Water management strategies for desirable IWRM implementation and application to the initiative projects, Korea

Stratégies de gestion de l'eau pour la mise en œuvre et l'application souhaitables de la GIRE aux projets de l'initiative, Corée du sud

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Abstract. K-water has led national policymaking in South Korea through a master plan established in 2015 to raise national awareness on integrated water resources management (IWRM). It has promoted leading pilot projects as a short-term plan. Since the construction of the initial dam on the Seomjin River in 1928, inefficient water management has persisted. There was a jumble of agreements, treaties, regulations, and various institutions that could not keep up with the changing conditions in dam operation and water use caused by the construction of the new dam and auxiliary spillways on the river. Also, there were four agencies designated as dam usage right-holders: Two more were added to the original two dam licensees. Accordingly, the initiative project established a consensus on the need to streamline dam operations and promoted deriving social agreements through a council composed of the field-level departments of each water management agency. After government mediation, dam management regulations were revised to determine adjustments in the dam usage rights and the basic priorities in water use. This IWRM pilot model, which promotes the rational use of a dam by multiple users, successfully satisfied each stakeholder's agreed-upon rights in 2019, the first project year.

Résumé. K-water a dirigé l'élaboration des politiques nationales en Corée du Sud à travers un plan directeur en 2015 pour sensibiliser le pays à la gestion intégrée des ressources en eau (GIRE). Elle a promu des projets pilotes en tant que plan à court terme. Depuis la construction du barrage initial sur la rivière Seomjin en 1928, la gestion inefficace de l'eau persiste. Il y avait un fouillis d'accords, de traités, de règlements et de diverses institutions qui ne pouvaient pas suivre l'évolution des conditions de l'exploitation du barrage et de l'utilisation de l'eau causée par la

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construction du nouveau barrage et des déversoirs auxiliaires. En outre, quatre agences ont été désignées comme titulaires de droits d'utilisation des barrages. En conséquence, le projet a établi un consensus sur la nécessité de rationaliser l'exploitation des barrages et de parvenir à des accords sociaux à travers un conseil composé des départements fonctionnels de chaque agence. Après la médiation du gouvernement, les règlements de gestion des barrages ont été révisés pour ajuster les droits d'utilisation des barrages et les priorités de base en matière d'utilisation de l'eau. Ce modèle pilote de GIRE, qui promeut l'utilisation rationnelle d'un barrage par plusieurs utilisateurs, a satisfait aux droits convenus de chaque partie prenante en 2019, la première année du projet.

1 Introduction

The introduction and advancement of integrated water resources management (IWRM) is a global concern and a key task in preparing future water management. The concept has been expanding with the announcement of the IWRM Guidelines at River Basin Level at the World Water Forum (WWF) in 2009 and the adoption of the OECD Council Recommendation on Water in 2016 [8]. South Korea (Korea) also recognizes the need for a holistic approach to water management and is making various changes. Dams account for 56% of Korea's total water use (20.9 billion m^3) and will play an important role in improving the country's water management.

As a result, dams in Korea are undergoing changes as a reflection of a policy shift toward greater utilization efficiency under the country's water management development direction. These changes have raised new issues in the management and use of existing dams and lead to potential changes in dam usage.

This report aims to introduce K-water's IWRM initiative project that promoted the redistribution of the right to use water from the Seomjingang Dam, operating for over 50 years. This case includes the collection and analysis of the following data:

Current inefficiencies and problems in the utilization of the dam and its reservoir;

Process of coordinating differences in opinion among stakeholders to improve the use of the dam; and

Expected improvements from these changes.

This case study and its analysis will not only provide valuable examples to similar cases on how to improve dam usage but also provide K-water lessons for better collaboration in sharing water from a governance perspective.

2 Background on K-water's IWRM initiative projects

2.1 Korea's water management

2.1.1 Unfavorable conditions and current issues

Korea has a very unfavorable natural environment for water management because the amount of available water resources is insufficient due to a high population density in a small country (2,546 m^3 per capita as of 2016, about a sixth of the world average) and because 72% of its annual precipitation is concentrated in a distinct rainy season (June to August) [9].

