THEME 8 DAM MANAGEMENT: MANAGING AND OPERATING SAFELY

ABSTRACT

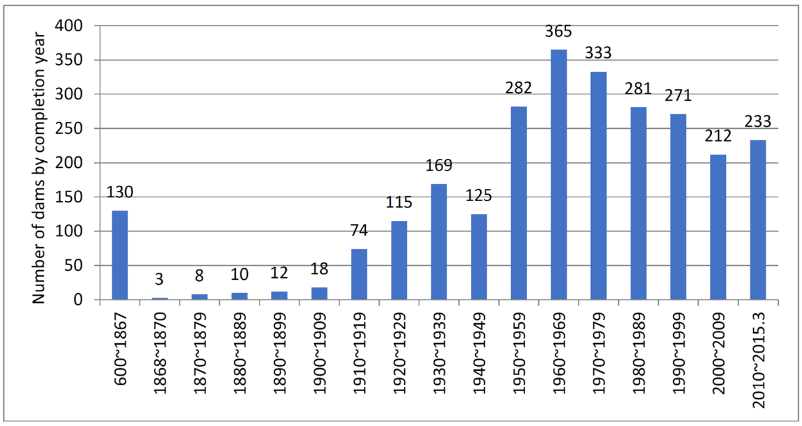
It is important to execute thorough safety management for dams to prevent breakage or the gate disoperation, which can cause extensive damage to the downstream areas. The establishment of technical standards for dam construction, systems for safety examination, and gate operation procedures is essential to ensure the safety of dams. To maintain dams in good condition, it is necessary to ensure their safety through the execution of routine and long-term inspections and maintenance, improve dam management, and reduce the lifecycle costs of dams. Dams must be operated in accordance with operation rules to ensure flood protection and an adequate water supply in a river basin. More than half a century has elapsed since the construction of modern dams began in Japan. Extending the service life of dams while maintaining and improving their functions is a challenge. The development of new technologies and dam rehabilitation projects are underway.

CHAPTER 1 INTRODUCTION

Dams can cause considerable damage to downstream areas when they break. In Japan, prone to frequent earthquakes and floods, safety management of dams is emphasized. The country has established various measures for this, such as technical standards, safety reviews in the design and construction stages, monitoring during operation, and necessary communication and inspection systems, together with the development of organizations and allocation of human resources.

The safety management of dams is important because dam failure has a severe impact on downstream areas. Safety is a priority in Japan, where earthquakes occur frequently, and the population is dense. This theme presents the technical standards and systems for dam safety and the guidelines for inspecting monitoring, and operating dams

Irrigation reservoirs have been constructed since ancient times. The oldest existing dams are Sayama-ike, which was constructed in the early 7th century, and Manno-ike, which was constructed in the early 8th century. From the 1930s to the high-economic growth period, many modern dams were constructed to secure water resources and reduce flood damage. Japan has experienced damage to dams caused by earthquakes and downstream areas caused by floodwater released from dams. In addition to ensuring dam safety in the design and construction stages, systems, rules, and organizations have been established to ensure dam safety throughout the dam operation period.



Source: Edited data from the Yearbook of Dams (Japan Dam Foundation)

Figure 1.1 History of Dam Construction in Japan

It is necessary to manage aging dams efficiently and maintain or improve their functions as necessary. Many dams were constructed in the 1960s and 1970s, and more than 50 years have passed, as shown in Figure 1.1. Because floods have become more severe in recent years, it is necessary to strengthen dam management with regard to both hardware and software.

Water resources management is closely related to the Sustainable Development Goals (SDGs), and the relationships between dam management and the SDGs are shown in the following box.

Relationships between Dam Management and the SDGs:

(1) To enhance the adaptability to the intensified flood damage and water-related disasters due to climate changes through dam inspection and maintenance based on the systems and subsequent improvement, reinforcement, and improvement of the functions

SDG 13 "Climate Action":

13.1 "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters"

13.3 "Improve education, awareness-raising, and human and institutional capacity on climate-change mitigation, adaptation, impact reduction and early warning"

(2) To contribute to solving water scarcity through the efficient operation of the existing dam facilities and improvement of their functions

SDG 6 "Ensure access to water and sanitation for all":

6.1 "Achieve universal and equitable access to safe and affordable drinking water"

6.4 "Ensure sustainable abstraction and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity"

6.5 "Implement integrated water resource management"

6.6 "Protect and restore water-related ecosystems"

CHAPTER 2 SAFETY MANAGEMENT OF DAMS

2.1 Standards and Systems for Ensuring Safety of Dams

The basic requirements for the safety of dam structures are provided by laws and supported by the standards, guidelines, and manuals from the planning stage to completion.

(1) Dam Accidents in Japan

The breaking of a dam may result in severe damage. The malfunctions of gate operation, outlet works, and other facilities may cause floods in the downstream areas or a dam break owing to the overtopping of the reservoir water. Table 2.1 presents dam breaks that have occurred in Japan. Most of the breaks occurred in dams constructed before current technical standards were established. The major causes of these breaks were defective construction or overtopping reservoir water. Some irrigation reservoirs constructed away from the river had not been evaluated for the construction stipulated in the River Law. It is possible that they did not satisfy the technical criteria for river facilities.

Table 2.1 Examples of Accidents of Dams in Japan

Name of Dam	Year Constructed	Year of Accident	Type of Dam	Description of Accident	Damage
Iruka-ike	1633	1868	Earthfill dam for irrigation	Heavy rain caused overflow and collapse.	941 persons dead
No. 1 Regulating Pond, Komoro Hydropower Station	1927	1928	Buttress-type concrete dam for hydropower	The dam was constructed without regulatory approval. The foundation ground was improper, and seepage water caused piping phenomena in the foundation.	5 persons dead
Horonai Dam	1939	1941	Gravity-type concrete dam for hydropower	Malfunction of gates due to clogging with flood wood resulted in overflow on the dam. The break was caused by shoddy construction work without removal of the sand layer and gravel in the foundation.	60 persons dead
Heiwa-ike	1949	1951	Earthfill dam for irrigation	Heavy rain caused overflow and collapse.	75 persons dead
Yoake Dam	1952	1953	Gravity-type concrete dam for hydropower	Heavy rains caused the water to overflow over both abutments and washed out earth behind the abutments. Some gates could not be fully opened, owing to the loss of power.	No direct damage
Taisyo-ike	1949?	1953	Earthfill dam for irrigation	The main dam was overflowed and collapsed, together with a downstream's reservoir.	105 persons dead
Wachi Dam	1968	1967	Gravity-type concrete dam for hydropower	One month after completion, the gate broke and collapsed during an operation test due to the gate's vibration.	1 person dead
Fujinuma Dam	1949	2011	Earthfill dam for irrigation	The dam collapsed due to the Great East Japan Earthquake in March 2011.	8 persons dead or missing

Source: Edited data from the documents of the No. 21 Expert Meeting on future policy and the concept of flood management.

(2) Mechanism of Evaluation for Planning, Design, and Construction

Safety is ensured at the planning, design, and construction stages through multilayered permits and approvals from the River Management Offices (RMOs) and third-party agencies. The River Law stipulates that “facilities located on the river should be safe in terms of water level, discharge, topography, geology, and expected loads such as dead weight and water pressure”. The project-executing agency requires project approval from the supervising authority. The Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) or prefectures require permission to occupy the river land and water and install structures and dams (Table 2.2). Technical experts inspect the design, foundation, and structure of the dam at the designing, construction, and completion stages. The RMOs approve the operation rules. The main technical standards and guidelines are presented in Extra Table 1.

Table 2.2 Mechanism for Permissions and Approvals for Dam Construction in Japan

Purpose of Dam		River Class[a]	Dam Operator	Project Approval	Permission of Construction [b]	Approval [c]
Multipurpose dam (including single-purpose dam for flood protection)		A	MLIT, JWA, local governments	MLIT	MLIT	MLIT
		B	Local governments	Local governments	Local governments	
Water use dam	Irrigation	-	MAFF, JWA, local governments	MAFF	MLIT	MLIT MAFF
	Hydropower	-	Electric power companies	METI	MLIT	MLIT METI
	Domestic/ industrial water supply	-	JWA, local governments	MHLW METI	MLIT	MLIT MHLW METI

Notes:

a: A-class rivers in Japan are designated as rivers that are important with regard to nationwide land conservation and the national economy. B-class rivers are designated by the governors of the local governments as rivers that are important for public interest.

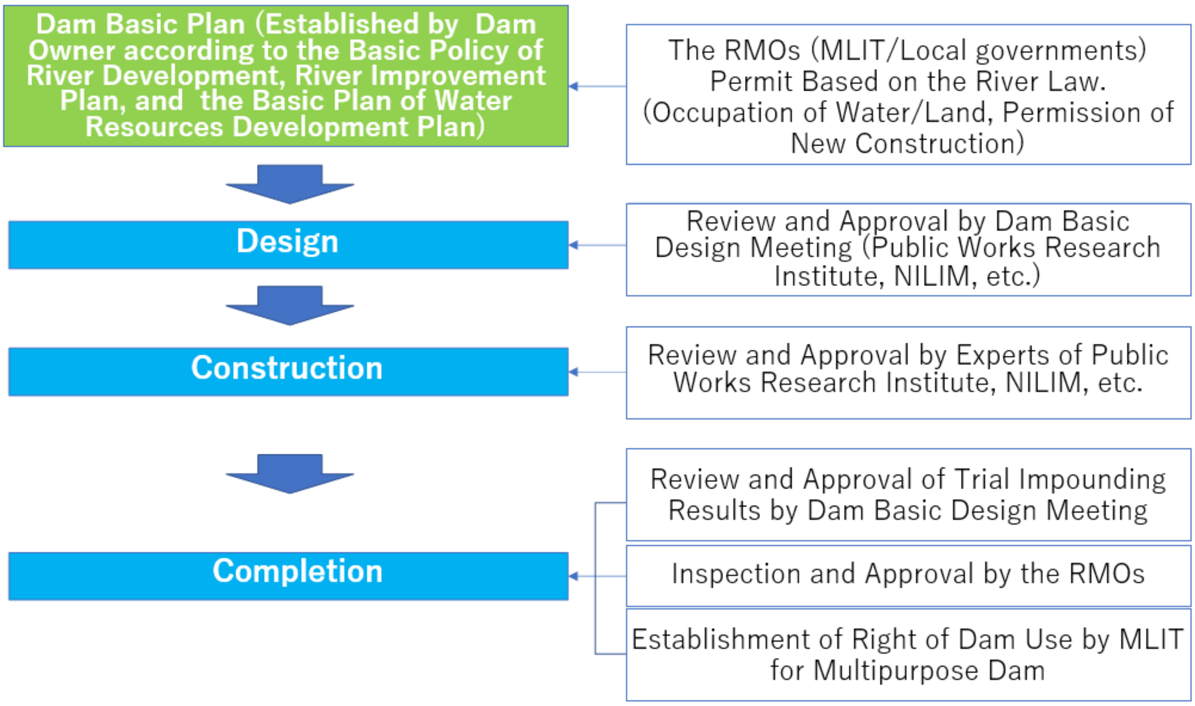
b: Permission from the RMOs for construction or installation of structures across the river.

c: Approvals for planning, design, and construction, including inspections upon completion and operation rules for the dam and appurtenant structures.

Abbreviations:

JWA, Japan Water Agency; MAFF, Ministry of Agriculture, Forestry, and Fisheries; METI, Ministry of Economy, Trade and Industry; MHLW, Ministry of Health, Labor and Welfare

Source: Preparation based on River Law, Specific Multi-Purpose Dams Act, "Construction of Multipurpose Dams" published by Japan Dam Engineering Center



Source: Preparation based on "Construction of Multipurpose for Dams" published by the Japan Dam Engineering Center

Figure 2.1 Technical Approvals of Multipurpose Dams at Planning, Design, and Construction Stages

(3) Review of Technical Standards Based on Disaster Experience

In Japan, where major disasters such as earthquakes and floods occur frequently, the safety of structures is ensured by studying the damage after major disasters updating the design criteria based on the new knowledge.

1) Review of Seismic Design Criteria after the Great Hanshin-Awaji Earthquake

The Great Hanshin-Awaji Earthquake in 1995, with magnitude 7.3, struck the urban area of the Hanshin region. This earthquake led to studies for evaluating the safety of various structures against large earthquakes. There were approximately 50 dams within a 50-km range of the epicenter. The maximum earthquake ground motion was recorded at Hitokura Dam (height of 75 m) a gravity-type concrete dam with a maximum horizontal acceleration of 183 Gal (0.19 g) in the bottom gallery and 482 Gal (0.49g) in the upper gallery. Post-surveys confirmed that there was no severe damage[1], but minor damage, such as cracks, was observed in some dams.

