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Riverbed Management by Changing Reach Scale Channel Configuration

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Synopsis

Many rivers experienced channel alternation, riverbed degradation and vegetation expansion result from artificial disturbance. Thus, works of channel reconstruction carried out as a river restoration such as channel widening, excavation or making meandering. This study presents possibility of channel widening by changing reach scale channel configuration (RSCC). RSCC and their historical changes in the Kizu River during 1961 and 2010 were plotted in biplot dimension of width/depth ratio and specific stream power. And based on their historical changes, we predict resultant RSCC after manipulation of channel width. According to results, most of recent channel types were distributed in the range of low width/depth ratio. However, channel widening about 1.8-2.0 times in upper and lower site could be changed to the range of high width/depth ratio having high potentials of biodiversity in the Kizu River.

Keywords: RSCC, channel widening, width/depth ratio, biodiversity, bifurcated wandering channel

1. Introduction

In the last decade, many rivers experienced riverbed degradation and vegetation expansion in response to reduction of peak discharge and flood frequency (Williams and Wolman, 1984). Alternation of channel geomorphology due to reduction of disturbance influenced degradation of habitats and decrease of species diversity (Takemon, 2010). According to these alternation, river restoration has emerged as an increasingly important to enhance biodiversity and resilience. Especially, channel reconstruction carried out as a work of river restoration; e.g., channel alignment (widening or narrowing; Brierley and Fryirs, 2005), excavation of floodplain material to the river bottom level (Jahnig et al., 2009) and making meandering (Kondolf, 2006). However, some projects without reflecting potential river characteristics, experienced failures (Kondolf, 2006). He said that meanders have been created in many channel re-constructions on rivers that were not historically meandering, and in many cases, these meanders have subsequently washed out. For sustainable river management, development and application of river management practices requires knowledge of the natural range of morphological adjustment for different river types (Thomson et al., 2001). In order to establish a scheme of river management aiming at maintaining a target riverbed geomorphology (Takemon, 2010), characteristics of river should be focused on historical changes.

In this respect, geomorphic reach scale channel configuration (RSCC) could be used as a powerful device for riverbed management if the linkage among hydraulic, geomorphology and ecology is understood. Thus, this study tried to make methods of riverbed management using historical changing RSCC in terms of understanding relations between geomorphology and hydraulic. RSCC can be classified by hydraulic-geomorphic parameters such as discharge and slope (Leopold and Wolman,

1957), depth-grain size ratio and width/depth ratio (Muramoto and Fujita, 1977), sediment load and lateral stability (Schumm, 1985), width/depth ratio and specific stream power (Burge, 2005). Among these various parameters, this study focused on width/depth ratio and specific stream power (Burge, 2005) in order to detect possibility of channel widening and narrowing as manipulation of river restoration. The purpose of this study is to detect historical changes of RSCC in the Kizu River based on relations between width/depth ratio and specific stream power, and to predict the possibility of channel changes in the future. To achieve purpose, RSCC during 1961 and 2010 was plotted on biplot dimension of width/depth ratio and specific stream power, and historical changes of RSCC were investigated on the biplot dimension. Finally, the possibility of channel changes in the future was predicted by manipulation of channel width.

2. Methods

A total of 90 reaches (one reach is 2 km) were divided into 8 channel types in the Kizu River (0-26 km) during 1961-2010 (Choi, 2014). RSCC in the Kizu River was classified into single, slightly wandering straight and sinuous, quite wandering straight and sinuous, bifurcated wandering straight and sinuous, and braided channels using geomorphic parameters, e.g., number of channels, sinuosity, channel width, slope, ratio of landscape. And the classified channel types were evaluated by habitat diversity and soundness (diversity x total habitat abundance), and bifurcated wandering channels had maximum habitat diversity and soundness. Habitat diversity and soundness influence high biodiversity. A 'habitat heterogeneity hypothesis' (Simpson, 1949) states that an increase in the number of habitats and/or an increase in their structural complexity leads to increased species diversity. Thus, bifurcated wandering channel had high potential of species diversity (Choi, 2014).

