Key Issues:
5- Water Quality
14- Development of Regional Industries

Climatic Zone:
Cf: Temperate Humid Climate

Subjects:
- Selective intake, techniques to operate a group of dams

Effects:
- Mitigation of turbid water persistence

Project Name: Hydropower Dams in Hida River System
Country: Gifu Prefecture, Japan (Asia) (N35˚56' – N36˚4', E137˚15' – 29')

Implementing Party & Period
- Project: Chubu Electric Power Co., Inc.
1969 (Completion of construction) -
- Good Practices: Chubu Electric Power Co., Inc.
1983 (Commencement of operation) -

Key Words:
turbid water, selective intake, operation of reservoirs

Abstract:
In the Hida River basin, there are several power stations, and turbid water persistence became a problem shortly after the completion of the Asahi Dam in 1953. To solve this problem, selective intake facilities were constructed at the Asahi Dam and the Takane No.1 Dam. Using these facilities, coupled with power plant operation at 4 dams in the Hida River, the persistent turbidity has been gradually decreasing.

1. Outline of the Project

The Hida River is the Kiso River System's largest tributary with a total watercourse length of 134km and a total catchment area of 2,177m^2 that originates in Mt. Norikura and Mt. Ontake located in the southernmost part of the North Japan Alps and flows southward meeting many tributaries including the Akigami and Maze Rivers to finally join the Kiso river in Mino Kamo City (Fig.-1). Many power source development projects have been conducted in the Hida river basin since long ago, and currently the total number of power stations and the total of the permitted/approved maximum outputs are 23 and approximately 1.14 million kW, respectively (Table-1).
In particular, the group of dams in the upstream river basin including the Asahi and Akigami Dams completed in 1953 and the Takane No.1 and No.2 Dams completed in 1969 have been playing an important role in ensuring stable supply of electricity during peak electricity demand periods. Fig.-2 shows the elevations of these upstream dams.
The upstreammost Takane No.1 Power Station is a pumped storage type power station with 4 generators and the No.3 unit is equipped with a selective intake that is capable of extracting a maximum of 75m^3/s of water from the top or middle water layer of the reservoir. The No.3 unit does not allow pumped storage operation when the intake is in the top layer intake position.
The Asahi Dam has a selective intake that is capable of extracting water from the top or middle water layer of the reservoir. The water extracted at the Akigami Dam is sent to the water intake tower of the Asahi Dam by way of the Akigami Dam's intake (which does not have a selective intake) and a

connection conduit (that uses the water level difference between the two dams' reservoirs to transport water (maximum allowable water level difference = 12m, maximum flow rate = 12.5m^3/s)) and used together with the water extracted at the Asahi Dam to generate power.
The water used at the Asahi Power Station to generate power flows downstream to the Higashi Ueda Dam by way of the downstream Kuguno Dam, Kuguno Power Station and Osaka Power Station. Currently turbid water mitigation measures are being taken to reduce the turbidity level of the water discharged from the Higashi Ueda Dam to 15ppm or less (and preferably to 10ppm or less) except during floods by means of power generation and utilization coordination among this group of dams including the Higashi Ueda Dam. These target values were determined based on an analysis of the impacts of different turbidity levels on the commercial fishing of sweetfish using live decoys and other fishing activities in the river basin downstream of the Higashi Ueda Dam and landscapes in the Gero Hotspring Resort area which are important for the area's tourism industry.

