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2D REPRODUCTION ANALYSIS OF RESERVOIR SEDIMENTATION CAUSED BY FLOOD

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ABSTRACT

Reservoir sedimentation of an existing hydroelectric dam was reproduced by two-dimensional numerical analysis. To make the calculation simple, numerical analysis was based on parametric studies. As a result, reservoir sedimentation was reproduced by two-dimensional analysis, in terms of sediment's volume. In addition, relation between reservoir level and inflow, for the effective dredging of sediments, were estimated to some extent. We will conduct additional experimental operation and numerical analysis to obtain more information about moving sediments into the dead storage effectively.

1. GENERAL INSTRUCTIONS

Moving sediments into the dead storage of reservoir is one of the effective countermeasures for reservoir sedimentation by dredging method, such as pump dredging, but the high cost remains to be an issue. In order to reduce the cost, authors studied a way to move the sediments into the dead storage of reservoir by drawing down the reservoir water level during flood. On the other hand, however, drawing down the reservoir water level will cause loss of electric power production. In this study, reservoir sedimentation of an existing dam was reproduced by two-dimensional numerical analysis, so as to contribute to the cost analysis of dredging method.

2. ANALYSIS CONDITION

2.1 Terrain Model

Terrain model range is shown in Figure 1. Terrain model is 2.5km long from upstream to downstream direction of the existing dam reservoir. Upstream boundary includes area where river-bed level is higher than designed HWL (high water level), due to sedimentation. Downstream boundary have less or no sedimentation.

Figure 1. Terrain model range

Computational grid of the terrain model is shown in Figure 2 and Table 1. Grid size of downstream area were made larger than upstream area to shorten the calculation time.

