Dams in Japan Overview 2025

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

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 2025).

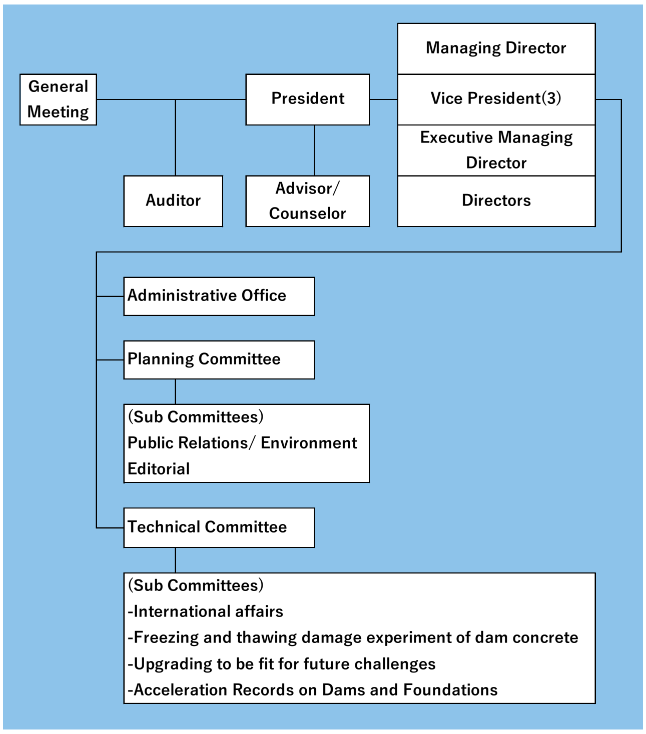


Figure-1 Organization Chart of JCOLD

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 Current Activities on 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, 2018 and 2022).

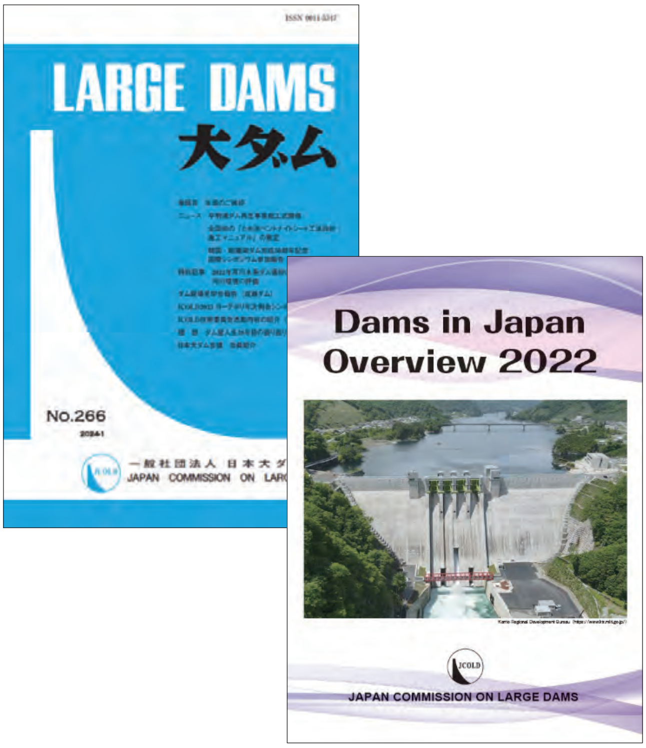


Figure-2 Publications of JCOLD

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 (2023)

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 Naruse Dam (2023)

Contribution to ICOLD

JCOLD submitted 398 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 Meetings 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), Tadahiko SAKAMOTO(2011-2014) and Tetsuya SUMI(2023-) 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 (Antalya)	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
2022	France (Marseille)	7
2023	Sweden (Gothenburg)	62
2024	India (New Delhi)	64

Table-2 Number of submitted papers

Year	No.	Host country (Host city)	Number of submitted papers
1933	1	Sweden (Stockholm)	3
1936	2	United States (Washington)	5
1955	5	France (Paris)	4
1958	6	United States (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)	9

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.

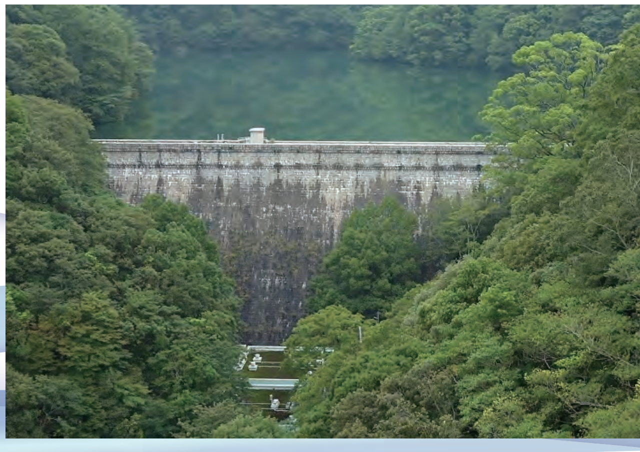


Figure-5 Nunobikigohonmatsu Dam

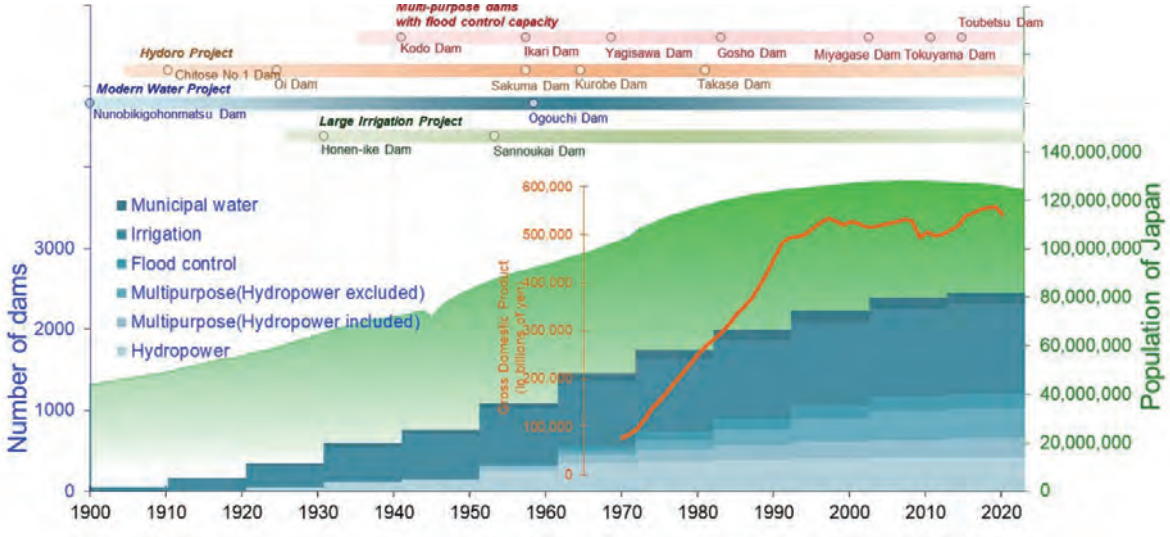


Figure-6 Development of Dams, Economy of Japan and Population

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 Tokuyama Dam

Figure-8 Miyagase Dam

Hydroelectric power plants in Japan

The output of hydroelectric power plants in Japan accounts for about 19% 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	Shinojiya	206	Miyanaka Dam
9	Hitotsuse	180	Hitotsuse Dam
10	Shinanogawa	177	Nishiotaki 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 2021 - 2023 in Japan

Dams completed in 2021-2023 in Japan are counted in 6 dams. The features are summarized below.

Dams Completed in 2021-2023 in Japan are counted in 6 dams. The Features are summarized below. These dams are illustrated in the following pages.

	Name of Dam	Location	Dam					Owner	Com-pleted
			Purpose (s)	Type	Height (m)	Length of Crest (m)	Reservoir capacity (kilo.m^3)		
1	Yanagawa	Iwate	C,S,H	PG	77.2	243	19,100	Iwate. Pref.	2021
2	Togo	Hokkaido	I	ER	47.5	375	510	Hokkaido Development Bureau, MAFF*1	2021
3	Koishiwara-gawa	Fukuoka	C,S	ER	139.0	558	40,000	Japan Water Agency	2021
4	Tamarai	Oita	C	PG	52.0	145	4,090	Oita Pref.	2022
5	Biratori	Hokkaido	C,S	PG	55.0	350	45,800	Hokkaido Development Bureau, MLIT*2	2022
6	Aigawa	Osaka	C	ER	76.5	338	18,000	Osaka Pref.	2023