The Japan Society of Civil Engineers (JSCE) proposed that the seismic performance of structures should be checked against the most probable earthquake motion at the structure site (Level 2 earthquake motion[2]). The MLIT established "Guidelines for the Seismic Performance Verification of Dams against Large-Scale Earthquakes (Draft)" to include this proposal in 2005. Before this earthquake, the earthquake-resistant design of dams was developed via the traditional method of static rigid-body

[1] Hanshin-Awaji Earthquake Journal, January 1997, Hyogo Prefecture
[2] In contrast to Level 2 earthquake ground motions, Level 1 earthquake ground motions are those with a probability of occurring once or twice during the service period of a structure and with an intensity too low to damage the structure.

stability verification of the seismic intensity method) using inertial forces calculated by multiplying by the self-weight of the dam. The design seismic intensity was determined empirically for each region.

2) Damage Due to Excessive Flooding

Flood damage occurred in the downstream areas of dams owing to floods that exceeded the flood-protection plan, although the dams were operated appropriately to release water in accordance with the operation rules. For example, flood damage occurred in July 1995 in the downstream area of the Kanogawa Dam on the Hiji River, and the flood damage occurred in July 2006, in the downstream area of the Tsuruda Dam on the Sendai River. According to these cases, a review of soft measures is underway, such as the utilization of information transmission measures, public awareness, forecasting technologies, and measures for hard facilities. Details are presented in Section 3.

(4) Safety Management of Irrigation Reservoirs

Approximately 210,000 reservoirs are used for irrigation in Japan. Approximately 65,000 reservoirs have beneficiary areas of ≥2 ha. Approximately 75% of the 65,000 reservoirs were constructed prior to the Edo period (1603–1868). Most reservoirs, including those constructed in the early Showa period (1926–1945), were constructed in the period from the 7th century to World War II[3]. For many reservoirs, there is no information on the reservoir foundations or construction materials. Numerous levees face problems of settlement and leakage due to deterioration caused by aging. Generational change among reservoir owners and users is progressing. Their relationships and rights to reservoirs have become unclear and complex. Management organizations have suffered from farmers leaving and aging, causing difficulties in the daily maintenance of the structures.

Some reservoirs cause damage to downstream areas owing to dam collapse due to large-scale earthquakes and floods. Eight people were killed when the Fujinuma Dam collapsed because of the Great East Japan Earthquake in 2011. The torrential rains in July 2018 caused the collapse of dams in 32 reservoirs in western Japan, resulting in human casualties. The Act Concerning Management and Conservation of Agricultural Reservoirs was enacted in 2019 to gather information on agricultural reservoirs and prevent disasters caused by the dam collapse. The Framework of Legal Systems for Disaster Prevention Projects for Ponds and Small Reservoirs is shown in Figure 2.4. The following measures were implemented.

- Developing a database and disseminating information about irrigation reservoirs
- Recommending that dam owners conduct disaster prevention work
- Designating reservoirs in danger of collapse resulting in damage to surrounding areas as “specific irrigation reservoirs”
- Restricting threatening actions
- Disseminating information to residents about reservoir collapse and evacuation (Figure 2.3)
- Ordering disaster prevention works to ensure proper management
- Managing reservoirs by the municipalities when their owners are not specified

[3] A guide to creating reservoir hazard maps, 2013, MAFF

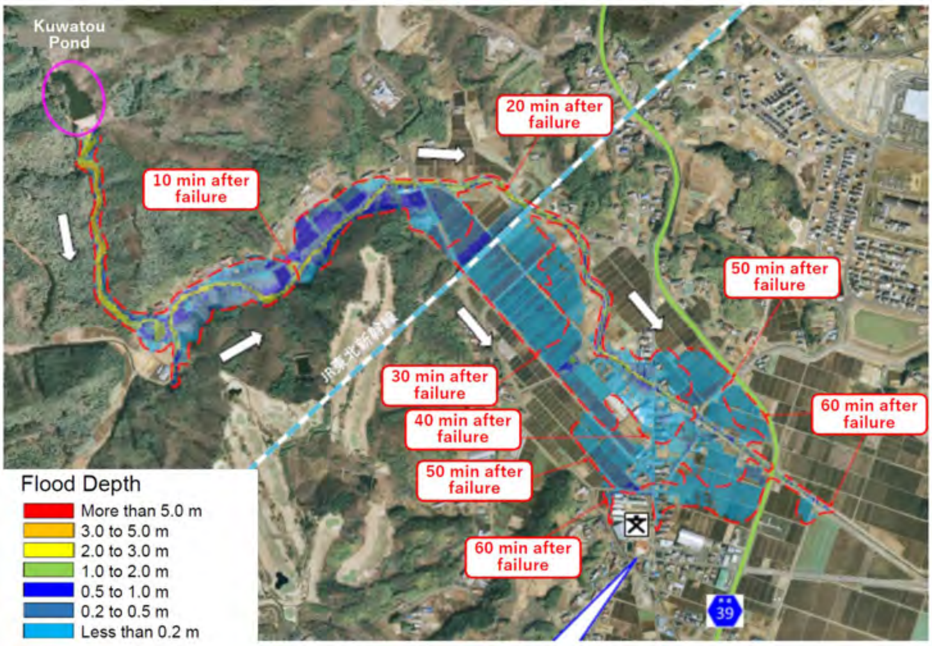
Failure of Fujinuma Dam Caused by the Great East Japan Earthquake[4]

Source: Brief session by Tohoku University one month after Earthquake dated on 13 April 2011

Figure 2.2 Failure of Fujinuma Dam

The Fujinuma Dam in Fukushima Prefecture, which had a height of 18.5 m and was a homogeneous earthfill-type dam, was completed in 1949 and irrigated 837 ha of farmland with a storage capacity of approximately 1.5 million m^3. The Ebanagawa Engan Agricultural Irrigation Area Improvement and Management Association was responsible for its maintenance. On 11 March, 2011, the Great East Japan Earthquake with a magnitude of 9.0 caused the dam to collapse, resulting in seven fatalities, one missing person, and damage to 124 houses. The upper part of the dam near its crest slipped into the reservoir, which triggered multiple slips (Figure 2.2). The slip was attributed to the following two factors:

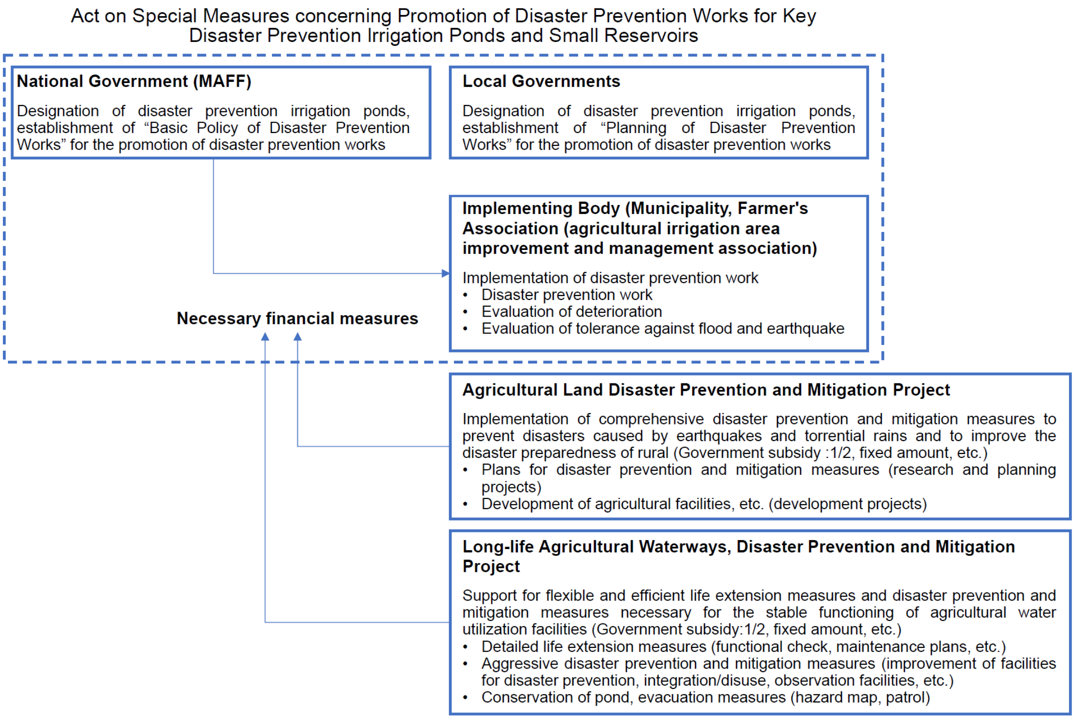
- The dam was constructed in the postwar period during which construction conditions were poor; the degree of compaction was low, and the embankment contained materials rich in the sand. The strength of the saturated part was reduced by the strong earthquake motion.
- The maximum seismic motion at the top of the embankment was 442 Gal (0.45g), and motion of >50 Gal lasted for 100 s, making the ground shaking unprecedented.



Source: Natori City Website

Figure 2.3 Example of Information Disseminated for the Failure of Ponds and Small Reservoirs and Evacuation Using a Hazard Map (Kuwatou-Tameike, Natori City, Miyagi Prefecture)

[4] Report of Survey on Causes of Failure of Fujinuma Dam, January 2012, Review Committee on Seismic Safety of Irrigation Ponds and Small Reservoirs in Fukushima Prefecture



Source: Preparation based on Act on Special Measures concerning Promotion Disaster Prevention Works for Key Disaster Prevention Irrigation Ponds and Small Reservoirs

Figure 2.4 Framework of Legal Systems for Disaster Prevention Projects for Ponds and Small Reservoirs

Example of Management of Old Ponds[5]

Lake Sanna (also known as Otani Pond) is owned and managed by the Fujioka Agricultural Irrigation Area improvement and Management Association in Fujioka City, Gunma Prefecture (Figure 2.5). It is an irrigation reservoir built in 1933 and irrigates approximately 380 ha. The homogeneous earthfill-type dam has a height of 19.7 m. Two staff members of the association manage several reservoirs, headworks, and irrigation channels. They adjust the water supply volume according to the demand of water users and operate gates accordingly. Once a year and as necessary after earthquakes with Japanese seismic intensities of ≥ 4, they conduct visual inspections of the facilities to investigate the deformation of the embankment and seepage lines in observation holes. They conduct cleaning of waterways, mowing, and maintenance of gates three times a year. The water users bear the management costs, including personnel costs. The prefectural and national governments provide subsidies for the rehabilitation of facilities damaged by disasters. The Sanna Lake Dam was constructed before the current structural ordinance was enacted, and seismic resistance reinforcement work is underway.

Source: Agricultural and Rural Development Plan in Gunma Prefecture (2020)

Figure 2.5 Seismic Resistance Reinforcing Works for Sannako Dam

[5] East Asia & Pacific and South Asia Regional Workshop and Exposure Visits for Dam Safety Management and Disaster Resilience, World Bank, April 4, 2017 and Website of Gunma Prefecture

(5) Capacity Building

MLIT and JWA staff receive on-the-job training at offices and national institutes. The Japan Dam Engineering Center consolidates dam technologies and allows engineers from prefectures to improve them. In the private sector, engineers are certified as general supervisory engineers for dam construction and as professional engineers (PE). Dams managed by parties other than the RMOs must be assigned personnel qualified as chief dam management engineers. To qualify, candidates must attend training at the National Construction Training Center and pass an examination. The center also contributes to the capacity building of dam managers by providing practical training in dam operation skills. The JWA has an online system for training involving a simulator of the gate operation during flooding.

The MLIT and local governments conduct "dam management exercises" at each office before the flood season. Assuming a flood that exceeds the planned flood-protection scale, the following drills are provided to communicate information and respond to extreme flooding.

A) Information dissemination (communication with relevant agencies, notification warnings on releasing flood discharges, and patrols)
B) Operation of dam gates (calculation of discharges to be released and setting of gate opening)
C) Risk management (use of emergency power supply and actions when the remote operation becomes impossible for gates and other facilities)

2.2 Inspection for Dam Safety

> Maintenance of dam safety, improvement of management, and reduction of lifecycle costs can be achieved by ensuring inspections and evaluating the inspection results from a third-party perspective.

