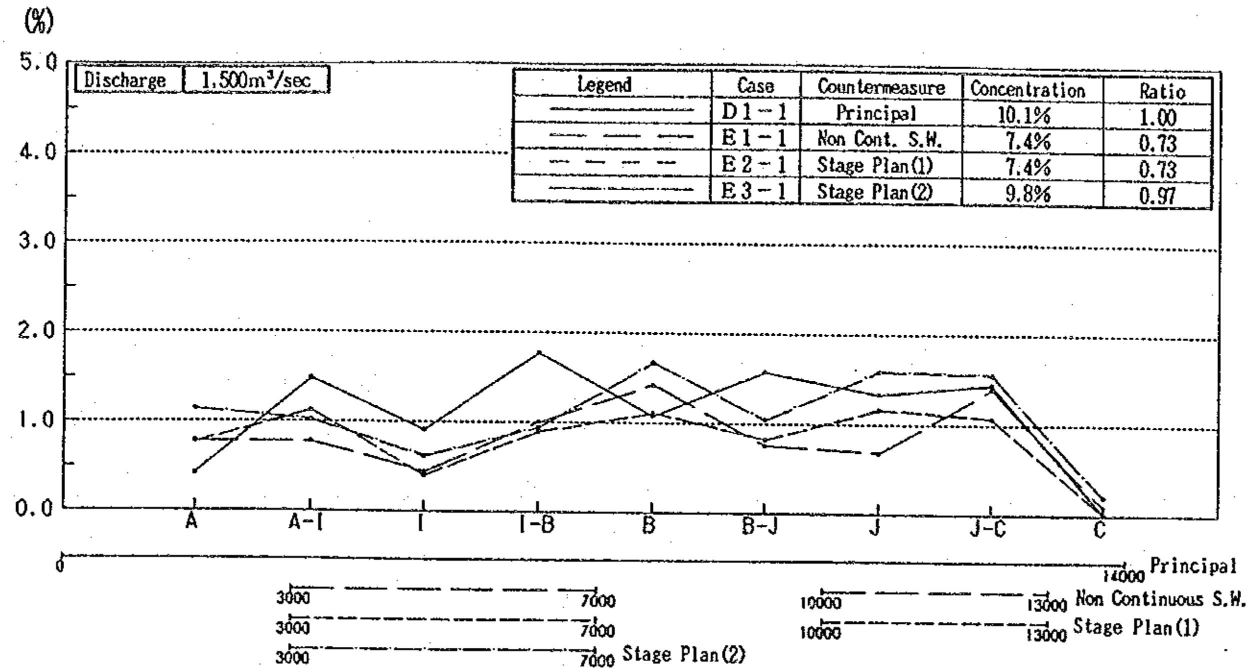


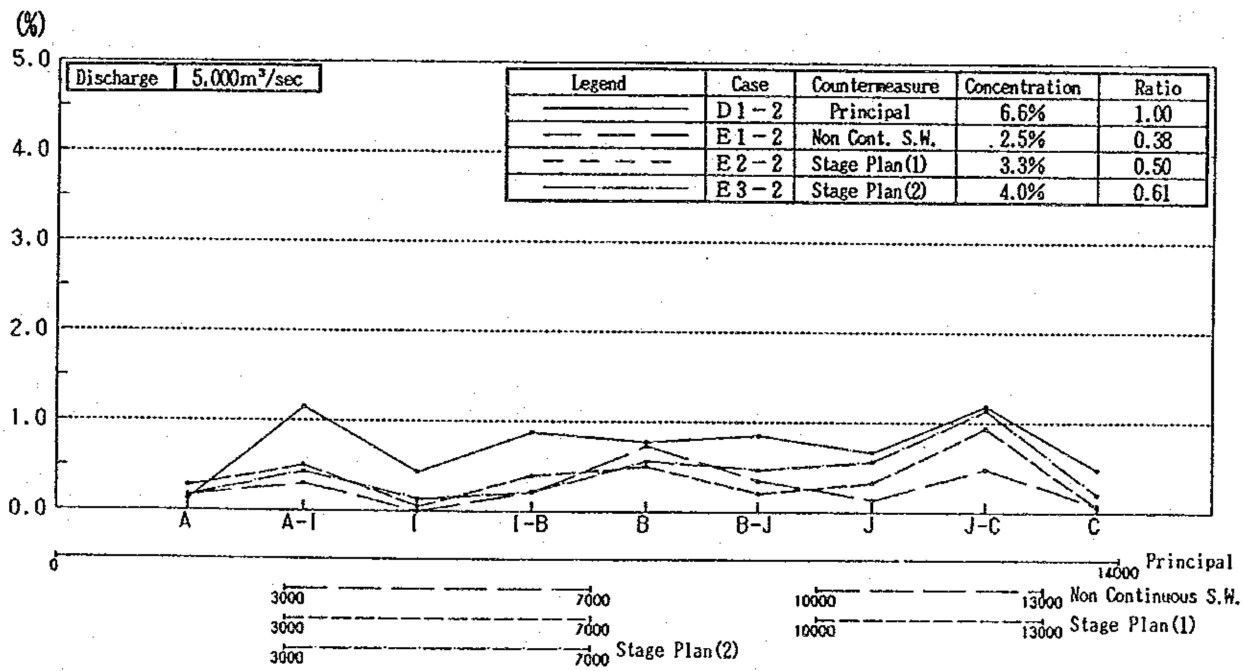
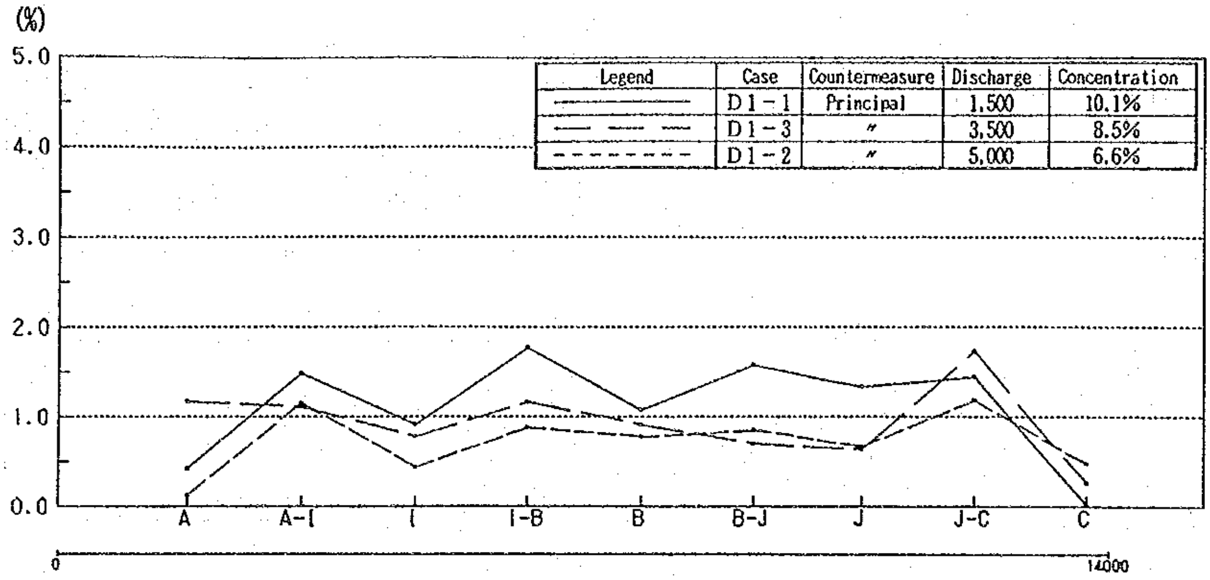


Fig. IV.1.4-15(6) Concentration of Tracer in the Bottom Layer of the Channel



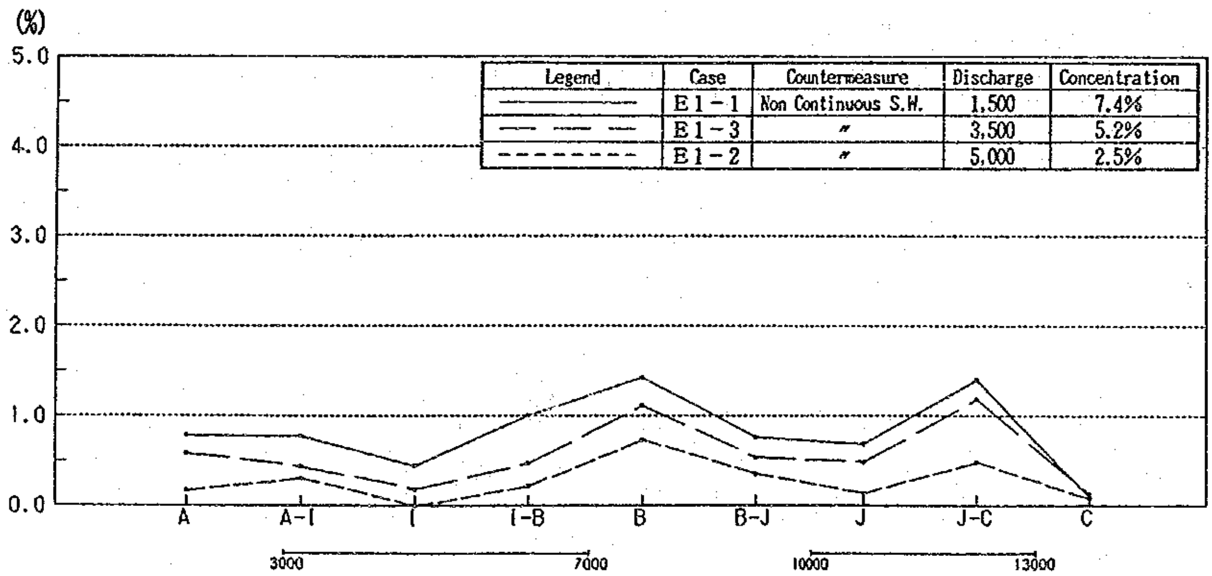


Fig. IV.1.4-15(7) Concentration of Tracer in the Bottom Layer of the Channel

1-5 Two Dimensional Hydraulic Model Test

1-5-1 Aims of Model Study

The aims of the 2-D hydraulic model test were to supplement the results of the 3-D tests and to obtain basic understanding of the phenomena taking the limitations in reproducing the field situation in the 2-D model into consideration. The aims can be summarized as follows.

Tracer tracking tests utilizing dyed saltwater of concentration higher than sea water were conducted in the 3-D hydraulic model tests in order to examine the effectiveness of a submerged wall in obstructing fluid mud and preventing it from flowing into the channel. The height of the submerged wall used in the 3-D model tests was 1cm. A distorted model with horizontal scale 1:1000 and vertical scale 1:100 was adopted in the 3-D model tests.

The 2-D hydraulic model tests using a undistorted model were carried out to observe the effectiveness of the submerged wall when the height of the wall was changed, and a comparison of the results between the undistorted and distorted model was made to observe if the distorted model would have any influence.

1-5-2 Test Facilities and Equipment

(1)Current Flume

Tests were performed using the current flume as shown in Fig. IV.1.5-1.

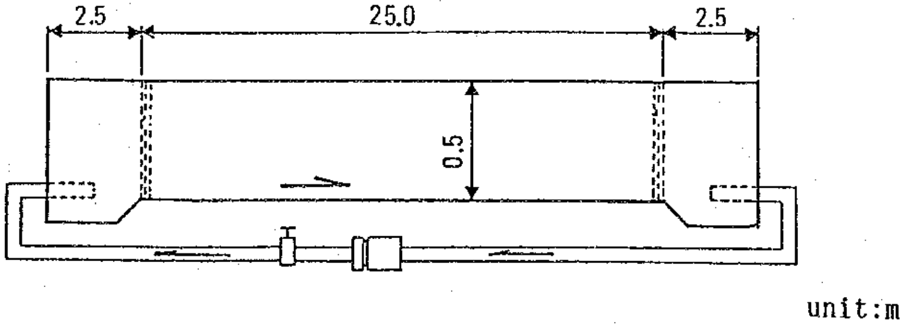


Fig. IV.1.5-1 Current Flume

(2)Model Scale

Undistorted : Horizontal and Vertical Scales 1:100

Distorted : Horizontal Scale 1:1,000, Vertical Scale 1:100

(3)Current Velocities Crossing the Channel

Model(cm/sec)	Prototype(m/sec)
3.0	0.3
5.0	0.5

(4)Model and Water Depth

The model details are shown in Fig. IV.1.5-2 together with the water depths.

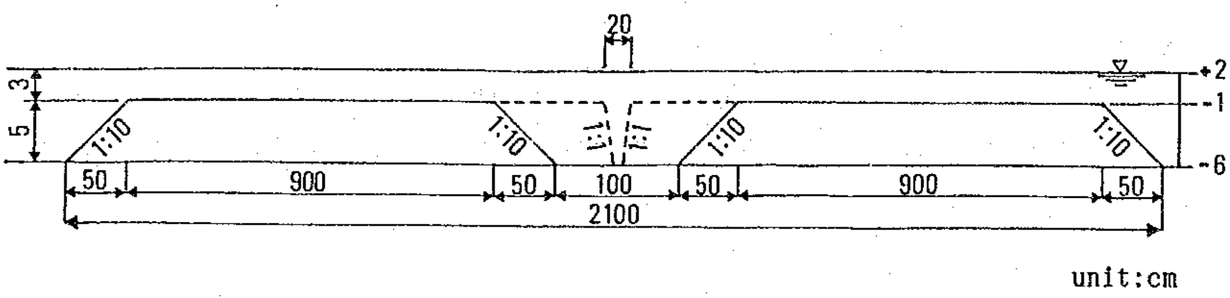


Fig. IV.1.5-2 Model

(5)Tracer Used in the Tests

A tracer utilizing saltwater dyed with Water Blue was used in the tests. The concentration of the tracer was 4% and 7%.

1-5-3 Test Cases

Test cases were as shown in Table IV.1.5-1.

Table IV.1.5-1 Test Cases

Case	Model	Tracer Concentration (%)	Current Velocity (cm/sec)	Dimentions of S.W. (cm)
A' - 1 ～ 3	Undistorted	4	3	Without S.W. ,1.0, 1.5
A - 1 ～ 3		7	3	〃
A - 4 ～ 6		7	5	〃
B' - 1 ～ 3	Distorted	4	3	〃
B - 1 ～ 3		7	3	〃
B - 4 ～ 6		7	5	〃

Note S.W.: Submerged Wall

1-5-4 Summary of Test Results

The concentrations of tracer held in the channel were observed and the findings are shown in Fig. IV.1.5-3 along with a comparison of the heights of the submerged walls. Concentrations observed were higher in the distorted model than in the undistorted. The submerged wall successfully blocked and diffused the tracer before it flowed into the access channel and the concentration of tracer in the channel was reduced in proportion to the wall height. The reduction rates of concentration regarding the changes in the submerged wall height showed little difference between the undistorted and distorted models.

In the case of the 3cm/sec cross current velocity, the 1.5cm height submerged wall reduced the concentration of tracer trapped in the channel to nearly zero when 4% tracer concentration was used. In the case of the tracer of 7% concentration, a significant deal of tracer was trapped.

In the case of the 5cm/sec cross current velocity, both the 1.0cm and 1.5cm height walls reduced the tracer concentration observed in the channel to nearly zero i.e. increased velocity resulted in increased effectiveness of submerged wall with regard to reduction of tracer concentration.

In the 3-D hydraulic model test, the results of the tracer tracking tests were evaluated by means of a relative comparison between the with and without submerged wall situations. The same approach was adopted for the 2-D model test as shown in Fig. IV.1.5-4. In the figure, the concentrations of tracer measured vertically are totaled for each test case. The concentration per unit width of the channel and those relative values based on the case of the submerged wall not in place are shown in the vertical axis as percentages. As the rates of tracer concentration reduced by the submerged wall showed little variation between the undistorted and distorted models, evaluation of the wall effectiveness in the distorted model was probably adequate as long as the relative comparison described previously was adopted between the with and without submerged wall situation. On the whole, the 1.5cm submerged wall remarkably reduced the tracer concentration accumulated in the dredged channel.

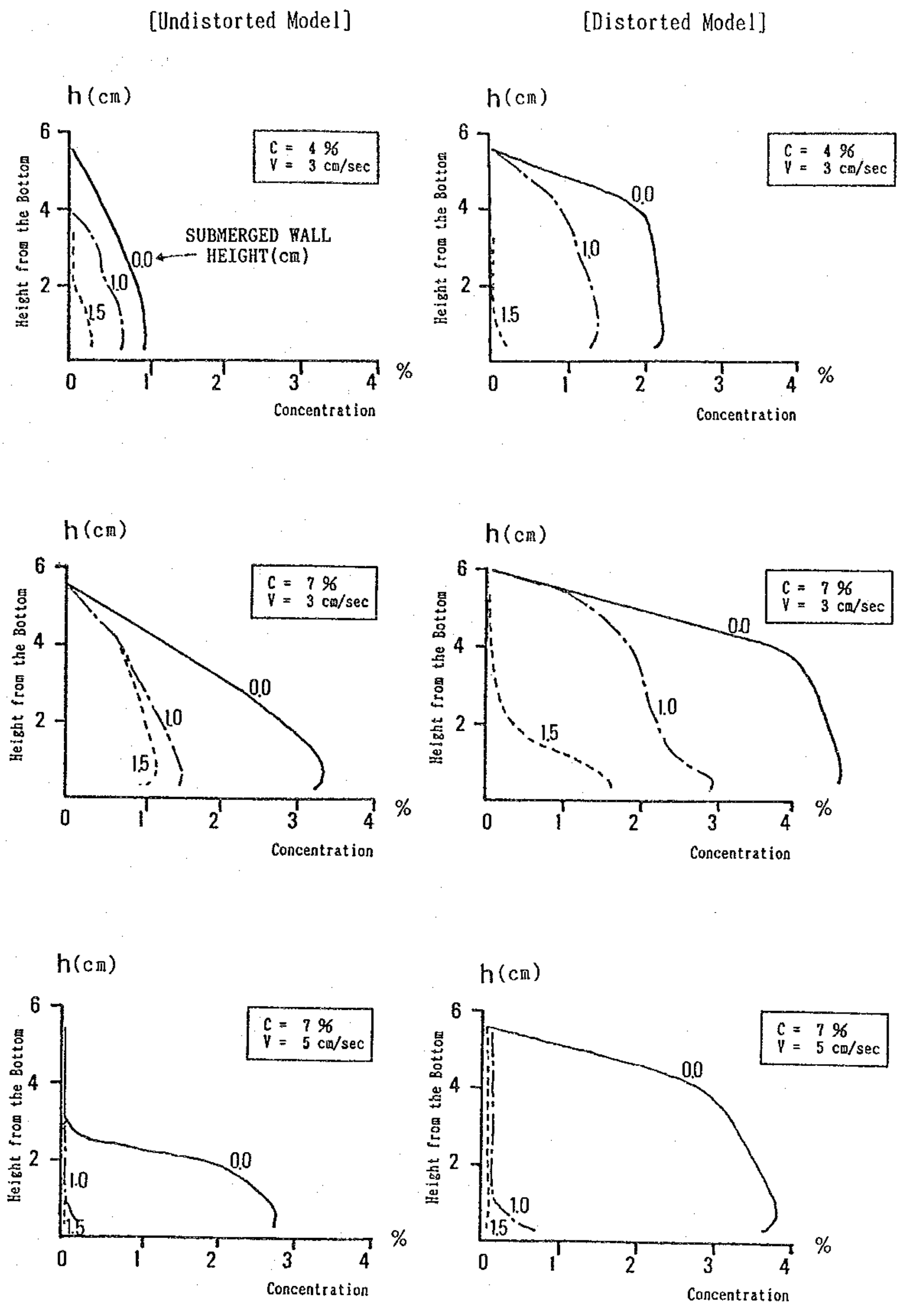


Fig. IV.1.5-3 Concentrations of Tracer in the Channel

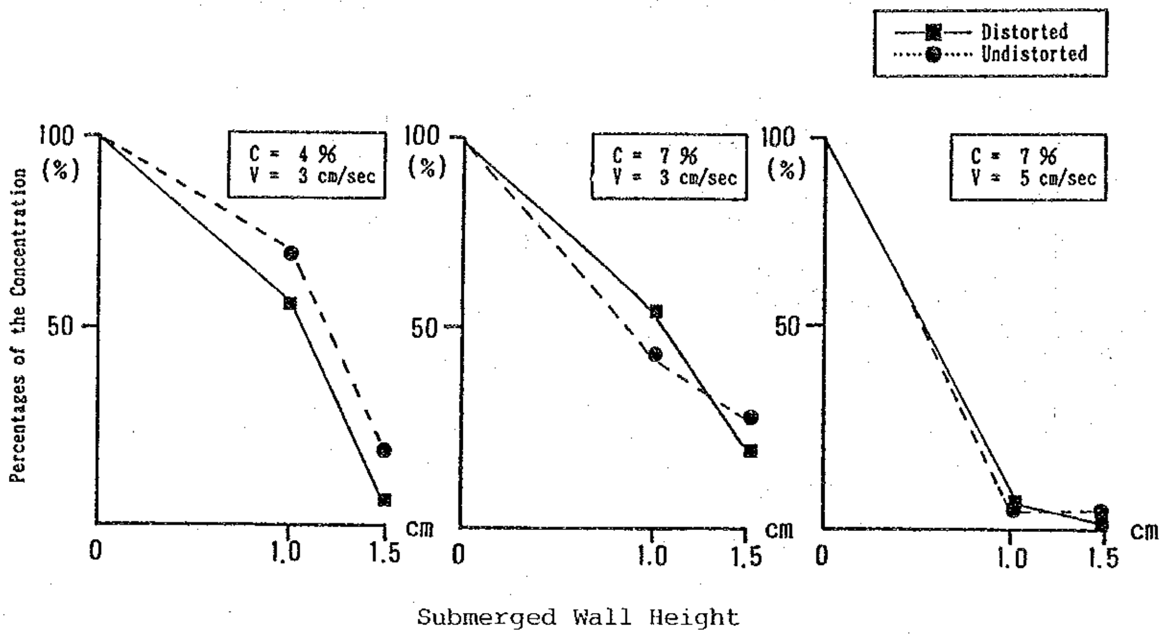


Fig. IV.1.5-4 Relative Concentration Based on the Without Submerged Wall Situation

Chapter 2 Laboratory Tests and Numerical Simulations

2-1 Purposes

The purposes of the laboratory tests of mud are to analyze physical characteristics and behavior of in-situ mud in the Banjarmasin Channel and to provide the numerical simulation model with information on important parameters to be employed.

The purposes of the numerical simulations of siltation are, through appropriate modeling of flow due to tides, waves, and river discharge; and sediment movements, including erosion, suspension, diffusion and settling to:

(1) Reproduce the present pattern of siltation, and
(2) Predict future siltation, taking account of the plans of countermeasure facilities.

2-2 Laboratory Tests of In-situ Mud

2-2-1 Test Items and Experimental Apparatus

The three following kinds of tests are carried out by the PHRI:

(1) Fluidity

This is to make clear the reological properties of natural muds at the site, or to examine the shear stress, τ, and the rate of deformation, D, in the form of:

$$\tau = \tau_y + \mu_B D, \qquad \cdots\cdots (1)$$

and to determine the yield stress, τ_y and the Bingham viscosity, μ_B.

This shear stress-shear rate relationship (flow curve) of the mud is obtained by using a viscometer owned by the PHRI which can create a laminar flow of a test fluid in the annular space between two concentric cylinders.

(2) Erosion and Deposition

On these subjects, the three following series of laboratory tests are carried out:

1) Erosion and Deposition of Cohesive Sediment by an Alternating Current

This is to understand the characteristics of erosion and deposition mechanism of cohesive sediments by tidal current.

2) Erosion Rate of Cohesive Sediment

This is to determine how the relationship among the erosion rate, E; water content of mud, W; the shear stress, τ; and critical shear stress, τ_e, acts on the bottom sediment, i.e.,

$$\tau_e = \alpha \cdot W^{\beta} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

$$E = M \cdot \left(\frac{\tau}{\tau_e} - 1 \right)^n \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (3)$$

where α, β, M, and n are empirical constants.

3) Deposition Behavior of Suspended Materials in Steady Flow Conditions

This experiment concerns the settling property of suspended materials in flowing water. Homogeneous initial concentration of suspended materials is provided for the test. After that the deposition tests are started under the prescribed shear stress on the bottom of the channel.

The above experiments are all done with an annular rotating channel in PHRH.

(3) Settling and Consolidation

1) Setting Behavior

In order to investigate the settling behavior of the bed materials, settling tests were carried out by using a large settling tube with a height of 2 m.

2) Consolidation Behavior

After the above steeling, the samples were tasted in terms of their consolidation speed.

2-2-2 Samples Tested

Bottom materials sampled at twelve stations on the bank are used for the fluidity tests. The amount of sampled mud is 1 liter for each station. At Spot No.11,000 in the access channel, an amout of 400 liters was sampled and the mud was used for the experiments of erosion, deposition and settling. The salinity of pore water of the mud is from 4 to 28 o/oo.

The grain distribution curve of Spot No.11,000 mud is shown in the Fig. IV.2.2-1. The texture of the mud is as follows; sand 18.5%, silt 36.5% and clay 45.0%. The liquid limit is 88.9% and the plastic limit is 38.7%.

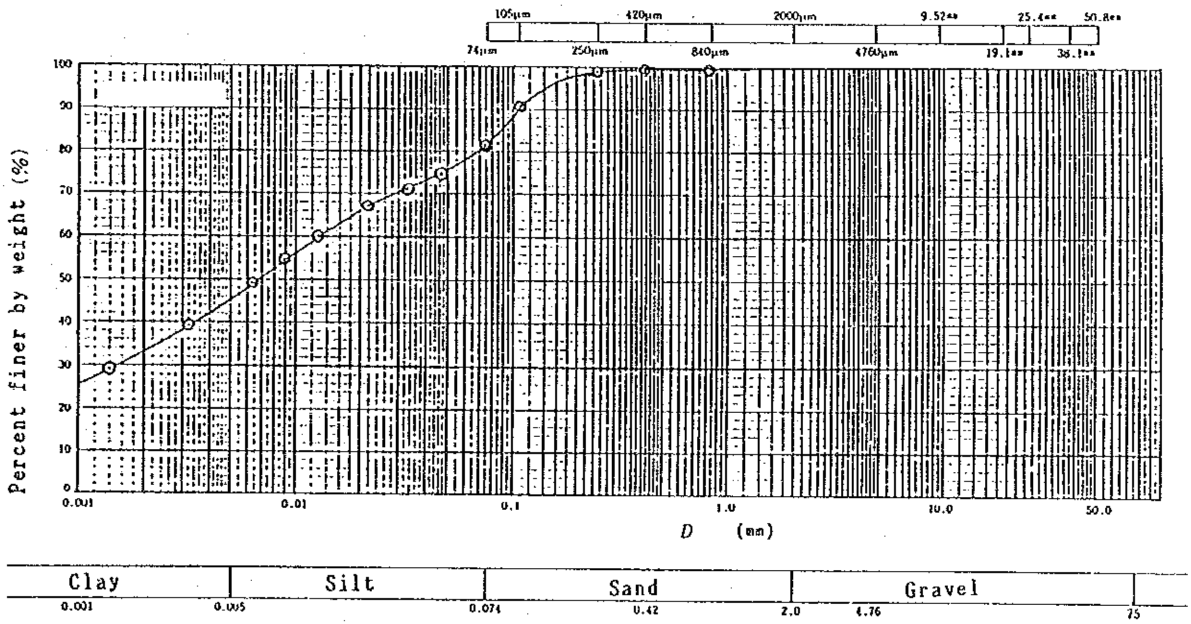


Fig. IV.2.2-1 Grain Distribution Curve

2-2-3 Results of Laboratory Tests

(1) Fluidity

Fig. IV.2.2-2 shows the relationship between the yield stress and the water content. Although the experimental values are very scattered, it can be recognized that the critical shear stress decreases almost exponentially with the increase of water content. The similar relationship between the Bingham viscosity and the water content is shown in Fig. IV.2.2-3.

(2) Erosion and Deposition

1) Erosion and Deposition by an Alternating Current.

A result is shown in Fig. IV.2.2-4 that the concentration of suspended materials in the channel increases positively with the bottom stress, and vice versa.

2) Erosion Rate

The relationship between the critical shear stress for erosion and water content of mud is shown in Fig. IV.2.2-5. It is known that the critical shear stress for erosion (τ_e) decreases the value inversely with the water content of mud(W).

The number of α and β in Eq.(2) are 4.0×10^4 Pa and -2.15 respectively.

As shown in Fig. IV.2.2-6, it is found that the erosion rate can be expressed by dimensionless bottom shear stress of Eq.(3), which means parameters M and n for each bottom materials are determined uniquely independent from the water content. The values of M and n estimated as an averaged value for the experimental cases are M = 0.27 mg/cm^2.sec and n = 1.0.

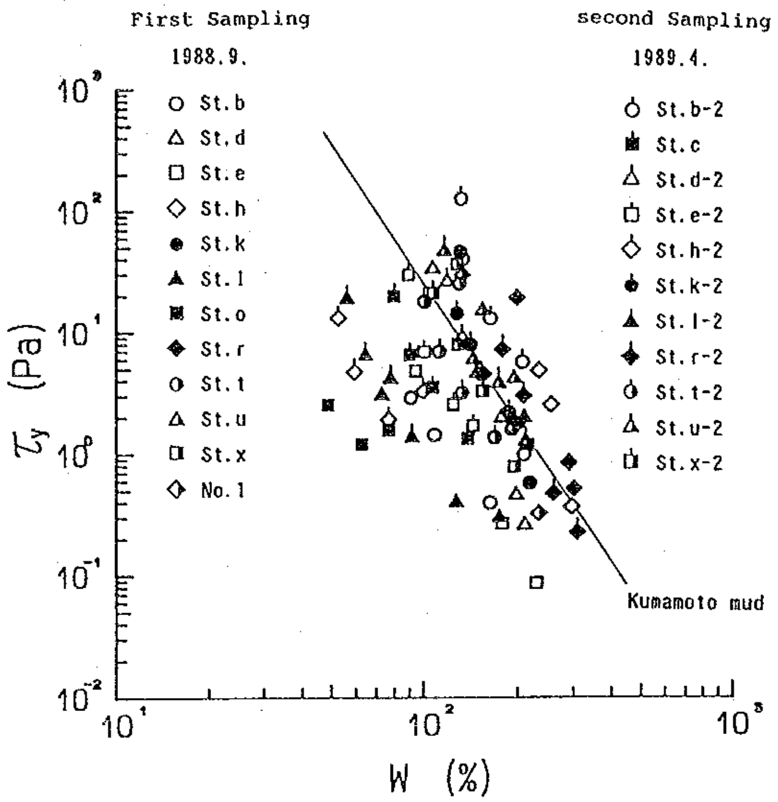


Fig. IV.2.2-2 Relationship between Critical Shear Stress τ_y and Water Content W

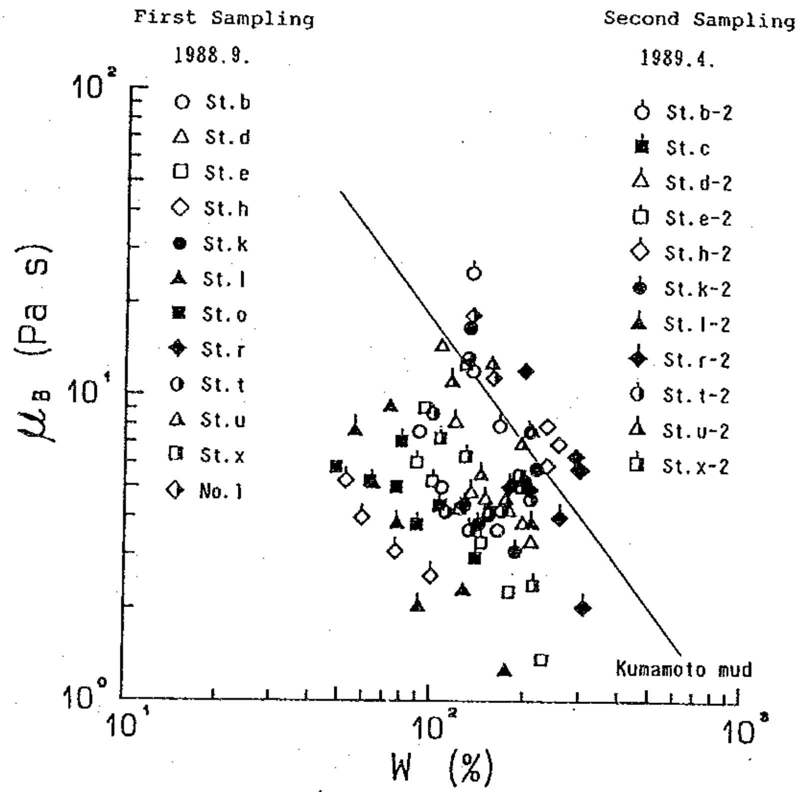


Fig. IV.2.2-3 Relationship between Bingham Viscosity μ_B and Water Content W

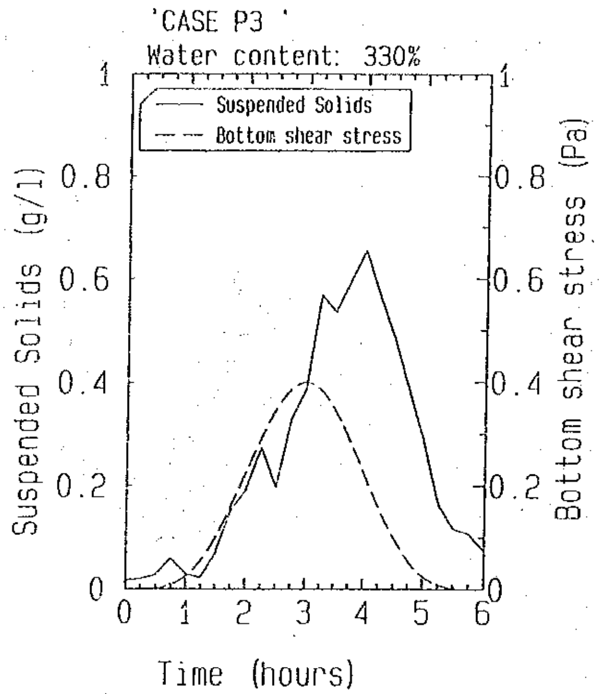


Fig. IV.2.2-4 Concentration of Suspended Materials

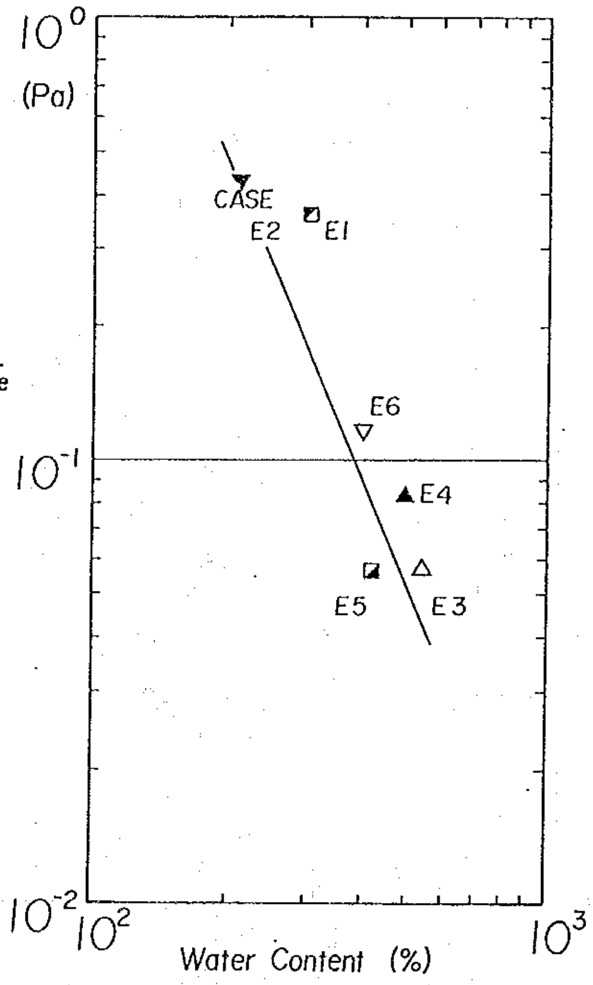


Fig. IV.2.2-5 Critical Shear Stress for Erosion Versus Water Content of Mud

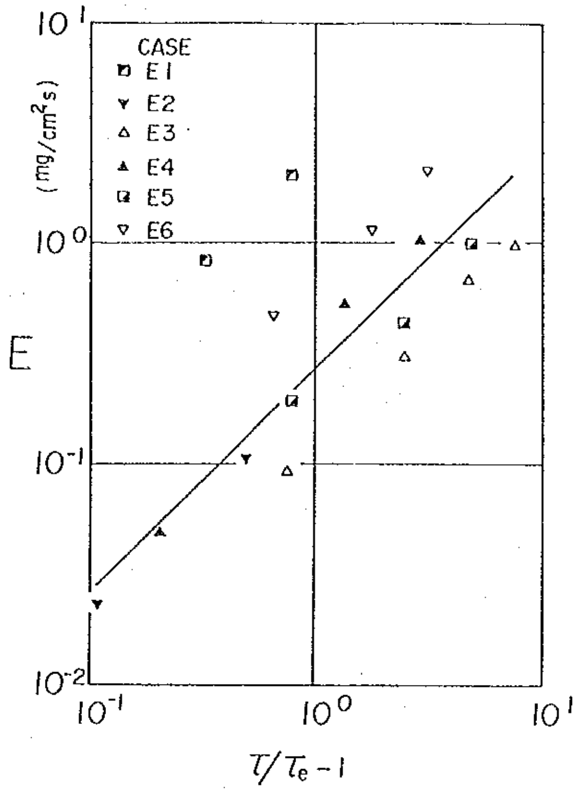


Fig. IV.2.2-6 Erosion Rate of Bottom Sediment versus Dimensionless Bottom Shear Stress

3) Deposition in Steady Flow

It became clear that the ratio of final to initial SS concentrations (dimensionless equilibrium concentration) C_∞/C_o decreases gradually as the bottom shear stress decreases from 0.4 Pa to 0.08 Pa. However, the value decreases rapidly when the bottom shear stress decreases to less than 0.08 Pa. From the result, the critical shear stress for deposition is estimated about 0.07 to 0.08 Pa. for Banjarmasin's bottom materials.

(3) Settling and Consolidation

1) Settling Behavior

Fig. IV.2.2-7 shows the relationship between the height of the interface which differentiates the upper clear water from the mud. The settling velocity can be obtained by taking the initial inclination of the curve which is rather fast and finishes within 10 hours. For the flocculated free settling, the settling velocity was calculated by measuring the distribution of the suspended sediment concentration with time.

Fig. IV.2.2-8 shows the relationship between the settling velocity and the suspended sediment concentration. In the figure, results of the flocculated free settling are plotted with open circles whereas those of the zone settling are plotted with closed circles. For comparison, the results of the Severn Estuary mud in the United Kingdom are shown by means of a solid line in the figure.

