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CHALLENGES OF DAM RESERVOIRS FOR THE COMING JAPANESE SOCIETY AND SEVERAL PROPOSALS*

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SUMMARY

This communication is to introduce the core contents of the report compiled by the special committee of Japan Society of Dam Engineers (JSDE) in 2016, which aims to clarify important targets in planning, operation and maintenance of dam reservoirs, with full and adaptive utilization of dam stock for the coming Japanese society in mind.

Approx. 2,700 existing dam reservoirs play indispensable role in supply of water, energy, mitigation of flood damage, maintenance of normal function of the river flow, and recreational function. With increase of aged dams, there is an increasing number of re-development project of dams, whose major purpose is enhancement of flood control capability and recovery from excessive sedimentation. Importance of "backup" capacity is pointed out here.

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* *Défis des réservoirs pour la société japonaise du futur et plusieurs propositions*

After examining three influencing factors, namely decline in population, climate change, and rare but devastating disasters, major issues will be mitigation of flood damages, maintenance of normal function of the river flow, hydropower, and sediment management. Necessity of flood control capacity for long-term river improvement plan is confirmed. Hydropower's stabilizing function for solar and wind power is also focused.

A basic framework consisting of four phases is presented, to make the stock of dam reservoirs function fully, with proper maintenance and adaptive operation to changes. They are 1) Long service life, 2) Wise use, 3) Capacity increase, and 4) Network use.

Finally, nine proposals of high priority are shown as follows.

1. Enhancement of flood control capacity
2. Securing water supply in a crisis situation
3. Promotion of hydropower
4. Networking of dam reservoirs at a basin level and efforts for consensus building
5. A method to concretize backup capacity
6. Improvement in reservoir operation
7. Securing dam safety
8. Technology development for longer service life of dams
9. Better understanding of dams and fostering engineers of next generation

Keywords: Dam, Reservoir, Plan, Operation, Maintenance, Rehabilitation.

RÉSUMÉ

Cette communication présente les principaux contenus du rapport compilé par le comité spécial de la Society of Dam Engineers du Japon en 2016. Elle vise à clarifier les objectifs importants de planification, d'exploitation et de maintenance des réservoirs de barrages, avec une utilisation complète et adaptative du parc de barrages pour la société japonaise à venir.

Environ. 2.700 réservoirs de barrages existants jouent un rôle indispensable dans l'approvisionnement en eau, l'énergie, l'atténuation des dégâts des inondations, le maintien du débit normal de la rivière et la fonction récréative. Avec l'augmentation de barrages anciens, il existe un nombre croissant de projets de réaménagement des barrages, dont l'objectif principal est l'amélioration de la capacité de contrôle des inondations et la récupération des sédiments excessifs. L'importance de la capacité de «sauvegarde» est soulignée ici.

Après avoir examiné trois facteurs d'influence, à savoir le déclin de la population, le changement climatique et les catastrophes rares mais dévastatrices, les

problèmes majeurs seront l'atténuation des dommages causés par les inondations, le maintien du débit de la rivière, de l'hydroélectricité et de la gestion des sédiments. La nécessité de la capacité de contrôle des inondations pour le plan d'amélioration à long terme est confirmée. La fonction de de l'énergie hydroélectrique pour stabiliser l'énergie solaire et éolienne est également concernée.

Un cadre de base composé de quatre phases est présenté, afin de faire fonctionner complètement le parc de réservoirs, avec une maintenance adéquate et un fonctionnement adapté aux changements. Celles-ci sont : 1) Longue durée de vie, 2) Utilisation judicieuse, 3) Augmentation de capacité, et 4) Utilisation du réseau.

Enfin, neuf propositions de haute priorité sont présentées comme suit.

