4 THREE DIMENSIONAL DISTORTED MODEL TEST

4.1 Objectives

Distorted model is applied to the tests determining suitable location and type of the flood distributing structure with keeping the similarity of bed configuration and sediment transportation between the prototype and the model.

The test aims to examine the followings.

i) Evaluation on the bed morphology and the fluctuation of flood distribution into the channels at the existing status,

ii) Evaluation on the suitable location and the flood distribution of the structure,

iii) Evaluation on the flood distribution by the guide walls, and

iv) Quantitative evaluation on the flood distribution and degradation of the bed in each channel.

4.2 Test Conditions

4.2.1 Model

Distorted model with distortion of 4 is used for the test. Supplied sand has 0.16 mm in average diameter.

The width and gradient of the model was determined by the condition that the outflow of sediment to maintain the equilibrium of each channel bed of the South and the North branches and the Escape.

The width and gradient of each channel was decided by computation using the sediment transportation equation determined in Section 3.3. Computed bed width and gradient are shown in Table-4.1.

Table-4.1 Width and Gradient at the Riverbed in Equilibrium
(Discharge Q=1,000 m3/sec)

Channel	Model		Prototype	
	Width B (m)	Gradient i	Width B (m)	Gradient i
1	1.85	1/143	275	1/570
2	3.44	1/84	516	1/336
3	1.61	1/63	241	1/250
4	1.89	1/55	283	1/220
5	1.92	1/54	288	1/215

Table 4-2 Width and Gradient at the Riverbed in Equilibrium
(Discharge Q=1,500 m3/sec)

Canal No	Model		Prototype		Note
	Width B(m) {ft}	Gradient i	Width B (m) {ft}	Gradient i	
1	1.85 {6}	1/143 {901.6}	275	1/570	Upper reaches of Model
2	3.37 {11.28}	1 / 84	505 {1,691.8}	1 / 336	
3	1.56 {5,28}	1 / 63	234 {790.16}	1 / 250	Discharge is $500\ m^3/sec$ for each channel
4	1.83 {6.20}	1 / 55	275 {927.87}	1 / 220	
5	1.87 {6.30}	1 / 54	280 {944.26}	1 / 215	
3	1.56 {5.28	1 / 89	234 {790.16}	1 / 356	Flow is for North and South Branches, $Q=750\ m^3/sec$ each
4	1.83 {1.89}	1 / 77	275 {283}	1 / 310	
3	1.56	1 / 161 {5.28}	234	1 / 644 {790.1}	Flow is for North channel only

Table 4-3 Width and Gradient at the Riverbed in Equilibrium
(Discharge Q=2,000 m3/sec)

Canal No	Model Width B(m) {ft}	Model Gradient i	Prototype Width B (m) {ft}	Prototype Gradient i	Note
1	1.85 {6}	1/143	275 {901.6}	1/570	Upper reaches of Model
2	3.33 {11.28}	1 / 84	500 {1,691.8}	1 / 336	
3	1.54 {5,28}	1 / 63	231 {790.16}	1 / 250	Discharge is 667 m^3/ sec for each channel
4	1.80 {6.20}	1 / 55	270 {927.87}	1 / 220	
5	1.84 {6.30}	1 / 54	276 {944.26}	1 / 215	
3	1.54 {5.28	1 / 89	231 {790.16}	1 / 356	Flow is for North and South Branches,
4	1.80 {1.89}	1 / 77	270 {283}	1 / 310	Q=1000 m^3 / sec each
3	1.54 {5.28}	1 / 161	231 {790.1}	1 / 644	Flow is for North channel only

Table 4-4 Width of each Branch on Distorted Scale Model

Name of Branch	Model Width B(m) {ft}	Model Gradient i	Prototype Width B (m) {ft}	Prototype Gradient i
North Branch	1.61 {5.28}	1/62	241 {790.16}	1/250
South Branch	1.89 {6.20}	1/83	283 {927.87}	1/332
Escape	1.38 {4.52}	1 / 63	207 {678.69}	1/250

4.2.2 Discharge

Discharge in the test needs more than 1,000 cumecs to keep the similarity of the bed configuration.

There are two possible levels of discharge for the test, one is 1,000 cumecs (2-year return period) which has higher possibility of its occurrence, another is 2,500 cumecs (25 year return period). The former is better for observing the bed alteration with time.

Discharge in the test is 29 liters/sec computed by reduced scale shown in Table-2.4.

4.2.3 Duration of the Test

Total volume of run-off is estimated 59,335,209 m^3 at the design flood of 2,500 cumecs using design hydrograph. By the same hydrograph, it is estimated 23,738,800 m^3 at 2-year flood of 1,000 m cumecs. In the test, total run-off volume at the design flood is applied. But the discharge is 2-year flood. Then the test condition is followings.

Total run-off	59,335,209 m3
Discharge	1,000 cumecs
Test period	59,335 sec=16.5 hrs

Test period is determined 40 min applying reduced scale of time of 24.5 by Froude's law of similarity. On the other hand, using reduced scale of time based on bed morphology is 64.1, and the test period is 16 min. Therefore, the test period based on run-off volume is 2.5 times of floods based on bed morphology.

4.2.4 Quantity of supplied Sand

Sediment concentration is determined 1.1% by the sediment transportation equation and experiments in the preliminary test. Total supply of sand is 0.766 m3 for one trial of 40 min, the volume is equivalent to 646,000 m3 in the prototype.

4.2.5 Contents of the Test

Three dimensional distorted model tests include following contents.

No.	Test	Structure	Condition
2	Test for reproducing bed in equilibrium	None	Discharge 29 l/sec 1,000 cumecs in prototype
3	Test for evaluating the structure-1	With Cross structure. at M-11 and Guide walls	Duration 40 min. Sediment Concentration in supply for 1.1%
4	Test for evaluating the structure-2	With Guide walls	
5	Test for evaluating the structure-3	With Cross structure. at mouth of the channels	

4.3 Test for Reproducing Bed in Equilibrium

4.3.1 Objectives

The test aims to examine the bed alteration in each channel when Hadwari bund is removed. Plan of the model is shown in Fig.4-1.

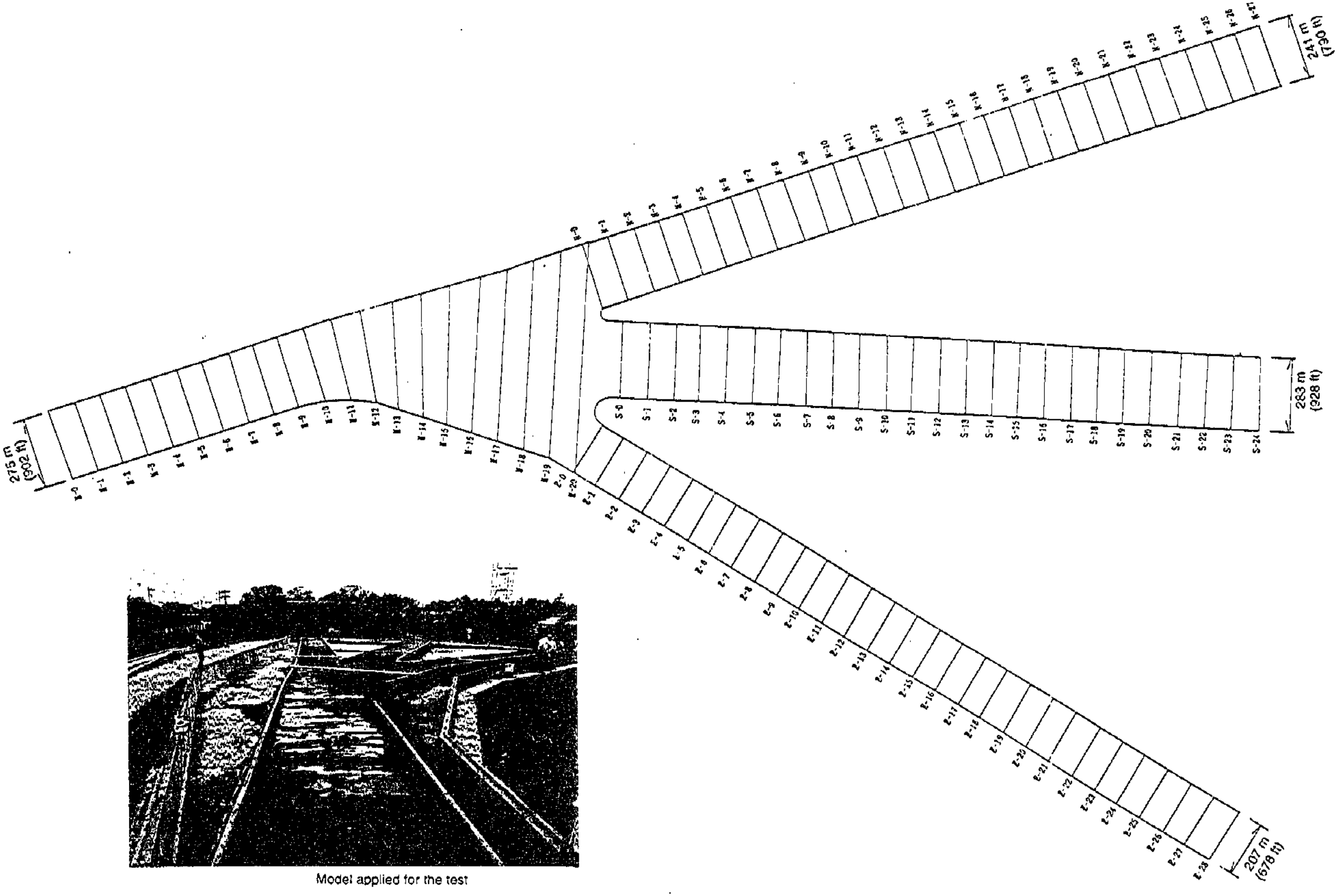
4.3.2 Result

1) Flow

The flow condition during the test is shown in Photo-1 and -2. It oscillates between the North branch and the Escape, because of occurrence of the bed alteration in the widened area of the model. Local scouring developed to 4 m deep at the upstream end of the guide walls.

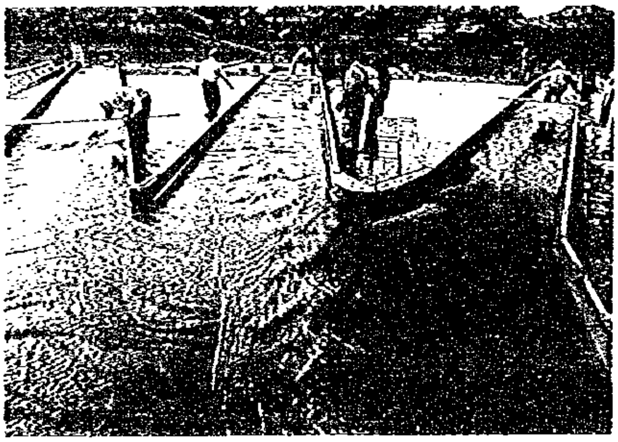
2) Distribution of Flow and Variation of Sediment Concentration

The change of the shares of distribution with the passage of time is shown in Fig.-4.2 The main part of the flow oscillates between the North branch and the South branch in the early stage of the test, and it finally concentrated into the Escape. About 80% of the flow concentrates into one channel at the maximum during the test.

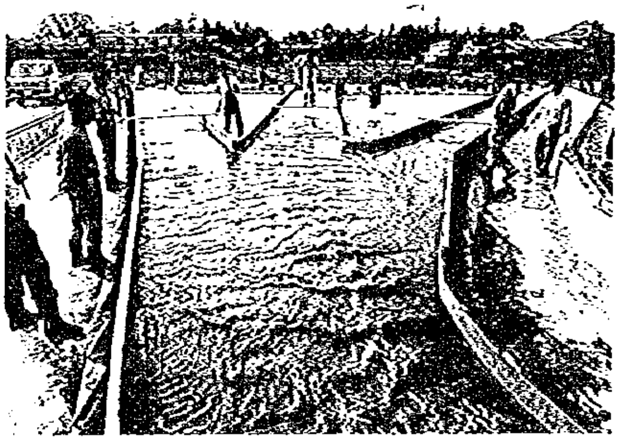


Model applied for the test

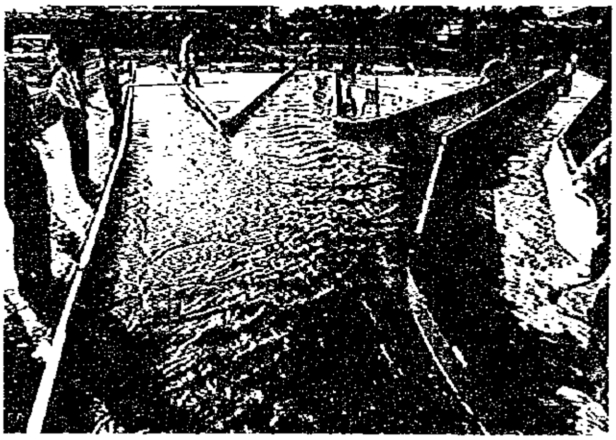
Fig.-4.1 Plan of the model for the confirmation of bed gradient in equilibrium (Case 2)



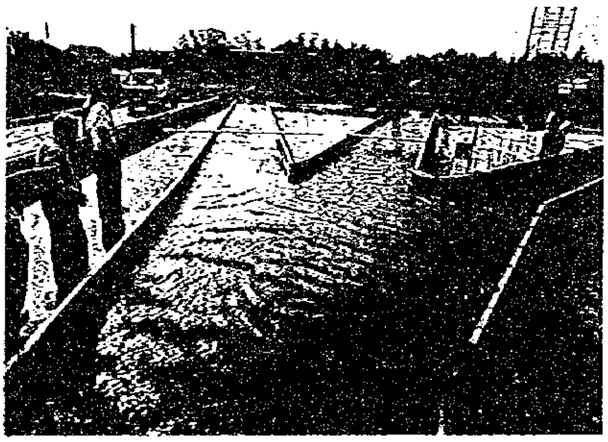
1) 9 minutes pasted, flow concentrated into the South branch.



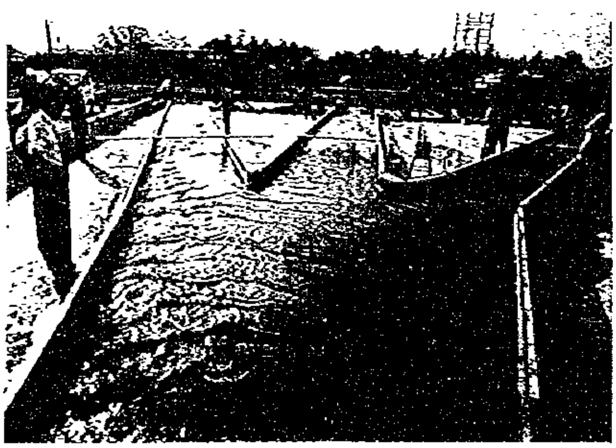
2) 19 minutes passed, flow diverted into the North Branch and South Branch



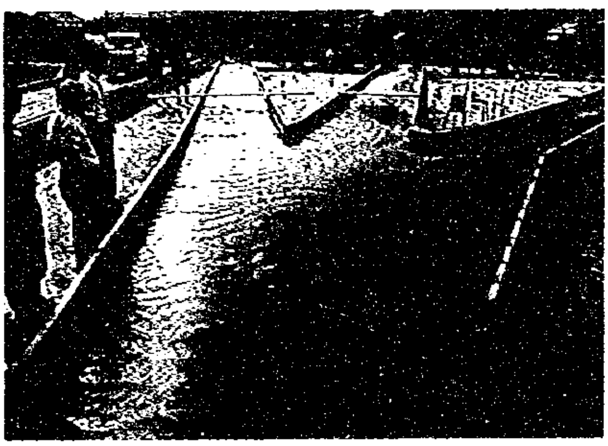
3) 27 minutes passed, flow concentrated into the South Branch again.



4) 35 minutes passsed, flow distributed equally into the three channels.