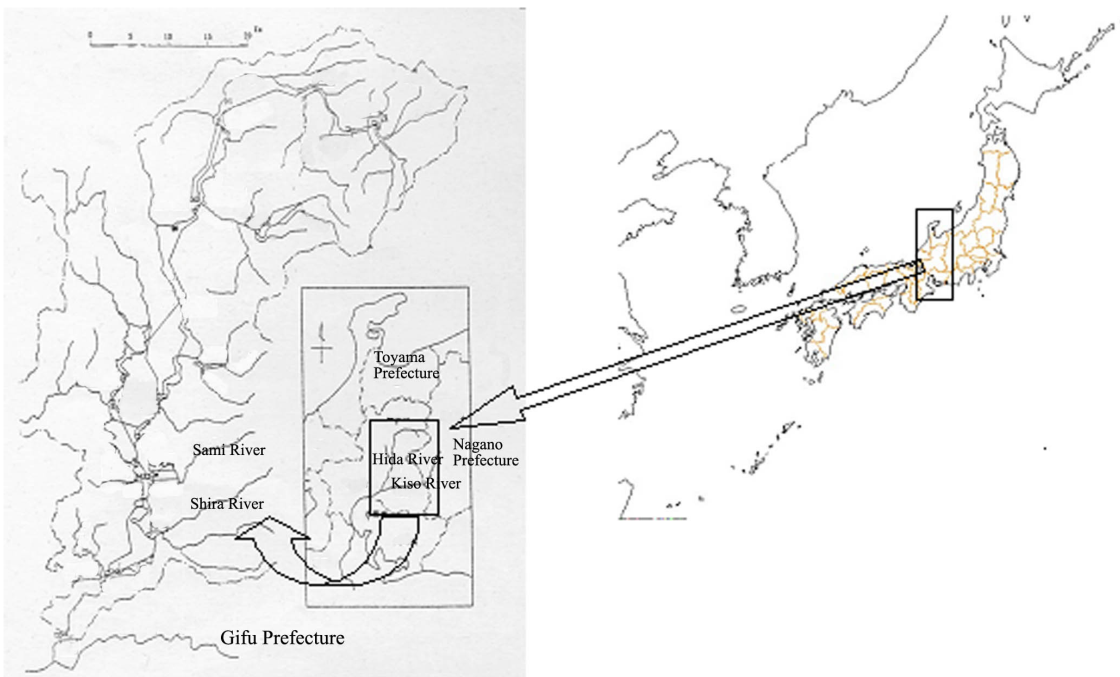

Fig.-1 Location of the Hida River System

Table-1 Basic Data on the Power Stations in the Hida River System

Power Station Name	Permitted Maximum Output	Permitted Maximum Discharge	Energy Conversion Factor of Discharge	Effective Head	Catchment Area	Effective storage volume	Operational since
	(MW)	(m^3/s)	(KW/m^3/s)	(m)	(km^2)	(x 1000m^3)	(Year/month)
Takane No.1	340.0	300.0	1,124	135.0	159.8	33,188	1969/9
Takane No.2	25.1	40.0	628	74.7	173.0	5,359	1969/3
Asahi	20.5	32.1	639	77.0	308.3	37,741	1953/12
Kuguno	38.4	34.6	1,110	127.5	312.3	386	1962/11
Osaka G1, G2	18.0	16.7	1,078	130.0	485.9	-	1930/11
Osaka G3	31.0	28.0	1,107	128.9	312.3	-	1966/1
Osakagawa	21.0	6.0	3,500	431.7	38.3	-	1983/11
Higashi Ueda	35.0	40.0	875	104.7	770.0	561	1954/12
Churo	13.3	20.0	650	79.0	-	-	1978/6
Seto No.1	27.0	32.0	844	102.3	924.7	-	1924/3

Power Station Name	Permitted Maximum		Energy Conversion Factor of Discharge	Effective Head	Catchment Area	Effective storage volume	Operational since
	Output	Discharge					
	(MW)	(m^3/s)	(KW/m^3/s)	(m)	(km^2)	(x 1000m^3)	(Year/month)
Seto No.2	21.0	15.5	1,357	161.1	223.2	204	1938/9
Takeharagawa	1.0	2.5	400	63.6	52.8	-	1922/1
Shimohara	22.2	80.0	278	34.6	1,563.7	592	1983/12
Mazegawa No.1	288.0	335.0	853	100.5	1,034.9	98,999	1976/6
Mazegawa No.2	66.4	113.0	584	70.6	1,049.0	6,052	1976/6
Ohfunato	6.4	64.0	100	12.3	1,574.0	415	1929/12
Shin Shichiso	19.7	95.0	207	24.9	1,574.0	415	1982/6
Shichiso	6.2	50.0	123	155.7	1,616.8	312	1925/11
Samigawa	0.3	1.1	233	37.9	56.7	-	1928/12
Nagura	22.2	80.0	278	34.1	1,685.7	382	1936/11
Shin Kamiaso	60.2	80.0	753	87.0	1,685.7	382	1987/6
Kami aso	27.0	62.6	432	51.3	2,021.2	251	1923/11
Kawabe	30.0	155.0	194	24.2	2,159.0	1,724	1937/12
Total	1,139.9	-	-	-	-	-	-

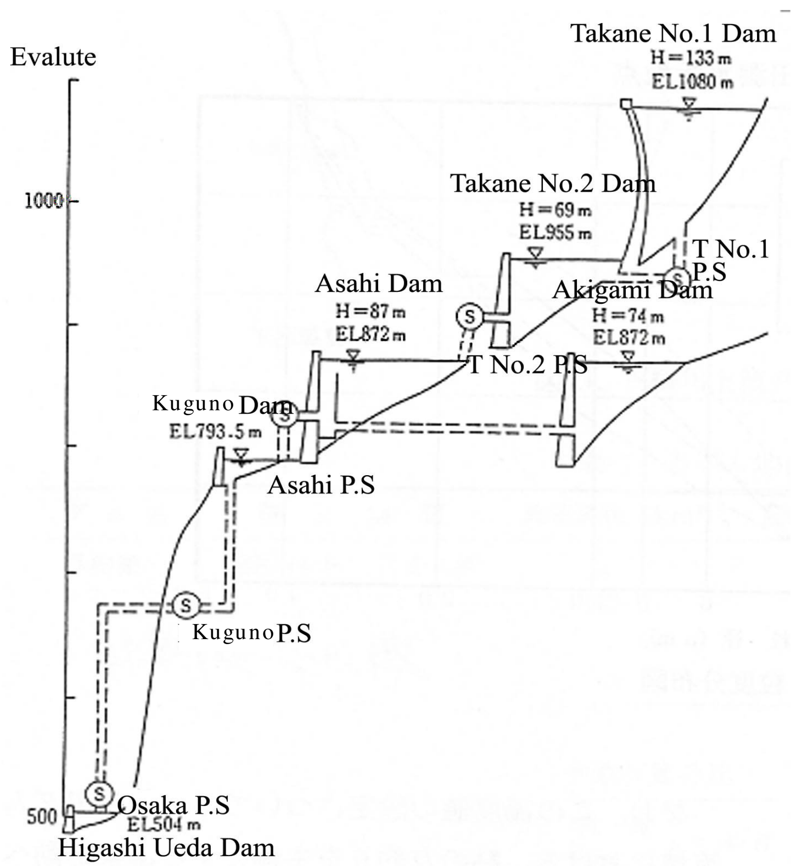

Fig.-2 Elevations of the Upstream Dams in the Hida River Basin

2. Features of the Project Area

2.1 Topography

The area is characterized by lava plateaus and gorges radially developed around two large volcanoes (Mt. Norikura located to the north-northeast of the river basin and Mt. Ontake located to the east of the river basin).

