Flow characteristics of compound open channel flow with discontinuous flood plain

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1. INTRODUCTION

An embayment is a stagnation area where sediment has accumulated on a dike installed in a river channel. The low flow velocity within the embayment makes it an ideal habitat, breeding and evacuation site for a variety of organisms. In order to conserve the environment inside the embayment, it is necessary to control sedimentation and water circulation. In particular, during a flood, the embayment is submerged and becomes a compound channel flow with discontinuous flood plain, which causes a great change in sedimentation in the embayment. For this purpose, this study clarifies the detailed three-dimensional flow velocity characteristics of the flow field, the spatiotemporal characteristics of the cohenrent structure formed in the flow field, the correlation between the behavior of the cohenrent structure and the flow velocity distribution, and a conceptual model of the flow field.

2. EXPERIMENTAL EQUIPMENT AND EXPERIMENTAL METHOD

In the study, a straight open channel made of a total acrylic resin plate with a length of 10 m, a width of 60 cm and a height of 15 cm is used. A 15 cm wide, 4 cm high, 1cm long board made of PVC resin will be laid on the right side wall of the channel. At that time, a space of 30cm in length is provided at a point 5m from the upstream, and it is used as a notch on the high water floor. An overview of the experimental channel is shown in Figure 1, and the cutout is shown in Figure 2. PTV (Particle Tracking Velocimetry) was adopted for flow velocity measurement. Figure 3 shows the irradiation position of the laser slit light film. Fluorescent dye injection method was used to visualize the internal structure of flow.