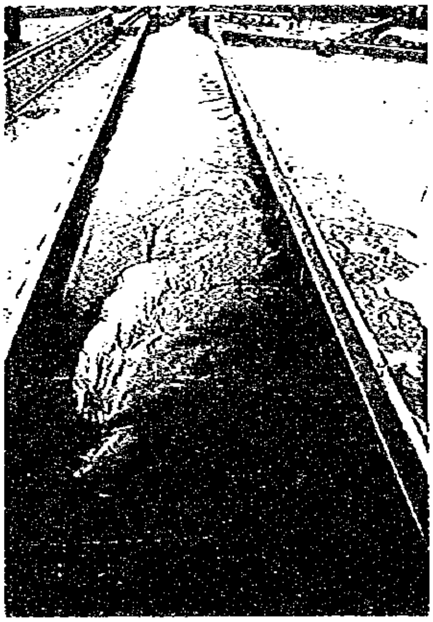


5) 38 minutes passsed, flow concentrated into the North Branch

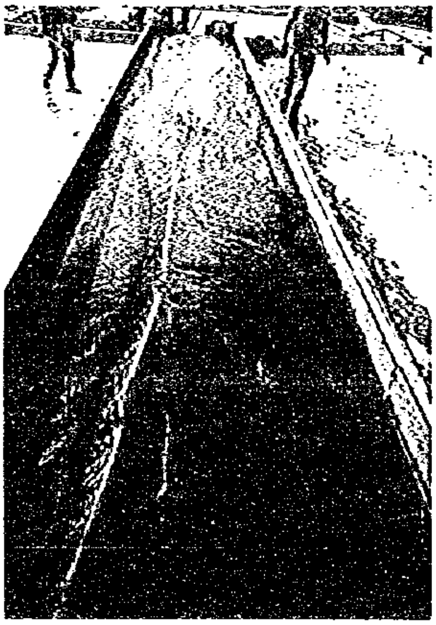


6) After the test

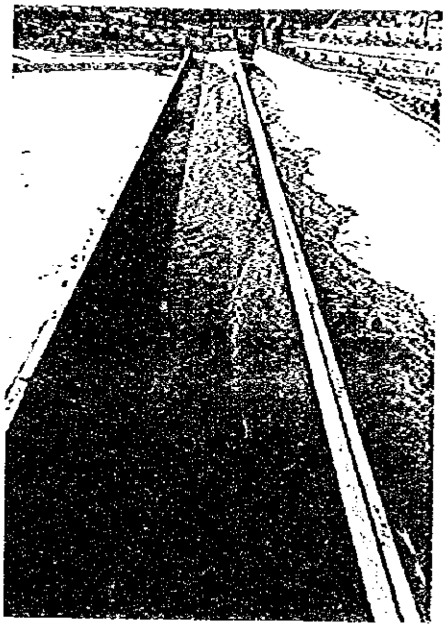
Photo-1 Flow condition in the Test for confirmation of Bed Gradient in Equilibrium (CASE - 2)



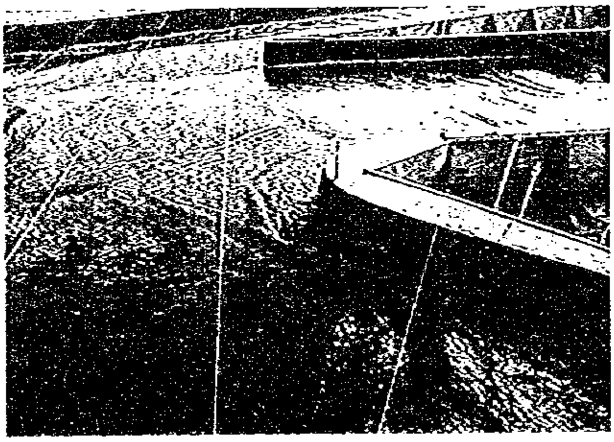
7) After the test, bed condition in North Branch.



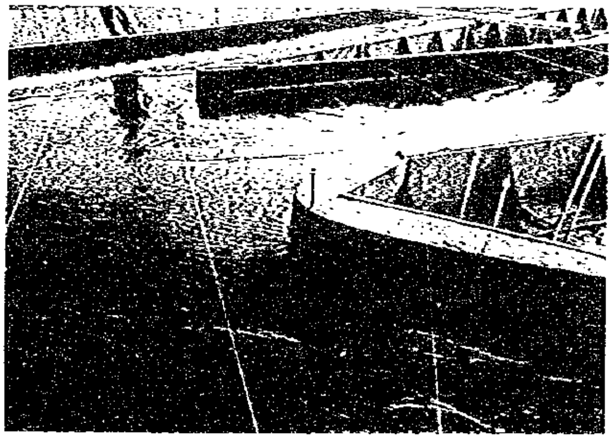
8) After the test, bed condition in he South Branch.



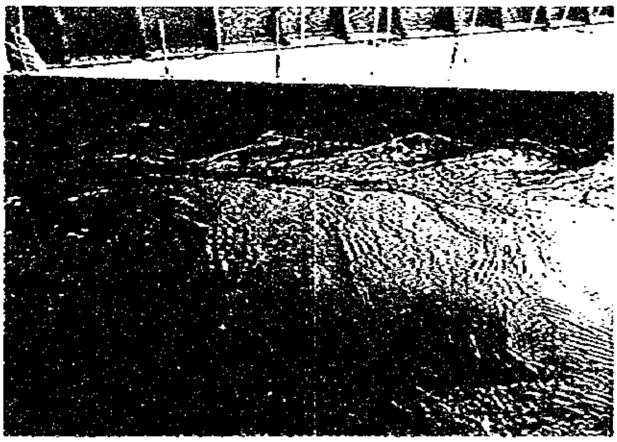
9) After the test, bed condition in the Escape.



10) Scoured depth reached to 7m (23 feet) at the maximum at the head of the guide wall.



11) Scoured part was found being filled up with sediment after the test.



12) Scoured depth reached to 4 m (12 feet) at the maximum along the guide wall.

Photo-2 Flow condition in the Test for confirmation of Bed Gradient Equilibrium (CASE - 2)

3) Bed Alteration

a) North branch

Average inflow was 1/3 of the total discharge. The bed gradient at the end of the test was same to that of initial.

b) South branch

The inflow was 2/3 of the total discharge. The bed gradient at the end of the test was gentler than that of the initial.

c) Escape

Discharge increased at the final 3 minutes of the test. The deepest points of the riverbed ware parallel to that of the initial.

Form the result mentioned above, it was confirmed that the sediment transportation equation could be applied to the test and it could describe the river bed alteration qualitatively.

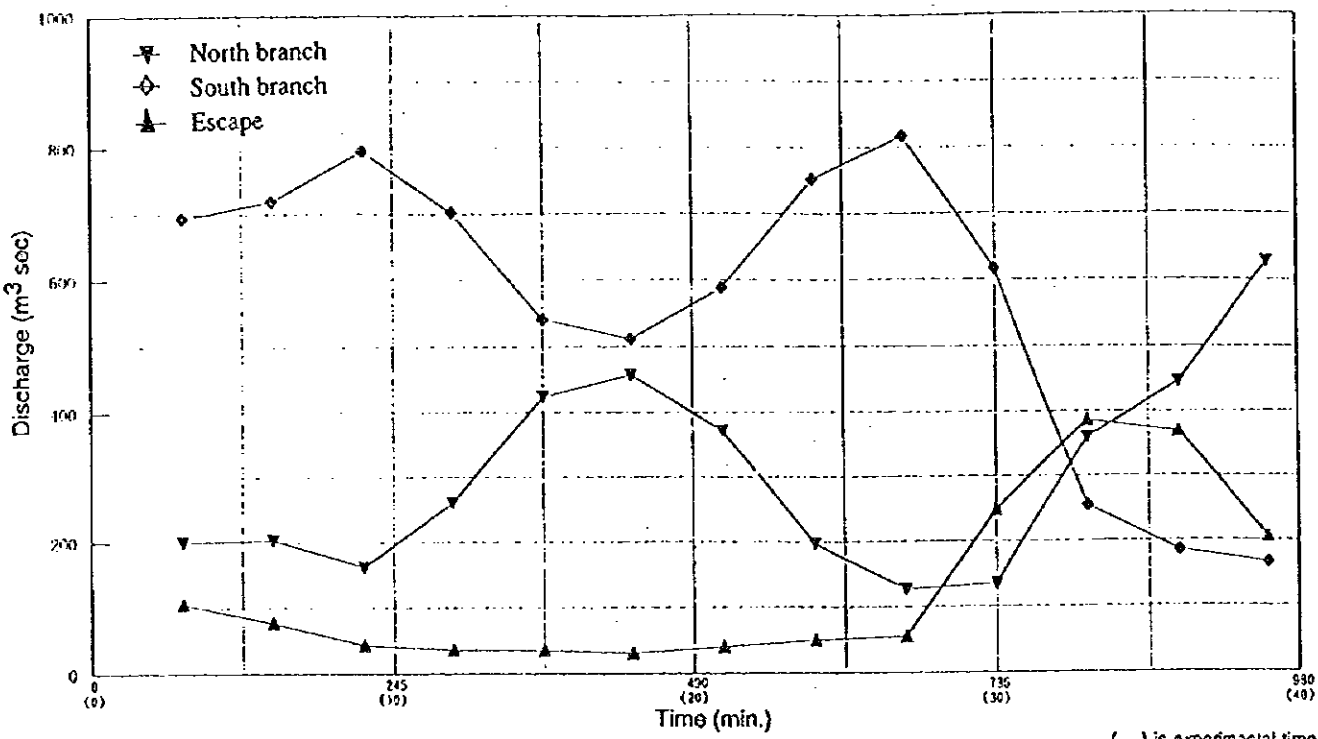


Fig.-4.2 The variation of the share of flow with time (Case 2)

4.4 Test for Evaluating Function of the Structure (Case-3)

4.4.1 Objectives

The cross structure was placed immediate upstream of the point where the bed width widened (at M-10 in Fig.-4.3) with the guide walls from the cross structure to the mouth of each channel shown in Fig.-4.3. The cross structure was divided into 3 parts equally for each channel.

To examine the effect of flow concentration to the bed alteration, following three conditions are applied.

1) Case 3 -1 : Equal diversion into 3 channel (North, South and Escape),

2) Case 3 -2 : Flow diverted into 2 channel (North and South), and

3) Case 3 - 3 : Flow concentrated into one channel (North branch)

4.4.2 Results

1) Flow

Flow condition are shown in Photo-3 to -6.

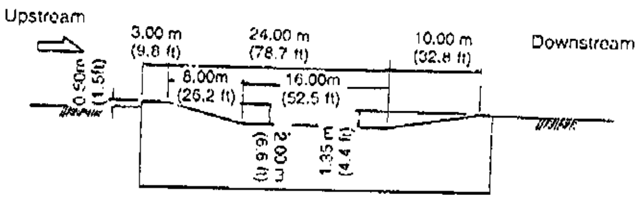
a) Case 3 - 1

The flow distributed equally into 3 channels at the beginning of the test, but it gradually concentrated into the North branch. Change of the flow direction is slower than that of Case-2 (with no structure).

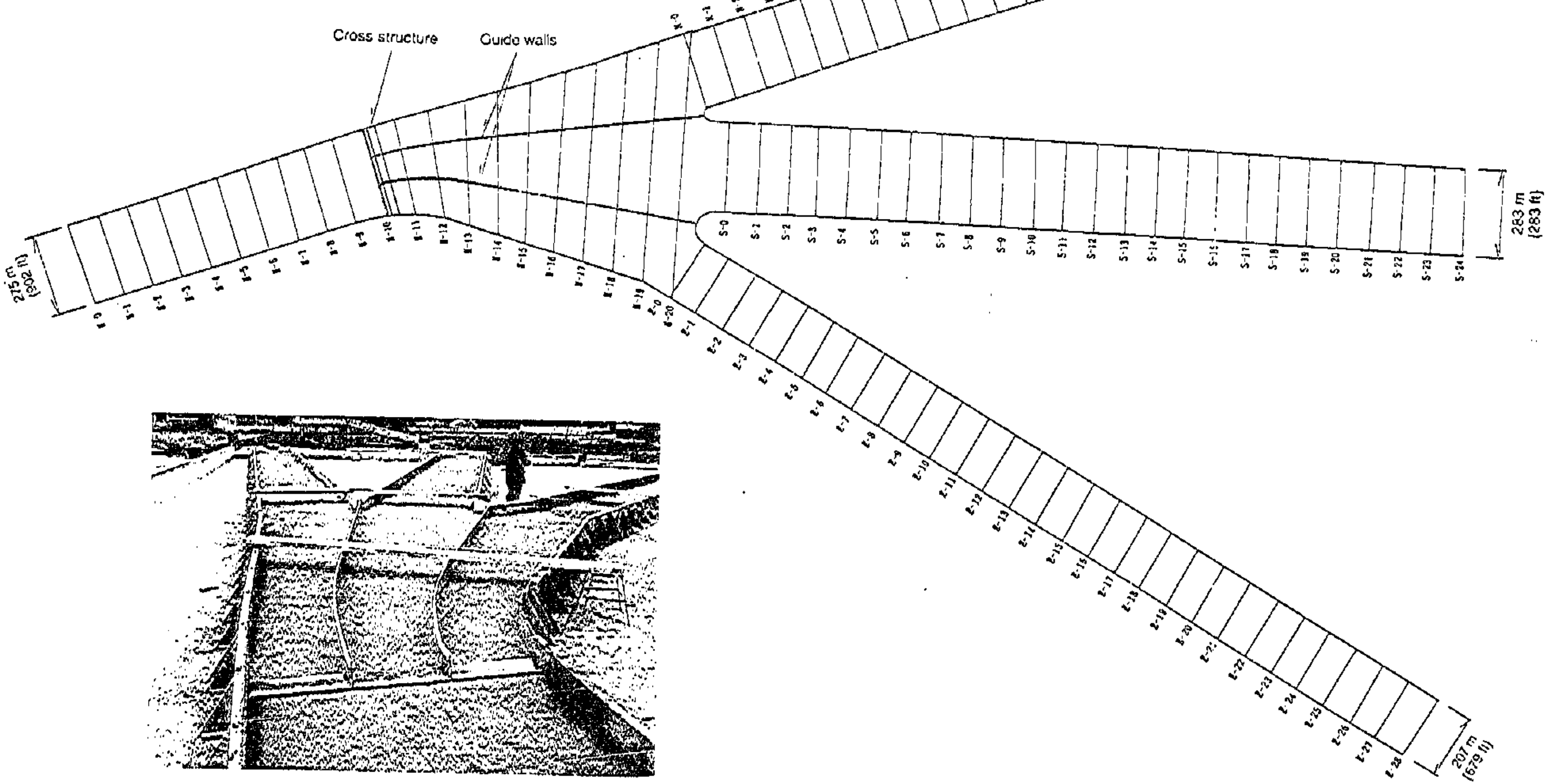
Then in the last half of the duration, discharge in the South branch and the Escape increased and it reduced in the North branch. Scour depth is about 7 m immediate downstream of the cross structure to the North branch and the Escape. But it is 3 m to the South branch where the inflow of sediment was much.

b) Case 3 - 2

Discharge was equally distributed into the two channels until 20 minutes from the start of the test, then it concentrated into the South channel for a short time and again equally distributed into the two.

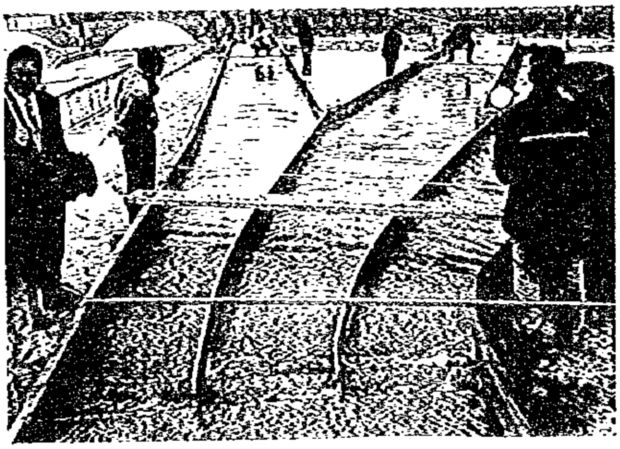


Cross section of cross structure

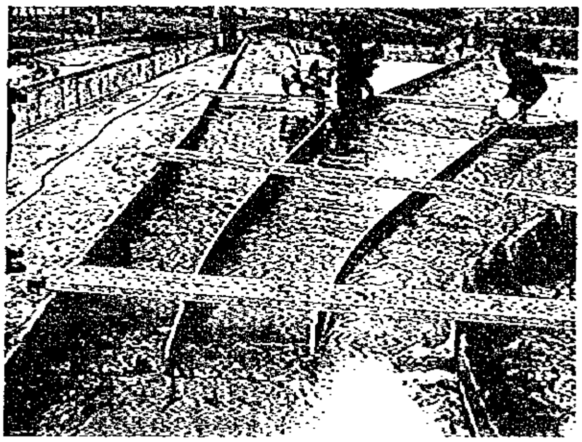


Model appliede the distubutor

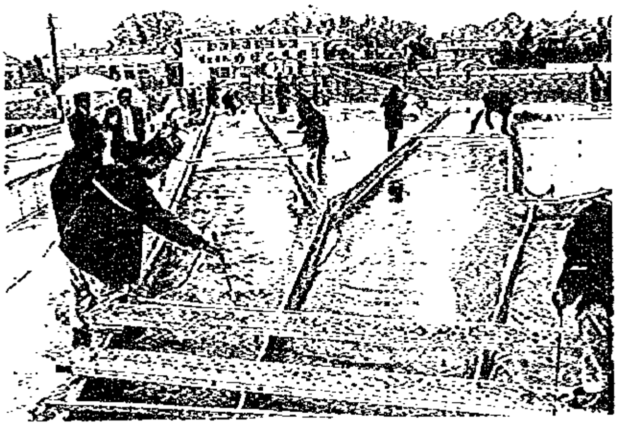
Fig.-4.3 Plan of model with the distributor (Case 3)



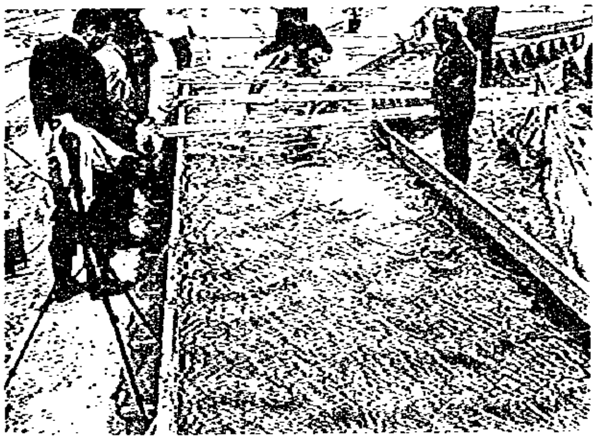
1) 5 minutes passed, flow distributed equally into the North branch, the South branch and the Escape.



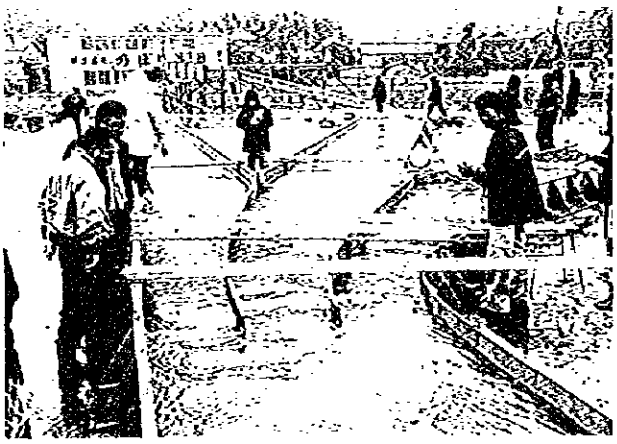
2) 10 minutes passed, flow into the Escape reduced a little.



