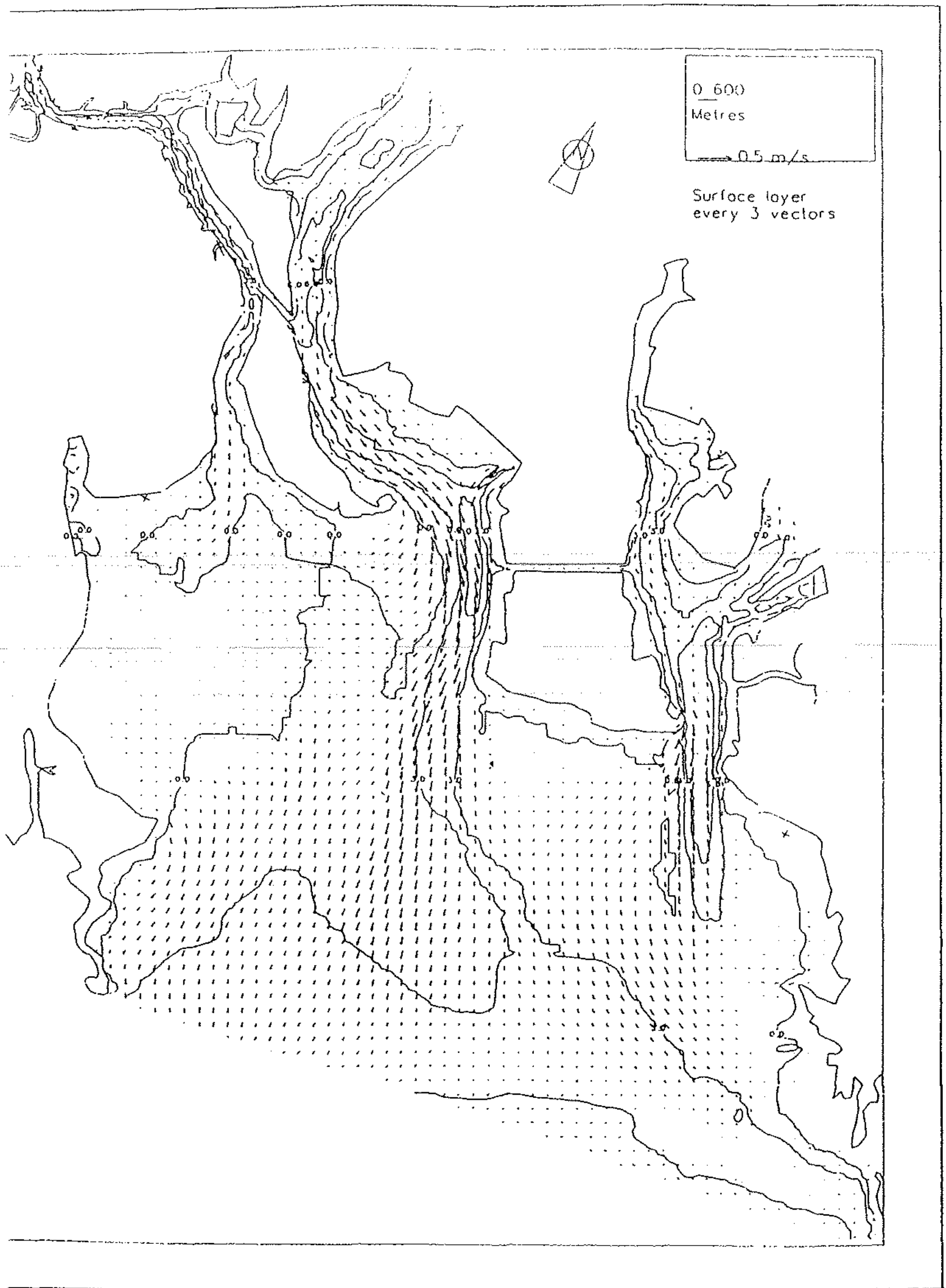


Figure 4.2.20.(a)
Residual Current Vectors - Surface layer
Wet season neap tide
Dinh Vu Dam removed, existing channel

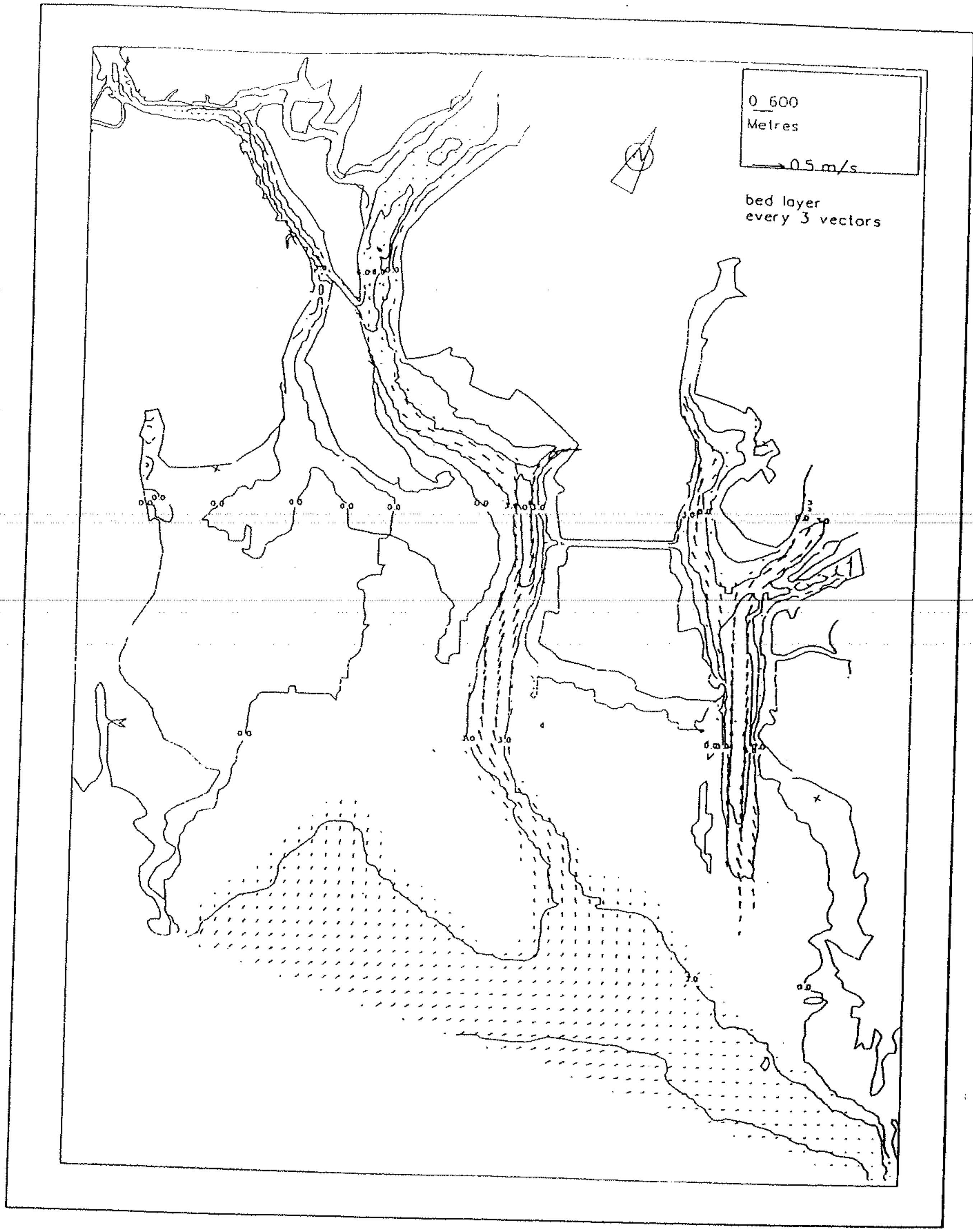


Figure 4.2.20.(b)
Residual Current Vectors - Bed layer
Wet season neap tide
Dinh Vu Dam removed, existing channel

4.2.4.4. Summary of the impact of the alternative channel configurations

The different channel configurations have been tested for dry spring and wet neap tides as these are able to show the influence of the bathymetry changes on the tidal currents and on the gravitational circulation respectively.

In general the deepening of the channel is discovered to result in a lower current as a larger channel cross section is used to carry essentially the same tidal discharge. The exception to this is where the channel crosses the bar where speed increases in the channel are found (figures 4.2.21. and 4.2.22(a) and 4.2.22(b)) by a kind of "channalization" of the flow. The removal of the Dinh Vu dam also causes a decrease in the current speed in the existing channel on the other side of Dinh Vu island as more of the current is carried past the dam site and less passes through the Dinh Vu channel. Alternatives 3 and 4 are similar to the other schemes landward of the Trap Canal and they have a similar effect there (reduction of speed caused by the increase of cross sectional area).

The deepening of the channel also results in an increase in the effectiveness of the gravitational circulation as evidenced by the patterns of residual current at the bed which tend to show a null point moving further landward and of the salinities at Bach Dang section which become larger (than zero for existing conditions). The C.D. - 7.3 m and C.D. - 9.0 m channels on Alternative 1 and the C.D. - 9.0 m channel on alternative 4 all showed such increased salinity at the Bach Dang section, indicating increased gravitational circulation. However the alternative 4 result showed a lower salinity at Bach Dang section compared with the C.D. - 9.0 m channel being closer to the C.D. -7.3 m channel result. The removal of Dinh Vu dam does not appear to show any significant effect on gravitational circulation.

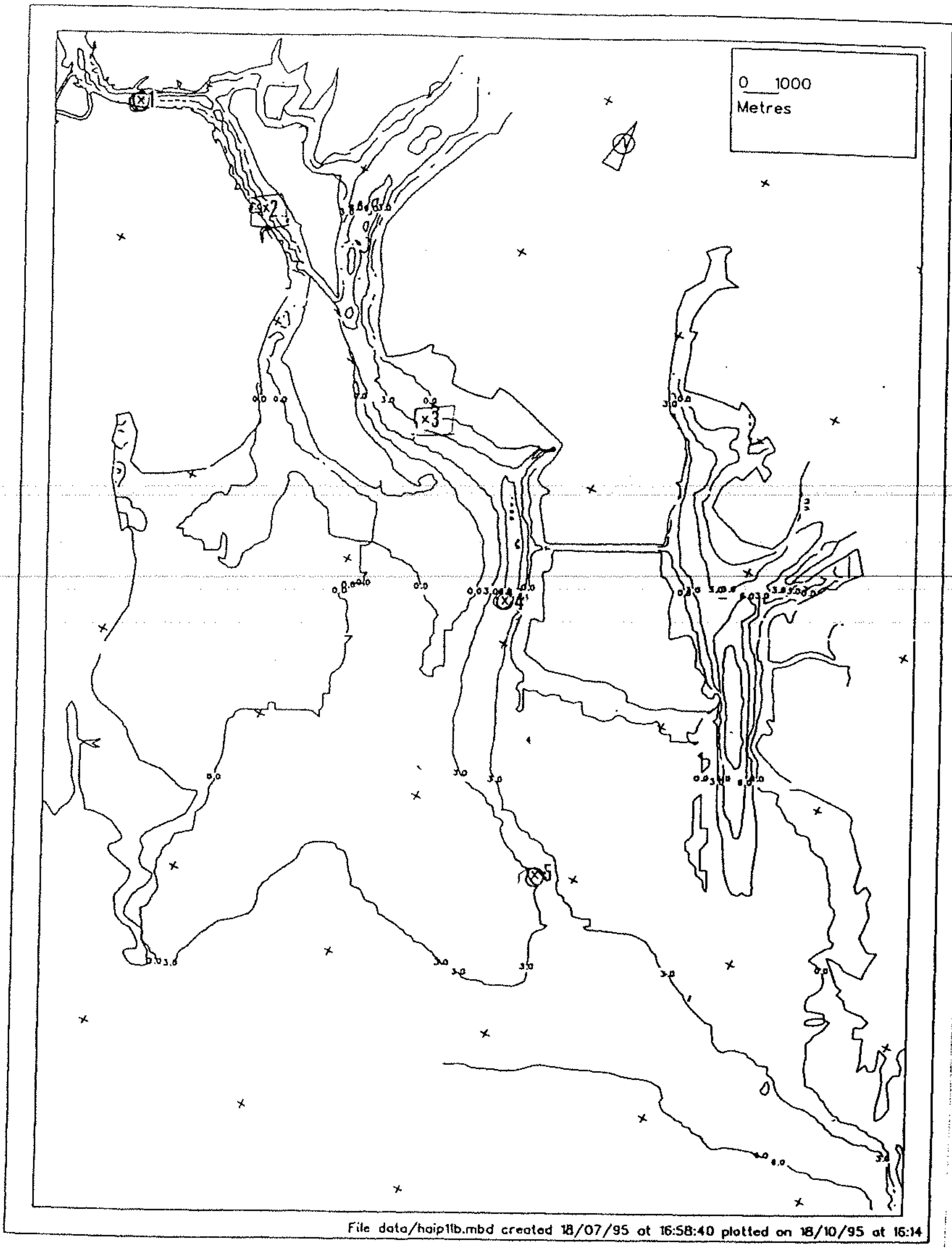


Figure 4.2.21.
Hai Phong approaches model
Positions

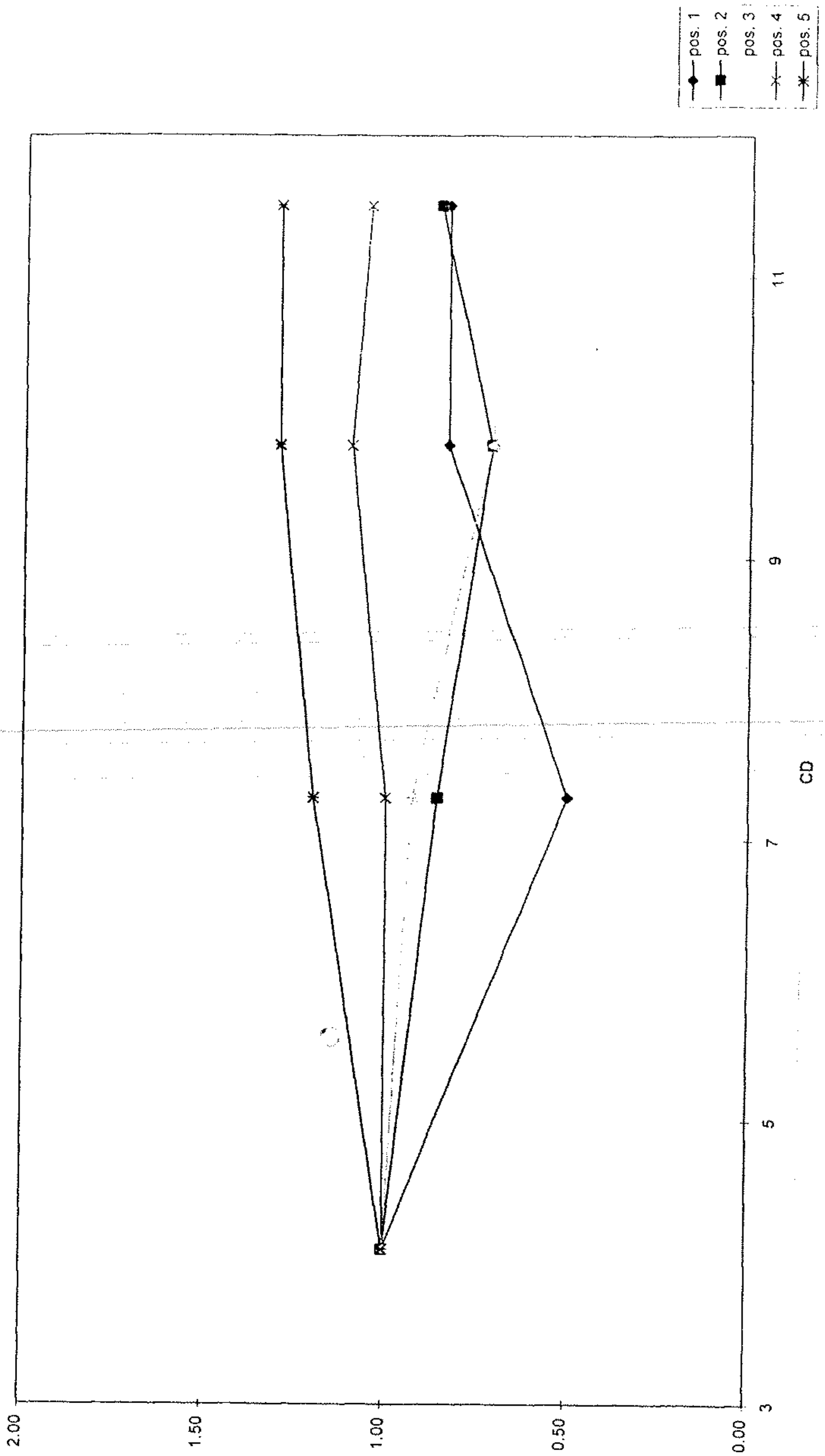


Figure 4.2.22.(a)
Difference in magnitude of speed
Comparison of existing conditions and alternative 1
Dry season - Peak ebb

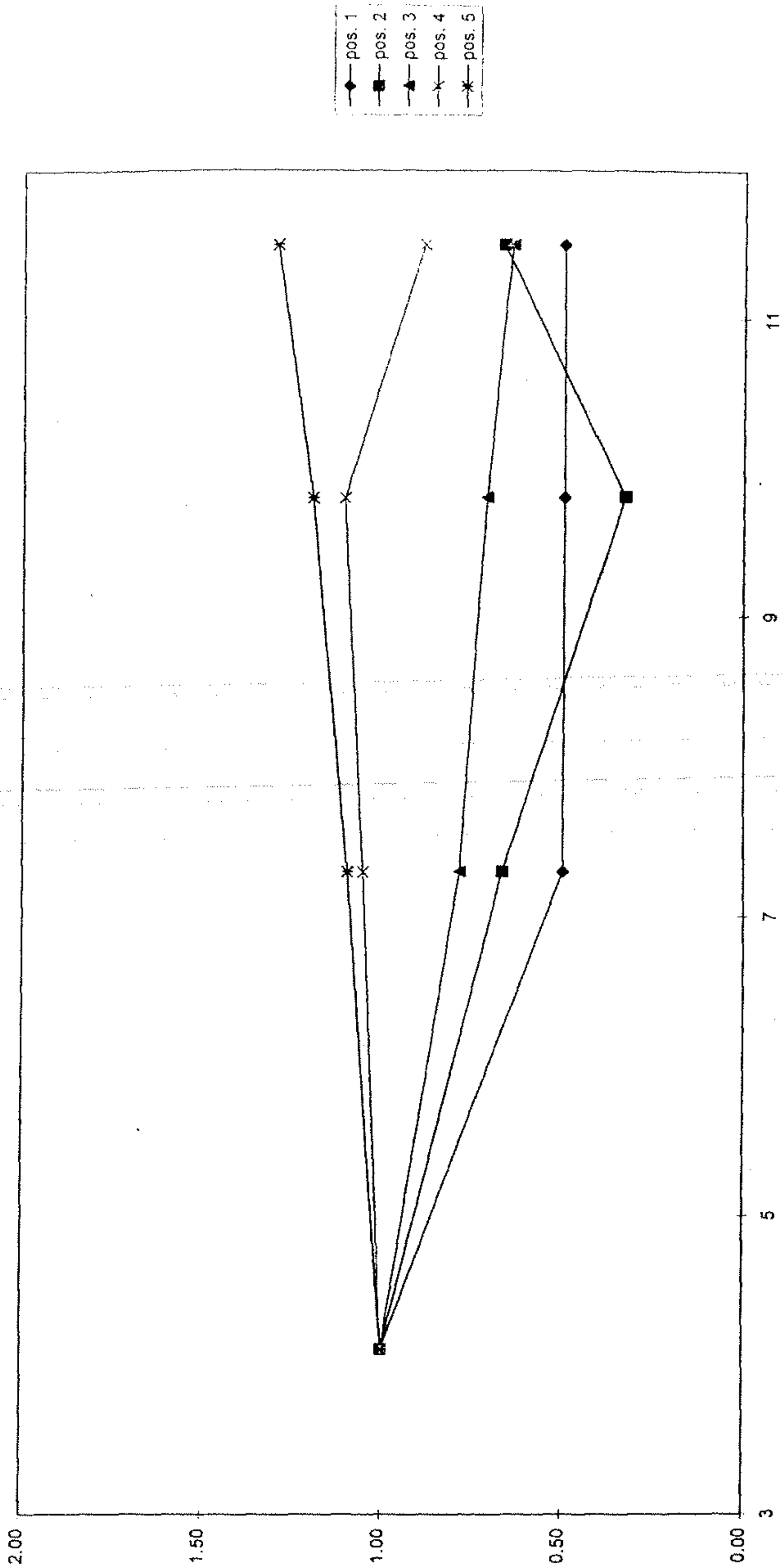


Figure 4.2.22.(b)
Difference in magnitude of speed
Comparison of existing condition and alternative 1
Dry season - Peak flood

4.2.5. Sedimentological modelling results

4.2.5.1. FLUIDMUDFLOW Model set-up

Model tests have been carried out for the existing condition, and for the 4 alternatives with the model FLUIDMUDFLOW. The model was the validated 3D-flow fields described in par. 4.2.2. and the calculated wave fields (see par. 4.2.3.5.).
The boundary conditions applied for suspended sediment, which strongly influence the input of sediment to the modelled area were as follows (based on the results of the UNDP survey) :

125 - 600 ppm Cua Cam (variable according to season)
75 ppm Bach Dang
50 - 400 ppm offshore (variable according to tide and location)
50 ppm Ham River
50 ppm Chanh River
10 ppm Lang Bay

The initial condition for the model tests used a uniform suspended concentration of 50 ppm, but this is quickly altered by the influence of settling and inflow from the boundary conditions.
The initial distribution of sediment on the bed was set up based on the bed samples from the 1995 survey and includes areas of mud, sandy mud and sand. The sand areas are treated as being inerodible as the mathematical model only applies to mud transport.

4.2.5.2. Simulations of the existing conditions

When analysing the sediment-fluxes to and from the channel-bed in the existing Nam Trieu Channel based on the available channel monitoring data (1992, 1993), the following can be concluded :

a. during dry season average sedimentation is approx. 0.30 m/month corresponding to sediment fluxes of about 3 to 6 kg d.s./m^2 tide (depending upon density : 300 or 600 kg d.s./m^3) ;
b. during wet season average sedimentation is between 0.30 m/month and 1.00 m/month corresponding to sediment fluxes of about 3 to 20 kg d.s./m^2 tide and probably very much dependent upon the wave activity (figure 4.2.23.).

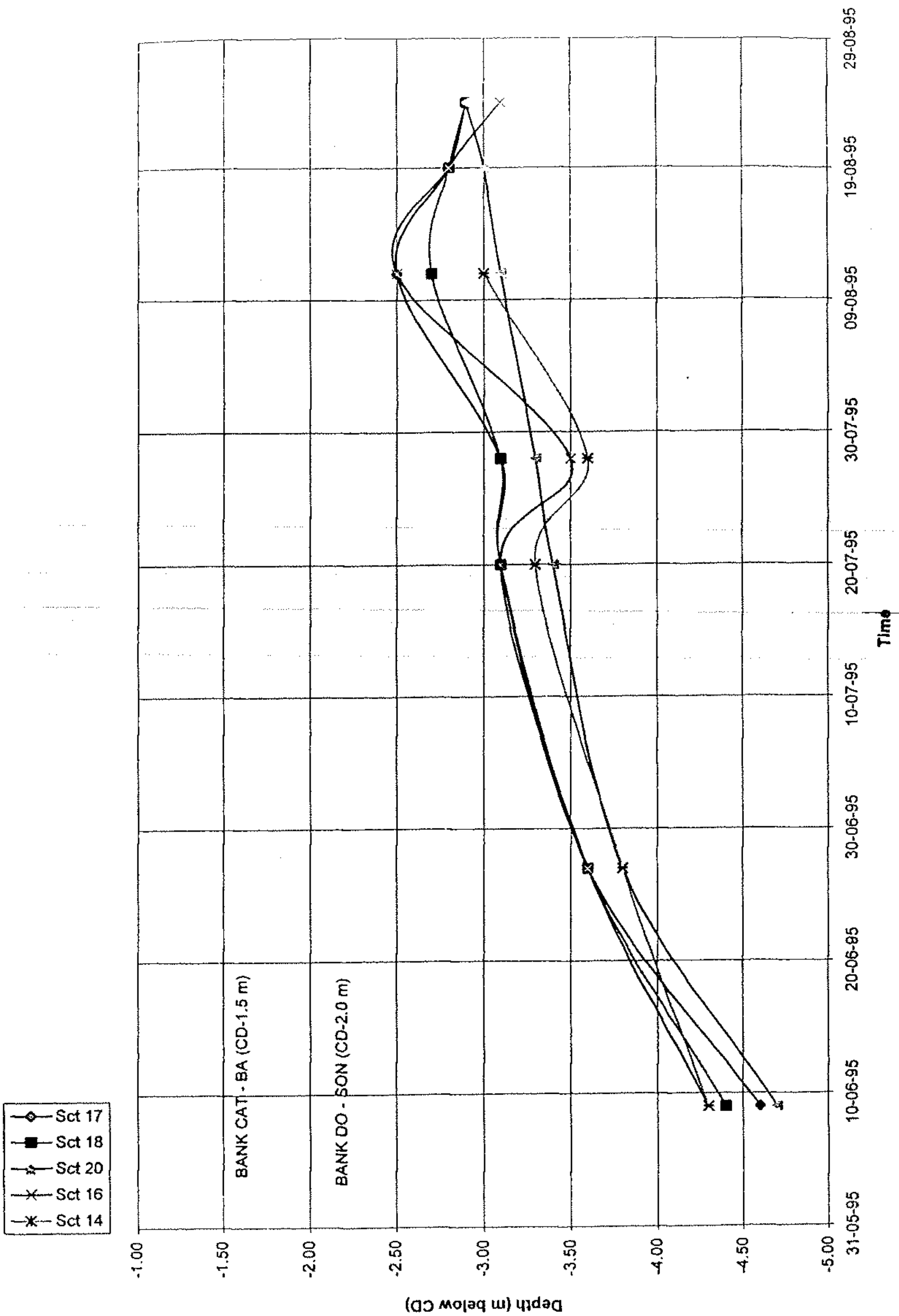


Figure 4.2.23.
Monitoring of Nam Trieu Channel Sedimentation (June - August '95)

When comparing these pictures with the modelling results (figure 4.2.24 for model section subdivision and figure 4.2.25 for simulation of erosion/deposition flux of dry season spring tide without waves) one can conclude that :

a. no significant sedimentation trend occur between Dinh Vu Canal and South Limit of Bach Dang (Aval) ; in a lot of cases even erosion occurs ;
b. average sedimentation is between 0.25 and 0.70 kg d.s./m^2 tide.

When repeating this simulations for different wave activities, it appears that above significant wave heights (Aval) of more than 1.00 m, deposition rates of mud increase substantially (figure 4.2.26). Siltation rates can reach under severe storm conditions up to 100 kg d.s./m^2 tide, and under typhoon conditions up to 400 kg d.s./m^2 tide.

It appears consequently that the channel sedimentation is very sensitive to the prevailing wave action (in this case above H_s = 1.00 m at Aval). This is a general finding from all mathematical simulations that the sedimentation is mainly governed by storms or events (such as the wet season typhoons) stirring up vast quantities of the bed mud ; this mud is than mobilised by the (tidal) currents, the residual wave transport and fluid mud density flows.

When analysing the seasonal effects it appears that wet season, neap tidal conditions and with storm action (H_s = 1.60 m) give rise to quite different patterns of deposition (figure 4.2.27.) : there is almost no deposition in the outer part of the channel and the deposition concentrates in the inner part (between Aval and buoy 11).

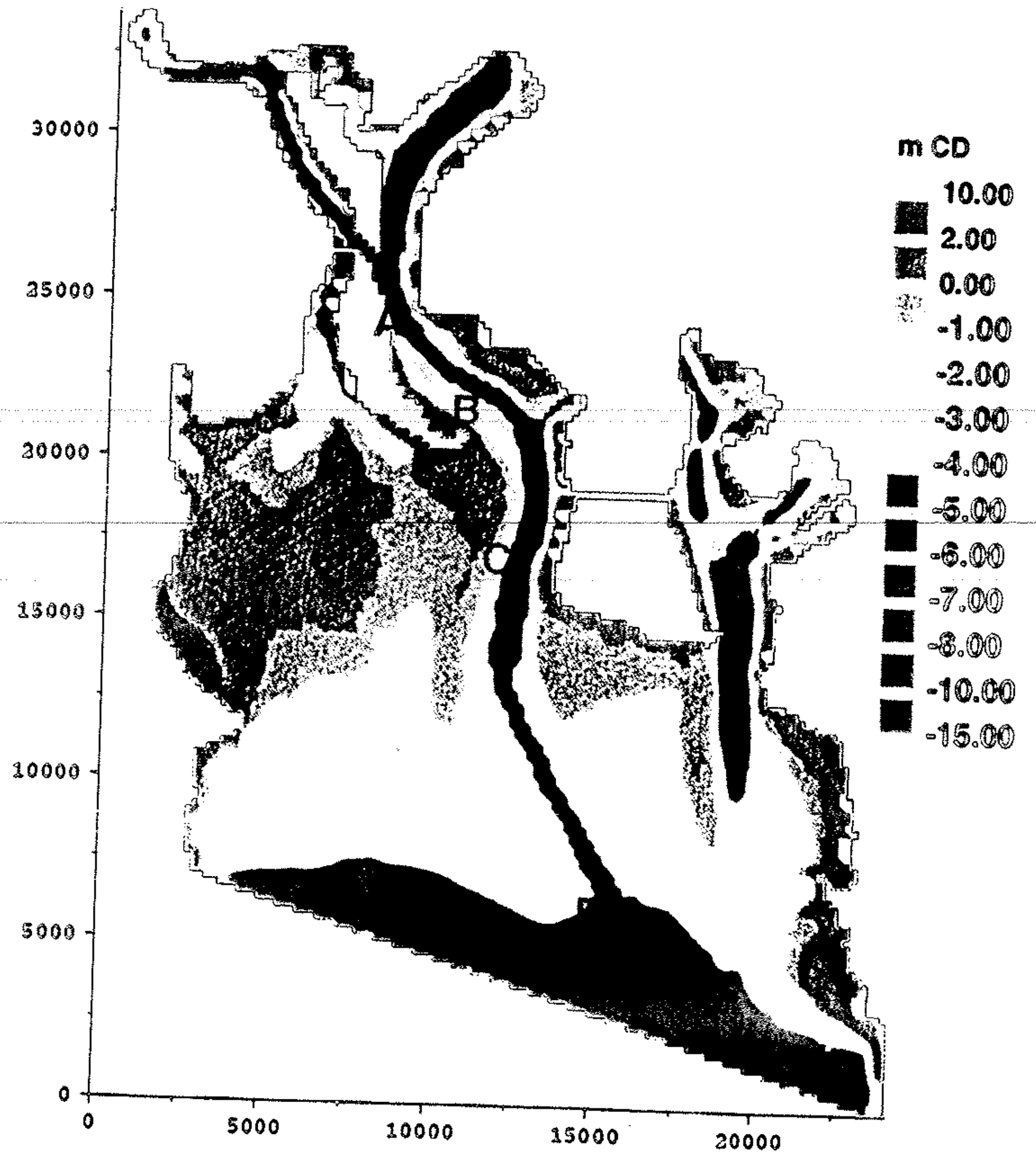


Figure 4.2.24.
Location of Channel Sections for existing channel (alternative 1)

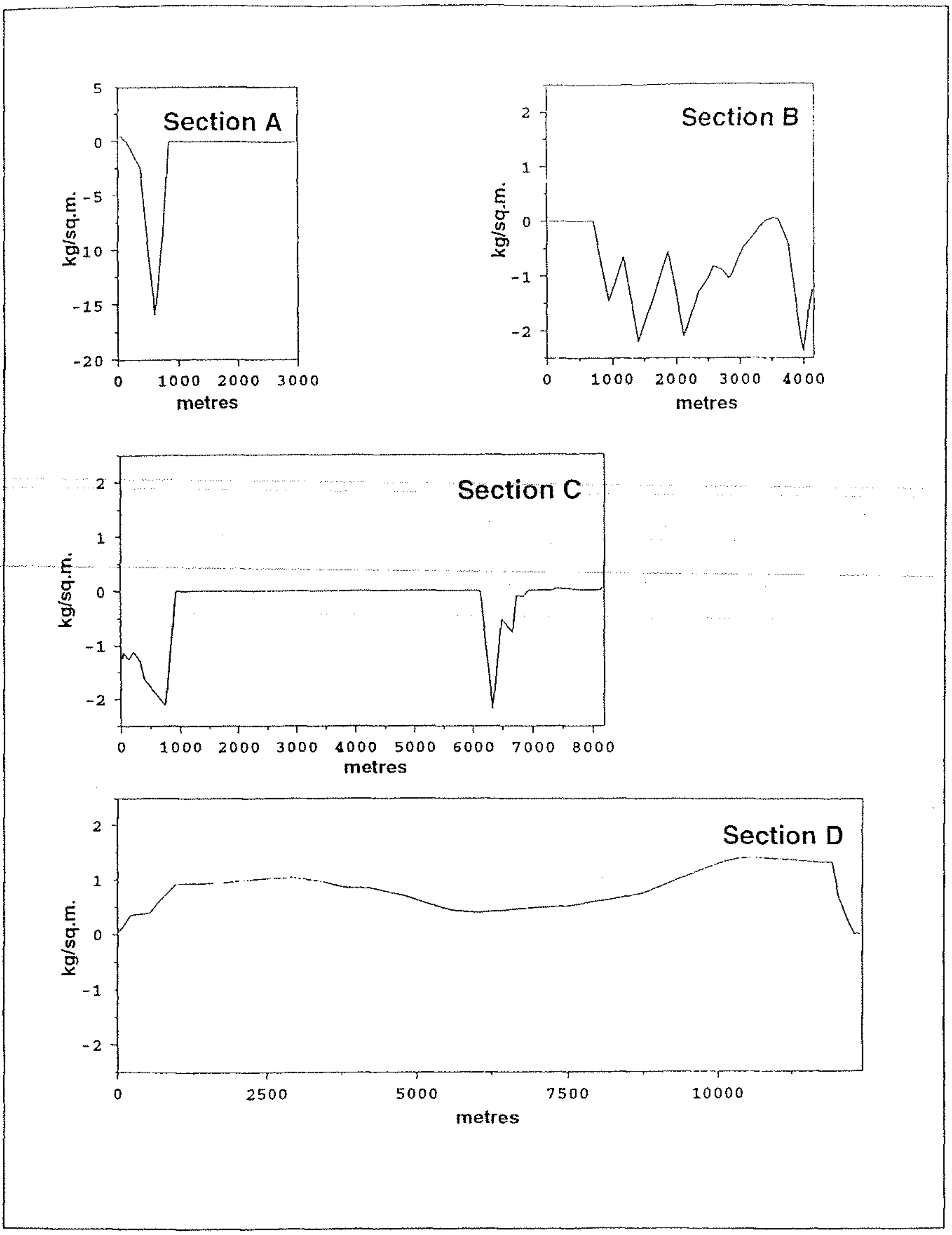


Figure 4.2.25.
Sedimentation/erosion fluxes calculated for the existing channel
(dry season ; spring tide ; no waves)

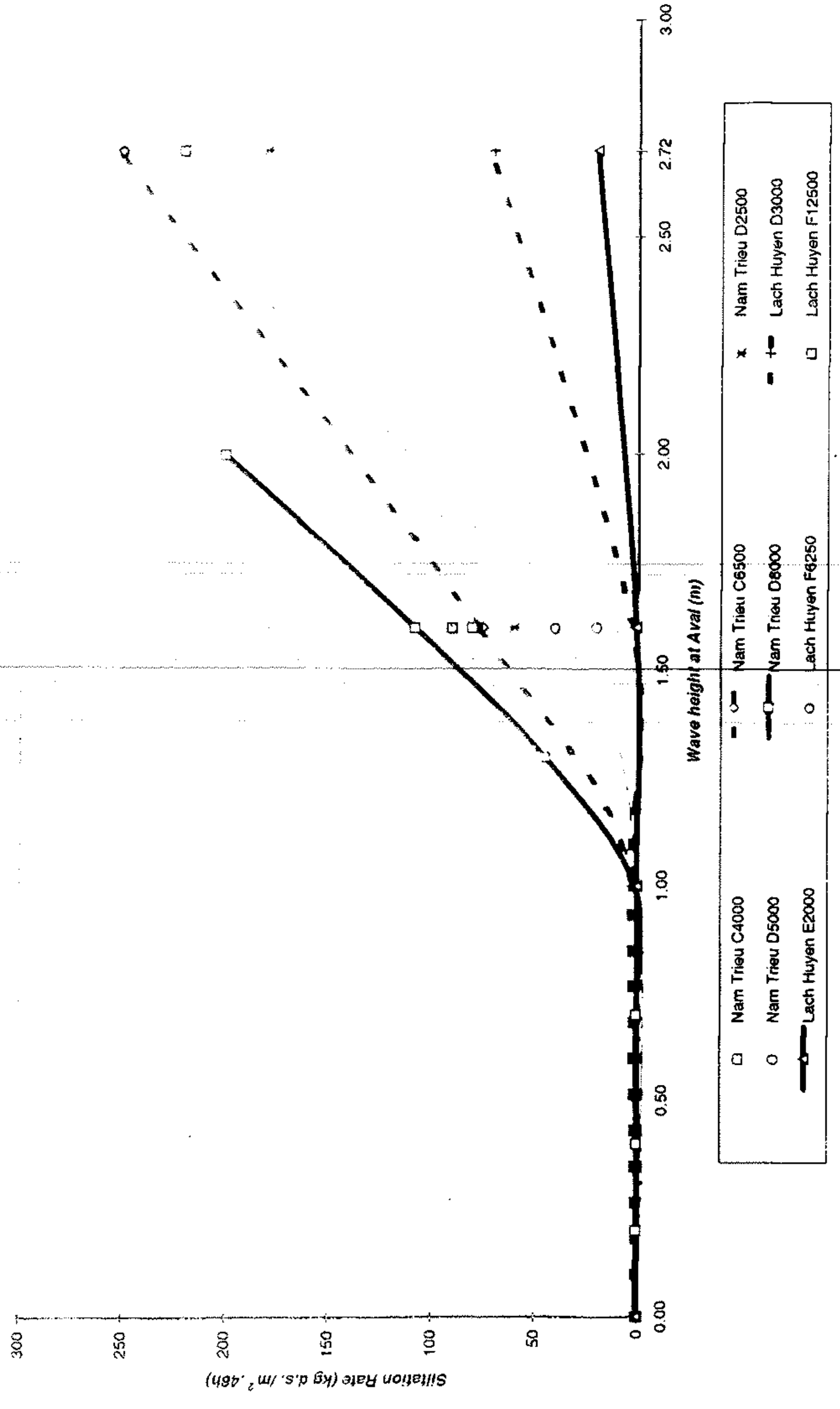


Figure 4.2.26.

Effect of wave action on sedimentation

(Nam Trieu Channel ; section C4000, C6500, D2500, D5000, D8000 and Lach Huyen channel ; section D3000, E2000, F6250, F12500)

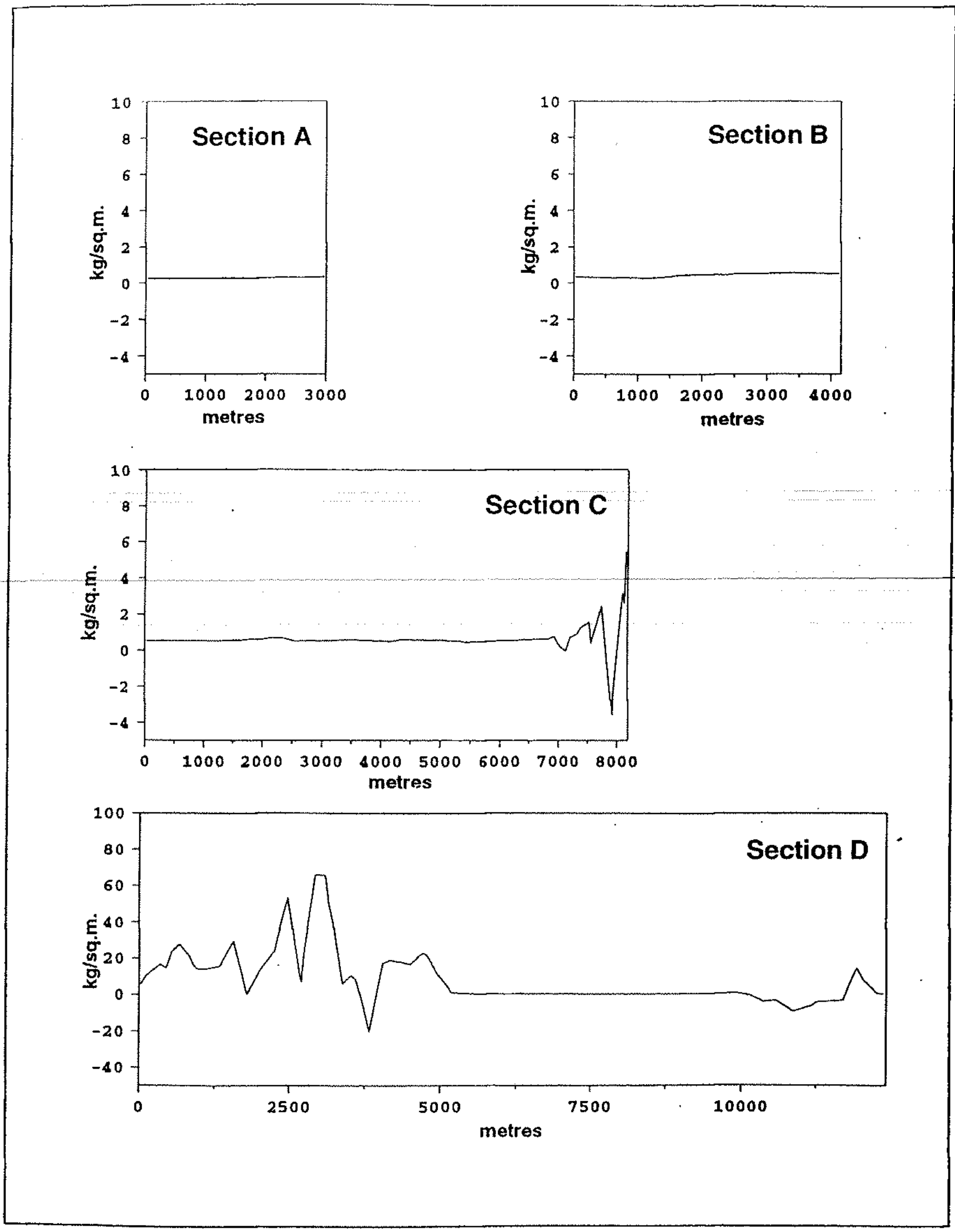


Figure 4.2.27.
Sedimentation/erosion fluxes calculated for the existing channel under wet season (neap tide ; H_s (Aval) = 1.60 m)

4.2.5.3. Simulation of sedimentation/erosion fluxes for the 4 channel alternatives

4.2.5.3.1. Comparison of the sedimentation behaviour in the 4 alternatives

With the FLUIDMUDFLOW-model as described above a series of simulations of the sedimentation/erosion fluxes has been performed. The following comparisons have been executed :

- channel alternatives 1, 2, 3 and 4 dredged at channel bed level C.D. -9.0 m (for dry season, wet season, with and without waves and typhoon storm waves) ;
- channel alternative 1 dredged at channel bed levels C.D. -4.1 m (existing situation), C.D. - 7.3 m, C.D. - 9.0 m, C.D. - 11.5 m.

