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A STUDY ON THE FLOW CHARACTERISTICS INFLUENCED BY HYDRAULIC STRUCTURE AT A CHANNEL JUNCTION

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Natural rivers consist of various networks such as junction and streams. Sedimentation and erosion are occurring by specific stream condition. During the flood season, large discharge flows into the river and as a result the river bed changes by high flow velocity, especially the junction area, where the flow characteristics are very complex. The purpose of this study is to analyze the flow characteristics in channel junction, which are most influenced by large discharges like flooding and input water from tributary. We investigated the flow characteristics by using hydrodynamics and sand transport module in MIKE 3 FM. MIKE 3 FM model was a helpful tool to analyze 3D hydrodynamics, erosion and sediment effect on the channel's bed. We analyze the flow characteristics at channel junction. We also took into consideration hydraulic structures (bridge pier) which are influencing flow characteristics such as: flow velocity, water level, erosion and scour depth in channel bed. In the model, we controlled the discharge condition according to the flow ratio difference in main stream and tributary. In the result, the flow velocity, water level, erosion and sediment depth are analyzed. Additionally, we were comparing these result relationships with equations. This study will help understand flow characteristics and the influence of hydraulic structure in a channel junction.

INTRODUCTION

The natural stream has several tributaries and consists of a complex network. In a channel junction, hydraulic characteristics are changed sensitively. Especially in the flood season, the river bed changed rapidly by high flow velocity and as a result flow junction area shows more complexity stream status. In this study, we construct various conditions of discharge ratio and implement a hydraulic structure like bridge piers which are located in channel junction. We analyze the velocity and erosion characteristics at the channel junction by using MIKE 3 FM model. Hydrodynamics and sand transport module was helpful to estimate the maximum velocity and erosion depth. By using erosion equation, we compare the difference between the equation's erosion depth and modeling result depth. Dr. Park Y. S. (2003) [1] and Dr. Kim Y. G. (2004)[2] suggests a flow characteristic in a channel junction by a hydraulic experiment. The channel junction area needs to be divided into specific areas by velocity difference (fast velocity area and stagnant area), each one with their own hydraulic characteristic.

Model Set-up

The bathymetry of the junction channel was built with the Mesh Generator from MIKE 3FM using as input values the coordinates taken from a given designed area and the elevation given for each channel. Unstructured mesh shown in Figure 1. Left side is main stream, upper side is tributary.

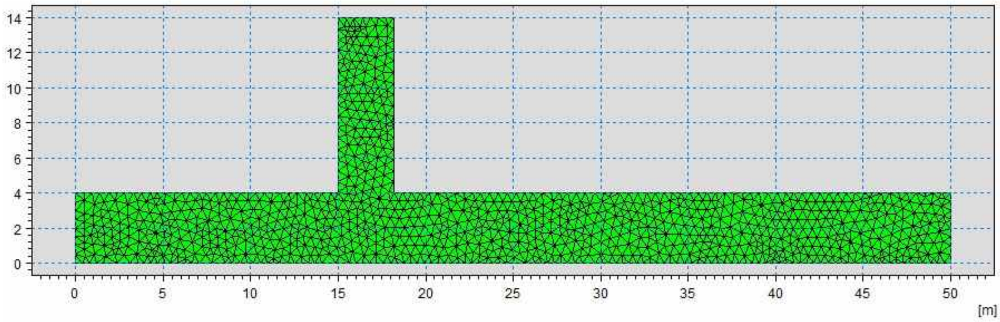


Figure 1. Unstructured mesh

Each boundary was set by discharge condition. Channel depth decided before research from Dr. Kim. Y. K. [2]. He researches the relationship with mainstream and tributary in Han River (Korea) such as ratio of channel width and discharge. These relationships are shown Figure 2.

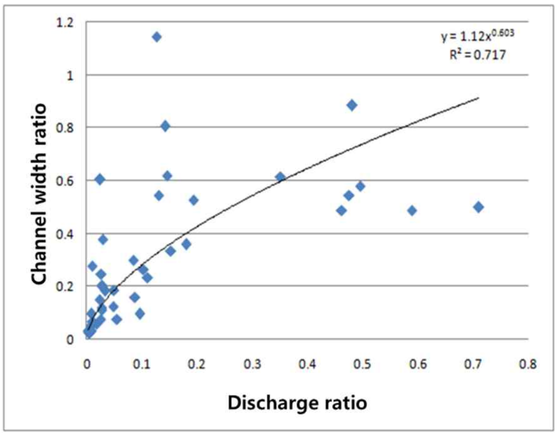


Figure 2. Relationship of mainstream and tributary in Han River [2].

