Test-run plan and environmental monitoring plan for reservoir sedimentation control facilities in Miwa Dam Redevelopment (interim report)

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Abstract

Sedimentation is progressing in the Miwa Dam due to the inflow of large amounts of sediment resulting from floods. In order to recover storage functions, a redevelopment project has been underway since 1987. In the redevelopment project, the sediment bypass facilities which are sediment bypass tunnel, diversion weir and check dam completed in 2005 whereas additional reservoir sedimentation control facility, which is the first trail in Japan, is still under construction. This facility will dredge and convey sediment, which overflowed the diversion weir during floods and accumulated in the dam reservoir, to a "stockyard" located upstream of the diversion weir. When the sediment bypass facilities go into operation, these sediments will be eroded and discharged to the sediment bypass tunnel by the tractive force of the guided water flow from upstream channel during floods. This paper reports on the test-run plan and the environmental monitoring plan for this additional reservoir sedimentation control facilities.

Key words: Miwa dam, sediment control facility, stockyard, environmental monitoring

1 Introduction

The Miwa Dam was completed in 1959 on the Mibu River, which is the largest tributary of the Tenryu River. It is a multipurpose dam intended for flood control, power generation and irrigation. The location and parameters of the Miwa Dam are shown in Fig. 1 and Table1.

The Mibu River flows from its source on Mt. Senjogatake (elevation: 3,033 m) in the Southern Japanese Alps through steep topographies, and produces a lot of sediment partly due to complex geological features along the Median Tectonic Line and large amounts of sediment flow out during flood. Right after the completion of the Miwa Dam, large floods occurred in 1959 and 1961, and, because about 6.8 million m^3 of sediment accumulated in the reservoir and exceeded the initially planned volume of sedimentation, the allocation of reservoir capacities was reviewed in 1966. Even after that, large floods occurred in 1972, 1982 and 1983, and about 7.9 million m^3 of sediment accumulated in the reservoir. Therefore, redevelopment of the Miwa Dam was started in 1987. At present, flood control functions are being enhanced and, at the same time, additional reservoir sedimentation control measures are being implemented.

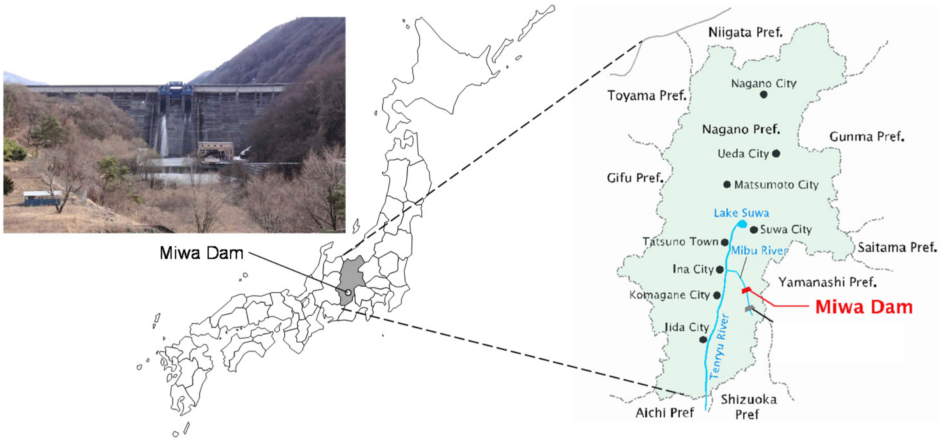


Fig. 1: Location of the Miwa Dam

Table 1: Parameters of the Miwa Dam

Dam reservoir		Dam body	
Catchment area	311.1 km^2	Dam type	Gravity concrete
Gross capacity	29,952,000 m^3	Dam height	69.1 m
Effective capacity	20,745,000 m^3	Crest length	367.5 m
Dead storage	2,621,000 m^3	Emergency spillway	1 crest radial gate
Sediment-storage capacity	6,586,000 m^3	Main spillway	2 orifice gates

The sediment bypass facilities composed of a sediment bypass tunnel, diversion weir and check dam were completed in 2005 and have been operated 14 times up until 2016. In terms of the cumulative amount of sediment over the 14 times of operation, about 1.19 million m^3 of sediment was trapped by the check dam and diversion weir, and, of the roughly 1.06 million m^3 of sand and silt that flowed over the check dam and into the diversion weir, about 550,000 m^3 or 52% were bypassed. Thus, reservoir sedimentation of about 1.74 million m^3 in total was prevented (Fig. 2).

