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FIELD OBSERVATION ON THE TIME VARIATION OF CONCENTRATIONS OF SALINITY AND SUSPENDED FINE SEDIMENTS IN THE TIDAL REACH OF A RIVER

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SYNOPSIS

The results of two times of field observations made in the tidal reach of the Tsurumi River, a typical "urban-river" which flows into Tokyo Bay, on the time variation at various cross-sections,of flow velocities, the concentrations of salinity and suspended fine sediments, and suspended sediment particle sizes, are herewith reported. The rate of deposition during a tidal cycle was analyzed by the use of the conservation equation of suspended sediments. Comparison was made between the rate of deposition or redetachment of suspended sediments thereby analyzed and the velocity distributions in relevant cross-sections and was discussed.

INTRODUCTION

The Tsurumi River is a typical "urban-river" which is situated to the west of Tokyo and flows into Tokyo Bay. Its basin area is 235km^2 in which more than 188km^2 is urbanized. The basin area is composed mostly of hills and partly of terraces and alluvial plains. The drainage pattern is dendritic, and the length of trunk stream is 42.5km. With the advance of the work of turning the land into housing lots serious amount of cohesive sediments has been transported in suspension in the river, so that in the downstream part of the tidal reach of the river regular dredging has been needed for the maintenance of the river against siltation.

For the prediction of deposition of fine sediments in estuaries mathematical models are usually used. Construction of a mathematical model suitable for each river is desirable, and for this purpose collection of basic data is necessary. In the case of the Tsurumi River basic data on the boundary conditions of the river seems available to some extent for this purpose, but the unsteady hydraulic behaviour of suspended fine sediments in the downstream part of its tidal reach seemed not to have been measured by field study. It was for this reason that two times of field observations were performed by the writers.[1] In order to study the unsteady hydraulic behaviour of suspended fine sediments particularly in the tidal flow in the river the field observations were made at the times of spring tides of Tokyo Bay.

A number of field studies have already been made on the depositional behaviour of cohesive fine sediments in estuaries. It seemed to the writers, however, that few data have previously been published on the spatial distribution of the size of suspended sediment particles and of the concentration of the volatile solids contained in suspended fine sediments. In the field study conducted at the Tsurumi River, measurments were made not only on water levels, velocities of flow, salinity concentrations and concentrations of suspended sediments, but also on suspended sediment particle sizes and the concentrations of the volatile solids contained in suspended sediments.

The present paper has been made by modifying a part of analysis made in, and supplementing with figures of velocity distributions, the writers' previous publication[1].

GENERAL DESCRIPTION OF THE FIELD OBSERVATIONS

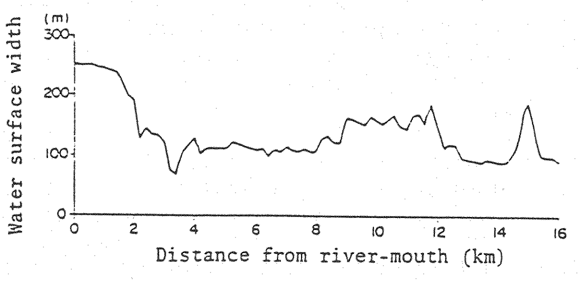
Field observation at the Tsurumi River was made twice, each having been conducted at the time of the spring tide of Tokyo Bay. The first one was made during the period December 23-24, 1980 and the second one for the period November 12-13, 1981.

In the first field observation, aiming at grasping the convective characteristics of flow of the river in the longitudinal direction, measurement was made in the seven cross-sections of main river located at distances from the river-mouth 0km, 1.75km, 4.89km, 7.88km, 9.05km, 11.11km, 13.09km upstream and three cross-sections of a tributary, for four times each with the interval of four hours, starting from the instant of high tide at the river-mouth.

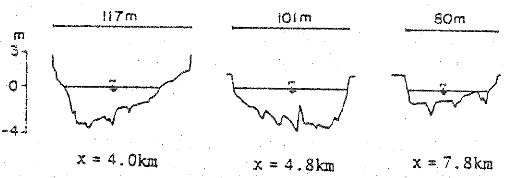
In the second field observation, measurement was made in the three cross-sections situated at 4.0km, 4.8km and 7.8km upstream from the river-mouth for 17 times with the interval of 50 minutes starting from the instant of full tide of the river-mouth, for the purpose of studying the mechanism of the variation of suspended sediments transported into the tidal reach.

Principal dimensions of the river can be seen in Fig. 1, which shows the surface-widths of the river and the three cross-sections mentioned above.

Quantities measured were water-levels, velocity distributions, concentrations of chloride ions and suspended sediments, particle diameters and specific gravity of suspended sediments. Measurement of water-level was made with automatic water-gauges in the first field observation, and by reading of staff-gauges in the second field observation. Velocity measurement was made by the use of Price-type current meters. Suspended sediment samples at each point were taken with a Van Dorn-type sampler. The concentration of chloride ions was measured by $AgNo_3$ titration, while that of suspended sediments with glass filters. The size distribution of the sediment particles was determined by a photometric method, and volatile solids were measured by igniting the dried sample.



(a) The Water Surface Width



(b) Typical Cross-Sections

Fig.1 The Scale of the Tsurumi River

THE FIRST FIELD OBSERVATION AND ITS RESULTS

Record of Tide at the River-Mouth

The record of an automatic water-gauge, which is installed at the river-mouth, during the period of the observation is shown in Fig. 2.

Rate of Discharge at the Cross-Section Situated Above the Upstream End of the Tidal Reach of the River

The section of river located at the distance of 15.8km upstream from the river-mouth is out of the tidal reach of the river, so that the time variation of the rate of discharge, the concentrations of suspended solids and chloride ions at this section were taken as boundary conditions at the upstream end of the tidal reach of the river. Figure 3 shows the record of rate of inflow at this section which is calculated from the record of an automatic water-gauge. The rapid increase of rate of discharge shown in this figure was owing to the rain started from $21_{p.m.}$, December 23, 1980.

Particle-Size of Bed Material

In Fig. 4 the particle mean diameter of bed material, which was sampled from river bed at various sections in 1979 and 1980, is plotted versus the distance from river-mouth in the figure.

