Dams in Japan
Overview 2022

Kanto Regional Development Bureau（https://www.ktr.mlit.go.jp/）

JCOLD

JAPAN COMMISSION ON LARGE DAMS

Welcome for your Virtual Visit to Dams in Japan

Source of the base map : Geospatial Information Authority of Japan (GSI)
（https://maps.gsi.go.jp/#5/37.932645/138.251953/&base=english&ls=english&disp=1&vs=c1g1j0h0k0l0u0t0z0r0s0m0f1）
Japan And Its Surroundings (Zoom Level 5-8), 1:1,000,000 INTERNATIONAL MAP (Zoom Level 9-11)
The bathymetric contours are derived from those contained within the GEBCO Digital Atlas, published by the BODC on behalf of IOC and IHO (2003) (https://www.gebco.net)
海上保安庁許可第292502号（水路業務法第25条に基づく類似刊行物）
Shoreline data is derived from: United States. National Imagery and Mapping Agency. "Vector Map Level 0 (VMAP0)." Bethesda, MD: Denver, CO: The Agency; USGS Information Services, 1997
Location of the dams on the map is basically derived from MLIT (https://nlftp.mlit.go.jp/ksj/gml/datalist/KsjTmplt-W01.html). Modification and addition of data are conducted by JCOLD and Campo Salado. QR codes on this map are added by JCOLD. Web design and programs are powered by Campo Salado.

CONTENTS

Japan Commission on Large Dams
- History ····· 1
- Operation ····· 1
- Organization ····· 1
- Membership ····· 1
- Publication ····· 2
- Annual lecture meeting ····· 2
- Contribution to ICOLD ····· 2

Dams in Japan
- Development of dams ····· 3
- Major dams in Japan ····· 4
- Hydroelectric power plants in Japan ····· 5
- Dams completed in 2017 – 2020 in Japan ····· 6
  - Asakawa Dam ····· 7
  - Arase Dam ····· 9
  - Apporo Dam ····· 11
  - Sanru Dam ····· 13
  - Okutainai Dam ····· 15
  - Gokayama Dam ····· 17
  - Yokozegawa Dam ····· 19

Japan Incorporates Climate Change Effects into River and Dam Planning ··· 21

Introduction to Dam Technologies in Japan
- Trapezoidal CSG dam ····· 24
- Sediment bypass tunnel (SBT) ····· 24
- Preservation measures of dam reservoirs ····· 24
- Advancement of flood control operation ····· 25
- Dam Upgrading Vision ····· 26
- Utilization of ICT in construction of dam ····· 28

Papers in ICOLD & Other Technical Publications
- Theme 1 Safety management and rehabilitation of existing dams ····· 29
- Theme 2 New construction technology ····· 30
- Theme 3 Spillway and outlet works ····· 33
- Theme 4 Sophisticated approach for dam operation ····· 34
- Theme 5 Earthquakes and dams ····· 37
- Theme 6 Reservoir sedimentation and sustainable development ····· 40
- Theme 7 Water quality, environmental conservation and social consideration ··· 42

Japan Commission on Large Dams

History

In 1931, three years after the International Commission on Large Dams (ICOLD) was established, Japan joined ICOLD as the Japan National Committee on Large Dams. In 1944, Japan withdrew from ICOLD during the World War II, then rejoined in March 1953. On September 13, 1962, the Japan Commission on Large Dams (JCOLD) was established, and in January 2012, it became a General Incorporated Association.

Operation

JCOLD is involved in operations such as surveys, research, international technology exchanges, etc. concerning large dams and related facilities (below, “large dams”), in order to improve the design, construction, maintenance, and operation of large dams and to contribute to the development of the Japanese economy. Responsibilities include:

(1) Collection of information, surveying, and research concerning large dams

(2) Exchange of technology and guidance concerning large dams

(3) Participation in ICOLD, assistance to its activities, and international exchange of technology concerning large dams

(4) Dissemination of and spreading awareness of the achievements of surveys and research concerning large dams

(5) Other activities necessary to achieve the goals of JCOLD

In recent years, JCOLD has actively conducted a program of surveys and research on methods of harmonizing dam development with the environment and on ways to mitigate their environmental impacts to achieve the sustainable development of dams.

Organization

Under the leadership of the Chairman, there is a Planning Committee, Technical Committee, and Administrative Office. These committees undertake work in their respective areas.

Membership

The members of JCOLD are incorporated bodies involved in dam construction. They include government bodies concerned with dam construction, electric power companies, survey and research bodies, academic associations, industrial associations, construction consultants, construction companies, and manufacturers (77 members as of January 2022).

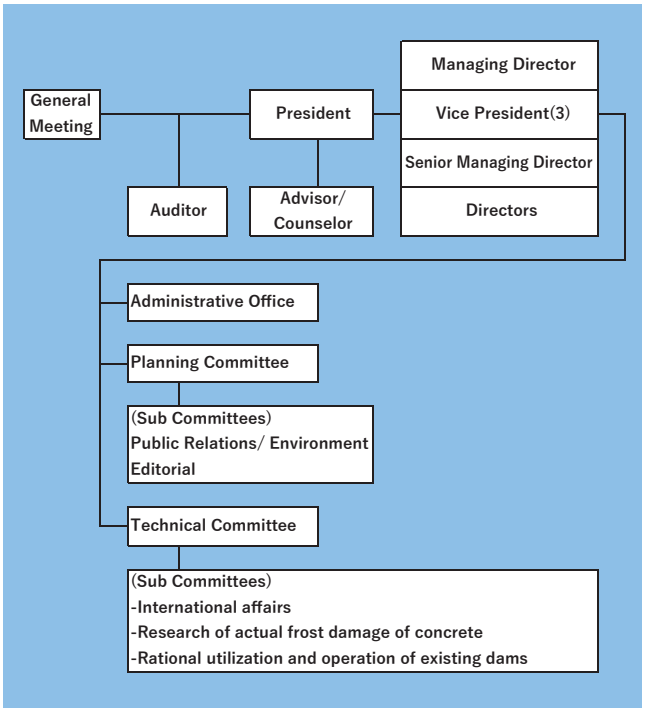


Figure-1 Organization Chart of JCOLD

Publication

JCOLD publishes its Journal, “Large Dams”, four times a year (January, April, July, October), which is distributed to members and subscribers. At ICOLD Congresses held once every three years, JCOLD publishes Dams in Japan in English, which introduces the state of dams and dam technologies in Japan, and distributes it to Congress participants (1997, 2000, 2003, 2006, 2009, 2012, 2015 and 2018).

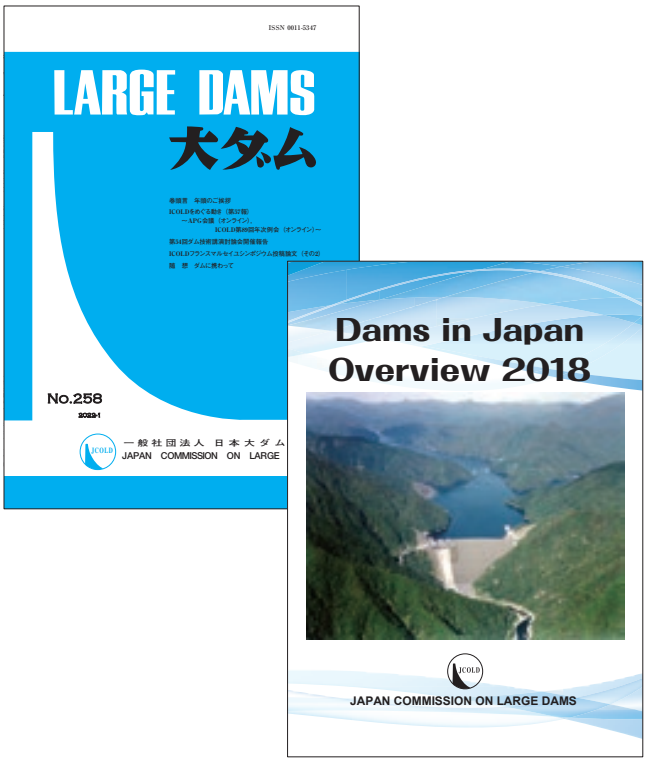


Figure-2 Publicaitons of JCOLD

Annual lecture meeting

Dam Technology Lectures and Discussion Meetings

(Held jointly with the Japan Association of Dam & Weir Equipment Engineering)

At the meeting, the results of surveys and research by the various JCOLD technical sub committees, papers presented to the ICOLD Congress, and results of activities by the Japan Association of Dam & Weir Equipment Engineering are reported widely to people concerned with dams. In addition, the lecturers and participants in the Technology Lecture and Discussion Meeting discuss the reports in order to improve the technologies, maintenance, and operation of dams.

Figure-3 Dam Technology Lecture and Discussion Meeting

Study Tour

To increase mutual awareness among engineers, including JCOLD members and others concerned with dams, on improving dam and hydroelectric power plant technologies and the construction of dams, JCOLD holds tours of dams and hydroelectric power plants still under construction with the cooperation of various organizations.

Figure-4 Tour of the site of the Shin katsurazawa Dam(2019)

Contribution to ICOLD

JCOLD submitted 389 ICOLD Congress papers until now. In addition, Many Japanese engineers participate in ICOLD Annual Meeting and Congress.

JCOLD participates in 22 technical committees at Annual Meeting and exchanges technical information.

JCOLD held Annual Meeting in 1960(Tokyo) and 1984(Tokyo), and Congress in 2012(Kyoto).

Susumu NAGATA(1957-1960), Masayoshi NOSE (1966-1969), Shigeru ICHIURA (1982-1985), Kyohei BABA (2001-2004), Norihisa MATSUMOTO(2007-2010) and Tadahiko SAKAMOTO(2011-2014) served as a vice president of ICOLD.

Table-1 Number of participants from Japan

Year	Host country (Host city)	Number of participants from Japan
1998	India (New Delhi)	43
1999	Turkey (Anatolia)	56
2000	China (Beijing)	87
2001	Germany (Dresden)	60
2002	Brazil (Iguazu)	47
2003	Canada (Montreal)	49
2004	South Korea (Seoul)	143
2005	Iran (Tehran)	77
2006	Spain (Barcelona)	107
2007	Russia (St. Petersburg)	79
2008	Bulgaria (Sofia)	63
2009	Brazil (Brasilia)	46
2010	Vietnam (Hanoi)	75
2011	Switzerland (Lucerne)	70
2012	Japan (Kyoto)	398
2013	USA (Seattle)	73
2014	Indonesia (Bali)	79
2015	Norway (Stavanger)	80
2016	South Africa (Johannesburg)	58
2017	Czech Republic (Prague)	84
2018	Austria (Vienna)	91
2019	Canada (Ottawa)	85
2021	India (New Delhi)	19
2021	France (Marseille)	10

Table-2 Number of submitted papers

Year	No.	Host country (Host city)	Number of submitted papers
1933	1	Sweden (Stockholm)	3
1936	2	USA (Washington)	5
1955	5	France (Paris)	4
1958	6	USA (New York)	13
1961	7	Italy (Rome)	8
1964	8	United Kingdom (Edinburg)	13
1967	9	Turkey (Istanbul)	11
1970	10	Canada (Montreal)	8
1973	11	Spain (Madrid)	12
1976	12	Mexico (Mexico)	9
1979	13	India (New Delhi)	11
1982	14	Brazil (Rio de Janeiro)	12
1985	15	Switzerland (Lausanne)	17
1988	16	United States (San Francisco)	22
1991	17	Austria (Vienna)	29
1994	18	South Africa (Durban)	25
1997	19	Italy (Florence)	28
2000	20	China (Beijing)	16
2003	21	Canada (Montreal)	20
2006	22	Spain (Barcelona)	23
2009	23	Brazil (Brasilia)	15
2012	24	Japan (Kyoto)	37
2015	25	Norway (Stavanger)	16
2018	26	Austria (Vienna)	20
2022	27	France (Marseille)	12

Dams in Japan

Development of dams

In Japan, the major purpose of dams was irrigation from ancient times to the end of the feudal period in the mid nineteenth century. The Sayama-ike irrigation pond (Osaka Prefecture), which is considered to be Japan's oldest dam, was completed in 616, and is recorded in the official historic documents.

As Japan was modernized and urbanized after the Meiji Revolution (1867), Japan started to build dams with modern technology, to meet the increased demand for water and electric power. In 1900, the Nunobikigohonmatsu Dam (Hyogo Prefecture) was completed as water supply dam. As for hydropower, the Chitose No.1 Dam (Hokkaido) was first completed in 1910. Later, multi-purpose dams with flood control capacity were constructed, with the first, the Kodo Dam (Yamaguchi Prefecture), completed in 1940.

To make more efficient use of water resources and control of flood, comprehensive projects are promoted under the concept of integrated development of river systems. Also, in recent years, redevelopment projects, such as raising the height of dams, excavating reservoirs, and upgrading discharge facilities, are being carried out more and more.

Figure-5 Nunobikigohonmatsu Dam

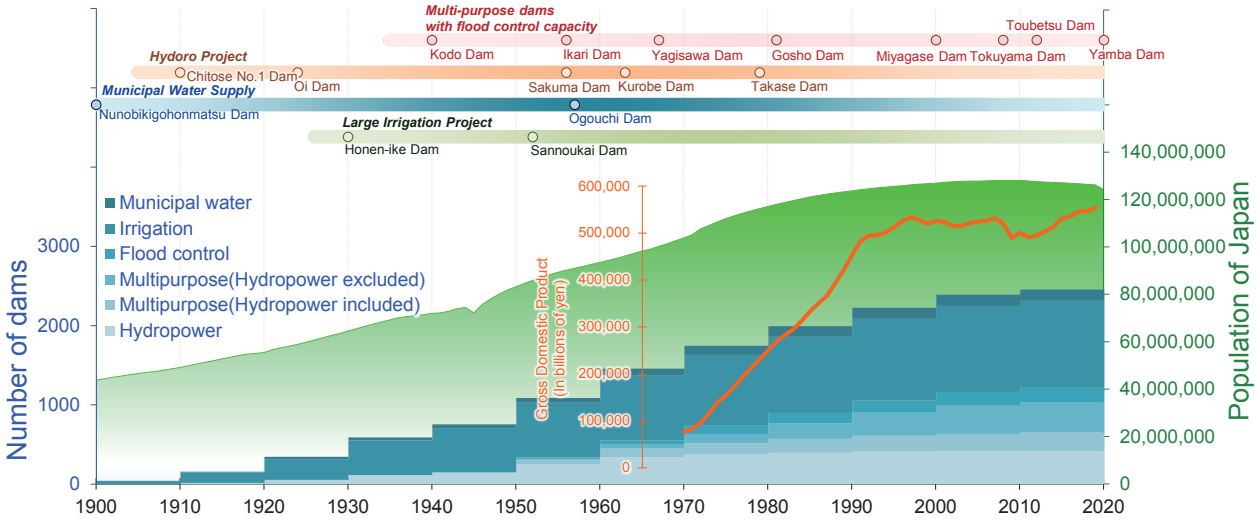


Figure-6 Development of Dams, Economy of Japan and Population

Major dams in Japan

There are many dams over 100 meters high in Japan, though, their reservoir capacities are smaller than those of other dams around the world, reflecting the geographical features of Japan (narrow islands and steep terrain).

Table-3 Ranking of dams by height in Japan

	Dam name	Type	Height (m)
1	Kurobe Dam	Arch	186
2	Takase Dam	Rockfill	176
3	Tokuyama Dam	Rockfill	161
4	Naramata Dam	Rockfill	158
5	Okutadami Dam	Gravity	157
6	Miyagase Dam	Gravity	156
6	Urayama Dam	Gravity	156
6	Nukui Dam	Arch	156
9	Sakuma Dam	Gravity	155.5
10	Nagawado Dam	Arch	155

Table-4 Ranking of dams by reservoir capacity in Japan

	Dam name	Reservoir capacity (million m^3)
1	Tokuyama Dam	660
2	Okutadami Dam	601
3	Tagokura Dam	494
4	Yubari Shuparo Dam	427
5	Miboro Dam	370
6	Kuzuryu Dam	353
7	Sakuma Dam	343
8	Ikehara Dam	338
9	Sameura Dam	316
10	Hitotsuse Dam	261

Figure-7 Naramata Dam

Figure-8 Miyagase Dam

Hydroelectric power plants in Japan

The output of hydroelectric power plants in Japan accounts for about 17% of all electric power sources, and pumped storage hydroelectric power occupies top 10s of the electric power output rankings.

Table-5 Electric power output ranking of Conventional hydropower plants

	Hydroelectric power plant	Electric power output (MW)	Dam name
1	Okutadami	560	Okutadami Dam
2	Tagokura	400	Tagokura Dam
3	Sakuma	350	Sakuma Dam
4	Kurobegawa 4	335	Kurobe Dam
5	Arimine 1	265	Arimine Dam
6	Tedorigawa 1	250	Tedorigawa Dam
7	Miboro	215	Miboro Dam
8	Ojiya 2	206	Yamamoto 2
9	Otori	182	Otori dam
10	Hitotsuse	180	Hitotsuse Dam

Table-6 Electric power output ranking of Pumped Storage hydropower plants

	Hydroelectric power plant	Electric power output (MW)	Dam name (upper reservoir / lower reservoir)
1	Okutataragi	1,932	Kurogawa Dam / Tataragi Dam
2	Okukiyotsu	1,600	Kassa Dam / Futai Dam
3	Okumino	1,500	Kaore Dam / Kamiosu Dam
4	Shintakasegawa	1,280	Takase Dam / Nanakura Dam
4	Okouchi	1,280	Ota Dam / Hase Dam
6	Okuyoshino	1,206	Seto Dam / Asahi Dam
7	Tambara	1,200	Tambara Dam / Fujiwara Dam
7	Matanogawa	1,200	Doyo Dam / Matanogawa Dam
7	Omarugawa	1,200	Ouseuchi Dam / Ishikawauchi Dam
7	Kazunogawa	1,200	Kamihikawa Dam/ Kazunogawa Dam

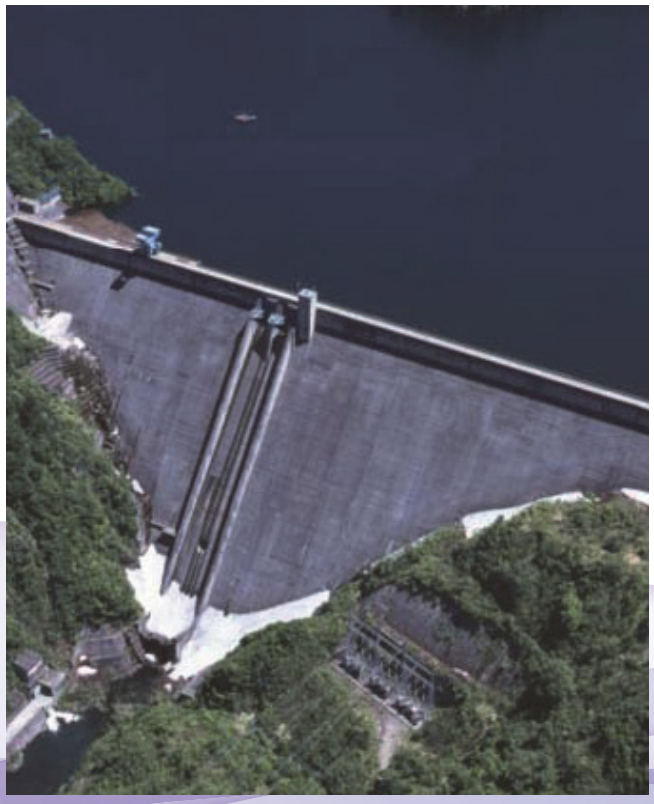


Figure-9 Okutadami Dam

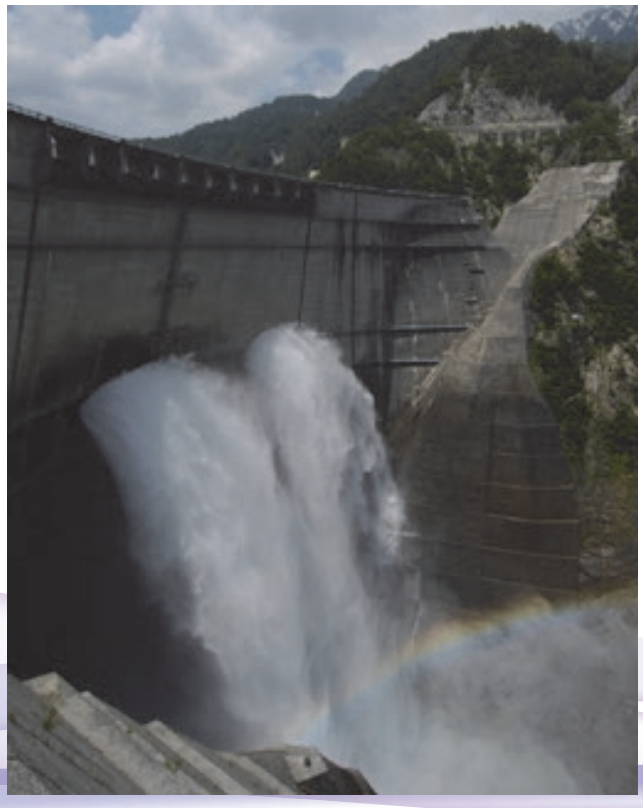


Figure-10 Kurobe Dam

Dams completed in 2017 - 2020 in Japan

Dams completed in 2017-2020 in Japan are counted in 12 dams. The features are summarized below.