From this extensive set of simulations the following conclusions can be drawn :

1. Existing situation

   - approximately 70 % of the total yearly sedimentation is occurring during the wet season (rainy season) ;

2. Alternative 1 : Widening and deepening the existing channel (C.D. -9.0 m)

   - dry season : sedimentation is essentially and uniformly spread over approx. 6500 m of the outer channel (figure 4.2.28) ;
   - wet season : sedimentation is concentrated in Bach Dang and north parts of Nam Trieu (figure 4.2.29a) ;
   - typhoons : sedimentation pattern is similar to those found for smaller waves, however the more extreme waves seem able to carry sediment much further up the dredged channel. Sections A and B were largely unaffected by accretion for the "severe storm" case, while in the typhoon case considerable accretion has occurred along these sections (figure 4.2.29b) ;

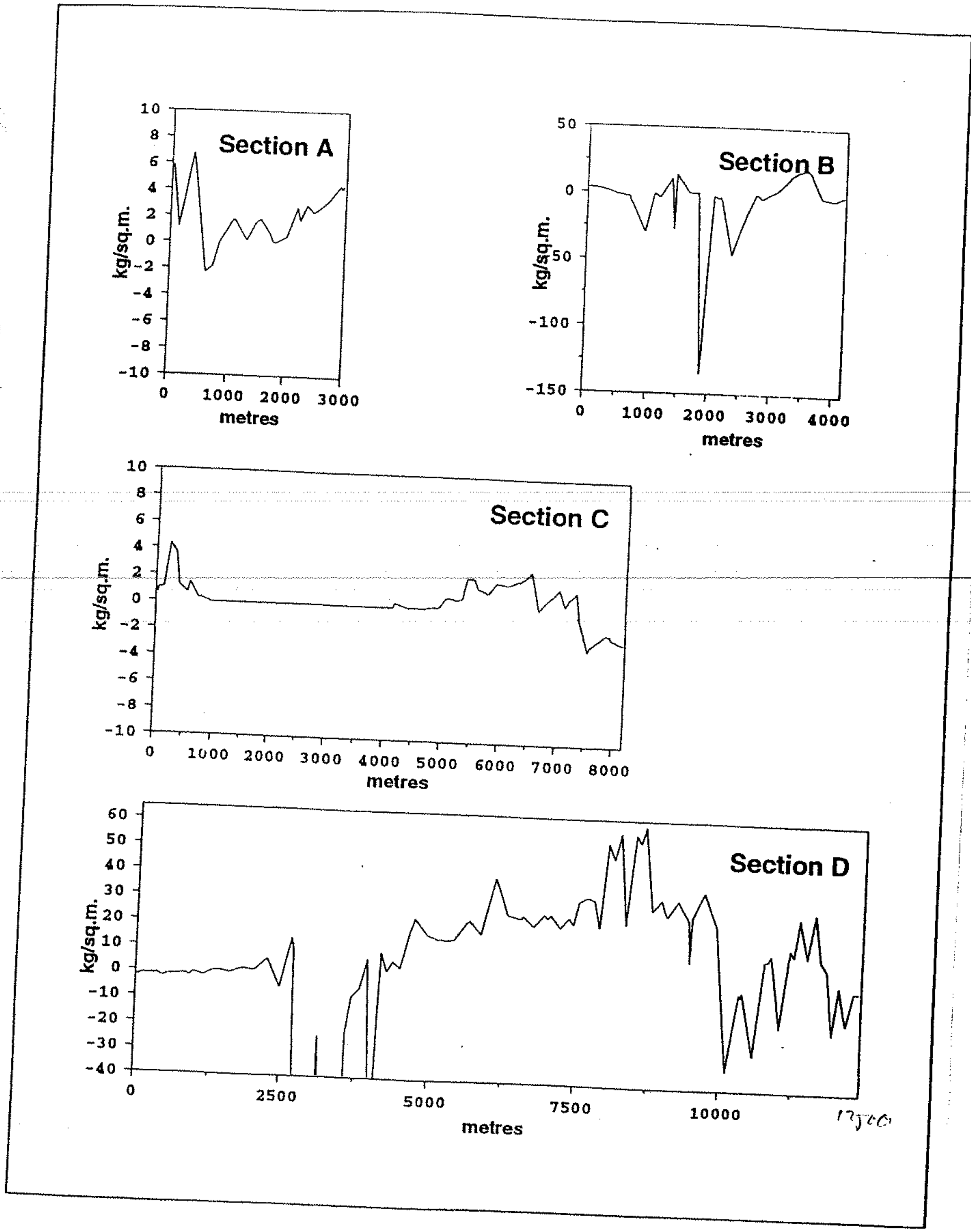


Figure 4.2.28.
Sedimentation/erosion fluxes in the channel alternative 1 (C.D. - 9.0 m) for dry season, spring tide (H_s = 1.60 m)

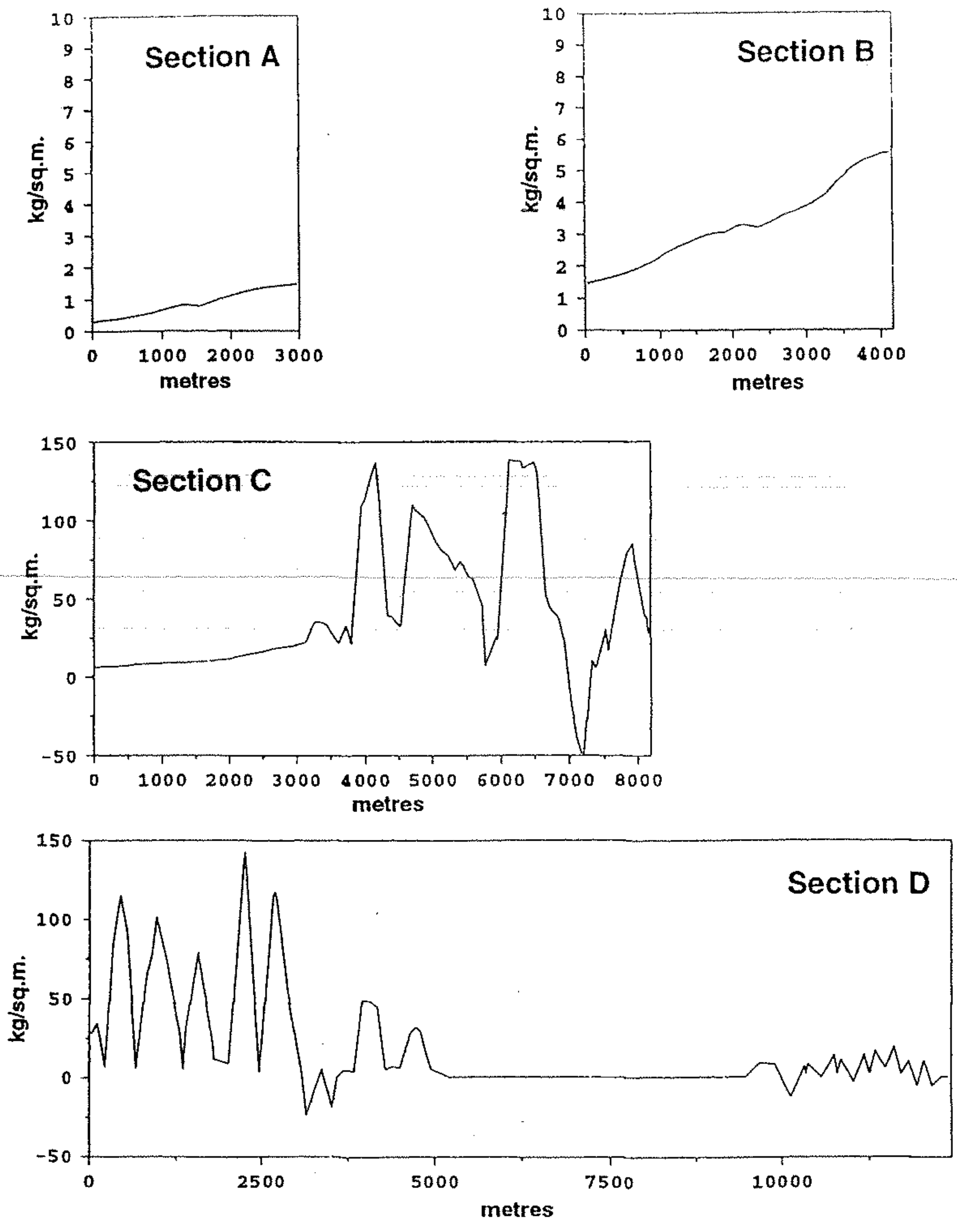


Figure 4.2.29.(a)
Sedimentation/erosion fluxes in the channel alternative 1
(C.D. - 9.0 m) for wet season, neap tide (H_s = 1.60 m)

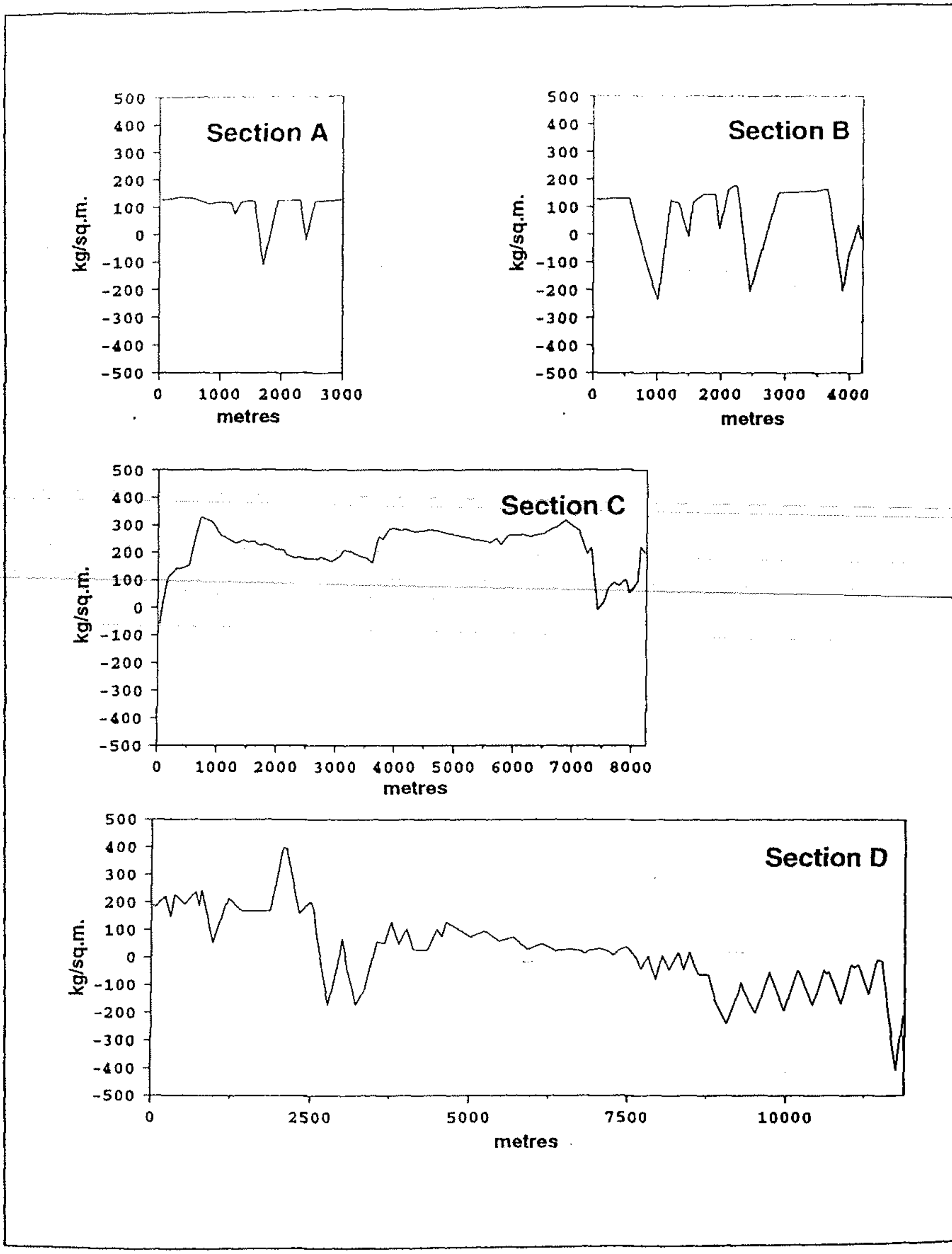


Figure 4.2.29.(b)
Sedimentation/erosion fluxes in the channel alternative 1
(C.D. - 9.0 m) for wet season, neap tide (Typhoon storm waves)

3. Alternative 2 : New Nam Trieu Channel

- dry season : sedimentation is concentrated at the offshore end of the channel there where the channel crosses the submerged spit and the bar (over a length of approx. 2,000 m : figure 4.2.30.) ;
- wet season : sedimentation is concentrated on 2 spots, the crossing of the submerged spit and the Bach Dang between Trap Canal and Aval.

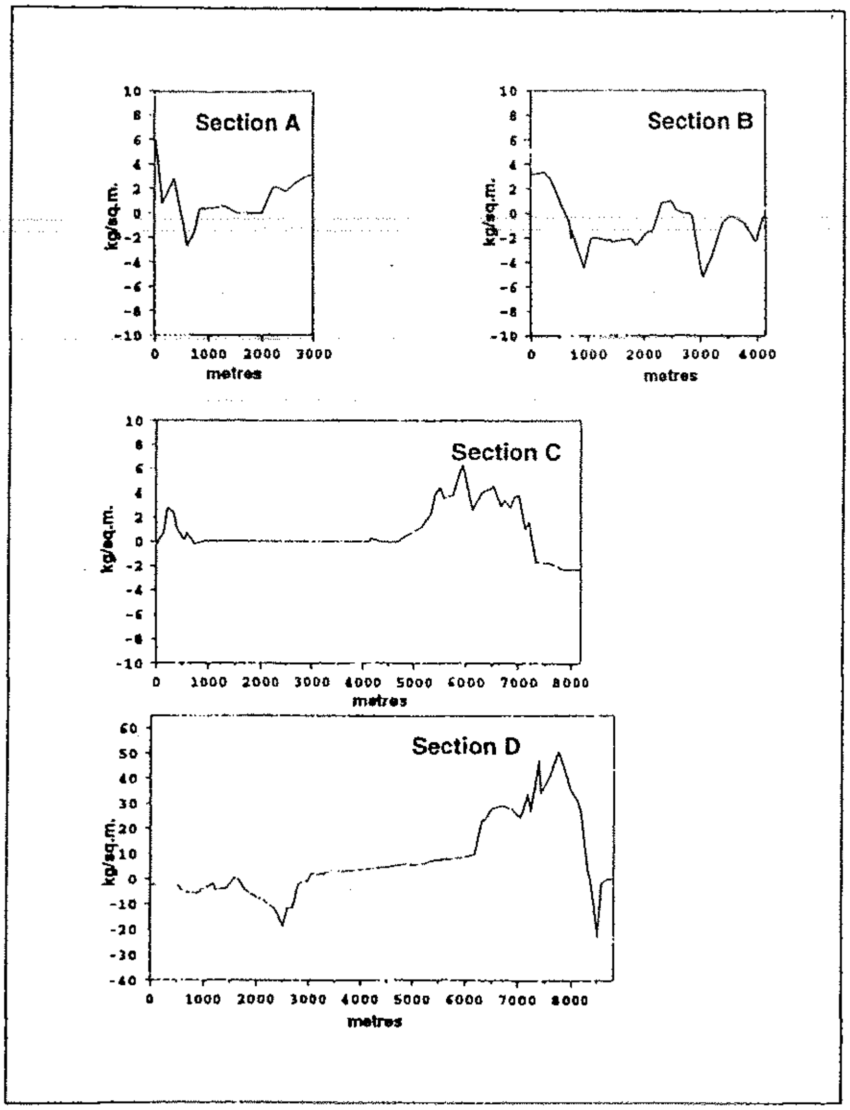


Figure 4.2.30.
Sedimentation/erosion fluxes in channel alternative 2 (C.D. - 9.0 m) for dry season, spring tide (H_s = 1.60 m)

4. Alternative 3 : New alignment in Lach Huyen through Ha Nam Canal

- dry season : sedimentation is very much concentrated in the 3,000 m long crossing of the offshore bar (seaward front) ; almost no sedimentation is occurring elsewhere (figure 4.2.32) ;
- wet season : sedimentation occurs on 2 marked spots, i.e. the seaward and landward front of the offshore bar in the Lach Huyen ;

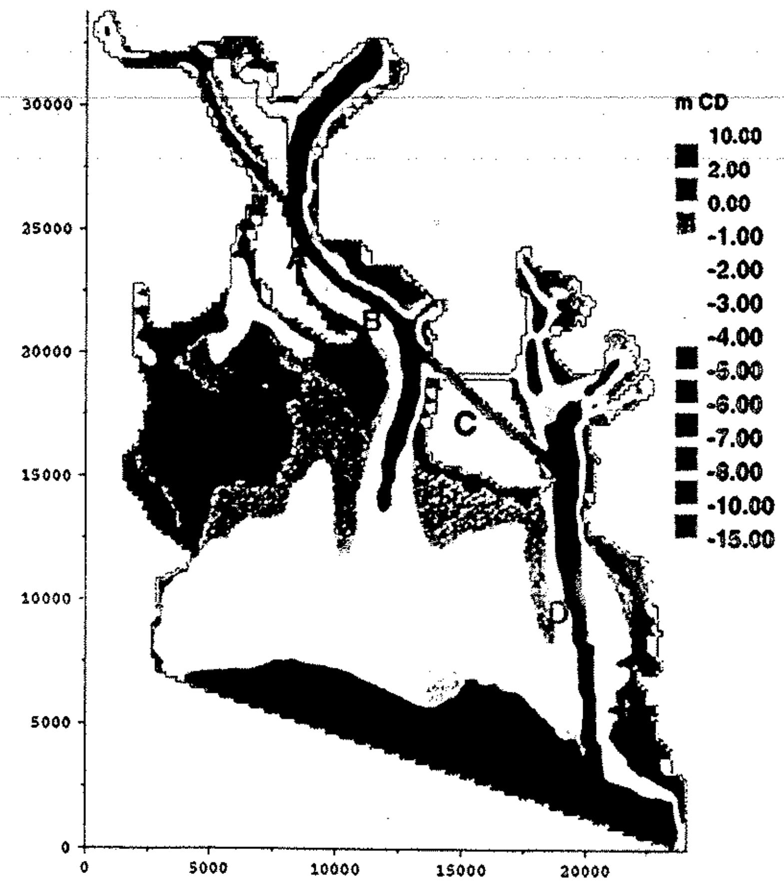


Figure 4.2.31.
Locations of cross-sections for channel 3 alignment

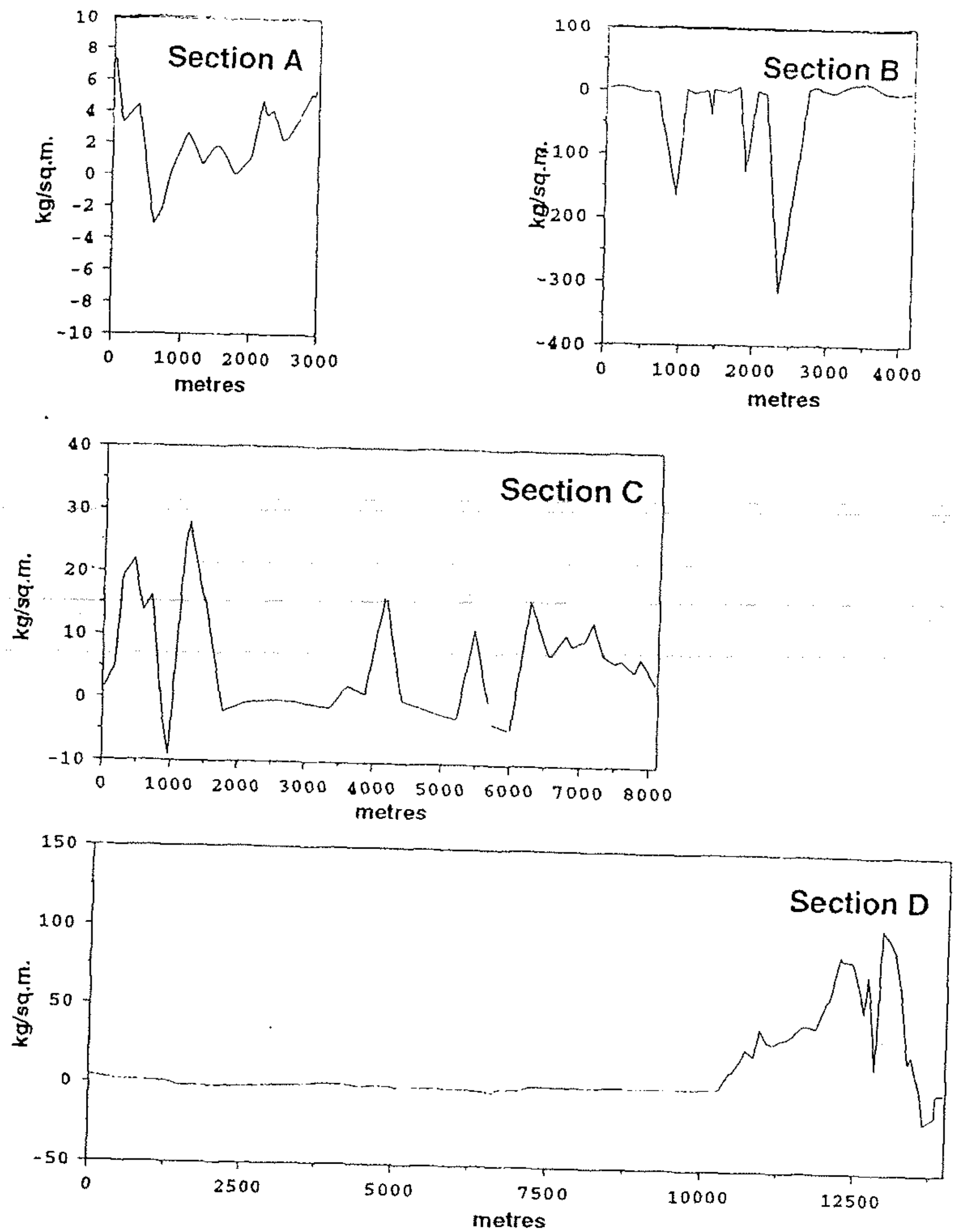


Figure 4.2.32.
Sedimentation/erosion fluxes in the channel alternative 3 (C.D. -9.0 m) for dry season, spring tide, severe storm waves

5. <u>Alternative 4 : New alignment in Lach Huyen through Trap Canal</u>

- <u>dry season</u> : sedimentation is very much concentrated in the 3,000 m long crossing of the offshore bar (seaward front) ; almost no sedimentation is occurring elsewhere (figure 4.2.33) ;
- <u>wet season</u> : sedimentation occurs on 2 marked spots, i.e. the seaward and landward front of the offshore bar in Lach Huyen (figure 4.2.34a) ;
- <u>typhoon</u> : the main aspects of the siltation pattern are similar to those found for smaller waves such as the accumulation in the west, erosion in the muddy areas to the south of the modelling area and to the sides of dredged channels, and the accumulation of sediment along the dredged channel along section F. However, as in the case of alternative 1, the typhoon waves are able to carry sediment further into the bay and sections A, B, C, D and E experience significant accretion along their lengths. Section F fluctuates between 150 and 400 kg/m² along its length.

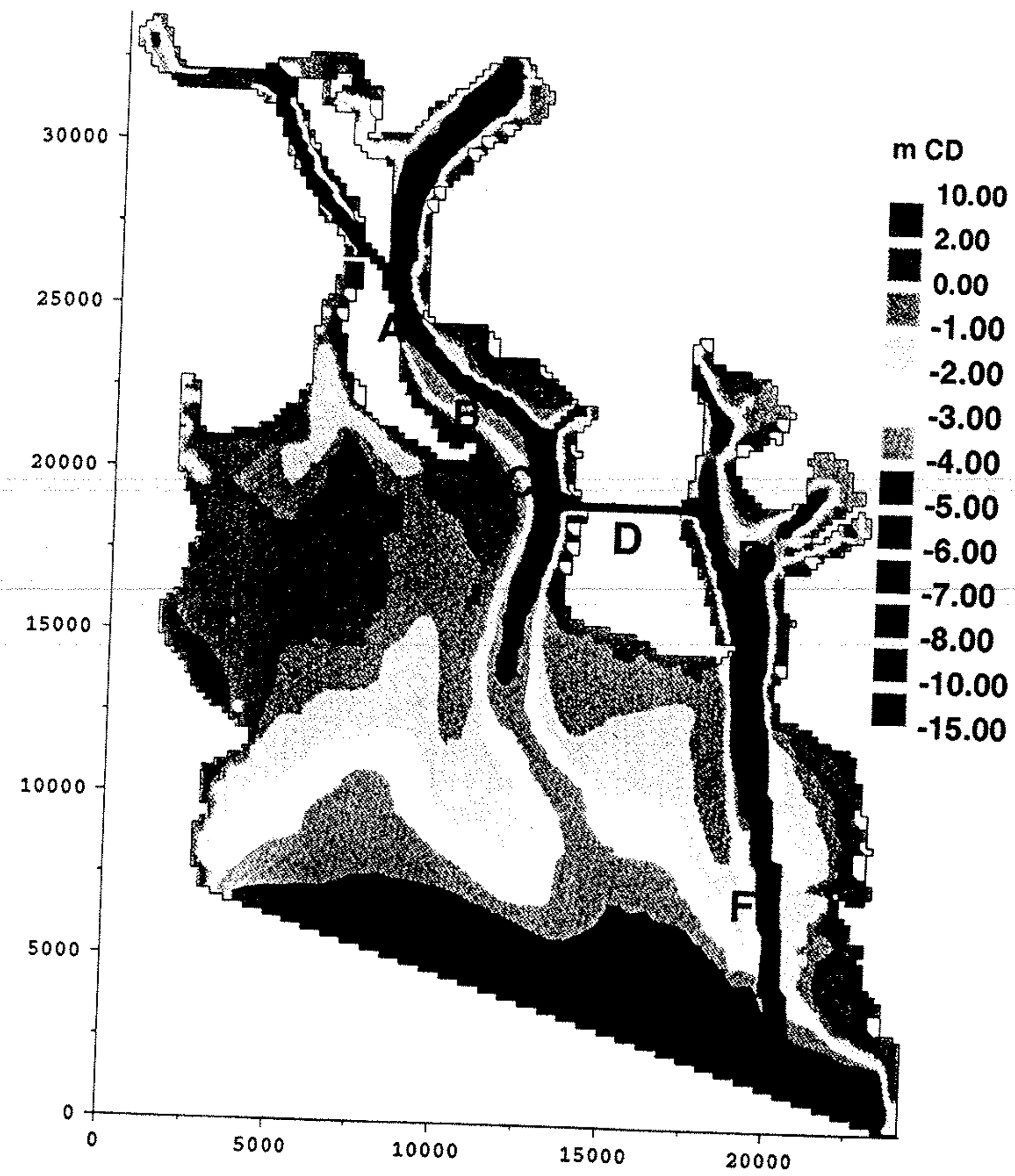


Figure 4.2.33.
Locations of cross-sections for channel 4 alignment

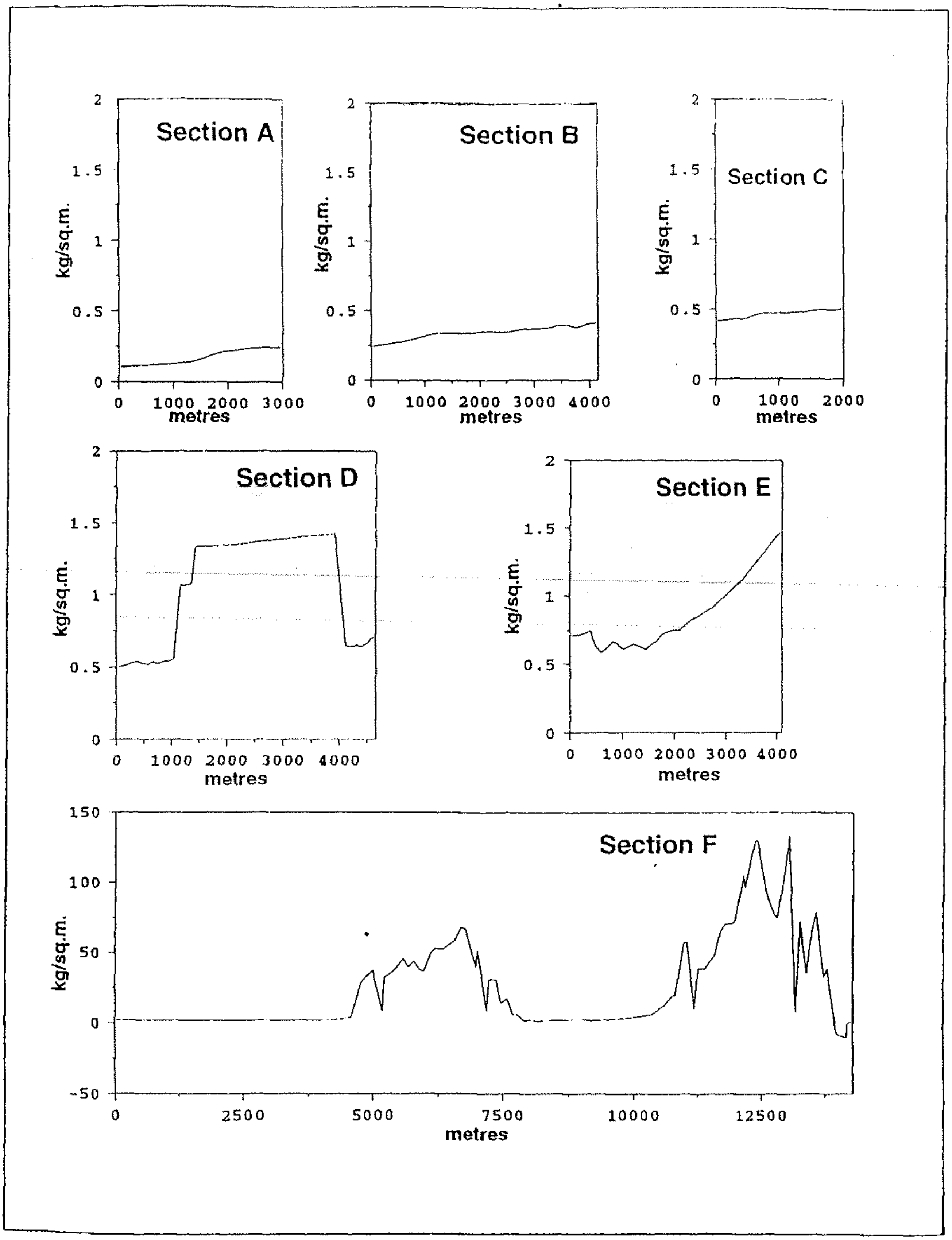


Figure 4.2.34.(a)

Sedimentation/erosion fluxes in the channel alternative 4 (C.D. - 9.0 m) for wet season, neap tide, severe storm waves (Hs = 1.60 m)

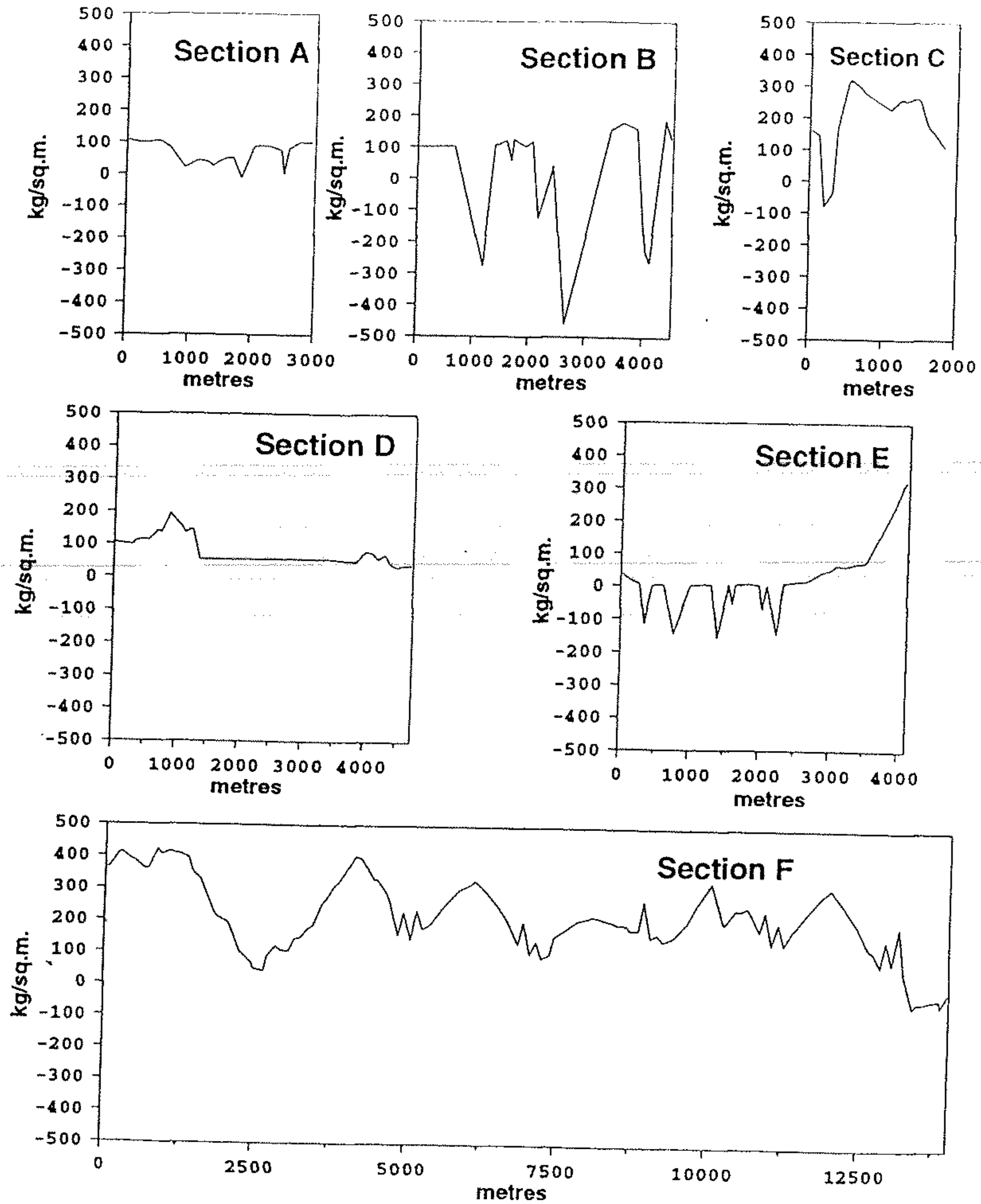


Figure 4.2.34.(b)
Sedimentation/erosion fluxes in the channel alternative 4 (C.D. - 9.0 m) for wet season, neap tide (Typhoon storm waves)

4.2.5.3.2. Influence of channel dredged level on siltation rate

From the hydraulic simulations it appeared that the deepening works by capital dredging will have following hydraulic impacts :

a. channelization of flow-both tidal currents and river discharge-inducing current increase in the channel ;
b. current-slackening on the banks of the river such as in Cam or Bach Dang, ...

When analysing the siltation area over two tidal cycles in spring tide, dry season and Hs = 1.60 m wave conditions for the existing channel alternatives and for different dredged levels, the following conclusions can be drawn (see also table 4.T.10. and figure 4.2.35. :

1. the main siltation always occurs in the outer channel or the seaward part (70 to 75 %) ;
2. the further deepening of the channel appears to reduce the amount of siltation (Table 4.T.10) ; this is probably due to the increase in current velocity in the channel by channelization and the reduction of the current velocity on either side of the channel.

Channel	Dredged level	Siltation (tons d.s./48 hrs)
Existing	CD - 4.5 m	45,000
Altern. 1	CD - 7.3 m	81,000
Altern. 1	CD - 9.0 m	46,000
Altern. 1	CD - 11.50 m	34,000

Table 4.T.10.
Influence of the deepening of the existing channel on the overall siltation rate (dry season, spring tide, Hs = 1.60 m waves)

This finding of the mathematical simulations is of outermost importance because it means that it could be more economic w.r.t. maintenance dredging to dredge the access-channel to C.D. -9.0 m or more. An attempt has been made to translate these findings into annual siltations. This, of course, has to be ascertained for the alternatives 3 and 4.

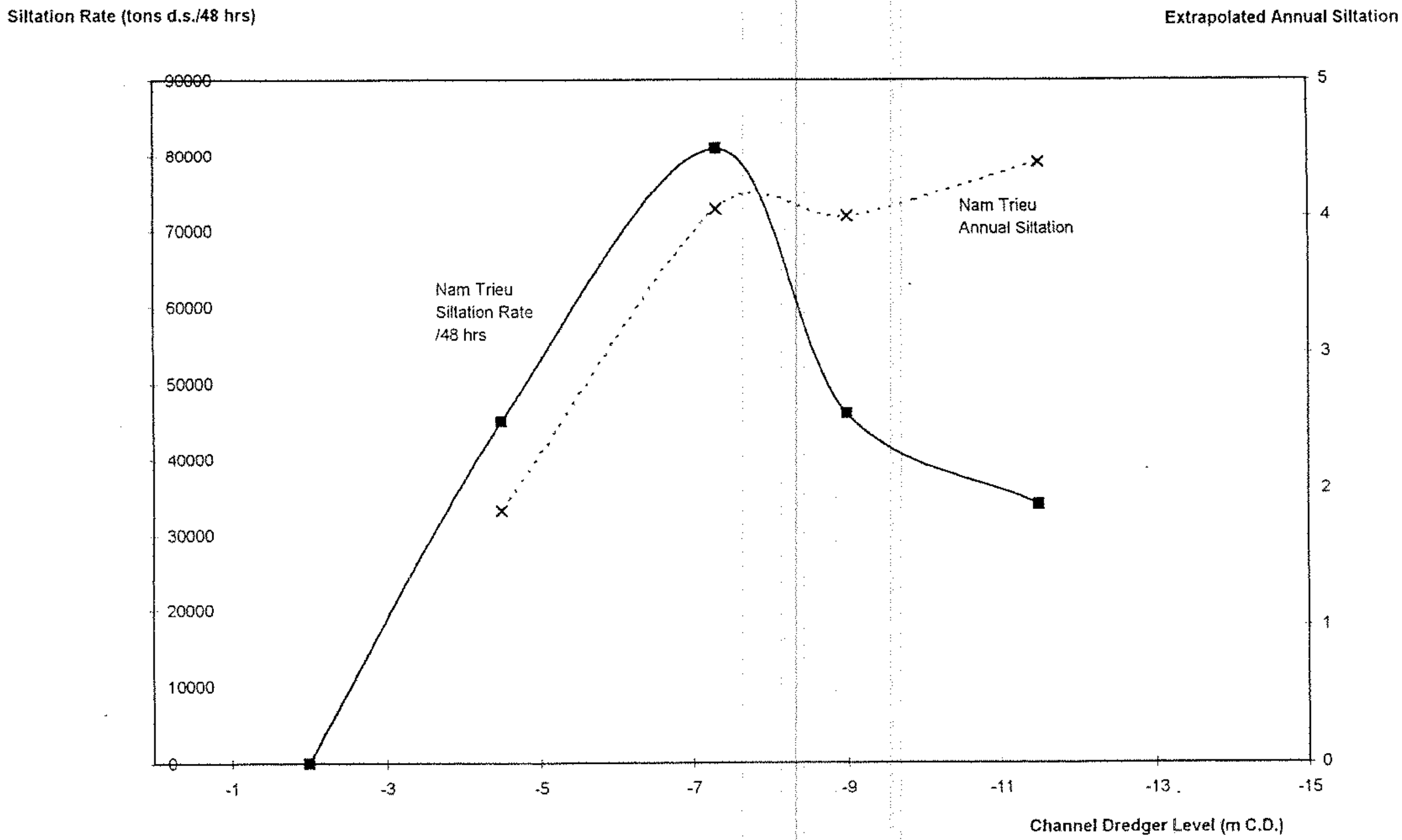


Figure 4.2.35.

Influence of the deepening of the existing channel (alternative 1) on the overall siltation rate

(dry season, spring tide, Hs = 1.60 m waves)

However, it must be said that the deeper the channel will be, the bigger the long-term hydraulic section will be because of the mild slopes. With slopes of 1:20 a C.D. - 11.5 m channel bed level will have slopes extending to 190 m on either side of the channel limits, whilst a C.D. - 7.3 m channel bed level will only have 105 m slope areas on both sides. Therefore will the variations of siltation rate in function of dredged level be buffered to some extent (Table 4.T.11) :

Channel	Dredged level	Extrapolated annual siltation Mtons d.s./year
Existing	CD - 4.5 m	1.85
Alternative 1	CD - 7.3 m	4.05
Alternative 1	CD - 9.0 m	4.00
Alternative 1	CD - 11.50 m	4.40

Table 4.T.11.
Rough estimate of the influence of the deepening of the existing channel (Alternative 1) on annual siltation

Progressive slope-infill is not addressed by the mathematical model but will be commented in par. 4.3.

4.2.6. Morphological changes

With the results of the mathematical model it is also possible to get a better insight in the overall modified sedimentation/erosion pattern in the whole bay. These morphological changes are of course related to the deepening and widening of the channel and to the resulting channelization of the flow (tidal currents + river discharge).

In all four the cases the excavation of the channel will induce an increased sedimentation :

a. in the Cam River axis and banks ;
b. in the Bach Dang River sedimentation will be enhanced on the river banks (Dinh Vu side + Left bank) ;
c. on the foreshore of Dinh Vu Island.

It has already been said that the major driving force for the remobilization of the bed-mud is the wave-action during storms and typhoons ; sedimentation location itself seems to be governed by the nodal points of the residual sediment transport (both salt wedge and river supply) and consequently essentially governed by :

a. tidal coefficient ;
b. river discharge.

During storms, there will be essentially erosion along the course of the old Cam River (Do Son side of the bay) and in front of Cat Hai ; this is illustrated by a set of figures :

a. figure 4.2.36. :
   Sedimentation/erosion fluxes for existing situation during dry season, spring tide and storm waves ($H_s = 0.5 - 1.0$ m) ;

b. figure 4.2.37. :
   Sedimentation/erosion fluxes for existing situation during wet season, neap tide and severe storm waves ($H_s = 1.60$ m) ;

c. figure 4.2.38. :
   Sedimentation/erosion fluxes for channel alternative 1 (C.D. - 11.5 m) during dry season, spring tide, severe storm waves ;

d. figure 4.2.39. :
   Sedimentation/erosion fluxes for channel alternative 3 (C.D. - 9.0 m) during dry season, spring tide, storm waves ;

e. figure 4.2.40. :
   Sedimentation/erosion fluxes for channel alternative 4 (C.D. - 9.0 m) during wet season, neap tide, typhoon storm waves.

