CHAPTER 5 EVALUATION ON COUNTERMEASURE OF COMPARTMENTED RESERVOIR WITH NEW GATE AND ITS OPERATION

The compartmented reservoir allows the two (2) reservoir portions to be operated separately. Water level in the Keduang reservoir can be lowered with keeping the main reservoir at NWL or CWL level so that flushing and/or sluicing of sediment-laden flood flow from the Keduang river can be carried out. In this case, sediment release efficiency is related to the operation method of the new gate for flood releasing in Keduang river and can be improved. In this Chapter, this alternative will be evaluated in details by the reservoir sedimentation analysis model --- NKhydro2D model.

5.1 Operation Rule of the Keduang Reservoir

The layout of the Compartmented Reservoir with New Gate is shown in Figure 5.1.1. The facility plan is listed in Table 5.1.1. The facility consists of a closure dike and a new sediment flushing facility. The new sediment flushing facility consists of four (4) gates with the width 7.5m each. Crest of the new sediment flushing facility is at 127m.

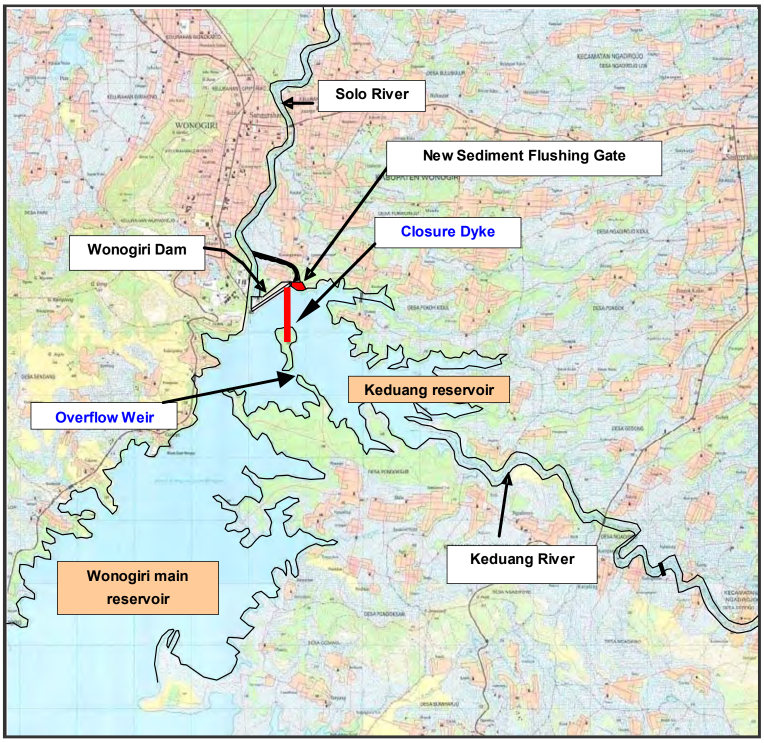


Figure 5.1.1 Layout of Compartmented Reservoir with New Gate

Table 5.1.1 Facility Plan of Compartmented Reservoir with New Flushing Gate

Facility	Dimension	
Closure Dike	Double-wall sheet pile method	L=650m, H=15.0m, B=10.0m
Overflow Weir	Filling and revetment	L=100m, B=10m
Sediment Flushing Gate	Radial gate	H12.6m x B7.5m x 4nos
Spillway	Chute type spillway and channel	B=30m, L=723m, I=1/108
Forebay excavation	Sediment deposit level	EL.127.0m

Source : JICA Study Team

For evaluating reasonably sediment release by the new facility, the Keduang reservoir portion is operated based on the current reservoir operation rule as summarized below.

a. In the beginning of wet season (November to December)

All of the water inflowing into the Wonogiri Reservoir from tributaries is stored. The reservoir outflow is released only through waterway for hydropower generation. New flushing gate is closed. (Figure 5.1.2)

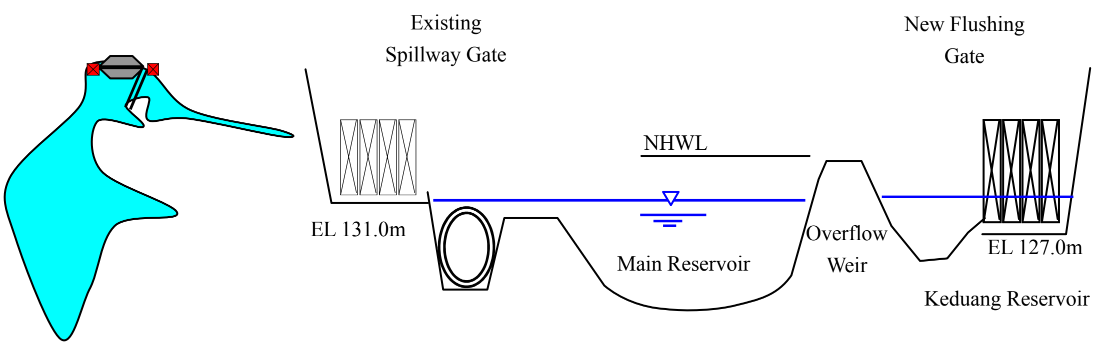


Figure 5.1.2 Illustration of Operation of Compartmented Reservoir (1/3)

b. In the middle of wet season (December to January)

Because of very small capacity of the Keduang reservoir portion, the water level therein rises rapidly. When water level of the Keduang reservoir portion exceeds the crest of overflow weir (El. 135.3 m), water of the Keduang reservoir portion overflows into the Wonogiri main reservoir portion. (Figure 5.1.3)

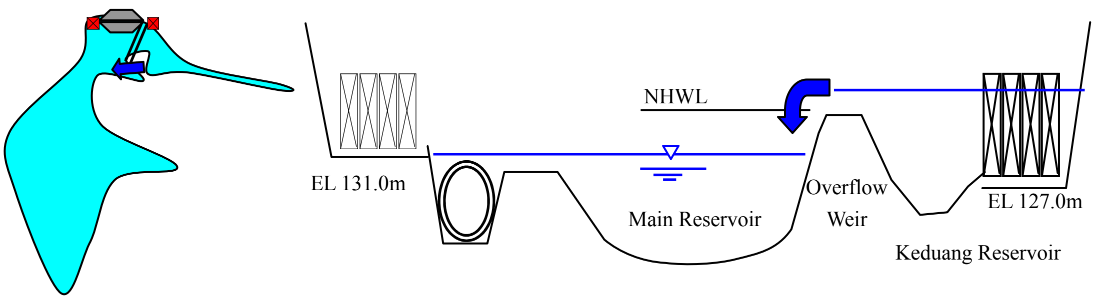


Figure 5.1.3 Illustration of Operation of Compartmented Reservoir (2/3)

c. At the end of wet season (February to April)

If the water level in the main reservoir portion becomes CWL (El. 135.3 m), water storage in the main reservoir portion is completed. In the hydrologically ordinal year and wet year, flood inflow from the Keduang River occurs. When flood occurs in the Keduang River basin, sediment sluicing and flushing with water stored in the Keduang reservoir portion will be made by opening the new flushing gates. The excessive flood inflowing into the main reservoir portion is designed to be overflowed into the Keduang reservoir area through the overflow weir. This sediment releasing operation is able to be continued until April 15. (Figure 5.1.4)

After that, the gate will be closed and water release will be only through the intake for hydropower plant and irrigation.

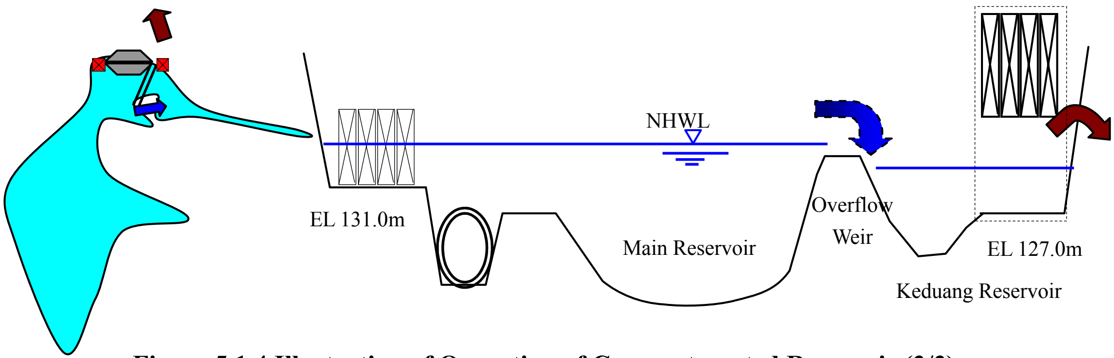


Figure 5.1.4 Illustration of Operation of Compartmented Reservoir (3/3)

5.2 Reservoir Sedimentation Simulation at the Facility Plan of Table 5.1.1

5.2.1 Computational Conditions

Computational conditions are listed in Table 5.2.1.