2) Consolidation Behavior

In order to investigate consolidation behavior of the Banjarmasin mud, two kinds of consolidation tests were carried out, i.e., the conventional consolidation test and a low-pressure consolidation test. Fig IV.2.2-9 shows the relationship between the coefficient of consolidation, c_v, and the average consolidation pressure, p, for normally consolidated region. In the Figure, results of the Tokyo Bay mud are also shown for comparison.

As shown in the Figure, the coefficient of consolidation of the Banjarmasin mud under low pressure is extremely smaller than that of the Tokyo Bay mud although the differences are almost negligible under high pressure. Because consolidation proceeds under very small pressure in siltation, the rate of consolidation of the Banjarmasin mud is far slower than that of the Tokyo Bay mud. This may be one of the reasons why we seldom suffer from siltation in Japan. The low value of c_v of the Banjarmasin mud may be attributed to the small water content because the permeability decreases with the water content.

According to the self-weight consolidation theory, the approximate time factors, T, corresponding to 50% and 90% consolidation degree are T_{50}=0.1 and T_{90}=1.0, respectively. Because the time factor T is equal to $C_v t/H^2$ where H is the drainage path, the rate of consolidation depends on the depth of fluid mud in siltation.

If we assume the depth of the fluid mud is 1m, the following results can be obtained based on the value of C_v=1cm²/day for Banjarmasin mud.

t_{50} (time when consolidation degree becomes to 50%) = 1,000 days
t_{90} (time when consolidation degree becomes to 90%) = 10,000 days

Because it takes approximately three years for consolidation degree to reach 50%, we cannot expect the consolidation progress in the siltation in Banjarmasin channel.

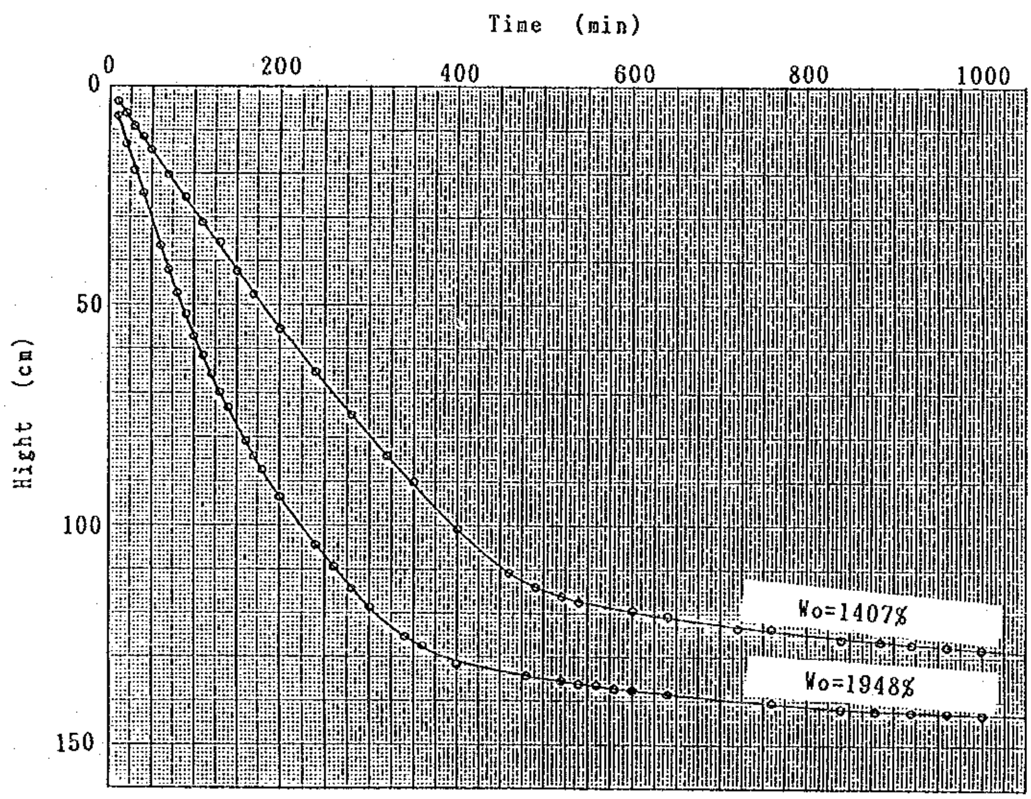


Fig. IV.2.2-7 Change of the Interface Height

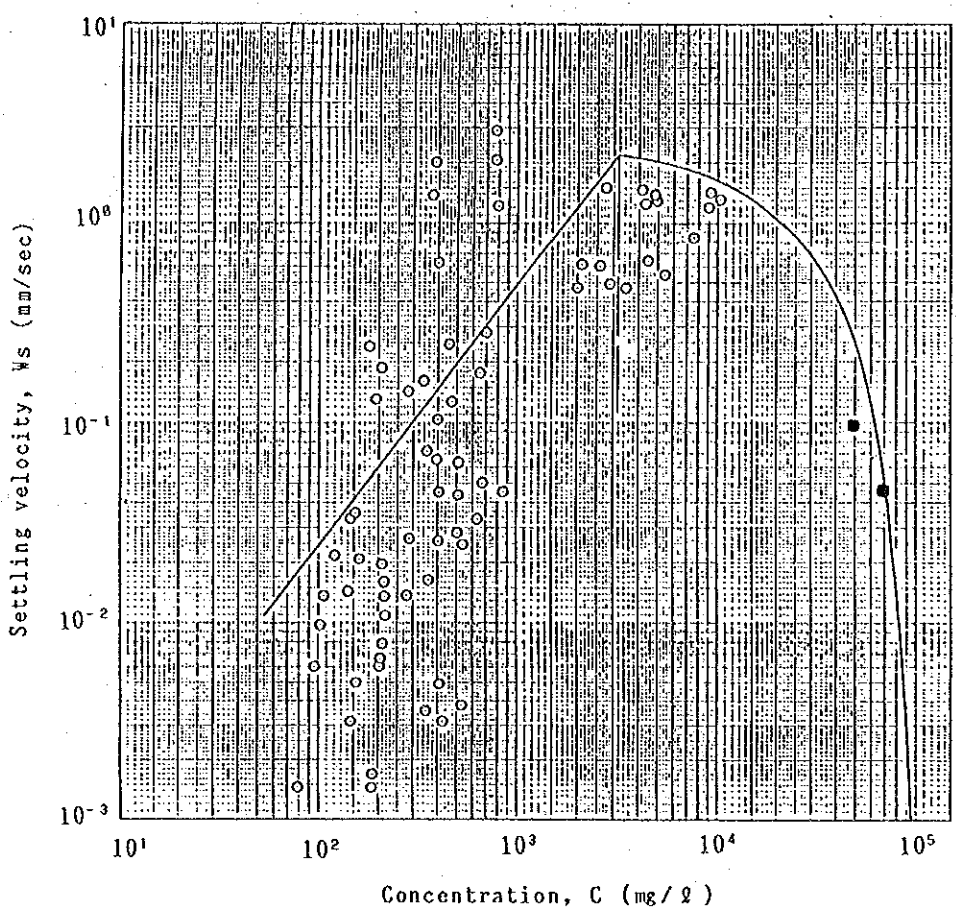


Fig. IV.2.2-8 Settling Velocity versus Concentration

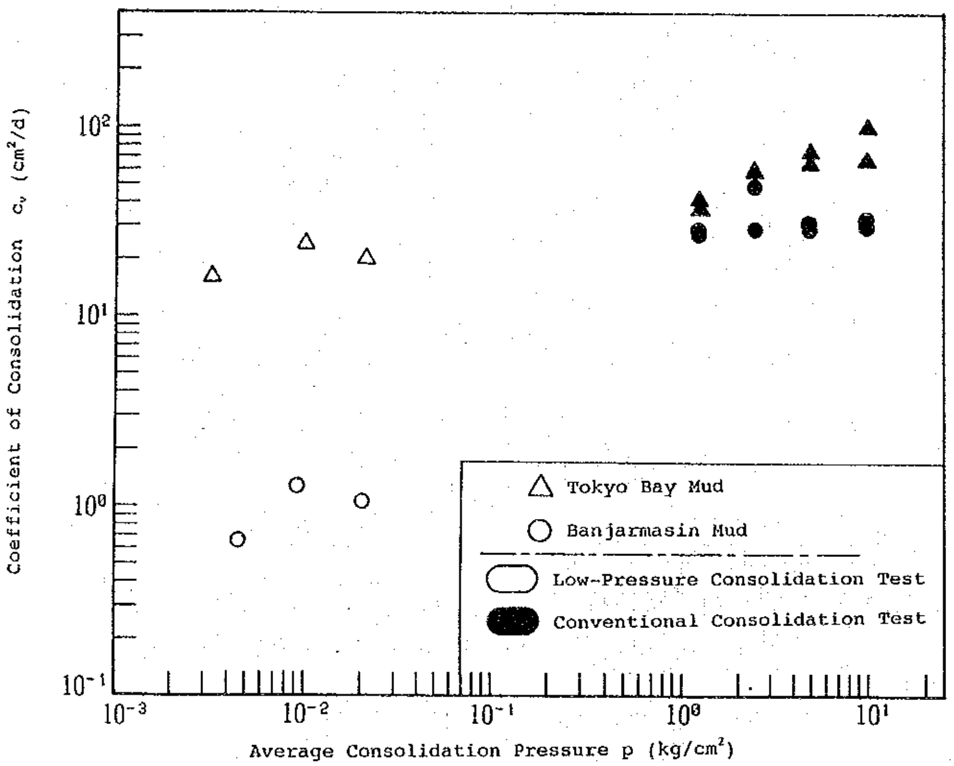


Fig. IV.2.2-9 Coefficient of Consolidation versus Consolidation Pressure

2-3 Numerical Model and Test Cases

2-3-1 Model Structure

The main external forces governing the mud movement and transport are tidal and wave-induced currents and waves. As the coastal area around the Barito River mouth consists of a wide shoal of soft mud, it is very important to predict the tidal and wave fields to estimate the mud transport accurately. The present model can deal with the movement of the coastline in a very shallow beach.

An aggregate flow chart of the siltation model is given in Fig.IV.2.3-1. The program is mainly divided into three parts. The tidal current model is a three-dimensional level model (Fig.IV.2.3-2). This consists of the Nested Grid Model which can treat the composite arrangement of rough and fine meshes. The wave deformation model includes the wave refraction, diffraction, shearing and the interaction between surface waves and the mud bed. Finally the total amount of deposition within each mesh is estimated from the calculated results of erosion and deposition.

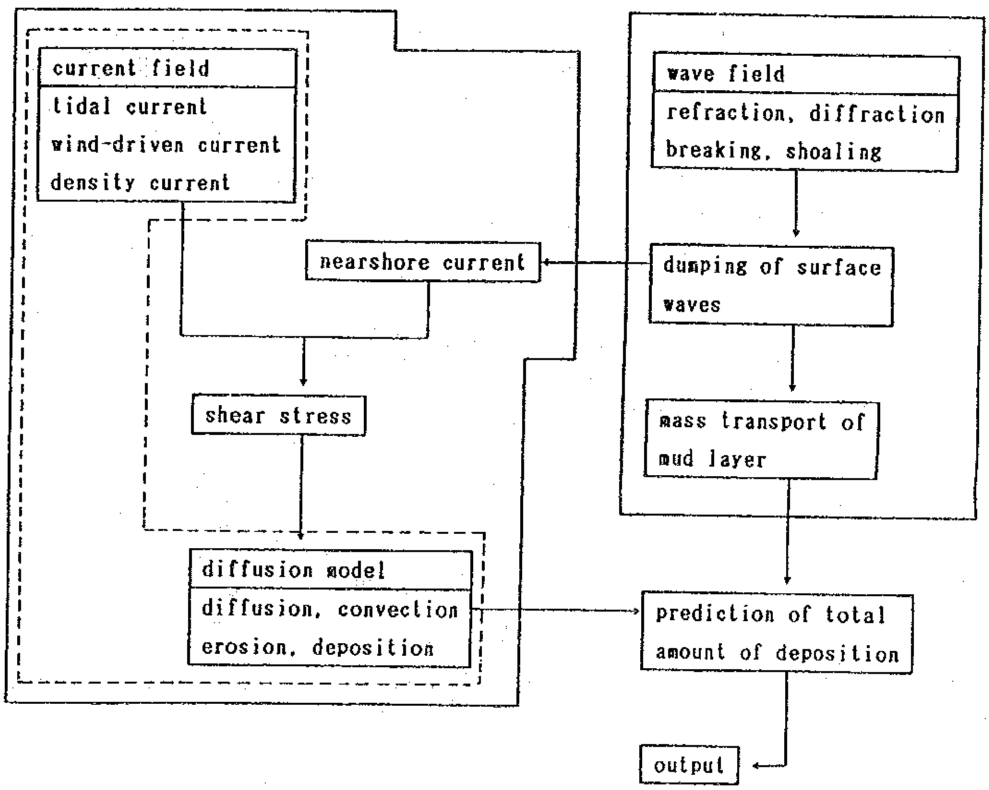


Fig. IV.2.3-1 Aggregate Flow Chart of Siltation Model

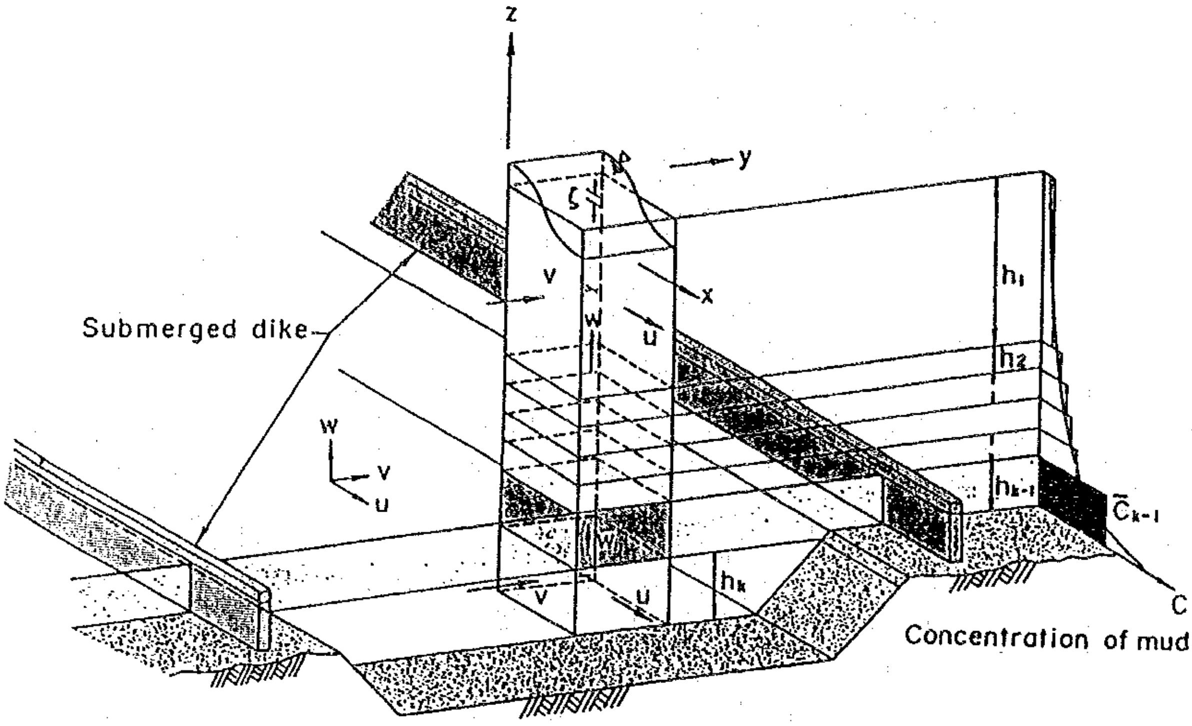


Fig. IV.2.3-2 Tree-dimensional Level Model

This program also includes the calculation of wind driven current and nearshore current. The nearshore current is calculated from the distribution of radiation stresses induced by waves. The program of tidal currents and diffusion on the shoal consists of (1) continuity equations, (2) equations of motion, and (3) mass conservation equations of salinity and suspended solids.

The contour map within the area of calculation is reflected to the depth at each rectangular mesh which is adopted in the present model and is expressed in Fig.IV.2.3-3.

Fig.IV.2.3-4 shows the vertical partition of the horizontal layer.

2-3-2 Numerical Constants Used in the Simulations

For the calculation of tidal currents, the following numbers are employed:

a. Mesh size

Large area: 270m x 2,700m

Intermediate area: 90m x 900m

Channel area: 30m x 300m

b. Horizontal eddy viscosity (cm^2/sec)

1) x direction (A_x)

Large area: 80,000

Intermediate area: 19,000

Channel area: 4,400

2) y direction (A_y)

Large area: 1,800,000

Intermediate area: 410,000

Channel area: 100,000

c. Friction coefficient

Middle layers (γi^2): 0.001

Bottom layer (γb^2): $gn^2/h^{1/3}$

d. Manning's roughness coefficient (n): 0.02 (MKS unit)

e. Time step (Δt): 1.5 sec.

For the calculation of diffusion, the following numbers are introduced:

a. Horizontal diffusion coefficient (cm^2/sec)

1) x direction (K_x)

Large area: 80,000

Intermediate area: 19,000

Channel area: 4,400

2) y direction (K_y)

Large area: 1,800,000

Intermediate area: 410,000

Channel area: 100,000

b. Vertical diffusion coefficient (K_z): 1.0 cm^2/sec.

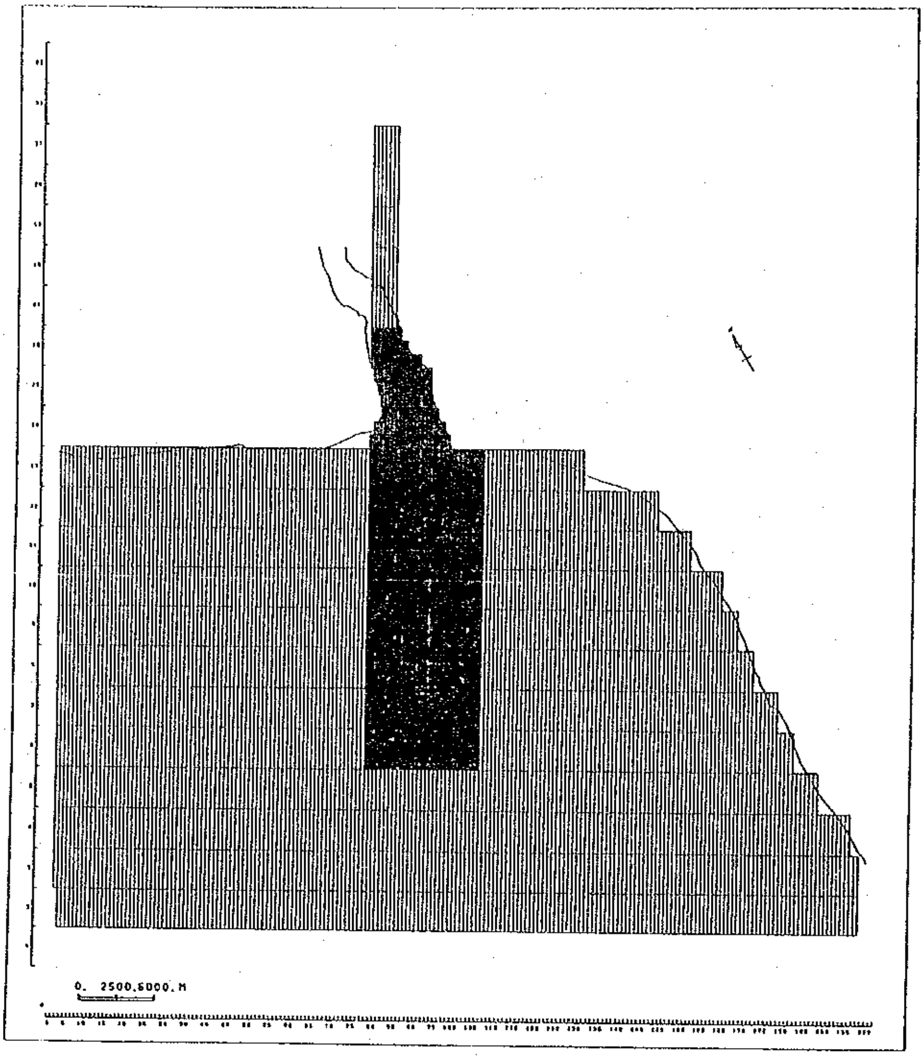


Fig. IV.2.3-3 Mesh Map around the River Mouth

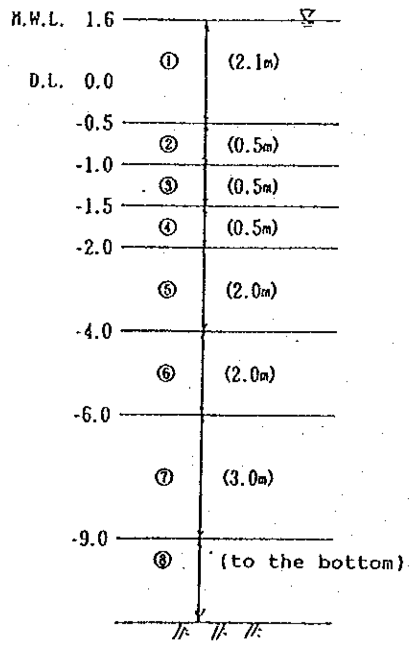


Fig. IV.2.3-4 Partition of Horizontal Layer

c. Settling velocity of sediments (w_s)

1) Sands (Rubey's Formula): 2.5 cm/sec.

2) Muds (Function of concentration, C)

$w_s = A \times C^B$ for $C \leqq C_H$

$= 2.6 \times 10^{-1}$ cm/sec for $C > C_H$

where $C_H = 4.3$kg/cm^3, $A = 0.6 \times 10^{-3}$ m^4/kg/sec and $B = 1$.

d. Constants for mud erosion rate (E)

$E = M\ (\tau/\tau_e - 1)$

where $M = 0.02$ kg/m^2/min.

$\tau_e = 0.3$ Pa for erosion depth < 1cm,

0.6 Pa > 1cm, and

1.0 Pa > 2cm on the bank, and

= 0.6 Pa in the river.

e. Time step (Δt) : 15 sec.

2-3-3 Test Cases

Simulations were made for the cases shown in Table IV.2.3-1. They are selected from the alternative plans as minimum requirements for assessment.

Wave conditions were given through refraction analyses based on observations at the site. For the calculation of the present conditions, the wave direction from SW was employed as the average from March to May 1989. The average wave height and period were 41cm and 3.5 sec., respectively. For the other simulations, the wave height and period were 58cm and 4.0 sec. in the rainy season, and 43cm and 3.5 sec. for the dry season.

Tidal level and river discharge for the present conditions are as shown in Fig.IV.2.3-5.

The density of suspended solids supplied from the river were 30, 50, 60mg/l respectively for the discharges of 1,500 (dry season), 3,500 (present conditions) and 5,000 (rainy season) m^3/sec.

Table IV.2.3-1 Cases of Numerical Simulations

Case No.	Classification	River Discharge (m3/sec)	Channel Depth and Width	Layout	Crown Height
I-1 I-2 I-3	Present Condition	3,500 5,000 1,500	-6m 60m	- - -	- - -
II-1 II-2	Principal Plan	5,000 1,500	-6m 100m	- -	- -
III	Submerged Wall (1)	5,000	-6m 100m	Sp. 3,000 -9,000	1m ab. sea bed
IV	Submerged Wall (2)	5,000	-6m 100m	Sp. 2,000 -10,500	1m ab. sea bed
V	Submerged Wall (3)	5,000	-6m 100m	Sp. 2,000 -13,000	1m ab. sea bed
VI-1 VI-2	Submerged Wall (4)	5,000 1,500	-6m 100m	Sp. 2,000 -13,000	1.5m ab. sea bed
VII	Training Wall +Subm. Wall	5,000	-6m 100m	Sp. 2,000 -13,000	HWL+1m 1m ab.s.b.
VIII	Trap	5,000	-6m 180m	Sp. 4,000 -13,500	-
IX	Expansion Plan	5,000	-8m 120m	- -	- -
X-1 X-2	New N-S Alignment	5,000 1,500	-6m 100m	- -	- -
XI-1 XI-2 XI-3	Present Con. + submerged Wall (4)	3,500 5,000 1,500	-6m 60m	Sp. 2,000 -13,000	1.5m ab. sea bed
XII-1 XII-2	Non-contin. Subm. Wall	5,000 1,500	-6m 100m	Sp. 2,000 -6,000 Sp.10,000 -13,000	1.5m ab. sea bed

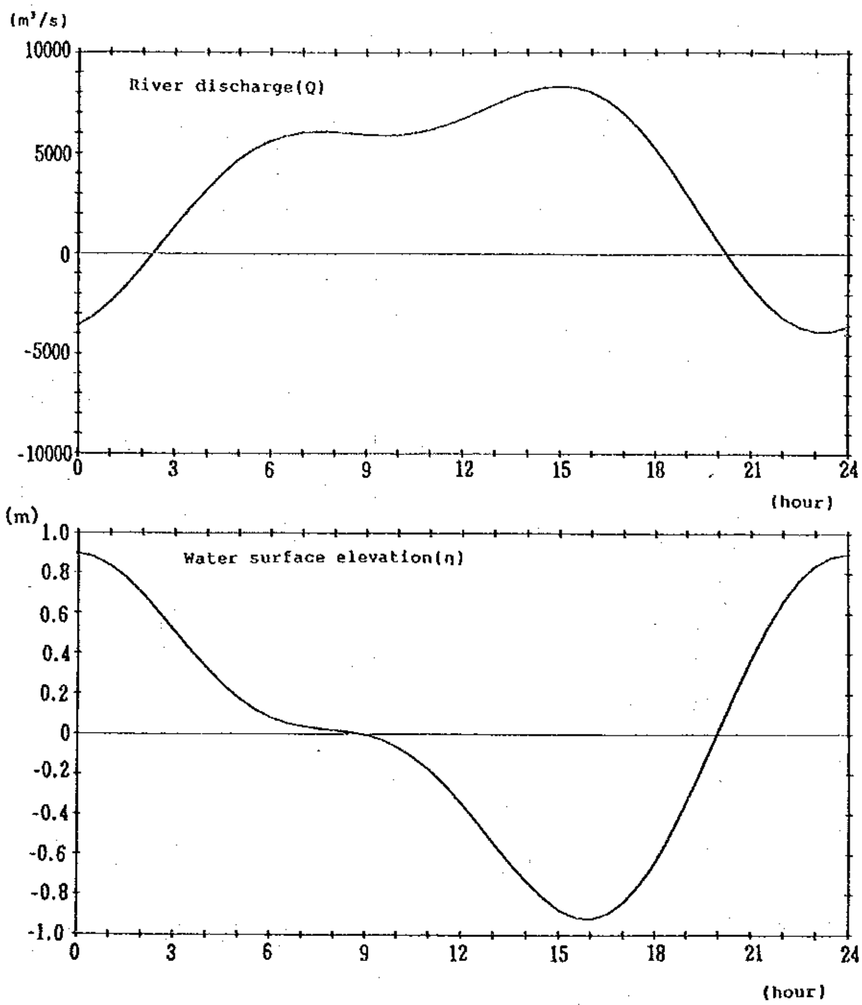


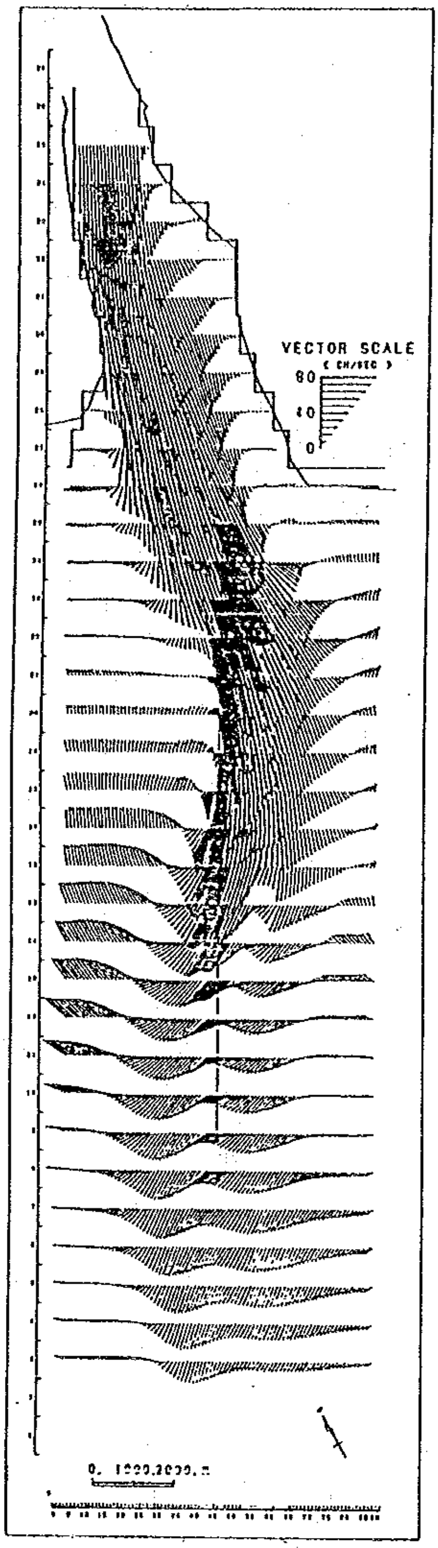
Fig. IV.2.3-5 Time Variation of River Discharge and Water Surface Elevation at the Pilot Station

2-4 Results of Reproduction of Present Conditions

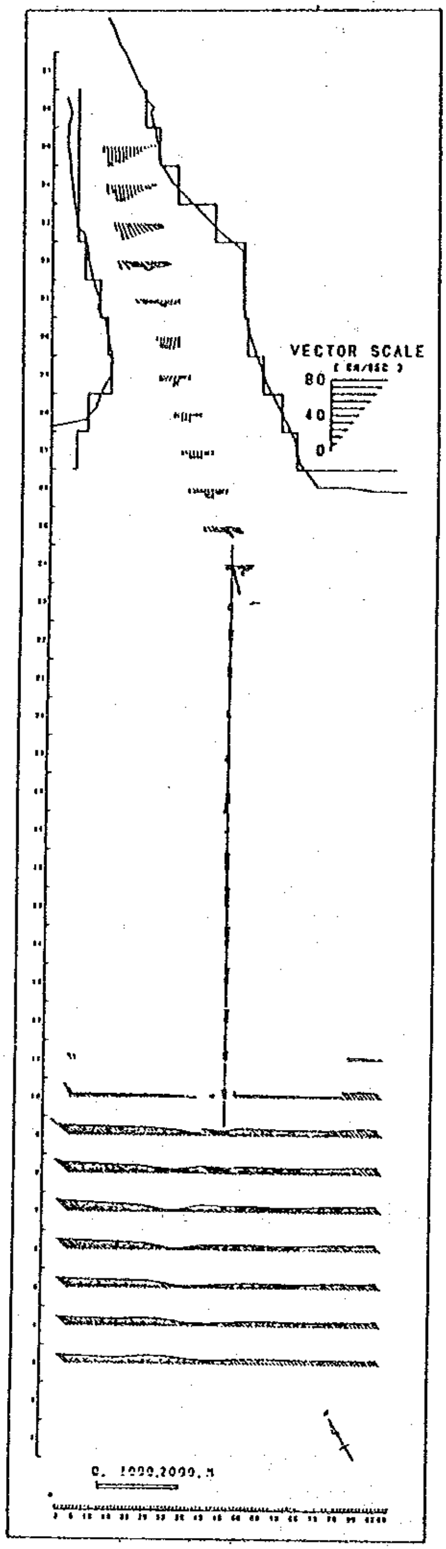
2-4-1 Flow Pattern

Current vector distribution diagrams by layer are presented for magnified area around the channel in Fig. IV.2.4-1(1) and (2). One is at 1800 or ebb current and the other is at 2400 or flood current.

The distributions in general can be understood that the reproduction of currents in the numerical model is quite well in terms of S-shape bend of the center of ebb currents.

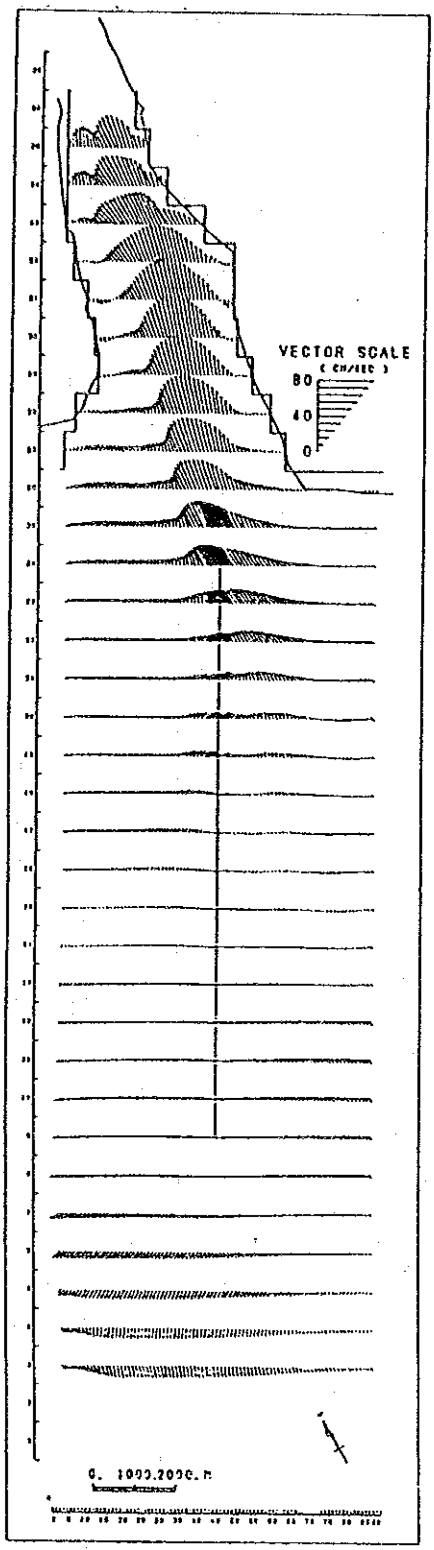


1st Layer

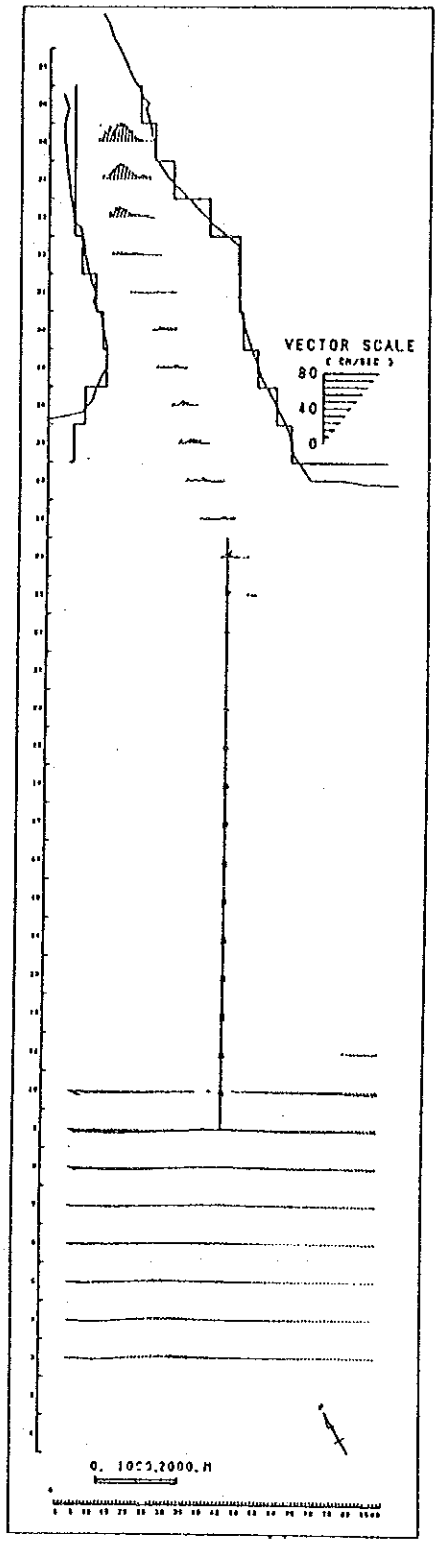


6th Layer

Fig. IV.2.4-1(1) Current Vector Distribution
(at 1800, Average Discharge 3,500m^3/sec)



1st Layer



6th Layer

Fig. IV.2.4-1(2) Current Vector Distribution
(at 2400, Average Discharge 3,500m^3/sec)

2-4-2 Tidal Ellipse

The similarity of tidal ellipses between observed and simulated ones is checked at the locations shown in Fig. IV.2.4-2.

The results of the simulation are shown in Fig. IV.2.4-3(1) and (2) in comparison with those obtained from the site observation. Their correspondence is fairly good, although the roundishness of ellipses was not enough at some stations, such as Sts. 3, 8 and 9.

