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Physical Condition in Wandoat Right Bank of the Kako River Mouth, Japan

PHYSICAL CONDITION IN WANDO AT RIGHT BANK OF THE KAKO RIVER MOUTH, JAPAN

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ABSTRACT

Wando is a semi-closed water area which is different from the hydraulic characteristics of the river. It served as a spawning place and nursery ground of fish juveniles. However, the dead water zone like *Wando* decreased by the river improvement works. As a result, habitat environment of the aquatic organisms is threatened, especially in urban area. Maintenance and creation of *Wando* is working in various regions of Japan now. It is necessary to comprehend physical conditions such as wind, tidal current and salinity field. In this study, field observations were carried out to understand physical conditions of *Wando*. Study site is at the right bank of the Kako River mouth. The change of salinity of pore water at a depth of 50cm was not able to be confirmed neither in the river nor in *Wando*. However, salinity just below the river bed has decreased by the rain. On the other hand, the change of salinity was not confirmed in *Wando*. As a result, it has been understood that the *Wando* forms steady salinity field.

1. INTRODUCTION

Wando is a semi-closed water area which is different from the hydraulic characteristics of the river. It served as spawning place and nursery ground of fish juveniles. However, the dead water zone like *Wando* decreased by the river improvement works. As a result, habitat environment of the aquatic organisms are threatened, especially in urban area. Recently, maintenance and creation of *Wando* is working in various regions of Japan. It is necessary to comprehend physical conditions such as wind, tidal current and salinity field.

In this study, field observations were carried out to understand physical conditions of *Wando*. Study site is the river mouth of the Kako River (Figure 1). The Kako River is the biggest river in Hyogo Prefecture, Japan. Its length is 96 km and its basin area is 1,730 square km. In the river mouth, a huge *Wand* is formed at the right side bank and it is the venerated sanctuary for many organisms, such as *Uca Lactea* (a kind of fiddler crab) and snipe.

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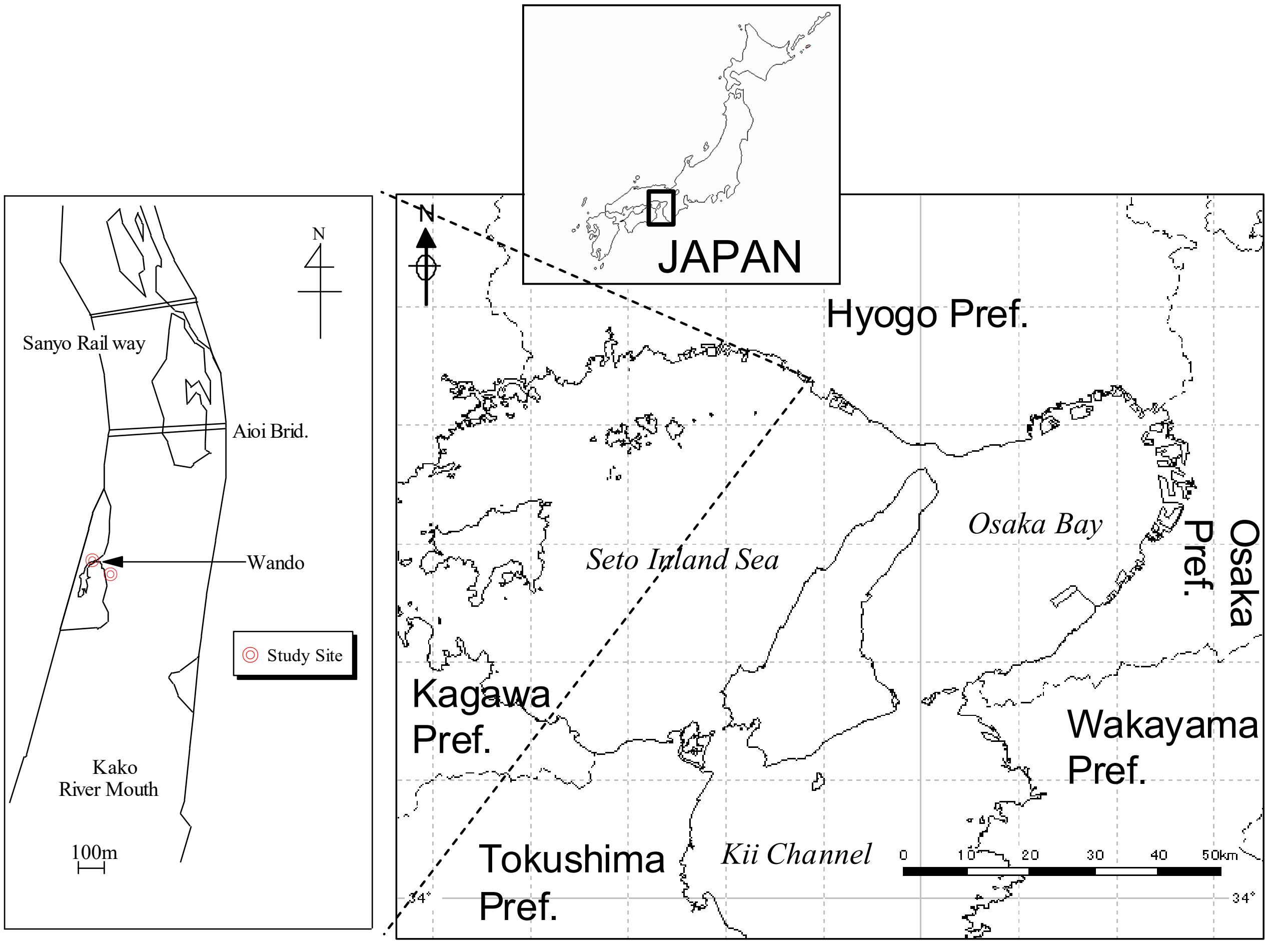