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

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

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

*1 Ministry of Agriculture, Forestry and Fisheries

*2 Ministry of Land, Infrastructure, Transport and Tourism

Yanagawa Dam

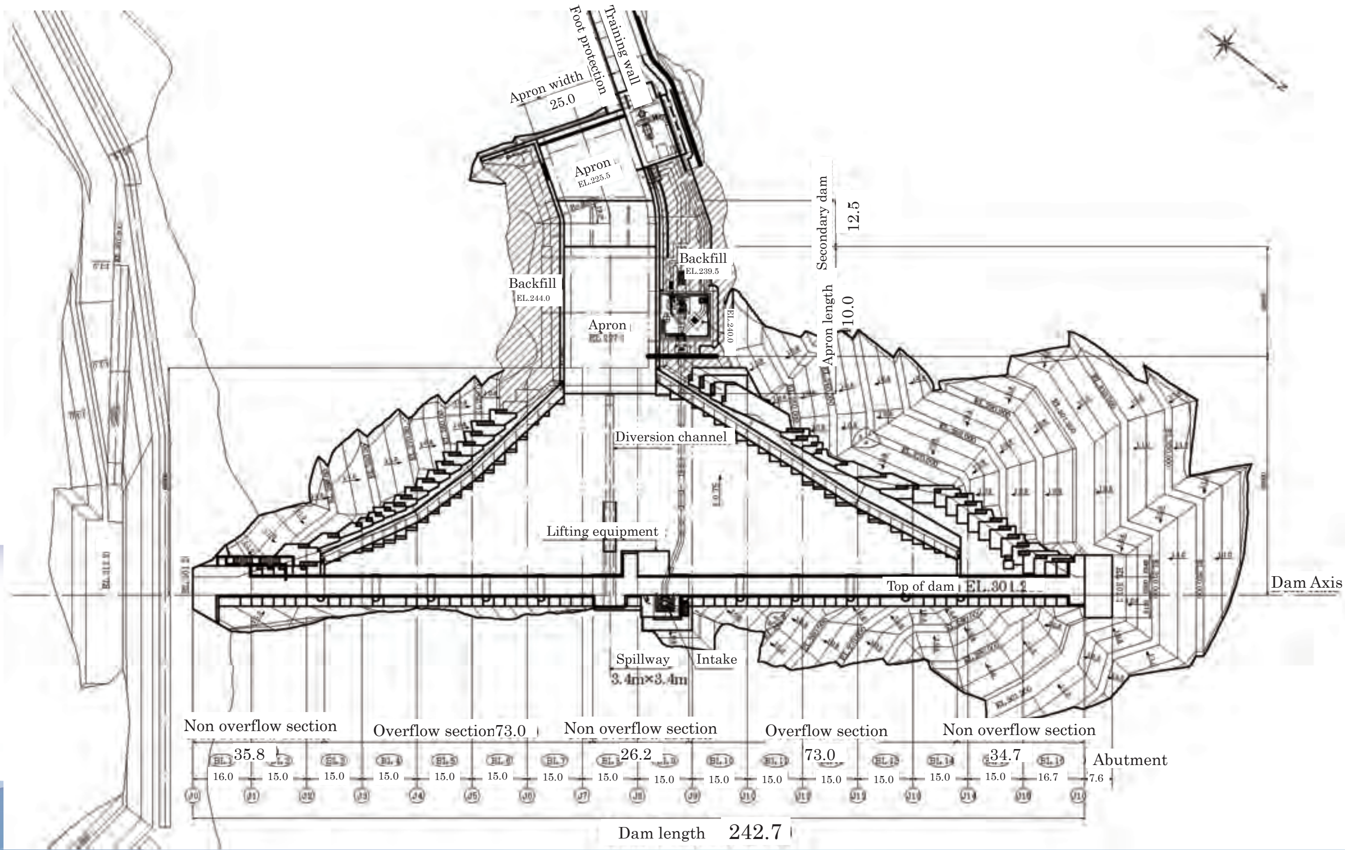


Figure-1 Plan

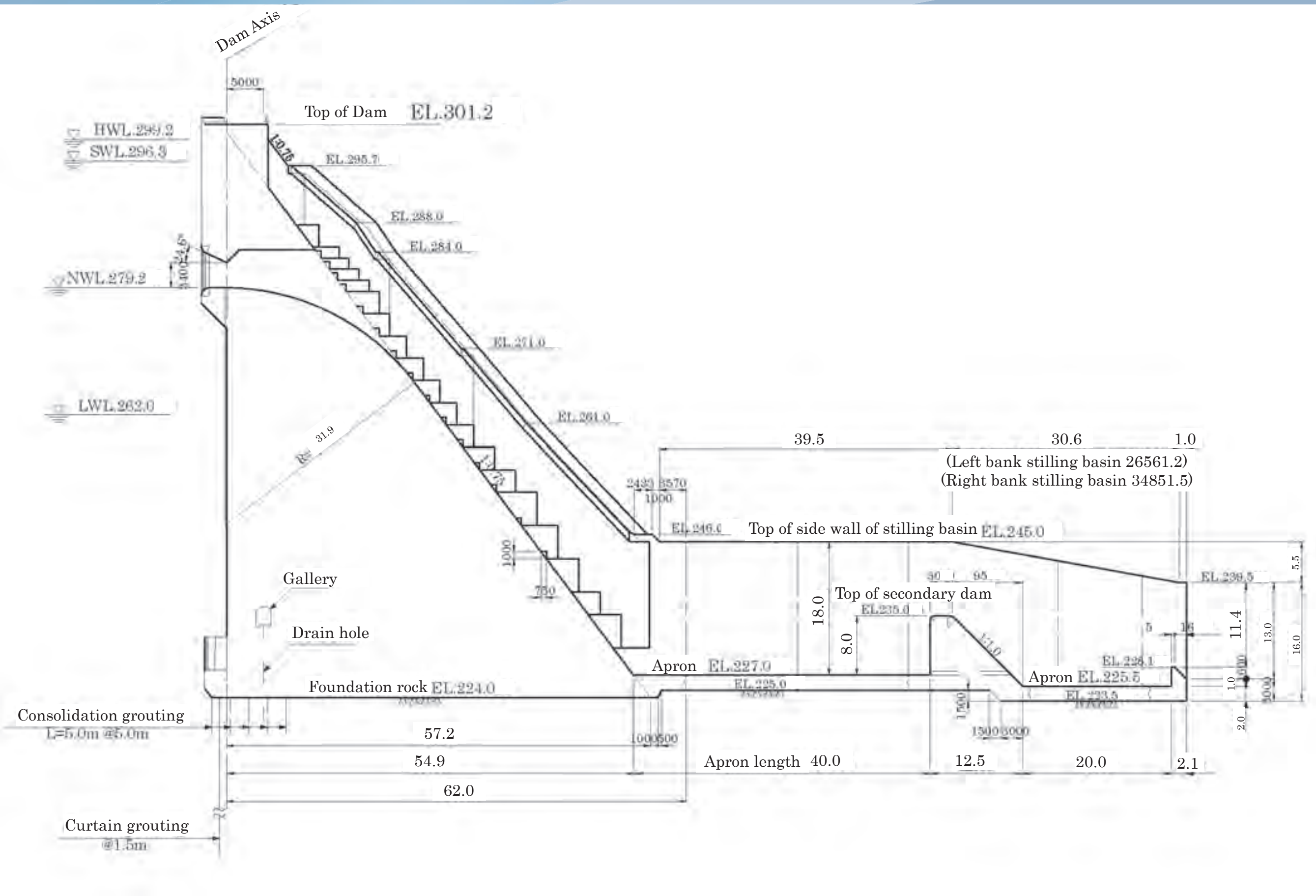


Figure-2 Typical section

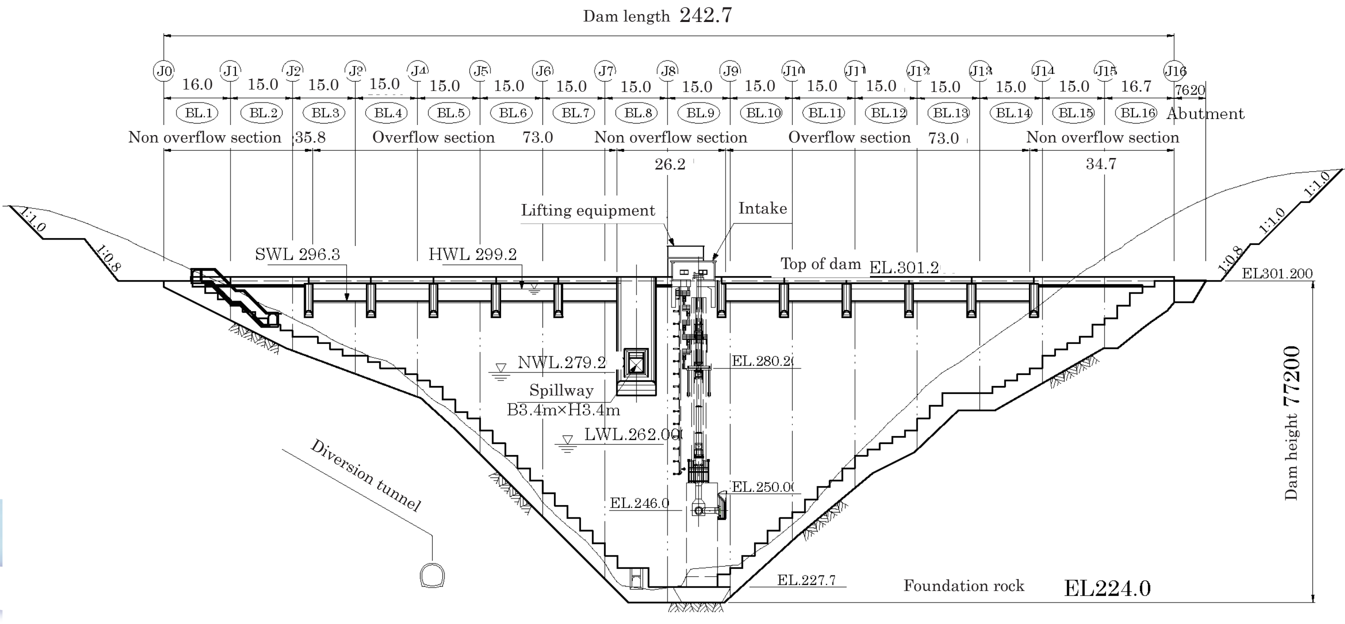


Figure-3 Upstream face

Togo Dam

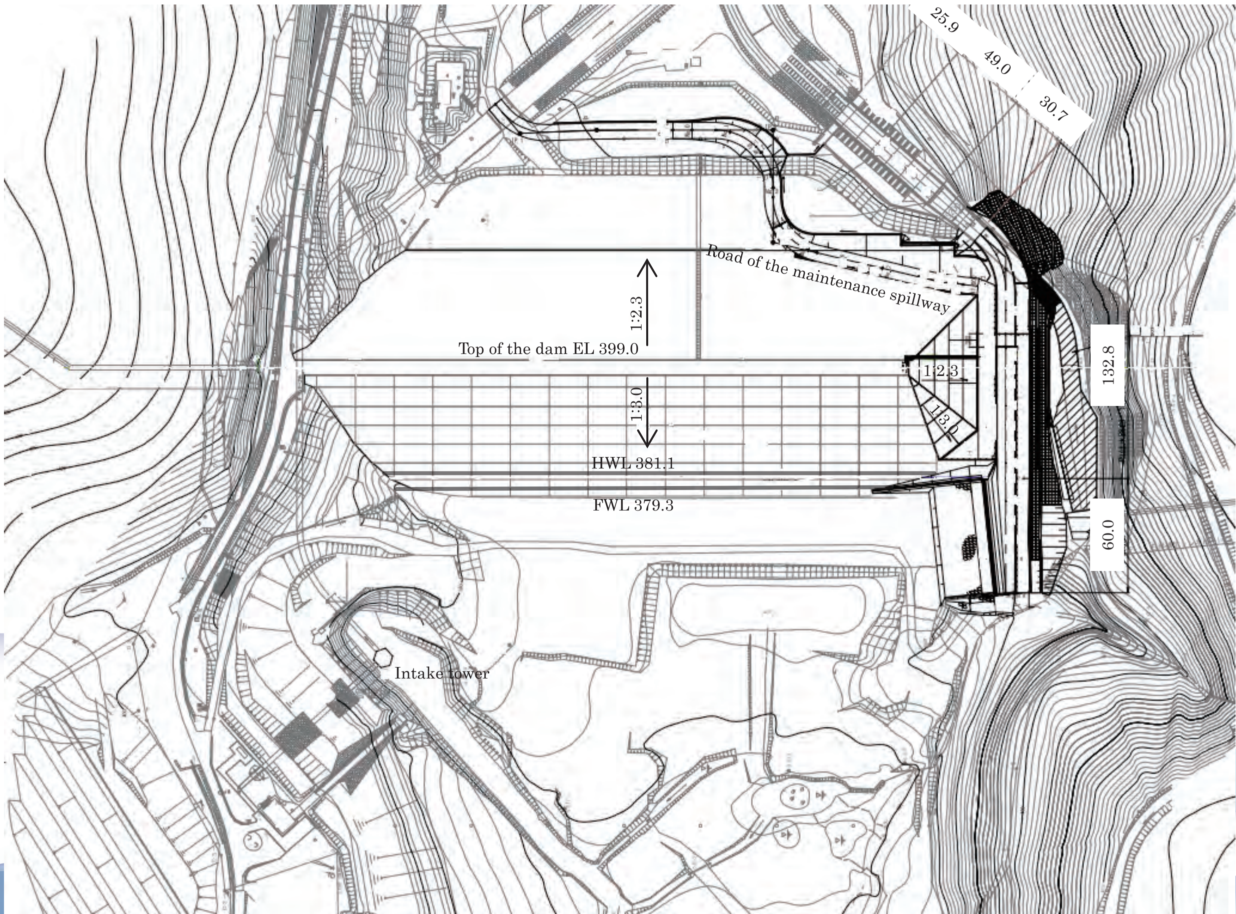


Figure-1 Plan of upper reservoir

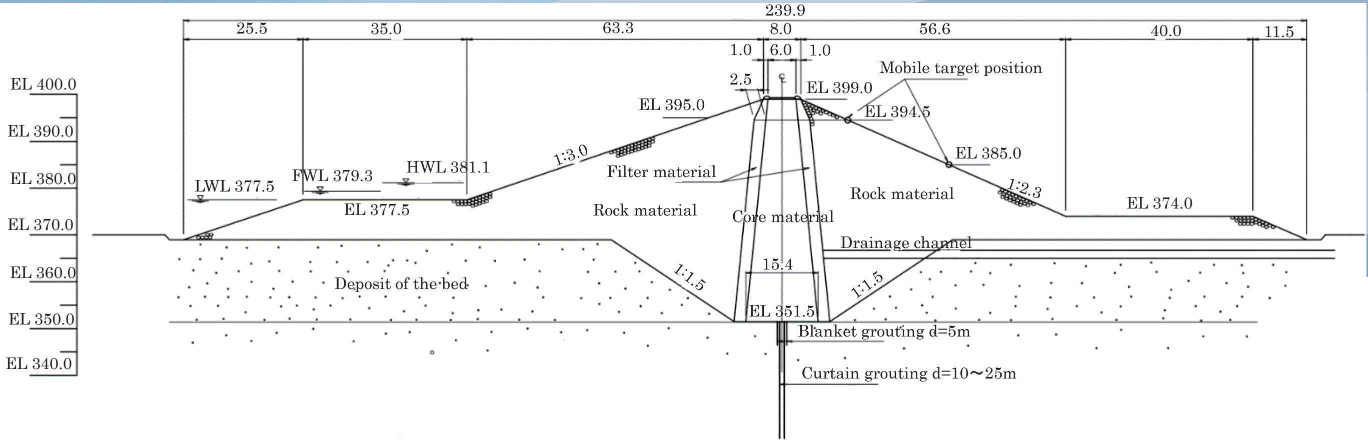


Figure-2 Longitudinal cross secition

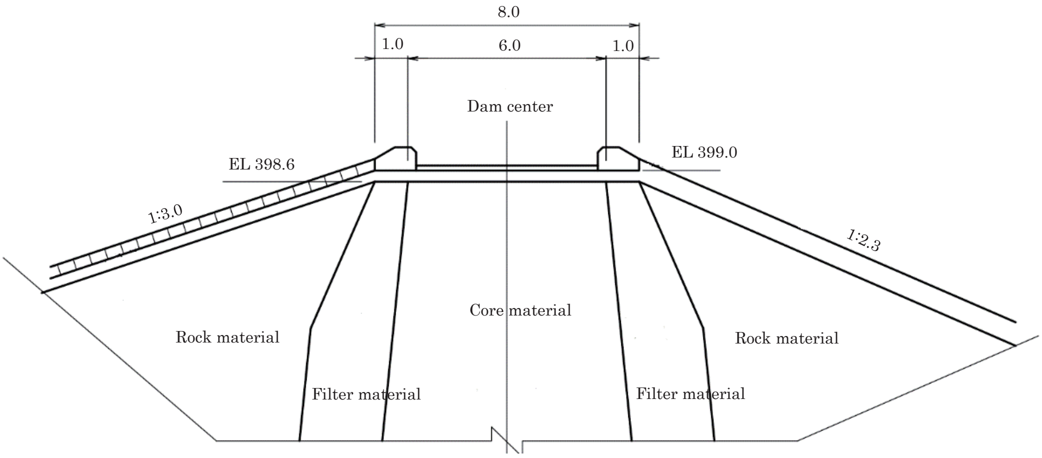


Figure-3 Cross section of the dam top

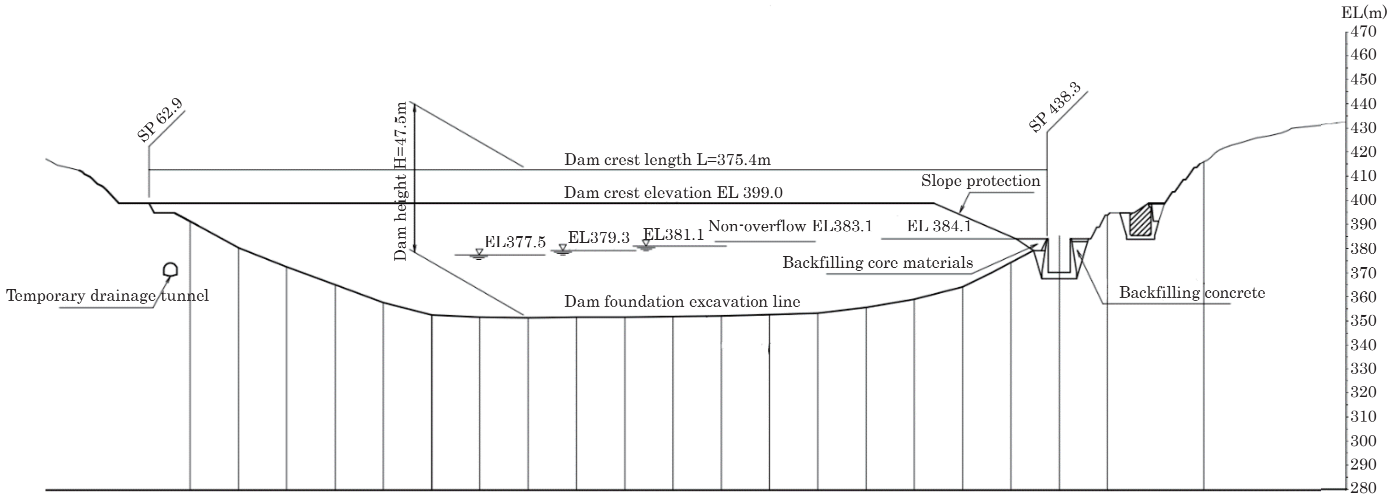


Figure-4 Upstream face

Koishiwaragawa Dam

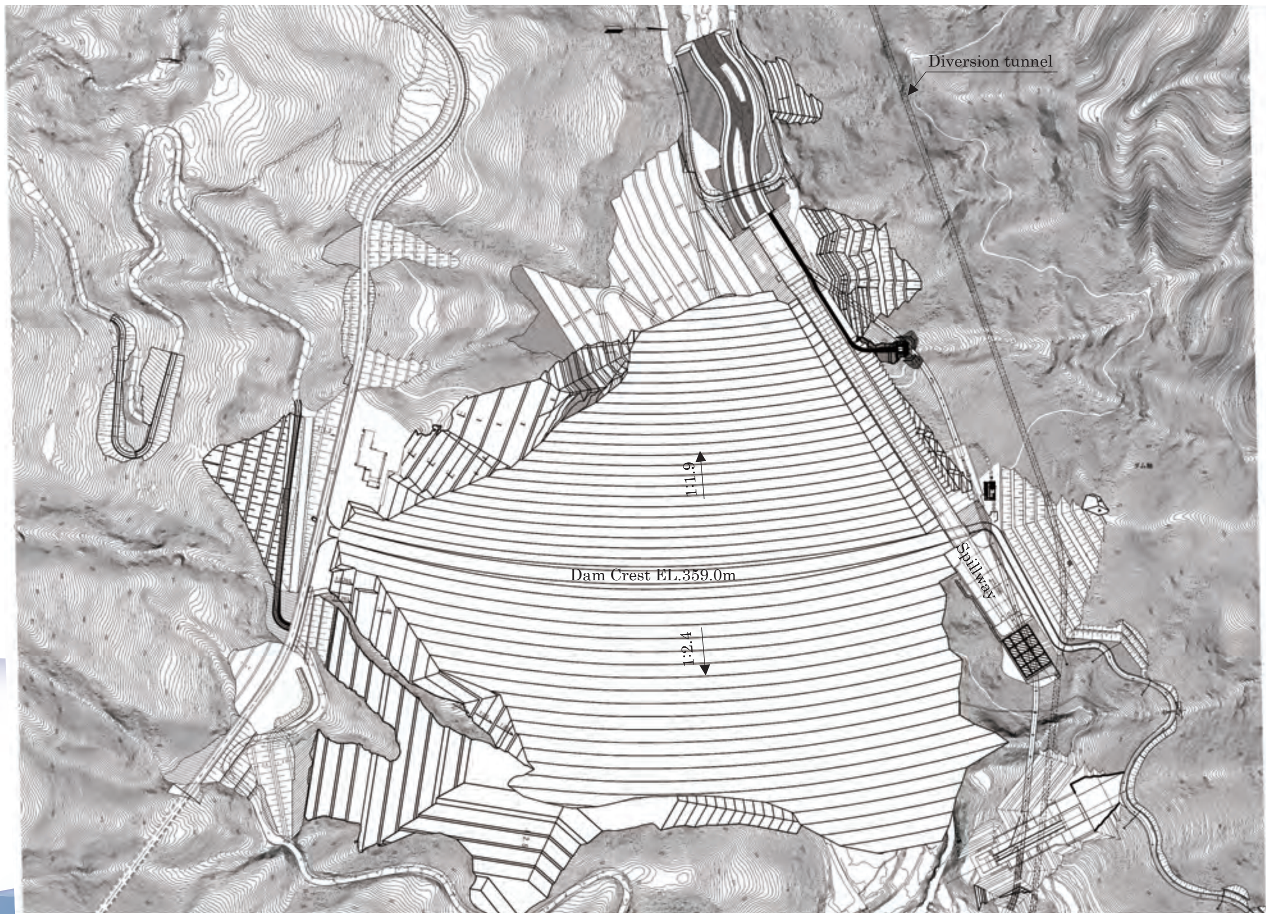


Figure-1 Plan

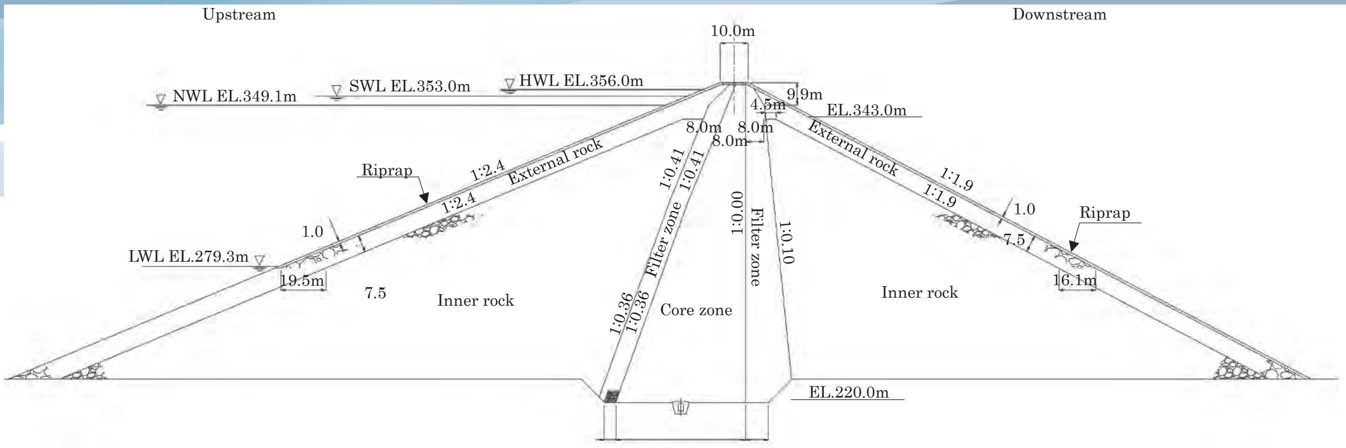


Figure-2 Typical Section

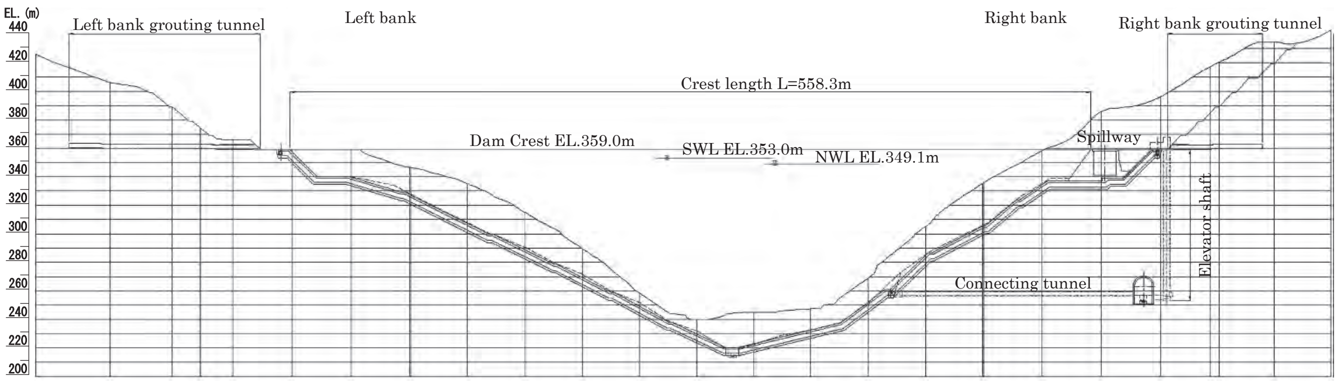


Figure-3 Longitudinal profile

Tamarai Dam

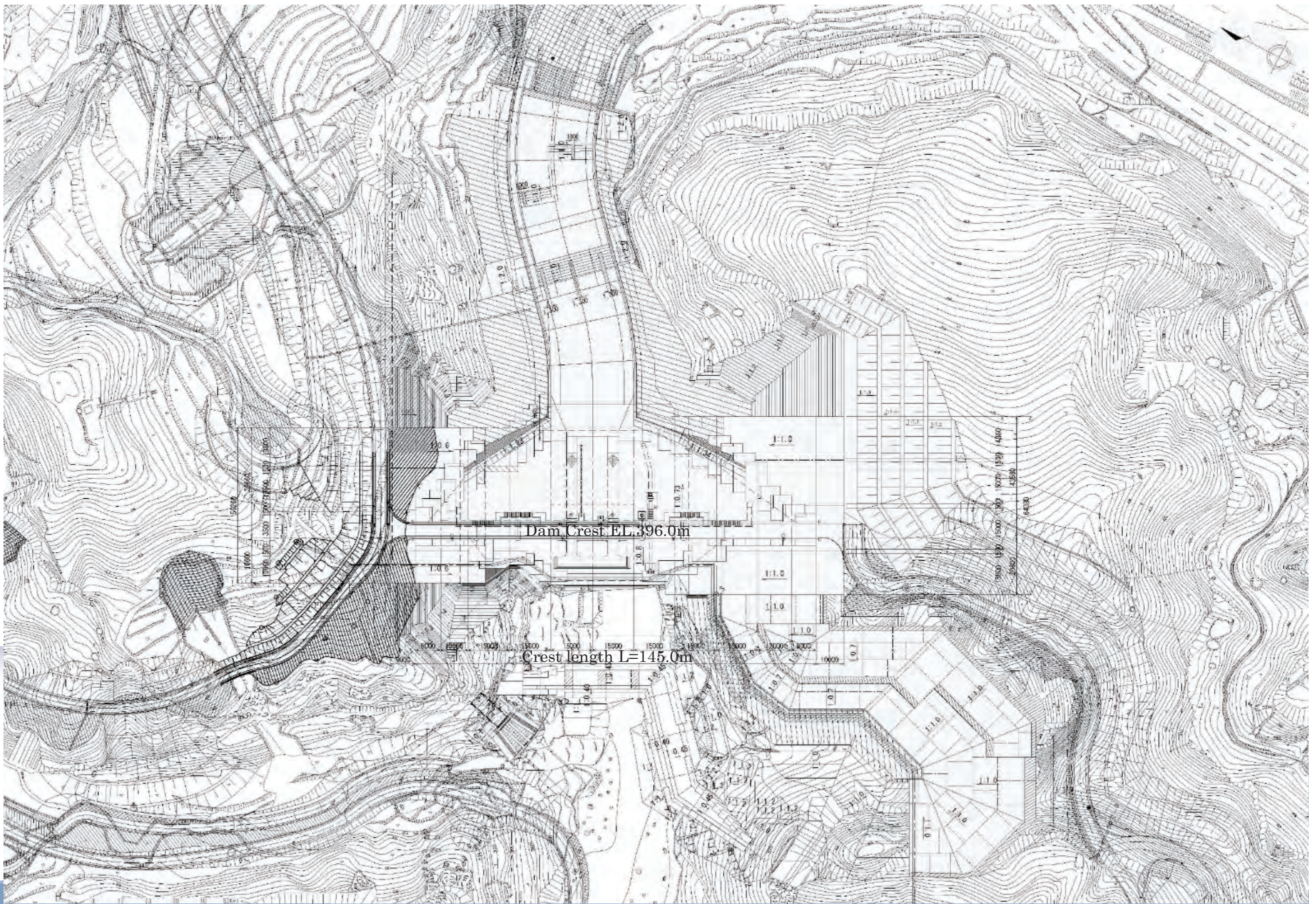


Figure-1 Plan

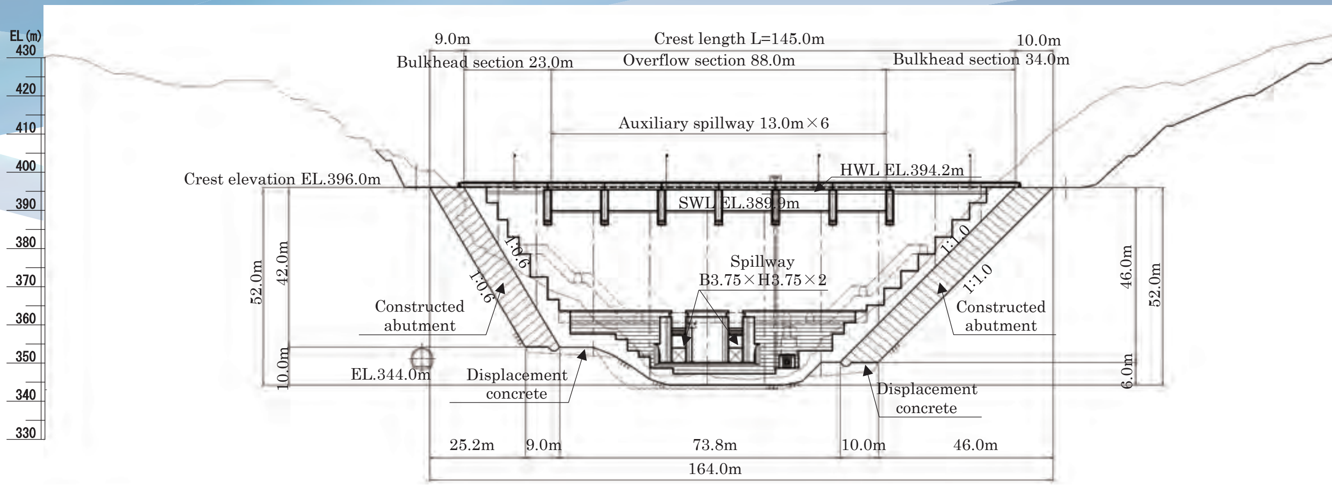


Figure-2 Up stream face

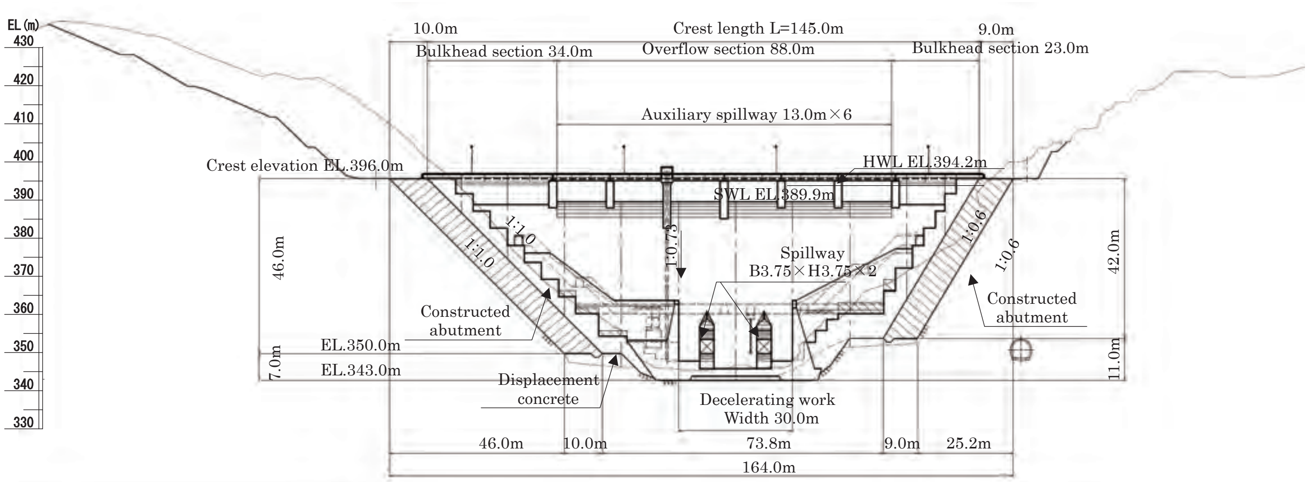


Figure-3 Down stream face

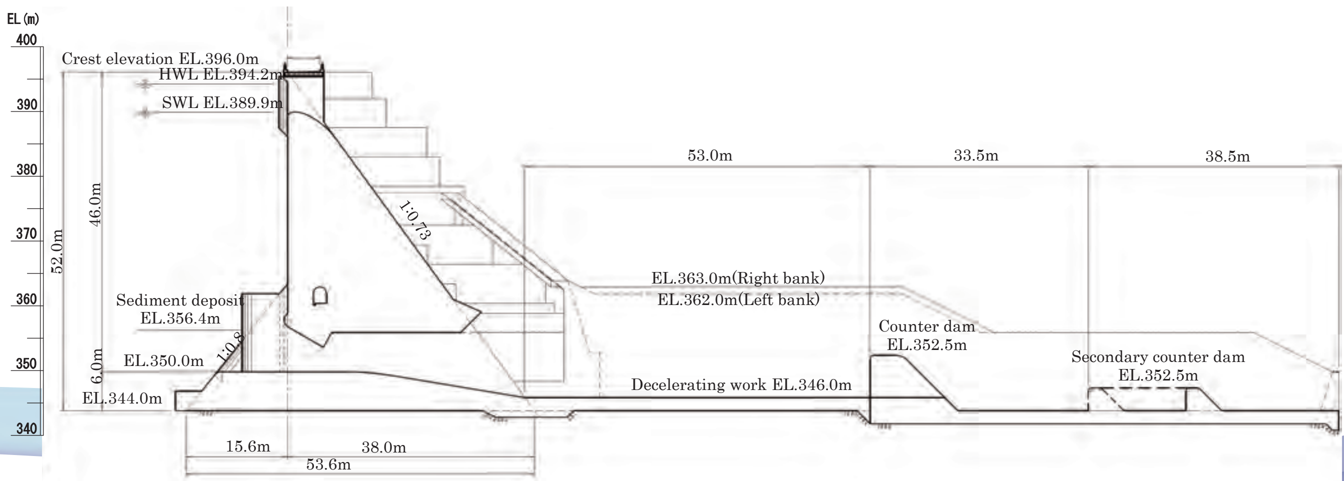


Figure-4 Typical Section

Biratori Dam

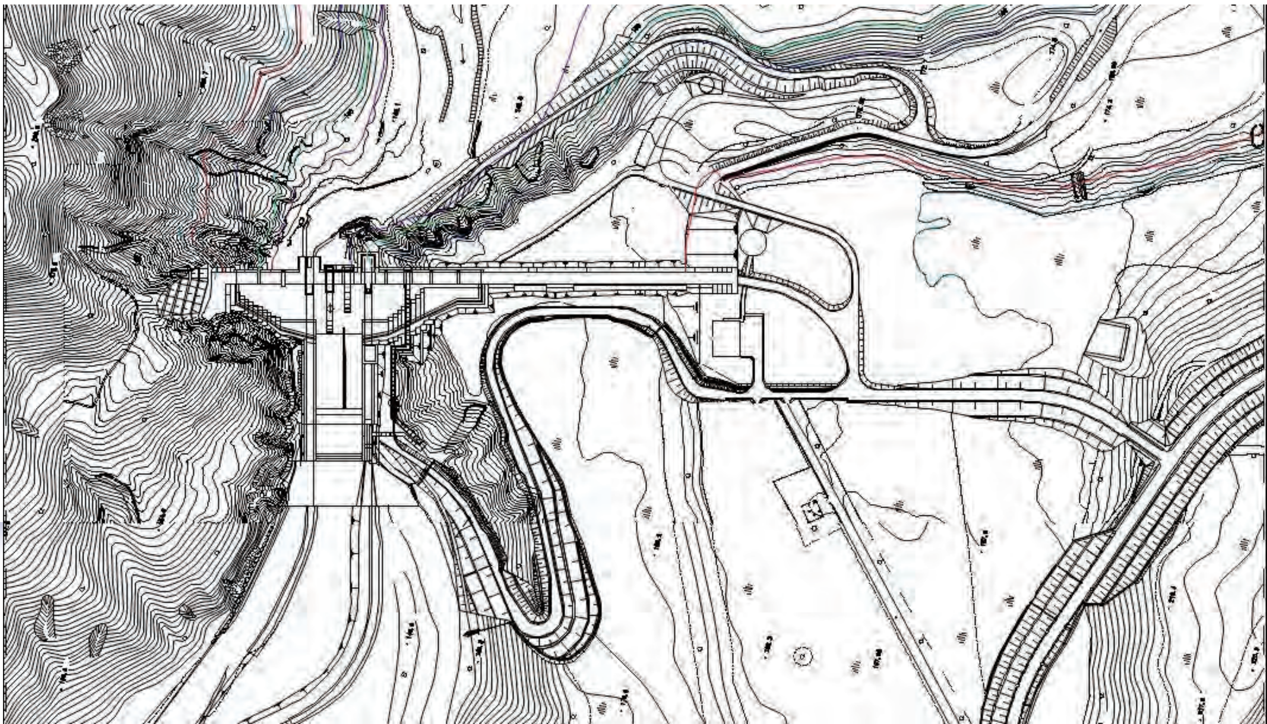


Figure-1 Plan

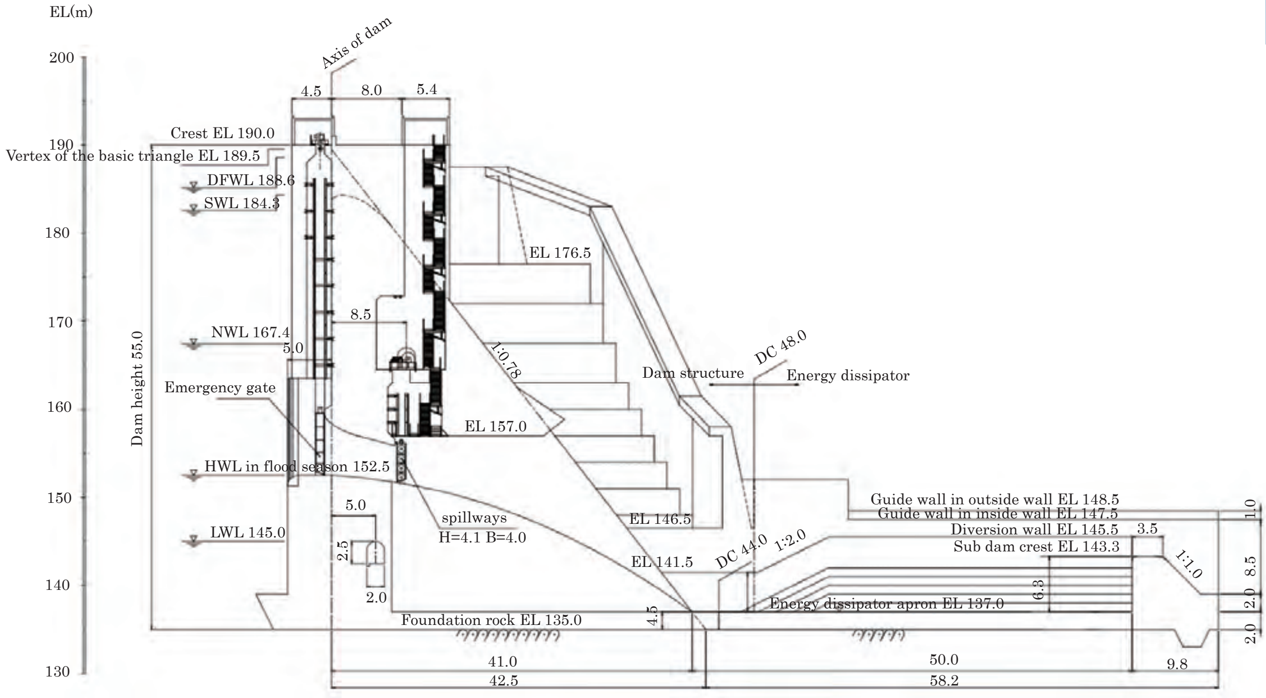


Figure-2 Typical section

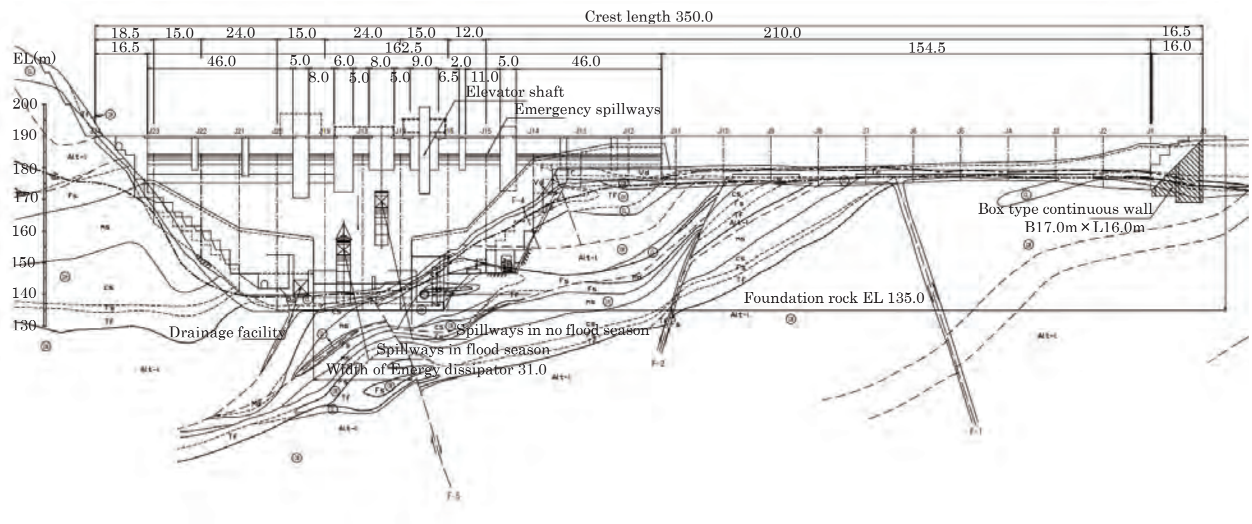


Figure-3 Downstream face

Aigawa Dam

Figure-1 Plan

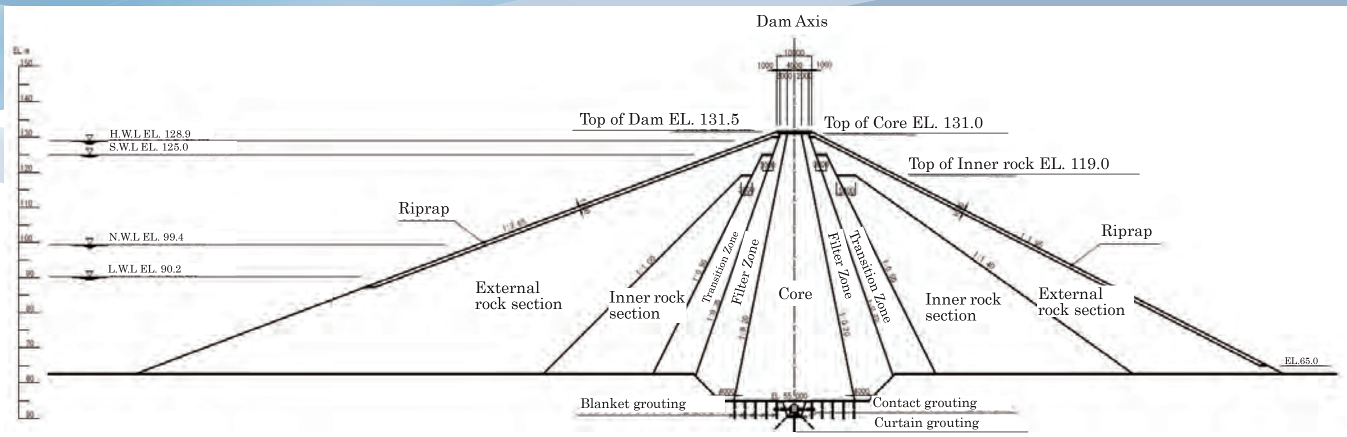


Figure-2 Typical section

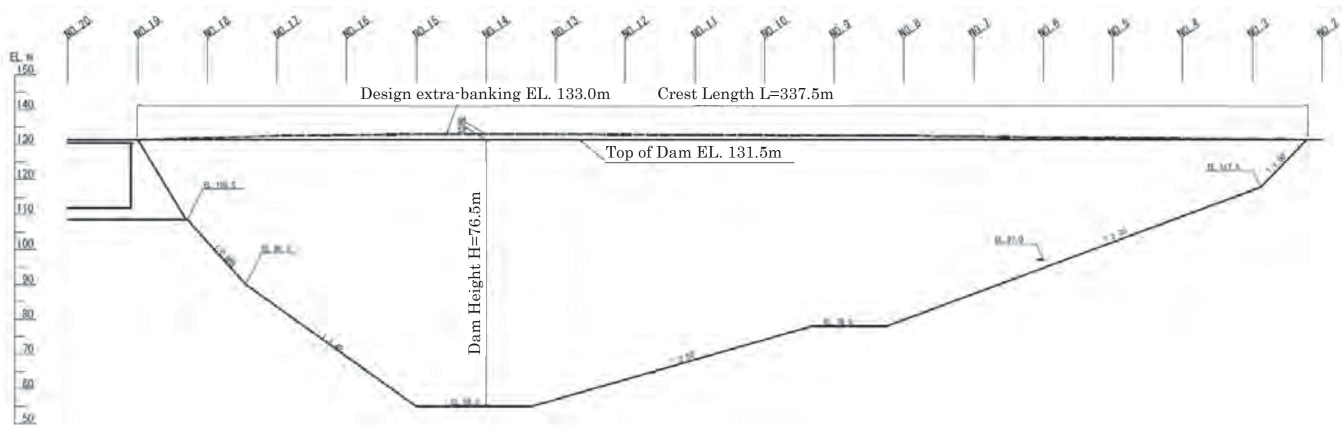


Figure-3 Longitudinal Profile

Dam Upgrading Vision

Japan is subjected to harsh weather conditions, with a high overall annual rainfall, the early summer rainy season, the autumn rainy season and concentrated torrential rains during the typhoon season. Furthermore, since rivers in Japan generally have steep gradients, they are subjected to flooding when the water level suddenly rises owing to rainfall, or to the water shortage when the water level falls over a short period as soon as the rain ends. Although dams have been constructed in accordance with characteristics of river basin to handle flooding and water usage issues, the number of suitable sites for new dam construction is limited in Japan due to various economic, social and environmental constraints.

Moreover, existing dams in Japan were constructed on mountain rivers with large amounts of sediment, and as such the dam capacity decreases quickly, sedimentation control measures are necessary to maintain long-term reservoir capacity. Additionally, extreme weather events (increased rainfall and drought intensity) due to climate change will increase high demand on dam storage capacity.

So, the need for effective utilization of existing dams and extension reservoir life have increased dramatically. To make effective use of existing dams as limited resources and to hand them over to the future generation in good condition, continuous investment and development of maintenance and management technologies are required. In order promote this investment and development, “A vision for upgrading dams” was formulated in 2017 by the Ministry of Land, Infrastructure, Transport and Tourism (“MLIT”). As shown in Fig. 1, dam upgrading include both structural and operational measures.

Case Examples of Dam Upgrading Technology

Temporary Cofferdam Method

One of the effective means of dam upgrading is to expand discharge facilities to increase flood control capacity. Under these circumstances, new technologies have been developed in Japan to drill holes in existing dam body and add discharge facilities. This is usually applied to gravity concrete dams. Naturally, the expansion of discharge facilities was not planned from the initial design, and the additional placement is restricted by existing facilities and their operation. In Japan, it may be difficult to lower the reservoir water level to maintain reservoir water use during dam upgrading work, and construction at higher depths is necessary. Therefore, it is necessary to consider the installation of large-scale underwater temporary cofferdams to regulate floods during dam upgrading work. For this purpose, technology related to the temporary cofferdams on the upstream side is important, and many efforts have been made so far.

