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CALCULATION OF THE TURBIDITY TRANSPORT IN DINH AN COASTAL ZONE

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ABSTRACT. In the paper, the results of the calculation of turbidity transport in Dinh An coastal area by using the software named RDPOL based on random walk techniques developed by CMERCS are presented. In previous study, the carried out numerical model has been verified well by remote sensing images for classification of the turbidity distribution of Red, Thai Binh, Han, Thu Bon, Sai Gon-Dong Nai and MeKong estuaries. In this study, computed results, that the complexity of the bathymetry, the river flow of the MeKong River system and seasonal monsoon winds are taken into account, are compared with the observed data at 19 stations including 10 stations in March and 9 stations in October, 1997 in Dinh An coastal zone and show its reasonable agreement. Some maps of turbidity distribution in the area have been carried out and several remarks have been made.

§1. Introduction

In this report, the results of the calculation of turbidity transport in Dinh An coastal area by using the software named RDPOL based on random walk techniques developed by CMERCS are presented. The Dinh An coastal area's water body is located at the South Coast of Vietnam, between the 9°-10°N. In this study, the complexity of the bathymetry, the river flow of the Mekong River system and seasonal monsoon winds are taken into account. The computed results are compared with the observed data at 19 stations including 10 stations in March and 9 stations in October, 1997 and shows its reasonable agreement. Some maps of turbidity distribution in the area have been carried out.

2. Mathematical background

2.1 Calculation of currents

In order to simulate the sea water level oscillation and circulation caused by tide propagation and wind stress, the Tide-2D software developed by CMESRC has been used. The model is based on the 2D nonlinear shallow water equations. The software Tide-2D has been calibrated and verified for different Vietnam sea areas including Dinh An coastal area. See [5] for more details.

Boundary condition

At the open boundary, the water level is given and at the solid boundary, the velocity components normal to walls are null, i.e. $U_n = 0$.

Initial condition

At the initial time $t = 0$, current velocity and water level are set to zero:

$$U = 0, \quad V = 0, \quad Z = 0.$$

The realistic current field is obtained after as many as 7 days of calculation, and they will be used in turbidity transport calculation, see [5].

Current fields have been calculated for 2 cases with 2 representative speeds in March and in October as follows:

+ NE uniform wind in March with average speed of 7m/s

+ NE uniform wind in October with average speed of 8m/s

2.2 Calculation of turbidity transport: Random walk model [1,2]

Governing equation

It is well known that the track of a contaminant particle in convection and turbulent field can be calculated from the following equation:

$$\frac{d\vec{r}_i}{dt} = \vec{U}_i + \vec{u}_i \quad (i = 1, 2, \ldots, N), \tag{2.1}$$

where, $\vec{r}_i$ is a radius vector of a contaminant particle, $\vec{U}_i$ is a mean velocity, which can be given from solution of the 2D shallow water model for the tide and wind drift currents with some effects of wave motion taken into account, $\vec{u}_i$ is a turbulent velocity or velocity fluctuation, which can be described as a random value.

Counting the polluting particles contained in fixed boxes, the concentration of pollutants can be estimated.

The turbulent velocity $\vec{u}_i$ is estimated as random value by which a contaminant particle moves away a distance of $\Delta X(x, y, z)$ that is defined according to the statistical distribution as follows:

Ignoring the convection term, the 1D-diffusion equation becomes:

$$C_t = DX_{xx}. \tag{2.2}$$

Assuming that at the initial time, contaminant distribution has the form of Dirac function, this means, that contaminant concentration in a small enough area is $C(x, 0) = M\delta(x)$. The solution of equation (2.2) is

$$C(x, t) = M(4\pi Dt)^{-1/2} \exp[-x^2/(4Dt)].$$

Setting $\sigma^2 = 2Dt$, replacing it into the above formula, it can be seen that, the turbidity concentration has the normal distribution and its mathematical expectation equals zero, its variance equals σ. According to the theorem of the central limitation in the theory of probability, the Gauss normal distribution is the limit of the symmetrical binomial distribution which demonstrates accidental movement of particles. Assuming that particles move away in left or right direction for the same distance of ΔX with probability of σ. Therefore, after n time steps, the i-th contaminant particle can moves away for a distance of