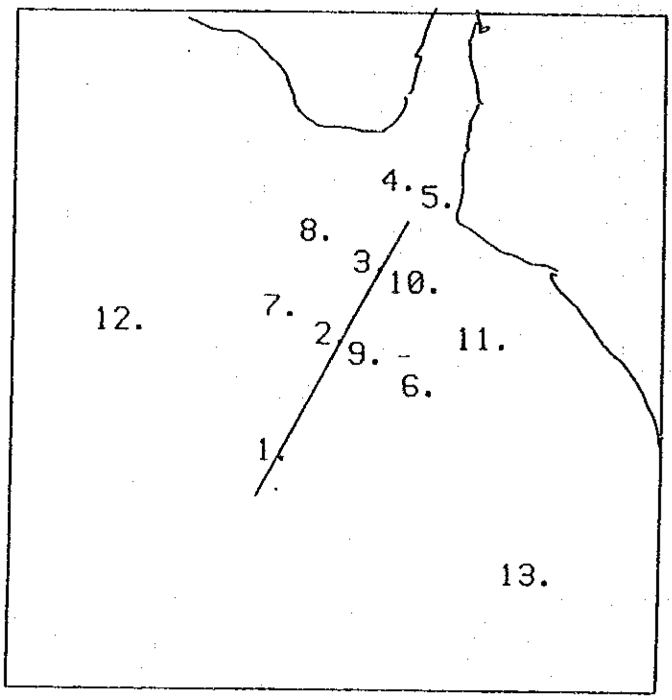


Fig. IV.2.4-2 Stations for Checking Tidal Ellipses

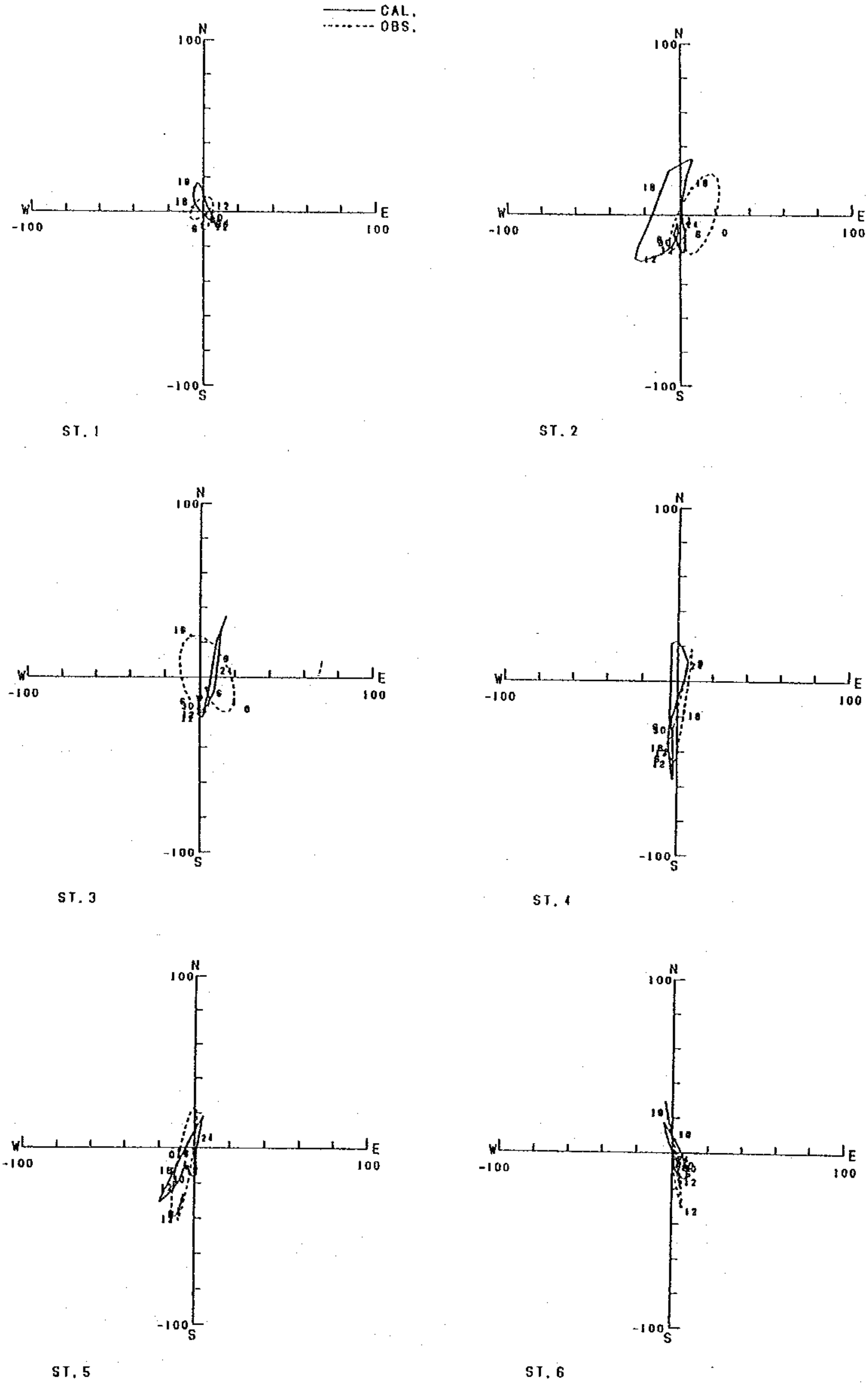


Fig. IV.2.4-3(1) Comparison of Tidal Ellipses

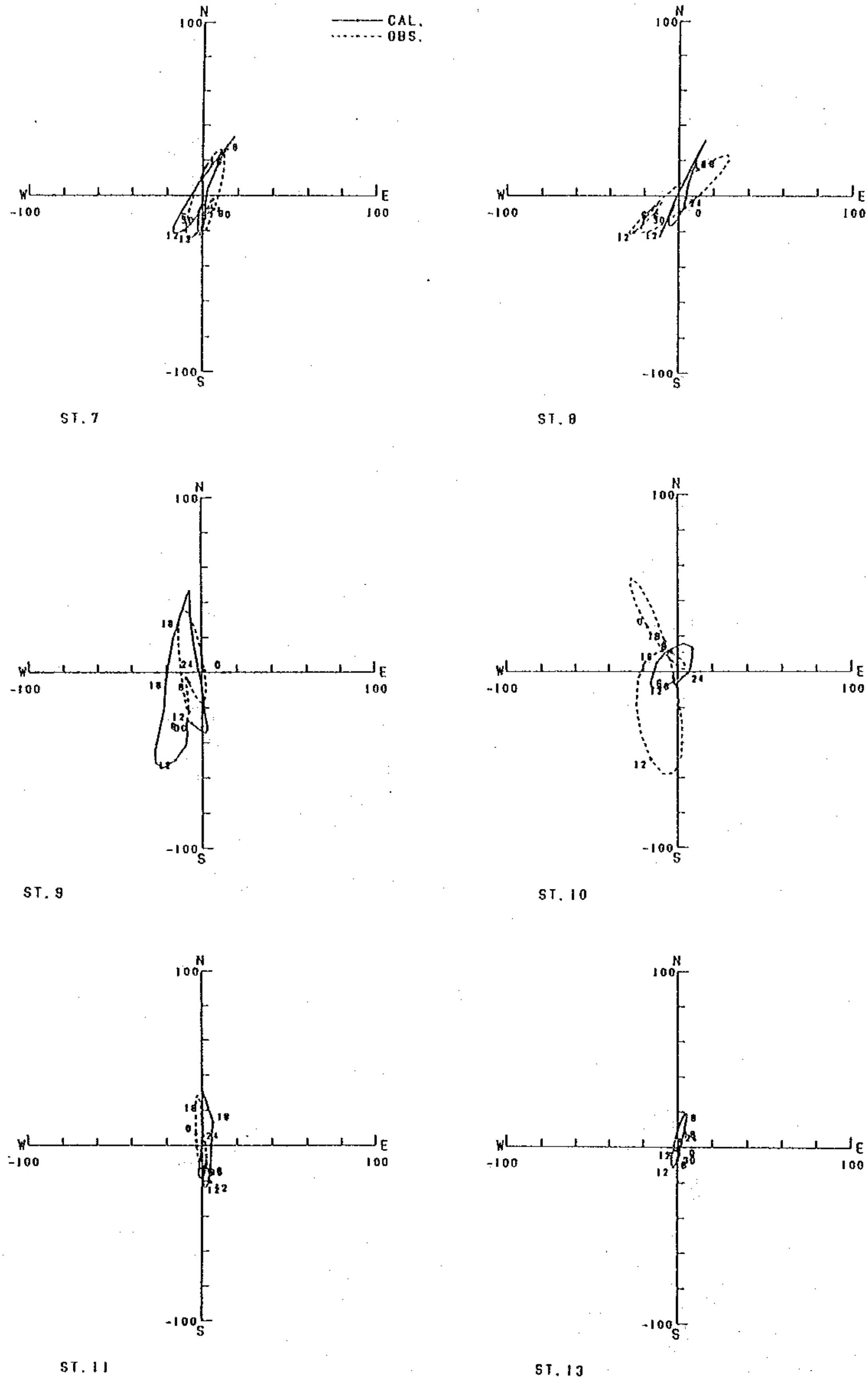


Fig. IV.2.4-3(2) Comparison of Tidal Ellipses (May 1989)

2-4-3 Siltation

Siltation volume in the channel under the present conditions for 85 days from March to May 1989 is calculated with 300 meters length interval and 100 meters width of the channel. The result is compared with the observed actual siltation volume and shown in Fig.IV.2.4-4.

Their distribution pattern agrees quite well each other. Among others, we can understand that simulation has been successful in reproducing some characteristic siltation phenomena, including appearance of a peak between Sp. No.11,000 and 12,000, a second peak behind it, and wide massive accumulation in the area further downstream.

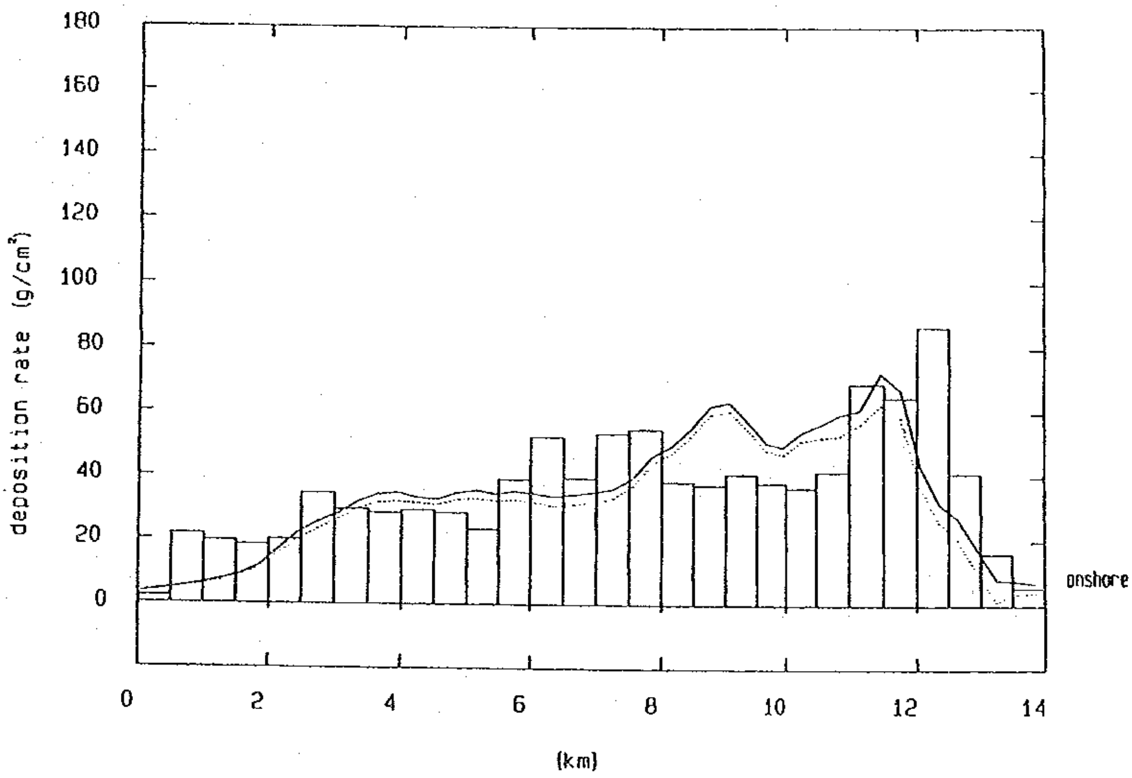
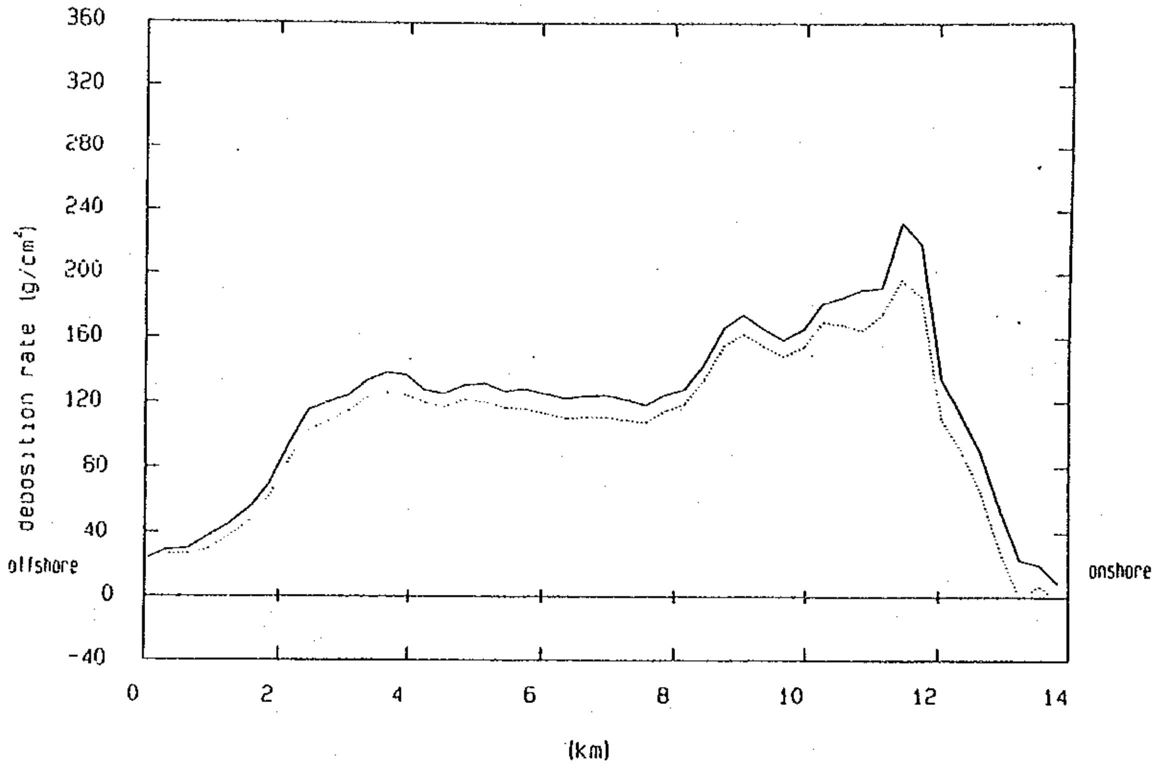


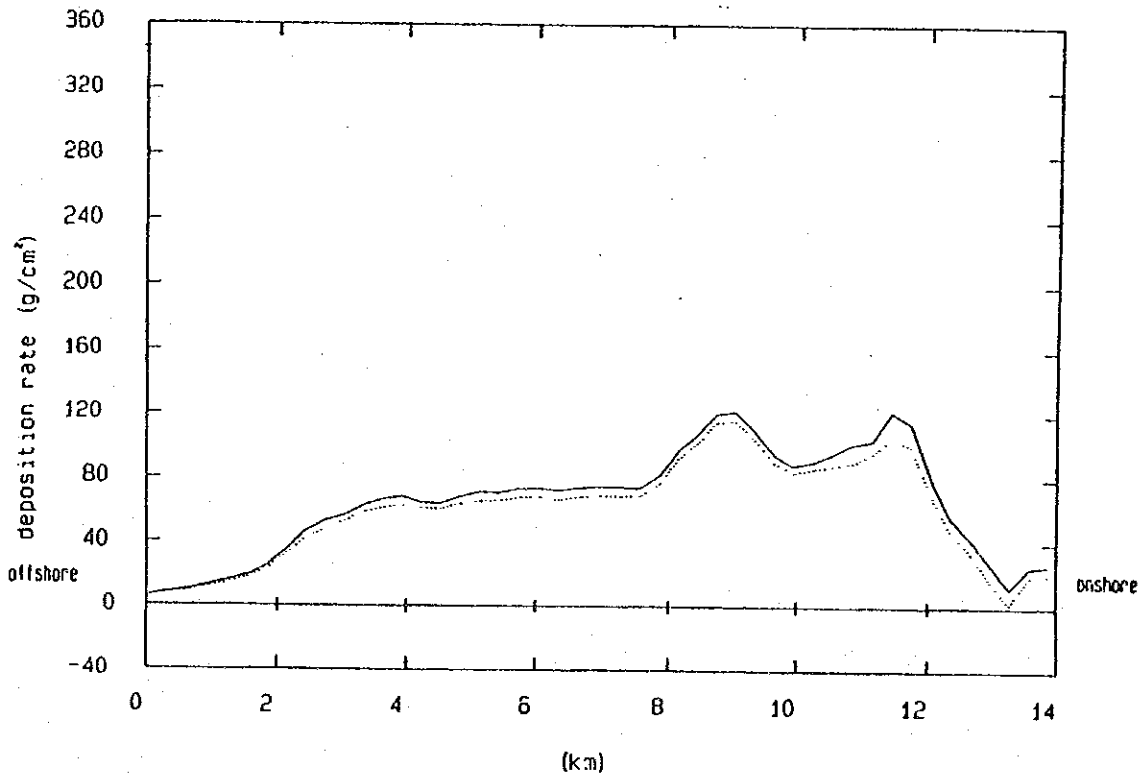
Fig. IV.2.4-4 Actual and Simulated Siltation (Discharge 3,500m^3/sec, Case I-1)

Another result is introduced here for the case of a discharge volume of 5,000 and 1,500 m^3/sec. in Fig.IV.2.4-5. If the river discharge increases, siltation volume could also increase, following almost the same pattern as with present conditions.

It is to be noted that the output of the simulations is deposition rate of sand and mud in g/cm^2. On the other hand, the actually surveyed volume of siltation is in m^3, which was 1.73 million m^3 in total within 100m width of the channel accumulated during 5th to 7th survey. Conversion of this volume into the deposition rate was done by dividing the fluid mud layer into three layers, and by supposing the very bottom layer between the bottoms confirmed by the 5th and 7th survey which was detected by a 33 kHz echo-sounder to have a water content of 110% and a bulk density of 1.45 gr/cm^3. And the layer between the levels of 33 kHz and 210 kHz is devided into two layers : the lower one having the water content and bulk density of 300% and 1.21 gr/cm^3, and the upper one having 1,000% and 1.09 gr/cm^3, respectively.



a. Discharge 5,000m^3/sec (Case I-2)



b. Discharge 1,500m^3/sec (Case I-3)

Fig. IV.2.4-5 Simulated Siltation Volume (Present Condition)

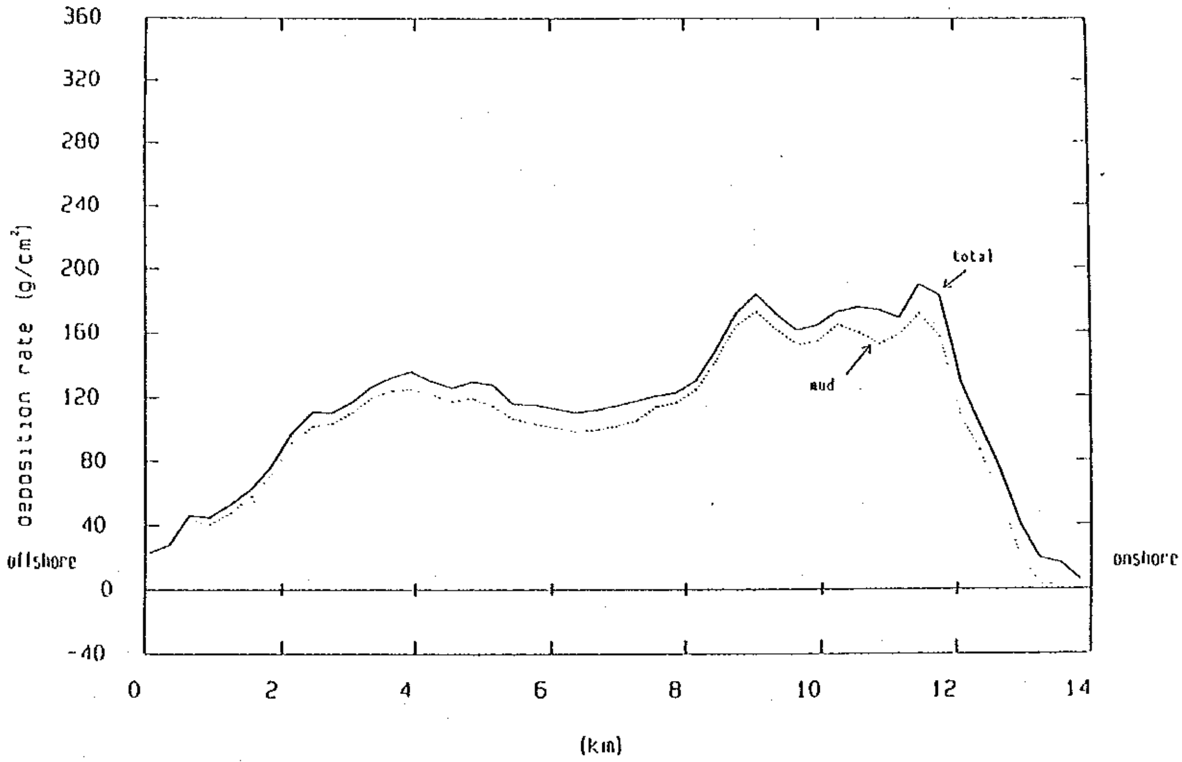
2-5 Results of Improvement Plans' Tests

2-5-1 Principal Plan

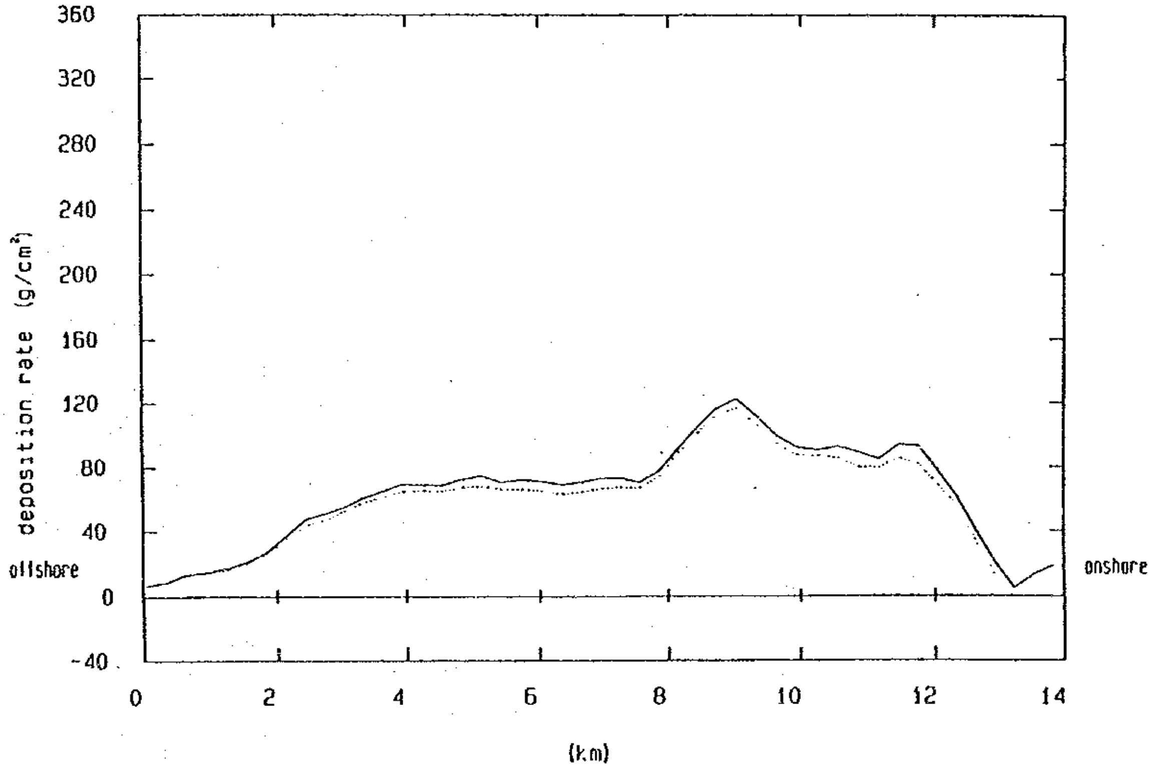
The channel width is expanded from the present 60m to the planned 100m without any protection facilities. The results of forecast simulations are shown in Fig.IV.2.5-1. The absolute values of deposition rate decrease slightly compared with the present condition, as seen in Fig.IV.2.5-2. It is to be noted that, due to the expansion of the width, the total siltation volume in the channel increases by about 20% in the case of the Principal Plan.

Here, it should be remembered that the outputs of the simulations are given by deposition rate in g/cm^2 separately for sand and mud. The conversion from the deposition rate into siltation volume was done by supposing that the sand has a specific gravity of 2.65 and a porosity of 40%, and the mud has a water content of 110% and a bulk density of 1.45 t/m^3. These numbers correspond to those measured at the bottom of the channel during the semi-capital dredging. In other words, the above converted volumes obtained through simulations could be the volume to be dredged at the site regardless of the existence of the fluid mud.

The widths of the channel within which siltation volume is calculated are 120m (4 meshes) for the present channel and 150m (5 meshes) for the expanded Principal Plan and others.



a. Discharge 5,000m³/sec (Case II-1)



b. Discharge 1,500m³/sec (Case II-2)

Fig. IV.2.5-1 Forecast of Siltation Volume for the Princpal Plan

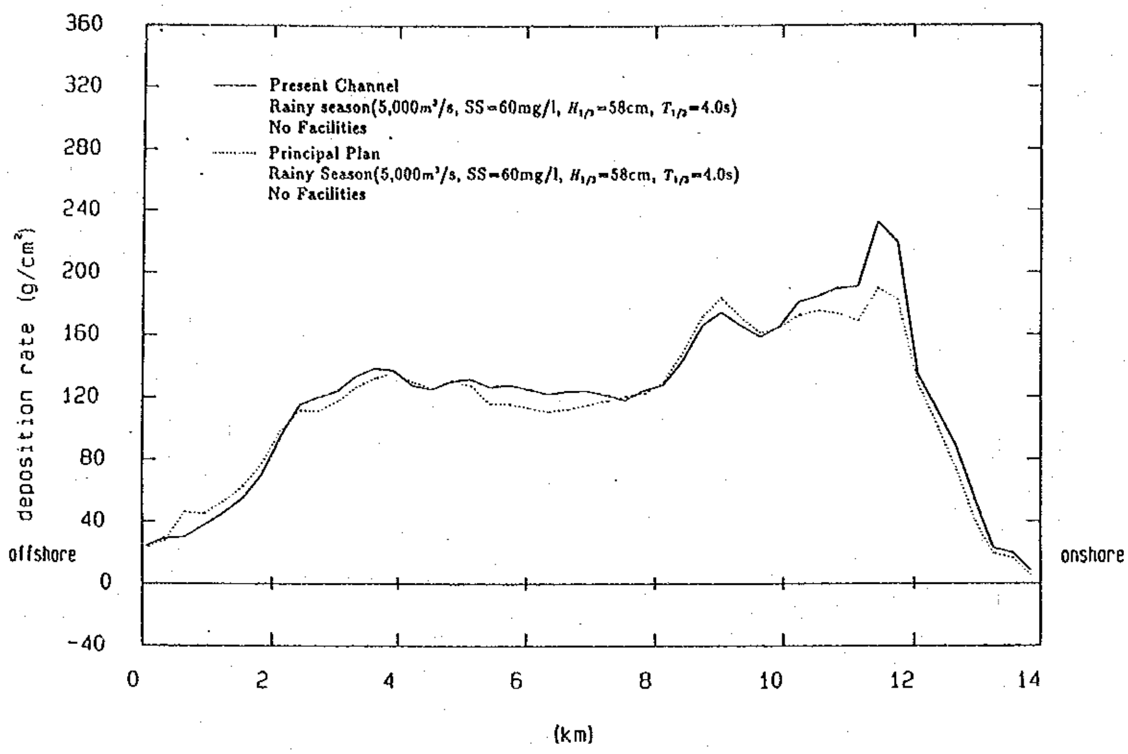
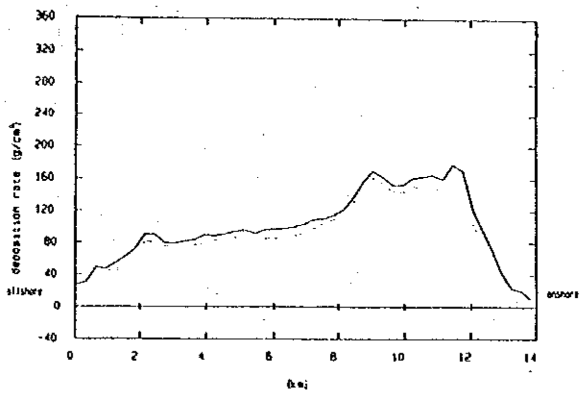


Fig. IV.2.5-2 Comparison of the Siltation between the Present Channel (Case I-2) and the Princial Plan (Case II-1)

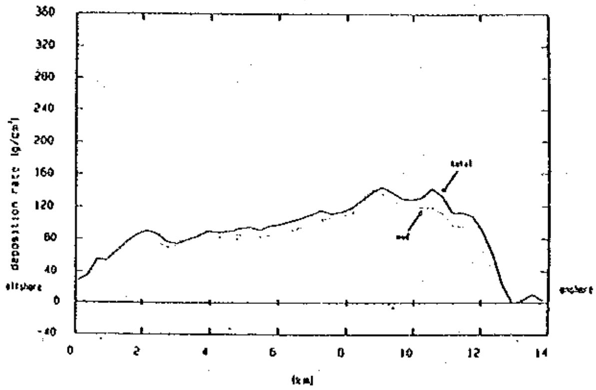
2-5-2 Submerged Wall Plans

Siltation volume is forecast for various types of siltation countermeasures.

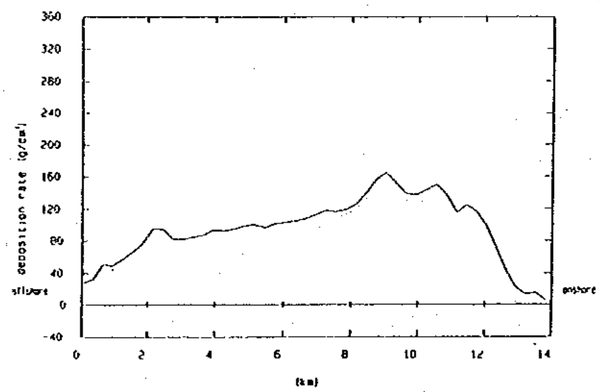
Some of the interesting results are presented here in Fig.IV.2.5-3 for the case of submerged walls. From these figures we can compare the effect of the length and height of the submerged walls, which are presented in Fig.IV.2.5-4. The longer and higher the walls, the grater the effect becomes. Among others to cut off a peak of siltation around Spot No. 11,000 to 12,000, the walls should be extended up to Spot No. 13,000. The effect of raising a height of 0.5m could be a 5% decrease in siltation volume.



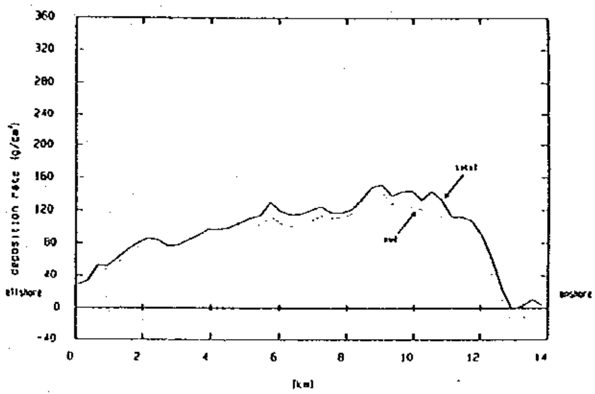
a. Length: Sp. 2,000 - 10,500
Height: 1m (Case IV)



c. Length: Sp. 2,000 - 13,000
Height: 1.5m (Case VI)

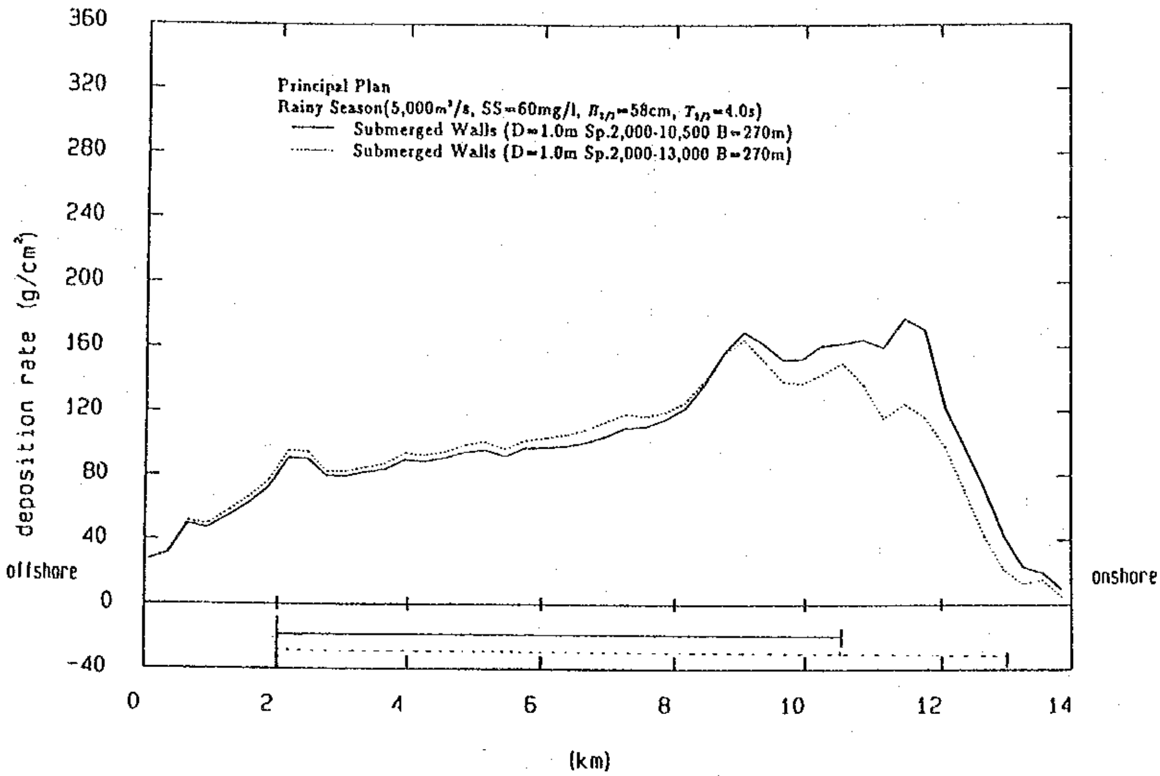


b. Length: Sp. 2,000 - 13,000
Height: 1m (Case V)

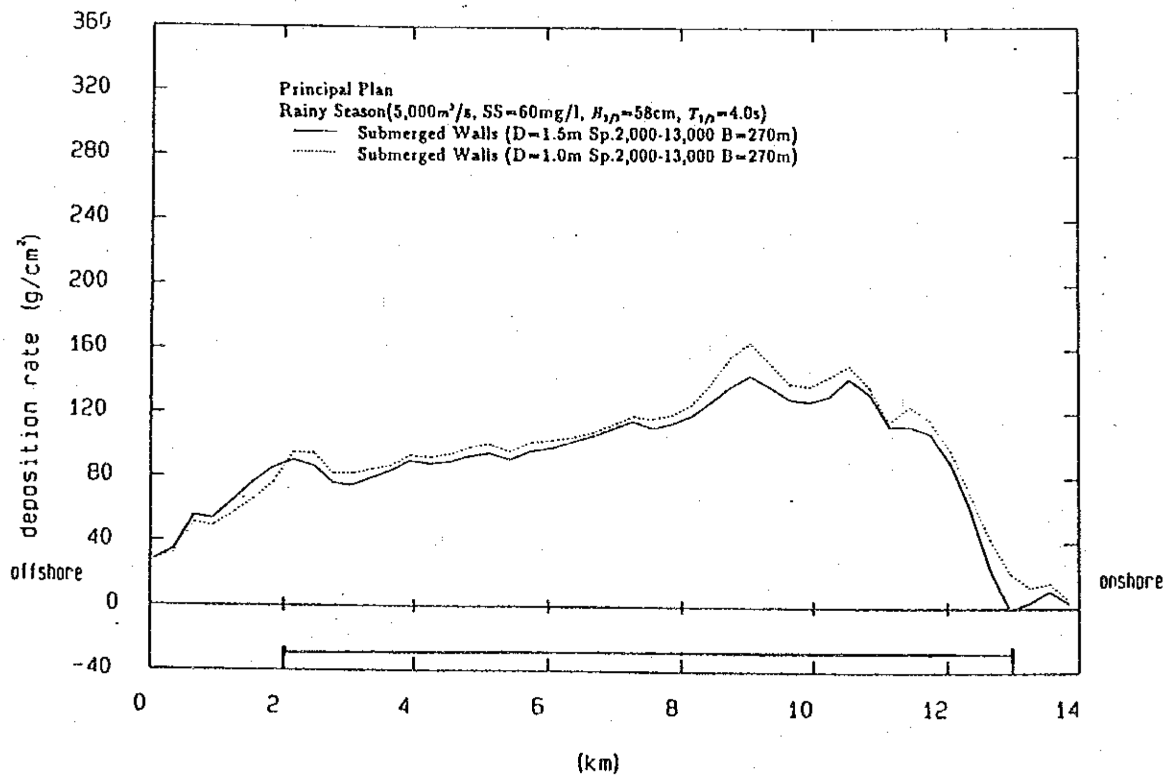


d. Length: Sp. 2,000 - 6,000
10,000 - 13,000
Height: 1.5m (Case XII-1)

Fig. IV.2.5-3 Forecast of Siltation Volume for Submerged Wall Plans
(Discharge : 5,000 m^3/sec, Distance between Walls : 270 m)



a. Effect of Length (Case IV and V)



b. Effect of Height (Case V and VI)

Fig. IV.2.5-4 Effects of Submerged Walls

In order to save construction costs of submerged walls, it is important to make them as short as possible. The most cost- efficient way is to install walls where they are most effective. Such discussion can be made referring to Fig.IV.2.5-5(1) and (2). If we construct submerged walls non-continuously from Spot No. 2,000 to 6,000 and Spot No.10,000 to 13,000, the contrary effect or inferiority to the full length walls, both compared with the Principal Plan without any wall, could be expected to be on the order of 4%, and the non-continuous wall would still be able to decrease siltation volume by about 20%.

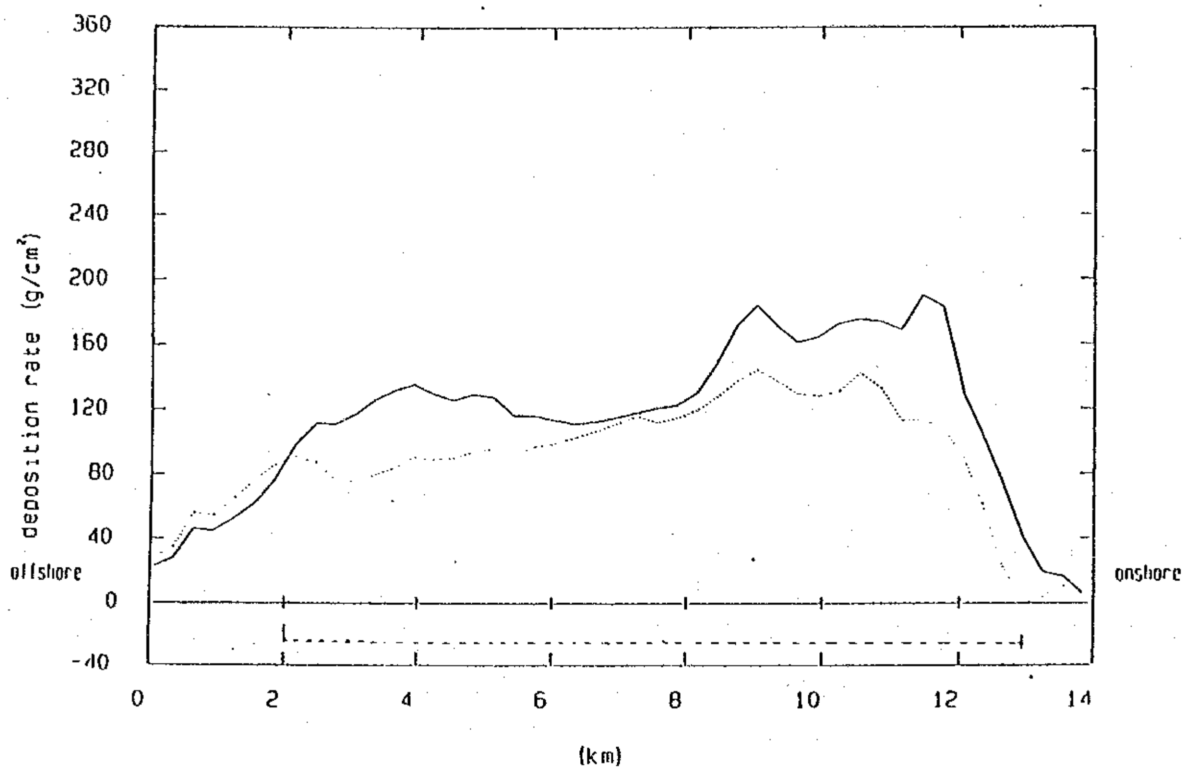
One of the important parameters is the distance between walls on both sides of the channel. Fig.IV.2.5-6 is the comparison between walls 270m and 210m apart. Based on the Principal Plan without any wall, the difference of the effect of these distances on siltation volume is about 2%, which mainly comes from the mud portion only.