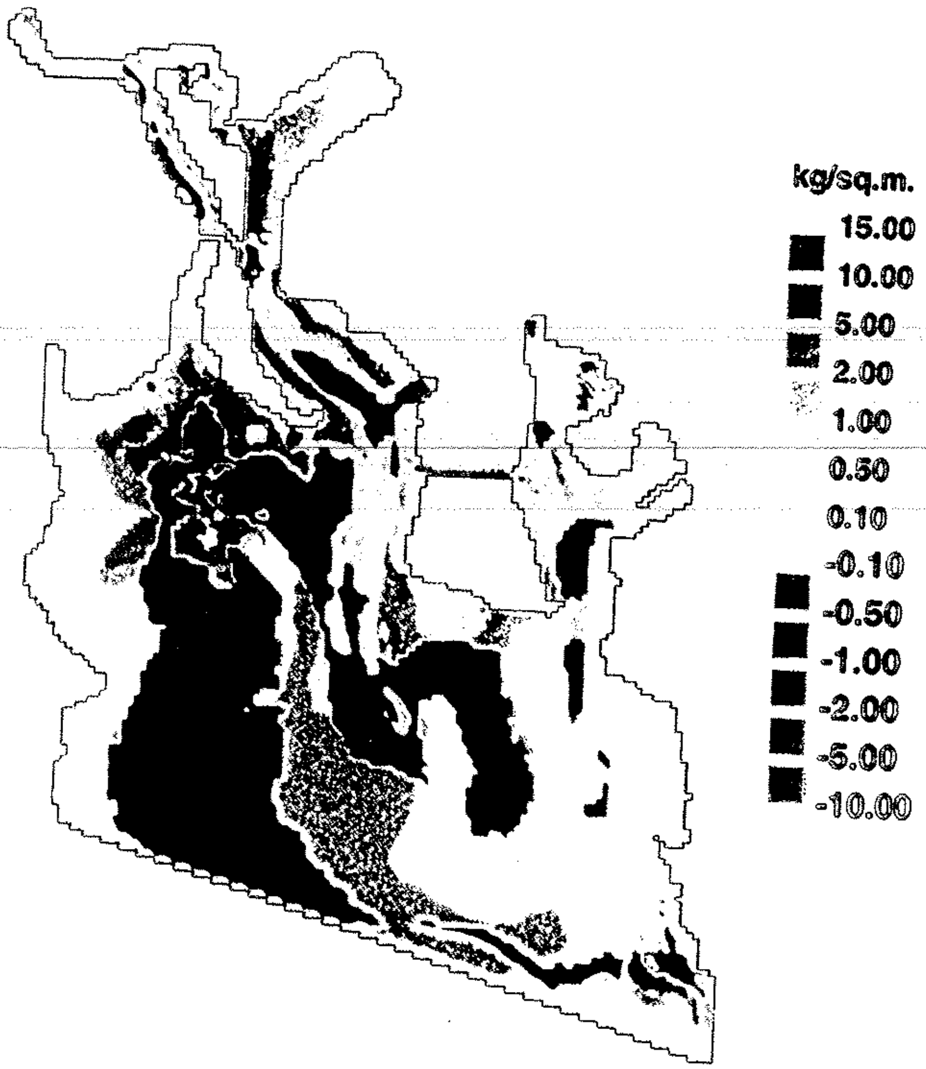


Figure 4.2.36.
Sedimentation/erosion fluxes for existing situation during dry season, spring tide and storm waves

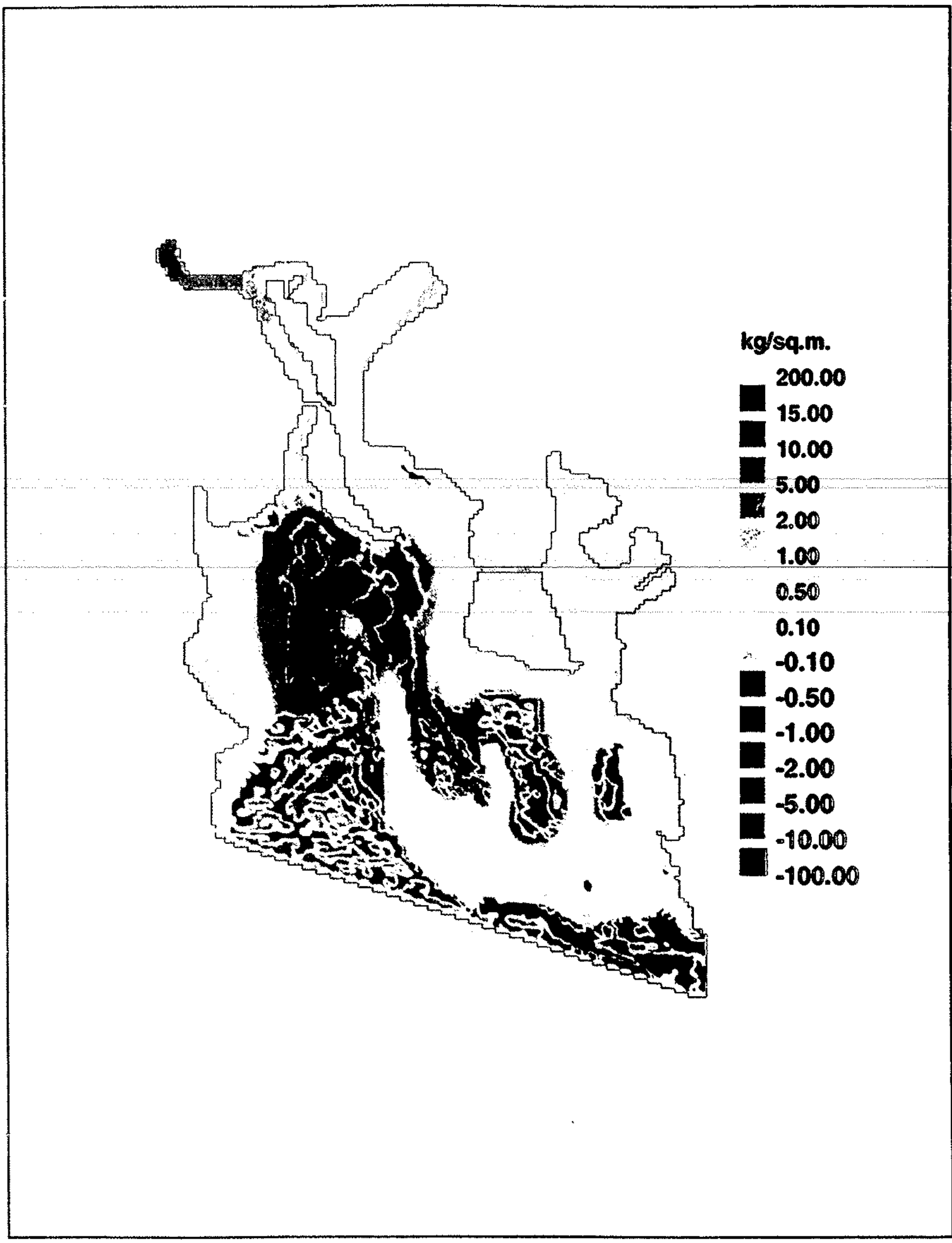


Figure 4.2.37.
Sedimentation/erosion fluxes for existing situation during wet season, neap tide, severe storm waves

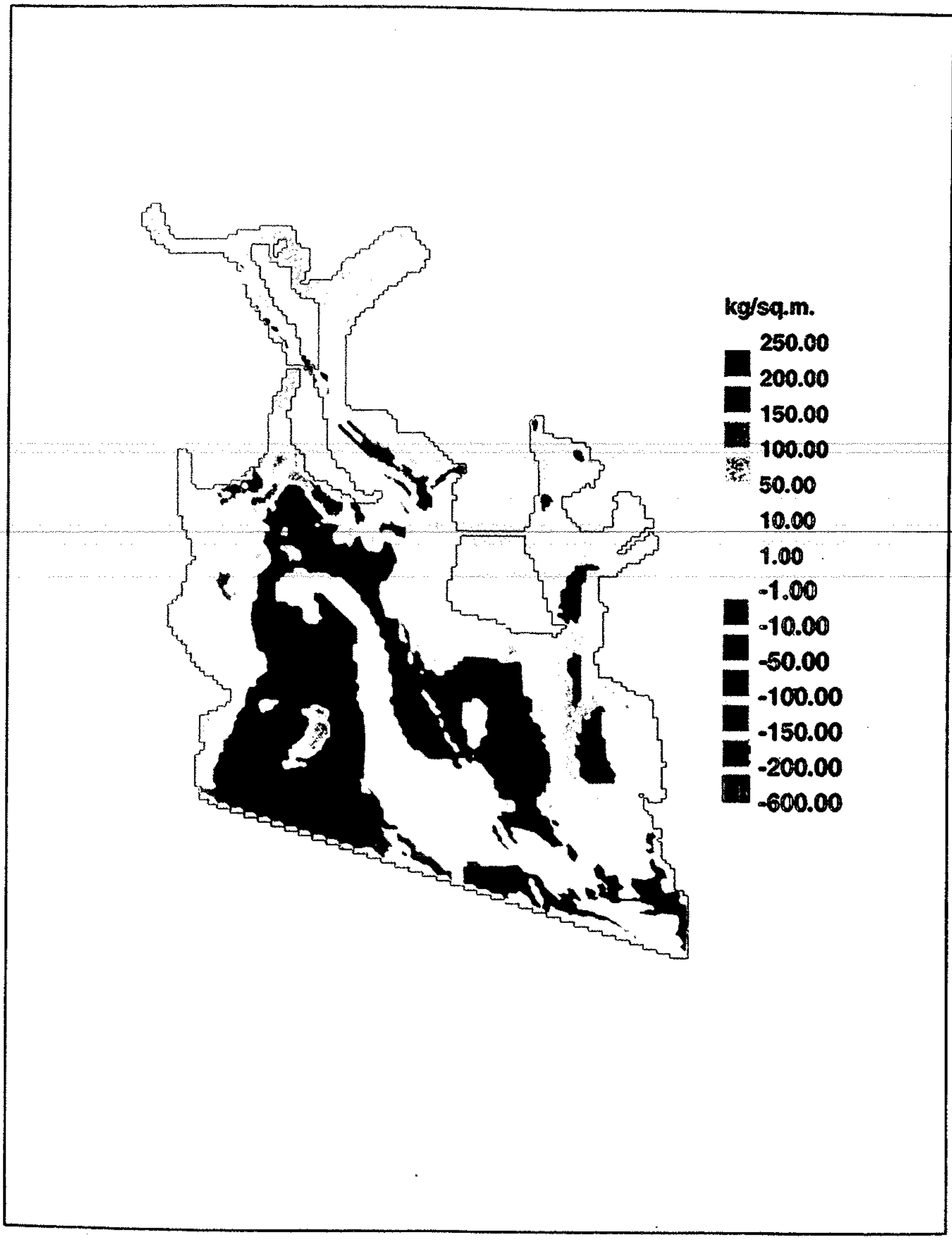


Figure 4.2.38.

Sedimentation/erosion fluxes for channel alternative 1 dredged at C.D. -11.5 m during dry season, spring tide, severe storm waves

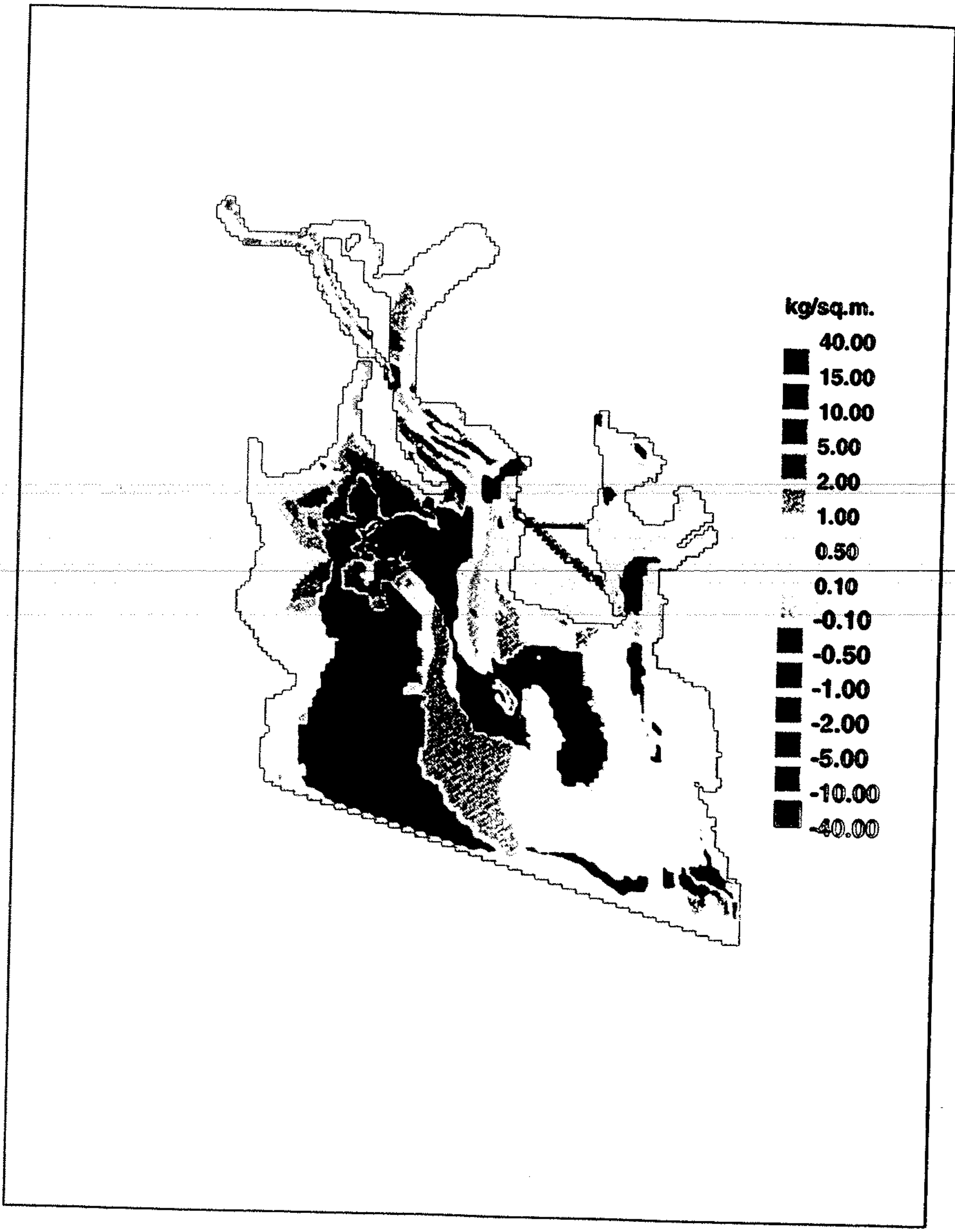


Figure 4.2.39.

Sedimentation/erosion fluxes for channel alternative 3 dredged at C.D. -9.0 m during dry season, spring tide, severe storm waves

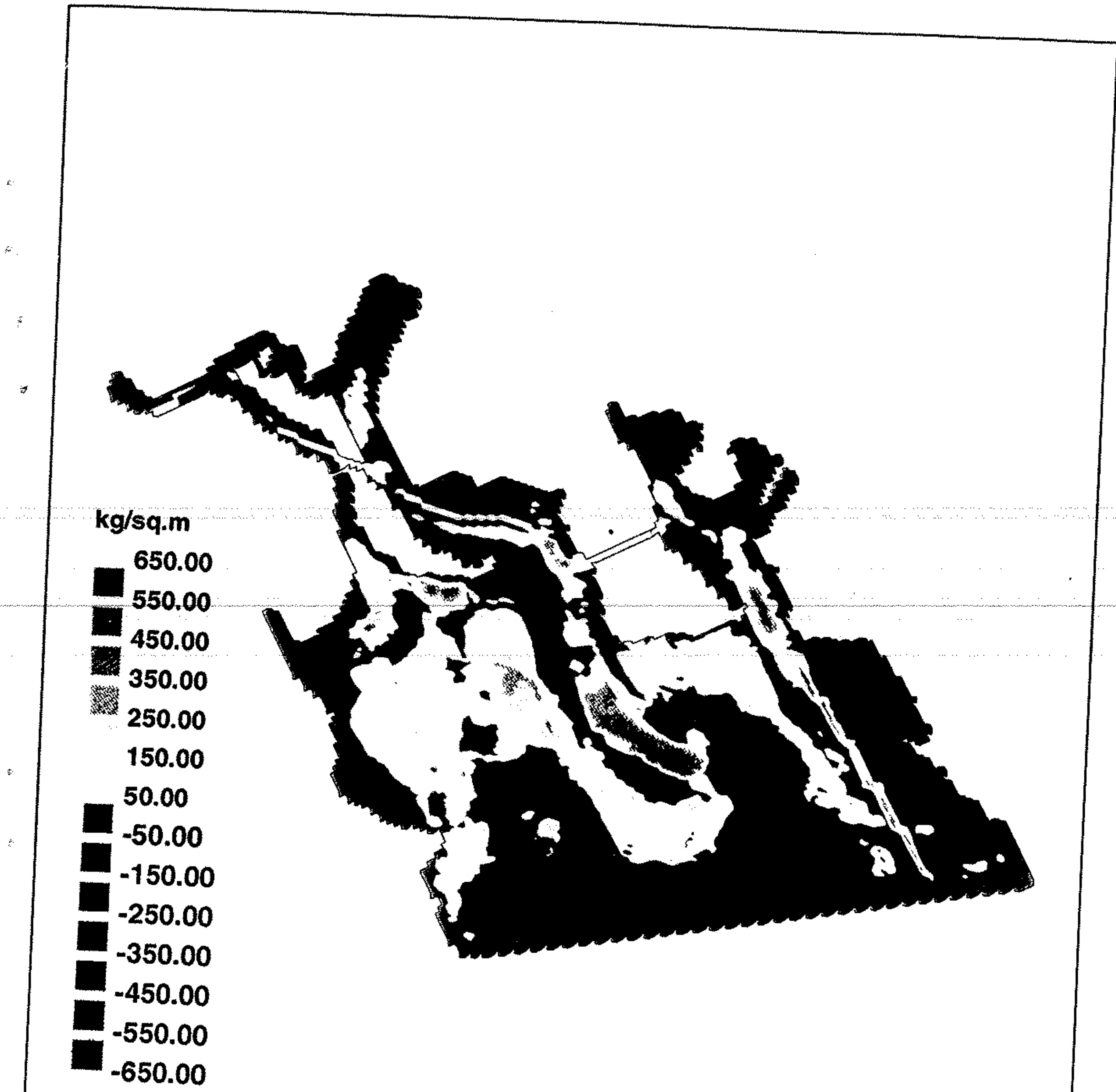


Figure 4.2.40.

Sedimentation/erosion fluxes for channel alternative 4 dredged at C.D. -9.0 m during wet season, neap tide, typhoon storm waves

4.2.7. Conclusions about the mathematical modelling

1. According to the T.O.R.'s the morphological and sedimentological changes and the prediction of siltation should be based on a mathematical simulation using a validated model. The hydrodynamic, wave field and sedimentological models described in this par. 4 were calibrated and validated against existing field data and data obtained during the additional survey and monitoring program. It must be kept in mind that the conclusions are based on the results of mathematical simulations and that real values of siltation may differ with a great extent due to the unpredictability of the hydrometeorological conditions and due to the necessary simplification of the natural sedimentology to allow modelisation.
   Nevertheless, the simulations have been used essentially to compare the different channel alternatives and to help the decision-making for the access-channel to Hai Phong.

2. A 3-D hydrodynamic model was set up and calibrated for both dry and wet season flows in Hai Phong Bay. It was considered, based on the observations of salinity and current, that a depth-integrated model representation was suitable for modelling the dry season tides at Hai Phong. Multilayer modelling was used for the wet season tides when strong stratification may occur, especially during neap tides when tidal action is not available to mix the salt through the water column. The aim of the simulation of wet season modelling was to produce conditions that can be regarded as typical of a kind of tide when gravitational circulation (density currents) as well as tidal currents are important. This aim was achieved with the model being satisfactorily calibrated for wet season conditions.

3. A range of different channel configurations were tested for dry spring and wet neap tides as these were able to show the influence of the bathymetry changes on the tidal currents and on the gravitational circulation respectively. In general the deepening of the channel is discovered to result in a lower current as a larger channel cross section is used to carry essentially the same tidal discharge. The exception to this is where the channel crosses the bar, where speed increases in the channel are found. The removal of the Dinh Vu dam was also investigated in the model. The removal causes a decrease in the current speed in the existing channel on the other side of Dinh Vu island as more of the current is carried past the dam site and less passes through the Dinh Vu channel.

4. The deepening of the channel also results in an increase in the effectiveness of the gravitational circulation (density flows) as evidenced by the patterns of residual current at the bed which tend to show a null point moving further landward and of the salinities at Bach Dang section which become larger (than zero for existing conditions). The C.D. -7.3m and C.D. -9.0 m channels on alternative 1 and the C.D. -9.0 m channel on alternative 4 all showed such increased salinity at the Bach Dang section, indicating increased gravitational circulation. However the alternative 4 result showed a lower salinity at Bach Dang section compared with the -9.0 m C.D. channel being closer to the -7.3 m C.D. channel result. The removal of Dinh Vu dam does not appear to show any significant effect on gravitational circulation.

5. Waves within Hai Phong Bay were predicted using a wave refraction model with boundary conditions provided from VOS wave data. Wave conditions were predicted at six locations within the Bay and provided input to the sediment transport model.

6. The sensitivity tests carried out in the wave model, indicated that waves inshore were slightly more south-easterly in direction at MHWS compared to MLWS. However there was very little difference in the distribution of wave heights at MHWS and MLWS. At outer locations in the Bay approximately 96% of the waves are less than 2.0 m (Hs), less than 0.5% are between 2.0 m and 4.0 m. At MHWS a further 0.01% were between 4.0 m and 4.5 m.

7. The model results were also used to assess the influence of seasonal variability on waves. This shows that during the wet season, June to September, inshore waves are predominantly from directions between South-South-east and south (135°N to 195°N). For the dry season, December to March, the directions are more south-easterly and are between 105°N and 165°N. This is consistent with the wet season conditions being more southerly offshore than the dry season which are predominantly from the north-east.

8. A comparison of these predicted wave conditions with measured data at Aval, shows a reasonable similarity between the two, for the limited period for which data was available.

9. Analysis of field observations and the results of the sediment transport modelling suggest that the siltation in the navigation channel is dominated by the effect of extreme events. In the modelling work, the effect of extreme wave conditions has been examined and found to dominate the long term siltation rate. Observations suggest that extreme river flood events may also be influential.

10. All of the Channel Alternatives follow the same route between Hai Phong and the Trap Canal and the effect of deepening this part of the channel, regardless of the alignment of the deepened outer part of the channel, is to enhance the siltation rate landward of the Dinh Vu Canal. Accretion occurs on all tide types but is greater during the wet season. It is possible that extreme fluvial flows may have an erosive effect in this area, but such conditions have not been tested in the model. In stormy conditions there is some tendency for increased siltation adjacent to Dinh Vu Island, but this is small compared to the effect of storm events on the outer part of the channel.

11. Deepening of the existing channel alignment (Channel alternative 1) will affect both the wave and current conditions. Currents will generally be faster in the outer part of the deepened channel and more aligned with the direction of the channel. A deeper channel will reduce the effect of the waves at the channel bed and may modify the distribution of waves. The changes to currents tend to promote less accretion in the channel while the waves tend to promote more accretion in the channel. These competing trends lead to the complex behaviour.

12. The predicted patterns of siltation for Channel alternative 1 and Channel alternative 2 are very similar to each other. The siltation patterns associated with Channel alternative 3 and Channel alternative 4 are also very similar to each other. For alternatives 1 and 2, the siltation is more evenly distributed over the length of the channel seaward of the Trap Canal than it is for alternatives 3 and 4, where most of the siltation is predicted to occur over a few km at the seaward limit of the channel, with the rest of the channel tending to keep itself clear.

13. According to the above-mentioned considerations the following preference-classification is given for the different channel-alternatives
    - best : Alternative 4
    - second best : Alternative 1
    - medium : Alternative 3
    - least : Alternative 2

4.3. MAINTENANCE DREDGING

4.3.1. General

Based on the various simulations about the sediment transport mentioned under par. 4.2. the annual total maintenance dredging volume has been computed. For the estimation of the total sedimentation in the excavated channel (to nautical depth of C.D. - 9.0 m) the following statistical distribution have been taken into account :

1. **Seasons :**
   Wet Season : 58 % of time (7 months)
   Dry Season : 42 % of time (5 months)

2. **Tides :**
   Spring Tide : 50 % of time
   Neap Tide : 50 % of time

3. **Waves**
   (Significant Wave Heights at Hon Dau ; report VAH 1351/00513)

Significant Wave Height (m)	Frequency of Exceedance (%)	
	Dry Season	Wet Season
0.2	70	70
0.4	40	41
0.7	20	21
1.0	10	11
1.4	5	6
1.6	2	3
2.7	0	1

Table 4.T.12.
Wave Height Distribution (Aval Reference Station) used for maintenance dredging computations

4. **Typhoons** : 8/year
   (with Hs > 2.70 m at Aval)

Total mud sedimentation on annual basis is then calculated with the results of the FLUIDMUDFLOW simulations and according to the design profile of the access-channels, i.e. :

- bottom width : 100 m
- nautical depth : C.D. - 8.5 m
- dredging depth : C.D. - 9.0 m
- slopes : 1/15

But the total sedimentation in the access-channel is to be linked with different forms of sediment supply :

a) in the Outer Sea Channels Nam Trieu or Lach Huyen :

- mud inflow by density flows, decantation and bedload-trapping. This process appears to be very sensitive to storms or typhoons ;
- gradual weakening of the channel-banks : slope-weakening (estimated evolution from 1:15 towards 1:20 or 1:40 in approx. 10 years) ;
- bedload trapping of sand sediments where the channel crosses the spit-like morphological features.

b) in the upper Reaches Bach Dang and Cam River :

- mud inflow by density flows, decantation and bedload trapping ;
- bedload trapping of sand sediments (upstream supply).

4.3.2. Siltation rate and slope-weakening in the Outer Sea Channel

Based on the results of the sedimentation modelling it is now possible to make a prediction about the annual siltation (mud sediments by density flows and slope-weakening) in the different channel options (dredged to C.D. - 9.0 m).

The results of these simulations for the C.D. -9.0 m case are given on figure 4.3.1. (graph of siltation expressed as a total quantity of sedimentation in Mtons of dry solids/year) showing the differences between the 4 different channel alternatives and in comparison with the actual situation, i.e. the Nam Trieu Channel with a nautical depth of C.D. - 4.5 m. Total sedimentation is calculated as if the channel is dredged and is then allowed to sedimentate until original seabed levels are recovered (full sedimentation). This is of course without the action of the maintenance reduction infrastructures (see par. 4.9.).

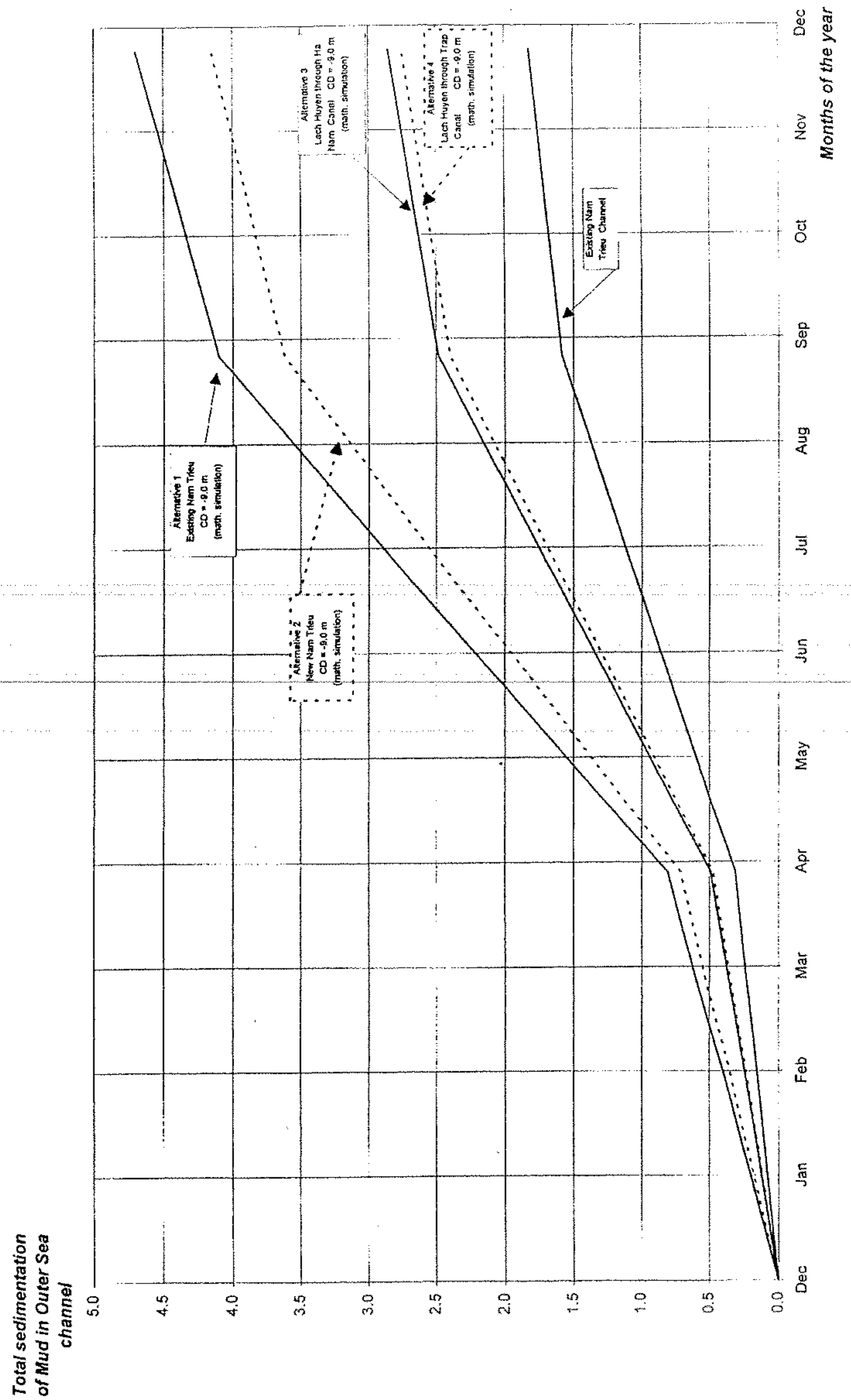


Figure 4.3.1.

Simulation of siltation in the outer sea channel for the four alternatives (expressed as a total quantity of sedimentation in Mtons of dry solids/year)

Siltation is estimated from the following computations :

1. Siltation by density flow and decantation of mud in the sedimentation-prone areas of the channel ; mud density flow and decantation have been calculated by using the mathematical models described in par. 4.2. and the statistical distribution of hydrodynamic conditions mentioned in par. 4.3.1. ;

Channel Alternative	Sedimentation of mud Mtons of d.s./year
1. Deepening and widening the existing Nam Trieu Channel	4.0
2. New Nam Trieu Channel	3.6
3. Lach Huyen alignment through Ha Nam Canal	2.6
4. Lach Huyen alignment through Trap Canal	2.5

Table 4.T.13.
Values of siltation by density flow and decantation

2. gradual slope-weakening from the capital dredging value of 1:15 towards 1:20 or 1:40 spread over 10 years will deliver the following additional siltation volumes :

   a. Alternative 1 : 400,000 m³/yr - 2,000,000 m³/year
   (or 240,000 t.d.s./yr - 1,200,000 t.d.s./yr)
   b. Alternative 2 : 270,000 m³/yr - 1,347,500 m³/yr
   (or 162,000 t.d.s./yr - 808,500 t.d.s./yr)
   c. Alternative 3 : 122,500 m³/yr - 612,500 m³/yr
   (73,500 t.d.s./yr - 370,000 t.d.s./yr)
   d. Alternative 4 : 122,500 m³/yr - 612,500 m³/yr
   (73,500 t.d.s./yr - 370,000 t.d.s./yr)

Slope evolution in Lach Huyen was estimated by taking into account the soil layering and the maintenance dredging actions.

The top sand layer will probably adopt equilibrium slopes in the range of 1:100 whilst the underlying consolidated mud (clay) layer will remain stable under 1:15 or 1:20. However, it is very likely that by weakening of the mud (water adsorption) and by undermining action linked to maintenance dredging slopes in the clay layer will partially collapse. The combined

processes will lead to a resultant slope somewhere in between 1:20 and 1:30 (in the worst case).

Slope evolution in Nam Trieu and New Nam Trieu is expected also to tend towards weaker slopes of 1:20 or even 1:40 ; despite the cohesive mud soil because of :

a) weakening of consolidated mud by progressive water adsorption ;
b) more intense wave action than for Alt 3 or Alt 5 ;
c) the horizontal dredging tolerance during future maintenance dredging operations.

4.3.3. Sand-infill in the Outer Sea Channel

In some parts of the Outer Sea Channel reaches sandy deposits are crossed (see drawings VAH 1351/34.20/006 and 007). In these areas - essentially characterized by spit-like submerged banks - a significant sand sedimentation is expected. Sand sediments are transported by tidal currents and are strongly remobilized during storms and typhoons. The residual sand transport pathways calculated by Sediment Trend Analysis (ref. report VAH1351/00540 ; map 34.20.008) indicate that e.g. in the Lach Huyen bar crossing sand is transported from West to East whilst in the New Nam Trieu Channel sand is rather transported from East to West.

Based on the comparison of occurring shear stress velocities (under tides and waves) with critical shear stress velocities for fine sand under wave action, transport capacities for sand (both bedload and suspension) have been computed using Van Rijn (1980 : equation 4 & 5) and Grass (1981 : equation 6) formulae :

$$\text{Bedload : } q_b = 0.005\ \delta_s\ Uh \left[\frac{U - Ucr}{\left[(s-1)gd_{50}\right]^{0.5}}\right]^{2.4} \left(\frac{d_{50}}{h}\right)^{1.2} \qquad (4)$$

$$\text{Suspended load : } q_s = 0.012\ \rho_s\ Ud_{50} \left[\frac{U - Ucr}{\left[(s-1)gd_{50}\right]^{0.5}}\right]^{2.4} D_x^{-0.6} \qquad (5)$$

Where q_b, q_s measured as mass of sediment/unit width/unit time (kg/m/s)

U = current speed (m/s)
d_{50} = median grain diameter (m)
h = water depth (m)
ρ_s = sediment density kg/m³)
s = sediment specific gravity

g = gravitational acceleration (m/s²)

$$D_x = d_{50}\left[\frac{(s-1)g}{V^2}\right]^{1/3}$$

ν = kinematic viscosity of water (m²/sec)

Grass argued that sediment entrainment is a function of the turbulent kinetic energy, which in turn is proportional to U^2. When waves of r.m.s. orbital velocity U_0 are superimposed on the current, additional turbulence, proportional to U_0^2, is generated, of which a proportion B is available for sediment entrainment. Thus for sediment entrainment, the term U^2 in a current-only case should be replaced by ($U^2 + B\ U_0^2$) in a wave-plus-current case.

He further argued that the entrained sediment is transported by the current at a speed U, which is unchanged in the wave-plus-current case. Thus in the power U^n in Eq (6), a factor U is associated with transport, and a factor U^{n-1} with entrainment.
The wave-enhanced suspended transport rate q_{s+} is thus

$$q_{s+} = A\ U\ (U^2 + B\ U_0^2)^{\frac{n-1}{2}} \qquad (6)$$

in which :
A = empirical dimensional constant
n = typically 3 or 4
B = factor related to drag and rugosity

Since bedload transport is usually ≤ 20 % of q_t, it is reasonable to use the Grass approach to enhance q_t, rather than just q_s. Adapting the arguments, it can be shown that the wave-enhanced formula, including a treshold velocity, is given by :

$$q_{t+} = A\ U \left[\left(U^2 + BU_0^{\ 2}\right)^{1/2} - U_{cr}\right]^{n-1} \qquad (7)$$

After computing the induced velocities and shear stresses under current and wave actions (including statistical distributions), the sand transport potential can be calculated. This sand transport is expected to be almost completely trapped in the excavated trench. From this a sand sedimentation on annual basis can be deduced (Table 4.T.14).

Channel Alternative	Length of spit crossing (m)	Expected Sand Sedimentation	
		Mton d.s./year	Mm³/year
1. Deepening and widening the existing Nam Trieu Channel	1000	0.52	0.35
2. New Nam Trieu Channel	2500	1.04	0.69
3. Lach Huyen alignment through Ha Nam Canal	3000	1.08	0.73
4. Lach Huyen alignment through Trap Canal	3000	1.08	0.73

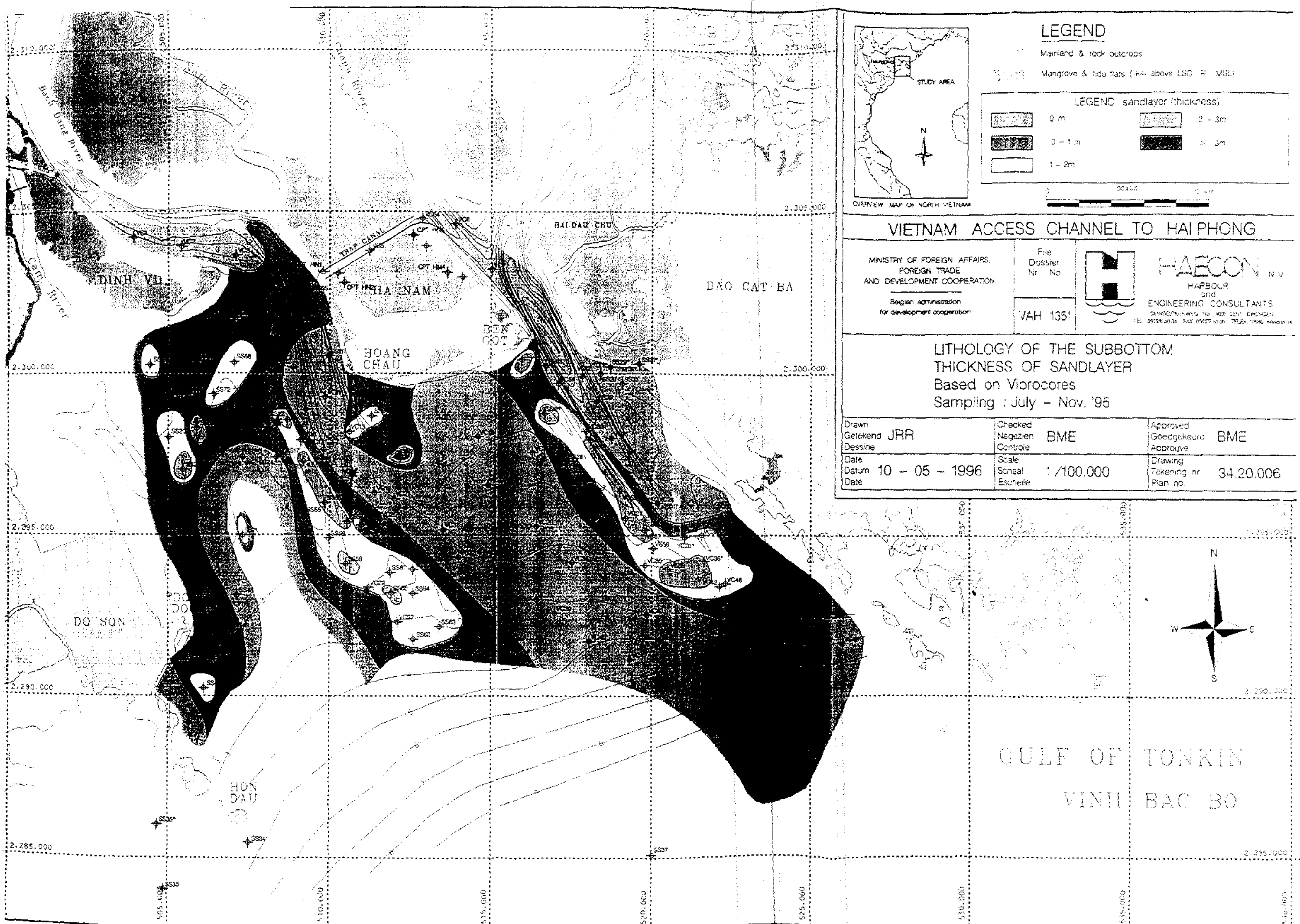
Table 4.T.14.
Expected sedimentation of sand in the outer reaches of the channel

One has to note that these values are the expectations in the first years after the excavation has been terminated. A gradual decrease of the sand-infill is to be expected on the long run.

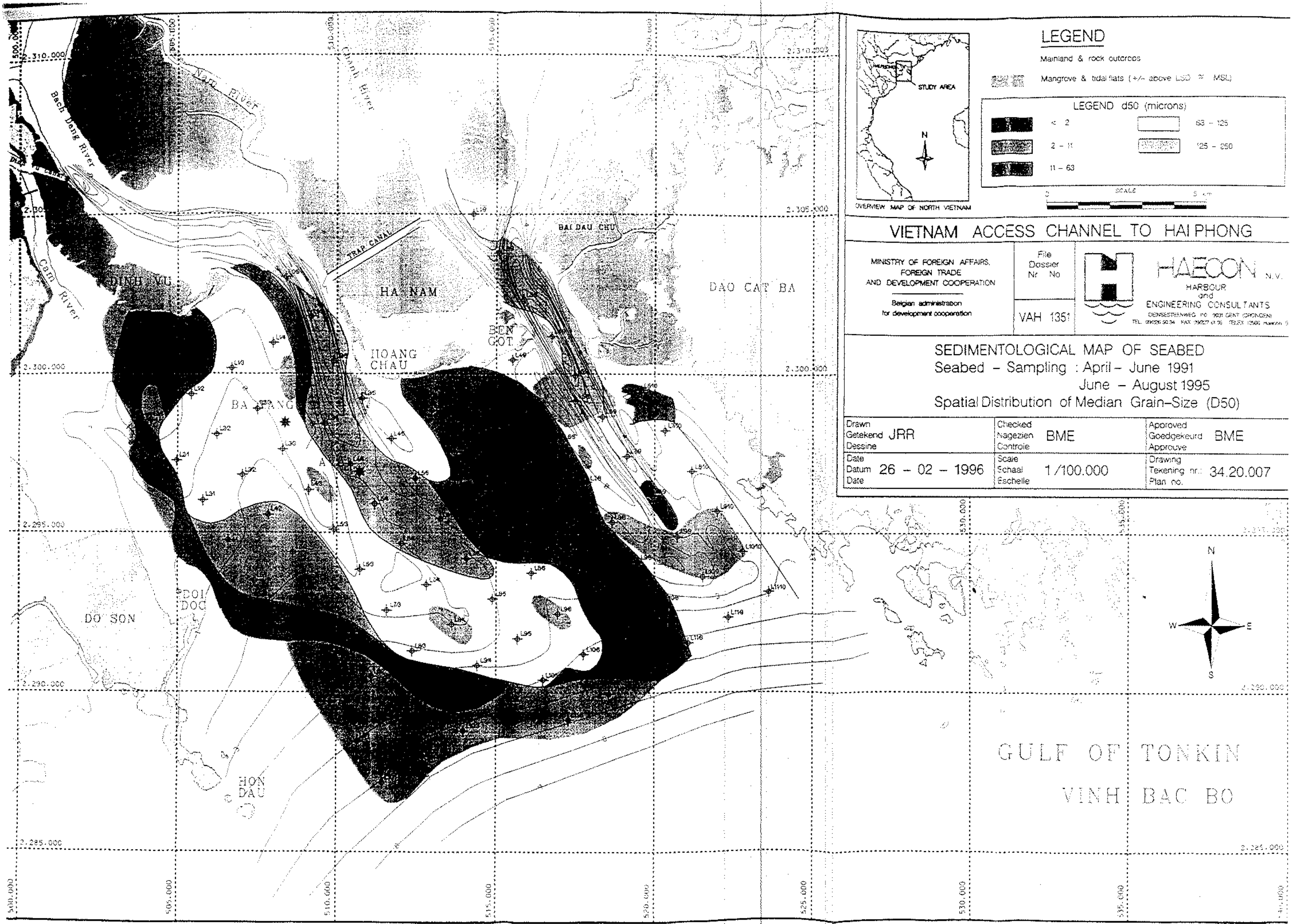
By the Nuclear Institute of Dalat several sand bedload tracer tests have been executed on both banks of the Nam Trieu channel. These tests indicated :

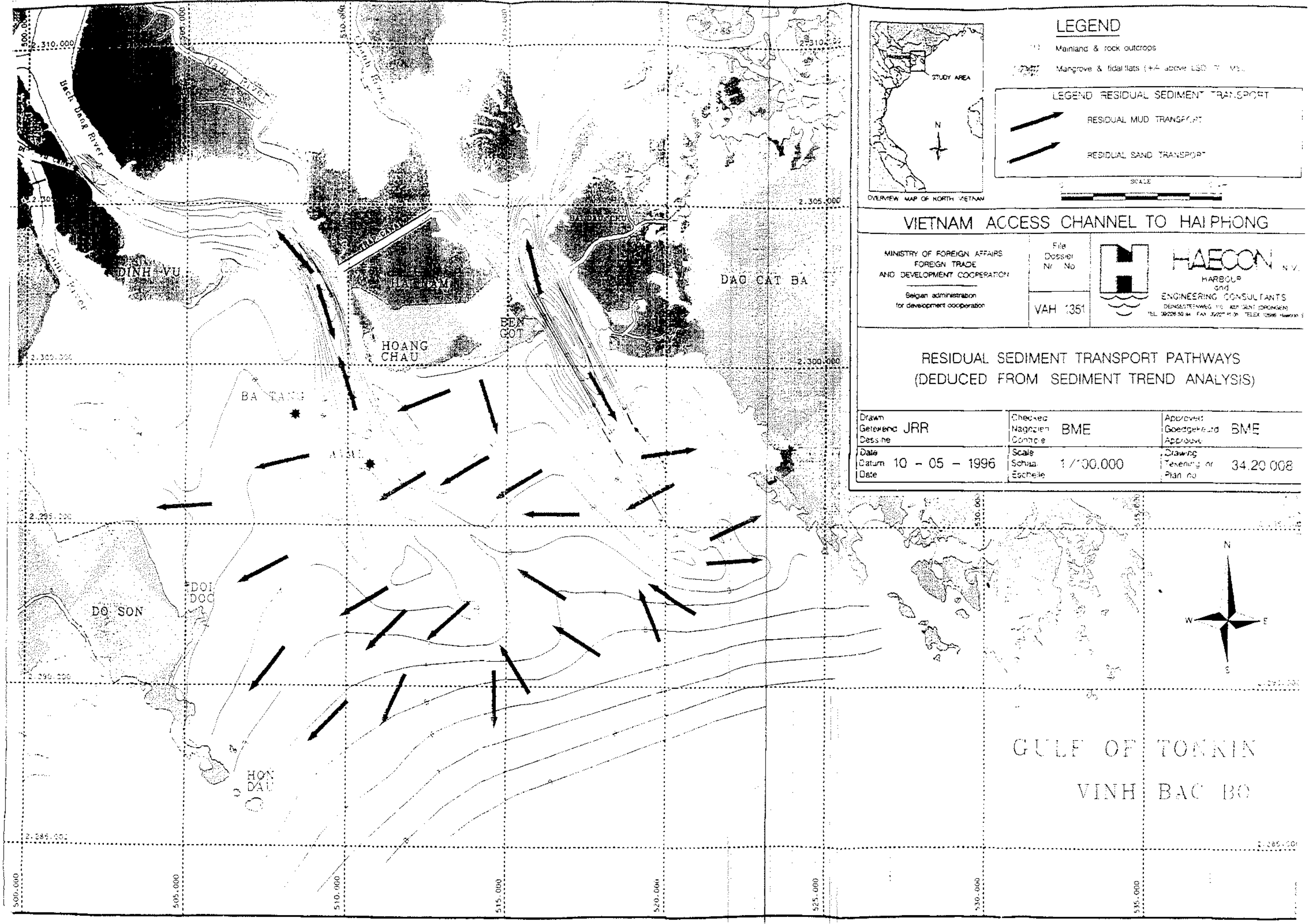
- transport velocities : 10 to 20 m/day ;
- bedload layers : 0.01 to 0.04 m ;
- bedload transport rates : 0.4 to 0.8 m^3/m' day.