$$\Delta X = \pm\Delta x \pm \Delta x \pm \cdots \pm \Delta x(n \text{ times}) : \; x = \Delta x(2p - n)$$

where,

$$p = {}^nC_p(0.5)^n. \tag{2.3}$$

The variance: $\sigma^2 = n\ \Delta x^2/\Delta t$, deducing

$$\Delta x = \pm(2D\Delta t)^{1/2} \tag{2.4}$$

Sign of (2.4) is defined in random. From (2.4), we can find out $\vec{u}_i$

Boundary conditions

In the case of limited area, the boundary conditions are given as follows:

- At liquid boundaries: if a particle reaches the liquid boundary, it will be ignored in the following time steps.

- At solid boundaries: the effects of shore line and bed are taken into account by assuming that the particles are able to be stranded or reflected. It much depends on the shore line type and the properties of the particles.

It can be noted that the crucial point of this method is the definition of water velocity.

Initial condition

At the initial time, $t = 0$: contaminant particles are located at the source's position, that is, at the river mouth.

$$\vec{r}_i = \vec{r}_0 \quad (i = 1, 2, \ldots, N)$$

Programme

A package of programmes named RDPOL has been carried out on FORTRAN-77 and has been used for description of river water plumes in number of estuarine regions of Vietnam Coastal areas. In this case, remote sensing images have been used for calibration and verification of the capability of the software to predict the boundary and the highest density area of turbidity plume. The obtained results provided for 6 biggest river systems along the coast of Vietnam show that the developed software is able to do this in an acceptable way. Calculation results show that turbidity distribution can be used to compare with the observed data after about 200h of calculation, [1].

3. Application of the Model

3.1 Physical parameters and discretization

The computational domain is extended from the latitude of 105°04' to 106°55' and from the longitude of 8° 16' to 10°00' including Dinh An and Tranh De river mouths. The domain is discretized by a 137 × 136 uniform grid with the longitudinal space step $dx = 1463.978\,\mathrm{m}$ and the latitudinal one $dy = 1474.391\,\mathrm{m}$. The time step is 1800s.

3.2. Input data

Currents

Current fields has been calculated from the Tide-2D software as mentioned above and they are used as the input data for the model of calculation of turbidity transport.

River discharge

The series of discharges in every hour from 27/9-17/10/1997 of Dinh An and Tranh De mouths are collected from data bank of Cuu Long River Survey Department. In March, due to shortage of observed data, the constant discharges are adopted.

Turbidity

Turbidity at 2 river mouths of Dinh An and Tranh De calculated from 2D width integrated model of Numerical simulation of hydrodynamics, salinity intrusion and sediment transport in Hau river and its branches is used as input data which varies from 50 to 150mg/l in dry season and from 200 to 300mg/l in rainy season [3].

IV. Results and analyses

For verification, results of field survey in March and in October 1997 are used. Turbidity at Dinh An and Tranh De estuary has been calculated for 2 seasons, from 7 to 17 March 1997 and from 4 to 14 October 1997. On the figs. 1-10, the comparison of turbidity at 10 stations in March and on the figs. 11-19, the comparison of turbidity at 9 stations in October are presented (Location of observation stations, see tables 1 and 2). Due to scarce data collected, this comparison can provide only some conclusions with orientation character.