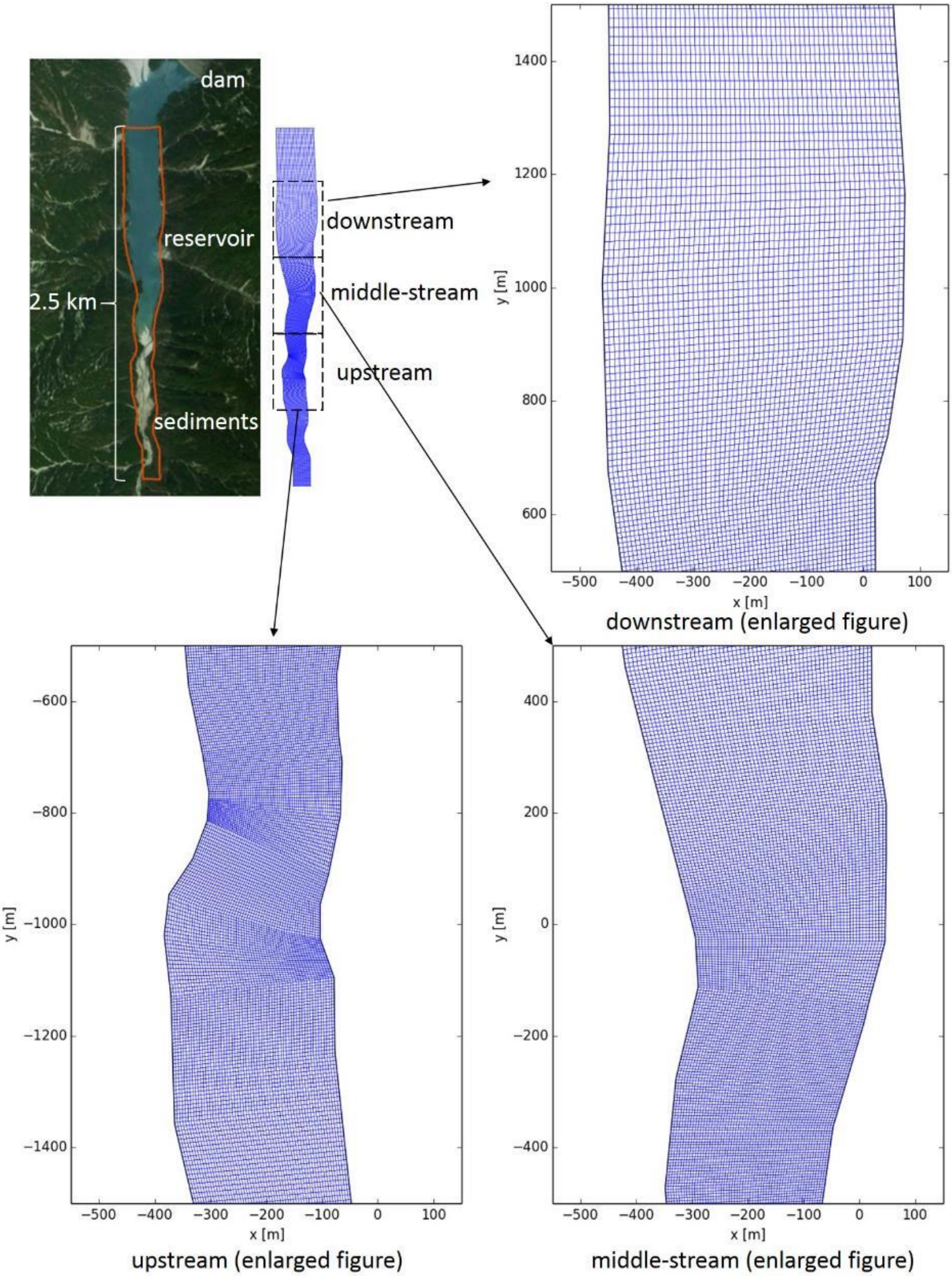

Figure 2. Computational grid of the terrain model

Table 1. Computational grid condition

	Grid number	Grid size
Upstream to downstream direction	543	4.4~20m
Transvers direction	60	3.7~8.9m

2.2 Estimation of Sediment Volume

Sediment volume of the reservoir between 2004 and 2006 was estimated by subtracting the river-bed altitude of 2004 from that of 2006, which were measured by bathymetry. Altitude of the river-bed (2006), ZB[2006], and altitude difference of the river-bed (2006 - 2004), ZB DIFF[2006-2004], are shown in Figure 3. Sediment volume is shown in Table 2. River-bed is forming a delta at y = -300~200m, where 430,000m^3 sediments, which accounts for nearly 60% of the total sediments, are moving between 2004 and 2006.

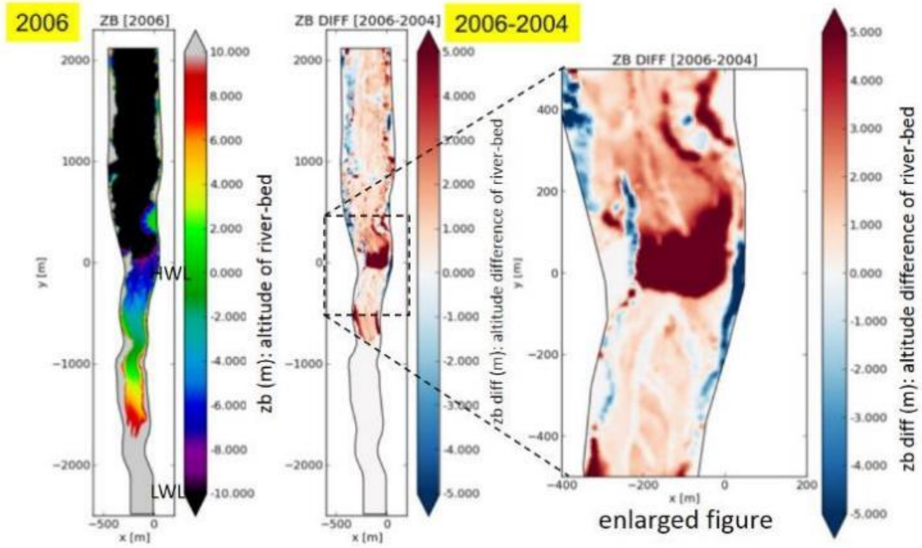

Figure 3. Altitude of the river-bed (2006) and altitude difference of the river-bed (2006 - 2004)

Table 2. Sediment Volume

		y (upstream to downstream direction)		
		-800~500m	-800~200m	-300~200m
year	2005-2004	295,000m^3	195,000m^3	130,000m^3
	2006-2005	445,000m^3	425,000m^3	300,000m^3
	2006-2004	740,000m^3	610,000m^3	430,000m^3

2.3 River Inflow

River inflow and reservoir level from 2004 to 2006 is shown in Figure 4. Thirteen floods were extracted for “short period calculation”, twenty-four for “long period calculation”, from the whole data. “Short period calculation” was conducted to identify the major parameters in short calculation time, followed by “long period calculation” for detailed analysis.

