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Observation on Behavior of Flowing Diriftwoods around Bridge Pier

OBSERVATION ON BEHAVIOR OF FLOWING DIRIFTWOODS AROUND BRIDGE PIER

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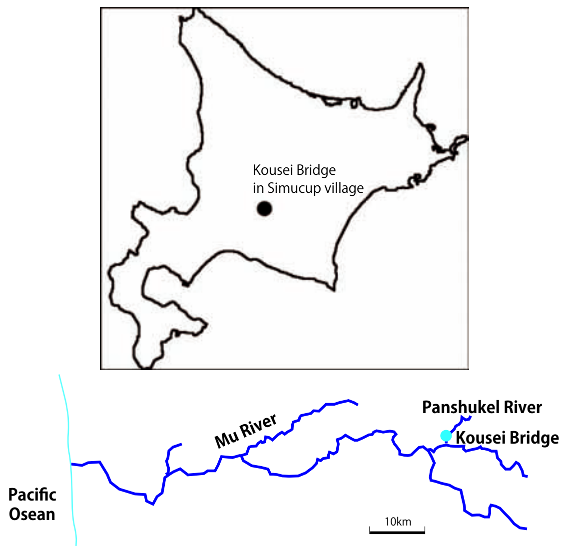
ABSTRACT

It is very important to recognize the behavior of driftwoods for taking measure to prevent destruction of river structure and over flowing bridge area. Because of heavy rains or flowing in melting water of snow in spring season, soft ground slope of mountain or shore of river or sandbanks are collapsed or scraped off. Then the trees in these area flow into the river and become driftwood. We tried to know the behavior of driftwood around the pier under flood condition using remote-controlled surveillance camera at Kouseihashi-bridge in Shimukappu village in Hokkaido. In this observation at high water level flow we get many pictures of colliding driftwood with pier and behavior of flowing driftwood in the river.

Key Words : *Driftwood, field observation, bridge pier, disaster, surveil lance camea system*

1. INTRODUCTION

Flooding due to heavy rain and snowmelt tends to cause slope erosion or collapse, bank erosion and sandbar destruction, resulting in trees on mountainsides, sandbars and riversides sliding into the water. These trees become driftwood and accumulate around bridge piers and intake facilities, often causing extremely hazardous situations including afflux and the loss of bridge piers, and causing a severe hazard to human activity. To prevent disasters related to this phenomenon, it is necessary to clarify the mechanism of driftwood accumulation. This research aims to clarify the behavior of driftwood around a bridge pier using a surveillance camera to ascertain how wood flows in the river and accumulates around the pier at the time of flooding.