In addition, water is a continuous and mutually affecting basin-level organism that must be managed in an integrated and connected manner. However, various problems have arisen

due to the diversified management system established in the process of rapid economic development, including the Ministry of Land, Infrastructure and Transport (MOLIT), Ministry of Agriculture, Food and Rural Affairs (MAFRA), the Ministry of Trade, Industry and Energy (MOTIE), and the Ministry of Environment (ME) [7]. The efficiency in the use of existing water resource facilities is low due to overlapping investments and overinvestment, and water management-related disputes, such as water price disputes, water distribution conflicts, and disputes between upstream and downstream regions, continue to occur and are becoming a social issue. Water disasters, such as floods, are increasing rapidly in small- and medium-sized rivers where investment is delayed. Also, the water quality-aquatic ecological conditions are poor due to an increase in livestock manure and other nonpoint source pollution (from 27% in 1998 to 58.9% in 2012) [8].

2.1.2 Assessment of Korea's IWRM level

Korea's IWRM is well-implemented overall as it ranks 14 out of the 91 countries worldwide that have introduced IWRM. However, UN-Water (2012) has evaluated it as being lower than the advanced water management countries with unfavorable water management conditions, such as the Netherlands and Japan. By sector, infrastructure development is relatively high, but governance and institutional framework are low. The Progress on Integrated Water Resources Management (UN-Water, 2018) also reported similar levels.

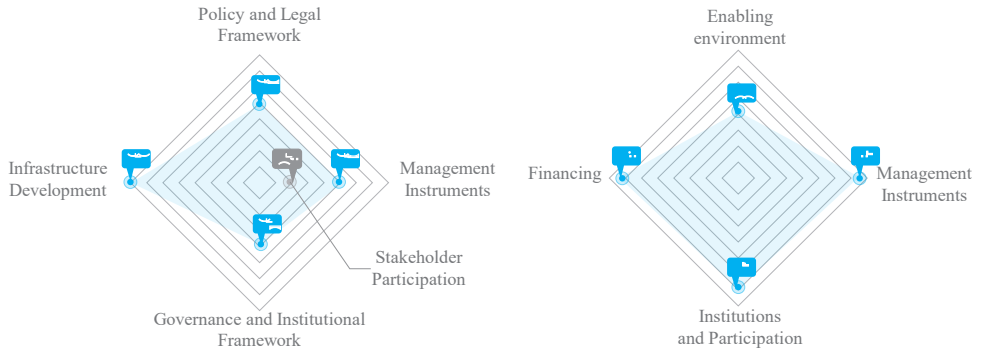


Fig. 1. UN-Water assessment of IWRM in Korea. 2012 Status Report on the Application of Integrated Approaches to Water Resources Management (left); and 2018 Progress on Integrated Water Resources Management (right).

2.2 Purpose of initiative projects implementation efforts

2.2.1 Led by an agency specialized in water management

The Korean government has made efforts to resolve the water problem, which has faced limitations due to individual approaches. However, these efforts have not been realized for a long time. As an institution that supports and implements national policies in a situation where development toward integrated water management is slow, K-water determined that it was necessary to lay the foundation for the provision and verification of IWRM guidelines to form and establish national consensus. Accordingly, a master plan was formulated for pilot projects and to form a consensus. The following three directions were suggested for improving water management: i) Reorganize the system into an integrated planning system

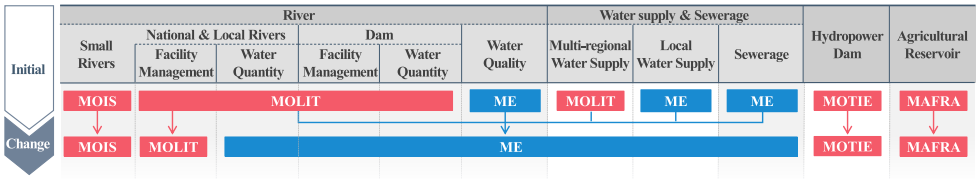
at the basin-level, ii) introduce a bottom-up planning system led by the region, and iii) reinforce verification and reflection between departmental plans.

2.2.2 Promoting pilot projects by basin

In order to prove the actual effect, it is most effective to combine the concept of IWRM with the current issues and conflicts it faces and solve it in a short period. To this end, a water collaborative council (governance) was formed for each watershed, and the process of sharing facts, strengthening trust, and building consensus on win-win measures was carried out to experience a healthy water environment and collaborative water culture and to share and expand the results nationwide.