We decide discharge condition in the model from figure 2. The ratio of discharge is decided 1:0.2, 1:0.35, 1: 0.5 (main stream: tributary). And discharge condition we followed before research, the critical discharge is decided 5.65 m3/sec. And sediment diameter is 0.02mm, specific gravity is 2.65. Discharge condition is shown Table 1.

Table 1. Discharge condition in model (unit: m3/s)

Discharge ratio (mainstream : tributary)	1:0.2	1:0.35	1:0.5	Total discharge
Mainstream discharge	4.7144	4.1906	3.7715	5.6573
Tributary discharge	0.9429	1.4667	1.8858	

In order to compare erosion depth some equation is used as comparing modeling result. The formula is described below:

Table 2. Erosion equation

Laursen-Toch (1956)	$d_s = 1.5\, K_a K_s b^{0.7} y^{0.3}$
Laursen (1960)	$\frac{b}{y} = 5.5\, \frac{d_s}{y}\left[\left(\frac{d_s}{1.15\, y} + 1\right)^{1.7} - 1\right]$
Neil (1964)	$\frac{d_s}{b} = 1.5\left(\frac{y}{b}\right)^{0.3}$
C.S.U (1975)	$\frac{d_s}{y} = 2.0 k_1\, k_2\, k_3\, k_4 \left(\frac{b}{y}\right)^{0.65} (Fr)^{0.43}$
Melville (1975)	$11.5\, y = \dfrac{d_s}{\left(1 + \dfrac{0.182}{d_s/b}\right)^{0.589} - 1}$ 1) $Fr < 0.5$ 2) $Fr > 0.5$ $d_s = 3.4\, b\, Fr^{0.67}$
Froehlich (1987)	$\frac{d_s}{b} = 0.32\, \psi \left(\frac{b\prime}{b}\right)^{0.62} \left(\frac{y}{b}\right)^{0.46} Fr^{0.2} \left(\frac{b}{D_{50}}\right)^{0.08} + 1$

Where, ds: scour depth

y: water depth

b: pier width

Ka: pier-alignment factor

Ks: pier-shape factor

Modeling case is decided by different discharge ratio and location of bridge pier. Bridge pier is locate through the distance from channel width such as 0, 0.5, 1.0 width of channel junction. Also, these pier locations divide two ways. One is fast velocity line area and second is stagnant area. This area is decided from Park. Y. S. [1]. Total experiment case is shown Table 3.

Table 3. Modeling Cases

Case. No	Discharge		Location of bridge pier	Remarks
	Main stream	Tributary		
Case 1-1	4.7144	0.9429	None	Discharge ratio different condition
Case 1-2	4.1906	1.4667		
Case 1-3	3.7715	1.8858		
Case 2-1	3.7715	1.8858	2-1	Pier location different condition
Case 2-2			2-2	
Case 2-3			2-3	
Case 3-1			3-1	
Case 3-2			3-2	
Case 3-3			3-3	

Location of Pier is shown Figure 3. Each dimension unit is meter unit. Case 2 line is fast velocity zone and Case 3 is stagnant zone.

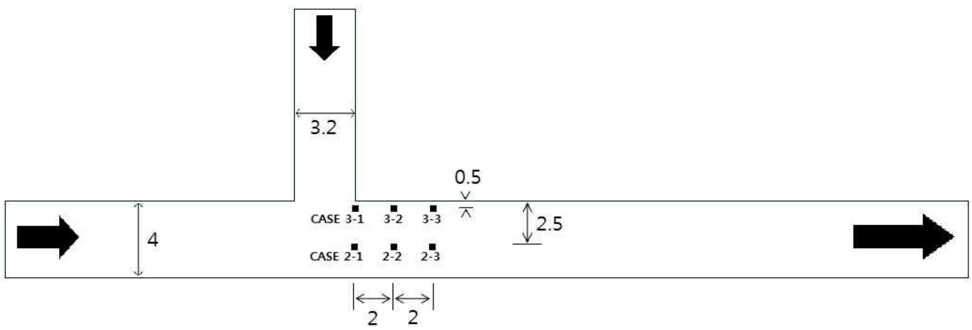


Figure 3. Location of bridge piers

MODELING RESULTS

In the result, Figure 4 is shown velocity and transport result in the Case 1. Maximum velocity occurred in Case 1-3(1.53m/s) this value is fast than Case 1-1(1.38m/s) in the downstream area. Comparing erosion depth, Case 1-3 is the more effect from erosion occurred than other cases. This is cause of tributary impact. If tributary water ratio increased the erosion area is wider.