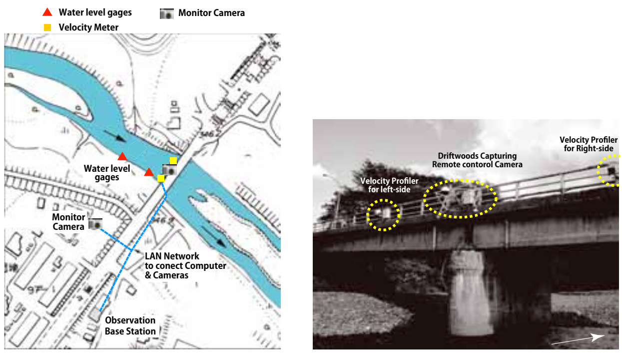


Fig–1 Research location, River basin and monitoring site

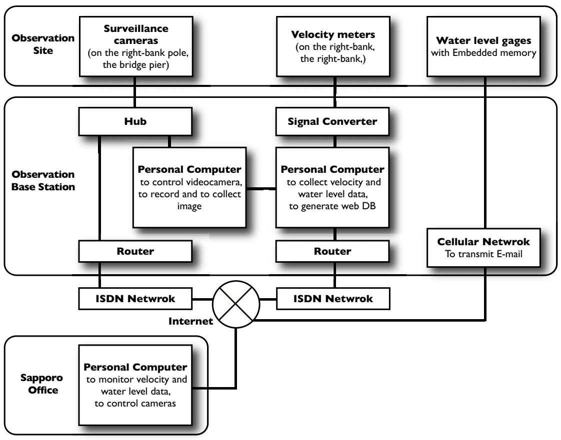
2. SUMMARY OF MONITORING SYSTEM

2.1 Monitoring Site

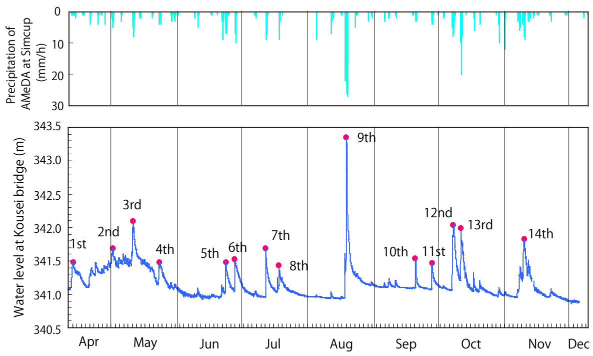
To effectively monitor driftwood that accumulates around bridge piers, it was necessary to choose a small- or medium-scale river with a bridge supported by a pier in the middle of the river channel. To this end, the monitoring was conducted in the Pankeshuru River (**Fig–1**), a tributary of the first-grade Mukawa River that has a rehabilitated bridge where the accumulation of driftwood had been observed in the past. The Pankeshuru River with its rehabilitated bridge is not a long body of water, measuring just 12.4 km in total channel length and 73 km2 in basin area. It flows into the Mukawa River at Shimukappu Village in Hokkaido's Yufutsu District. The rehabilitated bridge was located 300 meters upstream from the confluence of the Mukawa and Pankeshuru rivers. This structure of approximately 60 meters in length has a 1.8-meter-wide pier at its center that stands in the middle of the river channel.



Fig–2 Placement of on-site monitoring devices



Fig–3 Communication line structure of the system for monitoring driftwood around the bridge pier



Fig–4 Rainfall and water level conditions observed in 2006

2.2 Placement Of On-Site Monitoring Devices

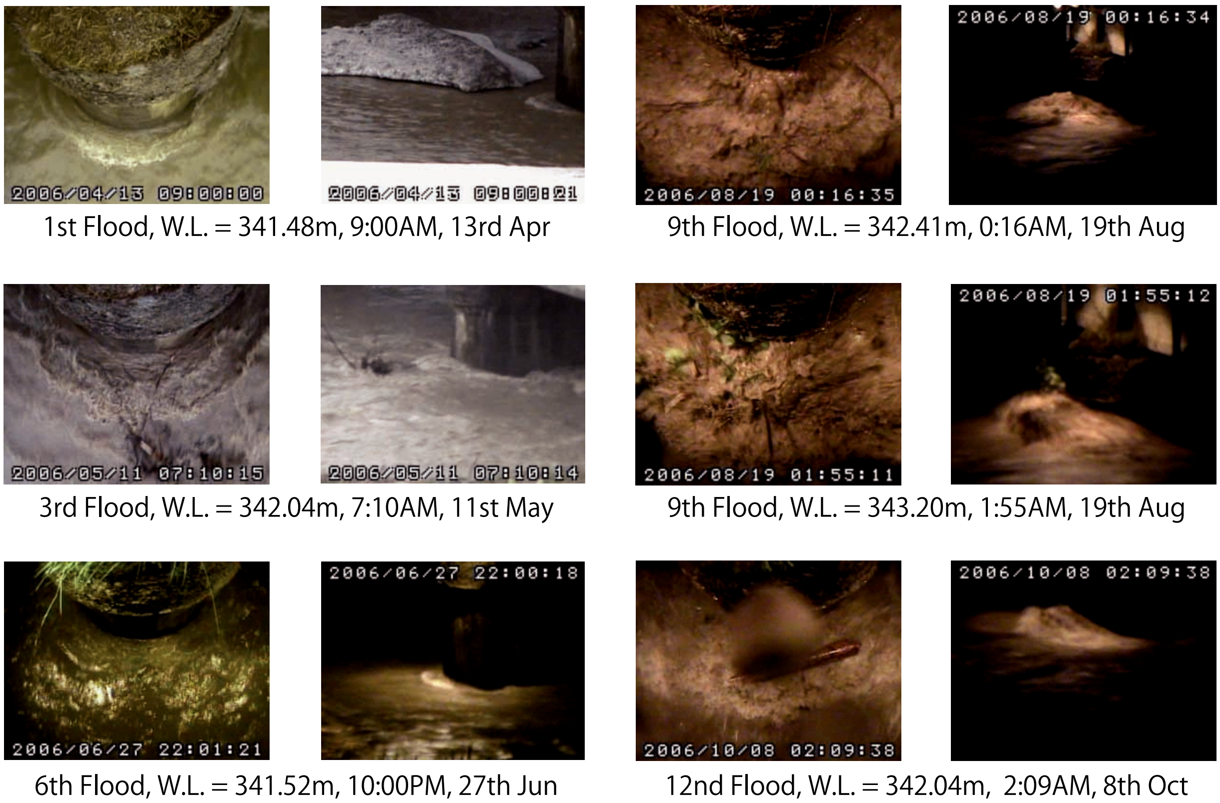
To monitor the flowing driftwood, two monitoring camera systems (Canon, 26 x optical zoom, vertical 0 to 90 degrees, horizontal 340 degrees), each equipped with an internal KES server and stored in a simple waterproof dust-tight container, were placed directly above the bridge pier and on a 10-meter-high pole inside the right-bank dike, respectively.