2.3 Changes for IWRM

Korea's water management system, where inefficiencies persisted, has recently reached a turning point. In accordance with the Presidential Instruction No. 5 (May 22, 2017), water management was unified to accomplish balanced water management in one consistent water quantity, water quality, and disaster prevention system. In June 2018, three laws related to water management (Government Organization Act, Framework Act on Water Management, and Act on Development of Water Management Technologies and Promotion of Water Industry) passed the National Assembly. As a result, water management functions scattered across different ministries were reorganized around the Ministry of Environment, thereby laying an institutional foundation for improving institutional fragmentation. The legislation also includes establishing the Water Management Committee with a governance concept that allows the review of all water-related statutory plans and the discussion, deliberation, and decision-making on water management issues across watersheds [5].



Note: MOIS: Ministry of the Interior and Safety; MOLIT: Ministry of Land, Infrastructure and Transport; ME: Ministry of Environment; MOTIE: Ministry of Trade, Industry and Energy; and MAFRA: Ministry of Agriculture, Food and Rural Affairs.

Fig. 2. Water management function by departments before and after unifying water management in June 2018.

3 Seomjingang Dam IWRM initiative project

Considering the location and use of the Seomjingang Dam located in a wide plain granary, local residents and a person who holds the right to use the dam (dam usage right-holder) would not have expected that the dam could be converted to function for any other purpose other than irrigation before the start of discussions on improving the use of the dam in May 2005. The dam was part of the community environment that remained unchanged for as little as 50 years and as long as 90 years. Thus, it has been difficult to change the current status through public intervention in this sentiment.

3.1 Dam description

The Seomjingang Dam is a concrete gravity dam with a height of 64 meters and a length of 344 meters. It is equipped with Korea's first hydroelectric power plant, Seomjingang Hydropower Plant (34,800 kW), and a tunnel to supply agricultural water (Unam intake tunnel). The Seomjingang Dam was first constructed in 1928 to overcome severe food and power shortages. The current dam was newly constructed 2 kilometers downstream from the original dam that was built in 1968. Lake Okjeong, with a reservoir area of 26.5 km^2 and a total storage capacity of 470 million m^3, was created by the dam. All of the stored water is supplied as agricultural water to 30,000 hectares of plains and tidelands outside of its original river basin, and electricity is generated using the supplied agricultural water. The state owns the dam and guarantees water use by receiving some dam construction costs from an agriculture water supply agency and a power generation agency and licensing dam usage rights [4].

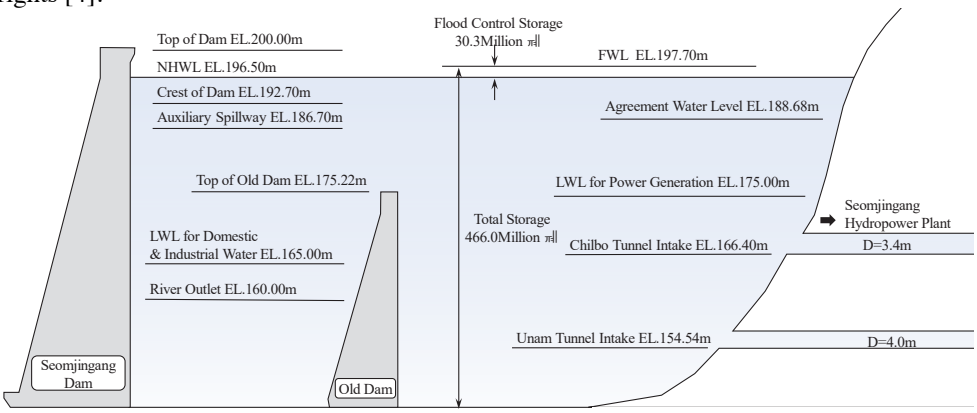


Fig. 3. Seomjingang Dam water storage capacity and water levels.

3.1.1 Lake Okjeong operations

K-water is entrusted by the state with the dam management and is in charge of controlling floods and managing the dam structures and reservoir areas. Korea Hydro & Nuclear Power Co., Ltd. (KHNP), a dam usage right-holder, owns and operates facilities related to power generation, and the Korea Rural Community Corporation (KRC) owns and operates facilities related to agricultural water. In order to properly ensure the dam licensees' rights, matters pertaining to dam operation, water allocation, and flood control are made through agreements and treaties between the necessary agencies and a management committee.

Water consumption throughout the year is managed by securing a specific water level at a particular time to ensure agricultural water, which is the highest water priority, based on experience and operational performance, and not by a predictive method based on dam inflow-outflow simulation. In other words, power producers use water for hydroelectric power generation during the non-irrigation period from October to March of the following year but must secure the agreement level for agricultural water of El.188.68m at the end of March. From April to September, the irrigation period, demand for agricultural water is supplied foremost [6].