1. Amélioration de la capacité de contrôle des inondations
2. Assurance d'approvisionnement en eau en situation de crise
3. Promotion de l'hydroélectricité
4. Mise en réseau des réservoirs au niveau du bassin et efforts pour la construction de consensus
5. Méthode pour concrétiser la capacité de sauvegarde
6. Amélioration de l'exploitation du réservoir
7. Assurance de sécurité des barrages
8. Développement de la technologie pour une durée de vie plus longue des barrages
9. Meilleure compréhension des barrages et soutien aux ingénieurs de la prochaine génération

Mots-clés: Barrage, Retenue, Plan, Exploitation, Entretien, Rehabilitation.

1. INTRODUCTION

Japan Society of Dam Engineers (JSDE) set up a special research committee in September 2015, in order to clarify important targets in planning, operation and maintenance of dam reservoirs, with full and adaptive utilization of dam stock for the coming Japanese society in mind.

To address various functions of dam reservoirs, experts in the related fields were involved in this activity. Members of the committee and its working group are listed in Table 1. After one year's study and discussion, the committee compiled a report in November 2016 with a subtitle of "Challenges of dams to support the coming one hundred years".

This communication is to introduce the core contents of the report. First, it deals with the current condition of the dam stock and its roles in Japan, then, examines three important influencing factors: decline in population, climate change, and gigantic natural disasters. Next, it makes prospects for the future roles of dams, and presents four phases as a basic framework for the future challenges. Finally, it makes nine proposals including strengthening of flood control capability, full utilization of hydropower potential, and basin-wide reorganization of dam reservoirs.

Table 1
Members of the Committee and the Working Group

Committee Member	
Name	*Affiliation*
Harumi SAITO	The Japanese Institute of Irrigation and Drainage
Hideki ISHII c)	NEWJEC INC.
Hideto MORI b)	CTI Engineering Co., Ltd.
Hiroyuki SHINTO	Japan Water Agency
Joji YANAGAWA	Japan Dam Engineering Center
Kenji TAKASHIMA	Electric Power Civil Engineering Association
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Tetsuya SUMI	Kyoto University
Yoshiro YAMAMOTO	Maeda Corporation

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Akio OKA	NEWJEC INC.
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Secretariat	
Name	*Affiliation*
Takashi IKEDA	Civil Engineering & Eco-Technology Consultants
Yoshinori USHIKU	Japan Dam Engineering Center

Remarks: a) Chairman b) Vice chairman c) Working Group leader

2. PRESENT STATUS OF DAM RESERVOIR STOCK IN JAPAN

2.1. EXISTING HIGH DAMS IN JAPAN

Fig.1 shows the number of existing dams in Japan (dam height equal to or over 15m) and share of purposes of dams. Fig. 2 is a time-line of completed dams by period (basically 10 years) and by type of dam [1].

Since at least 7th century, the Japanese people has built dams for irrigation. After starting modernization of Japan in 1868 (Meiji Restoration), dam construction was accelerated utilizing modern engineering. The peak of dam completion is in 1960's, and many of the dams are more than fifty years old.

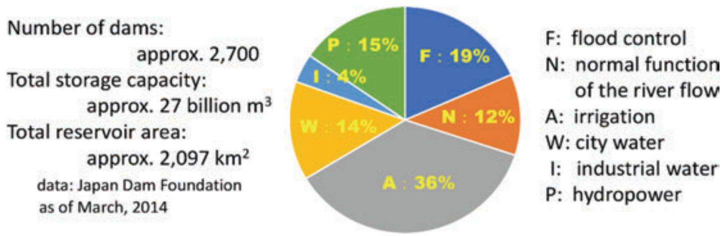

Fig. 1
Number of high dams and share of purpose of dams
Nombre de barrages élevés et part de l'objectif des barrages

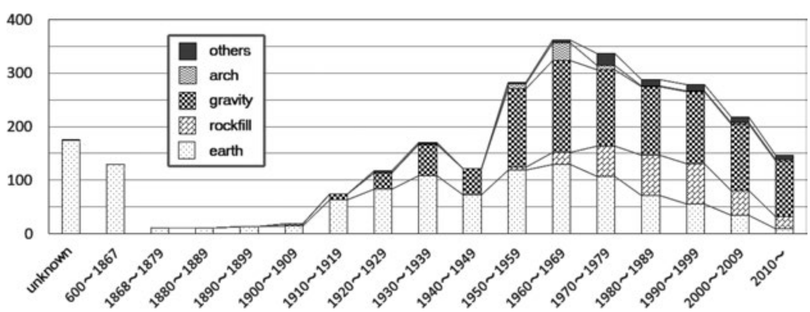

Fig. 2
Number of completed dams by period and type
Nombre de barrages terminés par période et par type

