

FACTORS AFFECTING THE CONTINUITY OF RIVER BED ELEVATION AT THE SLIT THE SITE OF SLIT TYPE CHECK DAM

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ABSTRACT

Shiretoko Peninsula, located east of Hokkaido, was registered as a World Heritage Site in July 2005. In order to be registered as a World Heritage Site, river works located in the Shiretoko Peninsula area were evaluated for the run-up of salmonids. As a result, 13 river structures including check dams in 5 rivers were evaluated as necessary for improvement. One of these rivers, the Iwauetsu River, has seven check dams. Five of these seven check dams were improved to be slit-type dams. In the Iwauetsu River, the remaining two check dams are scheduled to be slit. Among the five slitted dams, there were cases where the continuity of riverbed heights upstream and downstream of the dam could be secured, but there were also some dams that could not. In order to slit the remaining two dams, it is necessary to understand the sediment movement characteristics of the slit dam. Hydraulic experiments and numerical simulations were performed to understand the basic phenomena in order to clarify the response of a river channel when a slit was made. As a result, it was found that the slitting eliminated the riverbed degradation that had occurred downstream of the check dam, and that the shape of the sandbar before and after the slitting could affect the salmon spawning environment. In addition, it was revealed that the numerical experiment almost reproduced the hydraulic experiment result and could be used for the examination of the slit width and the like.

Keywords: check dam, hydraulic experiment, numerical simulation, sediment transport

1. INTRODUCTION

The Shiretoko Peninsula, located east of Hokkaido, was highly evaluated for it can easy see the ecosystem that connects from sea to land, it has become a habitat of rare animals and plants and that a management system is preserve these creatures. For this reason, the Shiretoko Peninsula was listed as a World Natural Heritage Site on July 17, 2005. In registering for World Natural Heritage, the International Union for Conservation of Nature (IUCN), an advisory board to the UNESCO World Heritage Committee, called for measures to allow free movement of salmonids on river structures in the region. For the response to this request, the Ministry of the Environment established the Shiretoko World Heritage Regional Science Committee and its subordinate organization, the River Structure Working Group, in July 2004. The Working Group evaluated 100 structures on 14 rivers around the World Heritage Area. The items of this evaluation included salmon habitat status and the impact on the natural environment of check dams. As a result, it was evaluated that 13 river structures with 5 rivers should be improved, and improvement works have been conducted to date.

In the Iwauetsu River system located on the Shiretoko Peninsula, debris flow and flood disasters occurred from August 5 to August 6, 1981 due to heavy rainfall, and seven check dams were constructed as countermeasures. In the Iwauetsu River system, the improvement of five check dams was judged to be appropriate for registration as a World Natural Heritage Site, and all five improvement works were completed in the 2010 fiscal year. It is expected that the remaining two dams will be slit in the future. In order to consider more appropriate measures, it is necessary to clarify the response of the river channel in the slit. Therefore, in this study, basic hydraulic model experiments and numerical experiments were conducted as the first step to verify the response of the river channel by slitting.

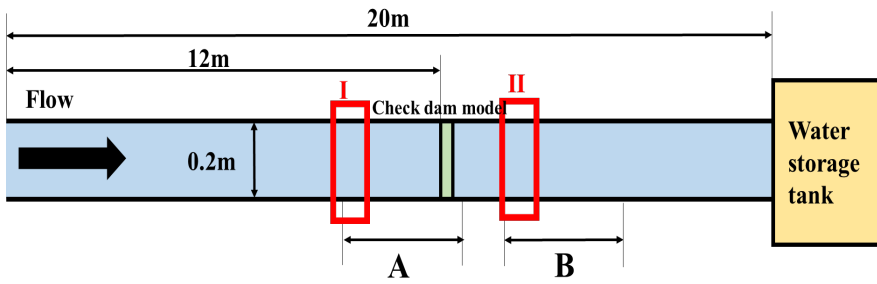


Figure-1 The waterway

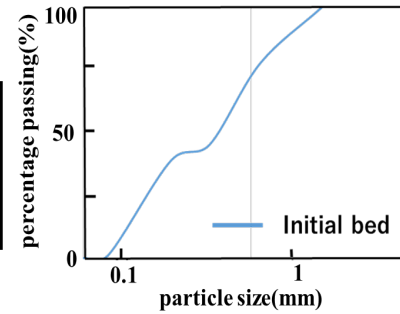


Figure-2 The percentage size (Initial bed)

2. HYDRAULIC EXPERIMENT

A movable bed experiment was conducted in a straight channel with a model of a check dam. After sediment was deposited at the upstream part of the check dam model, the response of the bed configuration was confirmed by slitting the dam.