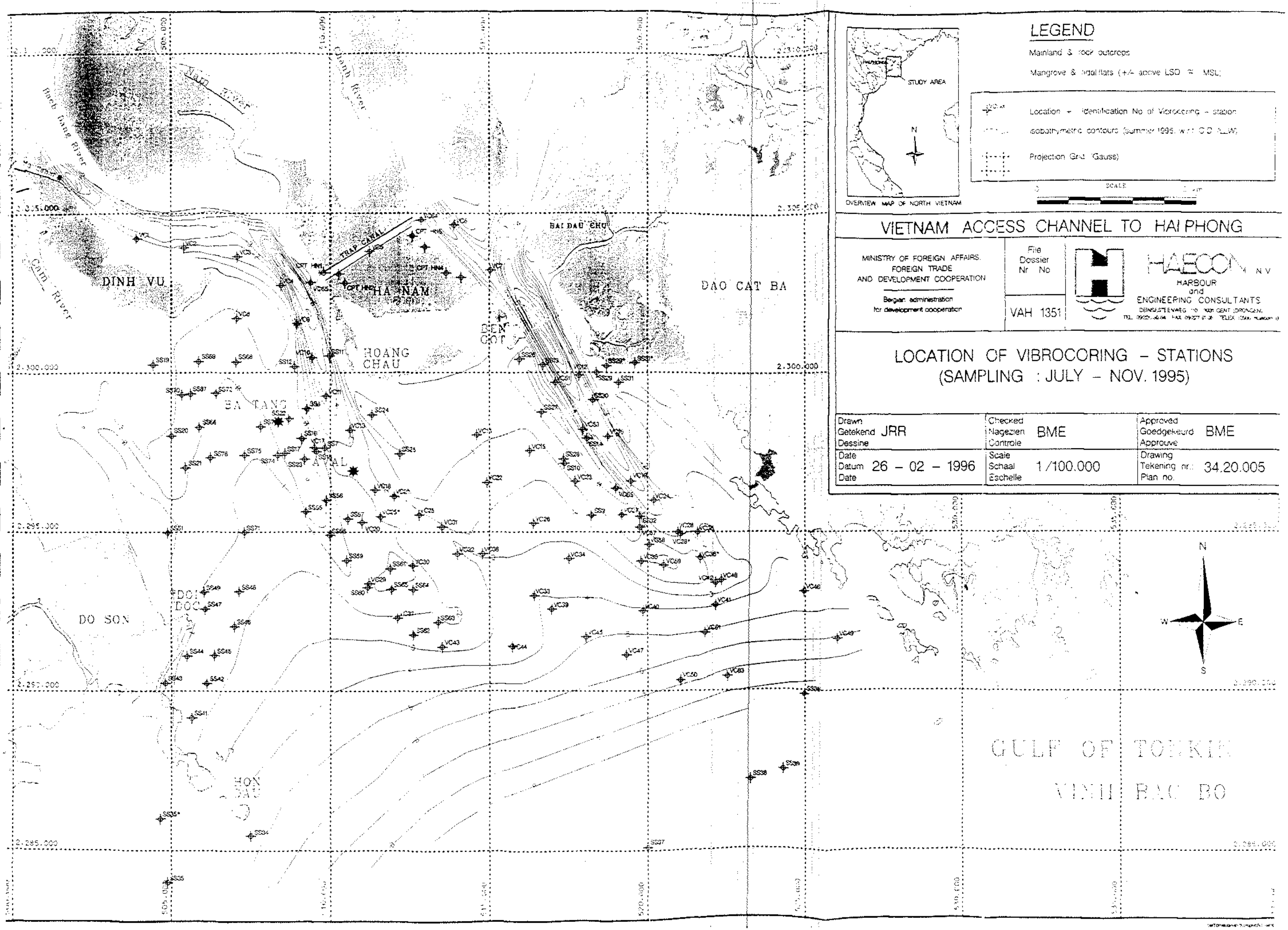
These bedload transports correspond in order of magnitude with the above mentioned computed values.



LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+A above LSD = MSL)
LEGEND sandlayer (thickness)
0 m
0 - 1 m
1 - 2m
2 - 3m
> 3m
SCALE
STUDY AREA
OVERVIEW MAP OF NORTH VIETNAM
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V
HARBOUR and ENGINEERING CONSULTANTS
LITHOLOGY OF THE SUBBOTTOM
THICKNESS OF SANDLAYER
Based on Vibrocores
Sampling : July - Nov. '95
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 10 - 05 - 1996
Scale Schaal Echelle 1/100.000
Drawing Tekening nr Plan no. 34.20.006
Bach Dang River
Cam River
DINH VU
TRAP CANAL
HA NAM
BAI DAU CHU
DAO CAT BA
BEN GOT
HOANG CHAU
DO SON
HON DAU
GULF OF TONKIN
VINH BAC BO
N
S
W
E
2.300.000
2.295.000
2.290.000
2.285.000
505.000
510.000
515.000
520.000
525.000
530.000
535.000


LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+/- above LSD ≈ MSL)
LEGEND d50 (microns)
< 2
2 - 11
11 - 63
63 - 125
125 - 250
SCALE
STUDY AREA
OVERVIEW MAP OF NORTH VIETNAM
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
SEDIMENTOLOGICAL MAP OF SEABED
Seabed - Sampling : April - June 1991
June - August 1995
Spatial Distribution of Median Grain-Size (D50)
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 26 - 02 - 1996
Scale Schaal Echelle 1/100.000
Drawing Tekening nr. Plan no. 34.20.007
Nam River
Bach Dang River
Chanh River
Cam River
DINH VU
TRAP CANAL
HA NAM
HOANG CHAU
BEN GOT
BAI DAU CHU
DAO CAT BA
BA LANG
DO SON
DOI DOC
HON DAU
GULF OF TONKIN
VINH BAC BO
N
S
W
E
2.310.000
2.305.000
2.300.000
2.295.000
2.290.000
2.285.000
500.000
505.000
510.000
515.000
520.000
525.000
530.000
535.000


LEGEND
Mainland & rock outcrops
Mangrove & tidal flats
LEGEND RESIDUAL SEDIMENT TRANSPORT
RESIDUAL MUD TRANSPORT
RESIDUAL SAND TRANSPORT
STUDY AREA
OVERVIEW MAP OF NORTH VIETNAM
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS
FOREIGN TRADE
AND DEVELOPMENT COOPERATION
Belgian administration
for development cooperation
File
Dossier
Nr No
VAH 1351
HAECON N.V.
HARBOUR
and
ENGINEERING CONSULTANTS
RESIDUAL SEDIMENT TRANSPORT PATHWAYS
(DEDUCED FROM SEDIMENT TREND ANALYSIS)
Drawn
Getekend JRR
Dessine
Checked
Nagezien BME
Controle
Approved
Goedgekeurd BME
Approuve
Date
Datum 10 - 05 - 1996
Date
Scale
Schaal 1/100.000
Echelle
Drawing
Tekening nr 34.20 008
Plan no
Nam River
Bach Dang River
DINH VU
HA NAM
HOANG
CHAU
BEN
GOT
DAO CAT BA
BA TAN
DO SON
HON
DAU
GULF OF TONKIN
VINH BAC BO
N
W
E
S
2.310.000
2.305.000
2.300.000
2.295.000
2.290.000
2.285.000
500.000
505.000
510.000
515.000
520.000
525.000
530.000
535.000


LEGEND
Mainland & rock outcrops
Mangrove & tidalflats (+/- above LSD ≈ MSL)
Location + identification No of Vibrocoring - station
isobathymetric contours (summer 1995; w.r.t. C.D. LLW)
Projection Grid (Gauss)
SCALE
OVERVIEW MAP OF NORTH VIETNAM
STUDY AREA
N
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
LOCATION OF VIBROCORING - STATIONS
(SAMPLING : JULY - NOV. 1995)
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 26 - 02 - 1996
Scale Schaal Eschelle 1/100.000
Drawing Tekening nr.: Plan no. 34.20.005
DINH VU
HA NAM
HOANG CHAU
BAI DAU CHU
BEN GOT
DAO CAT BA
BA TANG
DOI LOC
DO SON
HON DAU
TRAP CANAL
Nam River
Chanh River
Bach Dang River
Cam River
GULF OF TONKIN
VINH BAC BO
N
S
E
W

4.3.4. Total Outer Sea Channel infill or sedimentation

The total sedimentation can consequently be deduced based on the above-mentioned values. Total sedimentation is assuming that the channel is excavated e.g. in December and that it is allowed to the channel to infill over 12 months without any intervention.

Siltation and sedimentation are in consequence estimated accordingly ; the values of sedimentation for the different channel alternatives are tabulated in table 4.T.15. below (Outer Sea Channel) ; all quantities are expressed in Mtons of dry solids to allow for a standardised comparison.

Channel alternative	Total capital dredging volume ~~(Mm³ in situ)~~ (Section I + II)	Annual Sedimentation			
		Mud inflow Mton d.s./yr	Sand sed. Mton d.s./yr	Slope evol. Mton d.s./yr	**Total Mton d.s./yr.**
1. Deepening and widening existing Nam Trieu Channel	12.00	4.0	0.52	0.70	**5.22**
2. New Nam Trieu Channel	12.76	3.6	1.04	0.55	**5.19**
3. Lach Huyen alignment through Ha Nam Canal	16.20	2.6	1.08	0.25	**3.93**
4. Lach Huyen alignment through Trap Canal	15.17	2.5	1.08	0.25	**3.83**

Table 4.T.15.
Comparison of computed sedimentation quantities for the different channel alternatives (C.D. - 9.0 m dredged level - Outer channel)

Sedimentation is expressed in Millions of tons of dry solids as a general accepted reference unit. For maintenance dredging the mud sedimentation (mud inflow + slope evolution) is the major item to be considered because the expected rapidness of sedimentation.

These values indicate very clearly that the channel alternatives 3 & 4 are the best appropriated for the Access-channel to Hai Phong. Moreover, it is expected that in the course of the years the lateral inflow of sediments in the Lach Huyen bar crossing will decrease because of the limited stock of sandy material and because the obtained equilibrium slope of the channel banks (see table 4.T.16).

Mechanism	Annual Sedimentation in Lach Huyen (Alt 3 + 4) (Mtons d.s./yr)	
	First 10 years	After 10 years
Mud inflow	2,5	2,5
Sand sedimentation	1,08	0,2
Slope evolution	0,25	/
To	3,83	2,70

Table 4.T.16.
Illustration of expected decrease in annual sedimentation for maintenance dredging in Alt 3 and Alt 4

Channel alternative 4 - i.e. the alignment through the Trap canal - is the channel alternative which on the long run will be the most interesting because of the lowest expected annual sedimentation (nearly 30 % less than for Alternative 1 !).

4.3.5. Comparison between predicted and actual sedimentation values in existing Nam Trieu Channel

The mathematical models described above are essential tools for comparison of different channel-alternatives, but in general, it can be said that absolute values of sedimentation predicted with these models should rather be seen as an order of magnitude rather than exact values. This is also due to the fact that sedimentation-simulations are based upon statistical distributions of prevailing hydrometeorological conditions.

Despite all this, one is always interested in the comparison between measured and predicted sedimentation. To a certain extent, is this possible under the present study because of the extensive Channel Monitoring Programme (still ongoing) in :

a) the existing Nam Trieu Channel ;
b) the Pilot Channel in the Lach Huyen.

From this Monitoring Program observed shoaling rates in both channels can be deduced on annual basis (see figure 4.3.2) :

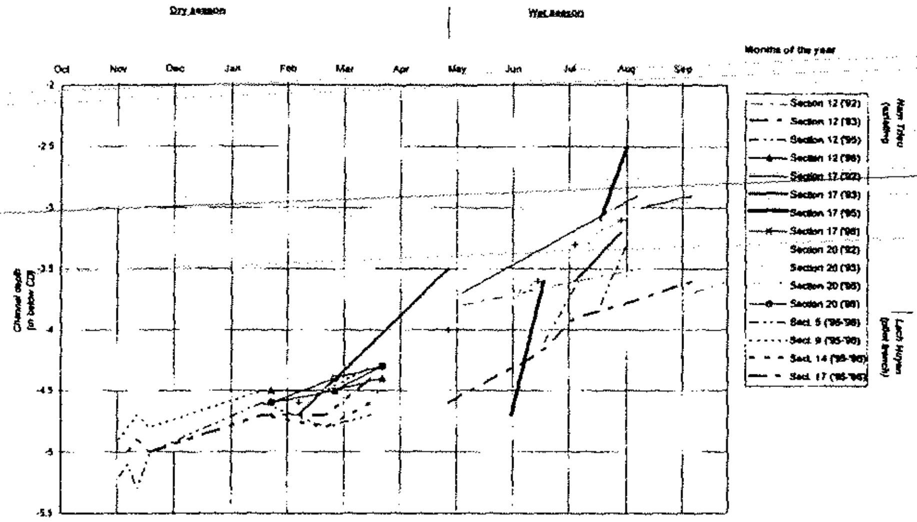


Figure 4.3.2.
Preliminary results of Nam Trieu Channel and Lach Huyen Pilot Channel Monitoring (Monitoring of shoaling)

From this figure the following conclusions can be drawn :

a) shoaling rates are dependent upon the season : high shoaling rates in wet season (1 m or more/month) and low shoaling rates in dry season (0.10 to 0.30 m/month) ;

b) shoaling in Nam Trieu Channel is larger in dry season than in the Lach Huyen Pilot Channel (sedimentation is sand).

When transforming the shoaling graph into sedimentation graph (expressed in tons of dry solids assuming various dry densities) it is possible to compare with the mathematical simulations of total sedimentation in the existing Nam Trieu Channel. This is represented on figure 4.3.3.

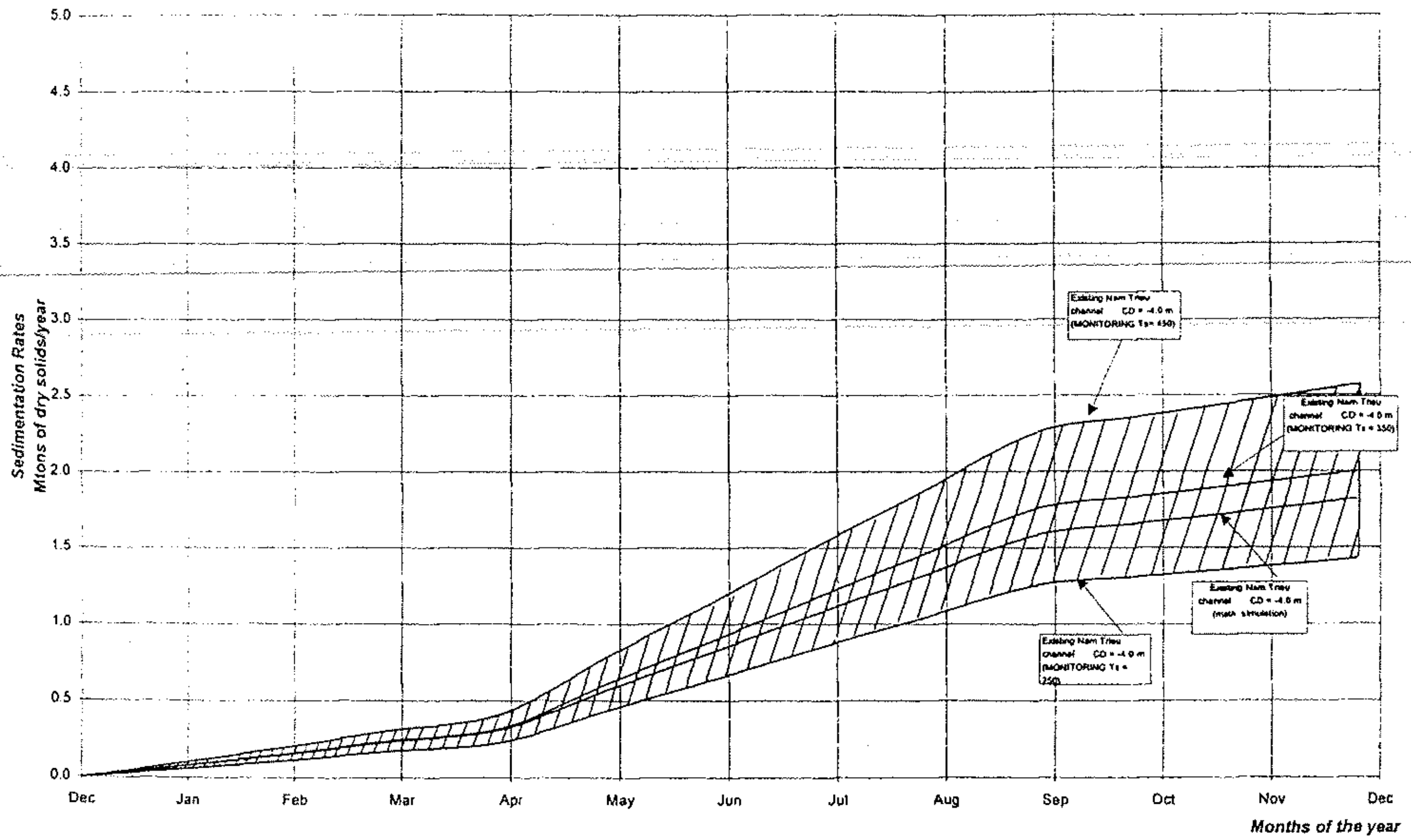


Figure 4.3.3.

Comparison between calculated and observed total sedimentation rates in existing Nam Trieu Channel

From figure 4.3.3. it appears that the mathematical simulations tend to :

- describe quite well the seasonal variations of the sedimentation rates ;
- be in line with the order of magnitude of the observed sedimentation rates ;
- may be underestimate slightly (10-20 %) the real sedimentation rates.

From the observations of the sedimentation in the Lach Huyen Pilot channel during the Dry Season 1995-1996 the following comparison with mathematical simulations can be made :

a)	mathematical simulations	:	
	- siltation	:	1200 tds./138 days ;
	- sand sedimentation	:	500 tds./138 days ;
			± 1700 tds/138 days
b)	observations	:	± 1600 tds/138 days.

In our opinion can these Quality Assurance Checks be considered as a sufficient validation procedure for the adopted mathematical simulation of the sedimentation rate.

4.3.6. Maintenance dredging in Outer Sea Channel : quantities and costs

Of course will the required maintenance dredging effort be directly related to the siltation rate. But they are not necessarily equal. Indeed must here the concept of acceptable tolerance on Nautical Bottom (N.B) be introduced. The N.B tolerance is the maximum shoaling which is acceptable to the Port Authority to consider the access-channel to be safely navigable.

Current practice in maintenance dredging is so that 2 times a year the Access-Channel is deepened to N.B = C.D. - 4.5 m, once in April/May and once in December/January. After this deepening (slopes 1/15) shoaling of 2 to 3 m are allowed resulting in a near No-channel situation after some (2-3) months.

If the N.B tolerance concepts is introduced in Hai Phong, the following major advantages will be gained for the Port :

1. ship's navigation safety and accessibility will improve and remain constant all-year round ; this will attract more traffic ;

2. the maintenance dredging effort will be optimized and reduced in comparison with a practice of 1, 2, 3, ... annual dredging campaigns.

The decrease in required maintenance dredging effort is directly related to the cross-profile of the Access-Channel and to the acceptable N.B tolerance. Current practice in modern western ports is a N.B tolerance of 0.50 m. These N.B variations are carefully monitored and especially in the areas with high siltation rates such as the Nam Trieu Channel. As soon as a shoaling of 0.50 m on N.B design level is observed a dredging campaign is organized in order to maintain the channel at its design depth (this is the reason why specialists speak about Maintenance Dredging).

When comparing the maintenance dredging effort for a methodology with one or two dredging campaigns/year to a dredging programme with a Nautical Bottom tolerance of 0.50 m, one can deduce from figure 4.3.4. that an optimisation of ca. 20 % can be easily achieved.

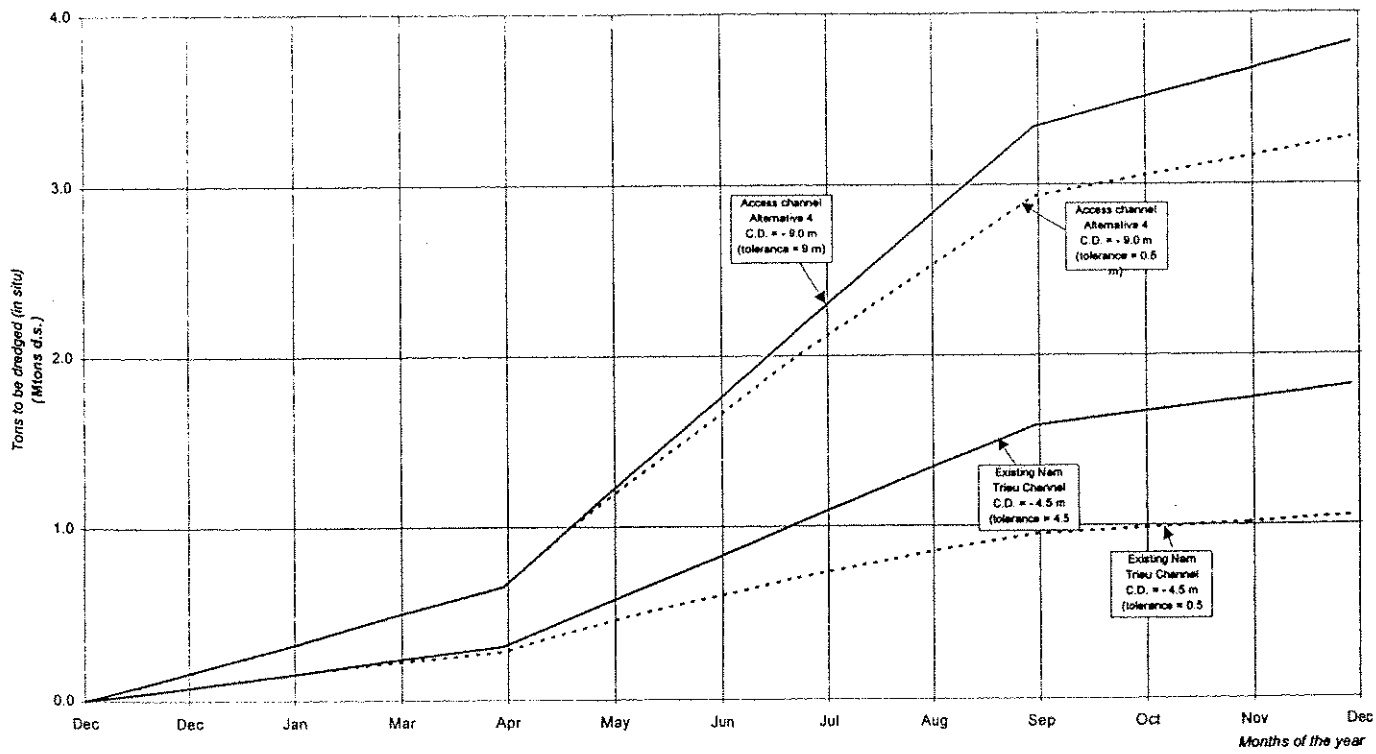


Figure 4.3.4.

Calculated required maintenance dredging effort for various dredging scenarios :

1. ***some dredging campaigns without N.B tolerance***
2. ***frequent dredging campaigns with N.B tolerance = 0.50 m***

From this type of analysis, it is possible to simulate the most appropriated Maintenance Dredging Methodology and the minimum required hopper volume for executing the maintenance dredging.

To achieve these goals the following steps were made :

- the required maintenance dredging volume (with N.B tolerance of 0.50 m) is recalculated as hoppervolumes ;

- the maintenance dredging efforts (expressed in tons of d.s.) are graphed as a function of time over 1 year (figure 4.3.5).

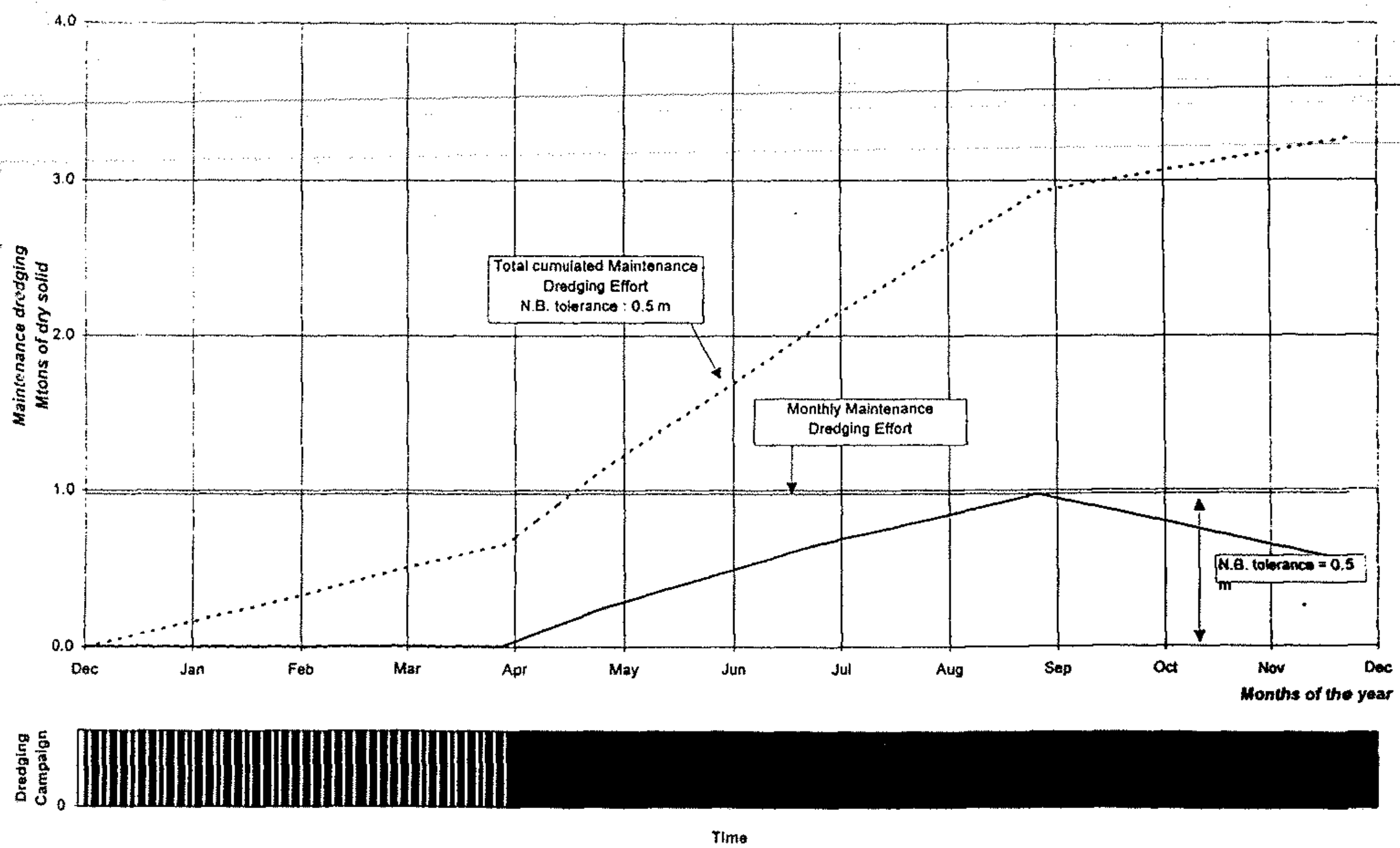


Figure 4.3.5.
Calculated required maintenance dredging tons of dry solids in Lach Huyen (density = 1.20 ; N.B tolerance = 0.50 m ; hopper capacity = 3820 m³)

- the required weekly or monthly maintenance dredging volume within the 0.50 m N.B. tolerance is plotted (see figure 4.3.5 ; lower graph) ;

- the above mentioned exercise is repeated several times for various available hopper capacities and for various production times (a dredging cycle of 3 hours is taken into account) on figures 4.3.6. This is expressed for :

  a) the existing Nam Trieu Channel maintained at a N.B. of C.D. - 4.5 m ;
  b) the Lach Huyen Channel maintained at a N.B. of C.D. - 8.5 m.

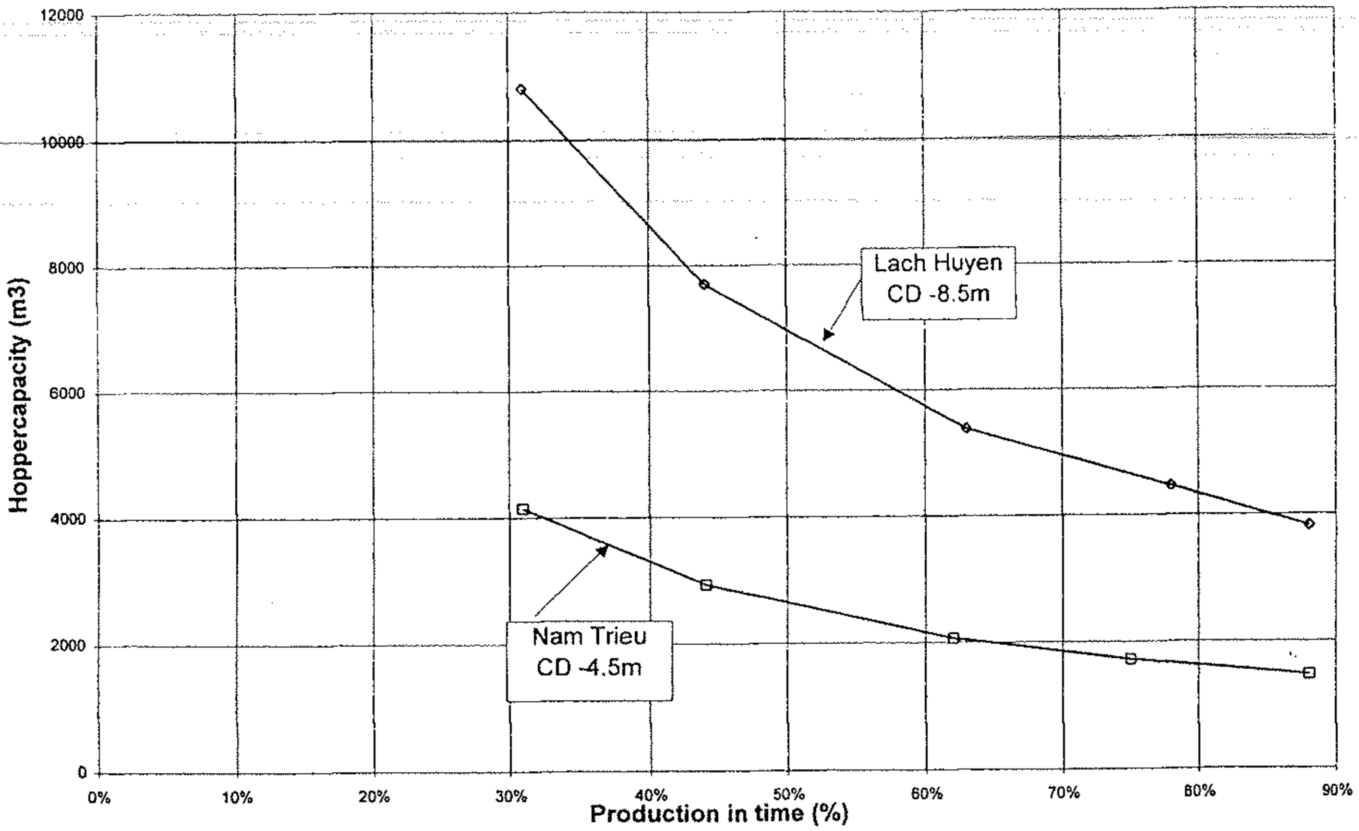


Figure 4.3.6.
Required hopper capacity for maintenance dredging

The above-mentioned series of analysis lead to the following conclusions regarding the required maintenance dredging :

a) to maintain the access-channel to Hai Phong at constant width and depth (N.B.-tolerance : 0.50 m) very regular maintenance dredging is required and especially in the wet season ;

b) to maintain the existing Nam Trieu Channel at C.D. - 4,50 m (N.B.-tolerance : 0.50 m) a total hopper-capacity of ± 2,200 m³ with an occupation time of 60 % should be installed ;

c) to maintain the new Lach Huyen Channel at C.D. - 8.50 m (N.B.-tolerance : 0.50 m) a total hopper-capacity of ± 5,600 m³ with an occupation time of 60 % should be installed.

With the same reasoning and the comparison of siltation for different channel depths it can be deduced that for the existing Nam Trieu Channel deepened at a nautical depth of C.D. - 7.20 m the following rough figures should apply :

- a total maintenance dredging need of approximately 5 Mtons of dry solids a year ;
- a total required hopper-capacity of ± 10,000 m³ with an occupation time of 60 %.

Similarly to maintain the Lach Huyen Channel at a nautical depth of C.D. -7.20 m (Stage 1 : Urgent Channel Rehabilitation Plan) the following estimate can be given :

- a total maintenance dredging of approximately 3.7 Mtons of dry solids a year ;
- a total required hopper-capacity of ± 6,000 m³ with an occupation time of 60 %.

The above-mentioned figures are based on a maintenance dredging cycle which can be described as follows :

- navigation from dredging zone to dumping zone (distance 15 km) : 1 hour ;
- dredging + overflow : 1 hour ;
- navigation from dumping zone to dredging zone : 1 hour.

For the Lach Huyen Channel maintenance at C.D. - 8.50 m and with a total installed hopper-capacity of 5,600 m^3 an average cost price of 1.25 MUSD/month is calculated ; in this month, those TSHD's should execute approximately 150 dredging cycles (this corresponds to approximately 2.20 - 2.40 USD/m^3 in-situ).

Assuming an in-situ dry solid content of 500 kg d.s./m^3 the maintenance of the Full Channel Development Plan (Stage 2) would cost approximately 6.60 Mm^3 x 2.30 USD/m^3 = 15.2 MUSD/year.

Similarly can the maintenance of the Urgent Channel Rehabilitation Plan be estimated at approximately 17.0 MUSD/year.

It must be repeated that these figures can not be compared with the present-day situation because for the time being no definite nautical accessibility can be guaranteed (design nautical depth is available for approximately 4-5 months/year).

Finally the required TSHD hopper capacities for maintenance dredging do fit quite well with the capacity of the new TSHD under construction for VINAWACO (HV = 6,000 m^3).

4.3.7. Maintenance dredging in the other reaches of the access-channel

From the modelling results it appears clearly that the major changes in siltation and the greatest siltation/sedimentation rates are to be expected in the outer channel, this means from the Gulf of Tonkin down to the exit of the Trap Canal. Moreover, the upstream sections of Bach Dang, Dinh Vu Canal and Cam River are common to all alternatives ; therefore these are not considered in the comparison of the Channel-Alternatives.

Further upstream other morphological changes are to be expected :

a. in the Bach Dang between Trap Canal and Dinh Vu Canal it is expected that the channelization of flow will keep the channel clear, but important mud sedimentation is to be expected on both banks ;
b. in the Dinh Vu Canal no significant modifications in the sedimentation pattern are expected despite the section widening ;
c. the most significant changes in sedimentation in the upstream part of the channel are to be expected in the deepened sections of the Cam River (in front of Hai Phong Port).

Therefore, some considerations will be given to the expected increased sedimentation in the Cam River. Nowadays total quantities of annual required maintenance in Cua Cam vary between 100,000 m³ and 700,000 m³ dredged volume annually with an average of 350,000 m³ per year.

The deepening from an average depth of CD - 6.5 m to CD - 8.0 m will probably have the following effects :

- the self-scouring effect (induced along the Right Bank by the river groynes) will be diminished ;
- in some cases siltation will increase w.r.t. the existing situation but it appears also that sometimes the siltation will be lower dependent upon the season ;
- maintenance dredging in Cam river is expected not to increase to more than 0.8 Mtons of dry solids/year ; indeed are ebb currents not expected to slacken with more than 20 % on average.

Maintenance dredging in the river reaches of Bạch Dang and Song Cam can be executed as in current practice with Grab Dredgers or Bucket Wheel Dredger and dumping on disposal sites on river banks. Cost is estimated at 1.5 to 2.0 USD/m³ in-situ. If aquatic dumping is envisaged in the nearly future additional transport costs are to be considered (one-way transport time = ± 4 hours).

The deepening and maintenance of appropriate turning basins and berths is not considered in this study. It is recommended however to carefully design these dredging works taking into account :

a) the quay-wall foundation and structure ;

b) the impact on the hydraulic section and consequent sedimentation/ erosion patterns ;

c) the stability of the port and river-bank infrastructures.

4.3.8. Considerations about impact of maintenance dredging on port development

Maintenance dredging is the major concern regarding the selection and design of the new channel to Hai Phong Port because the costs associated to these ever recurrent yearly costs will have a significant impact on the economic balance of Hai Phong Port.

When comparing some broad figures of the present day situation of Hai Phong Port with projections obtained from extrapolations and from the previous mentioned maintenance dredging volumes, the following can be concluded :

1. Situation 1993 :
   - Total cargo volume TCV = 2.7 Mtonnes (stat.)
   - Total maintenance dredging tonnage : TMT = ± 1.0 Mtons d.s. (stat.)
   - Nautical depth : ND = C.D. - 4.1 m
   - TMT/TCV = ± 0.37

2. Situation 2000 :
   - Total cargo volume : TCV = 5.5 Mtonnes (proj.)
   - Total maintenance dredging volume : TMT = 4.0 - 6.0 Mtons d.s.
   - Nautical depth ND = C.D. - 8.5 m
   - TMT/TCV = 0.73 - 1.09

3. Situation 2010 :
   - Total cargo volume : TCV = 8.4 Mtonnes (proj.)
   - Total maintenance dredging volume : TMT = 4.0 - 6.0 Mtons d.s.
   - Nautical depth : ND = C.D. - 8.5 m
   - TMT/TCV = 0.48 - 0.71

The large variations in the estimated maintenance dredging tonnage and consequently in the ratio TMT/TCV mentioned above can not be used for detailed economic analyses. Therefore, a lot of efforts have been made in this study project to estimate more accurately the future maintenance dredging volume by using present-day's most sophisticated sediment transport mathematical model. This has been described in paragraph 4.2. to a large extent.

Regarding the choice of the channel development options - Stage 1 : Urgent Channel Rehabilitation and Stage 2 Full Channel Development will Haecon recommend to decide at once for the Full Channel Development because :

a) the capital dredging investment is only 28 % more ;
b) the time-accessibility of the port increases with 50 % for the design ship ;
c) the maintenance dredging is not expected to be significantly different.

4.3.9. Conclusions about maintenance dredging

Based on the above-mentioned considerations the following preference-classification is given for the different channel-alternatives :

- best : Alternative 4
- second best : Alternative 3
- medium : Alternative 2
- least : Alternative 1

4.4. CHANNEL STABILITY

The "channel stability" criterium is related to the vertical, horizontal and slope stability on the short and long run.

Vertical stability means the rate of change in nautical depth for instance between 2 soundings. In the par. 4.2. and 4.3. attention has been given to the siltation rates in the different sections of the channel. From the past experience and from the simulations, the following can be concluded :

1. Cam River : siltation of approx. 0.20 m/month in dry season and 0.40 m/month in wet season ;
2. Nam Trieu Channel : (bar area) siltation of approx. 1.00 m/month (first months) decreasing progressively as channel bottom in approaching the natural sea-bed level ;
3. Lach Huyen Channel : (bar area) siltation of approx. 0.70 m/month probably also decreasing when channel bottom is approaching the natural sea-bed level ;

The vertical stability is analysed here essentially for the ship's navigation safety aspects with respect to the underkeel-clearance variations.

From these considerations it is obvious that any channel solution for Hai Phong Port must be associated with :

a. a <u>better and very regular channel monitoring system</u> with fast data-processing ;
b. an appropriate <u>maintenance dredging system</u> where dredgers can be made readily available to prevent too large vertical changes in nautical depth.

The <u>horizontal channel stability</u> is related to the lateral stability of ebb and flood channels and the alignment with the prevailing tidal currents.

The <u>slope stability</u> is related to the evolution of the side-slopes of the channel in function of time. The high densities of the mud deposits will guarantee the stability of slopes under 1:5 or 1:15. However, it is to be expected that - due to wave action and mud-weakening - slopes will evaluate over the years by regular maintenance to much milder equilibrium values and probably to approx. 1:40. Slope stability is of course very dependent upon the soil type.

4.4.1. Vertical stability

As said in the introduction of par. 4.4. the vertical stability is related to the expected siltation rate - dependent upon the season and the occurrence of typhoons - and has yet been addressed in the paragraphs par. 4.2. and 4.3.

4.4.1.1. Alternative 1 : Deepening and widening the existing Nam Trieu Channel

Siltation profiles here indicate a rather uniform pattern in which sudden shallowings of approx. 0.50 m per event (1 storm tide) can occur over a length of more than 5,000 m.

4.4.1.2. Alternative 2 : New Nam Trieu Channel

Despite the better alignment of the New Nam Trieu Channel with the prevailing ebb and flood currents on the "channelization"-effect siltation rates are expected to be very high and concentrated on the offshore extremity (approx. 2,000 - 3,000 m), due to :

a. the crossing of the submerged sand spit ;
b. the crossing of the offshore mud bar at its largest extension with the supply from the river, the sea and the side slopes.

Sudden siltations after e.g. a storm-event can amount to approx. 0.20 m shallowing.

4.4.1.3. Alternative 3 : New alignment in Lach Huyen through Ha Nam Canal

The high siltation area is limited here by the relative narrow offshore bar crossing.
Sudden siltations at the offshore bar after e.g. a storm-event can amount to approx. 0.40 m shallowing.

4.4.1.4. Alternative 4 : New alignment in Lach Huyen through Trap Canal

The high siltation area is limited here by the relative narrow offshore bar crossing.
Sudden siltations at the offshore bar after e.g. a storm-event can amount to approx. 0.40 m shallowing.

4.4.2. Horizontal Channel Stability

4.4.2.1. Alternative 1 : Deepening and widening the existing Nam Trieu Channel

The alignment of the existing Nam Trieu Channel with the change in bearing reflects also the local morphology where the sand spit to the West of the Nam Trieu gets a sharp eastwards bend south of Aval. The morphology of this bended sand spit is probably related to a complex hydrosedimentary interaction between the tidal currents, the (slackened) river discharge and the wave action.

. It is expected that the horizontal channel stability of this alternative is relatively good ; this is also ascertained by the relatively symmetrical siltation observed in the Nam Trieu, (despite the cross-current alignment of the channel in the south-part).

4.4.2.2. Alternative 2 : New Nam Trieu Channel

The crossing of the sandbank by the new Nam Trieu Channel is likely to adversely affect the horizontal stability and this, despite the better alignment with the prevailing tidal currents.

4.4.2.3. Alternative 3 : New alignment in Lach Huyen through Ha Nam Canal

The horizontal stability of this alternative is expected to be good, excepted in the far south extremity of the channel where a similar inflected sand spit end crosses the channel-route as in alternative 2. The impact of this bar on the channel stability is expected to be very limited although quite difficult to foresee ; it is probable that this sand spit will induce additional maintenance dredging (see par. 4.3.).

In order to reduce the lateral sand spit extremity inflow, the bearing of this part of the channel have been inflected slightly to the east.

4.4.2.4. Alternative 4 : New alignment in Lach Huyen through trap Canal

Same conclusions as for alternative 3 (see par. 4.4.2.3.).

4.4.3. Slope stability

As described in this preliminary design report, the proposed channel slopes for capital dredging is 1:15 for Nam Trieu/Lach Huyen Channel,1:5 for Trap/Ha Nam Canal and 1:7 for Bach Dang and Cam River. The evolution to milder slopes is to be seen over several years (10 years) of maintenance dredging.

4.4.3.1. Alternative 1 : Deepening and widening the existing Nam Trieu Channel

It is obvious from the channel monitoring that slopes on 1:15 to 1:20 are stable on longer terms. No evidence of slope collapsing can be found in the cross-sections. But the high densities (above 1.40 density) and the associated relatively high initial rigidities (more than 100 Pa) suggest that even steeper slopes of 1:5 to 1:10 can be considered as relatively stable.

However, the extra excavation to C.D. - 8.50 m nautical depth in Nam Trieu will induce on the long run milder slopes due to soil-weakening and wave action on the "channel-shoulders" ; therefore it is expected that the slopes will evaluate to the milder values of 1:20 or more.