Table–1 Flooding event in 2006

Flood	Water level at the Kousei Bridge (Unit: m)	Date at Max. Water level	Causes
1st	341.48	9:00AM, 13rd Apr.	Snowmelt, Rain
2nd	341.69	8:00PM, 1st May	Snowmelt, Rain
3rd	342.09	8:00AM, 11th May	Snowmelt, Rain
4th	341.48	8:00PM, 23rd May	Snowmelt, Rain
5th	341.48	6:00PM, 23rd Jun.	Rain
6th	341.52	10:00PM, 27th Jun.	Rain
7th	341.69	10:00AM, 12nd Jul.	Rain
8th	341.43	1:00PM, 18th Jul.	Rain
9th	343.35	4:00AM, 19th Aug.	Rain
10th	341.53	10:00AM, 20th Sep.	Rain
11th	341.46	2:00AM, 28th Sep.	Rain
12th	342.04	2:00AM, 8th Oct.	Rain
13th	341.99	1:00PM, 11st Oct.	Rain
14th	341.82	4:00AM, 10th Nov.	Rain

The following devices were placed to obtain continuous hydrological data. For flow velocity measurement, two low-power microwave velocity meters (MWH-17, Asia Kaientai Inc.) were installed, one on each side of the bridge, with the pier inbetween. To monitor the water level, hydraulic water gauges were placed on the upstream side of the bridge at intervals of 20 meters longitudinally. One of these gauges was equipped with a function to send measurement data via e-mail. The map in **Fig–2** outlines the placement of these devices at the monitoring site, and the photo in **Fig–2** shows a photo of the bridge after their installation.

As shown in **Fig–3**, monitoring data were transmitted through the LAN cable from the monitoring devices to PCs, which were installed at the on-site observation station to manage video images, control surveillance cameras, compute velocity data and create web databases. These PCs were connected to the Internet through an NTT ISDN line. The data for the normal water gauge was sent directly to a web database via e-mail. A system was developed to monitor the on-site conditions from the Sapporo observation station by viewing web databases that showed static images and hydrological data from the monitoring site every 10 minutes. Operation of the on-site surveillance cameras and checking of the live images were conducted via



Fig–5 Example of captured images of driftwoods in flood events of 2006

the Internet using special software. These cameras were remote-controlled both from the on-site station using PCs for image control and from the Sapporo station using monitoring PCs. The surveillance camera images were stored on expanded PC hard discs at the on-site station due to the limited capacity of the communications lines.

