Water Resources Management in the Republic of Korea

Korea's Challenge to Flood & Drought with Multi-purpose Dam and Multi-regional Water Supply System

Hwa Young Kim
Cheolkyun Shin
Yonghyo Park
Jiyoung Moon

Infrastructure and Energy Sector
Water and Sanitation Division

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WATER RESOURCES MANAGEMENT IN THE REPUBLIC OF KOREA:

Korea's Challenge to Flood & Drought with Multi-purpose Dam and Multi-regional Water Supply System







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IDB Inter-American Development Bank

Ministry of Environment

K water

Author & Editor:

Hwa Young Kim, Ph.D., Senior Water Security & Supply Specialist, Water Resources Policy Bureau of the Ministry of Environment (MOE), Sejong, Republic of Korea; General Director of Korea Water Resources Corporation (K-water), Daejeon, Republic of Korea; Faculty affiliate of Civil and Environmental Engineering Department, Colorado State University, Fort Collins, CO, USA: hwayeong.kim@gmail.com

Section Authors:

Chapter 2.4-2.5: Mr. Cheolkyun Shin, Principal Researcher of Integrated Water Resources Management Department, Korea Water Resources Corporation (K-water), Daejeon, Republic of Korea: kyun@kwater.or.kr; Wanhee Cho, Ph.D, Senior Researcher of Integrated Water Resources Management Department, Korea Water Resources Corporation (K-water), Daejeon, Republic of Korea: wanhee@kwater.or.kr

Chapter 4.2: Mr. Yonghyo Park, Expert of International Hydrological Programme in Division of Water Sciences Natural Sciences Sector, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France; Senior Manager of Korea Water Resources Corporation (K-water), Daejeon, Republic of Korea: yo.park@unesco.org

Appendices: Ms. Jiyoung Moon, Director of Water Supply System Design Department, Korea Water Resources Corporation (K-water), Daejeon, Republic of Korea: mjy@kwater.or.kr

Supervisors:

Byungwoo Gil, Ph.D, Contractual of Water and Sanitation Division, Inter-American Development Bank (IDB); Director General of the Ministry of Land, Infrastructure and Transport (MOLIT), Sejong, Republic of Korea: byungwoog@iadb.org

Tae-sang Shin, Director for International Cooperation in Water Resources Policy Bureau, the Ministry of Environment (MOE), Sejong, Republic of Korea: satise@korea.kr

FOREWORD

South Korea's mean annual precipitation is approximately 1,300mm, which is 1.6 times the global mean and seems like a relatively large amount. However, due to high population density, annual renewable water resource per capita is 2,546m3, just 1/6 of the global average. Also, most of the annual rainfall is concentrated in the summer months of July and August, and since the rivers in Korea have very steep gradients, the country is quite vulnerable to floods and droughts.

In this context, the Korean government recognized that flood control is a fundamental duty to protect people and has constructed 21 multipurpose dams and five flood control dams to improve flood control capabilities through integrated water resources management. The multipurpose dams have been used for flood control, waterpower generation, water supply, and various other purposes, and have a total storage capacity of 9.1 billion cubic meters of water (67% of total national water) to provide a stable supply of domestic/industrial/agricultural water, even in drought periods.

In addition, the water resources secured by means including those dams are distributed through 48 multi-regional water supply systems operated by the central government. Through the government's efforts, the imbalance of water resources in the country has been greatly reduced and has contributed to securing a stable water supply. South Korea's water supply rate is 96.5%, which means sanitary and stable tap water is being supplied to almost the entire population throughout the year without any service stoppages.

To cope with climate change, which has developed into an extreme phenomenon all over the world, South Korea is proactively taking actions to reduce droughts and floods by utilizing advanced ICT with the introduction of Smart Water Management (SWM), Integrated Water Resources Management (IWRM), and forecasting/alert technology. In addition, a great deal of research is underway to secure alternative water resources, including desalinated seawater, underground water, and recycled wastewater.