Concentration of Chloride Ions

Figures 5(a), (b), (c) and (d) show the distribution of salinity in the

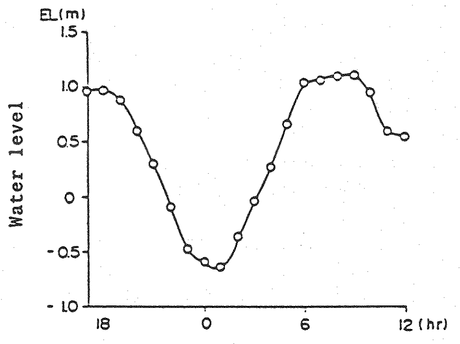


Fig.2 Record of Tide at the River-Mouth on December 23 and 24, 1980

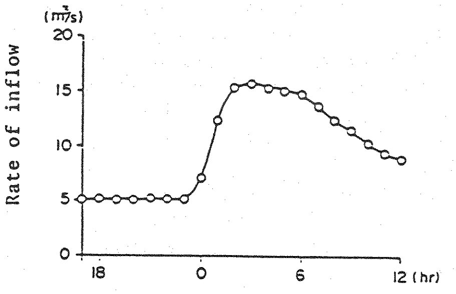


Fig.3 Record of Rate of Inflow at x = 15.8km on December 23 and 24, 1980

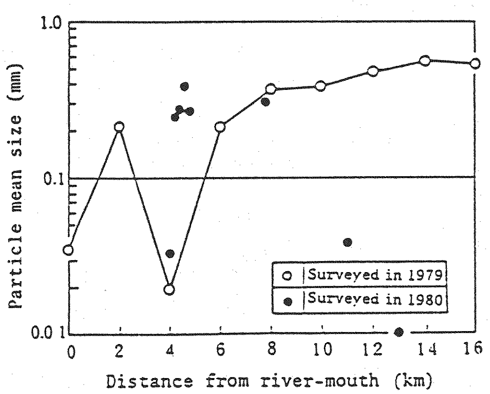


Fig. 4 Particle Mean Diameter of Bed Material

longitudinal direction at the instants of high tide, full ebb, low water and full flood, respectively.

It is seen from Fig. 5(a) that, at the instant of high tide, the concentration of chloride ions varies in the cross-section at the river-mouth from 15,900 ppm at the water surface to 17,800 ppm near the bottom, it gradually decreases with respect to the longitudinal distance and attains, at the distance 7.8km upstream from the river-mouth, the proper value of chloride ion concentration of river water 40 ~ 90 ppm.

At the instant of full ebb (Fig. 5(b)), the chloride ion concentration varies at the river-mouth from 12,700 ppm at the water surface to 17,200 ppm near the bottom, and in the cross-section located 4.8km upstream from the river-mouth the corresponding values are decreased to 972 ~ 1,500 ppm.

At the instant of low water (Fig. 5(c)) the chloride ion concentration at the river-mouth is 10,000 ~ 17,000 ppm and that at the section 4.8km upstream from the river-mouth it decreases to 106 ~ 96 ppm. This shows that the range of non-saline water has moved toward the river-mouth.

In Fig. 5(d) we see that the chloride ion concentration at the river-mouth varies from 10,900 ppm to 17,300 ppm near the bottom and has increased by the amount 500 ~ 900 ppm in comparison with its correponding values at the instant of low water. However, in the section 4.8km upstream from the river-mouth the chloride ion concentration has been decreased to 56 ~ 48 ppm owing to the increase of inflow at the upstream boundary.

It is seen from these figures that mixing of salinity is not of the type of salt wedge, but rather of the type of strong mixing.

Concentration of Suspended Sediments

Figures 6(a) - (d) show the distributions of concentration of suspended sediments at the instants of high tide, full ebb, low water and full flood, respectively. It is seen from Fig. 6(a) that the concentration of suspended sediments in every measuring section located in the range 0-13km from the river-mouth is in the range of 8-24 ppm and uniform in the vertical direction.

At the instant of full ebb (Fig. 6(b)), the concentration increases to 28 ppm ~ 110 ppm in the reach above the cross-section 9km upstream from the river-mouth.

At the instant of low water (Fig. 6(c)) the concentrations at the cross-sections 4.8km, 7.8km and 11km upstream from the river-mouth are 100 ppm, 230 ~ 300 ppm and 270 ~ 340 ppm, respectively, having been increased in comparison with their corresponding values shown in Fig. 6(b).

Figure 6(d) shows that, at the site 4.8km upstream from the river-mouth the concentration has been decreased to 27 ~ 59 ppm, while the concentration at the site 7.8km has been increased to 300 ~ 400 ppm.

It is to be noted from these figures that concentration of suspended sediments varies longitudinally, but varies little in the vertical direction throughout the river. This is a point of remarkable difference in comparison with the case for $d > 0.06$mm, d being the mean size of suspended solids.

Particle Size Distribution of Suspended Sediments

Figs. 7 (a) - (d) show the distribution of particle size of suspended sediments in the longitudinal direction. At the instant of high tide (Fig. 7(a)) the suspended sediments having the mean diameter 4 ~ 13 micron is distributed almost uniformly in the river up to the section 13.09km upstream from the river-mouth.

It is seen from Fig. 7(b), however, that at the instant of full ebb the mean size of the suspended sediments in the reach above the section 7.8km upstream from the river-mouth has increased to 6 ~ 29 micron.

At the instant of low water (Fig. 7(c)) the particle size at the section 4.8km upstream from the river-mouth has become 10 ~ 24 micron , and the tendency of increase of particle size propagated downstream.

The increase of particle size noticed above the section 7.8km upstream from the river-mouth is considered to be owing to the increase of the inflow.

The specific gravity of the suspended solids was measured as $s = 2.28 \sim 2.16$.

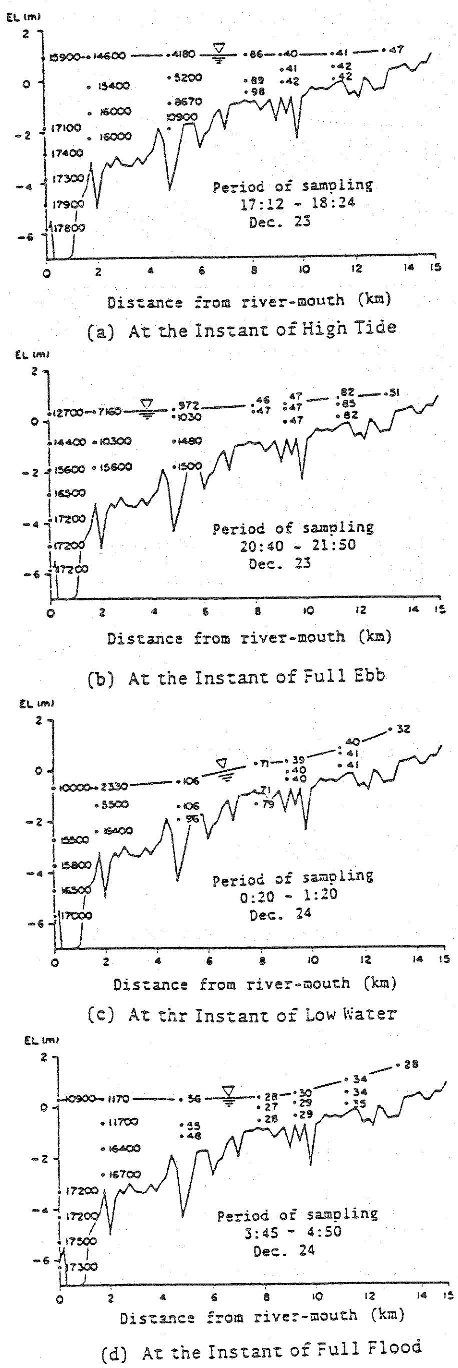


Fig.5 Concentrations of Chloride Ions (gr/m^3)