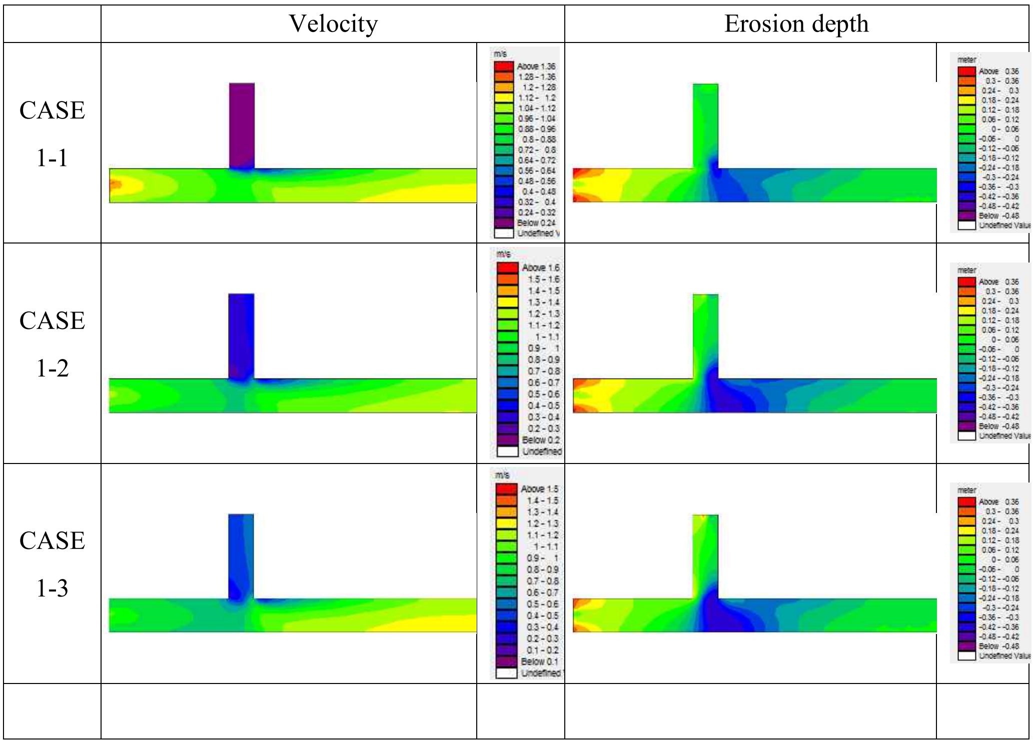


Figure 4. Velocity and Erosion depth result of Case 1-1 to Case 1-3

Figure 5 is shown velocity and transport result in the Case 2. In this condition, bridge pier locate in fast velocity area. Water movement is influenced from pier location. Maximum velocity occurred in Case 2-1(1.51m/s) this value is fast than Case 2-3(1.44m/s) in the downstream area. Comparing erosion depth, maximum erosion depth is all similar but Case 2-3, the bridge pier influence to sediment elevation in downstream area.

Figure 5. Velocity and Erosion depth result of Case 2-1 to Case 2-3

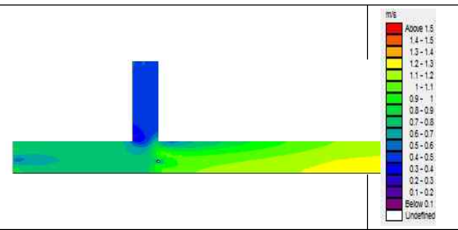
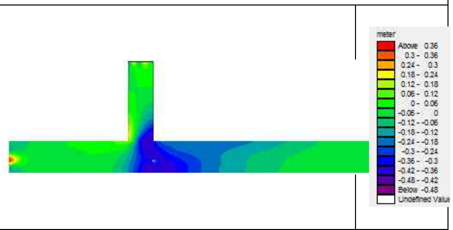
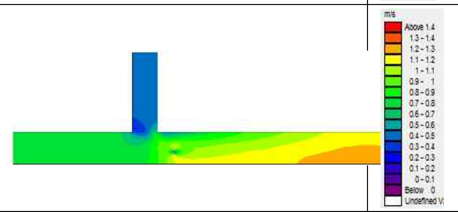
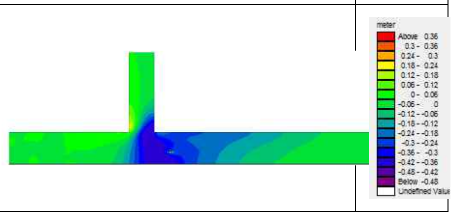
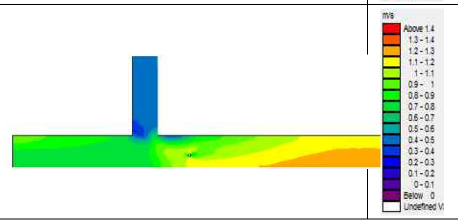
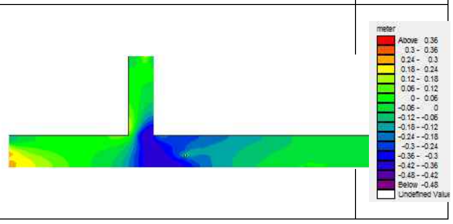
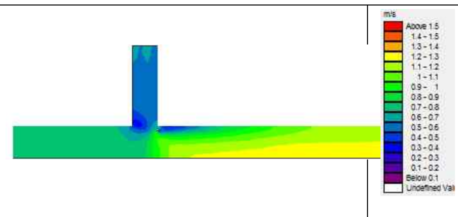
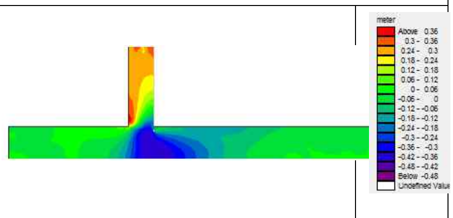
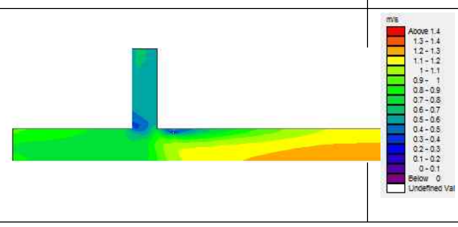
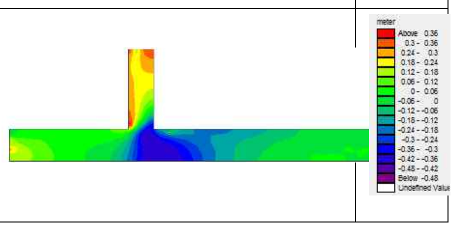
	Velocity	Erosion depth
CASE 2-1		
CASE 2-2		
CASE 2-3		