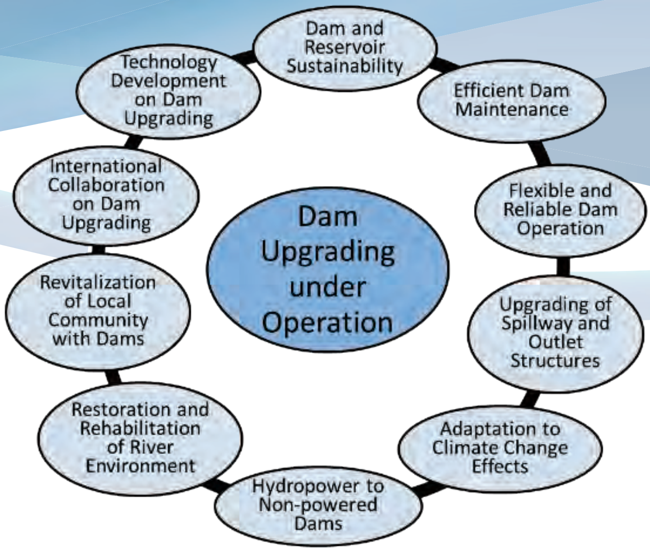


Fig. 1 Dam Upgrading Vision (MLIT)

Fig. 2 Floating type coffering facility

Smart Dam Operation using ensemble rainfall prediction

Hydropower dams are also expected to expand their water storage capacity for flood mitigation by prior release as a countermeasure to the recent increase in heavy rainfall. Currently, the period of prior release is generally for one to three days, but hydropower dams are expected to both “expand flood control functions” and “increase the amount of power generation” by using longer-term rainfall forecast and using stored water for power generation for instead of prior release.

A simulation was conducted on the assumption that long-term ensemble rainfall forecasts were used for past floods at Kurobe Dam in dam operation, and the effect of increasing power generation by reducing discharge through the valves was calculated. Fig. 3 shows time series of the water level of Kurobe Dam reservoir and the water volume released through the valves from Kurobe Dam calculated by the simulation. As a result, the release of water through the valves was reduced by approximately 12,000×103 m^3, or 17% of the actual amount of approximately 70,000×10^3 m^3. The effect of increased power generation was estimated to be approximately 15 GWh.

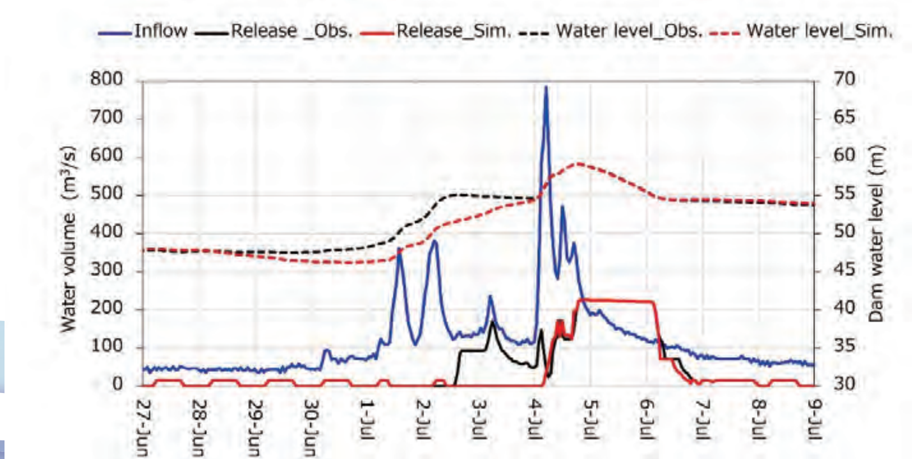


Fig. 3 Changes in Water Volume released from the Valves and Dam Water Level due to Smart Operation

Coordinated Sediment Flushing operation

In Kurobe River, the Dashidaira Dam (height: 76.7 m, gross capacity of reservoir: 9,010,000 m^3) owned by the Kansai Electric Power Co., Ltd., is located upstream of the Unazuki Dam (height: 97 m, gross capacity of reservoir: 24,700,000 m^3) which is controlled by MLIT. These two dams suffer extremely large amounts of sediment inflow compared to their gross storage capacity; therefore, they were the first in Japan where full-scale sediment flushing facilities (sediment flushing gates) were built. After 2001, sediment flushing and sediment sluicing have been conducted in coordination for two dams almost annually. Here, sediment flushing refers to a drawing down operation just after the peak water flow in the first flood event of the year. Sediment sluicing refers to the operation of sluicing the additional sediment flowing into a reservoir after sediment flushing, using an operation like sediment flushing. The basic sequence of operations is to draw down the reservoir water level, maintaining a free-flow state over several hours (the duration being determined by the amount of sediment to be flushed), and then allowing the reservoir water level to recover (Fig. 4).

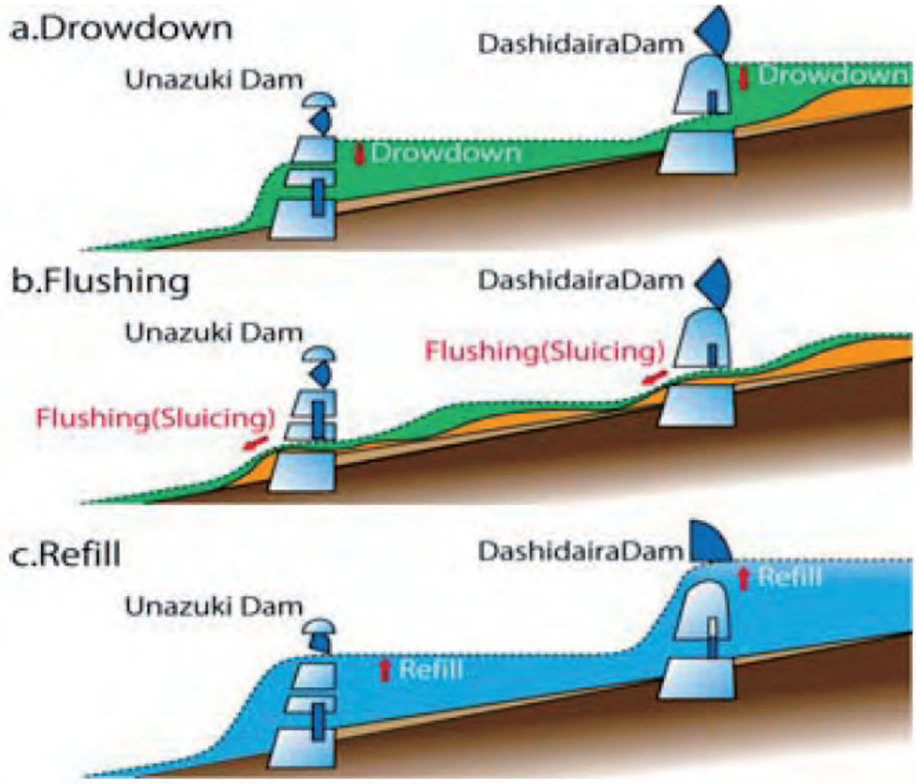


Fig. 4 Coordinated Sediment Flushing in the Kurobe River

Subcommittee on Dam Upgrading to be fit for future challenges

JCOLD has established a subcommittee on Dam Upgrading to be fit for future challenges. ICOLD has discussed rehabilitation to aging dams and measures to enhance dam safety. On the other hand, other important issues include enhancing flood mitigation effects under climate change, dealing with extreme droughts, and energy transitions, as well as the introduction of sedimentation countermeasures to extend reservoir life. These can be organized into three S's: dam safety, smart use, and sustainability (Fig. 5). JCOLD has proposed the necessity of dam upgrading, which encompasses all of these issues, as a way to strengthen dam functionality.

The outcome of this work will be a bulletin that includes a classification of dam upgrading technologies, examples from each country, and a database of technical information. By integrating the information from participating countries, a global classification and technological database of dam upgrading technologies will be completed. Based on these approaches, key technologies can be classified into well-established ones or not, and future challenges can be recognized. By participating in these approaches, ICOLD member countries will be able to understand the current status and challenges of their own country's technology. Furthermore, countries where dams will continue to deteriorate in the future will be able to effectively implement dam upgrading projects.

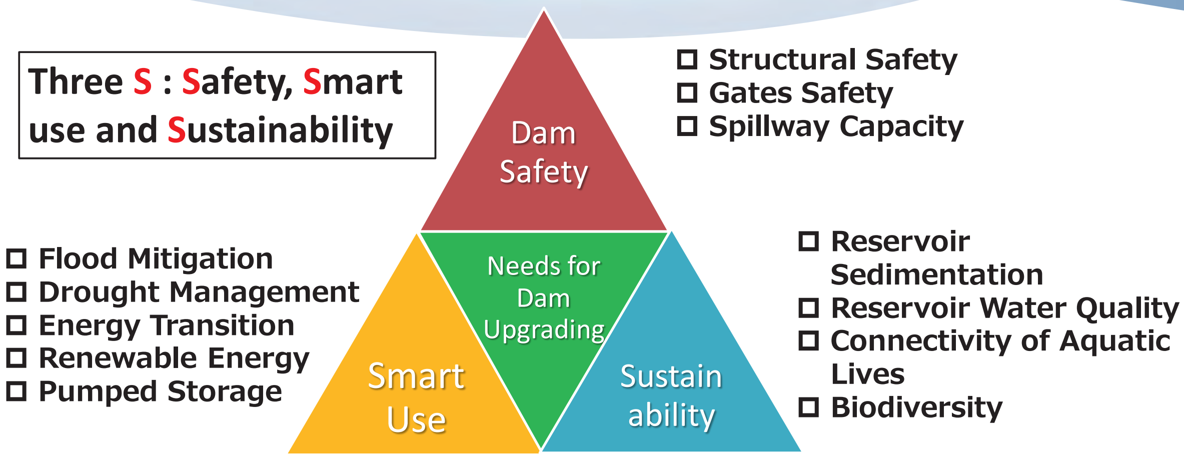


Fig. 5 Needs for dam upgrading (three S's: dam safety, smart use and sustainability)

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."