In this study, channel types were simplified, and thus, a total of 4 types were used (single and slightly wandering, quite wandering, bifurcated wandering and braided channels). All reaches in the Kizu River was plotted in dimension of hydro-geomorphic parameters consist of width/depth ratio (B/h) and specific stream power (Burge, 2005; classified into braided, meandering, wandering, single, anastomosed channels) (Fig. 1). Specific stream power is pgQaS/w, where p is the density of water, g is the acceleration due to gravity, Qa is the mean annual flood discharge, S is channel slope, and w is the bankfull channel width (Burge, 2005). Data of discharge was used by Yodogawa river offices (2011). Bankfull discharge was used as mean of the annual maximum daily discharge during 30 years in Inooka observatory (15-16 km). Bankfull width (B) was defined by the boundary line where terrestrial vegetation begins along the stream margin at bankfull discharge using aerial photos. Depth was used as mean depth from bankfull discharge by calculation of HEC-RAS. Width and depth were calculated using 10 sections in a one reach (2 km) and averaged. Bed slope was calculated using cross-section data per 2 km unit.

A range of 4 channel types was investigated based on mean values of B/h and specific stream power per each channel type and its standard deviation (SD). And then, historical changes of all site (0-26 km) were detected to understand historical changing patterns. However, representatively some site of upper (24-26 km), middle 1 (14-16 km), middle 2 (8-10 km), lower site (0-2 km) of the Kizu River were introduced.

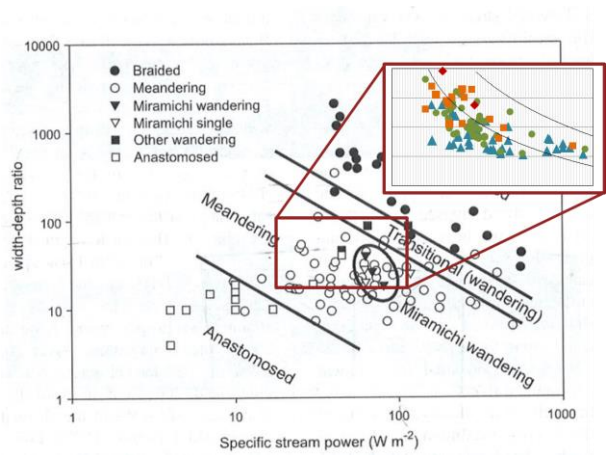


Fig. 1 RSCC in the Kizu River plotted in dimension of width/depth ratio and specific stream power (Burge, 2005). Kizu River was shown in meandering channel and transitional wandering channel.

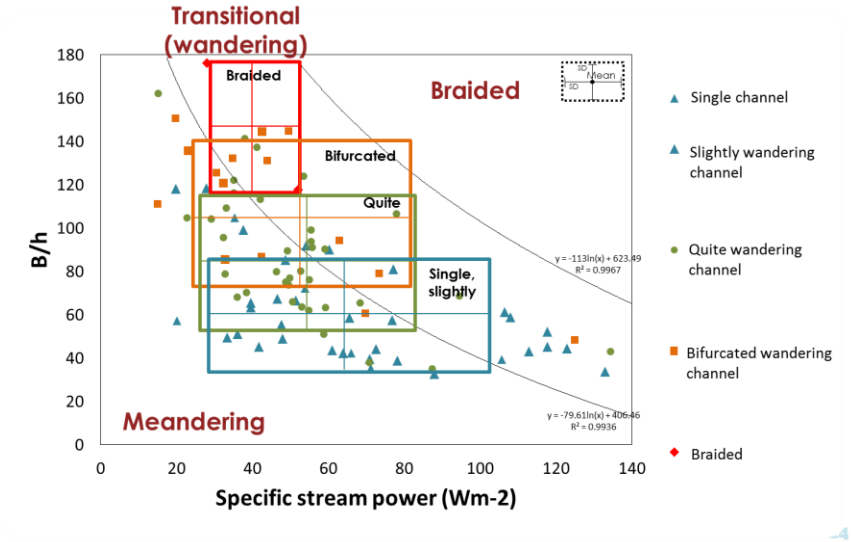


Fig. 2 Distribution of each channel type within the biplot dimension of width/depth ratio and specific stream power in the Kizu River. Ranges of channel types of single and slightly wandering is blue line, quite wandering is green, bifurcated wandering is orange and braided channels is red.

Based on these historical trace, equations and coefficient of determination of trend line per each reach were estimated, and changing channel ranges from current channel to bifurcated wandering channels were expected by changing (increases/ decreases) channel width.