2.3 Driftwood Monitoring Method

In this driftwood monitoring system, the web databases were monitored daily at the Sapporo observation station. The images from surveillance cameras were recorded over the previous data every three days, excluding flood periods. During floods, the recording was switched to a continuous mode, and the two cameras were angled to show the area around the bridge pier. These operations were remote-controlled from the Sapporo observation station. The recorded images were collected, and new footage was set after the flooding event. The collected data were sent back to the Sapporo station, reviewed using special software for picture reproduction, and stored as flood image data.

Table–2 Results of research on the amount of driftwood accumulation (conducted on September 15)

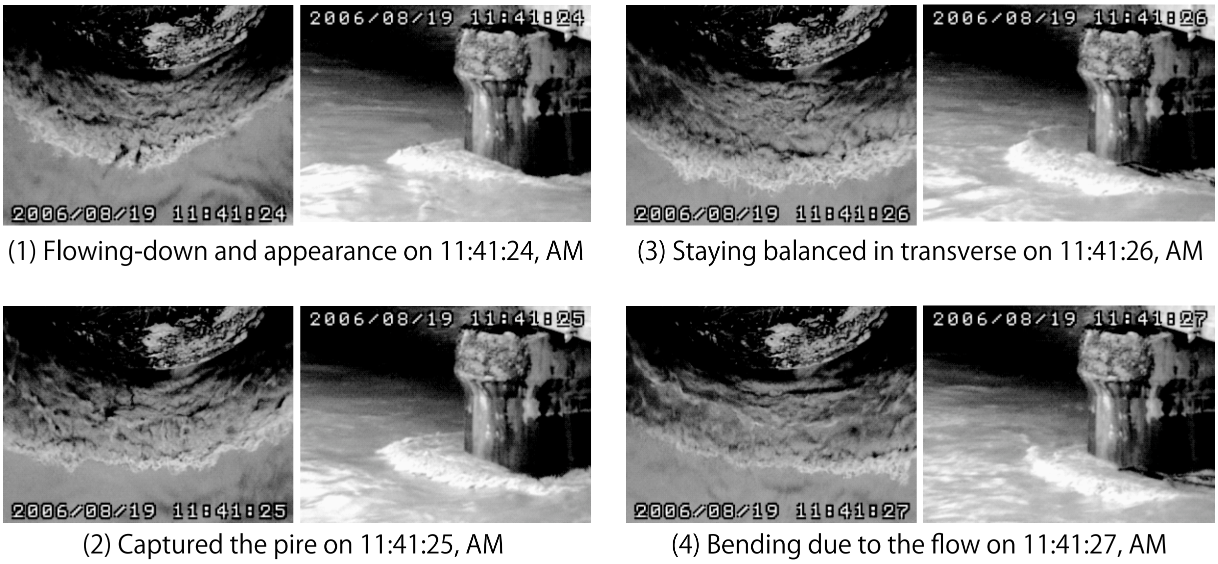
	Type of wood	Total Length (m)	Diameter at center of tree(m)	Remarks
No.1	Willow	9.5	0.04	With leaves
No.2	Willow	6.0	0.02	With leaves
No.3	Willow	7.2	0.04	With leaves
No.4	Unknown	1.2	0.05	Old tree (partly buried in soil)

2.4 Other Surveys

In addition to driftwood observation, the flow discharge was also monitored during floods caused by relatively large-scale rainfalls, and changes in river-channel morphology were examined through cross-section measuring. When driftwood accumulated around the bridge pier, the tree species and sizes involved, as well as the specific location of accumulation, were also examined.