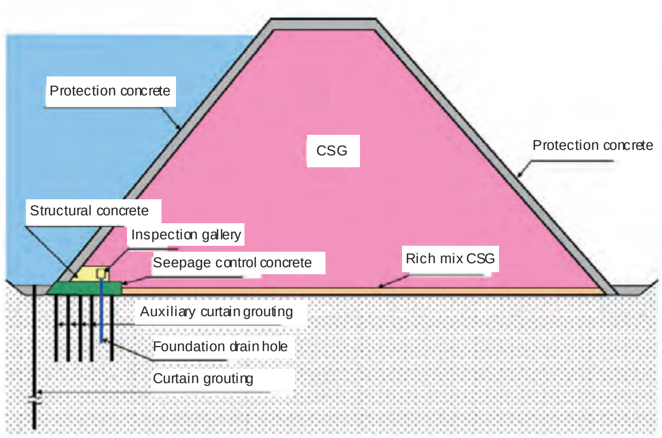


Figure-1 Concept of Trapezoidal CSG dam

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.

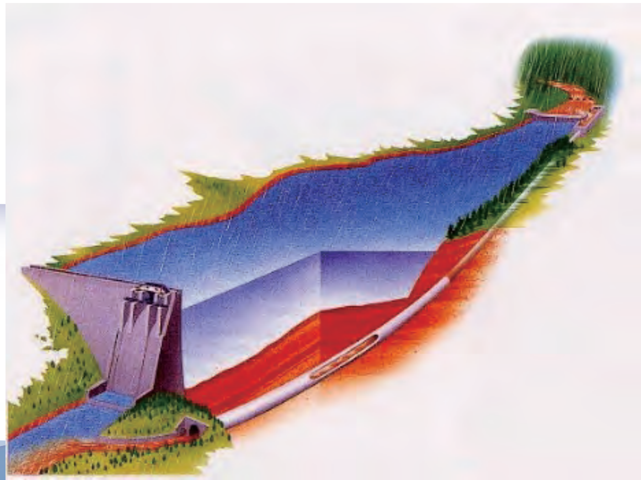


Figure-3 Sediment bypass tunnel (SBT)

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 mutrient salts from the catchment area.

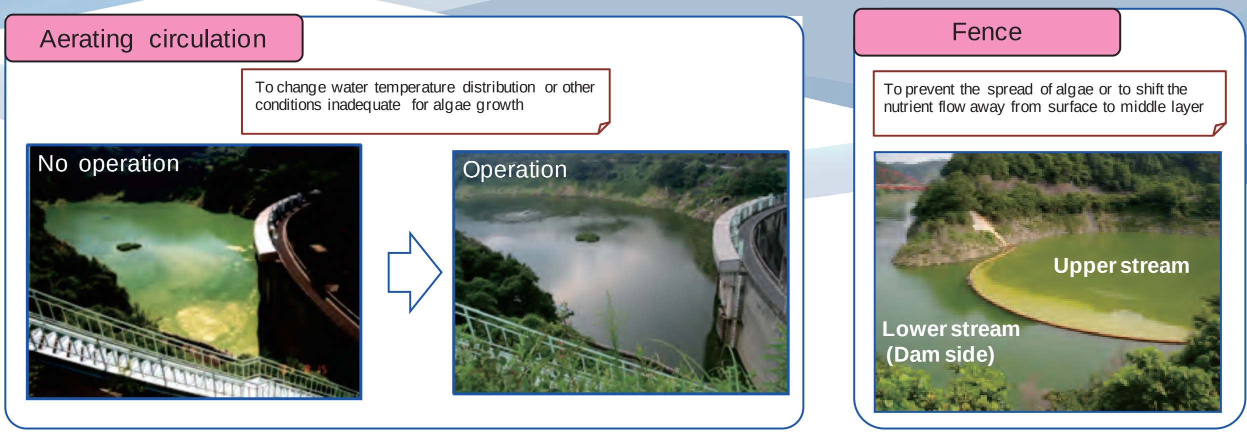


Figure-5 Reservoir Water quality facilities

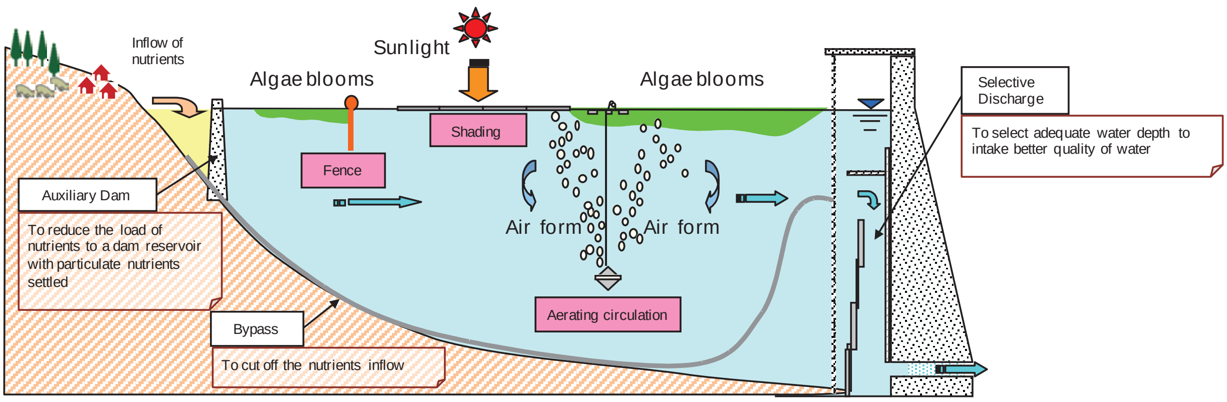
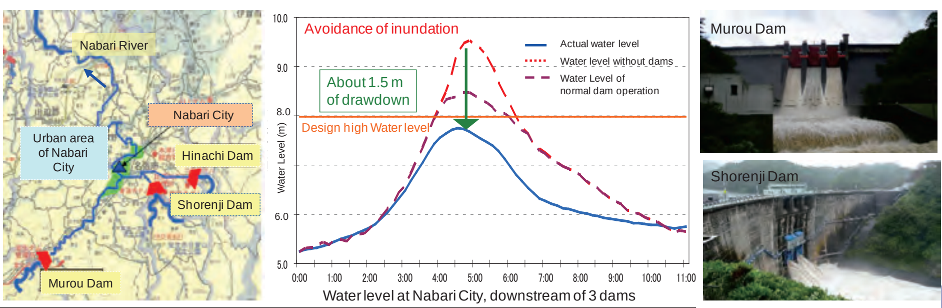


Figure-6 Example of quality conservation measures

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.



- 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 in view of 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 point.

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

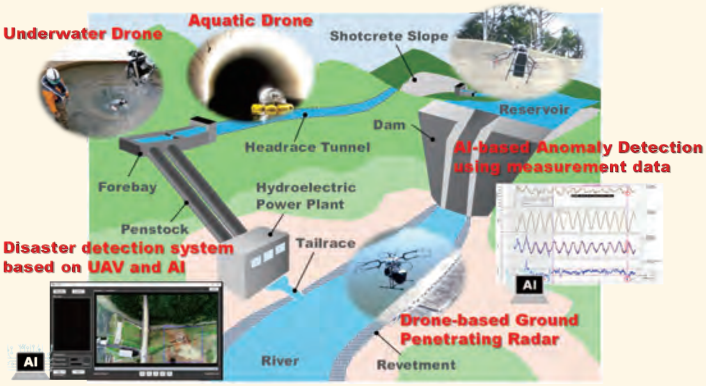
Automated Construction System

Japanese Advanced Dam Technologies for Achieving SDGs

Construction

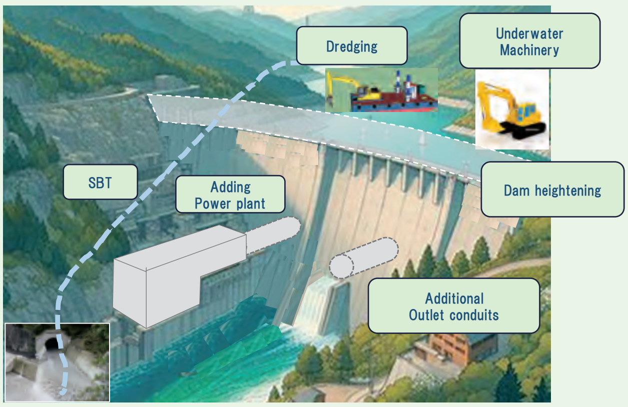
Automated construction systems, unmanned robots, and advanced technology utilizing digitalized platform

Operation and Maintenance



AI technology and digital transformation enable the operation precisely and efficiently as well as the inspection on dams and reservoirs

Upgrading



Upgrading discharge function, power generation and restoring the reservoir during the operation of existing dams

SUSTAINABLE DEVELOPMENT GOALS

A Construction

Unmaned Robot and Automated construction

A-1

autonomous control

T-iROBO® Roller
-Vibrating-Roller operates remotely and automaticallys-

TAISEI CORPORATION

A-2

autonomous control

T-iROBO® Excavator
-Hydraulic-Excavator operates remotely and automatically-

TAISEI CORPORATION

A-3

autonomous control

T-iROBO® CrawlerCarrie
-Crawler-Dump operates remotely and automatically-

TAISEI CORPORATION

Unmaned Robot and Automated construction

A-4

autonomous control

T-iROBO® Bulldozer
-Bulldozer operates remotely and automatically-

TAISEI CORPORATION

A-5

autonomous control

T-iCompaction®
-Measure hardness of compaction while running the Vibrating Roller -

TAISEI CORPORATION

A-6

Movie

autonomous control

Automatic operation of hydraulic power shovel - Demonstration experiment-

HAZAMA ANDO CORPORATION

Unmaned Robot and Automated construction

A-7

Movie

autonomous control

Robotics Construction
-Developing the Future of Construction-

OBAYASHI

A-8

Movie

autonomous control

KAWAKAMI DAM
-Construction of Next Generation Dams by Autonomous Tower Cranes-

OBAYASHI

A-9

Movie

autonomous control

NARUSE DAM

NARUSE DAM Construction Project
-Largest Trapezoidal CSG dam in Japan-

KAJIMA CORPORATION

Unmaned Robot and Automated construction

A-10

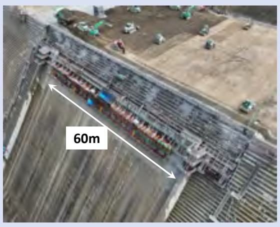
Movie

autonomous control

A4CSEL
-Automated/Autonomous/Advanced /Accelerated Construction system-

KAJIMA CORPORATION

A-11



Automatic sliding form for dam
-Fully automated formwork sliding operation without the use of a crane-

KAJIMA CORPORATION

A-12

Movie

autonomous control

Unmanned construction technology
Unmanned construction of Fill Dam Construction at Ookirihata Dam

KUMAGAI GUMI

A Construction

Unmaned Robot and Automated construction

A-13

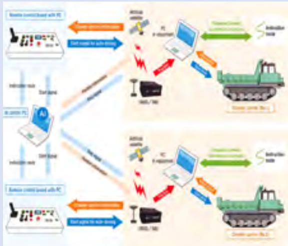
autonomous control

Autonomous Driving and Remote Operation Technology.
Ookirihata Dam, currently under construction, has implemented the autonomous driving and remote operation tech. developed by Kumagai Gumi for embankment construction.

KUMAGAI GUMI

A-14

autonomous control



AI-Based Auto-Drive Technology for Crawler Carriers
The Technology was introduced in the Aso Ohashi Bridge Area Slope Disaster Reconstruction Project

KUMAGAI GUMI

A-15

Network Style Unmanned Construction System
Network Style Unmanned Construction System for Disaster Prevention Work on the slope in Asoohashi area

KUMAGAI GUMI

Unmaned Robot and Automated construction

A-16

Movie

autonomous control

Dam Concrete Automatic Placement System

SHIMIZU CORPORATION

A-17

autonomous control

Dam Concrete Automatic Placement System

SHIMIZU CORPORATION

A-18

Movie

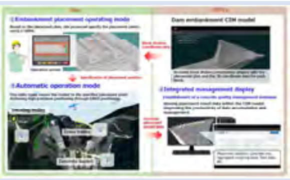
T-iCraft
-Platform for coordinated operation of multiple automated construction machines-

TAISEI CORPORATION

Unmaned Robot and Automated construction

A-19

autonomous control



Cable crane autonomous driving system
-This system enables automation in dam embankment construction.

NISHIMATSU

Project Management using BIM

A-20

Movie

KAWAKAMI DAM
-Construction of Next Generation Dams by BIM-

OBAYASHI

A-21

Cloud-based BIM/CIM system "CIM-CRAFT®"
Using the web application built on our in-house cloud system, you can register and reference models, attribute information, and various reports in accordance with the completion model and progress of the construction project.

KUMAGAI GUMI

Advanced technology utilizing digitalized platform

A-22

Movie

Digital transformation(DX) of embankment work management technology for the next generation

HAZAMA ANDO CORPORATION

A-23

SHIMARISU
-Dam Concrete Compaction Assessment Device-

HAZAMA ANDO CORPORATION

A-24

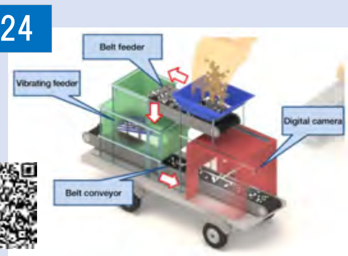


Image Processing-based CSG Material Particle Size Measurement System

HAZAMA ANDO CORPORATION

A Construction

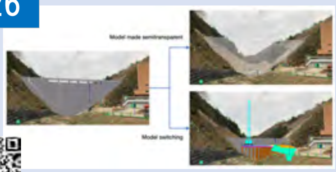
Advanced technology utilizing digitalized platform

A-25

ARAIGUMA
-Green Cutting Machine-

HAZAMA ANDO CORPORATION

A-26



Augmented Reality(AR) Technology using Visual SLAM

HAZAMA ANDO CORPORATION

A-27

Movie

Robotics Construction
-Developing the Future of Construction-

OBAYASHI

Advanced technology utilizing digitalized platform

A-28

Movie

KAWAKAMI DAM
-Construction of Next Generation Dams by automating Digital Transformation-

OBAYASHI

A-29

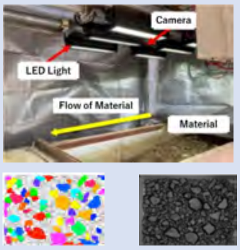


Image Granularity Monitoring
Rapid determination of particle size distribution of geomaterials by digital camera image analysis

KAJIMA CORPORATION

A-30

Movie

Network Style Unmanned Construction System
Aso Ohashi Bridge Area Unmanned Construction Movie for ACECC Awards

KUMAGAI GUMI

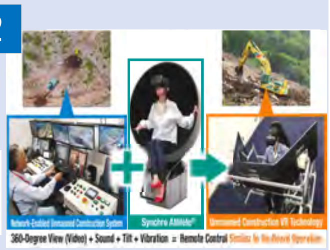
Advanced technology utilizing digitalized platform

A-31

Dam Construction Quality Management Technologies
Kumagai Gumi's Dam Construction Quality Management Technologies using ICT in Concrete Dam Construction

KUMAGAI GUMI

A-32



Unmanned Construction VR Technology
Kumagai Gumi has developed, in collaboration with the National Institute of Technology, Tokyo College,an "Unmanned Construction VR Technology"

KUMAGAI GUMI

A-33

Comprehensive approach by i-Construction
Unmanned Construction System adapted to i-Construction
Adaptation of i-Construction on on-site construction

KUMAGAI GUMI

Unmaned Robot and Automated construction

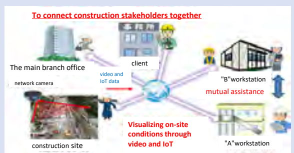
A-34

Concrete Aggregate AI Arrival Management System
Prevent human errors by comparing aggregate images using AI recognition and OCR reading of incoming delivery documents

KUMAGAI GUMI

Others

A-35



T-iDigital Field
-On-site management system that utilizes video and IoT data-

TAISEI CORPORATION

A-36

Obayashi Dam World
-Let's know about the dam-

OBAYASHI

A Construction

Others

A-37

Obayashi Dam World
-Obayashi Corporation and its involvement in dams-

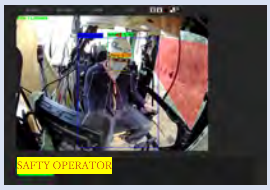
OBAYASHI

A-38

T-iFinder®
-Human detection system using AI-

TAISEI CORPORATION

A-39

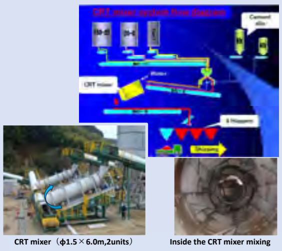


T-iSafety® Operator
-System for monitoring construction machine operator-

TAISEI CORPORATION

Others

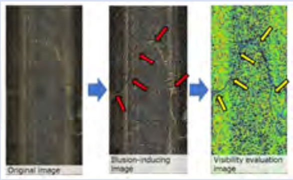
A-40



CRT(DKS- Ⅱ) mixing plant
-It is possible to continuously and high-quality mix materials for CSG and RCD concrete

NISHIMATSU

A-41



N-IESS
-The images from the borehole camera used in ground investigations at dam sites can be clarified

NISHIMATSU

B Operation and Maintenance

Reservoir operation DX

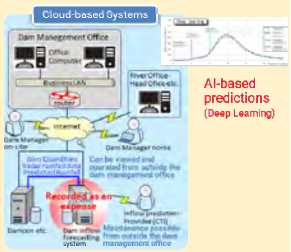
B-1

- Solid-state X-band MP radar accurately measures rainfall.
- Solid-state X-band MP radar enables low-cost construction of radar stations.
- The Global Ensemble Prediction System predicts long-term rainfall.
- It supports reservoir operations by predicting inflows to dam reservoirs.

Digital Transformation in the Operation of Dam Reservoirs Using Rainfall Forecast

NIPPON KOEI

B-2

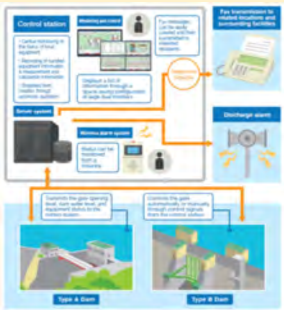


Support for Dam Operation Using AI and Cloud Systems
This enables us to provide a cost-effective and highly maintainable system that supports advanced dam operations

CTI Engineering Co., Ltd.

B-3

Control station



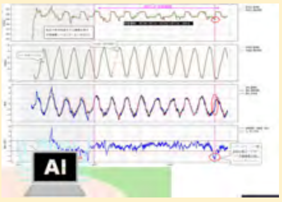
Supervisory control system for dam
Highly functional control system for centrally monitoring dam-releted facilities

NIPPON KOEI ENERGY SOLUTIONS

B Operation and Maintenance

Risk and Sustainability management

B-4



- We utilize AI to analyze dam measurement data and assess its integrity.
- AI and 3D modeling streamline maintenance planning, boosting operational efficiency.

AI-Driven Analysis

NIPPON KOEI

High-precision inspection DX

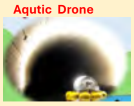
B-5

Drone-based Grand Penetrating Rader

This technology uses a radar mounted on a drone to probe deep underground structures and substances.

Underwater Drone

Aqutic Drone



Advanced drones and sensors for precise, efficient inspections of dams and headrace tunnels.

Precision-Enhanced Inspection Tools

Next-Gen Maintenance Technology

NIPPON KOEI

B-6

Automatic Leakage and Uplift Monitoring System

Benefits

- **Reduced manpower**
- **Improved data reliability**
- **Remote monitoring**
- **Automatic multipoint measurement**

KYOWA

C Upgrading

SBT

C-1

Movie

Sediment sluicing plan in the Mimikawa River system

KYUSHU ELECTRIC POWER CO.,INC.

C-2

Movie

Effects of sediment sluicing operation

Environmental assessment of sediment sluicing in the Mimikawa River system

KYUSHU ELECTRIC POWER CO.,INC.

C-3

Sediment bypass tunnel cross-section

Koshibu Dam -Sediment Bypass Tunnel-

Chubu Regional Development Bureau
Ministry of Land, Infrastructure, Transport and Tourism

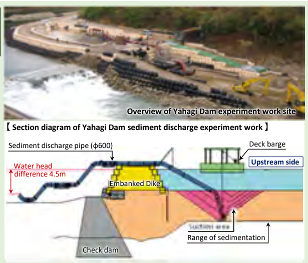
Dredging

C-4

REKIZO
-Special Ejector Pump System-
(Gravel Transportation)

HAZAMA ANDO CORPORATION

C-5



Obayashi Dam World
-Dam sediment discharge technology-

OBAYASHI

C-6

Movie

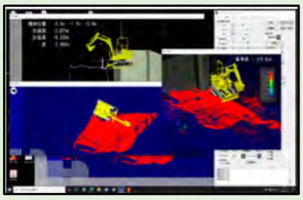
High-lift No-turbid Dredging Method
-Development of a high-lift dredging method that does not disturbing the water quality-

FUJITA CORPORATION

C Upgrading

Underwater Machinery

C-7



Introduction of underwater guidance System
ICT technology for underwater work Development of a small underwater backhoe

KUMAGAI GUMI

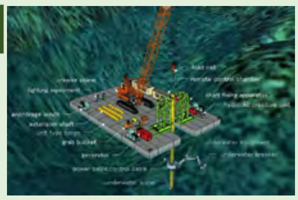
C-8

High Precision Underwater Positioning System "AquaMarionette"
ICT technology for underwater work Development of unmanned underwater construction technology

KUMAGAI GUMI

C-9

Movie



T-iROBO® UW
-Shaft-Style underwater construction machine-

TAISEI CORPORATION

Additional Outlet conduits

C-10

Movie

Floating Temporary cofferdam Method
-Achieved improvement in efficiency of temporary cofferdam work-

KAJIMA CORPORATION

C-11

Floating Temporary cofferdam Method
Innovative Dam Redevelopment – A New Coffering System for Underwater Work–

KAJIMA CORPORATION

C-12

Additional Outlet conduits
-After drilling through the existing dam concrete and installing a new conduit pipe, the area around the pipe was filled with high-fluidity concrete-

KAJIMA CORPORATION

Other upgrading

C-13

Raising Dam body
Technology to increase water storage capacity with minimal impact on existing dams in operation

KAJIMA CORPORATION

C-14

Dam Reinforcement Technology
Reinforce the dam body to improve the earthquake resistance and stability of the dam

KAJIMA CORPORATION

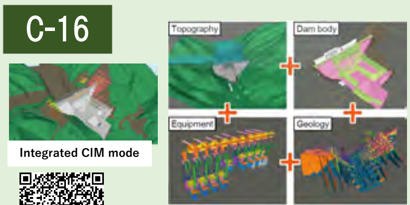
C-15

Kumagai Gumi's Dam Renewal Works
There are various types of renovation works involved in dam renewal, and here are a few representative examples

KUMAGAI GUMI

Other upgrading

C-16



Shin Maruyama Dam
-Making full use of DX(Digital Transformation) to Dam Reproduction-

Chubu Regional Development Bureau
Ministry of Land, Infrastructure, Transport and Tourism

Comprehensive inspection of dams

A comprehensive inspection of dams in long-term operation has institutionalised in Japan. This inspection evaluates the soundness and formulates maintenance plans to extend the dams' lifespan. Most dams in Japan, built during the economic boom of the 1960s and 1970s, now require systematic preventive maintenance due to their age. By 2020, 60% of these dams will be over 50 years old.