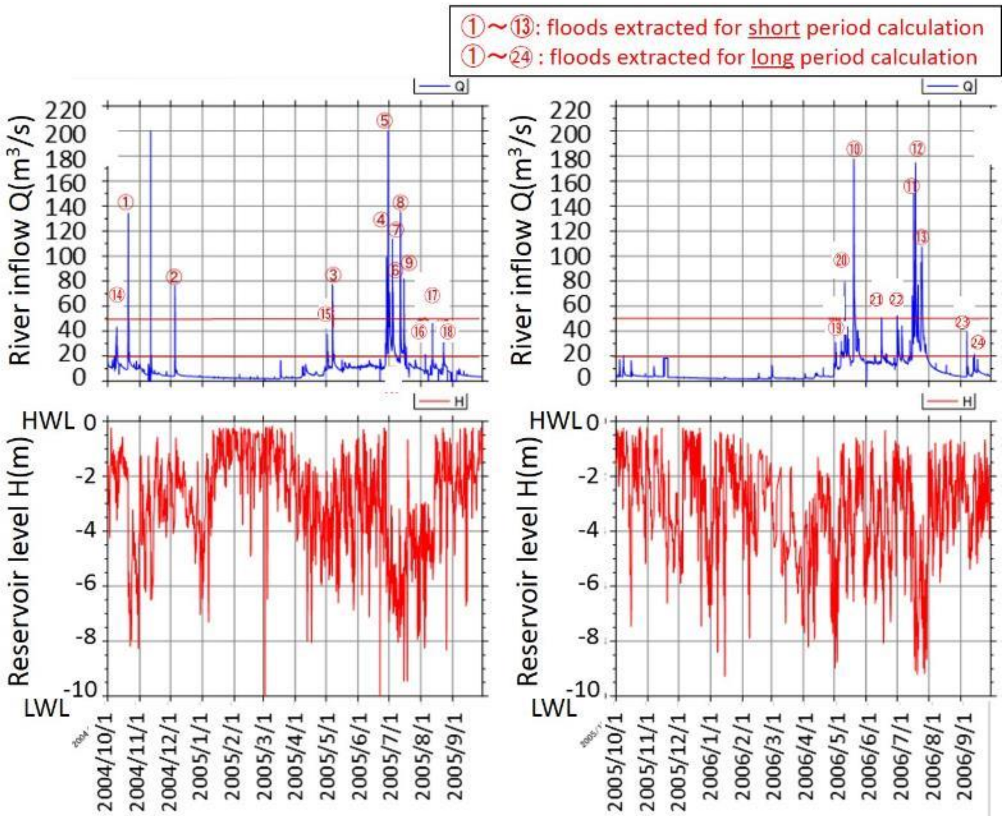

Figure 4. River inflow and reservoir level

Inflow under around 50m^3/s were omitted for short period calculation, 20m^3/s for long period calculation as well. In case of long period calculation, inflow under 20m^3/s have less or no influence on reservoir sedimentation. River inflow and reservoir level of short period calculation and long period calculation are shown in Figure 5 and Figure 6, respectively.