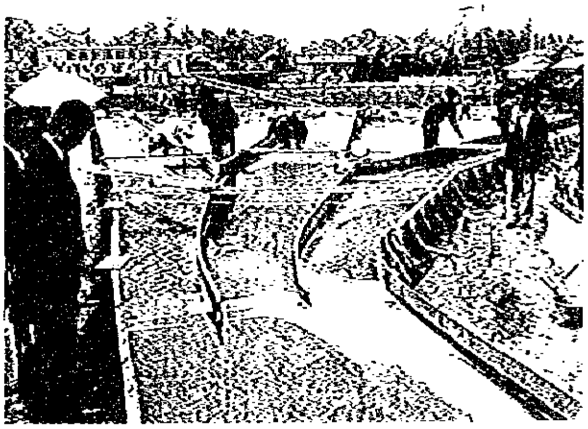
3) 20 minutes passed, flow concentrated into the North branch.



4) 25 minutes passed, flow concentrated into the North Branch.

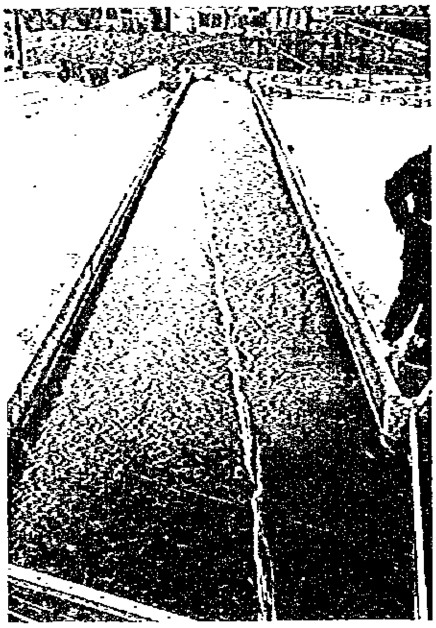


5) 39 minutes passed, flow concentrated into the Escape.

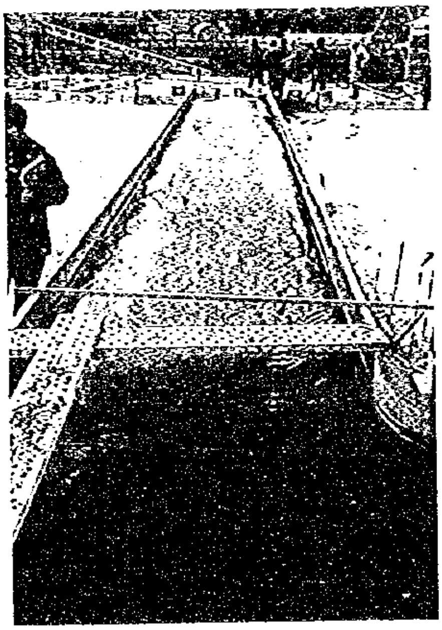


6) After the test.

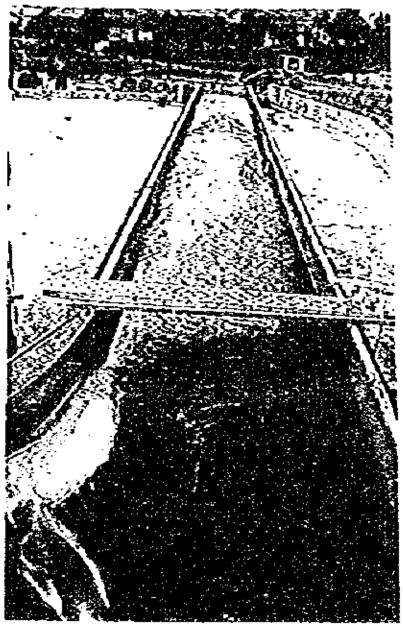
Photo-3 Flow condition in the Test with the Distributor (Case - 3. 1)



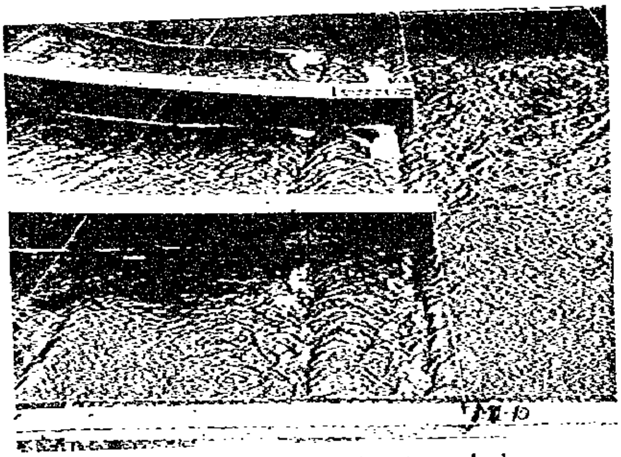
7) After the test, bed condition in the North branch.



8) After the test, bed condition in the South branch.

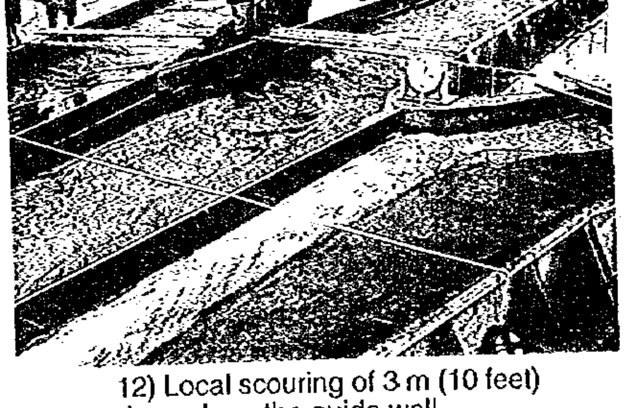


9) After the test, bed condition in the Escape.



10) Flow over the cross structure during equal distribution into the three channels.

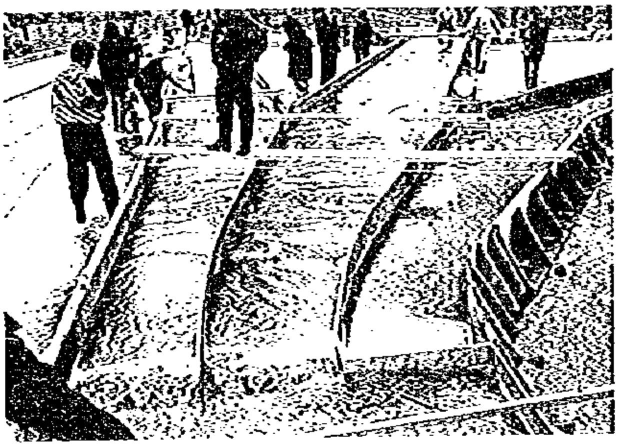
11) Flow over the cross structure during concentration into the South Branch.



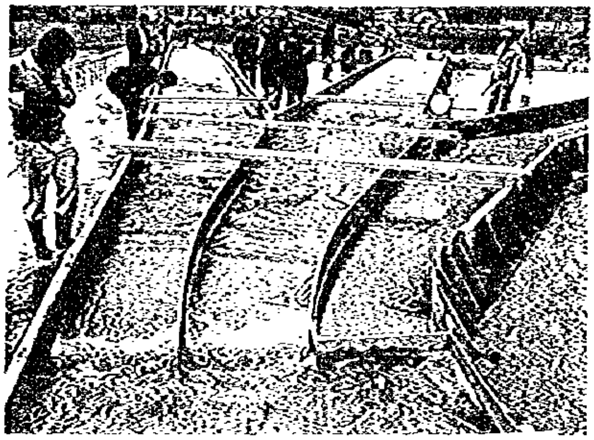
12) Local scouring of 3 m (10 feet) deep along the guide wall.

13) Local scouring immediate downstream of the cross structure.

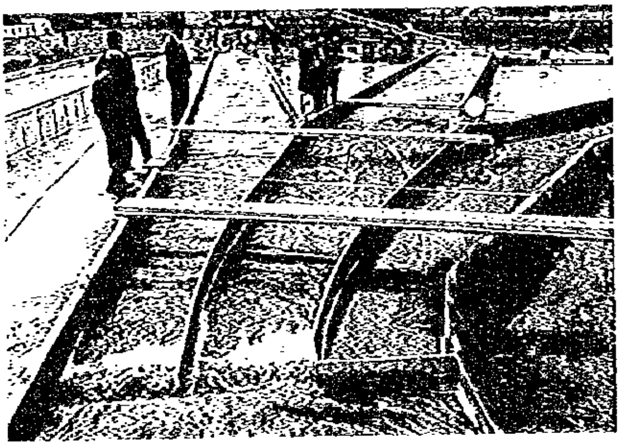
Photo-4 Flow condition in the Test with the Distributor (Case - 3. 1)



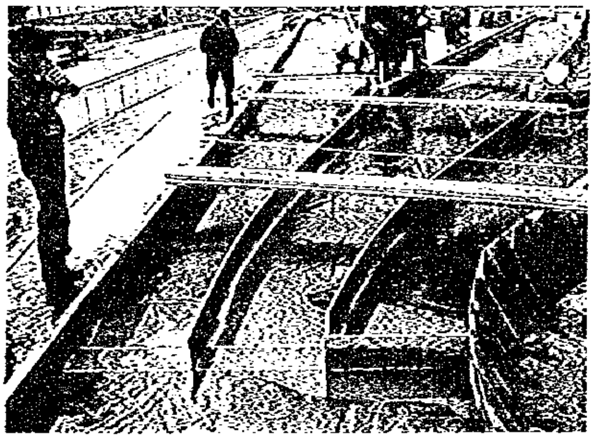
1) 10 minutes passed, flow distributed equally into the two channel.



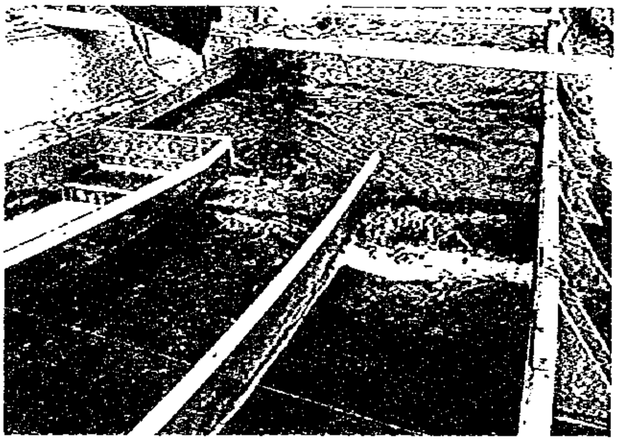
2) 35 minutes passed, flow distributed equally into the two channel.



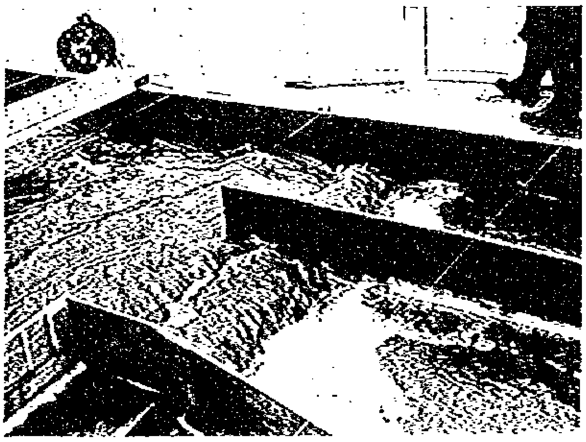
3) 40 minutes passed, flow distributed equally into the two channel.



4) After the test.

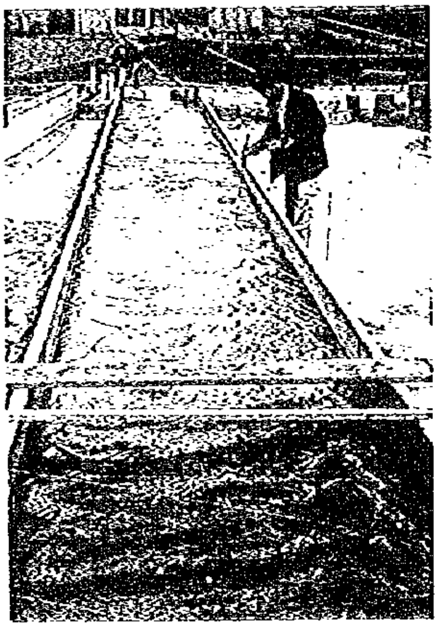


5) Local scouring immediate downstream took place with development of bed degradation in the downstream channel.

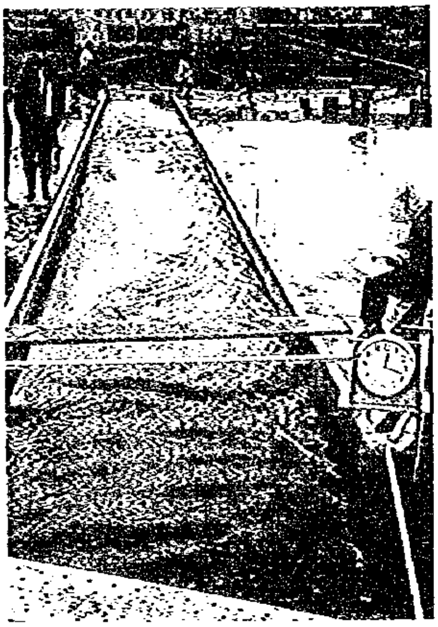


6) Local scouring immediate downstream of the cross structure accelerated with progress of downstream bed degradation.

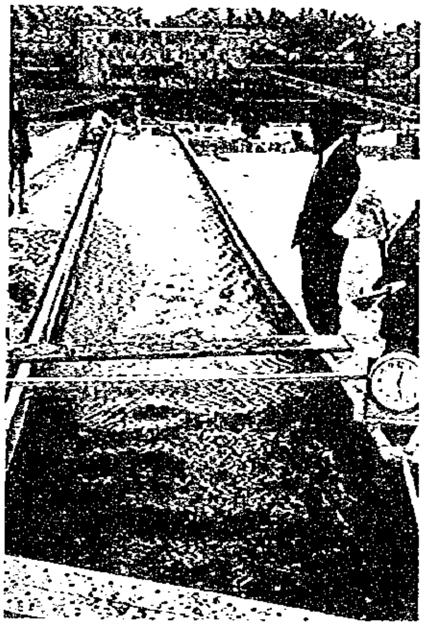
Photo-5 Flow condition in the Test with the Distributor with two channels (Case - 3. 2)



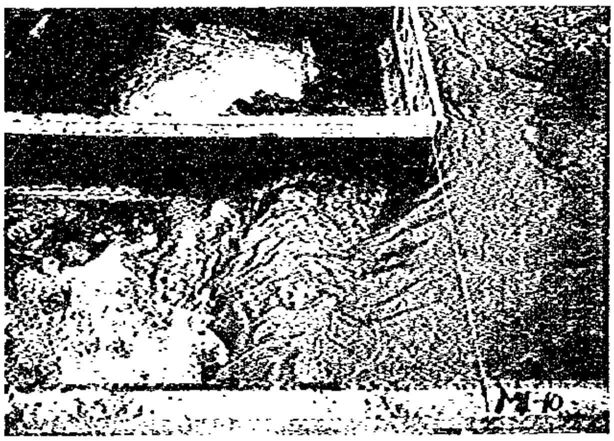
1) 10 minutes passed, flood flows width of the channel.



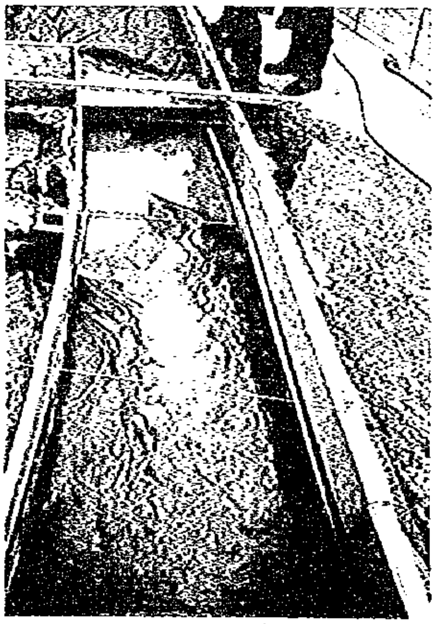
2) 17 minutes passed, alternate bar over full appears on the water surface on left side



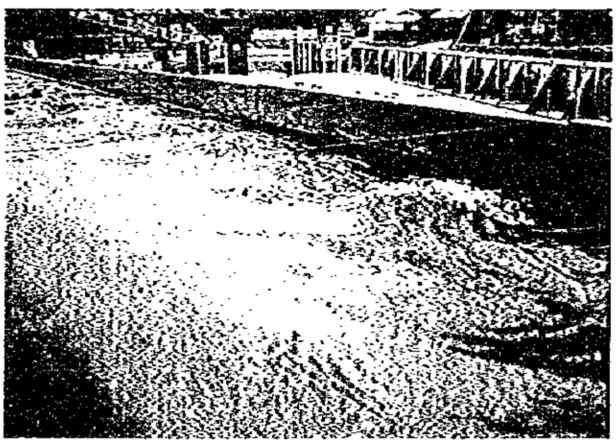
3) 26 minutes passed, alternate deep bar become clear because of scouring in right side.



5) Flow over the cross structure.



4) After the test, local scouring immediate downstream of the cross structure.



6) Local scouring reached 3.5m (11.5 feet) deep at the maximum.