No.	Dam name	Location	Dam					Owner	Com-pleted
			Pur-pose	Type	Height (m)	Length of crest (m)	Reservoir capacity (10^3 m^3)		
1	Asakawa	Nagano	C	PG	53.0	165	1,100	Nagano Pref.	2017
2	Arase	Kagoshima	I	ER	65.6	407.5	2,580	Kyushu Regional Agricultural Administration Office, MAFF*[1]	2017
3	Apporo	Hokkaido	CSI	CSG	47.2	516	47,400	Hokkaido Pref.	2018
4	Kanaji	Hyogo	C	PG	62.3	184	4,700	Hyogo Pref.	2018
5	Sanru	Hokkaido	CSH	CSG	46.0	350	57,200	Hokkaido Development Bureau, MLIT*[2]	2019
6	Kochigawa	Fukui	CSI	PG	77.5	202.3	8,000	Fukui Pref.	2019
7	Okutainai	Niigata	CSH	PG	82.0	198.9	10,000	Niigata Pref.	2019
8	Ichinoshinden	Niigata	I	ER	26.7	199	1,690	Hokuriku Regional Agricultural Administration Office, MAFF*[1]	2019
9	Gokayama	Fukuoka	CS	PG	102.5	556	40,200	Fukuoka Pref.	2020
10	Yokozegawa	Kochi	CH	PG	72.1	188.5	7,300	Shikoku Regional Development Bureau, MLIT*[2]	2020
11	Oso	Kumamoto	I	ER	69.9	262.1	4,300	Kyushu Regional Agricultural Administration Office, MAFF*[1]	2020
12	Yamba	Gunma	CSH	PG	116.0	290.8	107,500	Kanto Regional Development Bureau, MLIT*[2]	2020

Purpose: C - flood control, S - water supply, I - Irrigation, H - hydroelectricity

Type: PG - gravity in masonry or concrete, ER - rock fill, CSG - CSG

*[1] Ministry of Agriculture, Forestry and Fisheries

*[2] Ministry of Land, Infrastructure, Transport and Tourism

Several dams are illustrated in the following pages. The key to abbreviations is given below.

DFWL - Design Flood Water Level HWL - High Water Level
SWL - Surcharge Water Level NWL - Normal Water Level
LWL - Low Water Level