4.4.3.2. Alternative 2 : New Nam Trieu Channel

The existing soil information along the New Nam Trieu Channel route suggest that different soil types will be crossed :

1. crossing of the sandbank West of Nam Trieu :

   - 1 to 2 m thick surface layer of fine sand with limited mud fraction ;
   - expected equilibrium slope in sand : 1:10
   - expected long-run equilibrium slope in mud : 1:20

2. crossing of the muddy offshore bar

The slope stability of this alternative is therefore very much dependent on the final results of the soil investigation.

4.4.3.3. Alternative 3 : New alignment in Lach Huyen through Ha Nam Canal

The slopes in the Canal are defined on 1:5. The slope stability is essentially affected in the crossing of the offshore bar where a particular soil layering seems to occur :

1. a top layer of 1.5 m to 2 m (sometimes even 3 m) fine to medium sand ;
2. a subjacent consolidated mud layer with densities of 1.40 m and up.

After excavation of the channel under 1:15 it is very likely that the channel slopes will evaluate to milder values after several years of maintenance to 1:20 or more for the subjacent mud layer.

4.4.3.4. Alternative 4 : New alignment in Lach Huyen through Trap Canal

The Trap Canal is expected to get the same equilibrium slopes as the New Ha Nam Canal.

For the outer channel crossing the offshore bar, the same conclusions as for alternative 3 (par. 4.4.3.3.) do apply.

4.4.4. Conclusions about channel stability

Based on the above-mentioned considerations the following preference-classification is proposed :

- best : Alternative 4
- second best : Alternative 3
- medium : Alternative 2
- least : Alternative 1

4.5. SOCIAL IMPACT ASSESSMENT

4.5.1. General

Social impacts can be generated if large waterwork infrastructures are causing :

- necessity of relocation of people's housing ;
- modification in local transportation / communication ;
- modification of professional activities, especially regarding artisanal fishing activities ;
- loss of land.

Quantifying exactly the social impacts requires a separate study ; therefore, the different scenario's for alternative channels will be described in function of a potential social impact which will be qualitatively assessed.

4.5.2. Alternative 1 : Deepening and widening the existing Nam Trieu Channel

Deepening to C.D. - 9.0 m dredged level or to C.D. -11.5 m dredged level and widening (to bottom width of 100 m) the existing channel will essentially have an impact on hydraulic flow and sedimentological regime (see par. 4.2.). Hydraulic flow is expected to be influenced as follows according to the modelling results :

1. increase in current velocities, both at ebb and flood, in the channel itself (down to buoy 18/19) ;
2. decrease in current velocities on the adjacent banks and subtidal flats.

From a sedimentological point of view, it is also expected from the model results, that mud sedimentation will take place on the banks in size by the deepening and widening of the channel.

Relocation of people ought not to be considered for this alternative even for the widening of the Dinh Vu Canal.

Increase of shipping traffic will influence domestic transportation and traffic ; this is however true for all alternatives.

Fishing activities with fishing stakes and fixed nets along the banks may be significantly influenced because of the change in sea or riverbed. Yet the impact could be beneficial because of the extra supply of nutrient-rich mud improving benthic ecosystems, especially for non-sessile organisms (e.g. shrimps, crabs, ...).
The greater the selected nautical depth, the greater the impact, of course.

4.5.3. Alternative 2 : Excavation of a New Nam Trieu Channel

Excavating the new Nam Trieu Channel south of Aval will even more chanelize the ebb and flood currents because of a better alignment with the natural currents (see par. 4.2.).

Social impact is expected to be the same as for alternative 1 (Existing Nam Trieu Channel) i.e. (adverse or beneficial ?) impact on fishing activities along the subtidal flats. (Hoang Chau, ...).

4.5.4. Alternative 3 : New Alignment in Lach Huyen and channel through Ha Nam

This alternative will of course have an impact on social, economic and cultural conditions in Ha Nam island. The nearly 150 m wide Ha Nam Canal will make a new cut through the Ha Nam lowlands between the west-entry of Trap Canal and Thân Trân avoiding the human settlement areas.

Social impact is expected - for this alternative - to be mainly :

a. loss of approx. 75 ha of land (paddy fields, rice-fields) ; this loss can eventually be compensated partially if it is decided to landfill the Trap Canal ;
b. increased communication difficulties with mainland (2 canals to cross) ; can also be solved by landfilling the Trap Canal.

The modified current field at ebb and flood will have little or no effect on extra sedimentation along the banks of Lach Huyen (see par. 4.2.).

However, it is expected that increased sedimentation will occur in the existing Nam Trieu Channel affecting may be the fishing activities in this area.

4.5.5. Alternative 4 : New alignment in Lach Huyen and channel through Trap Canal.

The widening of the existing Trap Canal (now 80 m wide) to approx. 150 m will of course have a social impact mainly because of the loss of approx. 50 ha of land.

Other social impacts are similar to those described for alternative 3 (see par. 4.5.4.).

4.5.6. Conclusion about Social Impact

Based on the above-mentioned considerations the following preference-classification of the channel alternatives is proposed :

- best : Alternative 1
- second best : Alternative 2
- medium : Alternative 4
- least : Alternative 3

4.6. ENVIRONMENTAL IMPACT

Coastal zones like the one in the bay of Hai Phong have been dubbed the biologically most productive marine environments.
Many countries and large numbers of human beings depend on the production of fisheries along the coast not only for food income and employment, but for foreign trade as well. Thus, there is a need to protect these areas from pollution, from extensive exploitation and from any adverse impact in order to sustain their productive condition and the overall aquatic ecosystem of which we - humans - are part of.

As for other Southeast Asian regions, any major works modifying natural conditions, it is perhaps recommended that an in-depth environmental impact assessment be conducted, less physical, biological, economic and sociological consequences develop which would negatively reflect on the benefits derived from the current project. ~~HAECON could provide the expertise to carry-out such E.I.A.~~

In this area and in relation to the dredging works - both capital and maintenance - the environmental impacts can be related to :

1. impact on benthic ecosystems in the dredging areas ;
2. impact on benthic ecosystems in the dumping areas and the areas affected by the dispersion of fine-grained mud particles ;
3. impact on mangrove-ecosystems (when used for thin spreading disposal, or if bank erosion does occur, ...) ; on the figure 4.6.1. below, a satellite-image of the area (SPOT Panchromatic View ....) is given ; the dark-red and black areas on the river banks indicate the mangrove ecosystems with their complex tidal gulley systems.

The deepening and widening of the existing Nam Trieu Channel will affect the first 0.5 m of the sediments to which the benthic ecosystem is closely linked.

Environmental impacts in the dredging areas can be linked to (common to all alternatives) :

a. destruction of benthic communities of sessile organisms ;
b. stress-inductions due to disturbance, noise, ...
c. spillage of oil, fuel, ... (accidental) ;
d. remobilisation of nutrients in muddy sediments and temporal eutrophication ;
e. increase of oxygen demand in water column ;
f. changes in salinity.

Environmental impacts due to capital dredging works are generally temporary lasting as long as the execution of the works (approx. 1 year), and are proportioned to the area covered by the works.

Much bigger impacts (lasting as long as the works are executed) can be expected on the disposal areas of the dredged material and the areas affected by the dispersion of the dump-losses both upland and aquatic :

a. burial of sessile organisms ;
b. modification of substratum and consequently of habitat ;
c. increase of water turbidity ;
d. increase of nutrients by release during dumping ;
e. increase of oxygen demand in the water column.

All the environmental impacts on the disposal areas are however the same for all the four channel-alternatives. Consequently, no significant differences can be expected in this respect.

It is therefore, recommended to execute a dedicated Environmental Impact Assessment (EIA) once the channel has been selected. Moreover, it is recommended to execute a pilot-test with ecological monitoring to assess the feasibility of disposal by thin-spreading into the mangrove areas.

Regarding the Environmental Impacts related to the aquatic dumping of dredged material, HAECON recommends to follow the specifications of the London Dumping Convention (1972) and more specifically the 1983.

"Guidelines for the Management of Dredged Material" (accepted by the Oslo Commission (OSCOM) and prepared by Belgian Experts) in which the Concept at Best Environmental Practice (BEP) to optimise the disposal of dredged material was introduced. The OSCOM Guidelines describe the following items to be addressed in the choice of a dumping program :

1. Optimise the disposal quantities : this means minimise the quantity of dredging volume to a minimum ;
2. Improve the sediment quality : only applicable if the geochemical sediment characteristics indicate potentiality of toxicity, and adverse biochemical effects ;
3. Minimise the effects caused by the disposal of dredged material : this means choose a dumping site in order to minimize redispersion and recirculation of dump-losses and improve the efficiency of disposal operations (e.g. increase hopper density, ...).

Figure 4.6.1.
SPOT view of study area with indication of mangrove areas (21-05-88)

4.6.1. Alternative 1 : Deepening and widening the existing Nam Trieu Channel

The area covered by the deepening and widening works of the existing Nam Trieu Channel is approx. 500 m x 35,500 m = 17.75 km². In comparison to the approximately 320 km² water surface of the Hai Phong Bay and river system, this means that the works will affect approximately 5 % of the whole benthic ecosystem.

Deepening and widening the existing channel will modify the salt wedge penetration causing more saline waters to penetrate into the Bach Dang. This modification is likely to alter the benthic communities.

4.6.2. Alternative 2 : New Nam Trieu Channel

There is no significant difference between Alternative 2 and Alternative 1 regarding :

1. the influence of the dredging works on the benthic ecosystem ;
2. the increase further landward of the salt wedge.

4.6.3. Alternative 3 : New alignment in Lach Huyen through Ha Nam Canal

These dredging works of this alternative will affect approximately 6 % of the whole ecosystem.
Salt wedge penetration further landward in the Bach Dang is also occurring for this alternative to approximately the same extent as Alternatives 1 and 2.

4.6.4. Alternative 4 : New alignment in Lach Huyen through Trap Canal

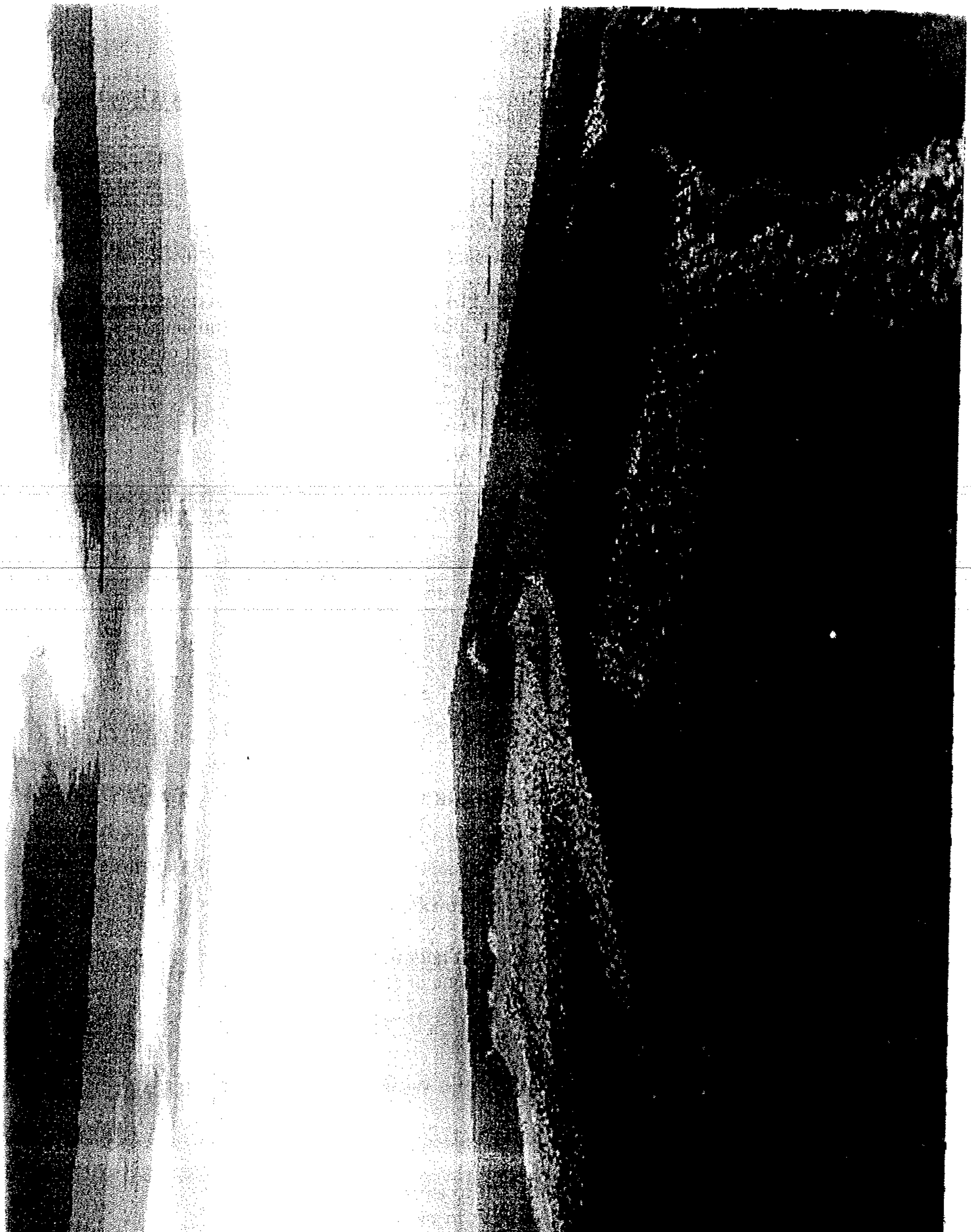
These dredging works of this alternative will have an impact on 6.25 % of the whole ecosystem of the bay (which is not significantly different from Alternatives 1, 2 and 3.

Salt wedge penetration further landward in the Bach Dang is here the least of all the four alternatives.

4.6.5. Conclusions about environmental impact

Although a dedicated EIA (Environmental Impact Assessment) should first be conducted, it is yet possible to compare and (preliminary) classify the different alternatives from an environmental impact point of view :

best :	Alternative 4
second best :	Alternative 3
medium :	Alternative 1
least :	Alternative 2



4.7. NAUTICAL ACCESSIBILITY

4.7.1. General

The different access-channels proposed in this study are designed according to the internationally accepted safety rules regarding width, keel-clearance and bending radius.

However, there are a number of other aspects related to the nautical accessibility which are important to be mentioned because they might influence the decision-taking regarding the best channel. These aspects are related to :

a. the presence of two-way traffic sections ;
b. the occurrence of cross-currents ;
c. the length of the channel ;
d. the potentiality for future developments (widening, deepening, ...).

The different alternatives will now be screened for these different nautical aspects. It has been assumed that the traffic capacity - this is the maximum number of sailing ships per tidal cycle - is equal for all four alternatives (for Hai Phong the Office of Maritime Safety accepts a time interval of 30 min. between 2 ships).

4.7.2. Alternative 1 : Deepening and widening the existing channel

Alternative 1 will present one single channel stretch of approx. 2,400 m in Bach Dang downstream where two-way traffic is possible (width = approx. 200 m - 250 m) ; a better regulation of fishing activities on the banks is here required.

The same cross-current pattern for navigation as in the existing situation is expected to prevail despite the better channelization of mainly the ebb-flow due to the deepening. However, it must be emphasised that nowadays cross-currents are rather limited to approx. 1 knot and 30° drift angle (during flood) causing no significant navigation hindrance.
Therefore it is not expected that for alternative 1 problems of cross-currents will be significant. The cross-currents at the entrance of Dinh Vu Canal are common to all four the channel-alternatives.

The length of the channel from buoy "0" to Hai Phong Main Port is still 35.5 km.

There are no specific limitations foreseen for further nautical accessibility improvement excepted the common Dinh Vu Canal width.

4.7.3. Alternative 2 : New Nam Trieu Channel

Alternative 2 will also have one single channel stretch of approx. 2,400 m length in Bach Dang downstream reach where two-away traffic is possible (width = 200 - 250 m).

Because of the better alignment of the channel with the prevailing tidal currents this alternative will provide a channel exempted from significant cross-currents.

The length of the channel from natural waterdepths in the Gulf of Tonkin to Hai Phong Main Port is 34.5 km, 1 km shorter than alternative 1.

4.7.4. Alternative 3 : New alignment in Lach Huyen through Ha Nam Canal

This alternative will provide 2 stretches of navigation channel where two-way traffic is possible, rendering this alternative quite attractive from this point of view :

a. in Bach Dang Downstream reach
   length : 750 m
   bottom width : 200 - 250 m
b. in Lach Huyen
   length : 4000 m
   bottom width : 500 m

Alternative 3 is well aligned with the sometimes quite strong tidal currents in the Lach Huyen and therefore no navigational problems due to cross-currents are expected here. Some problems may rise by entering and exiting the Ha Nam Canal ; therefore the entrance and exit will be designed locally with a greater bottom width of the canal (200 m). Nevertheless the magnitudes of differential cross-currents are not in that order that navigation will be rendered impossible. A special training programme for pilots could eventually be foreseen.

The length of the channel is approx. 39.5 km which is 4 km longer than alternative 1.

Future development of the channel will have to take into account the riverine development along both banks of the Ha Nam Canal : it is difficult to say now whether this will form a problem for future widenings or deepenings.

4.7.5. Alternative 4 : New alignment in Lach Huyen through Trap Canal

Here also 2 stretches of possible two-way traffic are associated to alternative 4 (cfr. alternative 3). Moreover, in the future the Ha Nam Canal concept as by-pass could still be developed in order to create a third two-way traffic stretch (with Trap Canal).

Regarding the cross-currents, some special care will be needed at the entry and exit of the deepened Trap Canal. It is expected however that the differential cross-current pattern at Lach Huyen entry of the Trap Canal will be less than for the new Ha Nam Canal because the tidal currents are weaker here. Pilot training with nautical simulations could greatly improve the experiences in these particular circumstances.

The length of the channel for alternative 4 is approx. 40 km.

Future developments will as for alternative 3 have to take into account the riverine land-use and development along both banks of the Trap Canal.

4.7.6. Conclusions about nautical accessibility

It is felt that the possibilities of two-way traffic and the cross-current pattern in the offshore reach of the channel alternatives are the dominant selection criteria regarding nautical accessibility.

Therefore, the following classification of the alternatives for nautical accessibility is given as follows :

best :	Alternative 4
second best :	Alternative 3
medium :	Alternative 2
least :	Alternative 1

5. MAINTENANCE DREDGING REDUCTION MEASURES

5.1. OPTIONS FOR MAINTENANCE REDUCTION INFRASTRUCTURES

- OPTION 1 : Improvement with sedimentation basin.

  One possibility to minimise the siltation in the Nam Trieu Channel (alternative 1 and 2) is to dredge a sedimentation basin in the upstream part.
  Such a sedimentation basin may provide advantages with respect to the concentration of the sediments in a limited area (silt-trap).

- OPTION 2 : Improvement with use of natural spit.

  Making use of the natural spit (alternative 3 & 4) offers another possibility to reduce maintenance dredging in the channel.
  Along the northern part of the straight section of Lach Huyen, on the west side, a shallower zone extends in the direction SSE-NNW.
  This zone might offer a natural protection against lateral inflow of sediments in the channel.
  Such protection shall be effective provided this zone is zone's top level is high enough. Therefore, an artificial supply of material (stones / sand) might be necessary.

- OPTION 3 : Improvement with training wall.

  The lateral inflow of bottom sediments might be reduced by building a training wall parallel to the axis of the Nam Trieu / Lach Huyen channel (alternative 1, 2, 3 and 4).
  The proposed structure is a submerged rubble mound breakwater to be constructed on bamboo mattresses as foundation and erosion protection layer.

Parallel to these works MOT plans to build a number of hydraulic infrastructures or execute interventions very likely to influence or interfere with the above - mentioned options :

1. the sequential removal of the Dinh Vu dam combined with the dredging of a channel in the old Cam River ;
2. the construction of 4 groynes on Bach Dang left bank ;
3. the construction of 9 groynes in the Cam River.

With respect to the management of the maintenance dredging and in compliance with the underkeel-clearance principles set forth for ship's safety the following is recommended :

1. Monthly surveys (2-3 weeks interval)on reference cross-sections (50) in the area of maximum sedimentation coupled with automatic data-processing ;

2. Programming of a monthly maintenance dredging allowing a maximum sedimentation of 0.50 m ; this will probably imply the setting-up of an improved dredging fleet or the availability of dredgers ;

3. Carry-out the maintenance dredging in box-cut over the bottom width and not on slopes ; natural collapsing and sliding will be induced and will form part of the maintenance work ;

4. Dumping the dredged material at an appropriate dumping site (great water depths or other sedimentological regime) so as to prevent recirculation of dump losses back to the channel and in order to comply to the guidelines of the London Dumping Convention for marine aquatic disposal of dredged material.

5. Execute bottom-levelling with sweep-beam to move shoals into deeper parts of the channel (maximum levelling distance : 2,000 m).

5.2. CONSTRUCTION OF A SEDIMENTATION BASIN

Sedimentation basins are constructed to concentrate the sedimentation of a channel in 1 single location, to improve the dredging productivity by increasing the in-situ soil density (consolidation) and to buffer sudden sedimentation peaks.

It has however been explained previously that sedimentation in Hai Phong bay is very closely linked to hydrodynamic events such as storms, typhoons, ... The mud sediments are stirred up and mobilised as fluid mud density flows or as suspensions. Together with the advected river sediments will these mud density flows then settle in the areas where nodal points of residual transport prevail ; these nodal points are linked with the salt wedge penetration and the position may vary between Bach Dang downstream and 5 km South of Aval depending upon :

a. the tidal coefficient ;
b. the river discharge ;
c. the wave activity.

The exact location will be difficult to define for Alternative 1 and 2 because of the great range in position of the residual nodal point. It is known that for the different industrial expansion projects in Hai Phong there is a need for landfill material. South East of Dinh Vu along the western submerged sand spit of the Bach Dang, there is quite a large body of sand. A possible synergy could be created here by the creation of a large sand extraction area which afterwards can be used as a silt trap. For Alternative 3 and 4 in the Lach Huyen, the sedimentation basin is easy to localize at the spots where the peak sedimentation occurs : on each side of the offshore bar (2 times : ± 2,500 m long).

It must be clear however that the sedimentation basin concept does not minimise the quantity of maintenance dredging but makes it easier to manage the siltation.

The preliminary design of a typical sedimentation basin (silt trap) suitable for the access-channel to Hai Phong has the following dimensions :

- length : 2000 m
- width : 300 m
- geometric capacity : ± 3 Mm^3

The opportunity of a sedimentation basin (silt trap) will greatly depend upon how MOT plans to organise the future maintenance dredging works.

5.3. REDUCTION OF LATERAL INFLOW WITH TRAINING WALLS AND REINFORCED SAND SPITS

5.3.1. General

From the mathematical simulations it appears that significant quantities of fluid mud are produced under storm activity. These fluid mud flows by density driven currents laterally into the channel(s).

This phenomenon of lateral inflow occurs mainly on the shallow parts of the Hai Phong Bay and more specially along the Nam Trieu, the subtidal flats south of Dinh Vu and to a lesser extent at the seaward reach of the Lach Huyen offshore bar.

Training walls or reinforced (heightened) sand spits bordering the access-channel could provide valuable infrastructures to reduce lateral inflow of mud or even liquified sand (spit). Training walls will not reduce sedimentation due to river sediment supply or due to upstream migration of sediments mobilised offshore under storms.

Moreover, the length of the access-channel to be protected by training walls is important in the decision making process because they will determine the infrastructure costs.

The construction methodology must be done in function of :

a. efficiency against lateral inflow
b. geotechnical soil stability ;
c. slope evolution of channel banks ;
d. costs.

5.3.2. Lay-out

Because the training wall - in combination with the natural sand spits - is essentially meant to reduce lateral inflow (by density nearbed sediment flow) it is obvious that the lay-out and the length of the structure will be different according to the alternatives considered (see also drawing 34.20.008) :

Alternative 1 :	-	approximately 2 x 6,500 m
	-	on both sides of the Nam Trieu Channel
Alternative 2 :	-	approximately 5,000 m
	-	on the East Bank of the New Nam Trieu Channel
Alternative 3 :	-	approximately 5,000 m (wet construction method) or 10,000 m (dry construction method from Ha Nam)
	-	on the West Bank of the Lach Huyen Channel
Alternative 4 :	-	approximately 5,000 m (wet construction method) or 10,000 m (dry construction method from Ha Nam)
	-	on the West Bank of the Lach Huyen Channel

5.3.3. Efficiency on sedimentation reduction

Because the major driving force for sedimentation of excavated channels in these areas are governed by moves from storms and typhoons, it is expected that the efficiciency of a training wall will be determined by its ability to interrupt the major sediment supply by density flows. The training wall will obviously <u>not</u> impede on supply by suspension, decantation, slope weakening, river and/or offshore supply.

Moreover is it to be expected that the training walls will induce a specific modified wave and current climate with particular scouring around the extremities.

It is expected that the training walls will reduce the specific density flow sedimentation with ± 30 %, reducing the overall required maintenance dredging with ± 20 to 25 %. This is deduced from the computations of the ratio between suspension and bedload transport (see figure 5.0).

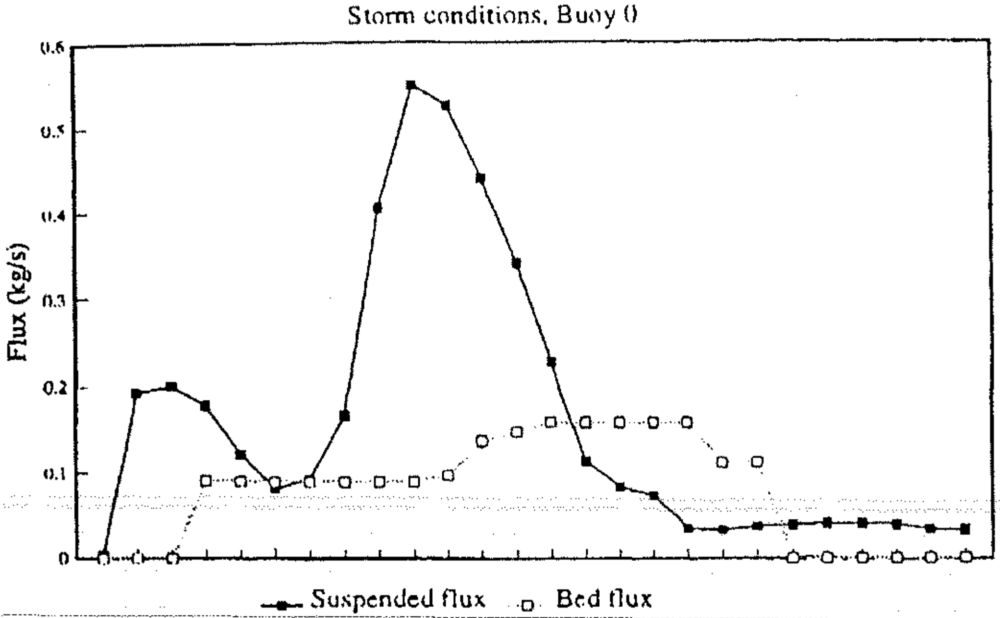


Figure 5.0.
Calculated proportion between suspended and bed-load flux

5.3.4. Construction

The training walls are proposed to be constructed as rubble-mound structures with a filter foundation (erosion protection). On top of the sandy seabed, a gravel layer is laid on top of which a quarry stone layer is dumped. The sand and stone layers are the filter foundation for the armour top layer of concrete blocks of approximately 3 tons each.

Two construction methods are envisaged for the training walls :

a) dry method where the start of the wall is initiated either at Dinh Vu or at Ha Nam Island (length : 10 km) ;
b) wet method where the subsequent layers are dumped from barges (length : 5 km).

5.3.5. Recommendation for construction planning

Because the efficiency of the training wall is not well known it is proposed to adopt the following planning :

- excavation of the stage 1 of the channel development (Urgent Channel Development) ;
- observe sedimentation in outer reaches ;
- after evaluation of real sedimentation rates decide upon construction of training wall and/or stage 2 of the channel development (Full Channel Development).

5.4. REMOVAL OF DINH VU DAM

The removal of the Dinh Vu Dam has been planned for a long period by MOT. This intervention will involve the dismantlement of ca. 100m of the 2 dams and the dredging of a canal in the course of the Old Cam River.

To evaluate the effects of these works the mathematical simulations on flow alterations and on modified sedimentation/erosion fluxes have been executed.

On figure 4.2.15.a and 4.2.15.b (see par. 4.2.) the modified ebb and flood flow after removal of the Dam are shown. It is obvious that the effect on the flood is almost insignificant compared to that one on the ebb.

On figure 5.1. the modified sedimentation/erosion fluxes after removal of the dam is shown.

When comparing the sedimentation/erosion flux after removal of the Dinh Vu Dam with the actual and deepened situation the following conclusions can be made :

1. sedimentation in Nam Trieu most landward section will increase only slightly ;
2. sedimentation in downstream part of old Cam River will increase significantly ;
3. sedimentation on Bach Dang Banks will reduce slightly.

In our opinion is the principle of restauring the old river hydraulics and sediment transport by the removal of the Dinh Vu Dam a good idea.

From the modelling results it appears however that the removal of the Dinh Vu Dam as it is planned today will have a very local influence on the sedimentation and erosion.

It is clear that the planned works regarding the Dinh Vu Dam are too small to be effective : a much larger section and wider canal linking the Cam River with the Bay should be necessary.

The demolition, dredging and bridging works are estimated by the P'sC of Hai Phong to approx. 3 MUSD. It is therefore recommended to study the opportunity of these works in more detail.

A dedicated study to assess the effects of different Cam channel lay-outs should be conducted. In this study - to be based on modelling works - the effects on sedimentation/erosion patterns must be studied for :

- channel widths : 20 m to 50 m ;
- channel depths : C.D. -3.5 m to C.D. -7.9 m ;
- channel lengths : 7 km tot 14 km.

After evaluating these effects a sound decision on the most appropriate demolition works can be taken.

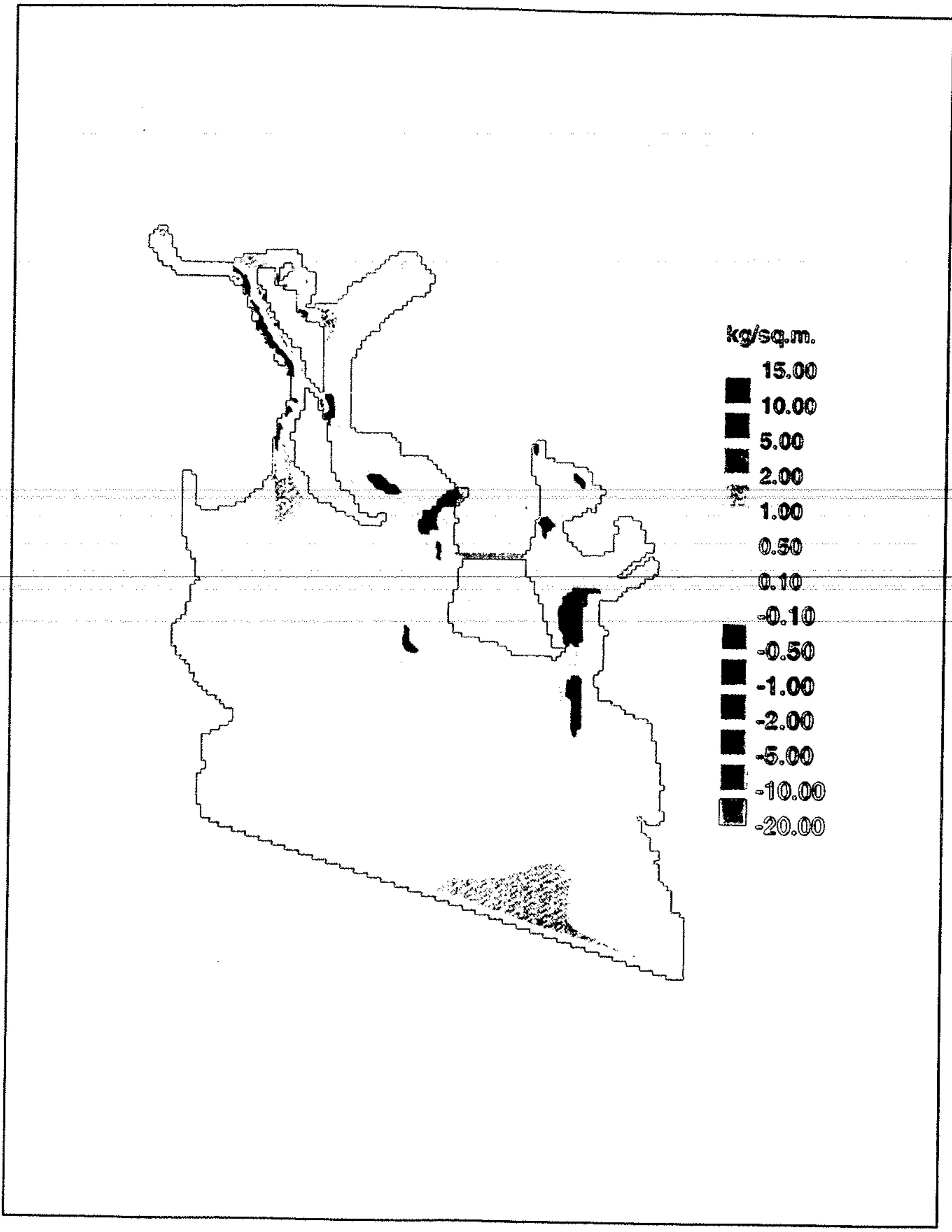


Figure 5.1.
Modified sedimentation/erosion flux after removal of Dinh Vu Dam
(dry season, spring tide)

5.5. CONSTRUCTION OF RIVER GROYNES

In Viet Nam there has been considerable experience gained the last 10 years about the construction of river groynes designed for :

a. channelize the flow and protect the river banks ;
b. induce the self-scouring of the river bed.

The effectiveness of river groynes on the sedimentation/erosion is however to be considered on a local scale. The induced modified flow field will have indeed only local effects influence distance (limited to 3 to 5 times the groyne-length). From the sedimentological simulations and investigations it appears that the dominant sedimentation mechanism is the balance of residual sediment transport on a large scale (approx. 10 km).

It is probable that the groyne -fields on Bach Dang will much affect the siltation rate in Nam Trieu but will rather help to improve the natural scour in front of Dinh Vu. Probably that local erosion will occur associated with increased (proportional) sedimentation further downstream in the Bach Dang pit. The 7 groynes in the Bach Dang are yet terminated.

The executed and planned groynes in the Cam river can be considered as effective measures to expell river sediments into the Bach Dang (or old Cam River after removal of Dinh Vu Dam ?). They will greatly help to reduce maintenance dredging after future deepening of the Cam River and in front of the berths. It is recommended however that the design of the river-groynes should be done in accordance with the channel design.

5.6. MANAGEMENT OF MAINTENANCE DREDGING

When analysing the current practice of maintenance dredging versus the sedimentation mechanism and the sediment dynamics some improvement-suggestions may readily be formulated :

a. dumping of dredged material following the present day practice is likely to induce recirculation ; therefore it is advised to dump the dredged material at least at 5 km from the channel and at least at 12 m waterdepths ; this is expected to reduce recirculation to a great extent ;

b. careful monitoring of the channel bed evolution by executing frequent bathymetric survey (one each 2-3 weeks) along ± 50 standard cross-sections ; the bathymetric survey should be linked to a computer-processing to allow rapid map-production ;

c. programming a monthly maintenance dredging (e.g. with a Trailer Suction Hopper Dredger in stand-by) in order to control the nautical depth and not to allow shoalings of more than 0.50 m ;

d. execute the dredging in boxcut on the bottom width and avoid less productive slope dredging ;

e. execute bottom-levelling with a sweep-beam to level shoals into deeper parts of the channel (maximum economic distance : 2,000 m).

To implement this option, special care must be given to :

a. a fast seaworthy bathymetric survey vessel ;
b. an office-based off-line processing and mapping system ;
c. a flexible dredging fleet (existing one, acquisition of a dedicated Trailing Suction Hopper Dredger or contracting a specialised dredging company) ;
d. an accurate dredger positioning system with plotter ;
e. a sweep-beam test.

6. MULTI - CRITERIA ANALYSIS

6.1. GENERAL

The multi-criteria analysis proposed here is preliminary because no weighing of the different criteria is applied. It is proposed to give a weighing factor after presenting this report to MOT and getting the remarks.

The channel-alternatives have been evaluated for the different criteria and a classification from 1 (least) to 4 (best) has been given based on the results of this study-report.

6.2. MULTI-CRITERIA ANALYSIS

In table 6.T.1. the different channel alternatives are given together with the criteria ; the classification is given with numbers from 1 (least) to 4 (best).

CRITERIA	1. EXISTING NAM TRIEU CHANNEL	2. NEW NAM TRIEU CHANNEL	3. LACH HUYEN THROUGH CANAL HA NAM	4. LACH HUYEN THROUGH TRAP CANAL
1. Capital dredging	4	3	1	2
2. Hydraulic and sedimentological impact	1	3	2	4
3. Maintenance dredging	1	2	3	4
4. Channel stability	1	2	3	4
5. Social impact	4	3	1	2
6. Environmental impact	2	1	3	4
7. Nautical accessibility	1	2	3	4
Sum of quotation	14	16	16	24

Table 6.T.1.

Multicriteria analysis of the different access-channel alternatives to Hai Phong

It is quite obvious from this multicriteria-analysis that Alternative 4 in Lach Huyen alignment is to be highly recommended.

Consequently, this alternative 4 will be described in the following chapter "Preliminary Design".

6.3. CONCLUSION ABOUT CHANNEL ALTERNATIVE SELECTION

The preliminary multi-criteria analysis proposed in this report is much in favour for the Lach Huyen alignment: Alternative 4.

This Alternative 4 involves an access-channel in the Lach Huyen and makes the link with Bach Dang through a (deepened and widened) Trap Canal.

It must be said that - apart from the advantages yet formulated during the multi-criteria analysis - this Alternative 4 also offers the advantage not to create much less interference between the capital dredging and the ongoing traffic.

According to the recommendations of TEDI the following criteria classified from high to low importance - have to be adopted :

1. Capital investment (weight : 5)
2. Maintenance dredging (weight : 4)
3. Safety of ship's navigation (weight : 3)
4. Social/environmental impact (weight : 2)
5. Possibilities for further development (weight 1)

With these weighing factors another multi-criterium analysis can be done (see table 6.T.2. This analysis leads to the same conclusions as the one mentioned in par. 6.2, i.e. that Alternative 4 is the best appropriated Access-Channel Route to Hai Phong.

Criteria	Alternative 1 : Existing Nam Trieu Channel	Alternative 2 : New Nam Trieu Channel	Alternative 3 : Lach Huyen + Ha Nam Canal	Alternative 4 Lach Huyen + Trap Canal
1. Capital Investment	20	15	5	10
2. Maintenance Dredging	8	4	12	16
3. Safety of Ship's Navigation	3	6	9	12
4. Social/Environmental Impact	4	4	4	6
5. Possibilities for further development	4	3	1	2
Sum of quotation	39	32	31	46

Table 6.T.2.
Weighted multi criteria analysis

7. PRELIMINARY DESIGN

7.1. GENERAL

Alternative 4 i.e. New Alignment in Lach Huyen through Trap Canal has been proposed as the best appropriated Access Channel route to the Port of Hai Phong.

This alternative 4 will now be presented with specific data regarding the preliminary design. This preliminary design is to be reviewed with the comments of MOT, the 1995 geotechnical survey data and other design data (satellite imagery, nautical expertise, ...).

A part from the basic design characteristics of the channel two other aspects will also be reviewed :

* the dumping of the capital and maintenance dredged materials ;
* the opportunity of a training wall in the Lach Huyen offshore bar area (to reduce fluid mud inflow).

7.2. CHANNEL DESIGN

The characteristics of the proposed lay-out are given in table 7.T.1. for the first stage and in table 7.T.2. for the second stage.

Design profile	Lach Huyen (Section I)	Trap Canal (Section II)	Bach Dang (Section III)	**Cam River (Section IV)**
- KM	39.80 - 20.38	20.38 - 16.50	16.50 - 8.60	**8.60 - 0**
- nautical depth	CD - 7.20 m	CD - 7.20 m	CD - 7.20 m	**CD - 7.20 m**
- channel dredged level	CD - 7.70 m	CD - 7.50 m	CD - 7.50 m	**CD - 7.50 m**
- bottom width	100 m at CD - 7.70 m	80 m at CD - 7.50 m	80 m at CD - 7.50 m	**80 m at CD - 7.50 m**
- slope	1/15	1/5	1/7	**1/7**

Table 7.T.1.
Channel design for alternative 4
Stage 1 : Urgent Channel Rehabilitation Plan

Design profile	Lach Huyen (Section I)	Trap Canal (Section II)	Bach Dang (Section III)	**Cam River (Section IV)**
- KM	39.90 - 20.38	20.38 - 16.50	16.50 - 8.60	**8.60 - 0**
- nautical depth	CD - 8.50 m	CD - 8.05 m	CD - 7.85 m	**CD - 7.85 m**
- channel dredged level	CD - 9.00 m	CD - 8.35 m	CD - 8.15 m	**CD - 8.15 m**
- bottom width	100 m at CD - 9.00 m	80 m at CD - 8.35 m	80 m at CD - 8.15 m	**80 m at CD - 8.15 m**
- slope	1/15	1/5	1/7	**1/7**

Table 7.T.2.
Channel design for alternative 4
Stage 2 : Channel Development Plan

N.B. : The slopes in the Trap Canal are defined on 1:5

On figure 7.1. a preliminary design of a cross-section in Trap Canal is presented according to the requirements of TEDI. The slopes of 1:5 may experience some instability due to wave and screw-actions generated by passing ships. In this case it is accepted that appropriate bank-protections (matrasses or gravel dumps) should be executed.

7.3. CAPITAL DREDGING

The capital dredging volumes according to the route of Alternative 4 described on the drawings 34.20.115 (Maps : Dinh Vu to Hai Phong) 34.20.116 (Map 2 : Ha Nam to Dinh Vu) and 34.20.117 (Map 3 : Lach Huyen) and to the Digital Terrain Model of the 1995 Bathymetric Survey is described in table 7.T.3.

Section	Description	Stage 1 Urgent Channel rehabilitation plan		Stage 2 Channel Development Plan	
		Geometrical volume	Material	Geometrical volume	Material
I	Lach Huyen offshore	7,000,000 m³	Fine sand + mud	10,600,000 m³	Fine sand + mud
II	Trap Canal	3,940,000 m³	Mud	4,570,000 m³	Mud
III	Bach Dang Upstream	1,300,000 m³	Mud	1,610,000 m³	Mud
IV	Cam River + Dinh Vu Canal	1,590,000 m³	Mud	2,160,000 m³	Mud
	Total	13,830,000 m³		18,940,000 m³	

Table 7.T.3.
Volumes of capital dredging for Alternative 4
(Stage 1 + 2)

The capital dredging itself will probably induce slightly bigger quantities due to immediate slope collapse. Moreover, the hydraulic dredging of this material will induce a dilution, probably with a factor 2 to 2.5.

The capital dredging itself is proposed to be executed in a sequence as described in Table 7.T.4.

Section	Description	Capital Dredging Method	**Production m³ in situ/day**
I	Lach Huyen	1) Cutter Suction Dredger with sidecasting (initial trench) 2) Trailer Suction Hopper Dredgers (2-3 ; 3000 - 5000 m³ hopper)	**30,000-40,000** **10,000-15,000**
II	Trap Canal	Cutter Suction Dredger with 8 km discharge pipe (diam. 600 mm)	**30,000**
III	Bach Dang	Cutter Suction Dredger or Bucket Wheel Dredger (2000 HP) + barges	**30,000** **15,000**
IV	Cam River + Dinh Vu	Cutter Suction Dredger or Bucket Wheel Dredger (2000 HP) + barges	**30,000** **15,000**

Table 7.T.4.
Capital Dredging Executing Methods

7.4. AIDS TO NAVIGATION

A new marker buoy system (with appropriate lightning for night navigation !) has to be installed along the offshore part of the new alignment of the proposed channel in Lach Huyen.
Fixed land based markers and lights can be installed along both banks of the Trap Canal.
In Bach Dang must the leading lights be realigned for the new channel alignment.
In Cam river can the existing buoyage system be maintained.

7.5. DUMPING

For the excavation of Lach Huyen offshore bar (submerged spit) it is expected to dig into a 1.5 to 3 m fine to medium sand deposit.

The capacity of the sand layer will probably not exceed 2-3 Mm^3 of sand. However, it is expected that this sand is well suited for landfill or beach replenishment.

In the Trap Canal itself, the soil layers consist essentially of soft dark grey sandy silt (2.5 m), and an underlaying soft clay with high plasticity.

For disposal and dumping of dredged material see paragraph 3.4. and drawing no 34.20.114. The vast majority of the capital dredging volumes are expected to be dumped on the aquatic dump site at such a place that recirculation is minimised.