This book highlights Korea's progress in the fields of water resource development and management. Until the 1960s, most Koreans had to walk vast distances to get drinking water for their homes from wells or rivers. However, we are now living with stable and bountiful water from our faucets. This is directly attributed to water resources policies established by the central government and the investment in water facility operation and management infrastructure, which the government recognized as being vital for protecting citizens from water-related disasters.

Although Korea is a leader in developing advanced technologies, we recognize that each country has unique characteristics. Based on South Korea's experiences and water management technologies developed over the past 60 years, I am confident that our nation can help solve the unique water problems your country is facing.

Park, Hajoon

Assistant Minister
Ministry of Environment, the Republic of Korea

FOREWORD

K-water is a government-owned corporation that is responsible for water resources management in Korea. Since our foundation in 1967, we have been at the forefront of efforts to improve people's quality of life by strengthening national services in the water sector to supply healthy water and to protect the lives and property of all citizens from water disasters such as floods and droughts. Currently, we provide water resources management and smart water management services that cover the entire water cycle, while our business scope includes the entire water sector.

The pathway that K-water has walked along is the very history of Korea's economic development, called 'Miracle on the Han River'. K-water constructed Soyang River dam from 1967 to 1973, which was the first multi-purpose dam built in Korea. After that, we developed National Industrial Complexes (e.g., Gumi City, Changwon City). Since 1974, the Korean government and K-water have been constructing and operating many multi-purpose dams and multi-regional water supply systems, covering about 50% of the national water supply in Korea.

The water services provided by K-water are not only of the highest quality but are also varied. In addition to water and wastewater projects, we are also taking the lead in the production of clean energy using water through the development of high-quality waterfront cities, hydropower, tidal power, and water photovoltaic power generation.

We are also actively promoting overseas business opportunities. Starting with the investigation work of the Boonha River basin in China in 1994, a total of 85 projects have been conducted in over 24 countries in the field of water resources management. Investment projects such as dam development and water supply system development, as well as ODA projects, such as the Pakistan Patrind Hydropower projects, which started commercial generation in 2017, and the Georgian Nenskra project, are also in full swing.

Water is the most essential prerequisite of life and is a human right. However, many people around the world still suffer from water issues, such as waterborne disasters and floods. This book shows how South Korea and K-water have progressed to meet these challenging issues. We hope that K-water's experience and technologies will help you to solve water issues in your country.

Park, Doo Soo

Vice President & CBO of Overseas Business Division
Korea Water Resources Corporation (K-water)
The Republic of Korea

FOREWORD

Latin America and the Caribbean (LAC) is the most water-rich region, with almost one-third of the world's freshwater resources. However, due to the irregular and unequal distribution of water resources, it is facing considerable challenges in terms of ensuring access to drinking water as well as adequate service quality and sector governance. Some 34 million people in the region –most of them living in rural areas– still have no access to a source of improved drinking water. Moreover, recent climate changes have made the region more vulnerable to extreme weather events, causing severe floods and droughts every year.

The Water and Sanitation (WSA) Division of the Inter-American Development Bank (IDB) works in partnership with IDB member countries to overcome such challenges and achieve regional development goals in a sustainable way. Since 1959, more than 400 projects have been financed through the WSA division for a total amount of US$23.6 billion. Aligned with the Bank's policies, intensive efforts are also being made to improve the access and quality of WSA services, to strengthen sector governance, to increase financial sustainability and service efficiency, and to ensure water security.

Knowledge sharing among nations is a key factor to make these activities successful. Many LAC countries are currently on a similar path of development as that taken by other nations in the past. South Korea is a good example – during the time of economic development, the government in Seoul successfully transformed the water and sanitation sector in a relatively short period and accumulated highly valuable experiences in this area. Although many economic and political features of the South Korean reality were quite different from those of LAC countries at present, those water and sanitation experiences can still be an excellent source of insight that can help identify different ways to address regional challenges through knowledge sharing.