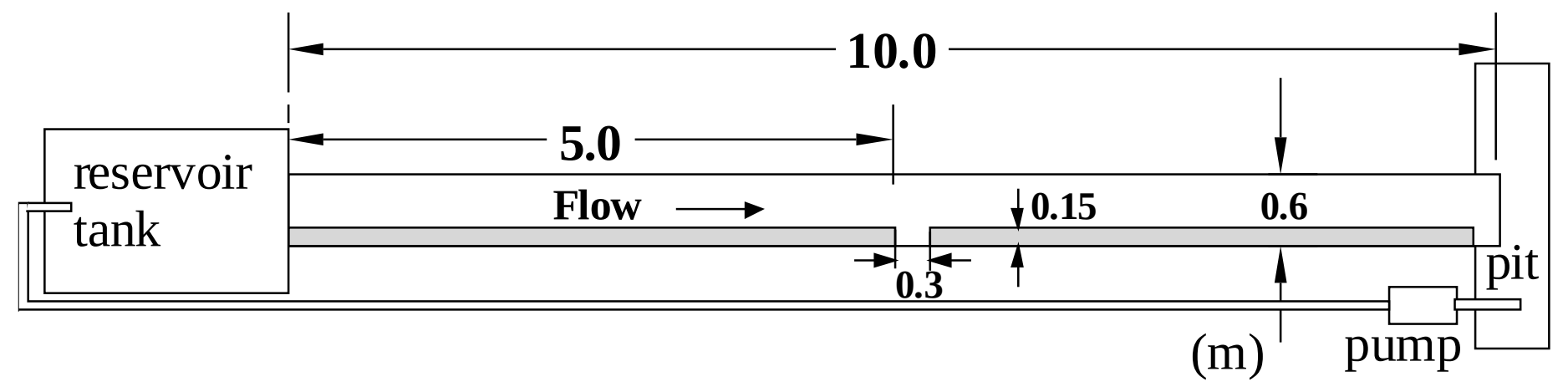


Figure 1. Outline of the test channel

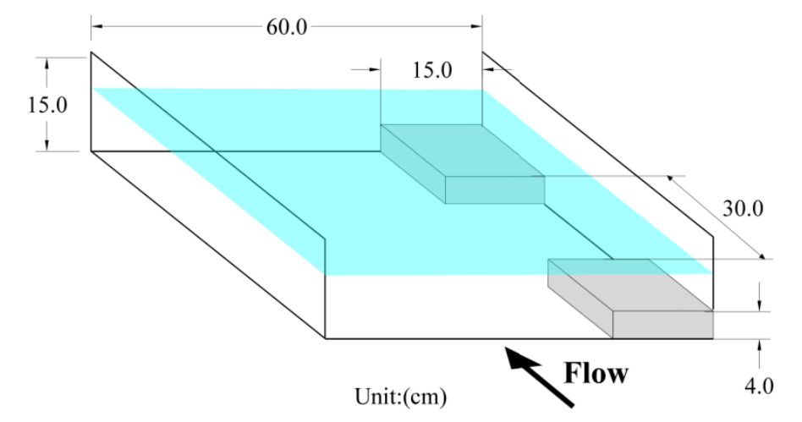


Figure 2. Outline of observation area

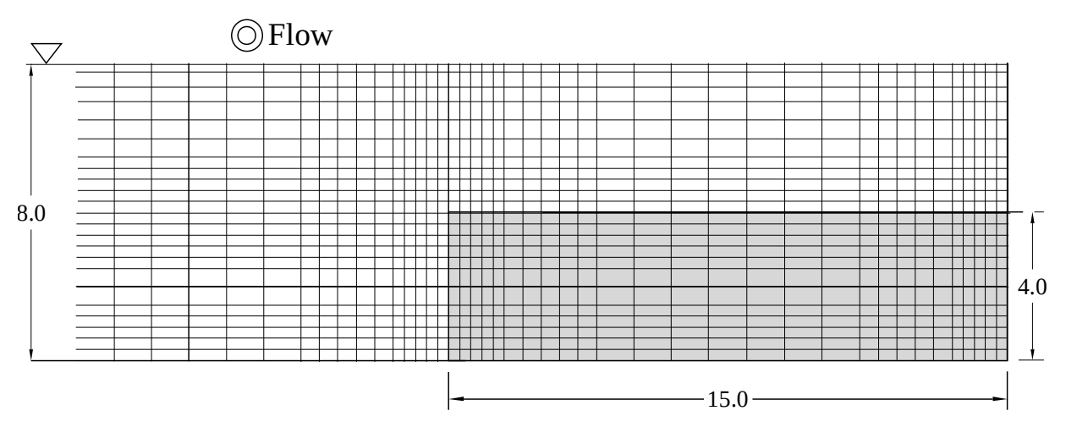
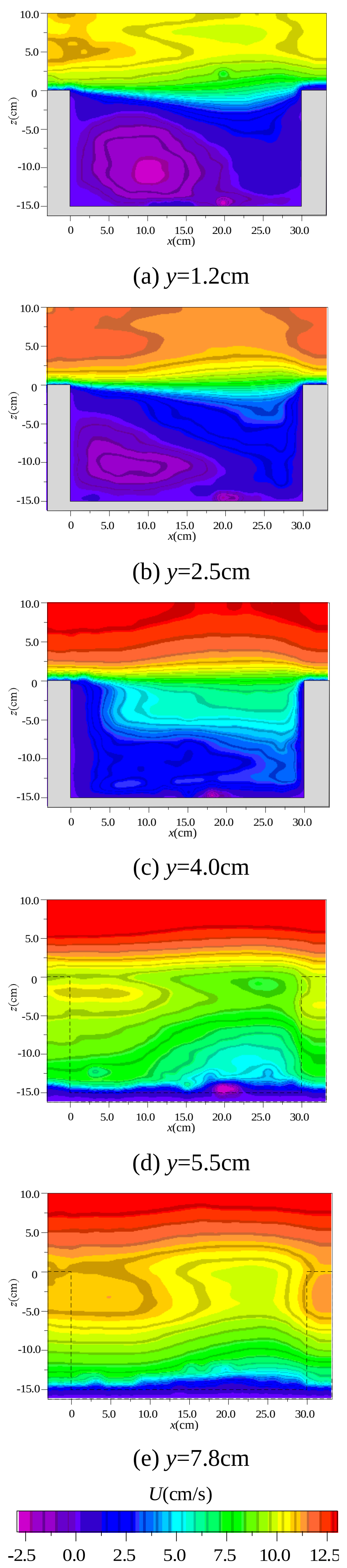