7.6. TRAINING WALLS

7.6.1. Layout

The lateral inflow of bottom sediments in the channel might be reduced by building a training wall parallel to the axis of the channel on the West Bank of the Lach Huyen Channel with a length of approximately 5,000 m (wet construction method) or 10,000 m (dry construction method) from Ha Nam (see figure 7.2).

The proposed retaining structure is a rubble mound dike to be constructed on a gravel layer as foundation and erosion protection layer.

The cost for this training wall is estimated at 40,000,000 USD.

7.6.2. Cross section

A cross section of the proposed structure is presented on figure 7.3.

The training wall is proposed to be constructed as a rubble-mound structure with a filter foundation (erosion protection). On top of the sandy seabed, a gravel layer is laid on top of which a (quarry) stone layer is dumped. The sand and stone layers are the filter foundation for the armour top layer of concrete blocks.

The unit weight of the blocks can be calculated based on the local hydrodynamic conditions. The first estimate leads to a unit weight of approximately 3 tons per block.

7.6.3. Construction of the rubble-mound dike

Two construction methods are envisaged for the training walls :

a) dry method where the start of the wall is initiated at Ha Nam Island ;
b) wet method where the subsequent layers are dumped from barges.

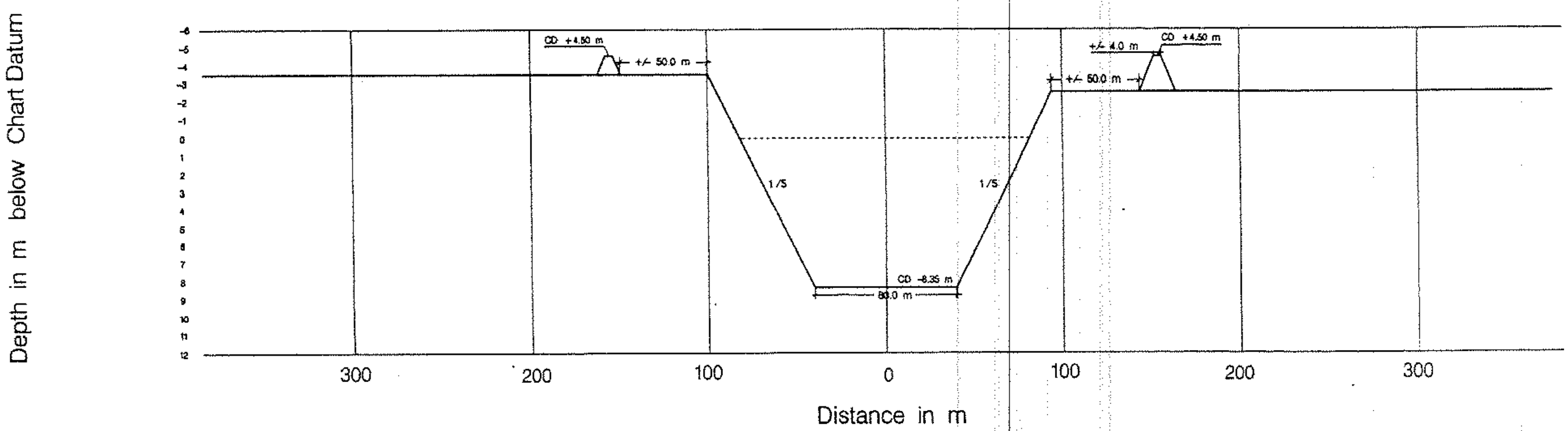
To achieve an immediate scour protection of the sea bottom, a soil protection with gravel is proposed. Also, during the building of the dam-core, the surrounding area must be protected against erosion resulting from turbulence induced by the construction front.

For the dry construction method the works are to be initiated from land by :

- first, the gravel layer ;
- secondly, the (quarry) stone layer ;
- finally, the concrete blocks together with an access road.

For the wet construction method the gravel layer can be dumped by split-barges in the trace-outline of the breakwater to a thickness of 0.50 m. Once the gravel layer is in place, pontoons with crawler cranes can dump a 1.00 m thick layer of stones. Also the placing of the blocks can be achieved afterwards by pontoons with cranes.


Nam Trieu
Ha Nam



topographic data : 1990

VERT. SCALE 0 – 5 m

HORIZ. SCALE 0 – 100 m

VIETNAM ACCESS CHANNEL TO HAI PHONG

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CROSS SECTION OF TRAP CANAL

DRA.: JRR	APP.: BLE	VA-I135/7	Fig 7.1

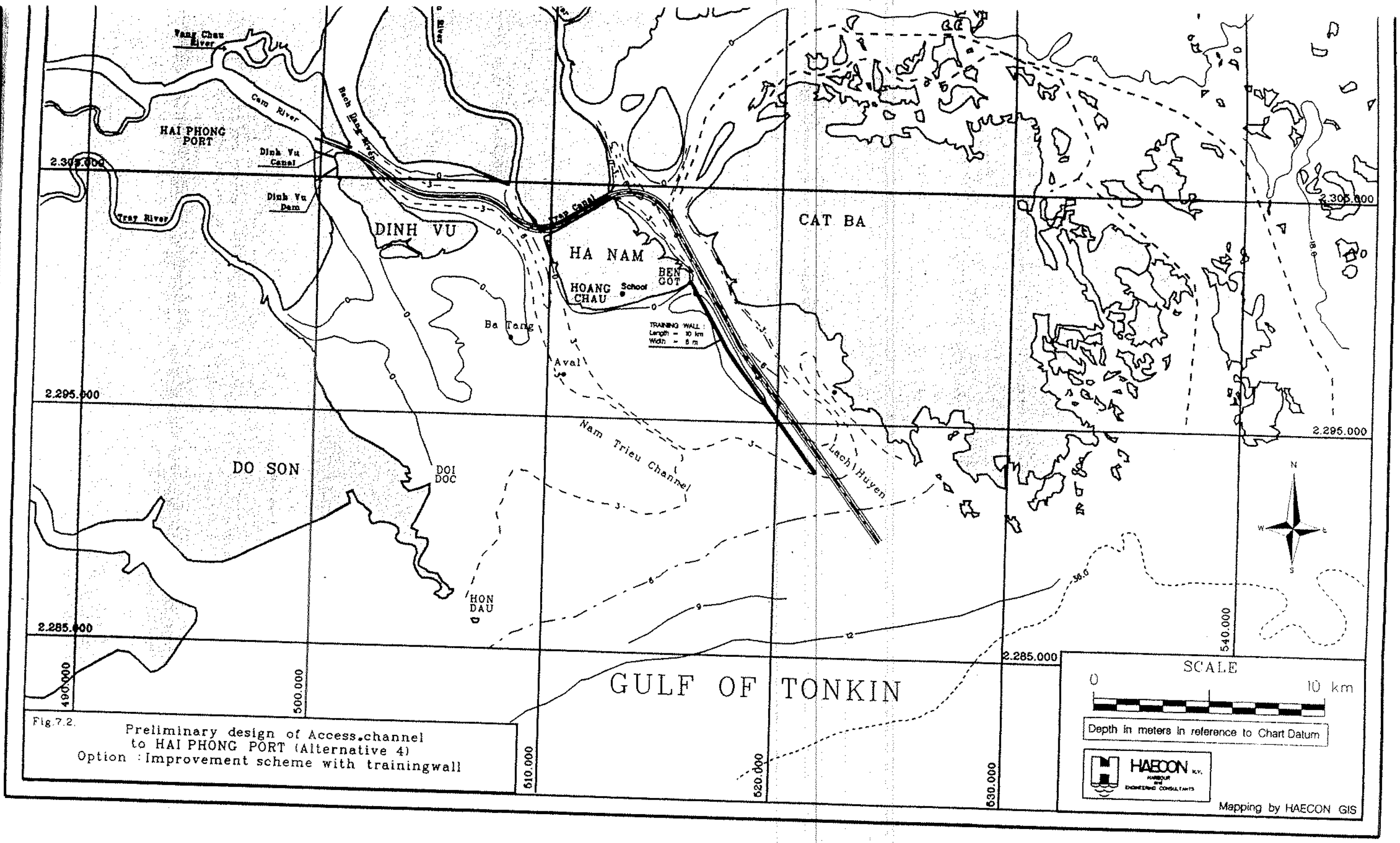
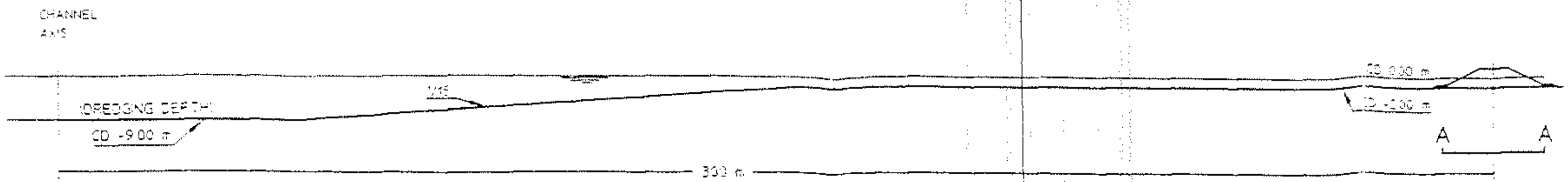
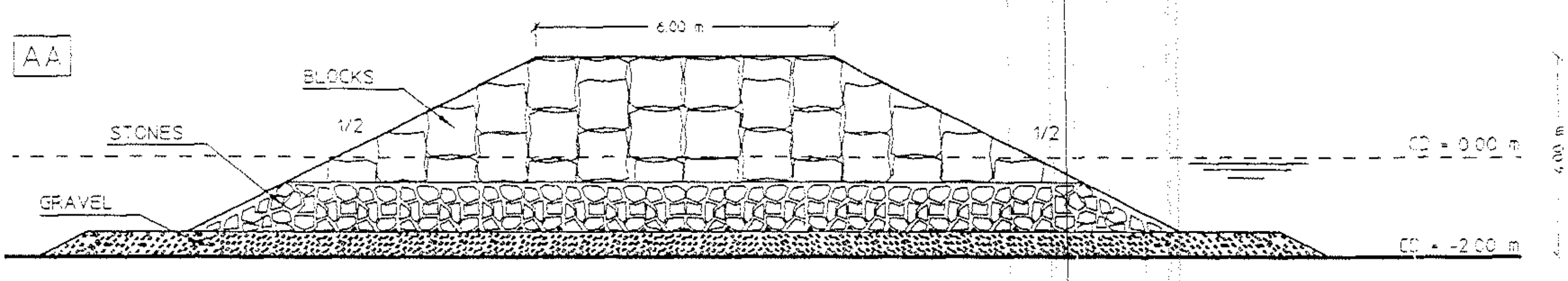


Fig.7.2. Preliminary design of Access channel to HAI PHONG PORT (Alternative 4)
Option : Improvement scheme with trainingwall



SCALE 1/1000



SCALE 1/100

A	20/12/95	New design of training wall	
INDICE	DATE	MODIFICATIONS-WIJZIGINGEN-MODIFICATIONS	CONTROL

VIETNAM ACCESS CHANNEL TO HAI PHONG

MINISTERIE VAN BUITENLANDSE ZAKEN,
BUITENLANDSE HANDEL
EN ONTWIKKELINGSSAMENWERKING

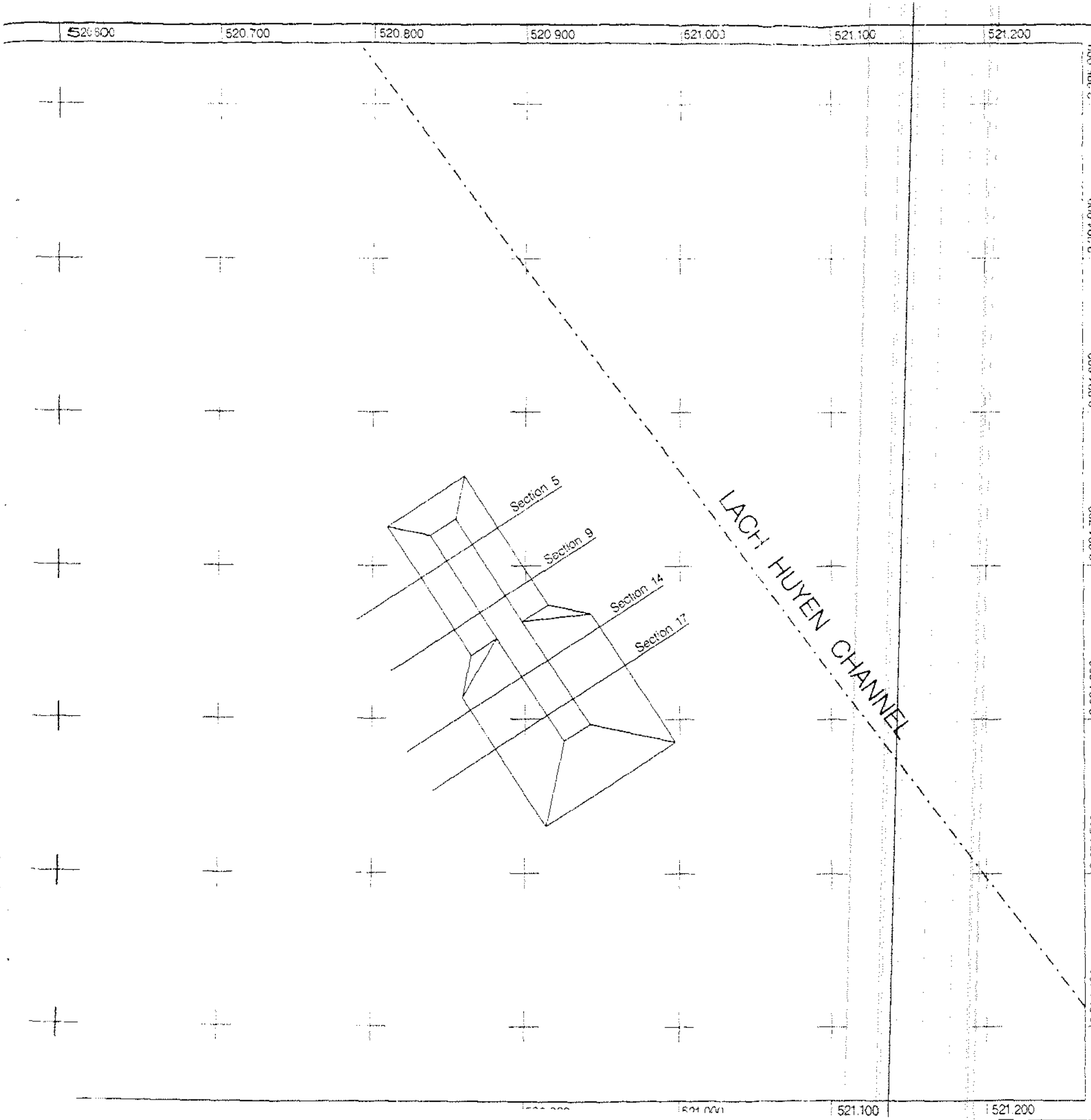
Algemeen Bestuur
van de Ontwikkelingssamenwerking

FILE
DOSSIER
Nr No
VAH.1351

HAECON
HARBOUR
and
ENGINEERING CONSULTANTS

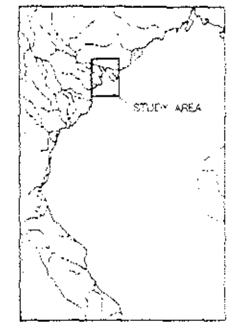
TRAINING WALL :
RUBBLE-MOUND DIKE

Drawn / Getekend / Dessine: JRP	Checked / Nagezien / Controle: BME	Approved / Goedgekeurd / Approuve
Date / Datum / Date: 30/08/95	Scale / Schaal / Echelle: 1/1000, 1/100	Figure / Figuur nr / Figure: 7.3 A



LEGEND

- Bathymetric lines (C.D. = LLW /depth in meters) Survey 1995 (ref TEDI)
- Bathymetric values (C.D = LLW /depth in meters) Survey 1995 (ref TEDI)
- Lighthouse
- Navigation Route
- Local coordinate grid (Gauss projection) Spheroid Krazovski 1940



OVERVIEW MAP OF NORTH VIETNAM

SCALE

0 100 m

VIETNAM ACCESS CHANNEL TO HAIPHONG

MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION

Belgian administration for development cooperation

File Dossier Nr. No. VAH 1351

HAECON N.V. HARBOUR and ENGINEERING CONSULTANTS

OVERVIEW MAP
PILOT TRENCH CROSS SECTIONS

Drawn Getekend Dessiné: JRH	Checked Nagezien Contrôlé: BME	Approved Goedgekeurd Approuvé: BME
Date Datum Date: 13 - 03 - 1996	Scale Schaal Echelle: 1/2 500	Drawing Tekening nr. Plan no: 34.20.003

8. CONCLUSIONS

8.1. After having screened different selection criteria for the 4 channel alternatives it appears that the New Alignment in Lach Huyen with link through Trap canal (Alternative 4) is the best appropriated access-channel solution for Hai Phong Port.

Selection criteria used for this screening are related to :

- volume (and costs) of capital dredging ;
- hydraulic and sedimentological impact of the works ;
- the required maintenance dredging ;
- the horizontal, vertical and slope stability of the channel ;
- the social impact ;
- the environmental impact ;
- the nautical accessibility.

8.2. The design of the access-channel to Hai Phong leads to the following scheme (full channel development) :

- bottom width : 100 m (outer reach) ; 80 m (inner reach) ;
- nautical depth : C.D. -8.50 m to C.D. -7.85 ;
- gross keel-clearance : 1.70 m to 1.05 m ;
- tidal window : C.D. +2.50 m ;
- nautical accessibility : 65 %

8.3. Because of economic contraints, the Vietnamese Authorities want to consider the opportunity of a spreaded investment by a staged channel development.

Stage 1 : Urgent Channel Development Plan :

- Nautical depths : C.D. - 7.20 m
- Gross keel-clearance : 1.20 m
- Tidal window : C.D. + 2.50 m

- Nautical Accessibility : max. 15 % (with additional restrictions during rough weather and particular caution with deep draft vessels).

Stage 1 : Full Channel Development Plan :

- Nautical depths : C.D. - 8.50 m to C.D. - 7.85 m
- Gross keel-clearance : 1.70 m to 1.05 m
- Tidal window : C.D. + 1.70 m
- Nautical Accessibility : 65 %

Regarding the choice of the channel development options - Stage 1 : Urgent Channel Rehabilitation and Stage 2 : Full Channel Development - will HAECON recommend to decide at once for the Full Channel Development because :

a) the capital dredging investment is only 28 % more ;
b) the time-accessibility of the port increases with 50 % for the design ship ;
c) the maïntenance dredging is not expected to be significantly different.

8.4. A major decision-taking criterium in this selection has been the estimated annual volume of maintenance dredging to keep the channel at its design depth and width. This estimation of maintenance dredging is based on 3D-mathematical sedimentological simulations of the channel infill.

From these computation it appears that for the Channel Development Plan at a nautical bottom of C.D. - 8.5 m, the expected maintenance dredging will involve approximately 4.0 Mtons of dry solids each year (both Outer Sea Channel, Trap Canal, Bach Dang and Cam River). This maintenance dredging is expected to decrease significantly over the years because :

a) the limited stock of sandy material ;
b) the obtention of an equilibrium slope in the mud + sand layer.

8.5. The capital dredging for Alternative 4 are the following :

a. Urgent Rehabilitation Plan : 13,9 Mm^3 (in situ) ;
b. Channel Development Plan : 18,0 Mm^3 (in situ) ;

8.6. From the possible countermeasures to reduce the maintenance dredging, a 5 km training wall at the offshore Lach Huyen bar (West side) is considered to be the most likely possibility.

This training is meant to prevent lateral inflow of density sediment flows ; expected reduction on maintenance dredging is in order of magnitude of 25 % (catchment of bed density flow).
The opportunity for construction of the training wall will be assessed after the implementation of the Stage I Urgent Channel Rehabilitation Plan.
The removal of the Dinh Vu Dam is in principle a good intervention ; however it appears that the demolition works as they are planned today have a too limited impact. It is recommended to study this in more detail. The groyne-system in the Cam river is appropriate to increase natural scour and sediment expelling. Because of tidal regime in Bach Dang, a decreased efficiency of the groynes w.r.t. sediment expelling is to be expected.

8.7. The sedimentation-mechanism prevailing in this area is closely linked to hydrodynamic events - storms or typhoons-stirring up large quantities of mud from the seabed. These sediments are then redistributed and sedimented together with the river advected sediment load in the areas of nodal points of residual transport, (determined by salt wedge penetration, by tidal coefficients, by waves and by river discharge). The mud is transported as a fluid mud bed layer and as a suspension.
Knowing this complex interaction between hydrodynamic forces, it is unlikely that relative small infrastructures will be able to modify the equilibrium governing this sedimentation.

8.8. It is strongly advised to select a nautical depth for the channel to Hai Phong Port in such a way that - at minimum - a 65 % time-accessibility for the design ship (10,000 DWT) is given. This is especially important for container traffic.

Therefore a nautical bottom of C.D. - 8.50 m is proposed for 10,000 DWT-ships in the full development stage.

There are 2 arguments to select C.D. - 8.50 m as the minimum channel nautical bottom :

- shallower depths will - quite surprisingly but explainable by decreased natural scouring - induce more siltation ;
- this value assures a 65 % time accessibility to the port : each day a design ship can call to Hai Phong Port.

9. RECOMMENDATIONS

9.1. If the staged development of the channel is chosen anyway the choice should be balanced in an economic way against investment and port's revenues. This should be adressed in a dedicated study in addition to this Channel Study and the Port Rehabilitation Study.

9.2. The aids to navigation should be improved. Nowadays, the numbering of the channel buoys is regularly modified which is very confusing for navigation purposes. Moreover an appropriate lightning of the channel buoys should get absolute priority for both safety and improvement during night navigation ; this lightning will also improve the overall nautical accessibility and reduce the waiting times.

9.3. A geophysical soil investigation should be executed prior to any capital dredging works to assess :

- presence of subsoil rock outcrops ;
- buried and surface wrecks ;
- mines

9.4. A detailed Environmental Impact Assessment (EIA) should be conducted on the selected channel. More specially it is proposed to study mangrove - landfilling (thin - layer spreading) with a pilot-experiment.
The vast majority of dredgings is proposed to be dispersed by aquatic dumping at a selected dumping site.
In order to minimise the environmental impact the "Guidelines for the Management of Dredged Material" of the Oslo Commission (new name OSPAR COM1993) should be used as a basis for the definition of the Best Environmental Practice (BEP).
The OSCOM'Guidelines describe the following items to be addressed in the choice with the philosophy of minimising the environmental impacts :

1. Optimisation of the disposal quantities ;
2. Improve the sediment quality ;
3. Minimise the effects caused by the disposal of the dredged material.

9.5. The planned groyne-system (in Cam and Bach Dang) should be designed in accordance with the channel design and in accordance with future port infrastructures. Especially the stability and the impact on local turbulences and scouring should be investigated.

9.6. The demolition works of the Dinh vu Dam should be studied in more detail in order to optimize their beneficial effects.

9.7. It is highly recommended to improve the maintenance dredging management in the Access-Channel to Hai Phong :

- execute regular soundings of the access-channel e.g. each 2 or 3 weeks (in a set of 50 cross-sections) ;
- implement a rapid off-line bathymetric survey data processing to make the bathymetric map readily available ;
- maintain one or two Trailer Suction Hopper Dredger(s) (with accurate positioning system) in stand-by operation in order to execute maintenance dredging as soon as more than 0.50 m shallowing occurs ; a total hopper capacity of 5,600 m^3 is considered appropriate to maintain the new channel at the required depth and width ;
- execute the dumpings of dredged material far away from the dredging site and at great waterdepths in order to avoid recirculation ;
- investigate feasibility of bottom-levelling by sweep-beam method.

9.8. It is clear that sedimentation has increased in Hai Phong bay over the last 10-20 years. There is a great likelihood that the increased supply of sediments is closely linked to the increased soil erosion in the Red River Basin due to deforestation.
It is strongly advised to study more in detail how bank protection, soil erosion countermeasures, reafforestation and channelization of sediment loaded river waters could be implemented in order to manage the maintenance of the access-channel to Hai Phong Port in an integrated way.

9.9. Seeking for synergy between the dredging for this project and the needs of landfill for other initiatives in Hai Phong Port Development Areas could improve the feasibility to a great extent.

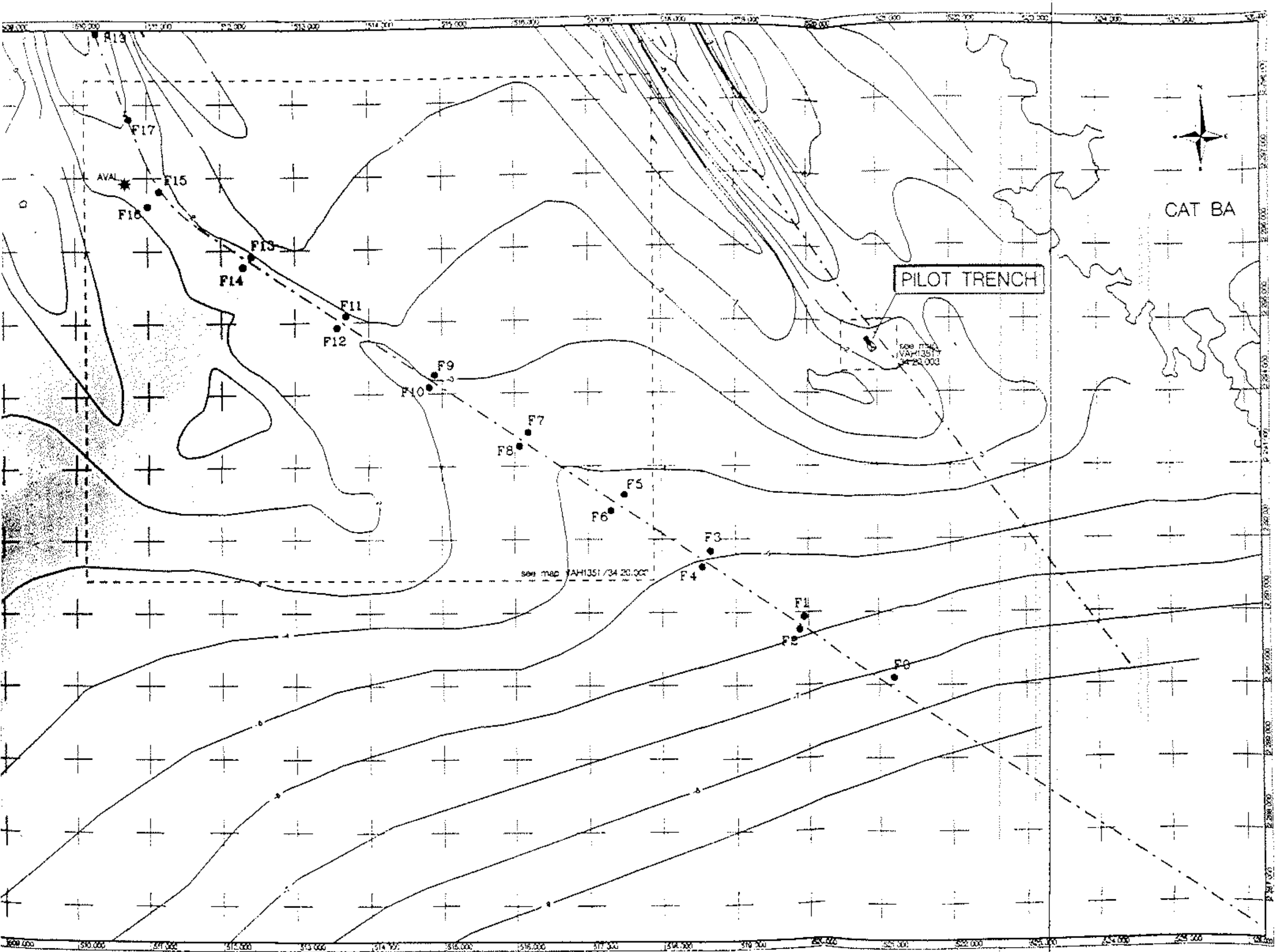
9.10. The monitoring results of the pilot channel in Lach Huyen seem to indicate that sedimentation rates here are less than in Nam Trieu and related to more sandy material. It is recommended to continue the planned monitoring campaign up till complete infill or up till end of September 1996.

9.11. A dedicated pilot training on simulator is to be recommended in order to train on the Trap Canal crossing.

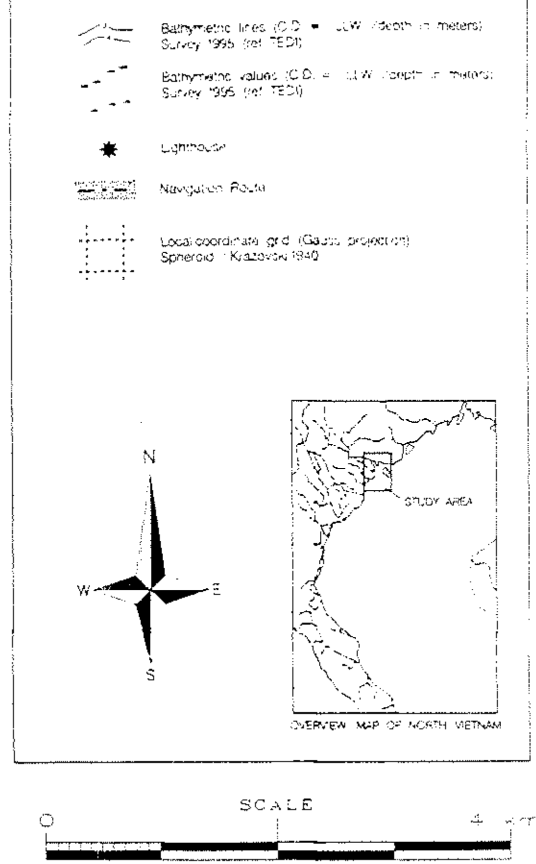
9.12. Finally, the conclusions and recommendations formulated in this first draft of the Preliminary Design of the Access-Channel to Hai Phong Port should be checked against the traffic forecasts and port development studies carried out for the Rehabilitation Plan of Hai Phong Port. Moreover, it is highly recommended to join to these 2 studies an overlapping port economy study in order to define also the economic optimum for Hai Phong Port regarding design ship, traffic, channel width and depth for the medium and long-term.

9.13. Compensation for the raisers of aquacultural products will be needed in the areas where upland disposal of dredged material (capital + maintenance) will be executed. The proposed areas are the left bank of the Cam River, the left bank of the Bach Dang River and the lowlands of Ha Nam (both banks of Trap Canal). In any case a disposal permit must be obtained from the Municipal People's Committee of Hai Phong.

N.V. HAECON
30-08-96



LEGEND



VIETNAM ACCESS CHANNEL TO HAI PHONG

MINISTRY OF FOREIGN AFFAIRS FOREIGN TRADE AND DEVELOPMENT COOPERATION — Belgian administration for development cooperation	File Dossier Nr. No — VAH 1351	HAECON N.V. HARBOUR and ENGINEERING CONSULTANTS

OVERVIEW MAP
LOCATION OF PILOT TRENCH

Drawn Getekend Dessiné JRR	Checked Nagezien Contrôle BME	Approved Goedgekeurd Approuvé BME
Date Datum Date 08 - 03 - 1996	Scale Schaal Echelle 1/60.000	Drawing Tekening nr. Plan no 34.20.001

ANNEXE III

SEDIMENT TREND ANALYSIS OF SEABED SAMPLES

Annexe III : Sediment Trend Analysis of Seabed Samples

A.III.1. METHODOLOGY

The principle of Sediment Trend Analysis (STA) is based on the determination of typical sedimentological characteristics (granulometry, mineralogy, ...) of deposited sediments (in rivers, sea, ...) and the assessment of statistical trends in space and/or time within these sedimentological characteristics.

The most common Sediment Trend Analysis technique discerns the net transport patterns from statistically determined relative changes of grain-size distributions of bottom samples, sampled according to a regular sampling grid. Existing data taken according to irregular sampling grids can also be processed and thus be revaluated.

The grain-size distribution of a sediment can be described by the determination of the contribution of the different grain-size fractions (sieve-fractions) or by characteristic grain-size distribution parameters such as the median, the mean grain-size, the sorting, fraction content, ...

The method of analysis is based on the spatial variations of some statistical parameters describing grain-size distributions :

1. the mean grain-size ;
2. the sorting (or standard deviation) ;
3. the skewness of the distribution ;
4. the relevant grain-size fraction percentages.

Moreover, the spatial variations of the different grain-size fractions are studied. The results are used as a complement to the interpretation of the results of the sediment trend analysis.

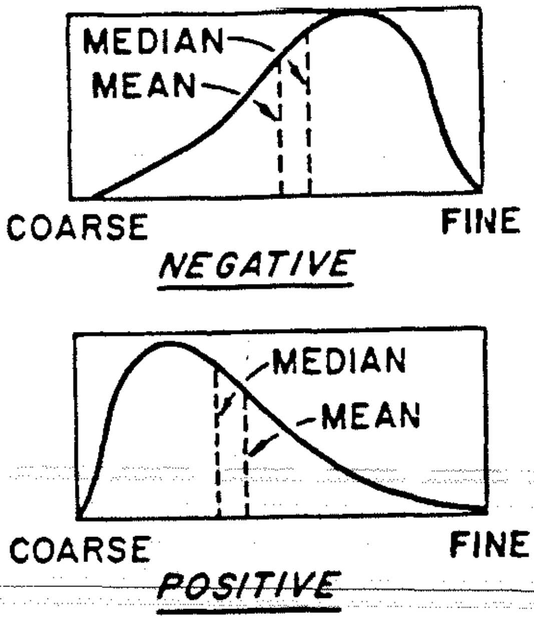


Figure A.III.1.
Graphs which illustrate negatively and positively skewed distributions. Phi-value increases and grain size decreases to the right

A.III.2. BASIC PRINCIPLES

The grain-size distribution of a sediment sample reflects the distribution of the source sediment and the hydrodynamic conditions that have acted upon it :

- a lag sediment will be coarser and more positively skewed than the source sediment ;
- successive deposits will be finer and more negatively skewed in case of decreasing energy in the transport direction, or coarser and more positively skewed in case of increasing energy in the transport direction ;
- sediments will almost always be better sorted in the direction of transport.

The used sediment trend analysis algorithm determines on any sampling station the character of the residual transport (direction, erosion or sedimentation). The numerical and graphical representation of the results can be interpreted as follows :

* Number of samples :	Total number of processed sediment samples ;
* Number of pairs :	Total number of pairs of samples analysed for transport ;
* Weighing distance :	Factor taking the distance between the samples in a pair into account (in order to weigh the importance of the calculated trend) ;
* Number of FB^- cases :	Number of trends which indicate sediment fining, better sorting and more negatively skewing : green colour ; sedimentation trend ;
* Number of FB^+ cases :	Number of trends which indicate sediment fining, better sorting and more positively skewing : blue colour ; sedimentation trend ;
* Number of CB^+ cases :	Number of trends which indicate sediment coarsening, better sorting and more positively skewing : red colour ; erosional trend ;
* Number of CB^- cases :	Number of trends which indicate sediment coarsing, better sorting and more negatively skewing : orange colour ; erosional trend.

The FB^- and FB^+ cases also indicate sedimentation, the CB^+ and CB^- cases indicate erosion.
The STA method is applied on the total sample, on the sand fraction and on the mud fraction, separately.

A.III.3. RESULTS OF SEDIMENT TREND ANALYSIS (STA)

As described before, HAECON's approach in STA on sedimentological samples is two-fold :
step 1 : STA on grain-size parameters
step 2 : STA on grain-size fractions

A.III.3.1. Sediment trend analysis on grain-size parameters

A.III.3.1.1. Computation results

The STA results can be summarised as follows :

a. Total sample (2000 μm → < 2 μm)

Number of samples :	85
Number of pairs :	7225
Weighing distance :	1500 m

Number of FB^- cases :	2088 (29 %)
Number of FB^+ cases :	526 (7,5 %)
Number of CB^+ cases :	2676 (37,5 %)
Number of CB^- cases :	1850 (26 %)

The results of the sediment trend analysis on the total sample are shown on figure 09.70.001.

b. Sand fraction (2000 μm → 63 μm)

Number of samples :	69
Number of pairs :	4761
Weighing distance :	1500 m

Number of FB^- cases :	2022 (43 %)
Number of FB^+ cases :	836 (18 %)
Number of CB^+ cases :	1654 (35 %)
Number of CB^- cases :	180 (4 %)

The results of the sediment trend analysis on the sand fraction are shown on figure 09.70.002.

c. Mud fraction (63 μm → < 2 μm)

Number of samples :	72
Number of pairs :	5184
Weighing distance :	1500 m

Number of FB^- cases :	2130 (42 %)
Number of FB^+ cases :	332 (6,5 %)
Number of CB^+ cases :	1832 (30 %)
Number of CB^- cases :	788 (15,5 %)

The results of the sediment trend analysis on the mud fraction are shown on figure 09.70.003.

A.III.3.1.2. Interpretation

The discrepancy of the results of the different fractions is mainly caused by the bimodal character of the samples : a fine sand population and a mud population. Therefore the results of the total sample analyses will not get a major consideration in this study.

The following interpretation can be given to the STA-results :

a. 2 trends - FB^- (± 40 %) and CB^+ (± 30 %) - clearly dominate the area ;
b. for both types of deposits - sand and mud erosion and sedimentation are more or less in balance ; this means that the sedimentologic regime could be essentially a (re)distribution of sediments under the hydrodynamic actions ;
c. in the Bay and land-inward the isobath of C.D. - 5 m the prevailing residual sediment transport directions is from ENE to WSW ; all happens as if sediments are transported from E to W without a major influence of the tidal flows in Nam Trieu or even Lach Huyen ;
d. offshore the isobath of C.D. - 5 m residual transports are more N-S directed with the mud fraction being transported from the Gulf of Tonkin in upstream direction and the sand fraction being expelled to the Gulf of Tonkin ;
e. in Bach Dang is mud essentially migrating in upstream direction, while the sand fraction is transported downstream (to approx. Ba Tang/Aval level).

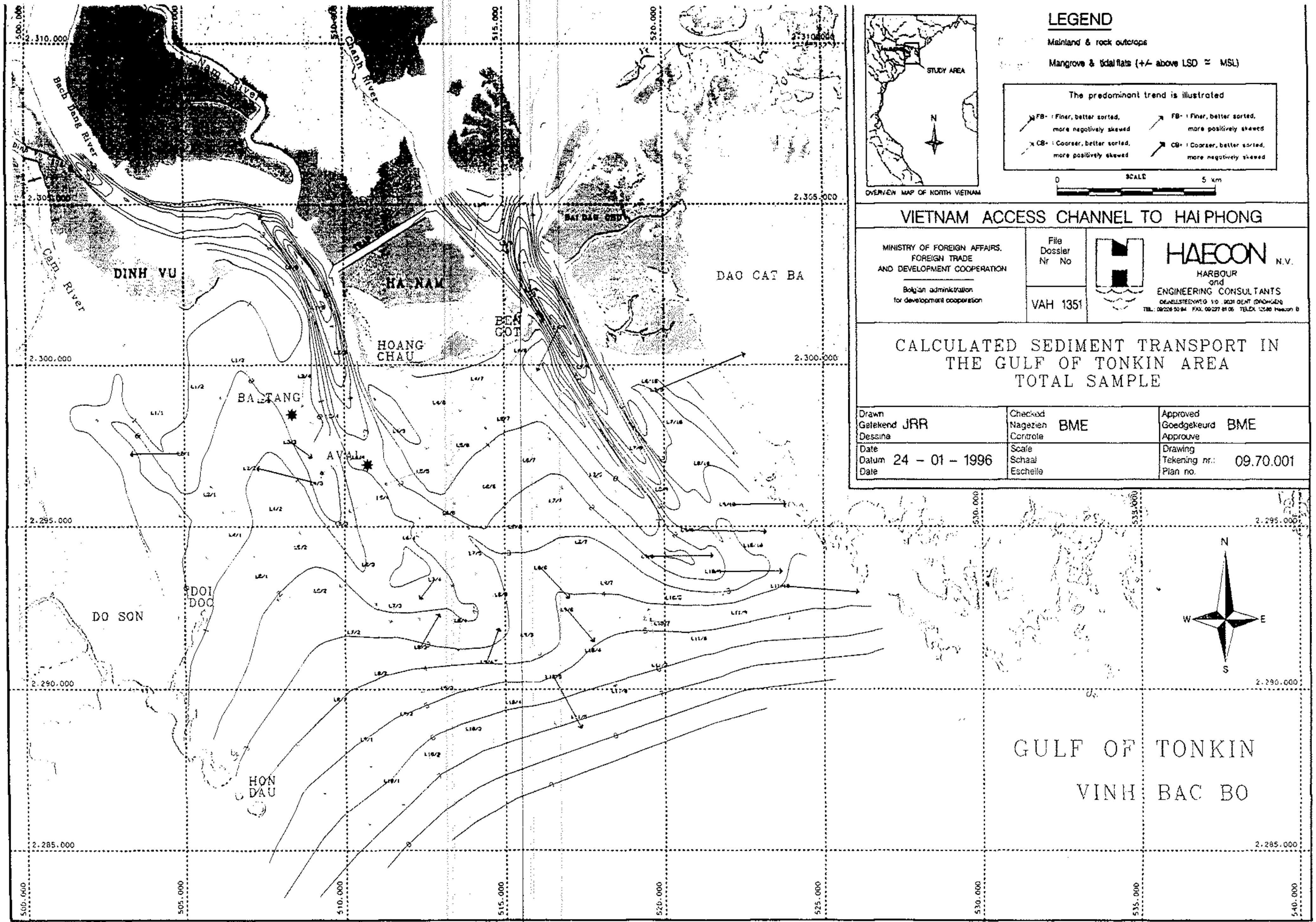
The difference between the sediment transport vectors and the residual water discharge vectors is probably to be explained by an important influence of wave action on the sediment transport. The existing wave climate, enhanced by the strong action of typhoons cause a shift of the sediment transport vectors to the WSW.

A.III.3.2. Sediment trend analysis on grain-size fractions

A.III.3.2.1. Computational results

The data used by the fraction analysis are calculated during processing of the granulometrical analysis results. Using the weight percentages for each grain-size interval (fraction) distribution maps are drawn.

The results of the fraction analysis are visualised by, for each fraction and the whole dataset, normalising the calculated values and expressing them in times the standard deviation w.r.t. the mean. Red values depict values lower than the mean, green values depict values higher than the mean.



VIETNAM ACCESS CHANNEL TO HAI PHONG

MINISTRY OF FOREIGN AFFAIRS,
FOREIGN TRADE
AND DEVELOPMENT COOPERATION

Belgian administration
for development cooperation

File
Dossier
Nr No

VAH 1351

HAECON N.V.
HARBOUR
and
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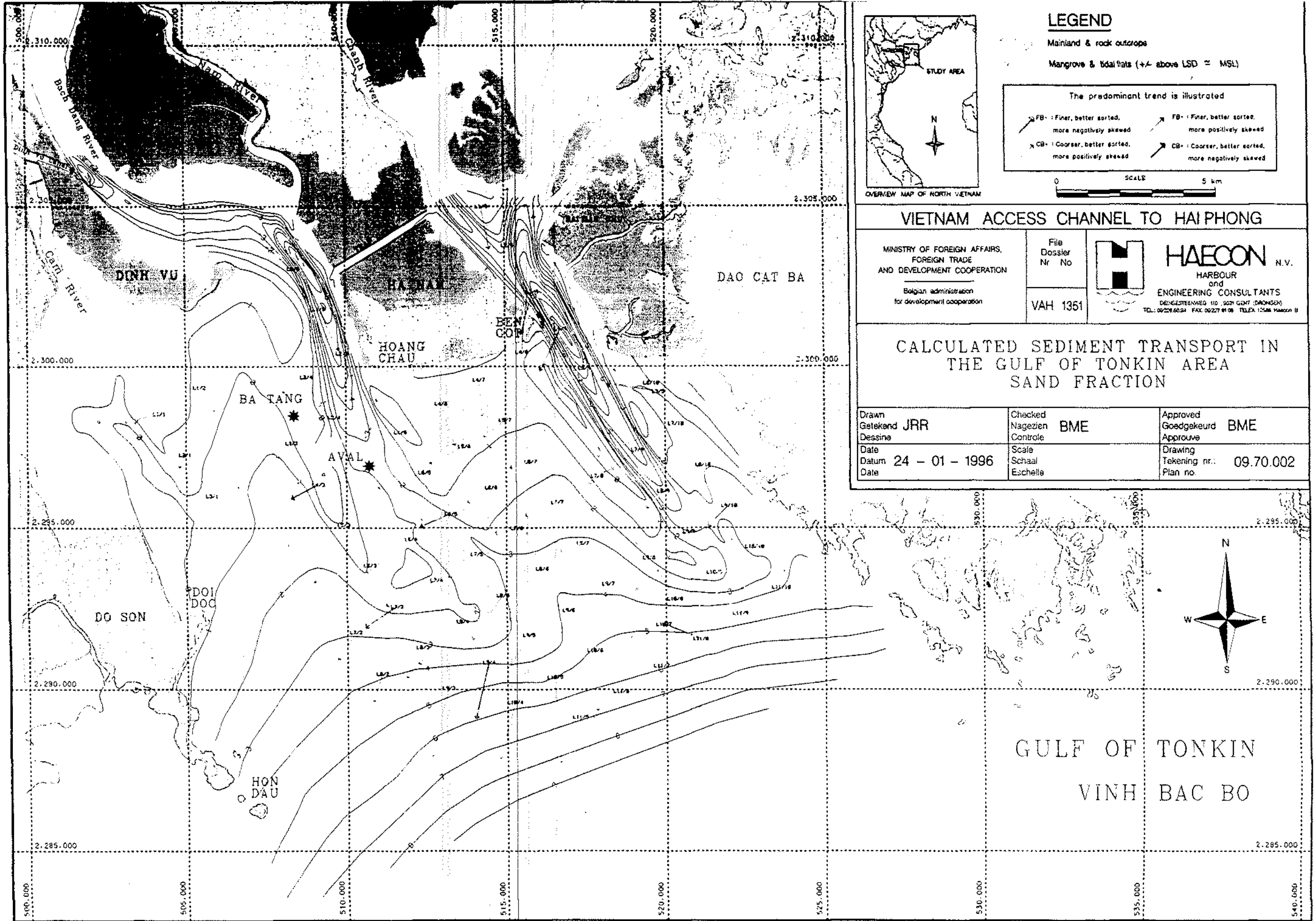
TEL.: 09/226 50 94 FAX. 09/227 81 05 TELEX 12580 Haecon B

CALCULATED SEDIMENT TRANSPORT IN THE GULF OF TONKIN AREA TOTAL SAMPLE

Drawn Getekend JRR Dessine	Checked Nagezien BME Controle	Approved Goedgekeurd BME Approuve
Date Datum 24 - 01 - 1996 Date	Scale Schaal Eschelle	Drawing Tekening nr.: 09.70.001 Plan no.


LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+/- above LSD ≃ MSL)
The predominant trend is illustrated
FB- : Finer, better sorted, more negatively skewed
FB+ : Finer, better sorted, more positively skewed
CB- : Coarser, better sorted, more positively skewed
CB+ : Coarser, better sorted, more negatively skewed
SCALE
0
5 km
STUDY AREA
N
OVERVIEW MAP OF NORTH VIETNAM
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
CALCULATED SEDIMENT TRANSPORT IN THE GULF OF TONKIN AREA SAND FRACTION
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 24 – 01 – 1996
Scale Schaal Eschelle
Drawing Tekening nr.: Plan no. 09.70.002
Nam River
Chanh River
Bach Dang River
Cam River
DINH VU
HAI NAM
BEN GOT
HOANG CHAU
DAO CAT BA
BA TANG
AVAL
DOI DOC
DO SON
HON DAU
GULF OF TONKIN
VINH BAC BO
N
W
E
S
2.310.000
2.305.000
2.300.000
2.295.000
2.290.000
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530.000
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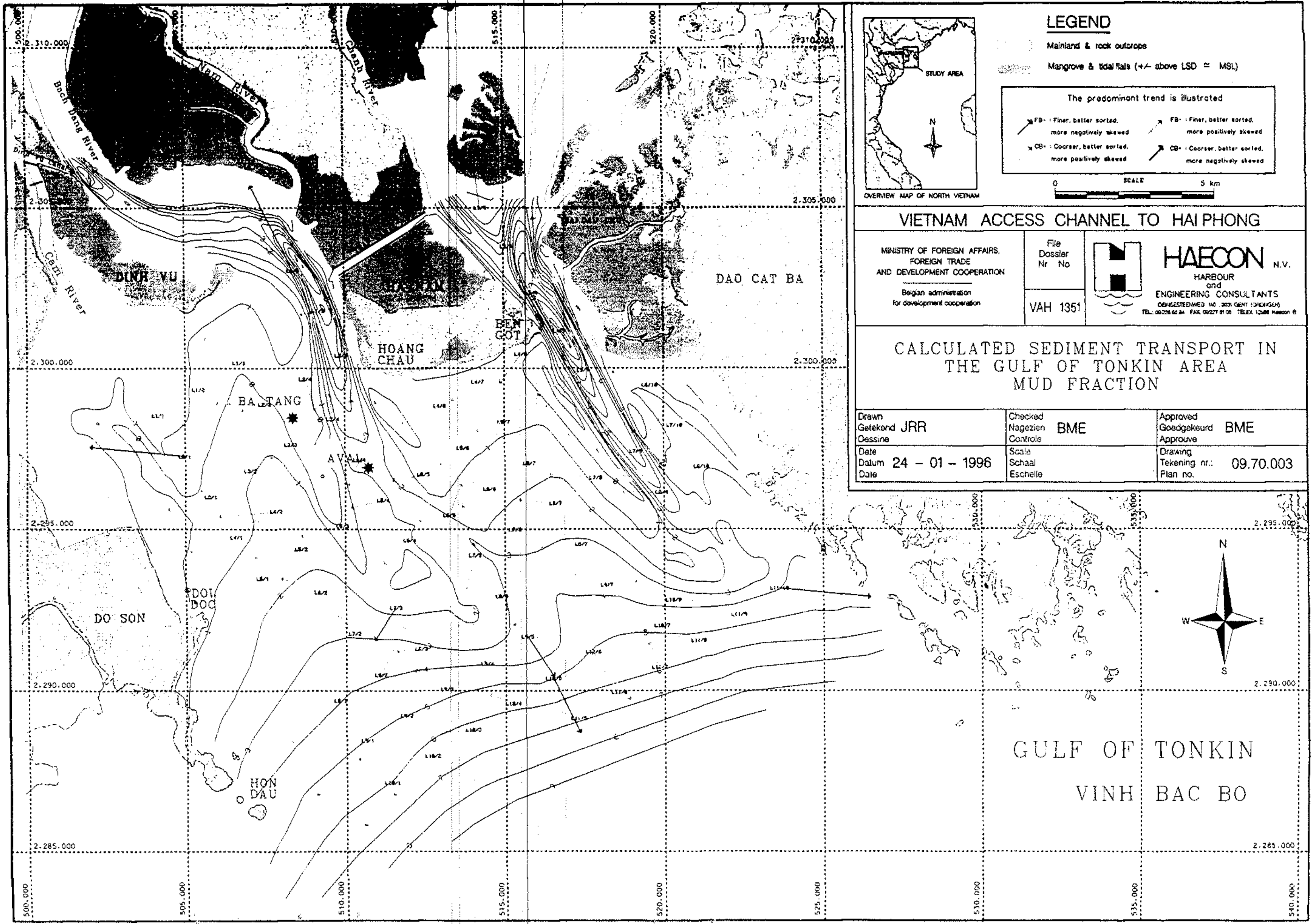
540.000



VIETNAM ACCESS CHANNEL TO HAI PHONG

MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION

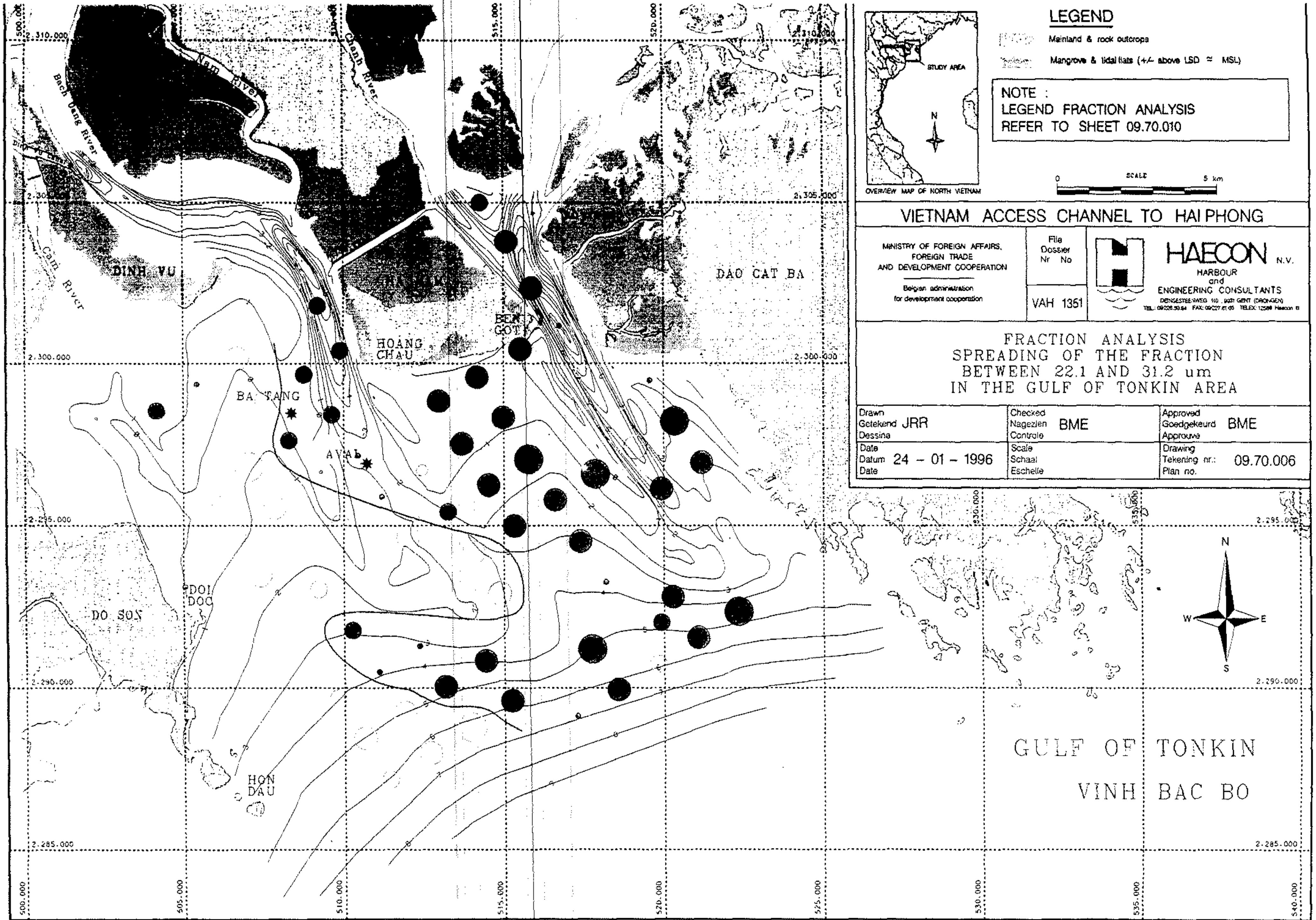
Belgian administration for development cooperation

File Dossier Nr No: VAH 1351

HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS

CALCULATED SEDIMENT TRANSPORT IN THE GULF OF TONKIN AREA MUD FRACTION

Drawn Getekend Dessine: JRR	Checked Nagezien Controle: BME	Approved Goedgekeurd Approuve: BME
Date Datum Date: 24 – 01 – 1996	Scale Schaal Eschelle	Drawing Tekening nr.: Plan no.: 09.70.003



VIETNAM ACCESS CHANNEL TO HAI PHONG

MINISTRY OF FOREIGN AFFAIRS,
FOREIGN TRADE
AND DEVELOPMENT COOPERATION

Belgian administration
for development cooperation

File / Dossier / Nr No: VAH 1351

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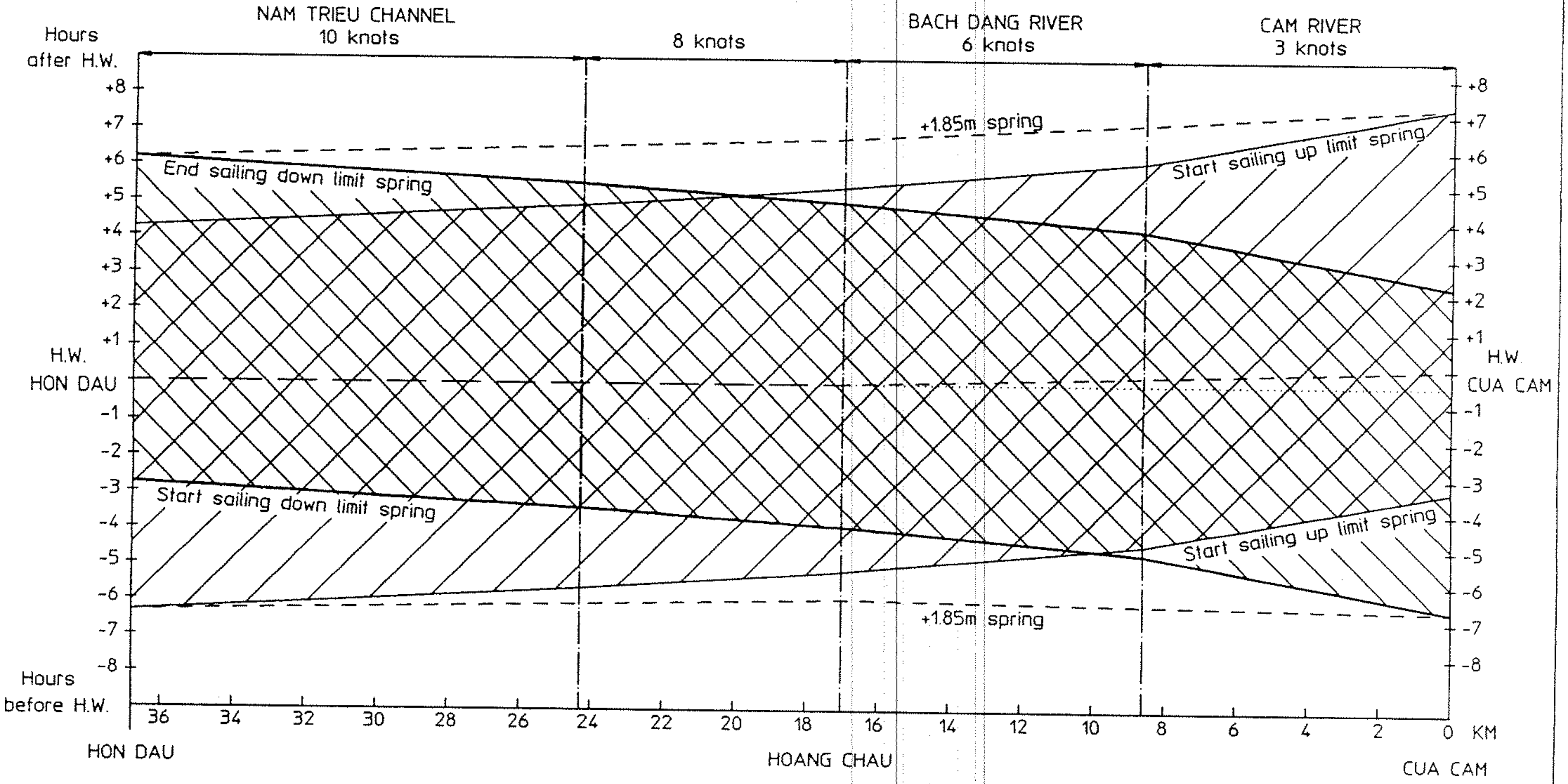
FRACTION ANALYSIS
SPREADING OF THE FRACTION
BETWEEN 22.1 AND 31.2 um
IN THE GULF OF TONKIN AREA

Drawn / Getekend / Dessina: JRR	Checked / Nagezien / Controle: BME	Approved / Goedgekeurd / Approuve: BME
Date / Datum / Date: 24 - 01 - 1996	Scale / Schaal / Eschelle:	Drawing / Tekening nr.: / Plan no.: 09.70.006



HAECON n.v
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Access - Channel to Hai Phong
Tidal window and sailing window at spring tide (9/10-01-93) in Nam Trieu (Alt. 1) C.D. +1.85 m fully loaded 30.000 DWT ships

GETEK: GDP	GEZ: BME	VAH051 Figure A13

A.I.1.4. Tidal window and sailing window

Present day experience shows that the Nam Trieu Channel from Buoy Nr. 0 to Hai Phong Port is upsailed in approx. 3 hours.

The tidal window for lightered 30,000 DWT-ships is set at C.D. + 1.70 m. For a full loaded 30,000 DWT ship, the tidal window is set at + 1.85 m.

From the UNDP tidal recordings (data from 9/10-01-93) the tidal wave propagation can be computed through the buoy up till Hai Phong Port. When comparing tidal wave propagation and ship's sailing speeds (upsailing and down-sailing) it becomes possible to calculate sailing windows.

This has been done and represented in 2 graphs :

1. figure A.I.2. Tidal and sailing window at Spring Tide (max. range) for lightered 30,000 DWT ships (C.D. + 1.70 m) in Nam Trieu (Alt. 1)
2. figure A.I.3. Tidal and sailing window at Spring Tide (max. range) for 30,000 DWT ships (C.D. + 1.85 m) in Nam Trieu (Alt. 1)

From these graphs and computations the following conclusions can be drawn :

- The upsailing window ranges from approx. - 6 hrs 40'/H.W. Hon Dau up to + 4 hrs 50'/H.W. Hon Dau for option A (tidal window set at C.D. + 1.70 m) (see figure A.2.)
  For option B 30,000 DWT ship (tidal window set a C.D. + 1.85 m), the upsailing window ranges from approx. - 6 hrs 20'/H.W. Hon Dau up to + 4 hrs 15'/H.W. Hon Dau (see figure A.3.)
- The down-sailing window ranges from - 7 hrs/H.W. Thai Binh (Cua Cam) to + 2 hr 40'/HW Thai Binh for option A and from - 6 hrs 40/HW Thai Binh to + 2 hrs 10'/HW Thai Binh for option B.

Of course, this kind of analysis is very much dependent upon sailing speeds and channel options. In Hai Phong it is - according to the JICA 1993 study report - acceptable and safe, that ship's time itervals are set at approximately 30 minutes ; this means that at maximum 24 design ships for option A and 22 for option B can sail up in 1 single tide or that a maximum 20 (option A) or 18 (option B) design ships can sail down under the present conditions and configuration.
No time-lag for the boarding/unboarding of pilots has been taken into account for these sailing window computations (only 1 pilot from buoy nr. 0 up to Hai Phong).

It must also be stressed that tidal window sailing implies that at berth locations in Hai Phong nautical depths must be available equalling the ships draught + approx. 10 %.

A.I.1.5. Determination of nautical bottom depth

Based on the deterministic calculation for the gross underkeel-clearance with an accessibility of ± 65 % for a lightered 30,000 DWT ship and with a ± 50 % accessibility for a 30,000 DWT ship, nautical depths and dredged depths are calculated as follows :

Design ship 30,000 DWT lightered

	Nam Trieu Lach Huyen (Open sea)	Nam Trieu Lach Huyen (Protected water)	Trap Ha Nam (Canal)	Bach Dang Cam (River)
Static draught	8.50 m	8.50 m	8.50 m	8.50 m
Gross keel-clearance (deterministic)	1.70 m	1.55 m	1.25 m	1.05 m
Required water depth	10.20 m	10.05 m	9.75 m	9.55 m
Tidal window CD	+ 1.70 m	+ 1.70 m	+ 1.70 m	+ 1.70 m
Nautical depth	- 8.50 m	- 8.35 m	- 8.05 m	- 7.85 m
Channel dredged level	- 9.00 m	- 8.85 m	- 8.35 m	- 8.15 m
Accessibility (% of the total time)	± 65	± 65	± 65	± 65

Table A.I.T.3.

Computation of nautical and dredging depths for a lightered 30,000 DWT-ship with an accessibility of 65%.

For full-loaded 30,000 DWT ships the nautical accessibility will in any case be restricted till the entrance of the Dinh Vu Canal. Because of existing port infrastructures and groynes a further deepening of the Cam River is excluded. Full-loaded 30,000 DWT ships wishing to call for Hai Phong Port will therefore have to be lighted before entrance in the Dinh Vu Canal.

Design ship 30,000 DWT

	Nam Trieu Lach Huyen (Open sea)	Nam Trieu Lach Huyen (Protected water)	Trap Ha Nam (Canal)	Bach Dang (River)
Static draught	11.30 m	11.30 m	11.30 m	11.30 m
Gross keel-clearance (deterministic)	1.60 m	1.50 m	1.25 m	1.15 m
Required water depth	12.90 m	12.80 m	12.55 m	12.45 m
Tidal window CD	+ 1.85 m	+ 1.85 m	+ 1.85 m	+ 1.85 m
Nautical depth	- 11.05 m	- 10.95 m	- 10.70 m	- 10.60 m
Channel dredged level	- 11.55 m	- 11.45 m	- 11.00 m	- 10.90 m
Accessibility (% of the total time)	± 50	± 50	± 50	± 50

Table A.I.T.4.

Computation of nautical and dredging depths for a 30,000 DWT-ship with an accessibility of ± 50%.

A.I.2. CHANNEL WIDTH

Based on the PIANC/IAPH approach, the navigable width of the maritime access-channel to the Hai Phong Port has been evaluated as follows :

	Nam Trieu Lach Huyen	Bach Dang River Trap Canal
Basic manoeuvring lane(W_{BM})	**1.5 B**	**1.5 B**
Addition for speed	**0.0 B**	**0.0 B**
Addition for cross wind	**0.4 B**	**0.4 B**
Addition for cross current	**0.5 B**	**0.0 B**
Addition for long. current	**0.1 B**	**0.4 B**
Addition for waves	**0.0 B**	**0.0 B**
Addition for aids to navigation	**0.2 B**	**0.2 B**
Addition for bottom surface	**0.1 B**	**0.1 B**
Addition for waterway depth	**0.2 B**	**0.4 B**
Addition for cargo hazard	**0.0 B**	**0.0 B**
Bank clearance (w_{br} + w_{bg})	**1.0 B**	**1.0 B**
Total	**4.0 B**	**4.0 B**
Channel width (B = 31.0 m)	**125 m**	**125 m**

Table A.I.T.5.
Access Channel width design (B = beam of design ships ; 31.0 m)

In any case is the channel width in the Cam River restricted to 80 m bottom width (also for lightered 30,000 DWT ships) because of the presence of existing port infrastructures and groynes. Therefore extra safety navigation rules for these large vessels in Cam River will have to be established.

A.I.4. VOLUMES OF CAPITAL DREDGING FOR THE DIFFERENT ACCESS-CHANNEL ALTERNATIVES

Layout	Alternative 1 Nam Trieu	Alternative 2 Nam Trieu	Alternative 3 Lach Huyen/ Ha Nam Canal	Alternative 4 Lach Huyen/ Trap Canal
Design profile				
Section I	Nam Trieu	Nam Trieu	Lach Huyen	Lach Huyen
- KM	KM 36.80 - 22.89	KM 34.50 - 22.89	KM 38.70 - 22.20	KM 39.80 - 20.38
- nautical bottom	CD -8.50 m	CD -8.50 m	CD - 8.50 m	CD - 8.50 m
- channel dredged level	CD -9.00 m	CD -9.00 m	CD - 9.00 m	CD - 9.00 m
- bottom width	125 m at CD-9.00 m	125 m at CD-9.00 m	125 m at CD-9.00 m	125 m at CD-9.00 m
- slope gradient	1/15	1/15	1/15	1/15
Section II	Nam Trieu	Nam Trieu	Ha Nam Canal	Trap Canal
- KM	KM 22.89 - 16.50	KM 22.89 - 16.50	KM 22.20 - 16.50	KM 20.38 - 16.50
- nautical bottom	CD -8.35 m	CD -8.35 m	CD -8.05 m	CD -8.05 m
- channel dredged level	CD -8.85 m	CD -8.85 m	CD -8.35 m	CD -8.35 m
- bottom width	125 m at CD-8.85 m	125 m at CD-8.85 m	125 m at CD-8.35 m	125 m at CD-8.35 m
- slope gradient	1/15	1/15	1/5	1/5
Section III	Bach Dang river	Bach Dang river	Bach Dang river	Bach Dang river
- KM	KM 16.50 - 8.60	KM 16.50 - 8.60	KM 16.50 - 8.60	KM 16.50 - 8.60
- nautical bottom	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m
- channel dredged level	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m
- bottom width	125 m at CD -8.15 m	125 m at CD -8.15 m	125 m at CD -8.15 m	125 m at CD -8.15 m
- slope gradient	1/7	1/7	1/7	1/7
Section IV	Cam river	Cam river	Cam river	Cam river
- KM	KM 8.60 - 0.00	KM 8.60 - 0.00	KM 8.60 - 0.00	KM 8.60 - 0.00
- nautical bottom	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m
- channel dredged level	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m
- bottom width	80 m at CD -8.15 m	80 m at CD -8.15 m	80 m at CD -8.15 m	80 m at CD -8.15 m
- slope gradient	1/7	1/7	1/7	1/7
Capital dredging (in situ m³)				
Section I	10,750,000	11,250,000	12,580,000	12,230,000
Section II	3,570,000	3,570,000	7,780,000	6,550,000
Section III	2,350,000	2,350,000	2,430,000	2,430,000
Section IV	2,160,000	2,160,000	2,160,000	2,160,000
Total	18,830,000	19,330,000	24,950,000	23,370,000
Costs of capital dredging (USD)	68,560,000	70,560,000	74,000,000	76,770,000

Table A.I.T.6.

Comparison of channel alternatives and volumes of capital dredging for ship traffic option A (30,000 DWT lightered)

A.I.3. BENDS

The PIANC guideline recommends bending radius to be within 5 LOA and 10 LOA.

To take a margin of safety with respect to cross-currents, (especially for entering and exit the Trap Canal or Ha Nam Canal), a turning radius of 12 LOA (R = 2750 m) is proposed.

The width in the bends is also set at 4 x B, but additional width is recommended for entering and leaving the New Ha Nam Canal (Alternative 3) or the Trap canal (Alternative 4) in order to allow for the cross current : 160 m at the bottom in the bend as opposed to 115 m in the straight sections.
According to PIANC guidelines additional width is preferably placed on the inside bank rather than on the outside bank of the bend.

Layout	Alternative 1 Nam Trieu	Alternative 2 Nam Trieu	Alternative 3 Lach Huyen/ Ha Nam Canal	Alternative 4 Lach Huyen/ Trap Canal
Design profile				
Section I	Nam Trieu	Nam Trieu	Lach Huyen	Lach Huyen
- KM	KM 36.80 - 22.89	KM 34.50 - 22.89	KM 38.70 - 22.20	KM 39.80 - 20.38
- nautical bottom	CD -11.05 m	CD -11.05 m	CD - 11.05 m	CD - 11.05 m
- channel dredged level	CD -11.55 m	CD -11.55 m	CD - 11.55 m	CD - 11.55 m
- bottom width	125 m at CD-11.55 m	125 m at CD-11.55 m	125 m at CD-11.55 m	125 m at CD-11.55 m
- slope gradient	1/15	1/15	1/15	1/15
Section II	Nam Trieu	Nam Trieu	Ha Nam Canal	Trap Canal
- KM	KM 22.89 - 16.50	KM 22.89 - 16.50	KM 22.20 - 16.50	KM 20.38 - 16.50
- nautical bottom	CD -10.95 m	CD -10.95 m	CD -10.70 m	CD -10.70 m
- channel dredged level	CD -11.45 m	CD -11.45 m	CD -11.00 m	CD -11.00 m
- bottom width	125 m at CD-11.45 m	125 m at CD-11.45 m	125 m at CD-11.00 m	125 m at CD-11.00 m
- slope gradient	1/15	1/15	1/5	1/5
Section III	Bach Dang river	Bach Dang river	Bach Dang river	Bach Dang river
- KM	KM 16.50 - 8.60	KM 16.50 - 8.60	KM 16.50 - 8.60	KM 16.50 - 8.60
- nautical bottom	CD - 10.60 m	CD - 10.60 m	CD - 10.60 m	CD - 10.60 m
- channel dredged level	CD - 10.90 m	CD - 10.90 m	CD - 10.90 m	CD - 10.90 m
- bottom width	125 m at CD -10.90 m	125 m at CD -10.90 m	125 m at CD -10.90 m	125 m at CD -10.90 m
- slope gradient	1/7	1/7	1/7	1/7
Section IV	Cam river	Cam river	Cam river	Cam river
- KM	KM 8.60 - 0.00	KM 8.60 - 0.00	KM 8.60 - 0.00	KM 8.60 - 0.00
- nautical bottom	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m	CD - 7.85 m
- channel dredged level	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m	CD - 8.15 m
- bottom width	80 m at CD -8.15 m	80 m at CD -8.15 m	80 m at CD -8.15 m	80 m at CD -8.15 m
- slope gradient	1/7	1/7	1/7	1/7
Capital dredging (in situ m³)				
Section I	20,560,000	20,150,000	16,690,000	23,560,000
Section II	8,290,000	8,290,000	16,480,000	9,140,000
Section III	5,510,000	5,510,000	5,710,000	5,710,000
Section IV	2,160,000	2,160,000	2,160,000	2,160,000
Total	36,520,000	36,110,000	41,040,000	40,570,000
Costs of capital dredging (USD)	134,600,000	132,900,000	127,600,000	136,800,000

Table A.I.T.7.

Comparison of channel alternatives and volumes of capital dredging for ship traffic option B (30,000 DWT)

ANNEXE II

MONITORING OF THE PILOT TRENCH IN THE LACH HUYEN CHANNEL

Annexe II : Monitoring of the pilot trench

A.II.1. INTRODUCTION

The firm of consultants TEDI (with the technical assistance of the Belgium Company HAECON) has signed a contract with River Dredging Company No. 1 for dredging a pilot trench for the project "General Study of the access-channel of Hai Phong Port".

The contract is written based on report 1.3. VAH1351/00158, that was prepared by HAECON. After receiving the survey and design results, given by TEDI, River Dredging Company No. 1 started the dredging operation on 14-10-95 and finished them on 05-11-95 under TEDI's supervision.

A.II.2. LOCATION OF THE PILOT TRENCH

Based on HAECON's report 1.3. VAH1351/00158, the pilot trench is located at the Lach Huyen channel axis (see drawing VAH1351/34.20.001).

A.II.3. PILOT TRENCH PROFILES

The pilot trench was dredged with the following parameters (see figure A.II.1)

- Profile 1
  - Height 2.0 m
  - Bed width 20 m
  - Length 80 m
  - Slope 1/10

- Profile 2
  - Height 2.0 m
  - Bed width 20 m
  - Length 80 m
  - Slope 1/20

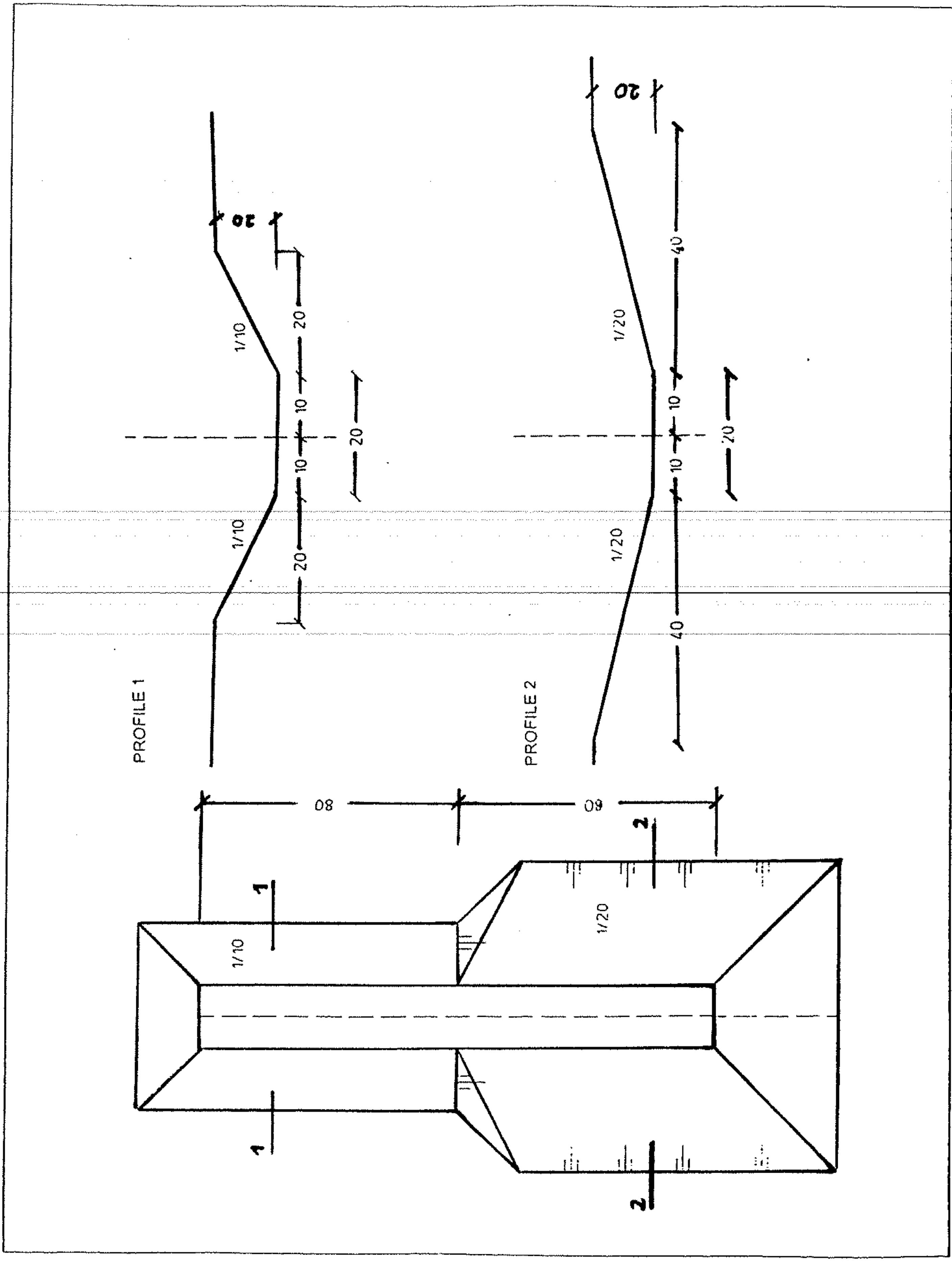


Figure A.II.1.
Trench profiles

A.II.4. VOLUME TO BE DREDGED

- In order to have data for designing and computing the volume to be dredged, TEDI has carried out a bathymetric survey (at scale 1/1000 with line spacing of 10 m) before dredging .The survey was carried out in a period of two days (7/8-10-95).
- Based on the survey results before dredging and the proposed volume of 20,000 m³ (limit by the project budget), TEDI designed a pilot trench with a depth of 4.6 m. This depth is situated at the centre of the pilot trench after dredging. The average natural depth in this area is 2.6 m.
- TEDI designed the pilot trench with a total volume of 19,890 m³ to be dredged.
- The pilot trench was dredged by River Dredging Company No.1 using a bucket dredger (Dredger 91) with different barges.

A.II.5. BATHYMETRIC SURVEY

The bathymetric survey with a scale of 1/1000 was carried out by TEDI's Survey Department from 04-11-95 at 15:48 until 05-11-95 at 00:15, just after the dredging work had been completed . Based on this result and the result surveyed before dredging, the dredged volume (24855 m^3) was calculated according to the requirement stated in HAECON's report. To define the position , a Microfix system and a Lasertrack system are used. The depth was determined by a Dual frequency Echosounder Elac and a Single frequency (200 Khz) Echosounder Echotrac.

The dredged volume is calculated based on 23 cross-sections along the longitude of the pilot trench. These cross-sections are spaced at 10 m interval.

In order to evaluate the stability of the pilot trench, bathymetric surveys were frequently repeated (11-11-95, 16-11-95, 21-11-95, 28-11-95, 28-01-96, 03-03-96, 28-03-96). These additional surveys were executed to determine the evolution of the pilot trench in time. To represent the time-related behaviour of the pilot trench, 4 sections (2 sections for each profile) were defined as shown in drawing VAH1351/34.20.003.

A.II.6. RESULTS OF THE BATHYMETRIC SURVEY

A.II.6.1. Monitoring results of section 5

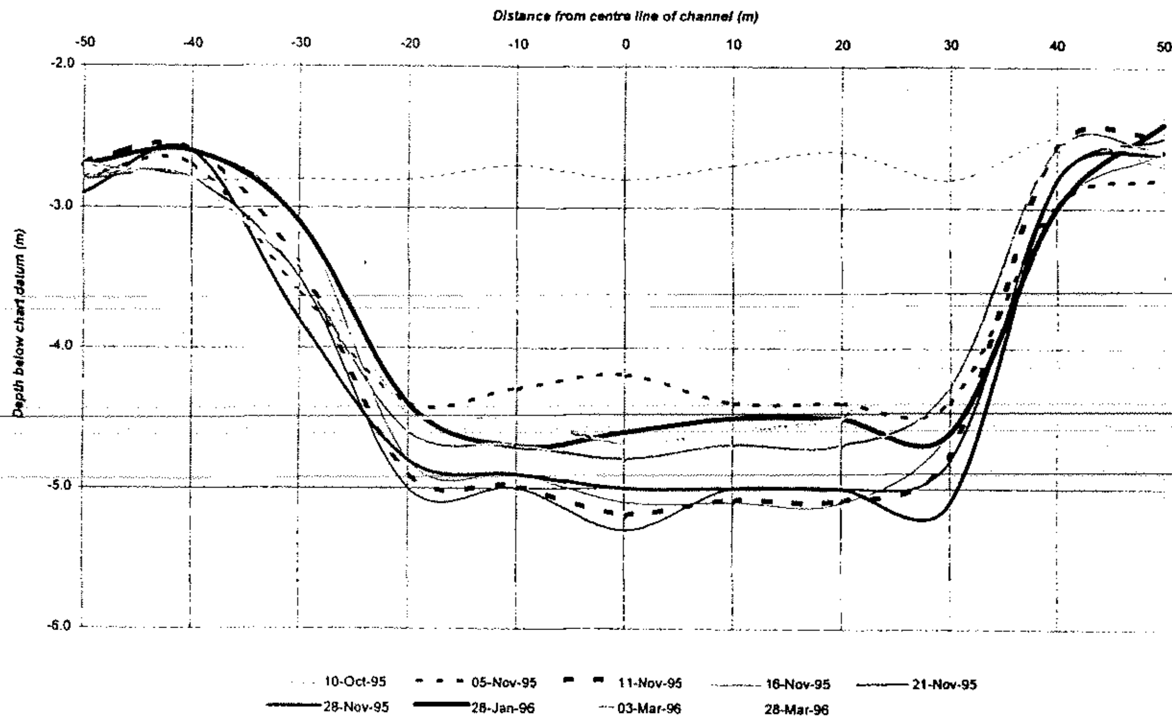


Figure A.II.2.
Evolution of the bed level in function of the time - Section 5

At 05/11/95 the dredging of the pilot trench was executed. For a while, the channel was deepened because of erosion as a result of the increased current. This behaviour keeps up until 21/11/95. After this date, the channel started to sedimentate again, but will be still deeper than the depth just after dredging. There can be concluded that just after the dredging there is a natural deepening, followed by sedimentation.
Following the survey report, a sedimentation of 0.656 centimeters a day can be expected. The time-related erosion and sedimentation of the centre line of the dredged channel is shown in figure A.II.3.

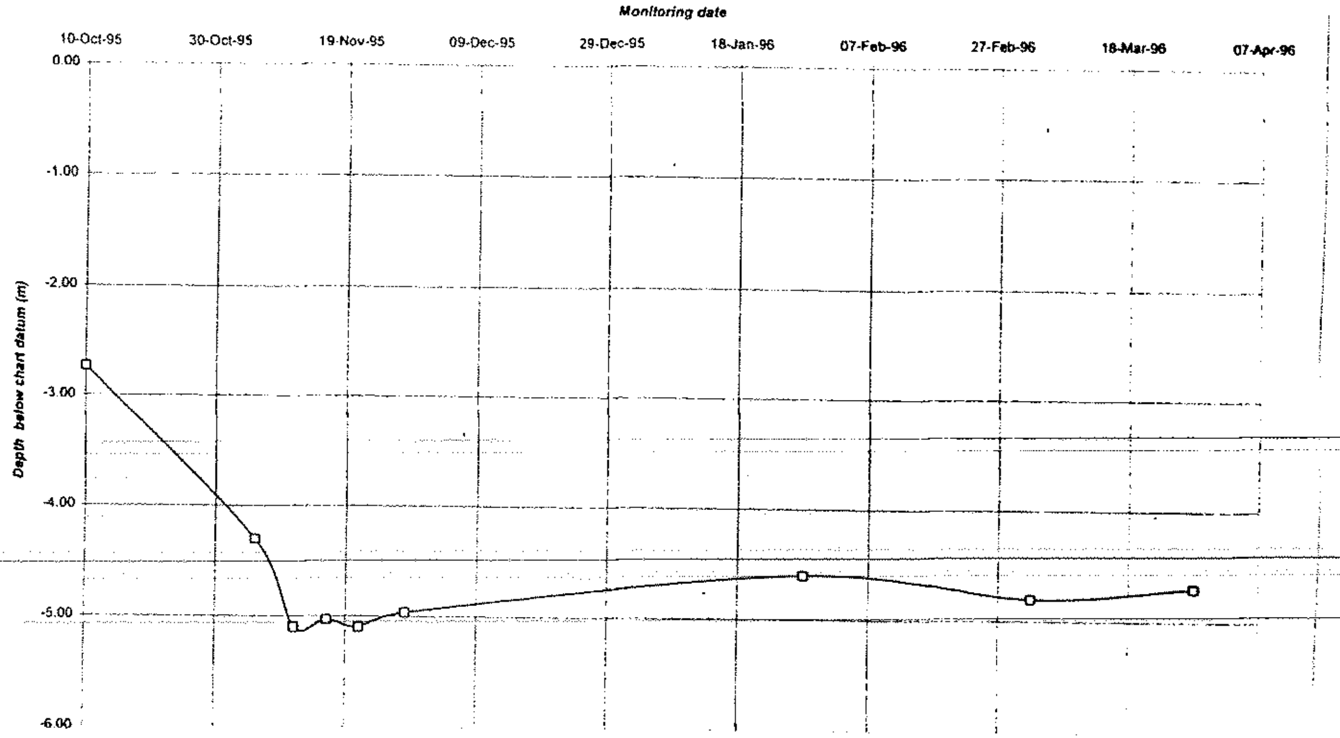


Figure A.II.3.
Evolution of the centre line of the pilot channel in function of the time - Section 5

At the meantime, the slope-values of the pilot trench are increasing and evoluating to their natural slopes. Some slope-values are presented underneath in Table A.II.T.1.

	10-10-95	*05-11-95*	*11-11-95*	*16-11-95*	*21-11-95*	*28-11-95*	*28-01-96*	*03-03-96*	*28-03-96*
East-slope	1/100	1/11	1/7	1/6	1/7	1/8	1/8	1/9	**1/9**
West-slope	1/33	1/7	1/5	1/6	1/5	1/4	1/6	1/6	**1/8**

Table A.II.T.1.
Slope-values of pilot trench - Section 5

A.II.6.2. Monitoring results of section 9

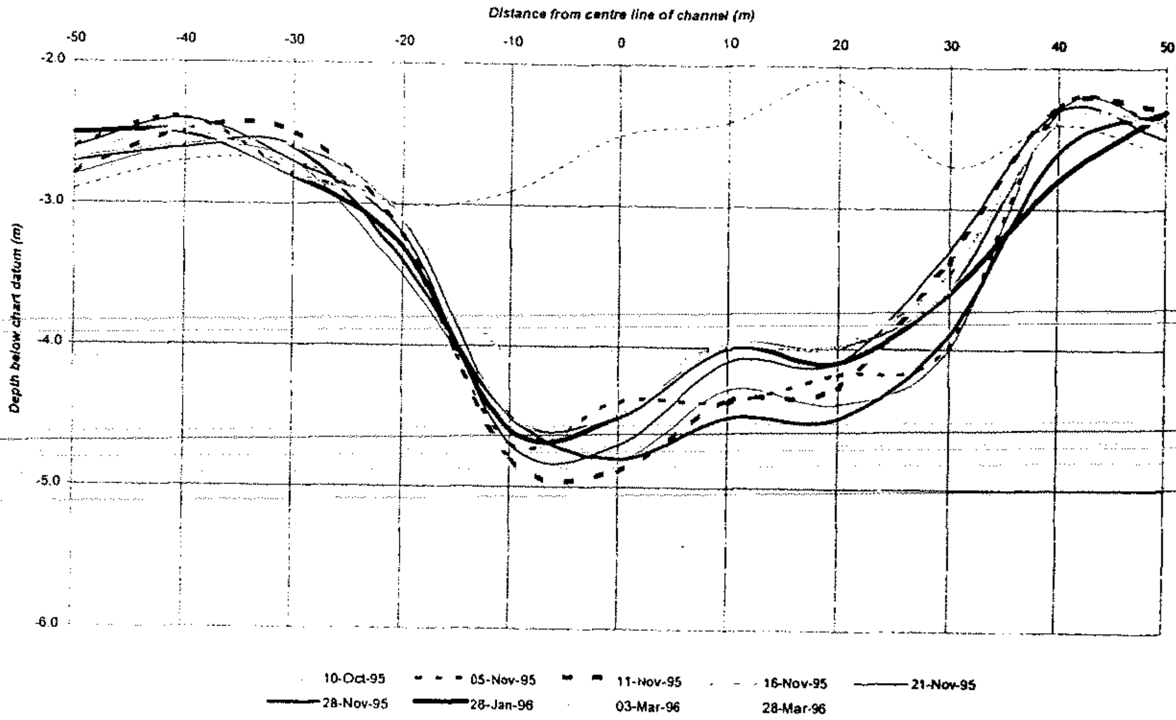


Figure A.II.4.
Evolution of the bed level in function of the time - Section 9

As for section 5, for a while the channel was deepened because of erosion as a result of the increased current. This behaviour keeps up until 28-11-95. After this date, sedimentation starts again. There can be concluded that just after the dredging there is a natural deepening, followed by sedimentation.
Following the survey report, a sedimentation of 0.492 centimeters a day can be expected. The time-related erosion and sedimentation of the centre line of the dredged channel is shown in figure A.II.5.