Photo-6 Flow condition in the Test with the Distributor with one channel (Case - 3. 3)

c) Case 3 - 3

With the passage of time, the partial flow becomes dominant, and the river bed was lowered gradually in the main flow course (degradation of 4 - 5m from the initial elevation). The scour depth is about 8 m immediate downstream of the cross structure.

2) Distribution and variation of sediment concentration

Fig.-4.4 and 4.5 shows the variation of the shares of flow with time and Fig.-4.6, -4.7 and -4.8 shows the change of sediment concentration with time.

When the cross structure is placed at the point of M-10, the cycle of oscillation of flow becomes longer. The maximum quantity of inflow into one channel reaches about 70% of the total discharge and the variation of discharge is smaller than the case of without the cross structure. The sediment concentration shows cyclic change without coinciding to that of the shares of flood distribution.

3) Bed Alteration

Fig.-4.9, -11 and -4.13 shows the longitudinal section of the deepest points on the bed after the test and Fig.-4.10, 4.12 and 4.14 shows the longitudinal section of the average elevation of river bed after the test.

a) Case 3 - 1 (flow diverted into 3 channels)

Bed gradient in the North and the South branches is gentler at the end of the test duration than that of at the initial condition, because higher tractive force in narrow flow width results bed lowing. But the bed gradient in the Escape is not changed during the test.

b) Case 3 - 2 (flow diverted into 2 channels)

The bed gradient in the North branch is same to that of the initial , but in the South branch, the final bed gradient is gentler than that of the initial. Scour depth is about 6 m immediate downstream of the cross structure to the North branch and about 10 m to the South branch.

The reasons are that local bed lowering by the scouring immediate downstream of the cross structure makes average bed gradient gentler and higher water depth upstream of the cross structure accelerate sediment deposition. Then sediment transportation to the lower reaches is decreased by reduced discharge toward the Escape.

c) Case 3 - 3 (flow concentrated into one channel)

The bed gradient in the North branch is gentler at the end than that of at the initial. The reasons are same to that of the above Case 3-2.

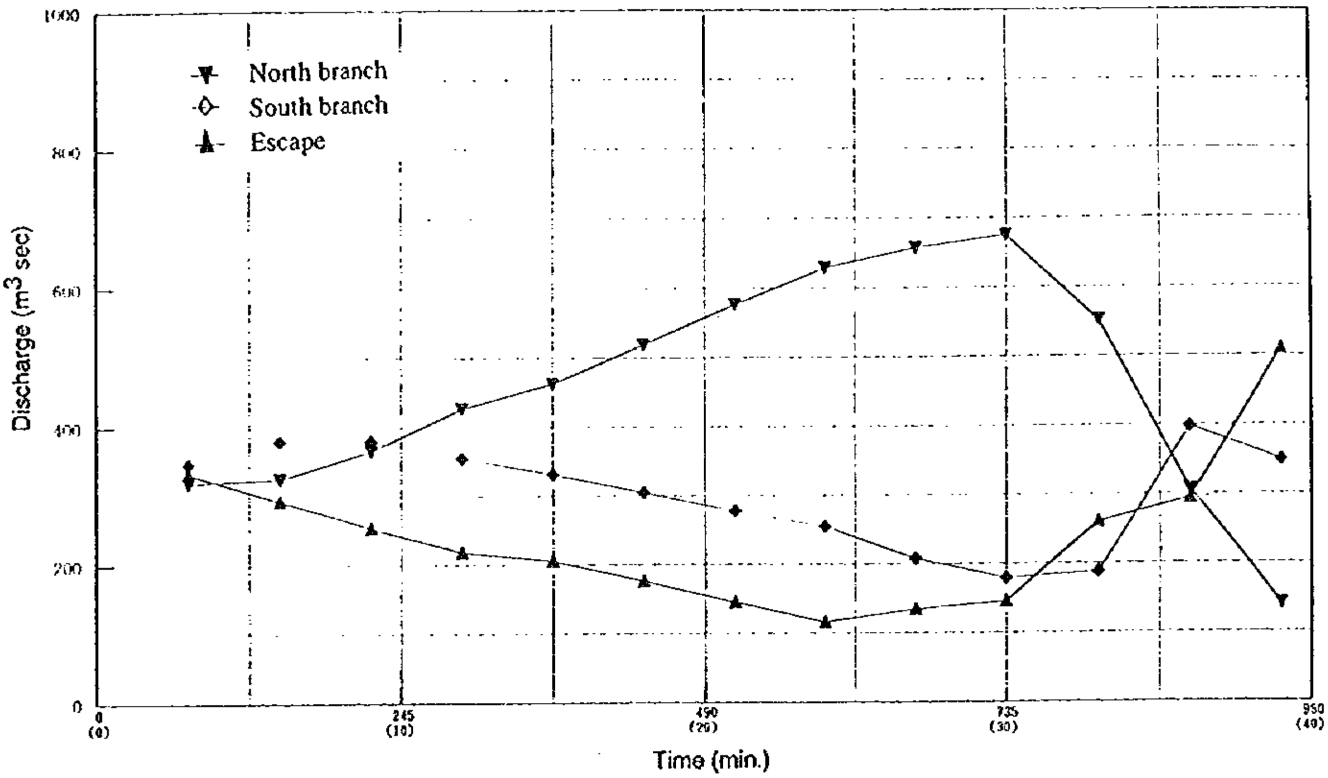


Fig.-4.4 The variation of the shares of flow with time (Case 3-1) ( ) is experimental time

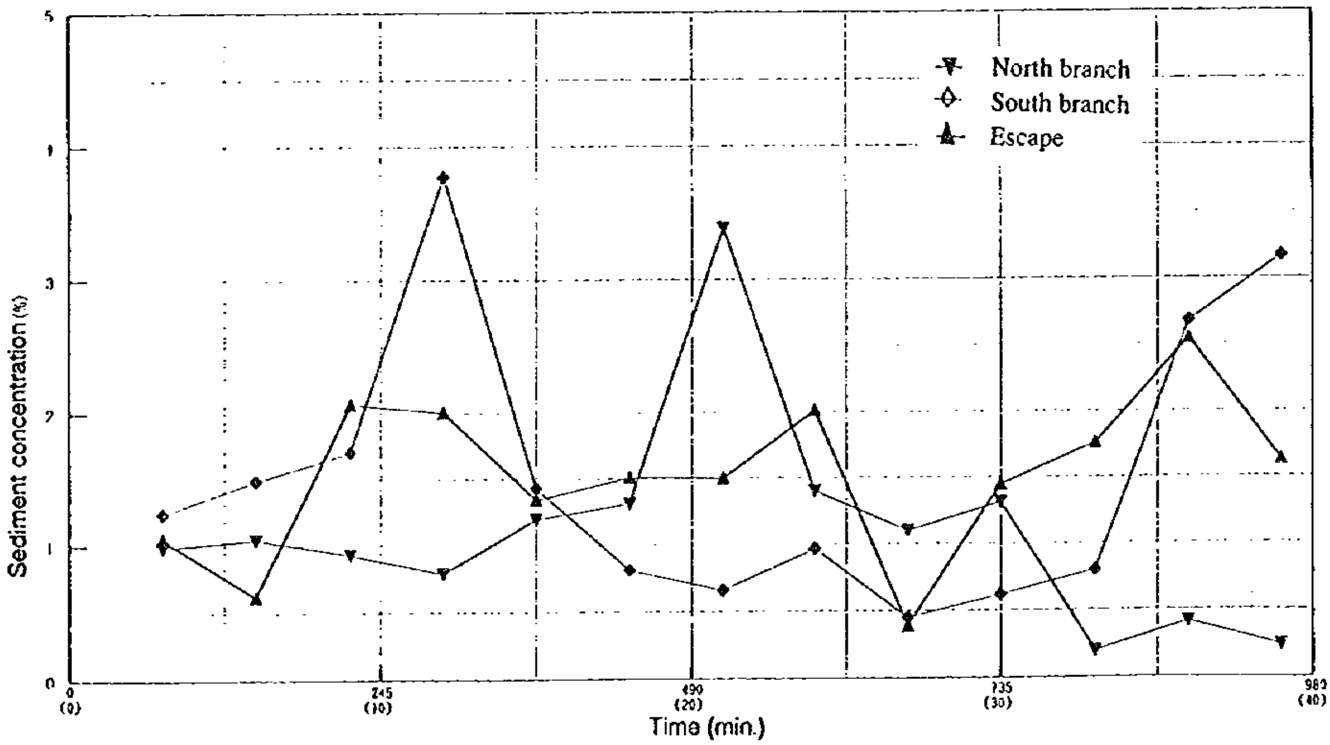


Fig.-4.5 The change of sediment concentration with time (Case - 2) ( ) is experimental time

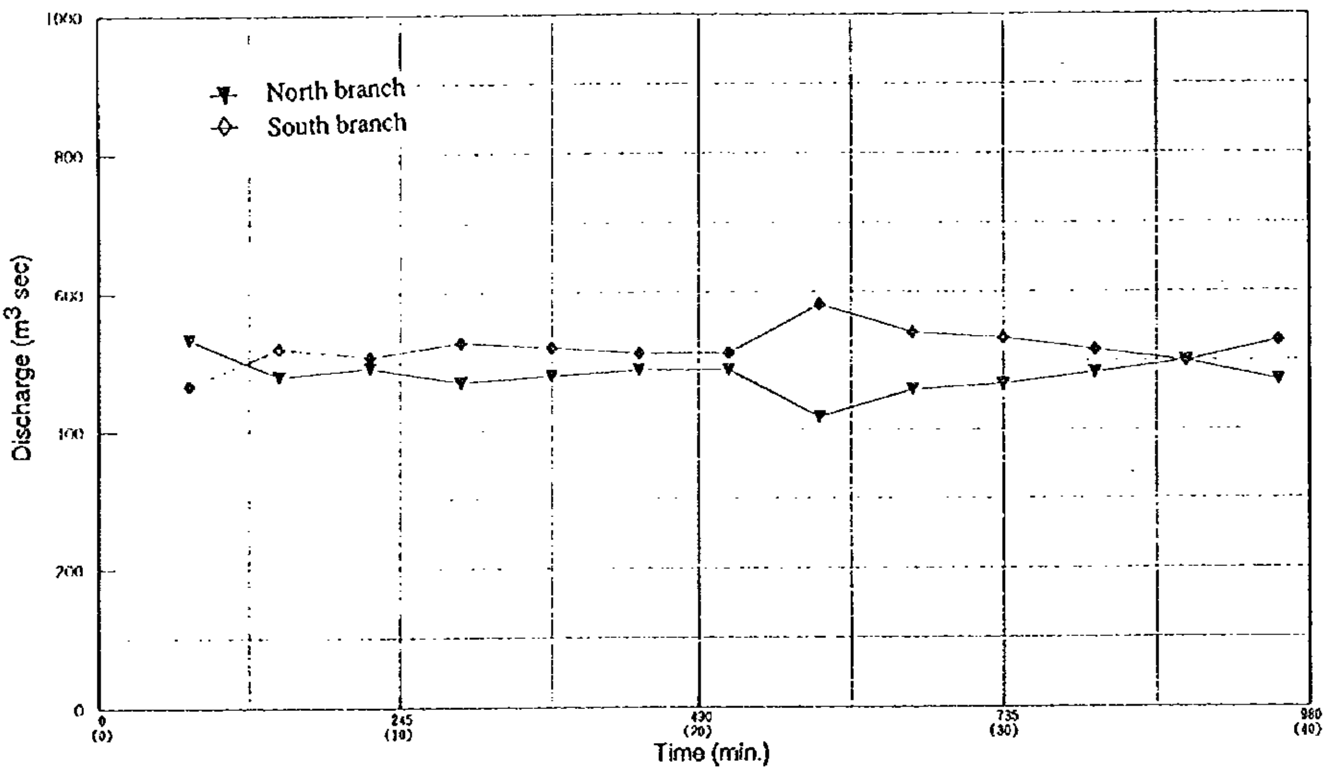


Fig.-4.6 The variation of the shares of flow with time (Case - 3-2) ( ) is experimental time

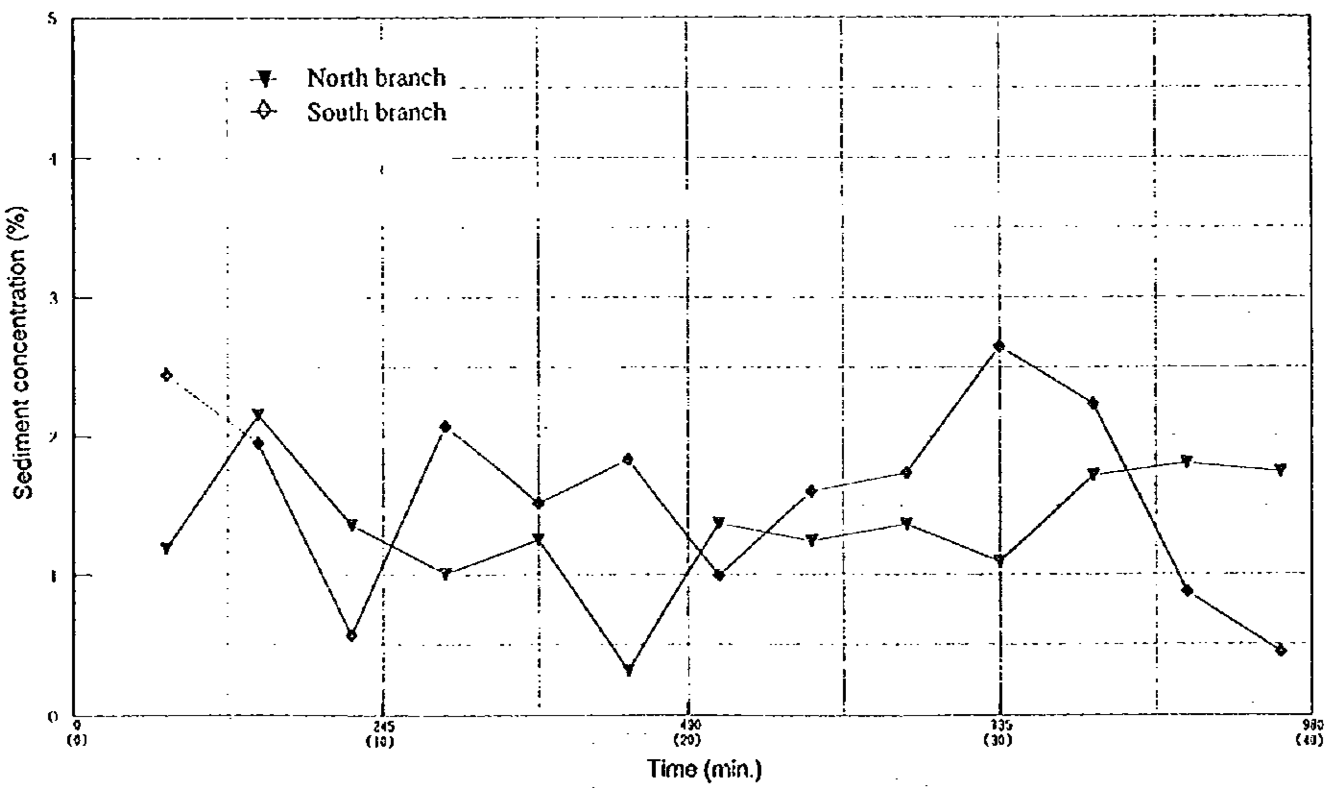


Fig.-4.7 The change of sediment concentration with time (Case - 3-2) ( ) is experimental time

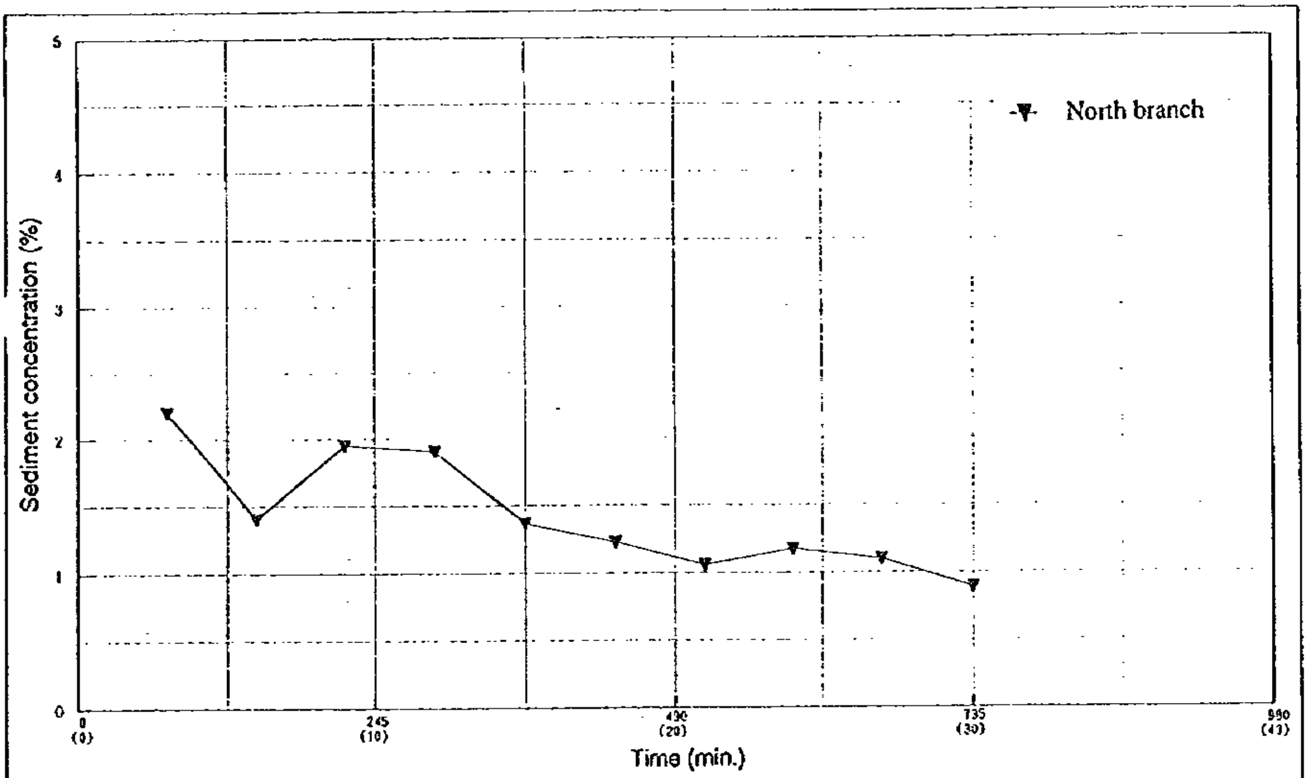


Fig.-4.8 The change of sediment concentration with time (Case - 3-2) ( ) is experimental time