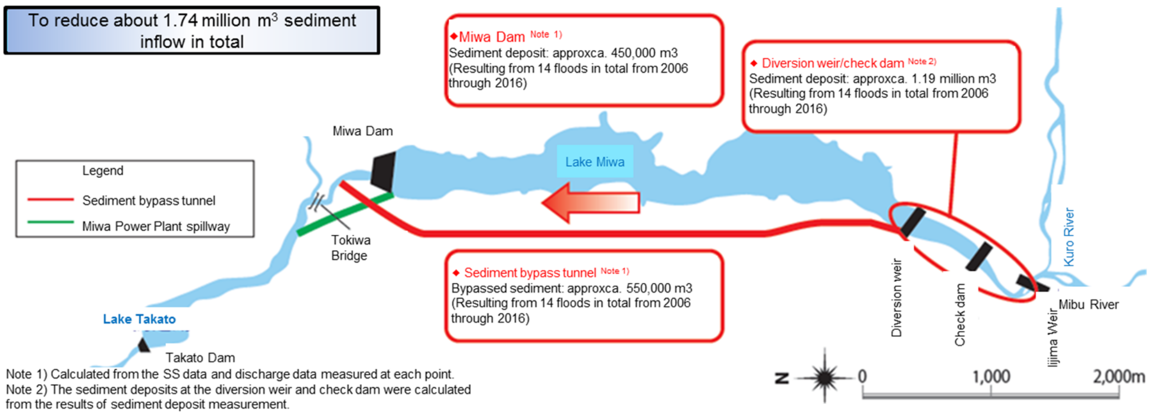


Fig. 2: Effect of the facilities as produced by operation of the sediment bypass

2 Overview of the additional reservoir sedimentation control facilities

A stockyard for storing sediment which is a part of the additional reservoir sedimentation control facilities is built upstream of the diversion weir. The accumulated sediment that has been deposited in the reservoir downstream of the diversion weir will be dredged during the non-flood period and transported to the stockyard. After that, when operating the sediment bypass during a flood, water is introduced from the check dam to the stockyard to carry the sediment to the bypass tunnel by means of the tractive force.

The construction method for the reservoir sedimentation control facilities was determined after studying five plans including one for underwater excavation and conveyance of the sediment to a spoil bank after sediment improvement and one for discharging sediment downstream of the dam by means of a suction pump during floods. Also, when designing the facility, the facility parameters were determined by carrying out numerical simulations and conducting model experiments on the condition that there would be no hindrance to the functions of the existing sediment bypass facilities, it would be possible to collect sediment up to a maximum of 30,000 m^3 as the planned amount for the control measures, and it would be ensured that the sediment in the stockyard would be discharged. As for the collection of sediment, sediment is collected in a submerged state in a stockyard of 20 m in width x 2 rows and 220 m in length, at a water depth of 1 m with a height of collection of 4 m. The sediment to be collected is sand and silt of 2 mm or less in particle size (Fig. 3).

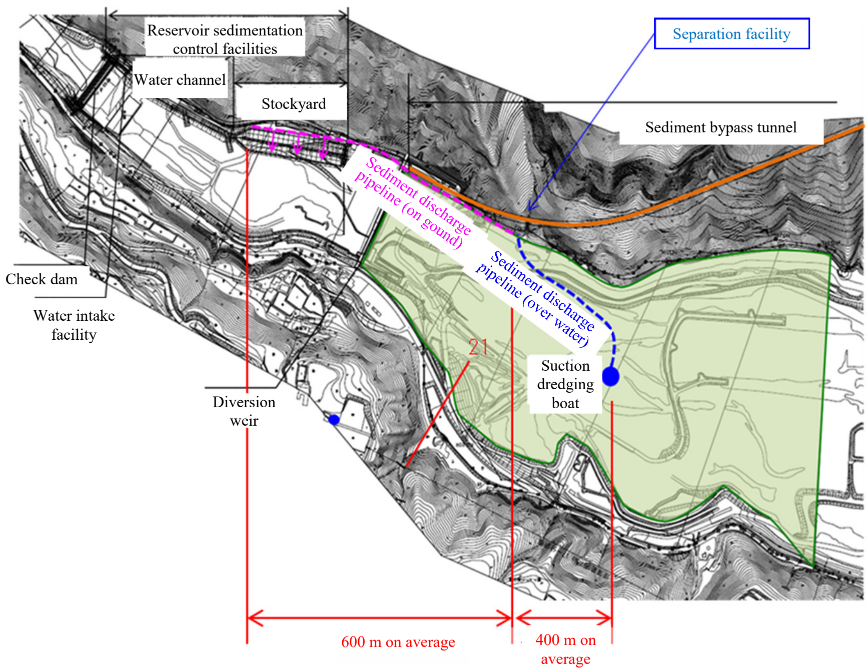


Fig. 3: Layout of the reservoir sedimentation control facilities

3 Operation plan for the reservoir sedimentation control facilities

Operation of the reservoir sedimentation control facilities is to be started when a flood over 100 m^3/s of discharge into the dam is expected to occur, by introducing water of up to the maximum of 40 m^3/s from the location of the check dam into the stockyard, and the sediment that has been collected is allowed to flow downstream (Fig. 4).

The mode of discharge of sediment from the stockyard is assumed based on the results of experiments into the outflow of collected sediment by means of a model. Namely, it has been found that the mode of outflow is such that, of the 4 m height of the collected sediment, sediment up to about 70% of the height from the crown flows downstream as a result of erosion of the top of the slope, while the remaining 30% of the sediment flows downstream as a result of sheet erosion (Fig. 5). The progress of sediment discharge and the time required for it are shown in Fig. 6. Cases where the time for sediment discharge is the fastest and the slowest are assumed based on the result of model experiments.