2.2. ROLE OF DAM RESERVOIRS IN JAPAN

Dam reservoirs support Japanese society and economy in various aspects. As for stable supply of water for agriculture, city water, and industrial production, water supply secured by dam reservoirs plays indispensable role. Looking into supply of city water all over Japan, 47 per cent of the source is of dam origin [2].

It must also be noted that the central and local governments have made lasting efforts to substitute excessive withdrawal of ground water which caused large-scale land subsidence in Tokyo and Osaka metropolitan area, with stable supply of surface water enabled by dams.

Many of dams built by river administrator (Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and Prefectural Governments) have reservoir capacity for securing normal function of river flow. This capacity helps to maintain river flow even at a severe drought.

As for supply of electricity, hydropower including pumped storage hydropower has a share of 9 per cent of total power generation [3]. Recently the Government promotes utilization of renewable energy including solar, wind and small-medium sized hydropower.

In the field of mitigation of flood damages, recent cases of flood control by dams, such as the case of Hiyoshi Dam in September 2013, proved its effectiveness against record-breaking heavy rains which seem to be on the rise. In addition, a case of Singuu river system is reported, where hydropower dams contribute to flood control through preliminary release of water.

As for sedimentation in reservoirs, data of one thousand dams shows that 20 per cent of them have already more sediment volume than the planned capacity for sediment, and that 60 per cent of them have higher sedimentation speed than originally expected [4]. Transfer, dredging of sediment load is commonly done. There are a few cases of construction of a tunnel for bypassing sediment.

As for environmental issues related to dam reservoirs, dam owners are taking necessary measures, such as a selective intake system against cold water problem, aeration and reduction of pollution load against eutrophication, a fish path to secure upstream and downstream movement.

Lakes created by dams are valuable for tourist attraction. More than 13 million people in total are estimated to be engaged in recreational/touristic activities around MLIT and JWA dams in a year.

2.3. Re-development of dams

There is an increasing number of re-development project of dams. Here are major cases of re-development:

- ✓ Increase of flood control capacity by raising a dam body or acquisition of other capacity
- ✓ Increase of capacity for normal function of river flow
- ✓ Improvement of gate facility or installation of a bypass channel to strengthen flood control capability, and/or to cope with sedimentation problem
- ✓ Connection of two reservoirs by a channel and introduction of integrated operation
- ✓ Re-allocation of capacities among plural existing dam reservoirs
- ✓ Re-allocation of capacities among existing dam(s) and newly constructed dam(s), including separation of flood control function and water supply function

Relating to re-development works, "alternative capacity" was introduced first in Japan to the plan of Kawakami Dam (Japan Water Agency). This capacity enables another JWA dam which needs removal of sediment or other re-development works to lower the water level of its reservoir during the work, contributing to efficient and low-cost execution. This "backup" function will be necessary more in the future.

3. MAJOR INFLUENCING FACTORS FOR THE COMING SOCIETY

3.1. Decline in population

The population of Japan had constantly increased during 20th century. However, due to sharp drop in birth rate, it reached the peak of 128 million in 2008. In case this trend continues, the population is estimated to be 87 million in 2060, and to decrease furthermore afterward. In case the birth rate shows considerable rise, the population is projected to be stabilized at the level of 90 million in the long run [5].

In any case, Japan faces the impact of population decline which has never been experienced in its modern history.