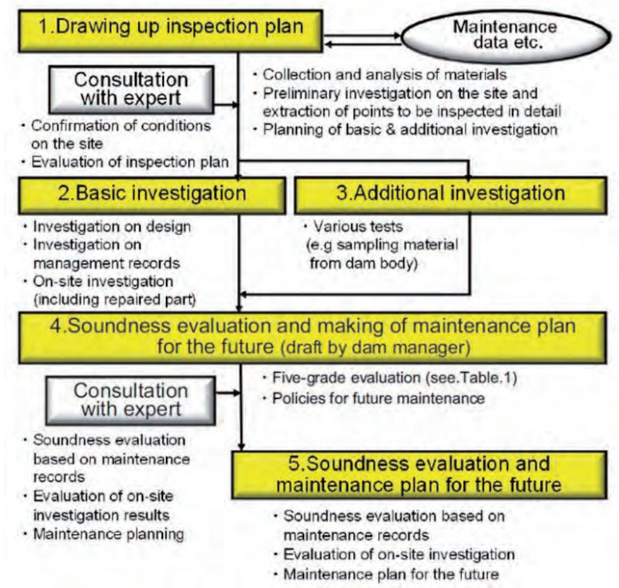
Routine inspections and periodic examinations every three years have traditionally confirmed dam safety. However, the comprehensive inspection, introduced in 2013, enhances these efforts by assessing deterioration or damage and implementing preventive measures. This inspection involves a thorough analysis of design records, construction processes, and maintenance history, alongside detailed on-site investigations.

Key aspects of the inspection include evaluating concrete and embankment dams, spillways, and foundations. Common issues like cracks, leaks, and material degradation are meticulously documented and analysed. For instance, cracks in concrete dams are examined for depth and impact on structural stability, while embankment dams are monitored for settlement and slope stability.

Geotechnical issues such as foundation deformation, leakage paths, and material quality are also scrutinised. Advanced methods like water quality analysis and tracer tests identify leakage paths, while physical property tests of materials assess their integrity.

This comprehensive approach ensures that all components, including mechanical and electrical systems, are inspected and maintained systematically. The integration of new technologies like UAVs and remote sensing further enhances the inspection process.

In conclusion, the comprehensive inspection of dams in Japan is a crucial initiative for ensuring the long-term safety and functionality of these critical infrastructures. By adopting systematic preventive maintenance, the lifespan of dams would be extended, safeguarding communities and supporting societal needs.



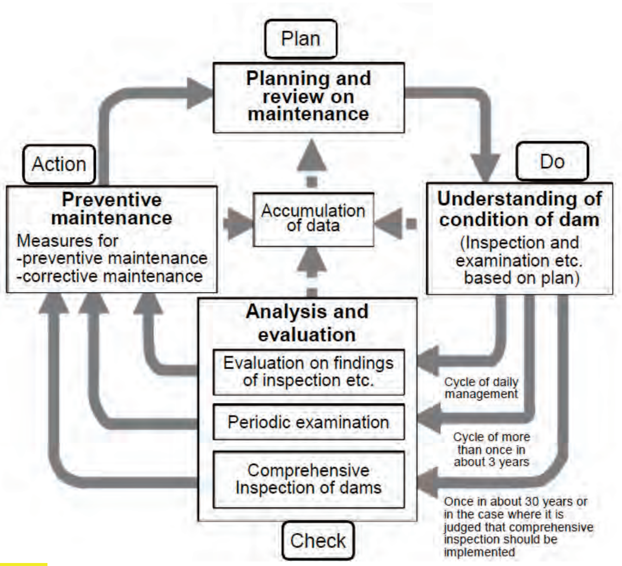


Figure-8 **Procedures for the comprehensive inspection** **Figure-9** **PDCA cycle-based management system for dams**

Reference: Kondo, M. and Anan, S.: Comprehensive Inspection of Japanese Dams in Long-Term Operation, Journal of Disaster Research, Vol.13, No.4, 2018)

Papers in ICOLD & Other Technical Publications

Theme 1 Safety management and rehabilitation of existing dams

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Reproduction analysis by finite element method in a massive concrete cylinder affected by alkali aggregate reaction

H. Kagimoto, M. Kawamura & Z. Cao

In order to elucidate the mechanisms of alkali aggregate reaction (hereafter referred to as ASR) deterioration in massive concrete bodies, it is significant to understand the internal humidity and expansion within those exposed to environments. We have measured the expansive pressure generated in various concrete prisms (100 × 100 × 400mm) under various degrees of uniaxial restraint to reveal the characteristics of expansive pressure, the longitudinal and the transversal expansion and cracking in the concrete prisms. It is found from the studies that non- or less-expansive layers were formed in near-surface regions in the concrete cylinder in the drying process. ASR expansions actively progressed with time in inner portions. As a result, tensile stresses were induced in the non- or less-expansive layers in near-surface regions. When tensile stresses exceeded the tensile strength, surface cracks were produced. The objective of this study is to show the reproducibility of finite element method simulation (hereafter referred to as FEM) of ASR affected massive concrete cylinder. ASR deterioration is subjected to various fac-tors, such as elastic modulus, compressive strength, constrained stress and relative humidity (here-after referred to as R.H.) etc., and one of the most important factors is elastic modulus (α value) of the ASR gel. In this study, an evaluation method for elastic modulus (α value) has been pro-posed and FEM simulation has been conducted. Many concrete dams throughout the world are suffering from deterioration problems caused by ASR. The quantitative prediction and the evaluation of the influence of ASR on dams certainly contribute to the safety and maintenance of dams. It is necessary to develop FEM simulation which correctly reproduced real ASR deterioration, based on the relatively massive concrete cylinder's acceleration test data in future.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Refurbishment of the historically valuable masonry dam using prestressed anchors

A. Tokunaga, C. Ota, T. Nakakura & H. Kawasaki

Refurbishment of Senbon Dam is the first case in Japan that PS anchor method has been used for aseismatic reinforcement of a dam body. Its reservoir is still necessary for the source of water supply for Matsue City after 100 years operation. It is not permissible to cut off the water supply. The surface of the dam body is covered by masonry. In order to protect the historic value and beautiful appearance of the dam, we selected PS anchor method to reinforce the dam body, opposing to the conventional method of additional concrete placement over its surface. Due to local conditions such as climatic conditions, specific composition of the dam and foundation bedrock, the following technical issues were encountered: (1) the risk of delay due to bad weather during the construction of the overflow section that occupies two-thirds of the total crest length, (2) countermeasure to the weak part of the dam body and the vulnerable part of the foundation bedrock, and (3) restoration of masonry landscape after construction of tension end on top of the dam. We overcame the above issues through modification of temporary design and establishment of a construction cycle that minimize the risk of delay, drilling with double pipes and unique tension force introduction technology, and restoration with careful consideration including the use of stone materials of the same quality as the existing dam body. This paper describes a series of dam body refurbishment works using the PS anchor method in Japan and correspondence to the problems.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Technical features on the renewal of large-scale prestressed rock anchors in Kawamata Dam foundation

H. Kawasaki, T. Satoh, T. Nakazawa & Y. Hashira

Kawamata Dam is a concrete arch dam with 117 m high which was completed in 1966. A huge underground transmitting wall for sustaining the arch thrust force was constructed in the left bank bedrock. In addition, the world largest class prestressed (PS) anchors by total capacity in that time were installed for the purpose of tightening this wall along with too many existed nearby high-angle faults, stabilizing of the bottom of slope and prevention for the surface loosening. Additionally, big retaining walls were constructed to support PS anchors as pedestals. These structures are called bedrock PS works. However, after passing of 50 years, deterioration of PS anchors was confirmed by irregular behaviors observed in measured values, and damages in anchor heads found by integrity surveys for PS anchors. After these anomalies were checked by the technical committee, the renewal plan by the full installation of PS anchors and the repairment of the retaining wall was determined in 2013. From 2014 to 2016, additional surveys, the design of PS anchors for the renewal and detailed construction planning was implemented. The content of the renewal plan consists of a total number of 124 units of PS anchors with 2352 kN/unit of anchor load, and the repairment of the right bank retaining wall. According to this design, as the first phase renewal, 59 units of PS anchors were installed at the location of rock foundation of Kawamata Dam until 2021. The renewal works were executed under very strict site condition such as the steep and deep cliff terrain, no access ways, very hard rock foundation, frozen condition in winter and flood discharge during flood season. On the other hand, many technical developments were achieved using the latest technology, such as stag-ing along cliff, tools and materials, corrosion protection, drilling in hard rock, tendon setting, grout mix, tensioning method, quality control, measuring instrument, maintenance method, and others. As a result, this works laid the basis of PS anchor technology for dams in Japan. We describe the judgement renewal decision-making and the main technical points of the design and construction, mainly concerning to the PS anchors reinforcing the rock foundation.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Cyclic behavior of RC structures using round rebars with ultra-low rebar ratio and applicability of the bond-slip model

Y. Matsuoka, Y. Otsubo & T. Arimitsu

Given the recent occurrence of large-scale and frequent earthquakes, there is a critical need for seismic evaluation of infrastructures on hydropower plants. The evaluation of dam gated piers, structures supporting the spillway gates in dams, is essential to ensure its water storage and discharge functions after earthquakes. The dam gated pier is constructed using reinforced concrete (RC). Certain older dam gated piers utilize round rebars as their main reinforcement, and the tensile reinforcement ratio (hereinafter, referred to as the reinforcement ratio) is ultra-low reinforcement ratio even lower than the typical low reinforcement ratio of 0.20%. In seismic evaluation, it is necessary to elucidate the internal hysteretic behavior and fracture morphology, collectively referred to hereinafter as seismic behavior, exhibited by a target structure at the time of earthquake and to appropriately model them. Existing studies have revealed the seismic behavior of an RC structure employing round rebars with low reinforcement ratio of 0.26%. To replicate this seismic behavior, a model involving a bond stress-slip relationship between the reinforcement bar, referred to hereinafter as rebar, and concrete is proposed. However, the seismic behavior and applicability of the bond stress-slip model remain unclear for RC structures employing round rebars with an ultra-low reinforcement ratio like the dam gated pier. In this study, a cyclic incremental loading test on an RC rectangular specimen was conducted to clarify the seismic behavior of an RC structure employing round rebars with ultra-low reinforcement ratios. In addition, a reproduction calculation of the test was performed via nonlinear finite element analysis using a solid element. Findings affirm the suitability of the existing bond stress-slip model for demonstrating the seismic behavior of the RC structure employing round rebars possessing ultra-low reinforcement ratios.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Development of an Operation Support Tool for dam safety management using artificial intelligence

K. Inoue, T. Kobori & T. Sakurai

In the safety management of dams, according to the Cabinet Order Concerning River Control Facilities, various data such as leakage volume, deformation, and uplift pressure are measured; and monitoring these measurement data is a basic and important means of detecting anomalies. However, a survey of dams in Japan regarding the use of this measurement data for safety management revealed that there were some problems, including an experienced engineer saying "it is difficult to clearly decide whether there are any anomalies even if you get reliable data." In addition, the number of dams in long-term operation is increasing, whereas the number of experienced and qualified engineers who are familiar with dams is decreasing. Therefore, dam operators need to accurately use the measurement data, which represents objective information, to assess whether increased monitoring is required and countermeasures need to be taken. For this reason, artificial intelligence (AI) technology has been investigated that supports the dam operator in deciding anomalies based on fluctuations in the measurement data, and developed an operation support tool for dam safety management (Henceforth referred to as "Operation Support Tool"). In this paper, an example of the estimation of long short-term memory, which is an AI technology used in the Operation Support Tool is presented, as well as how to use the Operation Support Tool and examples of its use.

E. ICOLD 28th Congress in, Chengdu, May 2025

Investigation of construction optimization of a heightened concrete gravity dam

N. Yasuda, Z. Cao, T. Nishimura & M Sato

Climate change is expected to cause more frequent and severe water-related disasters in the future. Although dams are effective at controlling floods in watersheds, the number of suitable dam sites in Japan is limited. Therefore, there is a growing need to increase the flood control capacity of existing dams; thus, the need for dam rehabilitation is increasing. Among possible measures, dam heightening is an effective means of dam rehabilitation. This study examines the Shin-Katsurazawa Dam, which is a case of coaxial heightening of a concrete gravity dam. (1) The mechanical properties (elastic modulus, unit weight, compressive strength, and tensile strength) of the existing dam concrete, which is 67 years old, were determined based on the results of material tests of core specimens. (2) It was clarified that concrete placing at relatively high elevations should ideally be planned when the reservoir water level is relatively low if the reservoir is continued to be operated all year round.

E. ICOLD 28th Congress in, Chengdu, May 2025

Case Study and Analysis of surge wave and Excessive Flood in hydroPower Dams

C. Onda, K. Morimoto & T. Sumi

This paper investigates the impact of extreme hydrological events on hydropower dams, examining the surge wave phenomena, excessive sedimentation, and flood flows exceeding design capacities. The occurrence of these events has become more frequent due to climate change, necessitating revised and innovative approaches to dam safety and management. The study outlines the evolution of design flood flow standards in Japan, highlighting that many existing dams, constructed based on past standards, may not be equipped to handle current and future hydrological challenges. It presents detailed case studies of three dams: Hiranabe, Horoka, and Setoishi, each experiencing unique issues such as debris flow-induced surge waves, sedimentation from heavy rainfall, and flood flows significantly beyond their design capacity. For Hiranabe Dam, a landslide triggered by a typhoon caused a surge wave, resulting in overflow. Numerical analysis was used to investigate the debris flow and surge wave behavior, leading to the implementation of measures to improve the watertightness of flood spillway gate control devices. Horoka Dam faced sedimentation challenges from heavy rainfall, leading to the cessation of power generation. A sediment bypass tunnel was selected as a permanent countermeasure, expected to increase the dam's discharge capacity, and manage sediment more effectively. Setoishi Dam experienced a flood flow 1.7 times its design capacity, highlighting the need for improved flood spillway gate control systems, downstream warning devices, and sediment management strategies to ensure continuous operation and safety. The paper emphasizes the importance of considering both flow and sedimentation measures in dam management to address the increasing risks posed by climate change. It suggests that understanding the specific characteristics and vulnerabilities of each dam is crucial in developing targeted safety measures. Moreover, it advocates for the use of numerical analysis to predict future challenges and select appropriate sedimentation measures, contributing to the sustainable management of dams. In conclusion, the study underscores the need for integrated and forward-thinking strategies in hydropower dam management, incorporating both structural and operational measures to enhance resilience against extreme hydrological phenomena.

Theme 2 New construction technology

A. 11th East Asian Area Dam Conference in Daejeon, September 2022

Shortening the Construction Period of Yamba Dam by Effective Spillway Works

G. Yasuda, A. Matano

Yamba Dam started initial impoundment on 1st October 2019. Just eleven days later, the Dam stored all the flood water from upper reaches caused by Typhoon Hagibis and contributed to preventing levee failures downstream and to saving lives and assets in Tokyo Metropolitan Area. This achievement would never have been possible if innovative measures to reduce the work period of the dam body have not been conducted. This paper mainly introduces what IHI Infrastructure Systems Co., Ltd. has done in this respect. The construction works of the dam body were conducted jointly by Shimizu Corporation, IHI Infrastructure Systems Co., Ltd. and Tekken Corporation. The pull-in method, which employs pre-assembling on the stage constructed at the upper side of the dam body and minimize the works on the dam body after the pull-in, applied to the mid-height spillway installation made it possible to cut down the suspension period of the concrete placing by 61 days. Batch setting of the outlet for water level control by large blocks with employing a heavy-duty carrier, which can suspend 750 tons and enables reduction of the number of the parts, also reduced the suspension period of the concrete placing by 53 days. Installation of the conduit pipe also employed large blocks and pull-in method to shorten the work period by 8 days. Synchronization of the timing of the installation of a siphon tube of the selective water intake facility with concrete placing at 2-4 stages lower also shortened the work period by 18 days. Accumulation of these efforts with respect to gates and spillway works shortened the work period by 140 days. Other parts of the dam body construction works also took in various innovative measures. On the total, the joint venture succeeded to shorten the work period by 514 days and made it possible to operate the dam before the arrival of the Hagibis. This presentation shows contents of the efforts and their outcomes.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Clarification of reaction mechanism of concrete with Class C fly ash for RCC dams in the Nam Ngiep 1 Hydropower Project in Lao PDR

Y. Aosaka, T. Yamamoto, S. Tsutsui, T. Miki & M. Conrad

In order to secure the safety of roller-compacted concrete (RCC) dams, it is required to have sufficient strength and water-tightness especially at lift joints by coping with surrounding conditions. Class F Fly Ash (CFFA) containing pozzolanic materials and less CaO is globally used in RCC dams as a cementitious material, since it has an effect in controlling hydration heat generation early in the age and pozzolanic activities in long-term age. On the other hand, features of Class C FA (CCFA) containing rather much CaO (including free lime (f.CaO)) inducing hy-dration have not been well studied and rarely used for RCC. In Nam Nigep 1 Hydropower Project in Lao People's Democratic Republic which has a 167m high RCC dam, the applicability of fly ash was studied and there was no way except to select CCFA procured from Mae Moh Coal-fired Power Plant in Kingdom of Thailand from the geographical reasons. However, it has a better performance than expected on control of hydration heat generation and long-term strength development of RCC. In order to verify the applicability of CCFA for RCC dam, that is to say to clarify the reaction mechanism for CCFA, the morphology and chemical features of FA particles and reaction state of the concrete core specimens were analyzed and evaluated by using a variety of analysis such as Field Emission - Electron Probe Micro Analyzer (FE-EPMA) and so on in addition to conventional material and concrete tests. This paper presents that, the positive use of CCFA, which has rarely been used until now, is demonstrated to expand the choice of materials for design of mix proportion of RCC dam in hydropower project and to contribute to the economy and environment in Southeast Asia region requiring effective use of coal from the view of energy security.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Digital Transformation (DX) in construction. Digital twin management at Kawakami Dam project.

M.Omata, K.Ueko

This paper delineates the transformative approach adopted in the construction of the Kawakami Dam, with a particular emphasis on the advanced application of Building Information Modeling (BIM) since the commencement of the project in the fiscal year 2017. In dam construction in Japan, ensuring flood control capacity is an important element, and the construction process became more complicated as the number of discharge structures and equipment in-creased. On the other hand, in this project, the paper highlights the challenges posed by the lack of standardization in construction techniques, especially in the context of varying scales of dam projects. We introduced optimized construction methods for medium-sized dams by conducting prior verifications. The consistent use of BIM from the ordering stage has been advocated by the Ministry of Land, Infrastructure, Transport, and Tourism in Japan, and we have been promoting this pioneering initiative at the Kawakami Dam. We defined three digital twins and promoted supervision by BIM at the site. First, we created accurate production design drawings that enhanced the accuracy of the BIM model. Since the construction process is standardized, it is relatively easy to prepare drawings. Based on these production design drawings, we proceeded with construction that is standardized and streamlined like a factory. Accurate BIM serves as the hub for various business applications and forms the foundation for the second digital twin, "construction management data storage and system integration." Data storage settings have become clear, making it easier to maintain and manage accurate construction data. Finally, in the effective utilization of BIM, we also took on the challenge of coordinating with autonomous construction machinery. By utilizing the digital twin as a Cyber-Physical System (CPS), we achieved the autonomous operation of tower cranes. This paper discusses the process of implementing such cut-ting-edge initiatives. (M.Omata, 2022. Theoretical considerations on the construction method of Kawa-kami Dam, Japan Dam Engineering Center)

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Development of a remote-controlled underwater excavator for hard rock in reservoirs

S. Hatakeyama & H. Arai & T. Kitahara

In dam redevelopment projects in Japan, it is often necessary to safely and efficiently excavate sediment and bedrock from the reservoir bottom while maintaining a water level high during dam operation. In 2014, Taisei Corporation developed “T-iROBO UW”, underwater work equipment that excavates sediment and bedrock from the reservoir bottom by remote control using machine guidance. The machine was applied to rock excavation in the Amagase Dam redevelopment project in Kyoto Prefecture in 2015. On the other hand, hard rock with few cracks distributed near the dam foundation is difficult to excavate with a breaker, and it has been an issue to establish technology for underwater excavation applicable to such conditions. Therefore, we developed two attachments for hydraulic rock splitting for hard rock excavation, "T-A Slot Driller" for slot excavation and "T-A Rock Splitter" for rock splitting. We conducted demonstration tests on land to verify the excavation capability of the developed attachments and the work accuracy of remote control using machine guidance. The slot formation capacity was 0.45 m/h at an excavation depth of 1.5 m and the rock splitting capacity was 3.0 m^3/h at a bench height of 0.75 m. This result showed that the developed attachments had sufficient excavation capability for the assumed excavation specifications even in the case of remote control, and it was confirmed that the positional accuracy of the tip of the attachment is as high as ±5 cm or less. We compared the processes of the T-iROBO UW method and the conventional all-casing method in the condition of the Amagase dam redevelopment project, assuming that the excavation target was all hard rock. As a result, the excavation period for the T-iROBO UW method was reduced to 50% of that for the conventional method by omitting the installation of temporary piers. This development has expanded the scope of application of T-iROBO UW, and it can excavate any target from sedimentary soil to hard rock with few cracks using the developed attachments for rock splitting collectively with other existing attachments.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Innovative technologies for quality inspection works on trapezoidal CSG dam construction -Test results in Naruse Dam-

M. Okamoto, K. Tanaka, M. Masutani, Y. Okamoto, K. Fujisaki, A. Ooi, T. Matsumoto & H. Kobayashi

Trapezoidal CSG dam is a newly developed Japanese dam construction technology to achieve excellent economic efficiency and reduction of environmental impacts. One of the core policies constituting this technology is the rationalization of the material to form the dam body. Cemented Sand and Gravel (CSG) is provided by mixing cement and water with the CSG material, which is rock based sandy gravel obtained near the dam site with relatively low efforts. Since it is necessary to consider the water content and grain size distribution of the CSG material to complete the CSG strength, these parameters are always checked by laboratory tests in every 1-2 hours during the CSG production. Then, a large number of sample inspection works are consequently obliged, because the continuous mass production of CSG is usually conducted to improve economic efficiency of the dam project. To secure the CSG strength required to stabilize the dam body under seismic condition, it is also important to achieve the high density of CSG by compaction in the placing phase. Despite the progress of mechanization and automatization on CSG placing process, in-situ density inspection is manually performed every placing day to control the quality of CSG. Because of the importance of saving human efforts for the sustainable development of dam projects, some innovative technologies have been developed to simplify these quality inspection works. In this paper, the outline of an automated full-inspection system for water content and grain size distribution of the CSG material, is mentioned. It is also described that the overview of the movable resistivity measurement system which could be applied to planar quantification of the compaction quality of CSG placing surface. Furthermore, trial test results of each technology in Naruse Dam project, are reported.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Development of dam concrete transportation facility using bag-shaped belt conveyor