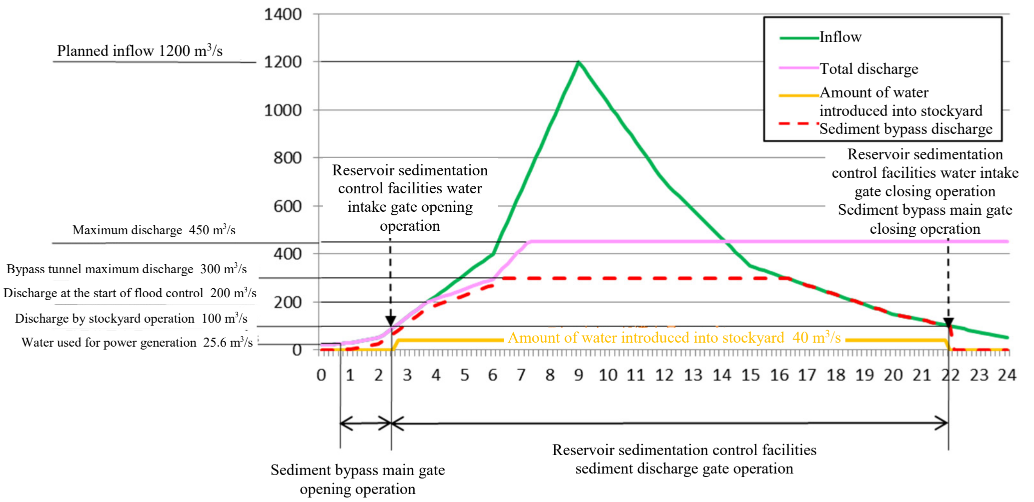


Fig. 4: Operation plan for the reservoir sedimentation control facilities

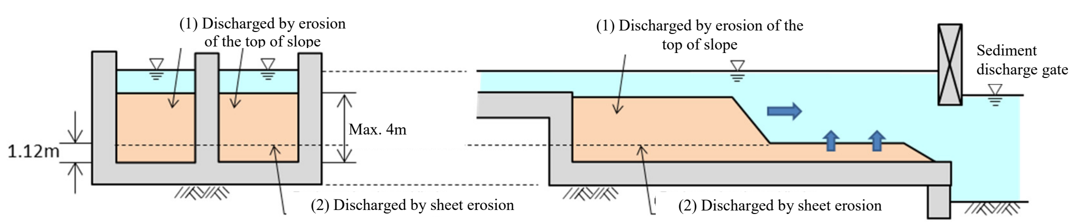


Fig. 5: Image of the mode of outflow of the sediment accumulated in the stockyard

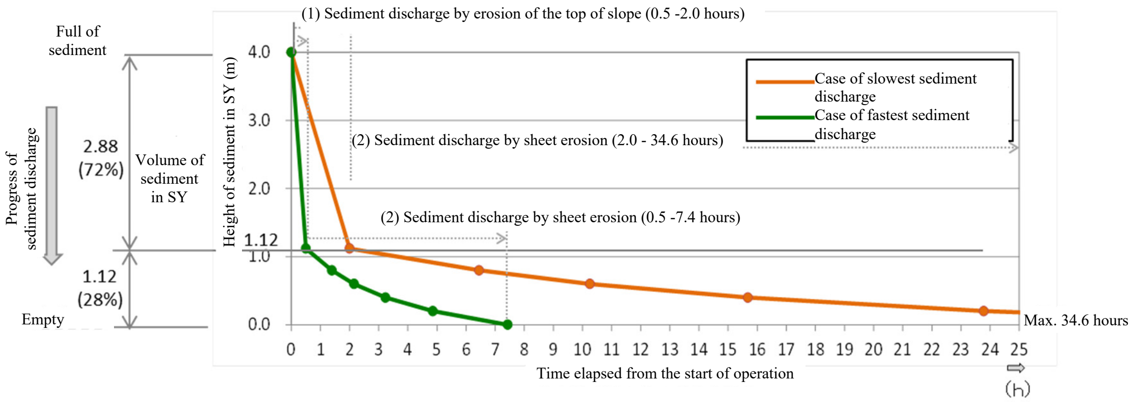
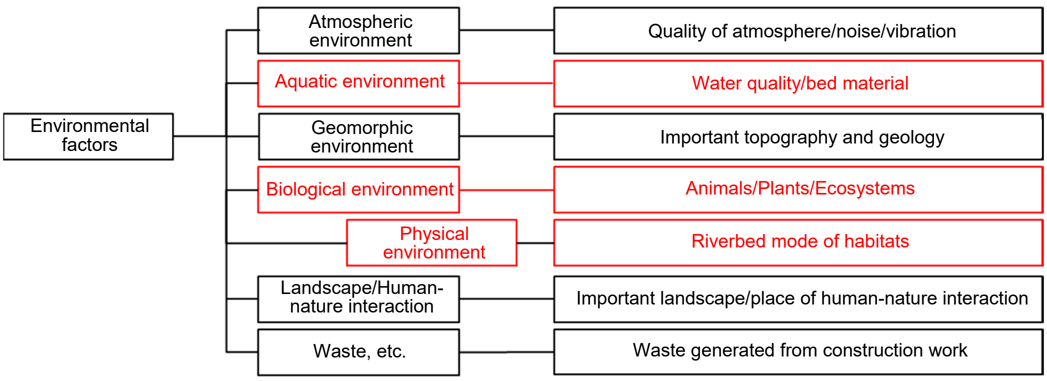