Figure 3. PTV measurement cross section position

3. EXPERIMENTAL RESULTS AND DISCUSSION



(a) *y*=1.2cm

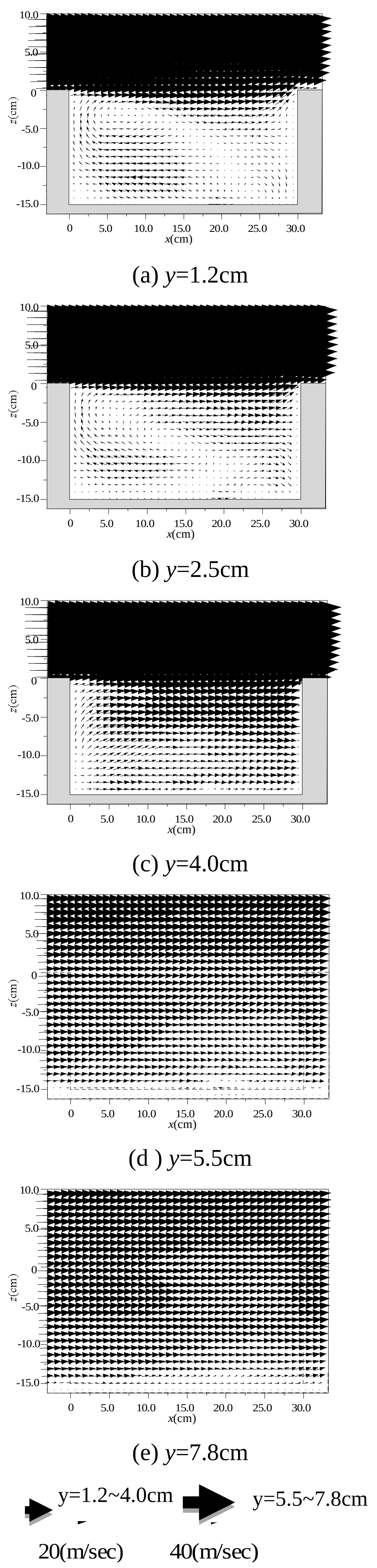
(b) *y*=2.5cm

(c) *y*=4.0cm

(d) *y*=5.5cm

(e) *y*=7.8cm

Figure 4. Average primary velocity distribution (*U*)



(a) *y*=1.2cm

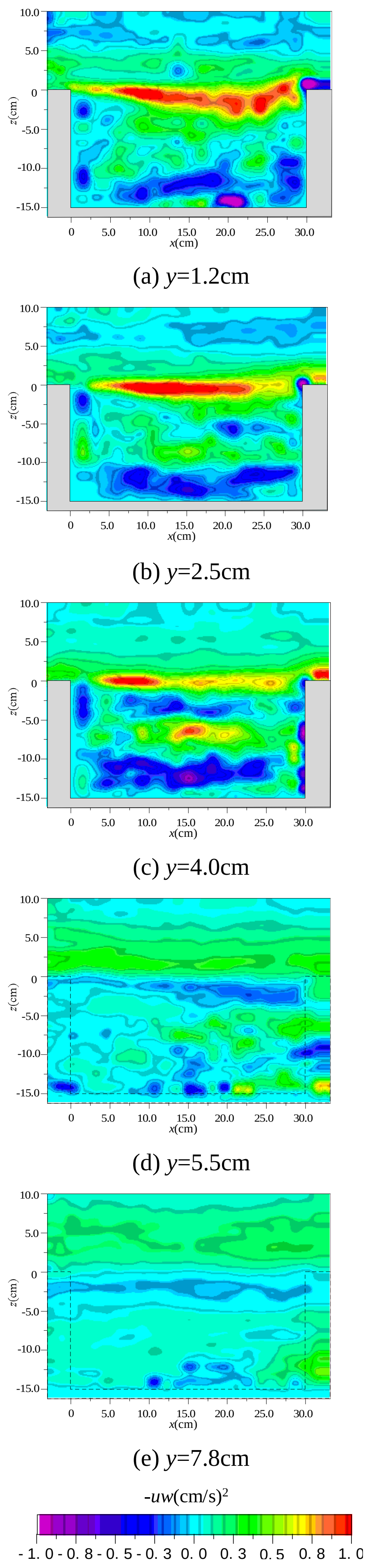
(b) *y*=2.5cm

(c) *y*=4.0cm

(d) *y*=5.5cm

(e) *y*=7.8cm

Fig 5. Flow velocity vector distribution (*U*, *W*)



