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Technologies to construct a dam

Technologies to construct a dam

Various technologies are needed to construct a dam.

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Technologies to select the site to construct a dam

It is necessary to select the appropriate site which has firm rock foundation to bear the dam body and make the reservoir with maximum water volume and the minimum-sized dam height.

It is also necessary to use the technologies to select the best location in terms of topographical and geological features as well as minimizing the compensation cost for the submerging properties, construction work and operation & maintenance stage after completion.

Technologies to determine the size and type of a dam

There are various types of dams, such as concrete dams, rock-fill dams (consisting of rocks and soil materials), and earth dams (just with soil materials only).

Such technologies are needed to select the most suitable type and size of the dam, considering the topographical features of the site, condition of the foundation to bear the dam body as well as the water pressure which acts on the dam.

Technologies to construct a dam in consideration of surrounding environment

The construction project of a dam gives an impact on the environment because of large scale excavation work of the dam site, quarry site and relocation of roads, etc. Thus, such technologies are needed to minimize the impact on the environment in terms of flora and fauna preservation, landscape conservation and restraining noise and vibration, etc.

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Technologies to reduce the construction cost

When constructing a dam, it is essential to maximize the use of locally procured materials from a cost perspective. For that purpose, test and analysis are made to investigate whether those materials are suitable for the dam or not.

It is also necessary to properly decide the selection of construction methods and their procedures, and make the entire work plans before implementing the construction works. In addition, to efficiently and safely manage and operate the completed dam, proper designs and construction works have to be carried out.

Above all, the technologies to minimize the related costs are also needed.

A dam project is composed of many elements driven by comprehensive civil engineering technologies.

A dam project requires various specialized expertise and knowledge in the area of not only construction of dam body, related structures including bridges, tunnels, waterways, and roads, etc. but also researches and surveys on topographical and geological features, hydrometeorology and natural environment, etc.

The Japan Water Agency (JWA) holds the comprehensive capacity to implement such needed technologies.

In the following slides, we would like to provide the examples of technologies we have practiced and accumulated in constructing dams up until now. They include exclusive systems and technological development out of our creative efforts.

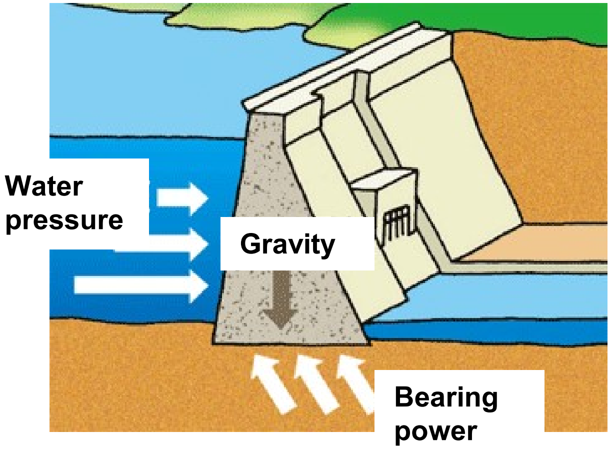
Types of dams

In Japan, a dam is defined as having a height of 15m or more.

【Concrete dam】

Arch dam
Gravity dam
Hollow gravity dam

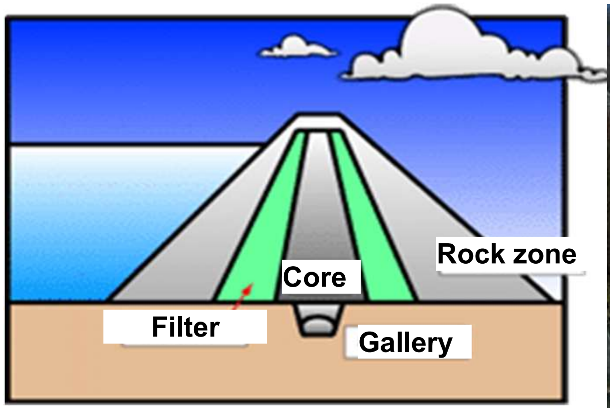
- Dam body material: concrete
- Firm foundation ground is needed to bear high load concentration.

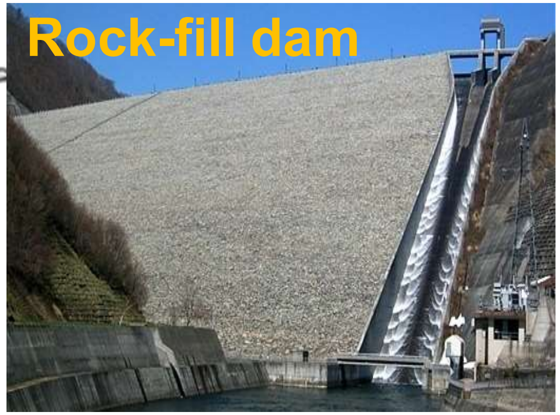


【Fill dam】

Zoned dam
Facing type dam
Homogeneous type dam

- Dam body materials: soil, sand and rock
  Dam body consisting of soil, sand and gravel
- Good foundation ground is not necessary because of low load concentration





Dam construction methods

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【Column construction method】

Conventional method (Dominant until the 1980s)

【Plane construction method】

RCD, ELCM (Dominant since the 1990s)

Conventional method

（Column construction method）

・A large amount of cement
→concrete placement into columnar blocks for cracking control

・Distance between longitudinal joints: max 35m

・Distance between transverse joints: max 15m

面状工法による打設面の全景

Plane construction method：RCD

（Roller Compacted Dam Concrete）

・Tomisato Dam, Hiyoshi Dam, Takizawa Dam, etc.

・Lean-mix concrete with zero slump

・Hauling by truck→spreading and levelling by bulldozer
→vibrating joint cutting →compacting by vibrating roller
→compaction by roller for finishing

・World’s first development by the (former) Ministry of Construction

・The advantages of this method are shortening construction period, cost reduction, and enhancing safety

(1) Development of ELCM for concrete dam construction

The JWA has been striving for a new construction method to reduce the cost and shorten the construction period while ensuring the safety of dam structure and efficient construction works, then developed ELCM(=Extended Layer Construction Method).

Adopted it for the construction works of Nunome Dam, which was completed in 1992 and located in Nara Prefecture, this was the first application of this method in Japan. This method allowed us to save 700 Million yen of construction cost with shortening the construction period by about two months.

This method has been adopted for the dam construction by national and local governments since then.

Conventional method
(Shimokubo Dam in Gunma & Saitama Pref.)

The dam body was divided into many columnar blocks and every block was placed with concrete one after another. Thus, dam body gradually rose up.

ELCM (Nunome Dam under construction)

Concrete was placed into much wider (more than double areas of a columnar block) area than conventional method where the dam body was raised evenly and entirely with few height difference.

ELCM（Extended Layer Construction Method）

・Dams adopted ELCM: Nunome Dam, Hinachi Dam, and Oyama Dam
・Slump concrete（3～4cm）
・Compaction by immersion vibrator
・Shortening construction period, cost reduction, enhancing safety