3. RESULTS

On-site observation using this monitoring system was conducted for eight months from mid-



Fig–9 Trees observed around the bridge pier after flood due to snowmelt (right: an image observed at the Sapporo station; left: a close-up of the image)

Table–3 Number of pieces of driftwood and route of flow on the river

	11th May Flood	19th Aug. Flood	8th Oct. Flood
Time at Max. Water level	9:00AM, 11th May	4:00AM, 19th Aug.	3:00AM, 8th Oct.
Max. Water level (m)	342.09	343.35	342.04
Max. Dsicharge (m^3/s)	56.98	174.96	34.54
Measurement Start Time	1:00PM, 10th May	5:00AM, 18th Aug.	10:00AM, 7th Oct.
Measurement Completion Time	4:00PM, 12th May	4:00AM, 20th Aug.	4:00PM, 8th Oct.

Number of drifting tree to downstream with the camera on the bridge

		11th May Flood	19th Aug. Flood	8th Oct. Flood
Camera on the bridge	Pre flood peak	196	109	172
	Post flood peak	57	82	50
	Total	253	191	222
Number of tree/ hour	Pre flood peak	10	5	10
	Post flood peak	2	3	4

Number of drifting tree to downstream with the camere on the right bank

		11th May Flood	19th Aug. Flood	8th Oct. Flood
Left bank side	Pre flood peak	16	22	6
	Post flood peak	2	20	3
	Subtotal[1]	18	42	9
Center	Pre flood peak	121	20	11
	Post flood peak	16	32	5
	Subtotal[2]	137	52	16
Right bank side	Pre flood peak	22	8	3
	Post flood peak	9	4	4
	Subtotal[3]	31	12	7
Grand Total (=1+2+3)	Pre flood peak	159	50	20
	Post flood peak	27	56	12
	Total	186	106	32
Number of tree/ hour	Pre flood peak	8	2	1
	Post flood peak	1	2	1

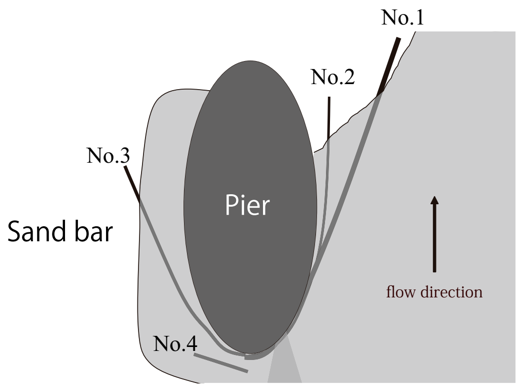
Fig–6 Trees observed around the bridge pier after flood due to snowmelt (right: an image observed at the Sapporo station; left: a close-up of the image)

Fig–7 Accumulation of driftwood after flood in August

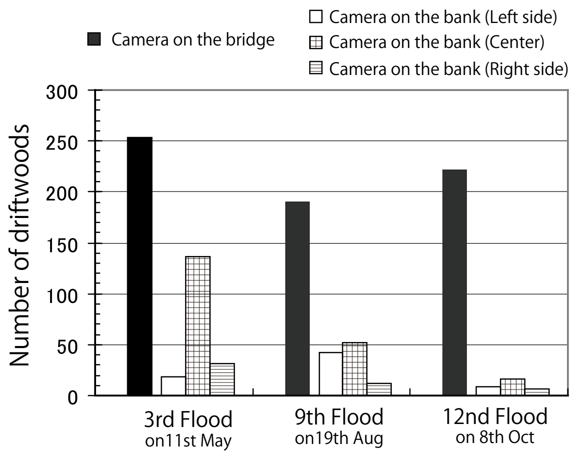
April (the snow melting period) to early December. The findings of this research were as follows:

3.1 Rainfall, Water-Level Conditions & Flooding Events

Fig–4 shows the hourly changes in rainfall in Shimukappu based on the Meteorological Agency's AMeDAS (Automated Meteorological Data Acquisition System), while Table 1 lists the factors of actual flooding events. During the snowmelt season from mid-April to late May, the water level gradually rose and became higher at times of rainfall, causing four floods of different scales. From summer to autumn, flood occurred approximately 10 times due to rainfall. The flood from August 18 to the early morning of the next day was caused by heavy rain due to a stationary front. According to AMeDAS data from



Fig–8 Illustration of driftwood accumulated around the bridge pier, surveyed on 15th Sep.