Table 5.2.1 Input Data for the Simulation (Compartmented Reservoir with New Gate)

Item	Data	Note
Methodology	Depth-integrated 2-dimensional sediment transport model—NKhydro2D model	Based on boundary-fitted orthogonal curvilinear grids
Topogrphical Map	Topographical map with the scale 1:25,000	Published in 1999
Bathymetric data	Cross-section data measured in October 2004	
Inflow Discharge	Temporal discharge (hourly) is employed. Hydrological drought year: Figure 4.4.2 and 4.4.3 Hydrological average year: Figure 4.4.4 and 4.4.5 Hydrological flood year: Figure 4.4.6 and 4.4.7	Data in rainy season are used.
Water Release through intake	Monthly-averaged discharge at Colo weir: Table 4.4.1	
Water Release through existing spillway	No water released through the existing spillway	
Water Release through a new gate	Operated according to the rule stated in 5.1	The crest is at the level 127m
Water Exchange by overflow weir	Water exchange by the overflow weir occurs when water level in one of or both sides excesses 135.3m.	The crest is at the level 135.3m
Water Level	The initial water level is specified to 129m.	
Bed Material	Data of particle size distribution at different locations sampled in October 2004. As non-uniform material (consists of 9 classes in simulation)	The size in deeper area is quite fine.
Sediment Transport Mode	As both the bed load and suspended load	Non-uniform sediment (consists of 9 classes in the simulation)
Sediment Supply	Sediment transport rate for bed load is calculated by Ashida & Michiue's formula. Concentration of suspended sediment is specified as function of river discharge.	Particle size distribution is considered.
Sediment Release	Sediment release accompanied with water release through the spillway and intake is considered.	Bottom concentration of suspended sediment is specified as the release concentration from the intake.
Other Information	Rainfall, Evaporation, etc.	

5.2.2 Computational Results

(1) Water Release from the New Gate, Reservoir Water Level and Discharge at the Overflow Weir

Water release discharge and its total volume through the new gate, reservoir water level under different inflow conditions are shown in Figure 5.2.1 ~ 5.2.6. Minus discharge on overflow at the weir means the flow from the Keduang reservoir to the main reservoir, the plus means that from the main to the Keduang.

Total volumes of water release are 20 million m^3 in hydrological drought year, 0.5 billion m^3 in hydrological flood year and 0.67 billion m^3 in hydrological flood year, respectively.

It should be noted that those water is normally released from the reservoir according to the dam operation rule for the safety of the dam.

In hydrological drought year, there is no water flowing from the main reservoir to the Keduang reservoir through the overflow weir because of less inflow from the other tributaries. In both hydrological average year and hydrological flood year, flow both from the main reservoir to Keduang reservoir and the reverse through the overflow weir occurs. According to the new operation rule, in all hydrological years, the reservoir water level can be kept at higher level by the end of the rainy season.

Typical velocity vector of the Compartmented Reservoir with New Gate in hydrological flood year is shown in Figure 5.2.7(a). For comparison, velocity vector at the same time with the current facility (spillway) only is shown in Figure 5.2.7(b).

In Compartmented Reservoir with New Gate, sediment-laden flood flow from the Keduang river is shut out by the closure dike. Therefore, there is no sediment-laden flow passed through the area around the intake. On the other hand, in the current situation with the existing spillway only, sediment-laden flow from the Keduang river passes through the area around the intake. This feature of the flow will inevitably affect the sedimentation in the area.

(2) Distribution of SS Concentration

Typical distribution of SS concentration contour of the Compartmented Reservoir with New Gate in hydrological flood year is shown in Figure 5.2.8(a). Also for comparison, typical distribution of SS concentration contour at the same time with the current facility (spillway) only is shown in Figure 5.2.8(b).

In the Keduang reservoir, SS concentration is quite high while that near the intake in the main reservoir is lower. The feature of SS concentration distribution is similar with that of the velocity. In the area around the intake, SS concentration is lower than that in the current condition. It is believed that comparing to the current situation, sedimentation in the area around the intake will be improved.

(3) Sedimentation Distribution and Sediment Release from the Reservoir

Sedimentation distribution after the wet season is shown in Figure 5.2.9(a). For comparison, sedimentation distribution with the current facility (the existing spillway) only is shown in Figure 5.2.9(b). In the Keduang area and the area around the intake, the sedimentation is reduced a lot.

Sedimentation volume in different area of the reservoir (Figure 3.2.1) is listed in Table 5.2.3. In the ‘Area’ column of Table 5.2.3, ‘SandGate’ means the sediment release through the new sediment flushing gate.

By the results, it can be calculated that sediment trap ratios under different inflow conditions are 88.8%、68.2%、67.2%, respectively. Comparing to those in the above simulation with different operation rule of the new gate, the sediment trap ratios in the reservoir decrease a lot (about 16%) in both hydrological average year and hydrological flood year. In hydrological drought year, the sediment trap ratio increases about 9% because of shortage of water for sediment flushing. Sediment release volumes from the intake and the new gate are 209,700 m^3 and 61,200 m^3 in hydrological drought year, 96,500 m^3 and 1,067,500 m^3 in hydrological average year, and 112,100 m^3 and 1,279,800 m^3 in hydrological flood year, respectively. Sediment release through the new gate increases a lot although that through the intake decreases. Volume differences (increasing) of sediment release between the new operation rule and the former one are -224,000m^3 in hydrological drought year, 570,000m^3 in hydrological average year and 679,000m^3 in hydrological flood year, respectively. In the former operation, water level is very lower and can not be recovered by the end of wet season. It is unrealistic because of the risk of water storage for uses. Synthetically, sediment release efficiency increases remarkably.

With the same new operation rule but by the existing spillway only, sedimentation volume in different area of the reservoir (Figure 3.2.1) is listed in Table 5.2.4. In the 'Area' column of Table 5.2.4, 'Spillway' means the sediment release through the existing spillway. Sediment trap ratios under different inflow conditions are 88.8%、85.1%、82.8%, respectively. The sediment release efficiency is very low. Volume differences of sediment release between the new facilities and the existing facilities (all in new operation rule) are 0m^3 in hydrological drought year, 620,000m^3 in hydrological average year and 660,000m^3 in hydrological flood year, respectively.

The above analysis shows that the sediment release efficiency by the Compartmented Reservoir with New Gate with the new operation rule is quite higher. Furthermore, the water level can be kept at higher level by the end of wet season. It is safe for water use.

Table 5.2.2 Sedimentation Distribution and Sediment Release Volume (New Operation Rule of Compartmented Reservoir with New Gate)

Area	Sedimentation Volume (m3)		
	Drought Year	Average Year	Flood Year
Dam	165,800	110,800	143,100
Keduang	385,200	74,900	136,400
Tirtomoyo	313,900	509,800	618,600
Temon	103,900	87,200	142,200
Solo&Alang	303,900	628,100	801,100
CenterUP+ Wuryantoro3	499,500	563,200	525,700
Center	255,700	276,000	257,500
Wuryantoro	86,800	194,900	186,500
Wuryantoro2	24,900	51,800	47,600
PowerPlant	209,700	96,500	112,100
SandGate	61,200	1,067,500	1,279,800
Total	2,410,000	3,660,000	4,250,000

Table 5.2.3 Sedimentation Distribution and Sediment Release Volume (New Operation Rule, Existing Spillway only)

Area	Sedimentation Volume (m3)		
	Drought Year	Average Year	Flood Year
Dam	159,400	173,600	171,700
Keduang	382,100	654,100	818,400
Tirtomoyo	320,300	501,000	597,700
Temon	103,600	86,800	148,100
Solo&Alang	350,900	665,300	798,100
CenterUP+ Wuryantoro3	467,900	543,400	511,800
Center	242,400	242,500	242,900
Wuryantoro	88,400	197,700	182,500
Wuryantoro2	24,900	51,900	46,800
PowerPlant	243,800	258,800	313,000
Spillway	26,900	285,500	419,300
Total	2,410,000	3,660,000	4,250,000