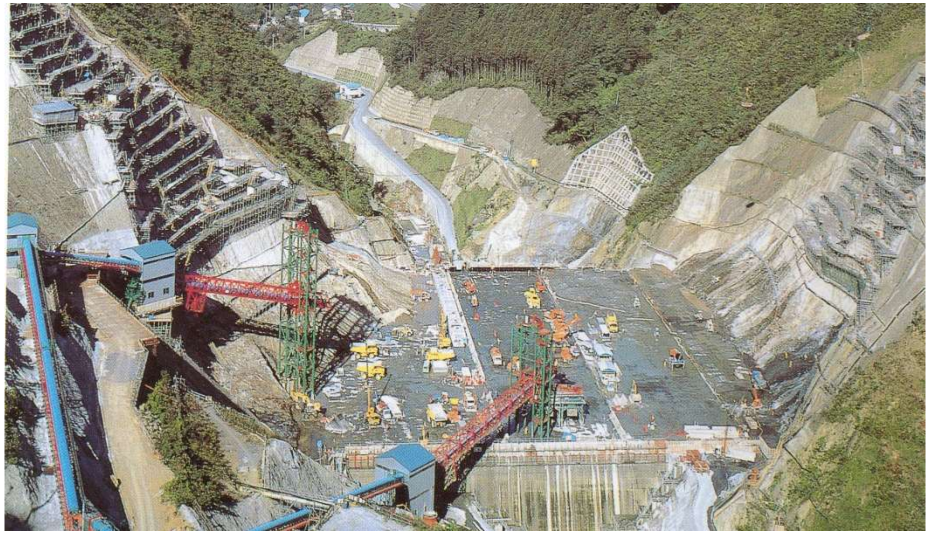
Concrete placement by ELCM

(2)Adoption of RCD method for concrete dam construction

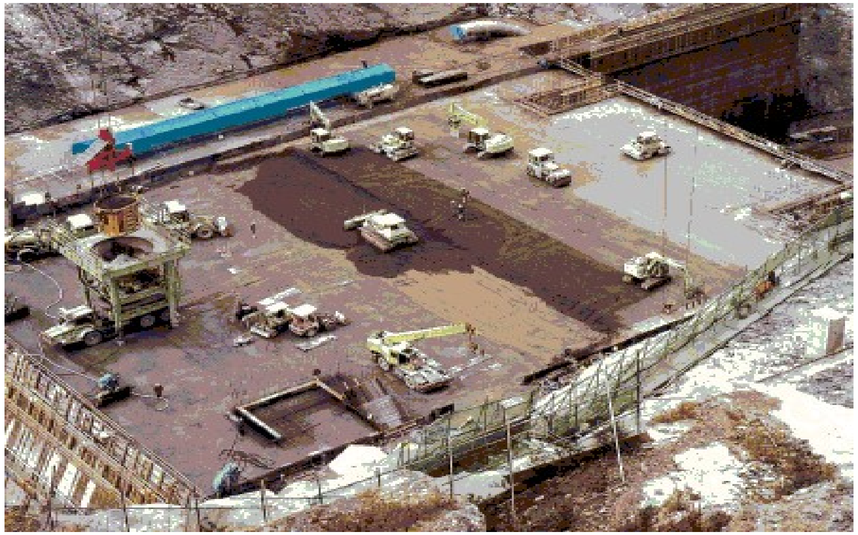
Urayama Dam in Saitama Prefecture was constructed in combination with ELCM and RCD (Roller Compacted Dam-Concrete) and consequently its construction cost was reduced.

In the case of RCD method in Urayama Dam, the concrete placement height was raised from conventional 75cm to 1 m, and consequently the number of the placements was reduced by 25%.

The JWA has conducted rationalization and cost reduction in construction works, and applied the technologies acquired through the past experiences of dam constructions to many projects.



Construction of Urayama Dam
(Dam height: 156m, Dam volume:1.74 mil. m^3)

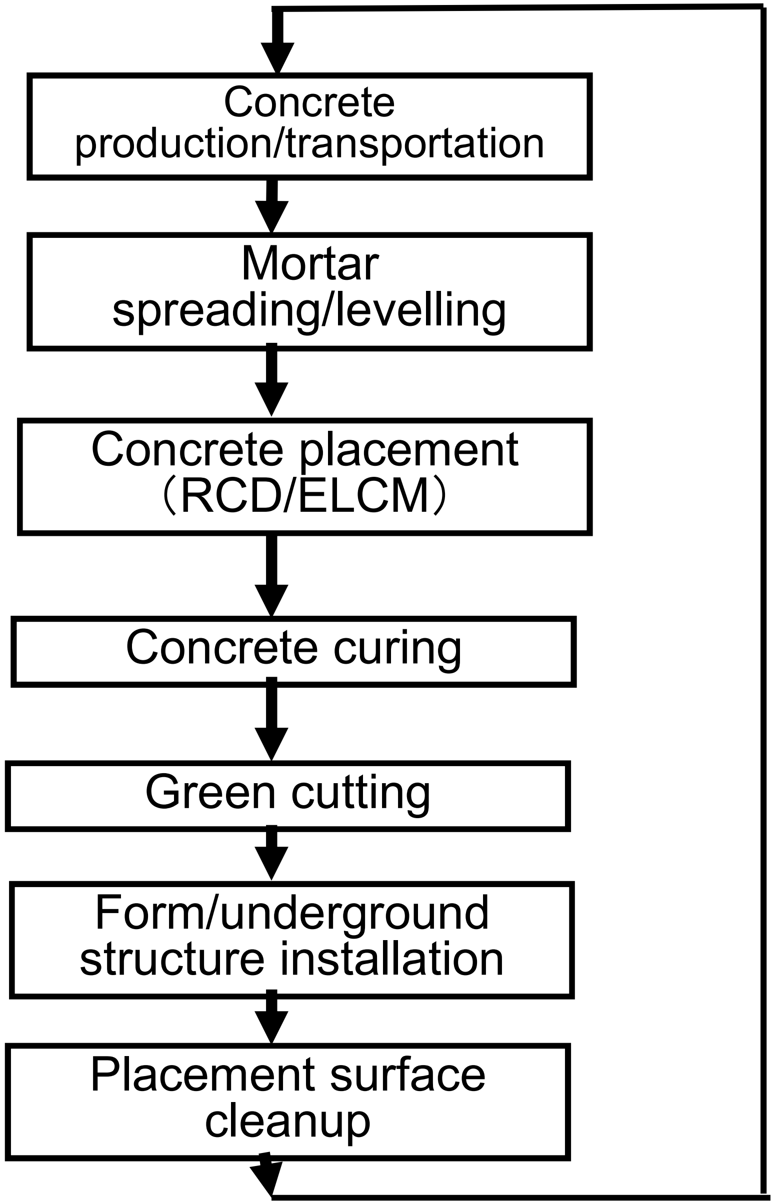


RCD Method(Tomisato Dam located in Ehime Pref.)

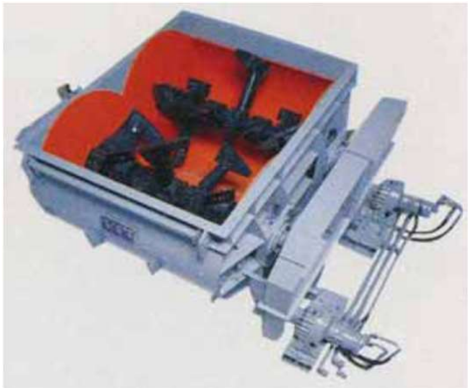
In the case of RCD method for Tomisato Dam, concrete with reduced cement and hard consistency was spread and levelled and then compacted by vibrating rollers. The advantage of this method is that hydration heat generated from concrete can be minimized, And a large amount of concrete can be placed at one time to large area, which is more advantageous than the conventional method.

The JWA has accumulated various experiences and knowledge on safe, economical and secured methods of the dam construction for over a half century of its activities.

Workflow of dam body construction



Dam body construction by RCD method



Double axis forced mixer

Type of concrete mixer

- Biaxial forced kneding mixers are used for RCD and ELCM.
- Homogeneous lean-mix concrete with less coarse aggregate separation
- Large wearing

Concrete placement and transportation equipment

Construction workflow in RCD method

Rock foundation inspection before concrete placement

Mortar spreading, levelling (1.5cm thick)

Placement/transportation

Dumping

Spreading/levelling

Joint creation (vibrating joint cutter)

Rolling compaction (vibrating roller)

Water Curing

RCD construction method

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Green cutting

Setting form

Embedding waterstop

Embedding spillway

Embedding an outlet conduit

Embedding water level gauges

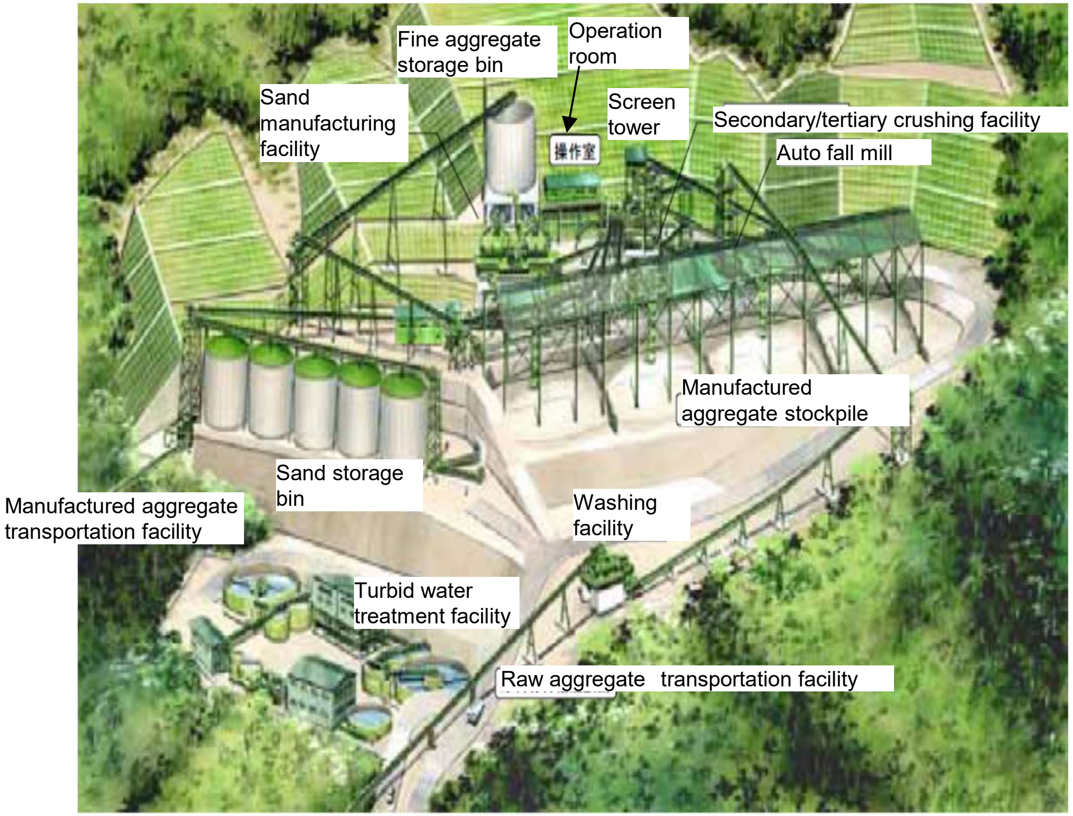
Quarrying works, construction facility/plant installation works