In these figures, in general, calculated results are in acceptable agreement with the observed data, especially at stations 06, 07, 10, 11, 12 and 13 in March and 20, 24, 26, 27, 28 in October. However, at some other stations such as station 14 in March and stations 25, 29 and 31 in October, computed results are still not much coincided with the observed data, perhaps, due to several constraints to the mathematical simulation of turbidity for Dinh An coastal zone as follows:

- Firstly, turbidity transport calculation has been carried out for only 2 sources which are Dinh An and Tranh De mouths. In reality, the turbidity concentration of this coastal area is affected not only by these 2 sources, but also by other river mouths (located not far from this place) such as Co Chien, Ham Luong, Dai, Tieu, Soai Rap and so on, especially, in October (in rainy season), when discharge of last river mouths is quite great. Further more, the studied area has very soft plain bottom of fine sand, mud and clay, and is very shallow. Under the action of waves, in some conditions, the bottom materials may be involved in movement. All these cause a considerable difference between calculated results and the observed data at some stations.

- Secondly, there is no synchronously and continuously observed data of turbidity of the 2 river mouths.

- Finally, shortage of river discharges data for period for Dinh An and Tranh De rivers as the sources of turbidity.

Table 1. Comparison of turbidity in March, 1997

Station No	Coordinate	Average observed(mg/l)	Computed (mg/l)	Diff.	Error (%)
		41.33	41.26	0.07	0.2
		68.33	48.18	20.15	29.5
03	9°27.60'S, 106°26.67'E	37.50	42.23	-4.73	-12.6
		42.17	42.63	-0.47	-1.1
		70.67	48.77	21.90	31.0
		35.67	47.18	-11.52	-32.3
06	9°17.23'S, 106°25.13'E	15.56	13.53	2.02	13.00
07	9°12.06'S, 106°17.07'E	14.44	16.24	-1.80	-12.45
08	9°08.00'S, 106°08.13'E	16.89	12.30	4.59	27.17
09	9°05.04'S, 105°59.00'E	17.11	13.14	3.97	23.19
10	9°21.21'S, 106°24.35'E	53.50	45.43	8.07	15.08
11	9°15.94'S, 106°16.28'E	31.50	26.81	4.69	14.89
12	9°14.78'S, 106°06.10'E	25.17	28.93	-3.76	-14.94
13	9°12.88'S, 105°55.38'E	22.67	20.21	2.45	10.83
14	9°31.40'S, 106°22.04'E	46.67	65.11	-18.44	-39.52