Lastly, a forecast was made for the present channel with 60m width. Installing long submerged walls on both sides of the present channel could decrease siltation volume by 25 to 30% from the present level, as demonstrated in Fig.IV.2.5-7.

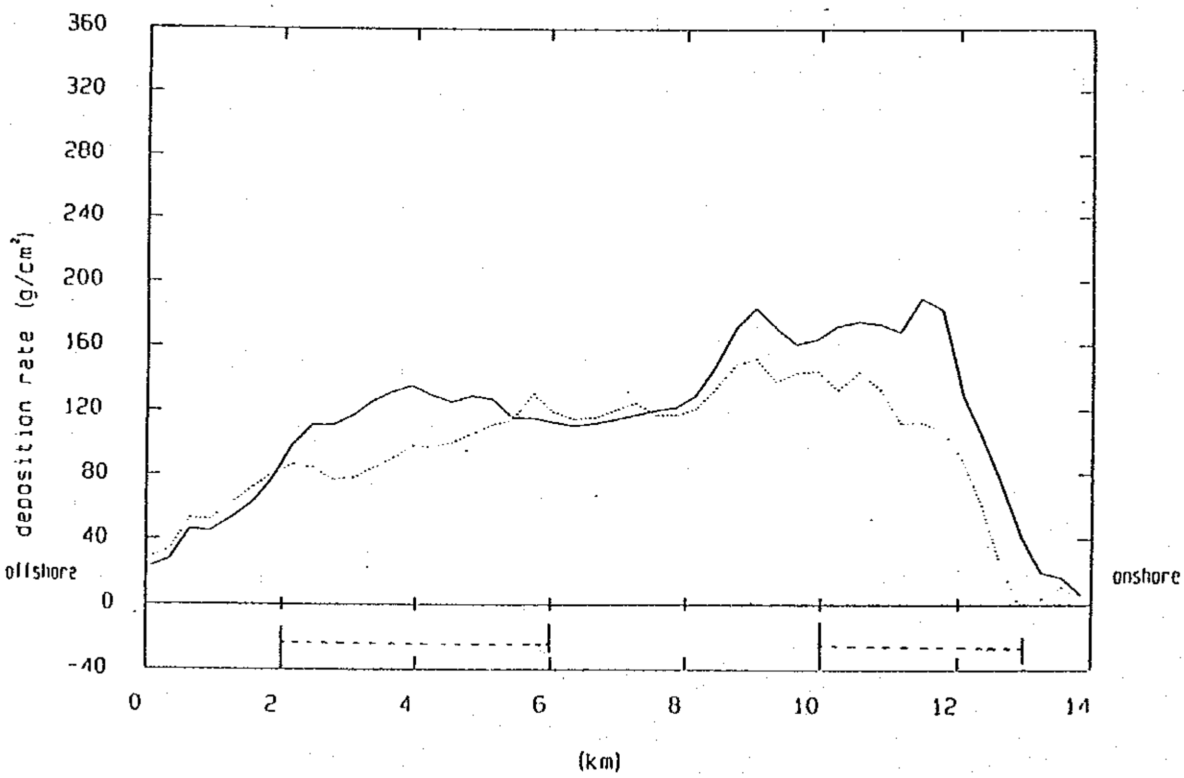
Thus, it became clear that the siltation volume decreases considerably in the area where submerged walls on both sides of the channel are installed. Hence, submerged walls could be one of the possible means to reduce siltation in such a channel as that at Banjarmasin.

2-5-3 Training Wall and Submerged Wall Plan

The result of the siltation forecast is presented in Fig.IV.2.5-8, compared with the case of the Principal Plan. The training wall installed from Spot No.9,900 to 13,000 cannot eliminate the two peaks of siltation from 9,000 to 12,000. The reason is that the first peak at 12,000 is mainly due to erosion of sea bottom between the training wall and the channel. However, the overall effect of reducing siltation volume is high for the whole length of the channel.



a. Long Submerged Wall (Case II-1 and VI-1)



b. Non-continuous Submerged Wall (Case II-1 and XII-1)

Fig. IV.2.5-5(1) Effects of Submerged Walls Compared with Principal Plan (Discharge : 5,000 m^3/sec, Distance between Walls : 270 m)

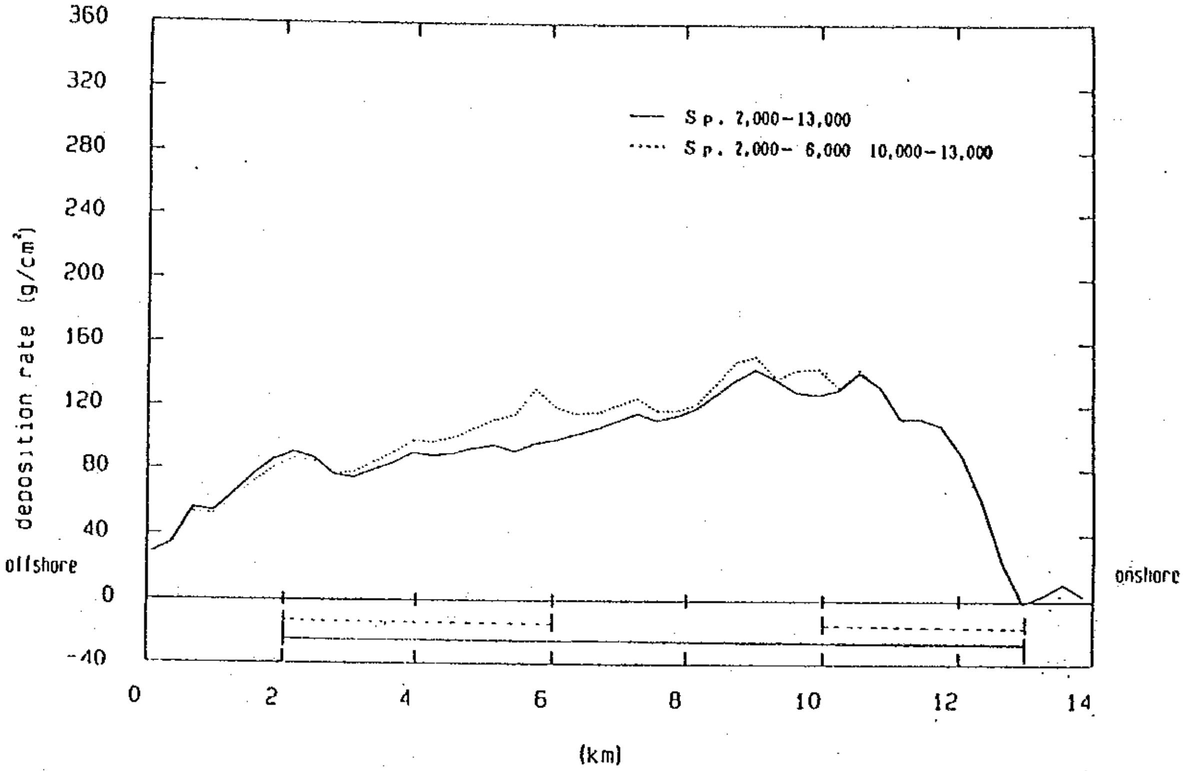


Fig. IV.2.5-5(2) Inferiority of Non-continuous Submerged Walls (Case VI and XII-1)

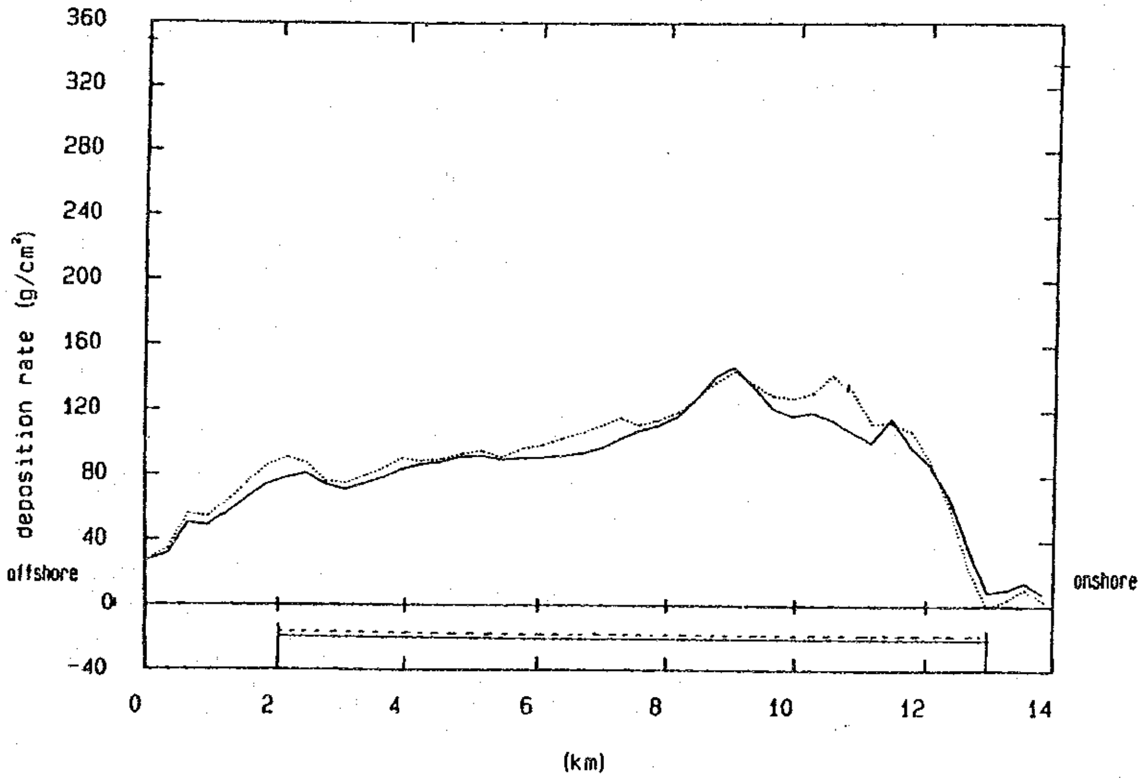


Fig. IV.2.5-6 Effect of Distance between Walls (Case VI) (Dotted line: 270m, Solid line: 210m)

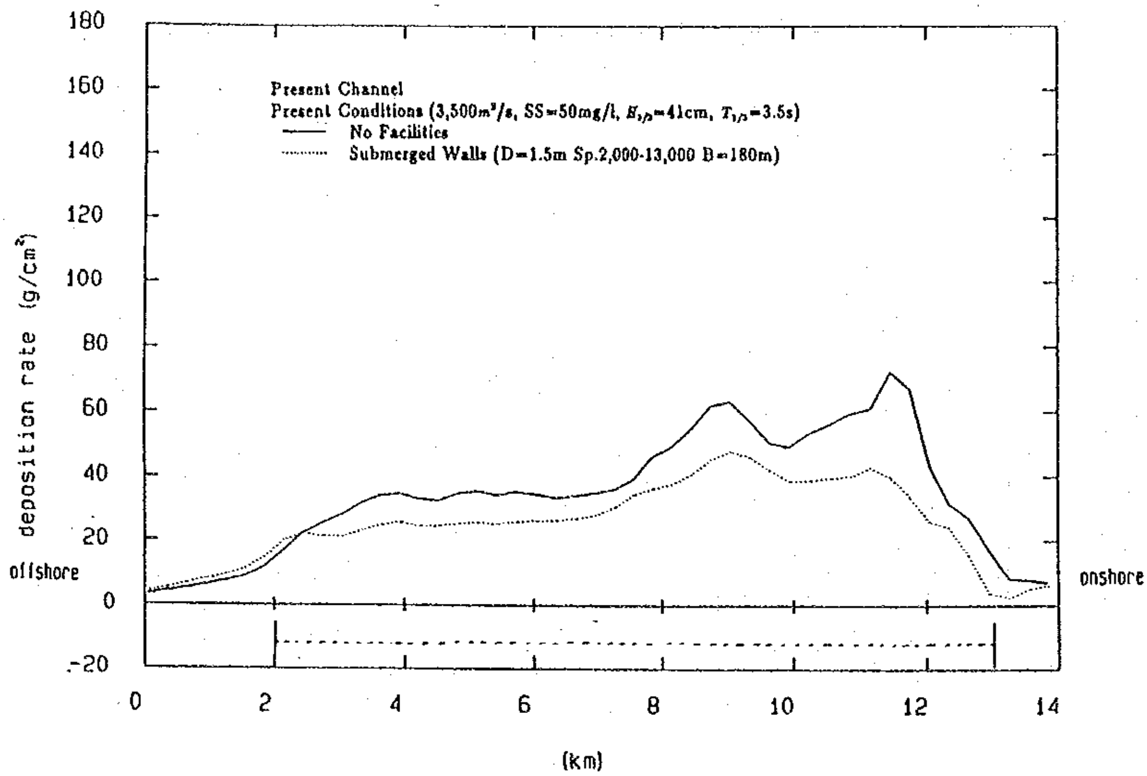


Fig. IV.2.5-7 Effect of Submerged Wall for the Present Channel (Case I-1 and X-1)

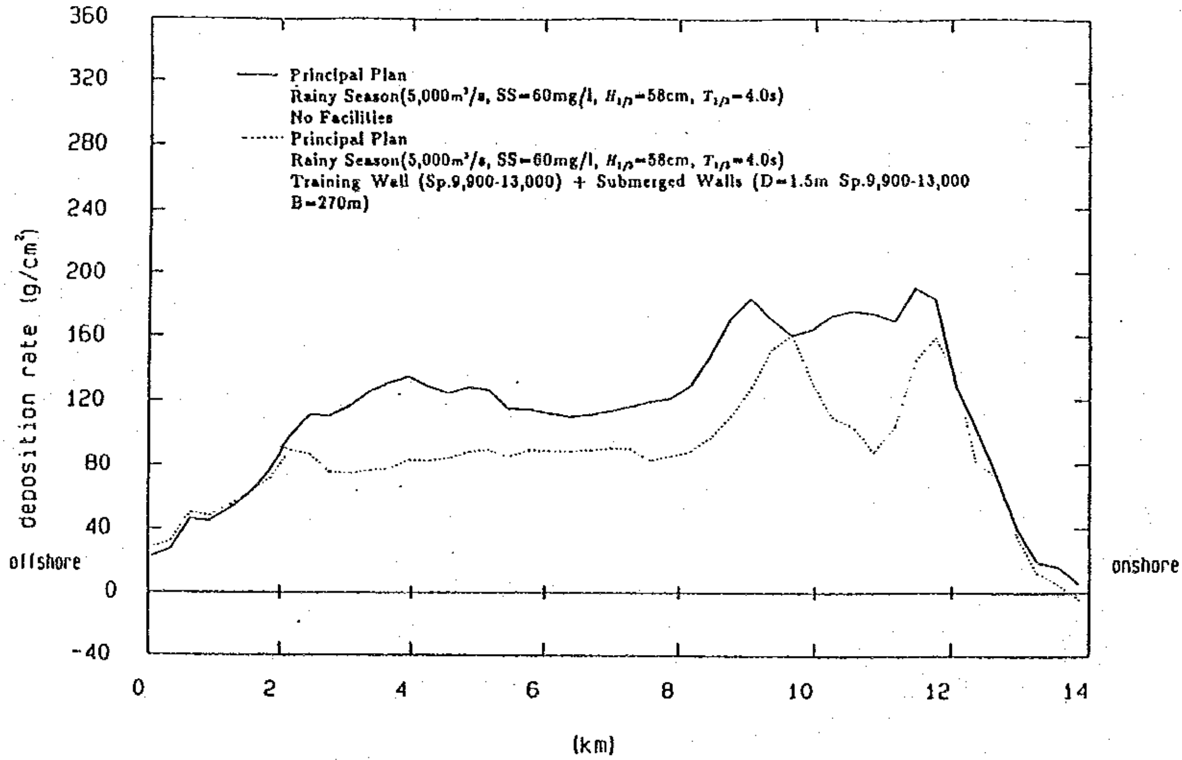


Fig. IV.2.5-8 Comparison between Training Wall and Submerged Wall Plan (dotted line) and the Principal Plan (solid line)

2-5-4 Expansion Plan and Trap Plan

In these cases the deposition rates decrease, but the siltation in the channel does not decrease so much due to the increase in width of the channel, as shown in Fig.IV.2.5-9.

2-5-5 New Alignment Plan

As introduced in Fig.IV.2.5-10 siltation occurs almost evenly at the upstream area from Spot No. 2,000, which is the location of the new outlet of the channel to the open sea, to the upstream entrance at Spot No. 14,000 due to deposition of suspended solids flown down from the river and resuspended bottom materials.

Siltation volume is larger than that of the present condition and smaller than that of the Principal Plan for the present channel.

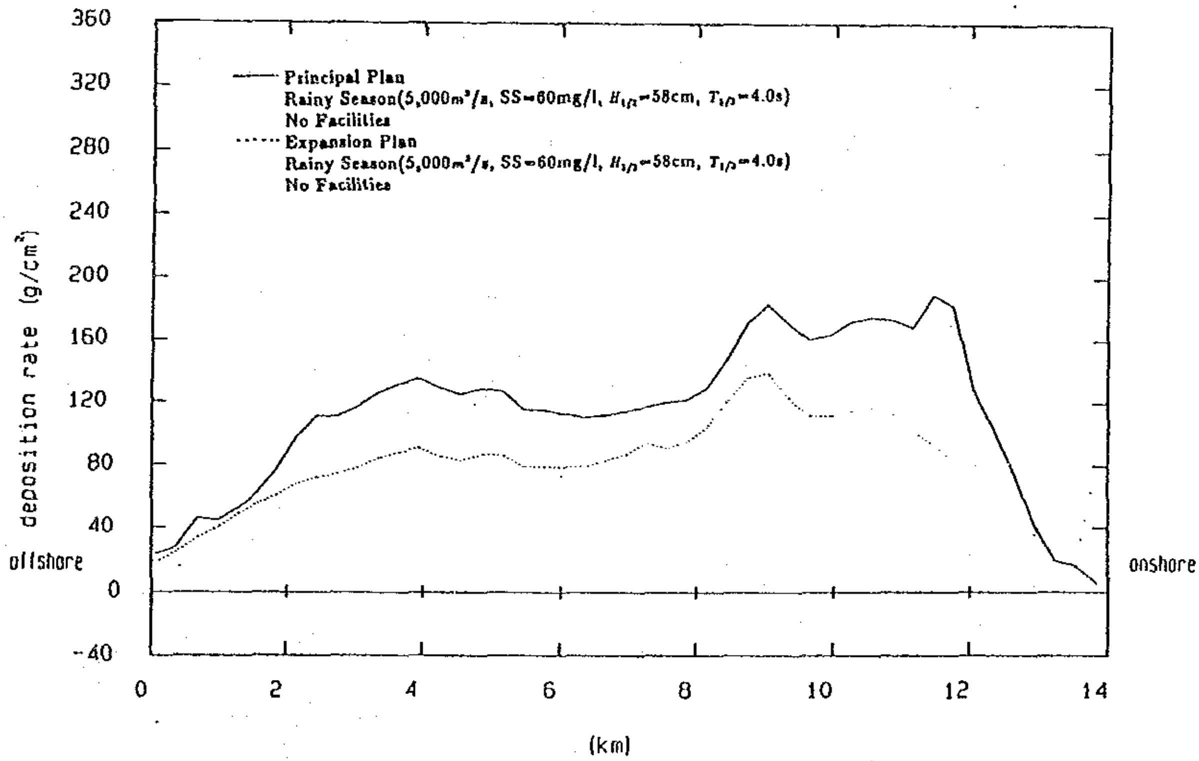
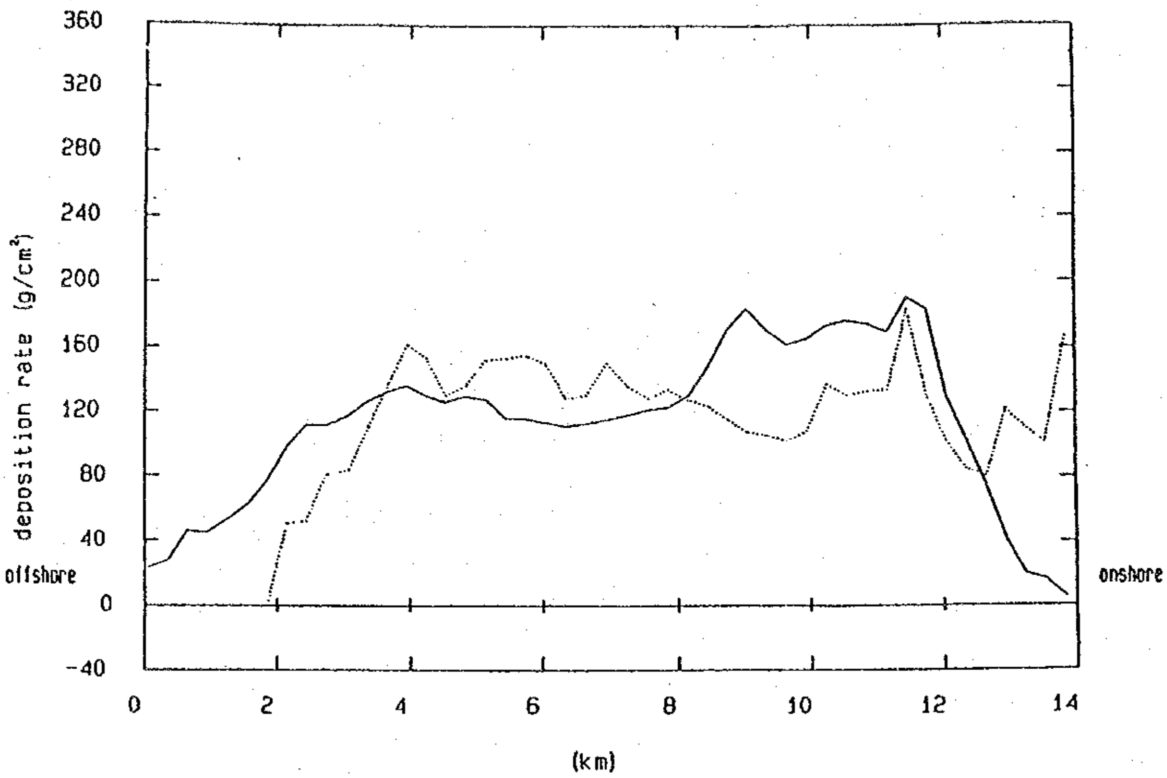
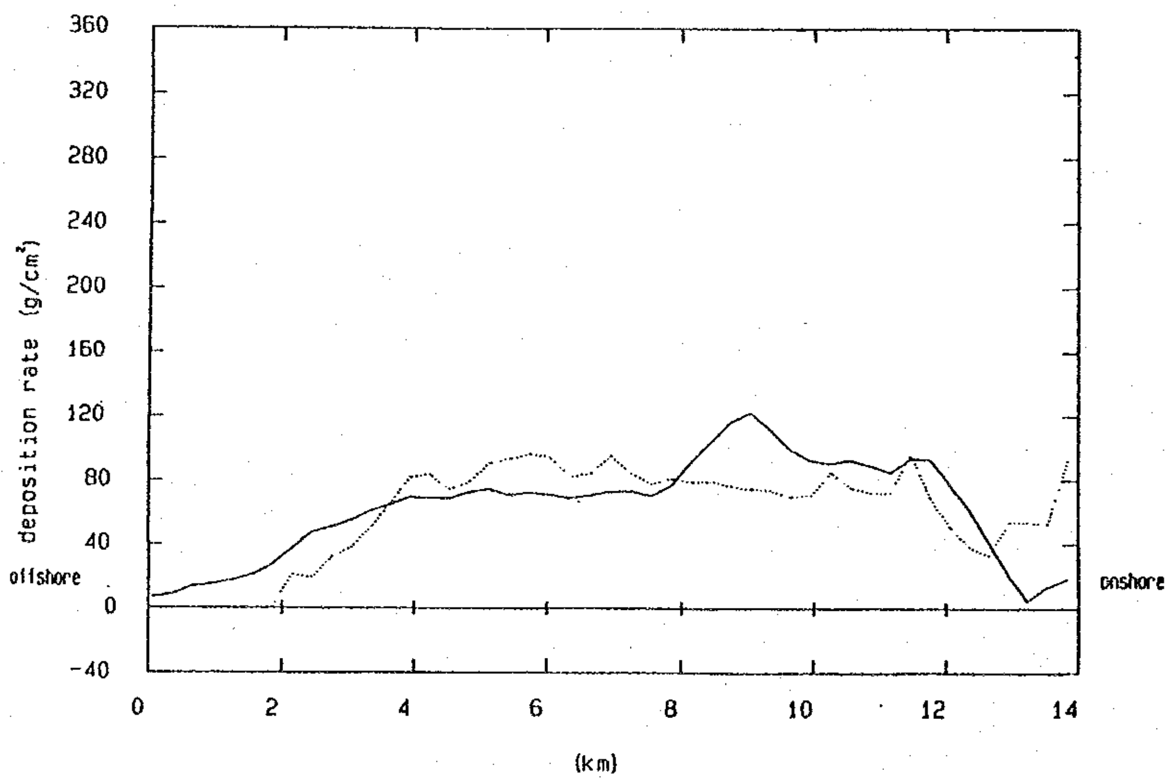


Fig. IV.2.5-9 Comparison between Expansion Plan (dotted line) and the Principal Plan (solid line)



a. Discharge: 5,000m3/sec (Case X-1)



b. Discharge: 1,500m^3/sec (Case XII)

Fig. IV.2.5-10 Comparison between New Alignment Plan (dotted line) and the Principal Plan (solid line)

Chapter 3 Effects of Siltation Countermeasures

3-1 Summary of the Results of Hydraulic Model Tests and Numerical Simulations

Tables IV.3.1-1 and 2 are the summaries of the results of siltation forecast for various countermeasure plans done above by means of hydraulic model tests and numerical simulations.

It should be noted that neither of those results by hydraulic and numerical experiments is all-inclusive; rather, they supplement each other. Tracer tracking in hydraulic models represents high-density muddy flow phenomenon relatively. On the other hand, numerical models reproduce such overall phenomena as resuspension, diffusion and settling of solids quantitatively very well.

It is also pointed out that the siltation volumes in Table IV.3.1-2 are calculated from the depostion rates obtained for one cycle time of tides and based on a density structure model as explained above in chapter 2, Section 2-5-1. Hence, these volumes are to be considered as average ones. It is also understood that the values are under maintenance dredging works. In the actual site, siltation volume should deviate from these figures due to annual variations of wave conditions, sediment supply from the river and other external factors.

3-2 Effects of Widening and Deepening Channel

From the quantitative results of siltation assessment by numerical simulations, it is known that for the present channel with a depth of -6 m, a planned width of 60 m, and slope of 1/10 (NM Case I), the annual siltation volume is 4.2 million m^3. The value for the Principal Plan (NM Case II), which expanded the width to 100 m, or 67% wider than that of the Present Conditions, is 5.1 million m^3, or 21% increase in siltation.

In the case of Expansion Plan (NM Case IX) with a width of 120 m or 20% increase and a depth of 8 m or 33% increase compared with those

Table IV.3.1-1 Results of Siltation Forecast by Hydraulic Model Tests

(1) Ratio of Tracer Density for the Present Conditions

Case No.	River Discharge	Present Cond. (3,500m³/sec)	Rainy Season (5,000m³/sec)	Dry Season (1,500m³/sec)	Remarks
C-1	3,500m³	-	1.00 (2.66)*	1.00 (2.27)*	Without a dam
C-2	1,500				
C-3	5,000				
C-4	1,500m³	-	1.06	1.03	Without a dam
C-5	5,000				
C-6	3,500				

*) Compared with the principal plan (D1)

(2) ratio of tracer Density Density for Improvement Plans

Case No.	Classification	River Discharge (m³/sec)	Channel Depth and Width	Layout	Crown Height	Present Cond. (3,500m³/s)	Rainy Season (5,000m³/s)	Dry Season (1,500m³/s)
D1-1	Principal Plan	1500	-6m, 100m	-	-	-	1.00	1.00
D1-2		5000						
D1-3		3500						
D2-1	Long Jetty	1500	-6m, 100m	6km	MWL	-	0.52	0.90
D2-2		5000						
D3-1	Submerged wall (3)	1500	-6m, 100m	SP. 2,000 -10,500	1m ab. sea bed	-	0.38	0.65
D3-2		5000						
D4-1	Submerged wall (1)	1500	-6m, 100m	SP. 3,000 -9,000	1m ab. sea bed	-	0.44	0.88
D4-2		5000						
D5-1	Submerged wall (2)	1500	-6m, 100m	SP. 3,000 -9,000	2m ab. sea bed	-	-	-
D5-2		5000						
D6-1	Jetty + Subm. Wall	1500	-6m, 100m	6km above(3)	MWL 1m	-	0.11	0.72
D6-2		5000						
D7-1	Training Wall	1500	-6m, 100m	SP. 9,900 -13,000	HWL 1m	-	0.76	0.94
D7-2		5000						
D8-1	Trap	1500	-6m, 170m	SP. 4,000 -13,500	-	-	0.30	0.80
D8-2		5000						
D9-1	New N-S Alignment (29°)	1500	-6m, 100m	-	-	-	0.21	0.59
D9-2		5000						
D9-3		3500						
D10-1	New N-S Alignment (48°)	1500	-6m, 100m	-	-	-	0.58	0.87
D10-2		5000						
E1-1	Non-Continuous Subm. Wall	1500	-6m, 100m	SP. 3,000 -7,000 SP.10,000 -13,500	1.5m ab. sea bed	-	0.38	0.73
E1-2		5000						
E1-3		3500						
E2-1	Subm. Wall During Construction(1)	1500	-6m, 100m	SP. 3,000 -7,000 SP.10,000 -13,500	1.5m ab. sea bed	-	0.50	0.73
E2-2		5000						
E3-1	Subm. Wall During Construction(2)	1500	-6m, 100m	SP. 3,000 -7,000	1.5m ab. sea bed	-	0.61	0.97
E3-2		5000						

Table IV.3.1-2 Results of Siltation Forecast by Numerical Simulations

(Unit: million m^3)

Case No.	Classification	River Discharge (m^3/sec)	Channel Depth and Width	Layout	Crown Height	Present Condition	Rainy Season	Dry Season	Annual Total
I-1 I-2 I-3	Present Condition	3,500 5,000 1,500	-6m 60m	- - -	- - -	0.8<1.00>	2.7<1.00>	1.5<1.00>	4.2<1.00>
II-1 II-2	Principal Plan	5,000 1,500	-6m 100m	- -	- -	-	3.3<1.22> (1.00)	1.8<1.21> (1.00)	5.1<1.21> (1.00)
III	Submerged Wall (1)	5,000	-6m 100m	Sp. 3,000 -9,000	1m ab. sea bed	-	2.9(0.89)	-	-
IV	Submerged Wall (2)	5,000	-6m 100m	Sp. 2,000 -10,500	1m ab. sea bed	-	2.9(0.88)	-	-
V	Submerged Wall (3)	5,000	-6m 100m	Sp. 2,000 -13,000	1m ab. sea bed	-	2.7(0.82)		
VI-1 VI-2	Submerged Wall (4)	5,000 1,500	-6m 100m	Sp. 2,000 -13,000	1.5m ab. sea bed	-	2.5(0.77) 2.4**(0.75)	1.4**(0.75)	3.8**(0.75)
VII	Training Wall +Subm. Wall	5,000	-6m 100m	Sp. 2,000 -13,000	HWL+ 1m ab.s.b.	-	2.4(0.74)		
VIII	Trap	5,000	-6m 180m	Sp. 4,000 -13,500	-	-	3.0(0.92)		
IX	Expansion Plan	5,000	-8m 120m	- -	- -	-	3.8(1.15)		
X-1 X-2	New N-S Alignment	5,000 1,500	-6m 100m	- -	- -	-	2.8(0.85) <1.03>	1.6(0.87) <1.06>	4.4(0.86) <1.04>
XI-1 XI-2 XI-3	Present Con. + submerged Wall (4)	3,500 5,000 1,500	-6m 100m	Sp. 2,000 -13,000	1.5m ab. sea bed	*0.6<0.74>	1.9*<0.71>	1.1*<0.73>	3.0*<0.71>
XII-1 XII-2	Non-continuous Subm. Wall (4)	5,000 1,500	-6m 100m	Sp. 2,000 -6,000 Sp.10,000 -13,000	1.5m ab sea bed	-	2.7(0.81)	1.6(0.85)	4.2(0.83)

Notes *) Distance between walls: 180m
**) Distance between walls: 210m, the others are 270m,

of the Principle Plan, the volume becomes 3.8 million m^3 in the rainy season, which is 15% greater than that of the Principal Plan.

Supposing that the siltation volume V is exponentially proportional to the bottom width B and depth D of the channel, we can express that:

V = Vob x exp(b x B)   for fixed D, and
V = Vod x exp(d x D)   for fixed B,

where Vob and Vod are the siltation volume in a channel with B = 0 (V-shapes channel) and D = 0 respectively, and b and d are parameters. Assuming the values of b and d to be non-variable, and applying the above results of simulations, we can extrapolate siltation volume in various conditions of B and D as shown in Fig. IV.3.2-1 and results of some representative cases are introduced in Table IV.3.2-1. The increase of siltation by widening is larger than by deepening. This is partly because of the effect of erosion of channel sides which is counted as minus siltation. In the case of deepening to -8 m, keeping the width of 100 m, the annual volume is expected to be 5.4 million m^3, 0.3 million increase than the value of the Principal Plan.

In the case of Trap plan with 170 m in width and 9.5 km in length, a figure of 3.0 million m^3 is simulated in the rainy season which is smaller than the expected volume of about 4.1 million m^3 derived from the above method.

3-3 Effects of Submerged Walls

Submerged walls have considerable effects to prevent siltation, according to the results of the numerical and hydraulic tests. The results are illustrated in Fig.IV.3.3-1 in terms of the ratio of siltation, rv, or tracer density, rt, relative to the Principal Plan. The horizontal axis is wall uncoverage coefficient, Cu, which is defined as the ratio of the channel length not-protected by walls over the total channel length. If a wall is laid on one side of channel, the length is half counted.

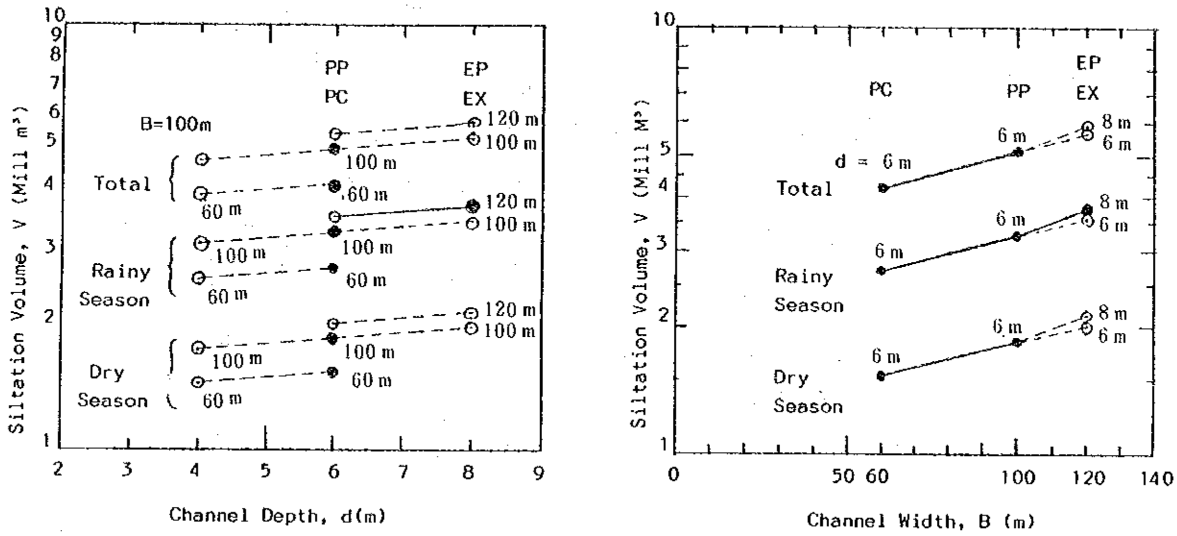


Fig. IV.3.2-1 Estimate of Siltation Volume for Various Channel Sizes by Extrapolation of Numerical Simulations

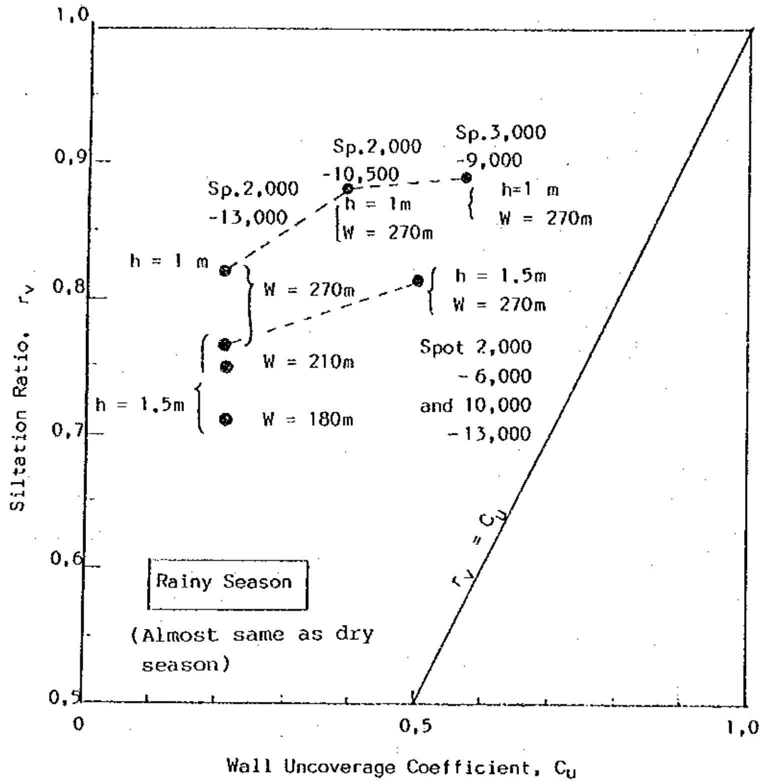
(Present Channel Alignment without Facility)

Table IV.3.2-1 Result of the Estimate of Siltation Volume for Various Sizes of the Present Channel

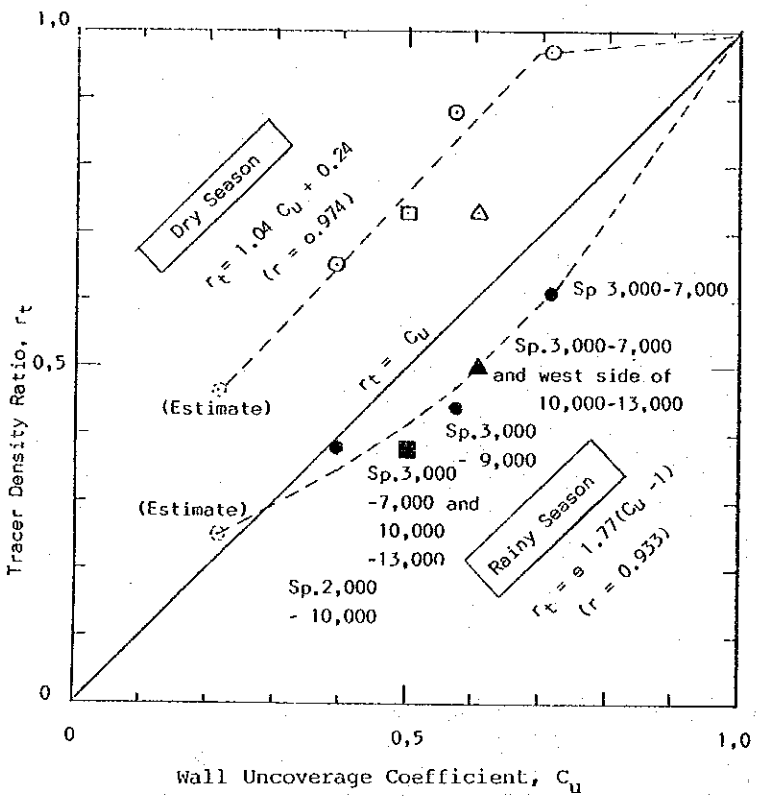
(Unit : Million m^3)

Case No.	Classification	D x B (mxm)	Rainy Season	Dry Season	Annual Total
A-1	Retreat(1) (R1)	-4m x 60m	2.5 *)	1.5 *)	4.0 *) (0.95) (0.78)
A-2	Retreat(2) (R2)	-4m x 100m	3.1*)	1.7 *)	4.8 *) (1.14) (0.94)
I.	Present Condition (PC)	-6m x 60m	2.7	1.5	4.2 (1.0) (0.82)
II.	Principal Plan (PP)	-6m x 100m	3.3	1.8	5.1 (1.21) (1.0)
B-1	Expansion (Ex)	-6m x 120m	3.6 *)	2.0 *)	5.6 *) (1.33) (1.10)
IX.	Expansion Plan (EP)	-8m x 120m	3.8	2.1 *)	5.9 *) (1.40) (1.16)

*) Estimated Figures



(1) Numerical Simulations



(2) Hydraulic Model Tests

Fig. IV.3.3-1 Effect of Submerged Walls relative to the Principal Plan

The most effective results are for the rainy season by hydraulic model tests, whereas the effect in the dry season is comparatively smaller. The hydraulic tests show the effect of crown height of walls between 1 to 2 m is relatively small. Generally, the effect is proportional to the wall uncoverage coefficient, reflecting the nature of the tracer experiment.