◎Blasting quarry site and crushing rock to be 30-50cm in size
→ crumbling → sieving → storing

◎Aggregates are crushed into the following sizes:
G1(150～80mm), G2(80～40mm), G3(40～20mm), G4(20～5mm), S(5～0mm)
G：Coarse aggregate S：fine aggregate

Quarry site

Quarrying works



(Ex.) Layout of an aggregate production plant ($2^{nd}/3^{rd}$ stage crushing facility)

Aggregate production facilities

Grizzly (large rock removal)

1st stage crushing facility (Jaw crusher)

2nd and 3rd -stage crushing: cone crusher

2nd and 3rd stage crushing facility (cone crusher)

Aggregate manufacturing facilities

Aggregate washing facility (Drum scrubber)

Sieving facility（Screen tower）

Sand manufacturing facility（Rod mill）

Aggregate manufacturing facilities

Stockpile for manufactured coarse aggregate

Storage bin for manufactured fine aggregate

Turbid water treatment plant (Thickener)

PAC storage tank

Polymer coagulant dissolution tank

A concrete dam under construction by JWA

Name：Kawakami Dam in Mie Pref.
Type：Concrete dam
Dam height: 84m
Gross reservoir capacity: 31 Million m^3

Bird-eye view of Kawakami Dam

Concrete placement in progress

ICT-driven construction technologies -enhancing productivity and quality

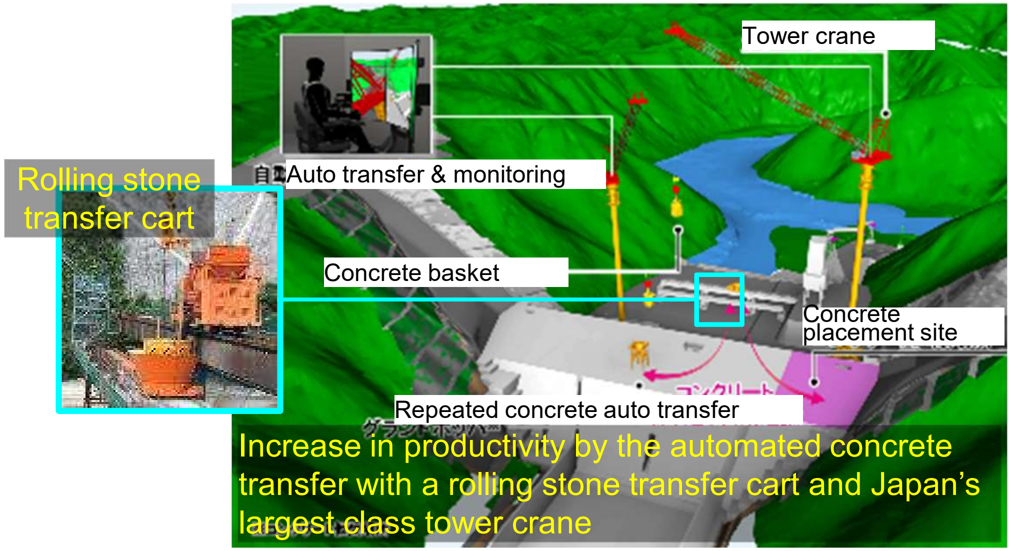


Photo: Automated concrete transfer

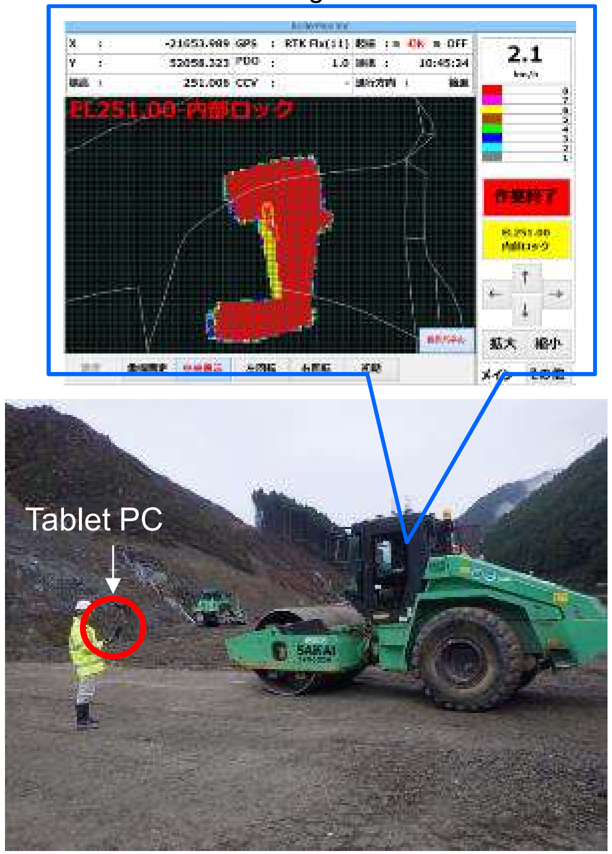
Photo: Compaction management system

(3) Construction of a large-scale rockfill dam

At Koishiwaragawa Dam, pioneering technologies were adopted in dam construction. For embankment process, ICT was proactively utilized, aiming at quality and productivity enhancement. As a result, the embankment works were completed about one month shorter than originally planed, i.e. in about 20.7 months for 8.3 mil m^3 of the embankment. This was an example of the achievements of higher quality embankment construction than existing dams which had only allowed discrete time-space quality management.

The embankment works were completed in July 2019.

