Key Issue:

3-Fish Migration and River Navigation

1-Biological diversity

Climate Zone:

Cf: Temperate Humid Climate

Subject:

- Confirmation of the Effect of the Fish Ladder in Facilitating Upstream Migration

Funagira Dam

Effects:

- Protection of Fish Resources

Project Name: Funagira Power Plant

Country: Shizuoka Pref., Japan (Asia)

Implementing Party & Period

- Project: Electric Power Development Co. Ltd. (J-POWER)
1972 (Commencement of construction) -

- Good Practice: Electric Power Development Co. Ltd. (J-POWER)
1977 -

Keywords:

Fish ladder, Investigation of Upstream Migration, Sweetfish, Fish Straying Prevention Device, Sodium Lamp Lighting

Abstract:

Following the installation of the fish straying prevention device in the dam and the fish ladder furnished with sodium lamps in the dam culvert, the investigation of upstream migration of sweetfish was performed on a continuous basis. Since the investigation confirmed that a maximum of several hundred thousands of sweetfish were migrating upstream, the installation of the fish ladder proved effective as part of environmental impact mitigating measures.

1. Outline of the Project

The Funagira Dam was constructed at the Funagira point along the Tenryu River (Funagira, Tenryu City, Shizuoka Prefecture: Fig. 1) for the purpose of ensuring water availability for power generation, irrigation, and city and industrial water supply.

As the most downstream project under the consistently planned development of the Tenryu River system, investigation and planning had been underway since 1958 for the construction of the Funagira Power Plant. The Funagira Dam, on the other hand, was planned and designed as a multi-purpose dam for the purpose of water intake for power generation, irrigation and

city and industrial water supply, as part of the Tenryu River downstream water utilization project by the Ministry of Agriculture, Forestry and Fisheries and Shizuoka Prefecture. The Funagira Power Plant began being constructed in 1972 and started operations in April 1977.

Table 1 shows the specifications of the Funagira Dam and the Funagira Power Plant.

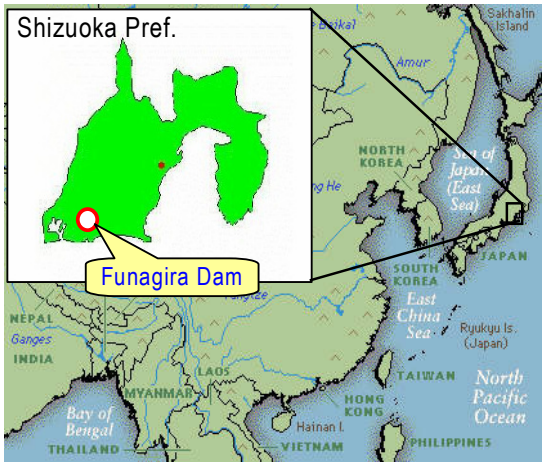

Fig. 1 Location Map of the Funagira Dam

Table 1 Specifications of the Funagira Dam and the Funagira Power Plant

Item	Specification	Item	Specification
Name of the dam	Funagira Dam	Name of the power plant	Funagira Power Plant
Type of the dam	Concrete gravity	Power generation method	Dam type power generation
Dam height	24.5 m	Effective head	14.5 m
Dam length	220.0 m	Maximum water discharge	270 m^3/s
Dam volume	54,000 m^3	Maximum output	32,000 kW
Effective storage	3,600,000 m^3	Annual electric energy generation	160,100 MWh

2. Features of the Project Area

The Funagira point is located in the downstream area of the Tenryu River, which runs a total distance of approx. 250 km (5^{th} in the national ranking) and has a catchment area of 5,090 km^2 (12^{th} in the national ranking). Located about 30 km upstream from the estuary of the river, the Funagira point has a catchment area of as large as 4,895 km^2.

The Tenryu River originates in Lake Suwa, runs through the Ina Valley that spreads between the Akashi Mountain Range on the east and the Kiso Mountain Range on the west, and then flows southward down the Tenryukyo Valley. The river gradually increases in size in its upstream reaches, by the merging of flood-prone rivers such as the Mibugawa River, Koshibugawa River and Achigawa River, and further increases in size, in its midstream and downstream reaches, by the merging of such rivers as the Toyamagawa River, Ochisegawa River, Mizukubogawa River and Kidagawa River. During this while, the river flows through midstream and downstream dams, the Hiraoka, Sakuma and Akiba Dam, and flows into the

Enshu Plain from the point about 5 km downstream of the Funagira point.