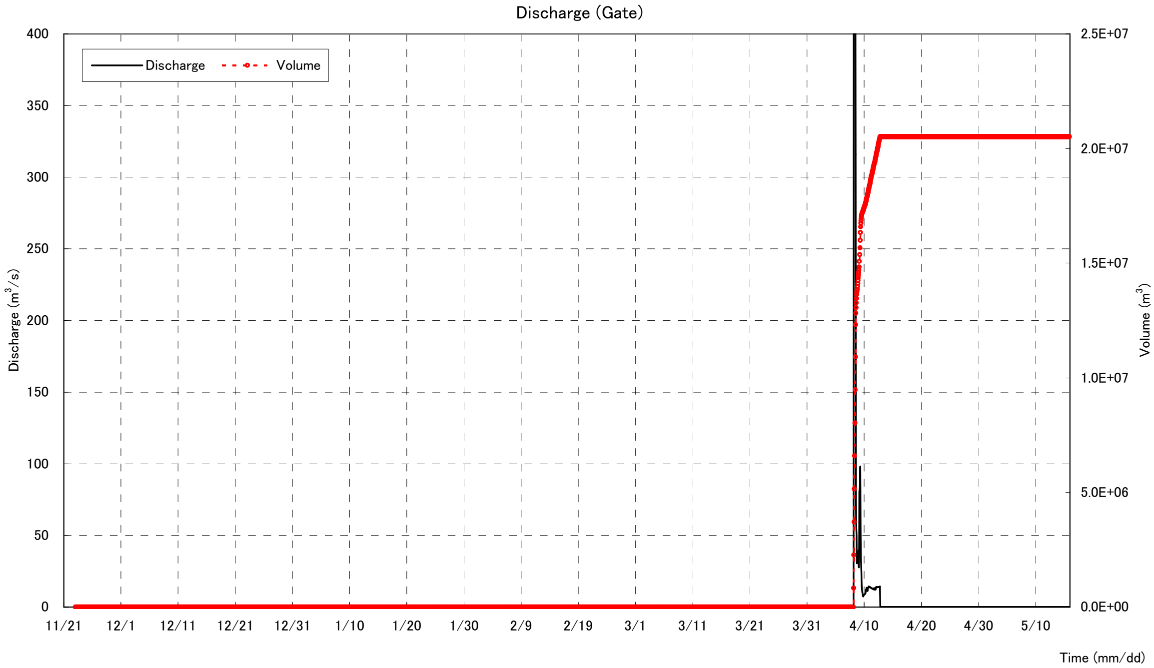


Figure 5.2.1 Release Discharge and its Total Volume through the New Gate in Hydrological Drought Year (New Operation Rule of Compartmented Reservoir with New Gate)

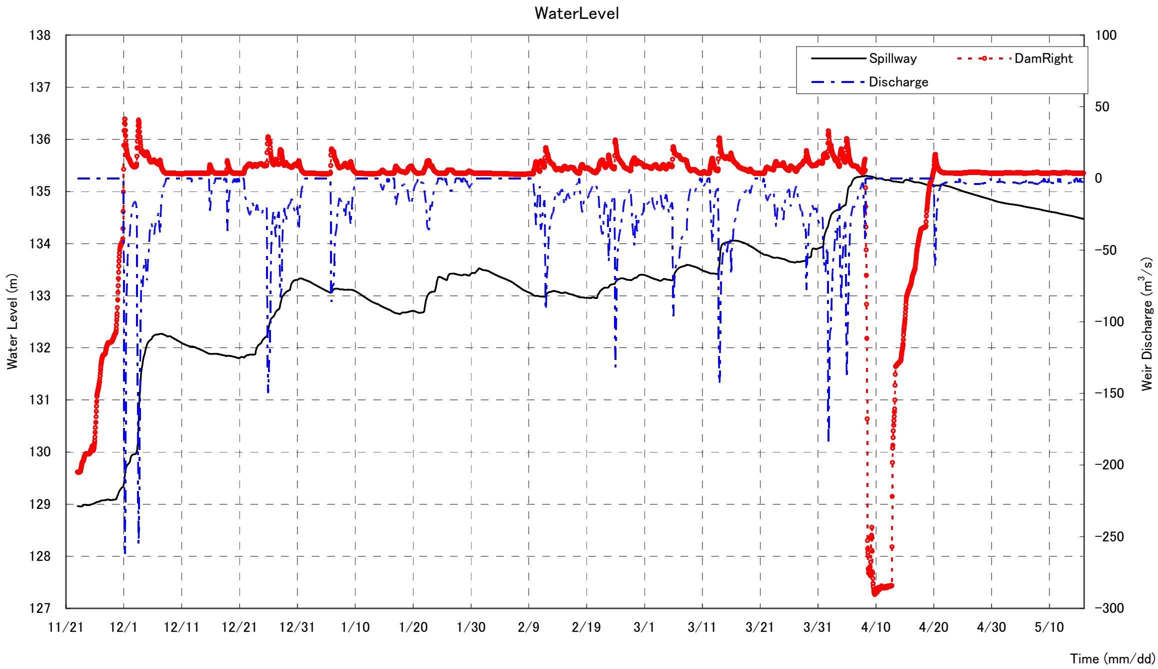


Figure 5.2.2 Water Level in Two Sides of the Wonogiri Reservoir and Discharge at Overflow Weir in Hydrological Drought Year (New Operation Rule of Compartmented Reservoir with New Gate)

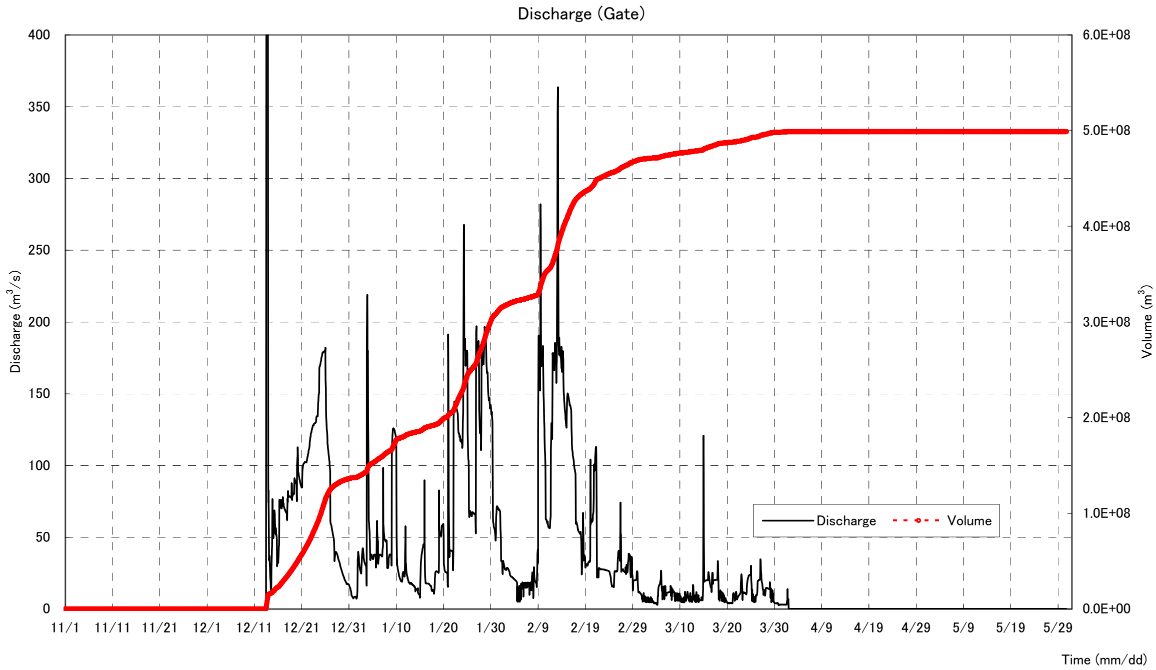


Figure 5.2.3 Release Discharge and its Total Volume through the New Gate in Hydrological Average Year (New Operation Rule of Compartmented Reservoir with New Gate)

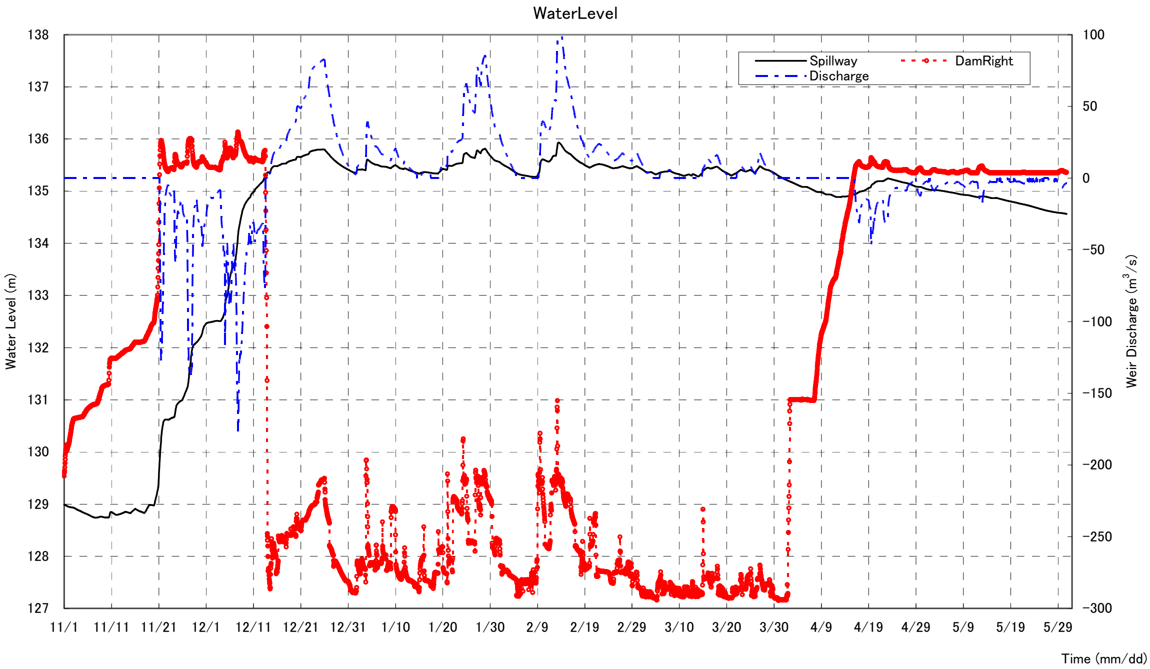


Figure 5.2.4 Water Level in Two Sides of the Wonogiri Reservoir and Discharge at Overflow Weir in Hydrological Average Year (New Operation Rule of Compartmented Reservoir with New Gate)