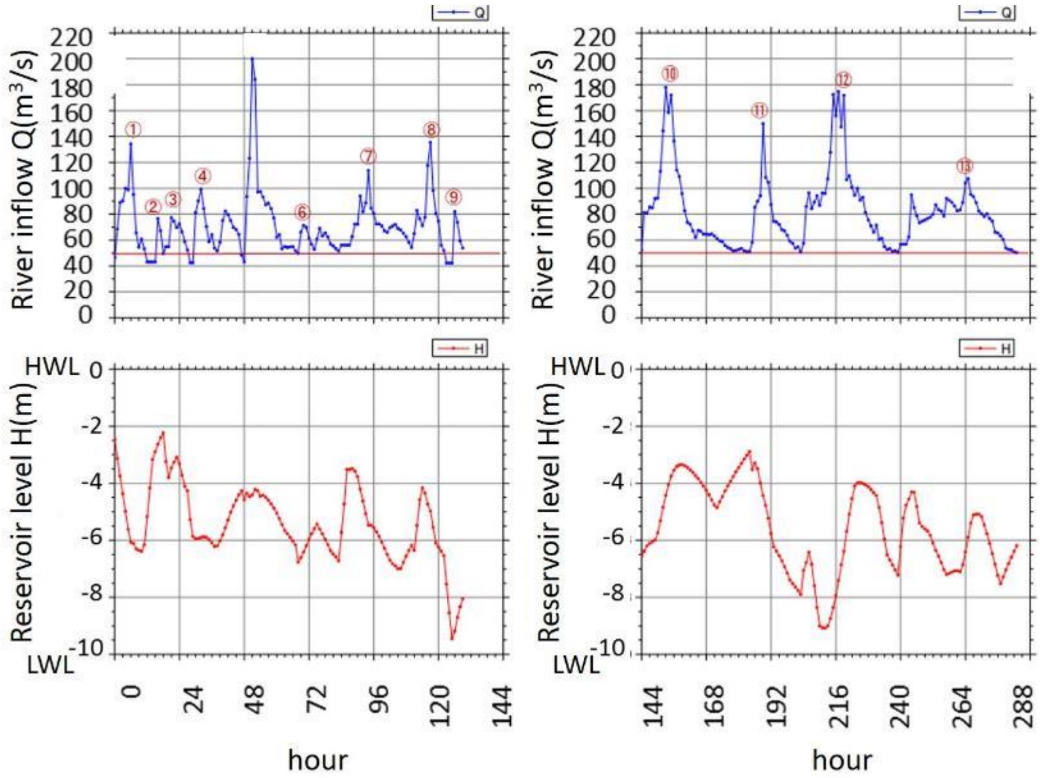

Figure 5. River inflow and reservoir level for short period calculation

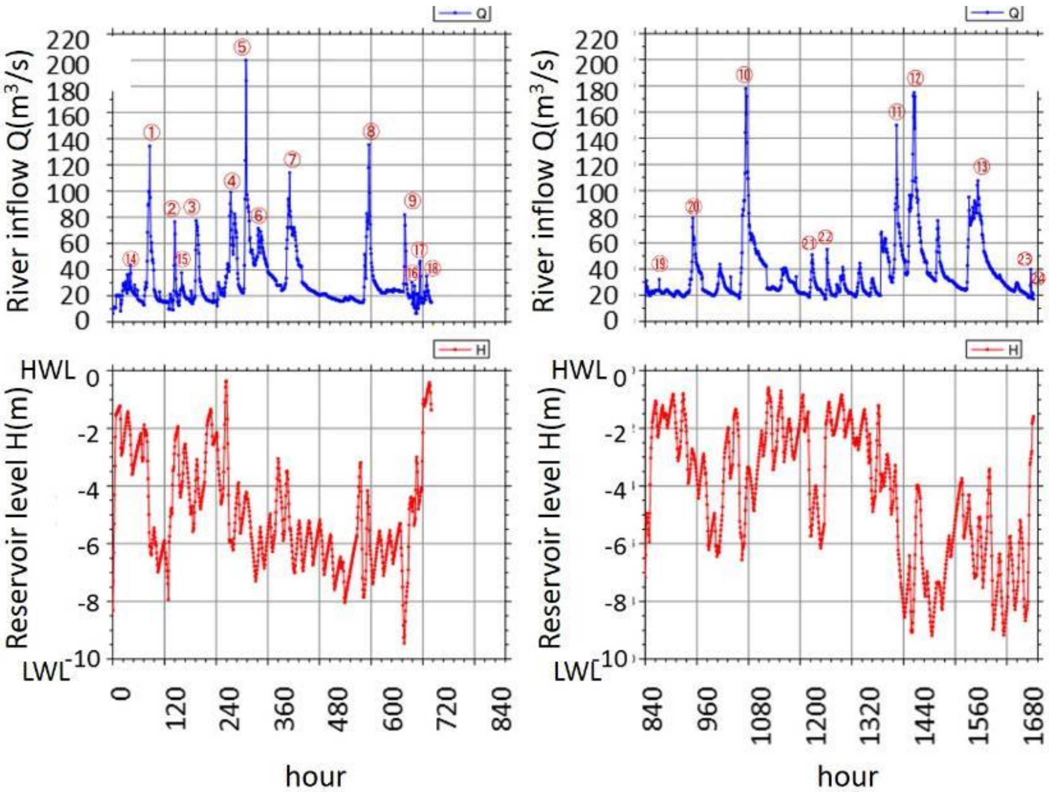

Figure 6. River inflow and reservoir level for long period calculation

2.4 Sediment Concentration

Sediment concentration was calculated by the formula shown below:

$$C = aQ^{b-1}$$ (C: sediment concentration, Q: river inflow)

Coefficient a and b were studied by trial calculations in order to fit the sediment volume and concentration monitored. Two alternatives were obtained shown in Table 3..

Table 3. Parameters of sediment concentration

Sediment concentration			Total river inflow (m^3)	Total sediment volume (m^3)	
a	b	C (average)	2004-2005, y = -800~200m	Calculated	Estimated
2.4e-3	1	2.40e-3	8,338	200,117	195,000
0.5e-4	2	1.87e-3		195,541	

2.5 Soil Particle

Particle size distribution was assumed to be singular, to shorten the calculation time. 1mm was applied for the particle size, from the boring survey, and, by concerning the relationship between particle size and type of sedimentation analysed in previous study (Kazuo A et al. 1974). In addition, the effect of repose angle of the sediments was considered to improve the accuracy of the analysis. As shown in Figure 7, soil particles, represented by cells, will move to the next cell when the gradient of the two adjoined cells exceeds the repose angle of 37 degrees. 37 degrees was applied for the repose angle considering the general repose angle of 30 degrees and 45 degrees for clay and sand, respectively. Shear stresses were not taken into account because the sediments of the site are composed of sandy soil, which were assumed to have less or no shear stresses inside the water.

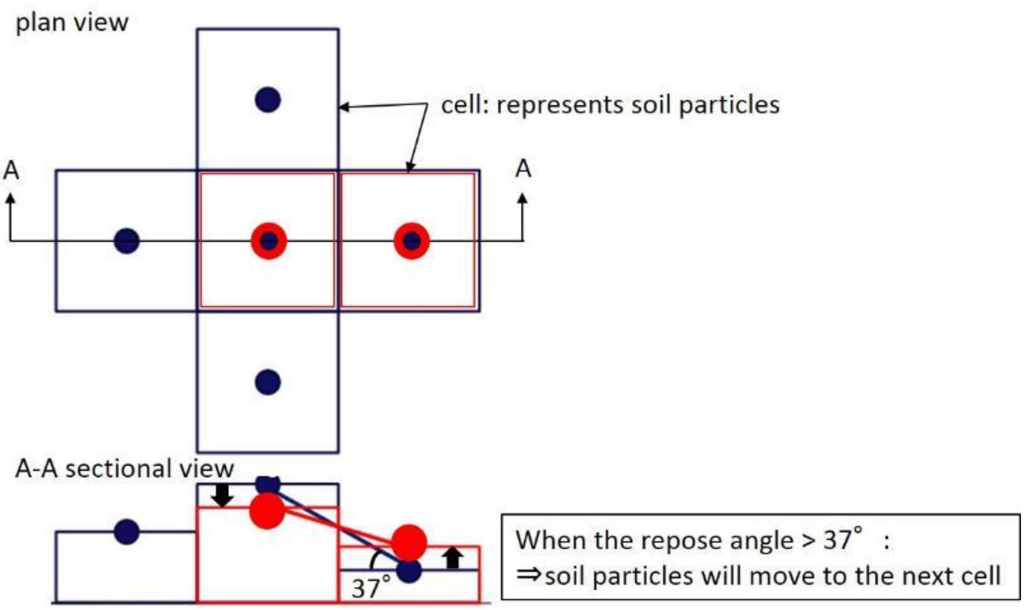

Figure 7. Effect of repose angle

2.6 Roughness Coefficient

For the roughness coefficient, n = 0.025 and 0.050 were considered in parametric study.