(a) *y*=1.2cm

(b) *y*=2.5cm

(c) *y*=4.0cm

(d) *y*=5.5cm

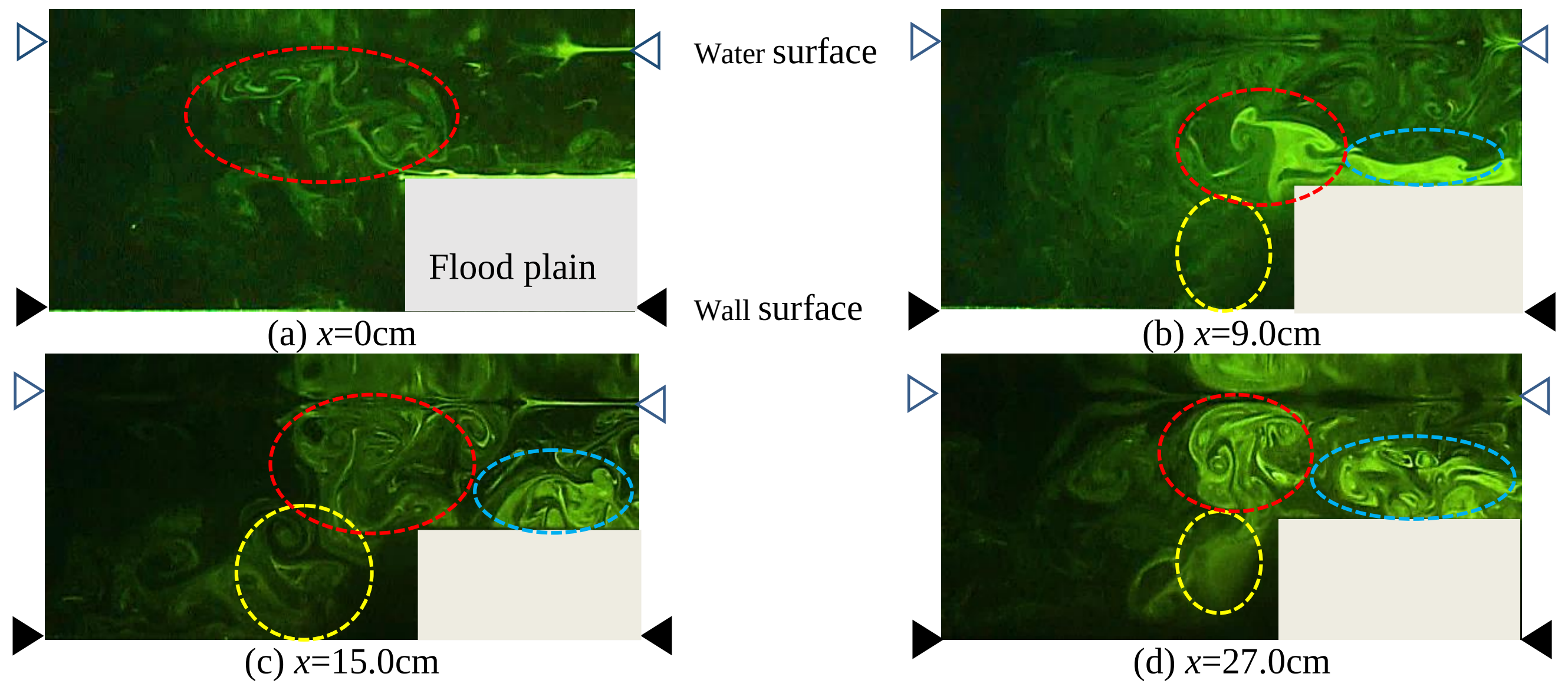
(e) *y*=7.8cm

Fig 6. Reynolds stress distribution (*-uw*)

Figure 4 shows the mean primary velocity distribution (*U*). At y = 1.2 ~ 4.0cm, the inside of the notch of the flood plain is relatively slower than the main stream side, and the backflow occurs near the side wall. At y = 5.5 ~ 7.8cm, it is noticeable that the speed near the downstream end of the notch is low.

Figure 5 shows the velocity vector (*U*, *W*). In the y = 2.5cm, the formation of a swirling flow in the hour hand direction is recognized on the upstream side. disappears.