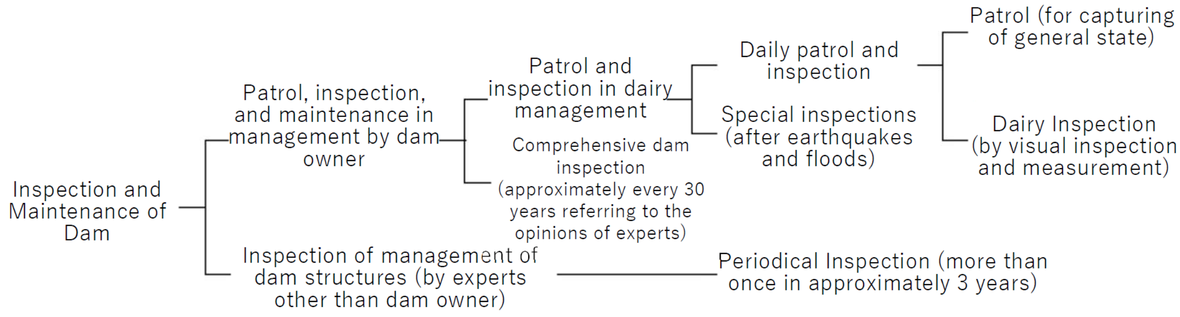
(1) Items, Methods, and Times of Inspection

Dam owners are obligated to maintain the facilities in good condition at all times. Mechanisms are in place to conduct daily inspections and patrols, and periodic inspections are performed by the RMOs and experts in accordance with various guidelines. Inspections of dams owned by the RMOs are classified as "daily patrols and inspections," "special inspections" after earthquakes and floods, "periodic inspections" conducted at least once every three years, and "comprehensive dam inspections" conducted approximately every 30 years (Figure 2.6). For daily patrols and inspections, the "Dam Inspection and Maintenance Standards" (details are presented in Extra Tables 2-4 attached to the end of this theme) specify the frequency of patrols, inspections, maintenance, and repairs in daily management.

1) Periodic inspection: approximately once every three years. When the necessity of improvement is pointed out, the dam owner must prepare a response policy and report its implementation status to the RMO.

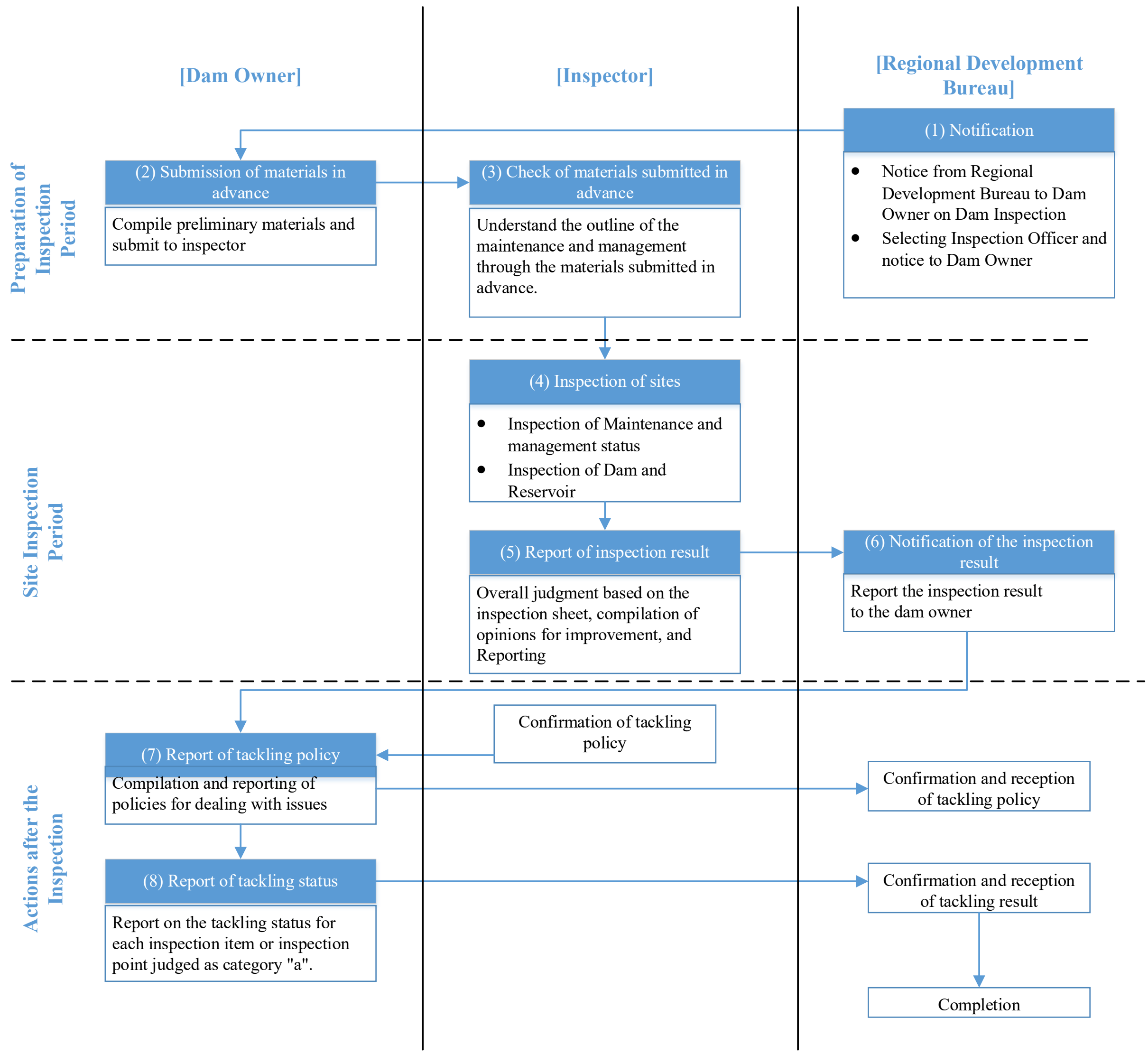
2) Comprehensive inspection: approximately once every 30 years, aiming at assessing dams from a long-term perspective and formulating maintenance and management policies, as summarized in Figure 2.7. Detailed investigations, such as nondestructive surveys and core sampling in dam bodies, are necessary, and dam management records are reviewed to assess

the soundness of dams. The major items for inspection are presented in Table 2.3.



Source: Operating Procedure for Dam Comprehensive Inspection and its Explanation, MLIT

Figure 2.6 Inspections and Maintenance for Dam-Structure Management



Source: Guide to Dam Periodic Inspection, MLIT

Figure 2.7 Procedure for Periodic Dam Inspection

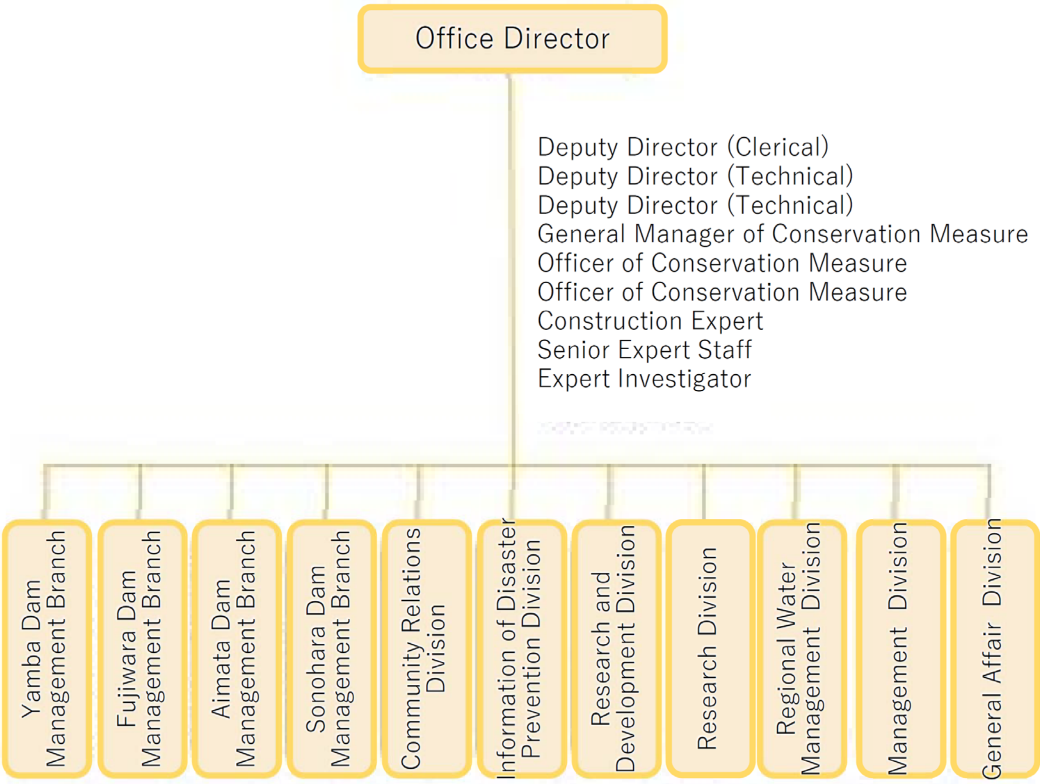
Table 2.3 Major Items of Periodic Inspection and Evaluation of Inspection Results

Classification	Major Inspection Items	Evaluation of Inspection Results
Inspection of the implementation status of maintenance	• Organization of dam management • States of dam operation, inspection and patrol, and data storage • Existence of measures based on lifetime improvement plan	A Urgent improvement is required. B Although some problems exist, these are no overall problems. C There are no problems.
Inspection of dam structures and reservoir	• Results of measurement and observation of dam and reservoir • Deterioration and damage of dam body and appurtenant structures	A Urgent measures against the deterioration or damage are required. B1 Although the structures are safe and functional, prompt measures are required. B2 Although the structures are safe and functional, measures are to be taken as necessary. C The structures are safe and functional. Inspections need to be continued.

Source: Guide to Periodic Dam Inspection, MLIT

(2) Management System

As an example of the organization of the dam management office, the Tone River Dams Integrated Management Office of the MLIT is shown in Figure 2.8 (see "Subclause 4.2: Integrated operation of dams"). The management branch offices of the four dams under the MLIT belong to the integrated management office.



Source: Website of Tone River Dams Integrated Management Office

Figure 2.8 Organization of the Tone River Dams Integrated Management Office

The standard personnel composition of each management branch office is seven to eight people in total: three staff members, one periodic service staff member, and three to four outsourced personnel. In the case of the Fujiwara Dam, the management office building is a four-story structure, as shown in Figure 2.9. Its layout is described in Table 2.4.

Table 2.4 Layout of the Fujiwara Dam Branch Office

4th Floor	Machine room (air conditioners)
3rd Floor	Operation room (consoles for gate operation), telecommunication equipment room
2nd Floor	Offices, conference rooms, lounge space, library
1st Floor	Nap room, power batteries for telecommunications during a power outage
Garage Building	Garage, generators for gate operation during a power outage

Source: Hearing from Tone River Dams Integrated Management Office

Source: Website of Tone River Dams Integrated Management Office

Figure 2.9 Management Branch Office of the Fujiwara Dam

CHAPTER 3 DAM OPERATION DURING FLOOD

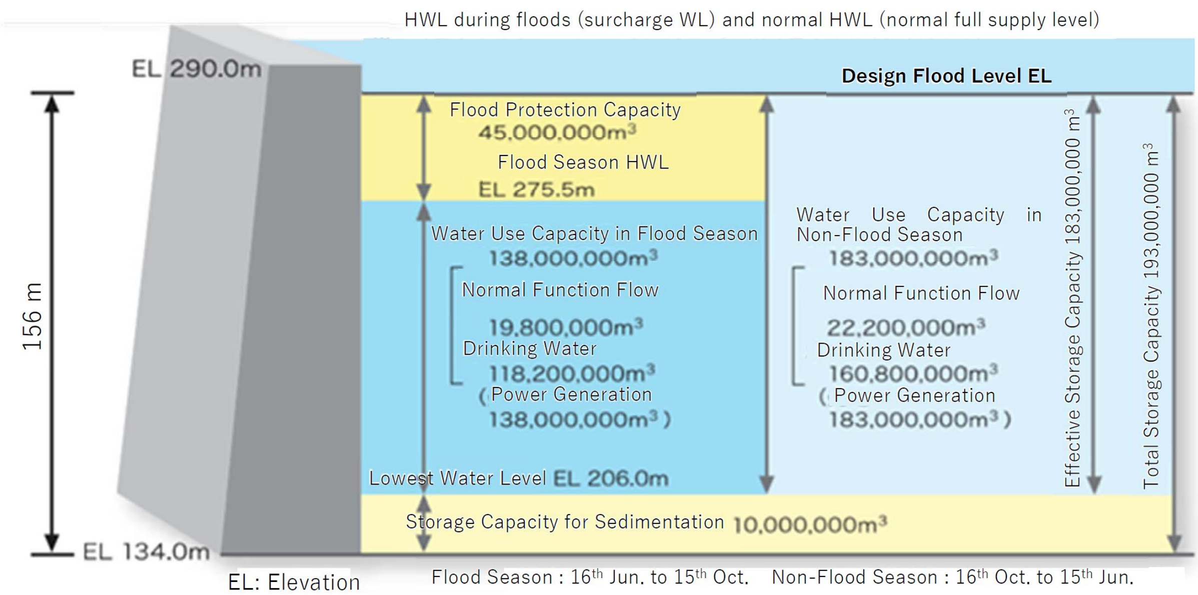
3.1 Storage Capacity Allocation and Flood Protection of Multipurpose Dam

The dam office determines the operation rules in accordance with the flood-protection plan of the river. During flooding, the office operates gates, patrols the downstream area along the river, and warns downstream people before releasing water.