3.2. Climate change

The 5th IPCC Report notes future rise in temperature and higher frequency of heavy rain in Japan area [6]. A simulation for A-class rivers indicates that frequency of major floods which exceed the scale of design flood for river improvement policy will be 1.8 – 4.4 times as high as the current situation [7]. The higher risk of inundation of low coastal area due to the expected rise of sea level is also pointed out.

As for influence on water use, there is concern for severer drought due to increase of number of days without rain, or decrease of snow amount, and for water shortage due to decrease of snow melting flow which is important for paddy irrigation [8].

3.3. Rare but devastating disaster

On 11th March 2011, Japan experienced a devastating disaster caused by an earthquake of Magnitude(Mw) 9.0 and massive tsunami. How to cope with this kind of rare but destructive disaster is a great challenge for us.

Basic approach proposed by the disaster management authority is:

1) to deal with comparatively frequent external force (so-called "level-1 external force"), proper disaster management facilities must be prepared for disaster prevention,
2) and to deal with greater external force (so-called "level-2 external force"), comprehensive plan for disaster reduction comprised of non-structural measures and disaster management facilities must be prepared, aiming at evading human casualty and catastrophic damages [9].

4. PROSPECTS FOR THE ROLES OF DAM RESERVOIRS

4.1. Stable supply of water

Decrease of population will bring decrease of demand for city water, which undermines the finance of water supply corporations. Industrial water demand has a high probability to decrease. Water demand for irrigation may remain almost at the same level, because the Government has a policy to increase paddy field for animal feeding, substituting decreasing paddy field for food.

Water supply organizations for city and industrial water have to tackle problems related to decrease in water demand, as well as how to handle reservoir capacity allocated for their use.

4.2. Flood control and low flow augmentation

In view of the recent record-breaking floods and prospect of higher risk of heavy rains in the course of climate change, increase of flood control capacity has a high priority.

The JSDE committee has made an investigation on the progress of provision for flood control capacity required in the Basic Policy for River Improvement. This Basic Policy, whose target flood has a return period of 100 to 200 years, is a long-term plan prepared for each 109 A-Class River System by MLIT. Individual project including banking and dams is based on this Policy, whose target flood has a return period of several decades.

As Table 2 shows, at least 2.6 billion m^3 of capacity must be secured to achieve the long-term goal.

As for low flow augmentation, the Basic Policy has also a target river discharge which is to be secured at a time of drought, to maintain normal function of the river flow. This goal is not also met in various river system, and the capacity for this purpose must be prepared.

Table 2
Progress of provision for flood control capacity

COMPLETED (IN OPERATION)	PROJECT UNDER CONSTRUCTION	NOT REALIZED
4.1	0.9	at least 2.6

unit: billion m^3, as of August 2016

4.3. Hydropower

Hydropower is a renewable and low-carbon energy source. After the 2011 off the Pacific coast of Tohoku Earthquake, almost all the atomic power plants have been stopped, which resulted in sharp increase in import of fossil fuel.

From the viewpoint of global warming and energy security, hydropower must be fully developed. Another advantage of hydropower is its load following ability. This helps hydropower to contribute to stabilizing fluctuation of output from solar and wind power. Pumped storage hydropower is also expected for grid-scale stabilization.

4.4. Sediment management

Along with increase of aged dams, sediment management becomes more and more important. In addition to the current measures such as transfer and dredging, introduction of the idea of "equilibrium sedimentation" is essential from the long-term view and continuity of sediment material from mountain to estuary. This is to keep the balanced condition by discharging the same amount of sediment from a dam reservoir as the reservoir had from upstream [10].

5. BASIC FRAMEWORK FOR FULL FUNCTIIONING OF THE DAM STOCK

Here, we propose a basic framework consisting of four phases, to make the stock of dam reservoirs function fully, with proper maintenance and adaptive operation to changes, as shown in Fig.3.