N. Hikawa, H. Yamaguchi, Y. Masai, T. Nagao, & N. Yamashita

In dam construction, transportation capacity of concrete is often the key to improving construction efficiency. We focused on bag-shaped belt conveyors to improve productivity in dam construction and developed equipment that can convey concrete on the steep slope of a dam without separation of materials. The conveying capacity was confirmed to be 280 m3/h. The material was transported at a downward inclination of 45°. The material separation resistance of concrete was evaluated by focusing on the difference in the amount of coarse aggregate of 40 mm or more before and after transport. The tests using a verification test machine confirmed that it is possible to transport RCD, and concrete with slump without material separation.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Mixing test and evaluation of basic properties of RCC using high Ca type class F fly ash

B. Egailat, Y. Aosaka, T. Yamamoto & S. Tsutsui

The Upper Cisonkan Pumped Storage Power Plant Project is a project by an Indonesian state-owned power company to construct the country's first large-scale pumped storage power plant with an output of 1,040 MW in the upper reaches of the Citarum River in West Java. Both the upper and lower dams have a height of 100 m, however by updating the seismic hazard analysis in accordance with the revision of the country's seismic hazard map in 2017, the maximum acceleration at the site increased from 0.5g to 0.8g. In order to ensure the stability of the dams, the dam volume of both dams must be increased by about 20%, and the RCC (Roller Compacted Concrete) must be strong enough to withstand strong earthquakes. Increasing the amount of cementitious materials to obtain a high-strength RCC (rich RCC) contributes to ensuring workability, however it is affected by temperature stress, therefore it is necessary by mixing fly ash to reduce the heat of hydration in short-term and to promote the pozzolanic reaction in long-term is the key to RCC mix design. On the other hand, it has been reported that the quality of FA from the Surabaya Power Plant, which can be procured in the Java Island, is not stable, and Class C or F with high Ca, which is unsuitable for RCC, is produced. Therefore, we started RCC mix design by changing the blending ratio of cement and class F fly ash. Analysis of the components of fly ash using an analyzer is carried out to understand the hydration and pozzolanic reactions, and contribution to workability of the RCC, which will be used as basic data for RCC dam design for the Project.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Report on the utilization of Construction Information Modeling/Management system in the management of Nunome Dam

H. Goya, D. Murai, T. Kubota, Y. Miyachi & A. Suzuki

There are growing demands for the introduction of digital transformation (DX) in construction sector in response to labor shortage, work style change, and the coronavirus pandemic. The introduction of a CIM (Construction Information Modeling, Management) system is one of the measures to meet those demands. CIM is an application of the concept of BIM (Building Information Modeling) to construction and management in the civil engineering field, and aims to improve the efficiency of construction and maintenance of facilities by using 3D models. At Nunome Dam, efforts to establish the CIM system for the purpose of enhancing efficiency and sophistication in management have been underway since fiscal year 2016, and it is currently in operation. This paper reports on the utilization status of the CIM system at Nunome Dam and the issues that have been identified to date.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Development and application of hybrid method to inhomogeneous geology for curtain grouting - The Nam Ngiep 1 Hydropower Project, Lao PDR –

T. Kawata, K. Nakamura, Y. Yoshizu, T. Fujii & S. Tsutsui

Curtain grouting for dam foundation treatment is one of the most crucial work items in dam construction to secure the impermeability of the foundation rock. Some decades ago, the Grouting Intensity Number (GIN) Method developed in Europe has been frequently applied to relatively simple geotechnical structures. On the other hand, the Conventional Method, which requires phased mix proportion and water pressure tests through a sequence of the works, is as yet reliable for inhomogeneous geology in Japan. This paper presents the development of a modified curtain grouting method and its application to the Nam Ngiep 1 Hydropower Project in Lao PDR, which has an inhomogeneous geology of sedimentary rock with weak layers affected by fold movement. As a result of the material test and the field grouting test, the new grouting method in the Nam Ngiep 1 Hydropower Project was developed. The method has been dubbed as “hybrid” because it garners both the economical superiority of the GIN Method in that it enables the use of a single thick mix proportion, and the flexible applicability of the Conventional Method in that the individual design pressure in each stage is based on water pressure tests.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Enhancing the sustainability and efficiency of trapezoidal CSG dams: An innovative approach using nonstandard fly ash

T. Ishida, T. Abe, N. Yasuda, Y. Yamaguchi & T. Suzuki

In this study, the feasibility of using fly ash (coal ash) as a partial substitute for cement material for the trapezoidal cemented sand and gravel (CSG) dam, is examined to reduce the environmental impact and effectively use resources during construction. A trapezoidal CSG dam is composed of rocky material mixed with cement and water as the dam body material. This rocky material is referred to as CSG material. Because of the shapes of the cross-sections of trapezoidal CSG dams, the stresses generated are small (a few MPa). With the appropriate mixing ratio, the decrease in strength at an early age may be acceptable due to the inclusion of fly ash. Conversely, the use of fly ash should reduce the risk of temperature cracking due to the reduction in hydration heat generation inside the dam body and the increase in long-term strength due to pozzolanic reactions, suggesting that the proactive use of fly ash is worthwhile. The fly ash used in this study is not the Japanese Industrial Standard (JIS) Class II fly ash currently used for concrete but instead a non-JIS product. Fly ash is blended into the outer mixture of cement. The test results are as follows. (1) Compared to those of the mixture without fly ash, the mixture with fly ash in the outer mixture tends to exhibit small changes in the CSG density and strength over time, confirming that this mixture is effective. (2) Of the formulations with fly ash, those with 200 kg/m^3 of fly ash show relatively high CSG strength. In the Naruse Dam, the CSG strength of 100 kg/m^3 of cement with material D (a mixture of dam site terrace deposits and crushed rock material from the Akataki quarry site) without fly ash is 2.5 N/mm^2. Furthermore, the mix with fly ash in the outer mixture has a strength approximately 2 to 3 times greater than the CSG strength. However, test results at 91 days of age are considered to reflect the physical properties of fly ash. Additional testing is desirable to confirm the long-term strength development that reflects the inherent chemical properties of fly ash.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Digital transformation (DX) in construction. Digital twin supervision at Kawakami Dam project

M. Omata, K. Ueko

Japan is becoming a society with a declining population. Additionally, a decrease in the number of dam projects is also leading to a shortage of experienced dam engineers. So, it is important to efficiently manage the vast construction site area with limited numbers of engineers. To achieve this and improve construction productivity, we have transformed several manual processes into digital ones. Kawakami Dam is a concrete gravity dam with height of H=84m and volume of V=455,000m^3. In this project, because of the short construction period, we automated many processes. For example, we applied Cyber-Physical Systems that analyze and display the information collected by sensors from the real world in cyberspace. This digitalization and digital information realize the automatic operation system of cranes. Two things are essential to display this dynamic data. One is the accurate Building Information Modeling and the other is the static point cloud data that serves as the background. For these purposes, we made advanced use of drones. For utilizing drones in construction sites, there was a change in the regulation. Before that, we could only operate the drone under the operators' visual sight. However, the revisions to the Civil Aeronautics Law have made it possible to fly Levels 3 and 4, which are flights "Beyond Visual Line of Sight" BVLOS. The purpose of this development is to improve the productivity of construction supervision with this technology. Specifically, we built a drone system that automatically performs 4 tasks. Patrols, inspections, measurements, and abnormality detection. This information is linked to the CPS, which centrally manages the job site. We took a partnership with a company called KDDI SmartDrone. Each company brought in their own strength for effective collaboration. The main focus of the development is the Level 3 flight. Since this site is in the mountains and has poor connectivity, we are also reinforcing the radio wave (LTE). The two companies' systems are highly linked, and flight instructions can be given from Obayashi's CPS to the drone flight system. This technology makes it possible to save labor in on-site supervision.

Theme 3 Spillway and outlet works

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Research on adopting low friction rubber seals for high-pressure gates

H. Yasui, G. Yasuda, N. Fukushima, A. Matano & T. Asano

The effects of the low friction rubber seal coated by ultra-high-molecular-weight-polyethylene (UHMWPE) for high-pressure gates was examined in laboratory. The frictional resistance of the rubber seal account for over 40% of the operating load in a high-pressure gate, and UHMWPE coating significantly reduces the friction coefficient of the rubber seal. The gate sliding tests for the low friction rubber seal were successful without any extraordinary deformation such as bites. The friction coefficient of the low friction rubber seals was reduced by 75-90% compared with the conventional rubber seal without UHMWPE. In addition, it was confirmed that the low friction rubber seal was possible to seal without water leakage under the water head of 100 m by devising crimp pressure, top shape of the rubber seal, and UHMWPE thickness suit-ably. Furthermore, the sufficient abrasion resistance of the low friction rubber seal was certified from the result of the compressive sliding tests. The low friction rubber seal has durability containing weather resistance, too. The high-pressure gate with the low friction rubber seal has durable for more than 20 years with normal operating frequency (twice a month). The low friction rubber seal has already been used in actual gates which was installed at dam upgrading projects, and the operating load of the gate was reduced by 20% or more than conventional rubber seal. The motor capacity of the hoist was reduced by approximately 40% successfully. This method contributes to the conservation of material and energy with respect to gate equipment.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Expansion of large gates in the Nagayasuguchi Dam remodeling project

T. Takahashi, Okamatsu

Nagayasuguchi Dam is a multi-purpose dam completed in 1956 for the purpose of flood control and electricity supply through hydropower generation. The remodeling project of the Nagayasuguchi Dam is intended to enhance the dam's functions to mitigate the damage caused by floods and droughts, which have been increasing in recent years. This paper describes the construction of the water gate facilities in this dam remodeling project. There are two major features of the project. The first feature is the large-scale cutting of the existing dam body for the installation of two new flood discharge gates to improve flood control functions. Since the new discharge gate will be large-scale (approximately 27 m height), a fixed gate (height 6.5 m) was installed at a distance of 1.5 m from the surface height of the overflow water determined by hydraulic model experiments. As a result, the height of the movable gate was kept to approximately 20m. Additionally, the movable gate has a three-leaves linked roller gate structure, and the main roller uses a rocker beam structure to ensure that the load is transmitted as evenly as possible to the rollers. As a result, we were able to reduce the opening/closing load by reducing the weight of gate leaf and improve the ease of installation on site. In order to safely improve the flood control function, the seal type used continuous rubber on the four edges of upstream face of gate, making it possible to stably adjust the flow rate at intermediate openings. This increased the flood control capacity from 10.96 million m^3 to 12 million m^3 by lowering the reserve discharge level. In addition, the flood control capacity was increased to approximately 18.4 million m^3 by lowering the storage level to the pre-discharge level (EL 214.7 m) through increased discharge capacity. The second feature is to add a selective intake system to the existing intake for power generation in order to prevent prolonged turbidity after a flood. Water from appropriate depth will be taken and discharged downstream to improve the environment of the downstream river.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Measures to control thermal cracking in the riverbed discharge facilities of the Asuwagawa Dam

S. Aoyama, H. Yamaguchi, Y. Masai, T. Hiratsuka, T. Shikada, & T. Kawabata

Since there was concern about cracks in the concrete around bottom outlet facilities of the Asuwagawa Dam, construction measures were taken. Specifically, the following measures were implemented, increased fly ash substitution rate, use of leavening agent in the concrete com-position around the discharge pipe, partial use of low heat Portland cement, concrete manufacturing temperature limited to 18℃ or less, implementation of shalf lift concrete placement and flowing cold water curing, decrease of internal temperature by pipe cooling, decrease of internal temperature difference by pipe warming. These effects of the measures were confirmed by ther-mal stress analysis. In addition, the amount of autogenous shrinkage of full-size aggregate was measured by an autogenous shrinkage test, which is rare for dam concrete, and the results were reflected in the analysis. In conclusion, we confirmed that the restraining strain is within the allowable value 100μ in the analysis. This paper provides an overview of the results.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Expansion of large gates in the Nagayasuguchi Dam remodeling project: a focus on the installation of selective water intake facilities

H. Okamatsu, T. Takahashi

Nagayasuguchi Dam is a multi-purpose dam completed in 1956 for the purpose of flood control and electricity supply through hydropower generation. The redevelopment project of the Nagayasuguchi Dam is intended to enhance the dam's functions to mitigate the damage caused by floods and droughts, which have been increasing in recent years due to the effects of climate change. There are two major features of the project. The first is the large-scale cutting of the existing dam body for the installation of two new flood discharge gates to improve flood control functions. Since the flood discharge gates to be installed are very large (approximately 30 m high), the height of the movable gate was reduced by separating the higher part into a fixed gate which located 1.5 m above the water surface estimated by hydraulic model test. This results the reduction of total cost due to reducing the size of the opening/closing device and the gate leaf weight which contribute the fabrication cost. The second feature is to add a selective intake system to the existing intake for power generation in order to prevent prolonged turbidity after a flood. Water from appropriate depth will be taken and discharged downstream to improve the environment of the downstream river. The withdrawal water depth can be selected in surface, middle, or low layer. Corresponding these depths, the intake was divided into two sections in which the surface and middle gate and the low gate are installed, respectively. The low layer intake gate installed in deep water area has a built-in security gate. This is a flap gate that starts to open without power when the difference in water level between the inside and outside of the intake channel is 1m or more, and this flap gate also has forced operating function by electrical motor. As a result, it is possible to more safely control the water level difference acting on the water intake gate, and to prevent the security gate from unintentionally opening and interfering with the existing concrete structure during the raising and lowering of the water intake gate.

E. ICOLD 28th Congress in, Chengdu, May 2025

Improvement of flood discharge facilities in the Sengozawa dam redevelopment project

F. Yamada

The Sengozawa Dam Redevelopment Project is a project to reconstruct the existing flood discharge to add a flood control function to an irrigation-only dam. Because the dam will continue to operate during the redevelopment project, the construction period is limited to approximately four months during the non-irrigation season. In flood discharge construction, it is important to plan temporary facilities that do not affect the dam function and to plan the construction to be completed under severe constraints. This paper describes the details of the temporary facility planning and the entire reconstruction work by lift schedule management using 4D-CIM.

Theme 4 Sophisticated approach for dam operation

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Efforts on pre-discharge operation to enhance the capacity of flood control at Kusaki Dam

H. Nishimura, M. Tsunoda N. Tomida & H. Sasahara

The pre-discharged operation has been recognized as one of the most effective dam operation methods to mitigate the risk of floods at downstream of the dam and the central government issued the new guideline on pre-discharged operation in 2020. Kusaki Dam carried out the pre-discharged operation against Typhoon Hagibis (Category 5) in 2019 and its effectiveness was actually proved. Based on post simulation referring to the guideline on above Typhoon by Kusaki dam office in 2020, the following points were presented as the key for consideration to reflect into the specific operation rule at individual dams: (1) The operation will be difficult if the pre-discharged volume needs to be changed every time following the forecast of rainfall and inflow volume. (2) It is important to consider the river water level at downstream rivers from the viewpoint of public safety. Based on these points, the pre-discharged operation rule at Kusaki dam was drafted.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Shared Challenges and Future Perspective revealed in the India-Japan Joint Workshop on Dam Management Issues including Dam Inspection and Water Efficiency

T. Konami, P. Gyamba

The Central Water Commission (CWC), Ministry of Jal Shakti of India and the Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT) of Japan have signed a memorandum of cooperation (MoC) focusing on the field of water resources in 2019. Based on this MoC, both parties had a discussion on dam-related issues such as dam inspection and water efficiency in December 2023 and held a joint online workshop on those issues in May 2024. This paper is reporting the outcome of the workshop to share the challenges raised in the workshop and possible solutions discussed based on the cooperation between CWC and MLIT. Both parties found that there are common challenges including dam inspection and dam rehabilitation, and possible measures such as capacity building and technical cooperation including with the private sector.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Characteristic analysis of predicted rainfall in dam basins in Japan and development of a decision-making support system for dam operation

Y. Morooka, T. Takeshita

In Japan, based on the Guidelines for preliminary release of dams, when flooding is predicted based on forecast rainfall information, the reservoir level is lowered in advance and the capacity for water utilization is temporarily used as capacity for flood control. However, due to the inaccuracy of predicted rainfall, there are cases where preliminary release of dams cannot be carried out. In this study, in order to compare the guidance predicted rainfall by the

Japan Meteorological Agency used in the Guidelines for preliminary release of dams and the actual rainfall, we calculated the threat score, false alarms rate, and misses rate in the upper basin of 1,480 dams in Japan. Furthermore, the ensemble predicted rainfall was also compared with the actual rainfall in order to examine the possibility of using it for preliminary release. In addition, there is a trade-off relationship between flood control and water utilization in terms of the storage volume of dams to be released in advance. Therefore, we have developed a system that supports the decision-making of the optimum preliminary release amount by the dam manager after comprehensively considering both risks using the ensemble forecast rainfall. And the usefulness of the system was confirmed.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Development of a dam operation support system for flooding using artificial intelligence technology

S. Takino, T. Teshigawara & T. Maekawa, K. Kojima, H. Shionoya & T. Onishi

Using an artificial intelligence (AI) technology called reinforcement learning, we constructed a dam operation support system that provides operation plans that are easy for operators to understand. According to dam operation regulations and manuals, actual dam operations are based on information such as predicted dam inflow discharge, heavy rainfall advisories, and rainfall in areas upstream of the dam. The information imparted to the AI in this study was based on the dam inflow and predicted dam inflow discharge, which are easy to formulate. For example, if the current dam inflow is low and the predicted inflow is also low, power generation is implemented. However, if the predicted dam inflow discharge is high, it is necessary to operate the dam during flood events, so the decision will be made to implement preliminary discharge and to stop power generation. The discharge policy is determined by combining the AI-generated discharge policy with a dam simulator that calculates the amount of water stored in the dam. The thresholds for dam inflow discharge and predicted dam inflow discharge need to be learned by the AI. Therefore, a reward function was defined in which the reward is higher if there is no violation of the regulation for the amount of water used for power generation or of the dam operation rules, and reinforcement learning was conducted for different flood events to identify the optimal threshold. In the inference process, optimal dam operation was determined by discharge calculations using a dam simulator based on the operation plan at the thresholds identified by the AI, in accordance with the inflow discharge and water level for each reservoir. Since real-time verification was not possible, a demonstration test was conducted by simulating dam operation with the same predicted inflow discharge. The operation plans produced by the AI were then compared with those proposed by dam operators. Comparing the results for human and AI decision making in one flood simulation, the AI proposed an operation plan that continued generating electricity for approximately 6 hours longer. It was also confirmed that the AI recommendations did not violate the dam operation regulations.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Initiatives related to smart operation and utilization of existing dams in Japan

T. Sumi, T. Matsubara

In Japan, in 2020, with the aim of strengthening flood control functions of existing dams, a new guideline to conduct pre-flood drawdown, the specific dam operation in Japanese river administration, including water utilization dams, based on rainfall prediction has been launched. Furthermore, in 2020, Japan declared its commitment to carbon neutrality, with the goal of achieving carbon neutrality by 2050. In order to cope with the increasingly extreme flooding associated with future climate change and to achieve carbon neutrality, it is necessary to make even more advanced use of flood control dams and water utilization dams. Therefore, JAPAN COMMISSION ON LARGE DAMS(JCOLD) has organized the specific committee focusing on smart operation and management for flood control and water utilization (hydropower and irrigation) by (1) investigating recent disaster events and social conditions, (2) researching the latest weather and climate change prediction, and adaptation measures, (3) evaluating the effectiveness of the pre-flood drawdown operation, (4) evaluating the possibility of improving flood control and water utilization by utilizing long-term ensemble rainfall prediction, and (5) surveying the latest technology trends. In particular, in order to evaluate the effectiveness of the pre-flood draw-down operation, we investigated the characteristics of each dam reservoir by the equivalent rainfall (pre-flood drawdown storage volume/catchment area) on multi-purpose dams, hydropower dams and irrigation dams, and confirmed the effectiveness of flood risk reduction by calculating reduced flood discharge through the simulation of the dam operation. In addition, to evaluate the possibility of improving flood control and water utilization by utilizing long-term rainfall prediction, we conducted a discharge simulation in the case where pre-flood drawdown operation starting 10 days before the flood was carried out by maximizing hydropower generation. As a result, we obtained that further flood risk reduction and increasing power generation can be possible if optimal operation is conducted by utilizing highly accurate rainfall prediction on with a longer prediction lead time (for example, long-term ensemble rainfall prediction). By compiling the results of these various surveys and evaluations, we will propose future actions for the advanced utilization of existing dams, including long-term rainfall prediction and the use of AI.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Enhancing flood control and hydropower capacity through the implementation of long-term ensemble rainfall forecasts

T. Tanaka, T. Endo, K. Kido, T. Sano, Y. Michihiro & T. Sumi

In Japan, a new initiative about dam operation has recently begun, which uses long-term ensemble forecasts (LEF) to enhance flood control capacity, water resource and hydropower generation functions. This paper describes the introduction of this dam operation concept. Ensemble forecasts is a “bundle” of multi forecasts and in our study the bundle consists of 51 forecasts. In order to implement the bundle of forecasts to actual dam operation, we must decide which forecasts for which type of operation should be adapted. In our concept, we classify dam operations into five chronological stages: such as normal times when there is no rainfall, a stage when rainfall is predicted in advance, a stage when flood control is actually carried out due to rainfall, and a stage when rainfall is expected to end, and we propose the effective implementation of LEF in each stage. Now more than 80 dams in Japan introducing LEF. We also intro-duce the current status of dam operations in Japan that utilize LEF and examples of the quantitative effects for flood control and hydropower generation. In addition, we will analyze the issues of institutional and social acceptability from the viewpoint of the management responsibility of dams which is the final gap in implementing new technology in dams as social infrastructure. Legal responsibility about meteorological/ hydrological forecasting and dam operation may be different in each country. We introduce the analysis of this issue under the Japanese legal system.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

New operation rule for increasing power generation by utilizing late flood discharge at Hitokura Dam

K. Sakamoto, H. Sasahara, S. Naito & H. Soda

The new rule of reservoir operation along rainfall prediction was formulated at Hitokura Dam of the Yodo River system in 2021. In this rule, the late flood discharge volume, which is being less than the flood scale at the flood control operation, can be stored into the flood control capacity. The relatively large inflow which does not reach the flood scale can be also applied as same rule, and then the stored water is utilized for the hydropower generation as the subsequent discharge following the flood control operation. Generally, the water level in the flood control capacity had to be smoothly lowered to the flood seasons basic water level by the gate operation of the late flood discharge appropriately. The new rule of Hitokura Dam is allowed to implement at the certain condition, that is, when upcoming rainfall is judged not to cause the negative situation by the subsequent flood control. Based on simulations, applicable conditions such as the implementation period, maximum water level that allows to store within the flood control capacity and criteria of judgement for implementation or cancellation are formulated. The applicable period of this new rule is set between July 16th and October 15th, with the available water level at 1.4m higher than the flood seasons basic water level which volume is 1.13 million m^3. This is the capacity that can be discharged in around 7 hours by the release through conduit gates. With regard to the time allowance of rainfall prediction, 39 hours by the Meso-Scale Model guidance (MSM-G) and 72 hours by the Global Spectral Model guidance (GSM-G) are referred, and not exceeding of 25 mm for 12 hours of accumulated rainfall was set as the applicable condition. As a result of trial calculation, 32.62 t-CO2 as maximum effect case was approximate value on reduction. During the actual operation of Typhoon Lan in 2023, the increase of hydropower generation of 65MWh and the reduction of 61 t-CO2 compared to the conventional operation could be achieved.