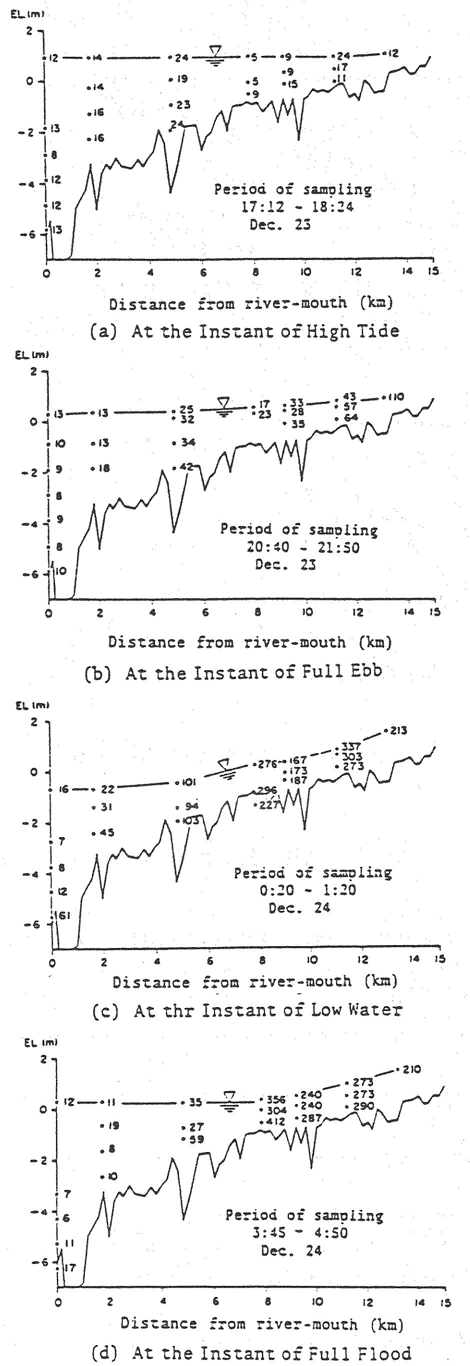


Fig. 6 Concentrations of Suspended Sediments (gr/m^3)

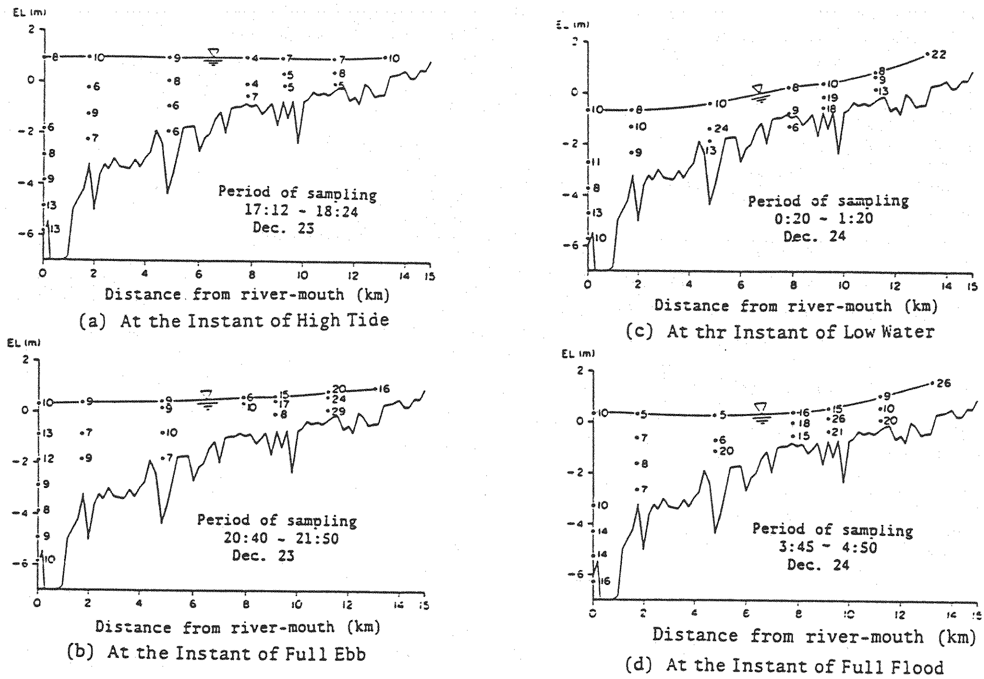
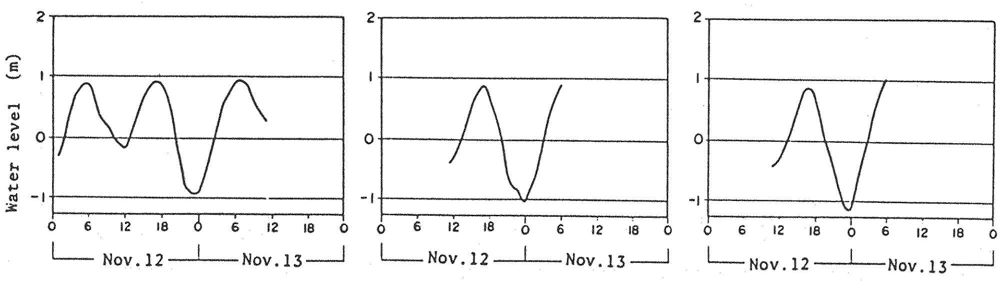


Fig. 7 Particle Size of Suspended Sediments in micron

THE SECOND FIELD OBSERVATION AND ITS RESULTS

Water Levels

The water level automatically recorded at the river-mouth and the water levels observed at the sections 4km and 4.8km upstream from the river-mouth are shown in Figs. 8 (a), (b) and (c), respectively.