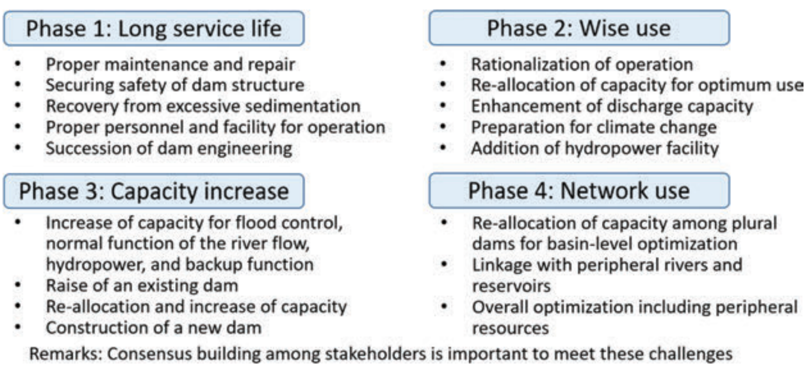

Fig. 3
Basic framework: Four phases and major challenges
Cadre de base: quatre phases et défis majeurs

First, extension of service life of existing dam reservoirs in safe condition by proper maintenance and repair is essential.

Next, maximization of their benefit must be pursued through improvement of operation, upgrading of discharge facility, and re-allocation of capacity among plural reservoirs.

C. 3

In case still more capacity is needed after afore-mentioned effort, enhancement of reservoir capacity must be addressed by raising the height of existing dams and/or construction of new dams.

In case there are more than one dam reservoir in a basin, networking of functions of individual dam reservoir, whose original plan was optimized for its own purpose, must be addressed to maximize the benefit at the basin level, by coordination of operation, re-allocation of reservoir capacity, and other measures.

6. NINE PROPOSALS

After screening of various issues which we must tackle, we present nine proposals of high priority as follows.

6.1. Enhancement of flood control capability

From the view point of fully functioning existing dam reservoirs, restraining sediment into reservoirs and recovery of reservoir capacity is basically important. Appropriate measures must be chosen in consideration of characteristics of sediment environment and economic efficiency. Introduction of "equilibrium sedimentation" idea, instead of conventional planning method to have a capacity for 100 years' sediment volume, is also a challenge.

To maximize flood control effect of existing flood control capacity, more efficient operation based on accurate forecast for rainfall, and refinement of operation during a major flood greater than the planned target flood, are needed. Improvement of flood discharge facility is also an important factor.

As stated in 4.2., a large amount of capacity for flood control is still necessary. In addition to this, climate change urges steady enlargement of flood control capacity, by raising dam body, re-allocation of capacity, and new dams.

6.2. Securing water supply in a crisis situation

Under normal conditions, stable supply of water will be achieved as a whole due to decrease in water demand associated with decline in population.

Nevertheless, supply of necessary amount of water at a time of crisis, such as an abnormal drought, large-scale earthquake, is of great importance.

In a crisis, wide range of measures for both demand and supply management are needed. Flexible water supply system supported by networks of sources and channels is effective. Reservoir capacity for abnormal drought and normal function of the river flow will contribute to a robust system. Effort for earthquake-resistant operating facilities and reduplication of access is also necessary.

6.3. Promotion of hydropower

The Feed-in Tariff system of the Government, which aims at promotion of renewable energy, targets hydropower less than 30,000 kW. Larger hydro-power must be developed as much as possible.

First, efforts to find large-scale hydropower sites must be done through reviewing the past nation-wide research for potential hydropower with current social and economic conditions. Administrative procedures must also be simplified.

Increase of hydropower generation must be pursued through enlargement of existing generation facilities or installation of new facilities, which might be realized by changing capacity allocation, raising a dam body, or installation of a re-regulating pond.

Solar and wind power has shown remarkable increase in this decade in Japan as a valuable renewable energy, though, their fluctuant nature brings instability to the grid. In the United States, pumped storage hydropower (PSH) is expected to stabilize this fluctuation [11]. We must try to make most use of this stabilizing capability of hydropower, and this will help more development of fluctuant renewable energy.

6.4. Networking of dam reservoirs at a basin level and efforts for consensus building

From the viewpoint of water supply, "series" type of plan is commonly applied, where a subsequent dam project premises data of river discharge after operation of a prior dam reservoir. This suggests a room for more efficient operation as a whole through integrated operation or other advanced ways.