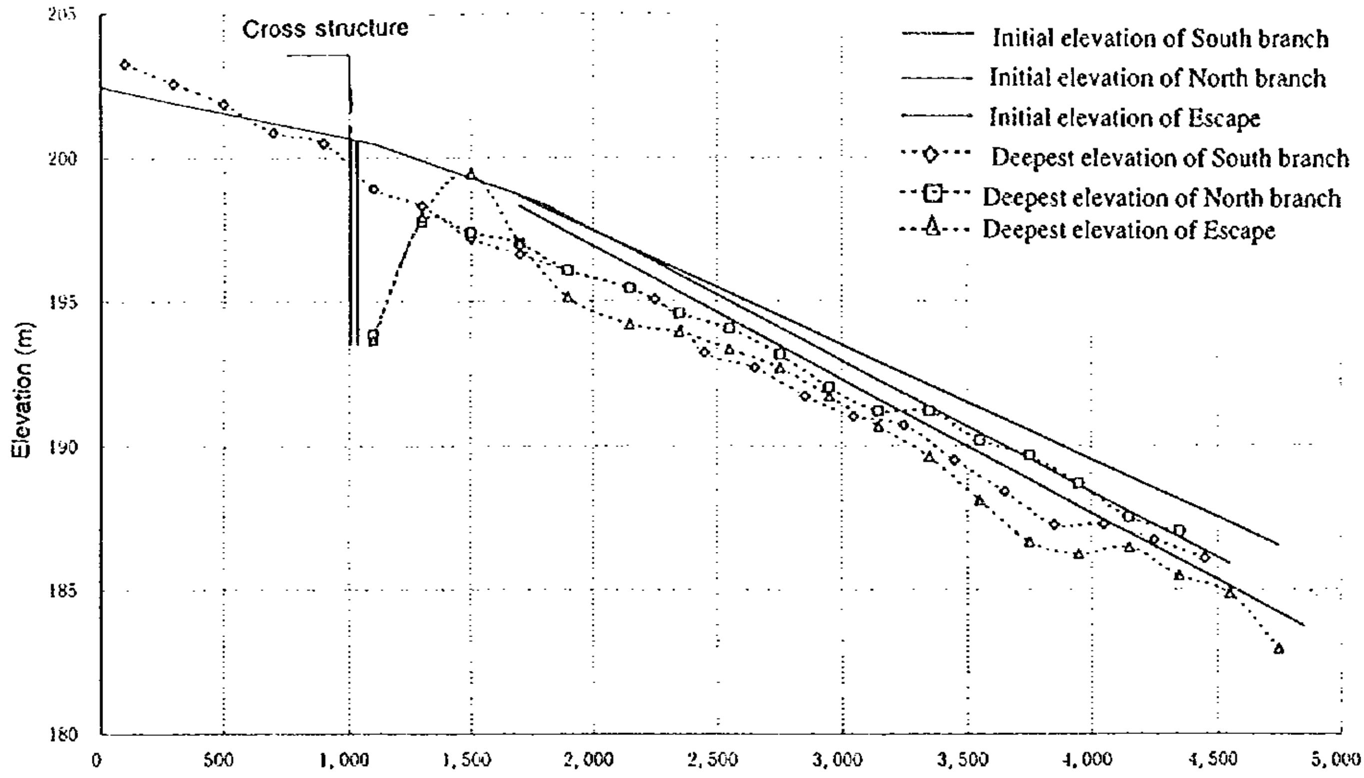


Fig.-4.9 The longitudinal cross section of the deepest of river bed after the test (Case - 3 - 1)

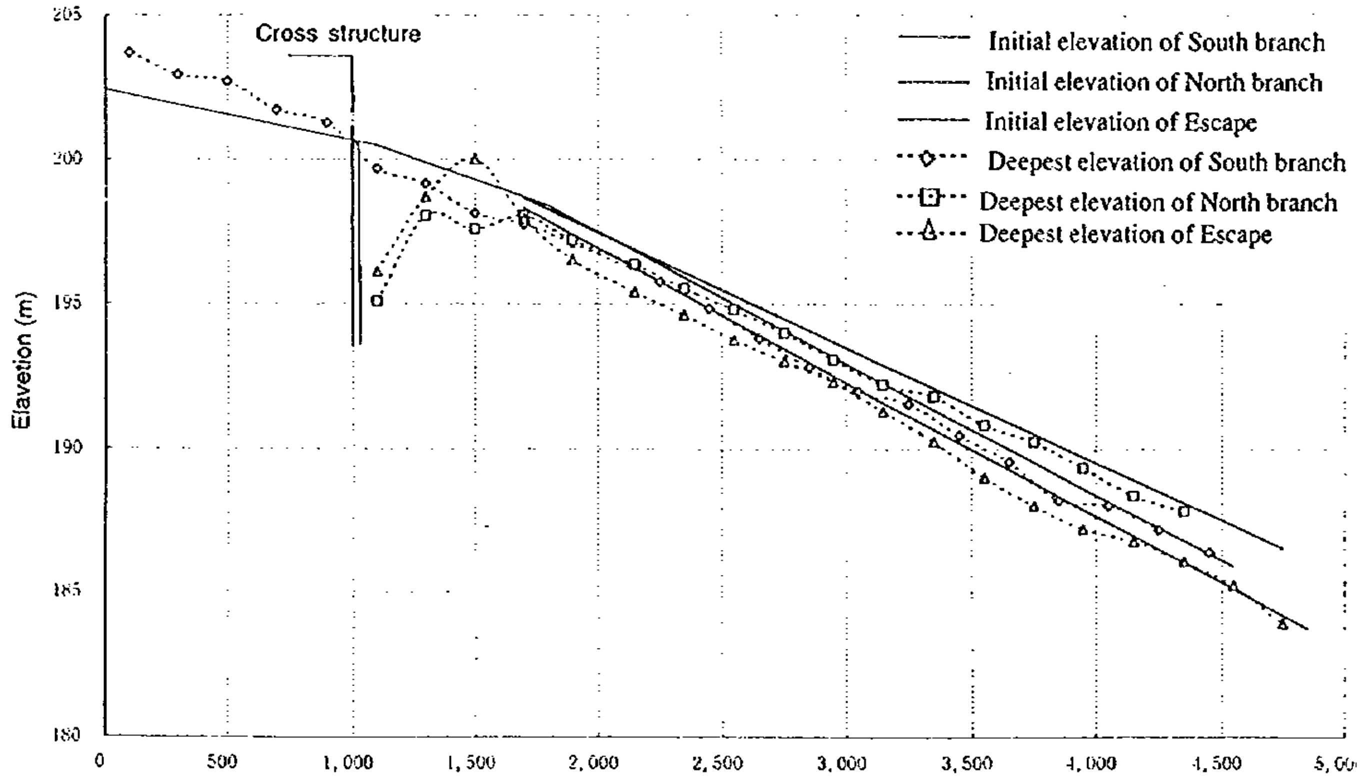


Fig.-4.10 The longitudinal cross section of the averag elevation of river bed after the test (Case - 3 - 1)

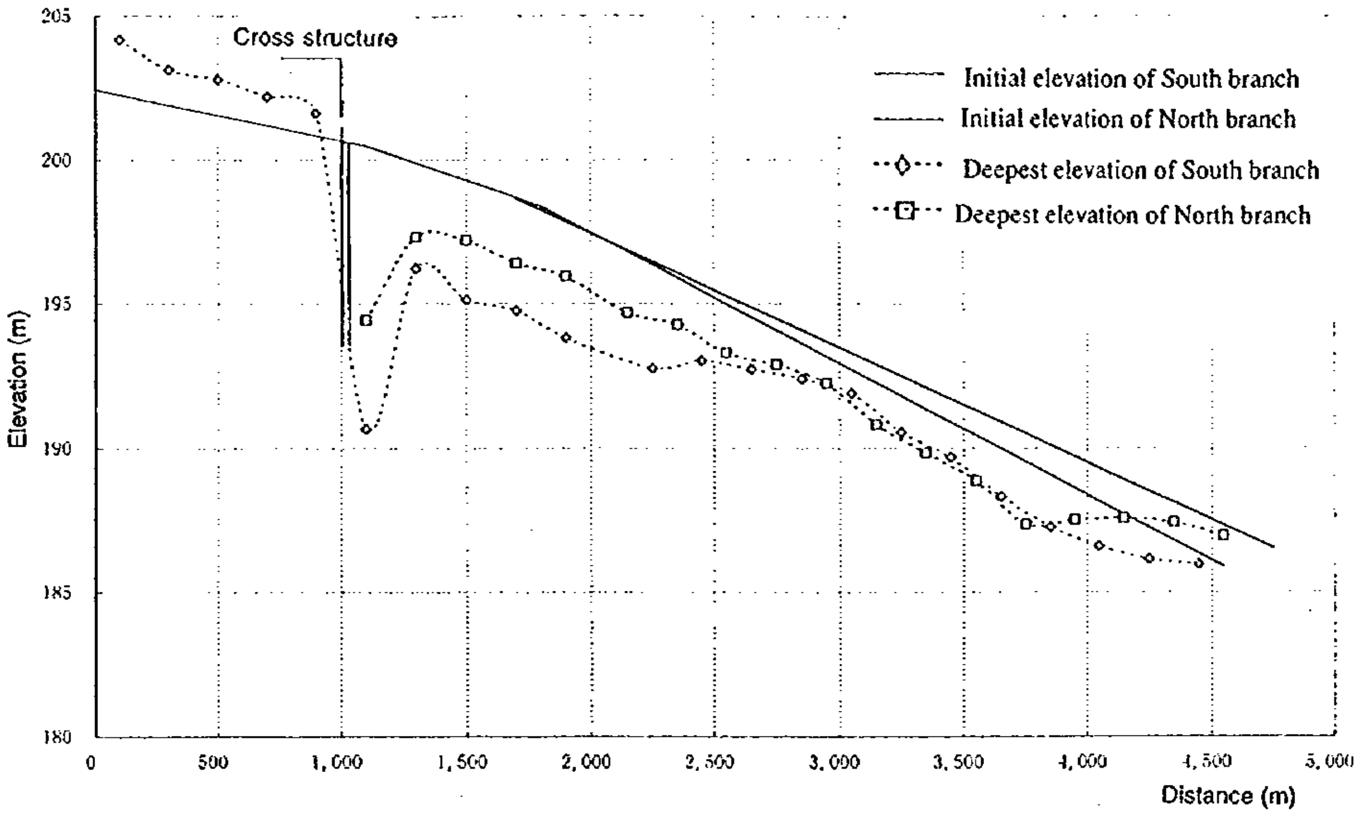


Fig.-4.11 The longitudinal cross section of the deepest of river bed after the test (Case - 3 - 2)

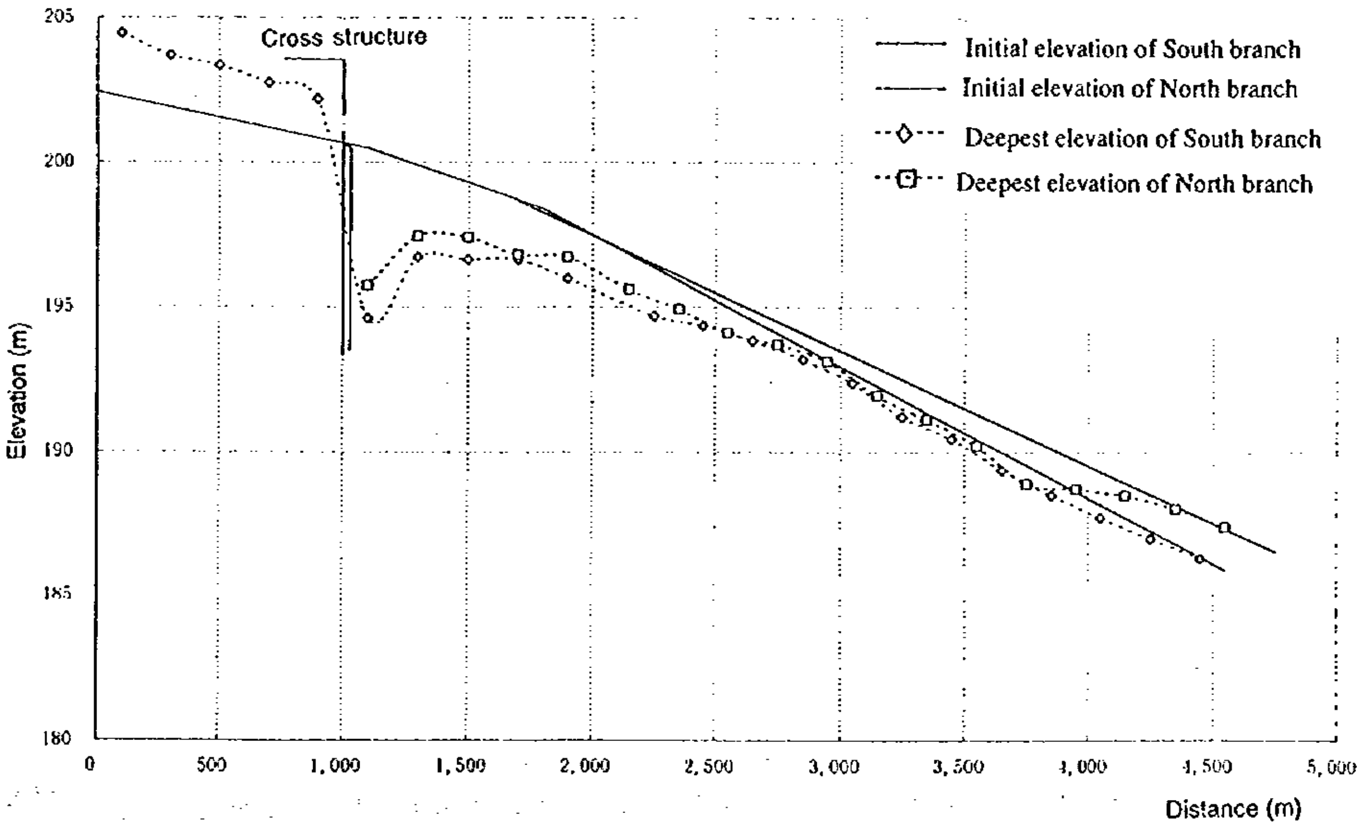


Fig.-4.12 The longitudinal cross section of the averag elevation of river bed after the test (Case - 3 - 2)

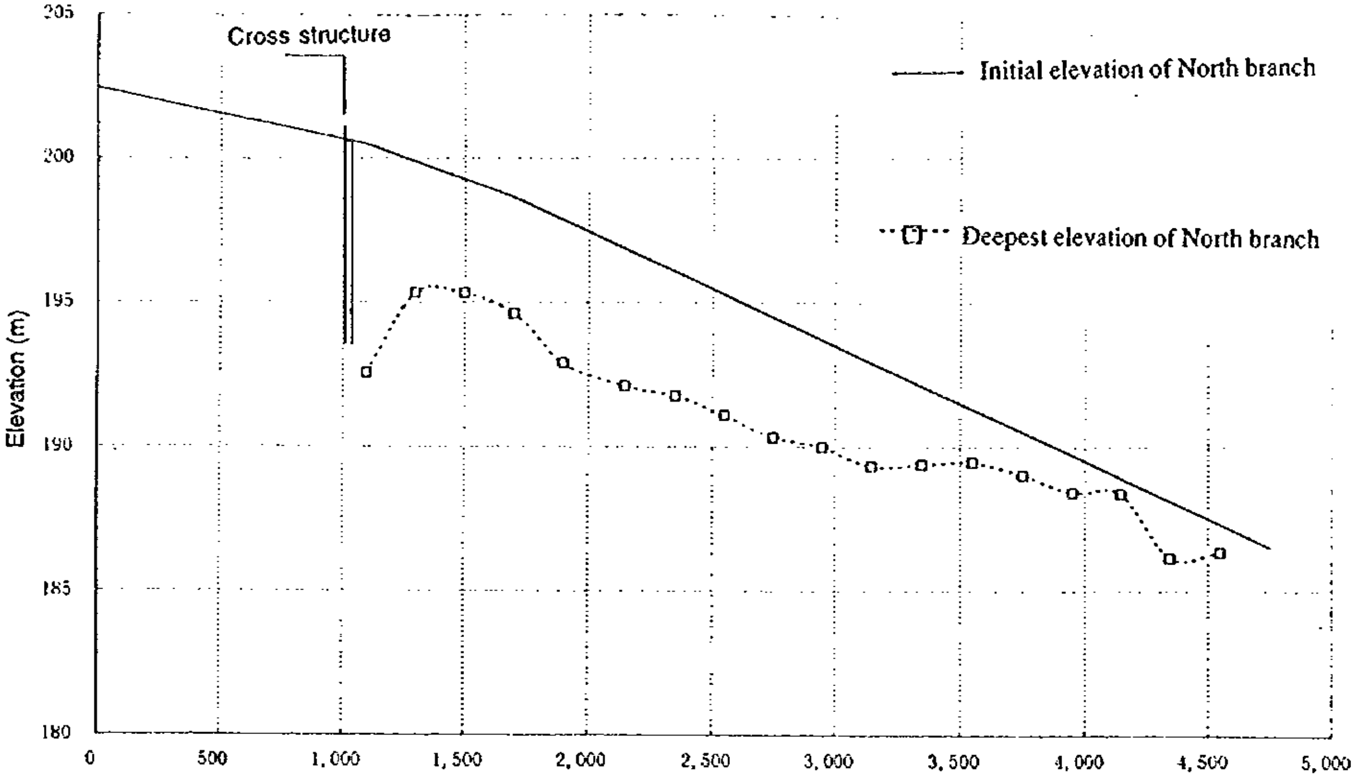


Fig.-4.13 The longitudinal cross section of the deepest of river bed after the test (Case - 3 - 3)