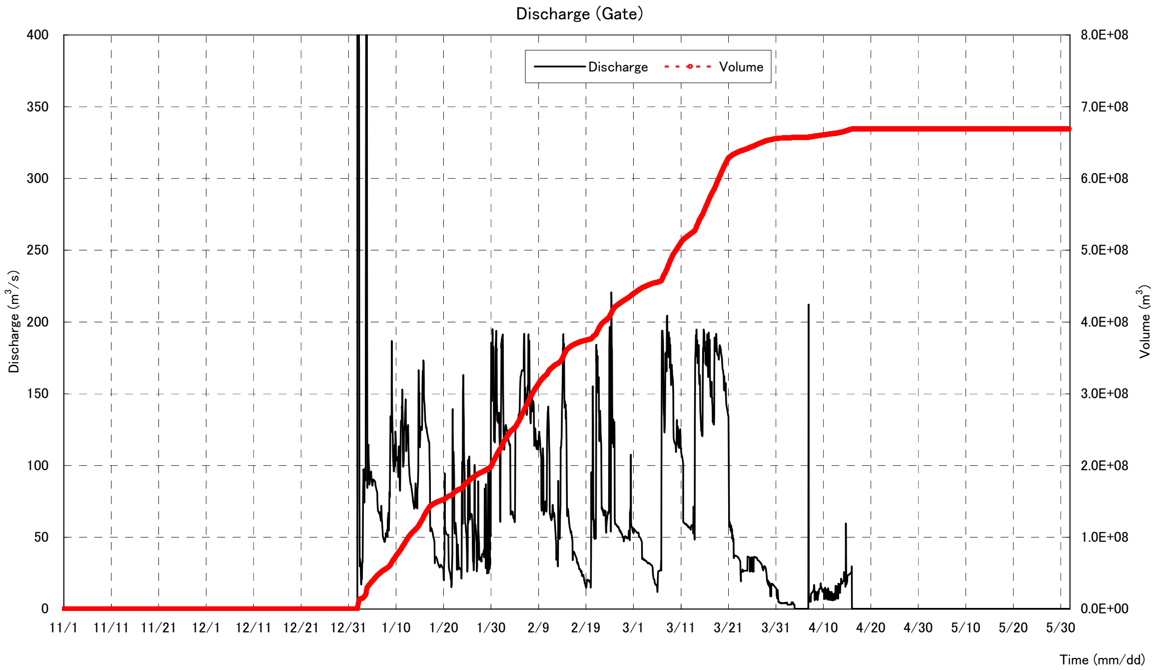


Figure 5.2.5 Release Discharge and its Total Volume through the New Gate in Hydrological Flood Year (New Operation Rule of Compartmented Reservoir with New Gate)

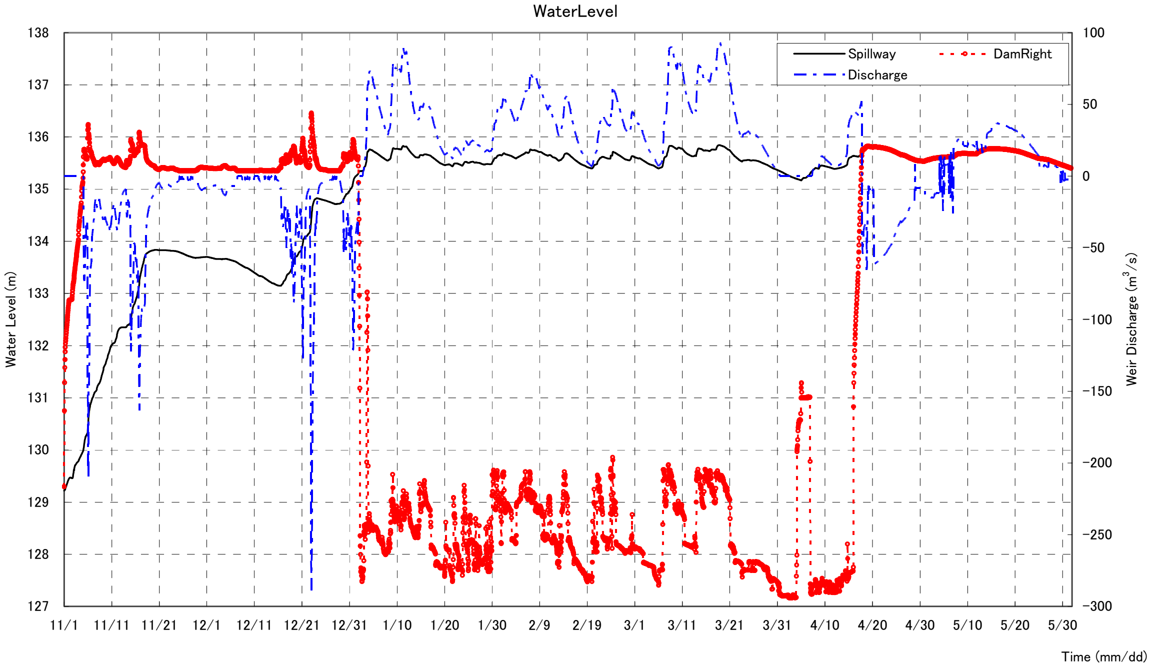
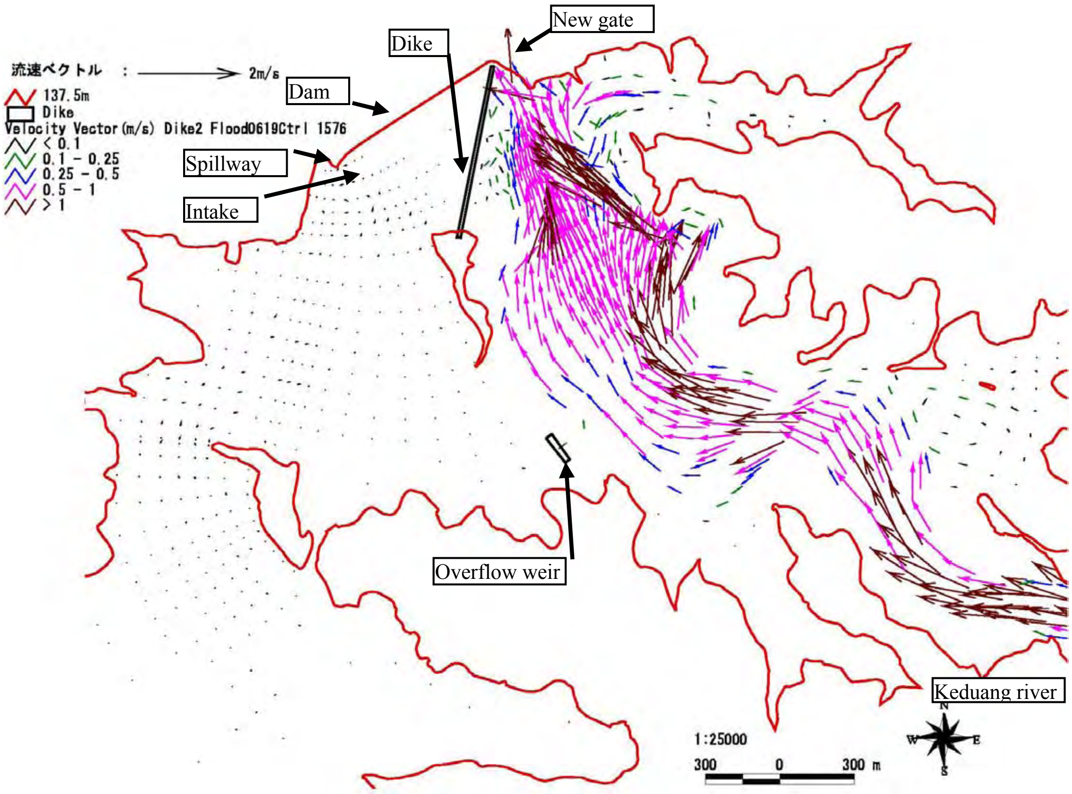
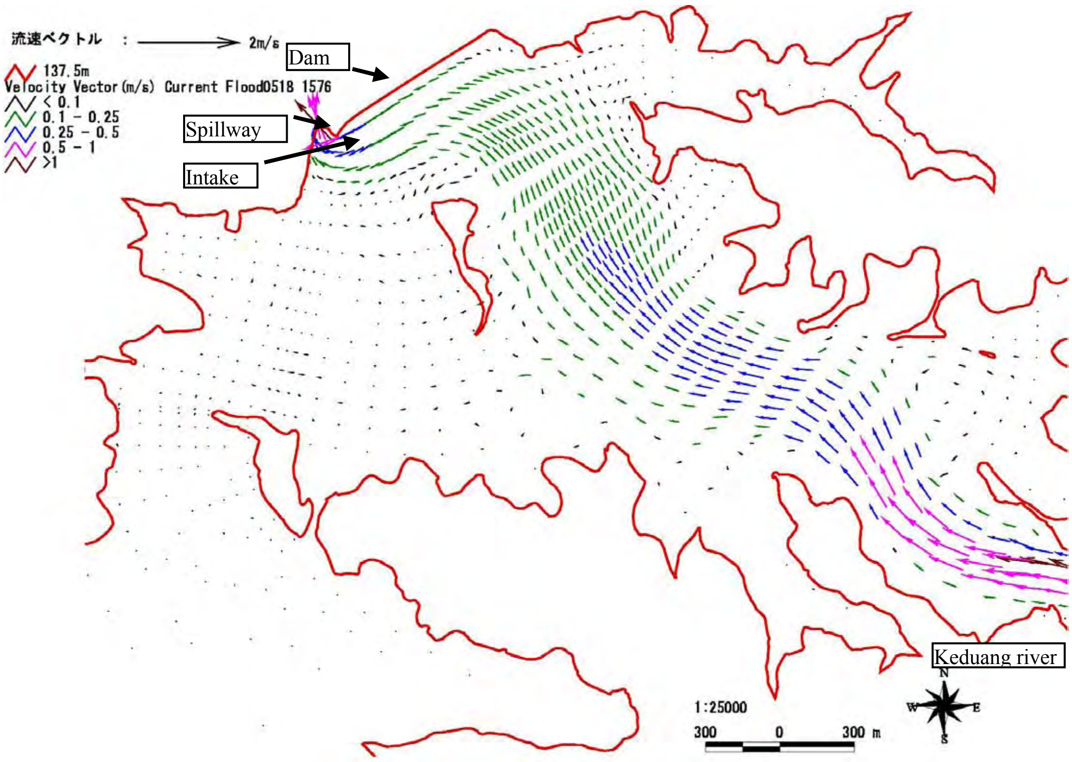