(1) Reservoir Operation

The operational rules of dams for flood protection and water supply are prepared in accordance with the overall flood-protection and drought management plans for the river. The maximum flow does not cause damage to downstream areas or various facilities in the river. This flow volume is named" harmless flow rate". Dames release water to supply water at the drought safety level of once-in-ten year in Japan.

Figure 3.1 shows the storage capacity allocation of the Miyagase Dam in the Sagami River system. An effective storage capacity of 183 million m^3 is used for water supply during the non-flood season. During the flood season, the reservoir allocates a flood-protection capacity of 45 million m^3 by lowering the reservoir water level to the normal water level of El.275.5 m, while water is supplied by using 138 million m^3 of reservoir water below El.275.5 m.



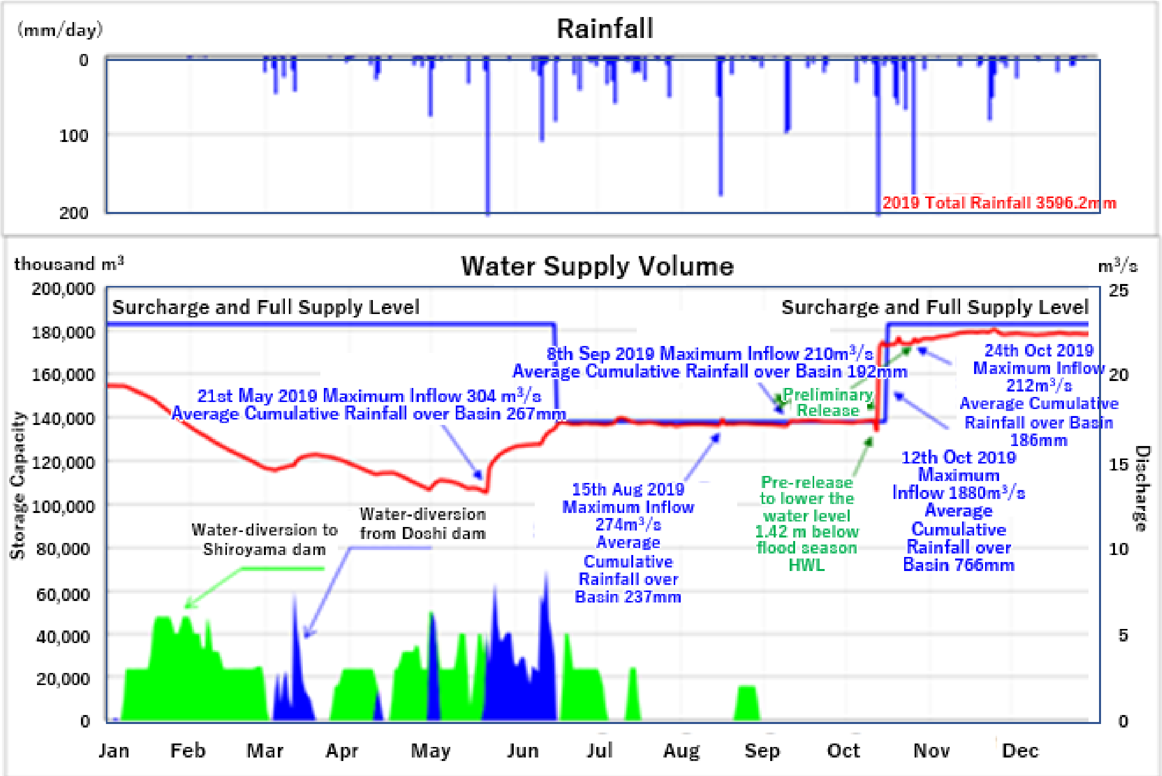
Source: Pamphlet of Miyagase Dam, Sagami River System Dam Management Office, Kanto Regional Development Bureau, MLIT

Figure 3.1 Storage Capacity Allocation of the Miyagase Dam

Annual Reservoir Operation of Miyagase Dam

Figure 3.2 shows the actual operating results for the Miyagase Dam in 2019.

- The reservoir was full as of December 2018, but the water level decreased owing to significant water release for water use during the non-flood season (January to May 2019).
- From June 2019 onward, the rainfall increased, and the water storage levels began rising.
- 15 June to 15 October was in the flood season; thus, the storage level was maintained below the flood season High Water Level (HWL) at El. 275.5 m for flood protection. The flow on the river that reaches downstream of the dam was sufficiently high for the required water abstraction (supply); thus, a small dam release was maintained. The storage level of the dam remained constant.
- After 15 October, it is in the non-flood season; thus, the storage level was restored to the full supply level to prepare for water supply during the non-flood season.



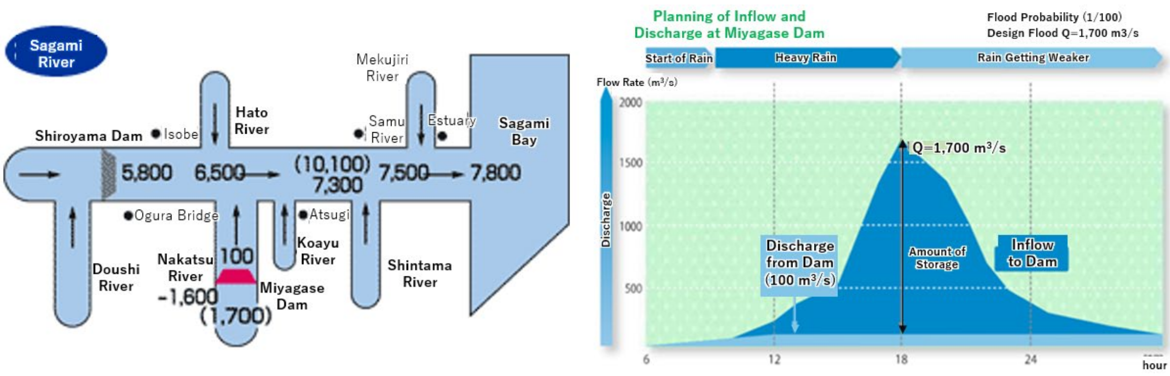
Note: Doshi dam diverts its water, when it is expected to start spilling therefrom, to the Miayagase Dam for storage therein while the Miyagase Dam diverts its water to the Shiroyama Dam, which has a shortage of stored water, to satisfy the water demand of Tokyo.

Source: Website of Sagami River System Dam Management Office

Figure 3.2 Annual Reservoir Operation Record of the Miyagase Dam for 2019

Operation of Miyagase Dam During Flood on 12 October 2019

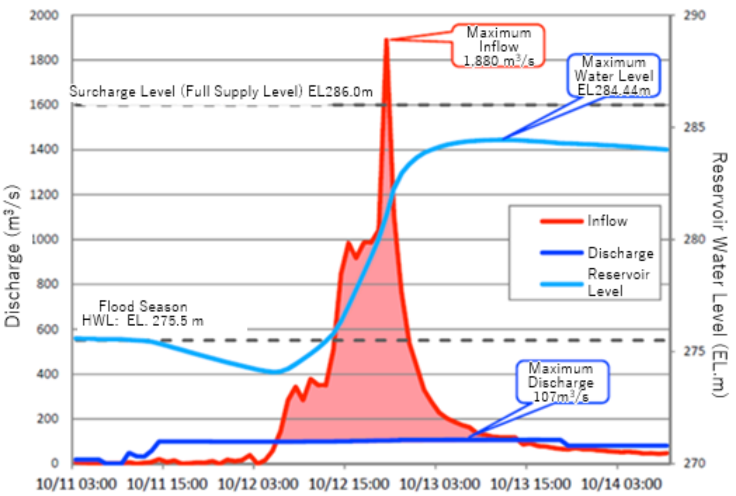
The left figure in Figure 3.3 illustrates the flood-protection plan for Sagami River. The discharge of the design flood before regulation at the reference point, i.e., Atsugi, is 10,100 m^3/s. The upstream dams were expected to reduce the flood discharge by 2,800 m^3/s, and the river channel carries the remaining 7,300 m^3/s. The Miyagase Dam is expected to reduce the flood discharge by 1,600 m^3/s. The right figure in Figure 3.3 shows the flood hydrograph in the control plan of the Miyagase Dam. The flood inflow at the peak is 1,700 m^3/s, corresponding to a probability of once in 100 years. The peak flood discharge stored in the reservoir is 1,600 m^3/s, and the discharge released downstream is 100 m^3/s.



Source: Website of Sagami River System Dam Management Office

Figure 3.3 Flood-Protection Plans for Sagami River and Flood Protection for the Miyagase Dam

Figure 3.4 shows the operation for the flood caused by Typhoon No. 19 in 2019. The inflow was 1,880 m^3/s, exceeding the planned peak discharge of 1,700 m^3/s. Forty-three million m^3 were stored in the reservoir, and the maximum discharge was 105 m^3/s. This resulted in a reduction of 1.1 m in the river water level at the flood-protection reference point (Atsugi Point). The maximum water level in the reservoir was El.284.44 m, which was 1.56 m below the planned maximum water level of El.286 m, because the reservoir level was lowered to a level below the flood season HWL by pre-release preceding the flooding according to the flood forecast.



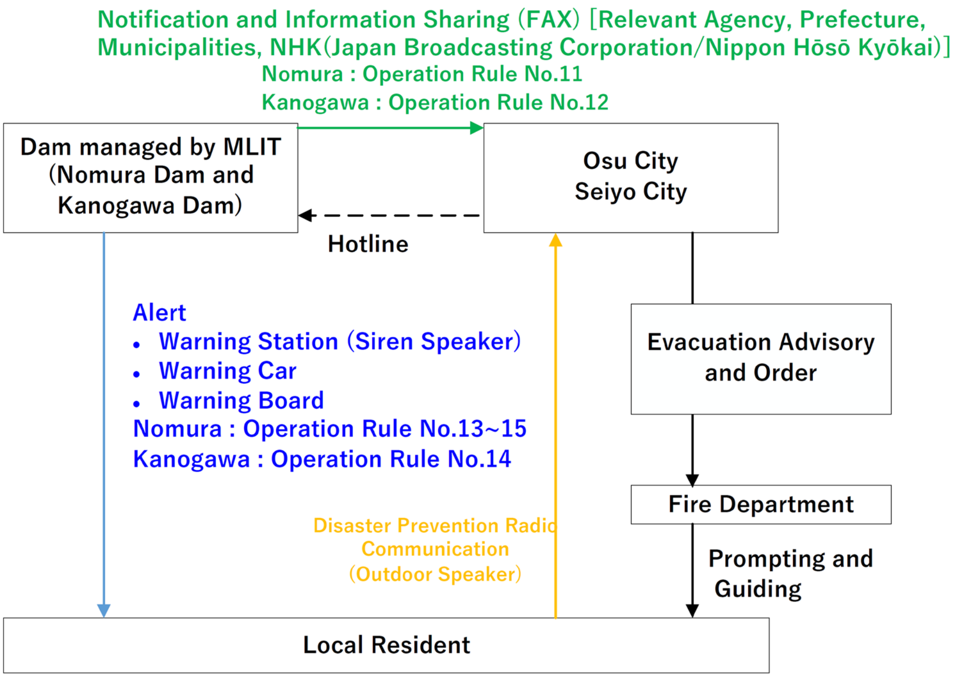
Source: States of Dams at Typhoon No. 19 in 2019, MLIT

Figure 3.4 Example of Flood Protection (Miyagase Dam for Typhoon No. 19 in 2019)

(2) Ensuring Safety of Residents and River Users in Downstream Area

In cases where the dam discharge increases rapidly, careful patrols and notifications should be made in advance to ensure the safety of residents and recreational users in the downstream area. The River Law stipulates that "the dam owner shall establish Dam Operation Rules and obtain approval from the RMOs". A diagram of the notification and sharing of information is shown in Figure 3.5. When the dam discharge is predicted to cause a sudden increase in the river flow in the downstream area, the dam discharge must be reported to the relevant local governor, mayors, and the chief of the relevant police station, as well as nearby residents and river users. Notification and dissemination methods should be specified in the dam operation rules. The notification methods include sounding, warning sirens and mobilizing warning vehicles. Further approval to operate during the extraordinary flood disaster prevention should be obtained from the Regional Development Bureau of the MLIT or the local governor.