Table 1. Contents of the agreement (MOLIT↔KRC, April 1977).

(Article 2) In order to secure water for irrigation, the water level shall be guaranteed to an elevation of 178.3 meters as of May 30, and KRC shall have the right to restrict the use of power generation water until this level is reached.

Note: Henceforth, two changes were made to the agreement, and the agreement level was raised to El.184.68m and EL.188.68m corresponding. The period was changed to the end of March.

3.2 Dam redevelopment

3.2.1 Issues and demands for change surrounding the dam

The Seomjingang Dam had continued to operate abnormally without fully utilizing the planned dam specifications due to the residents who settled and lived in the submerged area. The dam's hydrological stability against probable maximum flood (PMF) had not been secured, making it necessary to normalize dam operations for rational use. Also, there was a need to diversify the Seomjingang Dam's use to respond to new demand for domestic and industrial water in the dam's downstream area (about 90 kilometers apart). In addition, there was a change in the demand for agricultural water due to the transformation of industrial structure in the surrounding regions, and the country's dependence on hydroelectric power for electricity generation decreased (accounting for 0.4% of total power generation).

3.2.2 Renewal of dam function

Therefore, the government decided to redevelop the dam to resolve dam operation restrictions and strengthen flood control capabilities. The redevelopment project allocated the water restored through the normalization of dam operation to domestic and industrial waters (65 million m^3/year), and the flood control capacity was increased from the original 100-year frequency to PMF (3,268 $m^3/s \rightarrow$ 8,601 m^3/s) by repairing old facilities and establishing auxiliary spillways (D13.5m×2 lines, $L_1$674m, $L_2$624m).

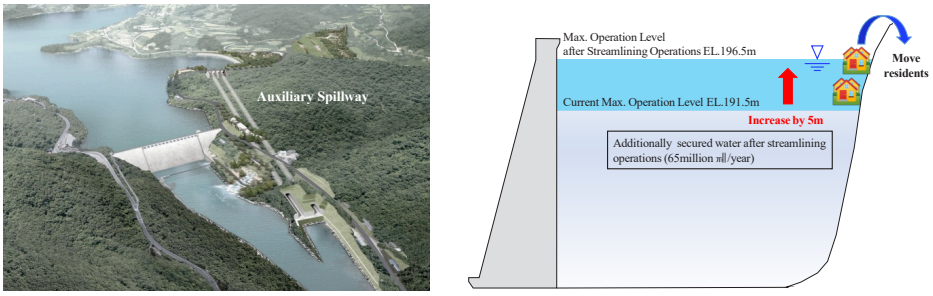


Fig. 4. Bird's eye view of the redevelopment project's auxiliary spillways (left); and schematic diagram of the restoration of the operation level (right).

According to the redevelopment, the number of dam usage right-holders changed from two to four. The usage ratio of the initial two dam usage right holders decreased.

Table 2. Changes in dam usage rights due to redevelopment.

Classification		Power Generation	Irrigation	Flood Control	Domestic and Industrial Water
Dam Usage Right	Right-holder	KHNP	KRC	State	K-water
	Ratio before redevelopment (%)	69%	31%	-	-
	Ratio after redevelopment (%)	27%	15%	38%	20%

3.2.3 Changes to be accompanied

The complexity in dam operation has increased after redevelopment, requiring precise and flexible decision-making in dam operations. There are limitations in the efficient use of storage water under the current dam operation circumstances because of self-centered decision-making. In 2012, the dam's water storage was secured at a level of 78% at the end of the flood period (September), but the water storage rate was only 49.1% at the start of the irrigation period of the following year (end of April) due to discharge for power generation during the non-irrigation period. In addition, the water storage rate decreased to 11.6% due to the 2013-2014 drought, and the water for irrigation continued to be discharged at a rate of 15-20 m^3/s, as under normal circumstances, even in a disaster situation where water conservation was requested in order to secure drinking water. It is difficult to comply with the agreement water levels under current dam operations because each licensee operates the dam for different purposes. The compliance rate over 40 years since 1975 stands at only 75%. The agreement water level has been raised twice to improve the stability of the agricultural water supply.