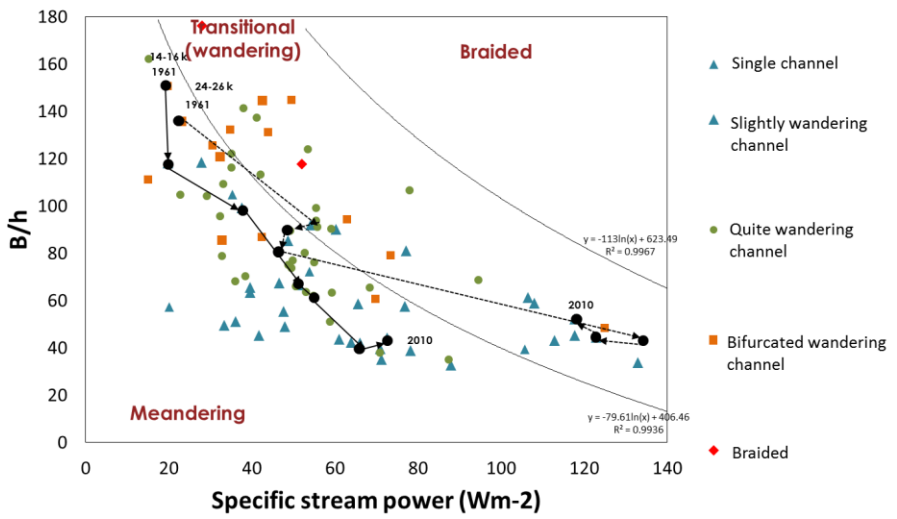
3. Results

All channel types in the Kizu River were plotted within a restricted range of meandering channels and transitional wandering channels in the dimensions of width/depth ratio and specific stream power (Fig. 1). Fig. 2 indicated plotted channel types and ranges of channel types of single and slightly wandering (blue line), quite wandering (green), bifurcated wandering (orange) and braided channels (red). Range of single and slightly wandering channels showed the lowest values of B/h and the widest range of specific stream power. Range of quite wandering channels included higher values of B/h than single and slightly wandering channels, and range of bifurcated wandering channels included higher values than quite wandering channels. Range of braided channels had the highest values of B/h and was included in area of transitional wandering channel type.

Historical changes of channel types were detected. Only upper, middle 1, middle 2 and lower reaches were shown representatively in Fig. 3. The upper site (18-20 km; dotted line) (Fig. 3a) moved from braided channel having the highest B/h to slightly wandering channel during 45 years. This reach experienced continuous decreases of B/h and increases of specific stream power. Middle 1 site (14-16 km; full line) (Fig. 3a) showed significant decreases of B/h in area of meandering channel type. Middle 2 site (8-10 km; dotted line) (Fig. 3b) showed decreases in values of B/h and changes from a quite wandering channel to a slightly wandering channel. On the other hands, lower site (0-2 km; full line) (Fig. 3b) moved from a quite wandering channel to a slightly wandering channel with only significant changes of specific stream power.

Based on changes of reaches, equations and coefficient of determination of trend were estimated. Relations between channel width (B) and B/h had equation, y (B/h) = $0.287B^{1.1}$, R^2=0.95. And relations between channel width (B) and specific stream power had various equations per each reach. Fig. 4 indicated that predictable channel changes by changing channel width using the equations. Only some reaches having values of high coefficient of

determination were shown (R^2>0.7). A recent channel type in middle site 1 (14-16 km) showed slightly wandering channel (mark of red cross in black square) (Fig. 4a). This reach tended to move to range of bifurcated wandering channel by increases of channel width about 1.8 -2.2 times. A recent channel type in middle 2 site (8-10 km) showed quite wandering channel (Fig. 4b). Although this reach showed quite, it was almost close to range of bifurcated wandering channel. And according to increases of channel width, channel may be moved to area of transitional wandering channel. A recent channel type in lower site (0-2 km) showed slightly wandering channel (Fig. 4c).