In addition to the above, in accordance with Article 52 of the River Law (Instructions for flood protection), river administrators may instruct the owner of the water supply dam to take measures such as temporary storing of floodwater to prevent flood damage (Extra Table 5).



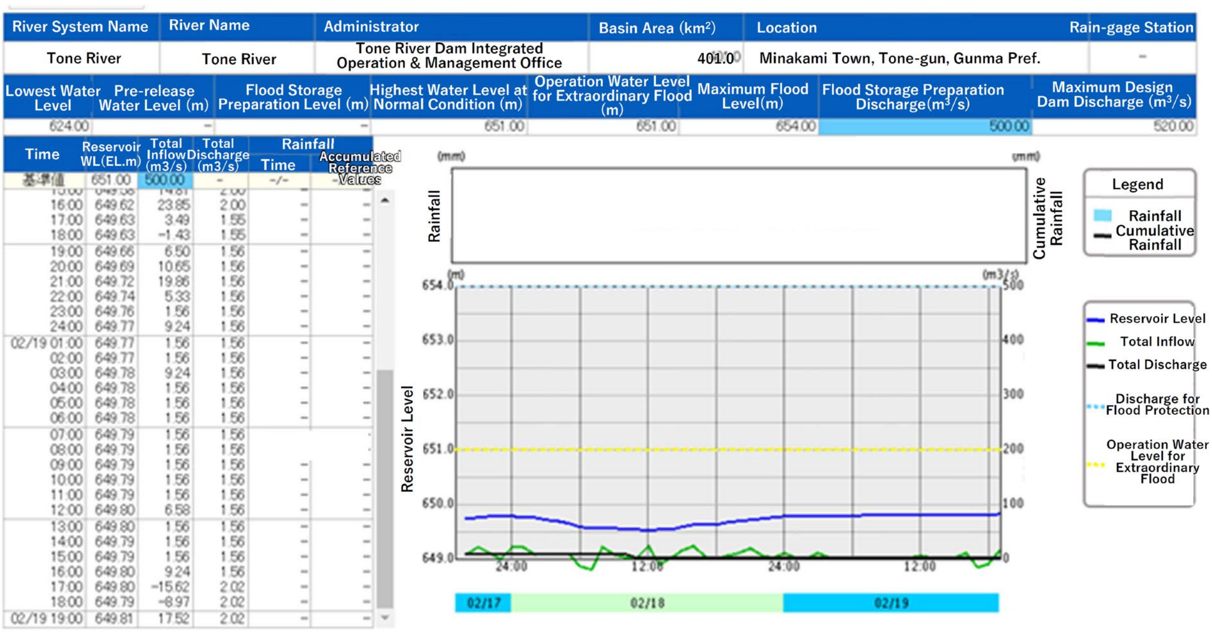
Source: Summary of Discussions for Verification of Information Sharing on the Operation of Nomura Dam and Kanogawa Dam, November 2018

Figure 3.5 Notification and Information Sharing

To share information with the public, (1) the dam information (inflow, discharge, reservoir water level, and rainfall) is provided in real time on the MLIT website (Figure 3.6), and (2) discharge warnings and other information are provided on the website. Each management office has a Twitter account that allows users to view the discharge status and other information (Figure 3.7).

It is necessary to avoid a sudden rise in the river water level due to dam discharge, which allows almost no time for river users to evacuate. The Guidelines for Planning and Designing Dam Discharge Warning

Systems (Draft) stipulate that the rate of increases of the water level due to dam discharge should be less than 30 cm in 30 min. at the most dangerous point on the downstream river.



Source: MLIT Website

Figure 3.6 Real-time Information Sharing for Hydrological Data of Dams via "Information of River Disaster Management"

Source: Fujiwara Dam

Figure 3.7 Information Sharing via Twitter for the Fujiwara Dam

(3) Records and Reporting

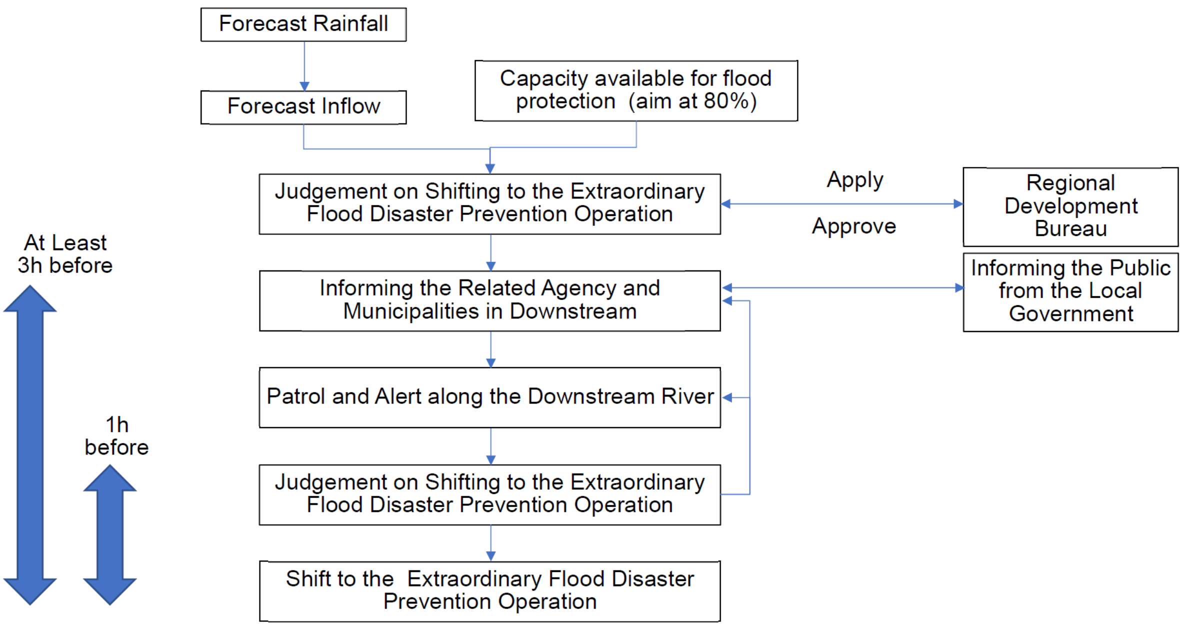
The River Law stipulates that "the dam owner records hydrological data such as inflow into the reservoir, discharge downstream, reservoir water levels, and river water levels at the dam, as well as the operation of the dam". They should notify the RMOs and local governments of the occurrence of floods. Observation, recording, and accumulation of hydrological data are necessary for not only the operation and maintenance of facilities but also verification of dam operations. This information is also important for formulating and reviewing flood-protection plans, studying conservation measures for the river water quality and biological environments, and implementing construction works. These data are shared with the public in real-time through the "River Disaster Prevention Information". Historical information from the past can be found in the "Dam Quantity Database".

3.2 Dam Operation During Extraordinary Flood Exceeding Design Discharge

> When the dam is predicted to be unable to store floodwater that exceeds the capacity of the flood-protection plan, the dam discharge needs to be maintained at the same level as the dam inflow to ensure the dam safety and prevent damage in downstream areas. The downstream damage must be managed so that it does not exceed the damage level without the dam.

(1) Operation for Disaster Prevention at the Extraordinary Flood

When a flood exceeding the planned flood protection occurs, and it is predicted that the dam is in danger, extraordinary flood disaster prevention operations are conducted to ensure the safety of the dam. The dam discharge is managed to prevent the inflow into the reservoir. A diagram of this procedure is shown in Figure 3.8.



Source: Hearing from Tone River Dams Integrated Management Office and Notes on Procedure for Operation of Nomura Dam

Figure 3.8 Procedure for Shifting from Normal Operation to Extraordinary Flood Operation

Lessons Learned from Extraordinary Flood Disaster Prevention Operation Conducted in July 2018 at Nomura and Kanogawa Dams in Hijikawa River

Source: MLIT

Figure 3.9 Flood Inundation along Hijikawa River

The record-breaking torrential rains in July 2018 caused flood damage to 995 ha of land, inundating 3,703 houses on the Hiji River in Ehime Prefecture (Figure 3.9). Two multipurpose dams of the Nomura and Kanogawa Dams, had inflows far exceeding the planned one with a 100-year probability. For both dams, extraordinary flood disaster prevention operations were conducted, and notifications and warnings were sent to the relevant organizations in accordance with regulations. However, the information may not have been disseminated securely to all the residents. Consideration and review of the flood disaster were undertaken by the national government, local governments, and academics to discuss and verify how to provide more useful information, how to inform residents, and how to operate dams more effectively. As a result of this verification, the following measures were proposed (Table 3.1).

Table 3.1 Proposed Measures for Reducing Flood Damage upon Extraordinary Flood Disaster Prevention Operation (Nomura Dam and Kanogawa Dam)

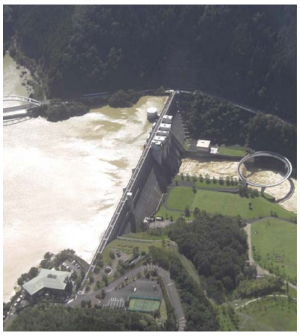
Subject	Main Measures
Information Sharing and Dissemination to Residents	• Establishment of criteria for issuing evacuation orders related to river water levels and dam discharge • Strengthening communicating with local governments using email and videophone • Dispatch of liaison personnel to provide information to local governments • Reinforcement of warning methods using electronic bulletin boards, local cable television, and administrative disaster prevention radio • Installation of water-level meters to provide detailed water-level information • Flood hazard maps related to Extraordinary Flood Disaster Prevention Operations • Development of a timeline (disaster prevention action plan) for government agencies to ensure evacuation • Briefing sessions and disaster drills for residents related to dam operations and information, publishing of disaster prevention books, and disaster prevention education at elementary and junior high schools.
Dam Operation	• Enhancement of advanced discharging (pre-releasing) based on flood forecasts • Modification of the Kanogawa Dam to increase the flood-protection capacity and revision of the flood-protection rules to make them more effective • Promotion of renovation of downstream rivers and accompanying changes in flexible dam operation rules

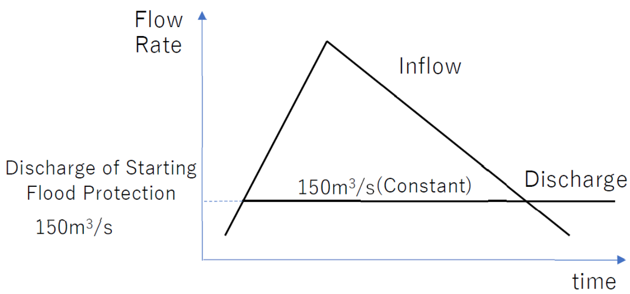
Source: Summary of Discussions for Verification of Information Sharing Concerning Operation of Nomura Dam and Kanogawa Dam, Shikoku Regional Development Bureau, MLIT

(2) Advanced Dam Operation During Heavy Flood

Advanced dam operation has been realized by adopting the latest technology, e.g., rainfall prediction. In the case of Typhoon No. 18 in 2013, the Hiyoshi Dam in the upper reach of the Katsura River in Kyoto Prefecture was operated by predicting the inflow volume. This significantly reduced the damage in the downstream areas.

The flood-protection plan of the dam involved applying the gate operation rule of constant release at 150 m^3/s to reduce the flood discharge to 1,360 m^3/s under the design flood with a peak discharge of 1,510 m^3/s. Typhoons caused a record inflow of 1,690 m^3/s into the reservoir, as shown in Figure 3.10. Because the river water level exceeded the flood risk level on the river reaches downstream of the dam, the JWA (the dam owner) and the Kinki Regional Development Bureau of the MLIT (the RMOs) decided to utilize the reservoir up to the highest water level of El.203.7 m, which was designed to ensure the safety of the dam. The dam stored floodwater level that exceeded the planned maximum flood level of El.201.0 m. Floodwater was retained in the reservoir up to the marginal level, judging by the remaining available reservoir capacity estimated from the rainfall and inflow forecasts based on the movement of rain clouds measured by weather radar. Although overtopping of the levee had already occurred on the downstream river reaches, the start of the extraordinary flood disaster prevention operation was delayed by 3 hours (Figure 3.11). It is estimated that the operation lowered the downstream river water level by 1.5 meters.