2.2 Geology

The geology of the area in and around the Hida River's water source area comprises seams of Norikura andesite, Ontake andesite, porphyrite, quartz porphyry and mud flow sediments which are characteristic of volcanic regions. The paleozoic strata in the area contain sandstone, shale and chert. The geology of the area upstream of the Asahi Dam is characterized by a dominance by volcanic sediments, which gives rise to the frequent occurrences of muddying of water in the area and makes the area susceptible to slope failure.

2.3 Locations of the Dams and the Rivers that Discharge into the Reservoirs

The locations of the dams and the rivers that discharge into the dam reservoirs are as shown in Fig.-3. The rivers that discharge into the Takane No.1 Dam's reservoir include the Nomugi River (Hida River mainstream) and the Hiwada River (tributary). The major tributaries that discharge into the Asahi Dam's reservoir include the Tokugoudani whose upstream part is located near the Nenohara High Plateau.

2.4 Annual Mean Precipitation

The annual mean precipitation in the Takane No.1 Dam area is 1,760mm and that in the Asahi Dam area is 1,728mm. These are approximately equal to Japan's annual mean precipitation.

2.5 Annual Mean Total Discharge into the Reservoirs and the Reservoir Capacities

The annual mean river flow rates at the Takane No.1 Dam area, Asahi Dam area and Akigami Dam area are $10.0m^3/s$, $14.3m^3/s$ and $6.2m^3/s$, respectively. Table-2 shows the ratio between the annual mean total discharge and reservoir capacity (α) for each of the reservoirs.

It is said that, under normal hydrological and meteorological conditions, a reservoir normally becomes a stable stratified (thermocline-forming) type reservoir when α is less than 10 and a mixed type reservoir when α is greater than 20. According to this generalization, the reservoirs of the Takane No.1 Dam, Asahi Dam and Akigami Dam are classified as a stratified type reservoir, a near-mixed type reservoir and a near-stratified type reservoir, respectively. In the reservoir of the Takane No.1 Dam, stratification intensifies in May and June and the circulation period starts in late September.

Table-2 Ratios between the Annual Mean Total Discharges to the Reservoirs and the Reservoir Capacities

Dam	Total Storage Capacity B ($10,000m^3$)	Effective Storage Capacity ($10,000m^3$)	Annual Mean Total Discharge A ($10,000m^3$)	α = A/B
Takane No.1	4,112	3,319	31,626	7.7
Asahi	2,296	2,166	45,010	19.6
Akigami	1,653	1,608	19,237	11.6

* The annual mean total discharges are averages over the 5-year period from 1989.

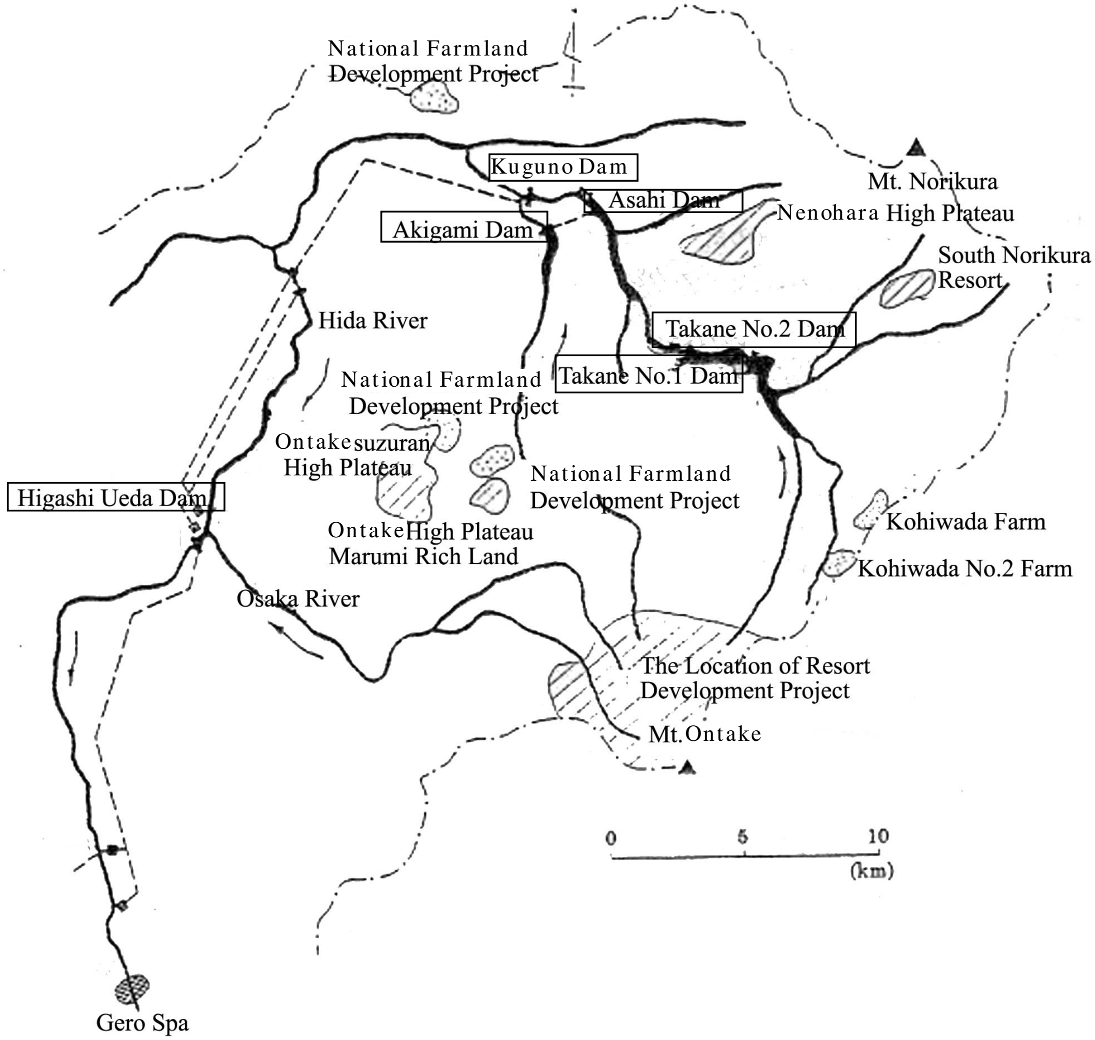

Fig.-3 Locations of the Upstream Dams in the Hida River Basin and the Locations of Development Projects Completed to Date

