Key Issues: **5- Water Quality**
4- Reservoir Sedimentation

Climatic Zone:
Cf : Temperate, Humid Climate

Subjects:
- Reservoir Bypass of Sediment and Turbid Water during Flood

Effects:
- Prevention of Turbidity Persistence
- Prevention of Sedimentation in Reservoir

Project Name: Asahi Dam
Country: Nara Prefecture, Japan（Asia）（N 34°10’, E 135°50’）

Implementing Party & Period
- Project: the KANSAI Electric Power Co., Inc.
1980 (Completion of construction) -
- Good Practices: the KANSAI Electric Power Co., Inc.
1998 (Commencement of operation) -

Key Words:
Bypass tunnel, Sediment, Turbid water persistence

Abstract:
The Asahi Dam had been suffering from the turbid water persistence. The KANSAI Electric Power Co., Inc. installed a bypass tunnel connecting between the upstream end of the reservoir and the downstream of the dam. The bypass tunnel helps to restore the downstream environment as well as to resolve the turbid water persistence.

1. Outline of the Project

The Oku-yoshino Power Plant is the third pumped storage type hydropower for the KANSAI Electric Power Co., Inc. with the maximum output of 1,206 MW, following the Kisenyama Power Plant (466 MW) and the Oku-tataragi Power Plant (1,212 MW).
The Oku-yoshino Power Plant was planned as a peaking plant to meet augmented electricity demand. The plant plays an important role for improving the grid efficiency and reliability with thermal power plants and nuclear power plants.
The plant had a lot of technical features. One was that the gross head, 530 m was almost highest at that time in Japan. Each unit of the plant was equipped with larger capacity and higher rotation speed. It was also the first plant in Japan at which the static starter was installed.

Table-1 Asahi Dam specifications

Item	Specifications	
River system	Asahi River, Shingu River System	
Catchment area	39.2 km^2	
Power plant (stand-alone pumped storage)	Name	Okuyoshino Power Plant
	Max. output	201 MW/unit x 6 units
	Max. discharge	288.0 m^3/s
	Effective head	505.0 m
Dam	Type	Arch
	Height	86.1 m
	Crest length	199.41 m
	Volume	147,300 m^3
Reservoir	Gross storage capacity	*15.47x10^6 m^3
	Effective storage capacity	*12.63x10^6 m^3
	Available depth	32 m

* when constructed

The investigation for the construction started in 1971 and the construction started in 1975 and ended in 1980.

The specifications is shown in Table-1 and the location is shown in Fig.-1.

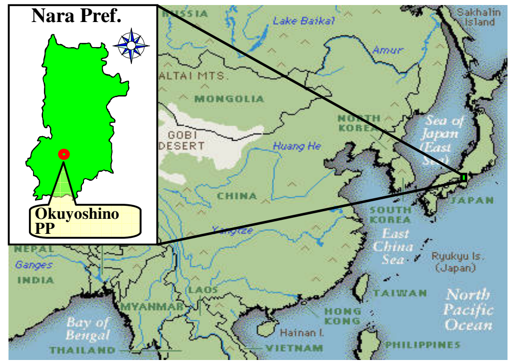

Fig.-1 Asahi Dam location

2. Features of the Project Area

The Asahi Dam is situated in the Shingu River System rising from the Omine Mountains in the southern part of Kii Peninsula, the rainiest area of Japan, and the site has an annual precipitation in excess of 2,000 mm. Precipitation is heavy during the period from the rainy season in June to the typhoon season in September with the past maximum discharge of 662 m3/s recorded in September of 1990.

Mature, rugged mountainland of elevation from 1,000 to 1,800 m is developed in the watershed. River valleys are V-shaped and river gradients are steep, from 1/6 to 1/7. Conifers such as cedar and Japanese cypress have been planted on the steep mountain slopes while there are also mixed stands of oak and red pine. Locations where collapses have occurred have been increasing in the catchment ever since construction and a comparison of survey results for 1966 and 1990 shows that collapsed areas have increased by 12 times.

Inspections of areas where logging had been carried out, geological conditions, and topography as factors causing collapses revealed that distributions of logged areas and of Omine acidic rocks overlapped where ratios of collapsed areas were high. Furthermore, the topography comprised precipitous slopes. It was considered that these were the causes of collapses.

3. Major Impacts

At the Asahi Dam Reservoir, the lower pond of the Oku-yoshino Power Plant, preventive measures against turbidity such as operation of selective intake, installation of a filtering weir immediately downstream of the dam, and protective works against slope collapses around the regulating reservoir had been carried out since the completion of the construction. However, due to changes in the watershed caused by activities upstream such as logging, and especially because of mountainside collapses resulting from large-scale floods brought by typhoons in 1989 and 1990, the problem of turbid water persistence has become prominent. In addition, sedimentation far in excess of original estimates has become a matter of great concern, and radical countermeasures have become necessitated.