Source: Outline of flooding by typhoon No.18 September 2013 Kinki Regional Development Bureau (MLIT)

Figure 3.10 Flood Release from the Hiyoshi Dam (Left) and the Flood-Protection Plan (Right)

Source: Outline of flooding by typhoon No.18 September 2013
Kinki Regional Development Bureau (MLIT)

Figure 3.11 Overflow in the Downstream River

3.3 Operation During Flood

> Even if a dam is constructed exclusively for the purpose of water supply, it must not increase the flood flow or worsen the flood damage compared with those without a dam. Flood forecasting technology is utilized in Japan to temporarily increase the flood-protection capacity by reallocating some of the reservoir capacity for water supply.

(1) Operation Under Current Legal Framework

The River Law stipulates that "dams shall maintain the function of the downstream river to carry flood discharge in the same manner before dam construction." Dams constructed for water supply must maintain downstream flood conditions to avoid exceeding these flood discharges. In addition, the RMOs may instruct the dam owner to take measures such as temporary storage of floodwater for preventing flood damage.

(2) Flood Protection Utilizing Pre-release water for Water Supply

In light of the increasing severity of flood damage, the water supply reservoir capacity of existing dams is reserved for flood protection by releasing the stored water in advance. The MLIT and there are seven water supply dams to be modified. The MLIT published the "Guidelines for Pre-release of Water" in April 2020. The guidelines cover as follows:

【Standard for Start of Operation】

- Pre-release is considered when the predicted rainfall level upstream of the dam is equal to or higher than the standard rainfall level.
- The standard rainfall is defined as rainfall that causes flooding in the downstream area (equivalent to the current flow capacity of the river downstream).
- The model predicts rainfall up to 84 h in advance.

【Method for Determining Lowering Extent of Reservoir Water Level】

- The pre-release decision is made 3 d in advance.
- Numerical forecast data predictions up to 39 h in advance are also used, as well as predictions from the 84 h model, for comparison with the standard rainfall.

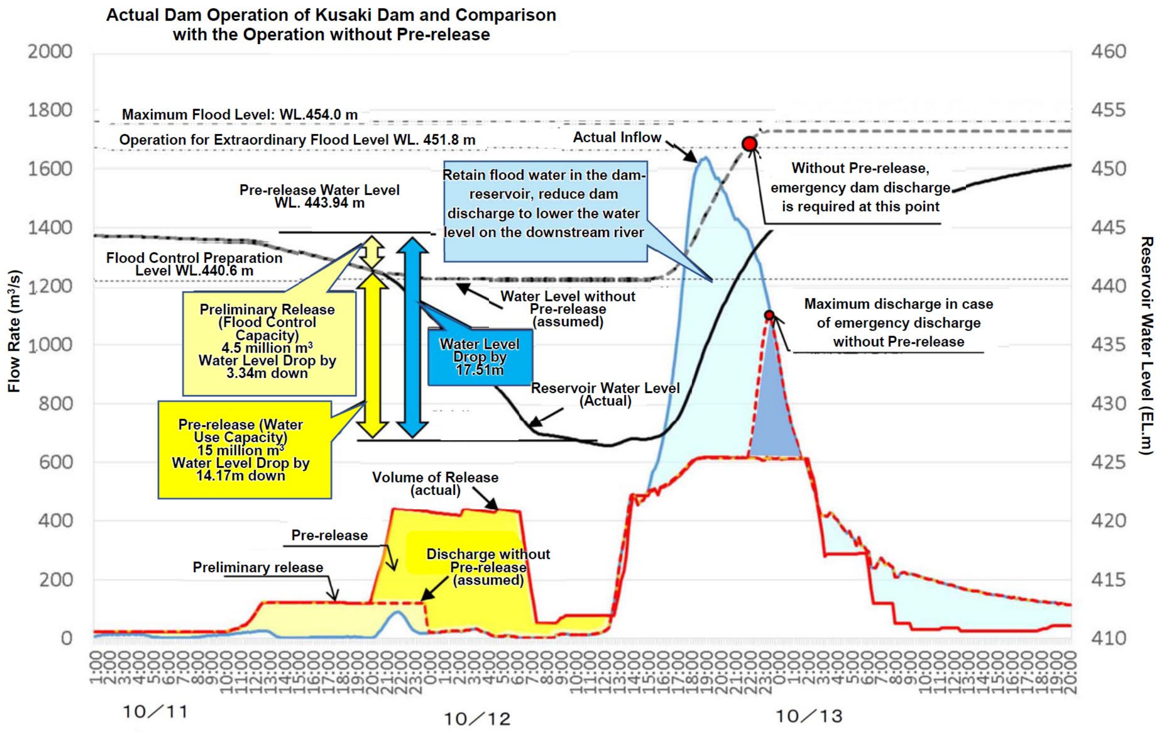
【Activities to be taken When Reservoir Water Level Does Not Recover After Pre-release Operation】

- If the water level lowered by the advanced release does not recover and water supply becomes difficult, the RMOs must provide the necessary information and ensure smooth coordination of water use among the parties concerned. Relevant water users must discuss water sharing at drought coordination meetings.
- If the water users suffer losses, the RMOs bears the costs.

Examples of Cooperation for Flood Protection by Pre-release Operation

Floodwater was partially stored in the reservoir of the Kazeya and Ikehara Dams for power generation on the Kumano River, after pre-release of water to prepare for the forthcoming heavy rain of Typhoon No. 10 in 2019. The operation lowered the river water level by 1.3 m on the downstream reaches and prevented damage to houses. The pre-release operation discharged 98 million m^3 of water in total, which was approximately 30% of the total effective reservoir capacity of the two dams (Figure 3.12).

The Kusaki Dam on the Watarase River released 15 million m^3 of water in advance of Typhoon No. 18 in 2019. In addition to the flood-protection capacity of 20 million m^3, a reservoir capacity of 35 million m^3 was secured, including the pre-release from the water supply capacity. Thus, the extraordinary flood disaster prevention operation was avoided to prevent an increase in the dam discharge to the downstream river.



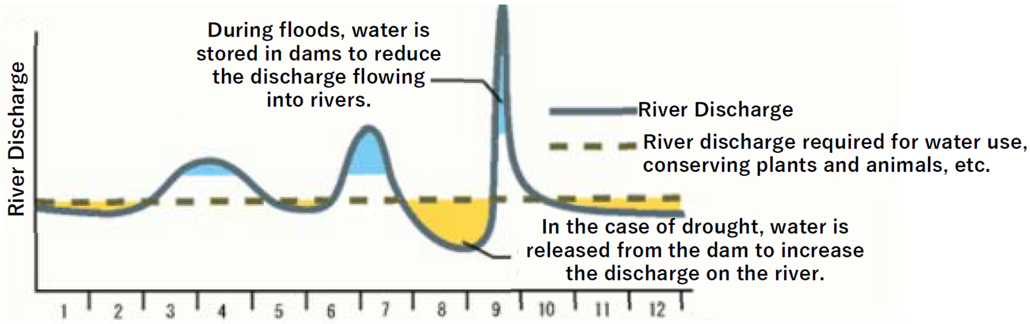
Source: MLIT Website

Figure 3.12 Pre-release Operation of the Kusaki Dam for Typhoon No. 18 in 2019 and Its Effect

CHAPTER 4 EFFICIENT OPERATION FOR WATER SUPPLY

Integrated operation of multiple dams allows efficient and appropriate use of reservoirs.

The reservoir capacity for water supply is determined to increase the river discharge during a drought, which generally occurs once every 10 years in Japan. When the discharge is lower than the normal level at the water use reference point, the dam reservoir is supplied. Figure 4.1 shows the river discharge changes over a year to supply the dam reservoir.



Source: MLIT Website

Figure 4.1 Water Supply Increase Caused by a Dam

The integrated operation of multiple dams located in a single river system contributes to the efficient use of reservoir water. This operation is performed by considering the locations, reservoir capacities, and basin characteristics of each dam. For example, nine dams in the Tone River Basin are utilized in the Tokyo metropolitan area, as shown in Figure 4.2. Because of the wide catchment area of the Tone River Basin, the rainfall characteristics (area, pattern, and duration) are not uniform. The river discharges from the sub-basins downstream of dams vary significantly, and the water use is complex. The river flow conditions vary over time. It takes a long time of approximately 1.5 days for the upstream dam discharges to reach the reference point, namely Kurihashi. Watarase Reservoir is close to Kurihashi. Owing to its location, Watarase Reservoir is mainly used for the supply adjustment of the discharge at Kurihashi, which may change rapidly.

Water supply priority is given to the dam that has the largest ratio of the catchment area to the reservoir capacity. This indicates that the reservoir has the highest probability of recovering full storage through flood operations. The priority order in releasing dam discharges is set to account for the snow depth of the current year, the annual time of reservoir water recycling, and other factors.

Source: Tone River Dams Integrated Management Office

Figure 4.2 Dams Operated by the Tone River Dams Integrated Management Office

CHAPTER 5 MEASURES FOR REHABILITATION AND IMPROVEMENT OF DAM FUNCTIONS

> The functions of existing dams can be used effectively and sustainably. The soft and hard technologies can enhance the functions of flood protection and water supply.

(1) Measures for Dam Rehabilitation

The impact of climate change has become apparent. The damage caused by floods and droughts has intensified and become more frequent. Amid financial constraints, it is important to utilize the existing infrastructure effectively while controlling the total cost. Existing dams should be used effectively and sustainably over the long term. The rehabilitation of dams is promoted to extend their service lives, maintain efficient and advanced dam functions, and restore and improve their functions. Dam rehabilitation efforts include the measures presented in Table 5.1.

Dam rehabilitation is efficient because of its relatively low cost, short duration, and minimal impacts on the natural and social environments. In particular, dam raising can significantly increase the water storage capacity with small submerged areas. The augmentation of dam discharge pipes facilitates the reallocation of reservoir capacity and the use of the water supply capacity for flood protection. In addition, sediment control facilities, such as sediment discharge bypasses, can extend the service life. Flood forecasting with rainfall radar is a soft measure that allows more efficient and advanced use of dams for a temporary capacity for flood protection.

(2) Dam Rehabilitation Technologies in Japan

1) Katsurazawa Dam Raising

The Katsurazawa Dam, which has a height of 75.5 m and is of the gravity concrete type, was constructed in 1957. It was raised by 11.9 m to enhance the flood-protection and water supply functions, as shown in Figure 5.1. In addition to efficiently increasing the water storage capacity with a small submerged area, dam raising is less expensive and less environmental impacts compared with the construction of a new dam.

(3) Dam Rehabilitation Technologies in Japan

1) Katsurazawa Dam Raising

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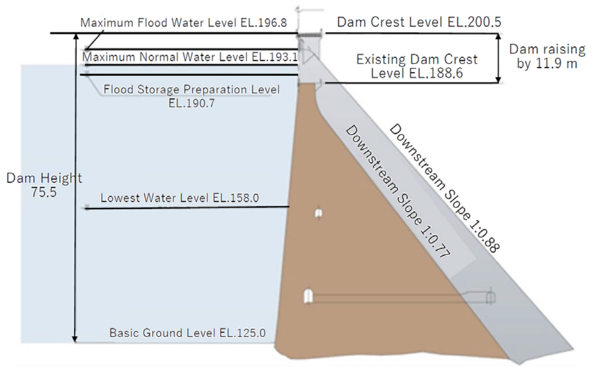
Table 5.1 Measures for Dam Rehabilitation