Figure 5.2.6 Water Level in Two Sides of the Wonogiri Reservoir and Discharge at Overflow Weir in Hydrological Flood Year (New Operation Rule of Compartmented Reservoir with New Gate)

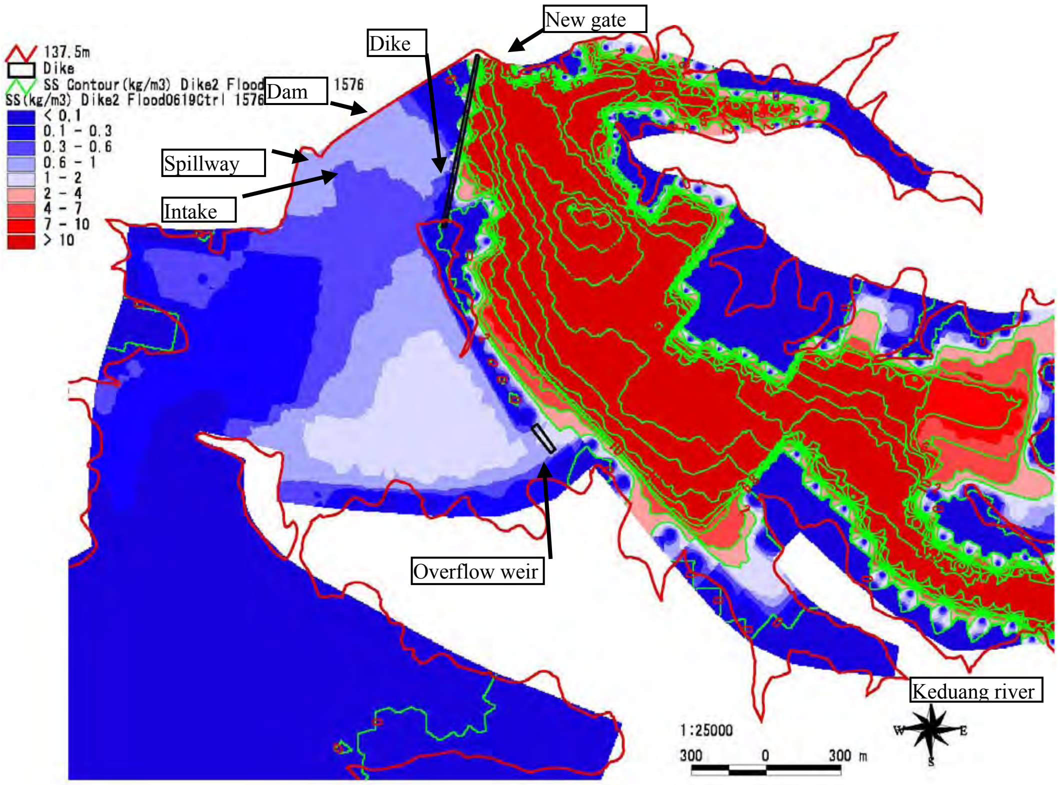


(a) New Operation Rule of Compartmented Reservoir with New Gate

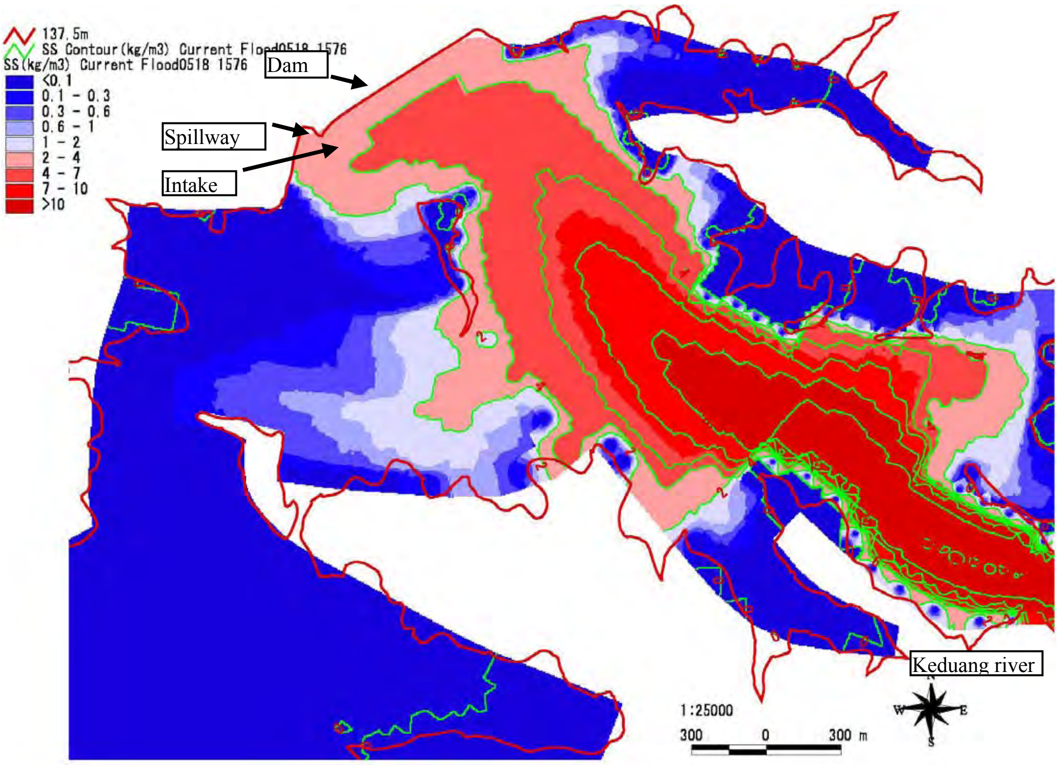


(b) Water Release from Existing Facility (Spillway) Only

Figure 5.2.7 Velocity Vector in Hydrological Flood Year
(Immediately After Spill Out at 16:00 on January 3rd)