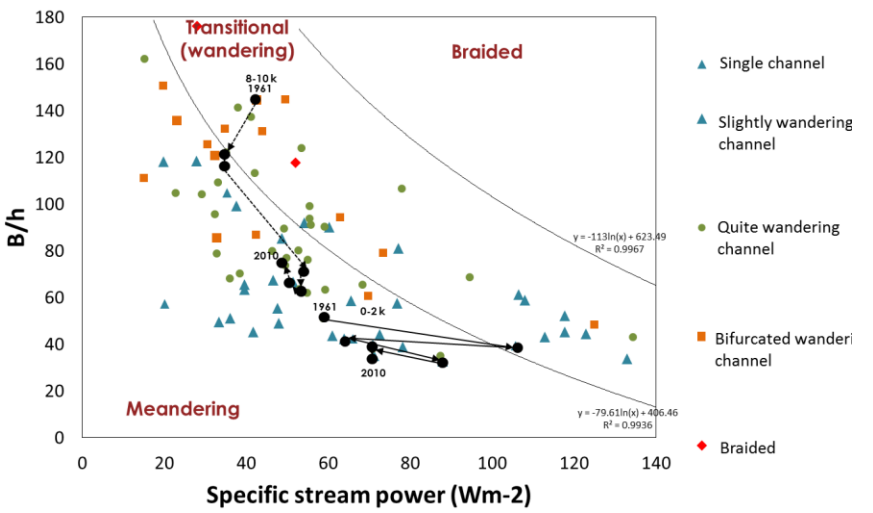


Fig. 3 Historical changes in channel types within the biplot dimension of width/depth ratio and specific stream power in the Kizu River from 1961 to 2010. The plots of upper site (24- 26 km; dotted line) and middle 1 site (14-16 km; full line) (a), the plots of middle 2 site (8-10 km; dotted line) and lower site (0-2km) (b) in study area