Theme 5 Earthquakes and dams

A. 11th East Asian Area Dam Conference in Daejeon, September 2022

Dynamic Displacement Monitoring of Dams using GPS Self-relative Single Positioning toward Upgrading Seismic Monitoring

M. Kashiwayanagi

Safety assessment of dams to earthquakes is commonly conducted by detailed inspection and deformation survey on a dam after earthquakes. Acceleration monitoring frequently at the dam crest and the base gallery indicates the acceleration behavior of dams during earthquakes. In case of exceptionally strong earthquake, reproduction analysis using dynamic numerical method is conducted to explore the detailed dam behavior accompanied by the reference to the monitored acceleration behavior of the dam. The stress and/or the strain in the dam are key indices which directly evaluate safety of the dam. However, these key indices cannot be verified due to the lack of the deformation behavior during the earthquake. Only GPS monitoring which has become popular recently in Japan can measure the relative displacement at the monitoring locations on the dam surface before and after the earthquake. These are not sufficient to make sure the validity of the analysis. From this point of view, a new method using GPS is proposed for dynamic displacement monitoring for large scale structures including dams. It is characterized by a three-dimensional dynamic displacement that can be measured with high accuracy. It is based on a carrier phase observation technique, like GPS relative positioning, and takes a time differential carrier phase, while it requires only one sensor as in GPS single positioning. Thus, it is called Self-relative Single Positioning. The method can monitor dynamic displacement of more than 2 mm to 5 mm of amplitude in less than half frequency of the maximum sampling frequency of the sensor used. The high frequency GPS sensor up to 100 Hz is applicable to the method so far. It is considered that the method with higher frequency sensors will provide sufficient performance to monitor the dynamic dam behavior during earthquakes. I will present the formulation of the method, the experiment results for investigating a practical application of the method to monitoring the dam behavior during earthquakes. In addition, the interactive software on a personal computer demonstrates how to enhance the applicability of the method. The contents of the presentation are listed below.

1) Background of dynamic displacement monitoring of dams during earthquakes
2) Formulation of Self-relative Single Positioning
3) Vibration test for verification of the method
4) Interactive software for practical application
5) Looking forward to dynamic monitoring of dams
6) Conclusion

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Examination of damping characteristics of concrete dams in damreservoir-foundation system

M. Kashiwayanagi, M. Yoda & Z. Cao

Estimation on current material properties such as shear modulus and damping ratio is practically essential issue for a safety assessment of existing concrete dams for earthquake loads. In this paper, the quantitative examination of damping ratio due to the interaction among a dam, a reservoir and foundation is conducted by a parametric study using a numerical model of the dam-reservoir-foundation system of the existing concrete dam of 101 m high. In-situ damping ratio of the dam during earthquakes is estimated using Damping Evaluation aided by Transfer Function Matrix (DE-TFM) method based on the monitored behaviors during earthquakes. Finally, these results are comprehensively addressed for further understanding on the damping characteristics of concrete dams. The radiation damping from the dam to the reservoir and the foundation is significant more than inner damping of the dam and the foundation itself. It reveals that the considerations on the interaction of dam-reservoir-foundation system is essential in analyzing the dynamic behavior of dams during earthquakes. The dam-reservoir interaction is gradually stronger under the water depth beyond approximately a half of the full depth, resulting in the increase of the damping ratio. The radiation damping due to the dam-foundation interaction is additionally involved, which relates only to the impedance ratio of the dam and the foundation. It is considered that the dam-foundation interaction depends heavily on the soundness of the foundation rock where the dam exists. The interaction in dam-reservoir-foundation system is naturally incorporated in a sophisticated analysis method with adopting 3-dimensional comprehensive numerical model where the inner damping of the dam and the foundation are necessary. However, the understanding on the mechanism of the interaction is important in the examination of the dam behavior clarified here. In the preliminary examination even with a simplified numerical model which requires a low-cost calculation, a reference to the above results helps to enhance the accuracy of the examination.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Evaluation of material properties of CSG based on actual earthquake behaviors and pressure-meter tests of a dam

N. Yasuda, Z. Cao & S. Amdo

In this study, the elastic modulus of cemented sand and gravel (CSG) and its dependence on the confining pressure were clarified by triaxial compression tests and pressure-meter tests in borehole. The results of these material tests were verified by a 3D reproduction analysis of the dynamic behaviors of the Apporo Dam, a trapezoidal CSG dam, during a strong earthquake, the 2018 Hokkaido Eastern Iburi Earthquake. It was found that the results of the in-situ pressure-meter tests are more realistic for the reproduction analysis of the dam than those obtained in laboratory tests because the influence of the confining pressure conditions, the material age of the CSG, and the grain size of the materials are assumed to be more significant in the laboratory tests. By analyzing 30 seismic records of the dam, the fundamental frequencies, the damping ratio and the acceleration amplification of the dam were clarified. The average damping ratio of the CSG is 5.5% when the maximum acceleration at the dam base is less than 0.3 m/s^2. The damping ratio of the CSG identified in the reproduction analysis is 10%, which is slightly larger than that of the analysis of the seismic records. It is believed that the new findings will be beneficial for the future construction and promotion of the new-type dam originated in Japan.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Dam-reservoir-foundation interaction on damping characteristics of trapezoidal CSG dams during earthquakes

M. Kashiwayanagi, Z. Cao

The damping characteristics of trapezoidal CSG dams are examined focusing on the interaction among a dam, a reservoir and a foundation. A numerical study has been conducted using the 3-dimensional (3-D) numerical model consisting of a dam, a reservoir and a foundation. The behaviors of an existing trapezoidal CSG dam during a large earthquake and its aftershocks are referred for making clear its damping characteristics and for the validation of the DE/TFM method invented by the authors. The damping ratios are essential parameters for the safety assessment of existing dams during earthquakes. The damping ratio is a material property of the dam or the foundation. However, the dam-foundation-reservoir system bring additional damping effects to the dynamic behaviors due to the mutual interactions in the system. There are some reproduction analyses focusing on the damping ratios in the dam-foundation-reservoir system. Few examinations are found on the damping characteristics due to the interactions. The authors have examined the damping characteristics of a concrete gravity dam by the numerical study and the evaluation of the damping ratios using the monitored behavior during earthquakes. In this paper, a similar examination for the trapezoidal CSG dam which has milder upstream slope and likely lower shear modulus of the dam material and the foundation is conducted. It is clarified that the interactions in the dam-foundation-reservoir system affect significantly on the damping characteristics of trapezoidal CSG dams.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Seismic performance evaluation of fill dams using velocity based space-time finite element method

K. Sakai, K. Fujisawa & A. Murakami

The seismic performance assessment of major fill dams against the mega-earthquake, indicated as Level 2 earthquake, has been consistently undertaken in Japan. In order to evaluate the seismic performance, the residual sliding displacement of the slopes or the settlement of the crest are commonly predicted upon the response acceleration computed by preceding dynamic response analysis employing the equivalent linear method. Nevertheless, this standardized approach sometimes encounters unacceptable results in practice. For example, the settlement is underestimated especially when vulnerable earthfill dams with lower stiffness are subjected to intense seismic motion. This paper discusses the limitation of the above conventional approach to the seismic performance assessment and reveals that the difference in shear strength used for the dynamic response analysis and the computation of the sliding displacement plays an important role in evaluation of the residual deformation. In addition, the seismic response analysis with an elasto-perfectly plastic constitutive model can be a feasible approach to the computation of the residual deformation under severe earthquake loading. Velocity based space-time finite element method, which can reduce numerical error and increase stability, is introduced for the dynamic analysis.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Investigation of the material and vibration properties of a heightened concrete gravity dam

N. Yasuda, Z. Cao, T. Mano & T. Nishimura

In recent years, flood disasters due to climate change have become more frequent and severe, and increasing the flood control capacity of existing dams by heightening them is one of the countermeasures. In this study, the material properties of a 65-year-old concrete gravity dam were investigated as a case study, and the material test results were verified through an analysis that reproduces the seismic behavior of the dam. It was found that the compressive strength of the 65-year-old concrete was the same or slightly higher than that at the time of dam construction and that the elastic modulus had not decreased. In addition, by analyzing the seismic records of the dam, changes in the vibration characteristics of the dam before, during, and after its heightening were clarified. Furthermore, the elastic modulus and damping ratio of the concrete of the new body were estimated by analyzing the reproduced seismic behavior of the heightened dam. The following conclusions are obtained. The mechanical properties of concrete in its present condition were clarified by reviewing the results of material tests using core specimens of dam concrete 65 years after its completion. Compared to the data published in the Standard Specifications for Concrete Structures by JSCE, it was determined that the elastic modulus of the dam concrete has not decreased after 65 years since its completion and has increased to some extent. The test results also revealed the relationship among the tensile strength, compressive strength, and elastic modulus of the dam concrete, as well as the relationship between the static and dynamic elastic moduli. The test results, including the elastic modulus, were verified by an analysis that reproduced the seismic behavior of the dam. The elastic modulus and damping ratio of the concrete of the newly constructed dam were identified after conducting a reproduction analysis of the seismic behavior of the dam after heightening and reverifying the physical properties of the existing dam. Notably, the mechanical properties of the concrete of the heightened dam were confirmed to be slightly smaller than those of the existing dam due to the early age of the materials.

E. ICOLD 28th Congress in, Chengdu, May 2025

Optimization of the cross-sectional design of trapezoidal CSG dams

N. Yasuda, Z. Cao & T. Nakamura

In this study, via numerical analyses, the effects of the elastic modulus of the CSG and the upstream and downstream slopes of the dam on the seismic performance of the dam were clarified. To improve dam safety and reduce construction costs, the upstream face was adjusted to a steeper slope in the analysis, and it was revealed that the internal stability was less satisfactory. In addition, it was also found that seismic safety can be improved by increasing the unit cement content in a limited area near the upstream and downstream ends of the dam base. That is, the construction cost of a dam can be significantly reduced through rational improvement of the cross-sectional shape and arrangement of the unit cement content.

E. ICOLD 28th Congress in, Chengdu, May 2025

Seismic Analysis and Reinforcement Method for Small Gravity Dam with Horizontal cracks

H. Kawasaki, N. Iwata, T. Suga & R. Kiyota

In Japan, guidelines outline the seismic performance criteria that dams must meet to withstand the maximum earthquake motion at their location in the future (maximum possible earthquake motion). For concrete gravity dams, these guidelines recommend evaluating seismic performance through nonlinear dynamic analysis, which accounts for the initiation and propagation of tensile cracks within the dam's body concrete, using an FEM model that assumes the dam body is initially crack-free. However, for small dams, this approach often fails to detect tensile cracks, as the stress induced by seismic activity is minimal. However, older dams, especially those with open horizontal construction joints, may not be as safe as they appear when the deterioration of the dam body is taken into account. In this study, a two-dimensional FEM model is developed for the Senbon Dam (16 m high, 109 m long, Matsue City Waterworks Bureau), which exhibits leakage along its horizontal construction joints. The model incorporates continuous horizontal cracks as joint elements to simulate these conditions. Seismic response analysis was conducted by inputting the maximum possible earthquake motion into the model, aiming to evaluate the impact of horizontal cracks on the behavior during an earthquake. In addition, the effectiveness of PS anchors, installed to reduce the tensile stress within the dam body, was evaluated. The results showed that even if the

sliding safety factor for the block above the cracks is high enough to prevent sliding, rocking motion could still induce displacement along the horizontal cracks. This rocking motion also generates significant acceleration due to the impact. However, introducing compressive stresses into the cracks via PS anchors was found to nearly eliminate displacement along the horizontal cracks.

E. ICOLD 28th Congress in, Chengdu, May 2025

long-term in-situ monitoring on Dynamic modulus of elasticity of dam concrete and its verification by the analysis of daynamic behavior of the dam

S. Nosaki, M. Kashiwakanagi

Japan Commission on Large Dams (JCOLD) has established the technical committee on Research on freeze-thaw impact on dams in 1961. The large-scale concrete specimens of 1m cube have been arranged at the six dams sites and been continuously monitored for 60 years since then. J-POWER has participated the research for the Otori dam (VA, 87m high) as well as large scale concrete specimens of the similar mix of the dam. The dynamic modulus of the elasticity has been perfectly secured in the Otori dam after 60 years passed. The large-scale concrete specimens shows different results somewhat according to the mix proportion. These elasticities have been gradually deteriorated to 80 % in minimum. The adverse effect of Fly ash is significant, while the influence of water-cement ratio and AE(Air-Entrained) is not clear. Combined effects can be considered. In addition, it is found that the number of freeze-thaw cycles makes the clear difference in the deterioration of the concrete of the similar mix proportion between the Otori dam and the specimens. The current dynamic modulus of the elasticity of the Otori dam is also identified by the reproduction analysis on the Otori dam behavior during the recent earthquake in winter as 40 kN/mm^2, while a value of 46.9 kN/mm^2 was initially estimated at the surface area of the Otori dam and currently monitored almost as same. Reasons for a certain disagreement in these values between the in-situ measurement and the reproduction analysis are considered as the effect of the zoning of the dam concrete in which the inner concrete is of less cementitious material of 140 kg/m^3 comparing to the outer concrete of 3.5 m thick is of 210 kg/m^3, and the structural effect due to the transverse joints of the Otori dam which may show less contact pressure in winter. Taking such influences, these values are equivalent. It verifies that both estimation methods for the dynamic modulus of the elasticity of the Otori dam are applicable reasonably.

E. ICOLD 28th Congress in, Chengdu, May 2025

Nonlinear analytical modeling of dam gated pier based on earthquake records

Y. Matsuoka, Y. Otsubo & T. Arimitsu

The frequent occurrence of large-scale earthquakes in recent years has necessitated the seismic evaluation of dams, spillway gate, and dam gated pier. In the seismic evaluation of dam gated piers, it is necessary to evaluate the contact behavior between dam gated pier and spillway gate during earthquakes, but conventional analytical modeling methods ignore the effects of overflow shape and stiffness of the dam body, and are not rational. Therefore, in this study, the effects of the overflow shape and stiffness of the dam body on the dam gated pier were evaluated, and appropriate restraint conditions were considered. The applicability was confirmed through a replicated analysis using seismic observation records of the actual dam, and a reasonable analytical model was proposed.

Theme 6 Reservoir sedimentation and sustainable development

A. 11th East Asian Area Dam Conference in Daejeon, September 2022

Modification for Sediment Sluicing at Yamasubaru Dam

J. Take, K. Otsuka

Triggered by the extensive flood damage caused in the Mimikawa River system, due to Typhoon Nabi in 2005, Miyazaki Prefecture, the river administrator, played a leading role in establishing the Integrated Sediment Flow Management Plan. As a part of this scheme, Kyushu Electric Power Co., Inc. created a plan to mitigate a flood risk upstream of three dams it owns: Yamasubaru, Saigou and Oouchibaru Dams, by sediment sluicing. Under this plan, by lowering water-level of dam reservoir in case of floods due to typhoons, the reservoirs would come close to the state of the original natural river, thereby allowing upstream sediment flow into the reservoir to flow downstream of the dams. At Saigou and Oouchibaru Dams, modifications for sediment sluicing are already completed, and sediment sluicing operation is carried out at two dams from 2017. In this publication, the modification at Yamasubaru Dam that has been completed in 2022 is showed. In this construction, two spillway gates located in the middle of the eight existing spillway gates were removed, and the overflow section in the middle of the dam structure was cut down by 9.3m. Then the lower body was newly constructed, and a single steel radial spillway gate with sediment sluicing function, one of the largest gates in Japan, was installed. In this construction, it was necessary to keep functions to control floods and generate power. So, temporary cofferdam was installed at the upstream of dam. Because of using this coffer dam to divert river water into intake for power generation, we could continue generating power during construction. And we could control floods and keep construction secure by discharging river water from this coffer dam in flood situation. Furthermore, to address a damage by abrasion and crush that would be caused by sediment sluicing, new technology and materials, such as duplexed watertight rubber used at the bottom of gate and stainless clad steel employed for the skin plate, were adopted. With completion in 2022 after eleven years of construction, sediment sluicing is carried out at three dams in cooperation for the first time in Japan.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Modification for sediment sluicing at the Yamasubaru Dam

K. Otsuka, J. Take

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B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Risk assessment of a hydraulic structure due to reservoir sedimentation and submerged wood debris

S. Takata, T. Sumi & T. Koshiba

Dam spillways and outlets are crucial for dam safety and flood control. The bottom outlet of the Susobana Dam in Nagano prefecture, Japan was blocked in 2017 due to sediment and submerged wood debris. Since sedimentation in the reservoir had reached the height of the bottom outlet, sediment and submerged wood debris were likely pulled into the front of the bottom outlet during gate operation. Following the incident, investigations carried out using a remotely operated underwater drone confirmed the presence of submerged wood debris near the bottom outlet. Since only a few cases of bottom outlet clogging have been reported in Japan, this study investigated the following in order to prevent its recurrence in other dams: First, the impact on flood control functions as a consequence of bottom outlet clogging was analyzed. In Japan, many dams that are designed for flood control have bottom outlets installed to ensure high discharge capacity at lower reservoir water levels during a flood in order to keep vacant flood control pools before the peak discharge. Therefore, a malfunction of the outlets may lead to a sudden rise in the water level, causing a significant increase in discharge downstream. Second, we conducted a questionnaire to dam managers at the Ministry of Land, Infrastructure, Transport and Tourism to further elucidate the reservoir management issues associated with submerged wood debris. Consequently, both obstruction during excavation and dredging of deposited sediments, and blockage of water intakes were identified as the primary concerns. Furthermore, it was found that after flood events, it took around 1–6 months to collect driftwood from reservoir surfaces. Finally, a laboratory experiment was conducted to determine the sinking process of driftwood captured at the Susobana Dam and green wood in the upstream basin, resulting about 25% of the green wood sank within a month because of the density changes. It is necessary to continue to study countermeasures as well as the issue of sediment management around the gate.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Optimizing drawdown operation of two cascading dams to enhance cooperative sediment flushing in the Kurobe River

T. Takeshita, S. Ida, K. Noguchi & T. Sumi

Cooperative sediment flushing of the Dashidaira and Unazuki dams in the Kurobe River has been executed since 2001 to control floods and maintain the water utilization system. Cooperation among relevant administrative organizations and fishery cooperatives in the Kurobe River Basin is necessary to ensure cooperative sediment flushing. The people living near the dams requested for the reduction of the sediment deposit by the dams to manage soil quality deterioration and lower suspended sediment concentrations without affecting the fish quality and density. Therefore, we assessed the improvements in the dam operational method through numerical analysis and experiments. During the conventional operation, the water levels in both dams are lowered simultaneously, which results in sediment flushing of the Dashidaira Dam first, as it has less storage capacity than the Unazuki Dam. In contrast, the drawdown operation of the Unazuki Dam is analyzed where gates of the Dashidaira Dam are operated after the water level in the Unazuki Dam is lowered to the half of the usual level. Based on this, we conducted demonstration experiments. In 2020, the annual deposited sediment volume of the Unazuki Dam was 10,000 m^3, which was equivalent to a 97% reduction compared to the estimated value (310,000 m^3) in the conventional operation, while the maximum suspended sediment concentration was 37,000 mg/L, equivalent to a 26% reduction, compared to the estimated value (49,893 mg/L). The same results were acquired in 2021. Globally, some cascade dams conduct cooperative sediment flushing on various rivers, such as the Rhone River (Peteuil et al. (2013)). However, optimizing the operational sequence of sediment flushing operations among upper and lower dams is an issue that needs to be addressed in the future. The analysis and experiments conducted in the Kurobe River through this study provide significant insights on the sediment flushing operations of cascade dams.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Construction record of sluicing countermeasure work for Yamasubaru Dam

K. Yoshida, K. Yoshioka, A. Isayama, T. Sekine & K. Kawazoe

The Mimi River, which flows through northern Miyazaki Prefecture, has seven hydropower plants that provide more than 20% of Kyushu Electric Power's general hydroelectric power generation. The river's watershed is in an area with high sediment yield, and heavy rainfall in 2005 led to slope failures and sedimentation of in dam reservoirs. In the wake of those disasters, a comprehensive sediment management plan suitable for a river basin with a large amount of sediment was drawn up. The plan called for a switchover to sediment sluicing to be performed through coordinated operation of three dams in the Mimi River system. This construction work involved sediment sluicing countermeasure at the Yamasubaru Dam, one of the three dams mentioned above. In the project due to structural and time constraints for maintaining the dam's operational capability for power generation while ensuring safe discharge during flood season, a long construction period of 11 years in total was required. This paper chronicles the Yamasubaru Dam Improvement construction work, which was safely completed in June 2022.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Environmental assessment downstream of dams ater simultaneous sediment sluicing operations of three dams in the Mimikawa Rever system

S. Yamamoto, Y. Kitagou, R. Mori & K. Otsuka

Triggered by the extensive flood damage in the Mimikawa River system, located in Miyazaki Prefecture int he Kyushu region of Japan, resulting from Typhoon Nabi which occurred in 2005, integrated sediment control for the entire river basin from the mountainous area to the sea is being implemented (under the "Mimikawa River Integrated

Sediment Flow Management Plan" formulated by Miyazaki Prefecture in 2011). With its core position within this plan, Kyushu Electric Power is carrying out sediment sluicing at three dams (in order from the upstream, the Yamasubaru, Saigou and Oouchibaru Dams) in the downstream of the river. Through the implementation of sediment sluicing, the movement of sediment in the river has undergone a large change. For this reason, the company is analyzing and assessing the effects of this on the river environment, appropriately incorporating the results in sediment sluicing plan and making improvements in sediment sluicing. This paper reports on the results of analysis and assessment of environmental changes int he downstream of the three dams at which simultaneous sediment sluicing was carried out for the first ti me during Typhoon Nanmadol in 2022 when river flooding occurred on the largest scale ever recorded.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Experimental investigation of dam sediment fine particles removal technology for effective utilization of sediment

T. Oku, S. Nakamura, M. Ono, T. Yatabe, M. Minematsu, H. Asada, & H. Katayama

Methods such as excavation/dredging are widely used as countermeasures against dam sediment. If the excavated/dredged soil contains a large fraction of fine particle soil (which is silt and clay: hereafter called "fine particles"), it may be difficult to meet the quality requirements for construction materials, or there may be concerns about the environmental impact when the soil is used for riverbed supply materials into the downstream. As a result, when the material contains a large fraction of fine particles, it cannot be effectively utilized and may have to be transported to sediment disposal sites. The Water Resources Environment Center and the Association of Water Resources Sedimentation Technology have developed a method for classifying dam sediment, which removes fine particles, gravel, and dust from excavated/dredged soil and extracts high-quality sand, to effectively utilize excavated/dredged sediment from the dam reservoir as a dam sediment control measure. The objective of the joint research and development is to reduce the cost for the measure and improve the accuracy of fine particles removal by combining general-purpose machines. In this paper, we report on the results of formulation process of optimal system, in which we selected equipment configuration using a combination of general-purpose machines and confirmed the accuracy of fine particles removal, then on the results of classification experiments, in which we aimed to achieve under 10% fine particles con-tent ratio (hereafter called "FC"). The prospects for the future development of classification technology are also presented.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Operation of sediment bypass tunnel and stock yard facility to increase bypass efficiency in Miwa Dam upgrading project