(a) Record of Automatic Gauge at the River-Mouth (x = 0km)

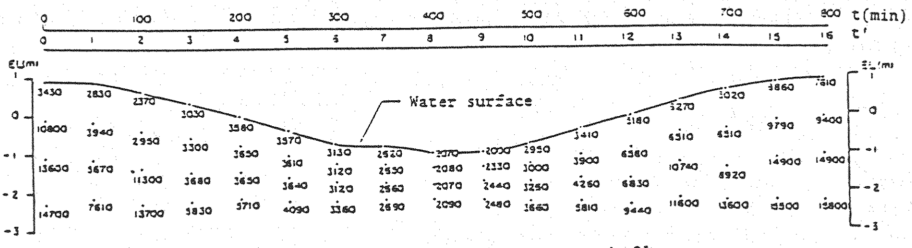
(b) Record at x = 4.0km

(c) Record at x = 4.8km

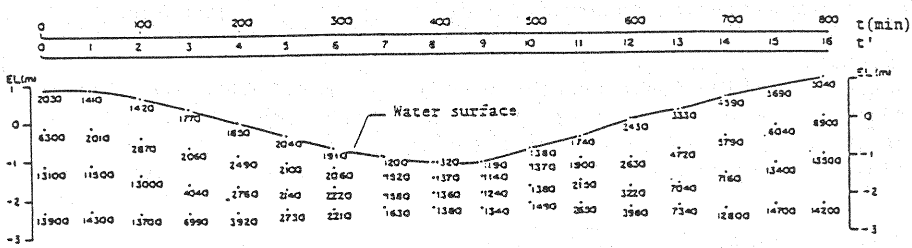
Fig.8 Record of Water Levels on November 12 and 13, 1981

Rate of Discharge

Measurement of velocities was made at five points on each of the three verticals as shown in Fig. 9 in the two cross-sections located 4.0km and 4.8km upstream from the river-mouth. For sake of brevity these two cross-sections will

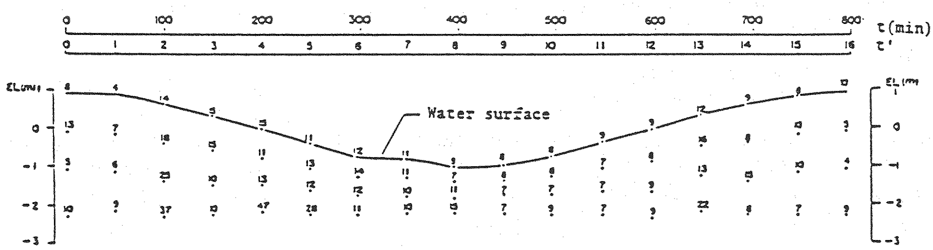


(a) In the Cross-Section at x = 4.0km

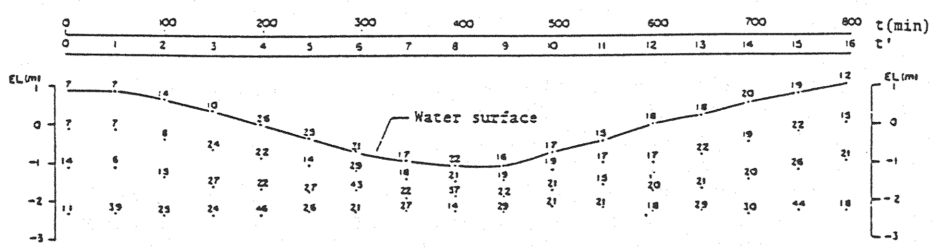


(b) In the Cross-Section at x = 4.8km

Fig.10 Time Variations of the Concentrations of Chloride Ions During a Tidal Cycle (Concentration in ppm)



(a) In the Cross-Section at x = 4.0km



(b) In the Cross-Section at x = 4.8km

Fig.11 Time Variation of the Concentrations of Suspended Sediments During a Tidal Cycle (Concentration in ppm) hereafter be called as the cross-section at $x = 4.0$km and 4.8km. The rate of discharge was calculated by the following equation.

$$Q = \sum_{\ell=1}^{3} \sum_{k=1}^{5} U_{\ell k} \Delta A_{\ell k} \qquad (1)$$

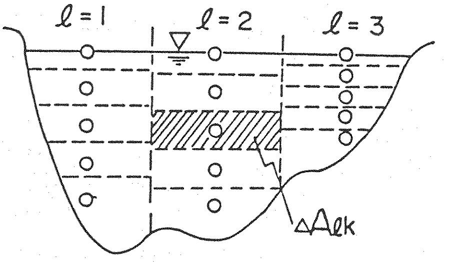


Fig.9 Points for Velocity Measurement

Concentration of Chloride Ions

Saline water samples were taken at four points on a vertical near the center of each of the two cross-sections at $x = 4$km and 4.8km. Figs. 10(a) and (b) show the variation of chloride ion concentration observed during a tidal cycle in the cross-sections located at $x = 4$km and 4.8km, respectively. It is seen from these figures that in the both cross-sections chloride ion concentration varies from 3,430 ppm at the water surface to 14,700 ppm near the bottom at the instant of high tide, while at the instant of low water it varies from 2,070 ppm at the water surface to 2,090 ppm near the bottom, a remarkable change of concentration during a half tidal cycle being noticed.

Concentration of Suspended Solids

Figures 11(a) and (b) show the time variations of the concentrations of suspended solids during a tidal cycle in the cross-sections at $x = 4.0$km and 4.8km.

Figure 12 shows the time variation of the depth-averaged value of concentration of suspended solids, C, in the two cross-sections.

Deposition and Scour

The rate of detachment from the bottom in the reach between $x = 4.0$km and 4.8km can be calculated basing on the conservation equation of suspended solids,

$$\frac{\partial (CA)}{\partial t} + \alpha \frac{\partial}{\partial x}(A' vC) = M, \qquad (2)$$

in which $v = Q/A$, A' = cross-sectional area subtracted by the area of no velocity, α = energy coefficient, and M = rate of detachment of bed material per unit longitudinal length of river. Assuming that $\alpha = 1.0$, Eq. (2) is written partly in finite difference form as

$$\frac{\partial}{\partial t}(CA)_m \Delta x + (A_2' v_2 C_2 - A_1' v_1 C_1) = M \Delta x \qquad (3)$$

Here
$$(CA)_m = \frac{1}{2} (C_1 A_1 + C_2 A_2) \qquad (4)$$

The subscripts 1 and 2 are relative to the quantities at $x = 4.8$km and $x = 4.0$km, respectively, and $\Delta x = 857$m which is the axial, actual distance between the two cross-sections at $x = 4.0$km and $x = 4.8$km.

The term in the right-hand side of Eq. (3) expresses the rate of total detachment of bed material in the reach between two cross-sections.

Figure 13 shows the variations of $C_1 A_1$, $C_2 A_2$ and also $(CA)_m$, the last one being shown, after smoothing, with a solid line. The notation t' is dimensionless time given by $t' = t/50$min, 50min being the averege time interval of measurement.

Figure 14 shows the variations of v_1 and v_2, v being the flow velocity averaged over a cross-section.

Next, the values of $A_1' v_1 C_1$ and $A_2' v_2 C_2$ are calculated and are plotted in Fig. 15, and the value of $A_2' v_2 C_2 - A_1 v_1 C_1$ is drawn to scale with a fine solid line in Fig. 16. The value of $\partial (CA)_m / \partial t$ can be obtained numerically from the smooth curve of $(CA)_m$, and the magnitude of $\partial (CA)_m / \partial t$ thus obtained multiplied by Δx (= 857m) is drawn to scale with a fine broken line in Fig. 16.