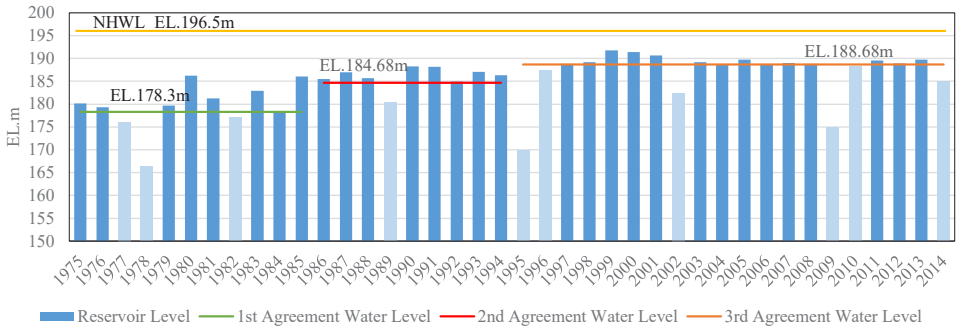


Fig. 5. Agreement water level standards and compliance status.

As in the present case, if the use of power generation water continues above the agreement level during the non-irrigation period, the water supply reliability of 65 million m^3/year of domestic and industrial water, which was planned to be additionally secured, will be at a level of 80%, which falls short of the normal level of 95%. Therefore, an agreement between the dam users on a detailed dam operation plan is necessary.

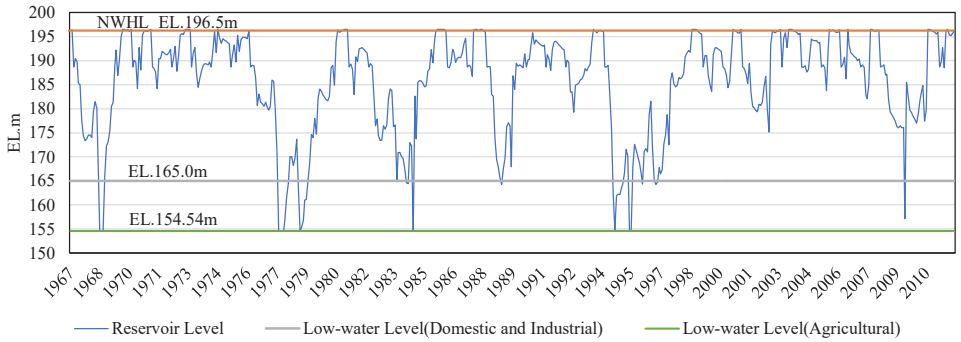


Fig. 6. Simulation results of reservoir operation based on the agreement water level (EL.188.68m).

Securing PMF flood capacity makes it possible to control floods by using auxiliary spillways along with the existing floodgates. It is necessary to prepare in advance on matters such as agreeing on when to open the floodgates to prevent floods because the experience of discharging the mainstream after the dam was installed is minimal. According to a dam operation simulation using the rigid reservoir operation method (rigid-ROM) that considers pre-release based on the 2011 flood event criteria, which is the largest recorded flooding, a pre-release of 200 m3/s for 33 hours is required to avoid exceeding the flood water level. The planned maximum discharge rate without causing damage to the downstream of the reservoir is 400 m3/s. In the event of a flood that exceeds the plan, cooperation is necessary to discharge floodwater outside the watershed through the discharge facilities installed for power generation and irrigation. When a system of inter-agency sharing and cooperation is established, pre-release is expected to be reduced from 17-33 hours to 14-23 hours when evaluated with the 2011 flood event criteria (100-year frequency-based design flood ↔ 500-year frequency of occurrence flood), thereby reducing the risks associated with pre-release.

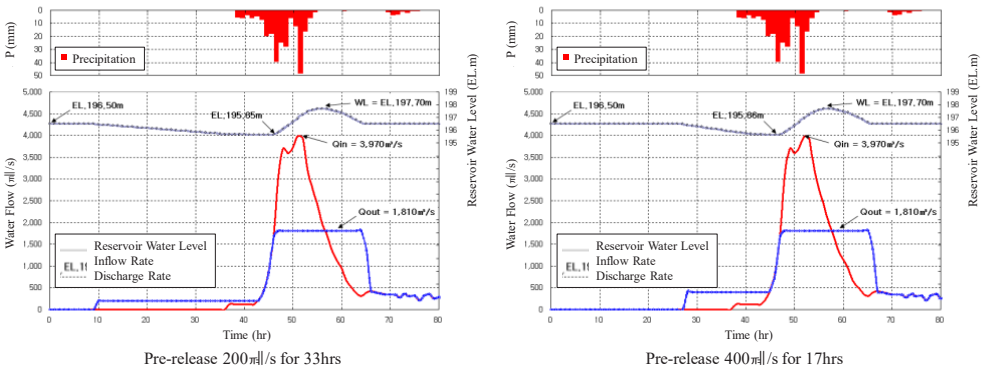


Fig. 7. Reservoir flood routing results according to preliminary discharge volumes.