Figure 6 is shown velocity and transport result in the Case 3. In this condition, bridge pier locate in stagnant area. Water velocity is similar in all cases, so the bridge pier is small influence to channel junction flow. Comparing erosion near the bridge pier zone. Maximum erosion occurred in Case 3-1. On the other hand, Case 3-3 erosion depth represented very small height.

Figure 6. Velocity and Erosion depth result of Case 3-1 to Case 3-3

	Velocity	Erosion depth
CASE 3-1		
CASE 3-2		

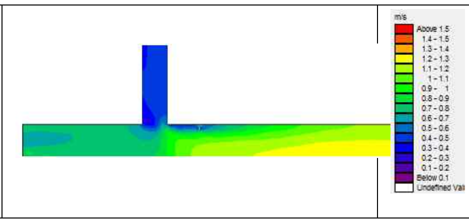
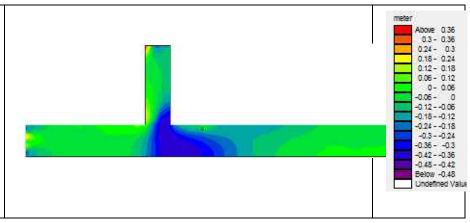
CASE 3-3		

Table 4 is the result of erosion equation and modeling result. In the equations, the erosion range is 1.7 ~ 3.3m, on the other hand modeling result is showing more small values(maximum erosion is 0.416m at channel junction). In the model, erosion is effected from junction stream flow, So pier area's erosion depth trend is different. In Table 4, if distance from conjunction section increased the pier area's erosion is decreased.

Table 4. Erosion depth of equation and numerical model (unit: meter)

case	Equation result							modeling result	
	Laursen-Toch	Laursen I	Neil	C.S.U	Melville		Froehlich	all area	pier area
					Fr<0.5	Fr>0.5			
2-1	3.139	1.730	2.615	2.603	1.732	2.047	3.274	0.416	0.267
2-2	3.119	1.711	2.599	2.682	1.713	2.170	3.284	0.416	0.171
2-3	3.113	1.705	2.594	2.816	1.708	2.349	3.311	0.416	0.052
3-1	3.129	1.721	2.607	2.775	1.723	2.274	3.309	0.416	0.342
3-2	3.100	1.694	2.583	2.052	1.696	1.445	3.127	0.416	0.065
3-3	3.103	1.696	2.585	2.290	1.698	1.712	3.187	0.416	0.072

CONCLUSION

The purpose of the current study was to find the hydraulic characteristics in channel junction. Then analysis the bridge pier influence to channel junction flow and erosion impact. The numerical modeling result help to estimate flow characteristic and represent by 2D contour map.

The velocity at each modeling case is analyzed, so we suggest maximum velocity increased by discharge in the upstream channel and the discharge the ratio between the main channel and tributary. In stagnation zone erosion depth is decrease than faster zone of channel junction. The bridge pier is influence water flow characteristics but in channel junction flow more influenced from input discharge condition.

The result can be used as the basic data for maintenance of structure in channel junction area.

ACKNOWLDEGEMENT

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