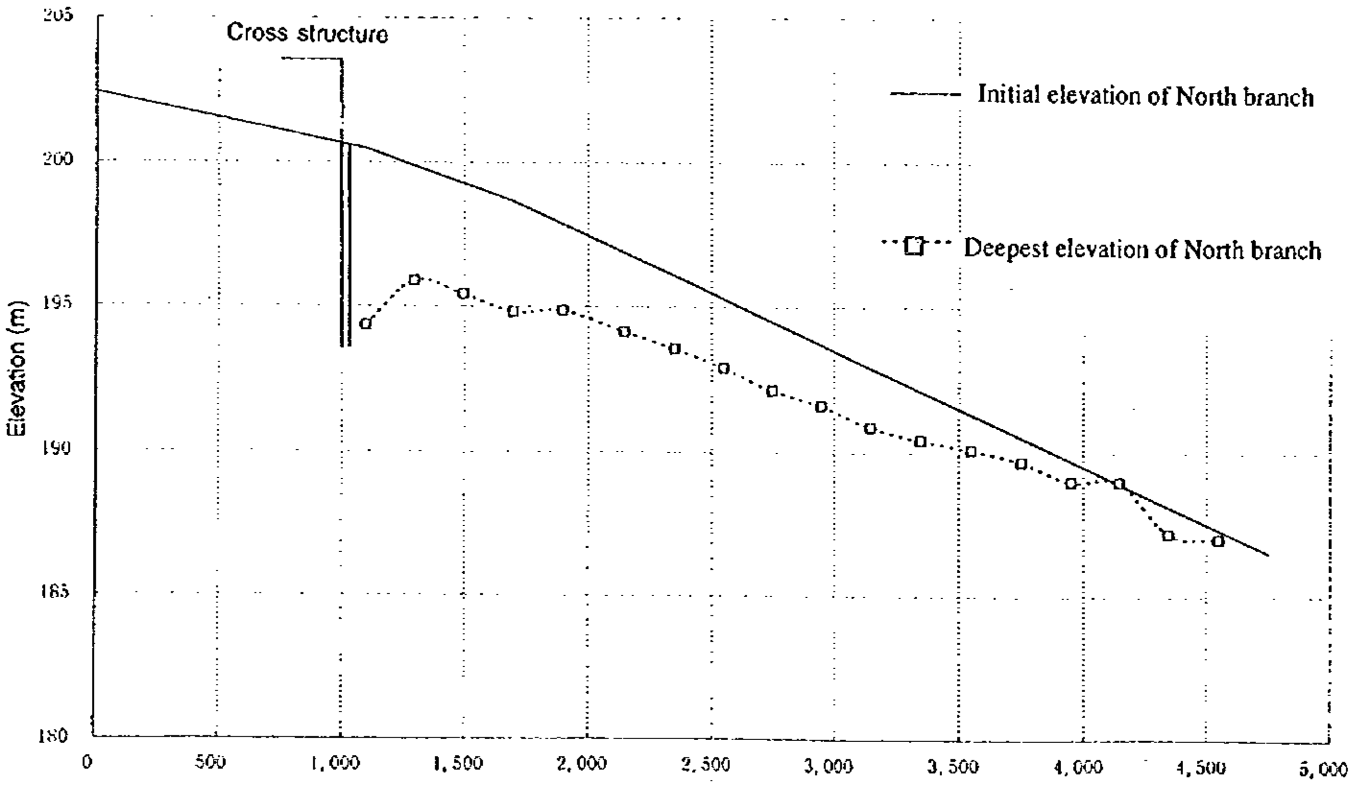


Fig.-4.14 The longitudinal cross section of the averag elevation of river bed after the test (Case - 3 - 3)

4.5 Test for Confirming the function of the Guide Walls (Case-4)

4.5.1 Objectives

The test aims to examine the function of the guide walls on the flood distribution, bed alteration and the local scouring. Cross structure is removed and only guide walls are remained. Plan of the model is shown in Fig.-4.15.

4.5.2 Results

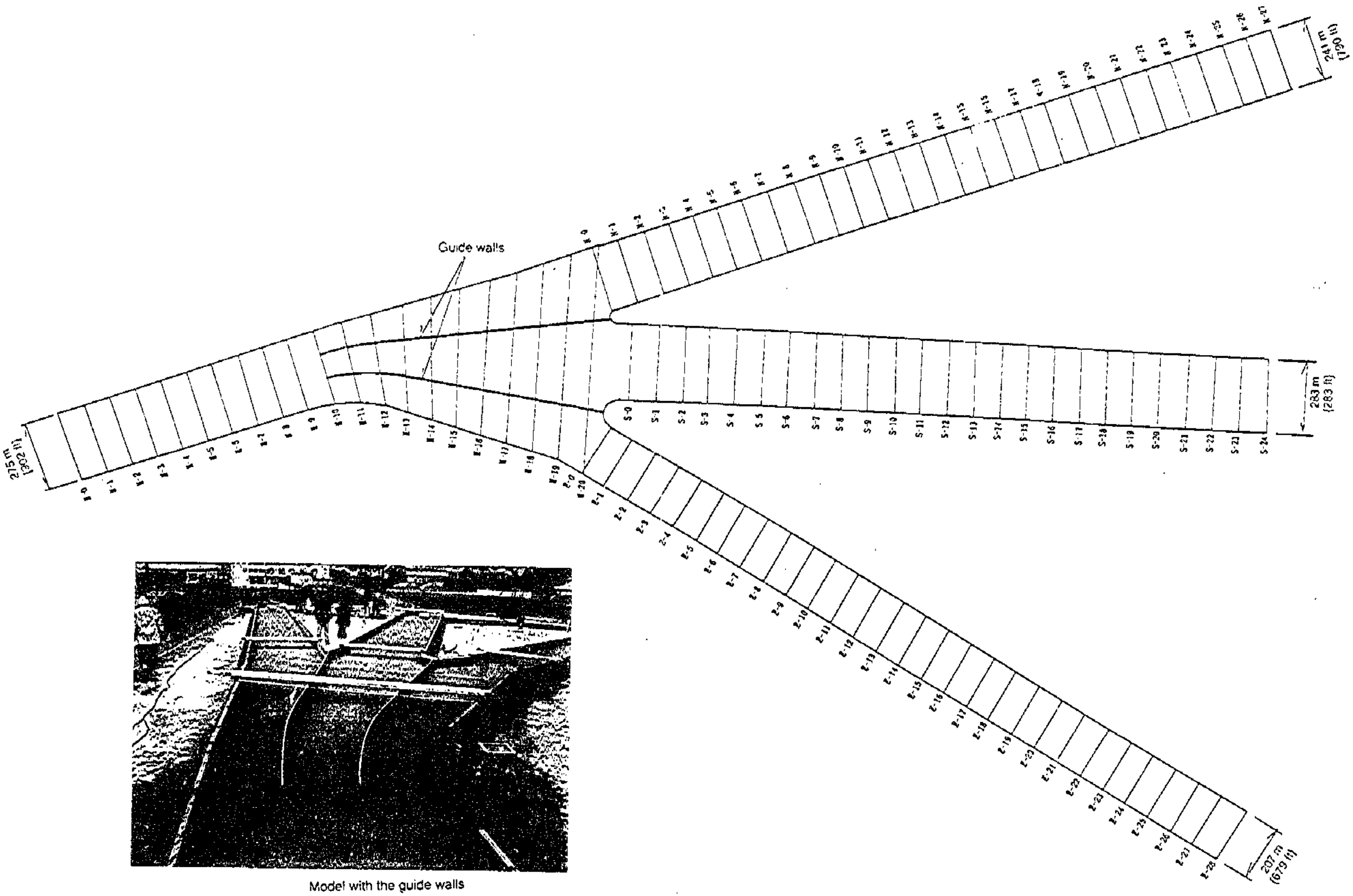
1) Flow

The flow condition are shown in Photo-7 and 8.

The flow oscillates between North branch and Escape. The cycle of flow oscillation is shorter than that of Case 3-1. Local scouring at the lead of the guide walls is 4m deep.

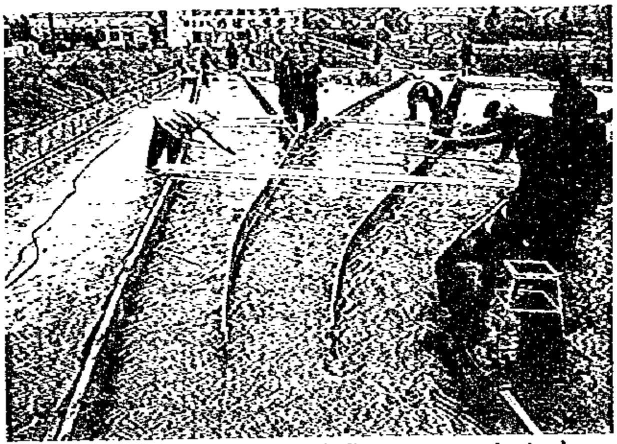
2) Distribution of Flow and Variation of Sediment Concentration

Fig.-4.16 shows the time variation of the distribution of flow. Fig-4.17 shows the change of sediment concentration. The flow oscillates between the North branch and the Escape. Cycle of oscillation is about 20 minutes, same to the Case-2 of without structure. Maximum quantity of inflow into one channel is a little less than 70% of total discharge.

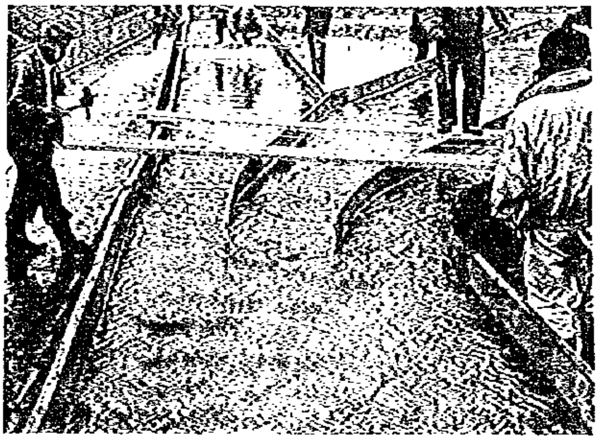


Model with the guide walls

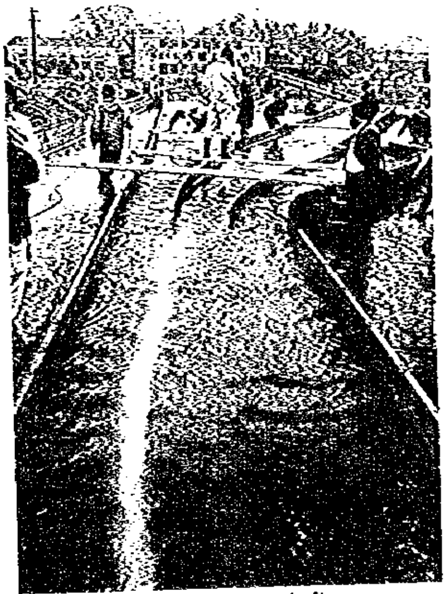
Fig.-4.15 Plan of the model with Guide Wall (Case 4)



1) 5 minutes passed, flow concentrated into the Escape.



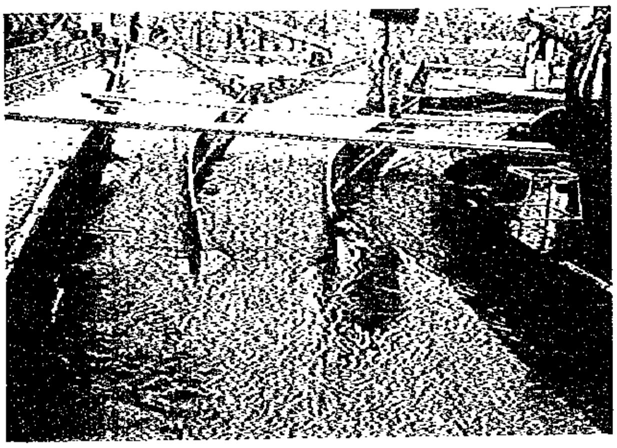
2) 10 minutes passed, flow concentrated into the Escape.



3) 15 minutes passed, flow increasedgradually into the North Branch and the South Branch.

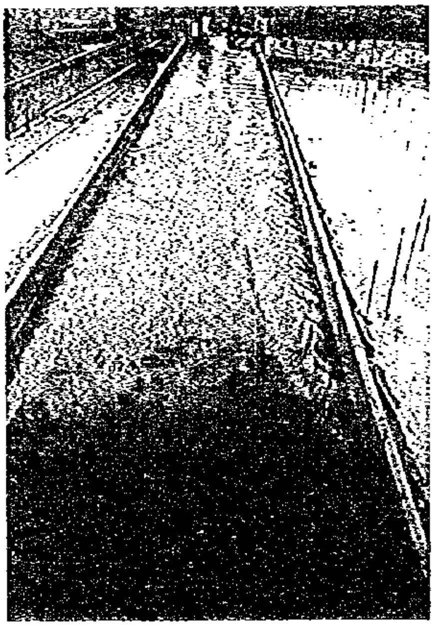
4) 30 minutes passed, flow increased into the North Branch and he South Branch.

5) 37 minutes passed, flow increased into the South Branch.



6) After the test.

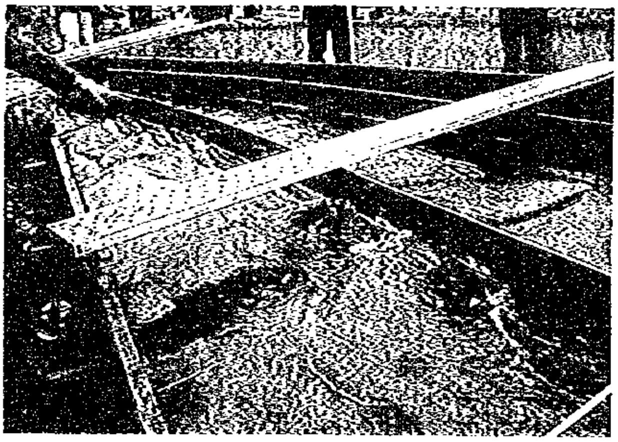
Photo-7 Flow condition in the Test with the Guide Wall only (Case - 4)



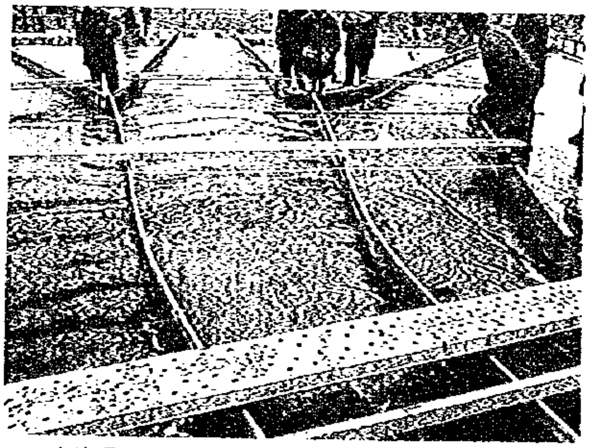
7) 10 minutes passed, bed condition in the North branch.

8) 10 minutes passed,bed icondition in tthe South branch.

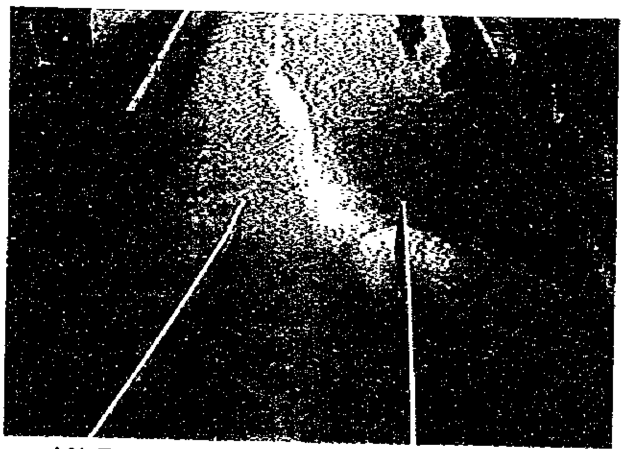
9) 10 minutes passed, bed condition in the Escape.



10) Flow concentrated along the guide wall, resulting 3m (10 feet) deep scouring.



11) Developed sand bar in the Escape



12) Depth of scouring reached about 4 m (13feet) at the head of the guide wall.