Fig. 6: Progress of sediment discharge and elapsed time

4 Environmental impact on the downstream river

The environmental factors to be considered in the operation of the reservoir sedimentation control facilities are shown in Fig. 7. They were selected from the environmental factors of "dam projects" of which status is specified in the ministerial ordinance of the Ministry of Land, Infrastructure, Transport and Tourism pursuant to the Environmental Impact Assessment Law.



Environmental factor	Item	Remarks
Physical environment	Riverbed configurations (riverbed shape/riverbed material)	To carry out evaluation of the habitat as an environmental factor inherent in the evaluation of the biological environment
Aquatic environment	Water quality (SS/Dissolved oxygen (DO))	To address items that arouse concern based on the impact
	Bed material (NH4-H, total sulfide)	To be specified based on the result of research in the past related to items of health
Biological environment	Living things in water zone (Attached algae/benthic animals/fishes) Living things in land zone (Vegetation)	To address items that arouse concern based on the impact

Red letters: Environmental factors to be considered

Fig. 7: Environmental factor to be considered in facilities operation

Fig. 8 shows the impact/response flow up to the present of the Mibu River, which was conjectured from literature, papers and past research results. Also, Fig. 9 shows the impact/response related to the reservoir sedimentation control facilities to be operated from now on.

It is conjectured that, by operating the reservoir sedimentation control facilities, the amount of flow of sand and silt increases, whereby the concentration of turbid water in the flowing water rises and, at the same time, the duration of such rise is prolonged. Consequently, an impact is made on the aquatic environment (turbid water, dissolved oxygen), physical environment (riverbed materials, riverbed shape), and biological environment (attached algae, benthic animals, fishes, terrestrial vegetation). In particular, the prediction of changes in the aquatic environment, and the prediction of the concentration of turbid water are important points.