2.6 Land Use

About 95% of the land of Takane and Asahi Villages (located in the water source area in the river basin) are forests. In this river basin, many development projects were conducted in the past, including power source and road development projects that started in the first half of the 1950s, aggressive forest development projects that started in the first half of the 1960s (3,250ha), projects to develop tourism and recreational facilities in the Hiwada, Nenohara, Nomugi, Minami Norikura, Ontake and Suzuran High Plateau areas in the river basin that were driven by the tourism development boom during the high economic growth period, a large-scale resort development project (2,000 ha) on the foot of Mt. Ontake and a national farmland development project started in 1988.

Fig.-3 shows the locations of these projects. These development projects became one of the main causes of the incidence of turbid water in 1958 because they were conducted mainly in the Asahi Dam's river basin. The land developed in relation to the tourism and recreational facility development projects started in the late 1960s was bare land when the development projects were completed, but is now covered with substitutional vegetation. Because recent projects that involve land development incorporate turbid water prevention measures, turbid water persistences like those seen in the past do not occur these days.

2.7 Current Status of the Use of the Downstream Part of the River by Fishers, Hikers, etc.

A total of 50,000 to 60,000 people come to the Hida River annually, with fishers accounting for about 90% of the total at 40,000 to 50,000. Most of the fishers fish sweetfish and fishing activities are most intensive in the river section between the downstream side of the Higashi Ueda Dam and Gero Hotspring Resort. The total quantity of the artificially hatched sweetfish released into the river by the members of Mashita River Fisheries cooperative association based in this area (the part of the Hida River that is located upstream of the middle section of the Hida River is locally called the Mashita River) and the total catch by the members in 1991 were approximately 10 and 84 tons, respectively. Both the total quantity of the artificially hatched sweetfish released into the river by the members of Mashita River Fisheries cooperative association and the total catch by the members in 1991 are roughly four times as large as those about 20 years ago. In recent years, the number of people who come to the Hida River for non-fishing purposes has also increased as a result of increasing popularity of outdoor recreational activities.

Other than power generation, water of the Hida River is mainly used for city water, industrial water and agricultural water. Water for these purposes is extracted by the Water Resources Development Public Corporation at an extraction point located immediately upstream of the Kami Aso Weir (max. 9.54m^3/s). This has not caused any turbid water persistence in the past.

3. Major Impacts

3.1 Investigation of Grain Size Distributions of Suspended Matters

The average grain sizes of the suspended matters in the upstream river basin of the Hida River are as shown in the graphs in Fig.-4. It can be seen from the graphs that the average grain size of the suspended matters on the Nomugi side is relatively small. The suspended clay particles are negatively charged, when the particle size is 1 μ m or less, these particles repel each other in the water and thus become colloidal. According to Fig.-4, the share of these particles as percentage of the Hida River's total suspended matters is small at 5 to 10%, which means that turbid water management utilizing the suspended matter precipitation effect in the reservoir is possible.

3.2 Turbidity of Discharges from Rivers into Reservoirs

The characteristics of discharges from the major rivers during floods with respect to turbidity are as follows:

1) Discharges from the Nomugi river basin are very turbid, and remain turbid for relatively long periods.
2) Turbidity levels of discharges from the Hiwada river basin are about 100 to 200ppm even during peak periods and the discharges become clear within one day or so.
3) Turbidity levels of discharges from the Tokugoudani reach 1,000ppm during peak periods, but the discharges become clear water within a short period.
4) Turbidity levels of discharges into the Akigami Dam Reservoir are relatively low. The discharges are characterized by a large water volume and a relatively high temperature.