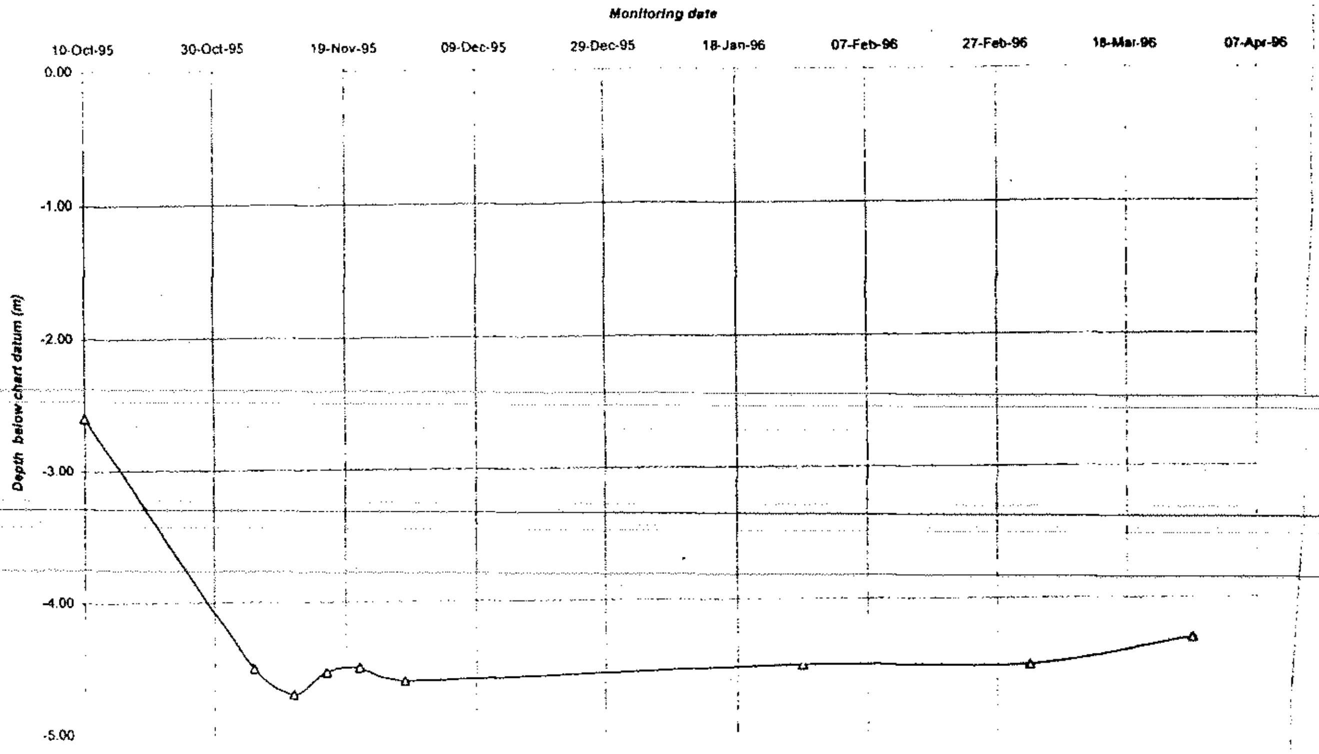


Figure A.II.5.
Evolution of the centre line of the pilot channel in function of the time - Section 9

At the meantime, the slope-values of the pilot trench are increasing and evoluating to their natural slopes. Some slope-values are presented in Table A.II.T.2.

	10-10-95	*05-11-95*	*11-11-95*	*16-11-95*	*21-11-95*	*28-11-95*	*28-01-96*	*03-03-96*	*28-03-96*
East-slope	1/33	1/7	1/6	1/10	1/7	1/9	1/8	1/7	1/10
West-slope	1/33	1/6	1/9	1/6	1/10	1/8	1/13	1/8	1/9

Table A.II.T.2.
Slope-values of pilot trench - Section 9

A.II.6.3. Monitoring results of section 14

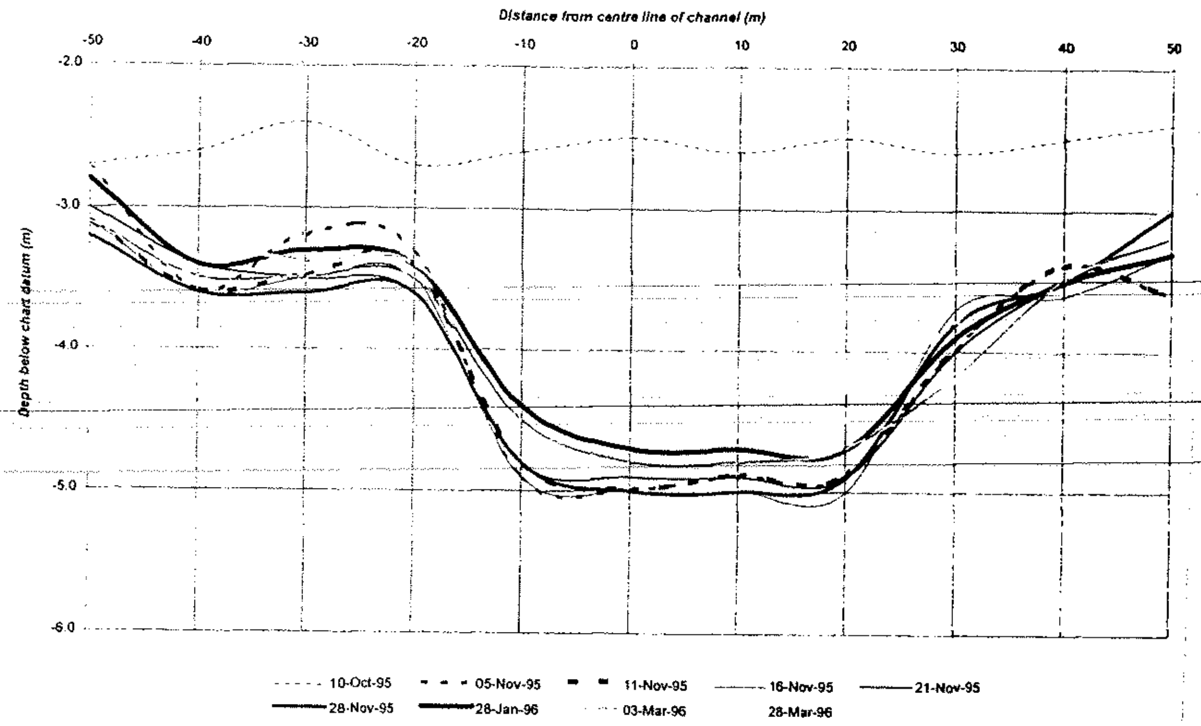


Figure A.II.6.

Evolution of the bed level in function of the time - Section 14

Contradictory to the previous sections, there is no notable deepening of the channel because of erosion. This confirms the theory that the erosion is the result of an increased current, while profile 1 (represented by sections 5 and 9) is narrower than profile 2 (represented by sections 14 and 17).Since the moment the dredge-work was finished, the channel started to sedimentate again. Following the survey report, a sedimentation of 0.492 centimeters a day can be expected. The time-related erosion and sedimentation of the centre line of the dredged channel is shown in figure A.II.7.

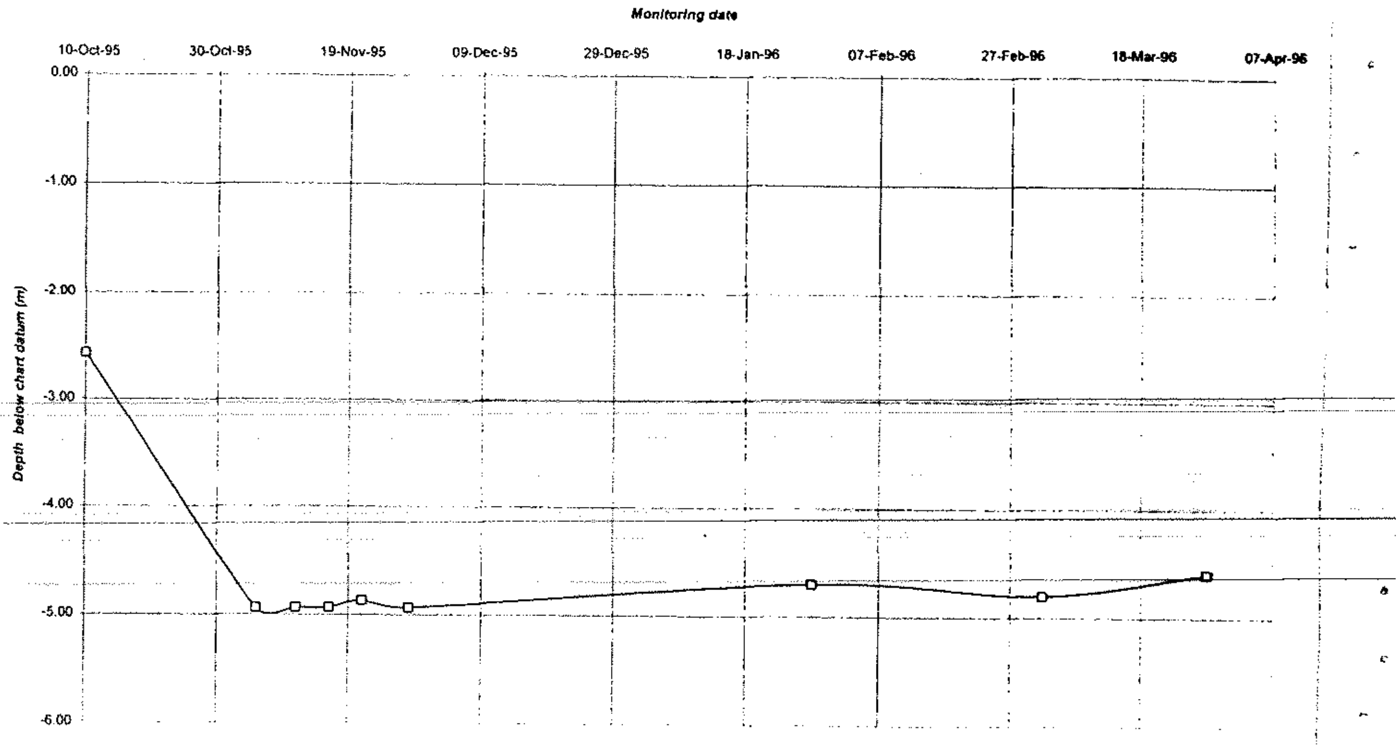


Figure A.II.7.
Evolution of the centre line of the pilot channel in function of the time - Section 14

At the meantime, the slope-values of the pilot trench are increasing and evoluating to their natural slopes. Some slope-values are presented in Table A.II.T.3.

	10-10-95	*05-11-95*	*11-11-95*	*16-11-95*	*21-11-95*	*28-11-95*	*28-01-96*	*03-03-96*	*28-03-96*
East-slope	1/33	1/6	1/7	1/7	1/8	1/8	1/10	1/10	1/13
West-slope	1/100	1/11	1/11	1/8	1/11	1/9	1/13	1/14	1/14

Table A.II.T.3.
Slope-values of pilot trench - Section 14

A.II.6.4. Monitoring results of section 17

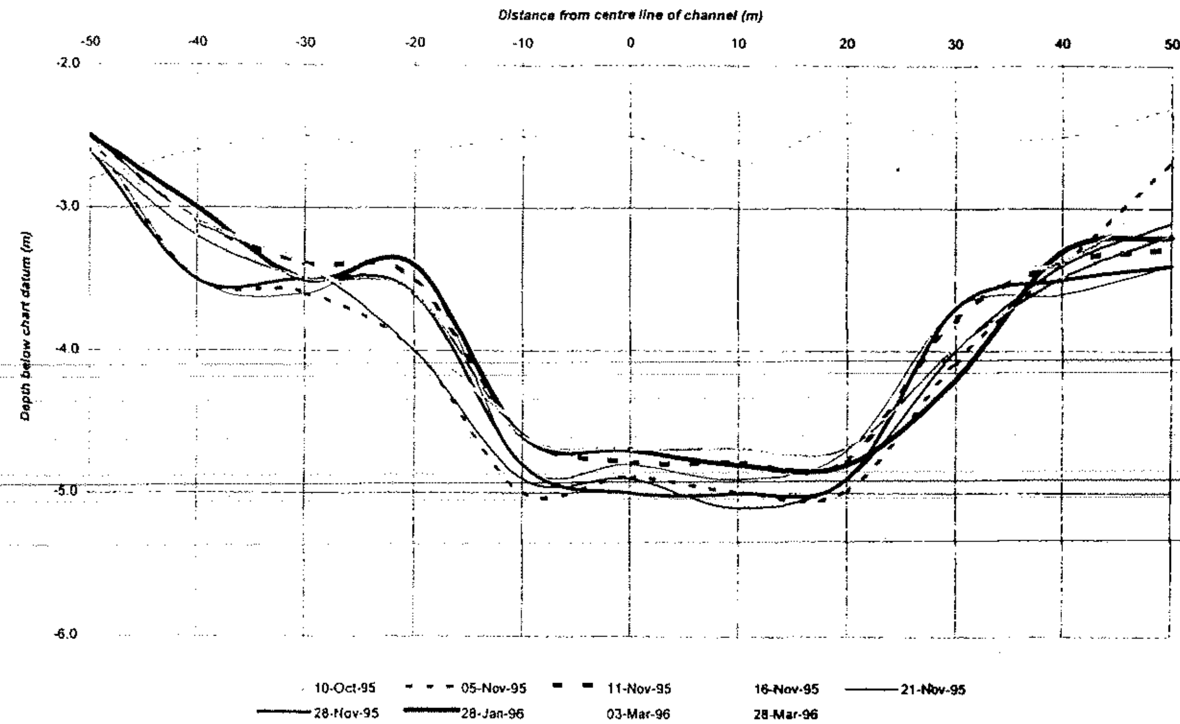


Figure A.II.8.
Evolution of the bed level in function of the time - Section 17

As section 14, the pilot trench started to sedimentate from the day the dredge-works were finished. Following the survey report, a sedimentation of 0.492 centimeters a day can be expected. The evolution of the depth of the centre line of the dredged channel is shown in figure A.II.9.

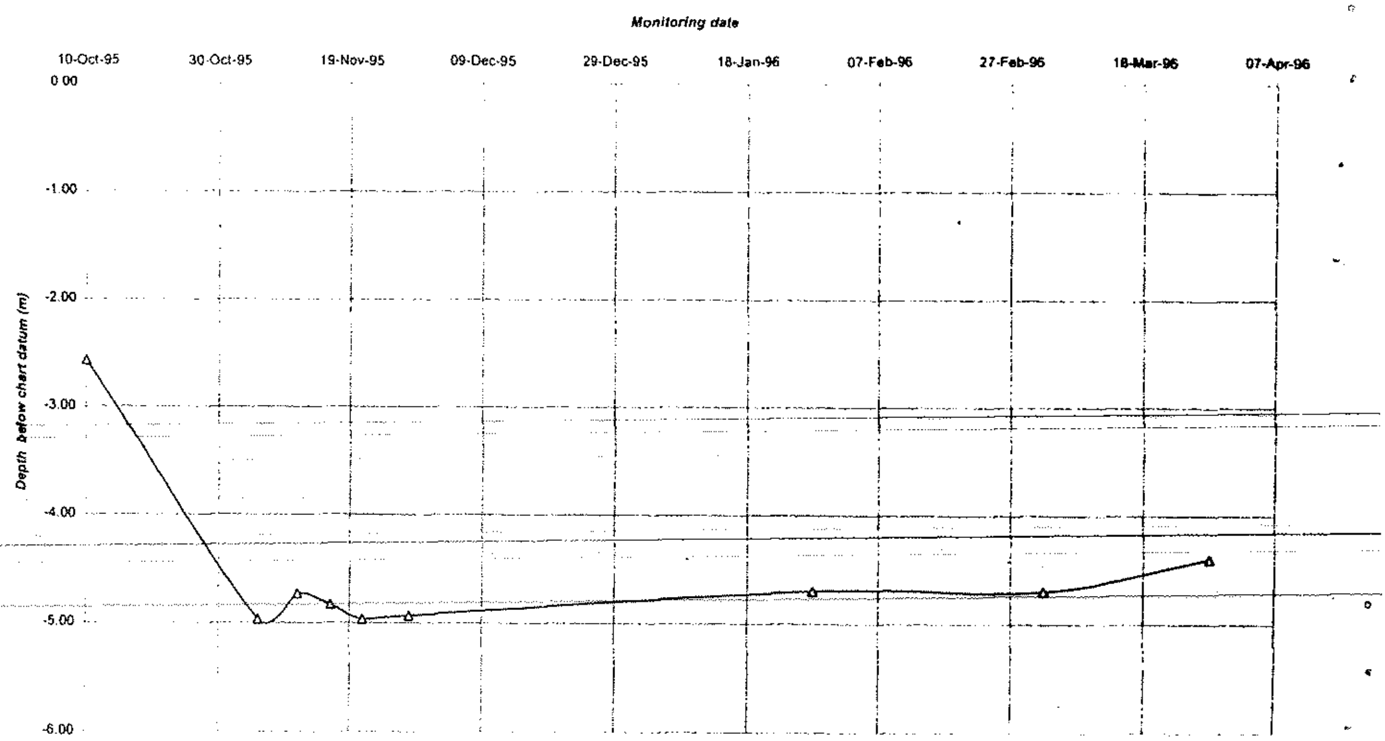


Figure A.II.9.
Evolution of the centre line of the pilot channel in function of the time - Section 17

At the meantime, the slope-values of the pilot trench are increasing and evoluating to their natural slopes. Some slope-values are presented in Table A.II.T.4.

	10-10-95	*05-11-95*	*11-11-95*	*16-11-95*	*21-11-95*	*28-11-95*	***28-01-96***	***03-03-96***	***28-03-96***
East-slope	1/100	1/10	1/9	1/7	1/11	1/8	**1/8**	**1/10**	**1/17**
West-slope	1/33	1/11	1/10	1/10	1/11	1/8	**1/11**	**1/14**	**1/9**

Table A.II.T.4.
Slope-values of pilot trench - Secion 17

List of drawings

VAH1351/34.20.006	Lithology of the subbottom. Thickness of sandlayer. Based on vibrocores (sampling : July - Nov. 1995)
VAH1351/34.20.007	Sedimentological map of seabed Seabed sampling : April - June 1991, June - August 1995 Spatial distribution of Median Grain-Size (d50)
VAH1351/34.20.008	Residual sediment transport pathways (deduced from sediment trend analysis)

List of tables

ANNEXE I

CHANNEL DESIGN FOR LIGHTERED 30,000 DWT SHIPS AND FULL-LOADED 30,000 DWT SHIPS

Annexe I : Channel design for lightered 30,000 DWT ships and full-loaded 30,000 DWT ships.

A.I.1. CHANNEL DEPTH

A.I.1.1. Ship characteristics

For the access-channel to Hai Phong, calculations are also done for :

- lightered 30,000 DWT ship (option A)	**Static Draught**	**T = 8.50 m (*)**
	Beam	**B = 31.00 m**
	Length	**LOA = 230 m**
- 30,000 DWT ship (option B)	**Static Draught**	**T = 11.30 m**
	Beam	**B = 31.00 m**
	Length	**LOA = 230 m**

(*) Static draught of a 10,000 DWT ship

The nautical depth will be determined for the two ships and the optimised tidal level.
Channel width in the one-way traffic sections will be determined based on the beam of a 30,000 DWT ship (B = 31.00 m). Parts of the channel were sufficient natural widths (> 8 B) and the natural depths are present, can be used as ship's crossing zones. Channel bending - radii wil be determined based on the length (LOA) of a 30,000 DWT ship.

A.I.1.2. Gross underkeel-clearance (m)

Based on the deterministic calculation (PIANC), the gross underkeel-clearance has been evaluated for the two ships :

a. 30,000 DWT lightered (draught of 10,000 DWT-ship) : Table A.I.T.1.
b. 30,000 DWT-ship : Table A.I.T.2.

Design Ship 30,000 DWT lightered
(± equivalent to 10,000 DWT with T = 8.50 m)

	Nam Trieu Lach Huyen (Open Sea)	Nam Trieu Lach Huyen (Protected water)	Trap Ha Nam (Canal)	Bach Dang + Cam (River)
<u>Keel-clearance components</u>				
1. Allowance for static draught uncertainties	0.10	0.10	0.10	0.10
2. Change in water density	0.00	0.25	0.25	0.25
3. Squat (dynamic trim + list)	0.70	0.50	0.40	0.30
4. Wave response allowance	0.50	0.30	0.00	0.00
5. Wind response allowance	0.10	0.10	0.20	0.10
6. Netto Keel-Clearance	0.30	0.30	0.30	0.30
Gross Underkeel-Clearance (m)	**1.70**	**1.55**	**1.25**	**1.05**

<u>Table A.I.T.1.</u>
Gross underkeel-clearance computation for a lightered 30,000 DWT-ship.
(draught of 10,000 DWT-ship)

Design Ship 30,000 DWT
(T = 11.30 m)

	Nam Trieu Lach Huyen (Open Sea)	Nam Trieu Lach Huyen (Protected water)	Trap Ha Nam (Canal)	Bach Dang + Cam (River)
<u>Keel-clearance components</u>				
1. Allowance for static draught uncertainties	0.10	0.10	0.10	0,10
2. Change in water density	0.00	0.35	0.35	0.35
3. Squat (dynamic trim + list)	0.70	0.50	0.40	0.35
4. Wave response allowance	0.45	0.20	0.00	0.00
5. Wind response allowance	0.05	0.05	0.10	0.05
6. Netto Keel-Clearance	0.30	0.30	0.30	0.30
Gross Underkeel-Clearance (m)	**1.60**	**1.50**	**1.25**	**1.15**

<u>Table A.I.T.2.</u>
Gross underkeel-clearance computation for a 30,000 DWT-ship

Apart from the underkeel-clearance, the bottom related factors have to be taken into account to calculate the channel dredge level. The following allowance has been taken into account :

1.	allowance for bed level uncertainties	:	0.10 m
2a.	allowance for nautical bottom changes between two dredgings in Nam Trieu / Lach Huyen	:	0.25 m
2b.	allowance for nautical bottom changes between two dredgings in the river system	:	0.05 m
3.	dredging execution tolerance : 50% of 0.30 m	:	0.15 m

Thus the total assumed allowance for bottom related keel-clearance factors varies between **0.30 m** (river system/canal) and **0.50 m** (Nam Trieu / Lach Huyen).

A.I.1.3. Tidal level

The accessibility to Hai Phong Port is tide-bound. A tidal window of C.D. + 2.50 m and a nautical depth of C.D. -7.30 m means a total time accessibility to Hai Phong for lightered 30,000 DWT-ship of 15 % of total time which is quite poor (accessibility for full loaded 30,000 DWT-ships is 0 %).

The optimisation of the tidal window has been done by means of an accessibility graph represented in figure A.I.1.

The accessibility (in % of total time) to Hai Phong is analysed for the 2 different ships and in function of the nautical depth.
The relationship shows that in order to improve the accessibility for a lightered 30,000 DWT ship from 15 % to 65 % only a slight increase in nautical depth is necessary.
Consequently, in order to increase the nautical accessibility to 65 % of the total time, the tidal window can be deduced and is equal to C.D. + 1.70 m for a lightered 30,000 DWT ship.
For a full-loaded 30,000 DWT ship, a tidal window of C.D. + 1.85 m corresponds to an accessibility of 50 % of total time.

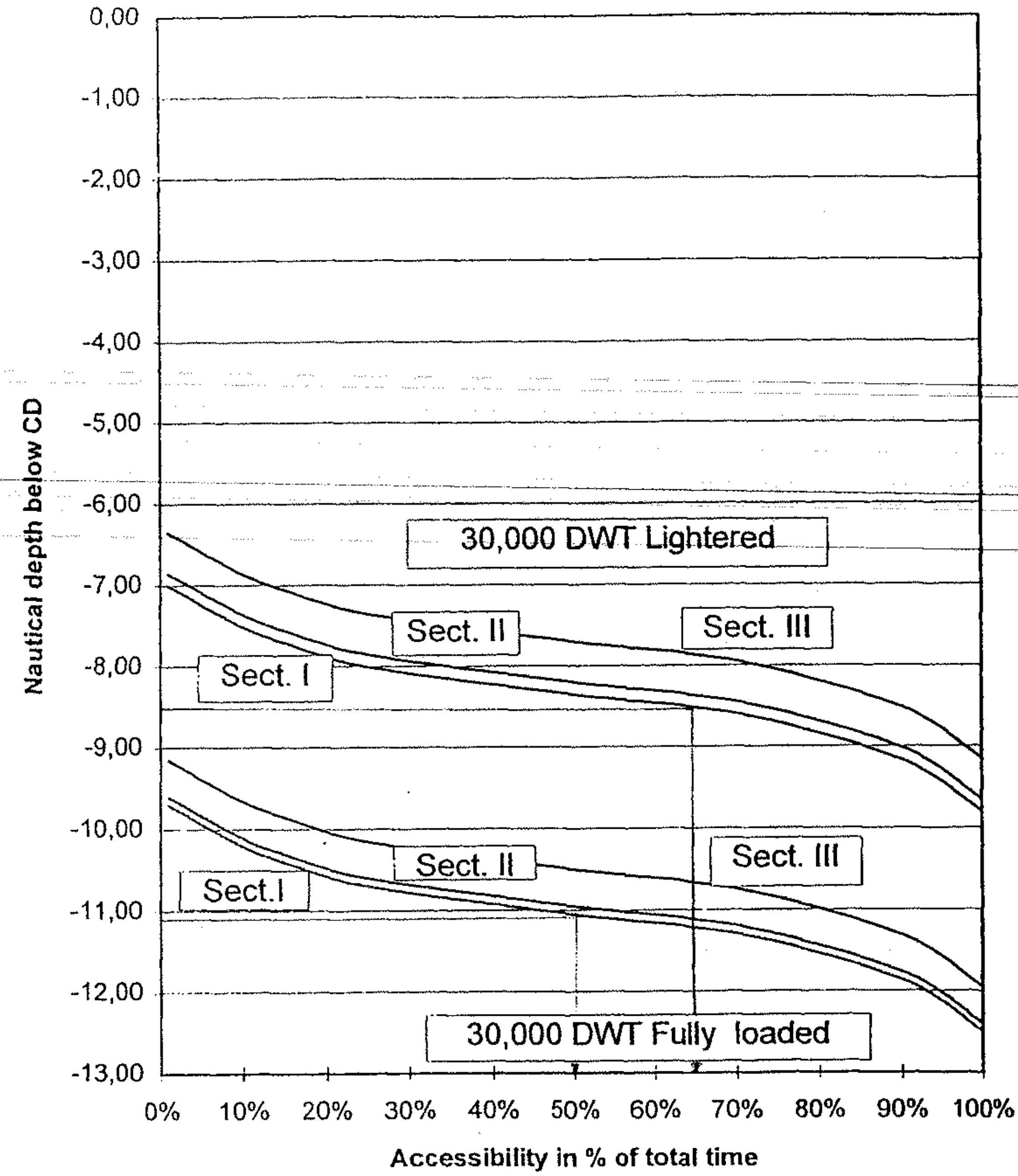
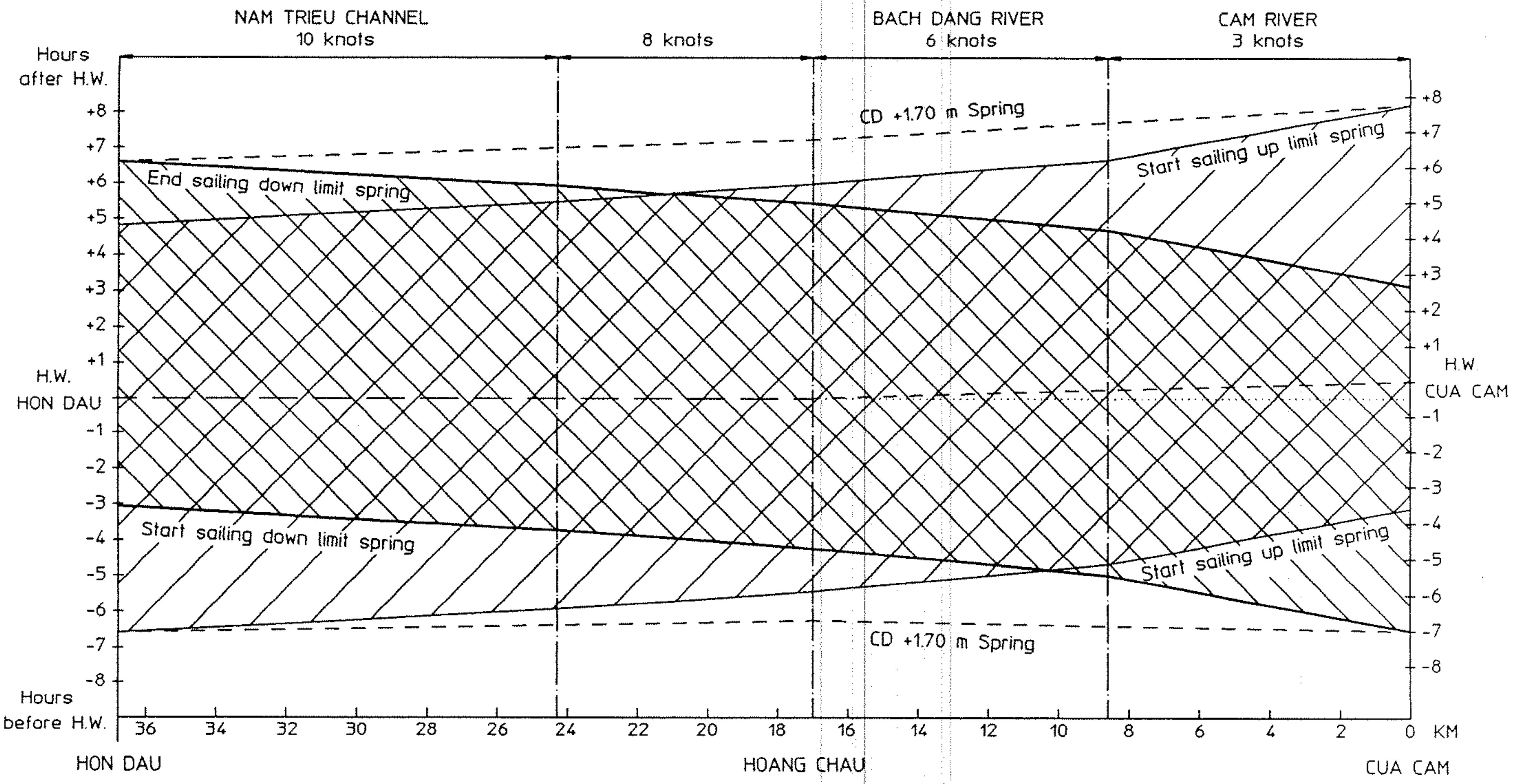


Figure A.I.1.
Accessibility graph to Hai Phong as a function of nautical depth and ship's size



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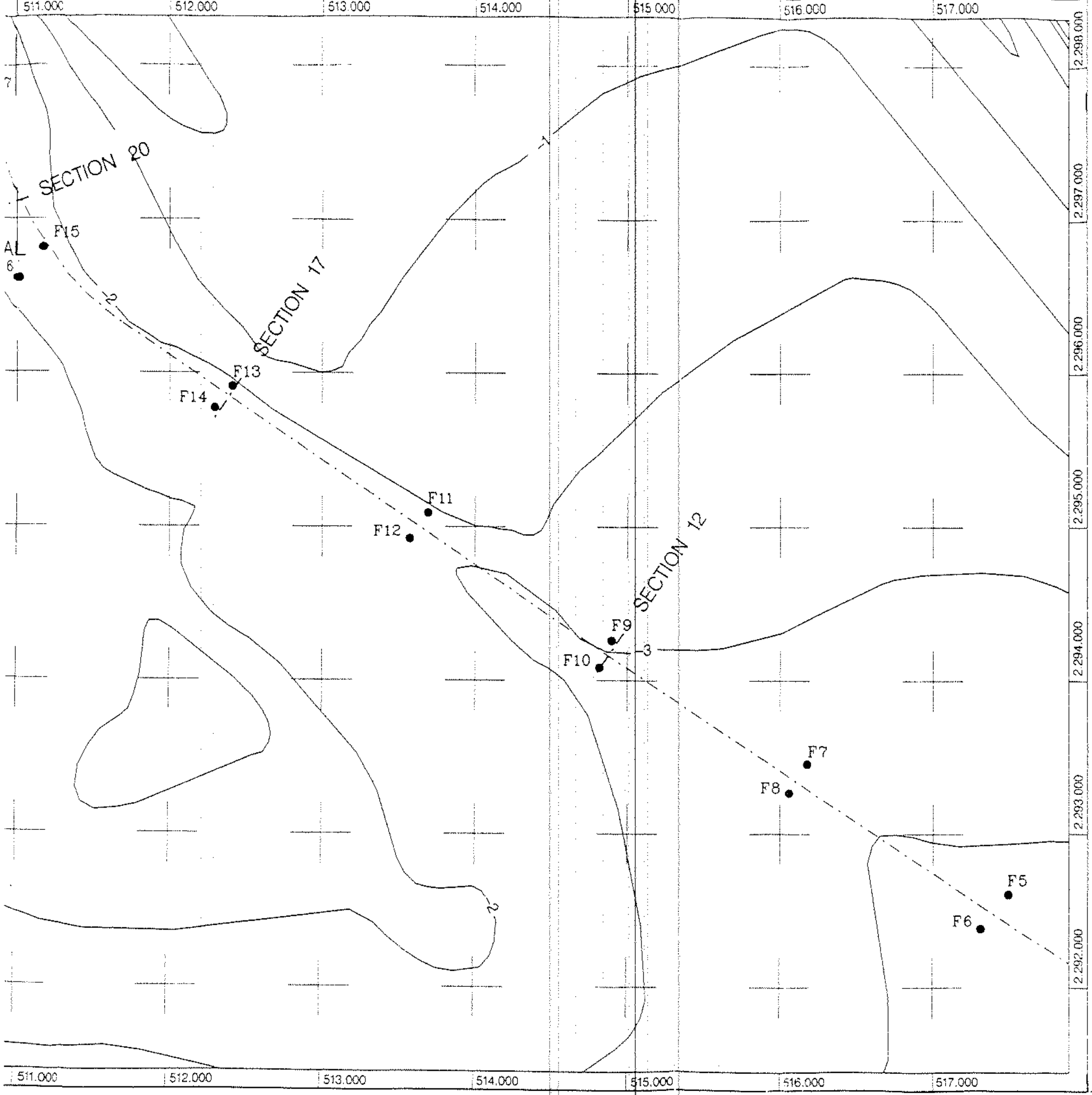
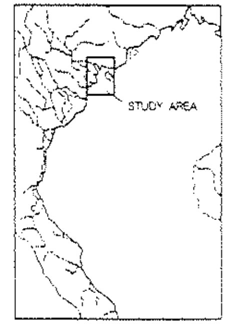
Access - Channel to Hai Phong

Tidal window and sailing window at spring tide (9/10-01-93) in Nam Trieu (Alt. 1) C.D. +1.70 m lightered 30,000 DWT ships



LEGEND

- Bathymetric lines (C.D = LLW /depth in meters) Survey 1995 (ref. TEDI)
- Bathymetric values (C.D. = LLW /depth in meters) Survey 1995 (ref. TEDI)
- Lighthouse
- Navigation Route
- Local coordinate grid (Gauss projection) Spheroid : Krazovski 1940



OVERVIEW MAP OF NORTH VIETNAM

SCALE

VIETNAM ACCESS CHANNEL TO HAI PHONG

MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation

File / Dossier / Nr No: VAH 1351

HAECON N.V. HARBOUR and ENGINEERING CONSULTANTS

OVERVIEW MAP
MONITORING OF SEABED LEVELS
IN THE NAM TRIEU CHANNEL

Drawn / Getekend / Dessiné: JRR	Checked / Nagezien / Contrôlé: BME	Approved / Goedgekeurd / Approuvé: BME
Date / Datum / Date: 13 - 03 - 1996	Scale / Schaal / Echelle: 1/25.000	Drawing / Tekening nr / Plan no: 34.20.002

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List of figures

Figure 4.2.10.(a) Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 1 : C.D. - 7.30 m channel

Figure 4.2.10.(b) Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 1 : C.D. - 7.30 m channel

Figure 4.2.11.(a) Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 1 : C.D. - 11.5 m channel

Figure 4.2.11.(b) Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 1 : C.D. - 11.5 m channel

Figure 4.2.12.(a) Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 2 : C.D. - 9.0 m channel

Figure 4.2.12.(b) Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 2 : C.D. - 9.0 m channel

Figure 4.2.13.(a) Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 3 : C.D. - 9.0 m channel

Figure 4.2.13.(b) Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 3 : C.D. - 9.0 m channel

Figure 4.2.14.(a) Hai Phong
Difference in magnitude of speed - Peak ebb
Alternative 4 : C.D. - 9.0 m channel

Figure 4.2.14.(b) Hai Phong
Difference in magnitude of speed - Peak flood
Alternative 4 : C.D. - 9.0 m channel

Figure 4.2.15.(a) Hai Phong
Difference in magnitude of speed - Peak ebb
Dinh Vu dam removed : C.D. - 2 m channel

Figure 4.2.15.(b) Hai Phong
Difference in magnitude of speed - Peak flood
Dinh Vu dam removed : C.D. - 2 m channel

A.III.3.2.2. Interpretation

The results are shown on maps 09.70.004 to 09.70.009, only the most relevant fractions being included in this report. Both the mud fractions and sand fractions show a fining to the WSW, resulting in the above mentioned WSW-transport directions (par. 3.1).

It appears that the sediments of the W-part of the Bay is enriched with :
a. fine sand (135 - 180 μ) ;
b. fine silt (2 - 10 μ).

The sediments of the E-part of the Bay are enriched with :
a. medium sand (180 - 250 μ) ;
b. coarse silt (> 20 μ).

A.III.4. CONCLUSIONS

The Sediment Trend Analysis (STA) study conducted on 85 seabed samples taken in Hai Phong Bay in the wet season of 1995 leads to the following conclusions/interpretations :

a. sediment regime is mainly governed by a redistribution of the sediment stock available in the shoals and bar system ;
b. residual sediment transport is mainly oriented from ENE to WSW and probably dominated by wave actions (typhoons, storms, ;..) ; tidal or discharge action is less important for sediment distribution ;
c. in the sheltered parts of Bach Dang and Lach Huyen, mud is transported in upstream directions ;
d. mud supply from offshore, probably by wave action, is occurring.

HAECON, 10-01-96

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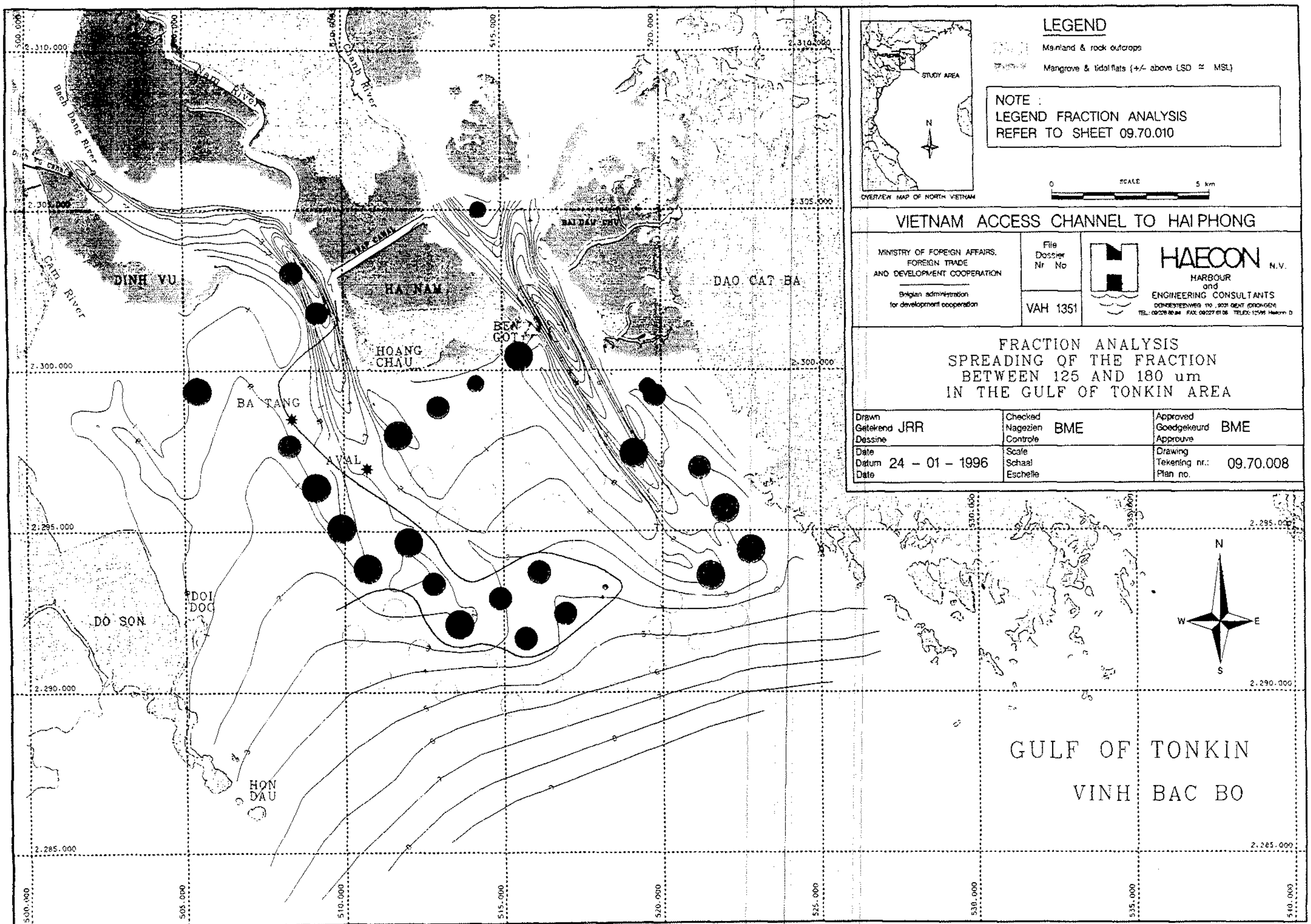
LEGEND
Mainland & rock outcrops
Mangrove & tidal flats (+/- above LSD ≈ MSL)
STUDY AREA
OVERVIEW MAP OF NORTH VIETNAM
N
NOTE :
LEGEND FRACTION ANALYSIS
REFER TO SHEET 09.70.010
SCALE
0
5 km
VIETNAM ACCESS CHANNEL TO HAI PHONG
MINISTRY OF FOREIGN AFFAIRS, FOREIGN TRADE AND DEVELOPMENT COOPERATION
Belgian administration for development cooperation
File Dossier Nr No
VAH 1351
HAECON N.V.
HARBOUR and ENGINEERING CONSULTANTS
FRACTION ANALYSIS
SPREADING OF THE FRACTION
BETWEEN 125 AND 180 um
IN THE GULF OF TONKIN AREA
Drawn Getekend Dessine JRR
Checked Nagezien Controle BME
Approved Goedgekeurd Approuve BME
Date Datum Date 24 - 01 - 1996
Scale Schaal Eschelle
Drawing Tekening nr.: Plan no. 09.70.008
Bach Dang River
Cam River
Lach Tray River
Chanh River
DINH VU
HAI NAM
BAI DAU CHU
DAO CAT BA
BEN GOT
HOANG CHAU
BA TANG
AVAL
DOI DOC
DO SON
HON DAU
GULF OF TONKIN
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2.310.000
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