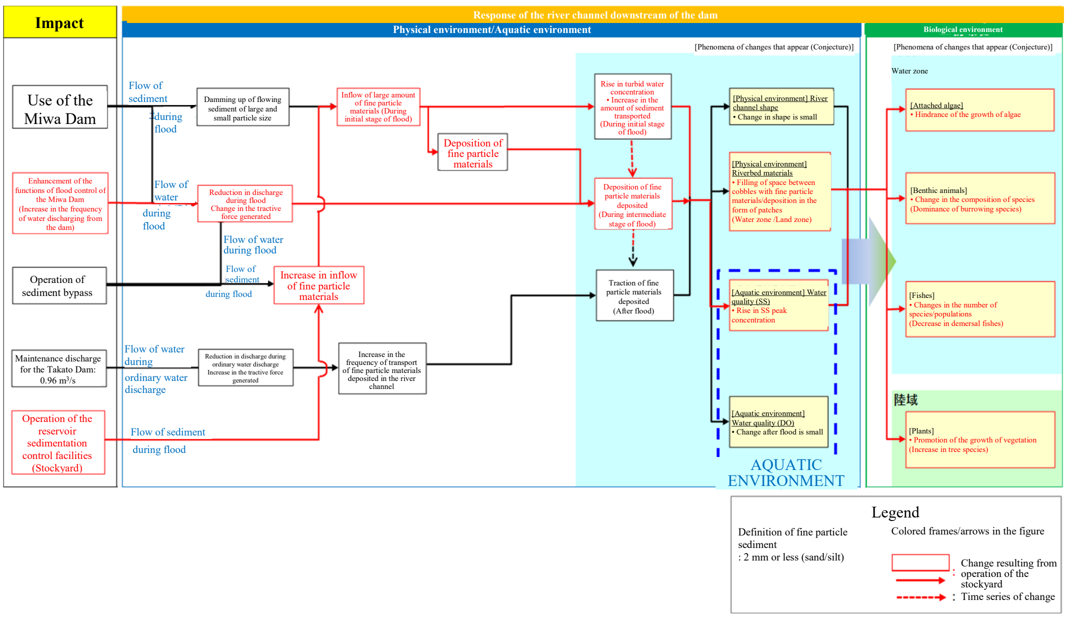


Fig. 8: Conjecture of impact/response flow in the Mibu River

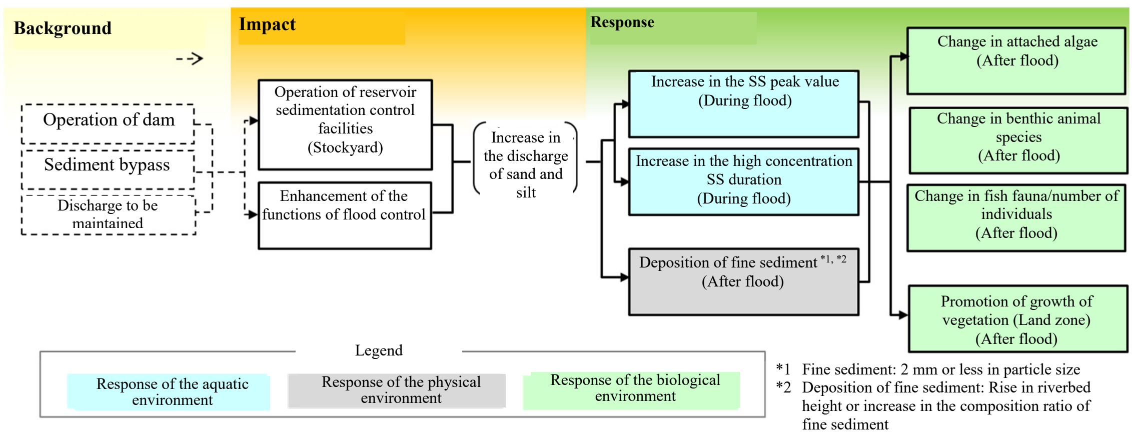


Fig. 9: Conjecture of impact/response flow related to the reservoir sedimentation control facilities

5 Prediction of the aquatic environment

5.1 Method of prediction

As the fine sediment volume bypassing increases, and as the concentration of the turbid water increases, the duration of influence increases. It is, therefore, necessary to predict changes in biological environment (attached algae, benthic animals, fishes, terrestrial vegetation). First, the impacts on the aquatic environment located upstream of response was predicted by means of a numerical simulation model for the SS concentration (Fig. 10). This model took into account the mixing and dilution of the SS concentration in the flow process, and the predicted values for the SS concentration were calculated at the locations ([1] - [14]) shown in Fig. 10.

Regarding the pattern of operation of the reservoir sedimentation control facilities, it was decided to compare and examine two patterns: [1] operation in which the sediment discharge gate of the reservoir sedimentation control facilities is fully opened; and [2] operation in which the amount of sediment discharge is controlled by adjusting the gate opening. Six floods, of which the occurrence probability was 1/100 - 1/1.1, were chosen from data on past floods (98 floods between 1982 and 2011) and the SS concentration was predicted at the location of merger with the downstream Fujisawa River (location [14]). It should be noted that the sediment outflow resulting from the operation of the reservoir sedimentation control facilities was conjectured from the speed of erosion in the aforesaid mode of erosion and cases of faster sediment discharge time that have great impact on the downstream environment were output.

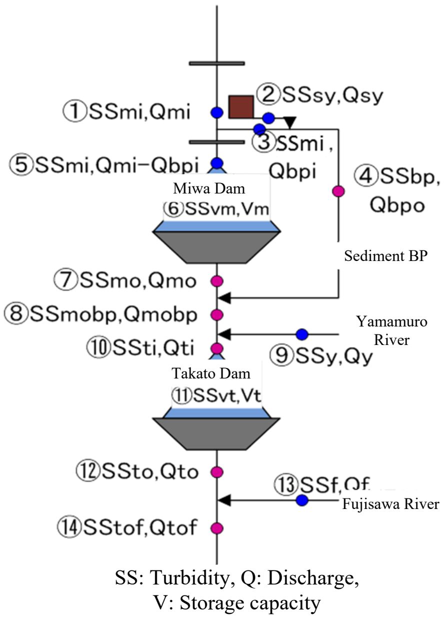


Fig. 10: Simulation model for the predicted values of SS

5.2 Lists

The results of prediction are shown in Fig. 11 and Tables 2 and 3.

In a flood of a relatively high probability of 1/100 and 1/30, the peak caused by the discharge of sediment from the reservoir sedimentation control facilities occurs earlier than the peak of turbid water in both operation patterns [1] and [2], but the SS concentration was about the same level as that before the operation of the reservoir sedimentation control facilities. Also, the downstream river channel is flushed as a result of the flood peak discharge being reached after the discharge of sediment from the reservoir sedimentation control facilities, and it is thought that the impact would be small.

It was confirmed that, in a flood of a relatively low probability of 1/3 - 1/1.1, in operation pattern [1], the SS concentration in the downstream river becomes very high, at 11 - 20 times that prior to operation of the reservoir sedimentation control facilities. Also, when comparing operation pattern [2] in the same manner, the SS concentration became 1.1 - 2.3 times, which is around 1/10 that of operation pattern [1] (Table 2). In the meantime, the amount of sediment discharged from the reservoir sedimentation control facilities became smaller in operation pattern [2], in which the turbid water concentration in the downstream river is adjusted by reducing the concentration, at 21% - 86% as compared with operation pattern [1] (Table 3).