Figure 1 Study Site (Kako River Mouth)

2. MATERIAL AND METHODS

2.1 Continuous monitoring

To grasp the water level change and the behavior of salinity in pore water, the observation well was placed in both *Wand* and main stream in Kako River, respectively.
Simultaneously, to confirm the behavior of salinity immediately above mud in *Wand*, the salt meter was directly buried into the mud. Each measurement was started just after 1 hour later from setting.
Figure 2 shows the outline drawing of observation well. It has multiple small pores at the head of well and ground water can easily move in and out the well. To prevent invasion of mud and soil, the screening was put in the well.

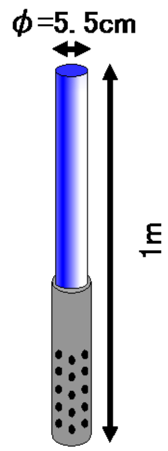

Figure 2 Observation well

2.2 Intensive Observation

To grasp the current field and the inflow and outflow of brackish water in *Wando*, intensive observations at *Wando* were carried out. Observation term was from one neap tide to the next. The measurement items were the current velocity on the channel connected between *Wand* and main stream in Kako River, the water level and salinity in both *Wand* and main stream in Kako River and the wave height in main stream. As for salinity, it was measured near water surface and just above the ground, respectively. Figure 3 shows the installation location of observation equipment and Table 1 shows the list of measurement device. The measurement interval of current velocity, water level, salinity and wave height were 0.5 sec, 1.0 sec, 1.0 sec and 0.25 sec, respectively. Moreover, during the intensive observation, the wind speed and wind direction at 10m above *Wando* was measured every 1 second. In this field observation, to avoid influence on the human disturbance, the observation started 1hour later form setting the equipments.