2.1 Experimental set up

The channel used in the experiment is a straight channel with a length of 20 m, a width of 0.2 m, and a side wall height of 21 cm. A model of a check dam with a height of 15 cm was installed 12 m downstream from the upstream end of the channel. Figure 1 shows the sketch of experimental set up. As an initial riverbed, silica sand with an average particle size of 0.60 mm was uniformly filled up in this channel at a thickness of 10 cm. Figure 2 shows the particle size distribution of the silica sand. The bed slope was set to 1/100 in consideration of the Iwaubetsu River. The slit width of the check dam was set to 2 cm as about 1/75 of the actual slit size. When simulating a check dam before slitting, an acrylic plate with a thickness of 1 mm was installed so as to be in contact with the upstream side of this dam model.

2.2 Hydraulic conditions

In order to make the non-dimensional shear stress in the experiment coincide with the non-dimensional shear stress when the peak discharge of a flood which has excess probability of about 1/20 to 1/30 in the middle part of the Iwaubetsu River, the discharge for the experiment was set. The discharge was 770cm³/s, where the uniform flow depth at the initial riverbed was 10mm. During the supply of water to the channel, the same sand as the bed material was supplied from the upstream end of the channel to maintain the bed elevation at the upstream end of the channel. The check dam was installed at a position where the backwater does not reach the upstream end of the flume at the initial condition. Due to sedimentation upstream of the check dam, backwater reached the upstream end of the flume at the end of the experiment.

2.3 Experimental method

In this study, the phenomena including the sedimentation at the upstream part of the check dam from the state before the construction of the check dam were attempted to understand. The experiment was conducted in two stages. The first is an experiment in which sediment is deposited upstream of the check dam, and the second is an experiment in which the check dam is slit and the sediment deposited upstream of the dam is flushed to the downstream. First, water supply to the channel was started after the slits of the check dam were closed with a 1.0 mm thick acrylic plate. It was confirmed that the upstream of the check dam was full of sand and the riverbed was in an equilibrium state, then the water supply was stopped, and the riverbed height was measured. The water supplied for 4.5 hours. After slitting the check dam, the time required for the riverbed to reach equilibrium was 6.5 hours. After stopping the water supply, the bed height was measured again. The river bed height was measured using a laser sand level gauge and a point gauge. From the upstream end of the channel to the downstream point 9.0m, the height of the riverbed was measured using point gauges at three points in the transverse direction at intervals of 20cm in the longitudinal direction. The three points in the transverse direction are set the point 3cm from the left and right channel walls and the center point of the channel. The riverbed downstream was measured by a laser sand level gauge at intervals of 20 mm and 5 mm in the longitudinal and transverse directions, respectively.