Asakawa Dam

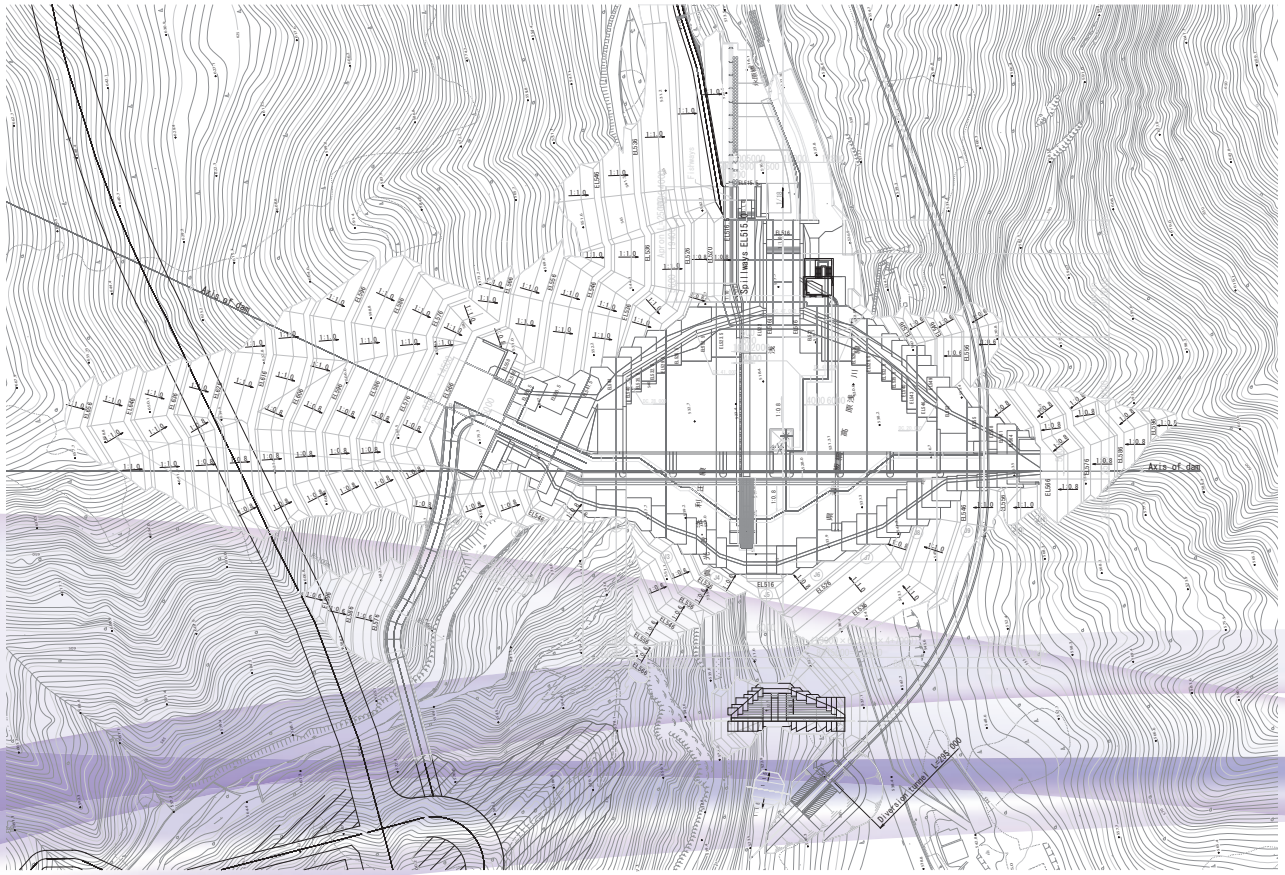


Figure-1 Plan

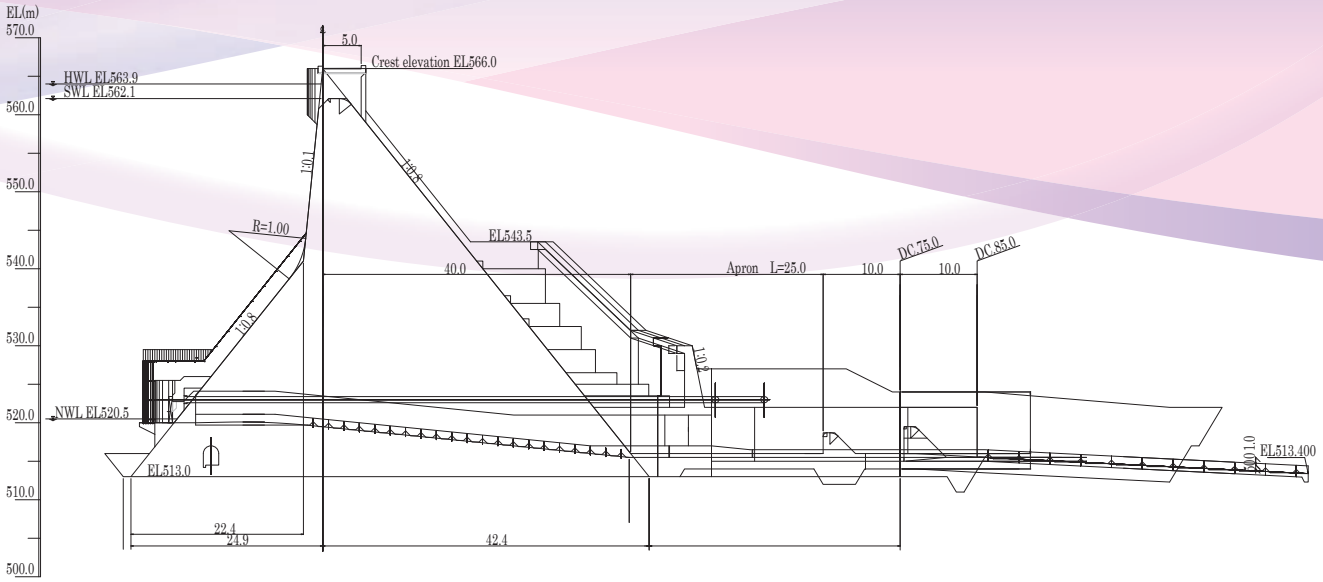


Figure-2 Typical section

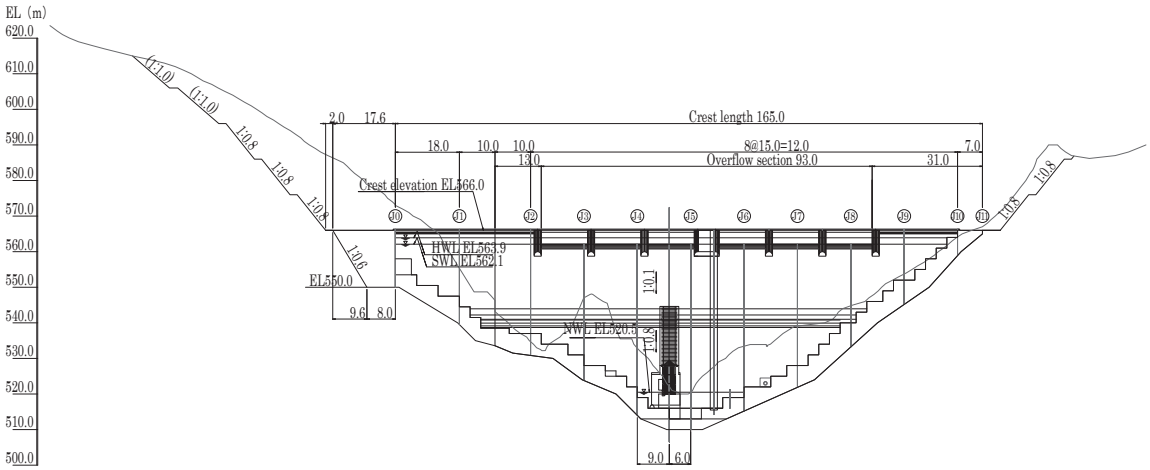


Figure-3 Upstream elevation

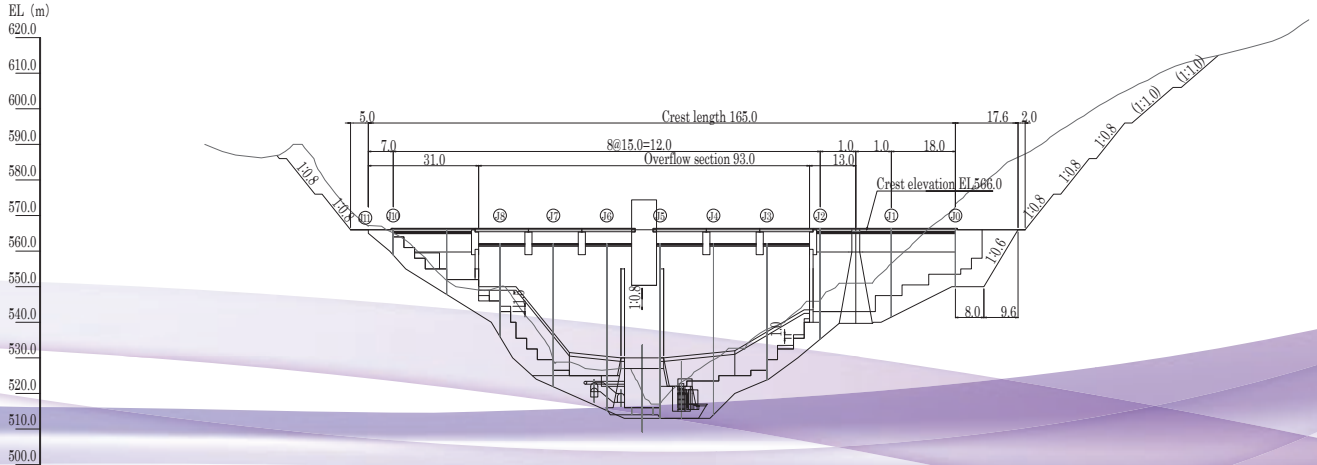


Figure-4 Downstream elevation

Arase Dam

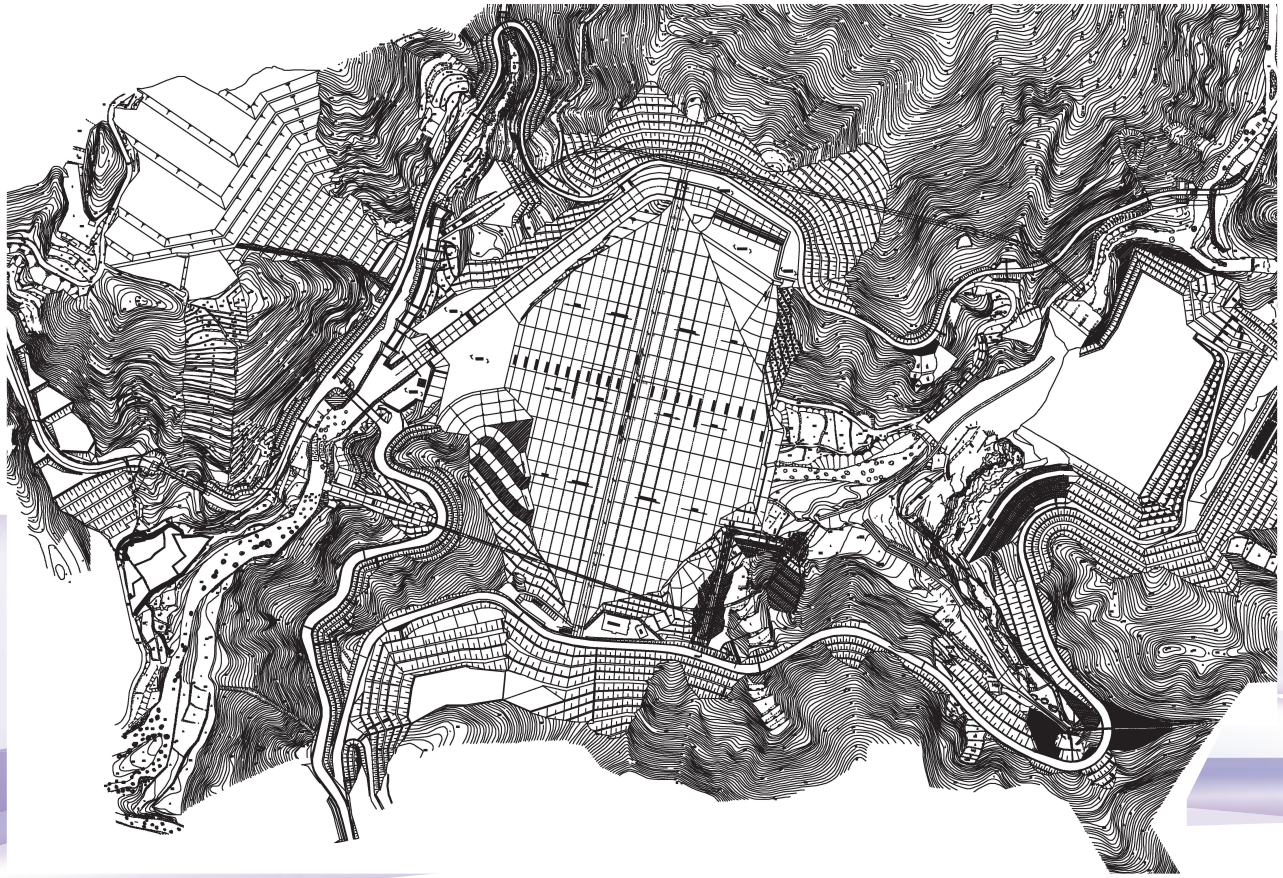


Figure-1 Plan

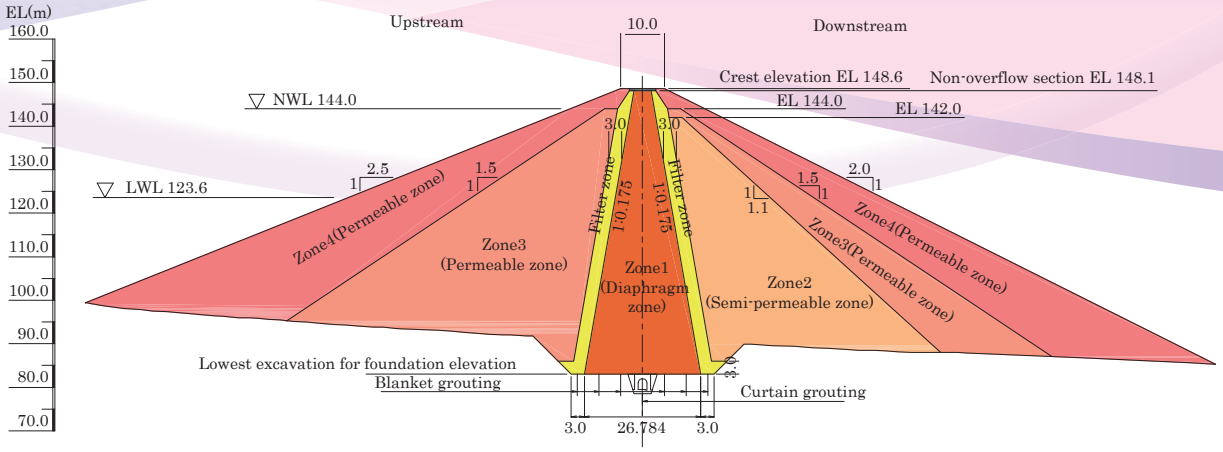


Figure-2 Typical section

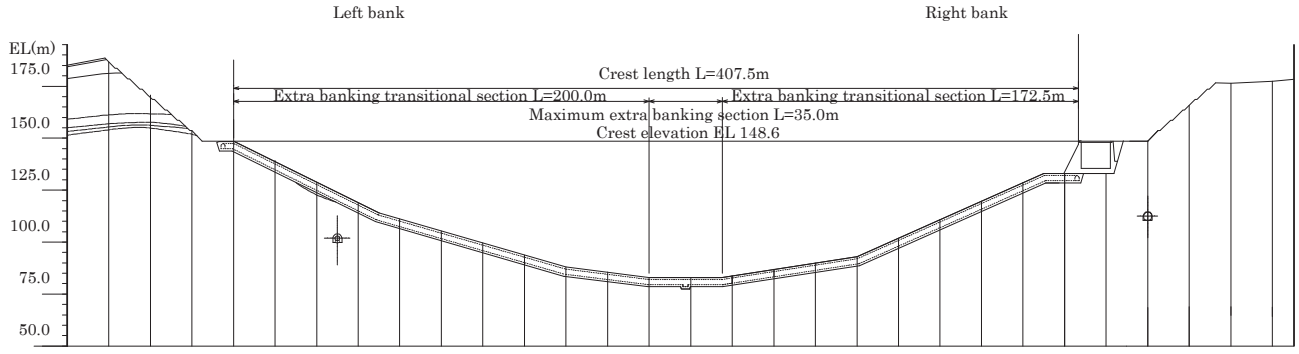


Figure-3 Longitudinal profile

Apporo Dam

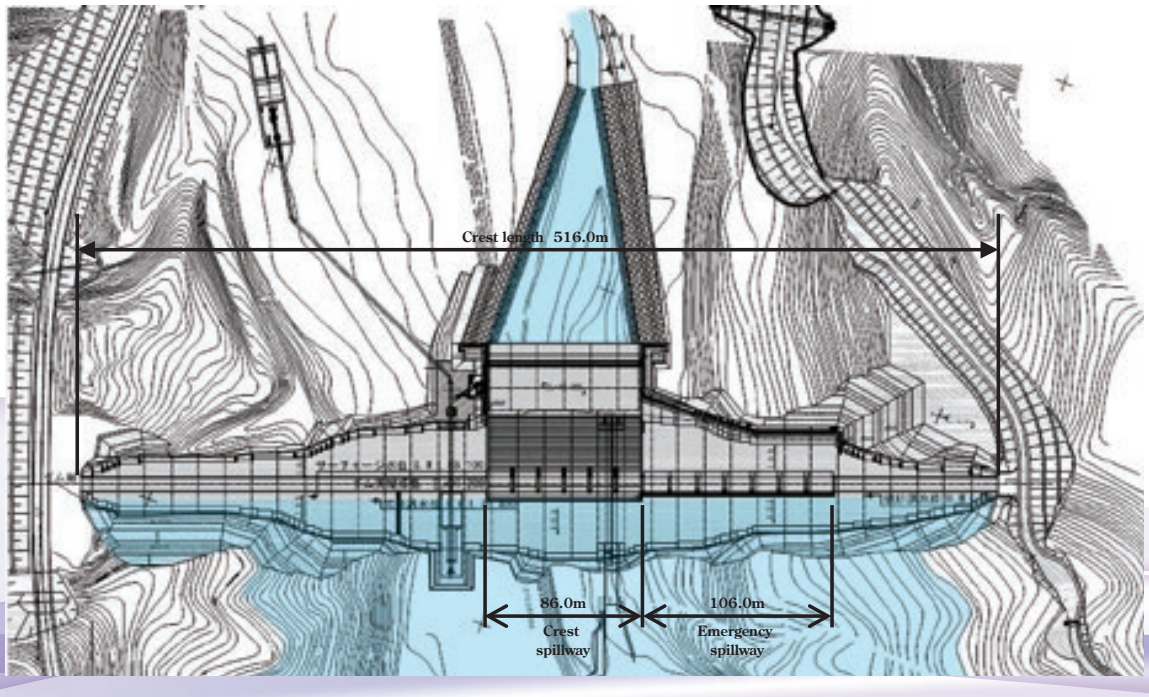


Figure-1 Plan

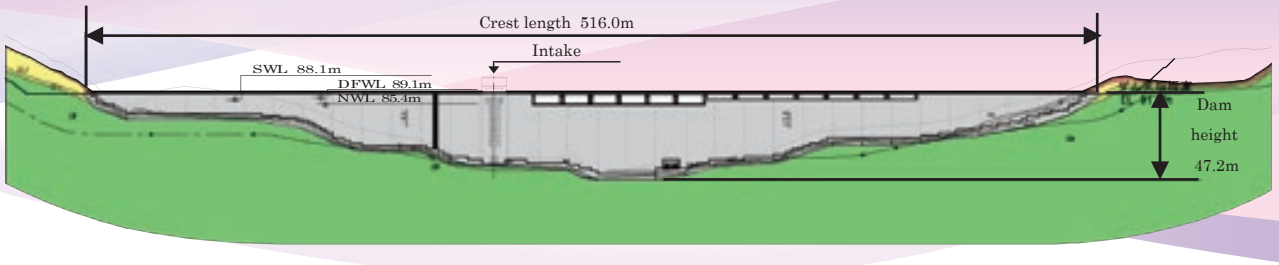


Figure-2 Upstream elevetion

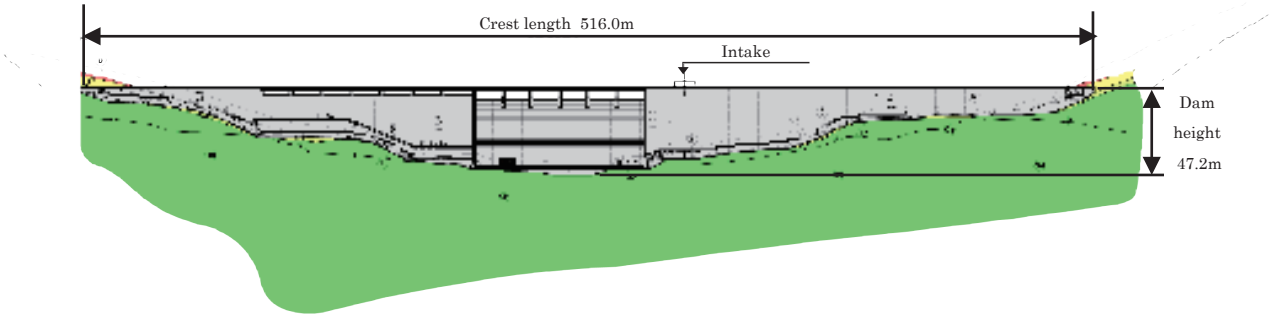


Figure-3 Downstream elevetion

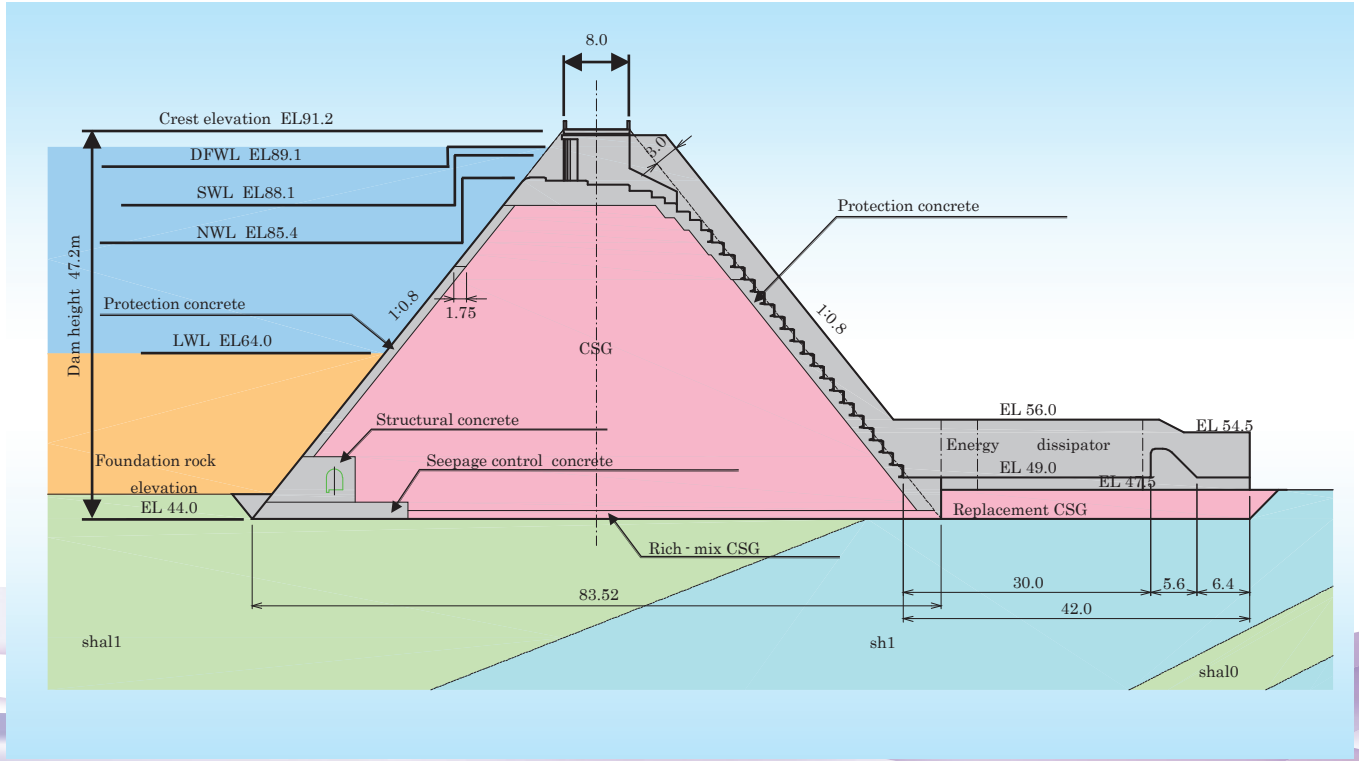


Figure-4 Typical section

Sanru Dam

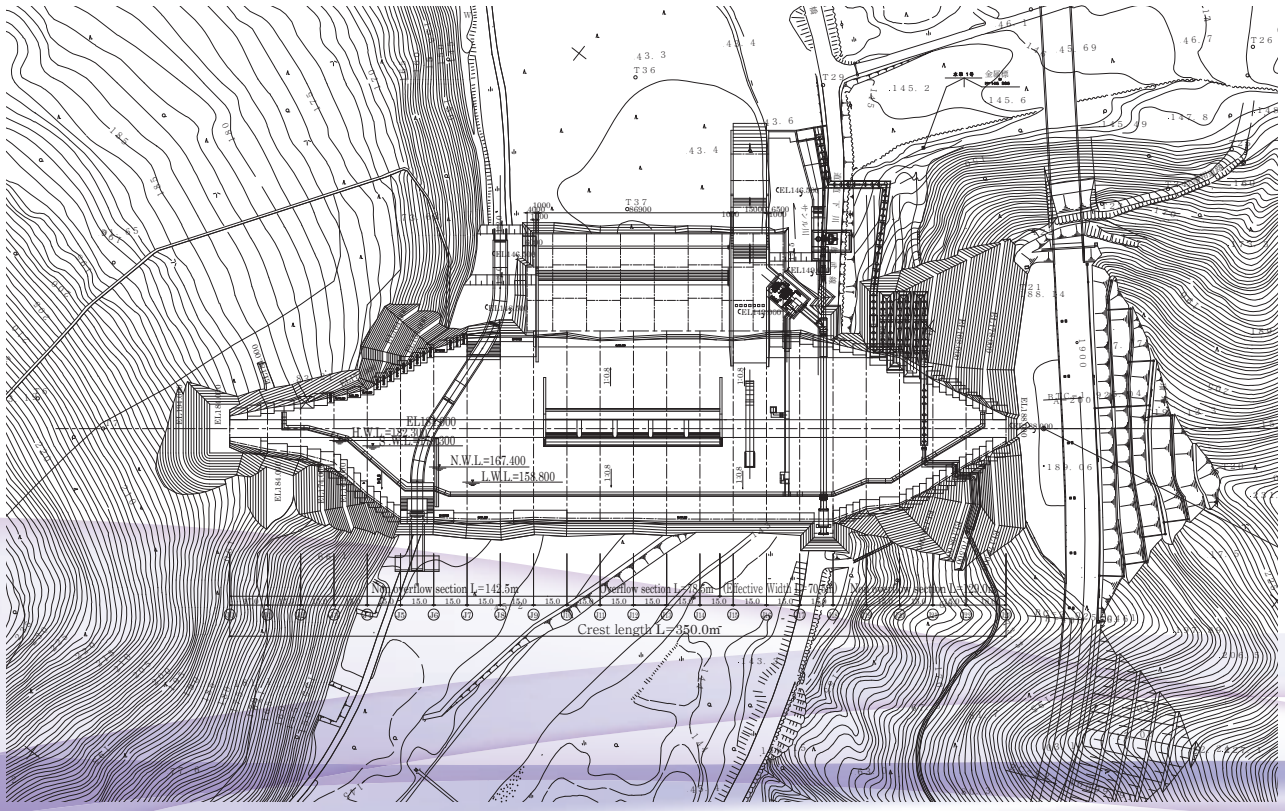


Figure-1 Plan

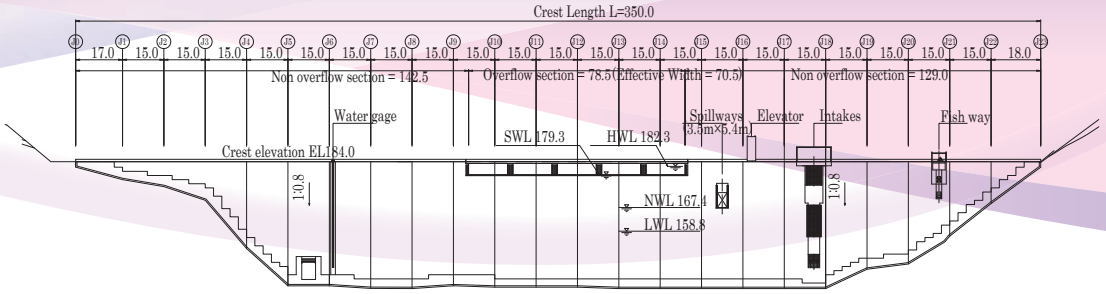


Figure-2 Upstream elevetion

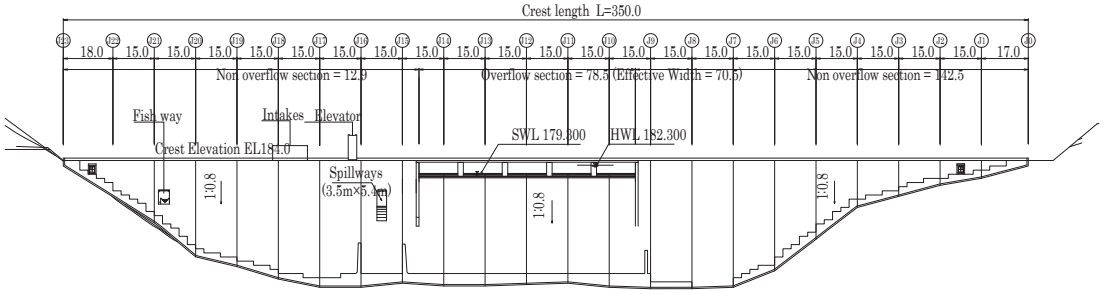


Figure-3 Downstream elevetion

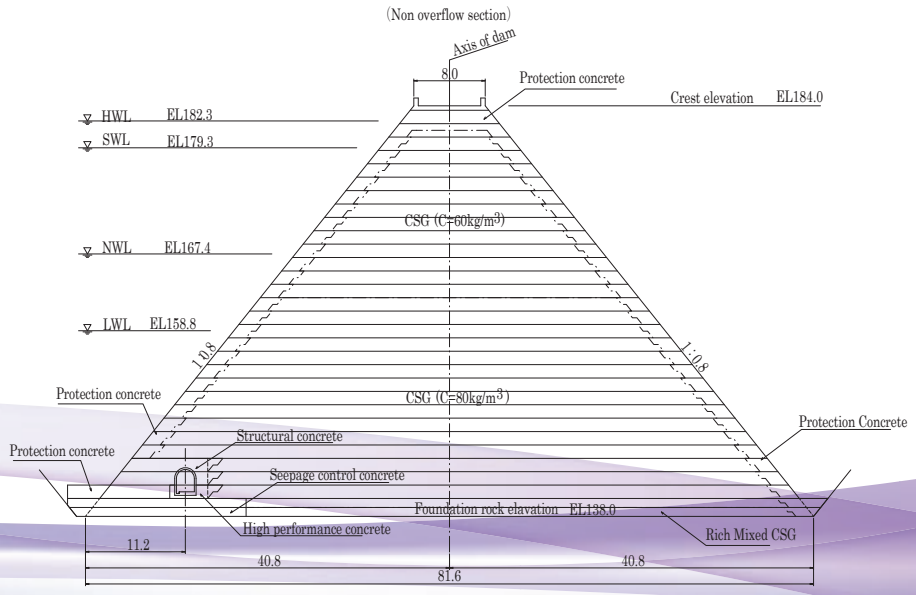


Figure-4 Typical section

Okutainai Dam

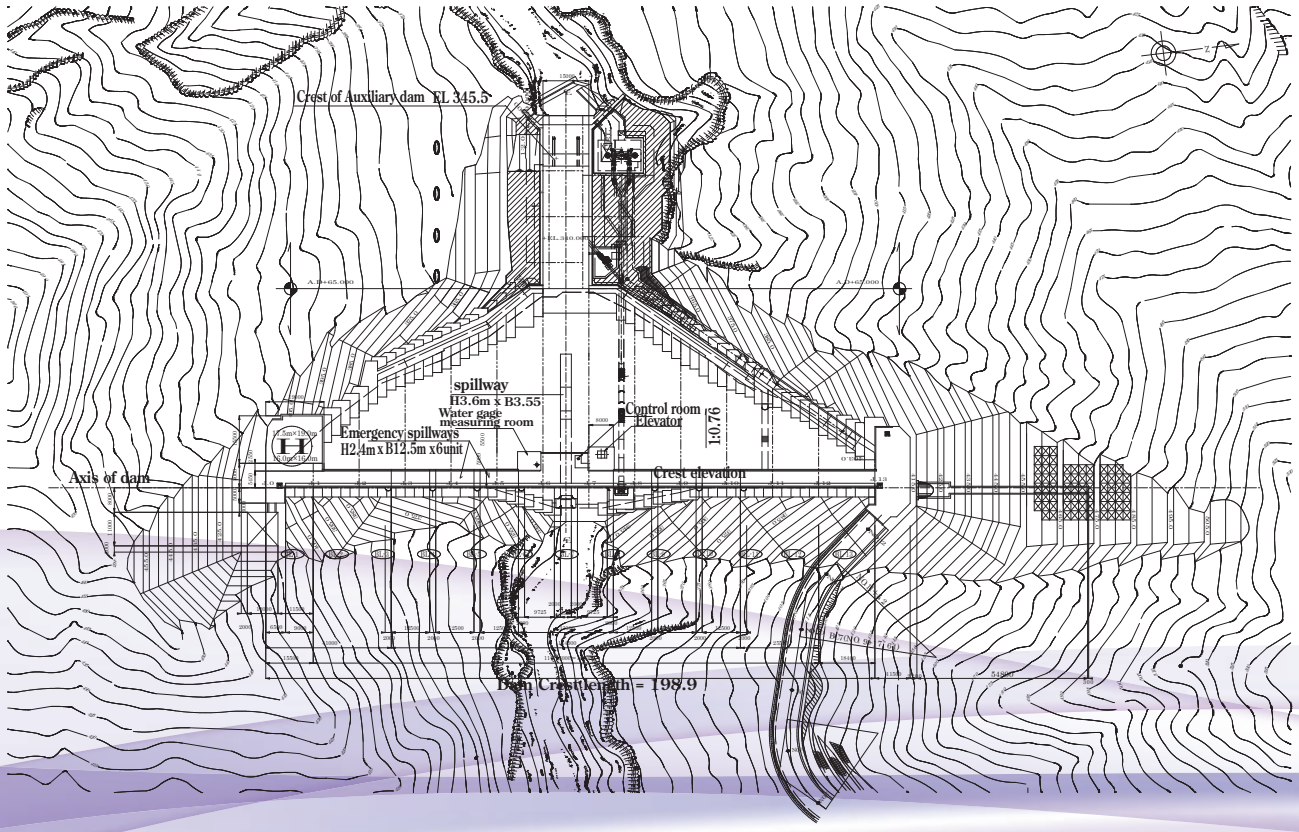


Figure-1 Plan

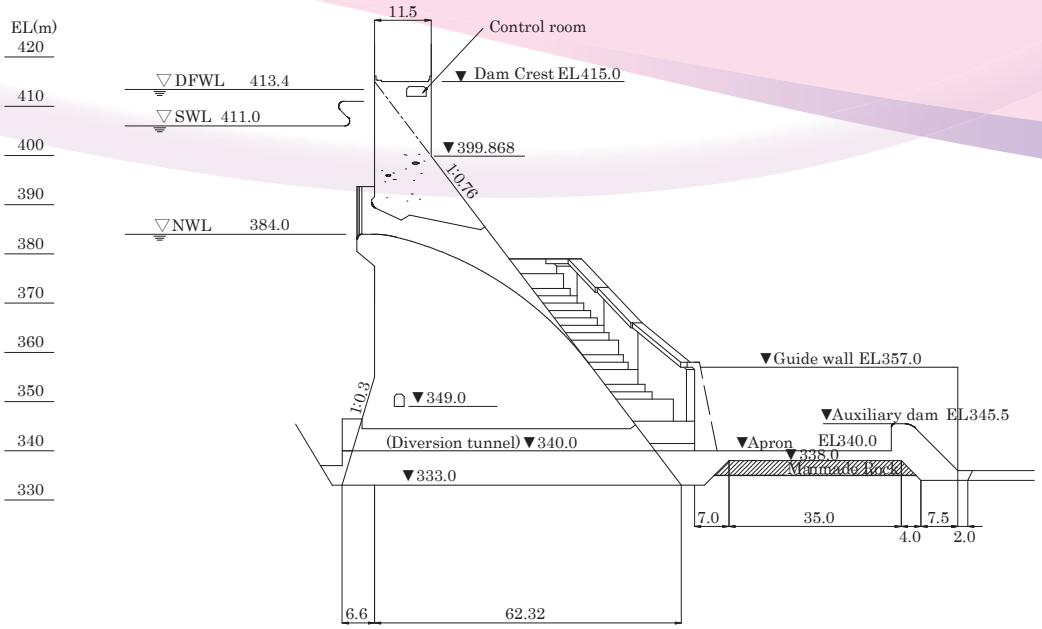


Figure-2 Typical section

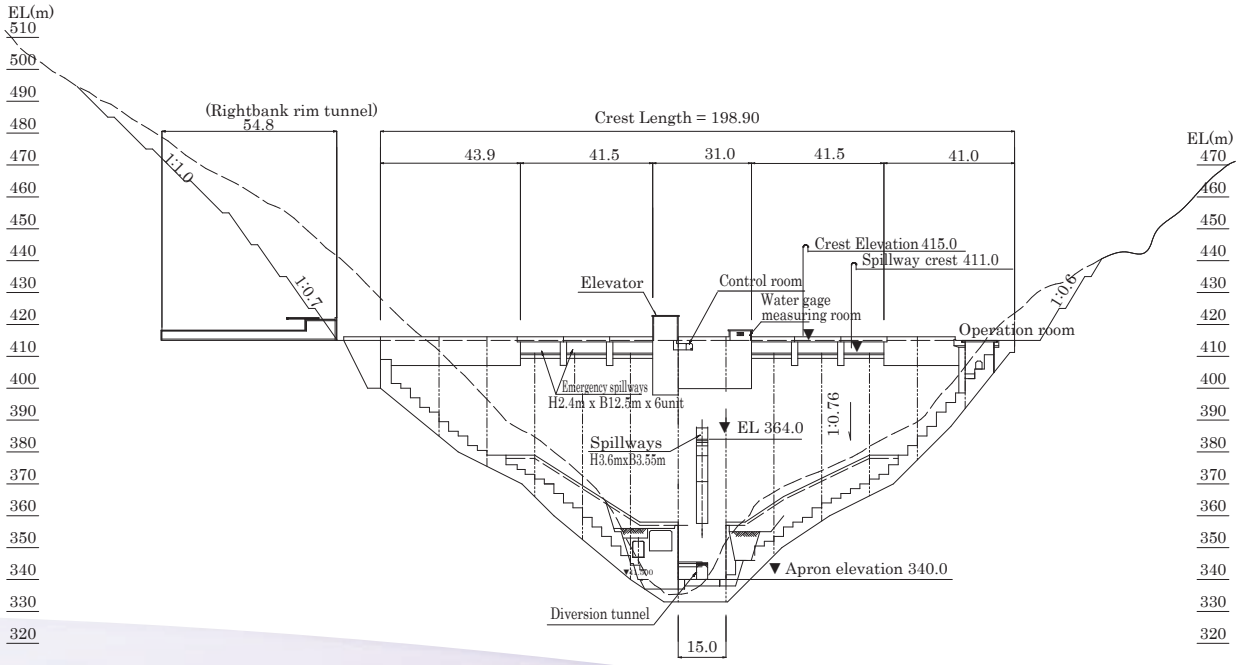