Since the problem of turbid water persistence became apparent, daily measurements have been carried out on turbidity and water temperature upstream of the dam, the regulating reservoir of the dam, and downstream of the dam. Also, water quality of the reservoir has been examined once a month. There are no houses upstream of the Asahi Dam to release domestic effluents, while inflow of turbid water and sediment to the reservoir, leaching of nutrient salts from bottom sludge resulting from sedimentation, and consequent tendency for eutrophication were nonexistent.

Fig.-2 shows the number of days turbidity persisted downstream of the Asahi Dam and the transition in the collapsed area ratio upstream of the dam. According to the results, collapsed areas gradually increased after operation of the dam, specifically triggered by the large-scale typhoons of 1989 and 1990. It caused that huge quantities of sediment were washed down from collapse areas and carried into the regulating reservoir to cause extremely turbid water persistence.

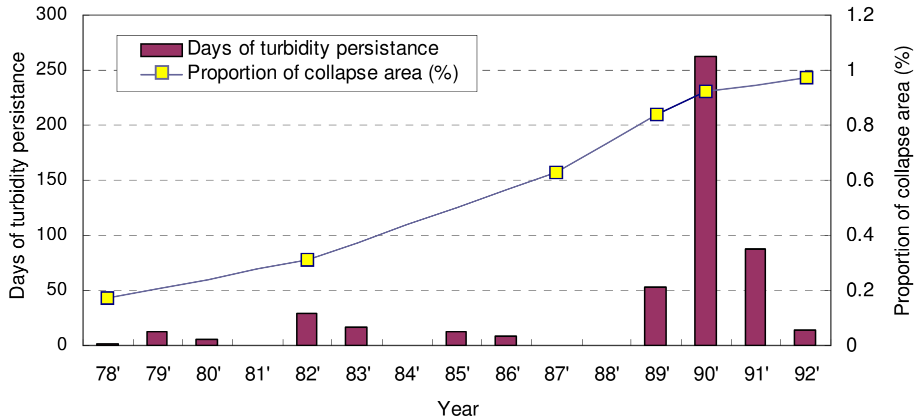

Fig.-2 Number of days of turbidity persistence downstream of Asahi Dam and ratio of upstream collapse areas

4. Mitigation Measures

Various countermeasures to turbid water persistence were carried out since the start of operation of the dam, but satisfactory results were not obtained against lasting turbidity caused by very large floods. With strong requests for improvement from the local community, proposals of mitigation measures were studied from 1991. Improvements on selective intake operations, protection of collapse areas, gravel filtration in the downstream channel, forcible settling through use of coagulants, filtering with turbidity-preventing membranes, and sediment bypassing were some of the steps contemplated, and installation of a bypass, the first in Japan, which would be a radical measure resolving the problem of sedimentation at the same time, was chosen.

To elaborate, there is no need to store water from the flow of the river since the plant is a stand-alone pumped storage type, while the catchment area is comparatively small. The sediment bypassing facility would consist of a bypass tunnel to route turbid water and sediment load around the reservoir and into the downstream river channel.

In planning and designing facilities, the fundamental layout was first selected based on characteristics of the site such as the river channel configuration, and not only wash load, but also suspended and traction loads were considered from the points of view of lessening turbid water persistence and of reducing sedimentation. Technical problems such as determination of the optimum tunnel

Sediment bypassing facility	Weir	Height x crest length	13.5×45.0 m
		Structure	Steel
	Intake	Height x width	14.5×3.8 m
		Length	18.50 m
		Structure	Reinforced concrete, steel lined
		Gate	1
	Bypass tunnel	Height x width	3.8x3.8 m (hood shape)
		Length	2,350 m
		Gradient	Approx. 1/35
		Max. discharge capacity	140 m^3/s
		Structure	Reinforced concrete lined
	Outlet	Width x length	8.0～5.0×15.0 m
		Structure	Reinforced concrete