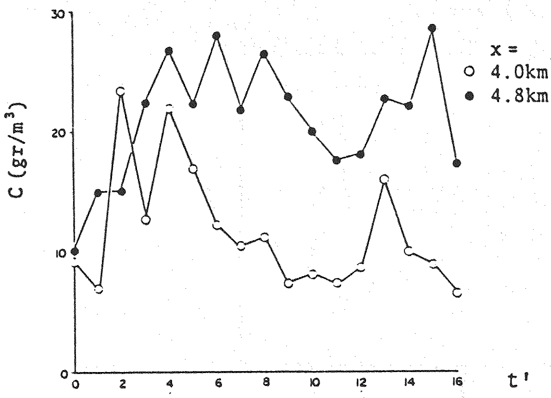


Fig. 12 Time Variation of the Depth-Averaged Concentrations of Suspended Sediments During a Tidal Cycle (Concentration in ppm)

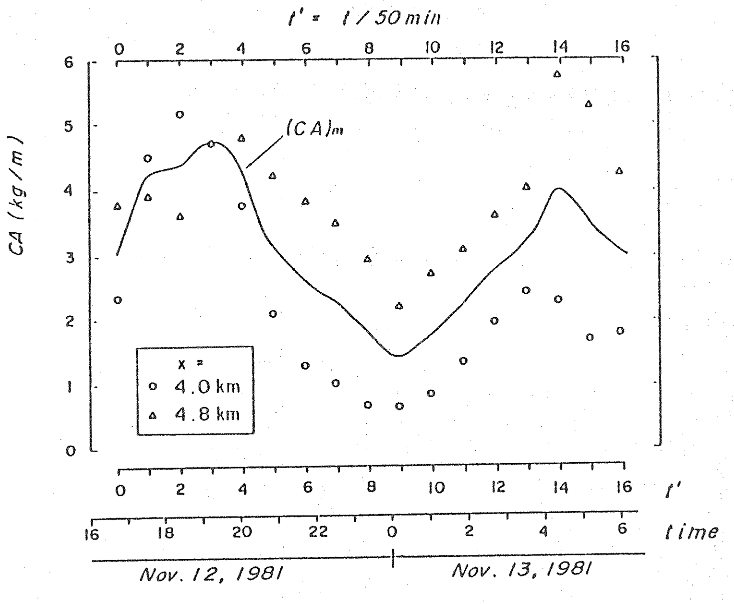


Fig.13 Variations of CA During a Tidal Cycle

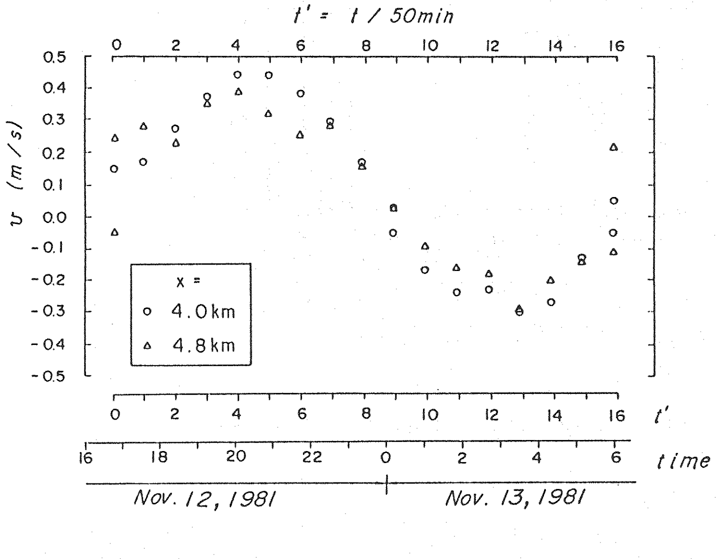


Fig.14 Time Variations of Cross-Sectional Area Averaged Velocities During a Tidal Cycle