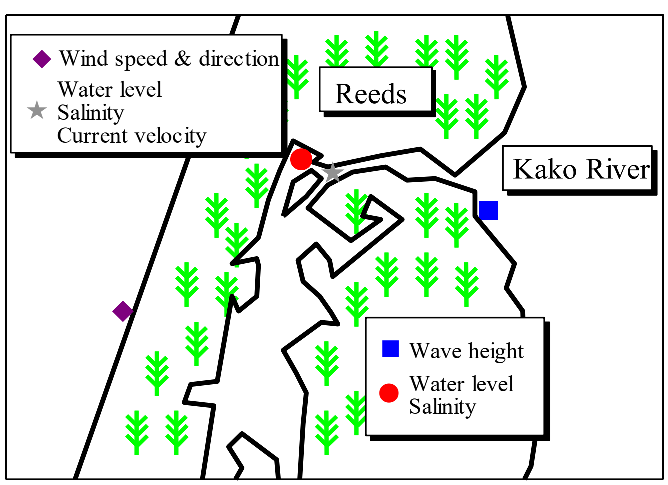

Figure 3 Installation location of observation equipments

Table 1 Measuring device

Measurement Item	Measuring device
Water level	HOBO U20 (Onset Co.)
Salinity (Water temperature)	COMPACT-CT (JFE ALEC Co.)
Current velocity	INFINITY-EM (JFE ALEC Co.)
Wind direction & speed	KADEC21 (North One Co.)
Surface flow	GPSmap 60CSx (Garmin)
Wave height	COMPACT-WH (JFE ALEC Co.)

3. RESULTS AND DISCUSSIONS

3.1 Sediment property

Table 2 shows sediment property of Kako River and *Wando*, respectively. The median grain size, uniformity coefficient and selection one were obtained from the result of the grain size test (JIS A 1204). On the other hand, the coefficient of water permeability was calculated from the result of constant head permeability test (JIS A 1218). As to the median grain size (D_{50}), we can see a big difference between Kako River and *Wando*. From the uniformity coefficient and selection one, bed material at Kako River tends to make homogeneous. On the other hand, from the results of those soil tests, we can see the sediment at *Wando* makes inhomogeneous. Moreover, the coefficient of water permeability at *Wando* indicates much smaller than that of Kako River.

Table 2 Sediment property

	Kako River	Wando
Median grain size D_{50}(mm)	0.24	0.041
Uniformity coefficient Uc	3.11	17.86
Selection coefficient S_0	1.54	2.17
Coefficient of water permeability k(cm/s)	2.5×10^{-2}	2.86×10^{-4}

3.2 Continuous monitoring

Figure 4 shows the time series of salinity from July 10 to 24, 2009. The water level at Aiya which is located 1.5 km upstream from the river mouth was measured by Ministry of Land, Infrastructure, Transport and Tourism.

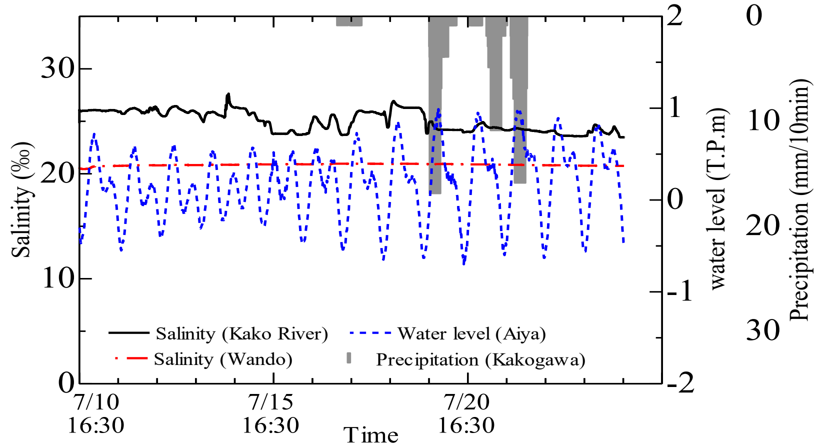

Figure 4 Time series of salinity
(2009/07/10-2009/07/24)

From July 17 to 22, 2009, in spite of confirming the rainfall, the salinity in the observation well at *Wando* kept the constant value. On the other hand, the salinity in the observation well at Kako River also kept the constant value. Therefore, the normal rainfall makes little impact on the behavior of salinity in both *Wando* and pore water in the river bed of Kako River.

Next, to discuss the behavior of salinity in *Wando* more closely, the equipment was buried into the surface layer at *Wando*. Figure 5 shows the time series of salinity from August 6 to 11, 2009. From August 8 to 11, 2009, we confirmed the rainfall, the salinity in the observation well at Kako River slightly decreased. However, the salinity in the observation well at *Wando* kept the constant value.