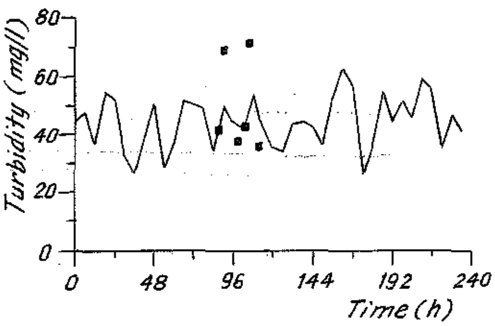

Fig. 1

Comparison of turbidity at ST.03

——: computed, ▪ : Observed

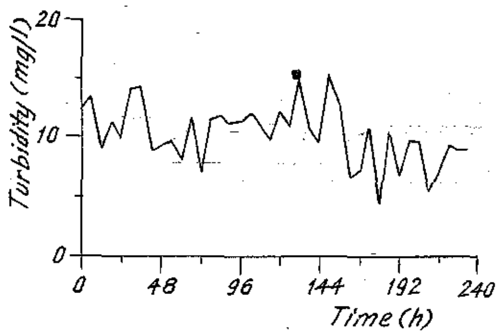

Fig. 2

Comparison of turbidity at ST.06

——: computed, ▪ : Observed

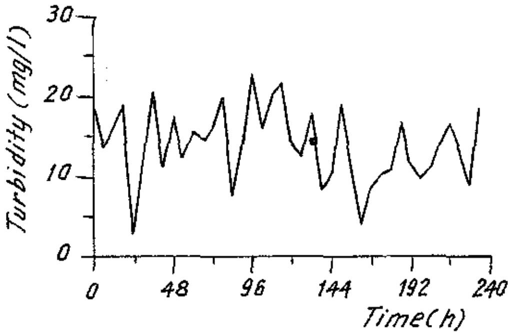

Fig. 3

Comparison of turbidity at ST.07

——: computed, ▪ : Observed

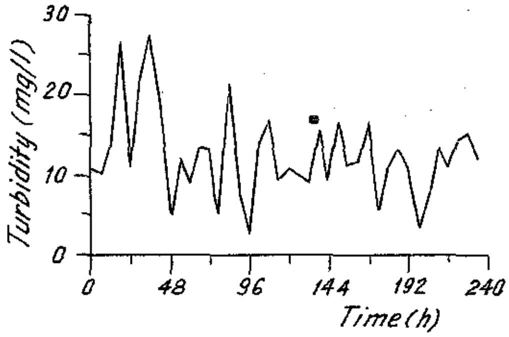

Fig. 4

Comparison of turbidity at ST.08

——: computed, ▪ : Observed

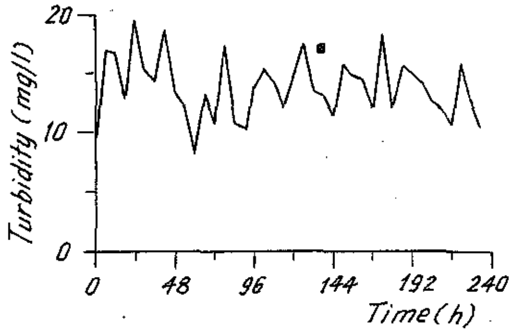

Fig. 5

Comparison of turbidity at ST.09

——: computed, ▪ : Observed

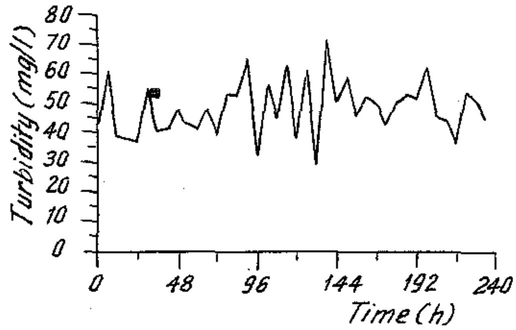

Fig. 6

Comparison of turbidity at ST.10

——: computed, ▪ : Observed

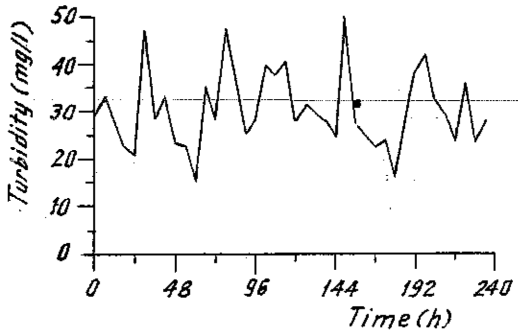

Fig. 7

Comparison of turbidity at ST.11

——: computed, ▪ : Observed

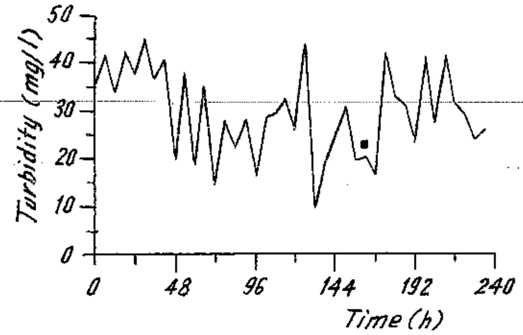

Fig. 8

Comparison of turbidity at ST.13

——: computed, ▪ : Observed