3. SHORT PERIOD CALUCULATION RESULTS

Sediment volume of the reservoir between 2004 and 2006 was estimated by subtracting the river-bed altitude of 2004 from that of 2006. In this case, altitude of the river-bed (2006) was calculated by short period calculation. Altitude difference of the river-bed (2006-2004), ZB DIFF, is shown in Figure 8. In addition, sediment volume is shown in Table 4. When the effect of repose angle is not taken into consideration, sediments accumulated in upstream area, and sediment volume was about five percent of the measured value. When the effect of repose angle is taken into consideration, sediment volume was about fifty percent of the measured value. The reason of the small sediment volume can be explained by relatively small river inflow in case of short period calculation. The difference in coefficient a and b for sediment concentration had little effect on the calculation result. For the roughness coefficient, sediment volume was about one-sixth of the measured value in case of n = 0.025, so, in this study, further calculation was conducted in case of n = 0.050.

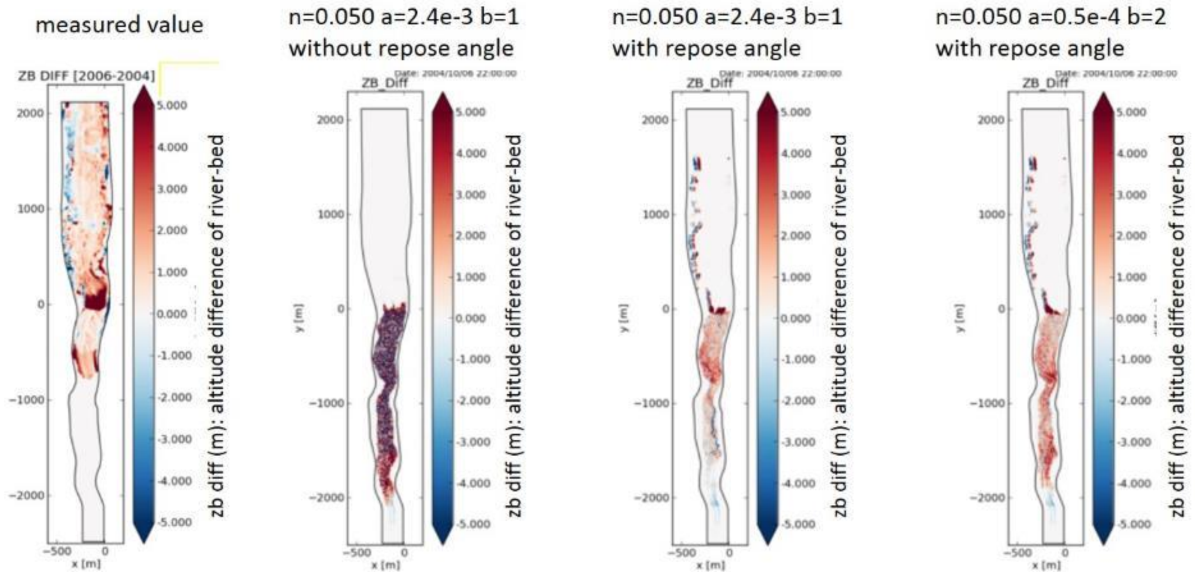

Figure 8. Altitude difference of the river-bed (2006-2004) by short period calculation

Table 4. Sediment volume (short period calculation)

Case	Parameters	y = -800~200m
measured value	-	610,000m^3
1	a=2.4e-3 b=1 (without repose angle)	35,000m^3
2	a=2.4e-3 b=1 (with repose angle)	315,000m^3
3	a=0.5e-4 b=2 (with repose angle)	315,000m^3

4. LONG PERIOD CALCULATION RESULTS

Sediment volume of the reservoir between 2004 and 2006 was estimated by subtracting the river-bed altitude of 2004 from that of 2006. In this case, altitude of the river-bed (2006) was calculated by long period calculation. Altitude difference of the river-bed (2006-2004), ZB DIFF, is shown in Figure 9. In addition, sediment volume is shown in Table 5. When the effect of repose angle is not taken into consideration, sediments accumulated in upstream area, and sediment volume was about fifteen percent of the measured value. When the effect of repose angle is taken into consideration, sediment volume was almost equal to the measured value. The difference in coefficient a and b for sediment concentration had little effect on the calculation result.