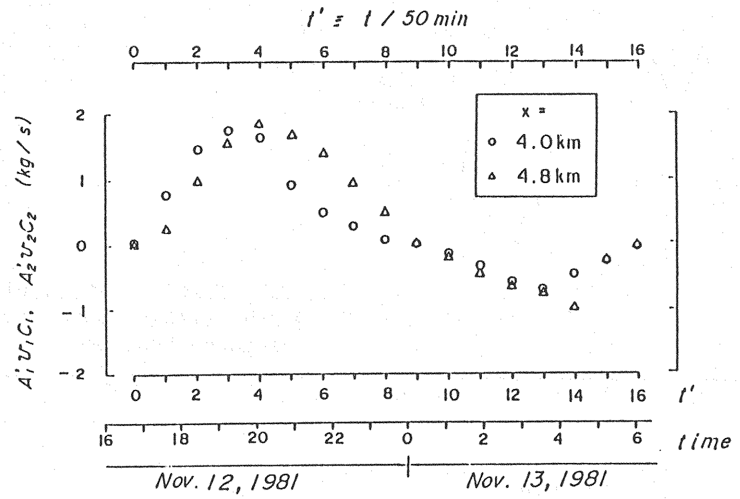


Fig.15 Time Variations of A'vC During a Tidal Cycle

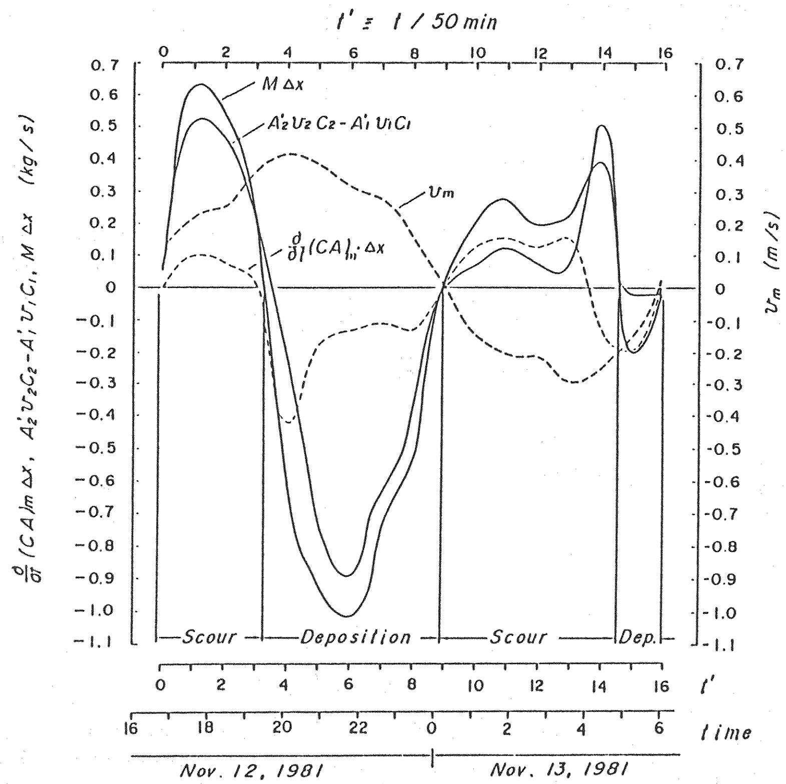


Fig. 16 Analysis of the Total Mass Detached from the Bed

With the values of $\partial(CA)_m/\partial t\cdot\Delta x$ and $A_2'v_2C_2 - A_1'v_1C_1$ thus obtained the rate of total detachment of bed material, $M\Delta x$, can be calculated by Eq. (3), this value being shown in Fig. 16 by the heavy solid line. In the same figure v_m is also shown. It is seen from Fig. 16 how scour and deposition occurred in the reach during one tidal cycle during which the field observation was made. The integrated value $\int_0^T(M\Delta x)dt$ gives the total mass detached from (or deposited on) the river bed in the reach during one tidal cycle. In the case of Fig. 16 this value is obtained as $\int_0^T(M\Delta x)dt = (437 - 1{,}150 + 393 - 56)\text{kg} = -376\text{kg}$, the sign - indicating deposition of suspended solids.

It is seen from Fig. 16 that $M\Delta x$ becomes positive when the direction of river flow is reversed, i.e. at $t' = 0$ and $t' = 9$. The cause for this phenomenon can be attributed to the occurrence of a large-scale circulation.

It is also seen in Fig. 16 that the value of $M\Delta x$ decreases rapidly around $t' = 3$ and 14 and turns to be negative. Figures 17, 18, 19, 20 and 21, 22, 23, 24 are shown for the purpose of comparison with the phenomena above described. Velocity distributions in the two cross-sections at x = 4.0km and 4.8km at the instsnts $t' = 0$, 1, 2, 3 and 9, 13, 14, 15 are shown in these figures.

In Figs. 17, 18, 19 and 20 we notice the following.

a) At $t' = 0$ adverse current still exists near the bed in the cross-section at x = 4.8km.
b) At $t' = 1$ the same situation as a) exists.
c) By $t' = 2$ adverse current has disappeared.
d) At $t' = 3$ velocity near the bed has appreciably been increased in comparison with that at the previous dimensionless instant.

The decrease of the positive value of $M\Delta x$ begins around $t' = 2$ and the value decreases rapidly around $t' = 3$ (Fig. 16). The cause of this can be interpreted by the observations described above in c) and d).

Next, in Figs. 21, 22, 23 and 24 we note the following.

e) At $t' = 9$ adverse current has appeared near the bed in the cross-section at x = 4.0km, while in the cross-section at x = 4.8km adverse current has not yet appeared, but there is still partically fair current.
f) At $t' = 13$ adverse current exists in the whole area in the cross-section at x = 4.0km, while in the cross-section at x = 4.8km there is an area near the left-bank and near the bed where the adverse current has not yet appeared. The latter fact implies the occurrence of large-scale circulation at x = 4.8km, which circulation has a vertical axis.
g) At $t' = 14$ in the both cross-sections the zero current near the bed has disappeared and there is adverse current in the whole area of either of the two cross-sections.

The value of $M\Delta x$ turns to be positive at $t' = 9$, begins to increase rapidly around $t' = 13$, and begins to decrease rapidly around $t' = 14$. These phenomena can reasonably be compared with the observations described in e), f) and g), respectively.

In Figs. 17 - 24 the concentrations of chloride ions and suspended sediments, the amount of volatile solids and the water temperature, at the measuring points indicated in the figures by triangles are summarized and listed in a table in each figure. In tables the following addreviations are used.

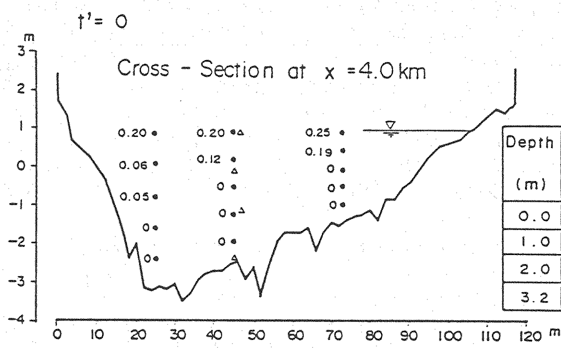
Cl : chloride ions, SS : suspended sediments, VS : volatile solids

The mass of suspended sediments is measured as

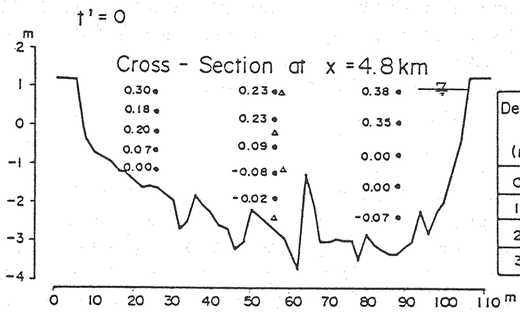
$$SS = VS + (\text{ignition residue}), \qquad (5)$$

where VS and ignition residue constitute the organic substance component and the inorganic substance component of SS, respectively. Therefore in the table of Fig. 17, for example, it can be read as follows:

At x = 4.0km and z = 0m,
Concentration of suspended sediments : 8 ppm
The constituents of the above —
Organic substance : 5 ppm ; Inorganic substance : 3 ppm

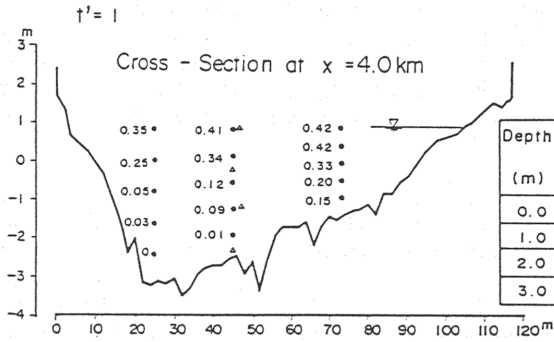


Depth (m)	Concentr. (gr/m³) Cl	SS	VS	Water Temp. (°C)
0.0	3430	8	5	14.6
1.0	10800	13	5	16.0
2.0	13600	5	2	16.6
3.2	14700	10	3	17.0

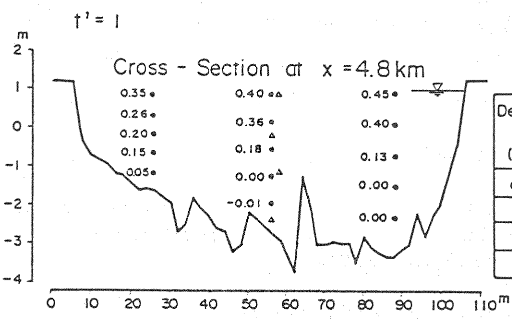


Depth (m)	Concentr. (gr/m³) Cl	SS	VS	Water Temp. (°C)
0.0	2030	7	3	14.8
1.0	6300	7	3	15.2
2.0	13100	14	4	15.9
3.2	13900	11	4	16.1