Photo-8 Flow condition in the Test with the Guide wall only (Case - 4)

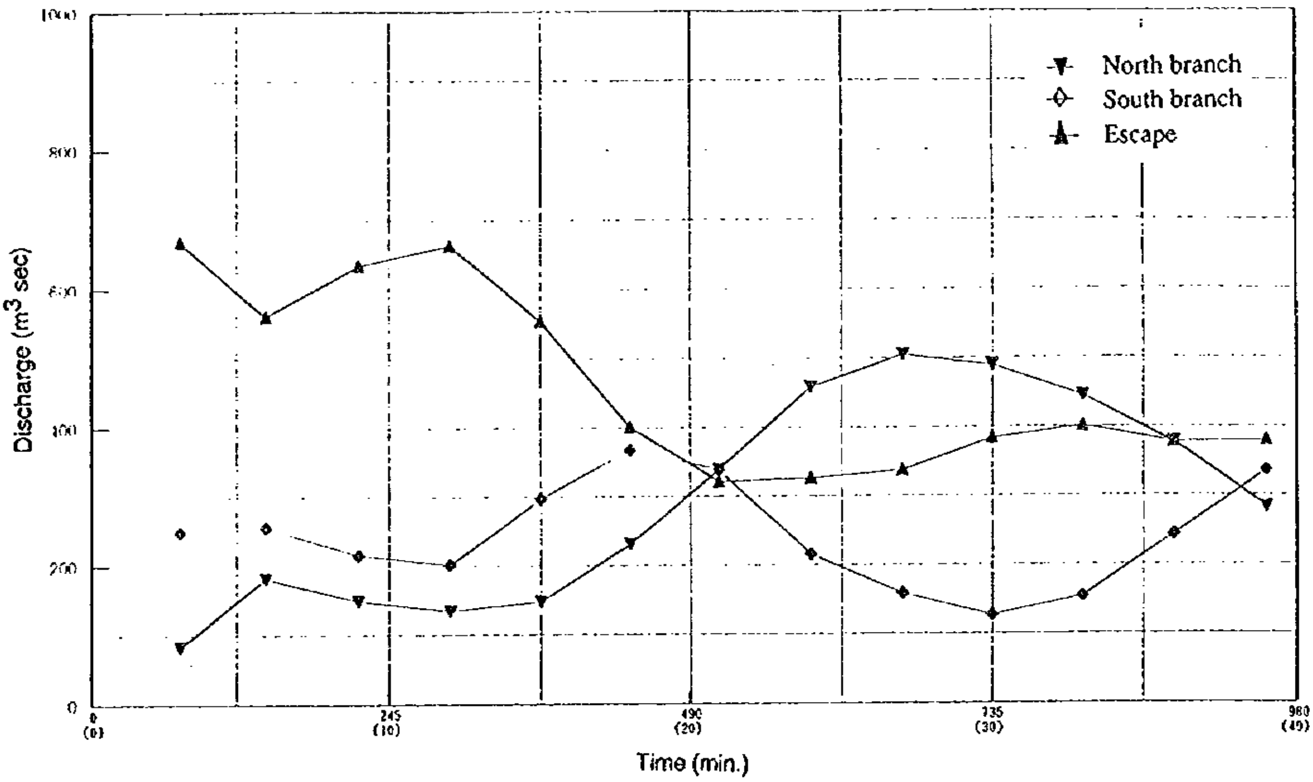


Fig.-4.16 The variation of the shares of flow with time (Case - 4) ( ) is experimental time

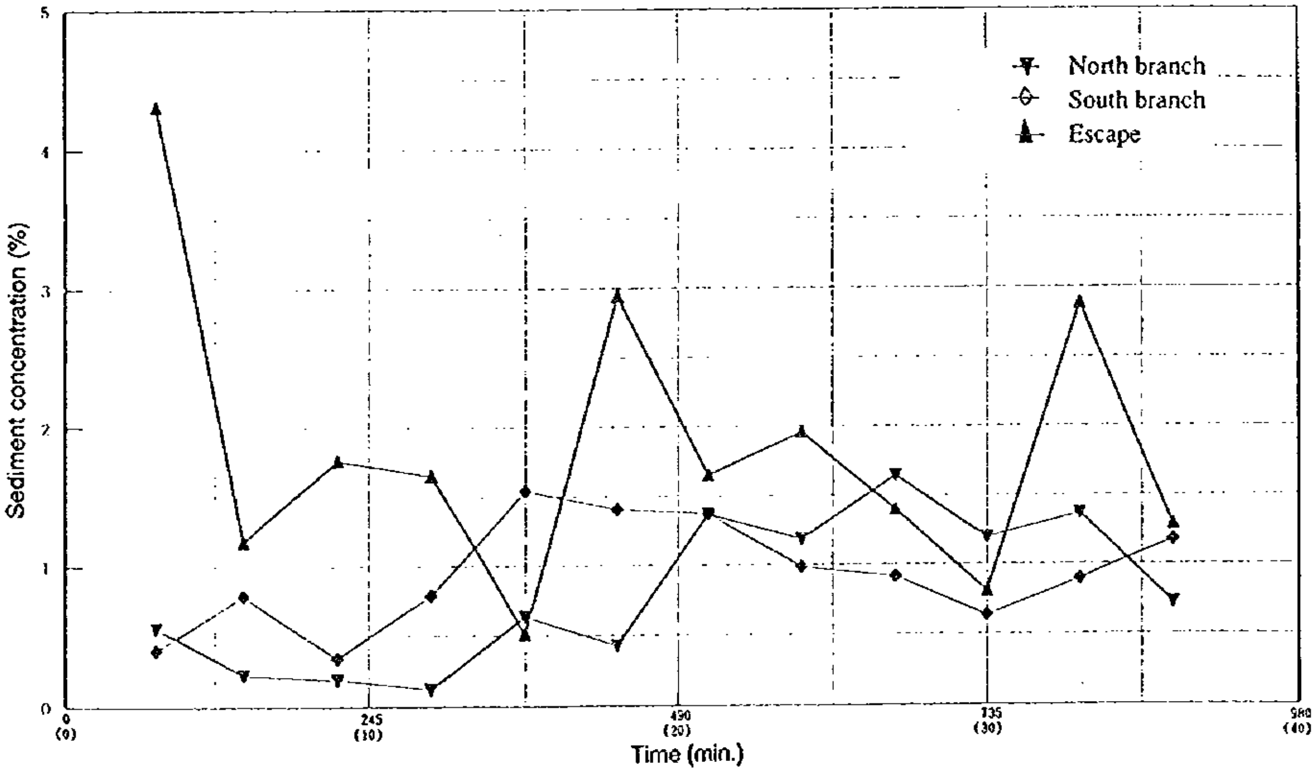


Fig.-4.17 The change of sediment concentrarion with time (Case - 4) ( ) is experimental time

4.6 Test for Examining the Function of Structure (Case-5)

4.6.1 Objectives

The test aims to examine the shares of distribution, bed alteration and the local scouring around the structure of which the cross structure placed at the mouth of each channel. Plan of model is shown in Fig.-4.18.

4.6.2 Results

1) Flow condition

The flow condition are shown in Photo-9 and -10.

Cross structures at the mouth of the channels cannot control the bed alteration developed in the widened channel upstream of the cross structure.

Therefore, the cycle of flow oscillation is nearly that of without structure (Case-2). Local scouring immediate downstream of the cross structure reaches 3 to 5m deep.

2) Distribution of Flow and Variation of Sediment Concentration

Fig.-4.19 shows periodical variation of the shares, and Fig.-4.20 shows the change of sediment concentration with time.

Maximum quantity of inflow into one channel reaches about 80 % of total discharge, similar to that of without structure (Case-3)

Discharge into the Escape increases temporarily after around 12 minutes from the start of the test, and discharge into the Escape increases in the last half of the test period.

3) Riverbed alteration

Fig.-4.21 shows the longitudinal section of deepest bed elevation after the test. Fig.-4.22 shows the longitudinal sections of average riverbed elevation after the test.

The riverbed gradient of the North branch after the test is same to that of the initial. In the South branch and the Escape, bed gradient after the test is gentler than that of the initial.

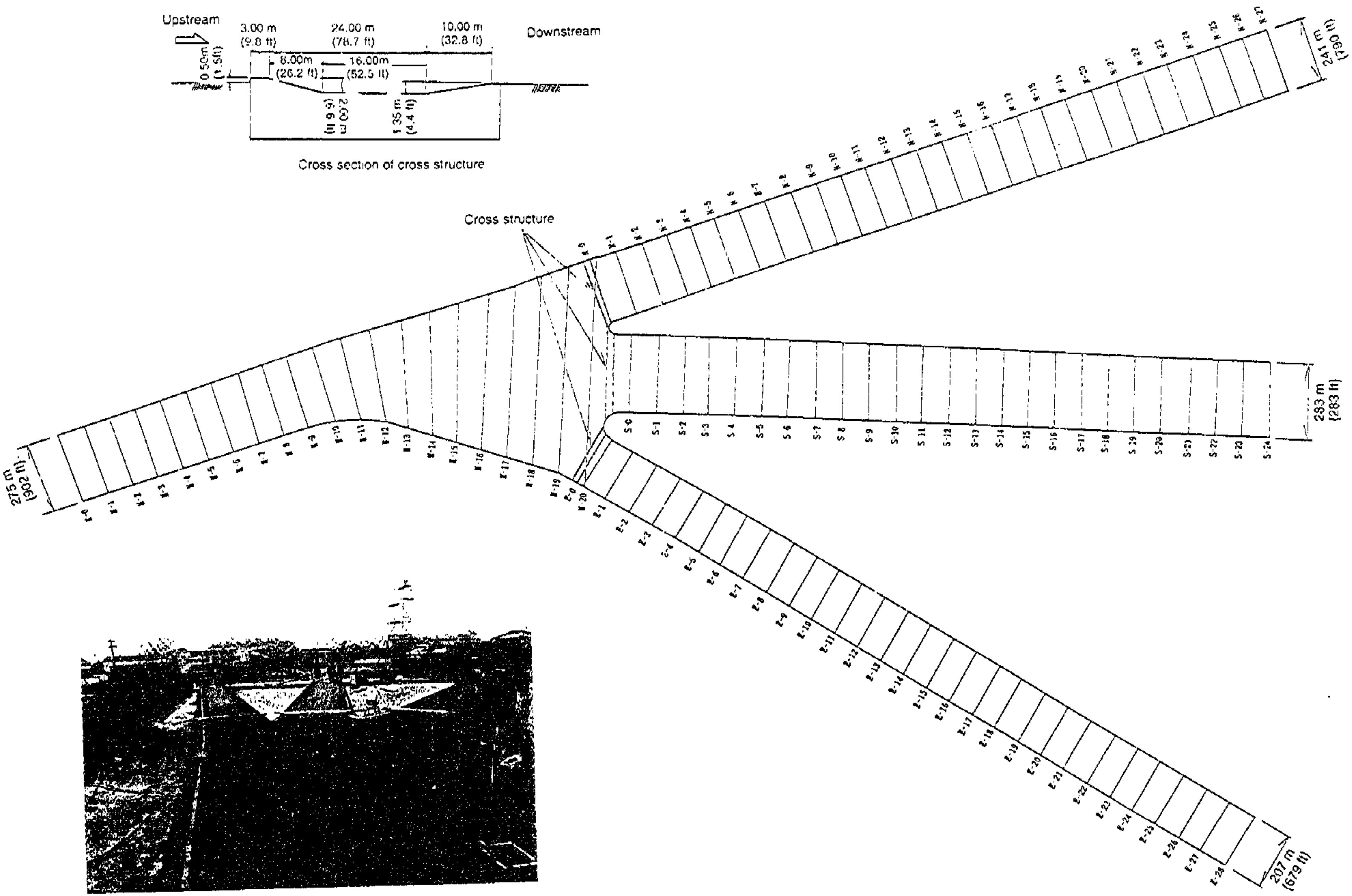
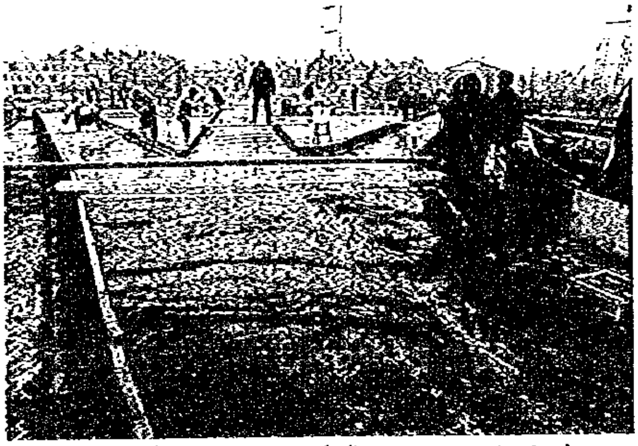
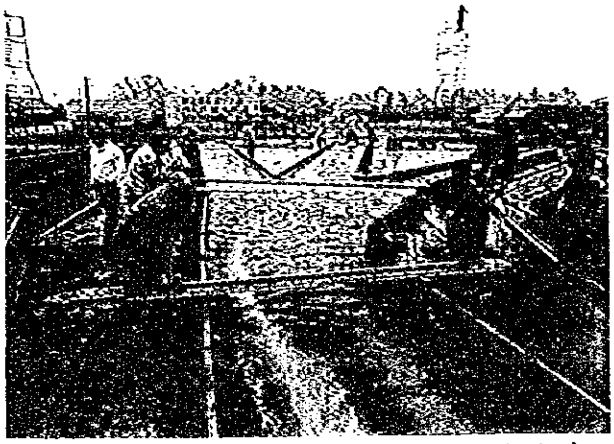


Fig.-4.18 Plan of the model cross structure at the mouth of each channel (Case 5)

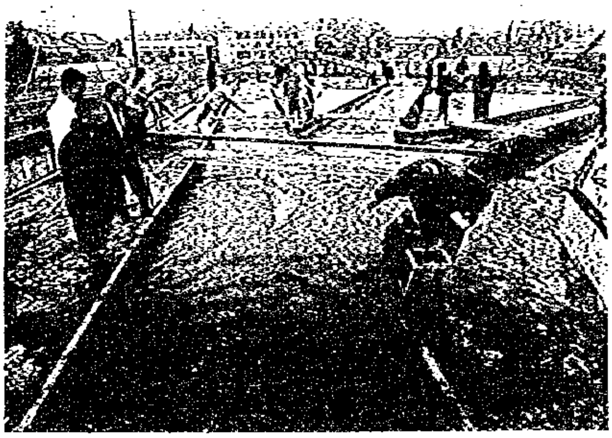


1) 5 minutes passed, flow concentrated into the Escape.

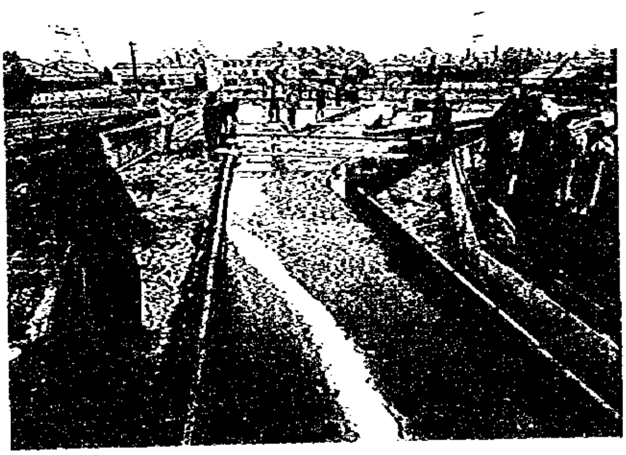


2) 14 minutes passed, flow concentrated into the Escape.

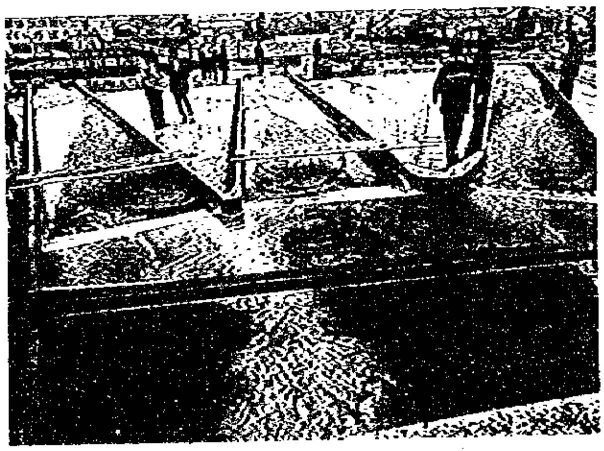
3) 25 minutes passed, flow concentrated into the North Branch and the South Branch.



4) 35 minutes passed, flow diverted into the North Branch and the Escape.

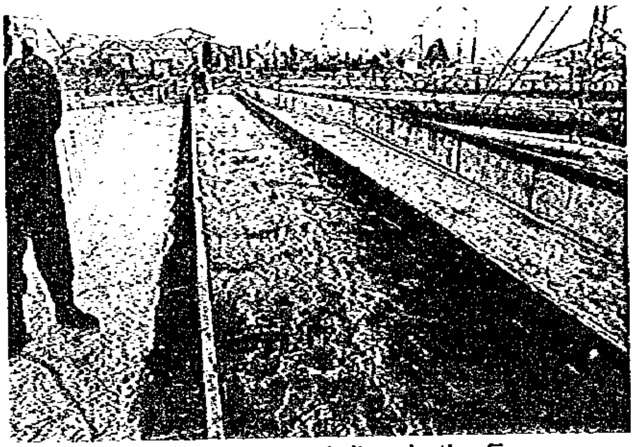


5) After the test.

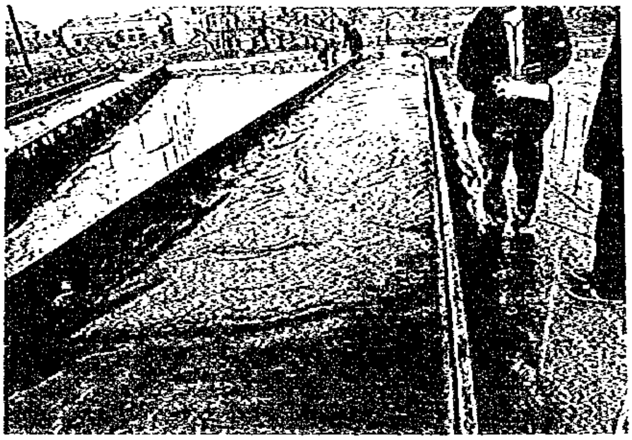


6) After the test.