Fig–10 Number of driftwood in three flood events

the Shimukappu station, the accumulated rainfall and maximum hourly rainfall were 201 mm and 27 mm respectively. At 4:00 a.m. on August 19, a water-level high of 343.35 meters was recorded at the monitoring site of the rehabilitated bridge. In addition to this flood, between one and three others occurred monthly during the monitoring period of 2006, and the driftwood conditions during floods of varying scales were observed.

3.2 Observation Images Taken During Flooding Events

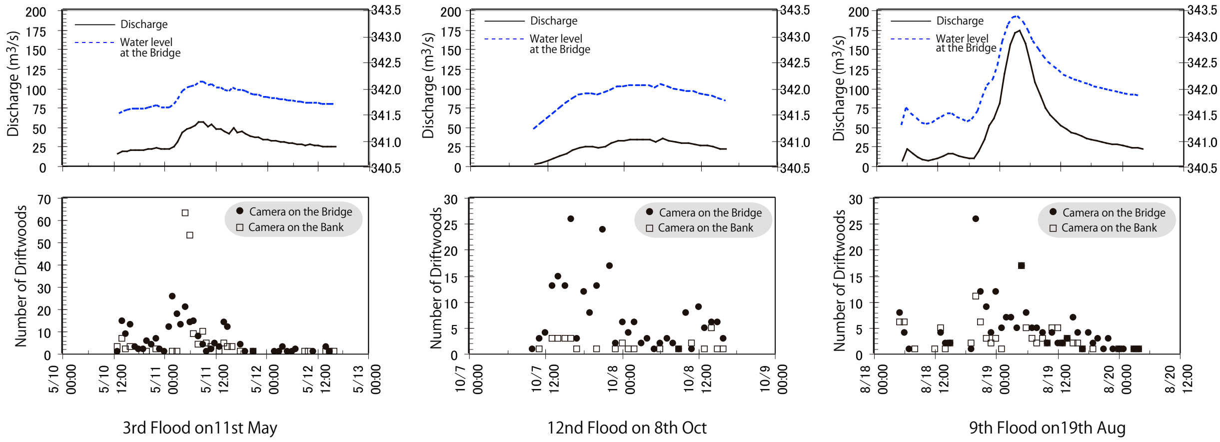
Fig–5 shows conditions around the bridge shown in static images picked out from those recorded during flood. The images on the left were filmed with the camera installed directly above the bridge pier, while those on the right were captured using the camera on the right-bank pole. These images show driftwood of various shapes and sizes colliding around the bridge pier or flowing on either side of it.

3.3 Driftwood Accumulated Around The Bridge Pier

In this research, driftwood that accumulated around the lower part of the bridge pier due to flood was observed when the water level fell after the event. The driftwood shown in **Fig–6** was observed at the end of May after a flood caused by snowmelt. Around five sunken trees of approximately 1.5 meters in length were observed, and were washed away at the time of flooding in mid-August. During a survey on the amount of sediment on September 15, a willow of approximately 8 meters in length was found in addition to old trees. As shown in **Fig–7** and **–8** and Table–2, these trees were drifting around the bridge pier with their roots pointing upstream. They were also washed away during an flood in October. No images recorded during flooding events showed driftwood stagnating and gradually accumulating around the bridge pier. However, a temporary accumulation of driftwood, as shown in **Fig–9**, was observed from 11:41 a.m. to 00:01 p.m. on August 19. Images (1) to (4) in this figure were picked out from among those recorded frame by frame, and show driftwood situations at four different stages: (1) drifting to the bridge pier, (2) captured by the bridge pier, (3) floating in a balanced state around the bridge pier, and (4) becoming unstable around the bridge pier due to drag caused by the flowing water. After hovering around the pier in such an unstable condition for 80 minutes, the driftwood finally left the pier and flowed downstream.