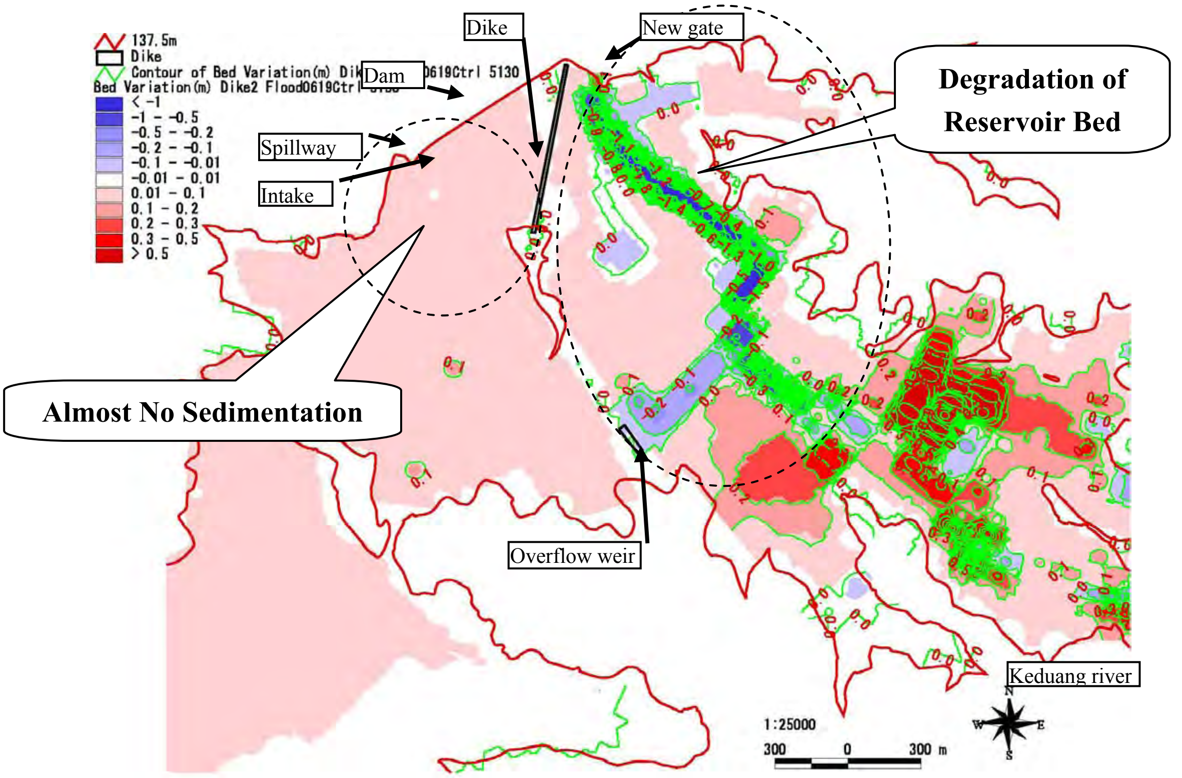


(a) New Operation Rule of Compartmented Reservoir with New Gate

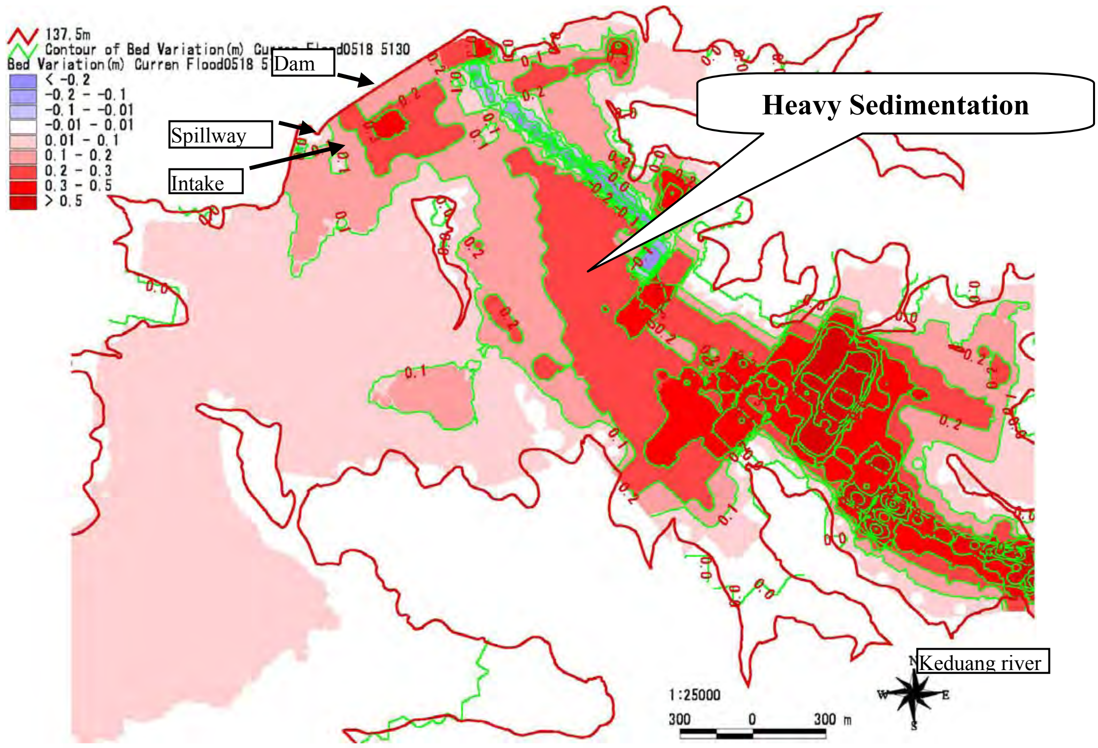


(b) Water Release from Existing Facility (Spillway) Only

Figure 5.2.8 SS Contour in Hydrological Flood Year
(Immediately After Spill Out at 16:00 on January 3rd)



(a) New Operation Rule of Compartmented Reservoir with New Gate



(b) Water Release from Existing Facility (Spillway) Only

Figure5.2.9 Simulation Result of Sedimentation in Keduang Reservoir After Wet Season in Hydrological Flood Year

5.3 Additional Simulation of Reservoir Sedimentation

The above analysis shows that the sediment release efficiency by the Compartmented Reservoir with New Gate (the width 30m) under the new operation rule is quite higher. In this section, more simulations are carried out under different size of the sediment flushing facility (width and crest level of the new gate) to evaluate the variation of the sediment release efficiency with different width and crest level of the gate. The operation rule is unchanged.

The flow and the other conditions are the same as those in Table 5.1.1 and Table 5.2.1.

5.3.1 Width of the Sediment Flushing Gate

(1) Gate Width 22.5m ($7.5m \times 3$)

Simulations with the gate width 22.5m ($7.5m \times 3$) are conducted. The crest level is at 127m, the same as the above. The facility plan is shown in Table 5.3.1.

The inflow and other conditions are the same as listed in Table 5.1.2.

Table 5.3.1 Facility Plan of Compartmented Reservoir with New Flushing Gate, the Width=22.5m

Facility	Dimension	
Closure Dike	Double-wall sheet pile method	L=650m, H=15.0m, B=10.0m
Overflow Weir	Filling and revetment	L=100m, B=10m
Sediment Flushing Gate	Radial gate	H12.6m x B7.5m x 3nos
Spillway	Chute type spillway and channel	B=30m, L=723m, I=1/108
Forebay excavation	Sediment deposit level	EL.127.0m

Source : JICA Study Team

Total volumes of water release are 20 million m^3 in hydrological drought year, 0.5 billion m^3 in hydrological flood year and 0.67 billion m^3 in hydrological flood year, respectively, which are almost the same as those with the gate width 30m.

Sedimentation volume in different area of the reservoir (Figure 3.2.1) is listed in Table 5.3.2.

Table 5.3.2 Sedimentation Distribution and Sediment Release Volume (Compartmented Reservoir with New Gate, the Gate Width 22.5m and the Crest=127m)

Area	Sedimentation Volume (m3)		
	Drought Year	Average Year	Flood Year
Dam	165,900	112,200	143,000
Keduang	387,500	73,400	165,000
Tirtomoyo	314,100	511,100	620,100
Temon	104,000	88,200	142,100
Solo&Alang	304,100	635,800	800,800
CenterUP+ Wuryantoro3	499,700	570,000	525,500
Center	255,700	279,500	257,400
Wuryantoro	87,000	197,300	186,400
Wuryantoro2	24,900	52,400	47,600
PowerPlant	209,800	97,600	112,100
SandGate	57,900	1,043,000	1,250,600
Total	2,410,000	3,660,000	4,250,000

By the results, it can be calculated that sediment trap ratios under different inflow conditions are 88.9%、68.8%、67.9%, respectively. Sediment release volumes from the intake and the new gate are 209,800 m^3 and 57,900 m^3 in hydrological drought year, 97,600 m^3 and 1,043,000 m^3 in hydrological average year, and 112,100 m^3 and 1,250,600 m^3 in hydrological flood year, respectively. Volume differences of sediment release between the gate width 22.5m and 30m are -3,200m^3 in hydrological drought year, -23,400m^3 in hydrological average year and -29,200m^3 in hydrological flood year, respectively. Comparing to those in the above simulation with the gate width 30m, the sediment trap ratios in the reservoir increase a bit.

In hydrological drought year, the sediment trap ratio is almost unchanged because the sediment release volumes are all little. However, in hydrological average year and flood year, the sediment trap ratio decreases 0.6~0.7%, because the water level in the Keduang reservoir rises and SS concentration becomes relative lower during the flood.

(2) Gate Width 15m ($7.5m \times 2$)

Simulations with the gate width 15m ($7.5m \times 2$) are conducted. The crest level is at 127m, the same as the above. The facility plan is shown in Table 5.3.3.

The inflow and other conditions are the same as listed in Table 5.1.2.