Fig.17 Distribution of velocities in m/s at t′ = 0. (•: Point of measurement of velocity; Δ : Point of measurement of the concentrations of Cl, SS and VS, and the water temperature)

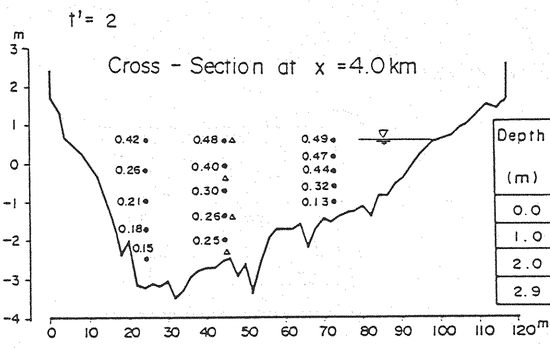


Depth (m)	Concentr. (gr/m³) Cl	SS	VS	Water Temp. (°C)
0.0	2830	6	3	15.0
1.0	3940	7	3	15.6
2.0	5670	6	2	15.8
3.0	7610	9	2	16.7

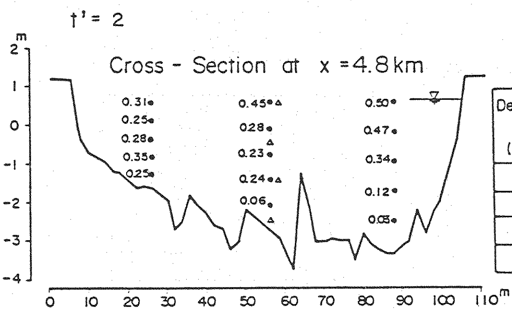


Depth (m)	Concentr. (gr/m³) Cl	SS	VS	Water Temp. (°C)
0.0	1410	7	3	14.0
1.0	2010	7	3	14.5
2.0	11500	6	2	15.6
3.2	14300	39	6	16.2

Fig.18 Distribution of velocities in m/s at t′ = 1

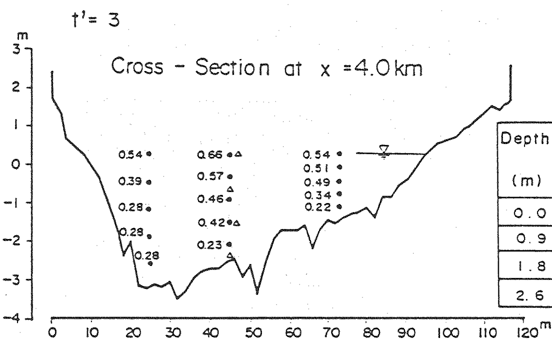


Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	2370	37	7	14.8
1.0	2950	25	4	15.0
2.0	11300	18	3	16.1
2.9	13700	14	2	16.6

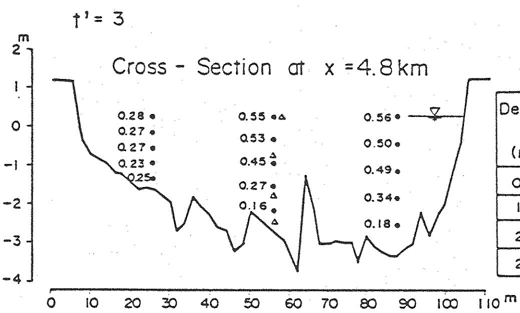


Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	1420	14	4	13.5
1.0	2870	8	4	14.3
2.0	13000	15	5	15.8
3.0	13700	25	6	15.9

Fig.19 Distribution of velocities in m/s at t´ = 2

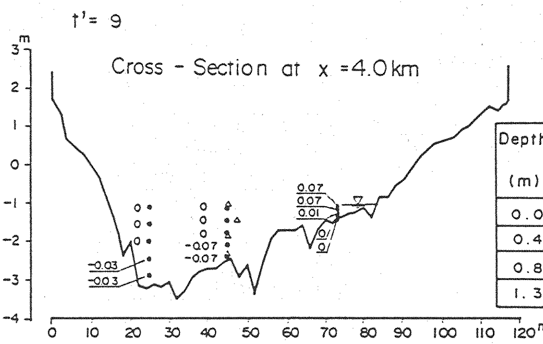


Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	3030	15	7	14.3
0.9	3300	15	5	14.4
1.8	3680	10	5	14.5
2.6	5830	10	4	15.1

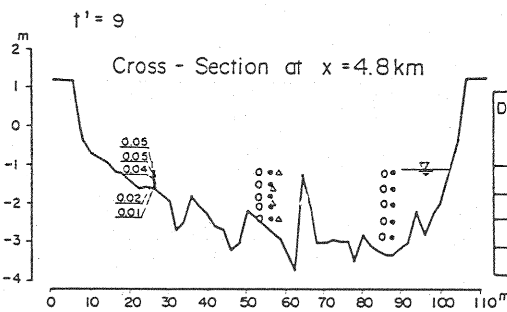


Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	1770	10	3	13.5
1.0	2060	24	4	13.8
2.0	4040	27	7	13.9
2.7	6990	24	5	14.5

Fig.20 Distribution of velocities in m/s at t´ = 3

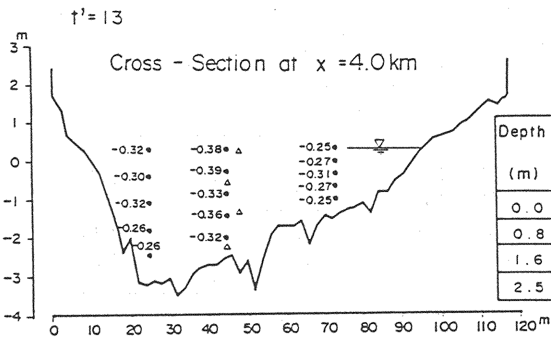


Depth (m)	Concentr. (gr/m³) CI	SS	VS	Water Temp. (°C)
0.0	2000	8	4	14.0
0.4	2330	8	4	13.9
0.8	2440	7	4	14.0
1.3	2480	7	3	14.0

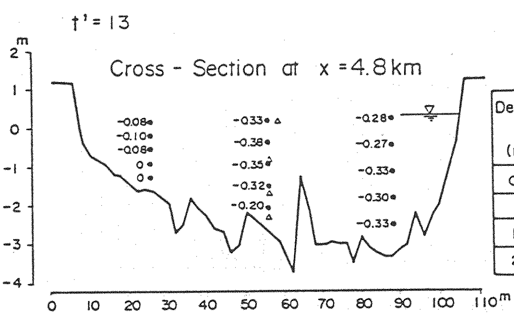


Depth (m)	Concentr. (gr/m³) CI	SS	VS	Water Temp. (°C)
0.0	1190	16	4	13.3
0.4	1140	19	5	13.4
0.8	1240	22	5	13.6
1.2	1340	29	6	13.3