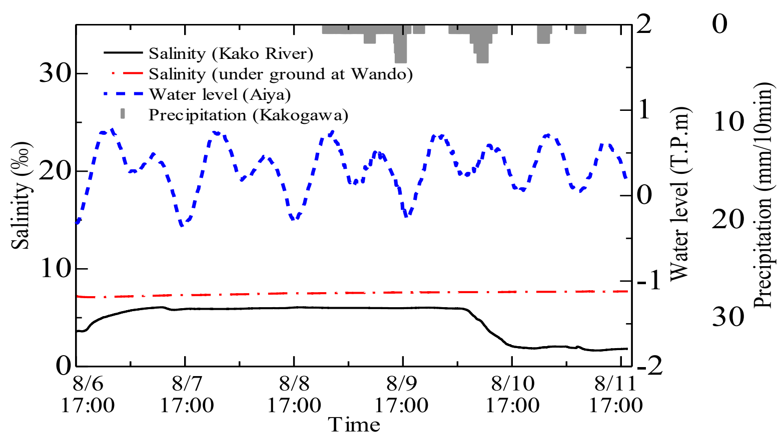

Figure 5 Time series of salinity
(2009/08/6-2009/08/11)

In Table 2, we had confirmed the coefficient of water permeability at *Wando* indicates much smaller than that of Kako River. Therefore, we can conclude the salinity of pore water at *Wando* has been extremely-stable.

Figure 6 shows the time series of water and soil temperature from August 6 to 11, 2009. At *Wando*, the daily range was from 3 to 4 centigrade. On the other hand, at Kako River, it was from only 1 to 2 centigrade. The water temperature at Kako River is more stable than at *Wando*. Water temperature at both the Kako River and *Wando* tends to reach a maximum value at low tide and decrease with the elevation of water surface. This means the behavior of water temperature is affected by tidal fluctuation. The ground elevation of the Kako River is lower than that of *Wando*, therefore, dry up time at the Kako River was short and the variation of water temperature was small. At rainy weather, heating the ground at low tide is not enough, therefore, there is no difference of water temperature variation between Kako River and Wand.

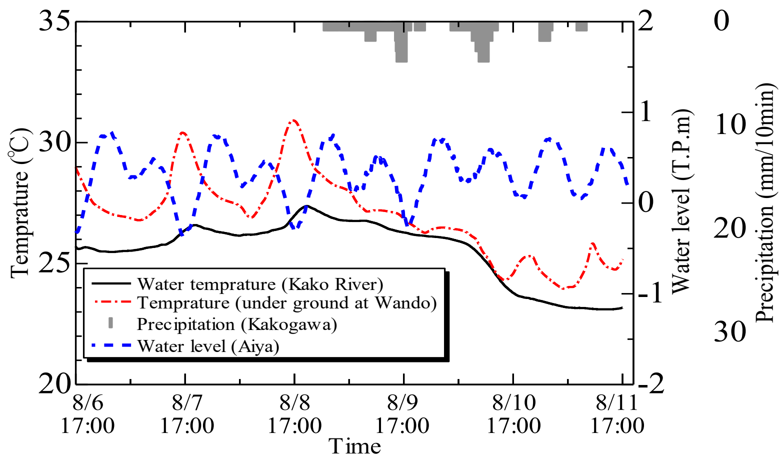

Figure 6 Time series of water and soil temperature
(2009/08/6-2009/08/11)

3.3 Intensive Observation

Figure 7 and Figure 8 show the behavior of Salinity, August 29 and September 11, 2011, respectively. We can see the coupled movement of salinity and water level and the ingress of tidal current into *Wando* on both days. In enlarged view shown in Figure 8, salinity slightly decreased around 13:00, September 11. The difference of salinity between the surface layer and the bottom one on the water-route was remarkable. It seem that high salinity water remained the pool at *Wando* provide to water-route. On the other hand, on August 29, there was no difference of salinity between the surface layer and the bottom shown in Figure 7.