Table 5.3.3 Facility Plan of Compartmented Reservoir with New Flushing Gate, the Width=15m

Facility	Dimension	
Closure Dike	Double-wall sheet pile method	L=650m, H=15.0m, B=10.0m
Overflow Weir	Filling and revetment	L=100m, B=10m
Sediment Flushing Gate	Radial gate	H12.6m x B7.5m x 2nos
Spillway	Chute type spillway and channel	B=30m, L=723m, I=1/108
Forebay excavation	Sediment deposit level	EL.127.0m

Source : JICA Study Team

Total volumes of water release are 20 million m^3 in hydrological drought year, 0.5 billion m^3 in hydrological flood year and 0.67 billion m^3 in hydrological flood year, respectively, which are almost the same as those with the gate width 30m as well as 22.5m.

Sedimentation volume in different area of the reservoir (Figure 3.2.1) is listed in Table 5.3.4.

Table 5.3.4 Sedimentation Distribution and Sediment Release Volume (Compartmented Reservoir with New Gate, the Gate Width 15m and the Crest=127m)

Area	Sedimentation Volume (m3)		
	Drought Year	Average Year	Flood Year
Dam	165,900	112,800	143,200
Keduang	390,400	181,200	301,200
Tirtomoyo	314,100	508,200	619,600
Temon	104,000	87,700	142,100
Solo&Alang	304,100	634,200	800,600
CenterUP+ Wuryantoro3	499,700	573,400	525,500
Center	255,800	280,500	257,600
Wuryantoro	87,000	197,700	186,400
Wuryantoro2	24,900	52,500	47,600
PowerPlant	209,800	98,500	112,200
SandGate	55,000	933,900	1,114,500
Total	2,410,000	3,660,000	4,250,000

By the results, it can be calculated that sediment trap ratios under different inflow conditions are 89%、71.8%、71.1%, respectively. Sediment release volumes from the intake and the new gate are 209,800 m^3 and 55,000 m^3 in hydrological drought year, 98,500 m^3 and 933,900 m^3 in hydrological average year, and 112,200 m^3 and 1,114,500 m^3 in hydrological flood year, respectively. Volume differences of sediment release between the gate width 15m and 30m are -6,100m^3 in hydrological drought year, -131,600m^3 in hydrological average year and -165,200m^3 in hydrological flood year, respectively. Comparing to those in the above simulation with the gate width 30m, the sediment trap ratios in hydrological average year and flood year increase 3.6~3.9%.

Volume differences of sediment release between the gate width 15m and 22.5m are -2,900m^3 in hydrological drought year, -108,200m^3 in hydrological average year and -136,000m^3 in hydrological flood year, respectively.

The results show that the sediment release volume will decrease maximum 165,200m^3 if the width of new gate reduces from 30m to 15m. However, it is still possible that about 1million m^3 is released from the reservoir in both hydrological average year and flood year.

(3) Gate Width 10m

Simulations with the gate width 10m are conducted. The crest level is at 127m, the same as the above. The facility plan is shown in Table 5.3.5.

The inflow and other conditions are the same as listed in Table 5.1.2.

Table 5.3.5 Facility Plan of Compartmented Reservoir with New Flushing Gate, the Width=10m

Facility	Dimension	
Closure Dike	Double-wall sheet pile method	L=650m, H=15.0m, B=10.0m
Overflow Weir	Filling and revetment	L=100m, B=10m
Sediment Flushing Gate	Radial gate	H12.6m x B10m
Spillway	Chute type spillway and channel	B=30m, L=723m, I=1/108
Forebay excavation	Sediment deposit level	EL.127.0m

Source : JICA Study Team

Total volumes of water release are 20 million m^3 in hydrological drought year, 0.47 billion m^3 in hydrological flood year and 0.67 billion m^3 in hydrological flood year, respectively, which are almost the same as those with the relative wider gate.

Sedimentation volume in different area of the reservoir (Figure 3.2.1) is listed in Table 5.3.6.

Table 5.3.6 Sedimentation Distribution and Sediment Release Volume (Compartmented Reservoir with New Gate, the Gate Width 10m and the Crest=127m)

Area	Sedimentation Volume (m3)		
	Drought Year	Average Year	Flood Year
Dam	166,000	111,000	143,200
Keduang	400,600	468,300	535,900
Tirtomoyo	314,200	499,100	622,400
Temon	104,000	87,500	141,900
Solo&Alang	304,200	637,600	799,800
CenterUP+ Wuryantoro3	500,000	574,500	525,000
Center	255,900	277,000	257,400
Wuryantoro	87,000	198,900	186,200
Wuryantoro2	24,900	52,700	47,600
PowerPlant	209,900	95,200	112,200
SandGate	43,900	658,800	878,900
Total	2,410,000	3,660,000	4,250,000

By the results, it can be calculated that sediment trap ratios under different inflow conditions are 89.5%、79.4%、76.7%, respectively. Sediment release volumes from the intake and the new gate are 209,900 m^3 and 43,900 m^3 in hydrological drought year, 95,200 m^3 and 658,800 m^3 in hydrological average year, and 112,200 m^3 and 878,900 m^3 in hydrological flood year, respectively. Volume difference of sediment release between the gate width 10m and 30m are -17,100m^3 in hydrological drought year, -410,000m^3 in hydrological average year and -400,800m^3 in hydrological flood year, respectively. Comparing to those in the above simulation with the gate width 30m, the sediment trap ratios in hydrological average year and flood year increase 11.2~9.5%.

Volume differences of sediment release between the gate width 10m and 15m are -11,000m^3 in hydrological drought year, -278,400m^3 in hydrological average year and -235,600m^3 in hydrological flood year, respectively. The results show that the efficiency of sediment release will decrease a lot if the width of new gate reduces from 15m to 10m.

(4) Efficiency of Sediment Release at Different Gate Width

Sedimentation in Keduang area (Figure 3.2.1) and sediment release through the new gate with the different width are compared in Table 5.3.7 and Figure 5.3.1~5.3.3.

The water releases through the facilities (existing spillway, intake and new gate) are almost in the same in different cases. In Table 5.3.8, volume of water release is shown. It should be noted that those water is normally released from the reservoir according to the dam operation rule for the safety of the dam. Under the conditions, the reservoir water level can be kept at higher level by the end of the rainy season in all hydrological years.

The comparison has shown that the efficiency of sediment release through the new gate decreases remarkably if the width of the new gate is reduced to be less than 15m. Wider than the width 15m of the gate, variation of the efficiency is not so greater. From the viewpoint of the balance between cost and benefit, it is recommended that the width of new sediment flushing gate is set to 15m.

Table 5.3.7 Sedimentation in Keduang Area and Sediment Release through the Gate (Compartmented Reservoir with New Gate, the Crest=127m)

Gate Width (m)	Flood Year (m3)		Average Year (m3)		Drought Year (m3)	
	Keduang Deposition	Gate Release	Keduang Deposition	Gate Release	Keduang Deposition	Gate Release
10.0	535,900	878,900	468,300	658,800	400,600	43,900
15.0	301,200	1,114,500	181,200	933,900	390,400	55,000
22.5	165,000	1,250,600	73,400	1,043,000	387,500	57,900
30.0	136,400	1,279,800	74,900	1,067,500	385,200	61,200

Table 5.3.8 Water Release through the Facilities (Compartmented Reservoir with New Gate, the Crest=127m)

	Drought (×10^6m3)	Average (×10^6m3)	Flood (×10^6m3)
Spillway	0	0	0
Intake	531	607	607
New Gate	20	500	670
Total	551	1,107	1,277

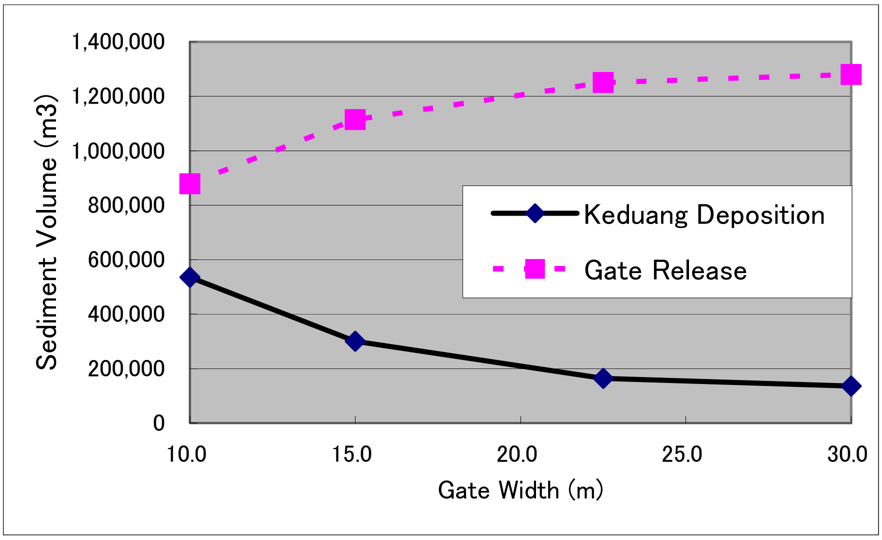


Figure 5.3.1 Sedimentation in Keduang Area and Sediment Release Through the Gate in Hydrological Flood Year (the Crest=127m)