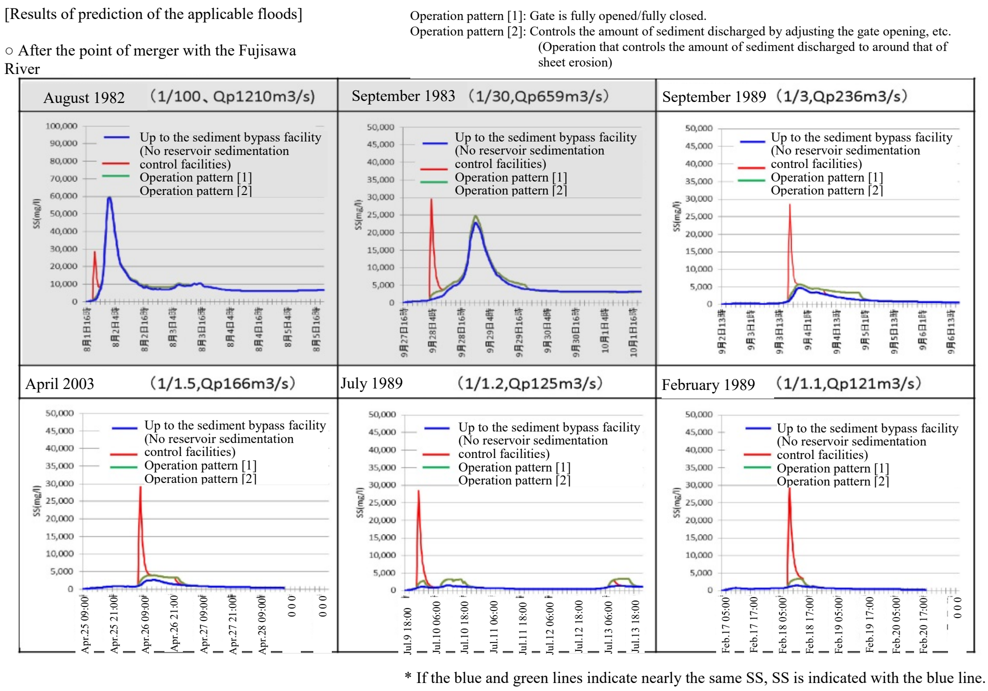


Fig. 11: Results of prediction of the SS concentration at the confluence of the Fujisawa River (location [14])

Table 2: Peak SS concentration at the confluence of the Fujisawa River (location [14])

(Unit: mg/L)

Applicable flood	Before operation of the reservoir sedimentation control facilities (A)	Pattern [1]	Pattern [2] (B)	(B)/(A)
August 1982	59,314	59,314	59,641	
September 1983	22,860	29,492	24,838	
September 1989	4,730	28,543	5,723	1.2
April 2003	2,596	29,113	3,904	1.5
July 1989	1,509	28,514	3,347	2.2
February 1989	1,471	29,614	3,304	2.3

* Red letters show an SS concentration that exceeds the value before operation of the reservoir sedimentation control facilities.

Table 3: Comparison of the amounts of sediment discharge obtained by operation of the reservoir sedimentation control facilities

(Unit: m^3)

Applicable flood	Before operation of the reservoir sedimentation control facilities (A)	Pattern [1] (A)	Pattern [2] (B)	(B)/(A)
August 1982	-	30,000	30,000	
September 1983	-	30,000	30,000	
September 1989	-	30,000	25,800	0.86
April 2003	-	30,000	14,190	0.47
July 1989	-	30,000	18,203	0.61
February 1989	-	26,330	5,590	0.21

* Red letters show cases where it is possible to discharge 30,000 m^3 of sediment as a result of operation of the reservoir sedimentation control facilities.

6 Plan for response to changes in the aquatic environment

The plan for response to changes in the aquatic environment at the present location in time is presented below, although how the operation of sediment discharge from the reservoir sedimentation control facilities and the SS concentration in the downstream river should be settled needs to be continually examined.

In the prediction of the aquatic environment described in the previous chapter 5, it was found that the change in the concentration of turbid water in the downstream river as a result of operation of the reservoir sedimentation control facilities became greater especially during a flood of relatively small magnitude. Since the concentration of turbid water in the downstream river becomes greater as a result of operation of the reservoir sedimentation control facilities, concern arises about the impact on fishes. The *Zacco platypus*, sweetfish, sand loach, *Salvelinus leucomaenis pluvius*, *Oncorhynchus masou ishikawae* and other species live in the Mibu River downstream of the dam, and these fish are known to cause behavior such as evasive behavior by river turbidity. Specifically improvements in the place where fishes temporarily take refuge during flood is scheduled during the operation of reservoir sedimentation control facilities (Fig. 12).