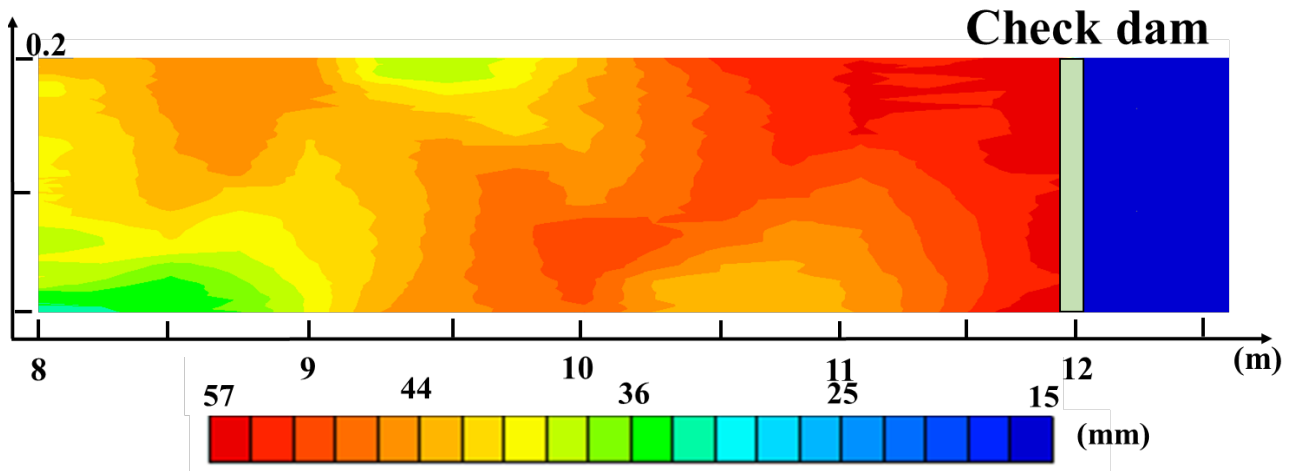


Figure-3(a) Before slit contour map of riverbed at the reach A

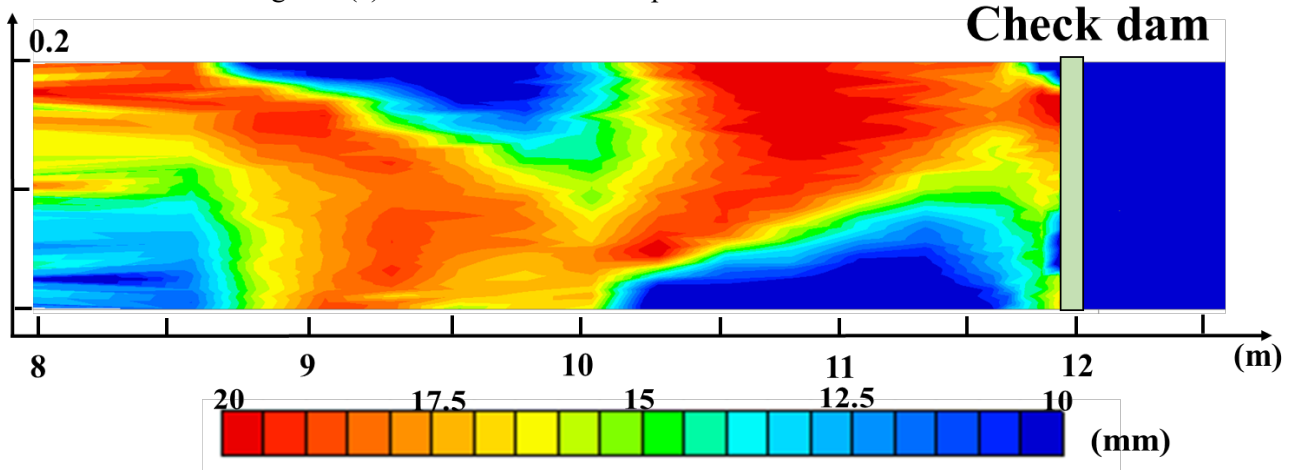


Figure-3(b) After slit contour map of riverbed at the reach A

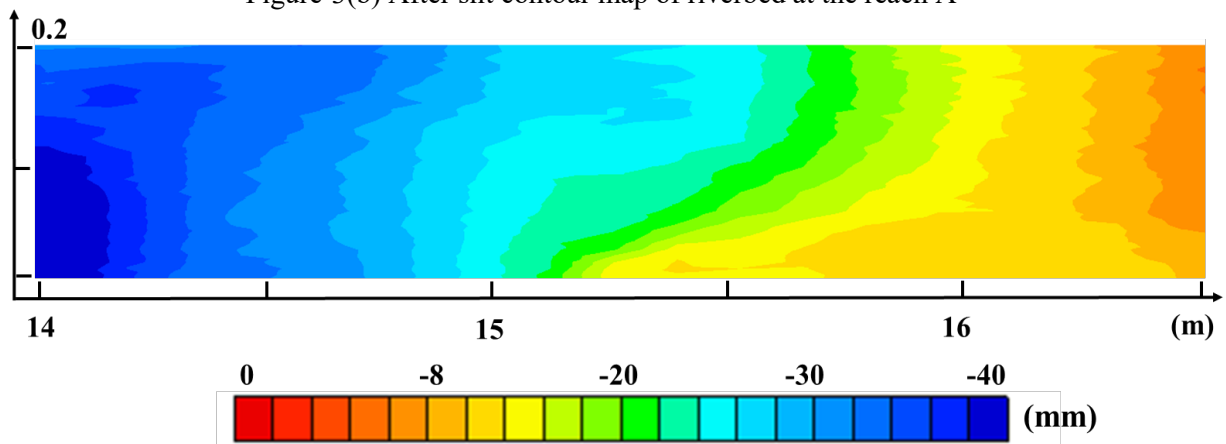


Figure-4(a) Before slit contour map of riverbed at the reach B

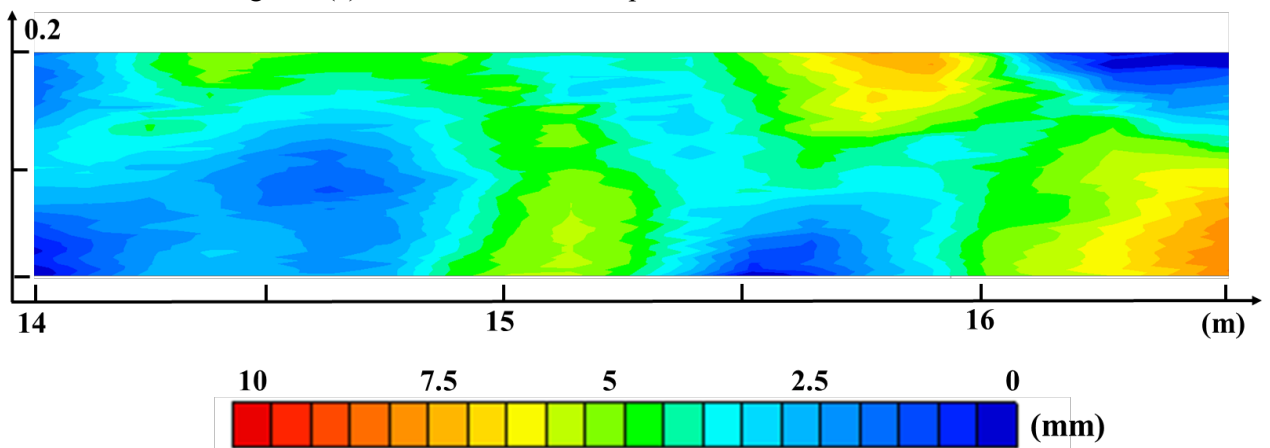


Figure-4(b) After slit contour map of riverbed at the reach B

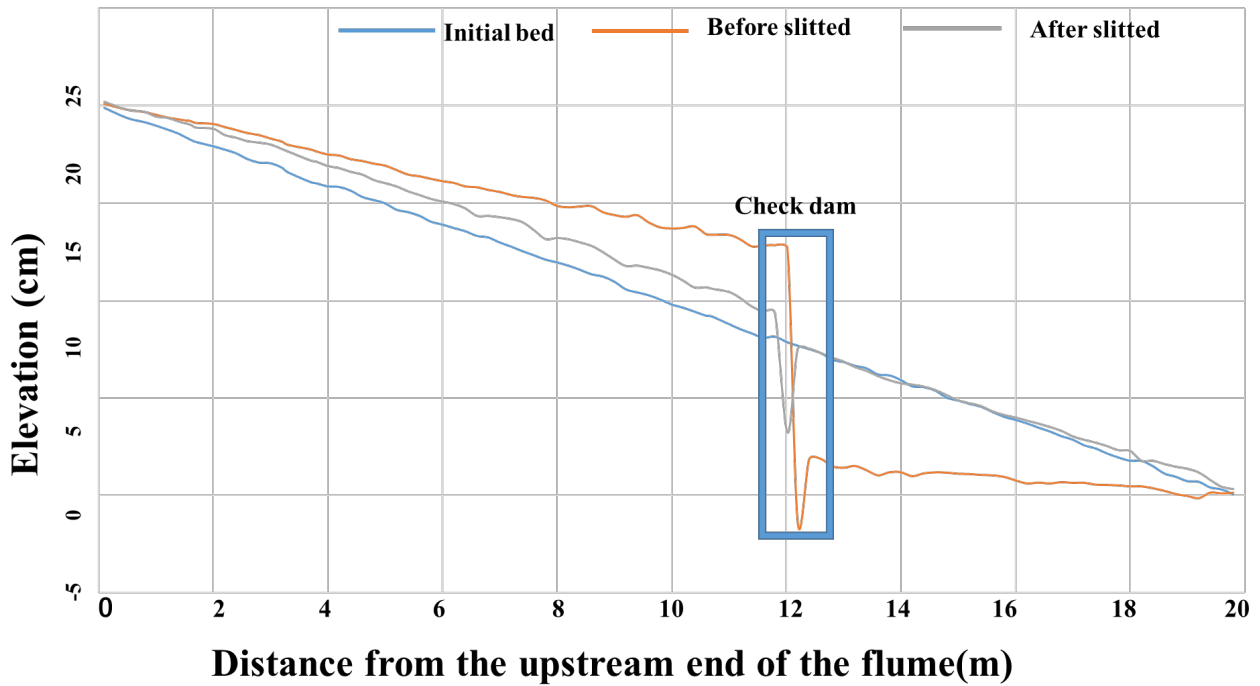


Figure-5 Longitudinal profile of bed elevation

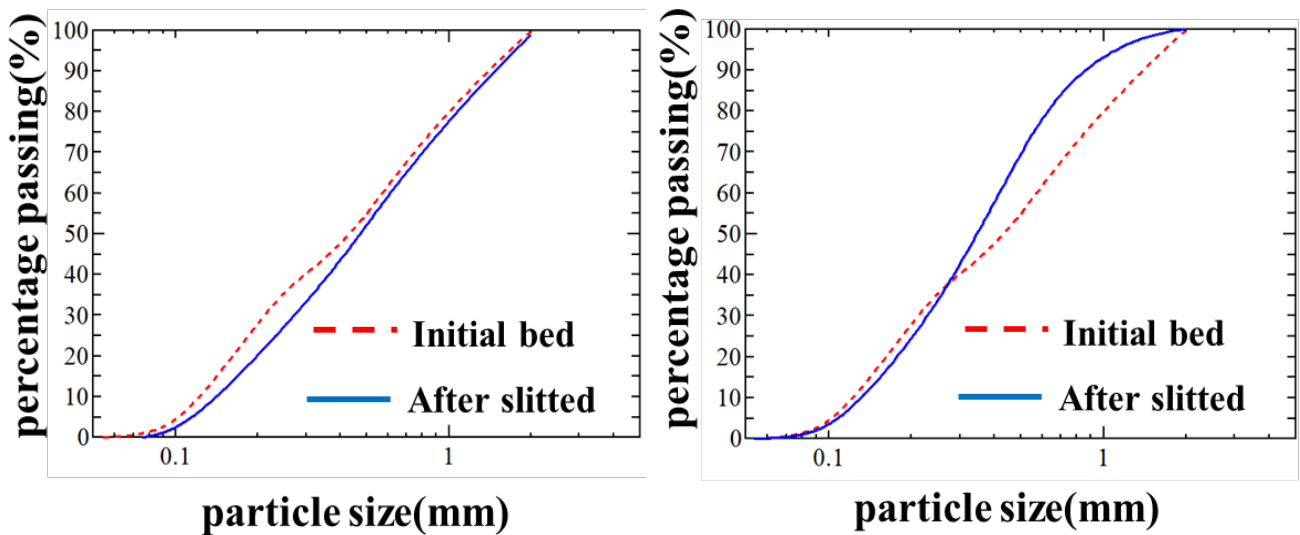


Figure-6(a) Particle size accumulation curve in reach I

Figure-6(b) Particle size accumulation curve in reach II

3. RESULTS OF HYDRAULIC EXPERIMENT

Figure 3 is a contour map of the riverbed in the reach A of Fig.-1, that is, the reach immediately upstream of the check dam. Figure 3(a) shows the situation when the check dam is full of sediment, and Fig.3(b) shows the situation when the riverbed height is in equilibrium after the check dam is slit. Figure 4 is a contour map of the riverbed in the reach B of Fig.-1, that is, the reach downstream of the check dam. Fig.4(a) shows the situation when the check dam is full of sediment, and Fig.4(b) shows the situation when the riverbed height is in equilibrium after the check dam is slit. Figure-5 shows a longitudinal profile of the riverbed elevation at the center of the channel. Figure 6(a) is a particle accumulation curve at 2m upstream from the dam where is in the reach I of Fig.1. Figure 6(b) is a particle accumulation curve at 2m downstream from the dam where is in the reach II of Fig.1.

3.1 Continuity of sediment transport