Figure-3 Downstream elevation

Gokayama Dam

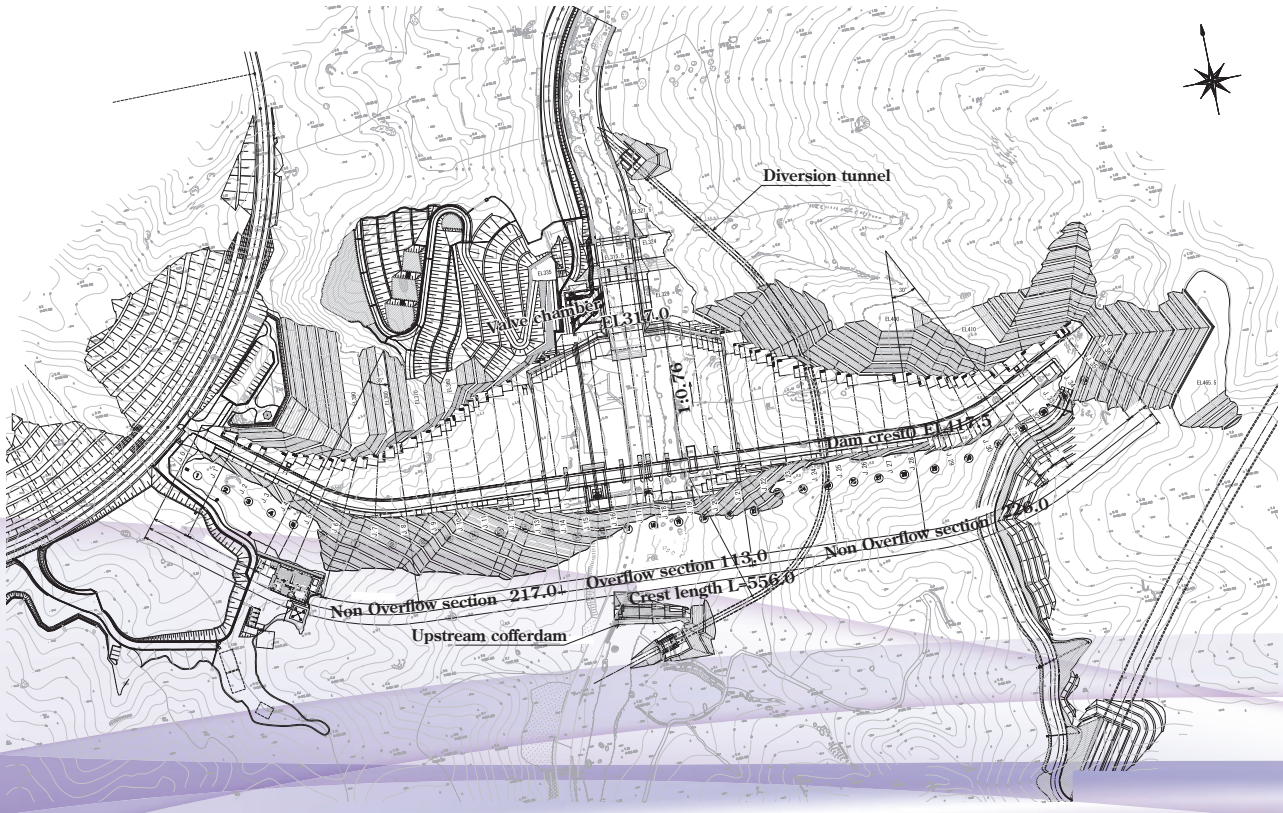


Figure-1 Plan

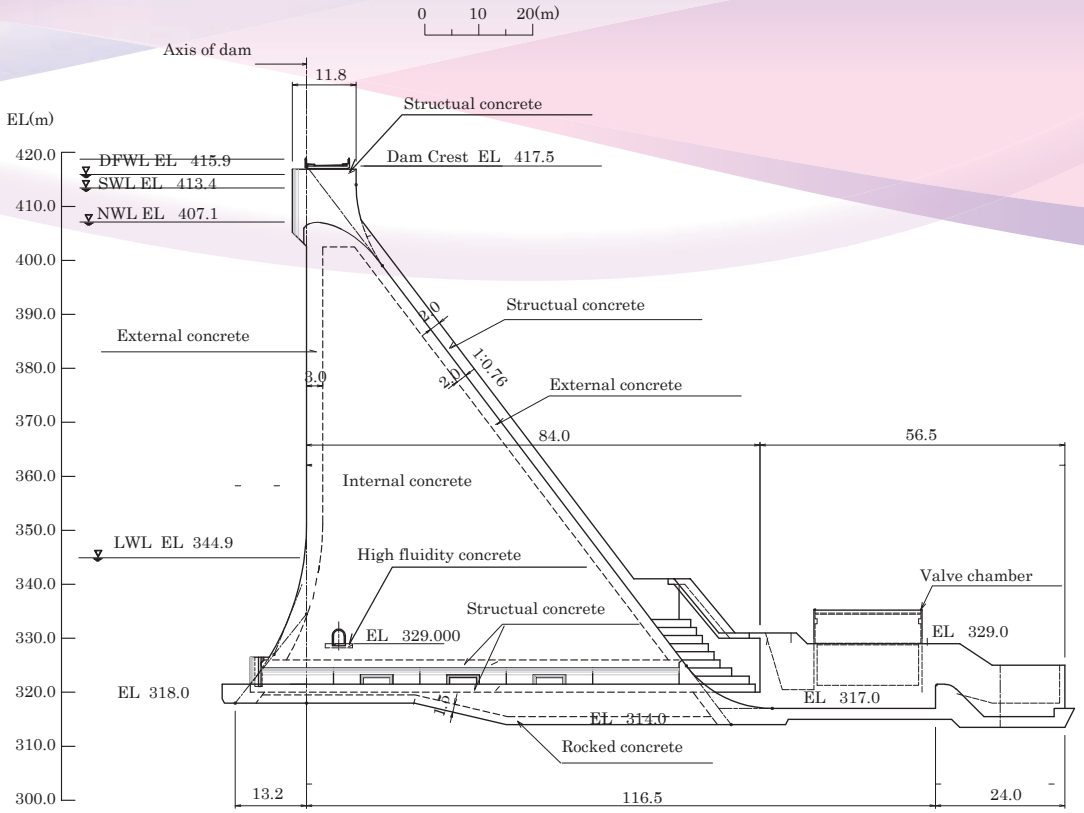


Figure-2 Typical section

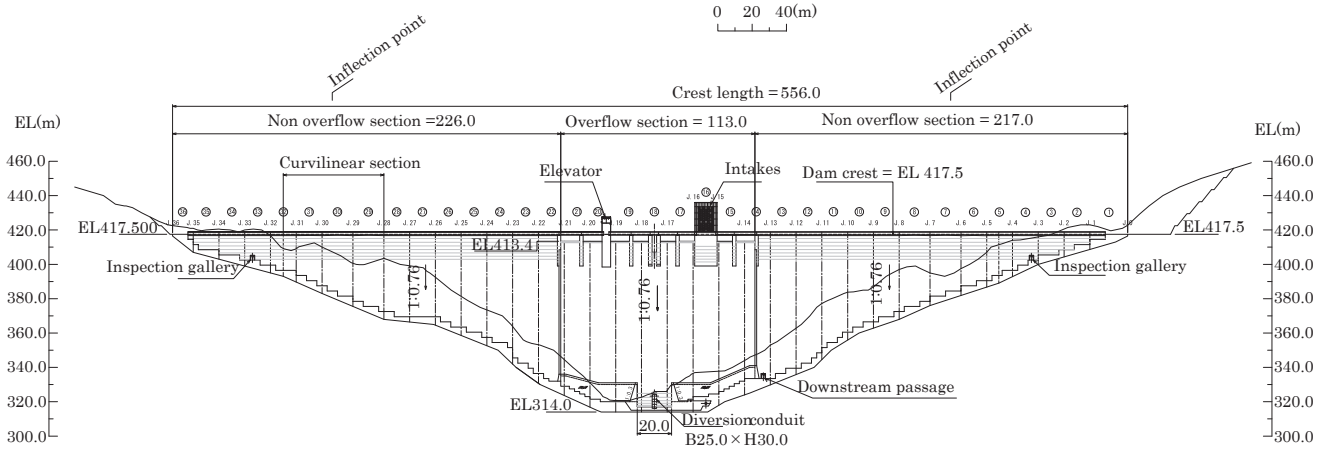


Figure-3 Downstream elevation

Yokozegawa Dam

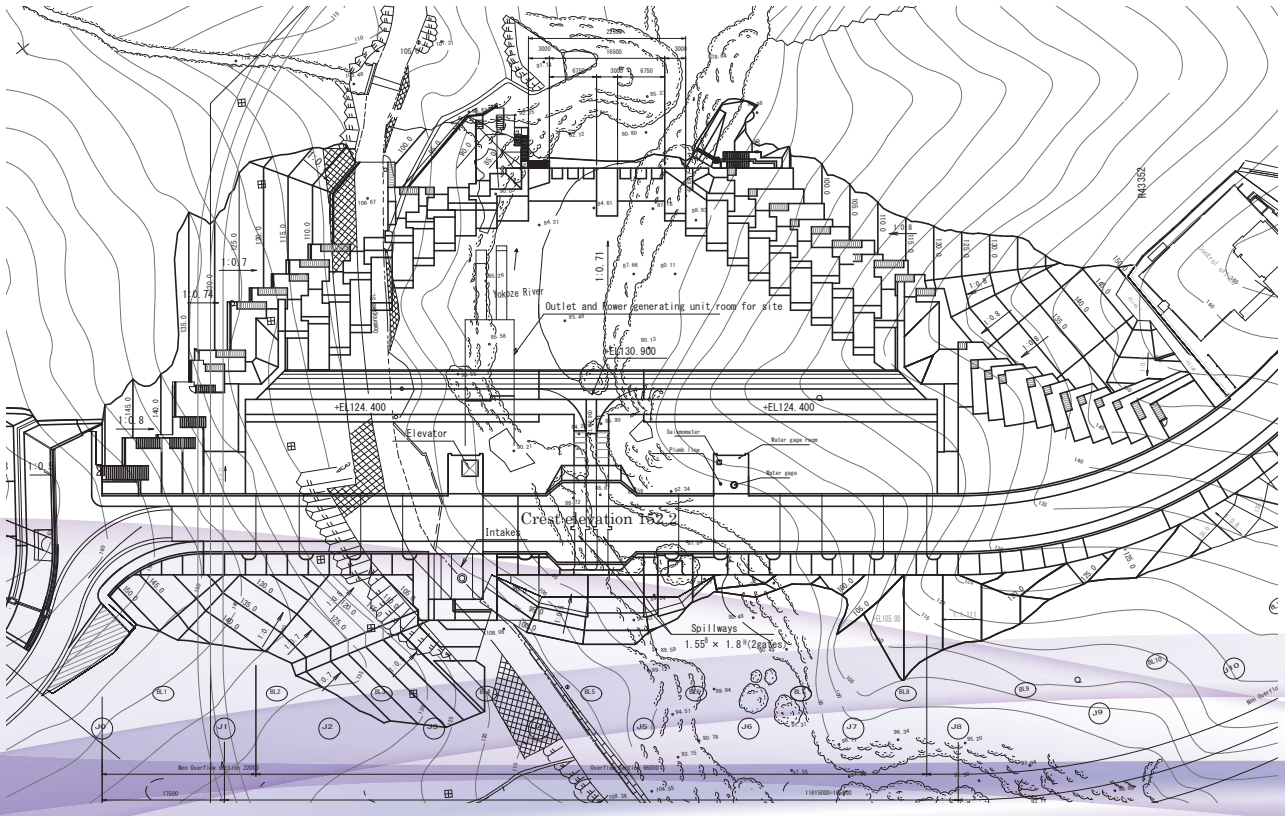


Figure-1 Plan

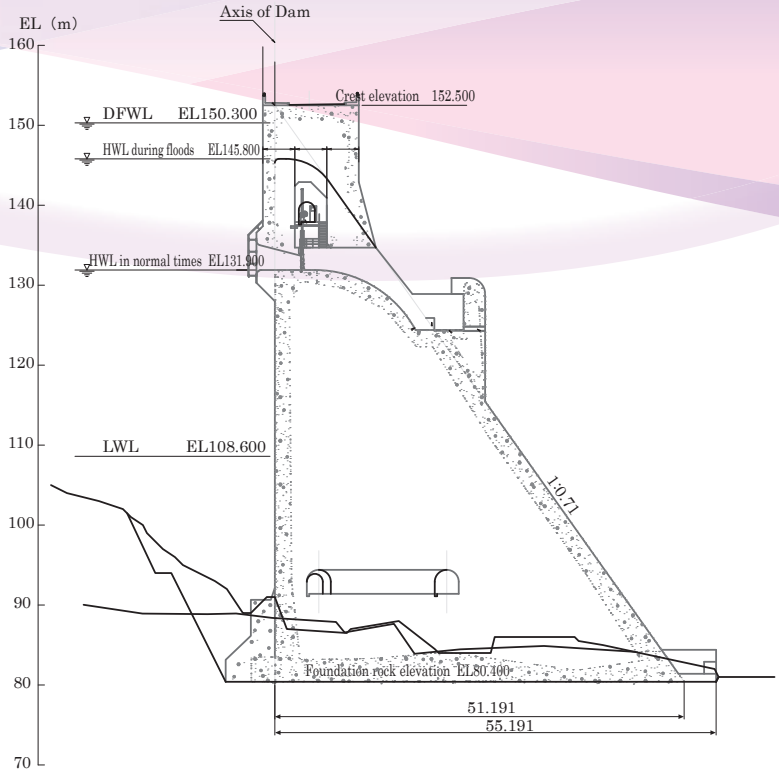


Figure-2 Typical section

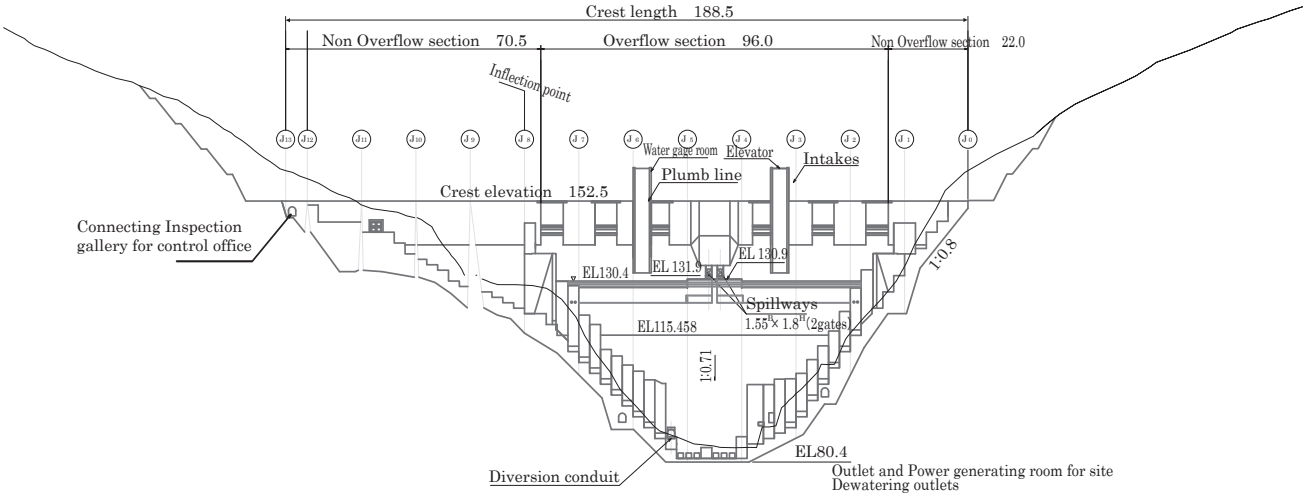
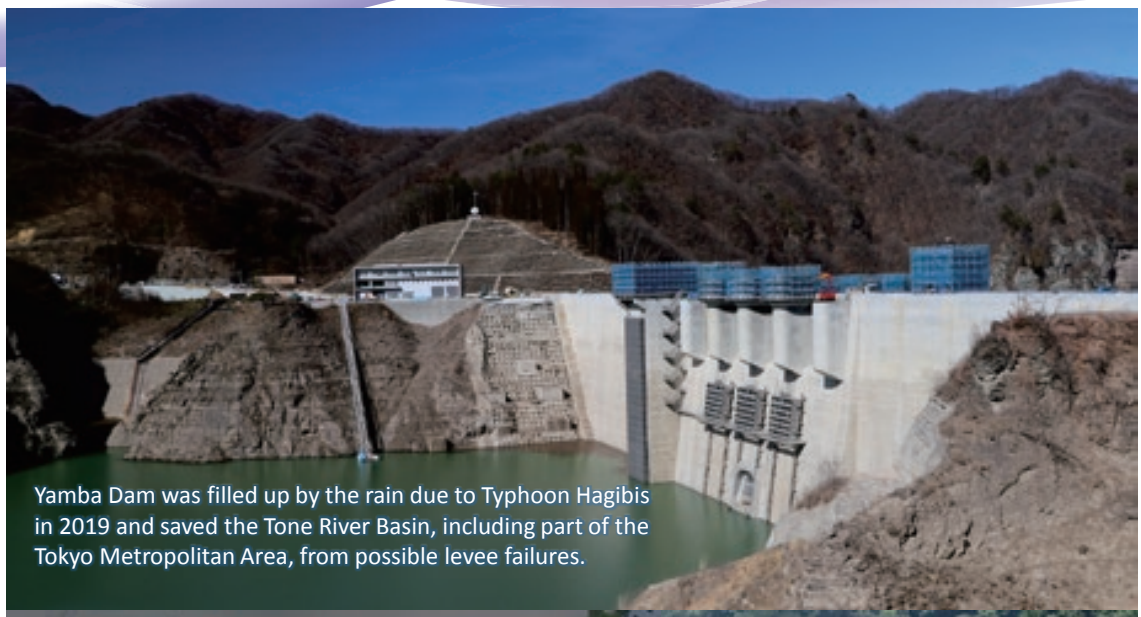
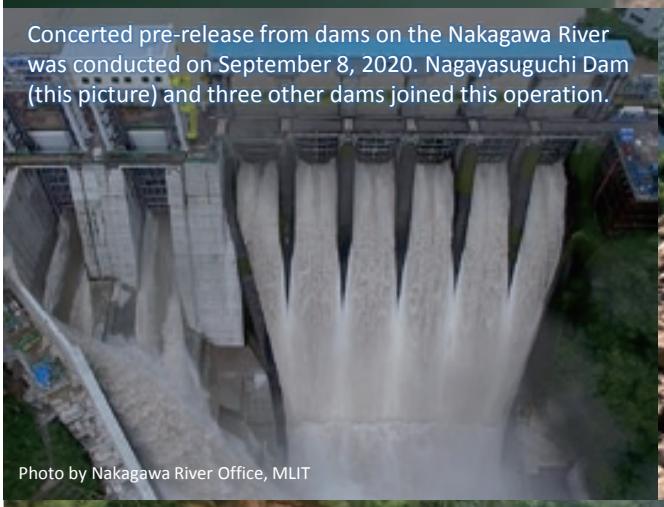


Figure-3 Downstream elevation

Japan Incorporates Climate Change Effects into River and Dam Planning

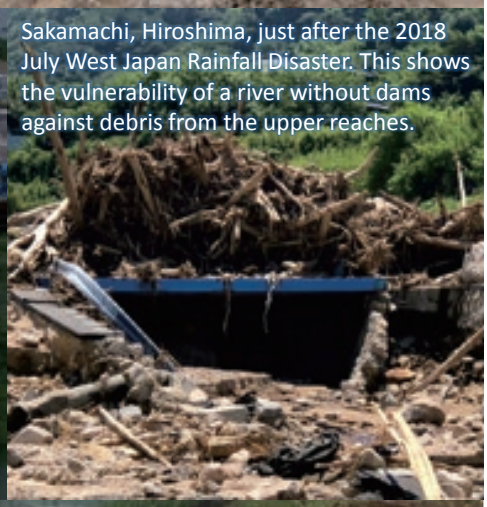


Yamba Dam was filled up by the rain due to Typhoon Hagibis in 2019 and saved the Tone River Basin, including part of the Tokyo Metropolitan Area, from possible levee failures.



Concerted pre-release from dams on the Nakagawa River was conducted on September 8, 2020. Nagayasuguchi Dam (this picture) and three other dams joined this operation.

Photo by Nakagawa River Office, MLIT



Sakamachi, Hiroshima, just after the 2018 July West Japan Rainfall Disaster. This shows the vulnerability of a river without dams against debris from the upper reaches.