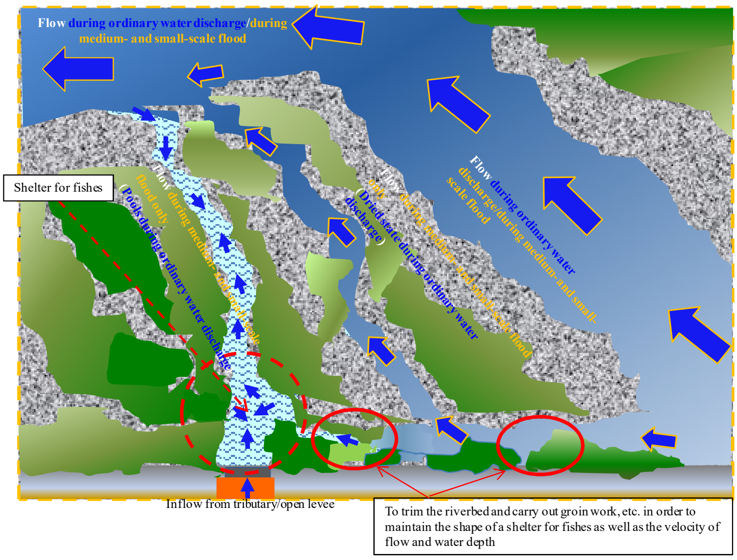


Fig. 12: Securing a place for taking refuge for fishes (Illustrated view)

The reservoir sedimentation control facilities are designed so that fine sediment that has been deposited in the dam reservoir is dredged and transported upstream of the diversion weir during the non-flood period and is temporarily stored there. Then, when operating the sediment bypass facility during a flood, the sediment is discharged by making use of the tractive force of the water flow.

Namely, the reservoir sedimentation control facilities do not allow the natural condition of a flood to be bypassed as is, but instead discharge sediment by increasing the concentration of turbid water by artificial operation. Hence, operation that gives as much consideration as possible to reducing environmental load downstream (Fig. 13) needs to be established.

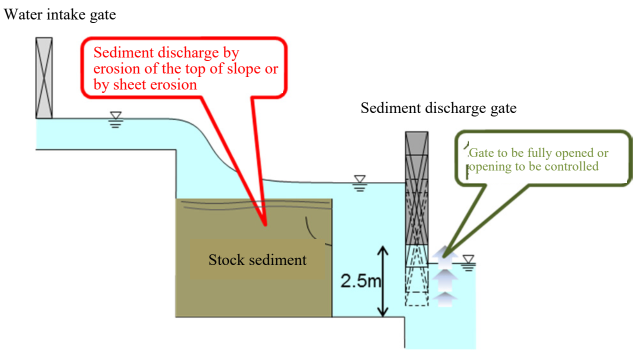


Fig. 13: Operation of the reservoir sedimentation control facilities (Illustrated view)

7 Test-run plan

It is necessary to materialize the plan for response to changes in the aquatic environment that was described in the previous chapter 6 and, at the same time, several matters need to be checked by setting the period of test-runs.

The test-run plan considered at present is as follows.

- If a flood of 100 m^3/s to approx. 250 m^3/s of inflow into the dam is predicted during the test-run period, operation shall be conducted to control the amount of sediment discharged. At first, the amount of sediment discharged shall be controlled to have a small environmental impact on the downstream river. Test runs shall be conducted one by one, and the concentration of turbid water and the act of fish taking refuge in the downstream river shall be investigated. Also, where necessary, places of refuge for fishes shall be improved and added.
- If flood of a magnitude exceeding approx. 600 m^3/s of inflow into the dam is predicted, the sediment discharge gate shall be fully opened and the environmental impact on the downstream river shall be investigated in the same manner as described above.

Table 4 shows the discharge that occurred at each magnitude of flood and the expected number of times of occurrence. By setting the test-run period to 3 years, 6-9 test-runs times in total can be performed including those having floods of a magnitude up to the maximum of about 250 m^3/s.

Table 4: Discharge of the magnitude of flood that can be expected and expected number of times of occurrence in 3 years

Period	Number of times that can be expected in each magnitude of discharge			Number of times of operation
	100m^3/s	200m^3/s	300m^3/s	
1st year	2 - 3	—	—	2 - 3
2nd year	3 - 5	1	—	4 - 6
3rd year	4 - 7	1	1	6 - 9

Performing the test-runs as described above also serves to find ways to conserve power when the reservoir sedimentation control facilities are put into full-fledged operation after transfer of management. The final goal is to completely automate of the operation and control of the facilities.

8 Draft monitoring plans

The draft monitoring plans for the aquatic environment, physical environment, and biological environment are shown in Table 5, Table 6, and Fig. 14. These draft monitoring plans have been prepared based on the separately reported "Sedimentation Control Effect and Environmental Impact of Sediment Bypass in Miwa Dam Redevelopment Project", and the predicted changes in the aquatic environment to come from operating the reservoir sedimentation control facilities, which is currently being examined.