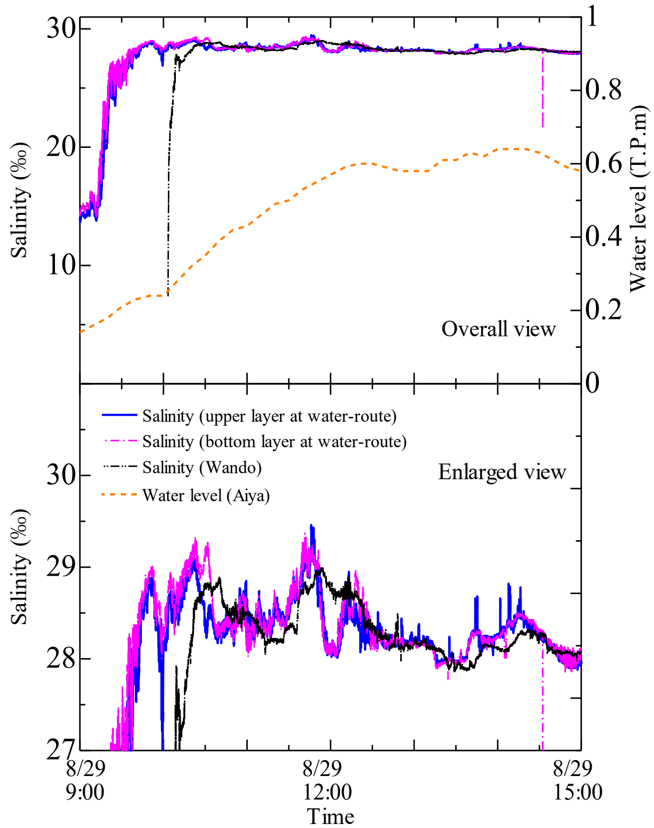

Figure 7 Salinity behavior (2009/08/29)

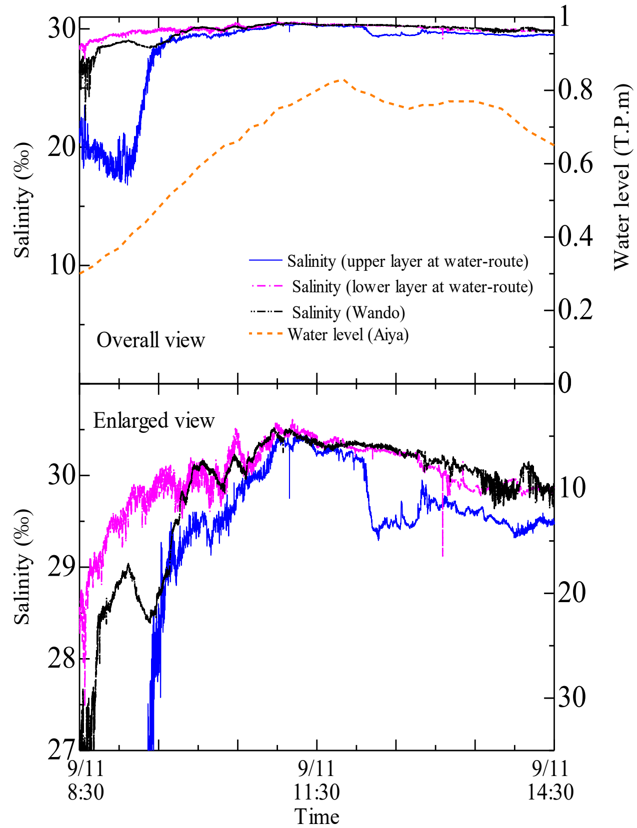

Figure 8 Salinity behavior (2009/09/11)

Figure 9 shows the track of float. On August 29, at first, the float stay one place, however, after around 14:45 the float moved into *Wando* and remained there at ebb tide. On the other hand, the float moved into *Wando* at flood tide and it remains there at ebb tide. Therefore, in spite of ebb tide, the float moved into Wand tends to stay there.