Monitoring screen



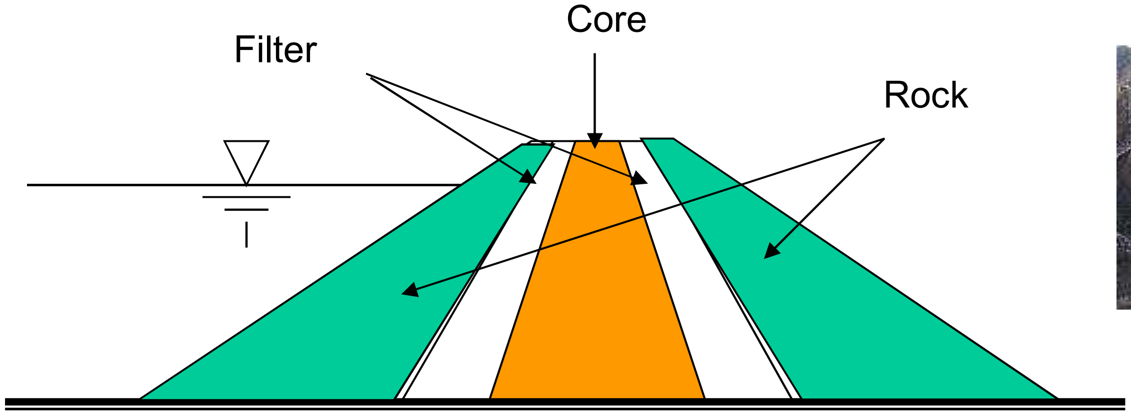
Real-time monitoring with a tablet PC

Rockfill dam

(Ex.) Koishiwaragawa Dam, Tokuyama Dam, Agigawa Dam, Misogawa Dam

Rockfill dam with central core

Zoned dam



Tokuyama Dam

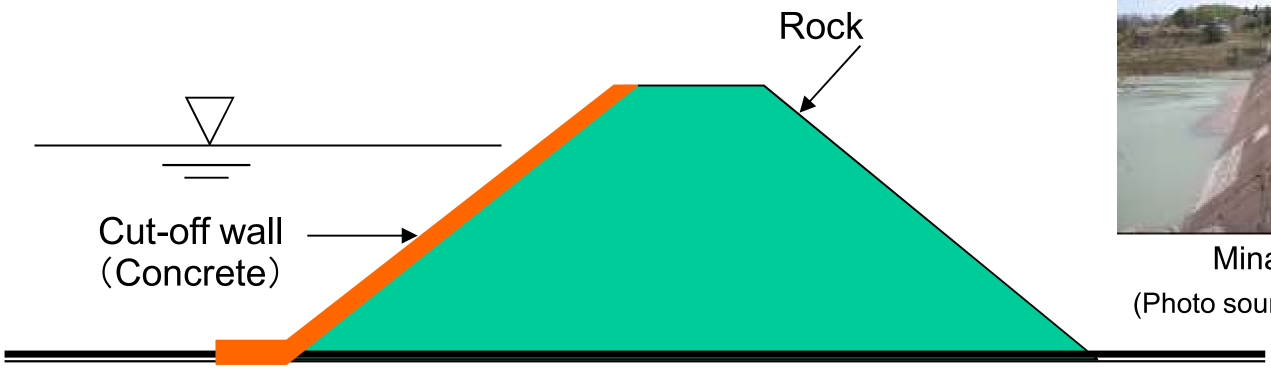
Agigawa Dam

Ishibuchi Dam, Minase Dam, Nanma Dam

Facing type rockfill dam

*Minase Dam in Akita Pref. 67m
Completed in 1963

*Ishibuchi Dam in Iwate Pref. 53m
Completed in 1953



Minase Dam
(Photo source: Dam listing)

Ishibuchi Dam
(Photo source: Dam listing)

Rockfill dam from upstream side (perspective view)

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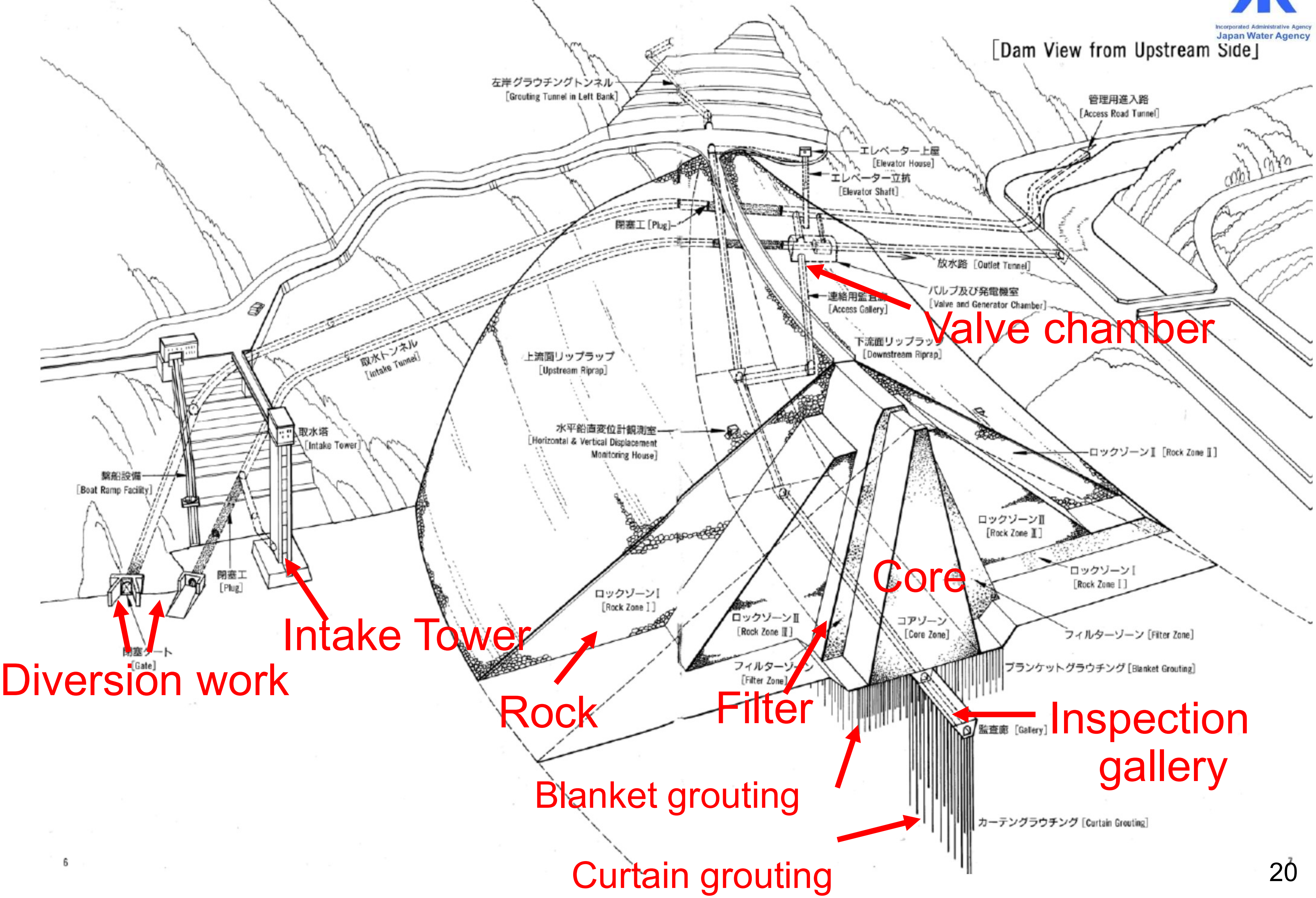
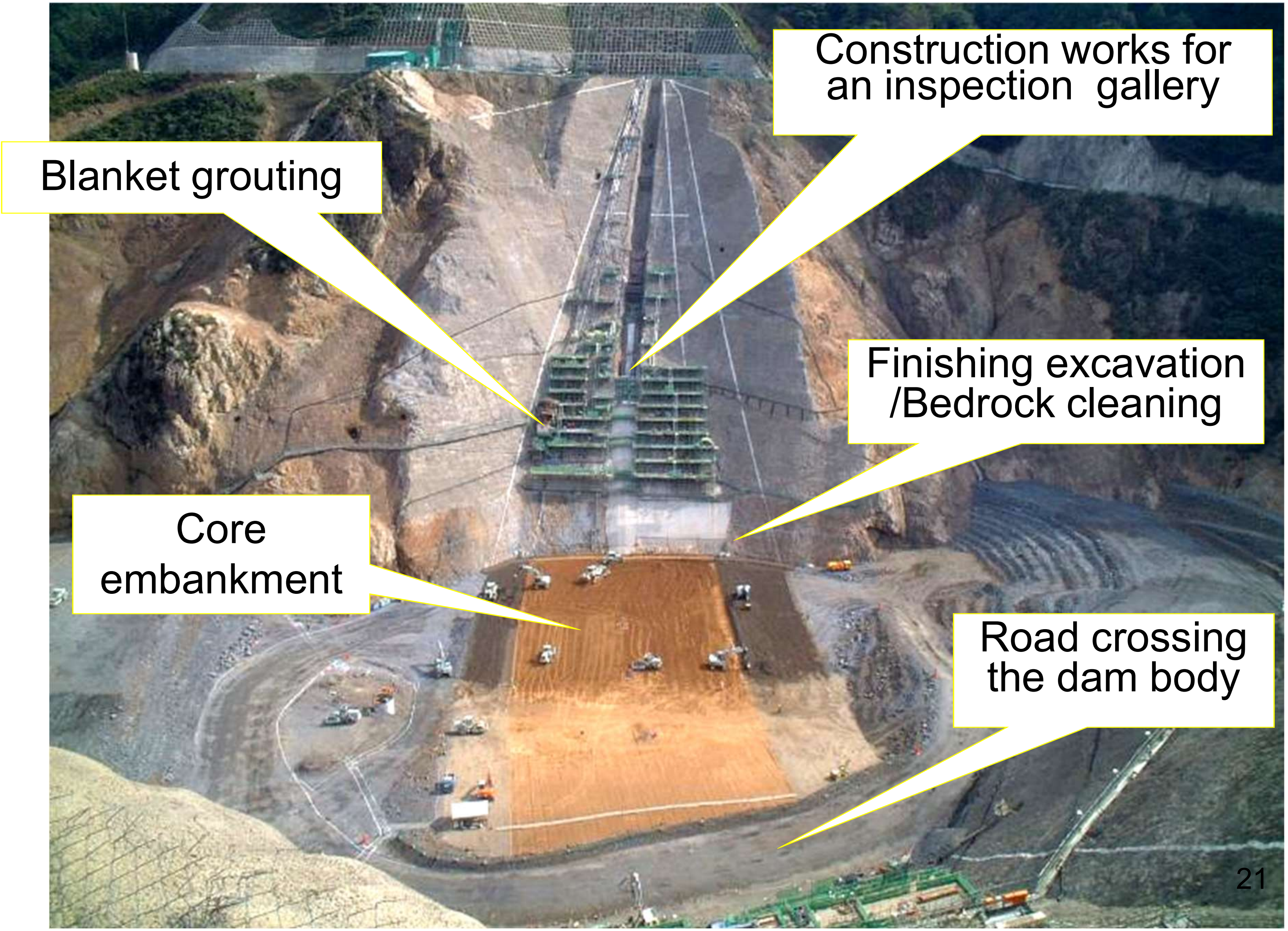
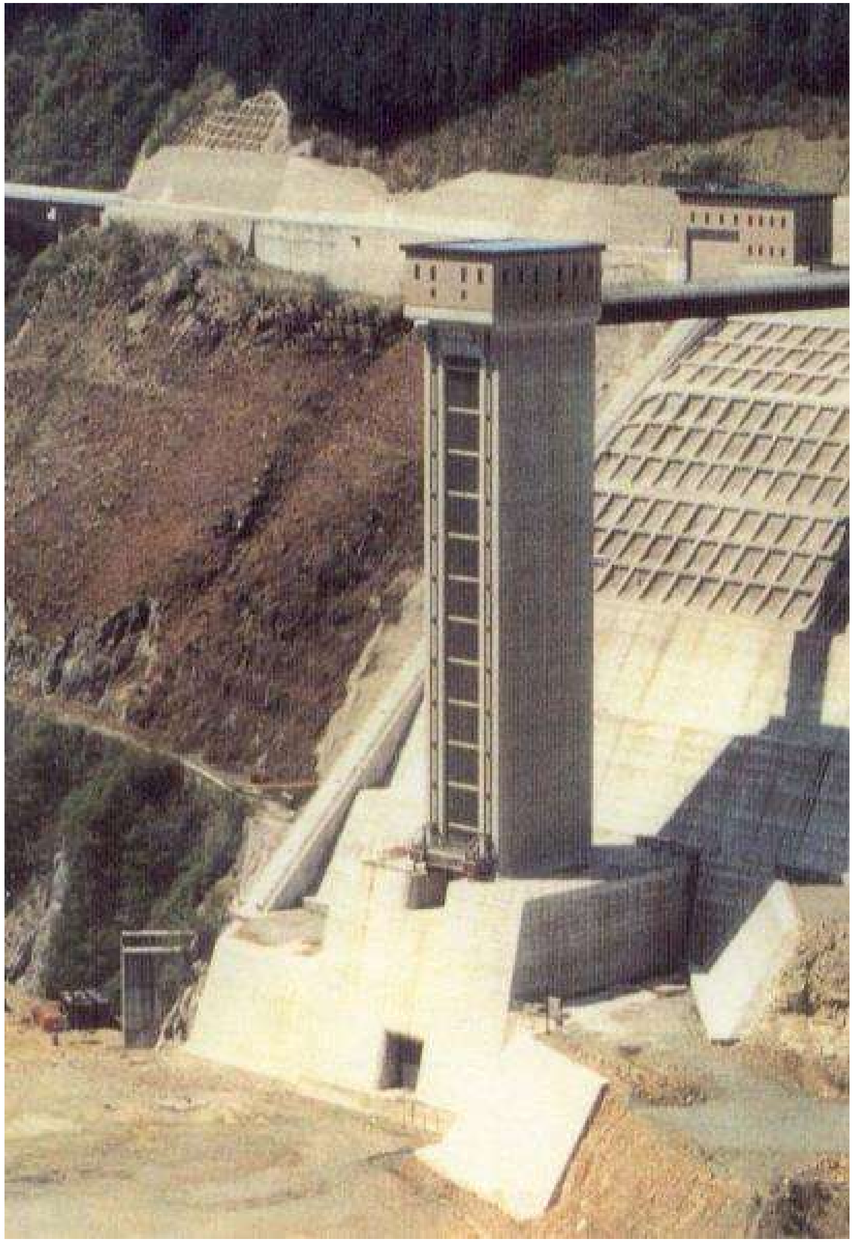