Table 5: Points of environmental monitoring and period of implementation

	Point in time	Purpose	Applicable items	Period of implementation
(1)	Before operation of the reservoir sedimentation control facilities	To obtain data for grasping the environment before operation of the facilities	Items related to the aquatic environment, physical environment, and biological environment	(1) Non-flood period (2) During flood (3) Right after flood (4) During the flood period, except during flood or right after flood
(2)	After operation of the reservoir sedimentation control facilities	To obtain data for grasping change in the environment		

Table 6: Contents of environmental monitoring

Classification	Monitoring Items			Monitoring Location	3 years before test runs	3 years after test runs
Aquatic environment	Water quality	Turbidity, SS		Reservoir River channels upstream and downstream of the dam	●	●
		Particle size		Reservoir River channels upstream and downstream of the dam	●	●
		DO		Reservoir River channels upstream and downstream of the dam	●	●
		NH_4-N, total sulfide		Reservoir River channels upstream and downstream of the dam	●	●
		Water temperature		Reservoir River channels upstream and downstream of the dam	●	●
	Bed material	Particle size composition, items of health		Reservoir	●	●
Physical environment	Riverbed shape	Aerial photograph, cross-sectional surveying		River channel downstream of the dam	●	●
	Riverbed material	Particle size distribution	Riverbed mixed layer	River channel downstream of the dam	●	●
			Riverbed surface	River channel downstream of the dam	●	●
Biological environment	Living things	Attached algae		River channel downstream of the dam	●	●
		Benthic animals		River channel downstream of the dam	●	●
		Fishes	Fishes	River channel downstream of the dam	●	●
			Act of taking refuge	River channel downstream of the dam	●	●
	Vegetation	Vegetation distribution		River channel downstream of the dam	●	●

9 Conclusion

Since the additional reservoir sedimentation control facilities discharge sediment artificially during floods by means of a sediment discharge method to be used for the first time in Japan, sufficient consideration needs to be given to the reduction of environmental impact on the downstream river when operating the facilities. Also, it is important that prior river channel improvement should be carried out in the downstream river to counter the possible changes in the aquatic environment, and the effect thereof should be investigated, evaluated, and, as necessary, improved. Subsequently, these studies are advanced, and it is aimed that the functions of the Miwa Dam reservoir sedimentation control measures are developed effectively and efficiently.

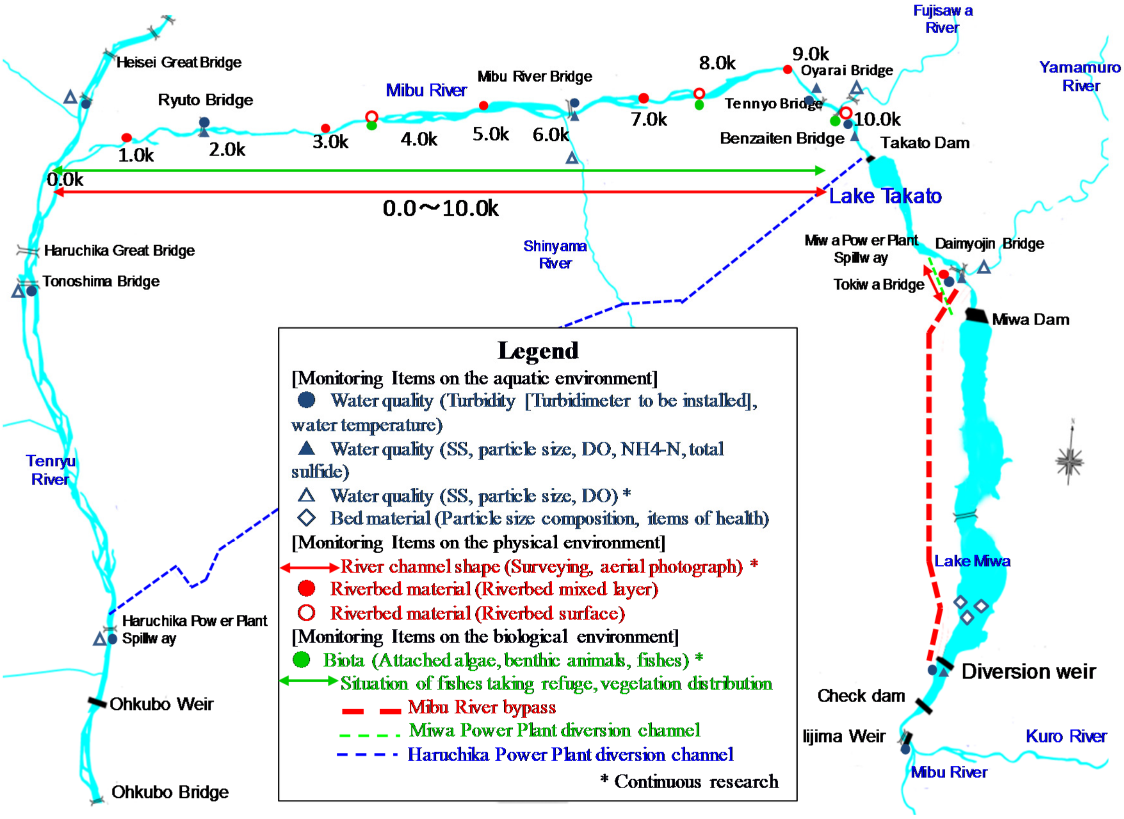


Fig. 14: Locations of environmental monitoring

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