Preparing a mechanism to adjust disagreements that could arise during the dam operation is necessary to prevent disputes among the dam users. The Seomjingang Dam Management Committee currently only mediates differences of opinions in budget-related issues, such as management expenses, and has a limited role in raising various issues related to the dam's operation or discussing the solutions.

3.3 Enactment of IWRM regulations

The Seomjingang Dam faces a demand for changes in water allocation and improvement in dam operation at a time when policy concerns are focused on how to manage and more efficiently distribute water resources that have already been developed rather than developing water resources. The key to achieving this need is to draw smooth consensus and concession among the various stakeholders, and the integration of IWRM that aims for efficiency, fairness, and sustainability through governance can be a major means of resolving the issue [1]. In principle, the pilot project is based on the agreement of the grantees of dam usage rights. It aims to adjust dam usage rights and enact IWRM regulations that reflect the changing conditions of dam management.

3.3.1 Attempts for successful governance

Although this redevelopment project determines the redistribution of available resources at the national level based on relevant laws, the stakeholders' conflicting demands or competition over water use may lead to disagreements on the dam's optimal operation [2]. Therefore, governance is used as a means to coordinate and reflect diverse opinions and interests.

The institutional level of collaborative governance to solve joint problems in Korea's water resources sector can be still considered low [3]. Thus, K-water, which acts as the national project coordinator, has played the role of confirming the position of each stakeholder from the standpoint of a conflict mediator, organizing the major issues of interest, and raising the awareness of members to increase the efficiency of the consultation process and derive win-win results. As a strategy for creating results, the actors, methods, and scope of governance are as follows:

The governance actors and scope are divided into three stages and gradually expanded over time. This is to increase communication efficiency and ultimately increase the possibility of reaching an agreement through cooperation. The first phase consists of "local governments, regional experts, and NGOs" to establish a consensus on using water rationally. The second phase is "the first phase members + central government and interest groups" for the purpose of public debate and policymaking, and the third phase is built on "the second phase members + direct stakeholders."

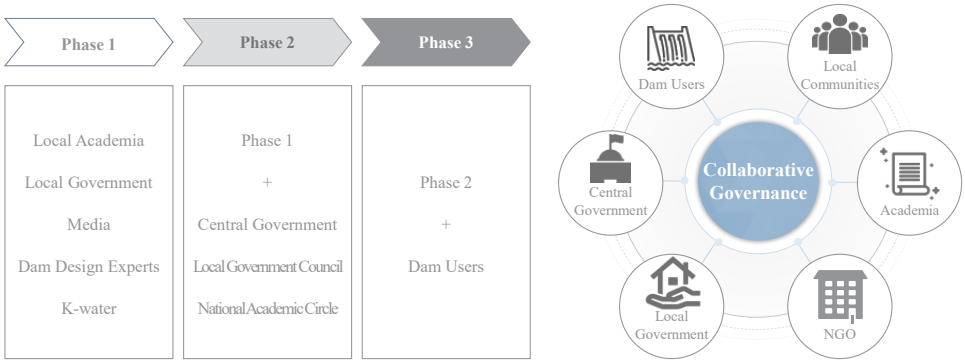


Fig. 8. Establishing governance.

Through governance, the aim is to establish consensus on the urgency of enacting IWRM regulations, secure the objectivity and reliability of IWRM regulations, and establish a support base by expanding social consensus in the upstream and downstream communities.

3.3.2 Activities over the past two years to reach consensus

The governance methods were conducting interviews with the dam and its related facility operation members to develop clear goals and holding workshops for a broad understanding of the current situation and recognizing problems. In addition, opinion was collected through consultation with local experts and holding discussion forums and commemorative events with the general public in order to gain support from the region.

In 2015, verification of the effectiveness of the redevelopment project was promoted through in-depth consultation with academic experts in the surrounding community, who are members of the first phase of governance; an MOU was signed with the downstream local governments affected by flood discharge; the 50th anniversary of the dam's construction was celebrated to raise public interest in the surrounding areas; and opinions were collected through public opinion surveys and discussion forums. The need and importance of organically streamlining the policies each agency is in charge of were communicated, mainly with members of the second phase of governance that are individual subjects of various water use policies.