In numerical simulations, the effect on halting siltation is not very high, at the most 30%. Making the crown height, h, higher, the wall distance, W, narrower and wall coverage longer, the greater the effect becomes.

The locational effect of submerged walls to prevent siltation is assessed from the tests of various coverage in terms of decrease in the ratio of tracer density/siltation per km, and the result is illustrated in Fig. IV.3.3-2. The distribution of locational effect is different in hydraulic and numerical tests. The tracer density ratio of submerged walls from Spots No.2,000 to 13,000, which case

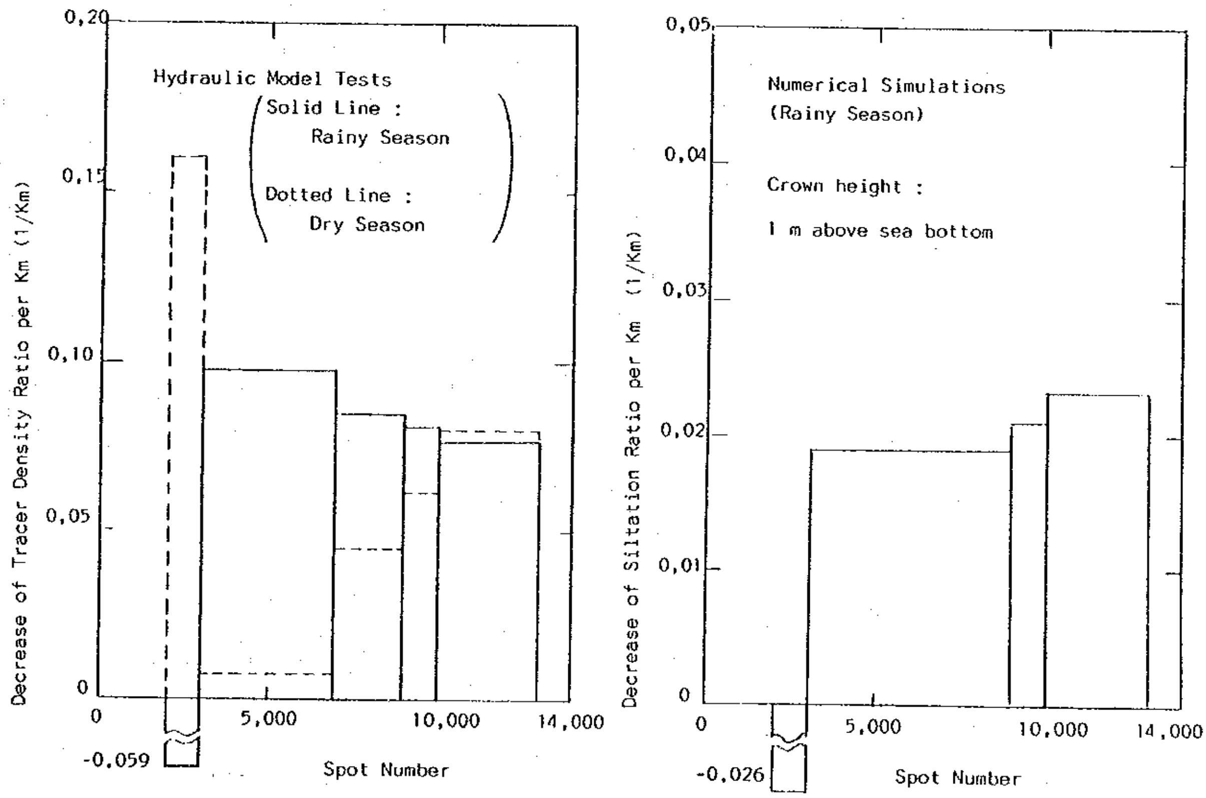


Fig. IV.3.3-2 Locational Effect of Submerged Walls was not carried out by the hydraulic model, can be calculated by this Figure to be 0.19 in the rainy season and 0.42 in the dry season.

Thus, the effect of submerged walls is quite different in hydraulic tests and numerical simulations. Apparently the former represents the density-flow type phenomena. The latter reproduces overall ones, but does not take account of strong effects of submerged walls against density flow, or fluid mud in a very thin layer on the seabed. Although the behavior of such high-density fluid mud is not fully clear technically, the following method is employed to combine the above effects. This is only applicable to cases with wall facilities beside the channel and not to cases without such facilities, which can be adequately covered by the numerical simulations as far as the total siltation volume is concerned.

The bottom mud is first resuspended, mainly by agitation of waves of more than 50 cm in height (if the wave height is less than 50 cm, the mud cannot be resuspended) and current speed of more than 50 cm/sec, and reaches an equilibrium state between suspension and settling, which in turn resettles on the seabed after the sea becomes calm when the wave height decreases below 50 cm, forming a fluid mud layer. The fluid mud has a density of 0.08 g/cm^2, and flows into the channel at a speed of 0.433 cm/sec which is observed in the hydraulic model tests regardless of the season. Such a flow is supposed to continue for 1 day or 2 days, depending on the previous maximum wave height of less than or more than 70 cm. According to the results of site survey from September 1988 to September 1989, such conditions existed at the site for 119 days (56% in the rainy season and 44% in the dry season). Then, the volume of fluid mud, Vfm, which flows into the channel is accessed to be the order of 1.4 million m^3 per year provided a density of 1.45 g/cm^3 and a water content of 110%.

The combinative volume of siltation, V, given by numerical simulations in the case of without-facility is expressed by:

$$V = Vds + Vfm, \quad \cdots\cdots (1)$$

where Vds is the siltation volume due to only diffusion and settlement. In the case of the Principal Plan, for example,

$$Vds = V - Vfm = 4.2 - 1.4 = 2.8 \text{ mill } m^3.$$

Finally, the siltation volume for submerged wall plans, Vsw, can be calculated by :

$$Vsw = Vo \times Vds/V + (rt)r(Vfm)r + (rt)d\,(Vfm)d, \; \ldots \; (2)$$

where Vo is the siltation volume given by numerical simulations, (rt)r and (rt)d are tracer density ratios, and (Vfm)r and (Vfm)d are fluid mud volumes in the rainy and dry seasons, respectively. Or, in a much simpler way, Eq. (2) can be replaced by:

$$Vsw = Vo \times Vds/V + Cu \times Vfm, \; \ldots\ldots\ldots\ldots \; (3)$$

where Cu is the wall uncoverage coefficient. The difference between Eq. (2) and (3) is rather small, because the average of (rt)r and (rt)d is close to Cu.

The volumes of Vsw obtained are 2.3 (ratio to the Principal Plan is 0.45), 2.8 (0.55), 2.9(0.55) and 3.5 million m^3/year (0.69) for long submerged walls with wall distance (channel width) of 180 m (60m), 210 m(100 m), 270 m (100 m) and non-continuous case with 270 m (100 m), respectively.

3-4 Effects of Training Wall

The effect of a training wall (HM Case D-7) along the face of the sandspit is not so high as the submerged walls, according to the tracer experiments. Once submerged walls are attached to it on both sides of downstream portion of the channel (NM Case VII), the effect is similar to the case of a submerged wall plan (NM Case VI).

3-5 Effects of Long Jetty

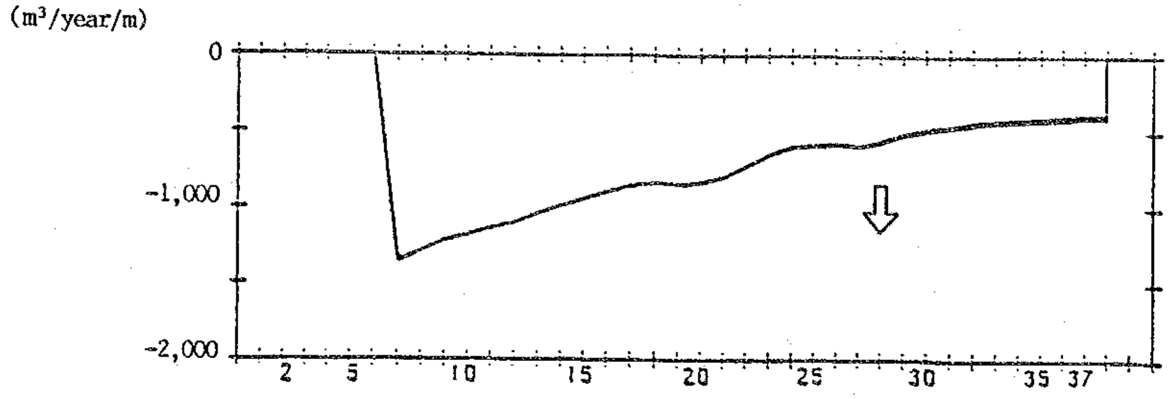
The effect of a long jetty (HM Case D-2) could be relatively high judged from the result of tracer experiments of the hydraulic tests. Once a submerged wall is incorporated (HM Case D-6), the effect is among the best as far as tracer density in the channel is concerned.

In order to evaluate the long-term effects of the jetty to moderate eastward sediment transport, forming a large scale sandspit at Spot No.11,000, the so-called one-line theory is adopted to enable quantitative assessment.

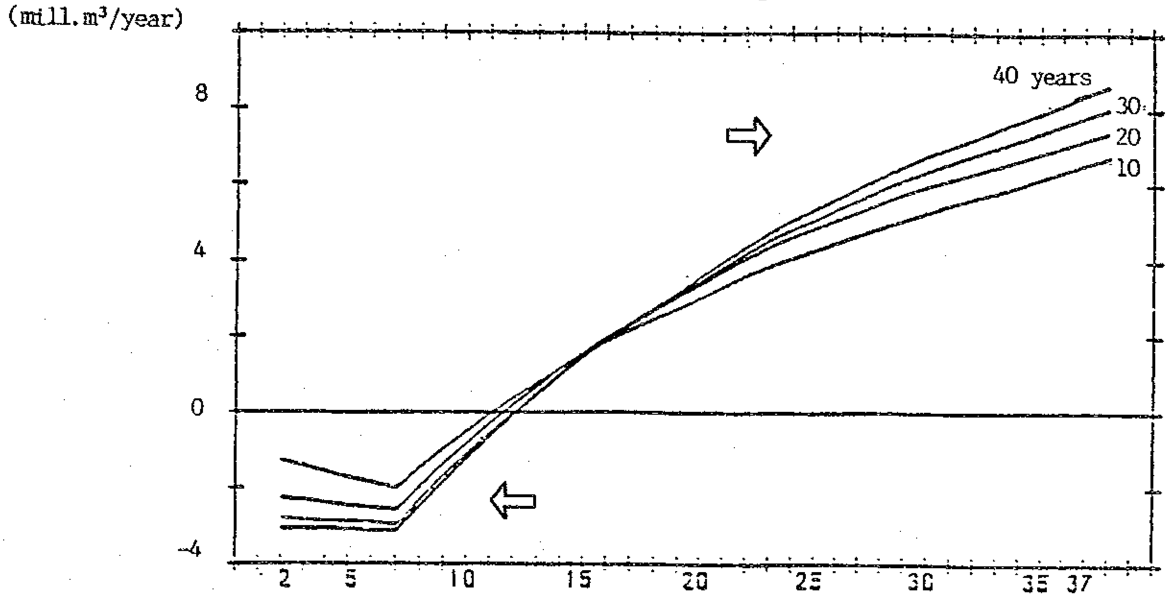
First, the past history of the progress of the west shoreline from 1906 to 1989 is reproduced, confirming the applicability of the theory. It is estimated that the volume of the longshore sediment transport to the east is on the order of 6 million m^3 per year presently. It was also found that there is westward transport from the middle of the west coast and the volume has an equivalent order to that of eastward transport, which explains the accretion of sediments at the western end of the fan-shaped bank.

Next, the forecast of the change in the coastal process after the construction of the long jetty (6 km in length) is carried out to predict the longshore transport and progress of shoreline. The result is presented in Fig. IV.3.5-1.

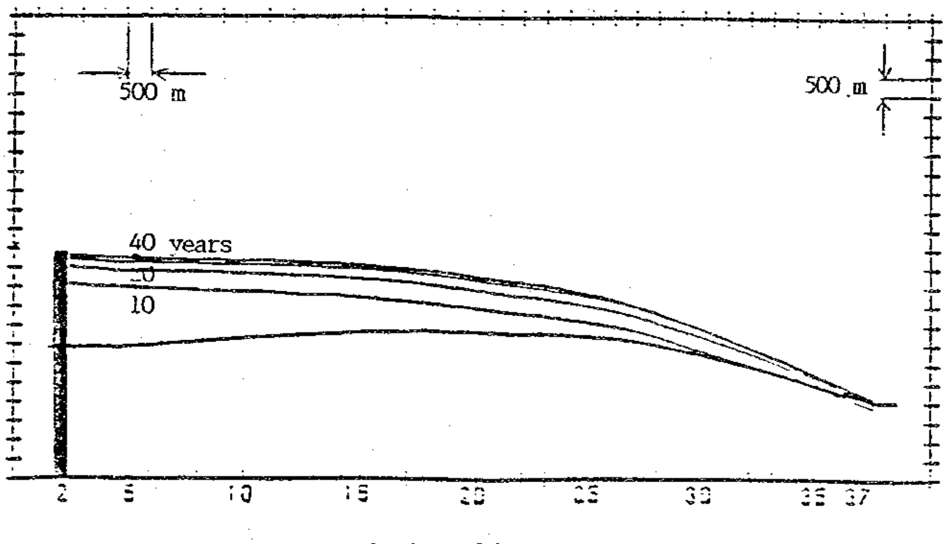
The wave conditions applied are: wave height H = 0.52 m and its period T = 3.7 sec. from the direction of S 41 degrees W on the west bank for 140 days per year, and H = 0.50 m and T = 3.6 sec. from S 2 degrees E on the east bank for 225 days per year. Fig. IV.3.5-1 shows that the eastward transport will decrease to the order of 1 million m^3/year just after the construction of the jetty and increase to 3 million m^3/year in 40 years. On the contrary, the westward transport will increase up to the order of 8 million m^3/year, which will expedite the accretion at the western end of the bank. The shoreline will continuously progress offshore and reach the tip of the jetty in 40 years.



a. Volume of Onshore Transport



b. Volume of Longshore Transport



c. Progress of Shoreline

Fig. IV.3.5-1 Forecast of the Change in the Wave Coast after Construction of a Long Jetty

3-6 Effects of changes in Channel Alignment

The result of changing the channel direction from the present one, i.e., 208 degrees, to 180 degrees (N-S direction) (HM Case D-9, and NM Case X) is such that the overall effect in drecreasing siltation volume compared with the Principal Plan at the present channel, i.e., 4.4 million m^3/5.1 million m^3 = 0.86, coincides exactly with an effect of shortening the channel length, i.e., 12 km/14 km = 0.86. Although the change in current speed and direction is great, the average flow distribution in the channel is quite similar, according to the result of the hydraulic model tests.

In the case of a change to 160 degrees, the effect is expected to be yet lower than the case of N-S direction, judging from the result of the tracer experiment (HM Case D-10).

3-7 Variation of Siltation

As already seen in Fig. II.2.2-3 and -4, rainfall and river discharge in Banjarmasin change considerably every year. Sediment supply from the Barito River naturally fluctuates accordingly. The relationship between the volumes of discharge and sediment transport in the river was presented in Fig. III.2.1-2.

In fact, the siltation rate surveyed in the past showed a large variation. For example, it was 0.75, 0.24, and 0.86 million m^3/month on the average from March to June in 1987, 1988, and 1989 respectively, when no dredging work was carried out and surveys were made by 210 kHz echo sounders. It should be noted that the above volumes mainly included fluid mud, judging from a record taken by 33 kHz in July 1988.

This variation of annual siltation volume might be caused by external forces. If we pick up only three major variables of wave height H(m), sediment transport volume from the Barito river S (ton/sec) and others as a whole, and if we could suppose that the siltation volume V (million m^3/month) can be expressed as :

$$V = aH^2 + bS + c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

the parameters of a, b, and c can be determined by introducing the result of simulations which give average siltation volumes in the rainy, dry and transitional seasons, i.e.,

Season	Period (days)	H (m)	S (ton/sec)	V (mill m^3)
Rainy	182	0.58	0.300	2.69
Dry	182	0.43	0.045	1.52
Transitional	85	0.41	0.175	0.80

The result is :

$$V = 0.721\ H^2 + 0.338\ S + 0.105 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Then, making use of Eq. (2), we can roughly examine the variation of siltation due to variations in wave height and sediment discharge.

Average wave height for half a year could be considered to fluctuate on the order of +20 to -10 cm in the rainy season and +10 to -5cm in the dry season. In the simulation the wave height was given by 58 cm and 43 cm respectively. Hence, the variation of siltation by waves could be expected as :

Rainy season : $((78 \text{ to } 48)/58)^2 = 1.8 \text{ to } 0.7$, and
Dry season : $((58 \text{ to } 38)/43^2 = 1.5 \text{ to } 0.8$.

Sediment supply depends on rainfall which was 240 mm (73% of 7-year average) in the rainy season and 100 mm (63%) in the dry season in 1988/1989. Hence, rainfall fluctuated at least $\pm$ 30% and $\pm$ 40% in the rainy and dry seasons, which corresponds to the fluctuation of river discharge. As the sediment supply is proportional to the 1.56th power of river discharge, as understood from Fig. III.2.1-2, variation in siltation could be expected:

Rainy season : $(0.30 \text{ to } 0.70)^{1.56} = 1.5 \text{ to } 0.6$, and
Dry season : $(1.40 \text{ to } 0.60)^{1.56} = 1.7 \text{ to } 0.5$.

Combining the above volumes and applying them to the above Eq.(2), we can conclude that the annual siltation volume could have a variation of -20% to +45% or could be more. Thus, the annual variation of siltation is not small.

An example of the application of Eq.(2) is to estimate the order of siltation rate through hindcasting siltation in 1988 to 1989 when we observed H and S, and to adjust the results to ordinary years taking account of the unusual decrease in rainfall and river discharge during the rainy season in 1988-1989 as seen from Fig. II.2.2-4. The roughly estimated siltation rate is respectively from January to December, 0.50, 0.40, 0.30, 0.25, 0.20, 0.20, 0.25, 0.25, 0.35, 0.35, 0.45 and 0.70 million m^3 per month, and in to total 4.2 million m^3/year.

It is to be noted again that the above volumes calculated in the simulation are those for substantial soils consisting of sand with a specific gravity of 2.65 and a porosity of 40% and mud with a water content of 110% an a bulk density of 1.45 t/m^3.

PART V EVALUATION OF ALTERNATIVE PLANS

Chapter 1 Siltation Reduction Plans

1-1 Viewpoints from Channel Planning

1-1-1 Traffic Demands and Planning Criteria

Based on the traffic forecast about 29 ships per day are expected to call at Banjarmasin port in the year 2000. Physical capacity of the channel with a depth of DL-6m is considered to be barely enough for design ships equivalent to 6,500 GRT, taking account of a tidal level of DL+2m. Thus, alternative plans for a channel depth of less than -6m are to be disregarded.

The width of the channel must be determined primarily from the viewpoint of navigational safety. The most critical type of ship in terms of channel width consists of tugboats towing a barge with a wire 100m long, which need a channel width of 100m under the most oblique strong ebb current condition crossing the channel with 30 degrees. For conventional cargo and container ships of 6,500 GRT size, design criteria of more than $L_{oa}/2$ or 5 B_{ext}, where L_{oa} is the overall length, 130m, and B_{ext} is the maximum width of the design ship, 20m, can be applied, and a channel bottom width, B, of 100m is considered to be a prerequisite. Hence, alternative plans for a channel width less than 100m are disregarded.

1-1-2 Future Expansion

After the year 2000, demand for a larger channel is anticipated to grow. In order to accommodate 11,000 GRT class ships, a water depth of DL-8.0m and a bottom width of 100 - 120m will be required, taking account of DL+2.0m tidal level.

Under the minimum requirement of -6.0m depth and 100m width and slope of 1/8, the distance between channel shoulders is to be no less than 210m at the shallowest central area of the channel. If a depth of -8m and a bottom width of 120m are required, the distance must be more than 230m. This requirement is related to cases with submerged wall plans. Alternative plans for submerged walls with a distance of less than 210m cannot be employed for the above reason, and that with a 240m distance is the minimum case.

1-1-3 Navigational Safety

(1) Evaluation of Alternatives from the Navigational Viewpoint

a. Present Channel

The planned present channel has a profile of -6m in depth and 60m in bottom width. Some important factors such as the following are taken into consideration:

1) The length of the channel is very long,

2) The crossing ebb current is rather strong,

3) Accidents in the channel should be anticipated, and

4) Other,

it is normally necessary to keep more than 5 x Bext for safe navigation as discussed above in the section 1-1-1 of this chapter.

Generally speaking, the burden of ship's maneuvering becomes higher for a navigator parallel to the decrease in water depth and width as well as the increase in the length of a channel . Assuming the helm of a ship is handled with an accuracy of one (1) degree in practice, the deviation of the ship's position from the channel centerline e(m) is in proposition of the distance D(m) from the leading mark(s) on the centerline, and can be expressed by:

$e = 0.02 \times D$ for a single mark, and

$= 0.014 \times D$ for two marks,

In the cases of D = 14 km and 7 km, the required channel widths ($B = 2 \times e$) are 400 m and 200m, respectively, which in practice are too wide to adopt. Marks such as channel buoys and lights become indispensable. Assuming that pair marks are arranged on both sides of the channel with an interval of 2.5 to 3.0 km, the deviations become 35 to 42 meters, respectively. The required channel width is about 100m.

If an accident happens due to grounding, choking of cooling water intakes, etc., the ship has to anchor in the channel. It is necessary to secure a channel width more than 60% of the overall length, L_{oa}, taking the 30 degree oblique current into account. For instance, for a design ship with a length of 130m a channel width of not less than 100m is required. Thus a 60 meter width of the present channel of one lane cannot satisfy these conditions.

So, a new planned channel with a width of 60 m is not advisable for the access channel of Banjarmasin Port.

b. Submerged Wall Plans

Generally, submerged walls should be constructed in areas not so far from the access channel.

According to our field survey, all ships entering and leaving the port have been passing through the inside of the access channel, so apparently the submerged walls do not menace the safety of navigation. And also, the results of simulations and hydraulic model tests showed that there are no remarkable current changes between the present condition and submerged wall condition.

Even if there is no remarkable change in these conditions, however, the submerged walls will represent a major new hazard for small vessels.

In addition, during the period of submerged wall construction, it is necessary to establish special navigational safety measures to ensure safe and smooth passage of ships and operations of working vessels.

c. New N-S Alignment Plan

According to the results of the field surveys and the hydraulic model tests, the center line of the new alignment access channel is apparently the same as the flow of the Barito River, and the current velocity in the new channel will not increase considerably compared with that in the present alignment.

So, from the point of view of ships' maneuvering, the layout of the new access channel could generally be better than the present one.

During the construction period of the new channel, ships can use the present channel. Hence, the dredging and other works at the new channel will not be hindered by ships' navigation.

(2) Allocation of Navigational Aids

The access channel requires adequate navigational aids that clearly indicate the navigational area. For navigational aids, a leading light beacon, a lighted buoy and a beacon are often used, and combinations of them are also used.

Generally, a leading light beacon indicates a navigational center line for a relatively short distance but does not clearly indicate the edge of a channel. On the other hand, a buoys-and-beacons synchronized flashing system installed along the channel clearly shows the line of the channel edge both day and night.

When submerged walls are installed, marking lights are necessary to show the representative locations of the invisible walls.

Based on the above concepts, allocations of navigational aids are planned as shown in Table V.1.1-1 for the following cases:

a. Present Channel Plan,
b. New N-S Alignment Plan, and
c. Submerged Wall Plan at the Present Alignment.

The allocations of channel buoys for a. Present Channel and b. New N-S Alignment are recommended to be a pair buoy system equipped with a synchronized flashing system for each access channel, as illustrated in Figs. V.1.1-1 and 2.

Table V.1.1-1 Allocation of Navigational Aids

(M : miles
m : meters)

Plan / Aids	Current Condition	Present Channel	New N-S Alignment	Submerged Walls
Leading Light-rear	Height-25m Visibility-10M	25 meters 12 Miles	25 meters 12 Miles	25 meters 12 Miles
Leading Light-fore	Height-11m Visibility-9M	15 meters 10 Miles With Racon	15 meters 10 Miles With Racon	15meters 10 Miles With Racon
Fairway Buoy	6Mx1	8Mx1 With Racon	8Mx1 With Racon	8Mx1 With Racon
Channel Buoy	4Mx2 6Mx1 Interval 4-5km	Pair Buoy System and Radar Reflector 4Mx10 6Mx2 Interval 2.5km-3km	Pair Buoy System and Radar Reflector 4Mx8 6Mx2 Interval 3km	Zigzag Buoy System and Radar Reflector 4Mx4 6Mx1 Interval 2.5km
Marking Light for Submerged Walls				4Mx8 Interval ab. 4km

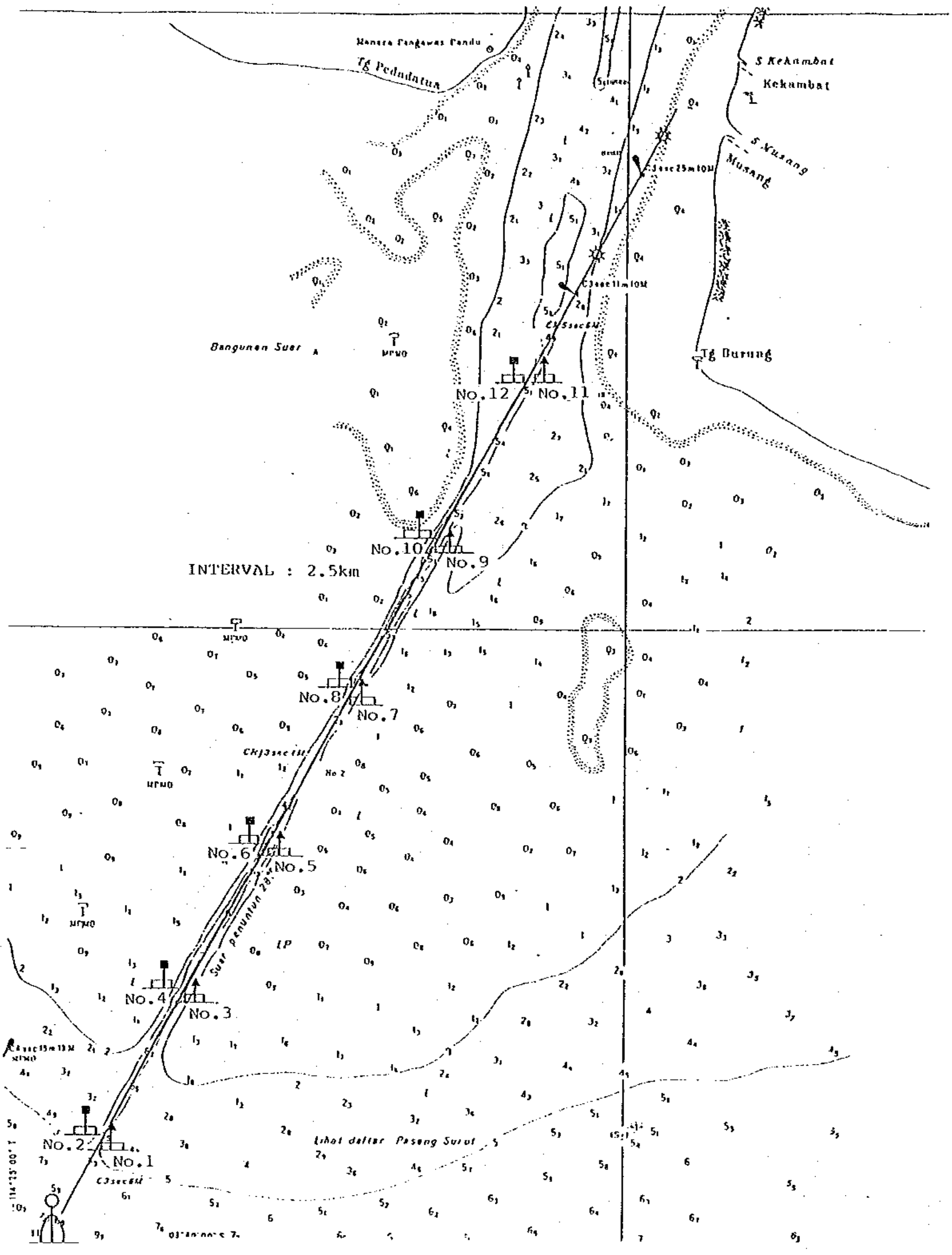


Fig. V.1.1-1 Arrangement Plan of Navigational Aids at the Present Channel

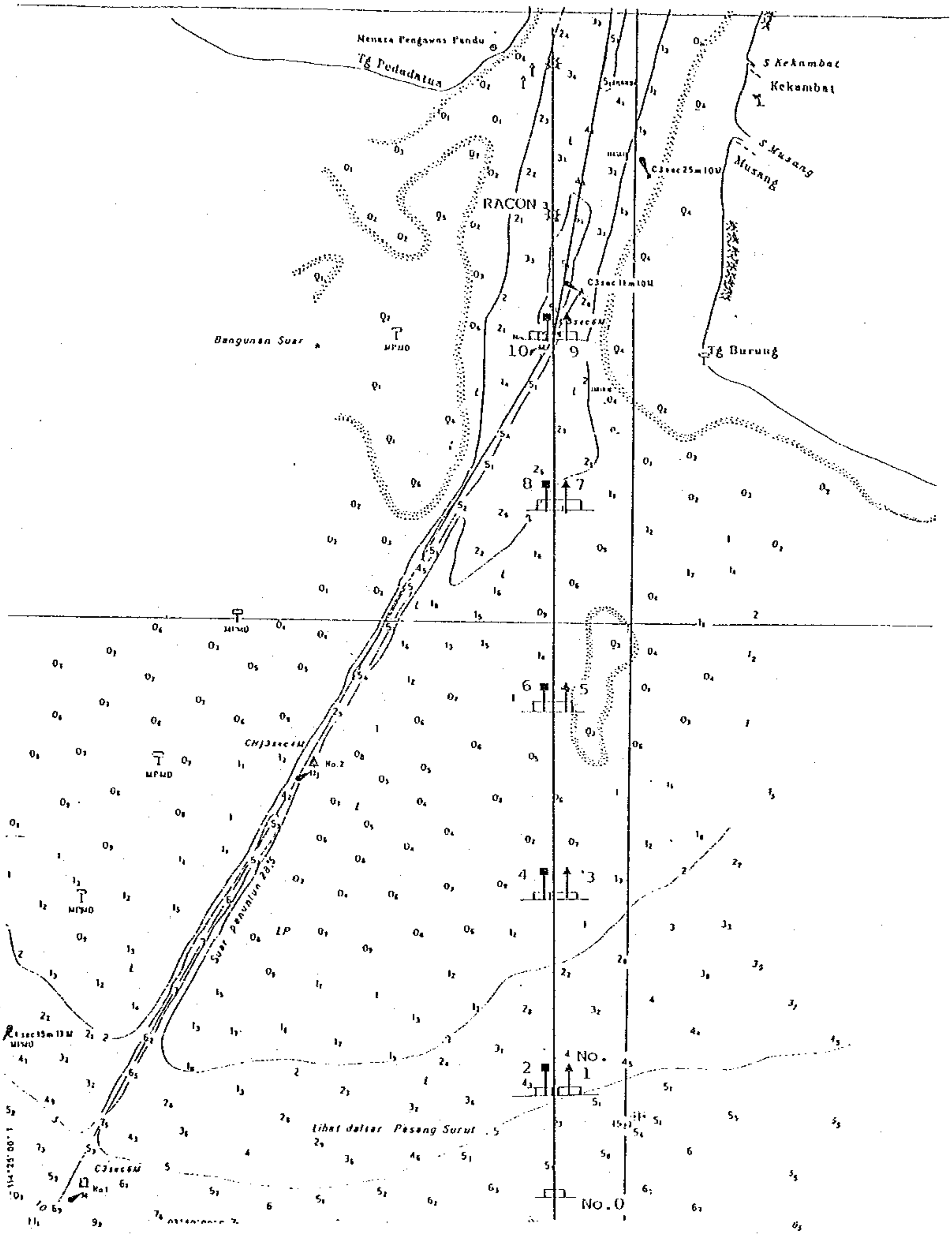


Fig. V.1.1-2 Arrangement Plan of Navigational Aids at the New Channel

According to the information provided to the study team at Banjarmasin, a similar pair buoy system was once used in the present channel. Some buoys were damaged very often by accidents and effort has been made to repair them. Taking this experience into account, the above pair buoy system for the present channel requires better traffic control and education/training regarding safer navigation of small vessels in the channel. In this context, a pilot boat should be introduced for the patrol of the channel area. For the new channel, the pair buoy system presents fewer problems of this kind owing to parallel currents.

As for the submerged wall plan at the present channel, the number of the channel buoys can be decreased and arranged in a zigzag fashion, considering the additional arrangement of pair marking lights on the submerged walls to be supplemental to the channel buoys, i.e. five (5) channel buoys at Nos. 1, 4, 5, 10 and 12 in Fig. V.1.1-1 and four (4) pairs of marking lights on the walls.

1-1-4 Environmental Impact

From the environmental point of view, serious problems are not anticipated for alternative plans including siltation reduction facilities such as submerged walls and long jetty. They will not cause noticeable deterioration of water quality nor backwater, the latter affecting the water level of Banjarmasin. Their effect of the environment, specifically as regards fish and shrimp is not clear, but is expected to be minimal compared with the other large-scale natural impacts of river discharge, agitation due to waves, etc., on the bank.

1-2 Prevention of Siltation

1-2-1 Advantageous Alternatives

One of the primary objectives of this study is to develop countermeasures to reduce siltation volume as much as possible.

There are 17 alternatives, examined by hydraulic and/or numerical tests. Judged only from the viewpoint of prevention and reduction of siltation, some alternatives can be discarded from the further discussions toward the formulation of the Comprehensive Plan.

Such alternatives to be disregarded owing to their relative inferiority may include Trap, New 160 degrees Alignment and Training Wall plans. The Training Wall plans could be substituted by Submerged Wall plans.

There are two special kinds of alternatives, the Long Jetty Plan and Expansion Plan. The long jetty would have a considerable effect in changing the large-scale coastal process and decreasing eastward sediment transport. It cannot be fully relied upon, however, in terms of stopping direct intrusion of sediment into the channel at Spots Nos. 11,000 - 12,500. Hence, the Long Jetty Plan is different in nature from the other alternatives and has to be considered most properly over a long time span, possibly after 2000 when a countermeasure will have been taken and its effect can actually be judged.

The other special alternative of the Expansion Plan up to a depth of -8 m and width of 120 m does not have to be considered for the time being.

In any event, the Long Jetty and Expansion Plans can be deleted from the list of Comprehensive Plans.

Thus, the relatively advantageous countermeasures are the group of Submerged Wall Plans and the New N-S Alignment Plan. Their siltation volume assessed in the above PART IV, Chapter 3, is summarized in Table V.1.2-1, in addition to Present Condition and Principal Plan as basic cases. They are re-numbered in the Table.