Facilities and Construction Works

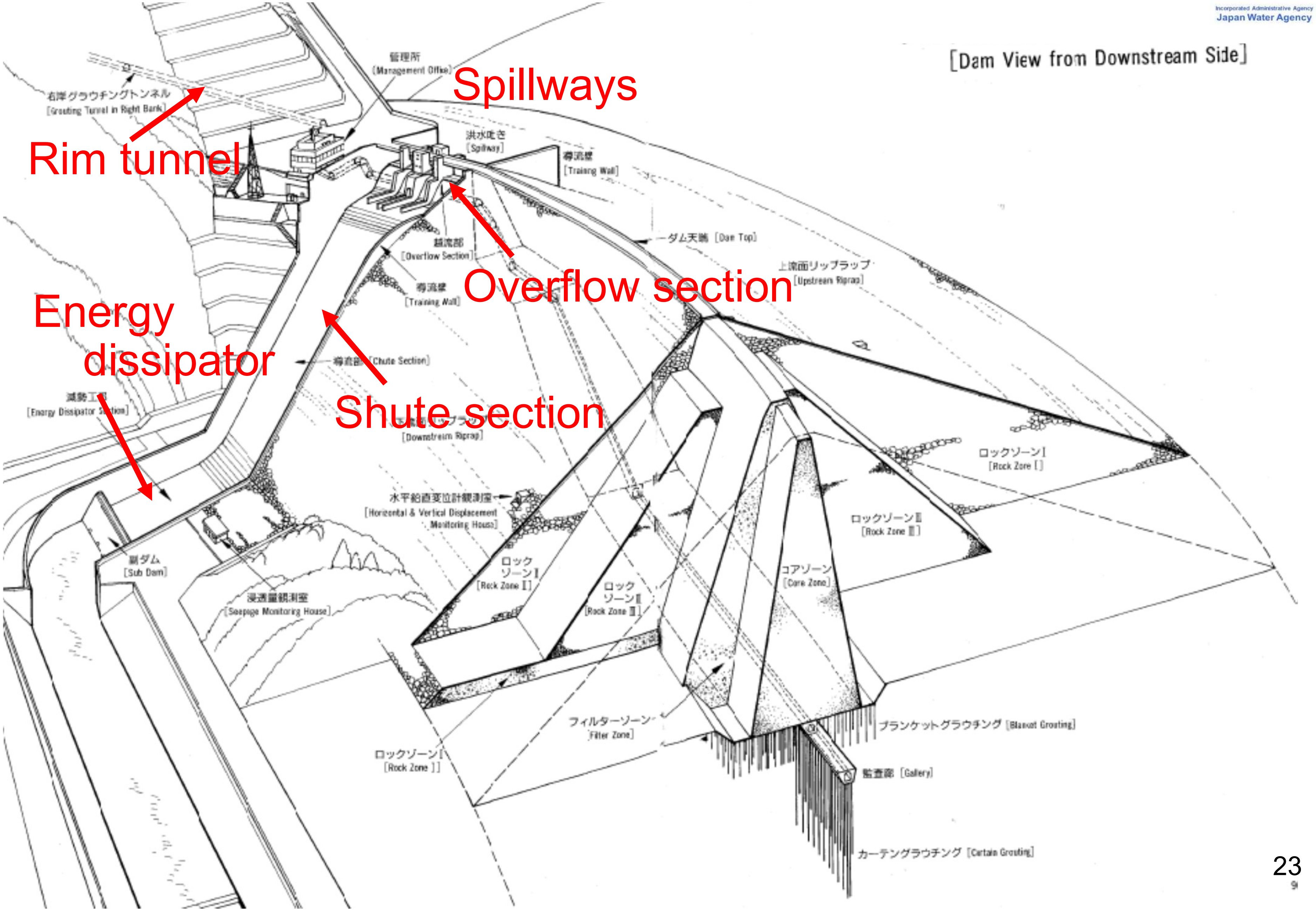


Intake tower



Diversion work

Rockfill dam from downstream side (perspective view)



Spillways

Initial impoundment

Initial impoundment of Koishiwaragawa Dam started in December 2018 before its full operations. In this process, the reservoir was gradually filled with water up to the surcharge water level and then the water was discharged to the lowest water level to ensure the safety of the dam body and its surroundings.