Fig.21 Distribution of velocities in m/s at t′ = 9

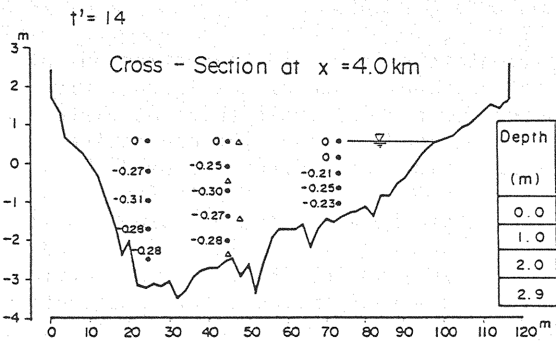


Depth (m)	Concentr. (gr/m³) CI	SS	VS	Water Temp. (°C)
0.0	6270	12	5	14.4
0.8	6510	16	4	14.5
1.6	10740	13	8	15.5
2.5	11600	22	5	15.6

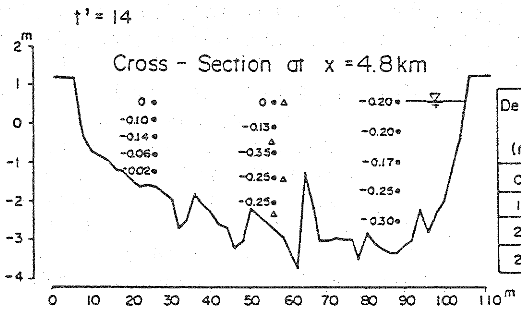


Depth (m)	Concentr. (gr/m³) CI	SS	VS	Water Temp. (°C)
0.0	3330	18	4	13.2
1.0	4720	22	5	13.4
1.9	7040	21	4	13.7
2.5	7340	29	6	14.0

Fig.22 Distribution of velocities in m/s at t′ = 13

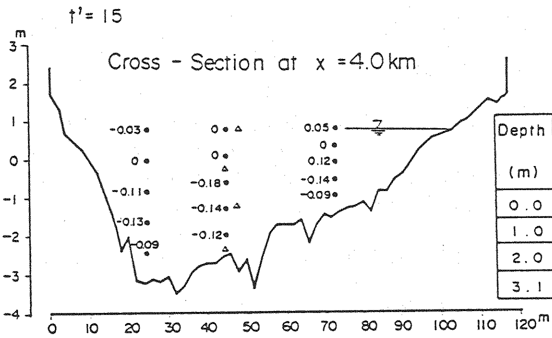


Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	5020	9	4	13.7
1.0	6510	8	4	14.2
2.0	8920	15	6	15.0
2.9	13600	8	4	16.2

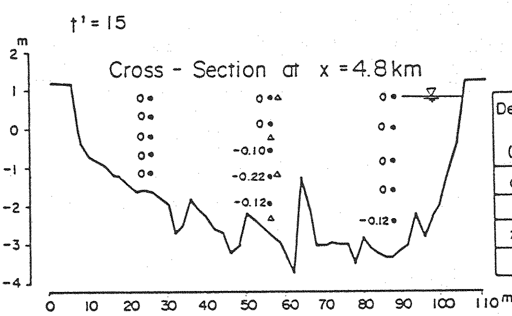


Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	4590	20	4	13.4
1.0	5790	19	5	13.7
2.0	7160	20	5	13.7
2.9	12800	30	6	15.0

Fig.23 Distribution of velocities in m/s at t′ = 14



Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	8860	8	3	14.6
1.0	9790	10	3	15.0
2.0	14900	10	2	16.4
3.1	15500	7	2	16.5



Depth (m)	Concentr. (gr/m³)			Water Temp. (°C)
	Cl	SS	VS	
0.0	5690	19	5	13.4
1.0	6040	22	5	13.7
2.0	13400	26	6	14.9
3.1	14700	44	8	15.5

Fig.24 Distribution of velocities in m/s at t′ = 15

CONCLUDING REMARKS

The time variations of current velocities and concentrations of chloride ions and fine suspended sediments in the tidal reach of the Tsurumi River in which adverse current occurs was measured for a tidal cycle twice at different time.

The First Field Observation was made to study the convective characteristics of river flow in the case of spring tide and ordinary river disharge. The observation revealed for this case that type of mixing of salinity in the tidal reach of the river is of strong mixing, that the mean size of suspended sediments in the tidal reach of the river varies in the range 4 ~ 24 micron (silt and clay) and that the concentration of suspended sediments varies little in the vertical direction throughout the tidal reach, but it increases in the upstream direction appreciably.

Basing on the experimental results obtained in the First Field Observation, the Second Field Observation was planned and performed to study the mechanism of deposition on, and redetachment from, the bed in the same river in a similar case as in the First Field Observation, i. e. in the case of spring tide and ordinary river flow. The mass conservation of suspended sediments in the reach limited between the two cross-sections at $x = 4.0$km and 4.8km was examined in detail. The rate of deposition (or detachment of deposited solids) was obtained on the basis of the mass conservation equation of suspended sediments applied to this reach.

Comparison of the rate of deposition (or detachment) of suspended sediments thus obtained with velocity distributions in the two cross-sections at various instants shows that detachment occurs when the direction of river flow is reversed. The cause of this can be attributed to the occurrence of large-scale circulation. Where the intensity of large-scale circulation is decreased, the rate of deposition of suspended sediments increases, even if the absolute value of river velocity itself has not yet been decreased by the time sufficiently.

Acknowledgement

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REFERENCE

1. HAYASHI, Taizo, TSURUMAKI, Yuichiro and OHASHI, Masakazu : Field observation and numerical computation on the time variation of the concentration of suspended substance transported into estuaries (in Japanese), Proc. 27th Conference on Hydraulics, Japan Soc. of Civil Engrs., pp. 323-334, Feb., 1983.

APPENDIX - NOTATION

The following symbols are used in this paper:

- A = cross-sectional area of river;
- A' = cross-sectional area subtracted by the area of no velocity;
- C = depth-averaged value of the concentration of suspended sediments;
- Cl = chloride ions;
- d = mean diameter of suspended sediment particles;
- M = mass rate of detachment of bed material per unit longitudinal length of river;
- Q = rate of discharge of river;
- s = specific gravity of suspended sediments;
- SS = suspended sediments;
- t = time of observation;

t' = dimensionless time of observation defined by $t' = t/50min$, 50min being the average value of intervals for measurement in the Second Field Observation;

T = tidal period;

U = flow velocity at a point in a cross-section of river;

v = flow velocity averaged over a cross-section of river;

VS = volatile solids;

x = longitudinal distance measured from the river-mouth;

Δx = actual axial distance between two adjacent cross-sections; and

α = energy coefficient.