Table V.1.2-1 Comparison of Siltation Volume of Alternative Plans

(Unit : Million m3, < > and ( ) are ratios)

Case No	Classification	Channel Depth and Width	Layout	Crown Height, Width	Numerical Simulations			Hydraulic Tests		Combinative Calculation				
					Rainy Season	Dry Season	Annual Total	Rainy Season	Dry Season	Seasonal: Rain S.	Seasonal: Dry S.	Seasonal: Annual	Direct Annual: W.U.coef.	Direct Annual: Annual
I.	Present Condition (PC)	-6m 60m*)	Present Alignment	No Facility	2.7 <1.00>	1.5 <1.00>	4.2 <1.00>	- <1.00>	- <1.00>	2.7	1.5	4.2	1	4.2 <1.00>
II.	Principal Plan (PP)	-6m 100m	Present Aligment	No Facility	3.3 <1.22> (1.00)	1.8 <1.21> (1.00)	5.1 <1.21> (1.00)	- <0.43> (1.00)	- <0.44> (1.00)	3.3	1.8	5.1	1	5.1 <1.21> (1.00)
III-1	Submerged wall(C1)	-6m 60m	Sp.2,000 -13,000	1.5m 180m ***)	1.9 <0.71> (0.58)	1.1 <0.73> (0.61)	3.0 <0.71> (0.59)	- v) (0.19)	- v) (0.42)	1.5	0.8	2.3	0.214	2.3 <0.55> (0.45)
III-2	Submerged Wall(C2)	-6m 100m	Sp.2,000 -13,000	1.5m 210m ***)	2.4 (0.75)	1.4 (0.75)	3.8 (0.75)	- v) (0.19)	- v) (0.42)	1.9	1.0	2.9	0.214	2.8 <0.68> (0.55)
III-3	Submerged Wall(C3)	-6m 100m	Sp.2,000 -13,000	1.5m 270m ***)	2.5 (0.77)	1.4 iv) (0.78)	3.9 iv) (0.77)	- iv) (0.19)	- iv) (0.42)	2.0	1.0	3.0	0.214	2.9 <0.69> (0.55)
III-4	Non-Continuous Submerged Wall(NC)	-6m 100m	Sp.3,000**) -7,000 and -10,000 -13,000	1.5m 270m ***)	2.7 (0.81)	1.6 (0.85)	4.2 (0.83)	- (0.38)	- (0.73)	2.2	1.3	3.5	0.500	3.5 <0.83> (0.69)
IV.	New N-S Alignment (NA)	-6m 100m	N-S Direction	No Facility	2.8 <1.03> (0.85)	1.6 <1.06> (0.87)	4.4 <1.04> (0.86)	- (0.21)	- (0.59)	2.8	1.6	4.4	1	4.4 <1.04> (0.86)

*) In Hydraulic Tests, width is 40m.
**) In Numerical Simulations, layout is from Sp.2,000 to 6,000 and Sp.10,000 to 13,000.
***) In hydraulic tests, width is 260m.
iv) Estimates
v) Supposed to be same as case C3.

1-2-2 Characteristics of the Advantageous Alternatives

The advantageous alternatives in Table V.1.2-1 can be classified into two groups, i.e.:

1) The present channel without submerged walls (Cast I and II) and that with submerged walls (Case III), and
2) A new alignment without submerged walls (Case IV).

as shown in Fig. V.1.2-1.

(1) Narrow Channel Plans

Among these alternatives, the cases of Present Conditions (Case I) and its Submerged Wall (Case III-1) are not eligible as candidates for the Comprehensive Plan, because of the inferiority of a narrow channel width of 60 m from the viewpoints of planning and safety of the channel as discussed above, although their siltation reduction rates are high. In addition, the narrow Submerged Wall (Case III-1) presents such problems as inability to allow future expansion of the channel depth and width, and higher risk of colliding with ships.

(2) Submerged Wall Plans with 100m Width

Submerged Walls (Cases III-2 and 3) with a channel width of 100 m have an almost equivalent effect in terms of siltation reduction. The wall distances, therefore, can be selected flexibly between 210 and 270 m, taking account of allowances for overdredging, erosion of channel shoulders, future expansion of depth and width and others. Hence, there are other candidates such as a case of 210 m wall distance with partly widened portions (III-2') as shown in Fig. V.1.2-2 and a case of 240m (III-3'). The siltation rates of Case III-2' and III-3' are estimated as about 2.8 and 2.9 million m^3 per year, respectively, or about a 45% reduction of siltation compared with the Principal Plan.

The Non-continuous Submerged Walls (Case III-4) are selected in the areas with relatively higher siltation reduction effect. The siltation rate is assessed as about 3.5 million m^3 per year. This plan can be understood as a stage of the continuous Submerged Walls (Case III-3). The long-term effects of the openings should be confirmed at the site later.

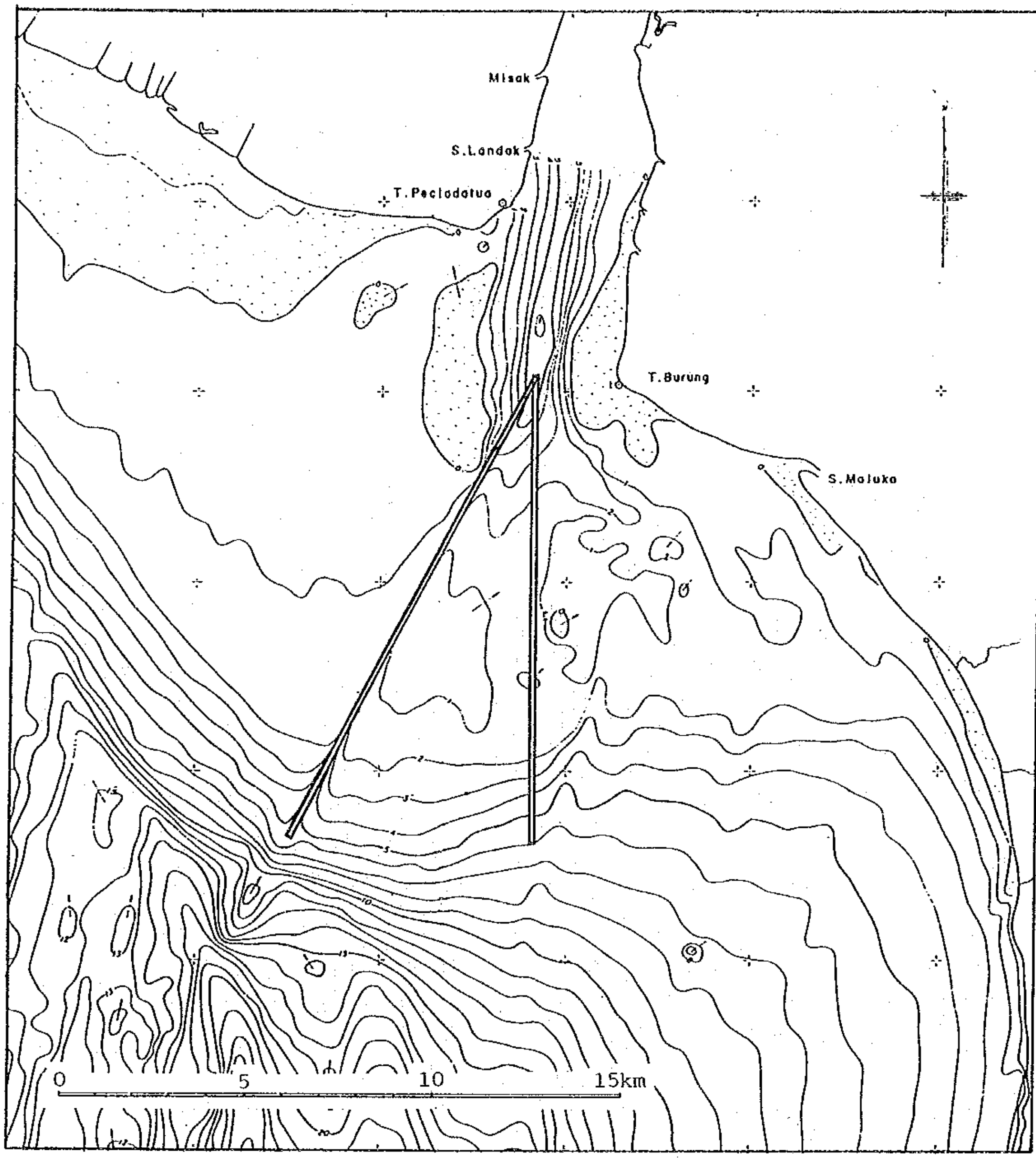
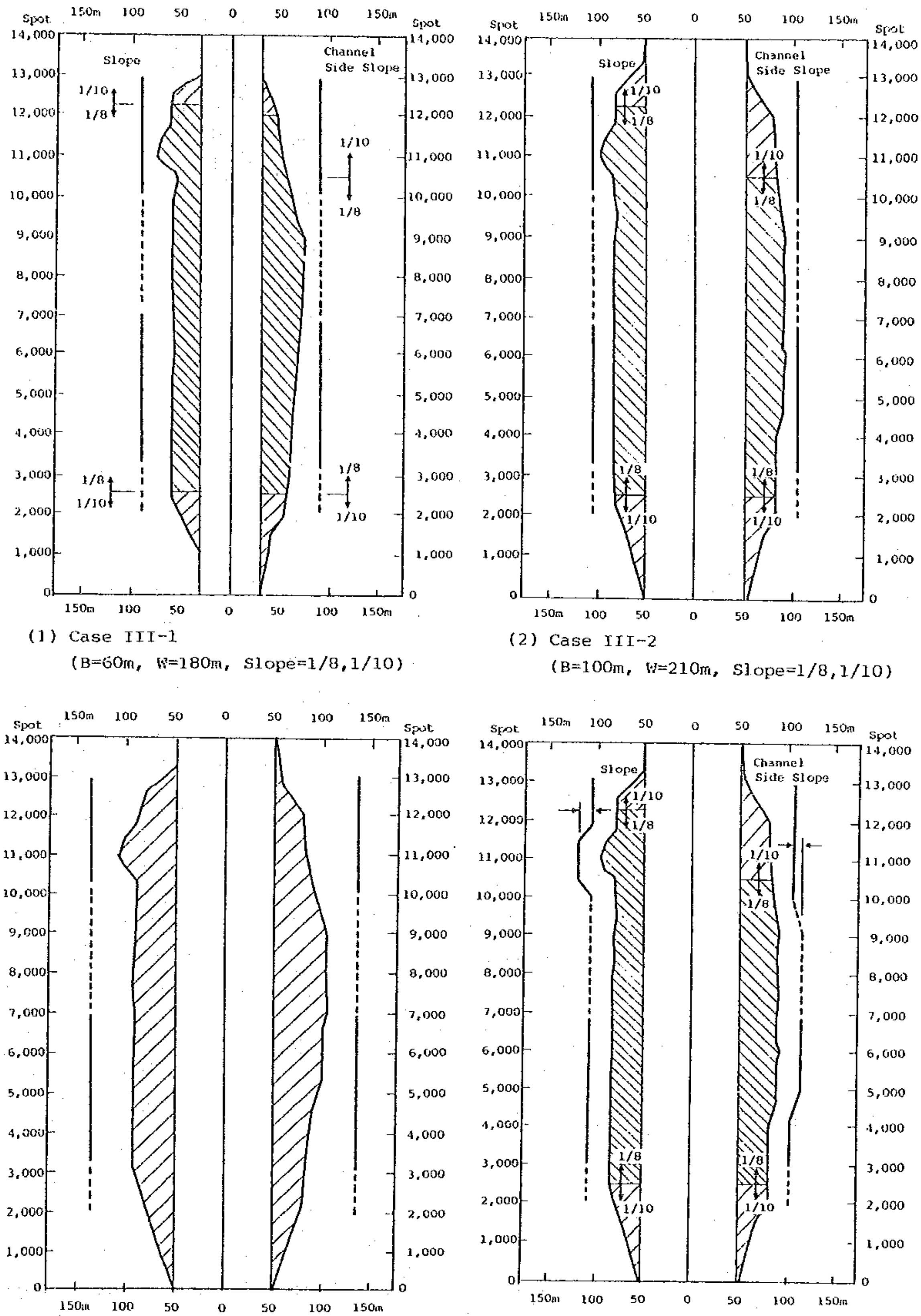


Fig. V.1.2-1 Candidate Layouts of the Access Channel



(1) Case III-1
(B=60m, W=180m, Slope=1/8,1/10)

(2) Case III-2
(B=100m, W=210m, Slope=1/8,1/10)

(3) Case III-3
(B=100m, W=270m, Slope=1/10)

(4) Case III-2'
(B=100m, W=240m, Slope=1/8,1/10)

Fig. V.1.2-2 Arrangement of Submerged Walls and Side Slopes

It is to be noted that the submerged wall against siltation is a rather new technology. And the characteristics of siltation differ from place to place affected by geography; source and nature of sediments;external forces such as tides, waves, and currents;seabed soils;etc. Hence, the submerged wall must be carefully designed, constructed and maintained taking into account the local conditions.

In these contexts there are technical subjects on which special attention is to be paid, i.e.:

a. Structure and Cost

b. Effect and Function

of the submerged wall.

Although these two subjects are interrelated, a. is mainly concerned to the durability of the structure itself and possibility of cost saving, which related to the detailed design. Condition of soft foundation, strong currents and moderate waves are major factors to be considered. The present technology can generally overcome these factors based on detailed surveys. If the ultimate cost-effectiveness is sought by rather a fragile structure, it might be examined only at the site.

With regard to above b., the submerged wall ensures substantial reduction of siltation volume. As the siltation in the channel takes place along almost entire channel length except for the two entrances, as the direction of current is oblique to the wall, and as the sediments can go around the ends of the wall, the submerged wall must be long enough to ensure the overall effect.

Besides the length, the crown level of the submerged wall should be kept more than 1.5m above the seabed as far as it is submerged. The siltation reduction effect cannot be achieved without preservation of the function of the submerged wall against accumulation and/or erosion of the seabed beside the wall, i.e. burying and/or stripping of the structure. There kinds of deformation could occur due to the existence of the wall as an obstacle for waves and currents, specifically during floods and storms. The force of waves and current are different from spot to spot, which implies the phenomena have local nature. Prediction of these local deformation is difficult to make quantitatively, given the present level of technology.

In the case of Kumamoto Port, a submerged wall with a height of 1m above the seabed at DL-2m (HWL +4.5m) proved that no significant deformation has occurred on the seabed after its experiences of several storms since 1986. In the Banjarmasin Channel, the downstream area has less severer conditions than the upstream area near the shallow bank at Spot No.10,000 - 14,000. Even considering Kumamoto's experience, possibility of a certain degree of local accumulation and/or erosion should not be denied especially at the upstream portion at the moment. It will not be serious, however if appropriate monitoring surveys and maintenance works will be done in addition to prudent detailed design, construction scheduling and execution.

(3) New N-S Alignment Plan

The New N-S Alignment (Case IV) expected to result in a 14% reduction of siltation compared with the Principal Plan. The new alignment, however, involves technically difficult judgment on the long-term and large-scale effects of excavating a new channel in a shallow water area such as:

a. After the present channel is buried by siltation without maintenance dredging, the sand spit presently formed to the west of Spot No. 10,000 to 12,000 will almost surely be extended in a south - east direction and will affect the siltation phenomena in the new channel in the long run.

b. The central portion of the new channel where the present water depth is only 1 m may possibly induce erosion of the channel shoulders in certain areas of both sides of the new channel.

c. The offshore portion from the center of the new channel could suffer from long-term and wide-range erosion due to diffraction of waves and formation of standing waves caused by excavation of the new channel.

d. Fluid mud on the seabed will more easily flow down into the new channel as a result of cross sectional slopes created by the above b. and c.

The degree of the above large-scale and long-term effects is difficult to assess quantitatively. It should be anticipated, however, that there might be a possibility of increase in siltation with an order of several hundred thousand cubic meters per year, considering the past 15-year history of the present channel after the initial capital dredging.

(4) Principal Plan

The Principal Plan (II) represents the worst case of the siltation volume among the above alternatives. The absolute value of the siltation rate is prohivitively high.

(5) Summary

Summarizing the candidate alternatives for further evaluation, the narrow channel plans (Cases I and III-1) are discarded. The submerged wall plans of 210 m and 270 m wall distance (Case III-2 and Cases III-3 and 4) can be replaced by the partly widened plan and plans of 240 m wall distance plans, respectively, as discussed above. The Non-continuous Submerged Walls (Case III-4) is considered as a part of the continuous Submerged Walls (Case III-3). Thus, Table V.1.2-2 is the list of candidate alternatives with information on siltation volumes by area.

Table V.1.2-2 Estimated Siltation Volume and Effect of Submerged Walls by Area of Candidate Alternatives

(Million m^3/year and ratio in ( ))

Case No.	Classification	Wall distance	Estimated Annual Siltation Volume				
			A	B	C	D	Total
II.	Principal Plan	-	0.8 (1.0)	1.4 (1.0)	1.8 (1.0)	1.1 (1.0)	5.1 (1.0)
III-2	Submerged Walls	210m ~225m	0.6 (0.82)	0.7 (0.50)	1.0 (0.55)	0.5 (0.47)	2.8 (0.55)
-3	Submerged Walls	240m	0.7 (0.85)	0.7 (0.51)	1.0 (0.55)	0.5 (0.47)	2.9 (0.55)
IV.	New N-S Alignment	-	1.0	1.3	1.1	1.0	4.4 (0.86)

Note: Areas are A: Sport No. 0-3,500, B: 3,500 - 7,000, C: 7,000 - 10,500 and D: 10,500 - 14,000.

1-3 Dredging Viewpoint

Concerning the four alternatives which are listed in Table V.1.2-2 in the above paragraph countermeasures, evaluations are made from the point of view of dredging.

1-3-1 Principal Plan (Case No.II)

The widening of the channel is required and a cutter suction dredger will be necessary. This type of dredger will hinder the navigation of other vessels during dredging. Agitation dredging efficiency is same as that of the present condition. Annual siltation volume will be the highest of all the cases.

1-3-2 Submerged Walls (Case No.III)

(1) Submerged Walls Between 210 m and 225 m Apart (Case No.III-2)

Annual siltation volume is estimated at about 2.8 million cubic meters and this is the lowest of all the cases. Compared with Case No.II, the present agitation dredging methods which dumping soils inside or near the channel will not be used because of submerged walls. In this case, agitation dredging is to be carried out so that the dredged material may dumped beyond submerged walls by side-casting. The necessary horizontal distance for dumping from a dredger is about 100 meters. If this kind of side-casting dredging can be carried out, the efficiency of side-casting dredging will greatly increase and the total dredging efficiency will also remarkably increase.

There will be one problem in surveying. Submerged walls are located near the top of the slope, so sounding survey crossing the channel is difficult above the slope. However, sounding surveys in longitudinal directions using accurate survey equipment will solve this matter.

(2) Submerged Walls 240 m Apart (Case No.III-3)

The most features of this plan are the same as those of Case No.III-2. The location of submerged walls from the channel is further than that of Case No.III-2, so side-casting dredging near the center line of the channel is more difficult. Annual siltation volume is nearly same as that of Case No.III-2.

1-3-3 New Alignment (Case No.IV)

Capital dredging will be carried out by a big cutter suction dredger. The alignment of the channel is similar to the direction of the predominant current, so agitation dredging will not be efficient. The length of the channel is about 12 km and annual siltation volume is estimated at 4.4 million cubic meters.

1-4 Preliminary Design, Execution and Rough Cost Estimates

In this sub-section, some items/aspects to be taken into account in the implementation stage of the project will be briefly discussed for each of the alternatives presented for siltation reduction. The volume of required capital dredging and structure of submerged walls will be discussed. All the alternatives will be compared from the viewpoint of cost.

1-4-1 Key Points of Execution

In establshing an implementation plan for the project, the following points should be taken into account for the alternatives.

(1) All Alternatives

To secure the design dimensions of the access channel, all the proposed alternatives include some dredging work. Dredging volume includes not only the net volume calculated as the difference between the exsisting maintained channel dimensions and the designed ones but also any extra dredging or over-dredging volume and dredging work required to remove any volume accumulated during the capital dredging work.

(2) Alternatives to Existing Alignment (Case II and III)

For Cases II and III both of which would utilize the existing channel alignment, special attention should be paid to ensure safe navigation of ships. Announcements concerning project execution aimed at channel users before and during execution and frequent patrols to call channel users' attention to the situation would be at least necessary.

For Case III, involving the submerged walls, construction scheduling and method for the submerged walls should be supplied to all concerned with the capital dredging to avoid any complications with the use of work vessels and/or other construction machinery.

(3) New Alignment (Case IV)

The new channel alignment (Case IV) doesn't include a submerged wall but does include capital dredging work. For the new channel alignment, execution should be done with special attention focused to minimize adverse influence on the existing channel from material depositing especially around the mouth of the Barito River where the existing and new channels are in close proximity.

The direction chosen for the capital dredging work would be one of the main factors affecting the efficiency of the dredging work. The overall water flow pattern over the new channel alignment indicates a flow direction which follows almost alongside the new alignment in a downward direction. This is especially true at ebb tide. Consideration of this flow pattern leads to the conclusion that the downward dredging direction would be preferable.

1-4-2 Preliminary Design

(1) Capital Dredging

As discussed above, all the candidate alternatives for the siltation reduction should include capital dredging work. After examination of the volume to be dredged, and taking the capacity of the dredgers and other technical and economic conditions into account, the capital dredging work of the existing channel alignment(Case II and III) can be done by a combination of the existing Perumpen's dredgers. The new channel (Case IV), however, cannot be dredged using the Perumpen's.

In the new channel alignment, the dredging work comes first and there is no way for trailing suction hopper dredgers to enter and work. The other Perumpen's dredgers, e.g. the cutter suction dredgers, do not have enough capacity to dredge the new channel. Even if dredging continued endlessly, the channel dimensions as desired would never be completed. The new channel alignment needs cutter suction dredgers of horse power 8,000 PS or more from a source other than Perumpen.

As for the existing channel alignment (Case II and III), a combination of the existing Perumpen's dredgers could carry out the capital dredging. In Case II, which has the largest dredging volume among the existing channel cases, two trailing suction hopper dredgers of 2,900 m^3 and 4,000 m^3 and one cutter suction dredger of 3,600 PS are judged to be enough to complete the dredging work within about 10 months. The proposed area assigned for the two kinds of dredger based on their characteristics is illustrated in Fig. V.1.4-1 and summarized below.

- Trailing Suction Hopper Dredger

  Area within the channel width and offshore half of the west bank

- Cutter Suction Dredger

  Onshore half of the west bank, all of the east bank and the turning basin

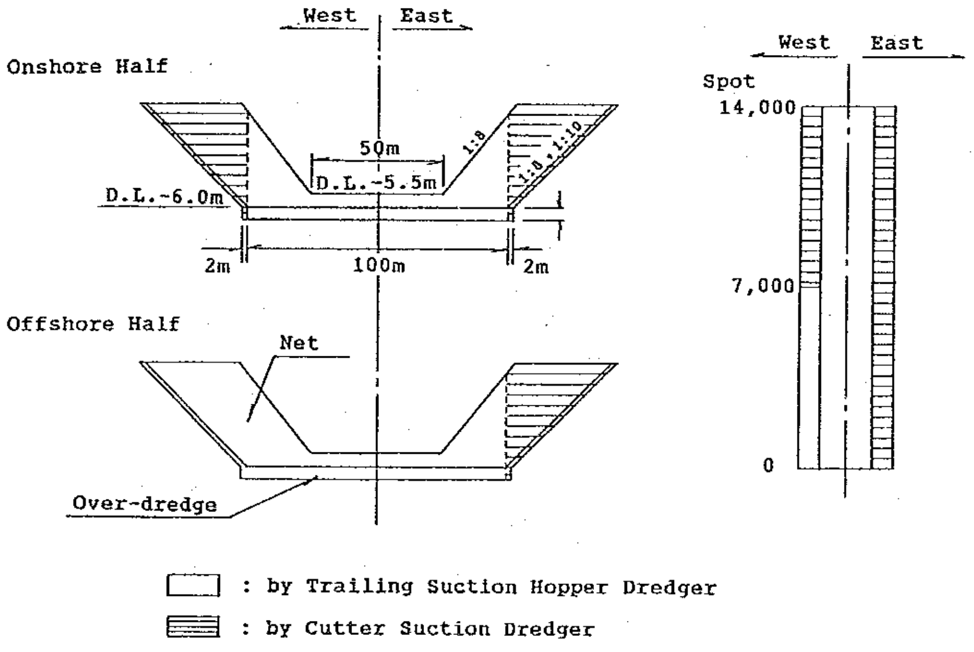


Fig. V.1.4-1 Dredging Area and Dredgers for Existing Channel Alignment

The capital dredging volumes in each alternative are shown in Table V.1.4-1. In the table, T.S.H.D. stands for trailing suction hopper dredgers and C.S.D. refers to cutter suction dredgers.

The turning basin will be discussed later in Chapter 2 of this part. The volume "Excluding Turning Basin" refers to the volume calculated by comparing the designed channel and present channel dimensions for the existing channel cases, including over-dredging and siltation in one year of capital dredging. The present channel dimensions for the calculation of dredging volume are DL -5.5m depth, 50m width and 1 on 8 slope, as shown in Fig. V.1.4-1, which is considered to be an average channel dimensions maintained by DGSC recently.

The siltation volume during capital dredging for the existing channel cases was assumed to be an average of the estimated annual siltation volumes of the Present Condition (4.2 mill. m^3) and that for each particular case. After the completion of the facilities the siltation volume would be the value of each case, but before completion the siltation volume can be considered as between the value for each case and that of the Present Condition which is the starting stage. This calculation is for the purpose of comparison of the alternatives and based on the same assumption that the all works in dredging and facility construction can be completed in one year.

In the case of the new channel the full annual siltation volume was considered. The total volume of this case is estimated at 11 mill. m^3 which is about double that of the net volume of about 6 mill. m^3. This assumption can be considered reasonable as it is close to the value found at the time of the initial capital dredging of the existing channel in 1975.

Table V.1.4-1 Capital Dredging Volume

Case No.	Classification	Channel Depth and Width	Layout	Crown Height, Width	Annual Siltation Volume (mill. m^3)	Excluding Turning Basin (A) ($000m^3$)	Turning Basin Additional (B) ($000m^3$)	Siltation During Dredging (C) ($000m^3$)	Total (A)+(C) ($000m^3$)	by Dredger ($000m^3$)		Total (A)+(B)+(C) ($000m^3$)	by Dredger ($000m^3$)	
II	Principal Plan (PP)	-6m 100m	Present Alignment	No Facilities	5.1	4,506	40	4,650	9,156	T.S.H.D.	6,534	9,196	T.S.H.D.	6,534
										C.S.D.	2,622		C.S.D.	2,662
III-2	Submerged Wall (C2)	-6m 100m	Sp. 2,000 -13,000	1.5m 210m	2.8	4,138	40	3,500	7,638	T.S.H.D.	5,532	7,678	T.S.H.D.	5,532
										C.S.D.	2,106		C.S.D.	2,146
III-3	Submerged Wall (C3)	-6m 100m	Sp. 2,000 -13,000	1.5m 240m	2.9	4,138	40	3,550	7,688	T.S.H.D.	5,572	7,728	T.S.H.D.	5,572
										C.S.D.	2,116		C.S.D.	2,156
IV	New N-S Alignment (NA)	-6m 100m	N-S Direction	No Facilities	4.4	7,006	50	4,400	11,406	T.S.H.D.	-	11,456	T.S.H.D.	-
										C.S.D	11,406		C.S.D	11,456

T.S.H.D.: Trailing Suction Hopper Dredger

C.S.D.: Cutter Suction Dredger

(2) Siltation Reduction Facility

The siltation reduction facility for Cases III-2 and 3 is submerged wall. In planning the structure, the following aspects should be taken into consideration.

a. Function of Submerged Walls

- impermeability as a wall structure
- durability against erosion
- stability from the viewpoint of crown height and
- stability against external forces, etc.

b. Construction Work

- very soft soil condition
- construction speed
- easily obtained and constant material supply
- simple procedure in construction works
- minimal influences from oceanographical conditions and
- minimal cost, etc.

c. Others

- easy maintenance or free from maintenance and
- applicability to staged plan, etc.

The design conditions will be described later in Chapter 2 of PART VII and the proposed standard cross section of the submerged walls is shown in Fig. V.1.4-2

(3) Navigational Aids

As for the navigational aids, the items necessary for each case are listed in Table V.1.1-1 in sub-section 1-1-3 of this chapter. For all cases, the purchase of one pilot boat is also proposed in the same sub-section.

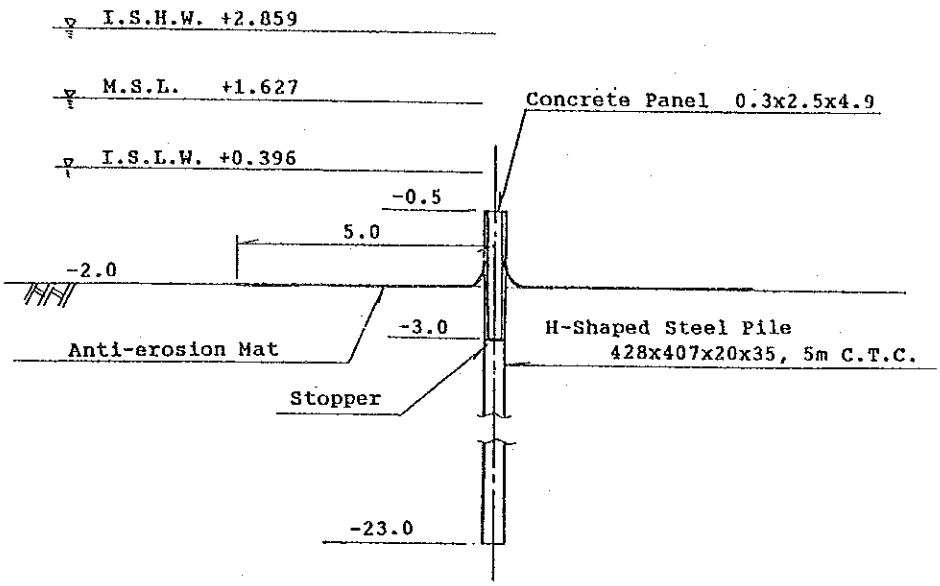


Fig. V.1.4-2 Standard Cross Section of Submerged Walls

1-4-3 Rough Cost Estimates

The initial costs for the candidate alternatives of siltation reduction plans are shown in Table V.1.4-2. As discussed previously, the capital dredging work of the existing channel is to be done by Perumpen's dredgers. The unit costs are estimated as 1,500 Rp/m^3 for trailing suction hopper dredgers and 3,200 Rp/m^3 for cutter suction dredgers. These values were calculated taking into account that the unit costs will be probably increased by the time of possible project implementation, around 1994 based on a degree of escalation similar to that for 1990, namely 980 Rp/m^3 to 1,200 Rp/m^3 for hopper dredgers and 1970 Rp/m^3 to 2,500 Rp/m^3 for non hopper dredgers. Other costs in the table are based on an international tender basis.

Table V.1.4-2 Costs of Siltation Reduction Plans

Case No.	Classification	Channel Depth and Width	Layout	Crown Height, Width	Annual Siltation Volume (mill.m³)	Capital Dredging by T.S.H.D. (mill.m³)	Unit Cost (US$) (/m³)	Dreadging by T.S.H.D. (000US$) (mill.Rp)	Capital Dredging by C.S.D. (mill.m³)	Unit Cost (US$) (/m³)	Dredging by C.S.D. (000US$) (mill.Rp)	Total Dredging (A) (000US$) (mill.Rp)	Facility Submerged Wall (000m)	Unit Cost (US$) (/m)	Total Facility (B) (000US$) (mill.Rp)	Sub Total (A)+(B) (000US$) (mill.Rp)	Navi. Aid (C) (000US$) (mill.Rp)	Grand Total (A)+(B)+(C) (000US$) (mill.Rp)
II	Principal Plan (PP)	-6m 100m	Present Alignment	No Facilities	5.1	6.53	0.81	5,288 9,778	2.62	1.73	4,531 8,378	9,820 18,157	-	-	-	9,820 18,157	1,126 2,081	10,945 20,238
III -2	Submerged Wall (C2)	-6m 100m	Sp. 2,000 -13,000	1.5m 210m	2.8	5.53	0.81	4,478 8,281	2.11	1.73	3,649 6,748	8,128 15,028	22	1,378.81	30,334 56,087	38,462 71,116	981 1,815	39,443 72,930
III -3	Submerged Wall (C3)	-6m 100m	Sp. 2,000 -13,000	1.5m 240m	2.9	5.57	0.81	4,511 8,341	2.12	1.73	3,667 6,780	8,177 15,120	22	1,378.81	30,334 56,087	38,511 71,207	981 1,815	39,493 73,022
IV	New N-S Alignment (NA)	-6m 100m	N-S Direction	No Facilities	4.4	-	-	-	11.41	2.57	29,366 54,297	29,366 54,297	-	-	-	29,366 54,297	1,078 1,992	30,443 56,290

T.S.H.D.: Trailing Suction Hopper Dredger

C.S.D.: Cutter Suction Dredger

Chapter 2 Dredging Efficiency Improvement Plans

2-1 Dredging Methods

2-1-1 Appropriate Method

Various dredging execution methods used in the world are shown in Table V.2.1-1. By combining one method with other methods, many methods can be developed and applied. Judging from the present conditions of the channel such as soil, climate, meteorology, sailing vessels, fuel oil supply, fresh water supply, profile, dumping area, etc., trailing suction hopper dredgers are most suitable for maintenance dredging of the channel. Supplementing normal hopper dredging, this type of dredger can carry out agitation dredging by side-casting.

2-1-2 Making the Turning Basin

Preparing a turning basin in this narrow channel is the best way to reduce cycle time and non-productive time. At present there are only a few chances for dredgers, especially dredgers with 2,900 m^3 or 4,000 m^3 hopper capacity, to turn in the channel due to the draft and length of dredgers and the channel condition. Based on the results of the semi-capital dredging, reduction of cycle time is estimated as explained in Section 5-2 of Chapter 5 of PART III.

In case of one turning basin, the middle of the channel will be the best. If turning basins are located at two places, the middle of area B and the middle of area C will be the best combination. The ratio of saved sailing distance to total sailing distance is 14.2% for one turning basin and 18.6% for two turning basins.

The calculated ratio depends on the dredging volume in each area. If the dredging volume is greater in the offshore part, the above ratio is higher. The proportion of the estimated siltation volume in the offshore part is higher that in the semi-capital dredging, so the ratio is higher than the above value. The ratio is calculated based

Table V.2.1-1 Dredging Execution Methods (1/2)

Main Classification	Individual type	Method of extraction	Method of transportation	Method of disposal
I. Mechanical	1.Dipper Dredger	Face shovel	Barge	Bottom discharge grab or suction pump
	2.Backhoe Dredger	Backhoe bucket	,,	,,
	3.Stationary bucket dredger	Bucket chain	,,	,,
	4.Sell-propelled bucket dredger	Bucket chain	,,	,,
	5.Sell-propelled hopper bucket dredger	Bucket chain	Own Hold	,,
	6.Pipeline bucket dredger	Bucket chain	Pipeline	Pipeline
	7.Dragline	Drag bucket	Barge	Bottom discharge,grab or suction pump
	8.Stationary grab dredger	Grab	,,	,,
	9.Self-propelled dredger	Grab	Own hold	,,
II. Hydraulic	1.Stationary suction dredger	Suction head (primary) Centrilugal pump (secondary)	Pipeline or barge	Pipeline Bottom discharge,grab or suction pump
	2.Jet pump suction dredger	Suction head (primary) Jet pump (secondary)	,,	,,
	3.Hopper suction dredger	Suction head (primary) Centrifugal pump (secondary)	Own hold	Pipeline or bottom discharge

Table V.2.1-1 Dredging Execution Methods (2/2)

Main Classification	Individual Type	Method of Extraction	Method of Transportation	Method of Disposal
	4.Cutter suction dredger	Cutter head (primary) Centrifugal pump (secondary)	Pipeline	Pipeline
	5.Bucket wheel excavator	Bucket wheel (primary) Centrifugal pump (secondary)	Pipeline	Pipeline
	6.Trailing suction hopper dredger	Draghead (primary) (with or without water jets or blades) Centrifugal pump (secondary)	Own Hold (mainly) Natural process (in case of necessety)	Bottom dump or pipeline (mainly) Natural process (in case of necessety)
	7.Trailing suction sidecasting dredger	Draghead (primary) (with or without water jets or blades) Centrifugal pump (secondary)	Natural process	Natural process
	8.Dustpan dredger	Dustpan head with water jets (primary) Centrifugal pump (secondary)	Pipeline	Natural process
III.Pneumatic	1.Pneumatic dredger (Ooze dredger)	Suction head (primary) (and drag head if necessary) Seabed pump (secondary)	Pipeline or barge	Pipeline Bottom discharge, grab or suction pump
	2.Air lift dredger	Suction head (primary) Air lift (secondary)	Barge	Bottom discharge, grab or suction pump

Source : Dredging : A Handbook for Engineers on some assumptions, so the ratio calculated from the results of the semi-capital dredging is considered from the safety side. Trailing suction hopper dredgers with 2,900 m^3 and 4,000 m^3 hopper capacity will reduce its sailing distance by 14.2%, so dredging efficiency will increase by 16.5% in the case of one turning basin below:

$$100 / (100 - 14.2) = 1.165$$

The plan of the turning basin is shown in Fig.V.2.1-1.

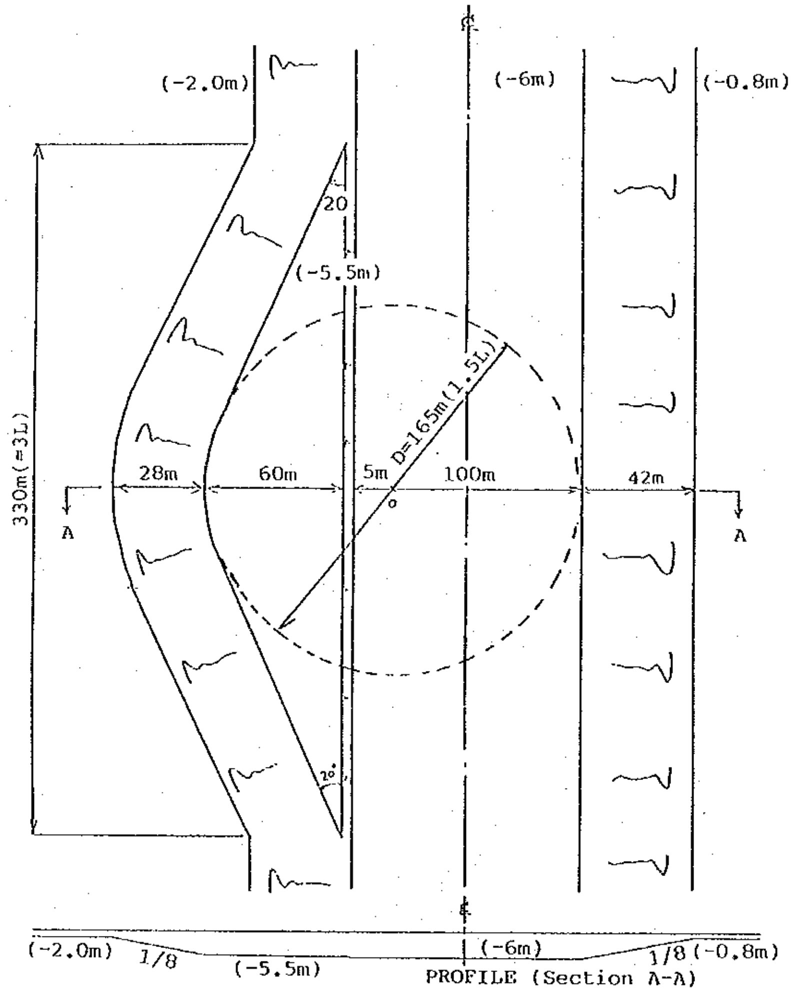


Fig. V.2.1-1 Plan of Turning Basin

2-1-3 Attachments to Dragheads

The draghead is the most important element in increase dredging efficiency. The spade has been proved to be useful for a wide rage of soil conditions through trials in Japan and will be useful in this channel. As shown in Table II.6.4-6 of Chapter 6 of PART II, the mean concentration ratio of IRIAN JAYA is around 47%. Other dredgers will increase its concentration ratio to the level of 47% by attaching spades to the dragheads.