Table-2 Specifications of bypass facilities

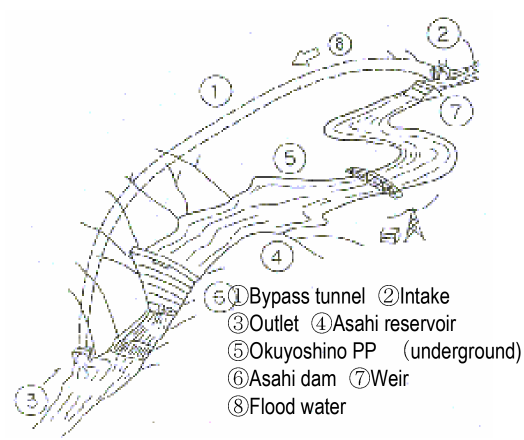

Fig.-3 Outline of Asahi Dam sediment bypassing facilities (Source: Ref. No.1) discharge capacity and avoidance of tunnel blockage by sediment were addressed carrying out model hydraulic tests and numerical simulations. Furthermore, various examinations were made concerning predictions of riverbed changes upstream and downstream of the bypass, hydraulic stability, and problems of maintenance such as abrasion among others. Since the start of operation in 1998, the bypass has basically been used only during floods to detour water and sediment through the tunnel, clear water in normal times being allowed to enter the reservoir. This is because the Asahi Dam is for the regulating pond of a pumped storage power station and thus does not require inflow of water for storage, but inflow would improve circulation of water inside the reservoir and prevent deterioration of water quality.

The particulars of the dam and sediment bypassing facility are given in Table-2 and a sketch of the waterway in Fig.-3 (hereafter referred to as "bypass"). The construction of the bypass was started in 1994 and its operation in April of 1998. As for the upper pond, turbidity problems do not arise since inflows to it are quite small.

5. Results of the Mitigation Measures

In order to ascertain the effectiveness of the bypass since starting its operation, investigations of water quality (turbidity persistence, eutrophication), sedimentation inside the reservoir, sedimentation in the river (river cross section), riverbed gradation, shoals and pools, and aquatic organisms have been carried out as indicated in Table-3. These investigations are for seeing how turbid water persistence and sedimentation have been lessened and what impacts there have been on the downstream riverine environment.

Table-3 Items of environmental impact investigation concerning bypass operation

Items investigated	Site investigated		Contents of investigations
	Dam	*DS river	
Water quality (turbidity persistence)	●	●	Water temperature, turbidity
Water quality (eutrophication)	●	–	Water temperature, turbidity, BOD, COD, T-N, T-P etc
Sedimentation condition	●	●	Cross sectioning
Shoal, pool conditions	–	●	Distribution survey, cross sectioning
Aquatic organisms	–	●	Habitat environment, attached algae, benthos, fish surveys

*DS: Downstream

According to the results of these investigations and measurements, it may be considered that sediment bypassing has been highly effective in mitigating persistent turbidity, inhibiting buildup of sedimentation, and restoring the environment of the river downstream.

Firstly, as an example of the effects concerning the problem of turbid water persistence, the results comparing turbidity conditions upstream and downstream of the dam and in the reservoir before and after starting operation of the bypass are shown in Figs.-4, 5, and 6. The floods used in comparison were of approximately the same scales. Even for floods from which turbidity had lasted close to one month before operation of the bypass (BO in the figures), after starting operation (AO), only three days after flooding had ended, the turbidity had become the same as that upstream with the condition back to normal, and the effectiveness was clearly confirmed. The turbidity inside the reservoir was at a fairly low level compared with that before operation, while it was found that sedimentation was held to approximately 1/10 compared with before operation.