M. Fujii, N. Iwata, S. Kobayashi & T. Sumi

Sedimentation is progressing in Miwa Dam due to large amount of inflow sediment transported from upstream during floods. Miwa Dam upgrading project has been undertaken since 1987 including large volume of sediment excavation to restore the reservoir capacity and permanent reservoir sediment management measures. The measures consist of a "sediment bypass tunnel" that guides sediment inflow directly to downstream during flood periods, and a "stock yard facility" that temporarily keeps sediment in front of the sediment bypass tunnel, which will be transported to the downstream through the sediment bypass by following floods. This is the first and unique test case of sediment management measures in Japan. In this paper, we report on the current situations of the operation of sediment bypass facilities and trial operations of stock yard facilities to increase bypass efficiency.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Project of sediment bypass tunnel at Horoka dam and verification of sediment flow effect by hydraulic scale model experimentst

Y. Shoji, Y. Ando, H. Niitsuma, & Y. Kitamura

At Horoka dam, upstream of Tokachi basin, sedimentation has increased since the hydroelectric power plant has operated in 1965. Sedimentation in the regulating reservoir has been excavated and transported to a disposal area to maintain the effective storage capacity. In 2016, the flood exceeding the design flood discharge of 300 m3/sec caused large quantities of sediment inflow. The reservoir filled up with sedimentation and the intake function of the hydro-

power plant has been lost. After that, the effective storage capacity was ensured by excavating sedimentation, and the power generation has restarted 20 months later. However, similar heavy rainfalls will be possible in the future because of recent climate change. When large quantities of sediment flow into the reservoir during floods, there is a risk of reduction in the effective storage capacity and loss of the intake function. Therefore, as the countermeasure for sedimentation, "Sediment bypass tunnel (here after, SBT)" was changed from the "excavation and removal" for the purpose of improving the sustainability of the power plant. This report describes the following: The alignment, design discharge and other specifications of SBT are designed, and sediment flow in SBT and riverbed fluctuation upstream of the tunnel are confirmed by hydraulic scale model experiments. In the design, design discharge of SBT is determined based on the effect of sediment discharged from SBT and sediment management cost. The cross section and the longitudinal slope of SBT is designed to satisfy hydraulic performance. Then, the validity of the design of SBT is verified by hydraulic scale model experiments. As the result, it was confirmed that no blockage by sediment occurred in the tunnel and sediment discharged without any problems. The flow regime and sediment dynamics upstream of SBT, and the volume of sediment discharged from SBT, differed depending on the scale of floods. In addition, the issues in the operation and maintenance of SBT are discussed. It is concluded that it is important to conduct both monitoring and simulations and to study the best way to operate the SBT based on these results.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Consideration of physical and biological environment changes assuming sediment replenishment downstream of Futatsuno dam

H. Iseki, N. Okamoto, N. Tabuchi, H. Ichiyanagi, I. Katano, & K. Morimoto

Sedimentation in dams has recently become a major problem. Although there are various methods for sediment control, sediment replenishment in rivers is considered a useful solution because it can improve the biological environment and flood control safety in rivers. This study continuously conducted physical and biological environment surveys downstream of the Futatsuno Dam at the Kumano River basin in Nara Prefecture for several years to accumulate data for implementing sediment replenishment. To understand the effects of dam discharge and the potential effects of sediment replenishment in the future, four survey points were established. Three points were located downstream of the dam affected by dam discharge, and two were located where the effects of sediment replenishment could be understood. Another point was established on a natural tributary unaffected by dam discharge or sediment replenishment. At each point, surveys were conducted annually prior to and after the flood season and during the post-flood period. The surveys comprised physical environment surveys to investigate the changes in riverbed material and biological surveys to investigate periphyton and benthos. We clarified that the response of the periphyton to the flood events indicated that the degree of detachment of the periphyton was dependent on the scale of the flood events in the river. In addition, we found that the benthos community downstream of the dam varied with the distance from the dam, and the benthos community farther from the dam was similar to that in the aforementioned tributary. Moreover, we identified the indicator species of the benthos for evaluating the effectiveness of sediment replenishment using the nonmetric multidimensional scaling method. This paper reports the results of multiyear environmental surveys conducted at several points downstream of the dam and in the aforementioned tributary. The study findings should be considered for the future implementation of sediment replenishment.

Theme 7 Water quality, environmental conservation and social consideration

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Verification of blue-green algae suppressing effect by reinforcing the shallow circulation facilities in Miharu dam reservoir

K. Asakura, F. Kimura & Y Maruo

In Miharu Dam reservoir, blue-green algal blooms have been occurring almost every year since the start of operation, causing landscape disturbances although there have been no serious damages to beneficial water use. Therefore, in 2014, the overall plan for water quality conservation measures was reviewed, and it was decided to reinforce the shallow circulation facilities, which are the core facilities for blue-green algae control measures. The reinforced shallow circulation facilities have been in operation since 2019 and monitoring surveys (demonstration operation surveys) have also been conducted to confirm the effects of the facilities. In this report, based on measured data obtained from past monitoring surveys, we report blue-green algae sup-pressing effect by reinforcing the shallow circulation facilities from four points of view, which are the change over time in algal blooms generation by indicators of total number of Microcystis genus colonies, cumulative solar radiation, average temperature and turnover rate, the change of circulation mixing degree by indicators of water temperature and water temperature gradient, the change of algae propagation degree by algae growth suppression indicators of hydrogen ion con-centration index and dissolved oxygen saturation and the change of lake landscape by indicators of total time of algae blooms observed.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

A report of the river restoration project by replenishing sediment at the downstream reach of Obara Dam

Y. Fukuda, M. Muramatsu, M. Hirai, H. Moriwaki, Y. Kawaguchi, Y. Miyagawa & H. Yoshioka

The downstream reach of Obara Dam, the Hii River, Shimane Prefecture, Japan (constructed in 2010 and operated by the Ministry of Land, Infrastructure, Transport and Tourism) has been suffering from severe riverbed armoring due to the lack of fine sediment supply from upstream reach. This is caused by the existence of the dam trapping the longitudinally transported sediment, thereby degrading the downstream river environment. Indeed, the total population of fishes such as Asiatic brook lamprey (Lethenteron reissneri) whose life history is sustained by sediment grains has been decreasing. Further, the overgrowth of filamentous green algae has been reported, suggesting that the riverbed environment is pos-sibly becoming an unsuitable habitat for Sweetfish (Plecoglossus altivelis altivelis) and the other fish species. To restore these undesirable situations, Obara Dam initiated a trial sediment supply project to restore the river environment two years ago. This is an interim report to explain the purposes and results of this project. Planning of the project was based on 1D and 2D morphological simulations to evaluate the accumulation of the replenished sediment downstream of the dam, from which the most effective sites for the replenishment have been determined. Supplying the sediment at 2 sites, upstream and downstream points of the nearest down-stream pool of Obara Dam, has been found to be the best practice. In addition, we introduced the concept of the exposed height of riverbed stones or rocks from sedimentary sand surface. This is an effective index for avoiding oversupplying sediment and to keep suitable habitats for periphytons as a good feeding place for the fishes. Moreover, the environmental monitoring results have been quantified, and the simulation to evaluate the contribution of the replenished sediment to physically remove the periphytons has been conducted based on the 2D Habitat. Suitability Index model for fish species.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Case study of biomass clearance and alternative fishery creation in large scale of dam reservoir

T. Yamamoto, K. Nakamura, K. Tomioka & S. Tsutsui

In the construction of a dam with a large reservoir, it is necessary to clear biomass—including standing trees in the reservoir area—in advance to minimize deterioration of water quality and greenhouse gas emissions after impounding. Poor quality water severely impacts not only reservoirs and downstream ecosystems, but also the livelihoods of local residents (farming and fishing) and social welfare, including sanitation. If biomass is not removed, its decomposition contributes to greenhouse gas emissions, for example, by producing carbon dioxide and methane. For the construction of the Nam Ngiep 1 (NNP1) Hydropower Project in Lao PDR, with a reservoir area of 67 km^2 and a main dam of 167 m high, water quality simulation was conducted according to Lao PDR guidelines, and an appropriate range of biomass clearance was set with con-sideration for topography, access, treatment of unexploded ordnance (UXO), precious species, and areas in which residents lived. Two years after the start of impounding, the cline of dissolved oxygen (DO) in the reservoir was spreading downward, and four years after the start of impounding, DO seems to have improved in the downstream and midstream areas of the re-regulating dam, which is located 6.5 km downstream from the main dam. The project owner is searching for more effective countermeasures, for example, by combining the aeration effects of both the re-regulating dam reservoir and the discharge from the main dam spillway gate. The number of fish caught in the reservoir and the lower Nam Ngiep River—which is affected by water quality improvements—increased significantly one year after the impounding, and fishery has greatly con-tributed to improving the livelihood of residents. On the other hand, residents (ethnic minorities) resettled near the re-regulating dam site are in the process of shifting from rotation-based agriculture—represented by slash-and-burn farming in the mountains—to stationary agriculture involving paddy fields on flat land. However, the benefits of creating reservoirs have not yet been enjoyed by residents. In the implementation of biomass clearance, risks such as delays in the resettlement of residents and commercial logging, in addition to the accessibility of biomass clearance areas, topographic conditions in the area, and work to remove UXO, have become apparent. We believe that establishing a risk management method that includes alternative measures against these risks, and preparing the appropriate budget and schedule contingencies, will lead to the avoidance of project delays and cost overruns.

In this paper, the procedure for risk management to solve issues from the planning of biomass clearance to its implementation is introduced by reviewing the reservoir water quality monitoring results. Furthermore, the influence that the appearance of a vast reservoir has had on restoring the livelihoods of ethnic minority residents re-settled from the reservoir area—and in particular, the influence of fishery areas newly provided by the reservoir—is evaluated.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Development of an efficient survey method using environmental DNA to assess fish fauna in dam reservoirs in Japan

T. Osugi, J. Okitsu, T. Minamoto, H. Ichiyanagi, Takami Adachi & T. Kodaira

In Japan, the Ministry of Land, Infrastructure, Transport, and Tourism conducts the National Census on River and Dam Environments, including baseline surveys of flora and fauna to gauge biodiversity. In recent years, survey methods employing environmental deoxyribonucleic acid (eDNA) analysis have emerged for assessing fish fauna, using sampled water from dams and rivers. This approach yields comprehensive data on biota, such as fish species, biomass, and density, from analysis of water samples at various collection points. Moreover, this method simplifies biodiversity assessment, requiring only bottles of sampled water. In this study, we compared eDNA survey results with river water census data to evaluate the efficacy of the former method in determining the fish species inhabiting dam reservoirs. Results revealed that the eDNA-based survey identified a greater number of species compared with the tradition-al sampling survey, aligning with approximately 80% of species identified in the sampling sur-vey. Thus, eDNA surveys emerged as a straightforward, cost-effective, and efficient method for elucidating biodiversity in dam reservoirs and rivers.

E. ICOLD 28th Congress in, Chengdu, May 2025

Large-scale reservoir dam management aimed at mitigation of long-term turbidity in the Hitotsuse river

K. Tokunaga, E. Wada, K. Yukimura, K. Higuchi & Y. Suzuki

Constructed by Kyushu Electric Power Company in 1963, Hitotsuse Dam is a large-scale electric power generating dam with a total reservoir capacity of 260 million m^3, located in the midstream of the Hitotsuse River which flows down through the central region of Miyazaki Prefecture, on the island of Kyushu, Japan. Soon after operation of the power station commenced, “long-term turbidity” occurred caused by continued discharge of high-turbidity water from the dam, impacting water use, the fishing industry and riverscape. With the aim of mitigating long-term turbidity, Kyushu Electric Power Company has studied and implemented a series of turbidity-mitigation methods. Until 2005, by carrying out water intake from the lower section of a selective water intake facility following flood, turbid water was discharged from the dam reservoir. This was the first time for a selective water intake method to be adopted in Japan and was effective in mitigating long-term turbidity. However, when flood on the largest scale ever recorded for the river resulting from Typhoon Nabi in 2005 caused huge inflows of turbid water into the dam reservoir, the effects of turbidity measures were limited. It became clear that with the measures adopted up until 2005, long-term turbidity could not be avoided. As a result of studies carried out through collaboration between industry, government, academia and private individuals, new measures were created. Under these measures, in times of large-scale flood, large quantities of turbid water are to be promptly discharged from the dam, reducing water level down to the dead water region, then the dam reservoir is to be replenished with clean water thereby diluting the turbid water. When Typhoon Nanmadol struck Miyazaki Prefecture in September 2022, maximum inflow into Hitotsuse Dam was comparable to the highest maximum ever recorded—that for Typhoon Nabi in 2005. A huge amount of suspended solids flowed into the dam reservoir, and for the first time since their formulation in 2008 the new measures were implemented. As a result of implementing the new measures, by discharging 70 % of water in the Hitotsuse Dam reservoir, including that in the dead water region, downstream, approximately 93 % of the amount of suspended solids in the reservoir was discharged. Further, the period of turbidity in the downstream was approximately 4 months, that is, 4 months shorter than the maximum period of 8 months for 2005. From the above, it was confirmed that by using the emergency outlet located in the base of the dam to promptly discharge turbid water and thereby reduce water level to the dead water region, even in the case of large-scale flood, mitigation of long-term turbidity in the downstream could be achieved to a certain extent.

Theme 8 Management of Reservoirs and Sediment in the era of Climate Change

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Efforts toward strengthening Hitokura Dam's flood control Function

T. Kawakami, S. Naito

The Inagawa River Basin, where Hitokura Dam is located, is near Osaka and has a large population and a number of offices and factories. The Inagawa River Basin has been suffering from both water shortage and flooding for a long time. Construction of Hitokura Dam was completed in 1983 to solve these issues. There were, however, still flood damage occurred many times in downstream areas even with flood control at the Dam due to the low safety degree against floods on the river at that time, because the original Hitokura Dam's flood control plan was capable of dealing with the flood which would occur once in 100 years. The flood control plan was, therefore, revised in 2000 based on progress of river improvement works to be effective for small and medium scale of floods. The revision of the flood control plan contributed much reduction of flood damage in downstream areas, but there is a risk that the flood control capacity could be insufficient for a large scale flood before its inflow into the dam reaches at its maximum, and in fact, the emergency spillway gate operation was carried out in 2018 for the first time since the dam operation started. On the other hand, the capacity of the river flow has improved by the river improvement works in downstream area recent years. This paper shows that the reduction of flood damage in downstream areas is possible even if maximum discharge rate from Hitokura Dam is get increased. Thus, the Hitokura Dam's flood control plan was revised again in 2019 after having discussions with related organizations and understanding of local residents. In this paper, the background and process of the flood control plan revision is explained in detail, and measures to reduce flood damage in downstream areas by making the most use of the flood control function of the dam are also reported.

B. ICOLD 91st Annual Meeting International Symposium in Gothenburg, June 2023

Weather pattern impacts on projected future changes in snowmelt streamflow in a heavy snowfall area in Japan

M. Ohba, R. Arai, T. Sato, M. Imamura & Y. Toyoda

Future changes in river discharge driven by climate change are expected to affect various water-resource sectors. In this study, we investigated the influence of climate change on streamflow in a heavy snowfall area of mountainous central Japan using hydrological model simulations driven by 5-km resolution of large ensemble climate projections. We projected an in-crease in snowmelt discharge during winter and a decrease in spring, along with a general de-crease in water resources and an increase in the frequency of annual maximum daily discharge during winter because of increasing future snowmelt. The additional analysis of weather pattern (WP) classification suggested that the impacts of climate change on streamflow varied by WP. The increase in future winter discharge was due to the strengthening of impacts of certain WPs, causing snowmelt. However, the decrease during spring could be due to changes in the predominant discharge-related WPs resulting from a decreasing snowpack. The obtained results can be useful information for considering adaptation strategies for sustainable management of water availability in heavy snowfall areas.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Impact assessment of climate change on seasonal operation of reservoir systems in heavy snowfall area in Japan using 150-year continuous climate experiment

D. Nohara, Y. Sato & T. Sumi

Climate change is projected to alter snow processes in heavy snowfall areas in the future. Snowfall and snowpack in such areas will decrease with global warming, while the timing of snowmelt will move earlier with warmer temperature, which can lead to prolonged low-flow season after the snowmelt season. These changes may cause severe impacts on water uses for hydropower, irrigation and municipal water in the river basins dependent on snowmelt water for water resources. Reservoir operation can therefore become difficult in such areas under the changing climate. In order to clarify an effective way to manage water resources in heavy snowfall areas in the changing climate, this paper investigated the potential impacts of climate change on seasonal operation of reservoir systems in the Tedori River basin, a heavy snowfall basin in Japan, through the simulation of long-term reservoir operation. Climate data was derived from outputs of the continuous climate experiment by Meteorological Research Institute, Japan, with their high-resolution model called MRI-AGCM3.2S (spatial resolution of 20km) for 150 years from 1950 to 2099. Time series of daily river flow and reservoir inflow were estimated from the experiment outputs, namely, precipitation, snowmelt water and evapotranspiration, by use of Hydro-BEAM, a distributed rainfall-runoff model. Statistical bias correction was then carried out for estimated river flow and reservoir inflow so that bias-corrected flow well simulates observation from 1980 to 2015. A model for operation of reservoir systems was developed based on reservoir operation rules to simulate water supply and hydropower operation on a daily basis. Impacts of climate change on seasonal reservoir operation were then investigated by analyzing results of reservoir operation simulation in the future climate. As a result of analysis with the developed simulation model, it was shown that impacts of climate change on seasonal reservoir operation can become significant especially in the second half of 21st century. The result also showed that changes in reservoir states and basin hydrological conditions could constrain hydropower potential in the river basin, and the extent of decrease in hydropower generation was projected to be up to 10%.

Theme 9 Promoting Renewable Energy with Dams

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

NEXUS SAKUMA PROJECT: upgrading hydropower station with advanced concepts

H. Nagase, T. Sasakawa & H. Okumura

J-POWER (Electric Power Development Co, Ltd.) has been operating Sa-kuma Hydropower Station since 1956, which is a dam and conduit type. The power station draws water from the Sakuma Dam reservoir located at the Tenryu River, and the total annual water usage is 5,000,000,000m^3 from the catchment area of 4,157km^2. Sakuma Hydropower Station generates approximately 1,400 GWh per year, with maximum output of 350,000 kW and maxi-mum water consumption of 306 m^3/sec. Since the hydropower station started its operation in 1956, it has achieved high operation for nearly 70 years and its facilities has been aging. J-POWER is planning to upgrade Sakuma Hydropower Station over a 10-year period time starting from 2026. We named the plan “NEXUS SAKUMA PROJECT”. The project has three concepts to realize a hydropower station in next generation. The concepts are “to increase power generation”, “to be in harmony with environment and local community", and “to apply advanced technologies”. This paper introduces NEXUS SAKUMA PROJECT and the details of increasing generation, countermeasure against long-term persistence of turbid water, and advanced technologies.

C. 12th East Asian Area Dam Conference in Nagoya, June 2024

Application study of long-term ensemble rainfall forecast for enhancing the operation of hydroelectric dam reservoirs

T. Abe, K. Yamada

This study examined methods of increasing power generation using long-term ensemble rainfall forecasts for multiple hydropower plants of varying scales throughout a water system. There are two methods to increase power generation. One is at each power plant, based on long-term forecasts, to lower the water level by power generation alone before flood event, and then to operate at high water levels after event, considering the subsequent normal water period. The other is, when there are multiple reservoirs and power plants of different scales in series, to coordinate the entire water system and to operate the reservoirs optimally with less overflow. In previous studies, the examination of reservoir operation using long-term ensemble rainfall forecasts was mostly for one power plant or one discharge. Therefore, in this study, we examined methods to enhance the coordinated operation between dam reservoirs using long-term ensemble rainfall forecasts, using the Oigawa River system, which has multiple reservoirs, as a model. The long-term ensemble rainfall forecast used allows for statistical handling of multiple forecasts with a forecast period of 15 days, which is longer than the 3-day-ahead rainfall forecast of the Meteorological Agency currently used for pre-discharge judgment. As a result of conducting reservoir operation simulations for the discharge periods (June to October) of the past three years with different discharge patterns and evaluating the total power generation of the water system, it was found that the power generation could increase by about 4% compared to the operation by conventional forecasts.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Economic performance and its availability of pumped storage hydropower under the carbon neutrality

M. Kashiwayanagi, T. Tobase

Increasing the share of the renewable energy in the electric power supply demands the needs for enhancing transmission lines and energy storage. It has been considered that offshore wind power will be promising in Japan due to the characteristics of the land surrounded by the sea. Possible sites of offshore wind power are prominent in the northern area in the main island in Japan. Due to few existing pumped storage plants, the development of the offshore wind power plants should proceed with the coordinated development with energy storage in these areas. A few kinds of energy storage are possible such as pumped hydropower, battery, and hydrogen. Under the condition of the carbon neutrality, the numerical simulation on the energy system has been conducted. It involved energy production and consumption, energy storage and energy trans-mission. The economic performance of the pumped storage hydropower is examined in the share combination of the renewable energy and other energy storages. It is clarified that the priority of pumped storage hydropower plants (PSHPPs) is maintained in the future energy system as energy storage facility enabling the electricity system balance. Less cost and intermittent renewable energy enhance the economic rationality of PSHPPs.

D. ICOLD 92nd Annual Meeting International Symposium in New Delhi, October 2024

Evaluation of the practicality of prior release by power generation using rainfall ensemble forecast for the Kurobe Dam

H. Naka, Y. Otsubo, & T. Arimitsu

Due to the recent increase in heavy rainfall, it is expected that hydropower dams utilize long-term ensemble rainfall forecasts. The aim is to use stored water for power generation as an alternative to prior release. This approach enhances both power generation and storage capacity for flood management. However, there are challenges to using ensemble rainfall forecasts for hydropower dam operations. Firstly, practical constraints need to be considered. These include the rules for dam operation concerning the timing and amount of discharge, and the time required to incorporate the prior release into power generation plans. Research on these topics is limited. Additionally, previous studies have only investigated whether the water level would be recovered if the amount of stored water used in hydropower generation equals the volume of prior release. However, to adopt the ensemble rainfall forecast, it is necessary to conduct a more detailed evaluation of the effects of water discharge on flood control and hydropower generation. In the case of cascade dams, to conduct prior release at the uppermost dam is preferred to significantly expand flood storage. On the other hand, since the operation of the uppermost dam affects the downstream dams, it is necessary to evaluate the utility of water, including the recovery of water levels after discharge and the effects of increased or decreased power generation during discharge, for the entire water system. In this study, we discuss using ensemble rainfall forecasts for the effective operation of dams. In addition, we propose using stored water for power generation instead of prior release and expanding the water storage capacity. We attempted to forecast floods 7–13 days in advance using the ensemble rainfall forecast for June and July, when there is a particularly high risk of discharge. Further, we evaluated the effect of discharge on the power generation of the Kurobe Dam and downstream dams considering the forecast accuracy. Our results show that by using the ensemble rainfall forecast, and using the stored water for power generation instead of prior release, hydropower dams can perform the flood storage function and increase the amount of power generation.

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