Before initial impoundment

As of 9:00am, 19 Jul., 2020
Reservoir volume: 35,457,000 m^3 (Storage rate:100%)
Reservoir water level: EL.349.44m

Full water reservoir
(The dam body and the reservoir shot from the upstream)

JWA's rockfill dam under construction

Name：Nanma Dam in Tochigi Pref.
Type：Concrete face rockfill dam(CFRD)
Dam height: 86.5 m
Gross reservoir capacity：31 mil. m^3

Nanma Dam (Rendering)

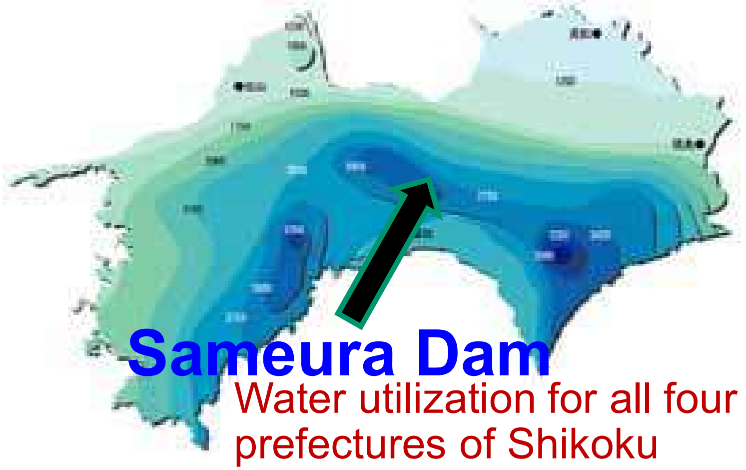
(4) Upgrading an existing dam under operation for more effective use of it

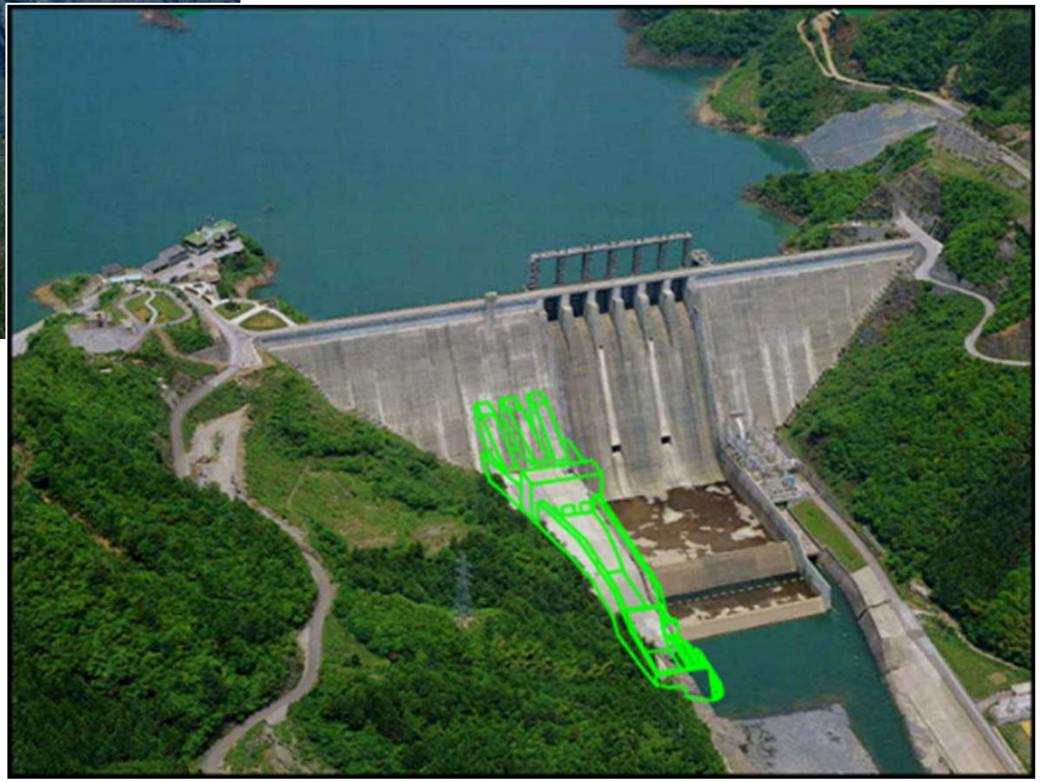
Upgrading project of Sameura Dam

The first dam upgrading project of JWA

〈Improving flood control function〉

Name：Sameura Dam in Kochi Pref.
Type：Concrete dam
Dam height：106m
Gross reservoir capacity: 316 mil. m^3
Completion：1975
This dam is called
“Life of four prefectures of Shikoku”





(5)Technologies to analyze complex water flow with model test

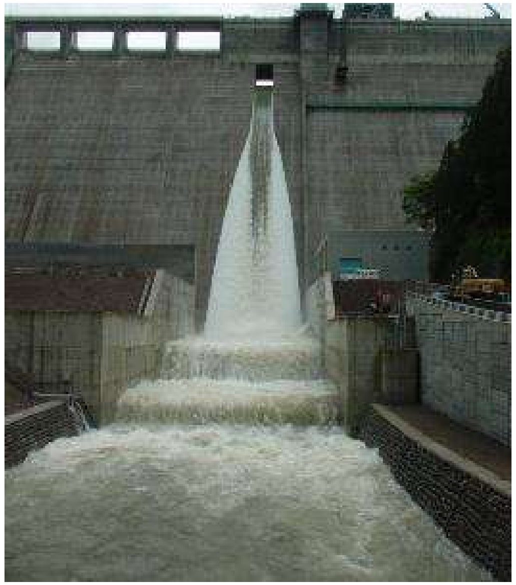
When designing a dam, a barrage or a canal, we need to study various factors such as topographical and geological features of the site where a facility is to be built and also management of such completed structures, etc.

The shape of a spillway, for example, could be very unique to best fit the site. In such a case, there would be some unknown factors which need to be checked as we are not sure to apply previous theories on water flow.

To deal with such factors, we need to conduct tests, observations and analyses along with the facility design.

Since 1966, we have conducted over 200 cases of experiments on dams, barrages and canals, and also particular gates and fishways, etc., all of which were fitted to the facility sites. Those facilities have shown that those designs were best suited to function on the sites.

Model test of a spillway of Oyama Dam
(Scale:1/40)



Actual discharge from a spillway
of Oyama Dam

Test facilities of JWA

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Water Resources Engineering Dept. conducts various tests, experiments and analyses related to JWA facilities

A bird-eye view of Engineering Dept. in Sakura-ku, Saitama City, Saitama Pref.

◇Hydraulic model test

When designing a dam, we conducts hydraulic analyses.

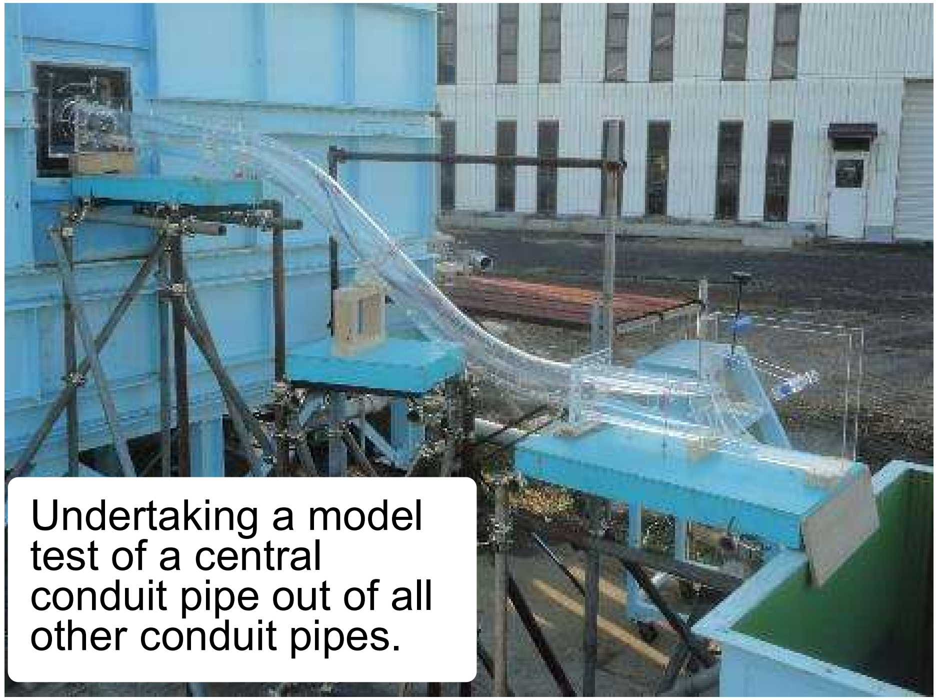
A Hydraulic model test of dam's spillways

・Check the dissipating effects to determine the most appropriate shape of spillways.