3. Major Impacts

The downstream reaches of the Tenryu River are one of the best fishing spots for natural sweetfish in Japan, and are also inhabited by such fish species as landlocked salmon, red spotted masu trout, carp, big-scaled redfin, crucian carp, tilapia and eel. The river is stocked with sweetfish, red spotted masu trout, carp, crucian carp and other fish species every year.

There was a concern that the construction of the dam may block upstream migration of fish species such as sweetfish and thus affect the ecosystem in the river and the fishing industry in the area.

4. Mitigation Measures

4.1 Structure of the Fish Ladder

The fish ladder was constructed in the excavated foundation of right bank structures, in consideration of the general layout of structures including the dam and power plant. Its length was determined according to the water level in the balancing reservoir, the downstream water level, and the gradient of the water surface in the fish ladder. The 280 m long fish ladder is comprised of a 71.95 m long downstream entry section, a 38.07 m long upstream exit section with an open channel structure, and a 169.40 m long intermediate section with a culvert structure (Fig. 2).

The water channel was 2 m in width and 1/13 degree in angle, considering the swimming capability of sweetfish. The water channel was made to look very much like a natural riverbed with a division wall set up every 4.05 m to create a pool and overflow and with several pebbles laid. A 30 cm x 30 cm opening was also set up in the lower part of the division wall for the upstream migration of eels.

When the fish ladder was first constructed, 10 cm x 70 cm notches were present alternately on the right and left sides of the overflow crests (Fig. 3). However, the notches were removed in 1996, based on the observation that the notches caused a disturbance to the surface flow and thus affected the upstream migration of sweetfish.

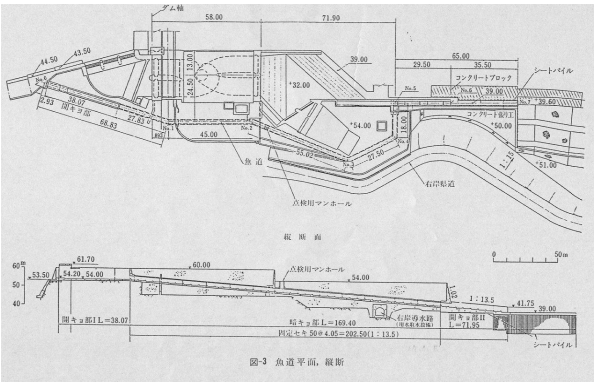

図-3 魚道平面，縦断

Fig. 2 Horizontal and Vertical View of the Fish Ladder

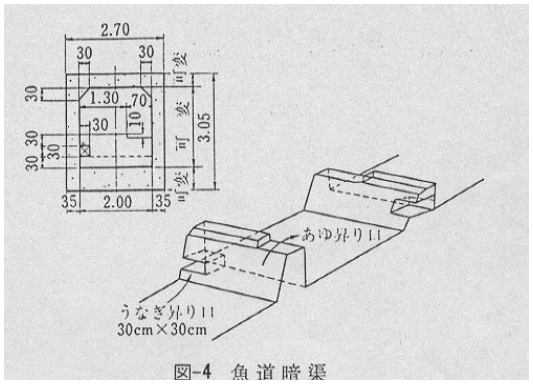

図-4 魚道暗渠

Fig. 3 Culvert Structure of the Fish Ladder (When Originally Constructed)

4.2 Accessory Facilities

4.2.1 Fish Ladder Gate

The fish ladder gate is comprised of a reserve gate and a control gate.

The reserve gate, a spindle and slide gate, is used during the inspection of the fish ladder or the control gate, and has a structure that can block flowing water. The gate has an interlocking mechanism: the opening of the gate is only enabled when the control gate is in the upright state in order to prevent quick inflow of water into the fish ladder.

The control gate is structured to automatically rise and fall according to water level fluctuations in the balancing reservoir with an available depth of 2.2 m used for power generation, in order to keep the flow rate along the fish ladder steady. The bottom of the door with a pin structure is made with a watertight rubber seal. The side of the door, in contact with the door-shaped doorstop, is also made with a watertight rubber seal.