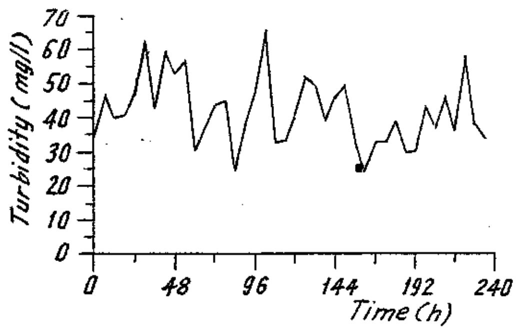

Fig. 9

Comparison of turbidity at ST.12

——: computed, ▪ : Observed

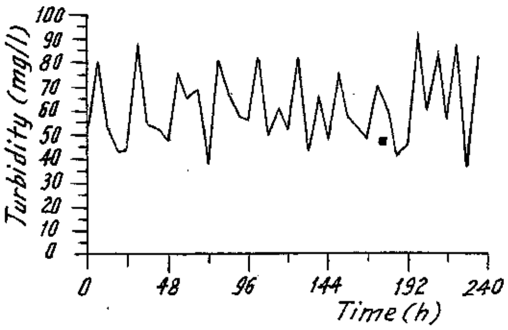

Fig. 10

Comparison of turbidity at ST.14

——: computed, ▪ : Observed

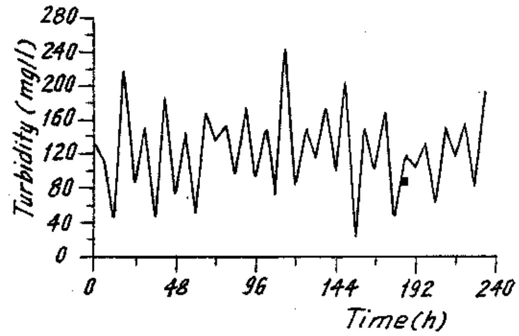

Fig. 11

Comparison of turbidity at ST.20

——: computed, ▪ : Observed

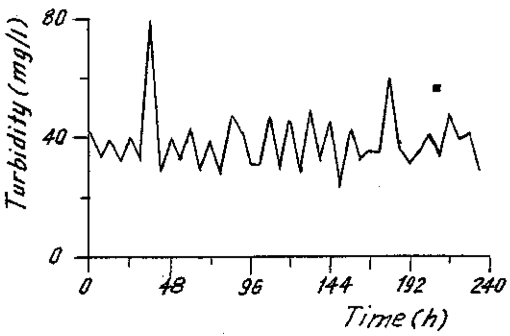

Fig. 12

Comparison of turbidity at HV6 St.25

——: computed, ▪ : Observed

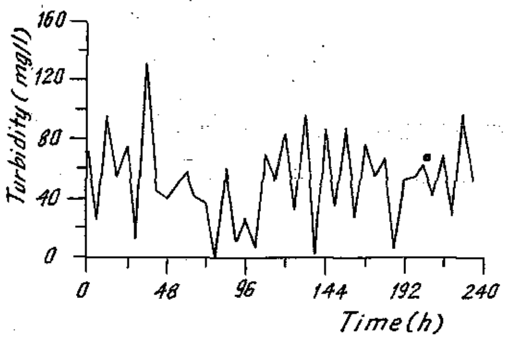

Fig. 13

Comparison of turbidity at ST.24

___ : computed, ▪ : Observed

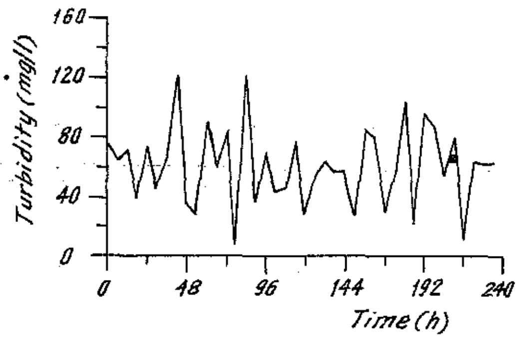

Fig. 14

Comparison of turbidity at ST.26

___ : computed, ▪ : Observed

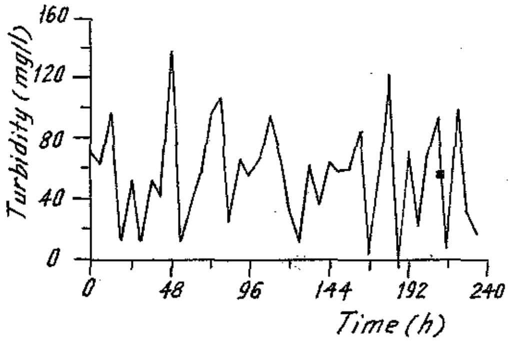

Fig. 15

Comparison of turbidity at ST.27

___ : computed, ▪ : Observed

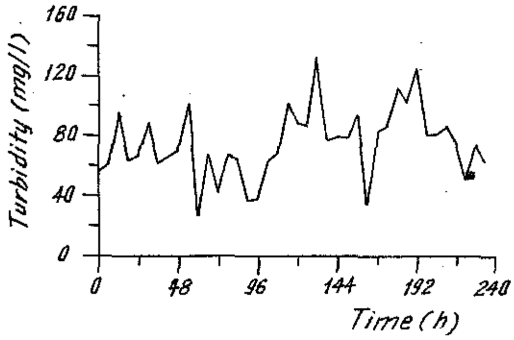

Fig. 16

Comparison of turbidity at ST.28