A hydraulic model test of a conduit pipe for flood control

・Obtain the data on water volume discharged from a conduit pipe by the model test to check the design discharge.

Full model spillways
(Sameura Dam scale: 1/62.5)



Section model (Sameura Dam scale:1/32)

◇Soil test with the large test equipment

We conduct various tests of materials used for dam constructions.

Large dynamic triaxial compression test

Permeability test

Specimen before the test

Specimen after the test

(6)Lessen the impact on natural environment due to building a dam

The projects of the JWA are likely to be implemented in nature-rich environment. As the construction of dams, canals and other facilities involves the change of nature, we endeavor to conserve the natural environment. For that purpose, we carry out surveys and predictions of the impacts prior to the constructions of new facilities or reconstructions of existing facilities. Based upon the results, we implement environmental conservation measures. We also make it a practice to verify the effects of such environmental conservation measures through monitoring surveys.

For Kawakami Dam construction project, for example, we have conducted various conservation measures, including preservation of giant salamanders based upon our surveys*. The giant salamanders have been nationally protected species since 1952.

We make it our rule to run a review whenever we find it necessary by confirming the effects, getting guidance and recommendations from experts.

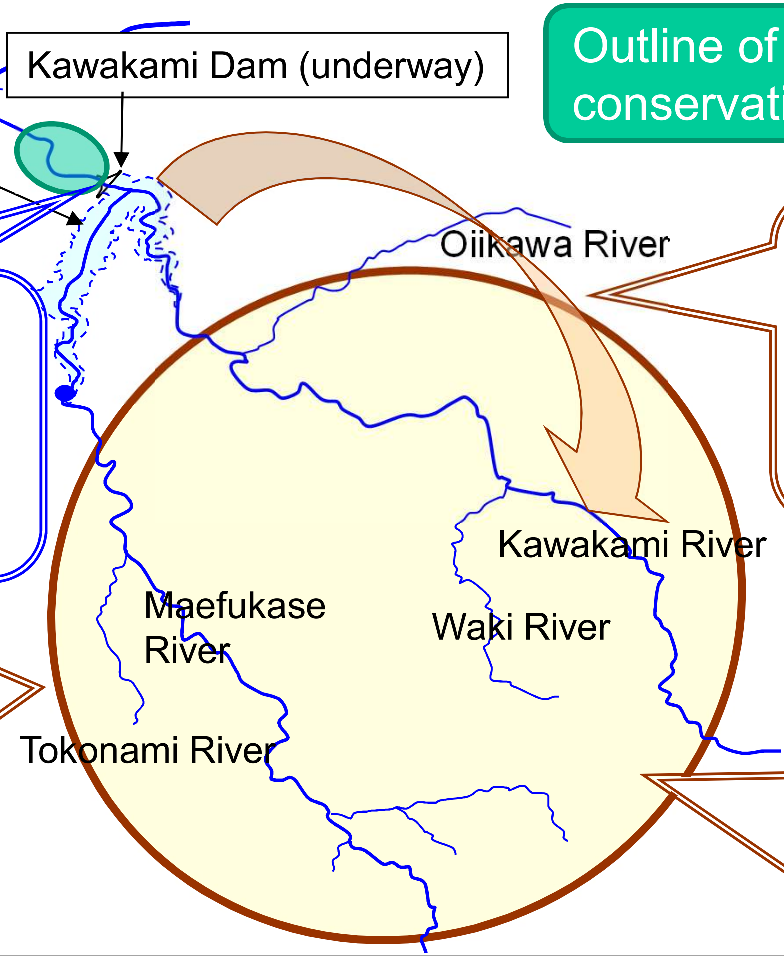
Conducting a survey

A giant salamander

*We conduct the surveys and the conservation measures under the permission of the Cultural Affairs Agency.

6)Reduce the impact on natural environment due to building a dam

Outline of our conservation measures



Improvement in the habitat downstream of the reservoir
-place rocks and stones to provide hideouts
-install selective intake facilities
-reduce the impact of discharged water temperature.

Relocation of salamanders to upstream side of the reservoir

Creating a better habitat (migration pass)

Organizing artificial burrows for inhabitation

・We relocate the salamanders in the impoundment area to the upstream area, following the guidance and recommendations from the experts.

・In the new expected habitat of the salamanders, dotted with structures crossing rivers and disturbing their easy movement, we install passes there for their migration.

・As the population of the salamanders increases in the new habitat upstream of the reservoir, we also make it a practice to proceed with the installation of artificial burrows to promote their breeding.

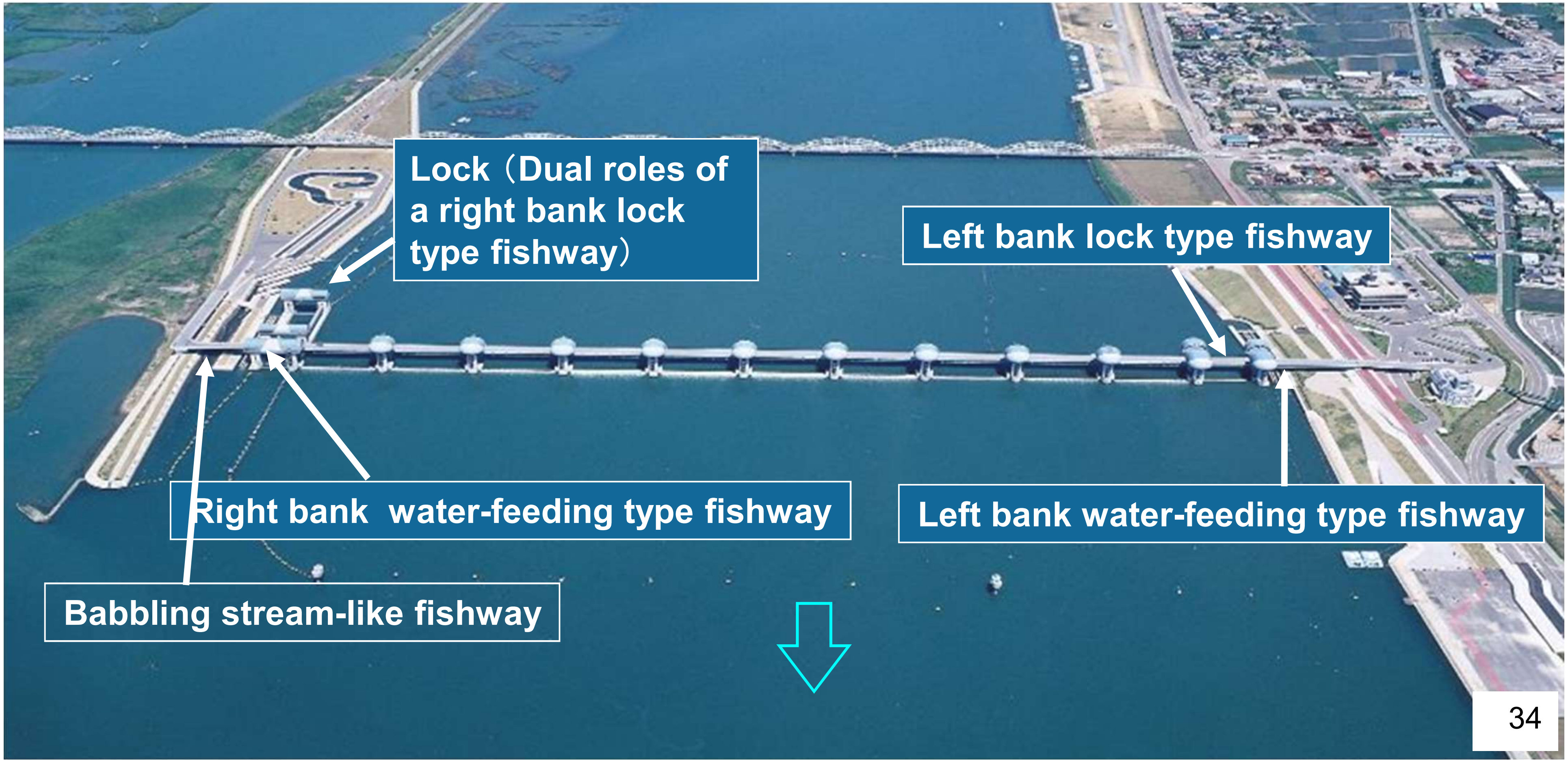
・We have verified their use of those artificial burrows and their upstream and downstream migrations upon our monitoring results.