The overflow crest of the control gate has 15 cm of water to maintain the flow rate that meets the swimming capability of sweetfish in upstream migration and to prevent the interruption of rapids that makes upstream migration difficult.

Both the reserve and control gate can be operated on-site or remotely from the control office. The specifications of these gates are shown in Table 2 and their general view is shown in Fig. 4.

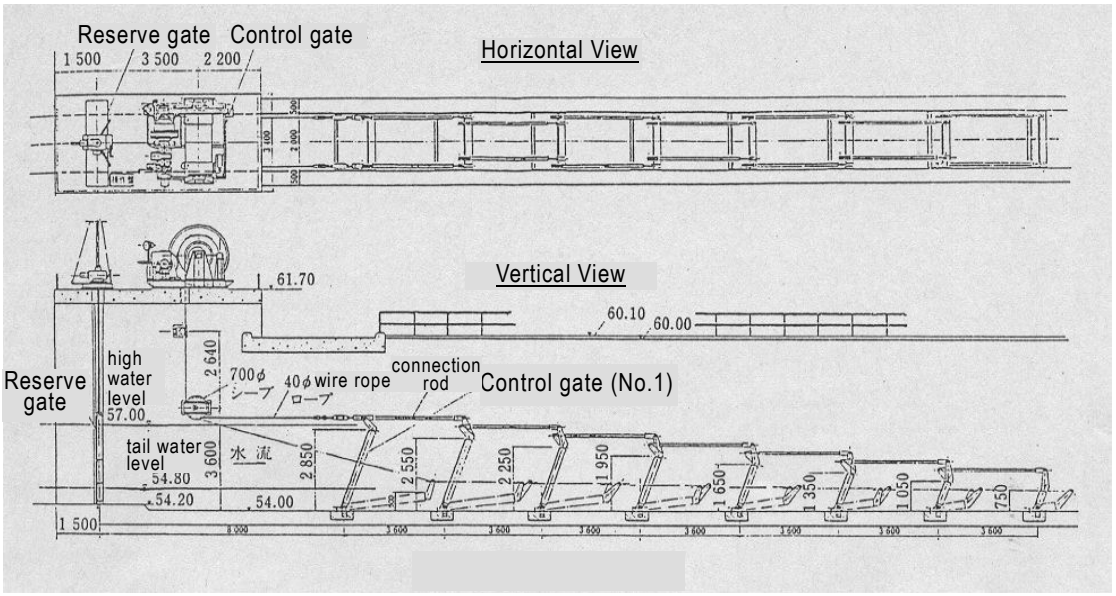

Fig. 4 General View of the Fish Ladder Gate

Table 2 Specifications of the Reserve and Control Gate

Item \ Name		Reserve Gate	Control Gate
Door and Doorstop	Type	Slide gate	Flap gate
	Dimensions	Span 2.0 m × Door body 3.1 m	Span 2.0 m × Door body 2.85 m to 0.75 m
	Q'ty	1	8
	Design water depth	3.7 m	Door body + 0.25 m
	Watertight method	Watertight rubber seal on the three front sides	Watertight rubber seal on the three sides
	Bend in the girder	1/800 or less relative to the normal design water depth	Same as the left
	Buffer thickness of the skin plate	1 mm	1 mm
	Doorstop height	6.7 m	---
Gate Hoist	Type	Hoisting by use of an electric spindle	Wire rope hoisting by use of an electrically operated drum
	Hoisting speed	0.10 to 0.20 m/min.	0.3 m/min. (Rope hoisting speed)
	Lift	3.8 m	
	Operating method	On-site or remotely	Same as the left
	Q'ty	1 unit	1 unit
	Hoisting load	Operated under all ranges of water pressure and automatic hoisting enabled	Same as the left
	Power supply method	210V 60Hz 3ϕ	Same as the left
	Motor	Enclosed outdoor type, 3-phase, AC, basket induction motor using magnetic braking	Same as the left

4.2.2 Lighting in the Culvert and Fish Straying Prevention Device

To prevent a delay in upstream migration in the culvert of the fish ladder, and prevent a delay in the entry into the fish ladder around the entry section in particular, 22 units of yellow sodium lamps (35 W) were set up every 8 m on the culvert ceiling when the fish ladder was first constructed, according to the specialist advice that young sweetfish like yellow color. Then, after the initial construction, additional 20 units were set up between previously installed lamps (Photo 1).