Figure 6 shows the Reynolds stress (*-uw*). The distribution of positive and negative Reynolds stress is formed in parallel in the boundary region between the notch of y = 5.5cm to 7.8cm and the main channel.



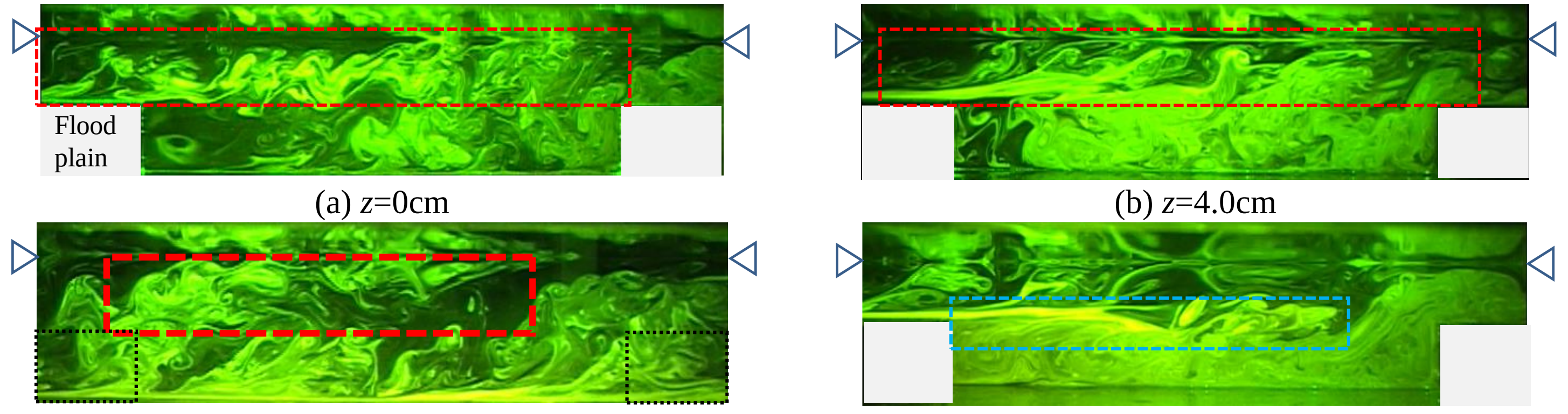
(a) *x*=0cm

(b) *x*=9.0cm

(c) *x*=15.0cm

(d) *x*=27.0cm

Figure 7. Results of cross-sectional view



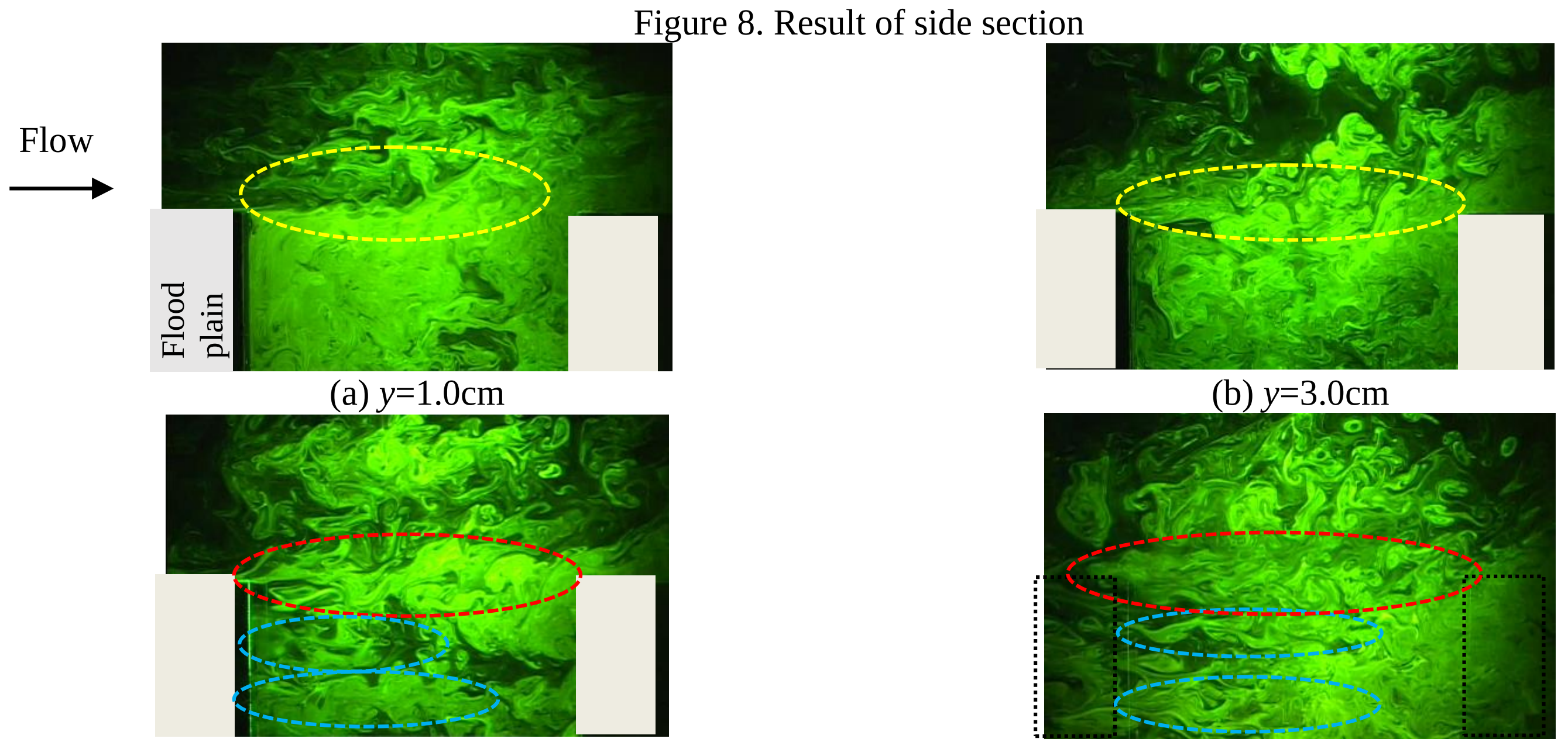
(a) *z*=0cm

(b) *z*=4.0cm

(c) *z*=-4.0cm

(d) *z*=12.0cm

Figure 8. Result of side section



(a) *y*=1.0cm

(b) *y*=3.0cm

(c) *y*=4.0cm

(d) *y*=5.0cm

Fig 9. Horizontal cross-sectional view results

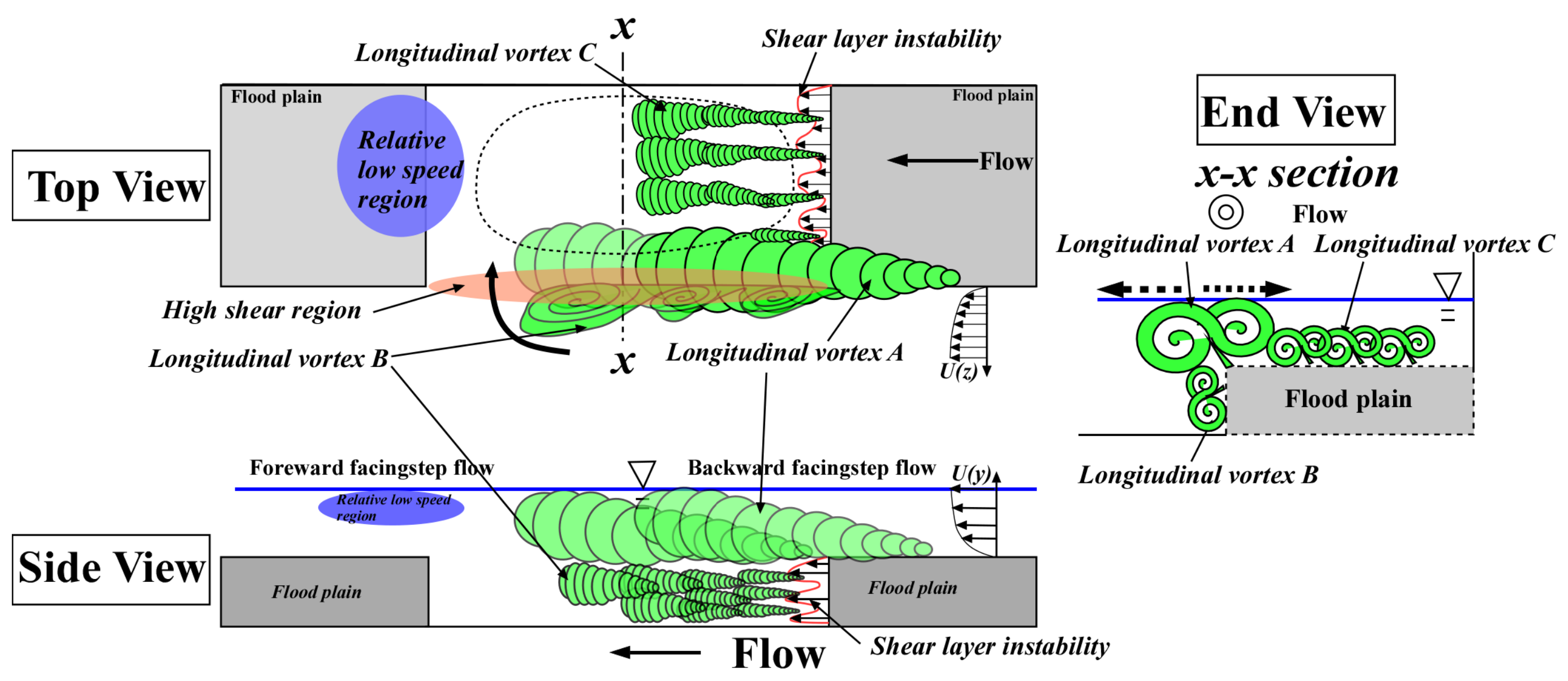


Fig 10. Conceptual model of multi-section flow with discontinuous high water bed

Figures 7, 8, and 9 show the results of horizontal, vertical, and horizontal cross-sections, respectively. The visualization of these flows revealed that three longitudinal vortex structures were formed in this flow field. One is that the longitudinal vortex structure formed at the tip of the flood plain upstream of the notch is also formed at the tip of flood plain at the notch. The cross-sectional views correspond to the areas surrounded by