For effective flood control, it is desirable that reservoirs are deployed well balanced in the basin, and that they have larger catchment area under their control. However, this is not always the real case.

Optimization of functions of dam reservoirs at a basin level by re-organizing and networking of existing dams requires high level of cooperation among various dam owners. Toward this goal, authorities concerned must make consensus building effort for various rules including cost burden and coordination of water right.

6.5. A METHOD TO CONCRETIZE BACKUP CAPACITY

In spite of the necessity of backup function, it is not easy to realize a new backup capacity shared by various dam owners, because of difficulty in clarifying necessity and cost allocation.

Here, we propose a method where a dam, which is operated for hydropower at the normal condition, is utilized temporally for backup of another dam under re-development. The user is supposed to bear the lost benefit of electricity. The user has no need for the initial investment for the backup capacity, and can judge the availability when needed.

6.6. IMPROVEMENT IN RESERVOIR OPERATION

To maximize flood control effect, more effective method for preliminary release and operation at a time of an extraordinary flood, as well as more precise prediction of rainfall must be pursued. The risk related to the uncertainty of prediction must be evaluated.

As for water supply, more efficient operation including integrated operation of plural reservoirs must be pursued. Institutional improvement of water management must also be studied.

6.7. SECURING DAM SAFETY

Dam safety is directly linked to the safety of a large number of inhabitants downstream. Risk management including study of behavior of dam structure against extraordinary force, failure mode, emergency plan must be addressed.

6.8. Technology development for longer service life of dams

To extend service life of dams, we must develop various technologies such as inspection, diagnosis, reinforcement and management with support of information and communication technology.

6.9. Better understanding of dams and fostering engineers of next generation

People's better understanding of dams and related issues is a basis for proper management and investment, as well as for fostering of human resources.

Nowadays, thanks to the activities of so-called "dam lovers" and various efforts of dam owners, attractiveness and roles of dams is gradually known to many people. Accessibility to dams and their related information must be improved furthermore.

For succession of dam engineering and development of human resources, knowledge management to transfer knowledge from retiring generation to the next one, and education management for young engineers are needed.

REFERENCES

[1] hamaguchi T. A brief history of dam construction in modern Japan. *Kasen (River), Japan River Association,* 2015, No.830. (in Japanese)

[2] JAPAN WATER WORKS ASSOCIATION. Historical analysis of water works statics. *Journal of JWWA,* 2016, No.983. (in Japanese)

[3] AGENCY FOR NATURAL RESOURCES AND ENERGY. White paper on energy, 2016. (in Japanese)

[4] JAPAN RIVER KEEPER ALLIANCE. Sediment data of Japanese dams (2013). (in Japanese)

[5] CABINET DECISION. Long term vision for cities, people and jobs. 27^{th} December 2014. (in Japanese)

[6] MINSTRY OF THE ENVIRONMENT AND METEOLOGICAL AGENCY. Result of calculation of climate change in consideration of uncertainty. 2014. (in Japanese)

[7] NATIONAL INSTITUTE FOR LAND AND INFRASTRUCTURE MANAGEMENT, MLIT. Interim report on climate change adaptation studies. 2013. (in Japanese)

[8] COMMITTEE FOR WATER RESOURCES, NATIONAL LAND COUNCIL, MLIT. Influence of climate change and adaptation measures. 2011. (in Japanese)

[9] CENTRAL DISASTER MANAGEMENT COUNCIL, CABINET OFFICE. Report of the special committee on disaster management measures for earthquake and tsunami, reflecting the 2011 disaster. 2011. (in Japanese)

[10] JAPAN DAM ENGINEERING CENTER. Prospect for re-development of dams. 2007. (in Japanese)

[11] PUMPED STORAGE DEVELOPMENT COUNCIL, NATIONAL HYDROPOWER ASSOCIATION, USA. Challenges and opportunities for new pumped storage development. 2014.