Since the exit section of the fish ladder from which water flows in is relatively near the head gate, a 300 W mercury lamp with a red filter with the effect of preventing the straying of fish was installed in the retaining wall between the water inflow section and the head gate to light up the water. This helped prevent the entry of fish in upstream migration into the head gate.

Moreover, the head gate in use for city, agricultural and industrial water supply is located immediately downstream of the water outlet of the Funagira Dam. Water discharge in large amounts for power generation increases the flow speed, making impossible the upstream

migration of sweetfish through the outlet. This caused no problems because the sweetfish that have swum upstream along the shore were led into the fish ladder. However, continuous water discharge in small amounts caused problems because they allowed the sweetfish to enter the outlet, with a part of the fish further led into the head gate in use for water utilization. Acrylic boards painted in white color – the color disliked by sweetfish – were laid in the entry section of the outlet to prevent the straying of sweetfish.

Photo 1 Sodium lamps installed in the culvert (when water is drained)

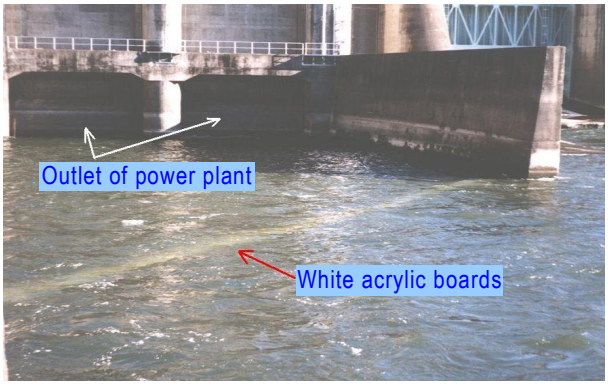

Photo 2 Water outlet of the power plant - fish straying prevention device - (white acrylic boards)

5. Results of the Mitigation Measures

Following the completion of the dam, the upstream migration of sweetfish was investigated visually from when the power plant operations started up to 1988 and by catching the fish during the upstream migration season of April to June from fiscal 1989 to 1992.

Table 3 Result of Upstream Migration Investigation

Year	Investigation Period	Number of Days for Investigation	Number of Fishes that Migrated Upstream
FY 1977	4/26 to 6/25	29	19,192
FY 1978	5/10 to 7/22	52	84,289
FY 1979	4/14 to 10/24	59	475,821
FY 1980	4/25 to 6/30	29	12,385
FY 1981	4/20 to 6/30	50	602,624
FY 1982	4/20 to 6/30	33	119,193
FY 1983	5/10 to 6/9	22	6,224
FY 1984	5/7 to 6/12	32	96,644
FY 1985	4/22 to 5/23	19	209,719
FY 1986	5/8 to 6/17	29	68,488
FY 1987	5/6 to 5/22	7	416
FY 1988	5/25 to 6/30	8	19,918
FY 1989	5/25 to 6/30	45	476,773
FY 1990	5/25 to 6/30	49	263,711

FY 1991	5/25 to 6/30	39	227,662
FY 1992	5/11 to 6/30	37	197,500

The investigation confirmed the effectiveness of the fish ladder: although variations were found depending on weather and river conditions during measurements, the upstream migration of several hundred thousands of sweetfish was observed during the upstream migration season (Table 3 and Photo 3 and 4).

Photo 3 Captured Sweetfish

Photo 4 Upstream Migration of Sweetfish

6. Reasons for Success

With regard to the installation of the fish ladder, advice from internal and external specialists and results of various research works were reflected in the determination of facility specifications, for example, the specifications of the structure of the fish ladder, lighting in the culvert and flow control using a gate. Even after initial installation of the fish ladder, the state of upstream migration of sweetfish and newly gained knowledge were reflected in the improvement of facilities. We hope to continue our efforts so that our involvement, for example, in the installation of the fish ladder, will be a help to the restoration of the river environment.

7. Further Information

7.1 References

1) Osamu Iwashita and Akinori Hishikawa: Investigation of Upstream Migration of Fishes through the Fish Ladder at the Funagira Dam, Dam Technology, No. 39, pp. 83 to 89, 1990

7.2 Inquiries

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