Source:Geospatial Information Authority of Japan (GSI)

Japan Commission on Large Dams

Kyushu has suffered from a spate of severe floods. Damage due to the floods differed substantially depending on the availability of flood control dams. For example, in the Chikugo River Basin, tributaries without major dams, such as the Akatani River in this picture, were severely damaged, while the Sada River with Terauchi Dam suffered little damage in the 2017 Northern Kyushu Heavy Rain Disaster. In 2020, a flood in the Kuma River Basin, Kumamoto, Kyushu, caused 50 fatalities and 6,110 houses were inundated. Kawabegawa Dam, which would have been under operation by the time of this flood if the original plan had gone ahead, was reauthorized to be built after this disaster.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) manages 109 trunk rivers in Japan. In 2019, MLIT formalized an increase in the amount of rainfall by 10 to 15% in flood control planning to cope with the effects of climate change in the future. In 2020, the Government also established a general rule to change, as far as it is effective, the operation rules of reservoirs to allow for pre-release from dams before the arrival of heavy rains by utilizing weather forecasts. In 2021, "Basin-wide Concerted Measures for Flood Risk Reduction Acts," which consists of amendments of nine affiliated acts, was enacted to tackle the increased rainfall due to climate change.

Japan Incorporates Climate Change Effects into Dam and River Planning

MLIT employed two climate change models. One is a 4 ℃ global warming model using the d4PDF (5 km downscaling) dataset comprising simulated weather data assuming weather in around 2090, along with the IPCC's RCP8.5 scenario. The other is a 2 ℃ global warming model using the d2PDF (5 km downscaling) dataset. It is the same as d4PDF except that the assumed weather is in around 2040. With each model, MLIT conducted simulation of rainfall for a duration ranging from 360 to 5,400 years. MLIT also conducted a simulation with current conditions (1951 to 2010) to obtain a baseline, which is not the same as the IPCC's. Considering uncertainty in the future, MLIT set the 2 ℃ warming case to be the main case used for dam and river planning while using the 4 ℃ warming case as a reference case for unmodifiable structures with long-range service duration, for example.
Table 1 shows the projected rate of increase of rainfall. Table 2 shows how much the flowrate and frequency of severe floods will increase. The significant increase in the flowrates makes it almost impossible to absorb the changes within current dam and river planning. Therefore, alternative methods are to be explored.

Climate change seems to be already affecting Japan hydrologically. Improving concerted pre-release from dams with more sophisticated use of weather forecasting, revision of design discharge, and effective sediment control for sustainable maintenance of dams are some of the imminent challenges we need to work hard to resolve.

Prof. Tetsuya SUMI
Ph.D. (Kyoto Univ.)
1985 Public Works Research Inst., MLIT
1998 Associate Prof., Kyoto Univ.
2009 Professor, Kyoto Univ.
2019 Vice-President Candidate at ICOLD 87th General Assembly at Ottawa
2020 Vice President, Japan Society of Dam Engineers

Table 1. Projected Increase Rate of Rainfall by Regions

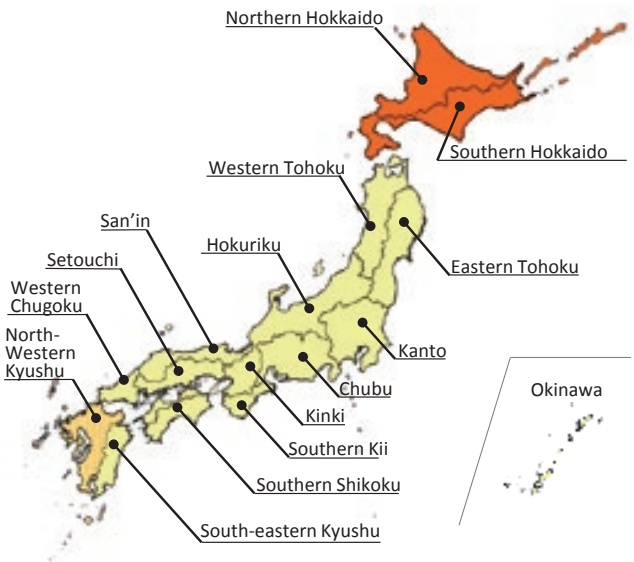
Region \ Case	2℃ Increase	4℃ Increase	
			Short Range
Hokkaido	1.15	1.4	1.5
North Western Kyushu	1.1	1.4	1.5
Rest of Japan	1.1	1.2	1.3

1. "Short-range" corresponds to rainfall within a range of three to nine hours.
2. This table is not applicable to rainfall within a range of three hours.
3. This table is applicable to a catchment area of no less than 100 km² although it can be applicable to a smaller catchment area by taking into consideration the possibility of a higher rate of increase of rainfall.
4. This table is applicable to floods with no more than a 200-year return period.

Table 2. Projected Increase of Flowrate and Frequency of Severe Floods

Climate Change Scenario	Rainfall	Flowrate	Frequency
2℃ Increase	approx.1.1	approx. 1.2	approx. 2
4℃ Increase	approx. 1.3	approx. 1.4	approx. 4

1. The rate of increase of flowrate is the average rate of changes in peak flowrates of design floods, which correspond to floods with a 100- to 200-year return period, at Class A rivers in Japan.
2. The rate of increase of frequency is the average rate of changes in the probability of design flood level rainfall at Class A rivers in Japan.



Basin-Wide Concerted Measures for Flood Risk Reduction

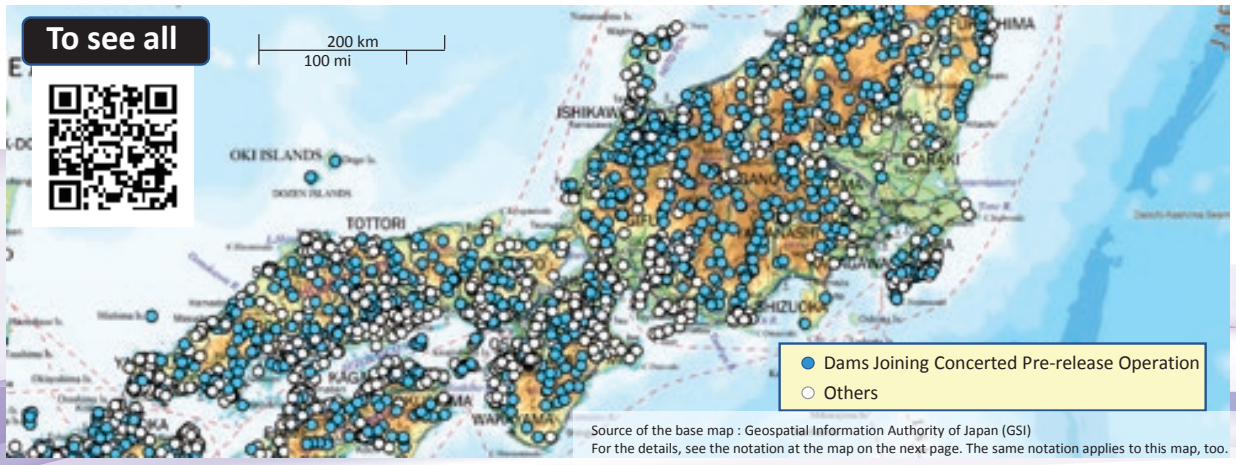
Japan's response to intensified rainfall is "Basin-wide Concerted Measures for Flood Risk Reduction" (which MLIT refers to as "River Basin Disaster Resilience and Sustainability by All"). With this concept, all stakeholders related to flood damage reduction are encouraged to work together to reduce flood disaster risks.

The Taskforce to Promote River Basin Disaster Resilience and Sustainability by All, which includes members from 16 ministries and agencies, was established at the central government level in 2020. The Taskforce drew up the "Action Plan to Promote River Basin Disaster Resilience and Sustainability by All" in 2021. It comprises various measures such as paddy-field dams (floodwater storage in paddy fields), relocation to low-risk places, delineation of inundation areas by PMF (probable maximum flood), and flood defense measures for key infrastructure as well as traditional flood control measures such as dams, levees, and retarding basins.

Image of Basin-wide Concerted Measures
For Flood Risk Reduction

Concerted Pre-release from Dams

A highlight of the basin-wide concerted measures for flood risk reduction is "concerted pre-release from dams." Under this scheme, various dam owners such as MLIT, MAFF, prefectures, power generation companies and irrigation organizations work together in each river basin to cope with heavy rains in the basin. By lowering the water level of a dam reservoir further below the top of the conservation pool, in effect, flood control capacity can be expanded or created. The Government has issued "Basic Policies for Enhancing Flood Control Function of Existing Dams." Under this new policy, based on "flood control agreements" among dam owners and river managers, the pre-release operation is conducted when an expected amount of rainfall in the upper reaches of a dam reaches a threshold beyond which flooding is likely to cause damage downstream. MLIT calculates the expected rainfall with weather forecasts supplied by the Japan Meteorological Agency (JMA). Larger estimates produced either by an 84-hour range Global Spectral Model (GSM) or by a 39-hour range Meso-Scale Model (MSM) are used for comparison with the threshold. MLIT has also formalized a compensation scheme in the event that pre-release operations happen to have adverse impacts on water supply and hydropower.



Dams Joining Concerted Pre-release Operations Based on Flood Control Agreements

Introduction to Dam Technologies in Japan

Trapezoidal CSG dam

The trapezoidal CSG dam developed in Japan is a new type of dam which combines the characteristics of a trapezoidal Dam and the CSG (Cemented Sand and Gravel) construction method. It rationalizes the construction of dams in three ways: "Rationalization of materials: because the dam body materials require less strength, the required performance of the material is low and there are few restrictions on the selection of materials," "Rationalization of design: The trapezoidal shape improves seismic stability, and so the strength required of the dam body materials is lower," and "Rationalization of construction: Construction work can be executed rapidly by simplified construction facilities."

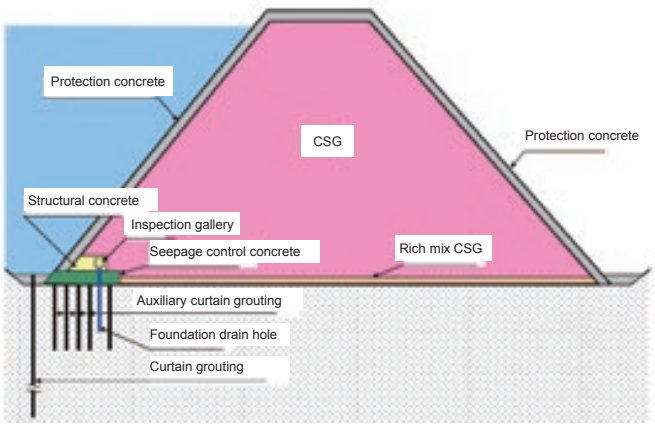


Figure-1 Concept of Trapezoidal CSG dam

Figure-2 Tobetsu Dam

Sediment bypass tunnel (SBT)

SBTs are one sustainable and effective strategy against sedimentation. The SBT connects upstream and downstream of a dam and bypasses sediment-laden floods into downstream. They are mainly operated in Japan, Switzerland and Taiwan.
In Japan, SBTs are operated at the oldest concrete dam in Japan, Nunobikigohonmatsu Dam (1900), Tachigahata Dam (1905), Asahi Dam (1998), Miwa Dam (2005). Also, they are currently undergoing trial operation at Koshibu Dam and Matsukawa Dam. The problem of SBTs is countermeasure against invert abrasion and elucidation of sediment hydrological behavior, and research is currently under way.

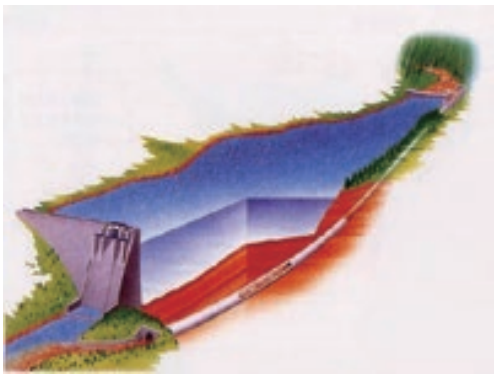


Figure-3 Sediment bypass tunnel (SBT)

Figure-4 Miwa Dam

Preservation measures of dam reservoirs

Water quality issues are closely associated with the size of the dam reservoir, and operation of the dam reservoir. One of water quality preservation measures for the dam reservoir is conducted by controlling outflow of pollutant and nutrient salts from the catchment area.

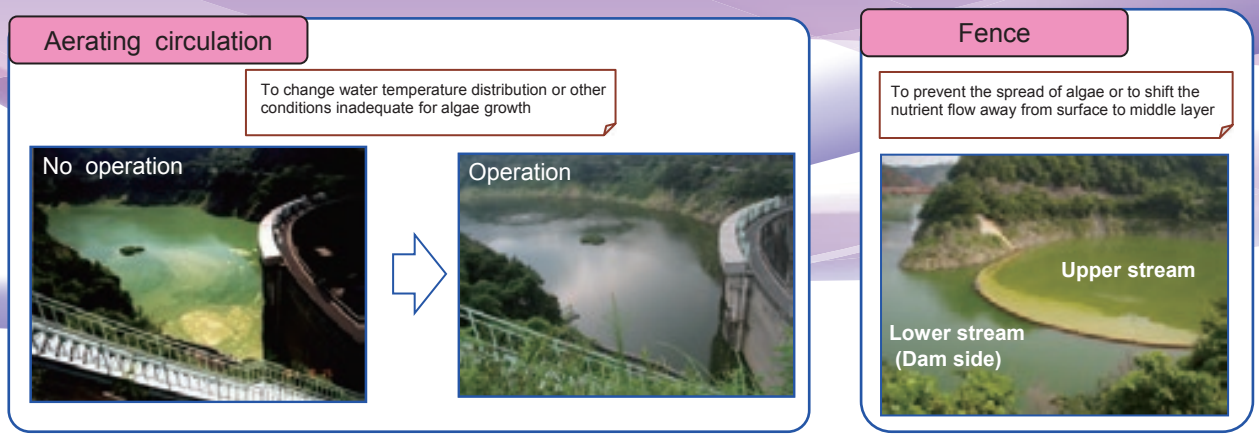


Figure-5 Reservoir water quality improvement facility

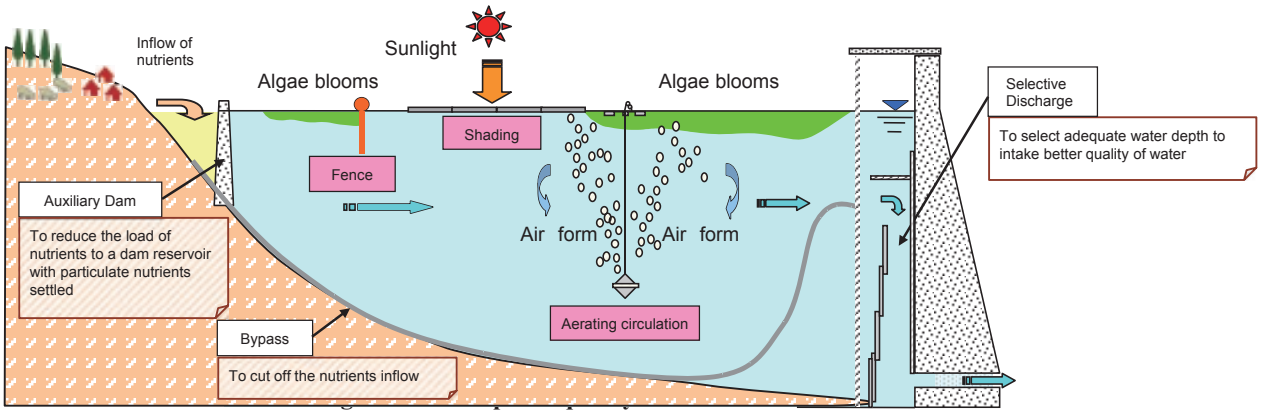
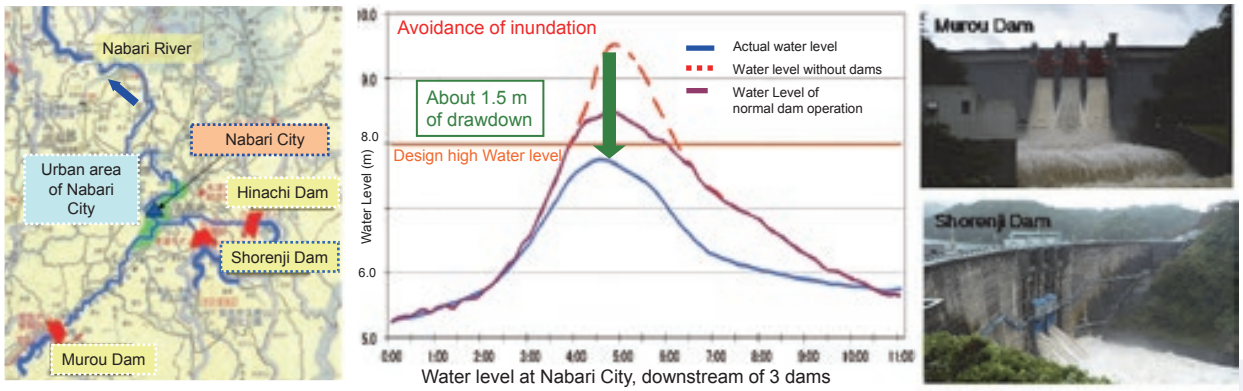


Figure-6 Example of quality conservation measures

Advancement of flood control operation

Recently, flood disasters caused by heavy rains occur frequently in Japan. It is set that the flood control operation of the dam should work most effectively for design flood or hydrograph. However, as the rainfall is a natural phenomenon the rainfall condition varies from time to time. Therefore, the appropriate operation is conducted at all times, making use of the rainfall prediction technologies and flood outflow analysis model and maximizing the flood control capacity of the dam so that the prevention or mitigation of flood damages can be achieved in the downstream areas.



Water level at Nabari City, downstream of 3 dams

- Heavy rain due to big typhoon threatened to cause inundation in Nabari River on October 8, 2009.
- Japan Water Agency's O&M offices conducted collaborative operations considering water level, rainfall, and dam capacity of each of the three dams under its integrated control.
- The above figures show that the water level of urban area was kept below the design flood water level at Nabari City.

Figure-7 Flood control through integrated and collaborative operation of three dams

Dam Upgrading Vision

It is important to effectively use existing dams while controlling total costs. Various technologies will be advanced as the number of cases of the effective use of existing dams grows.
On the other hand, more frequent and intense flood damage and more frequent droughts are concerns. Under this context, dam upgrading will be promoted by effectively using existing dams applying both hard and soft measures according to each basin's characteristics and issues.
The "Dam Upgrading Vision" which provides a strategy for the further promotion of dam upgrading efforts that effectively utilize existing dams has been formulated in 2017 by MLIT. These strategies for the vision are categorized below.

1) Dam Life Extension
2) Promoting Efficiency and Advancement of Maintenance
3) Flexible and Reliable Operation to Optimally Utilize the Capacity of the Facility
4) Improving Facilities for a more Advanced Functionality
5) Responding to Climate Change
6) Addition of Hydropower
7) Protection and Revitalization of River Environment
8) Regional Development utilizing the Dams
9) Promoting Dam Upgrading Technologies Overseas
10) Development and Implementation of Technologies to Promote Dam Upgrading

A typical example of utilizing an existing dam is shown in the figure.
This method is a temporary installation method that can be used to add penstocks for power generation and flood discharge pipes to the existing dam body without lowering the water level of the reservoir.

"Floating Type Temporary Cofferdam Method"

Conventional cofferdam construction requires long diving hours at a very deep water depth, large temporary equipment, and a long construction timeframe.
For the floating type temporary cofferdam method, steel plates (skin plates) are attached to both the inside and outside of the bulkhead to make an watertight structure, and this becomes the buoyancy chamber to make the bulkhead float. It is important to maintain the balance between buoyancy forces and dead weight by filling and draining the bulkheads blocks in the proper order.
For actual construction, bulkhead blocks made at local factories will be assembled on the reservoir as a cofferdam which will be towed to the installation position by a ship, and subsequently pulled by a winch and secured.
And then, water is drained from the cofferdam.
And this new method was used for the first time in the Tsuruda Dam upgrading.

＜ ***Efficiencies of this method*** ＞

This is dependent on scale of the cofferdam and construction depth, as large temporary facilities, such as pedestal concrete and support framework, are unnecessary and diving work can be greatly reduced, costs and processes can be reduced, and safety can be improved, leading to an increase in construction efficiency.
Moreover, when drilling holes in the same dam, it is necessary with conventional methods to dissemble and then reassemble the bulkheads, but with this method there is no need to disassemble the bulkheads; flood the cofferdam and detach the bulkheads from the dam-body and tow it as is to the next construction site where it can be installed.