___ : computed, ▪ : Observed

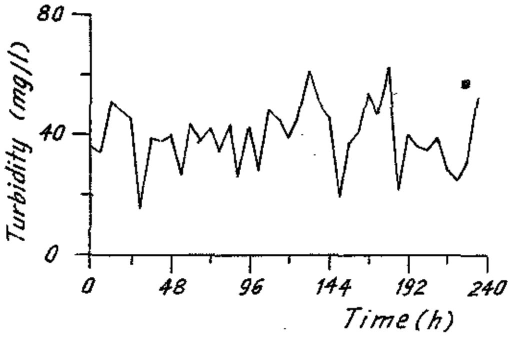

Fig. 17

Comparison of turbidity at ST.29

___ : computed, ▪ : Observed

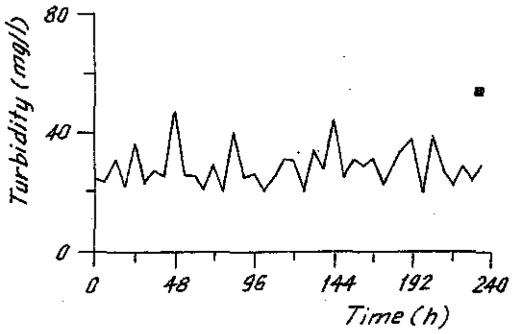

Fig. 18

Comparison of turbidity at HV6 St.31

___ : computed, ▪ : Observed

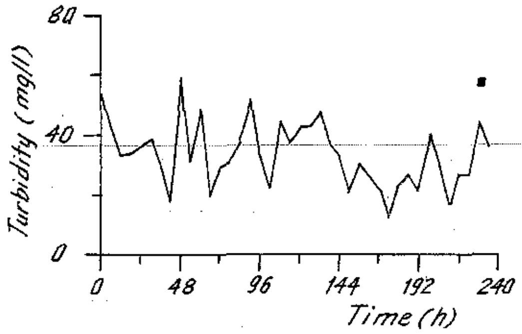

Fig. 19

Comparison of turbidity at ST.30

—— : computed, ■ : Observed

Table 2. Comparison of turbidity in October, 1997

Station No	Coordinate	Average observed(mg/l)	Computed (mg/l)	Diff.	Error (%)
20	9°28.25'S, 106°23.42'E	86.67	84.86	1.81	2.1
24	9°20.30'S, 106°24.12'E	67.78	61.65	6.13	9.0
25	9°17.00'S, 106°25.00'E	55.89	35.98	19.91	35.6
26	9°15.93'S, 106°15.85'E	65.22	58.80	6.42	9.8
27	9°15.61'S, 106°06.33'E	56.11	54.65	1.46	2.6
28	9°11.37'S, 105°55.21'E	54.33	51.97	2.36	4.3
29	9°04.97'S, 105°58.77'E	57.00	29.48	27.52	48.3
30	9°07.85'S, 106°07.77'E	57.78	41.19	16.58	28.7
31	9°06.99'S, 106°16.86'E	54.22	28.20	26.03	48.0