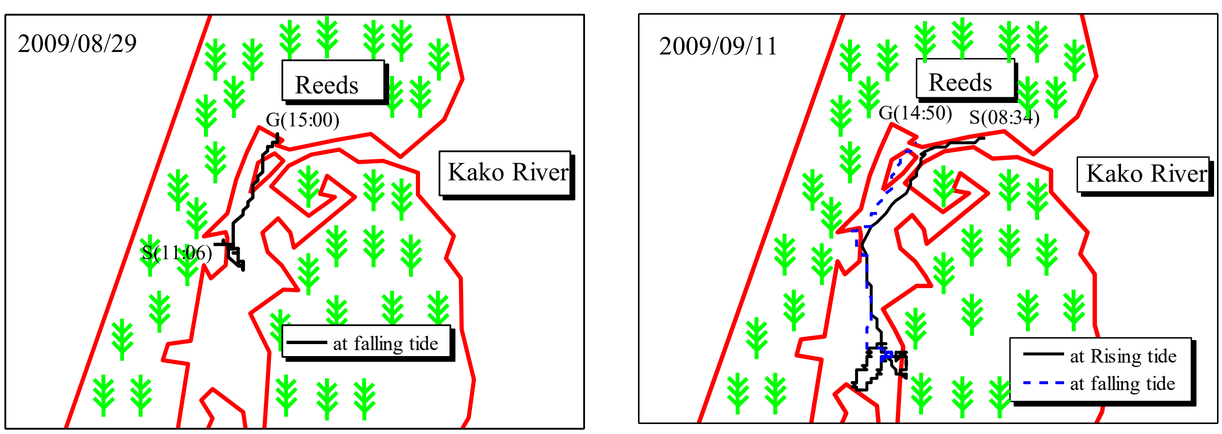

Figure 9 Track of float
(Left: 2009/08/29, Right: 2009/0911)

Figure 10 shows the time series of velocity on the water-route. On both August 29 and September 11, 2010, the velocity reached about 45 cm/s on the way to raising tide and decreased around flood tide.

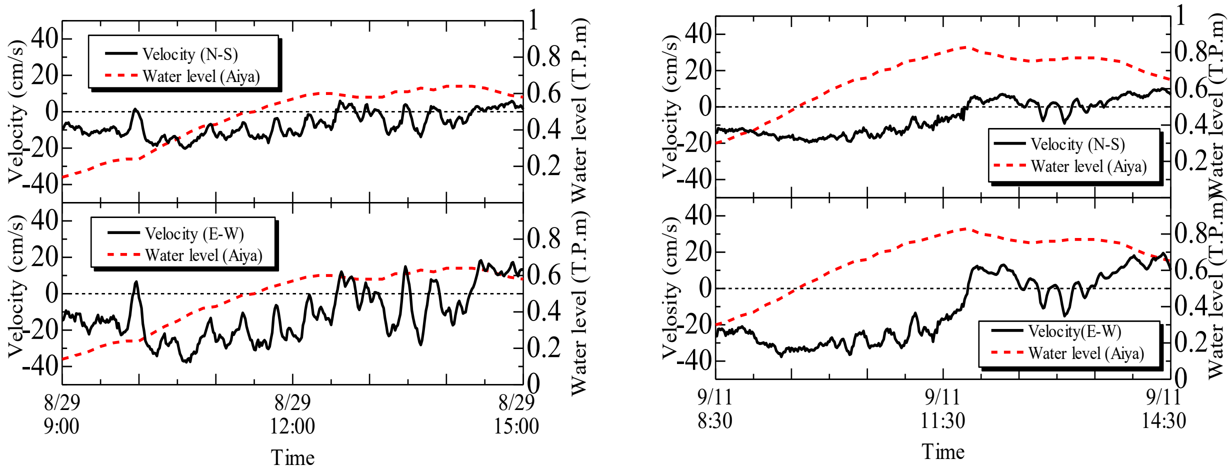

Figure 10 Time series of current velocity on the water-route
(Above: 2009/08/29, Below: 2009/0911)

Figure 11 shows the time series of velocity on December 14, 2008 at *Wando*. Compared with Figure 10, the velocity was extremely small and its maximum value was about 7 cm/s. The tidal level change on December 14 is larger than on both August 29 and September 11, 2010. From such tidal change, the velocity at *Wando* is enormously smaller than at water-route.