Comparing the bed elevations before and after slitting of check dam, it can be confirmed that there is a large difference at the check dam site which locates 12.0m from the upstream end of the channel. The difference in

Table-1 Wavelength and Wave Height Result (Hydraulic Experiment)

Hydraulic Experiment Result				
	Wavelength (cm)	Wave height (mm)	Wavelength (cm)	Wave height (mm)
	The upstream		The downstream	
Before slit	160	15	—	
After slit	250	13	230	10

Table-2 Channel Bed Profile Result (Hydraulic Experiment)

Hydraulic Experiment Result			
	Channel Bed Profile		The difference in bed elevation (cm)
	The upstream	The downstream	
Initial bed	1/100	1/100	—
Before slit	1/164	1/463	10.5
After slit	1/109	1/103	1.3

bed elevation at the check dam site is 10.5 cm before slit and 1.3 cm after slit. The bed slope before slit is 1/164 at the upstream of the check dam, 1/463 at the downstream of the check dam. On the other hand, the bed slope after slit is 1/109 at the upstream of the dam and 1/103 at the downstream of the dam. Although with the slit width which is set at this time, it is not possible to completely return to the initial bed slope, it is clarified that the bed slope became close to the value before dam construction by slitting the dam. The amount of sediment deposit at the upstream part of the check dam is about 65,900cm³ at before slit the dam and it is about 20,000cm³ at after the slit the dam. About 45,900cm³ of sediment flush to the downstream by the slitting.

3.2 Bed material size

As can be seen from Fig.6(a), the bed material size at the upstream part of the check dam after the slitting is slightly coarse compare to the initial bed material. The bed material size at the downstream part of the dam after the slitting is finer than in the initial bed according to Fig.6(b).