Numerical results are shown in tables 1 and 2. In these tables, two firsts column are station numbers and its coordinates in longitude and latitude, the next one is the depth-averaged observation data [4], the fourth column is calculated results, the following one is the difference between the depth-averaged observation data and computed result and the last column, the percentage of this difference over the depth-averaged observation data.

Map of turbidity distribution

Fig. 20 and 21 show the turbidity distribution in Dinh An coastal zone in March and October after 234h of calculation. Fig. 21 indicates that with NE wind 8m/s, turbidity plume can reach as far as Ca Mau cap. The numbers on these figures show the turbidity concentration in mg/l.

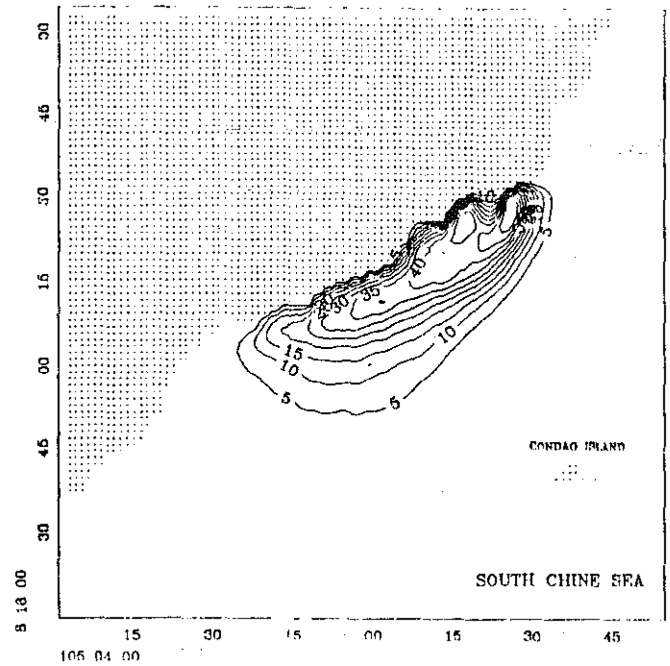

Fig. 20. Turbidity distribution in Dinh An coastal zone in March after 234h

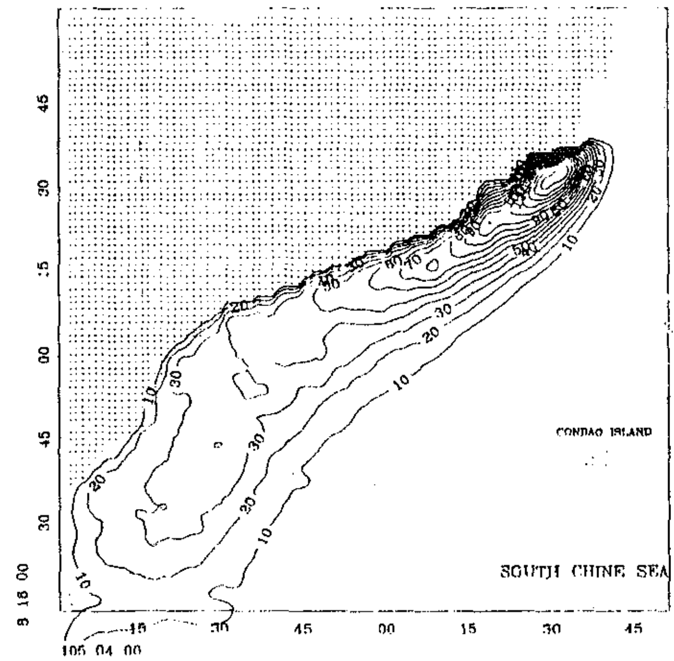

Fig. 21. Turbidity distribution in Dinh An coastal zone in October after 234h

V. Conclusion

The software RDPOL based on random walk method is used for calculation of turbidity transport in Dinh An-Tranh De coastal zone. Turbidity has been calculated and compared with the observation data at 19 stations. The results indicate that:

- In general, the computed results are in acceptable agreement with the observed data.