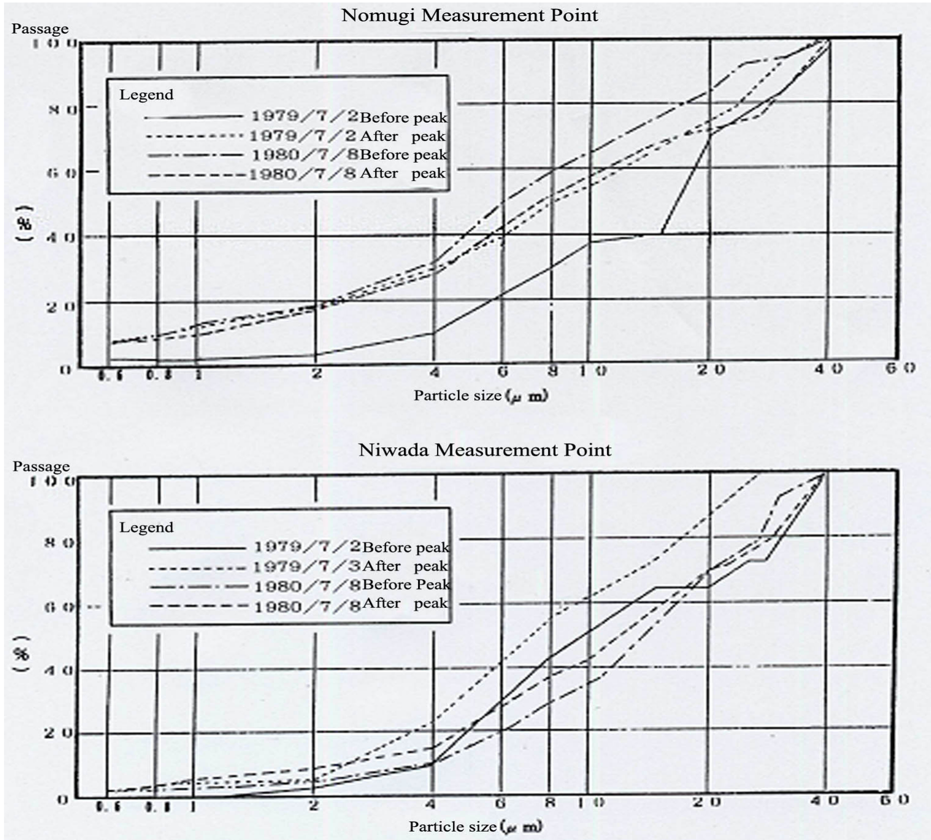

Fig.-4 Grain Size Distributions of Suspended Matters

3.3 Turbidity Level Monitoring

Continuous turbidity level monitoring is being made using fixed-depth turbidimeters installed on the front surfaces of the intakes of the Takane No.1, Takane No.2, Asahi and Akigami Dams and "continuous type" turbidimeters installed in the major discharging rivers and the outlets. In addition, manual measurement of the vertical profiles of the turbidity and water temperature levels of the reservoirs is being made regularly to improve the efficiency of the operation and management of the group of dams to reduce turbidity levels. Furthermore, the entire river system is being monitored continuously by using "continuous type" turbidimeters throughout the area up to the downstreammost Kawabe Dam. The data from the fixed-depth turbidimeters and "continuous type" turbidimeters are transmitted in real time to the Gifu Branch Office of Chubu Electric Power Co., Inc. to allow turbid water countermeasures to be taken in a timely manner. Fig.-5 shows a simplified overview of the turbidity measurement points.

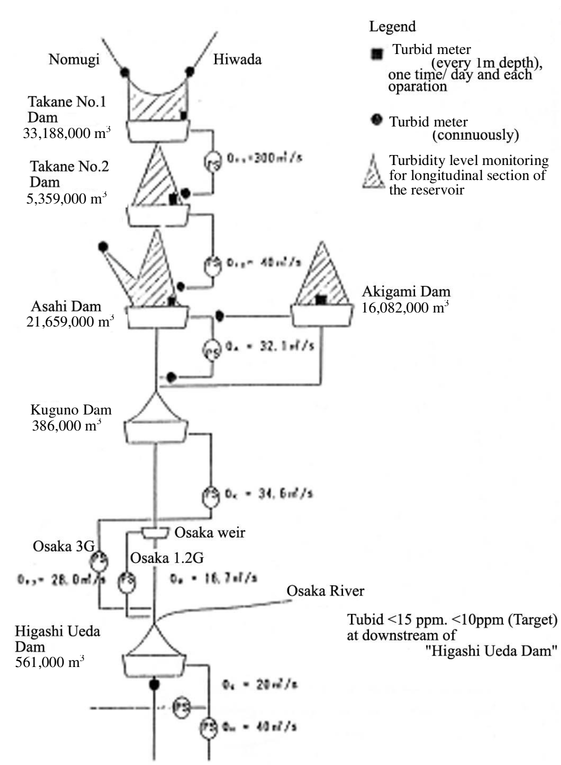

Fig.-5 Turbidity Measurement Points

3.4 History of Turbid water persistences

The first turbid water persistence in the area occurred in July 1958 (which was the fifth year after completion of the Asahi Dam construction project) as a result of a local torrential downpour that accompanied the Typhoon No.11 which passed the area. The total rainfall during the local torrential downpour reached 400 to 530mm in the upstream Hida river basin, and the Tokugoudani located 2km upstream of the Asahi Dam discharged a huge volume of turbid water containing a large quantity of sediment into the Asahi Dam Reservoir, leaving the reservoir water turbid for a long time. Faced with this problem, affected municipalities and fisheries cooperative associations as well as other organizations and groups in the river basin downstream of the dam made requests to the Gifu Prefectural Government and Chubu Electric Power Co., Inc. to take measures to solve the problem. In particular, the affected fisheries cooperative associations claimed damages for the lost fishing opportunities and the hindered multiplication of fishes, as a result of which the Hida River turbid water persistence attracted nationwide attention as a social and political problem.

The course of events to date after this can be largely broken down into the following 3 phases in connection with the phases of the development of the selective intake:

1) Phase I: July 1958 to March 1973

   (From the first incidence of turbid water to before the installation of the Asahi Dam's selective intake and the direct connecting of the Akigami Dam's connection conduit with the Asahi Dam's intake tower)

   Many projects to develop tourism and recreational facilities were undertaken one after another during the period of Japan's high economic growth (up to around 1973) in the upstream river basin where the group of dams was located. In addition, the projects to develop the Takane No.1 and No.2 Power Stations were conducted during the period between 1965 and 1969. Many turbid water persistences occurred during this phase.

2) Phase II: April 1973 to May 1983

   (Before the installation of the Takane No.1 Dam's selective intake)

   Many projects to widen national highways and prefectural roads and develop forestry roads were conducted. Earth materials generated from road works were directly dumped into the river and in the river basin. In this period, turbid water persistences subsided temporarily but recurred after floods in 1978.