In 2016, based on the first and second phases of governance activities, the future vision of the Seomjingang Dam was declared, and an MOU was signed with the full participation of all five parties to phase 3 of governance (the regional local government head, the council head of 13 local government heads, and the heads of the three grantees of dam usage rights); and policy consensus was established through the National Assembly and inspection of state administration to raise national awareness.

Fig. 9. Seomjingang Dam vision proclamation ceremony (November 2015).

Apart from the activities for verification and boom-up, a working-level council of the three water management agencies (K-water, KRC, and KHNP) was formed, and specific and practical issues were discussed through detailed dam operation technology review activities for two years in order to facilitate the participation and agreement process of the three direct stakeholder agencies. Through governance, an agreement to improve IWRM at the working-level departments of the three water management agencies was drawn, and the results of

agreements and non-agreement among the stakeholders were presented to the central government. The central government finally decided on the dam management regulations for multipurpose dams.

Table 3. Agreements of the working-level council of dam usage right-holders.

Key Agreements	Details
Direction of Dam Management Regulations	- Refrain from enacting new regulations; efforts to provide regulations by revising existing dam management regulations
	- Avoid excessively regulating details; prepare for flexible response in the early stages of dam operation
Water Use Priorities	- Domestic and industrial water can be used at water levels below the agreement water level for irrigation
Planned Supply by Water Use	- Clarify the water usage rights for each licensee; define the total annual water usage and the standard water usage per month
Council on Water Use	- Strengthen the function of the Water Management Committee; provide a mechanism to prevent indiscreet water use

3.4 Changed dam management

IWRM, in the aspect of efficient use of limited water resources, was attempted by modifying the use of the dam in accordance with changing circumstances and making efforts to reach consensus through governance.

As the newly secured water is always discharged downstream of the dam (daily average of 2.3 m3/s), the waterway cut off for 50 years was restored. This gave rise to the opportunity to transform the area around the river downstream of the dam into a water-friendly space to enjoy cultural life and leisure. The river, which flowed less than the instream flow for 111 days on a three-year average (2012-2014) based on 10 kilometers downstream of the dam, always flows more abundantly than the instream flow (0.76 m3/s) throughout the year.

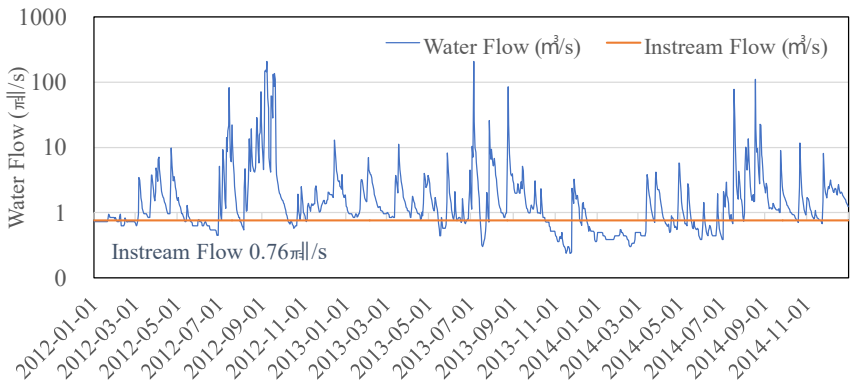


Fig. 10. Water flow in the downstream of the dam (before redevelopment project).

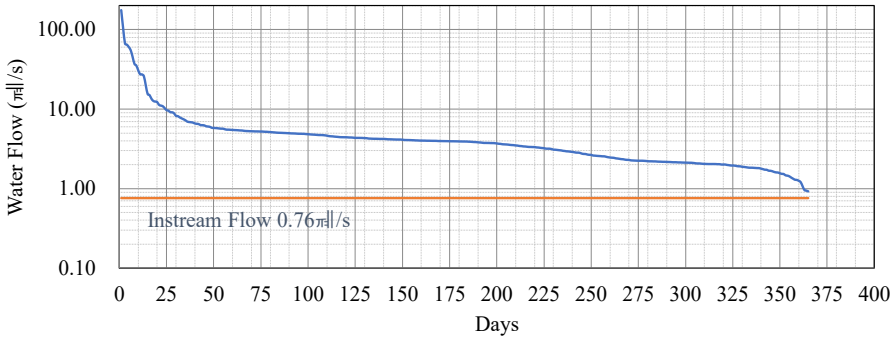


Fig. 11. Water flow in the downstream of the dam (after redevelopment project).