3.3 Bar formation

Alternate bars are formed as clearly show in Fig.- 4 and 5, except at the upstream part of the dam before the dam was slit. Since the shape of bars greatly affects the habitat of living organisms and the spawning environment of salmonids, the shape of bars is focused on. Table 1 summarizes how the wavelength and wave height of bar change before and after slitting the dam. After slit the dam, the wavelength becomes longer compare with the before slit. Also, after slit, the wavelength and wave height at the upstream and downstream of the dam are almost the same. The change in the shape of bars is thought to be due to the change in the bed slope.

4. NUMERICAL EXPERIMENT

The reproducibility of the numerical calculations was confirmed for enable examination under various conditions. In this study, it was decided to use the numerical simulation software iRICNays2DH, which reproducibility of various experiments was confirmed.

The flume used for the calculation was set the same size as the experiment, 20 m long and 20 cm wide. The calculation grid was 0.01 m in the transverse direction and 0.02 m in the longitudinal direction. The Manning's roughness of the bed was set to 0.012. The bed material was used a mixed-sized material with six particle sizes (2mm; 0.09%, 0.85mm; 22.46%, 0.452mm; 32.26%, 0.25mm; 6.3%, 0.106mm; 37.46%, 0.075mm;1.43%). Water flow was passed for 6 hours until sediment was stored in the upper part of the check dam. After that slitting to a width of 2cm, water flow was passed for 10 hours. At this time, the particle size distribution used in the initial riverbed is used. The time step of calculation was set to 0.005 seconds, the check dam was represented as fixed bed.