3) Phase III: June 1983 to Present

   (After the installation of the Takane No.1 Dam's selective intake)

   Since 1983, Chubu Electric Power Co., Inc. has been making serious efforts to investigate and analyze other entities' land development projects planned in the area in order to prevent incidences of turbid water in the upstream river basin (water source area) and request the project owners and operators (including contractors and subcontractors) to take turbid water prevention measures as part of their projects.

   In addition, the interested fisheries cooperative associations and the Gifu Prefecture Federation of Fishers submitted a petition entitled "Requests concerning Turbid water persistences in the Hida River Basin" to the Gifu Prefectural Assembly in March 1984. These activities and requests prompted the administrative authority to take measures to prevent incidences of turbid water in the upstream river basin including projects to increase and expand protection forest area and to construct soil erosion control dams.

   The land developed through the above-mentioned projects in Phases I and II had been bare land when the projects had been completed, but most of the land was covered with substitutional vegetation during this period. In addition, land collapses became much less frequent during this period (The substitutional vegetation is vegetation that has grown naturally over time. The reduced frequency of land collapses is considered to be attributable to flood control afferestation projects). Improvements made during this period in relation to the methods to operate and maintain the facilities also contributed to the subsidence of turbid water persistences during the period.

4. Mitigation Measures

4.1 Installation of Selective intake and Direct Connection of the Connection Conduit with the Intake Facilities

The Asahi Dam's intake facility was installed in stages through a series of projects including the project completed in February 1966 to install the intake tower bottom gate, the project completed in February 1968 to install the intake tower canvas gate (to enable top layer intake), the top layer intake gate improvement project completed in February 1973 and the project completed in 1980 to improve the top layer intake facility's lower gate. As part of the top layer intake gate improvement project completed in February 1973, the connection conduit from the Akigami Dam to Asahi Dam was directly connected to the intake facilities. The Takane No.1 Dam was equipped with a selective intake in 1983. Table-3 and Fig.-6 show the basic specifications and structures of these intake facilities, respectively.

Table-3 Basic Specifications of the Selective intake of the Takane No.1 and Asahi Dams

Item	Takane No.1 Dam	Asahi Dam
Intake volume (m^3/s)	75	32.1
Gate type	Semicircular 2-stage roller gage	Roller gate (the gate in the lower part of the intake tower is a slide gate)
Gate dimensions		
(Upper gate door)	3.350m (radius) × 30.500m (height)	3.530m (width) × 13.000m (height) × 8
(Lower gate door)	3.650m (radius) × 29.000m (height)	3.348m (width) × 19.000m (height) × 8
(Door in the lower part of the intake tower)	n/a	2.370m (width) × 7.000m (height) × 8
Gate winching method	Wire rope winching	Wire rope winching

4.2 Operation of a Group of Dams

The interrelationships among the main facilities and watercourse elements in the upstream Hida river basin including the 4 upstream dams that have a decisive influence on incidences of turbid water persistence in the Hida River are as shown in Fig.-2, and the storage capacities of the dams' reservoirs and the discharge for power generation at the dams are as shown in Table-1. The basic policies for the operation of the group of dams to alleviate the muddying of water are as follows:

1) The turbid water discharged into the dam reservoirs during floods should be removed from the reservoirs at an early stage, except for small floods where clear water can be discharged from the dams while keeping the turbid discharges in the reservoirs.
2) The discharges from the dams should be switched from turbid to clear water at an appropriate time after the flood, taking into consideration the following so that the turbidity target set for the area downstream of the Higashi Ueda Dam is met:
    a) Flow rates and turbidity levels in the area located in the river basin downstream of the Asahi Dam
    b) The dilution effect of the water fed from the Akigami Dam to the Asahi dam
    c) Clearing of the turbid water left in the reservoirs through the precipitation of the suspended matters