The revised dam management regulations enable all dam users to use the dam's water within the operating water level range throughout the year, while also increasing the probability of securing the water quantity given in the dam specifications. This IWRM pilot model, which promotes the rational use of a dam by multiple users, successfully satisfied each stakeholder's agreed-upon rights in dam operation in 2019, the first project year.

Table 3. Water-use by purpose, 2019.

(Unit: million tons/year)

Classification	Total	Domestic and Industrial Water	Agricultural Water
Planned	435	65	370
Actual	413	65	348

The agreement water level was satisfied at the start of the irrigation period in April. The reservoir level was used within the scope of each purpose-specific plan after the end of the irrigation period in September and thereby gradually recovered the normal level.

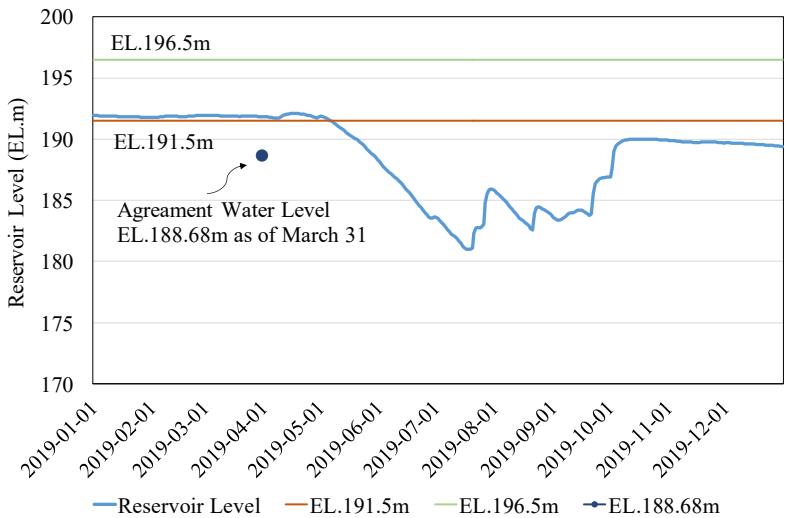


Fig. 12. Dam operation in 2019: Reservoir water level changes.

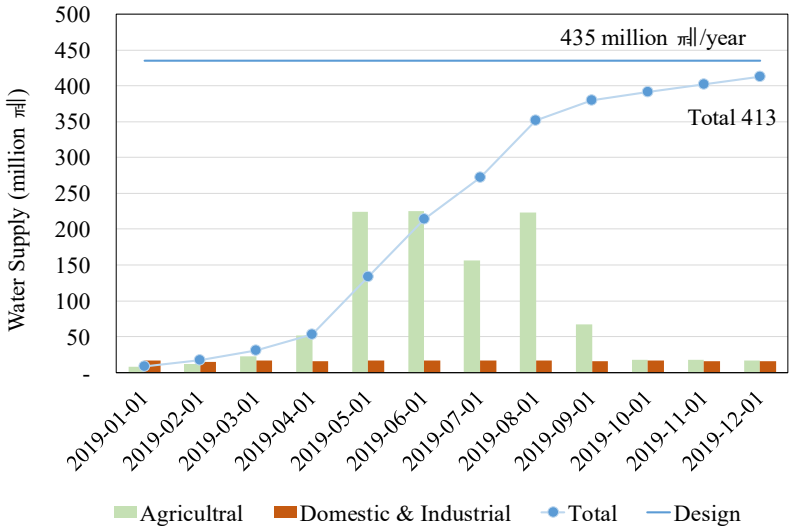


Fig. 13. Dam operation in 2019: Water use.

3.5 Future challenges

As the pilot project is the first attempt at amicable water use among multiple parties using a certain amount of water stored in one dam for specific purposes, some discussions have been delayed without being confirmed. There are plans to continue reviewing the integrated water management committee's composition and enhancing its functions based on the dam's operational results to improve the IWRM initiative project by streamlining the Seomjingang Dam operations and strengthening the conflict prevention and coordination functions. In addition, even in drought conditions, it is necessary to establish a standard for adjusting water supply to secure adequate water storage according to the pre-agreed priorities in water use. Considering that the flood water level was exceeded due to the unprecedented long rainy season and unexpected torrential rains resulting from climate anomalies in 2020, deliberation on how to respond more flexibly to floods is also necessary.

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