5. RESULTS OF NUMERICAL EXPERIMENTS

Figure 8 shows a longitudinal profile of the riverbed elevation at the center of the channel. Figure 9(a) and (b) show the calculation results of bed configuration at the upstream from the dam when the bed elevations are in the equilibrium state before and after the dam is slit, respectively. Figure 10(a) and (b) show the bed configuration at the downstream from the dam. Figure 11 is a particle accumulation curve where is at the reach I and II in Fig.1.

5.1 Continuity of longitudinal bed elevation profile

The outline of the longitudinal bed profile is reproduced although the reproducibility at the downstream of the dam is poor. Especially in the case of before the dam is slit, there is no local scouring at immediately the downstream of the dam and the bed elevation at the downstream of the dam is calculated slightly higher than the hydraulic experiment result. The bed slope before slit the dam is 1/172 at the upstream of the dam and 1/296 at the downstream of the dam.

On the other hand, the bed slope after slit the dam is 1/104 at upstream of the dam and 1/110 at downstream of the dam. Although the calculation results show that the scouring at the downstream side before slitting and the deposition at the downstream side after slitting are underestimated. The amount of sediment deposit at the upstream part of the dam is about 58,000cm³ before slit the dam and about 12,000cm³ after slit. About 46,00cm³ of sediment flush to the downstream by the slit of dam. The amount of sediment deposit from the initial riverbed is underestimated, but the amount of sediment flush to the downstream due to the slit is almost the same as the hydraulic experiment results.

5.2 Bed material size

Figure 11 shows the change over time in the average particle size of riverbed material at 2 m upstream from the dam (reach I) and 2 m downstream from the check dam (reach II) after the slit construction of the dam. The average particle size increase to 5 hours after the start of water flow, but then turned to become fine at the section I. The average particle size became finer over time at the reach II. The change of riverbed material downstream of the dam is able to reproduce the tendency of the hydraulic experiment, but the upstream of the dam show a different tendency from the hydraulic experiment in the latter half of the experiment. This is because the particle size distribution of the riverbed material deposit upstream of the dam before slitting is significantly different from that of the initial bed, and it may not be possible to express this condition in this numerical experiments. This point needs further study.

5.3 Bar shape

We focus on the shape of alternating sandbars since the formation of alternate bars is reproduced by numerical experiments.

Table 3 summarizes the characteristics of alternate bars simulated, indicating that the model underpredicts observed wavelength but overpredicts the waveheight.

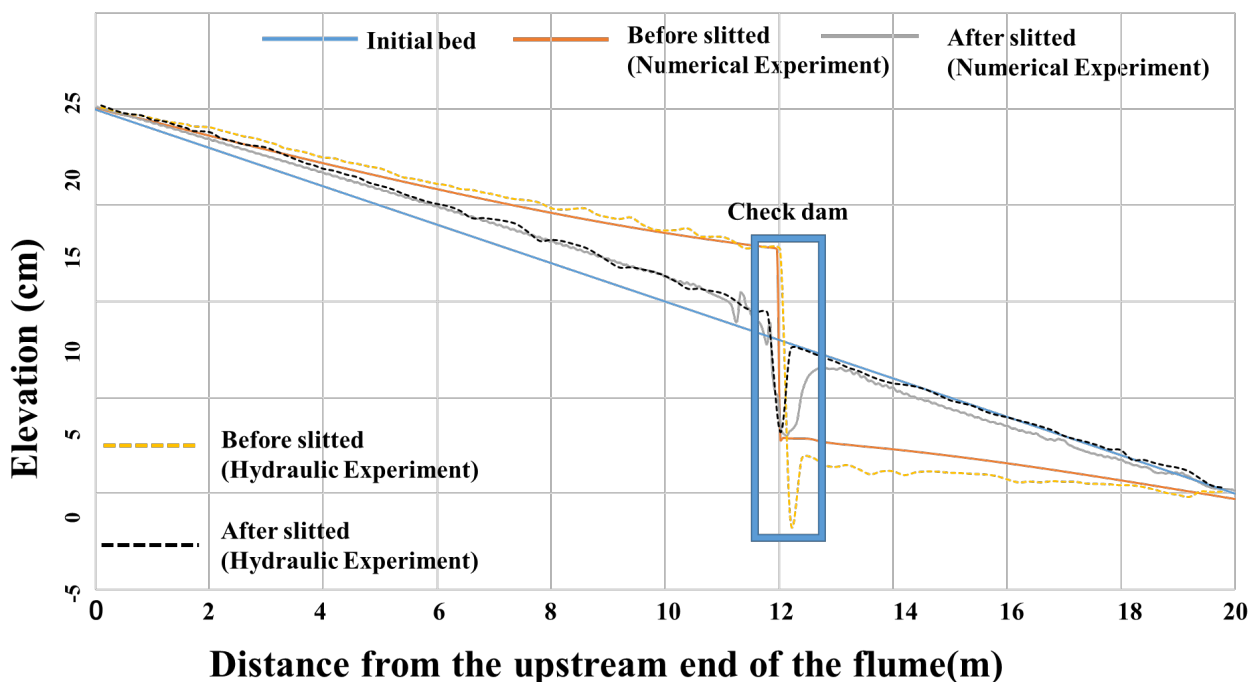


Figure-8 Longitudinal profile of bed elevation (Numerical Experiment)