3.4 Counting Of Trees Drifting Downstream

In this research, monitoring with surveillance cameras was conducted only around the bridge pier, and the capacity of night lighting facilities arranged was just enough for this purpose. The counting of driftwood was also conducted around the bridge pier only. Using images captured during several flooding events, the number of trees drifting downstream was counted. Three flooding events were picked out: May 11, when the largest-scale flood of the snowmelt season occurred (peak water level: 342.09 m; peak flow rate: 56.98 m3), August 19, which saw the year's largest flood in the river (peak water level: 343.35 m; peak flow rate: 174.86 m3) and a flood on Oc-



Fig–11 Chronological change in flow rate, number of trees drifting downstream and water level

tober 8 (peak water level: 342.04 m; peak flow rate: 34.54 m3). The counting was conducted using images taken by the cameras set on the bridge and on the right bank. Because of the restricted field of vision of the on-bridge camera, all the trees shown in the images were counted without considering their sizes, and an hourly total was calculated. As the right-bank camera had a wider range of view than the one on the bridge, the number of trees shown in the images from the right-bank camera was counted by categorizing them into those drifting down on the left side of the bridge pier, those flowing through the river's center and those drifting down on the right-bank side. Table 3 shows the result of this counting.

Table–3 also shows the numbers of trees that accumulated by separating them into those before and after the peak water level to examine differences, and **Fig–10** graphs the result. Of the three floods, the number of pieces of driftwood counted on August 19, the day of the year's largest flood in the river, was significantly lower than that for the other two flooding events.

This may be explained by the fact that higher water levels brought the water surface closer to the on-bridge camera, thus narrowing the shooting range. This, in addition to the strong splashing that accompanied it, made it difficult to distinguish driftwood. Since the flood on August 19 peaked at night, the lighting range may have been narrow, resulting in undercounting of driftwood. Likewise, the counts based on images from the camera on the right-bank side may have been smaller than the actual figures due to the limited lighting capacity. The significant differences in the total for the October 8 flood between the two cameras may also have been caused by the lighting limitation, because the water level peaked during the night.

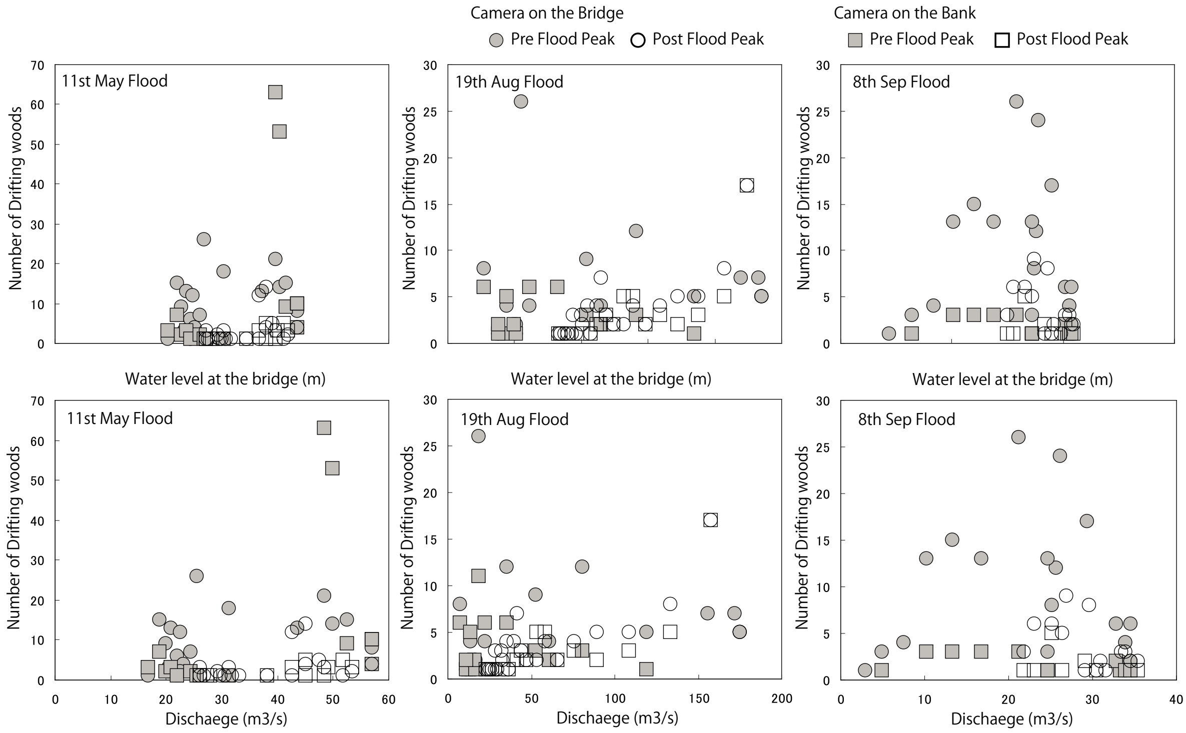
The contexts of the counts for each flooding event were as outlined above. When the tree totals based on the images from the two cameras were compared, that of the on-bridge camera was higher than that of the right-bank one. This may also be attributable to the inadequate night lighting system and the distance between the camera and the water surface.