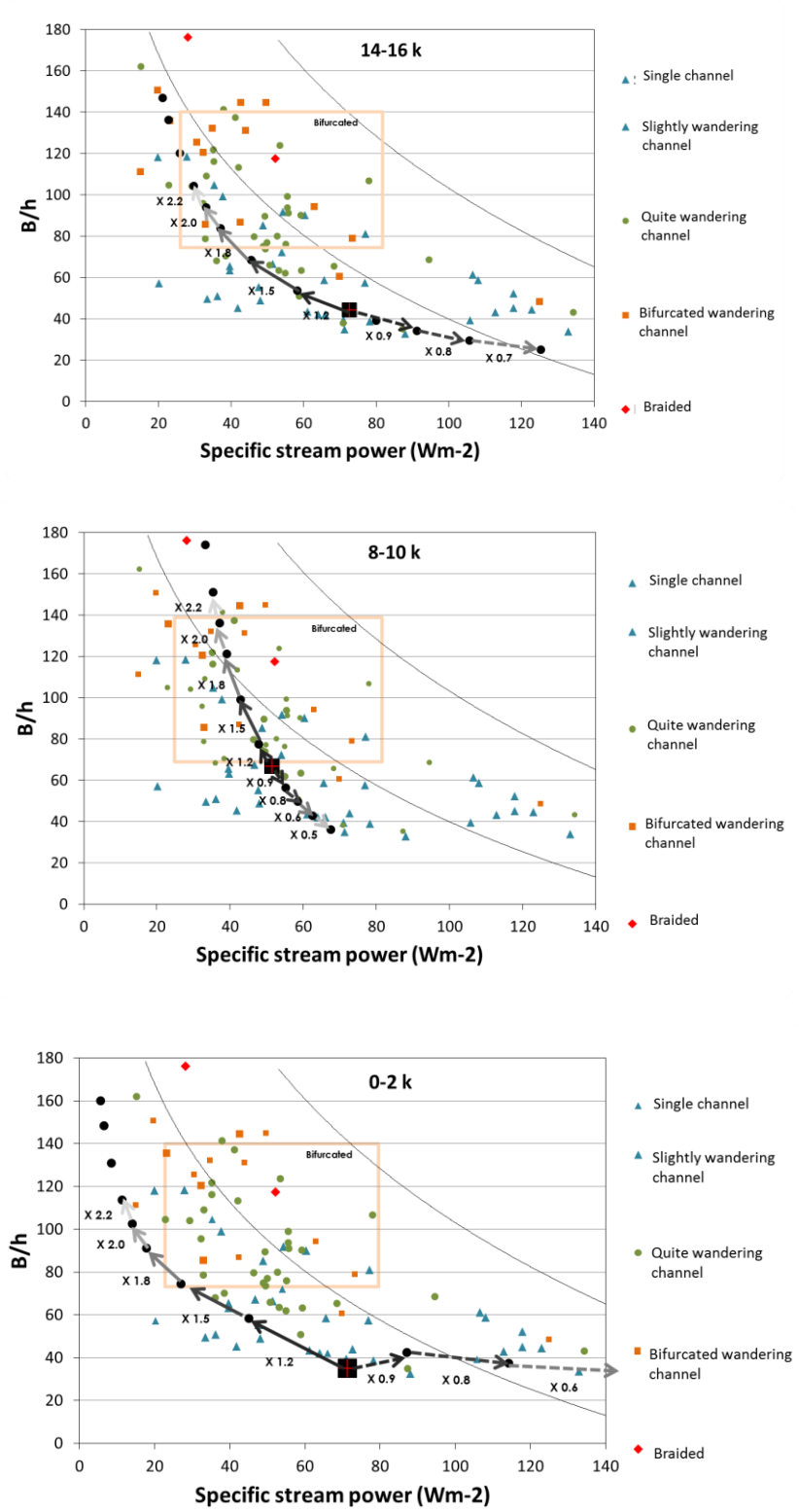


Fig. 4 Predictable channel changes of middle 1 site (14-16 km) (a), middle 2 site (8-10 km)(b) and lower site (0-2 km)(c) by manipulation (increases or decrease) of channel width. A mark of red cross in black square indicate recent channel. The black circles means predictable channel changes by increases (x 1.2, 1.5, 1.8, 2.0, 2.2) of channel width and decreases (x 0.9, 0.8, 0.7) of channel width. Orange line means range of bifurcated wandering channels having high potential for biodiversity. Arrows mean their direction by changes of channel width.

4. Discussion

According to the distribution of RSCC and their historical changes in biplot dimension of width/depth ratio and specific stream power, we could predict resultant RSCC after manipulation of channel width (Fig. 4). Most of channel types in 2010 were distributed in the range of single and slightly wandering channels. Increasing channel width could be moved from range of single and slightly wandering channel to the range of bifurcated wandering channels as target channel types for high potential of biodiversity.

We could propose increasing channel width as a short-term countermeasure for biodiversity for riverbed management (Fig. 4). The middle site (8-10 km) was close to the range of bifurcated wandering channels having maximum habitat diversity and soundness. In other words, this reach already satisfied habitat diversity with high biodiversity. Actually, according to Terada (2011), the middle site (8-15 km) showed intermediate floodplain vertical shape had the highest number of active ponds and terrace ponds than the upper or lower sites. In addition, Yodogawa River Bureau (2010) noted that bitterling and mussel were more detected in the middle site (7-18 km) than others. If we want to change the range of channel types from single and slightly wandering to bifurcated channel types, we should focus on lower or upper sites required channel widening about 1.8-2.0 times.

Some studies showed the effects of channel adjustment by comparison between restored sites and natural channel. Rohde et al. (2004) assessed the restoration success of river widening as a landscape approach. Restored site, near-natural, regulated site were compared by riparian landscape (vegetation) mosaic. They noted that river widening provide opportunities for re-establishing riparian landscapes. The widening mainly promotes pioneer stages and more complex mosaic than near-natural sites due to the limited size of widenings. Jahnig et al. (2009) analyzed effects of re-braiding on hydromorphology, floodplain vegetation, beetles and benthic invertebrates in mountain rivers based on restored and non-restored site. The excavation of floodplain material to the river bottom level, initiation of one or two secondary channel, or development by fallen tree in the absence of bank fixations were established in restored sites. They said that restoration increases habitat diversity and availability of biota in floodplain meshohabitat while the effects on aquatic microhabitats (substrate types, terrestrial plants, etc.) and assemblages were less obvious. And species richness, but not the species diversity, of floodplain vegetation and beetles increased following increased habitat diversity with no effects on benthic invertebrates. However, channel widening occurred sometimes armoring or flat shallow riverbed in case of small stream by simple river engineering works (Misa, 1996), thus, these works of channel adjustment should be considered with ecological function.

5. Conclusion

Historical RSCC variations in the Kizu River could be well explained by biplot dimensions of width/depth ratio and specific stream power. According to the distribution of channel types and their historical changes, we could predict resultant RSCC after manipulation of channel width and develop method of riverbed management.

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