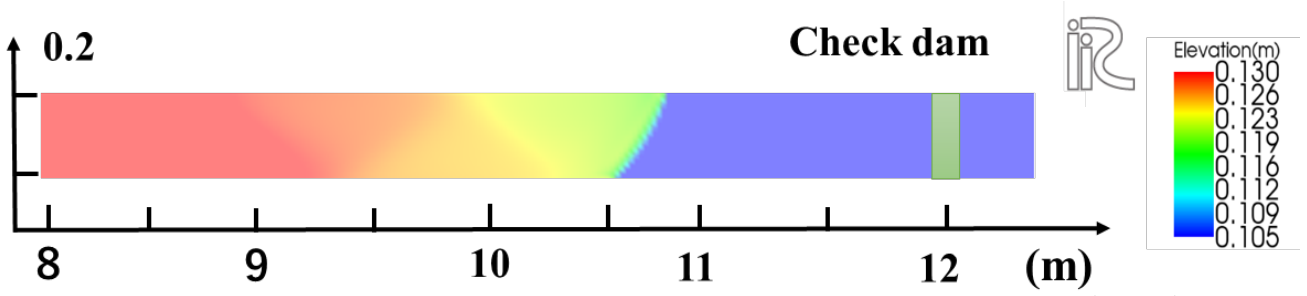


Figure-9(a) Before slit contour map of riverbed at the reach A

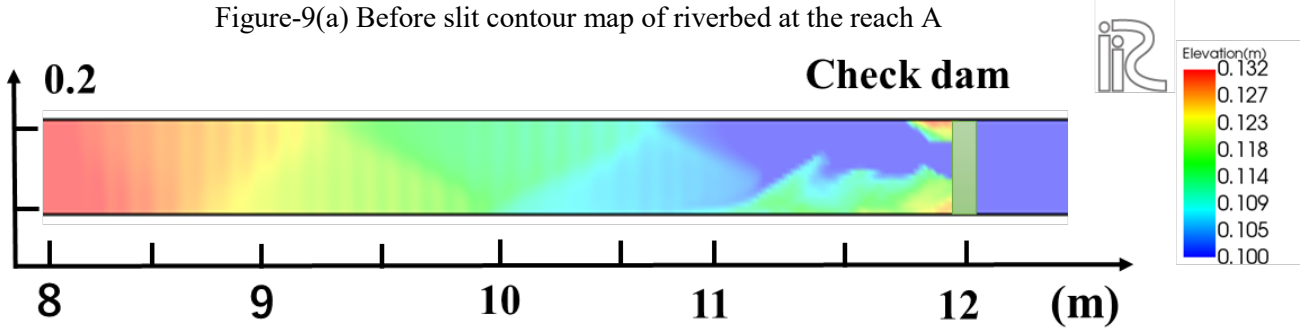


Figure-9(b) After slit contour map of riverbed at the reach A

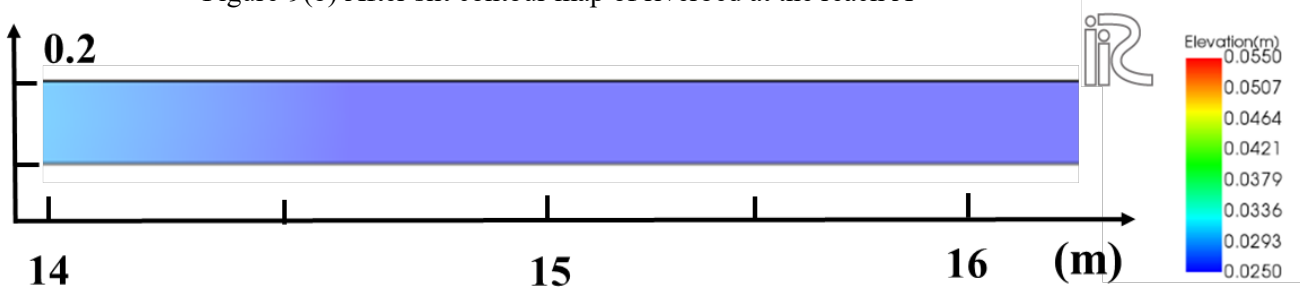


Figure-10(a) Before slit contour map of riverbed at the reach B

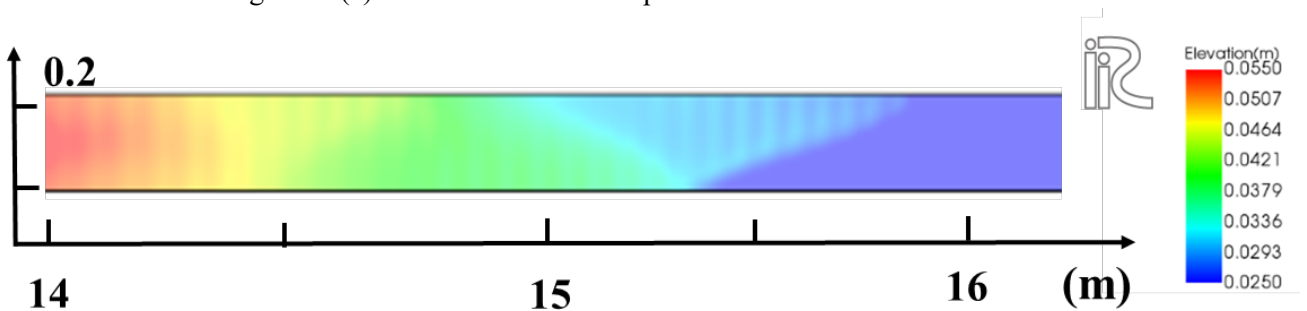


Figure-10(b) After slit contour map of riverbed at the reach B

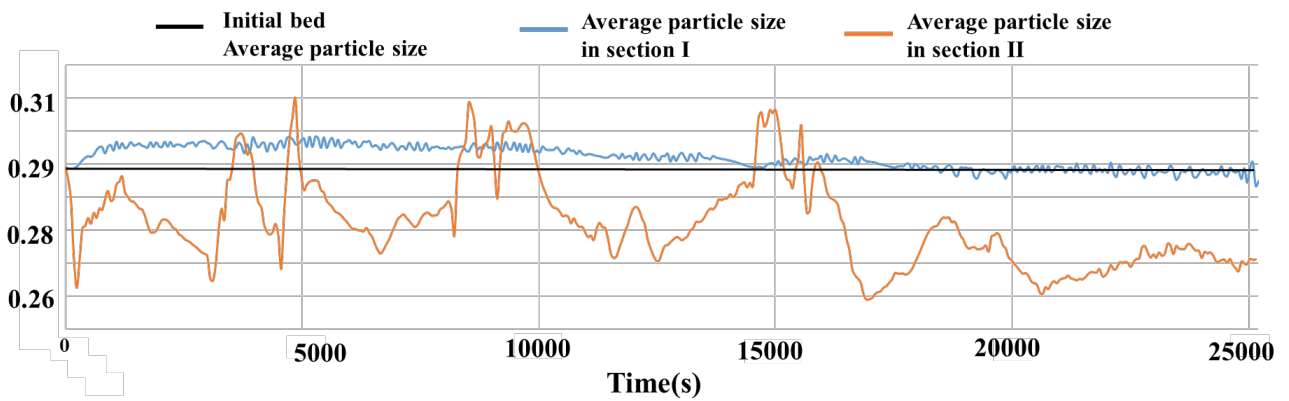


Figure-11 Change in average particle size after slit

Table-3 Wavelength and Wave Height Result (Numerical Experiment)

Numerical Experiment Results				
	Wavelength (cm)	Wave height (mm)	Wavelength (cm)	Wave height (mm)
	The upstream		The downstream	
Before slit	120	9	—	
After slit	160	11	170	18
	Wavelength (cm)		Wave height (mm)	
Not Check dam	180		15	

Table-4 Channel Bed Profile Result (Numerical Experiment)

Numerical Experiment Results			
	Channel Bed Profile		The difference in bed elevation (cm)
	The upstream	The downstream	
Initial bed	1/100	1/100	—
Before slit	1/172	1/296	9.8
After slit	1/104	1/110	2.5

When there is no check dam, the alternate bar has a wavelength of 180 cm and a wave height of 15 mm. Table-3 summarize the changes in the shape of alternate bars. Table-4 summarizes the 1D morphological features. Numerical calculations show the tendency of the experimental results that the bar wavelength form before the slitting of the dam becomes longer due to the slitting of the dam, although the wavelength is slightly shorter than the result of the hydraulic experiment. In addition, it has been reproduced that after the slitting, the wavelength becomes almost the same upstream and downstream of the dam. Regarding the bar height, it seems that the numerical results tend to be slightly lower than the hydraulic experiment results. However, the bar height downstream of the dam after slitting is about twice as high as that of the hydraulic experiment. Thus, no consistent trend is found for the bar height. The reproducibility of the bar formation is considered to be due to the reproducibility of the bed slope and particle size distribution of the bed material.

6. CONCLUSIONS

In this study, hydraulic experiments and numerical experiments on the effect of slitting the check dam were performed. It was found that the results of hydraulic experiments could be reproduced by numerical calculations.

It was found that the bed slope could be returned to the before check dam construction by slit the check dam. However, since the riverbed material deposited upstream of the dam has changed significantly from the original riverbed, the riverbed material upstream and downstream of the dam does not return to its original state even if the dam is slit. Since the bed material does not return to its original state, the sandbar shape does not return to its original state. It is necessary to clarify how long the effect of sediment deposited upstream of the dam will last.

7. REFERENCES

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