- In October, at 5 stations including 20, 24, 26, 27 and 28, the calculated results are in acceptable agreement with the observed data. This can be explained that these stations are situated very close to Dinh An and Tranh De mouths, therefore, the observation data of them are weakly influenced by other turbidity sources from river mouths of Mekong River System. In opposite, the rest stations 25, 29, 30, 31 are located at further sites and at smaller density plume so it is strongly affected by turbidity flow flushed from other rivers in the region.

- Most of the computed values of turbidity are smaller than the observed data, which can be interpreted that turbidity distribution in this coastal zone is not only affected by turbidity flow flushed from 2 rivers considered in this paper but also from other rivers in the region including other rivers of the Mekong River System and of Sai Gon-Dong Nai River System as well. Therefore, for the further calculations, effects of other river mouths in the region have to be taken into account.

- Some maps of turbidity distribution have been carried out. These maps show that the sediment is transported in the SW direction as far as to the Ca Mau Caps and so on. But in order to obtain better ones, it is necessary to have synchronously and continuously observed data at different stations used for verification.

REFERENCES

1. Pham Van Ninh, Phan Ngoc Vinh. Mathematical modelling of turbidity water plume at estuaries, Journal of Mechanics, No 4, T. XVII, Hanoi 1995.

2. Pham Van Ninh, Bui Minh Duc, Pham Trung Luong. Mathematical modelling and remote sensing methods for assessment riverine pollution inputs to the sea. Second Westpac Symposium, Malaysia, 1991.

3. Nguyen Kim Dan, Phan Ngoc Vinh, Guillou S., Barby N. Numerical simulation of hydrodynamics, salinity intrusion and sediment transport in Hau river and its branches by a 2D width integrated model. Proceedings of the International workshop on the Mekong Delta. Chiang Rai, Thailand, Feb., 1998.

4. Hydrometeorological, morphodinamical and environmental conditions at the

Mekong Delta coastal zone. Technical report of the first field survey EU CuuLong Project, Hanoi 7/1997.

5. Pham Van Ninh, Nguyen Thi Viet Lien. Technical report of calculation of current in Dinh An Coastal area. EU CuuLong Project, Hanoi 2/1998.

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TÍNH TOÁN LAN TRUYỀN ĐỘ ĐỤC Ở VÙNG CỬA SÔNG ĐỊNH AN

Bài báo trình bày kết quả tính toán lan truyền độ đục ở vùng cửa sông Định An bằng phần mềm RDPOL dựa trên phương pháp ngẫu hành do CMERSC phát triển. Trước đây, đã sử dụng ảnh viễn thám để hiệu chỉnh và kiểm chứng mô hình về ranh giới đục trong và vùng có độ đục cao nhất cho các vùng biển cửa sông Hồng, Thái Bình, Hàn, Thu Bồn, Sài Gòn - Đồng Nai và Mêkông. Lần này, các kết quả tính toán trong đó có tính đến địa hình phức tạp, lưu lượng của hệ thống sông Mêkông và chế độ gió mùa được so sánh với số liệu quan trắc ở 19 trạm trong đó có 10 trạm vào tháng 3 và 9 trạm vào tháng 10, 1997 ở vùng biển Định An và cho thấy bức tranh tương đối phù hợp. Đã xây dựng được các bản đồ phân bố độ đục cho vùng này và nêu lên một số nhận xét cần chú ý.