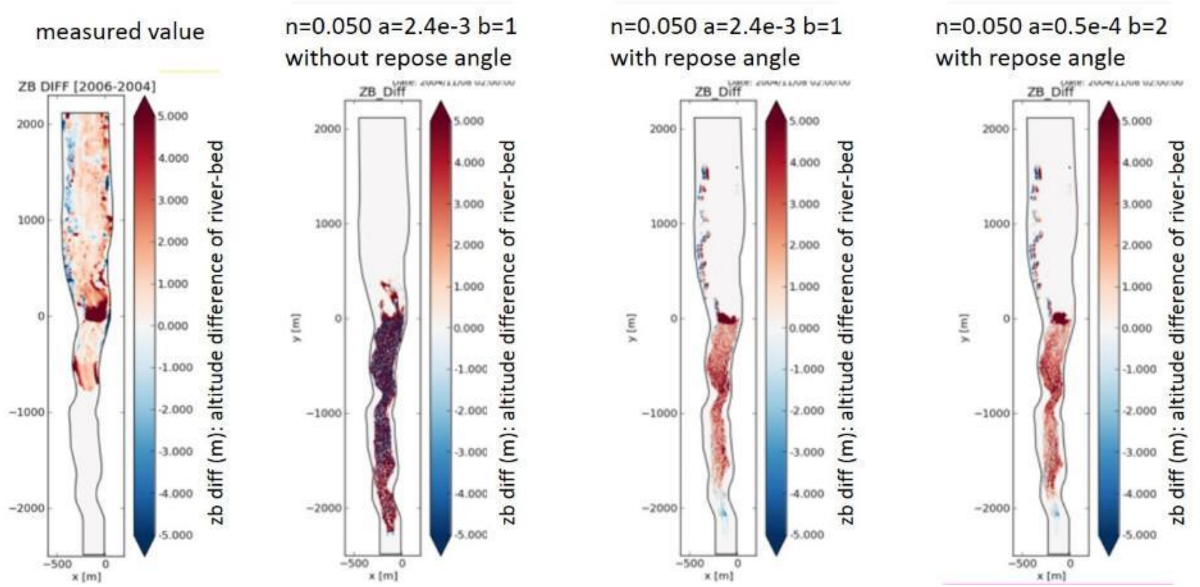

Figure 9. Altitude difference of the river-bed (2006-2004) by long period calculation

Table 5. Sediment volume (long period calculation)

Case	Parameters	y = -800~200m
measured value	-	610,000m^3
1	a=2.4e-3 b=1 (without repose angle)	90,000m^3
2	a=2.4e-3 b=1 (with repose angle)	595,000m^3
3	a=0.5e-4 b=2 (with repose angle)	585,000m^3

5. ANALISYS OF THE CALCULATION RESULTS

The influence on the sediment discharge is studied in terms of the reservoir depth and the water discharge by the long period calculation. The results are shown in Figure 10. The plots show the hourly sediment discharge in case 2 (Table 5) which are characterized by the plot diameters. The figures correspond to the designated locations of No.1 to No.12. For example, in case of location No.10, when river inflow Q=160m^3/s, and reservoir level H=-8m, approximately 1600m^3 sediments were moved. The result indicates that when river inflow is over 80 m^3/s, relatively large amount of sediments can be moved, under the circumstance of reservoir level being lower than five meters (operating water level: ten meters). On the other hand, when the river inflow is less than 80m^3/s, reservoir level should be lower than approximately three meters, in order to move sediments. These results corresponds with the actual phenomenon that in general, large inflow and low reservoir level creates stronger tractive force, which directly affects the movement of sediments.