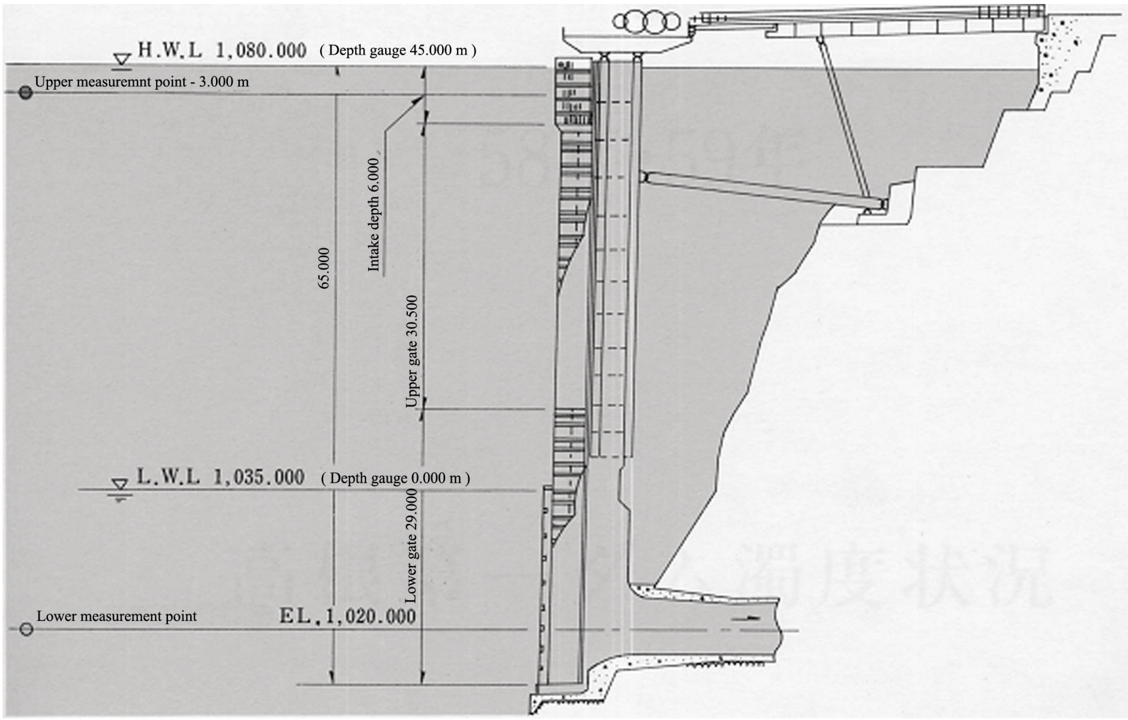

Fig.-6 (1) Takane No.1 Dam's Selective intake

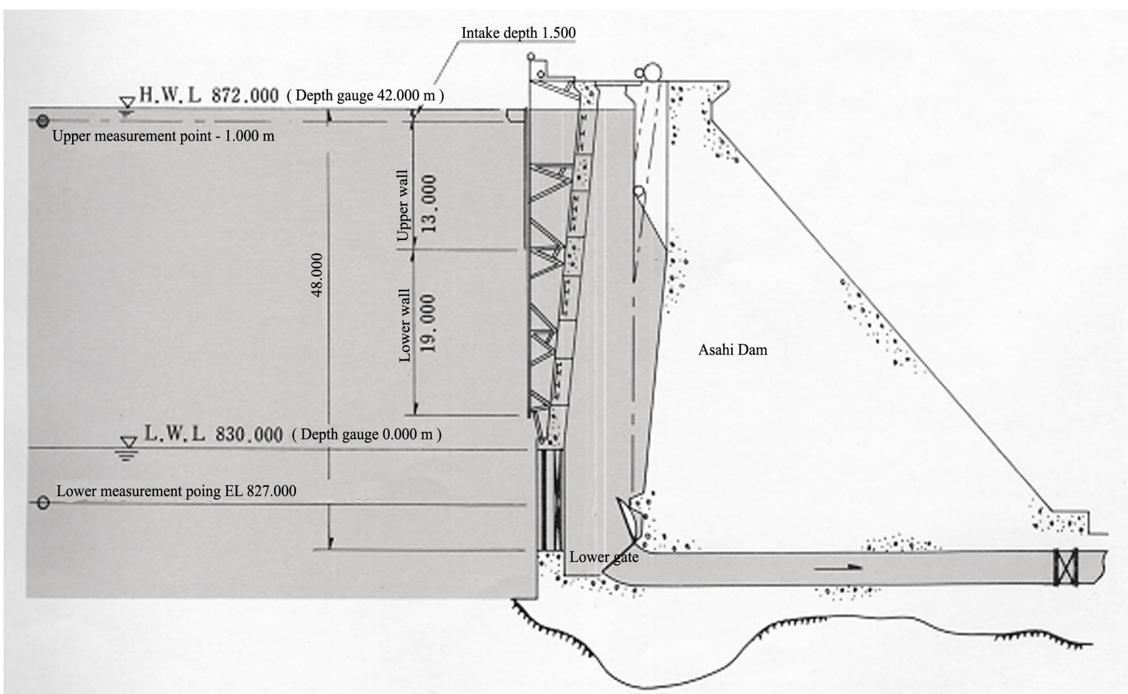

Fig.-6 (2) Asahi Dam's Selective intake

The characteristics of the major dams in relation to the actual operation of the group of dams based on the above policies are as follows:

1) The upstreammost Takane No.1 Dam has made almost no discharge through its flood spillway gates since its completion because of the large volume of discharge (300m3/s) for power generation at the dam. The dam will continue to allow the company to avoid discharges through its flood spillway gates by allowing water levels to be adjusted through adjustment of power output.
2) The Takane No.2 Dam has a small storage capacity and thus frequently makes discharges through its flood spillway gates to discharge the water discharged into its reservoir from the Takane No.1 Dam as a result of the Takane No.1 Dam's power generation operation
3) Both the Asahi and Akigami Dams are dams with a small storage capacity. In addition, both dams use only 32.1m^3/s of discharge for power generation. For these reasons, both dams are often forced to discharge water through their flood spillway gates during floods. However, the Akigami Dam has never discharged turbid water during floods in the past, because the river basin around the dam is stable and does not have many areas susceptible to slope failure.

For the above-mentioned watercourse and dams, the following basic dam operation methods to alleviate the muddying of water and prevent prolonged stays of turbid water were adopted:

1) When Discharges through the Asahi Dam's Flood Spillway Gates Are To Be Avoided:
   Increase the vacant capacity of the Asahi Dam Reservoir before the floodwater reaches the reservoir and operate the power station at full capacity during the flood so that as much water as possible is extracted from the bottom layer of the reservoir and discharges through the flood spillway gates are avoided. After the flood is gone, keep the downstream turbidity levels low by extracting water from the top layer of the Asahi Dam Reservoir and using the Akigami Dam as a supplemental source of clean water.

2) When Discharges through the Asahi Dam's Flood Spillway Gates Are To Be Made:
   Extract water from the bottom layer of the Takane No.1 Dam Reservoir to generate power during the flood. After the flood is gone, extract clean water from the top layer of the Takane No.1 Dam Reservoir and transport the clean water to the top layer of the Asahi Dam Reservoir via the Takane No.2 Dam. Dam operation after the transport of the clean water is the same as in case 1).