Measures	Descriptions
(1) Extending the service life	• Sediment control measures (excavation and dredging, installation of sand storage dams, sediment bypasses, and sand discharge gates) • Systematic maintenance and management of machinery and equipment based on the Plan-Do-Check-Act (PDCA) cycle through periodic inspections, life extension planning, levelling, and reduction of lifecycle costs
(2) Streamlining the maintenance and management	• Underwater maintenance robots (trial stage) • Flexible and safe inspection via remote inspection and measurement with a drone camera
(3) Improvement of flood protection and water use functions	
1) Operational improvements and capacity reallocation	• Expansion of the real-time high-precision rainfall radar (XRAIN) • Reduction of flood damage via flood forecasting using rainfall data obtained using rainfall radar • Utilization of the water supply capacity for flood protection through the pre-release of water and shifting of the reservoir capacity from water supply to flood protection (Hattahara Dam, Sakuma Dam)
1) Operational improvements and capacity reallocation	• Reallocation of the water storage capacity through reorganization of dam groups (Naruse River Integrated Development, coordination of dam groups upstream of the Kinugawa Dam, coordination of the Kitachiba Headrace and Misato Flood Bypass)
2) Increasing the water storage capacity	• Dam raising (Shin-Katsurazawa Dam, Tsugaru Dam)
3) Expanding the dam discharge capacity	• Construction of additional river outlet facilities via large-scale drilling of the concrete dam body (Tsuruda Dam, Amagase Dam) with construction technology under a high water pressure
(4) Improvement of river environment	
1) Improvement of river environment through flexible management	• Avoiding flow stagnation with flushing discharge (Sagae Dam) • Sediment supply to the downstream river reaches in combination with sediment control measures (Shimokubo Dam) • Creation of an unspecified capacity (environmental capacity) through dam coordination (Gojiri and Kawaji Dams)
2) Improvement of the river environment through facility development	• Continual sediment transport facilitated by a sediment bypass • Improvement of the water environment through a freshwater bypass, a selective water intake system, and an aeration circulation system (Urayama Dam) • Improvement of the biological environment through the installation of fishways and maintenance of forests (Tokuyama Dam)

Source: Vision of Dam Rehabilitation, Water and Disaster Management Bureau, MLIT

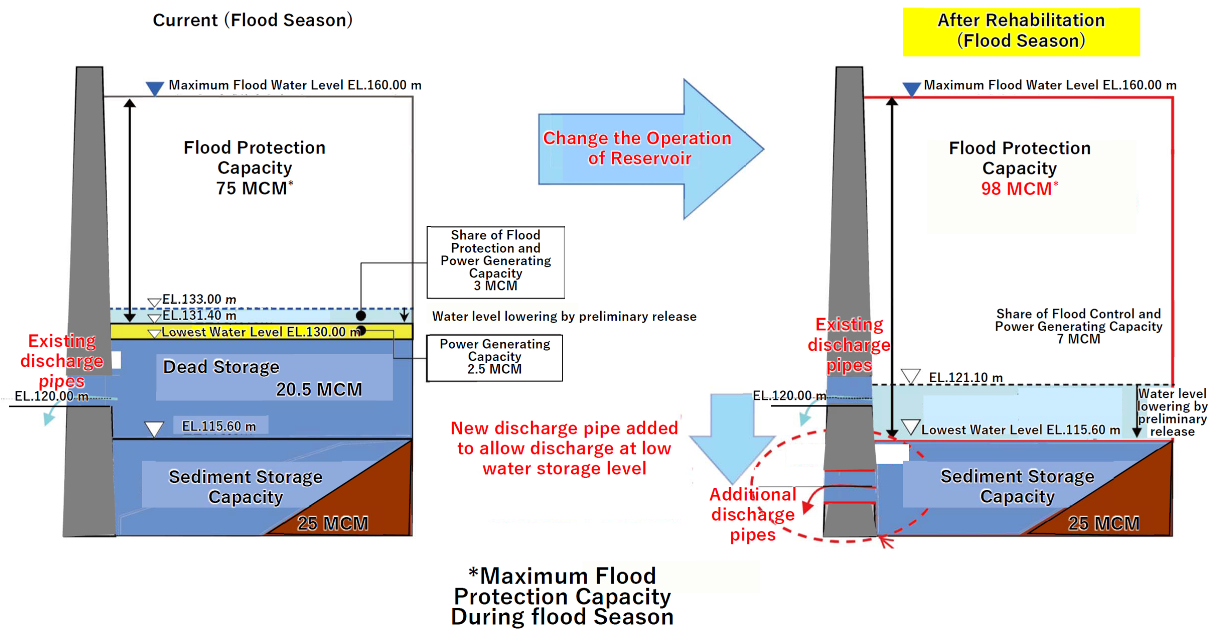


Source: Sapporo Development and Construction Office, Hokkaido Regional Development Bureau

Figure 5.1 Cross Section of the Body of the Shin-Katsurazawa Dam and Photograph of Construction Works

2) Installation of Additional River Outlet Facility via Drilling in Tsuruda Dam

The Sendai River was severely damaged in 2006, with two deaths, 2,777 ha of inundated land, and 2,347 houses damaged. This led to a rehabilitation project for enhancing the flood-protection function of the Tsuruta Dam, which is located upstream of the Sendai River. This dam, which is 117.5 m high and of the gravity concrete type, was constructed in 1966. It is a multipurpose dam used for flood protection and power generation. By reallocating some capacity for power generation to flood protection, the flood-protection capacity of 75 million m^3 (MCM) was increased to 98 MCM. Construction work was performed to drill and install flood discharge pipes, intakes, and penstocks for power generation in the existing dam body, as shown in Figure 5.2. Dam rehabilitation was conducted using the latest temporary coffering technology to minimize the interruption of the reservoir operation of existing dams during construction, as shown in Figure 5.3.



Source: Sendai-gawa River Office, MLIT

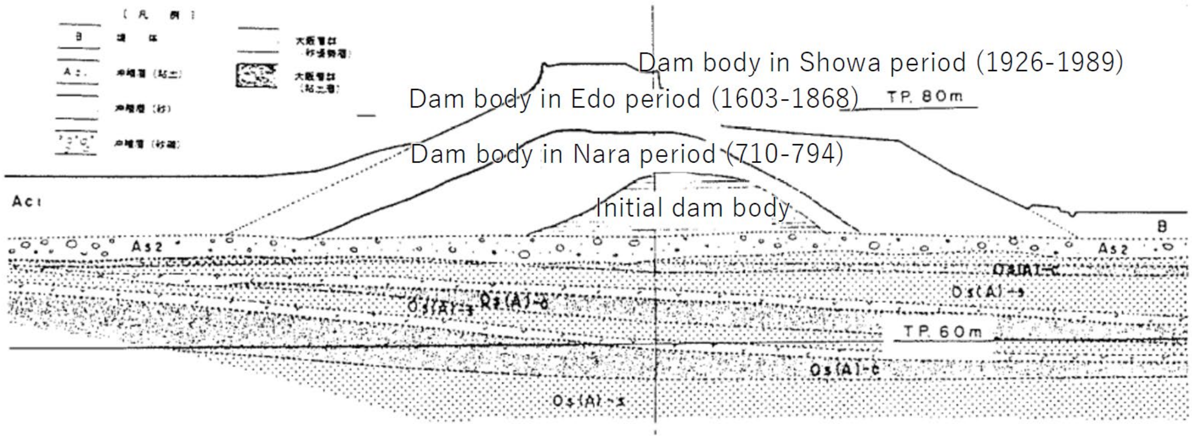
Figure 5.2 Reformulation of Reservoir Operation for the Tsuruda Dam

Note: (Upper left and center) upstream coffering, (Upper right) drilling of dam body, (Lower)before and after the works
Source: Sendai-gawa River Office, MLIT

Figure 5.3 Rehabilitation Works for the Tsuruda Dam

3) Rehabilitation of Japan's Oldest Dam (Sayama-ike)

The Sayama-ike (pond) in Osaka City was constructed for irrigation in the first half of the 7th century. It is the oldest dam reservoir in the country and is recorded in Kojiki (Records of Ancient Matters) and Nihonshoki (Chronicles of Japan). The dam has been renovated many times, e.g., by Gyoki in the Nara period, Chogen in the Kamakura period, and Katagiri Katsumoto in the Azuchi-Momoyama period. Figure 5.4 shows the cross-section of the dam body, which indicates the history of the embankment. In recent years, the number of paddy fields in downstream areas has decreased owing to urbanization, and flood damage has occurred frequently. In 1982, Typhoon No. 10 flooded the downstream Nishiyoke River, inundating more than 3,000 houses. In 2001, renovation was performed to add flood-protection functions. The pond bed was excavated approximately 3 meters down, and the embankment was raised by approximately 1.1 meters to secure a new flood-protection capacity of 1.0 MCM and a new water supply capacity of 1.8 MCM for agriculture, as shown in Figure 5.5.



Source: Sayama-ike Dam, Old Dam Talks about History of Civil Engineering, Kanamori et al, Historical Studies of Civil Engineering No. 15

Figure 5.4 History of Rehabilitation Works for Sayama-ike

Source: Website of Osaka Prefecture

Figure 5.5 Sayama-ike Before and After Rehabilitation

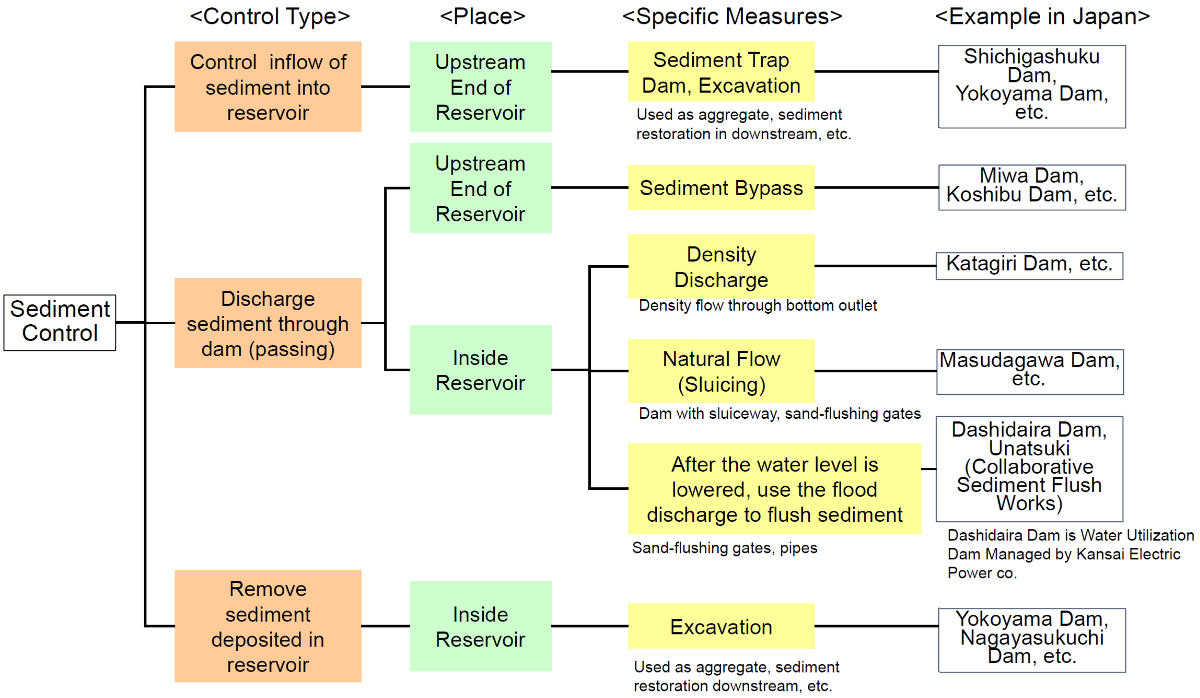
(4) Technologies for Sediment Control

The sedimentation capacity of the reservoirs is determined by estimating the sedimentation volume to be deposited over 100 years. Dams located on steep-sloped rivers with high rates of sediment production might be faster than estimated. In some cases, sedimentation reduces the reservoir capacity and degrades the functions by submerging intake facilities. Reservoir sedimentation changes the environment of the entire downstream river, including coarse-grained riverbed lowering, as well as the recession of the sea shoreline. The measures for sediment control in Japan are presented in Figure 5.6. Typical measures include the excavation and flushing of sediment by lowering the water level in the reservoir and the construction of a sand discharge bypass (Figure 5.7).

The excavated sediment materials were used by the local governments for road construction and other public works. In “to return sediment to the downstream river” (Figure 5.8), the excavated sediment materials are piled on the riverbed downstream to be transported downstream by flood flows. This can restore the natural and biological environment of the river by resolving the coarse-grained riverbed, washing, and renewing the old algae adhered to the riverbed.

(5) Enhancing Functions by Utilizing Rain Radar

The rain radar system covers almost all of Japan, with a resolution of 250 m. The delivery time interval is 1 min. Data from this system are utilized for flood forecasting, which enhances dam functions for flood protection and water supply.