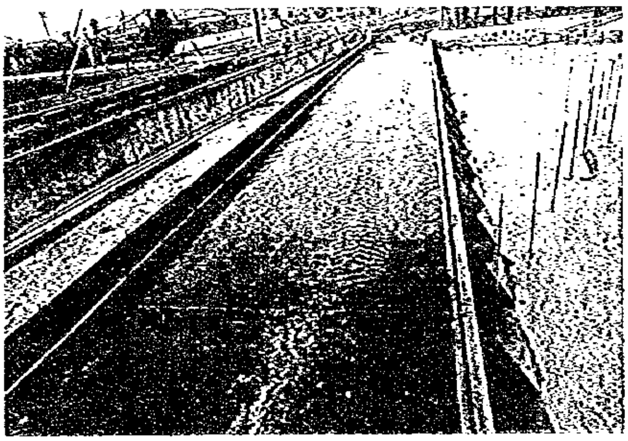
Photo-9 Flow condition of the Test with Guide Wall at Mouth of Branches (Case - 5)



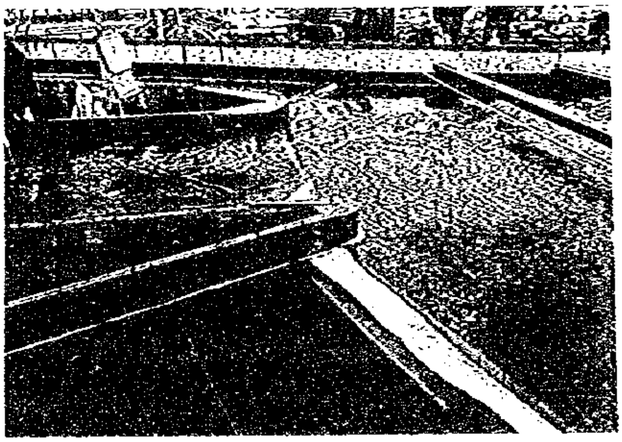
7) 10 minutes passed, flow in the Escape.



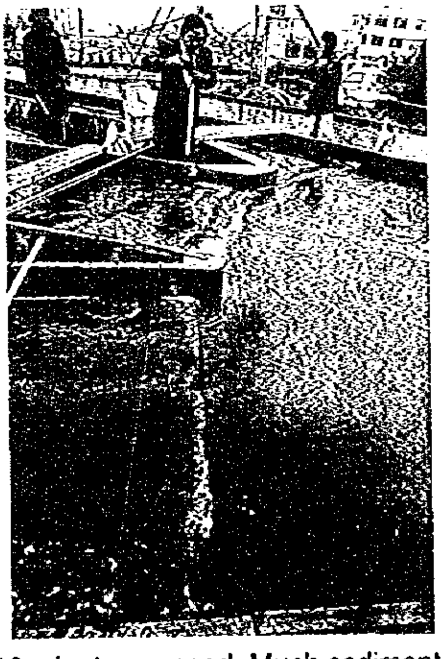
8) 10 minutes passed, flow in the South Branch.



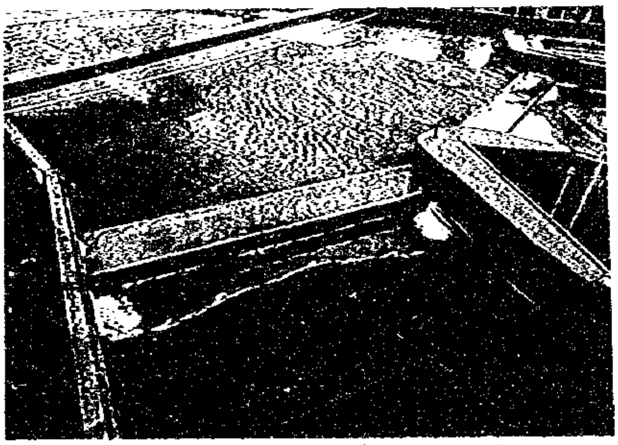
9) 10 minutes passed, flow in the North branch.



10) 5 minutes passed, a little sediment flows into the North Branch.



11) 18 minutes passed, Much sediment flows into the North Branch.



12) After the test, local scouring immediate downstream of cross structure.

Photo-10 Flow condition of the Test with Guide Wall at Mouth of Branches (Case - 5)

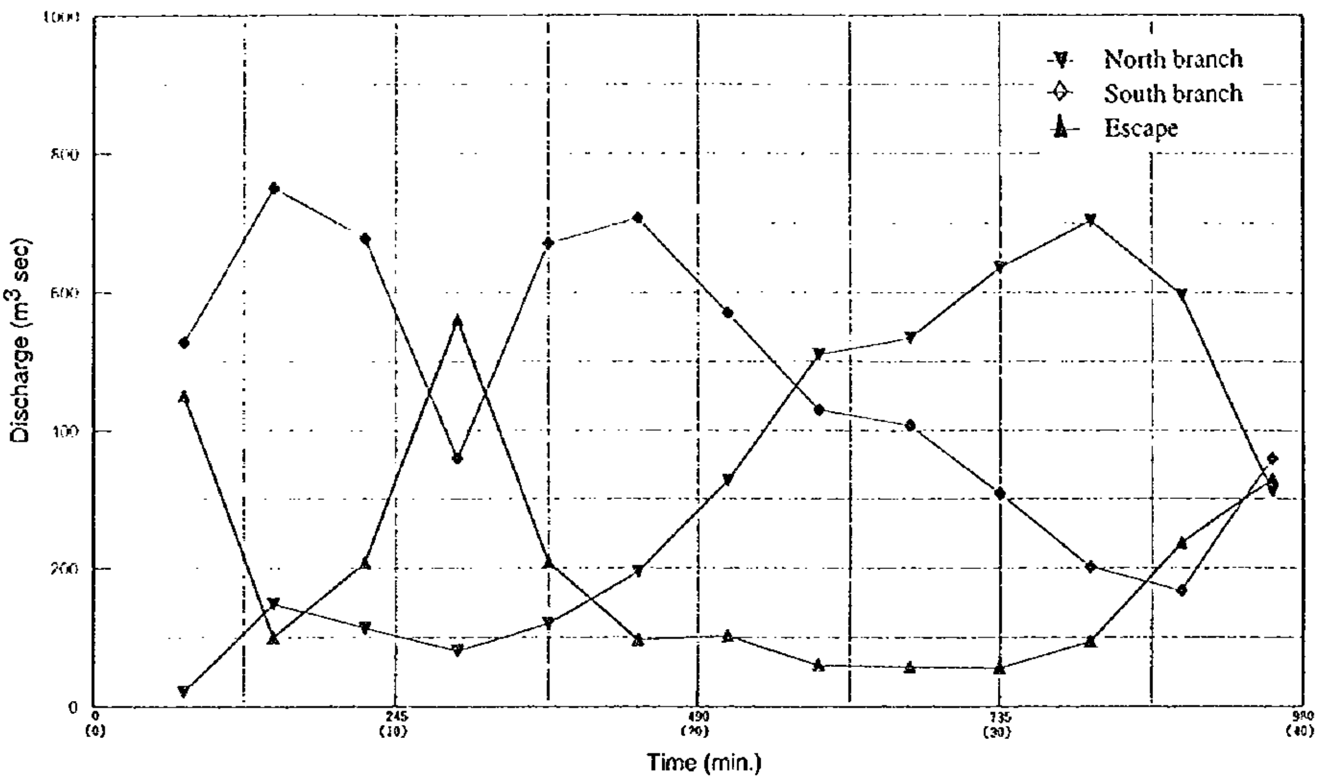


Fig.-4.19 The variation of the shares of flow with time (Case - 5) ( ) is experimental time

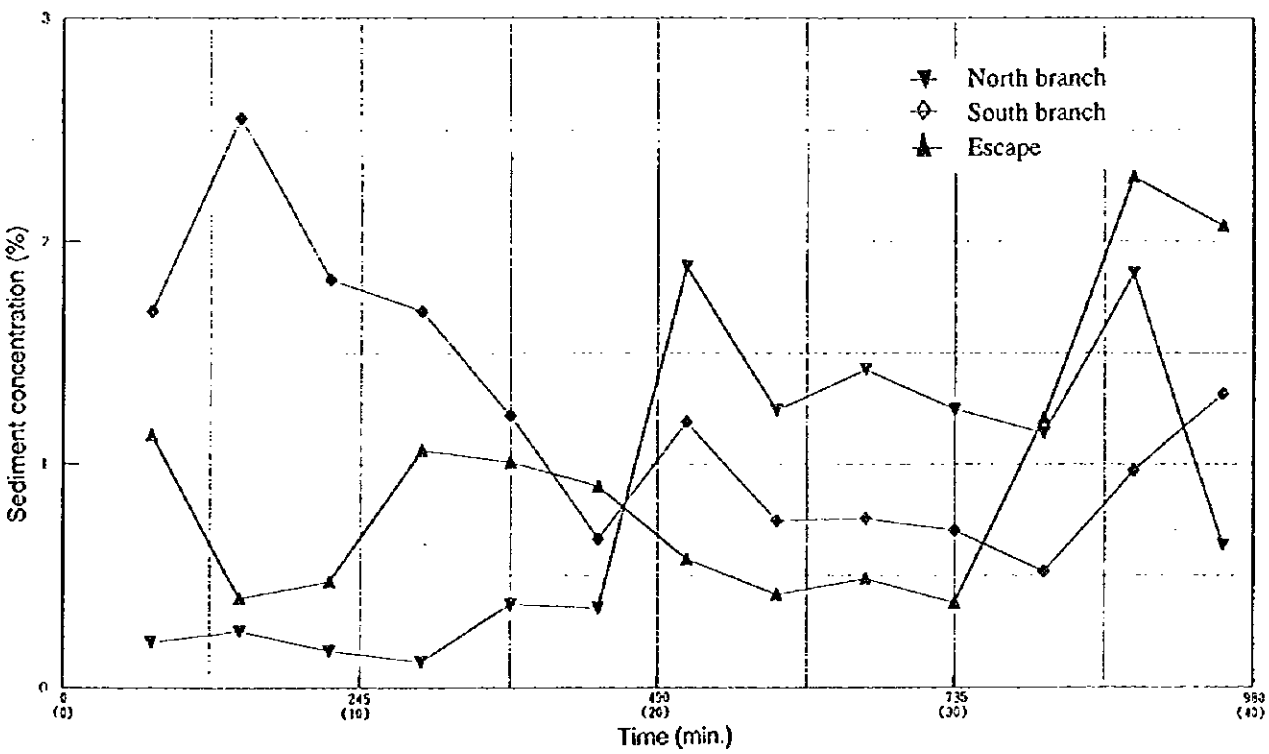


Fig.-4.20 The change of sediment concentrarion with time (Case - 5) ( ) is experimental time

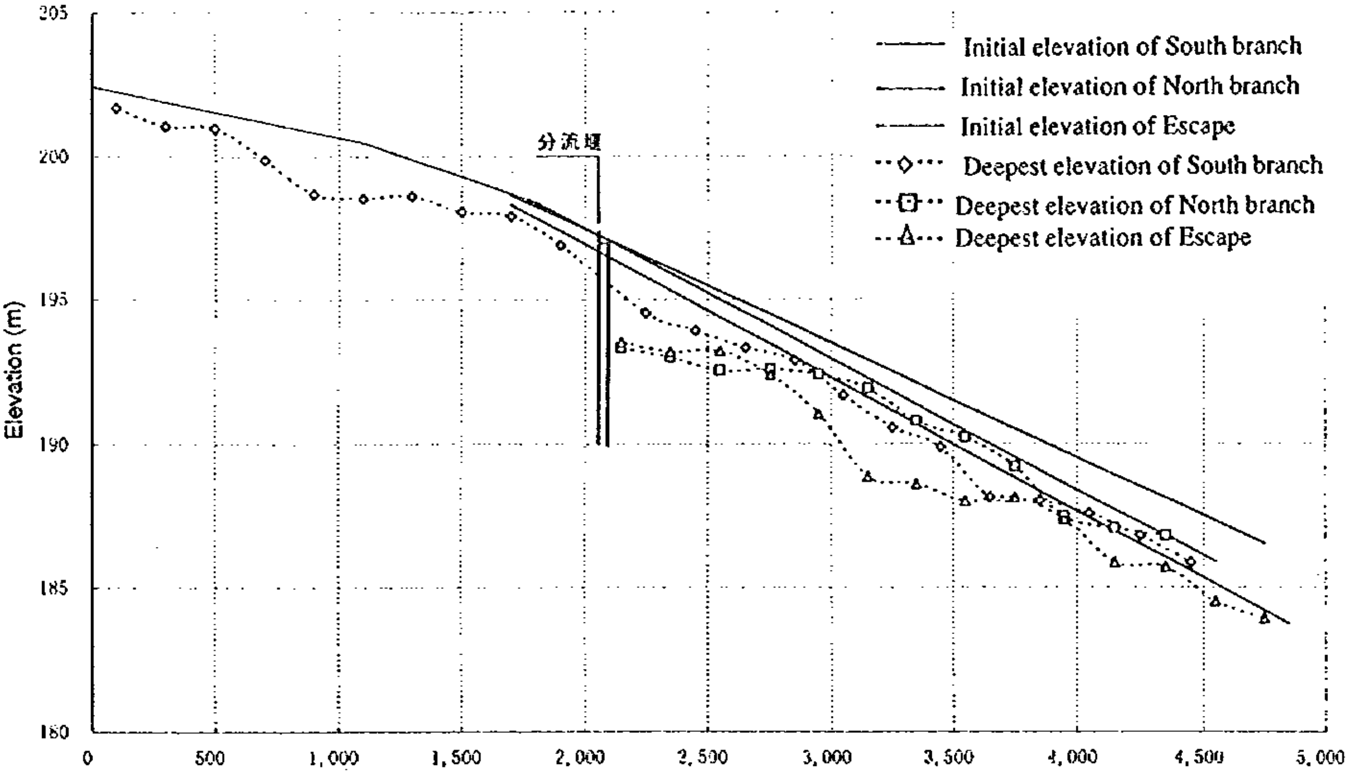


Fig.-4.21 The longitudinal cross section of the deepest of river bed after the test (Case - 5)

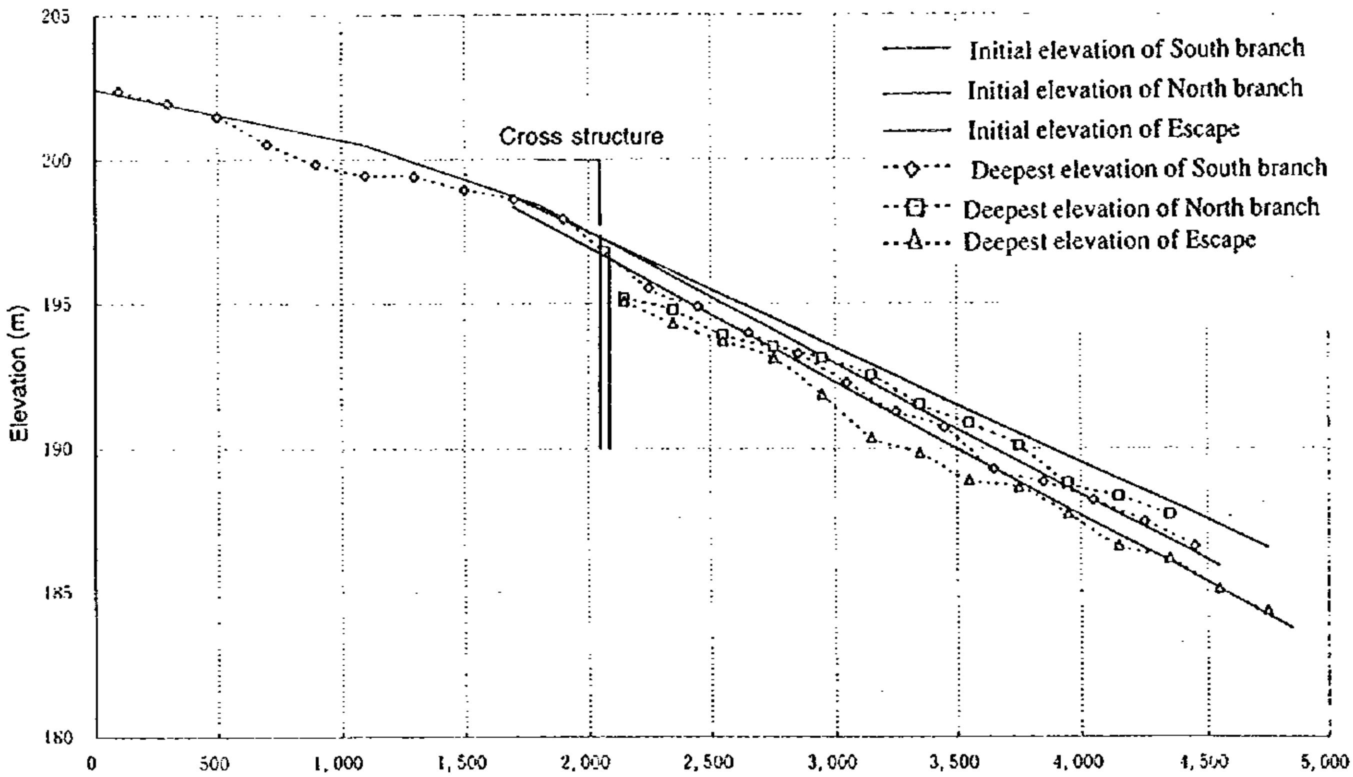


Fig.-4.22 The longitudinal cross section of the averag elevation of river bed after the test (Case - 5)