Driftwood passage routes were examined using images from the right-bank camera, and it was found that trees had primarily drifted downstream through the right-bank side at the time of flooding in May, the left-bank side in August and more on the right-bank side in October.

3.5 Chronological Changes In The Number Of Trees Drifting Downstream

Fig–11 shows the chronological changes in the number of trees drifting downstream, the flow rate and the water level at the time of the three flooding events outlined above to enable examination of the relationships between them.

The chronological changes in the number of drifting trees shown in the images from the on-bridge camera, whose total was larger than that of the right-side camera, were examined. In each flood, the driftwood flowed down at an hourly density of approximately 30 trees before both the water level and the flow rate peaked, after which the number of drifting trees gradually decreased. **Fig–12** shows the relationships between the number of drifting trees and the water level/flow rate by dividing that number into the values before and after the peak. In each flood-



Fig–12 Relationships between the number of trees drifting downstream and the water level and flow rate before and after the peak

ing event, the number of drifting trees before the peak outnumbered that after the peak. Although some positive correlations were observed before the peak between the water level or flow rate and the number of drifting trees, any clear relationships disappeared after the peak. The same applies to comparing the number of drifting trees per unit time before and after the peak. According to Table 3, the number before the peak was 1.7 to 5 times higher than that after the peak. This comparison, based on the images from the on-bridge camera, indicates that the number of trees drifting downstream may increase before the peak of the water level and flow rate.

4. FUTURE CHALLENGES

As the primary focus of this research was to clarify the behavior of driftwood around a bridge pier as it flows downstream, one camera was fixed directly to the bridge pier and two 500-watt projector systems were placed on each side of the camera. This resulted in a limited range of view for the surveillance camera depending on the time of day, and useful images were limited to those showing the front side of the bridge pier. The current monitoring system was therefore found to be inadequate to monitor both sides of the bridge pier. To enhance the efficiency of this monitoring system, it is necessary to change the height and location of the camera on the bridge and improve the lighting system.

It has also become clear that image processing technologies need to be applied to effectively analyze the direction, location, velocity and number of trees drifting downstream. In addition, it may be necessary in future surveys to reexamine the appropriateness of the monitoring method, site and devices currently in use.

The results of this research indicate that the number of trees drifting downstream at the beginning of flood tends to be higher. The above problems with the current observation technique make it necessary to improve the method and obtain further examples of observation on the behavior of driftwood during flood.

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TECHNICAL CONTRIBUTIONS

Fluvial Hydraulics