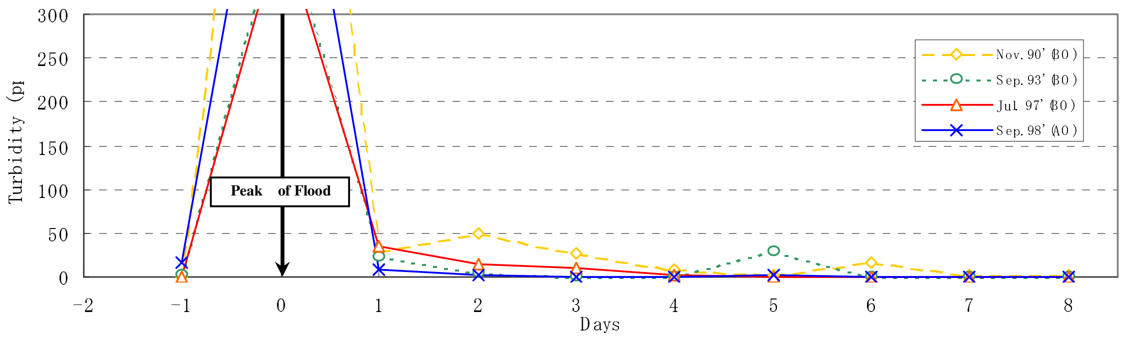

Fig.-4 Turbidity conditions upstream of dam

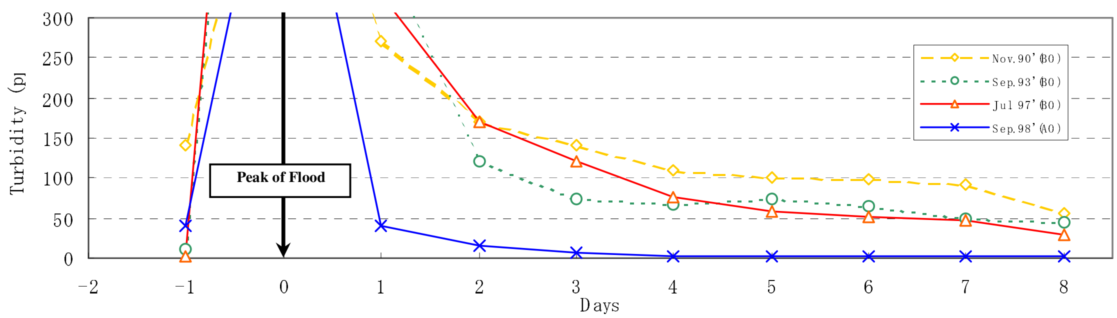

Fig.-5 Turbidity conditions downstream of dam

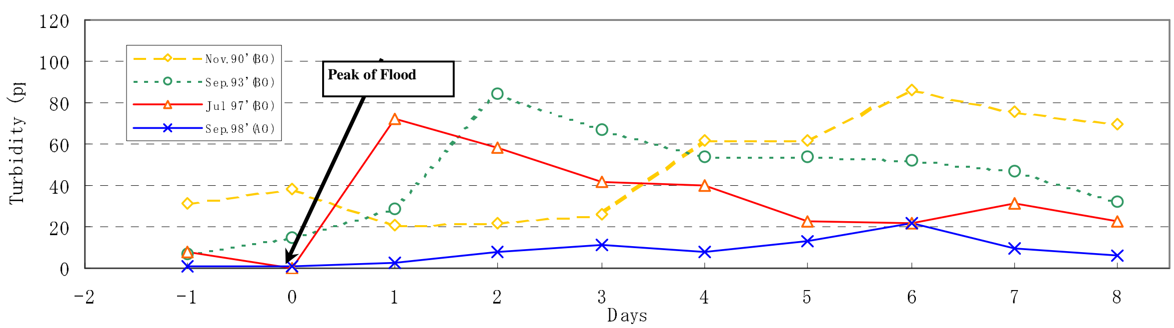

Fig.-6 Turbidity conditions in Asahi Dam regulating reservoir

Next, as the impact on the downstream environment of the river, it was made possible for sediment which had been stopped before by the dam to go downstream unobstructed via the bypass and this is thought to have had the effects of preventing degradation and armorcoating of the downstream riverbed. In fact, it was confirmed in investigations of shoals and pools and of riverbed gradation that the river profile had changed (recovered), and it was commented by local people that "Whities (pretty white pebbles specific to the upstream area) had been getting scarcer and scarcer since the dam was built, but now they've come back again. The river is returning to its old self."

6. Reasons for Success

The following may be cited as reasons for success.

1) Planning and Implementation of Sediment Bypassing as the Most Effective Mitigation Measure
   Various mitigation schemes, including examples in foreign countries, were compared and studied. Features of the site were taken into consideration and sediment bypassing of the reservoir was planned and implemented as a radical solution measure.
2) Detailed Investigations, Analyses, and Studies at Planning and Designing Stages
   Leading authorities on the subjects were consulted in detailed investigations and analyses of hydrology, meteorology, and topography at the planning and designing stage, and in hydraulic design of structures, large-scale hydraulic model experiments and numerical simulations were carried out, and the results were reflected in design.

7. Outside Comments

1) THE NIKKAN KOGYO SHIMBUN（May 31, 2000）
   "Kansai Electric Power Co. Inc. has completed construction of the first bypass facility in Japan, in Okuyoshino pumped storage Power Plant in Nara-prefecture, to deal with persisting turbid water. The facility proved its effectiveness in mitigating reservoir sedimentation and turbidity of river water contributing significantly towards restoration of downstream environment."

8. Further Information

8.1 References

1) Minoru HARADA, Masashi TERADA, Tetsuya KOKUBO: Planning and Hydraulic Design of Bypass Tunnel for Sluicing Sediments Past Asahi Reservoir, ICOLD 19th, 1997
2) Minoru HARADA, Hiroshi MORIMOTO, Tetsuya KOKUBO: Operational Results and Effects of Sediment Bypass System, ICOLD 20th, 2000

8.2 Inquiries

the KANSAI Electric Power Co., Inc.
URL: http://www.kepco.co.jp/english/index.html