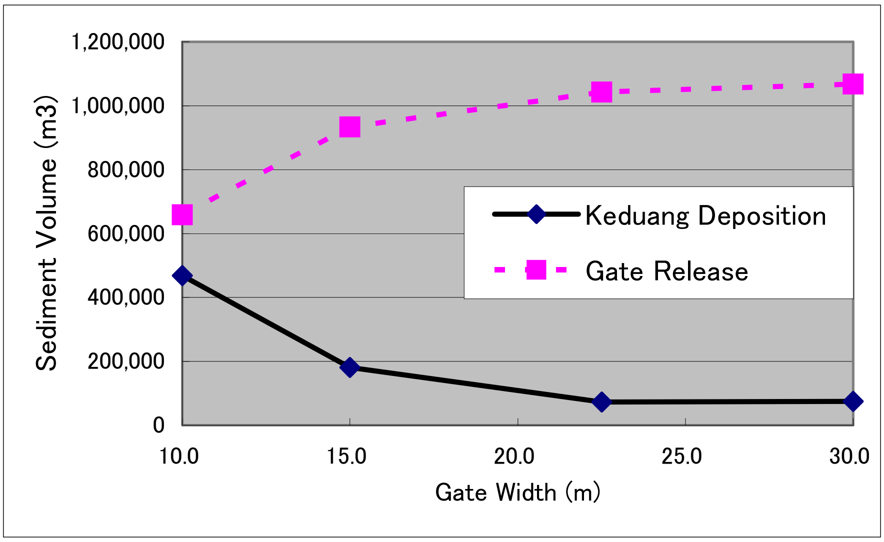


Figure 5.3.2 Sedimentation in Keduang Area and Sediment Release Through the Gate in Hydrological Average Year (the Crest=127m)

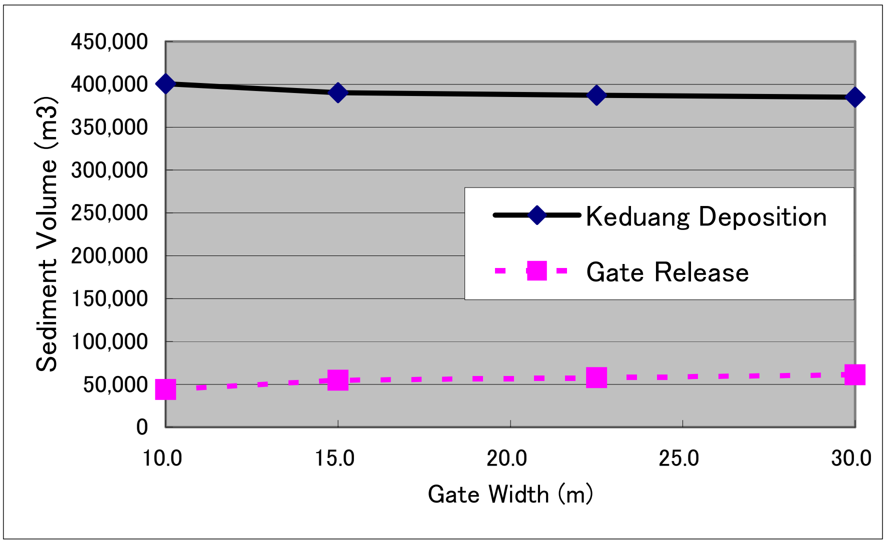


Figure 5.3.3 Sedimentation in Keduang Area and Sediment Release Through the Gate in Hydrological Drought Year (the Crest=127m)

5.3.2 Crest Level of the Sediment Flushing Gate

With the gate width 15m and reset the crest level to 128m, sedimentation simulation is also carried out. The facility plan is shown in Table 5.3.3, but the crest level at 128m.

The inflow and other conditions are the same as listed in Table 5.1.2.

Total volumes of water release are 20 million m^3 in hydrological drought year, 0.48 billion m^3 in hydrological flood year and 0.67 billion m^3 in hydrological flood year, respectively, which are almost the same as those at the crest level 127m.

Sedimentation volume in different area of the reservoir (Figure 3.2.1) is listed in Table 5.3.9.

Table 5.3.9 Sedimentation Distribution and Sediment Release Volume (Compartmented Reservoir with New Gate, the Gate Width 15m and the Crest=128m)

Area	Sedimentation Volume (m3)		
	Drought Year	Average Year	Flood Year
Dam	165,800	111,000	143,100
Keduang	401,100	539,900	565,300
Tirtomoyo	314,200	513,000	602,300
Temon	104,100	87,400	154,800
Solo&Alang	303,800	632,100	804,600
CenterUP+ Wuryantoro3	499,900	571,200	519,800
Center	255,800	283,600	252,700
Wuryantoro	86,600	197,000	187,800
Wuryantoro2	24,900	52,300	47,900
PowerPlant	210,000	94,300	112,600
SandGate	44,400	578,800	859,800
Total	2,410,000	3,660,000	4,250,000

By the results, it can be calculated that sediment trap ratios under different inflow conditions are 89.4％、81.6％、77.1％, respectively. Sediment release volumes from the intake and the new gate are 210,000 m^3 and 44,400 m^3 in hydrological drought year, 94,300 m^3 and 578,800 m^3 in hydrological average year, and 112,600 m^3 and 859,800 m^3 in hydrological flood year, respectively. Volume differences of sediment release between the crest level 128m and 127m (the gate width are all in 15m) are -10,400m^3 in hydrological drought year, -359,300m^3 in hydrological average year and -254,300m^3 in hydrological flood year, respectively. Comparing to those in the results with the crest level 127m (the gate width 15m), the sediment trap ratios in hydrological average year and flood year increase 9.8~6%.

The simulation shows that sediment release through the new gate with the width 15m and the crest 128m is almost the same as that with the gate width 10m but the crest 127m. Comparing to the sediment release with the gate width 15m and the crest 127m, the efficiency reduces a lot if the crest level is raised to 128 m, even the same gate width 15m is set.

CHAPTER 6 CONCLUSIONS

The sedimentation in the Wonogiri reservoir is severe and the situation is deteriorating from the following viewpoints.

- Sediment deposits near the intake
- Decrease of effective storage volume
- Higher sediment yield in watershed of the Wonogiri Dam

The countermeasures against the sedimentation problem in the Wonogiri reservoir are imminent.

In the study, in order to evaluating the effect of countermeasures against the sedimentation phenomenon, a depth-integrated two-dimensional numerical analysis model has been developed to study the flow condition and potential of sedimentation in the Wonogiri reservoir under different conditions. The model is first verified by the measured data of sedimentation in the reservoir and sediment release from the reservoir. The results showed that the model can be employed to simulate the sedimentation in the Wonogiri reservoir.

The simulation has shown that counter flow to the reservoir center due to the flood in the Keduang river occurred, and accordingly, the sediment-laden flood was inversely transported into the center of the reservoir from the Keduang River. Besides that, there was almost no sediment exchange between Keduang area and the reservoir upstream area in rainy season. This feature is very important when we consider the countermeasure against the sedimentation problem in the Wonogiri reservoir. The countermeasures for the Keduang river should be considered differently from those for other areas.

There are some countermeasures for the problem, including the soft and the hard (structure) alternatives. Conceivable structure alternatives for the sediment from Keduang river are as follows (Figure 4.4.1).

- Keduang River sediment bypass: diverting portion of Keduang river flood from the reservoir at the inflowing location
- Sediment sluicing by new gates: setting a new gate near the right end of the dam for sluicing the Keduang river flood
- Compartmented reservoir with new flushing gates and dike: constructing a dike up to the level 138.3m to divide the reservoir into Keduang portion (right) and the main body (left), a new gate near the right end of the dam for sluicing the Keduang flood and a weir for the water exchange between the Keduang portion and the main body. Through the new gate, sediment-laden flood inflow from the Keduang River can be passed through before deposition in the reservoir, without emptying main body of the reservoir.

The model has been applied to predict the effect of proposed mitigation countermeasures against the sedimentation in the reservoir. By the study, an effective mitigation countermeasure, the Compartmented Reservoir with New Gate, has been concluded as follows.

- The sediment release efficiency by the Compartmented Reservoir with New Gate under the new operation rule is quite higher. In both hydrological average year and flood year, volume of sediment release reaches to around 1 million m^3.
- Sedimentation in the area around the intake becomes slightly.
- Under the new operation rule, the reservoir water level can be kept at higher level by the end of the rainy season in all hydrological years. Therefore, it could be understood that the water use by the new sediment flushing gate is normally released from the reservoir according to the dam operation rule for the safety of the dam.
- At the crest level 127m, the efficiency of sediment release decreases a lot if the width of new gate reduces from 15m to 10m. Wider than the width 15m of the gate, variation of the efficiency is not so greater.
- The efficiency reduces a lot if the crest level is raised to 128m, even the same gate width 15m is set.

From the viewpoint of the balance between cost and benefit, it is recommended that the width and the crest level of new sediment flushing gate are set to 15m and 127m.