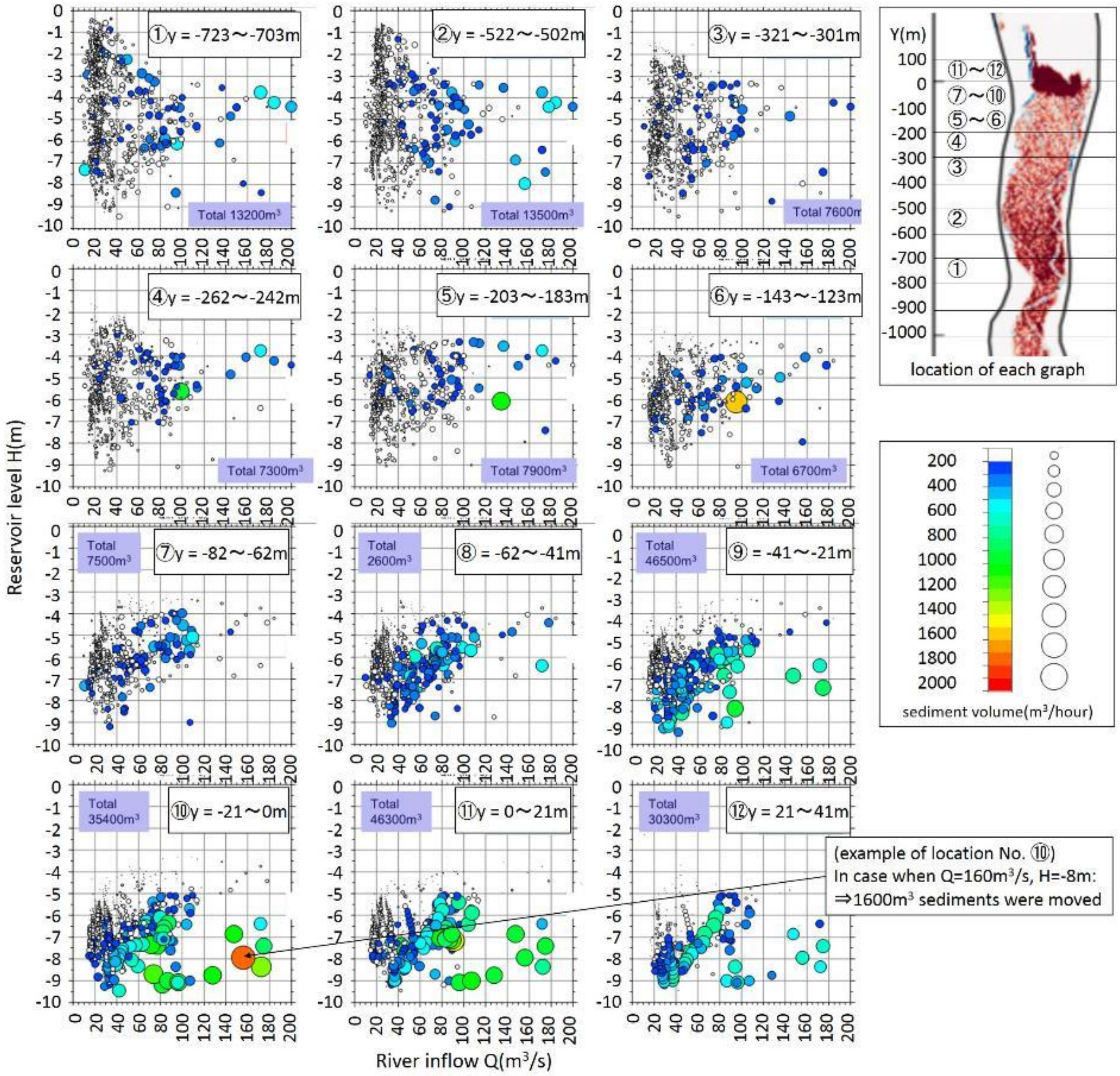

Figure 10. Relation between reservoir level H(m), inflow Q(m^3/s) and sediment volume(m^3/hour)

6. CONCLUSION

Reservoir sedimentation was reproduced by two-dimensional analysis, in terms of sediment volume. In addition, relation between reservoir level and river inflow, for the effective dredging, were analysed. In this study, the result indicates that when river inflow is over 80m^3/s, relatively large amount of sediments can be moved, under the circumstance of reservoir level being lower than five meters (operating water level: ten meters). On the other hand, when the river inflow is less than 80m^3/s, reservoir level should be lower than approximately three meters, in order to move sediments. These results are valuable for the cost analysis of dredging method. We will conduct additional experimental operation and numerical analysis to obtain more information about moving sediments into the dead storage effectively, so as to develop a standard for an economical dredging by reservoir operation.

7. REFERENCES

Kazuo A and Takenobu O (1974). *Study on Sedimentation in Reservoirs*, Disaster Prevention Research Institute Annuals. B-17, pp 555-570 (in Japanese)

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