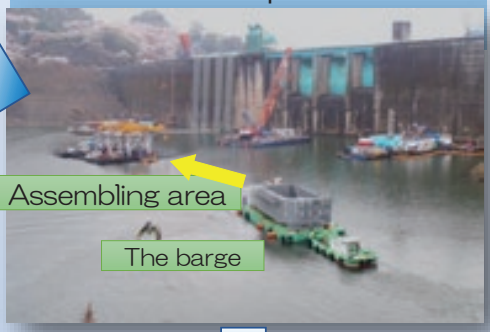
—New Temporary Cofferdam Method—

Floating Type Temporary Cofferdam Method

The workability of the temporary cofferdam method can be significantly improved by watertight structure in each bulkhead to provide buoyancy

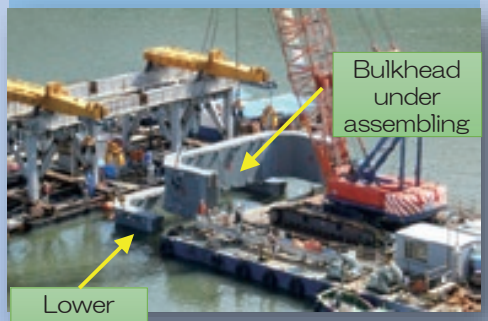
1.Loading of Bulkheads on the barge
—onto the barge on the reservoir—

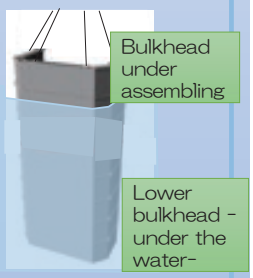
2.Transportation of bulkheads to assembling area by the barge
—reservoir transportation—



Overview of bulkhead

3.Assembling of bulkheads on the reservoir



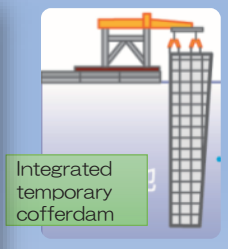


Overview of assembling

【Completion of Installation】

Heighten Workability **Heighten Safety**
Shortened Period **Cost Reduction**

4. Towing & Installation
—dewatering from the temporary cofferdam for floating and positioning of the temporary cofferdam—



Overview of towing

5.Dewatering from the temporary cofferdam
—securing a dry working space inside the temporary cofferdam—

All work from assembling of bulkheads to installation of temporary cofferdam can be done on the reservoir

Utilization of ICT in construction of dam

The construction industry in Japan aims at drastically improving productivity of all construction production processes by utilizing ICT, and its approach is called i-Construction.
Even in the construction of dams, the utilization of ICT has been advanced toward improving quality, safe site work, shortening of construction period, and reduction of construction cost.

In addition, using ICT to share information in real time and to utilize and accumulate 3-dimensional data can contribute to a dramatic rationalization of actions throughout the dam life cycle from the design stage, the construction stage to the operation and maintenance stage.

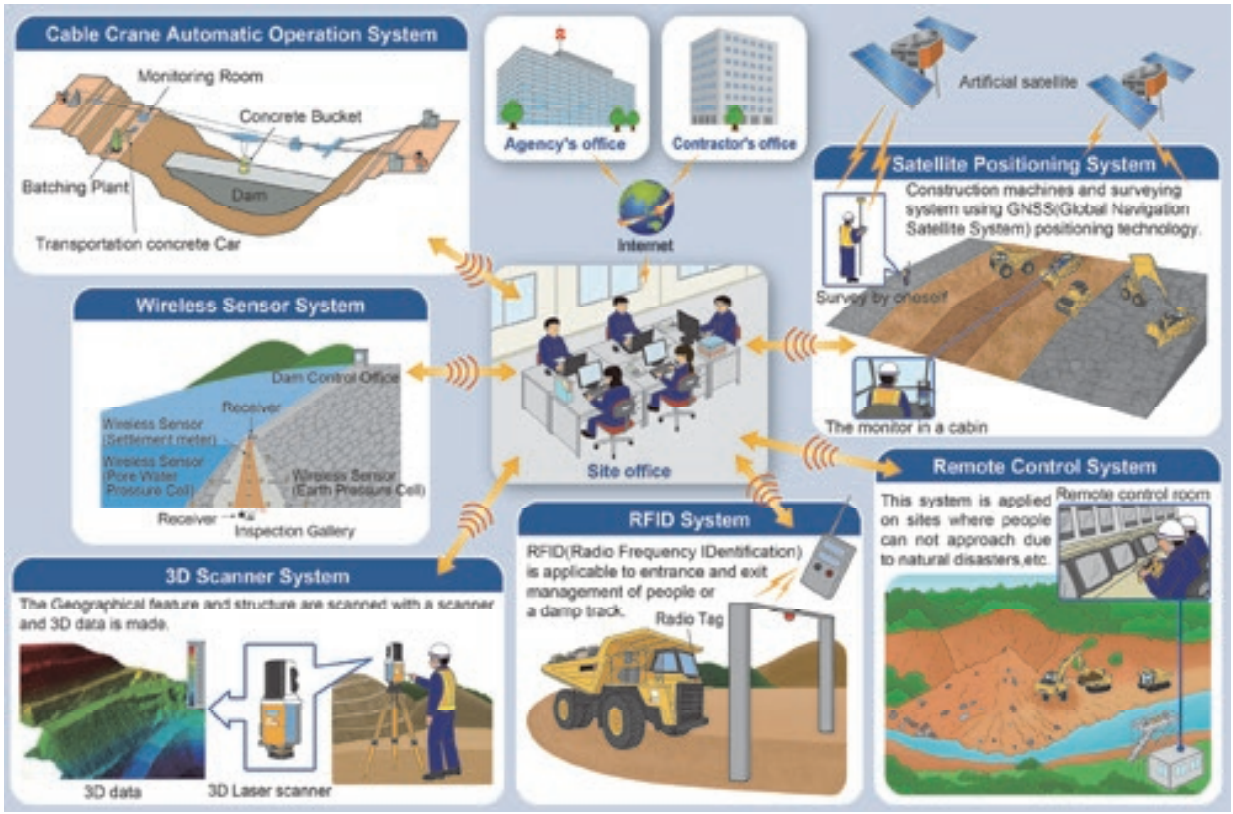


Figure-8 Application of ICT for Dam Construction

Papers in ICOLD & Other Technical Publications

Papers in ICOLD and EADC

Theme 1 Safety management and rehabilitation of existing dams

A. 10th East Asia Dam Conference in Zhengzhou, October 2018

Issues seen in existing concrete dams as the result of comprehensive inspections

K.Yamagishi, S.Takasu

As an effort to extend dam service life, comprehensive dam inspections were systematized in Japan in 2013, and comprehensive inspections are being carried out on dams that are roughly 30 years old. Comprehensive dam inspections is carried out by each dam manager applying technological expertise to perform a comprehensive fact-finding survey and evaluation of the soundness of the state of maintenance and degree of deterioration of civil-engineering structures of the dam, which are the constituent elements of each dam. Comprehensive soundness of civil-engineering structures of dams in particular, are evaluated by additionally performing advanced surveys on items which cannot be easily surveyed in daily and periodical inspections for methodological and cost reasons, and items which could deteriorate over time. This study organizes the results of comprehensive dam inspections controlled under the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) implemented for dams in Japan in recent years, looks at issues to note during comprehensive dam inspections, methods for examining issues, procedures for evaluating examination results, and summarizes the trend in maintenance issues for concrete gravity dams.

B. ICOLD 87th Annual Meeting International Symposium in Ottawa, June 2019

Design of seismic reinforcement by post-tensioned anchors in Senbon Dam

H.Kawasaki, S.Ishifuji, and H.Fukumoto

Senbon Dam is a water supply dam with 17 meters high operated by Matsue City, which was completed in March 1918. Since this dam is an old gravity type masonry dam and the cross section is also thin, Matsue City will perform the seismic reinforcement with post-tensioned anchors in 2019 and 2020.
As for experiences of the reinforcement by post-tensioned anchors for dams in Japan, there are old cases such as the construction of the auxiliary dam in the Fujiwara dam in 1955 and the reinforcement of the rock abutment in the Kawamata arch dam in 1963. However, under the latest requirement of high durability and high capacity, it is the first domestic experience of dam body reinforcement by the post-tensioned anchor in Japan.
As technical points for applying the post-tensioned anchor to the Senbon Dam, there are following issues: “coping with a large load at narrower dam crest, construction method of the overflow part that occupies 2/3 of the dam length, solution to partial weak zones in the foundation, preservation of masonry dam landscape and others”.

C. ICOLD 88th Annual Meeting International Symposium & 5th APG Symposium in New Delhi, February 2021

Japan’s “Follow-up System for Management of Dams” and its achievements

Y.Mogami, N.Asai, K.Sakamoto, T.Hara and G. Yasuda

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan started test operation of the Follow-up System for Management of Dams (FUSMOD) in 1996 and its regular operation in 2002. FUSMOD aims to facilitate statutory post-assessments of dam construction projects, and to improve management of 141 dams and reservoirs operating under the jurisdiction of MLIT. To comply with FUSMOD, each dam owner is required to perform surveys for post-environmental assessment as well as for the post-assessment of the project in charge. These post-assessments are not once-and-for-all type but a series of periodical reviews of dam projects. Using the results of surveys, each dam owner periodically reviews the hydrological records to

examine the performance of flood control and water supply, changes on sedimentation, water quality, flora and fauna, demography and regional economic effects. FUSMOD, by analysing data generated through various surveys and daily management, provides an opportunity for dam owners to realize how they need to rectify their management of dams. We demonstrate the benefits of FUSMOD by describing examples of operations that have been successfully rectified under FUSMOD. These include improved operation of water quality control facilities such as selective intake facilities and aeration facilities based on continuous water quality survey results. Another example is review of survey plan for water quality. The changes contributed to more efficient dam management through acquisition of pivotal data for dam management. Under FUSMOD, measures for controlling invasive alien species introduced in connection with dam construction projects, and evaluation of the impact of dams on local industries through water supply and their recreational function, for example, are also studied. The results lead to rectify related policies and procedures. FUSMOD enables dam owners to conduct meta-analysis through analyses and assessment results for various dams. The achievements thanks to meta-analyses include revisions of reservoir water quality survey guidelines and reservoir sediment management guidelines. Moreover, FUSMOD, through continuously released summaries of analyses and assessments to the general public by MLIT, ensures dam management is accountable.

Establishment and implementation of the emergency action plan on the Nam Ngiep 1 Hydropower Project in Laos

T.Tabuchi, Y.Aosaka, I.Sakai, Y.Yamamoto and S.Tsutsui

A 167 m high roller-compacted concrete (RCC) dam and a 270 MW main power station are being built in the Lao People's Democratic Republic (Lao PDR) under the Nam Ngiep 1 Hydropower Project (NNP1). The large reservoir of 70 km in length, 67 km2 in area and 2 billion m3 in volume has such risks as floodwater releases, extraordinary dam behavior and so on, that may impact human lives and properties along the downstream river basin. An Emergency Action Plan (EAP) consisting of dam emergency events, hazard map, notification, preparedness, and its procedure, is being established to mitigate issues caused by the above risks. So far, actions related to issues of extraordinary dam behavior have been taken twice during initial impounding. The reservoir water level was lowered to secure dam stability when the uplift pressure increased rapidly. A notification drill for emergency cases is being prepared by NNP1 and the Lao Government before starting commercial operation. This paper presents the process of establishing the EAP and its actions.

Theme 2 New construction technology

A. 10th East Asia Dam Conference in Zhengzhou, October 2018

Countermeasures for shorten the construction of Yamba dam

M.Kimura, T.Hiratsuka

Yamba concrete gravity dam with a height of 116 m and a volume of about 1,000,000 m³, is under construction on the Agatsuma River which is a branch of the Tone River that flows through the upstream region of the Tokyo area. The purpose of the dam is flood control , water supply, and hydro power, which is expected to be completed at an early period. The concreate placement period is being greatly reduced by measures as follows; using the Roller Compacted Dam-concrete (RCD) method for rationalizing the construction; shortening the construction period by extending the concrete placing facility to improve the placement speed; shortening the installation period by the method of preassemble and transfer of the flood discharge conduits facilities; adoption of precast members for outlet facilities and gate chamber, diversion which was installed in the dam body, inspection gallery and elevator shaft, overhang zone and changing point of slope gradient; and increasing the number of days of construction during winter by taking special countermeasures, etc..

B. ICOLD 87th Annual Meeting International Symposium in Ottawa, June 2019

Development of blasting management system and its application to verification of ground evaluation using logging while-drilling

K.Nagai, M.Yamagami and S.Katayama

Concrete aggregate production in dam construction is planned according to the distribution of good quality rocks estimated by preliminary surveys such as borehole exploration and geophysical survey. The accuracy in estimating the distribution of good quality rocks depends on the quantity of sur- vey and is generally low. This may lead to a limited enhancement in the aggregate production efficiency. To resolve the problem, we developed a rock blasting management system, which consists of a rational construction technique with an information and communication technology (ICT), and a demonstration experiment at a dam site. In this report , we will describe the overviews of the aggregate production work at the Gokayama Dam and the developed rock blasting management system with the results of a verification experiment on the drilling survey and a demonstration experiment at an aggregate production site.

Tallest RCC gravity dam in Lao PDR - need for high speed and solutions adopted at the Nam Ngiep 1 Hydropower

Y.Aosaka, T.Seoka, and S.Tsutsui

The high production rate of roller-compacted concrete placing which achieved during the construction of the main dam of the Nam Ngiep 1 Hydropower Project in Laos is outstanding.

The demand for the high production required the mobilization of materials, equipment, system and human resources to satisfy the Project's need for the rapid RCC placing rates averaging 97,500 m3/month and led the Project to select the compatible and optimum production, transporting and placing facilities. The optimization and selection of all in relating to RCC facilities are discussed in this paper. Furthermore, this paper discuss construction techniques and solutions adopted during construction to achieve the high productivity and efficiency while retaining the best quality and safety, and which includes the following 6 items,

1) Materials: Supply of materials from outside which are cement, fly ash and quarry; 2) Equipment: Optimization of all equipment which are crushing plant, aggregate stockpiling; RCC batching plant and RCC delivery conveyor belt; 3) System: Remarkable success of Sloped-Layer Method to achieve high production rates; To obviate manual trimming of feathered edges; 4) Safety procedure in regard to RCC placing; 5) Systematization of procedure in regard to dam zoning; 6) Human resources: Education and establishment of human relations.

C. ICOLD 88th Annual Meeting International Symposium & 5th APG Symposium in New Delhi, February 2021

Unmanned Maintenance Work with Underwater Remotely Operated Vehicle (ROV) for Discharge Facilities of Dams

S.Uchida, M.Kaida

For maintenance work of discharge facilities of dams, manned diving operations have been usually implemented. And in some cases, they have been carried out in deep water over 40 meters. However, manned diving puts divers at the risk of fatal accidents. Therefore, the use of an unmanned underwater Remotely Operated Vehicle (ROV) will make the maintenance works safe, and also will contribute to cost reduction by avoiding the use of expensive diving support equipment.

As a first approach, we developed an underwater ROV to carry out the work for setting a water shut-off cover at the tap of water filling pipe facing reservoir water. We tested this work in a laboratory water tank and then at actual dam sites. The evaluation results of the test at actual dam sites suggest that this work is ready for practical application.

The introduction effects of 3D information models in Koishiwaragawa Dam Construction Project

T.Miyazaki, T.Yoshida

The Construction Project of the Koishiwaragawa Dam, which is a rockfill dam and is to start operation from April 2020, is conducted by the Japan Water Agency. This project is a leading case of applying Three Dimensional (3D) information models to the design and construction process from the early stages of the owner's work. In Japan, the 3D information model in the civil engineering field is called Construction Information Modeling/Management (CIM).3D graphic models of the dam and surrounding structures were developed before starting construction of the dam body. Using Navisworks, an integrated application from Autodesk, the models incorporated a lot of construction-related information such as geological data on dam site and quarries, quality control data on embankment and monitoring data of the measuring devices installed in the

embankment. This made it easier to recognize each data spatially and chronologically, to grasp the construction process, and to share the acquired information among relevant people, eventually streamlining the entire work process. Currently, we are planning to upgrade this system to make the record management around the dam and reservoir more efficient, by inputting monitoring data of the displacementdam body, surrounding slopes and patrolling record data into the 3D models after the initial impoundment.

E. 27th ICOLD World Congress in Marseille, June 2022

Dam concrete automatic placement system – complete automation of dan concrete materials supply, production, transport, and placement -

N.Yamashita, T.Kase, S.Tachihana, S.Moriyama, and H.Mori

The concrete placement of concrete gravity dams accounts for about 60% of the construction cost and about 50% of the construction time. The operations for the concrete of production, transport, and placement are repeated for several years. The concrete placement also requires many experienced skilled workers for the operation of large heavy machines and the compaction work. When rail rope cable cranes are adopted for the concrete transport, the crane manipulation becomes a complex 3-dimensional operation, so greater experience and skill than usual are required. Therefore, we developed a "dam concrete automatic placement system" that aiming to automate the series of processes of a material supply to the batching plant, a concrete production, a concrete transport by a transfer car, and a transport and placement using a rail rope cable crane. This system integrates the automation technology that has previously been applied to the batching plant and transfer car, etc., with automation of the rail rope cable crane. This system was applied to about 40,000 m3 in the 213,000 m3 of total concrete using the rail rope cable crane on Yanagawa Dam (Morioka City, Iwate Prefecture), and the following effects were obtained as a result of its introduction. First, the cycle time per placement was reduced by about 20 seconds from 3 minutes 40 seconds to about 3 minutes 20 seconds, a 10% reduction in time. The placement time for the approximately 40,000 m3 to which this system was applied was reduced from 533 hours to 494 hours. Secondly, the number of workers required for placement in the dam was 2 crane operators, 6 batching plant operators, and 7 for concrete placement, or a total of 15 workers. However, by adopting this system it is expected that this conventional number of workers can be reduced to 2/3, with 1 crane operator, 4 batching plant operators, and 5 concrete placement workers, or a total of 10 workers. Thirdly, by automating operation of rail rope cable cranes with this technology it is possible to automatically and rationally transport the concrete bucket to the placement position, so the operation can be performed with the same work efficiency as a proficient operator despite the shortage of experienced operators, so this technology can help to respond to the shortage of proficient operators.

Investigation measures and controls against internal restraint cracks due to thermal stress of RCC dam - practice at Nam Ngiep 1 Hydropower project in Lao PDR -

Y.Aosaka, S.Tsutsui, T.Kawata, and B.Egilat

During construction of the Roller Compacted Concrete (RCC) dam at Nam Ngiep 1 Hydropower Project (NNP1) in Lao PDR, cracks in the direction of the dam axis emerged on the surface of the RCC placing on the left bank side where RCC placing had been suspended in order to install penstocks that would be embedded in the dam body. The NNP1 Power Company conducted a crack investigation and thermal stress analysis by applying the observed ambient temperature and variation in RCC strength, and was found that the main cause was the difference in concrete temperature between inner and surface portions of the RCC due to a sudden drop in ambient temperature in the middle of December 2017 that was larger than what occurs in an average year. This paper presents the process of the above investigation, related root cause analyses, dam stability check and effective measures taken to control cracks in RCC.

Introduction of 100% inspection based quality control method in embankment dam construction

H.Sakamoto, K.Someya, and Y.Matsuoka

One of the problems of conventional quality control method in embankment dam construction is that it is difficult to confirm the uniformity of quality throughout the entire embankment. To resolve this issue, we introduced 100% inspection-based quality control at Koishiwaragawa Dam (an earth core rockfill dam in Japan, H = 139 m). This new quality control comprises two quality control methods. The first is 100% inspection-based quality control through the application of ICT toward three elements that determine the engineering properties of embankments: (a) grain size distribution, (b) water content during construction, and (c) compaction energy level. The second is ICDM of impermeability performance based on upper boundary control of compacted soil stiffness .The development of these methods makes it possible to gain a understanding of the spatial and temporal distribution of measured values of each control item and substantially streamline the quality testing process to be performed on compacted embankment surfaces. This paper described the overview that went into applying these new quality control methods, as well as the resuts of applyment for Koishiwaragawa dam construction.

Theme 3 Spillway and outlet works

A. 10th East Asia Dam Conference in Zhengzhou, October 2018

Hydraulic design in upgrading dams under operation

T.Sakurai, T.Ishigami

In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) presented a "MLIT's Vision to Upgrade Dams under Operation" in June 2017. The vision introduces countermeasures to advance the upgrading of existing dams by applying both structural and non-structural measures to ensure that they are used more effectively than in the past.
There are cases raising the dam body and increasing the discharge capacity of the discharge facilities etc. in the past. At some existing dams, improvement projects are currently under construction.
There are challenges in hydraulic design of improvement and additional construction of discharge facilities in dam upgrading different from the construction of a new dam. Methods to cope with these challenges have been examined by hydraulic model experiments and so on. In this report, the outline of three major technologies to increase the discharge capacity in dam upgrading, cutting dam body, drilling dam body and tunnel spillway, are introduced. And taking Nagayasuguchi dam remodeling project as a representative example, the contents of the hydraulic design of the existing dam redevelopment project are explained.

B. ICOLD 87th Annual Meeting International Symposium in Ottawa, June 2019

Applying CFD analysis to scouring river bed caused by discharge flow from the dam and estimating effectiveness of some countermeasures

K.Hirao, F.Watanabe, S.Ohmori, T. Tsukada, and T. Kurose

Unexpected scour in a river had been observed at the downstream area nearby the discharge channel of the dam-type hydropower station of the Tokyo Electric Power Company Holdings, Inc. We assumed that rotational or three-dimensional (3-D) water flow induced by complicated river bed shape and retaining wall arrangement could be the cause of the scour described above. Applying 3-D computational fluid dynamics (CFD) analysis, we clarify the flow structure relating the scour and study the main factor of the scour. We also validate the effectiveness of some countermeasures against the scour by the CFD analysis. In one countermeasure, we alter the shape of the discharge channel outlet for the purpose of reducing the flow to the observed scour area, and results from the 3-D CFD analysis show the flow accomplished our aim.