A levelling blade will be used in the last stage of the project. The efficacy of levelling blades has been confirmed through experimental dredging in Japan. Experimental dredging using levelling blades in Japan showed that over-depth dredging with levelling blades is shallower by about 20 cm than dredging without levelling blades. More output was required for propulsion power and dredging pump power in case of dredging with blades and increased by about 6%.

2-1-4 Tugboat Equipped with a Blade

Using a tugboat equipped with a blade might be necessary to support maintenance dredging by a trailing suction hopper dredger. This kind of tugboat is widely used at present in many countries. A tugboat with a blade can remove high spots, level the sea bottom, remove many obstacles, sweep the sea bottom and carry out agitation.

In case of unsuitable sea conditions for an ordinary survey boat, this tugboat is used as a survey boat. Moreover, this tugboat might achieve the same effect by dredging with levelling blades. It is difficult to estimate the dredging improvement efficiency quantitatively. However, it is expected that dredging efficiency will increase by around 5% by using a tugboat with a blade.

2-1-5 Draghead Position Indicator System

Dredging efficiency will be increased by installing a draghead position indicator system, and thus the number of bathymetric surveys required will decrease.

2-1-6 Agitation Dredging and Side-casting

At present, agitation dredging is executed mainly to secure the navigation of the dredger itself at the initial stage of each maintenance dredging work at this channel and is sometimes carried out near the slope. It is not clear whether this method is effective or not, because the behavior of material dumped following agitation dredging is unknown. However, it can be said that agitation dredging is effective at least over a short period, because a trailing suction hopper dredger can operate safely after agitation dredging. The principles of agitation dredging and the agitation devices are explained in Section 5-2 of Chapter 5 of PART III.

In case where a dredger can side-cast the dredged material beyond submerged walls, it is expected that re-siltation of the dumped material will be greatly reduced due to submerged walls. So, a rough estimate of dredging efficiency by side-casting method in several cases is carried out below.

(1) Re-siltation Ratio

The re-siltation ratio, r, can be defined as a ratio of the returning volume against the dumped volume. Re-siltation behavior is different from sand and mud. Hence the ratio can be expressed by:

$$r = vs*rs + vm*rm$$

where

vs: ratio of the volume of sand against the total dumped volume,v,
vm: ratio of the volume of mud against the total dumped volume,v,
rs: re-siltation ratio of sand, and
rm: re-siltation ratio of mud

It is to be noted that the ratios depend on the place and facility where dumping works are performed.

(2) Volume to be Dredged

Assuming that siltation of new sediments does not occur during a series of dredging works, or only the re-siltation of the dumped soils is considered, the required maintenance dredging volume, D, becomes:

$$D = V /(1-r)$$

where

V : initial siltation volume in the channel to be dredged out, which consists of those of sand, Vs, and mud, Vm.

Or more precisely, the above expression should be expressed as :

$$D = V*\{vs/(1-rs)+vm/(1-rm)\}$$

(3) Time Saving Effect of Side-casting

By introducing the side-casting method, the time needed to dredge can be reduced by approximately 75% without traveling to and from the dumping site, which is located 5 km offshore from buoy No.0.

The area where side-casting can be applied covers 70% of a channel with a width of 100 m as shown in Fig.V.2.1-2, and 100% in a 60 m channel. In this area, a volumes of 86% and 100% of soils are accumulated, respectively. However, if the distance between submerged walls is 240 m, the area where side-casting can be applied covers 40% in a channel width of 100 m as shown in Fig.V.2.1-3 on the condition that the reaching distance by side-casting is about 100 m. Taking these facts into consideration, the time saving ratio, Et, compared with the conventional dredging and dumping method, is:

1) Channel with 60 m width

$$Et = 0.25*1.00 = 0.250$$

2) Channel with 100 m width

$$Et = 0.25*0.86+1.00*0.14 = 0.355$$

3) Channel with 100 m width and the distance between submerged walls is 240 m.

$$Et = 0.25*0.86*4/7+1.00*(0.14+0.86*3/7) = 0.631$$

(4) Assessment of Dredging Efficiency

The total dredging efficiency can be expressed as:

$$E = Et*D/Vr$$
$$= Et*(V/Vr)*\{vs/1-rs)+vm/(1-rm)\}$$

where

Vr : reference volume such as the volume of siltation in the present channel.

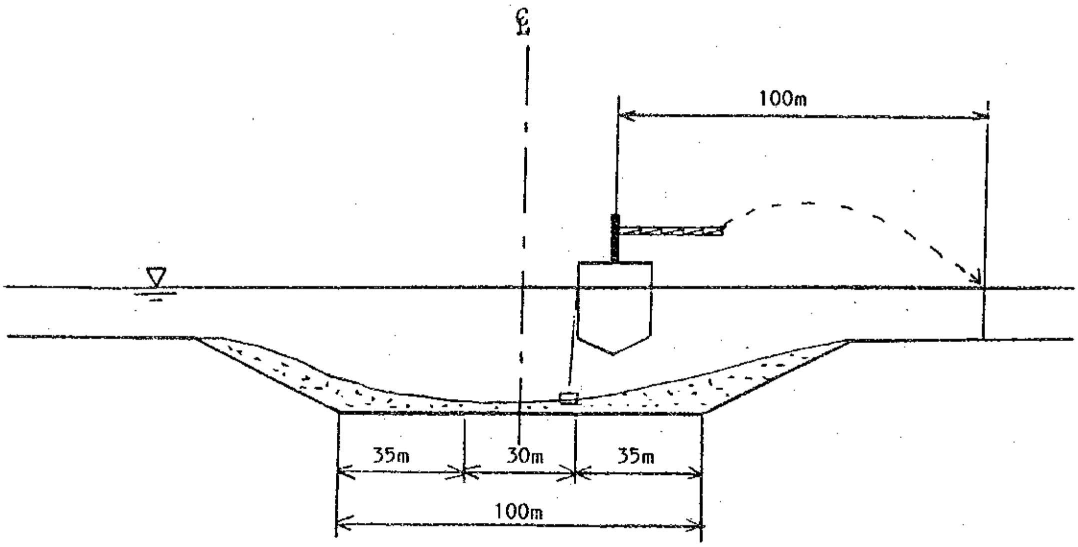


Fig. V.2.1-2 Image of Side-casting

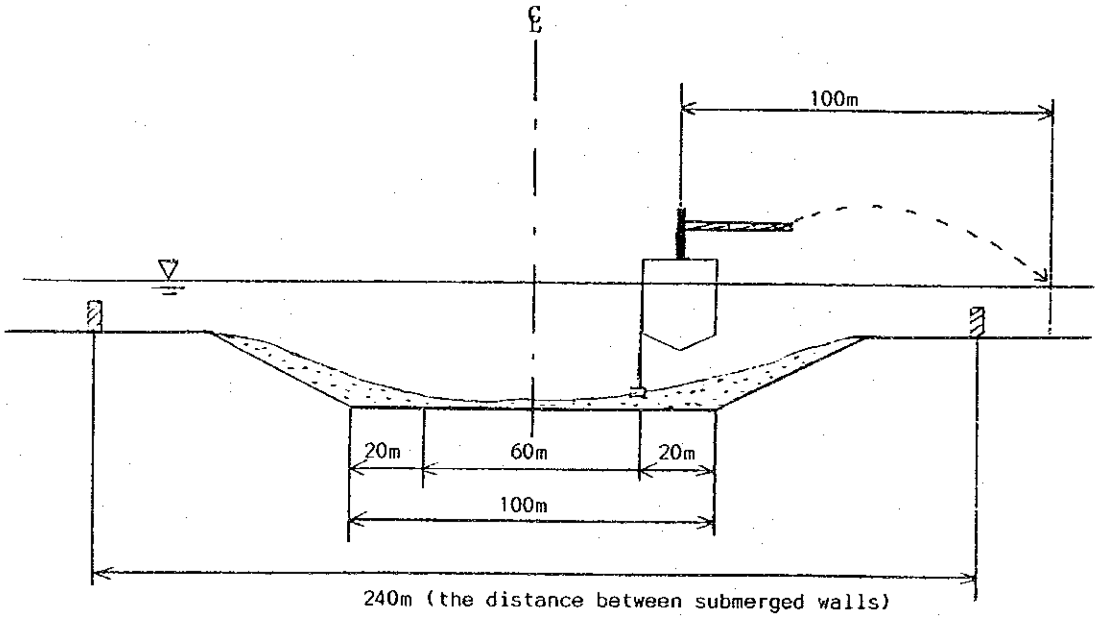


Fig. V.2.1-3 Image of Side-casting with Submerged Walls

An example of estimating the efficiency is presented here under some assumptions considering the result of our study :

Vr = 4.2 millions cubic meters which is the estimated volume of siltation for the present channel condition without any facility,

vs = 0.16,

vm = 0.84,

The calculation results are shown in Table V.2.1-2. This method will greatly improve dredging efficiency.

(5) Difficulty of Actual Operations

There will be some problems regarding this method. One problem is greatly influenced by the conditions of wind. Side-casting against the wind direction is impossible. Wear on the nozzle will be great and frequent replacement will be necessary. However, this side-casting operation is expected to be realized by remodeling the present trailing suction hopper dredger. For reference, horizontal reaching distance of jet and fire fighting boat are shown in Fig.A V.2.1-1 and Fig.A V.2.1-2 of the appendices, respectively.

Table V.2.1-2 Estimate for Dredging Efficiency by Side-casting

Dumping Site	Case No.	Width of Channel (m)	Et	V (mill. m^3)	rs	rm	E
Offshore	I	60	1.0	4.2	0.0	0.0	1.00
Inside the Channel	I III-1	60 60	0.250 0.250	4.2 2.3	1.0 1.0	0.9 1.0	very large very large
Outside the Channel and Submerged Walls	I II	60 100	0.250 0.355	4.2 5.1	0.3 0.3	0.6 0.6	0.58 0.78
	III-1 *	60 100	0.250 0.631	2.3 2.9	0.1 0.1	0.2 0.2	0.17 0.46

Notes : (1) Case No. is in accordance with cases of countermeasures in Table V.1.2-1.

(2) * is the case that the distance between submerged walls is 240 m and is same as Case No.III-3 of Table V.1.2-2.

2-1-7 Others

(1) Timing of Dredging

The aim of maintenance dredging of this channel is to keep the necessary depth and width of the channel throughout its whole length so that all vessels may navigate safely anytime. The annual siltation volume in this channel is large, so it is necessary that one dredger is always dredging throughout the year. If it is difficult to keep one dredger through one year, one alternative is to dredge during the rainy season using two dredgers. However, the channel cannot be maintained by this method. Because even in the dry season, the estimated siltation volume is about half that of the rainy season.

(2) Order of Dredging

It is preferable to dredge the entire length of the channel totally step by step. At present, the channel is divided into four sections every 3.5 km. The hopper of a dredger is fully loaded when a dredger dredges about 3.0 km. The order of dredging is planned so that the entire length of the channel is deepened concurrently. For example, the channel is dredged to be deepened every 50 cm through the whole length until the designed depth. Siltation seems to occur near Spot No.12,000 in the west part of the channel at first and then near Spot No.5,000 in the east part of the channel at present. This fact will be confirmed from Fig.V.2.1-4 showing the ratio of dredged volume during semi-capital dredging by each area and line. The estimated siltation volume is divided into four sections under some assumptions and the proportion is shown in Table V.2.1-3. More dredging will be required in area C.

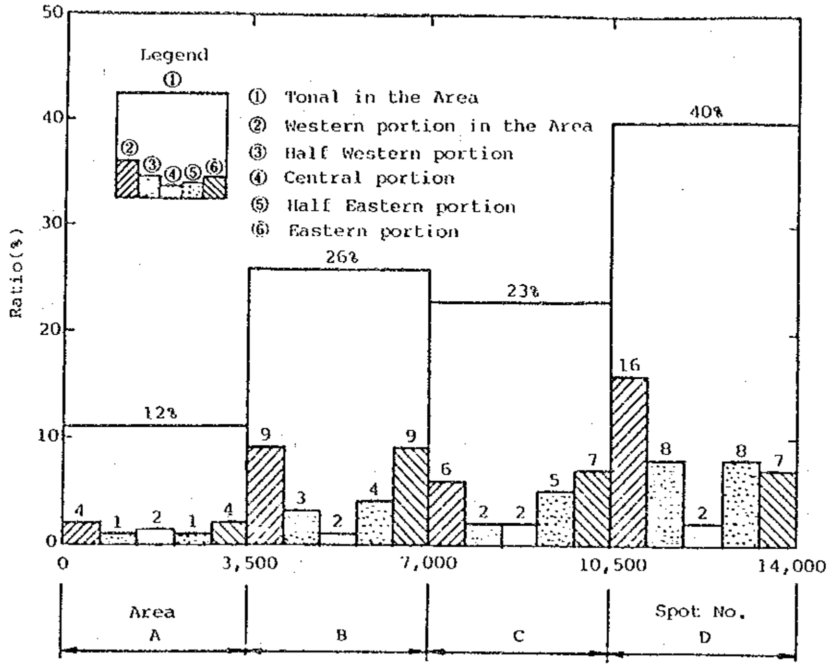


Fig. V.2.1-4 Ratio of Dredged Volume during Semi-capital Dredging by Area (Total volume: 3,075,000m^3 from June, 1988 to Feb., 1989)

Table V.2.1-3 Ratio of Estimated Siltation Volume by Area

unit : %

Case No.	Area A	Area B	Area C	Area D
I	14.3	27.3	34.1	24.2
II	15.4	27.3	35.4	21.9
III-1	23.3	23.7	32.0	21.0
III-2	22.8	24.3	34.6	18.3
III-3	23.2	24.3	34.5	18.0
III-4	19.2	26.5	39.0	15.3
IV	22.4	29.6	24.7	23.4

Note: Each case number is same as that of alternative plans of siltation countermeasures listed in Table V.1.2-1.

(3) Dumping Area

If it is found that dumping near the river mouth in the east is effective by trials, it might be effective to dump there during ebb tides especially when the dredging area is near river mouth, such as areas C and D. In cases where dredging is close to the offshore such as area A and B, the present dumping area will be used. The location of dumping areas excluding that mentioned in Case No.IV, is shown in Fig. V.2.1-5.

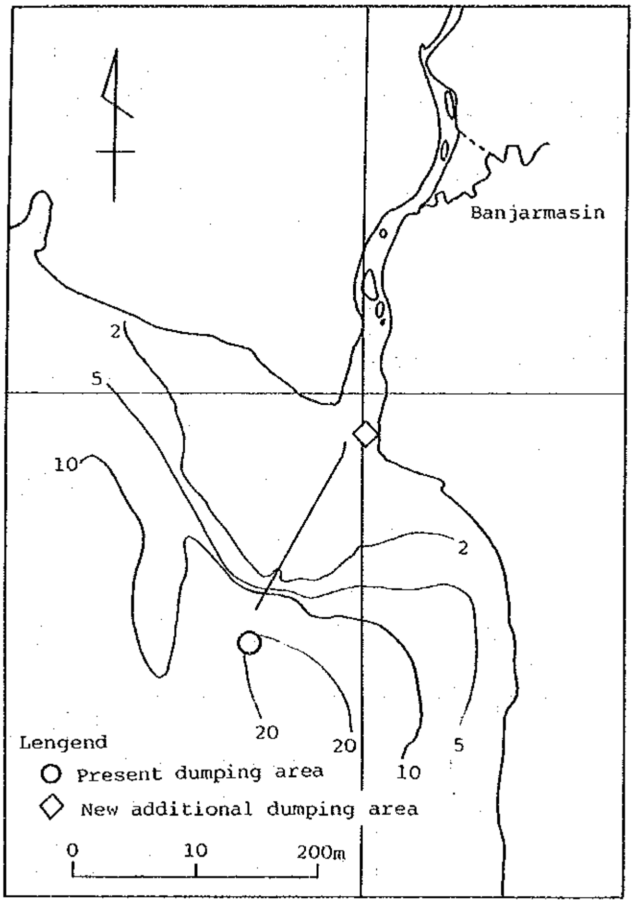


Fig. V.2.1-5 Location of Dumping Area

2-2 Dredging Equipment

2-2-1 Attachment to Dragheads

The spade can be easily attached to the present dragheads. The spade is described in Part III of Interim Report (1) and shown in Fig.III.5.2-4, Fig.III.5.2-9, and Fig.III.5.2-10 of Chapter 5 of PART III of this report.

The levelling blade will be also easily fixed to both sides of the present dragheads in the latter stage of the project. The levelling blade is shown in Fig.III.5.2-3, Fig.III.5.2-11 and Fig.III.5.2-12 of Chapter 5 of PART III.

2-2-2 Tugboat Equipped with a Blade

The tugboat equipped with a blade will be necessary to contribute to better operation by a trailing suction hopper dredger. The sketch of this tugboat is shown in Fig.V.2.2-1. One complete survey system is installed in this tugboat. It is necessary to know the exact position and depth where a trailing suction hopper dredger cannot dredge well. In case of unsuitable sea conditions for an ordinary survey boat, this tugboat will be used as a survey boat.

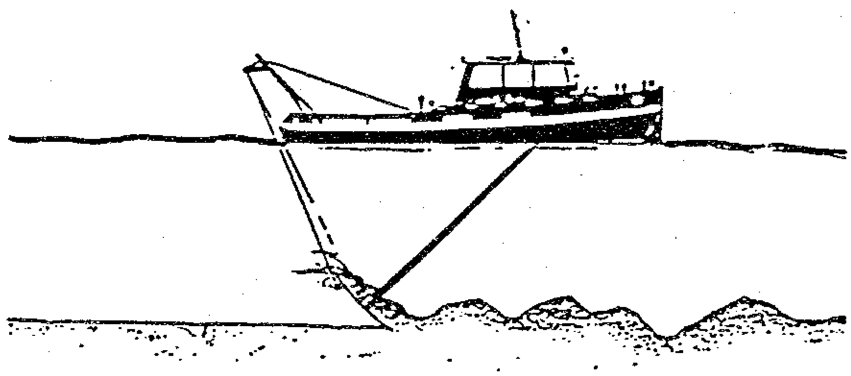


Fig. V.2.2-1 Tugboat Equipped with a Blade

2-2-3 Draghead Position Indicator System

The draghead position indicator system will be installed in a trailing suction hopper dredger and is illustrated in Fig.III.5.2-8 of Chapter 5 of PART III.

2-2-4 Remodeling of the Dredger

If submerged walls are constructed along the channel, the some amount of dredged material might be dumped beyond the submerged walls. It will be required to side-cast around 100 meters at least. In order to achieve this side-casting, it will be necessary to use a boom and jet. One plan is remodeling one of trailing suction hopper dredgers of Perumpen. A rotating boom is installed within the present open space on the deck. One additional dredging pump which can be connected to the one of the present two dredging pumps during side-casting will be installed.

2-2-5 Others

There is a replacement of dredger and supporting equipment plan in Repelita V by the DGSC and is listed in Table A V.2.2-1 of the appendices. There is the possibility that a grab dredger or a cutter suction dredger is partly used in the channel due to the Perumpen deployment plan. In such a case, suitable combinations of a dredger and supporting equipment are required. Examples of combinations are listed in Table A V.2.2-2 and Table A V.2.2-3 of the appendices.

2-3 Dredging Control and Survey

2-3-1 Dredging Control

(1) Elements of Control

There are four elements in the control of the dredging works: quality, progress, safety and cost. Quality control and progress control are important from the technical point of view. The quality of dredging works is checked by sounding surveys to confirm whether the dredged area meets the design profile or not.

Concerning progress control, the progress is always compared with the plan and the plan is revised based on the actual conditions. The original plan is often revised. Bar charts, graphs, drawings, etc., are used for progress control.

(2) Measuring Devices

It is necessary to know the re-siltation rate to control dredging operations. Dredged volume based on the transported volume is also necessary information. Some instruments such as flow, concentration and draft meter are useful. These instruments are sensitive and annual maintenance and calibration by the staff of the maker is required.

(3) Personal Computer

A personal computer will be very useful in controlling the daily dredging operation. Dredging volume calculation, the difference between the plan and the actual status, various costs, etc., can be easily calculated by a computer. A personal computer should be installed on site.

2-3-2 Survey

In the new guidelines for dredging set by the DGSC, the completion of one project is accepted when the design profile is cleared. So, the accuracy of the bathymetric survey should be improved. Sounding by dual frequencies such as 210 kHz and 33 kHz is necessary and a cross check should be made by lead.

It was reported by a consulting engineer supervising semi-capital dredging in the channel in 1988 and 1989 that tides are different in different locations. It is necessary to set two tide poles along the channel near Spots Nos.5,000 and 10,000 for bathymetric survey.
The position and condition of the present platforms are not suitable for survey purposes. One new platform will be constructed in the east part of the river mouth, as shown in Fig.V.2.3-1. If one reference station is set on this new platform and another reference

station is set on the leading tower front, the position of a survey boat and a dredger is can be determined.

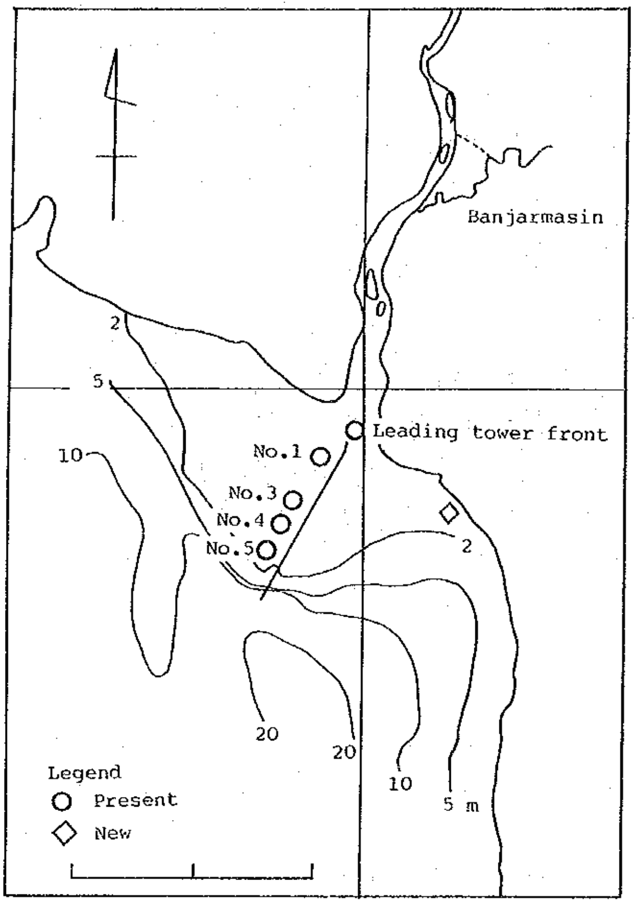


Fig. V.2.3-1 Location of Present and New Survey Platforms

2-3-3 Survey Equipment

The channel is long and dredging requirements are large. Therefore, a bathymetric survey should be carried out smoothly and accurately. One survey boat that can sail quickly and steadily will be required. Complete survey instruments including echo-sounder, positioning system, x-y plotter, data processor, etc., will be installed in the survey boat. Immediately after the survey, the dredged volume, the dredging requirement and high spot areas will be known through this system.

Concerning the present transducer including both 210 kHz and 33 kHz, it often happens that the sounding record by 33 kHz cannot be obtained. If the larger transducer is used and the electric power is increased, a sounding record by 33 kHz will be obtained.

One new survey platform will be constructed as shown in Fig.V.2.3-1 to set one reference meter. The height of this platform is similar to the height of the present leading tower front where one reference meter is usually set during the survey. The present survey platforms located in the west of the channel will not be used.

New instrument which can continuously record the underwater density will be developed. In comparison with the record by this new instrument and the record of echo-sounder, a system that can find the accurate nautical depth will be selected. Concerning the positioning system, a system using satellites will be realized by the year 2000.

2-4 Rough Cost Estimates

Various dredging efficiency improvement plans have been discussed in the previous sections 2-1 through 2-3. These plans are discussed from an investment cost viewpoint in this sub-section. The dredging efficiency improvement plans can be classified into two categories. One is related to the channel, namely the making a turning basin, and the other is related to the dredgers or other supporting equipment/machinery, e.g. spades to draghead and draghead position indicator, etc.

(1) Making Turning Basin

The cost of making the turning basin is expressed as extra dredging cost in addition to that for dredging to secure the designed channel dimensions. As discussed in section 2-1, the position of the turning basin is the middle of the channel, namely around Spot. 7,000, and the plan is shown in Fig. V.2.1-1. The dredging work will be done by a cutter suction dredger for both the existing and new channel alignments. As discussed previously in section 1-4 of this PART V, the dredging work for the existing channel alignment will presumably be carried out by Perumpen's dredgers while the new channel alignment would be by others. The costs of making the turning basin for each siltation reduction plan are shown in Table V.2.4-1.

Table V.2.4-1 Costs of Making Turning Basin

Case No.	Classification	Channel Depth and Width	Layout	Crown Height, Width	Annual Siltation Volume (mill. m^3)	Turning Basin Additional Volume ($000m^3$)	Unit Cost (US$) ($/m^3$)	Total (000US$) (mill.Rp)
II	Principal Plan (PP)	-6m 100m	Present Alignment	No Facilities	5.1	40	1.73	69.2 127.9
III-2	Submerged Wall (C2)	-6m 100m	Sp. 2,000 -13,000	1.5m 210m	2.8	40	1.73	69.2 127.9
III-3	Submerged Wall (C3)	-6m 100m	Sp. 2,000 -13,000	1.5m 240m	2.9	40	1.73	69.2 127.9
IV	New N-S Alignment (NA)	-6m 100m	N-S Direction	No Facilities	4.4	50	2.57	128.7 237.9

(2) Dredging Equipment and Other Machinery

According to sections 2-2 and 2-3, the proposed items of the dredging equipment and machinery are listed below.

- Building a tugboat equipped with a blade and survey equipment

- Building a fast survey boat equipped with complete survey equipment

- Fixing spades to draghead

- Installing a draghead position indicator in a dredger

- Constructing a new platform in the east part of the river mouth

- Installing a personal computer on the site

- Setting two tide poles along the channel near Spots. No.5,000 and No.10,000

- Remodeling the dredger for side-casting

The costs for the above items are shown in Table V.2.4-2.

Table V.2.4-2 Costs of Dredging Equipment and Machinery

Unit: thousands of US$

ITEM	UNIT	QUANTITY	UNIT COST	TOTAL
Dredging Equipment				
Tug Boat with a Blade & Survey Equipment				742.6
Tug Boat with a Blade (700PS)	Nos.	1	713.8	713.8
Echo Sounder (210KHZ/33KHZ)	Nos.	1	28.8	28.8
Survey Boat				656.8
Survey Boat (FRP, 20 knots Max.)	Nos.	1	480.4	480.4
Positioning System	Nos.	1	137.3	137.3
Echo Sounder (210KHZ/33KHZ)	Nos.	1	28.8	28.8
Data Processing System	L.S.	1	10.3	10.3
Spade for Draghead	Nos.	8	1.72	13.7
Draghead Position Indicator	L.S.	1	274.5	274.5
Survey Platform	Nos.	1	6.9	6.9
Personal Computer	Nos.	1	3.4	3.4
Tide Pole	Nos.	2	0.34	0.7
Hopper Dredger Remodeling	Nos.	1	14,687.2	14,687.2
Total without Hopper Dredger Remodeling				1,698.6 (mill. Rp.) 3,140.8
Total with Hopper Dredger Remodeling				16,385.8 (mill. Rp.)30,297.4

Chapter 3 Rough Economic Comparison

3-1 Method of Comparison

3-1-1 Purpose

The purpose of the economic comparison in this chapter is to roughly evaluate the alternatives and to help determine the comprehensive plan from the economic point of view.

3-1-2 Method

The comprehensive plan will be selected from the alternatives in the following three categories:

1) Channel Plans
2) Siltation Reduction Plans
3) Dredging Efficiency Improvement Plans

In this chapter we evaluate the alternatives for each item by a rough cost-benefit analysis using the internal rate of return (IRR).

The internal rate of return (IRR) is the rate that makes the discounted costs and benefits during the project life equal.
It is calculated by using the following formula:

$$\sum_{i=1}^{n} \frac{B_i - C_i}{(1+r)^{i-1}} = 0 \quad \text{------Equation V.3.1-1}$$

n : Period of economic calculation
B_i: Benefit in i-th year
C_i: Cost in i-th year
r : Discount rate

3-1-3 Prerequisites for Comparison

The following items are assumed as prerequisites:

1) Prices

Costs and benefits are counted in nominal prices without economic pricing.

2) "Without" Case

The cost-benefit analysis is carried out based on the difference between the "With" and "Without" investment cases. In other words, incremental benefits and costs arising from the proposed investment are compared and whether or not a net benefit is generated by the investment is examined.

3) Project Life

Considering the lifetime of the facilities, loan conditions and others, the project life is assumed as 30 years. Taking an initial one year for construction into account, the period of calculation is assumed to be thirty-one years between 1999 and 2029.

4) Unit Cost of Maintenance Dredging

The unit cost of maintenance dredging (DIP cost) is determined and revised every couple of years by the government. For instance, the unit cost will be revised from 980 Rupiah to 1,200 Rupiah in 1991. Considering the recent increase in the unit cost, it is assumed here that the unit cost increases 10% every three years.

5) Maintenance Costs of Facilities

It is assumed that the annual maintenance costs are equivalent to the following percentages of the construction costs:

Submerged walls: 0.3%
Dredging equipment: 5.0%
Navigational aids: 3.0%

6) Lifetime

The lifetime of the facilities and equipment after completion are assumed as follows:

Submerged walls: 50 years
Capital dredging: 50 years
Dredging equipment: 20 years
Navigational aids: 30 years

7) Residual Value

The residual value at the end of the project life is calculated by using the following formula:

$$\text{Residual Value} = \text{Construction Cost} \times \frac{(\text{Lifetime} - \text{Project Life})}{\text{Lifetime}}$$

--------Equation V.3.1-2

8) The Volume of Vessel Traffic at the Channel

The volume of vessel traffic assumed here is the same as the number estimated in the demand forecast and shown in Fig. III.1.3-1 in the year 2000.

3-2 Channel Plans

3-2-1 "With" and "Without" Case

The cases analyzed here are as follows:

Table V.3.2-1 Cases for Comparison of Channel Size

Case	Depth	Width	Annual Maintenance Dredging Volume	Remarks
"Without" Case	-4m	60m	4.0 Million m3	Present condition
Case A	-6m	100m	5.1 Million m3	Principal Plan
Case B	-8m	120m	5.9 Million m3	Expansion Plan

3-2-2 Benefits

The larger the channel, the shorter the waiting time of the navigating ships becomes. The difference between the waiting time in the "With" and "Without" cases is considered as a benefit of enlarging the channel.

The study team carried out a simulation of the channel traffic to estimate the amount of time saved by ship type. The results of the simulation are as follows:

Table V.3.2-2 Waiting Time by Ship Type

(Unit:Hours per Year)

Case	TOTAL	OCEAN-GOING	INTER-ISLAND	LOKAL	SAILING	SPECIAL	PASSENGER	BARGE *
Without Case	149,225	39,551	12,219	14,191	38,329	34,876	74	8,871
Case A	56,742	27,247	3,013	3,749	5,153	8,650	0	7,415
Case B	22,686	8,091	1,529	2,358	3,171	6,277	0	340

* For Offshore Cargo-handling

We can estimate the value of the time saved by using the average ship cost by ship type. (See Figure V.3.2-1)

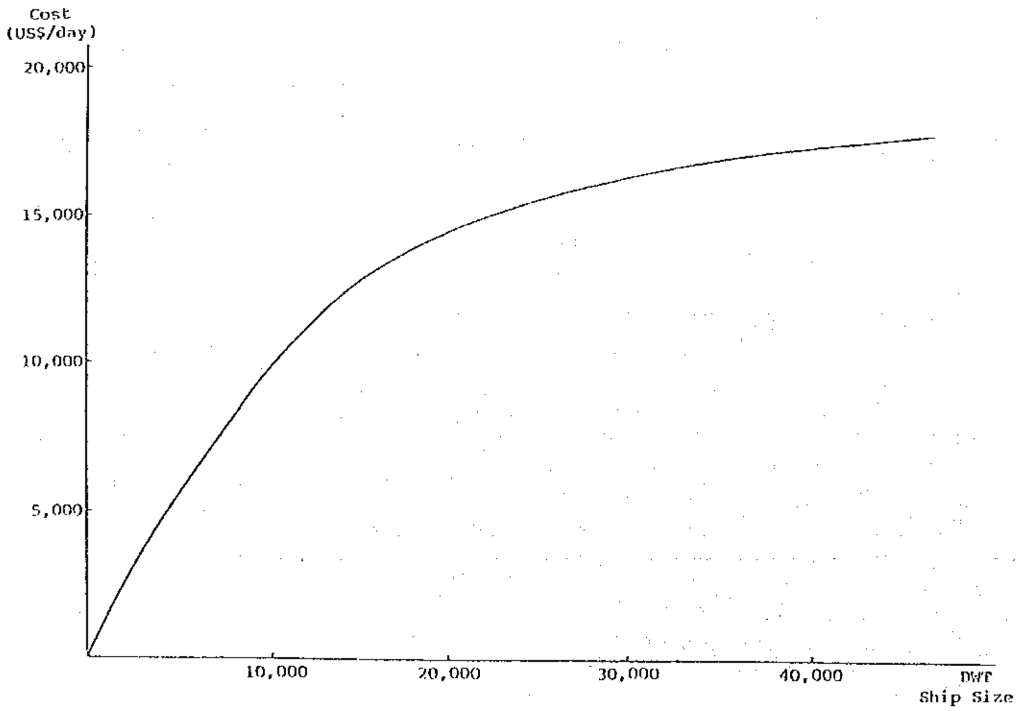


Figure V.3.2-1 Ship Cost and Ship Size

This saved Value is the benefit of each case. The results of the calculation are shown in Table V.3.2-3.

Table V.3.2-3 Estimated Benefits from Enlarging Channel

Case	Annual Benefits from Enlarging Channel	Annual Waiting Costs of Ships
"Without" Case	0	9.7 Million US $
Case A	4.7 Million US $	5.0 Million US $
Case B	8.0 Million US $	1.7 Million US $

3-2-3 Costs

The difference in cost between the "With" and "Without" cases is the cost for the cost-benefit analysis. Usually, the larger the channel, the higher the initial and maintenance costs are. The estimated costs are shown in Table V.3.2-4.

Table V.3.2-4 Calculated Annual Costs and Benefits of Each Channel Size

(Unit:Millions of US $)

Year	Construction Costs			Maintenance Dredging Costs			Maintenance Costs for Facilities			Total Costs			Benefits From Enlarging Channel			Benefits-Costs		
	Without (4m,60m)	Case(6m) -Without	Case(8m) -Without	Without (4m,60m)	Case(6m) -Without	Case(8m) -Without	Without (4m,60m)	Case(6m) -Without	Case(8m) -Without	Without (4m,60m)	Case(6m) -Without	Case(8m) -Without	Without (4m,60m)	Case(6m) -Without	Case(8m) -Without	Without (4m,60m)	Case(6m) -Without	Case(8m) -Without
1999	1.1	9.8	42.9	-1.3	1.3	1.3	0.0	0.0	0.0	-0.1	11.1	44.2	0.0	0.0	0.0	0.1	-11.1	-44.2
2000	0.0	0.0	0.0	3.5	1.0	1.6	0.0	0.0	0.0	3.5	1.0	1.6	0.0	4.7	8.0	-3.5	3.7	6.4
2001	0.0	0.0	0.0	3.5	1.0	1.6	0.0	0.0	0.0	3.5	1.0	1.6	0.0	4.7	8.0	-3.5	3.7	6.4
2002	0.0	0.0	0.0	3.5	1.0	1.6	0.0	0.0	0.0	3.5	1.0	1.6	0.0	4.7	8.0	-3.5	3.7	6.4
2003	0.0	0.0	0.0	3.8	1.0	1.8	0.0	0.0	0.0	3.8	1.0	1.8	0.0	4.7	8.0	-3.8	3.7	6.2
2004	0.0	0.0	0.0	3.8	1.0	1.8	0.0	0.0	0.0	3.8	1.0	1.8	0.0	4.7	8.0	-3.8	3.7	6.2
2005	0.0	0.0	0.0	3.8	1.0	1.8	0.0	0.0	0.0	3.8	1.0	1.8	0.0	4.7	8.0	-3.8	3.7	6.2
2006	0.0	0.0	0.0	4.2	1.1	2.0	0.0	0.0	0.0	4.2	1.1	2.0	0.0	4.7	8.0	-4.2	3.6	6.0
2007	0.0	0.0	0.0	4.2	1.1	2.0	0.0	0.0	0.0	4.2	1.1	2.0	0.0	4.7	8.0	-4.2	3.6	6.0
2008	0.0	0.0	0.0	4.2	1.1	2.0	0.0	0.0	0.0	4.2	1.1	2.0	0.0	4.7	8.0	-4.2	3.6	6.0
2009	0.0	0.0	0.0	4.6	1.3	2.2	0.0	0.0	0.0	4.6	1.3	2.2	0.0	4.7	8.0	-4.6	3.4	5.8
2010	0.0	0.0	0.0	4.6	1.3	2.2	0.0	0.0	0.0	4.6	1.3	2.2	0.0	4.7	8.0	-4.6	3.4	5.8
2011	0.0	0.0	0.0	4.6	1.3	2.2	0.0	0.0	0.0	4.6	1.3	2.2	0.0	4.7	8.0	-4.6	3.4	5.8
2012	0.0	0.0	0.0	5.1	1.4	2.4	0.0	0.0	0.0	5.1	1.4	2.4	0.0	4.7	8.0	-5.1	3.3	5.6
2013	0.0	0.0	0.0	5.1	1.4	2.4	0.0	0.0	0.0	5.1	1.4	2.4	0.0	4.7	8.0	-5.1	3.3	5.6
2014	0.0	0.0	0.0	5.1	1.4	2.4	0.0	0.0	0.0	5.1	1.4	2.4	0.0	4.7	8.0	-5.1	3.3	5.6
2015	0.0	0.0	0.0	5.6	1.5	2.6	0.0	0.0	0.0	5.6	1.5	2.6	0.0	4.7	8.0	-5.6	3.2	5.4
2016	0.0	0.0	0.0	5.6	1.5	2.6	0.0	0.0	0.0	5.6	1.5	2.6	0.0	4.7	8.0	-5.6	3.2	5.4
2017	0.0	0.0	0.0	5.6	1.5	2.6	0.0	0.0	0.0	5.6	1.5	2.6	0.0	4.7	8.0	-5.6	3.2	5.4
2018	0.0	0.0	0.0	6.1	1.7	2.9	0.0	0.0	0.0	6.2	1.7	2.9	0.0	4.7	8.0	-6.2	3.0	5.1
2019	0.0	0.0	0.0	6.1	1.7	2.9	0.0	0.0	0.0	6.2	1.7	2.9	0.0	4.7	8.0	-6.2	3.0	5.1
2020	0.0	0.0	0.0	6.1	1.7	2.9	0.0	0.0	0.0	6.2	1.7	2.9	0.0	4.7	8.0	-6.2	3.0	5.1
2021	0.0	0.0	0.0	6.7	1.9	3.2	0.0	0.0	0.0	6.8	1.9	3.2	0.0	4.7	8.0	-6.8	2.8	4.8
2022	0.0	0.0	0.0	6.7	1.9	3.2	0.0	0.0	0.0	6.8	1.9	3.2	0.0	4.7	8.0	-6.8	2.8	4.8
2023	0.0	0.0	0.0	6.7	1.9	3.2	0.0	0.0	0.0	6.8	1.9	3.2	0.0	4.7	8.0	-6.8	2.8	4.8
2024	0.0	0.0	0.0	7.4	2.0	3.5	0.0	0.0	0.0	7.4	2.0	3.5	0.0	4.7	8.0	-7.4	2.7	4.5
2025	0.0	0.0	0.0	7.4	2.0	3.5	0.0	0.0	0.0	7.4	2.0	3.5	0.0	4.7	8.0	-7.4	2.7	4.5
2026	0.0	0.0	0.0	7.4	2.0	3.5	0.0	0.0	0.0	7.4	2.0	3.5	0.0	4.7	8.0	-7.4	2.7	4.5
2027	0.0	0.0	0.0	8.1	2.2	3.9	0.0	0.0	0.0	8.2	2.2	3.9	0.0	4.7	8.0	-8.2	2.5	4.1
2028	0.0	0.0	0.0	8.1	2.2	3.9	0.0	0.0	0.0	8.2	2.2	3.9	0.0	4.7	8.0	-8.2	2.5	4.1
2029	0.0	-3.9	-17.2	8.1	2.2	3.9	0.0	0.0	0.0	8.2	-1.7	-13.3	0.0	4.7	8.0	-8.2	6.4	21.3
Total	1.1	5.9	25.7	163.9	46.7	79.7	1.0	0.0	0.0	166.1	52.6	105.5	0.0	141.0	240.0	-166.1	88.4	134.5

3-2-4 Evaluation

The internal rate of return (IRR) of the cases are shown in Table V.3.2-5. In addition to the base case, four cases are calculated in order to examine the impact of fluctuation of construction costs (C.C.) and the benefits from enlarging the channel (B.E.C.) in each case.