The use of methods 1) and 2) was made possible by the installation of the Asahi Dam's intake facility and the Takane No.1 Dam's selective intake, respectively. However, these methods are not very effective during the autumn circulation period or large floods in early spring, because stratification must have been completed in the Takane No.1 Dam and Asahi Dam and the temperature of the discharges relative to the temperature of the top layer of the reservoir must be low for the methods to be effective.

5. Results of the Mitigation Measures

Fig.-7 shows the numbers of days on which the turbidity levels in the area downstream of the Higashi Ueda Dam exceeded the target value of 15ppm for each of the 3 phases. Comparison between the figure for Phase I and that for Phase II shows that the installation of the Asahi Dam's selective intake and the direct connection of the Akigami Dam connection conduit greatly helped reduce prolonged stays of turbid water. Furthermore, a comparison between the figure for Phase II and that for Phase III shows that the installation of the Takane No.1 Dam's selective intake also helped reduce turbid water persistence.

A good example of the effects of the environmental impact mitigation measures can be seen in the records of the turbidity of the river during and after the heavy rain that lasted from July 11 to July 16, 1993 (During this rain, a total rainfall of 197mm, a maximum daily rainfall of 72mm and a maximum hourly rainfall of 17mm were recorded). According to the records, the number of days on which the turbidity levels in the area downstream of the Higashi Ueda Dam exceeded the 15ppm target was only 12 days (including such days during the flood) as a result of the company's efforts to remove the turbid water at an early stage through effective utilization of the selective intake and appropriate coordination of power stations, and out of the 12 days, the number of days on which turbid water adversely affected

fishing activities was 5 days excluding those days on which it was practically impossible to fish due to water level rises. On the other hand, the turbidity measurement data taken at the Asahi Dam shows that the turbidity of the bottom layer water of the Asahi Dam Reservoir remained high (15ppm or more) until the end of August, implying that the water would have remained turbid until the end of August (and significant adverse impacts would have been caused on recreational activities of a large number of people visiting the river on summer vacations) if there had not been for the selective intake. This means that the turbid period was reduced by one month as a result of the above-mentioned efforts.
Incidences of turbid water of similar magnitudes have been observed at a rate of once every 3 years since the installation of the Takane No.1 Dam's selective intake in 1983, but none of them has become a serious problem.

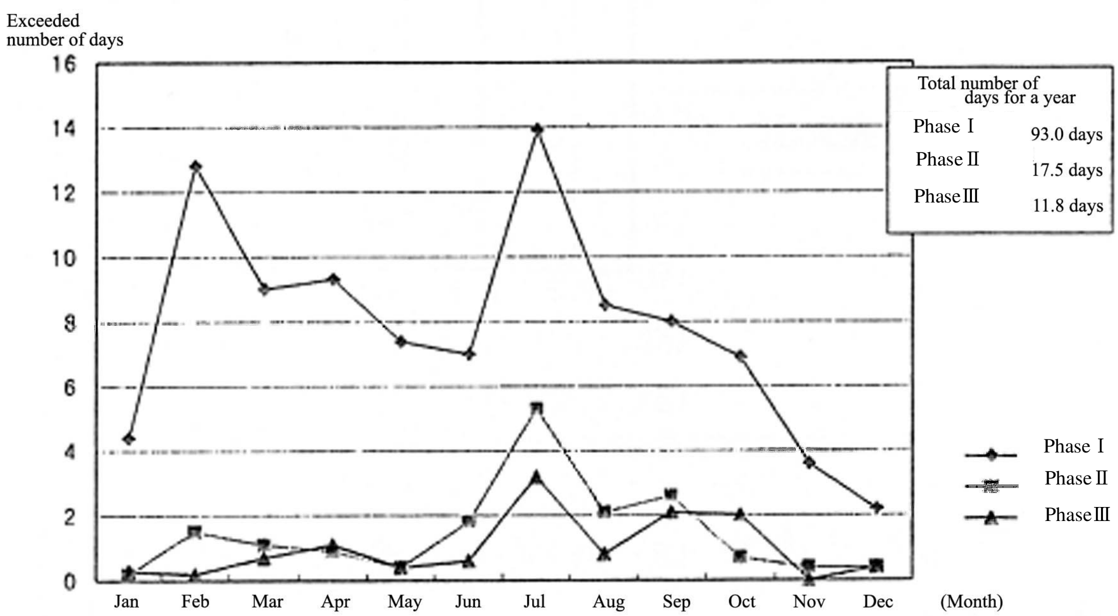

Fig.-7 Number of Days on which the Turbidity Target (15ppm) was Exceeded
in the Area downstream of the Higashi Ueda Dam (by month)

6. Reasons for the Success

The success of the project is attributable to the cautious operation of the dams based on the results of investigations to grasp the characteristics of the river basin. The success is also partly attributable to the efforts of the company' evaluation team that includes experts.

7. Outside Comments

1) Establishment of the "Gifu Prefecture Special Committee on Pollution Countermeasures" in July 1966
2) General Assembly Meeting of the "Gifu Prefectural Council on Countermeasures for Pollution in the Hida River" in September 1966
   The Governor of Gifu Prefecture promised to tell Chubu Electric Power Co., Inc. to rectify the structural problems of dams.
3) Establishment of the "Gifu Prefecture Committee on Turbid Water Countermeasures for the Hida River" in 1980
4) Recommendations from the "Gifu Prefecture Committee on Turbid Water Countermeasures for

the Hida River" in March 1981
5) Request from Gifu Prefecture to Chubu Electric Power Co., Inc. to install a selective intake on the Takane No.1 Dam, March 1981
6) There has been no further request or guidance from the prefecture since the above request

8. Further Information

8.1 References

1) "Investigation Report on the Hida River's Turbid water persistences," Technical Council on Countermeasures for Turbid water persistences in the Hida River Basin, 1981
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