Source: MLIT

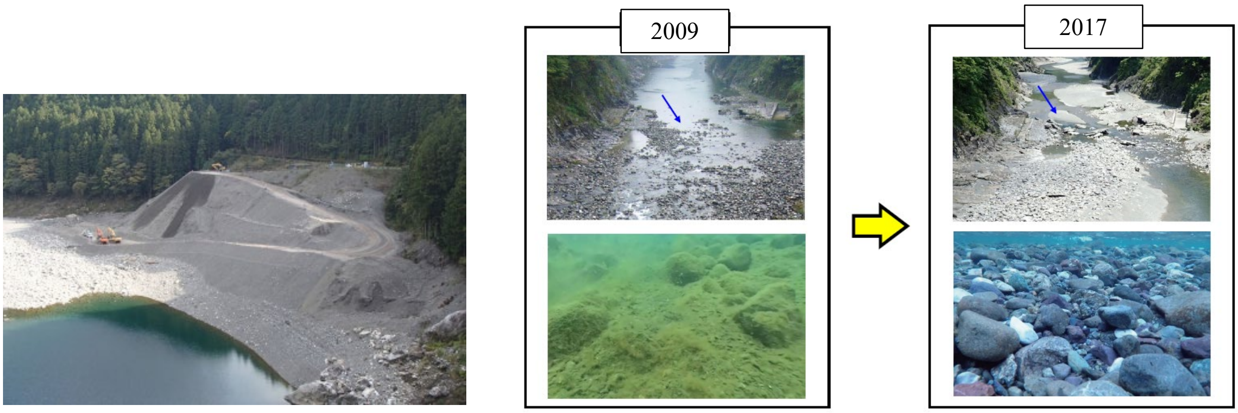
Figure 5.6 Measures for Sediment Control in Japan

Sediment bypass facility

Flushing through sediment gates

Source: Guide for Dam Sediment Control (Draft), Tenryu River Dams Integrated Management Office, Hokuriku Regional Development Bureau, MLIT

Figure 5.7 Examples of Sediment Control in Japan



Source: Nakagawa River Office

Figure 5.8 Example of an Activity for "Restoring Sediment Downstream" and the Improvement of the Riverbed Environment (Nagayasuguchi Dam)

CHAPTER 6 LESSONS LEARNED

(1) **To secure dam safety, legislation, technical guidelines, and examination system should be established.** The mechanisms of dam safety should involve thorough examination at each stage, i.e., planning, design, construction, and maintenance. It is important to conduct daily inspections and patrols, as well as periodic inspections, and not to overlook any small changes or signs of risk. The periodic and comprehensive inspections and establishment of extension plans for the service life can improve the management and reduce the lifecycle costs. Because many ponds built in the old days have structural problems, accidents should be prevented through legislation and financial support for the inspection and reinforcement of dam structures.

(2) **To secure a dam and its downstream areas during flooding, operation rules should be followed.** The operation rules prescribe gate operations and procedures for the patrol and warning methods for downstream areas. They also cover the gate operations for extraordinary floods that exceed the design flood. This is intended to prevent artificial flooding in downstream areas, even under extraordinary floods. The flood inflow should be discharged in the same amount as entering the reservoir. The inflow volume can be obtained from the flood-inflow forecast based on rain radar data. Flood forecasting is effective for introducing and deciding whether to pre-release reservoir water for increasing the flood-protection capacity before floods.

(3) **Integrated operation of multiple dams can ensure an adequate water supply.** The integrated operation of multiple reservoirs in the basin and reallocation of the reservoir capacity may enhance the reliability of the water supply and improve the river environment.

(4) **Rehabilitation works can extend lifetime and functions of dams.** Existing dams can be rehabilitated at a relatively low cost, in a short time, and with minimal burdens on nature and society. Additionally, it is possible to improve the dam functions by using the latest software and hardware technologies, e.g., flood forecasting and countermeasures for reservoir sedimentation, dam raising, and the construction of dam-discharging facilities. Some rehabilitation works can be implemented without interfering with the dam operation.

REFERENCES

Extra Table 1 Examples of Technical Standards for Surveying and Designing Dams in Japan

Standard	Contents
Cabinet Order on Structural Standards for River Management Facilities, etc. and its Ordinance for Enforcement	It establishes general technical standards required for the management of river structures such as dams, levees, and other permitted structures.
Technical Criteria for River Works and its Practical Guide	These are extensive technical standards for the investigation, planning, design, and maintenance of not only dams but also river and erosion control structures. They consist of four volumes for investigation, planning, design, and maintenance.
Construction of Multipurpose Dams	This contains technical standards for the planning, survey, design, construction, and management of multipurpose dams, which are applicable to all dams (not only multipurpose dams). It consists of chapters related to planning and administration, environment and research, design, construction, and management.
Technical Standards for Dam and Weir Structure	These are technical standards mainly for steel structures of gates and intake facilities of dams. They describe the hydraulic design, structural design, and inspection and maintenance procedures.
Detailed Technologies for Concrete Dams/Fill Dams	These are guidelines that describe the structures of concrete dams and earthfill dams in detail with examples.
Guidelines for Grout	These are guidelines for foundation treatment with curtains and consolidation grouting in dam design.
Technical Data for Design, Construction and Quality Control of CSG (Cemented Sand and Gravel) Trapezoidal Dam	This is a technical document on the original trapezoidal CSG dam published in Japan in 2012. The trapezoidal CSG dam is not yet listed in the structural ordinance for river management facilities; i.e., it is a non-legal dam type and requires special approval from the MLIT for its construction. (English version available)
Guidelines for Verification of Seismic Safety for Dams against Severe Earthquakes	These are guidelines on the requirements for seismic performance against Level 2 earthquakes (probable maximum earthquake at the site) and their verification method, which were published after the Hanshin-Awaji Great Earthquake in January 1995.

Source: Project Research Team

Extra Table 2 Standards for Dam Operation and Maintenance (Inspection) (1/2)

Structures		Inspection	Frequency	Timing and Method
Dam Body and Spillway		Normal inspection	Daily	Confirmation of changes in appearance by visual inspection, etc.
		Periodic inspection	Once/year	Confirmation of scouring, etc. by visual inspection, etc.
Measurement Instrument for Dam		Periodic inspection	Once/month	Check for abnormalities by operation check
Discharge Facilities	**River Outlet Facilities**	Periodic inspection	Three times/year	Check for abnormalities by operation test for maintenance before, during, and after flood season
		Inspection before discharge	Before each release	Check for abnormalities by visual inspection
		Inspection after discharge	After each discharge	Check for abnormalities by visual inspection
	Intake Facilities	Inspection during long-term closure	Once/year	Check for abnormalities by visual inspection
		Inspection after flood	After each flood	Check for abnormalities by visual inspection
Emergency Generators		Normal inspection	Once/month	Check for operation by controlled operation
		Inspection before flood	At each flood	Check for abnormalities by visual inspection, etc.
		Periodic inspection	Following safety regulations	Detailed inspection with controlled operation in accordance with safety regulations
Control Facilities for Dam Management		Normal inspection	Daily	Confirmation of display contents, etc. by visual check
		Periodic inspection	Once/year	Operation check by distant operation, etc.
Observation Facilities	**Observation Stations**	Periodic inspection	Once/year	Detailed inspection by test measurement
	Management Offices	Normal inspection	Daily	Visual inspection for display and records
	Observation Equipment	Periodic inspection	Once/year	Detailed inspection by test measurement
Discharge Release Warning System	**Management Office**	Normal inspection	Daily	Check for abnormalities by visual inspection
		Periodic inspection	Twice/year	Detailed inspection by test measurement
	Warning Stations	Periodic inspection	Twice/year	Check for abnormalities of power supply, etc. by test operation
		Inspection before flood	At each flood	Check for abnormalities of power supply, etc. by test operation

Source: Technical Criteria for River Works and its Practical Guide for Maintenance (Dam), MLIT

Extra Table 2 Standards for Dam Operation and Maintenance (Inspection) (2/2)

Structures		Inspection	Frequency	Timing and Method
Power Equipment		Normal inspection	Daily	Check for abnormalities by visual inspection, etc.
		Periodic inspection	Following safety regulations	Detailed inspection based on safety regulations
Telecommunication Equipment		Normal inspection	Daily	Check for abnormalities by call test, visual inspection, etc.
		Periodic inspection	Once/year	Detailed inspection including measurement of each part
Vehicles		Normal inspection	Daily	Check for abnormalities by inspection
Patrol Boats, Work Boats		Periodic inspection	Once/month	Check for abnormalities through controlled operation, etc.
Trash Booms		Periodic inspection	Once/year	Check for abnormalities by visual inspection, etc.
Mooring Facilities		Periodic inspection	Once/year	Check for abnormalities of equipment by test operation
Drainage Facilities	**Drainage Facilities**	Periodic inspection	Once/month	Check for abnormalities by visual inspection
	Abnormal Alarm Facilities	Periodic inspection	Once/two weeks	Check for abnormalities of facilities by test operation
Signs, Handrails, Lightings		Periodic inspection	Once/month	Check for abnormalities of facilities by hammer sounding, lighting, etc.
Tools for Survey and Measurement		Normal inspection	On each occasion	Detailed inspection of the tools
All Dam Structures		Occasional inspection	On each occasion	Check for abnormalities of structures after earthquakes and floods exceeding a certain scale

Source: Technical Criteria for River Works and its Practical Guide for Maintenance (Dam), MLIT

Extra Table 3 Standards for Dam Operation and Maintenance (Monitoring)

Measure-ment Item	Stage	Concrete Dams					Fill Dams	
		Gravity & Hollow Gravity Types			Arch Type		Homogeneous Type	Zoned & Facing Types
		<50 m high	50–100 m high	>100 m high	<30 m high	>30 m high		
Seepage	1	Daily						
	2	Once/week						
	3	Once/month						
Deform-ation	1	—	Once/ week	Daily	Once/ week	Daily	Once/week	
	2	—	Once/ month	Once/ week	Once/ month	Once/ week	Once/month	
	3	—	Once/ 3 months	Once/ month	Once/ 3 months	Once/ month	Once/3 months	
Uplift	1	Once/week			—	Once/ week	—	
	2	Once/month			—	Once/ month	—	
	3	Once/3 months			—	Once/ 3 months	—	
Seepage Line	1	—					Once/ week	—
	2	—					Once/ month	—
	3	—					Once/ 3 months	—
Seismic Motion		When an earthquake occurs, measurements must be performed at the dam crest, the dam foundation/bottom, and other locations.						

1st stage: Period between commencement of initial impounding and more than two months after the reservoir water level has reached its full supply level

2nd stage: Period between the end of the first stage and the time when the dam behavior is judged to remain stable, and measurement values respond properly to the reservoir water level (for dams with heights of ≥100 m and dams with special forms, the second stage can last more than three years)

3rd stage: After the second stage

Source: Technical Criteria for River Works and its Practical Guide for Maintenance (Dam), MLIT

Extra Table 4 Standards for Dam Operation and Maintenance (Patrol)

Structures		Frequency	Confirmation Items upon Patrol
Dam Body, Spillway, etc.		Once/week	Abnormalities of appearance, e.g., deterioration, abrasion, cracking, and opening of joints
Discharge Facilities		Once/week	Abnormalities of the facilities
Inspection Roads, Slopes around the Reservoir		Once/week	Abnormalities of the structures and reservoir
		After flood	Abnormalities of the structures and reservoir
Observation Facilities	Observation Stations	Once/month	Abnormalities of the facilities
Discharge Warning Systems	Warning Station	Once/month	Abnormalities of the facilities
	Notice Boards for Warning	Twice/year	Quantity, paint condition, damage to the facilities
Trash Booms		Once/month	Abnormalities of the facilities
Mooring Facilities		Once/month	Abnormalities of the facilities
Signs, Handrails, Lightings		Once/week	Abnormalities of the facilities

Source: Technical Criteria for River Works and its Practical Guide for Maintenance (Dam), MLIT

Extra Table 5 Types of Water Supply Dam and Necessary Actions to Release Flood Water

Type	Characteristics of Water Supply Dam	Necessary Actions
Type 1	The dam causes by its construction to increase in the flood flow velocity and results in greatly increasing the flood discharge in the downstream river of the dam compared with that in normal time. The dam reservoir has a space to control the increased volume of the flood.	The operation to release discharge equivalent to flood inflow into large-scale water supply dam leads to flood damages with shorter flood concentration time. The reservoir needs to store a part of the flood inflow.
Type 2	The dam of which the flood water level rises in the river near the upstream end of the reservoir due to sedimentation in the reservoir and its upstream river, or the area of land owned by the dam operator covers only the reservoir area without area allowance may have flood damage in the upstream river due to such rise of the water level. The dam needs to lower the reservoir water level to its preliminary release level in the summer season to provide a space for flood protection.	Advance release of reservoir water is required.
Type 3	The dam has spillways whose discharge capacity is large compared with the reservoir storage volume. Spillway gates operation is rather complicated. Such dams lower the reservoir water level in the summer season.	Flood protection by advance releasing the reservoir water is required to take appropriate actions when rapid rise of the reservoir water level is observed during the flood.
Type 4	There is no effect on the flood management.	None.

Source: Website of Japan Dam Foundation