Table V.3.2-5 Internal Rate of Return of Each Channel Size

Case	Base Case	Increase of C.C.by 10%	Decrease of C.C.by 10%	Increase of B.E.C.by 10%	Decrease of B.E.C.by 10%
Case A	33.2%	30.4%	36.5%	37.5%	28.8%
Case B	13.3%	12.0%	14.9%	15.3%	11.3%

Judging from the above figures, Case A is the best alternative for planning the channel. If the traffic volume increases in the future, Case B will have a higher IRR.

3-3 Siltation Reduction Plans

3-3-1 "With" and "Without" Case

The cases analyzed here, are as follows:

Table V.3.3-1 Cases for Comparison of Siltation Reduction Plans

Case	Kind of Siltation Countermeasure	Depth	Width	Annual Maintenance Dredging Volume
"Without" Case	None (Principal Plan (Case II))	-6m	100m	5.1 million m^3
Case III-2	Submerged Walls (C2)	-6m	100m	2.8 million m^3
Case III-3	Submerged Walls (C3)	-6m	100m	2.9 million m^3
Case IV	New N-S Alignment	-6m	100m	4.4 million m^3

3-3-2 Benefits

The reduction in siltation volume results in lower maintenance dredging costs. The difference between the maintenance dredging cost in the "With" and "Without" cases is considered as a benefit of investment in siltation countermeasures. The estimated benefits of each siltation reduction plan are shown in Table V.3.3-2.

Table V.3.3-2 Estimated Benefits of Each Siltation Reduction Plan

	Unit	Without Case (Case II)		Case III-2			Case III-3			Case IV		
Year	Cost /CBM (US $)	Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	Savings on Maintenace Dredging (000 US$)	Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	Savings of Maintenace Dredging (000 US$)	Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	Savings on Maintenace Dredging Costs (000 US$)
2000	0.86	5,100	4,405	2,800	2,419	1,987	2,900	2,505	1,900	4,400	3,901	605
2001	0.86	5,100	4,405	2,800	2,419	1,987	2,900	2,505	1,900	4,400	3,801	605
2002	0.86	5,100	4,405	2,800	2,419	1,987	2,900	2,505	1,900	4,400	3,801	605
2003	0.95	5,100	4,846	2,800	2,661	2,185	2,900	2,756	2,090	4,400	4,181	665
2004	0.95	5,100	4,846	2,800	2,661	2,185	2,900	2,756	2,090	4,400	4,181	665
2005	0.95	5,100	4,846	2,800	2,661	2,185	2,900	2,756	2,090	4,400	4,181	665
2006	1.05	5,100	5,331	2,800	2,927	2,404	2,900	3,031	2,299	4,400	4,599	732
2007	1.05	5,100	5,331	2,800	2,927	2,404	2,900	3,031	2,299	4,400	4,599	732
2008	1.05	5,100	5,331	2,800	2,927	2,404	2,900	3,031	2,299	4,400	4,599	732
2009	1.15	5,100	5,864	2,800	3,219	2,644	2,900	3,334	2,529	4,400	5,059	805
2010	1.15	5,100	5,864	2,800	3,219	2,644	2,900	3,334	2,529	4,400	5,059	805
2011	1.15	5,100	5,864	2,800	3,219	2,644	2,900	3,334	2,529	4,400	5,059	805
2012	1.26	5,100	6,450	2,800	3,541	2,909	2,900	3,668	2,782	4,400	5,565	885
2013	1.26	5,100	6,450	2,800	3,541	2,909	2,900	3,668	2,782	4,400	5,565	985
2014	1.26	5,100	6,450	2,800	3,541	2,909	2,900	3,668	2,782	4,400	5,565	885
2015	1.39	5,100	7,095	2,800	3,895	3,200	2,900	4,034	3,061	4,400	6,121	974
2016	1.39	5,100	7,095	2,800	3,695	3,200	2,900	4,034	3,061	4,400	6,121	974
2017	1.39	5,100	7,095	2,800	3,895	3,200	2,900	4,034	3,061	4,400	6,121	974
2018	1.53	5,100	7,805	2,800	4,285	3,520	2,900	4,438	3,367	4,400	6,733	1,071
2019	1.53	5,100	7,805	2,800	4,285	3,520	2,900	4,438	3,367	4,400	6,733	1,071
2020	1.53	5,100	7,805	2,800	4,285	3,520	2,900	4,438	3,367	4,400	6,733	1,071
2021	1.68	5,100	8,585	2,800	4,713	3,872	2,900	4,882	3,703	4,400	7,407	1,178
2022	1.68	5,100	8,585	2,800	4,713	3,872	2,900	4,882	3,703	4,400	7,407	1,176
2023	1.68	5,100	8,585	2,800	4,713	3,872	2,900	4,882	3,703	4,400	7,407	1,178
2024	1.85	5,100	9,444	2,800	5,185	4,259	2,900	5,370	4,074	4,400	8,147	1,296
2025	1.85	5,100	9,444	2,800	5,195	4,259	2,900	5,370	4,074	4,400	8,147	1,296
2026	1.85	5,100	9,444	2,800	5,165	4,259	2,900	5,370	4,074	4,400	8,147	1,296
2027	2.04	5,100	10,388	2,800	5,703	4,685	2,900	5,907	4,481	4,400	8,962	1,426
2028	2.04	5,100	10,388	2,800	5,703	4,685	2,900	5,907	4,481	4,400	8,962	1,426
2029	2.04	5,100	10,388	2,800	5,703	4,685	2,900	5,907	4,481	4,400	8,962	1,426
	Total	153,000	210,636	84,000	115,643	94,993	87,000	119,773	90,862	132,000	181,725	28,911

3-3-3 Costs

The difference in construction costs between the "With" and "Without" cases is the cost for the cost-benefit analysis.
The estimated costs are shown in Table V.3.3-3.

Table V.3.3-3 Calculated Annual Costs and Benefits of Each Siltation Reduction Plan

(Unit: Thousands of US $)

	Without Case (Case II)			Case III-2					Case III-3					Case IV				
Year	Construction Costs	Maintenance Costs for Facilities	Total Costs (A)	Construction Costs	Maintenance Costs for Facilities	Total Costs (B)	Net Costs (B)-(A)	Benefits -Net Costs	Construction Costs	Maintenance Costs for Facilities	Total Costs (C)	Net Costs CaseIII-2 (C)-(A)	Benefits -Net Costs	Constructio Costs	Maintenance Costs for Facilities	Total Costs (D)	Net Costs CaseIII-2 (D)-(A)	Benefits -Net Costs
1999	10,945	0	10,945	39,443	0	39,443	28,497	-28,497	39,493	0	39,493	28,546	-28,546	30,443	0	30,443	19,498	-19,498
2000	0	34	34	0	120	120	87	1,900	0	120	120	87	1,814	0	32	32	-1	606
2001	0	34	34	0	120	120	87	1,900	0	120	120	87	1,814	0	32	32	-1	606
2002	0	34	34	0	120	120	87	1,900	0	120	120	87	1,814	0	32	32	-1	606
2003	0	34	34	0	120	120	87	2,099	0	120	120	87	2,004	0	32	32	-1	667
2004	0	34	34	0	120	120	87	2,099	0	120	120	87	2,004	0	32	32	-1	667
2005	0	34	34	0	120	120	87	2,099	0	120	120	87	2,004	0	32	32	-1	667
2006	0	34	34	0	120	120	87	2,317	0	120	120	87	2,213	0	32	32	-1	733
2007	0	34	34	0	120	120	87	2,317	0	120	120	87	2,213	0	32	32	-1	733
2008	0	34	34	0	120	120	87	2,317	0	120	120	87	2,213	0	32	32	-1	733
2009	0	34	34	0	120	120	87	2,558	0	120	120	87	2,443	0	32	32	-1	806
2010	0	34	34	0	120	120	87	2,558	0	120	120	87	2,443	0	32	32	-1	806
2011	0	34	34	0	120	120	87	2,558	0	120	120	87	2,443	0	32	32	-1	806
2012	0	34	34	0	120	120	87	2,822	0	120	120	87	2,696	0	32	32	-1	887
2013	0	34	34	0	120	120	87	2,822	0	120	120	87	2,696	0	32	32	-1	887
2014	0	34	34	0	120	120	87	2,822	0	120	120	87	2,696	0	32	32	-1	887
2015	0	34	34	0	120	120	87	3,113	0	120	120	87	2,974	0	32	32	-1	975
2016	0	34	34	0	120	120	87	3,113	0	120	120	87	2,974	0	32	32	-1	975
2017	0	34	34	0	120	120	87	3,113	0	120	120	87	2,974	0	32	32	-1	975
2018	0	34	34	0	120	120	87	3,433	0	120	120	87	3,280	0	32	32	-1	1,073
2019	0	34	34	0	120	120	87	3,433	0	120	120	87	3,280	0	32	32	-1	1,073
2020	0	34	34	0	120	120	87	3,433	0	120	120	87	3,280	0	32	32	-1	1,073
2021	0	34	34	0	120	120	87	3,785	0	120	120	87	3,617	0	32	32	-1	1,180
2022	0	34	34	0	120	120	87	3,785	0	120	120	87	3,617	0	32	32	-1	1,180
2023	0	34	34	0	120	120	87	3,785	0	120	120	87	3,617	0	32	32	-1	1,180
2024	0	34	34	0	120	120	87	4,172	0	120	120	87	3,987	0	32	32	-1	1,298
2025	0	34	34	0	120	120	87	4,172	0	120	120	87	3,987	0	32	32	-1	1,298
2026	0	34	34	0	120	120	87	4,172	0	120	120	87	3,987	0	32	32	-1	1,298
2027	0	34	34	0	120	120	87	4,598	0	120	120	87	4,394	0	32	32	-1	1,427
2028	0	34	34	0	120	120	87	4,598	0	120	120	87	4,394	0	32	32	-1	1,427
2029	-3,928	34	-3,894	-15,385	120	-15,264	-11,370	16,055	-15,404	120	-15,284	-11,290	15,871	-11,746	32	-11,714	-7,820	9,246
Total	7,018	1,013	8,031	24,058	3,613	27,671	19,640	75,353	24,088	3,613	27,701	19,669	71,193	18,698	970	19,668	11,636	17,274

3-3-4 Evaluation

The Internal Rate of Return of the various cases are shown in Table V.3.3-4.

In addition to the base case, four cases are calculated in order to examine the effect of the change in construction costs (C.C.) and the increasing rate of unit price of the maintenance dredging (I.R.P.) in each case.

Table V.3.3-4 Internal Rate of Return of Each Siltation Reduction Plan

Case	Case III-2	Case III-3	Case IV
Base Case (I.R.P.=10%)	8.5%	8.1%	3.4%
Increase of C.C. by 10%	7.7%	7.3%	2.9%
Decrease of C.C. by 10%	9.4%	9.0%	3.9%
I.R.P every three years 15%	11.0%	10.6%	5.2%
I.R.P every three years 5%	6.1%	5.7%	1.8%

From the figures above, the submerged wall plans have substantial values of IRR.

3-4 Dredging Efficiency Improvement Plans

3-4-1 Making the Turning Basin

The effect of a turning basin is estimated in 2-1-2, Chapter 2, such that it will increase the efficiency of maintenance dredging by 16.5%.

This will result in reduced maintenance dredging costs for Perumpen, and it is thus expected that the unit price would eventually decrease proportionally.

The difference in maintenance dredging costs between the "With" and "Without" cases is considered as a benefit of the turning basin for the cost-benefit analysis. The costs and the benefits in Case II are shown in Table V.3.4-1. The benefits of the first year are already higher than the construction costs. It is obvious that this investment is very good from an economic viewpoint.

Table V.3.4-1 Costs and Benefits of Turning Basin

(Unit:Thousands of US $)

	Construction Costs of the Turning Basin	Annual Maintenance Dredging Costs(Year 2000)
"Without" Case	0	4,405
"With" Case	69	3,782
Costs	69	-
Benefits	-	624

3-4-2 Attachments to Dragheads

The effect of a attachments to dragheads is estimated in 2-1-3, Chapter 2, such that it will increase the efficiency of maintenance dredging by 13.8% in case of the dredger with hopper capacity of $2,900m^3$ or $2,000m^3$.

It is thus expected that the unit price will decrease proportionally.

The difference in maintenance dredging costs between the "With" and "Without" cases is considered as a benefit of the attachments to dragheads for the cost-benefit analysis. The cost and the benefit in Case II are shown in Table V.3.4-2. Annual benefits are higher than annual costs.

It is obvious that this investment is very good from an economic viewpoint.

Table V.3.4-2 Costs and Benefits of Attachments to Dragheads

(Unit:Thousands of US $)

	Annual Construction Costs of Attachments to Dragheads	Annual Maintenance Dredging Costs(Year 2000)
"Without" Case	0	4,405
"With" Case	14	3,871
Costs	14	-
Benefits	-	534

3-4-3 Tugboat Equipped with a Blade

The effect of a tugboat equipped with a blade is estimated in 2-1-4, Chapter 2, such that it will increase the efficiency of maintenance dredging by 5%. It is expected that the unit price will thus decrease proportionally.

(1) Benefits

The difference in maintenance dredging costs between the "With" and "Without" cases in Case II is considered as a benefit of the tugboat equipped with a blade for the cost-benefit analysis as follows:

Table V.3.4-3 Annual Benefits of Tugboat Equipped With a Blade

Year	Unit Cost /CBM (US $)	Without Case (Case II) Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	CaseII+Tugboat Equipped With a Blade Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	Savings on Maintenance Dredging Costs (000 US$)
2000	0.86	5,100	4,405	5,100	4,196	210
2001	0.86	5,100	4,405	5,100	4,196	210
2002	0.86	5,100	4,405	5,100	4,196	210
2003	0.95	5,100	4,846	5,100	4,615	231
2004	0.95	5,100	4,846	5,100	4,615	231
2005	0.95	5,100	4,846	5,100	4,615	231
2006	1.05	5,100	5,331	5,100	5,077	254
2007	1.05	5,100	5,331	5,100	5,077	254
2008	1.05	5,100	5,331	5,100	5,077	254
2009	1.15	5,100	5,864	5,100	5,584	279
2010	1.15	5,100	5,864	5,100	5,584	279
2011	1.15	5,100	5,864	5,100	5,584	279
2012	1.26	5,100	6,450	5,100	6,143	307
2013	1.26	5,100	6,450	5,100	6,143	307
2014	1.26	5,100	6,450	5,100	6,143	307
2015	1.39	5,100	7,095	5,100	6,757	338
2016	1.39	5,100	7,095	5,100	6,757	338
2017	1.39	5,100	7,095	5,100	6,757	338
2018	1.53	5,100	7,805	5,100	7,433	372
2019	1.53	5,100	7,805	5,100	7,433	372
2020	1.53	5,100	7,805	5,100	7,433	372
2021	1.68	5,100	8,585	5,100	8,176	409
2022	1.68	5,100	8,585	5,100	8,176	409
2023	1.68	5,100	8,585	5,100	8,176	409
2024	1.85	5,100	9,444	5,100	8,994	450
2025	1.85	5,100	9,444	5,100	8,994	450
2026	1.85	5,100	9,444	5,100	8,994	450
2027	2.04	5,100	10,388	5,100	9,893	495
2028	2.04	5,100	10,388	5,100	9,893	495
2029	2.04	5,100	10,388	5,100	9,893	495
	Total	153,000	210,636	153,000	200,605	10,030

(2) Costs

The construction cost, the replacement cost at the end of the lifetime and the maintenance cost of the equipment are calculated for the cost-benefit analysis.

The estimated benefits and costs are shown at Table V.3.4-4.

Table V.3.4-4 Calculated Annual Costs and Benefits of the Tugboat Equipped with a Blade

(Unit:Thousands of US $)

Year	Without Case (Case II) Construction Costs	Maintenance Costs for Facilities	Total Costs (A)	CaseII+Tugboat Equipped With a Blade Construction Costs	Maintenance Costs for Facilities	Total Costs (B)	Net Costs (B) - (A)	Benefits -Net Costs
1999	10,877		10,877	11,619		11,619	743	-743
2000	0	34	34	0	71	71	37	173
2001	0	34	34	0	71	71	37	173
2002	0	34	34	0	71	71	37	173
2003	0	34	34	0	71	71	37	194
2004	0	34	34	0	71	71	37	194
2005	0	34	34	0	71	71	37	194
2006	0	34	34	0	71	71	37	217
2007	0	34	34	0	71	71	37	217
2008	0	34	34	0	71	71	37	217
2009	0	34	34	0	71	71	37	242
2010	0	34	34	0	71	71	37	242
2011	0	34	34	0	71	71	37	242
2012	0	34	34	0	71	71	37	270
2013	0	34	34	0	71	71	37	270
2014	0	34	34	0	71	71	37	270
2015	0	34	34	0	71	71	37	301
2016	0	34	34	0	71	71	37	301
2017	0	34	34	0	71	71	37	301
2018	0	34	34	0	71	71	37	335
2019	0	34	34	0	71	71	37	335
2020	0	34	34	743	71	814	780	-408
2021	0	34	34	0	71	71	37	372
2022	0	34	34	0	71	71	37	372
2023	0	34	34	0	71	71	37	372
2024	0	34	34	0	71	71	37	413
2025	0	34	34	0	71	71	37	413
2026	0	34	34	0	71	71	37	413
2027	0	34	34	0	71	71	37	458
2028	0	34	34	0	71	71	37	458
2029	-3,900	34	-3,867	-4,272	71	-4,201	-334	829
Total	6,976	1,013	7,990	8,090	2,127	10,218	2,228	7,802

(3) Evaluation

The Internal Rate of Return of the various cases are shown in Table V.3.4-5.

In addition to the base case, three cases are calculated in order to examine the impact of the increasing efficiency rate due to these facilities (I.R.E.) and the increasing rate in the unit price of maintenance dredging (I.R.P.) .

Table V.3.4-5 Internal Rate of Return of Tugboat Equipped with a Blade

Case	Base Case	I.R.P. 5%
Base Case	26.1%	20.8%
I.R.E. Decrease by 10%	23.3%	18.2%

Judging from the above figures, this investment is feasible in any case.

3-4-4 Side-casting

The effect of side-casting is estimated in 2-1-6, Chapter 2, such that it will increase the efficiency of the maintenance dredging by 117% in Case III-3.

It is expected that the unit price will thus decrease proportionally.

(1) Benefits

The difference in maintenance dredging costs between the "With" and "Without" cases in Case III-3 is considered as a benefit of the side casting for the cost-benefit analysis as follows:

Table V.3.4-6 Annual Maintenance Dredging Costs of Side-casting

	Unit Cost /CBM	Without Case (CaseIII-3)		CaseIII-3+Side-casting		
Year	(US $)	Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	Maintenance Dredging Volume (000 M3)	Maintenance Dredging Costs (000 US$)	Savings of Maintenance Dredging Costs (000 US$)
2000	0.86	2,900	2,505	2,900	1,154	1,351
2001	0.86	2,900	2,505	2,900	1,154	1,351
2002	0.86	2,900	2,505	2,900	1,154	1,351
2003	0.95	2,900	2,756	2,900	1,270	1,486
2004	0.95	2,900	2,756	2,900	1,270	1,486
2005	0.95	2,900	2,756	2,900	1,270	1,486
2006	1.05	2,900	3,031	2,900	1,397	1,634
2007	1.05	2,900	3,031	2,900	1,397	1,634
2008	1.05	2,900	3,031	2,900	1,397	1,634
2009	1.15	2,900	3,334	2,900	1,537	1,798
2010	1.15	2,900	3,334	2,900	1,537	1,798
2011	1.15	2,900	3,334	2,900	1,537	1,798
2012	1.26	2,900	3,668	2,900	1,690	1,978
2013	1.26	2,900	3,668	2,900	1,690	1,978
2014	1.26	2,900	3,668	2,900	1,690	1,978
2015	1.39	2,900	4,034	2,900	1,859	2,175
2016	1.39	2,900	4,034	2,900	1,859	2,175
2017	1.39	2,900	4,034	2,900	1,859	2,175
2018	1.53	2,900	4,438	2,900	2,045	2,393
2019	1.53	2,900	4,438	2,900	2,045	2,393
2020	1.53	2,900	4,438	2,900	2,045	2,393
2021	1.68	2,900	4,882	2,900	2,250	2,632
2022	1.68	2,900	4,882	2,900	2,250	2,632
2023	1.68	2,900	4,882	2,900	2,250	2,632
2024	1.85	2,900	5,370	2,900	2,475	2,895
2025	1.85	2,900	5,370	2,900	2,475	2,895
2026	1.85	2,900	5,370	2,900	2,475	2,895
2027	2.04	2,900	5,907	2,900	2,722	3,185
2028	2.04	2,900	5,907	2,900	2,722	3,185
2029	2.04	2,900	5,907	2,900	2,722	3,185
	Total	87,000	119,773	87,000	64,578	64,578

(2) Costs

This equipment is planned to be installed in a dredger made in 1985. The remodeling cost, the replacement cost of the equipment at the end of the lifetime and the maintenance cost of the equipment, i.e., 5% of the remodeling cost, are taken into account for the cost-benefit analysis.

The lifetime of the facility is assumed as 15 years limited by that of the dredger in this paragraph.

The estimated benefits and costs are shown in Table V.3.4-7.

Table V.3.4-7 Calculated Annual Costs and Benefits of Side-casting

(Unit:Thousands of US $)

Year	Without Case (Case III-3)			CaseIII-3+Side-casting				
	Construction Costs	Maintenance Costs for Facilities	Total Costs (A)	Construction Costs	Maintenance Costs for Facilities	Total Costs (B)	Net Costs (B) - (A)	Benefits -Net Costs
1999	39,492		39,492	54,179		54,179	14,687	-14,687
2000	0	120	120	0	855	855	734	616
2001	0	120	120	0	855	855	734	616
2002	0	120	120	0	855	855	734	616
2003	0	120	120	0	855	855	734	751
2004	0	120	120	0	855	855	734	751
2005	0	120	120	0	855	855	734	751
2006	0	120	120	0	855	855	734	900
2007	0	120	120	0	855	855	734	900
2008	0	120	120	0	855	855	734	900
2009	0	120	120	0	855	855	734	1,063
2010	0	120	120	0	855	855	734	1,063
2011	0	120	120	0	855	855	734	1,063
2012	0	120	120	0	855	855	734	1,243
2013	0	120	120	0	855	855	734	1,243
2014	0	120	120	14,687	855	15,542	15,422	-13,444
2015	0	120	120	0	855	855	734	1,441
2016	0	120	120	0	855	855	734	1,441
2017	0	120	120	0	855	855	734	1,441
2018	0	120	120	0	855	855	734	1,658
2019	0	120	120	0	855	855	734	1,658
2020	0	120	120	0	855	855	734	1,658
2021	0	120	120	0	855	855	734	1,898
2022	0	120	120	0	855	855	734	1,898
2023	0	120	120	0	855	855	734	1,898
2024	0	120	120	0	855	855	734	2,161
2025	0	120	120	0	855	855	734	2,161
2026	0	120	120	0	855	855	734	2,161
2027	0	120	120	0	855	855	734	2,450
2028	0	120	120	0	855	855	734	2,450
2029	-15,404	120	-15,284	-19,076	855	-18,221	-2,937	6,122
Total	24,088	3,613	27,701	49,790	25,644	75,434	47,733	16,845

(3) Evaluation

The internal rate of return of this investment becomes 3.4% based on the above assumptions. The rate becomes higher, if the channel is expanded, or if the ratio of dredging volume by side-casting increases.

3-5 Effects of Total Dredging Efficiency Improvement Plans

The effect of the total dredging efficiency improvement Plans except for the side-casting mentioned above is estimated that it will reduce dredging costs by 22% in Case II. The estimated benefits and costs are shown in Table V.3.5-1 and Table V.3.5-2.

Table V.3.5-1 Calculated Annual Benefits of Total Dredging Efficiency Improvement Plans

	Unit	Without Case (Case II)		CaseII+Total Improvement Plan		
	Cost /CBM	Maintenance Dredging Volume	Maintenance Dredging Costs	Maintenance Dredging Volume	Maintenance Dredging Costs	Savings on Maintenance Dredging Costs
Year	(US $)	(000 M3)	(000 US$)	(000 M3)	(000 US$)	(000 US$)
2000	0.86	5,100	4,405	5,100	3,611	794
2001	0.86	5,100	4,405	5,100	3,611	794
2002	0.86	5,100	4,405	5,100	3,611	794
2003	0.95	5,100	4,846	5,100	3,972	874
2004	0.95	5,100	4,846	5,100	3,972	874
2005	0.95	5,100	4,846	5,100	3,972	874
2006	1.05	5,100	5,331	5,100	4,369	961
2007	1.05	5,100	5,331	5,100	4,369	961
2008	1.05	5,100	5,331	5,100	4,369	961
2009	1.15	5,100	5,864	5,100	4,806	1,057
2010	1.15	5,100	5,864	5,100	4,806	1,057
2011	1.15	5,100	5,864	5,100	4,806	1,057
2012	1.26	5,100	6,450	5,100	5,287	1,163
2013	1.26	5,100	6,450	5,100	5,287	1,163
2014	1.26	5,100	6,450	5,100	5,287	1,163
2015	1.39	5,100	7,095	5,100	5,816	1,279
2016	1.39	5,100	7,095	5,100	5,816	1,279
2017	1.39	5,100	7,095	5,100	5,816	1,279
2018	1.53	5,100	7,805	5,100	6,397	1,407
2019	1.53	5,100	7,805	5,100	6,397	1,407
2020	1.53	5,100	7,805	5,100	6,397	1,407
2021	1.68	5,100	8,585	5,100	7,037	1,548
2022	1.68	5,100	8,585	5,100	7,037	1,548
2023	1.68	5,100	8,585	5,100	7,037	1,548
2024	1.85	5,100	9,444	5,100	7,741	1,703
2025	1.85	5,100	9,444	5,100	7,741	1,703
2026	1.85	5,100	9,444	5,100	7,741	1,703
2027	2.04	5,100	10,388	5,100	8,515	1,873
2028	2.04	5,100	10,388	5,100	8,515	1,873
2029	2.04	5,100	10,388	5,100	8,515	1,873
	Total	153,000	210,636	153,000	172,652	37,983

Table V.3.5-2 Calculated Annual Costs and Benefits of Total Dredging Efficiency Improvement Plans

(Unit:Thousands of US $)

Year	Without Case (Case II)			CaseII+Total Dredging Efficiency Improvement Plan				
	Construction Costs	Maintenance Costs for Facilities	Total Costs (A)	Construction Costs	Maintenance Costs for Facilities	Total Costs (B)	Net Costs (B) - (A)	Benefits -Net Costs
1999	10,877		10,877	12,631		12,631	1,754	-1,754
2000	0	34	34	14	118	132	98	696
2001	0	34	34	14	118	132	98	696
2002	0	34	34	14	118	132	98	696
2003	0	34	34	14	118	132	98	776
2004	0	34	34	14	118	132	98	776
2005	0	34	34	14	118	132	98	776
2006	0	34	34	14	118	132	98	863
2007	0	34	34	14	118	132	98	863
2008	0	34	34	14	118	132	98	863
2009	0	34	34	14	118	132	98	959
2010	0	34	34	14	118	132	98	959
2011	0	34	34	14	118	132	98	959
2012	0	34	34	14	118	132	98	1,065
2013	0	34	34	14	118	132	98	1,065
2014	0	34	34	14	118	132	98	1,065
2015	0	34	34	14	118	132	98	1,181
2016	0	34	34	14	118	132	98	1,181
2017	0	34	34	14	118	132	98	1,181
2018	0	34	34	14	118	132	98	1,309
2019	0	34	34	14	118	132	98	-376
2020	0	34	34	1,699	118	1,817	1,783	1,309
2021	0	34	34	14	118	132	98	1,450
2022	0	34	34	14	118	132	98	1,450
2023	0	34	34	14	118	132	98	1,450
2024	0	34	34	14	118	132	98	1,605
2025	0	34	34	14	118	132	98	1,605
2026	0	34	34	14	118	132	98	1,605
2027	0	34	34	14	118	132	98	1,775
2028	0	34	34	14	118	132	98	1,775
2029	-3,900	34	-3,867	-4,756	118	-4,638	-772	2,645
Total	6,976	1,013	7,990	9,965	3,541	13,506	5,516	32,467

The internal rate of return of the total dredging efficiency improvement plans becomes 42% based on the above assumptions. It is obvious that this investment is very good from an economic viewpoint.

Chapter 4 Selection of Alternative Plans

4-1 Method of Evaluation

4-1-1 Siltation Reduction Plan

As discussed above, there are different viewpoints in terms of evaluating the siltation reduction plans listed in Table V.1.2-2. They can be classified into the following three categories:

(1) Planning Points of View

a. To cope with future traffic demands and planning criteria,

b. To secure navigational safety for various types of ships, including cargo ships of designed size, small ships such as KLM, tugs and barges, and

c. To allow future expansion of depth and/or width of the channel;

(2) Technical Points of View

a. To reduce siltation as much as possible,

b. To promote the improvement of dredging efficiency by means of drastic measures such as side-casting and dumping at the river mouth, and

c. To identify technical problems and reliability to be cleared in terms of effects, design, execution, and others; and

(3) Economic Points of View

To confirm the cost - effectiveness roughly.

The evaluation of the above individual items can be done by relative comparison of the advantages and disadvantages among them. Comprehensive evaluation will be carried out by establishing a priority regarding the viewpoints, with planning first, technical aspects second and economics third.

4-1-2 Dredging Efficiency Improvement Plan

Trailing suction hopper dredgers are most suitable for maintenance dredging of the channel. The aim of improving dredging efficiency is focused on this type of dredger. The dredging operation by a trailing suction hopper dredger consists of extraction, loading, transportation and disposal. Productivity mainly depends on extraction. The time used for transportation is non-productive and so it is important to reduce transportation time. Another important item is increasing the concentration ratio of mud inside the hopper. If the concentration ratio is low, the dredger only transports water.

Most dredging operations are analyzed by dredged volume. Accurate echo-sounding is necessary. The channel is so long that echo-sounding should be carried out smoothly.

Dredging operations are controlled in terms of quality, progress, safety and cost. The evaluation of each plan for improving dredging efficiency is carried out based on these four elements.

4-2 Siltation Reduction Plan

4-2-1 Planning Point of View

A relative comparison of the candidates for siltation reduction is made by putting relative marks of +(very good), 0 (good), and - (poor).

From the planning point of view, all the candidates are very good in terms of traffic demand and criteria. As for navigation safety, the submerged wall plans (III-2 and 3) could result in obstacles specifically to small ships if they do not observe traffic regulations and navigate outside of the channel. In general, the narrower the wall distance, the more the hindrance. In view of the port's future expansion, the submerged wall plan, III-2, has disadvantages in not allowing expansion of the channel width to 120m and increasing depth to -8m. Cases III-3 allows expansion. Plans without submerged walls (Cases-II and IV) present no such problems.

4-2-2 Technical Point of View

From the technical point of view, the Principal and New Alignment Plans (II and IV) involve prohibitively high siltation rates of 5.1 and 4.4 million m^3 per year, respectively. Among the alternatives, the continuous Submerged Wall Plans (III-2 and 3) are most advantageous in terms of siltation reduction effects. Dredging efficiency could be improved by constructing narrow submerged walls and dredging by side-casting. Technical problems are involved in the New Alignment Plan (IV), most critically in terms of the long time span and wide ranging changes in bottom topography and resultant siltation.

Construction of submerged walls is to be carefully executed in view of their stability and effect on surroundings.

4-2-3 Economic Point of View

According to the result of the rough economic analyses of the candidate plans based on nominal prices, the Submerged Wall Plans (Case III-2 and 3) have considerable IRRs of over 8% compared with the Principal Plan (Case II as the base case). It can be considered that there is not much difference of IRR among these submerged wall plans.

The New N-S Alignment Plan (Case IV) has a rather low IRR of 3.4%.

It is to be noted that, taking a benefit of amerialating ships' waiting time into consideration, the Principal Plan (Case - II) without submerged walls has enough IRR as analyzed above. However, it requires dredging works of more than 5 million every year, which result in higher costs eventually and hinder the traffic through the channel, causing an additional economic loss not quantitatively counted here.

4-2-4 Selection of a Candidate

The above evaluations are summarized in Table V.4.2-1.

Thus, the Submerged Wall Plan (III-2) can be disregarded from the planning point of view. The Principal Plan (II) and the New N-S Alignment (IV) are not preferable mainly from technical and economic points of view.

From general viewpoints the Submerged Wall Plan (III-3) can be considered as the most promising candidate for the Comprehensive Plan. And, the non-continuous submerged walls could be set down as a stage plan of the continuous plan, covering heavy siltation areas first, and being expected to have higher cost-effectiveness.

Table V.4.2-1 Evaluation of Canditates for Siltation reduction

Case No.	Classification/ Kind of Siltation Countermeasures	Bottom Width B (m)	Wall Distance W (m)	Planning			Technical			Economic
				Traffic Demands and Criteria	Navigation Safety	Future Expansion	Decrease of Siltation Volume	Improvement of Dredging Efficiency	Problems and Reliability	Cost Effectiveness
II	Principal Plan	100	-	+	+	+	-	-	+	
III-2	Submerged Walls	100	210 -225	+	-	-	+	+	0	+
3	ditto	100	240	+	0	+	+	0	0	+
IV	New N-S Alignment	100	-	+	+	+	-	-	-	-

Notes: + (very good), 0 (good), - (poor)

4-3 Dredging Efficiency Improvement Plan

Most of the plans described in Chapter 2 of PART V are to be applied concurrently. Dumping near the river mouth in the east is subject to trials, etc. Side-casting is also subject to trails, etc. Further study is necessary for these two methods. A tugboat equipped with a blade has a function of a levelling blade attached to dragheads, so the plan for fixing levelling blades to dragheads is not necessary.

The dredging efficiency improvement plan is:

a. Making a turning basin in the middle of the channel

b. Fixing spades to dragheads

c. Constructing a tugboat equipped with a blade and survey equipment

d. Installing a draghead position indicator in a dredger

e. Using devices such as flow, concentration and draft meters

f. Installing a personal computer on site

g. Carrying out sounding by dual frequencies such as 210 kHz and 33 kHz with cross-checking by lead

h. Setting two tide poles along the channel near Spots Nos. 5,000 and 10,000

i. Constructing a new platform for surveying in the east part of the river mouth

j. Constructing a fast survey boat equipped with complete survey instruments

PART VI THE COMPREHENSIVE PLAN

Chapter 1 Channel and Siltation Countermeasure Planning

1-1 Target of the Comprehensive Plan

The objectives of the channel and siltation countermeasure plan of the Comprehensive Plan is to facilitate smooth cargo flow and vessel traffic in view of the expected future increase in cargo throughput and traffic volume, while securing safe navigation and minimizing siltation by means of anti-siltation facilities.

The target year of the Comprehensive Plan is 2000. The cargo throughput in 2000 is expected to be about 8.3 million tons/m^3 in total, including foreign and domestic trades of 3.2 and 5.6 million tons/m^3, respectively. Ships' traffic volume will be about 11,000 ships per year.

The design ship of the channel is 6,500 GRT (10,000 DWT) class cargo vessels, including general cargo and container ships. The minimum required water depth is DL-6 meters. The plan envisages future development of the port so that it can handle 11,000 GRT (18,000 DWT) class cargo vessels which requires a water depth of DL-8 m.

1-2 Channel and Siltation Countermeasure Plans

1-2-1 Plans of Channel Layout and Dimension

Based on the in-depth analyses and comparisons of various kinds of alternatives made in Part IV and V, the selected alignment is the present channel with a length of 14 km oriented to the direction of 208.5 degrees.

The cross-sectional profile of the channel consists of a depth of DL-6 m, a bottom width of 100 m, and a side slope of 1/8 to 1/10 as a one-lane and 24 hours operational channel.

1-2-2 Arrangement Plans of Siltation Countermeasure Facility

The most advantageous way of reducing siltation volume in the present channel is judged to be submerged walls arranged parallel to the channel.

The crown height of submerged walls effective and suitable for the site conditions is 1.5 m high above the sea bottom.

The distance between the walls, which primarily depends on the bottom width and side slope of the channel, is the case of 240m , making allowances for erosion of shoulders, over-depth and width dredging, future deepening of the channel and others.

The submerged walls are to be arranged principally from Spots Nos. 2,000 up to 13,000 on both sides of the channel.

The plan and longitudinal cross section are shown in Fig. VI. 1.2-1 and 2.