The method for increasing the waterpower generation by using the storage volume for flood control in the multipurpose dams

H.Takeuchi, T.Ikeda, S.Nagasawa, and S.Tada

In Japan, in recent years, it has become increasingly important to make the maximum effective use of dams now in operation. At multipurpose dams managed by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) of Japan, the capacity for water use is clearly discriminated between the capacity for flood control and for water use such as power generation etc., but storing part of reservoir capacity for flood control and using it for hydropower generation etc. is considered as a method of more effective use of reservoir capacity. In this case, it is necessary to perform preliminary discharge quickly when flooding is predicted to ensure capacity for flood control, and when performing preliminary discharge, it is necessary to avoid abrupt raise of the water level in the river downstream from the dam. Considering such restrictive conditions, possible capacity for power generation in the capacity for flood control was calculated at two multipurpose dams on T River System, M dam and K dam. And the capacity which can be stored newly in two dams is 27% and between 4 and 6% of capacity for flood control respectively. And the results of a simulation have shown that when the new capacity for power generation has been used up, it is difficult to recover it because of the small inflow into the reservoirs. And the increase of power generation obtained from the capacity newly stored at two dams was small at only about 0.89%. But, in the future it will be necessary to expand such studies to cover all dams in Japan in order to consider the feasibility of increasing generated power.

C. ICOLD 88th Annual Meeting International Symposium & 5th APG Symposium in New Delhi, February 2021

Study of Computational Fluid Dynamics Analysis with Design on the Spillway of Hydroelectric Power Plant

M.Masuda, F.Watanabe, and S.Takano

In modification of the designing of the spillway used in our company's hydroelectric power plant, we conducted a hydraulic model experiment based on the conventional method. Using the results of this experiment, we performed a reproducibility analysis with the aim of substituting computational fluid dynamics (CFD) analysis for hydraulic model experiments in further design changes such as cost reduction studies. Based on the results of our detailed examination of the analysis model, such as changing the mesh size or applying an air entrainment model, we concluded the flow of hydraulic model experiment could be reproduced with high accuracy by CFD analysis. As a result, the prospect of substituting the CFD analysis for the experiment was obtained.

Theme 4 Sophisticated approach for dam operation

B. ICOLD 87th Annual Meeting International Symposium in Ottawa, June 2019

Development of new simulator for training of dam operation and its future outlook

K.Tamura, S.Kano

In recent years, severe floods caused by super-typhoons, linear rain bands and localized torrential rain, etc. occur frequently in Japan. Based on this fact, more advanced and proper dam operation by grasping the water level of the downstream rivers of dams is required to minimize the occurrence of flood damages in downstream of dams, especially in urban areas etc. Japan Water Agency (JWA) has developed a new simulator which enables acquisition of skill for proper dam operation. The developed simulator abounds in ingenuity for training by reproducing close to reality situations for flood control operation through changing the river flow of downstream along with outflow discharge from the dam after reflecting the river flow situations caused by rainfall in upstream and downstream areas. Furthermore, the simulator replicates the transition of rainfall, inflow to the reservoir and water level in downstream of the dam, in addition to the replication of operational feel of dam control facilities and has functions which enable to simulate all of the past floods which have been experienced since beginning of JWA's operation.

Improving prediction of river-basin precipitation by assimilating every-10-minute all-sky Himawari-8 infrared satellite radiances – a case of Typhoon Malakas (2016)

S.Takino, T.Tsukada, T.Honda, and T.Miyoshi

To operate hydroelectric power dams more effectively, it is essential to obtain accurate precipitation forecasts. This study aims to improve precipitation forecasts by assimilating every-10-minute all-sky Himawari-8 infrared radiance observations. We use an advanced ensemble data assimilation system developed in RIKEN. This study focuses on a single case of Typhoon Malakas (2016) which induced heavy precipitation in the mountain region of central Japan. The results demonstrate that assimilating the Himawari-8 radiance observations significantly improves the representation of Typhoon Malakas (2016) and cloud patterns. Moreover, ensemble forecasts initiated from the Himawari-8 data assimilation provide more accurate precipitation forecasts with uncertainty information. In particular, the forecasts with a longer lead time exhibit a better forecast skill compared to the Japan Meteorological Agency's operational regional model. These promising results suggest that assimilating the every-10-minute all-sky Himawari-8 radiances be effective for improving hydroelectric power dam operations by providing more accurate precipitation forecasts.

Dam operation support system utilizing Artificial Intelligence (AI)

Y.Hida, H.Takiguchi, K.Kudo, and M.Abe

In Japan, droughts and flood damages caused by abnormal heavy rain have occurred frequently due to the influence of climate change, so flexible operation that maximizes the function of the existing dam is required. With the change of social situation, efficient dam operation by only a few operators is required. On the other hand, in recent years, with the improvement of the processing capacity of computers, the utilization of artificial intelligence (AI) is becoming widespread. By recreating the dam operation made by using

human intelligence by computer, it is expected to improve efficiency and speed up process judgment. Here, in order to realize the advanced flood routing in dams by only a few operators, we studied the dam operation support system utilizing artificial intelligence (AI).

Application of mechanical facilities support system using tablet terminals for dam management

T.Yoshida, Y.Matsumoto, and K.Sasaki

Activities of operation and maintenance of mechanical facilities for dam management are quite diverse, which include inspection work, support for troubleshooting, and others. There are many management offices, in which only one mechanical engineer is assigned. Therefore, needs for support in improvement of operation and maintenance work, support for troubleshooting, and technical support for young mechanical engineers were growing. To cope with those, we are building a management support system of mechanical facilities using tablet terminals and WEB applications. It helps works such as inputting inspection data, accessing various dates through the network, and several supports by videophone. This paper reports its function and the method of the application.

D. ICOLD 89th & 90th Annual Meeting International Symposium in Marseille, November 2021 and May 2022

Decision support for preliminary release of reservoir for flood control using ECMWF medium-range ensemble rainfall forecast

D.Nohara, K.Kitani, Y.Michihiro, and T.Sumi

developed by considering medium-range ensemble rainfall forecast provided by European Centre for Medium-Range Weather Forecasts (ECMWF) to enhance reservoir's flood storage capability while maintaining its function for water use. Preliminary release operation, in which storage water for water use is released just before a flood occurs, is considered here. The desired timing and amount of preliminary release are estimated from ensemble prediction, maximizing the flood control capacity while securing storage recovery after the flood event. The case study with Shin-Nariwagawa Reservoir in the Takahashi River basin, Japan, demonstrated the effectiveness of introducing long-range ensemble prediction in decision making for preliminary release.

Challenges in flood control operation and dissemination of information -Lessons from the record-breaking heavy rain in July 2018, Japan-

T.Sumi, M.Mitsunari, and T.Hamaguchi

In July 2018, a record-breaking heavy rain hit western part of Japan, leaving severe damages. 213 dams under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) were engaged in flood control operation, and greatly contributed to the reduction of flood damages. Meanwhile, in case of 8 dams, the amount of rainfall was so huge that the emergency spillway gate operation by discharging equal to inflow volume was obliged to execute which caused severe flood damages in some of the downstream areas. In December 2018, Special Panel set up by MLIT finalized a report urging enhancement of flood control capability of dams and dissemination of related information, in preparation for the risk of extreme rainfall which may increase under changing climate condition. This paper briefly introduces the report, outlining the flood control activities at the 2018 flood event as well as the contents of the proposal.

Development of effective pre-release method for dams during super typhoons using long-term ensemble rainfall forecasts

K.Kido, H.Tano, T.Sumi, D.Nohara, Y.Michihiro, and K.Kitani

Against the background of increasing frequency of heavy rainfall due to climate change, an analytical approach to maximize the effective use of the reservoir from both flood control and water utilization was conducted. Simulations by applying statistical down-scaling method to the long-term ensemble rainfall forecast by ECMWF on a dam basin where a large inflow occurred during the Typhoon Hagibis in 2019 were shown. The results show that it is possible to use long-term ensemble rainfall forecasts to gain a temporal, stochastic understanding of total rainfall, required flood storage volumes, and recoverable reserves. Based on this understanding, a calculation method for setting release rates that correspond to effective pre-release start times and changes in rainfall forecasts in order to minimize both flood control and water service risks was proposed.

Development of the snowmelt prediction model using Artificial Intelligence (AI)

M. Abe, H.Takiguchi, and Y.Hida1

Droughts and abnormal heavy rains have frequently occurred in Japan due to the effects of climate change in recent years, and flexible operations that maximize the functions of dams are required. Especially in cold snowy regions, snowmelt water is stored in a dam to cover water demand from early spring to early summer, but during the snowmelt season, a sudden rise in temperature and heavy rain could cause large-scale floods. Therefore, the highly accurate prediction of dam inflow during the snowmelt season is extremely important from the viewpoint of effective use of water resources and prevention of snowmelt floods. On the other hand, in recent years, research utilizing Artificial Intelligence (AI) has also been promoted in the hydrological field.

This study clarified the problems of the conventional physical model (rainfall runoff model) and the prediction model by AI for the inflow of the dam during the snowmelt season in order to support efficient dam management. Then, by constructing a semi-physical model that complements the problems of the physical model and the AI model, we developed a more accurate model for predicting the inflow of snowmelt water during the snowmelt season compared to the single model.

Study on PMP estimation for the flood risk evaluation of hydropower dams in consideration of the future climate change

Y.Kobayashi, E.Nakakita, T.Takemi, Y.Otsuru, and T.Abe

It is important for hydropower dams to estimate PMP (Probable Maximum Precipitation) appropriately and to prepare the plan of facilities modification and operational changes in advance, because the future flood risk by climate change influence is getting higher. In this paper, we compared three methods of PMP estimation, the conventional method applying DAD (Duration Area and Depth) analysis based on the experienced rain results, the product of d4PDF (database for Policy Decision making for Future climate change) that is the latest climate model ensemble prediction, and the pseudo-global warming experimental results on the typhoon.

It was showed that PMP by d4PDF and the pseudo-global warming experimental results were larger than that by DAD analysis and fluctuated smoothly and reasonably over time. It is preferable and reasonable to evaluate the PMP risk applying DAD analysis at the rough examination, and the estimations applying d4PDF or pseudo-global warming experiment is suitable for more detailed examination.

E. 27th ICOLD World Congress in Marseille, June 2022

Dam body behavior monitoring by GNSS on Hachisu dam and applicability

K.Tomita, T.Sumi, A.Suzuki ,S.Jikan, S.Noyori, N.Sato, and C.Araya

Hachisu Dam is a concrete gravity dam, 78 m in dam height. Nearly 30 years have passed since the completion and the dam comprehensive inspection has been implemented. As part of the dam comprehensive inspection, a dam body deformation monitoring system using GNSS was introduced in Hachisu Dam in order to clarify the factors of dam body deformation measured in the plumb line.

This paper first reviewed the dam safety management system in Japan and the status of technical development in GNSS used in existing dams. Then, this paper studied the measurement values of GNSS, which is being used for measurement in Hachisu Dam, and the existing plumb line using multiple regression analysis and verified the applicability of GNSS in the dam body deformation measurement of Hachisu Dam and reported issues to address in the future concerning GNSS.

Benefits of introducing an ICT-based staff support system for disaster response work along the lake Biwa shoreline and its extended uses

M.Nakashima, S.Haruna, Y.Iwamatsu, S.Uchida, A.Goto, and K.Hatano

The Lake Biwa Development Integrated Operation & Maintenance Office (hereinafter "Lake Biwa O&M Office") of the Incorporated Administrative Agency Japan Water Agency faced the challenge of "to establishing a quick, safe and reliable operational system for all staff, regardless of job type" for the operation of drainage pump stations for disaster response work in 2013 during the incidents such as the total paralysis of public transport and road closures caused by flooding. Given the small number of specialized technical staff, there was a limit to how many of the staff can respond to pump and other equipment problems during disaster response work. Thus, it became necessary to make it possible for "all staff to be competent to handle faults at least at a minimum level."

To solve these problems, the Lake Biwa O&M Office developed and introduced two systems that utilize ICT (Information and Communication Technology).

One system is the "Drainage Pump Station Operational

Support System". It makes it possible to operate equipment/facilities by following the image and automated audio navigation steps displayed on a tablet screen, which shows the steps required to operate the drainage pump station in the form of a 'mission card'.
The other system is the "Fault Response Support System". It allows minor faults to be addressed. It uses head-mounted display (HMD) that allows the wearer to communicate with audio and video with support staff using a PC or such from a remote location and receive instructions from them.
The introduction of these two systems (hereinafter collectively called "Staff Support System") has made it possible for non-technical staff (i.e., staff not normally involved in facilities operation/maintenance) who are unfamiliar with procedures to quickly, safely, and reliably operate drainage pump stations at the time of actual disaster response work. These systems have also made it possible to restore the drainage pump station back to normal operation by an on-site operator sending information such as images to a remote location which responds with instructions on what actions to take.
Furthermore, it has been confirmed that the Staff Support System is not only capable of solving problems in disaster response work, but can also be utilized to improve efficiency in a wide variety of applications.
Although the Staff Support System was developed and introduced as a result of the issues that arose in disaster management operations, thanks to its wide range of applications that extend beyond disaster response work, We can expect its use and application in a wide range of fields as a means to realize efficient and effective operation and maintenance using a limited number of staff.

Evaluation of the flood control functions of existing dams in Japan in the context of climate change

H.Kojima, G.Nagatani, M.Kurahashi, I.Kawamura, and T.Sumi

In recent years, the frequency of floods in Japan that exceeded planned scales has been on an increasing trend, and the development of means for addressing increasing external forces has become a pressing issue. The purpose of this study against this backdrop was to conduct quantitative evaluations of the current flood control capacity of existing dams against “current probable maximum precipitation,” and to investigate the need for future measures, taking into account factors such as the roles that each of these dams play in their respective river systems. As a result, We have identified differences between major river systems in Japan as seen in river systems that are equipped with effective dam-based flood control functions, systems with existing reservoir functions that are less than adequate, and systems having water utilization dams which have not been incorporated in flood regulation regimes under flood control plans. We have also shown that if preliminary release operations can be performed in Class-A and Class-B river systems from both existing and hydropower dams, this can potentially provide flood control ability improvements equivalent to that of making dam height extensions.

Development of an advanced operation system for hydroelectric dam using machine learning

S.Takino, Y.Nakada, T.Tsukada, T.Honda, T.Miyoshi
M.Ohhigash, and S.Kotsuki

The operation of a dam at a hydroelectric power plant requires highly accurate precipitation forecast in the basin and the inflow discharge to the dam up to about half a day later. We have developed an operation optimization system for hydroelectric dams that utilizes machine learning. Using machine learning, we were able to predict rainfall and river discharge with high accuracy. As for dam operation, dam operation with high power generation efficiency was performed to keep the dam water level high for a long time without overflowing.

Theme 5 Earthquakes and dams

A. 10th East Asia Dam Conference in Zhengzhou, October 2018

Dynamic behaviour characteristics of Piano Key Weirs

M.Kashiwayanagi, Z.Cao

A Piano Key Weir (PKW) has been developed as free flow ogee crest to provide better hydraulic characteristic than conventional weirs. A PKW additionally features a small footprint due to the over-hanged structure, enabling easer arrangement on the dam crest. Thirty (30) PKWs have been operated worldwide as of 2017. Due to the structural characteristics of a PKW, the seismic safety evaluation is an essential issue in order to apply PKWs for dams located in earthquake prone area. The dynamic behavior of PKW is investigated by numerical simulations using the simple PKW model and the composite model of the dam and the PKW. Directional interference of the oscillation of PKW is a key for the resonance between the dam and the PKW. The water interaction on PKW wall is examined.

B. ICOLD 87th Annual Meeting International Symposium in Ottawa, June 2019

Analytical study on effects of fracture energy for crack propagation in arch dam during large earthquake

H.Sato, M.Kondo, T.Sasaki, H.Hiramatsu, and H.Kojima

In the seismic performance evaluation of concrete dams against large scale earthquakes, crack propagation analysis based on smeared crack model is sometimes performed as a method of nonlinear dynamic analysis to estimate damage process. But it is not easy to set some parameters required for the analysis appropriately, such as fracture energy which is one of the physical properties related to fracture characteristics of dam concrete, due to shortage of the number of full scale experimental tests. In this paper, we reviewed related past experimental studies including static and rapid wedge splitting tests with comparatively large fracture energy, and conducted analytical studies on the effects of difference in fracture energy for crack propagation in a concrete arch dam considering such experimental results data. The results showed that the fracture energy had an important influence on crack distributions and cracks in dam body were localized as fracture energy increased.

Dynamic analysis of a Piano Key Weir situated on concrete dams

M.Kashiwayanagi, Z.Cao, and T.Oohashi

Piano Key Weirs (PKW) have been developed as spillways to provide better hydraulic characteristic than conventional free flow ogee-crest. Due to the structural characteristics of PKWs, the seismic safety evaluation is an essential issue in order to apply PKWs for dams located in an earthquake prone area. To clarify the earthquake-resistant capability of PKWs by numerical analyses, the virtual PKW situating on the concrete dam crest is designed so as to discharge 1200 m3/s. The dynamic characteristics of PKW are investigated by numerical simulations using the PKW unit model, not combined in the dam. The behavior during a large earthquake is analyzed using the PKW model situated on a concrete dam crest of 100 m high. The conclusions are as follows. The predominant frequency of the PKW is almost 10 times of ones of the concrete dam, suggesting that the behavior of the PKW could be lightly affected by the interaction between the PKW and the dam. The investigation of hydrodynamic pressure acting inside of the PKW is challenging for the better seismic design of the PKW. The structural investigation such as reinforcement design and structural detail should be also the challenges to provide adequate earthquake-resistant capacity of the PKW.

C. ICOLD 88th Annual Meeting International Symposium & 5th APG Symposium in New Delhi, February 2021

A Few Considerations on Earthquake Monitoring of Dams

M.Ka shiwayanagi, Z.Cao, and N.Shimizu

A few considerations on earthquake monitoring of dams are introduced in terms of enhancement of earthquake monitoring and safety assessment of dams. These are based on examinations on thousands of earthquake data monitored in major dams of J-Power in more than 50 years in Japan. (1) Transfer function matrix clearly demonstrate that dams under earthquake load behave in a distinctive manner according to material, configuration and foundation condition. While concrete gravity dams behave selectively in upstream-downstream direction as 2D (two-dimensional) structures due to the high stiffness of dam concrete and rock foundation, the behavior of embankment dams is 3D (three-dimensional), attributing to dilatancy characteristics and the relatively low stiffness of materials and rock foundation. (2) Predominant frequencies of dams are various in earthquakes. Analyzing independent monitored data in short time segments clarified that the predominant frequencies decrease relative to the degree of acceleration of dam crest. It is considered that the interaction between the dam and reservoir works stronger in the higher response acceleration of dam. (3) Spillways arranged in the middle section could disturb the earthquake monitoring at the highest section of the dam due to adjoined piers and/or walls of the spillway. The numerical examinations using numerical models with and without spillway structures suggest that the disturbance is slight in acceleration response, but crucial in the stress around spillway. (4) The authors have proposed the new method of GPS (Global Positioning System) self-relative single positioning for the dynamic deformation monitoring of dams. When the new method using high frequency GPS receiver is combined with conventional accelerometers, earthquake monitoring of dams will be easily upgraded to monitor the deformation process during an earthquake simultaneously as well as the acceleration response.

Study on the engineering bedrock and seismic motion at it in the earthquake response analysis of a concrete dam

N.Yasuda, Z.Cao

In Japan, the dam safety against large-scale earthquakes is verified by numerical analysis. Seismic motion defined for verification of seismic performance of a dam is set based

on the distance attenuation formula which is obtained by statistical analysis of the earthquake records of many dams, the empirical Green's function method, and a method of adjusting ground motion record to the stipulated lower-limit acceleration response spectrum for verification. Generally, the input seismic motion for the earthquake response analysis is prepared by pulling the seismic motion back to the engineering bedrock hypothesized by numerical analysis method. However, lacking precise criteria for setting engineering bedrock for earthquake response analysis of a dam, the appropriateness of the preparation method of the seismic motion and of the prepared input seismic motion are not necessarily clarified. This study predicted seismic motion of deep bedrock using earthquake acceleration records during the Tokachi-oki Earthquake in 2003 (M. 8.0) inside bedrock at a depth of 57 m below the bottom of the Satsunaigawa Dam which is equipped with 8 seismographs. Based on the research results, it was pointed out that in the case of concrete gravity dams, the engineering bedrock should be set at a depth equal to about 1.5 times the dam height, and where the shear wave velocity of the bedrock should be no less than 2,000 m/s. Then, a procedure of preparing input seismic motion for earthquake response analysis is proposed.

E. 27th ICOLD World Congress in Marseille, June 2022

Seismic performance verification of a rockfill dam against large doublet earthquakes

N.Yasuda, Z.Cao

The purpose of this study is to clarify the behavior of a rockfill dam during large doublet earthquakes and to propose a procedure for verifying the seismic performance of rockfill dams during such earthquakes. Impacted by a strong earthquake, the dynamic characteristics of the Aratozawa Dam significantly changed temporarily. The behavior of the dam subject to another strong earthquake before its dynamic characteristics had recovered was predicted. Based on the analysis results, the seismic performance of the dam was evaluated. The results clarified that the change in the dynamic characteristics of the dam in response to the first event greatly affected the behavior of the dam during the second event. In addition, a method was proposed for predicting the final residual subsidence of the dam by summing the sliding displacement caused by each earthquake and the subsidence related to the shaking and rearrangement of soil particles. It is recommended that after a dam experiences a strong earthquake, the reservoir is adjusted to a safe water level and maintained at that level for a minimum of one week as an emergency response measure.