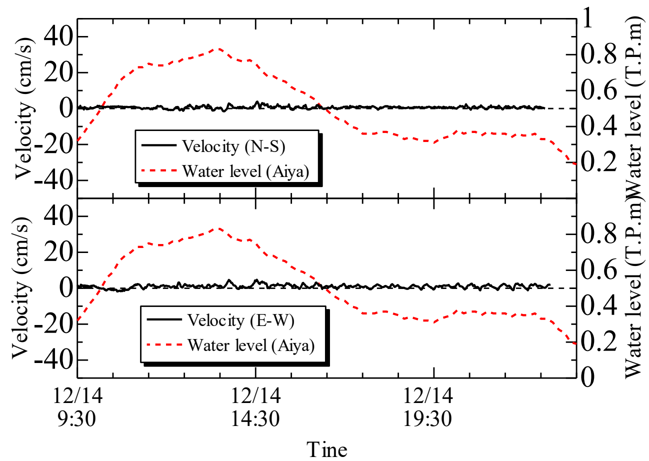

Figure 11 Time series of current velocity at *Wando*

Figure 12 shows hourly variation of velocity on the water-route on both August 29 and September 11, 2010. At the raising tide, the velocity of southwest direction stood out. However, around flood tide, we could not find out specified direction. At falling tide, the current from *Wando* to Kako River tends to distinguish.

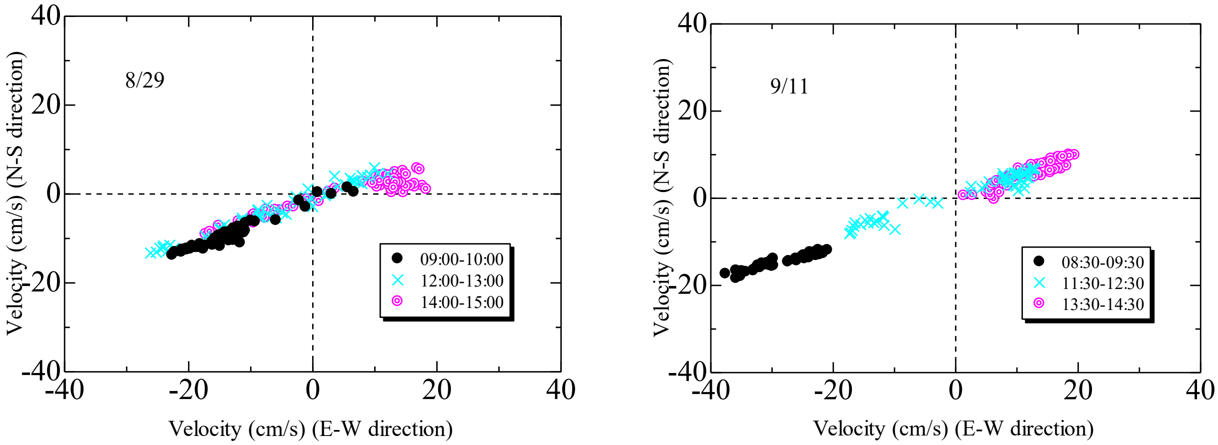

Figure 12 Hourly variation of velocity on the water-route
(Left: 2009/08/29, Right: 2009/0911)

Figure 13 shows the result of spectral analysis. The dominant frequency was from 0.25 to 0.30 Hz, namely, the wave period was estimated from 3 to 4 second. It is classified as the wind wave. Therefore, it was confirmed the wave from sea might progress into the river mouth.

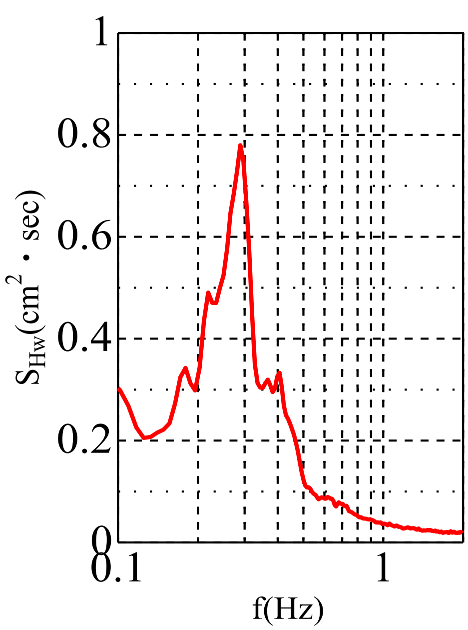

Figure 13 Result of spectral analysis

4. CONCLUSION

In this study, the physical condition of *Wando* which is dead-water zone formed river side was clarified by field observation. Obtained findings are as follows;

1. The pore water in *Wando* has been stable in spite of the existence of rainfall and tidal current.
2. The buoy moved to the closed-off section of *Wando* in rising tide and it tended to stay there.

3. It is clarified the *Wando* forms steady salinity and current field.

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