(7)Environment-friendly dam and barrage construction

○When constructing a barrage, we take care of the environment of fish and other creatures living in the river.

Ex.(1) Nagara River Estuary Barrage

The Nagara River is home to a variety of creatures such as sweet fish (Plecoglossus altivelis) and red-spotted masu trout (Onchorhynchus masou ishikawae), as well as benthic fish such as sculpins (Cottus pollux) and mokuzu crabs (Eriocheir japonicus) In consideration of these, we provided fishways that were as close to natural streams as possible.



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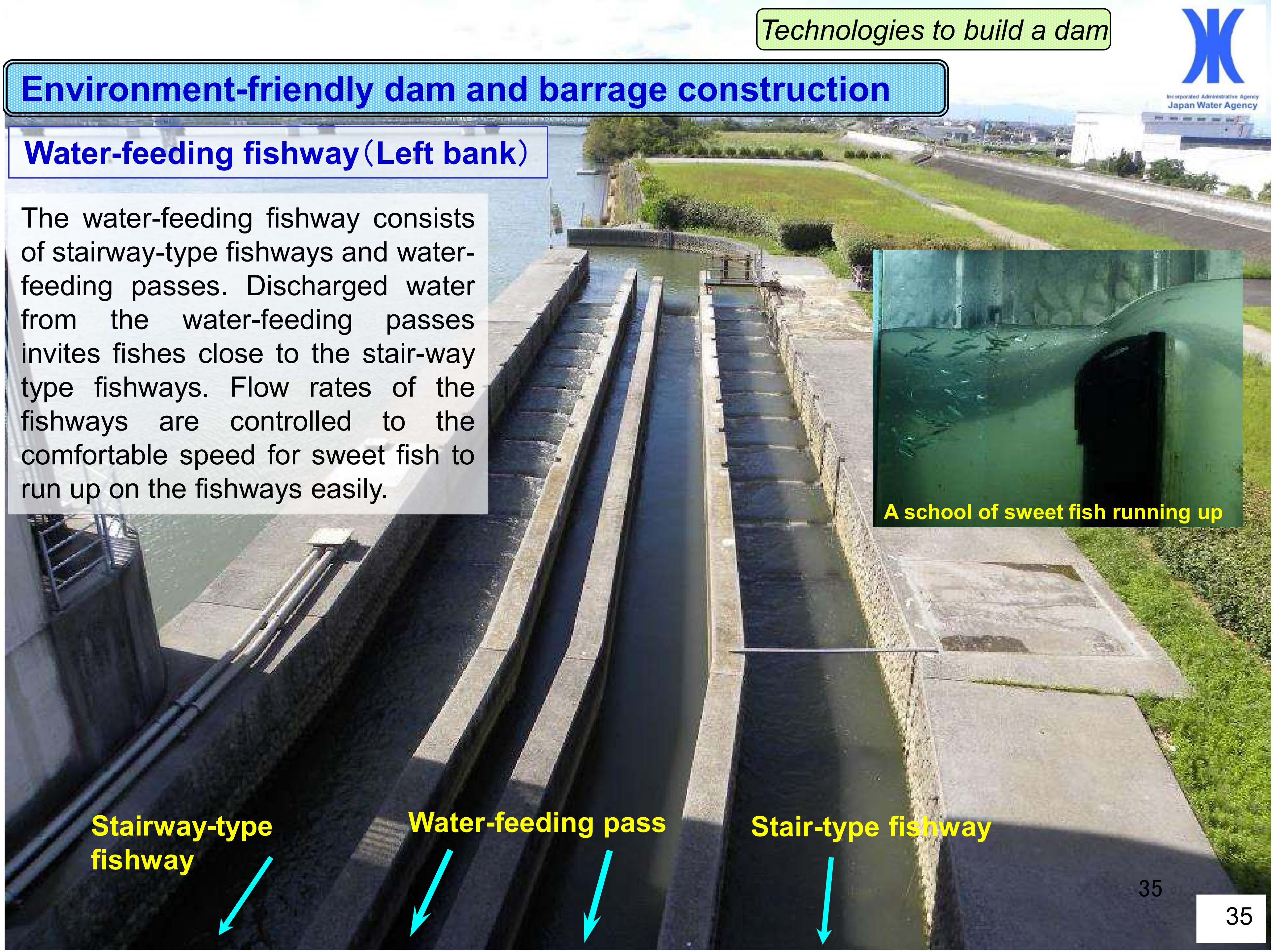
Environment-friendly dam and barrage construction

Water-feeding fishway（Left bank）

The water-feeding fishway consists of stairway-type fishways and water-feeding passes. Discharged water from the water-feeding passes invites fishes close to the stair-way type fishways. Flow rates of the fishways are controlled to the comfortable speed for sweet fish to run up on the fishways easily.



A school of sweet fish running up

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Environment-friendly dam and barrage construction

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Babbling stream-like fishway

A babbling stream-like fishway is designed for easier run-ups of small benthic creatures like sculpins and crustaceans of mokuzu crabs and many other types of fishes to the stream, by winding its course, placing natural pebbles and altering the water depth of the pass, etc., i.e. making the pass as close to the natural setting as possible.

Low tide

High tide

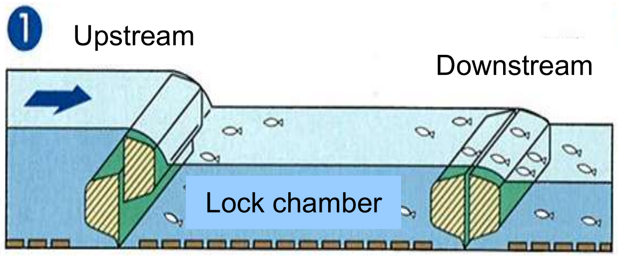
Environment-friendly dam and barrage construction

Lock type fishway

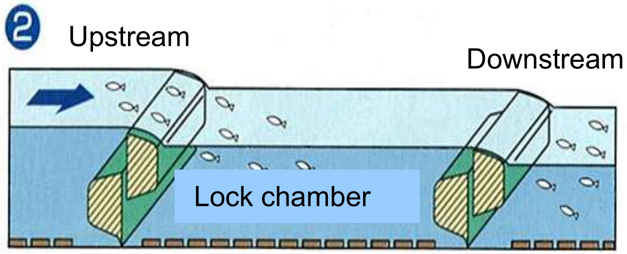
A lock type fishway adopts the similar mechanism to the lock in the canal. Operating a pair of two-stage gates to help fish go up and down along the river.

■Overflow operation

This operation is mainly designed to help the fish swim in shallow water such as sweet fish and trout.



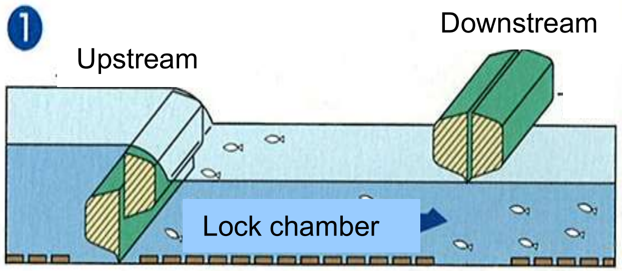
The downstream two-stage gate gets lowered to minimize the water level difference between the lock chamber and downstream for smooth swim over the downstream two-stage gate.



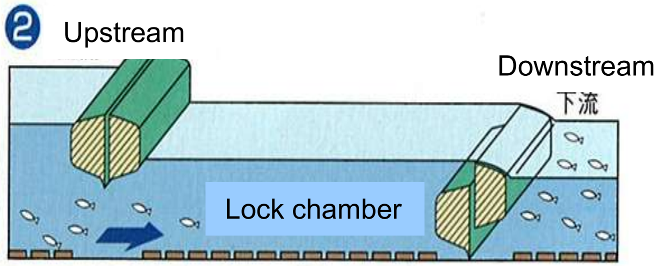
The downstream two-stage gate gets raised to minimize the water level difference between the upstream and lock chamber for smooth swim over the upstream two-stage gate.

■Underflow operation

This operation is mainly designed to help the benthic fish and other creatures move smoothly.



The downstream side gate gets raised for the fish and other creatures to freely enter into the lock chamber.



The downstream two-stage gate gets lowered and the upstream gate gets raised for the fish to freely enter into the upstream side of river from the lock chamber.

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Environment-friendly dam and barrage construction

Sweet fish run-ups at Nagara River Estuary Barrage in 2020