Investigation of damping characteristics of dams evaluated by DE/TFM method

M.Kashiwayanagi, Z.Cao

This paper examined the damping characteristics during earthquakes of 100 m high dams based on the monitored earthquake behavior using the DE/TFM method, which is newly invented by authors and uniquely relay on a free vibration extracted from the earthquake response behavior of the dam. The examination focused on the internal damping and dissipation (external damping) due to interaction among dam, foundation and reservoir of a concrete gravity dam, an arch dam and a rockfill dam. Following key findings are captured on the damping characteristics based on the estimated damping ratios of dams examined. The internal damping of concrete dams that is essential parameter for the dynamic analysis is identified as 3 % and 1.5 % for the concrete gravity dam and the arch dam examined, respectively. An additional internal damping proportional to the acceleration degree is inevitable for the arch dam to incorporate the non-elastic behavior such as displacement of transverse joints. Regarding the external damping of concrete dams, ones due to the interaction with the reservoir are identified proportional to the water depth and ones due to the interaction with the foundation are expected as similar degree as other damping. A non-linear dependency on an acceleration amplitude is the outstanding characteristics of the damping of the rockfill dam. It is interpreted that the non-linear properties of dam material depending on shear strain of the dam have emerged. The infiltration of the water into the rockfill dam absorbs the interaction with the reservoir.

Theme 6 Reservoir sedimentation and sustainable development

B. ICOLD 87th Annual Meeting International Symposium in Ottawa, June 2019

Experimental study on effective sediment channel with reservoir topography and morphology

Y.Kitamura, T.Ishino, and T.Okada

Measures to exclude the sedimentation in dam reservoirs are important for the sustainable maintenance and operation of dam reservoirs. There is sediment flushing and pass-through method for measures for reservoir sedimentation. This method is to lower reservoir water level during flooding, to increase tractive force, to accelerate erosion of sediment, to form sediment channel, and to pass sediment through spillway or sediment release gate. This method is economical measure because of utilizing the stream power during flooding. On the other hand, sediment channel formed in the reservoir has a great change in shape of meander and water passages depending on the plan shape of reservoir. Flushing efficiency also greatly differs. For this reason, in order to conduct flushing smoothly sediment in reservoir during flood period and passing effectively through reservoir, a hydraulic study on the sediment channel formed in reservoir is important.
In this paper, we report results of consideration about sediment channel to improve the efficiency of sediment flushing and pass-through during flooding. We investigate about characteristics concerning the sediment channels naturally formed in reservoir and artificially constructed beforehand by excavating and dredging in dry season through the mathematical and the hydraulic scale modelling experiments.

Sediment management plan in Sakawa River – the results of the first phase

Y.Fukuda, R.Akita, and K. Doke

Many sediment management plans are being planned in Japan to manage or recover its sediment routing systems. Among many sediment management plans, one for Sakawa River is characterized by the long-term environmental monitoring which consists of biological (vegetation, fish, benthos, algae) and geological (riverbed materials, riverbed elevation, suspended sedimentation) data. These data have been accumulated in more than 10 years in normal and flood conditions and these are still being accumulated so far. These longterm data of the sediment routing system in Sakawa River are very valuable to investigate the environmental conditions in the downstream area of the dam. The results of the investigation of Sakawa River's geological and biological data monitored until 2017 indicate that coarsening riverbed was temporarily recovered by sediment deposit in upstream area, and the catastrophic damage of severe flood caused by Typhoon Malou in 2010 is recovered in the ecosystem, the condition of riverbed materials and its elevation.

Turbidity control and sediment management using sluicing tunnel at hydropower dam

H.Okumura, C.Onda, T.Satoh, and T.Sumi

Hydropower emits no green-house effect gas and is renewable and domestic energy. It is necessary to solve the problems around dams and reservoirs which will be described in this paper to secure the stability of hydropower supply by effective and sustainable countermeasures. A dam stores not only clear water but also turbid water and sediment in a reservoir during flood. Turbid water stored causes long-term persistence of turbid water in the downstream area of the dam, because this turbid water is discharged repeatedly during generation. Sedimentation causes the loss of the reservoir capacity, obstacle against intake and outlet function, rising water level in the upper area of the reservoir and bad influence on river environment in the downstream area. In this paper, a countermeasure against problems at Futatsuno dam located in Kii peninsula, Japan is studied. It is planned that a sluicing tunnel which connects up- and downstream areas of the dam will make volume of turbid water stored after flood smaller and make sediment bypassing the dam. The numerical simulation has been implemented for the validation on capability of the plan. Then it is concluded that the sluicing tunnel is an effective countermeasure for turbidity control and sediment management.

C. ICOLD 88th Annual Meeting International Symposium & 5th APG Symposium in New Delhi, February 2021

Analysis on sediment transport processes around estuary and coastal shoreline area in the Sagami River Basin to promote reservoir sedimentation countermeasures and integrated sediment management

M.Hyodo, K.Horie, T.Kuchiishi, N.Osaki, T.Asaeda, and M.Sasaki

Sagami River Basin is a Class A River with the length of 113 km and basin area of 1,680 km2, coming from the Mount Fuji and merged with the Nakatsu River into the Sagami Bay in Kanagawa Prefecture. Several dams (8 dams) and weirs have been constructed in the Sagami River Basin. While they have provided numerous benefits to society, they also have negative impacts such as on sediment regimes due to reservoir sedimentation. They have reduced the sediment supply to downstream reaches, resulting in coastal erosion of the Chigasaki Coast, riverbed degradation, fixed-river channels and intensive riparian encroachments, highlighting the need to adopt integrated sediment management at the river basin scale. Several measures have been implemented using removed-sediment from dam reservoirs, such as direct sediment augmentation on the shorelines eroded, and indirect one on the riverbed expecting the sediment to be transported to the coastal shoreline. However, sediment transport processes are yet to be revealed, particularly around the lower reaches, i.e. from the river mouth and estuary area to coastal shorelines, where sand terrace around the river mouth has been decreased and may not be much functional in transporting sediment from fluvial systems to coastal shorelines. The governmental committee composed of Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT), Kanagawa prefectural governments, and Yamanashi prefectural government, issued the “Integrated Sediment Management Plan for the Sagami River Basin” in 2015, in close consultation and collaboration with the Committee on Integrated Sediment Management for the Sagami River Basin, in order to efficiently and effectively promote sediment management in an integrated and collaborative manner. This paper provides some results of quantitative evaluations of the sediment transport processes in order to develop the Plan and proposes a hypothesis of sediment transport processes in the Sagami River Basin, analyzing geographical survey data and numerical simulation results of fluvial and coastal systems, which is: “sand sediment transported from the Sagami River to the estuary area has been transported to the shoreline of the Chigasaki Coast by coastal waves though slowly”. If this hypothesis is revealed, we can quantitatively evaluate the sediment volume, which is needed to come from the Sagami River to the estuary area, in order to decelerate the coastal erosion and sustain the coastal shoreline of the Chigasaki Coast. This quantitative evaluation enables to determine goals of sediment transport processes to be achieved for integrated sediment management involving various stakeholders.

Bedload transport and abrasion monitoring at the Koshibu Dam sediment bypass tunnel and proposing countermeasures against the abrasion problem

T.Koshiba, T.Sumi

Sediment bypass tunnels (SBTs) is a leading technique, mainly operated in Japan, Switzerland and Taiwan, to mitigate sedimentation problems in reservoirs. SBT reduces sedimentation by di-verting sediment laden flood to a tunnel and draining directly to the downstream reach. A major issue in operating SBT is hydro-abrasion on the tunnel invert caused by a combination of high sediment transport rate and high flow velocity, whereas the countermeasure is not well established because the relation between sediment transport rate and the abrasion is not clear. Accordingly, at the Koshibu dam SBT in Japan, sediment transport is being monitored with a surrogate bedload monitoring system called an impact plate during all the SBT operations since the SBT completion in 2016. In addition, the abrasion of the entire tunnel invert is measured once a year using mobile mapping system (MMS) with a three-dimensional laser scanner. In this paper, monitoring results including grain size and transport dynamics, i.e. velocity, transport rate, spatiotemporal distribu-tion of bypassed sediment, and current progress of abrasion are reported. On the basis of those observation, design and operation of SBTs that may reduce invert abrasion with maintaining the suitable bypass efficiency is proposed.

Sedimentation management utilizing sluicing operation at the Setoishi dam

H.Okumura, C.Onda, and T.Sumi

The Setoishi hydropower plant on the Kuma River has been operating since 1958 in Kyushu area, Japan. Sedimentation rate of the reservoir is under 10%, but the risk of inundation around the reservoir exists during floods. As countermeasure, excavations with emptying the reservoir have been conducted since 2011. However, this is not sustainable: the amount of sediment to be excavated is too large, and power generation needs to be shut down. With this background, sluicing operation which is draw-down operation during flood to let sediment flow down through the spillway has been studied and the operation rules were aided by nu-merical analysis.

In 2016 and 2017, the test operations were conducted, and it was found that the rules were effective. In June 2018, the regular operation started, and a large flood took place with a maximum dam inflow rate of 4,450m3/s in July, equivalent to a 10-year flood. In this flood, 154,000m3 of sediment, that is 15% of the reservoir sediment, flowed down through the spill-way.

The sluicing operation needs improvement to minimize the risk of inundation. We have identified key improvement factors such as modification of the operation rules and removal of large rocks and coarse sediment left in the reservoir.

D. ICOLD 89th & 90th Annual Meeting International Symposium in Marseille, November 2021 and May 2022

Study on the Koshibu Dam sediment bypass tunnel operation based on sediment transport monitoring in upstream reaches

T.Koshiba, S.Miura, and T.Sumi

SBTs are a leading technique to mitigate reservoir sedimentation. SBTs consist of a tunnel connecting the upstream and downstream areas of a dam and diverting sediment-laden flood directly during flood events. A difficulty in operating SBTs is to reduce sediment inflow into the reservoir effectively, and at the same time, to sustain the dam functions: flood control and hydropower generation. These requirements settle on an optimization problem determining the timing to open and close the SBTs gates with the hydrograph and inflow sediment considered. Despite many studies on SBTs operation considering hydrograph, there are few of those on the temporal change of sediment inflow. Accordingly, this study aims at improving SBTs operation by understanding sediment inflow from upstream reaches using an indirect bedload monitoring system called impact plates. For that, the Koshibu Dam SBT was picked up because impact plates are already placed in several locations in the basin including inside of the SBT. This observation has revealed the amount of transported sediment in every season in a year, the relation between hydrograph and sediment inflow, and the spatial transient of sediment transport peaks. According to these observations, desirable rules for SBTs operation are suggested.

E. 27th ICOLD World Congress in Marseille, June 2022

Characteristic Evaluation And Countermeasure Planning Of Reservoir Sedimentation Utilizing The Long Term Survey Data In Hydropower Dam

H.Okumura, T.Sumi

The sedimentation management of hydropower dam reservoir is one of the major problems for the sustainable operation of the plants in Japan. In order to evaluate the sedimentation characteristics and plan a sedimentation management, utilizing the results of annual sedimentation survey data that has been conducted for several decades and has survey error is studied. It is found that, averaging the survey data is effective to eliminate the error and grasp the relationship between annual maximum dam inflow and annual sedimentation volume. Utilizing the relationship and numerical analysis, draw-down operation with spillway remodeling is useful to sustain the function of the hydropower reservoir.

Theme 7 Water quality, environmental conservation and social consideration

B. ICOLD 87th Annual Meeting International Symposium in Ottawa, June 2019

Development of a prediction model used in measures for reducing mold odor in dam reservoirs

Y.Okada, K.Shima, K.Okabe, N.Arakawa, Y.Watabe, M.Hongou, and H.Kushibiki

The introduction of water quality conservation facilities is an effective measure for reducing mold odor in dam reservoirs. However, depending on the hydraulic and water quality conditions, the countermeasures of changing the dam operations both by shortening detention time and by lowering surface water temperatures may be efficient and effective. This paper analyzes the results of field investigation and past surveys, clarifies the mechanism of mold odor occurrence in T dam, and develops a simple model that enables prediction and prevention of mold odor occurrence. The model makes it possible that dam administrators pre-vent mold odor by entering daily dam management data (inflow, outflow, and reservoir water temperature).Main factor of mold odor occurrence in T

Dam is growth of Cyanobacteria in dam reservoirs. And we clarified Cyanobacteria could grow under certain situation, such as long detention time, a lot of nutrient salts and higher water temperatures. The developed simple model can estimate the degree of risk of mold odor. Therefore, it enables to predict the effects of the countermeasures by the revised dam operation.

Comparison of reproducibility of water temperature and water temperature stratification formation by different methods in dam reservoir water quality prediction model

F.Kimura, T.Kitamura, Y.Tsuruta, T.Kanayama, R. Kikuchi, Y.Kitamura, T.Morikawa, and Y.Okada, Y.Fukuda, T.Shoji, A.Mieno, T.Suzuki, and M.Kobayashi

In order to properly maintain the water quality of the dam reservoir, it is necessary to properly operate the dam facility and the water quality preservation facility installed. In determining these operation methods, simulation using the water quality prediction method plays an important role. However, since there are differences in the basic formula and the discretization method of each water quality prediction method, it is inferred that the reservoir characteristics simulated do not always harmonize ones by other methods from the reproducibility point of view. In this paper, we focused on the water temperature, which is the most basic item among water quality predictions of the dam reservoir. We picked up some methods of water quality prediction that have been ever applied in dam reservoirs. The simulation results are compared in term of the formation conditions of water temperature and water temperature stratification in three case studies to verify the reproducibility and the distinction of each method.

National census on river and dam environments in Japan and utilization for appropriate dam management using the results

T.Osugi, E.Akashi, K.Yamaguchi, H.Kanazawa, and M.Nishikawa

National Census on River and Dam Environments in Japan is a periodical investigation for the purpose of collecting basic information about the environment of dam reservoirs and covers biological investigation and investigation on the number of tourists of the dam reservoir in Japan. This census targets at eight categories of plants and animals, such as fish, benthic animal, plankton, birds, etc. for the purpose of nationwide assaying the environment of a dam reservoir and its surrounding by accumulating data with keeping the survey accuracy. It has been carried out more than 20 years since 1990. In this paper, the objective species were selected and analyzed among the alien species expanding these population from the viewpoint of the dam and its lake management and environmental continuity of up- and downstream of the dam. For example, it has been found that Golden Mussel clogs water pipes and makes a great influence on hydroelectric power generation and that other alien species expanding its distribution makes a great influence on fishery activity. By utilizing this National Census Data we believe it is possible to upgrade dam management appropriately.

C. ICOLD 88th Annual Meeting International Symposium & 5th APG Symposium in New Delhi, February 2021

Dam break accident and resulting sediment management at downstream dams in Lao PDR - Highly turbid flood-flow and sediment flushing at Nan Ngiep 1 Hydropower Project -

T.Tabuchi, Y.Aosaka, Y.Murakami, and S.Tsutsui

In September 2017 a dam of the A Project, which is located 90 km upstream of the Nam Ngiep 1 Hydropower Project (NNP1) in Lao PDR, collapsed during construction and partially stored water of around 500,000 m3 in the reservoir was flushed away to the downstream river course. The highly turbid water had a serious impact on the ecology of the downstream river course, and sediment of around 700,000m3 was accumulated in main dam and the re-regulation dam reservoirs of the NNP1, while the turbid water flew through the diversion of the main dam of the NNP1 located 7 km upstream of the re-regulation dam which was under construction. It was feared from the beginning that when starting the operation of the re-regulation dam reservoir, the anaerobic and deteriorated clay and silt could be released together with the environmental flow through the re-regulation dam reservoir, and thus impact the ecology of the downstream river basin. In order to mitigate this harmful impact, the NNP1 determined to implement sediment flushing in the early dry season of 2017, when the NNP1 River had a certain volume of the flow before starting the initial impounding scheduled in May 2018. This paper presents the dam break impact on the downstream river course and the resulting sediment management at the downstream NNP1 reservoirs.

Backwater effect and compensation due to dam construction on Nam Ngiep 1 Hydropower Project in Lao PDR

K.Nakamura, T.Takahashi, K.Tomioka, and S.Tsutsui

A 167 m high concrete dam was constructed related to the Nam Ngiep 1 Hydropower Project in Lao PDR and, as a result, a reservoir of 67 km2 emerged. At the upper reaches of the reservoir, local residents enjoyed cultivation at the flood plain and near the riverbanks and a few houses existed in the expected inundation area by the reservoir. The residents feared that they would lose the land where they bore their lives and further land would be inundated by the backwater effect of the reservoir. The Nam Ngiep 1 Power Company (NNP1PC) estimated the inundation area based on a flood mark survey and a flood inundation simulation; and subsequently installed pegs as a benchmark for compensation measures and to show the predicted inundation area to the villagers. In addition, NNP1PC studied the possibility of drawdown during the rainy season to achieve an economic balance between minimised need for compensation and the loss of power generation. This paper presents the process of survey, study and compensation related to the backwater effect of the reservoir.

Operation of the selective water intake facility of Sameura Dam, taking account of downstream water temperature and turbidity

M.Tsuda, M.Moriya

Release of low-temperature water during summer and prolongation of muddy-water discharge from the dam reservoir after extreme floods have been big challenges in the operation of the Sameura Dam in Japan since the beginning of its operations in 1975. Release of low-temperature and muddy-water has a negative impact on fisheries and downstream water use. To address these issues, the surface-water-intake facility was converted to a selective water-intake facility in 1999. Since the conversion, the level of water withdrawal has been changed according to the vertical profile of water temperature and turbidity in the dam reservoir as observed by a real-time monitoring system. The rules of operation were determined through discussions with academic experts, local people, and river managers. Water-intake elevation has been set to be relatively low, and water temperature is cooler than that in the surface layer while also meeting the target level to conserve warm water. High-turbidity water is selectively discharged during flooding for early release of suspended matter. In our research, we quantified the effect of the operation by using a two-dimensional vertical water-quality model that numerically simulates water temperature and turbidity in the dam reservoir and downstream.

D. ICOLD 89th & 90th Annual Meeting International Symposium in Marseille, November 2021 and May 2022

Establishment of the comprehensive river environment conservation system in collaboration with river stakeholders on the Tenryu River

Y.Kitamura

The sedimentation, turbid water and water quality are typical environmental issues for dams and reservoirs which have impact on the reservoir and downstream of dams. These impacts are influenced from the upstream of a dam, and influence to the downstream. Therefore, a more integrated environmental management approach and consideration have been required for the whole river system. The Tenryu River in Japan flows through the erodible area near the Median Tectonic Line on Honshu, the main island of Japan, and continuously carries a lot of sediment during floods. The “Tenryu River Natural Resources Rebirth Promotion Committee” was established in 2012. The purpose of the committee is to restore fish resources and improve the river environment. The feature of the liaison committee is that it is composed of the Tenryu River fisheries association, academic experts, and dam owner and exchanges knowledge and technology information in spite of each interest. The current activities are related to the theme of "attached algae/environmental DNA survey", "turbid water measures in reservoir/spawning bed construction technique at downstream," and "information dissemination". In this paper, the activities of the comprehensive reservoir and river environment conservation system in collaboration with river stakeholders are introduced and described, including future prospects.

E. 27th ICOLD World Congress in Marseille, June 2022

Simultaneous multi-gate withdrawal with free-selective air-lock intake equipment in Tono dam, Japan

T.Suzuki, H.Yajima

Simultaneous multi-gate withdrawal (SMGW) with selective intake equipment in dam reservoir has hardly been reported in Japan. In this paper, the hydraulic phenomenon and water intake characteristics of SMGW have been verified by field observation and numerical analysis for Tono Dam (Tottori Prefecture, Japan) in which SMGW operation has been conducted. First, as a result of the field observation, the tendency was confirmed that the amount of water taken from each intake pipe by SMGW is not the same while larger amount of water is taken from the lower intake pipe under the condition that thermocline is formed. Next, the mixing mechanism of water quality inside the intake tower was clarified by numerical model that can reproduce the observation results for the intake tower. Finally, after the estimation of influential factors on the water intake rate of SMGW by sensitivity analysis, the water intake rate under SMGW operation can be estimated by applying the water-intake stability factor based on the ratio of the buoyancy occurring by thermocline to the inertial force induced by water intake.

Mitigation of social impacts by the Yamba dam project

G.Yasuda, K.Watanabe

The Yamba Dam, located in Gunma Prefecture, central Japan, was completed in 2020. The construction project has been opposed by local residents and was deadlocked for more than 30 years. One of the key devices which helped resolve the dispute and ensure that the burdens and benefits are fairly shared between the beneficiaries of the project and the locals around the dam was Japan's Act on Special Measures for Reservoir Area Development (ASMRAD). This paper first explains the features of the Yamba Dam and its history, followed by an outline of the ASMRAD. Applications of the ASMRAD and its affiliated Reservoir Area Development Fund (RADF) for the Yamba Dam are explained to highlight the effectiveness of the ASMRAD and its contribution to the project. Other measures used to mitigate the social impacts of the project are also described. Unique contributions of the dam owner and the main contractor to attract social attention and visitors proved that effective communication with the public can contribute to the regional economy and help mitigate social impacts. Finally, a provisional evaluation of the overall mitigation measures is described.

Editorial Committee for Dams in Japan

Chief editor: Goro YASUDA
Advisor: Hideki HIRAI, Ph.D
Member: Chihaya ONDA
Kensuke HAGIWARA
Toru HOSHINO
Yuta KANNO
Shigeru IKEDA, Dr. Eng.
Mitsuhiro YOSHIDA
Tatsuya MIZUNO
Hiroshi KURAHASHI
Junichi FUKUWATARI