red broken lines in Fig.7,8 and 9, respectively. The second is a group of longitudinal vortices formed downstream of the main channel side wall. This corresponds to the area surrounded by the yellow broken line in Fig.8 and 9. The third is formed downstream from the upstream end of the flood plain. This corresponds to the area surrounded by the blue broken line in Fig. 8 and 9.

Figure 10 shows a conceptual model of a compound open channel flow with a discontinuous flood plain. Longitudinal vortex A is considered to form a positive and negative high Reynolds stress (*-uw*) region of y = 4.0cm or more at the boundary between the notch and the main channel due to fluid transport accompanying vortex motion. Longitudinal vortex B is a group of longitudinal vortices formed by the instability of the separated shear layer downstream of the flood plain and the coexistence of two shear layers. Longitudinal vortex C is a longitudinal vortex structure group formed downstream of the upper surface of the flood plain. It is generated by the coexistence of the two high shear layer $(\frac{\partial u}{\partial y}, \frac{\partial u}{\partial z})$.

4. CONCLUSIONS

(1) A large swirling flow in the direction of the hour hand is formed below the upper surface of the high water bed at the notch. A relatively low-speed region is formed near the downstream end of the notch.

(2) Positive and negative high Reynolds stress (-uw) regions at the boundary between the notch and the low waterway. In addition, a region where the turbulence intensity (urms, wrms) is remarkable is formed near the height of the upper surface of the high water bed.

(3) In this flow field, vertical vortex structures were observed at the tip of the high water bed, downstream of the side of the high water floor, and downstream of the top of the high water floor. It is suggested that the vortex motion of these vertical vortex structures plays an important role in turbulence generation and swirl flow formation.

(4) A conceptual model of the internal structure was shown based on the characteristics of the flow field.

REFERENCES

Watanabe, K., Moriyama, T., Saga, T.(2009). Inner structure of oblique upward flow in one-sided compound open channel flow at low Reynolds number, Journal of Japan Society of Civil Engineers Ser.B1, Hydraulic engineeringVol.67, No.2, pp.41-53.