This publication contains some of the major efforts undertaken by the Korean government over a half century in dealing with recurring floods and droughts. It can also be helpful for LAC countries to get acquainted with several water resource management solutions that are applying information and communications technology and smart technology as a way of preparing for climate change. I hope this publication will provide some key insights to help Latin American and Caribbean countries achieve regional development goals.

Sergio I. Campos G.

Water & Sanitation Division Chief
Inter-American Development Bank

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ABSTRACT

The Republic of Korea (ROK, South Korea) boasts a 5,000-year history. However, it is better known for recovering from the complete destruction caused by the Korean War (1950-1953) and for accomplishing 'the Miracle of Han River'. In 2010, South Korea joined an OECD member nation to provide aid. In doing so, it became the only country that used to receive assistance from other countries to now provide aid to other countries. South Korea also became the ninth country to join 'the One Trillion-dollar Trade Club' in 2011.

Since the Korean War, South Korea has constructed various social infrastructures to recover from the aftermath of the war. Construction of multi-purpose dams was selected as one of the most important infrastructures. That decision was prescient. Flood prevention and stable water supply by multi-purpose dams have powered incredible economic growth.

This technical note was prepared to provide the countries in Latin America and the Caribbean (LAC) region with insight into ROK's water-related policies and technologies. Although the ROK's economic and political situations are surely different from those of the LAC countries, the experiences of Korea can be a good source of insight for LAC countries to find different ways to overcome their own challenges.

In this technical note, Chapter 1 outlines the characteristics of South Korean water resources, including an imbalance of rainfall and steep terrain. Chapter 2 presents Integrated Water Resources Management (IWRM). The measure for floods and droughts is explained in this chapter. The water infrastructures are introduced: multi-purpose dams; multi-regional water supply systems, and industrial waterworks. Operation policy and decision-making procedures are also explained in Chapter 2. Chapter 3 explains stable water supply systems. Multi-regional water supply systems and Industrial waterworks could be characterized by the state-run waterworks, which means that the government can solve some regional water resources imbalance problems. Also, non-revenue water reduction technology is explained. The topics of smart technology for adapting to climate change are reviewed in Chapter 4. This chapter introduces important operation centers, such as the Integrated Water Resources Operations Center for multi-purpose dams and hydropower plants. Moreover, the specific technologies needed for smart water resources management are briefly introduced in Appendices. The technologies were developed by Korea Water Resources Corporation (K-water), which is a policy implementation entity owned by the Korean government and is responsible for implementing and managing the water policy. Since 1967, K-water has been in charge of water resources management throughout the country, and plans, constructs, operates, and manages multi-purpose dams, multi-regional water supply systems, and hydropower plants. The water- related techniques in the Appendices are divided into three sections: IWRM; water supply; and clean energy techniques.

Keywords: Republic of Korea; South Korea; Water policy; Multi-purpose dams; Multi-regional water supply systems; Industrial waterworks; Smart Water Management; Korea Water Resources Corporation; K-water.

TABLE OF CONTENTS

FOREWORD III

ACKNOWLEDGEMENT VI

ABSTRACT VII

TABLE OF CONTENTS VIII
LIST OF TABLES X
LIST OF FIGURES XI
ACRONYMS AND ABBREVIATIONS XII

1. CHAPTER I - Features and Usage of South Korean Water Resources 1
1.1 Features of Water Resources 1
1.1.1 Comparison in Precipitation 1
1.1.2 Temporal Variation of Precipitation 1
1.1.3 Features of Topography and Stream Flow 4
1.2 Status of Water Resource Usage 5
1.2.1 Total Amount of Water Resources and Renewable Water Resources 5
1.2.2 Variation of Water Use 5
1.2.3 Water Supply to Dam, Reservoir, and Weir 7
1.2.4 Underground Water Usage 8
1.3 Condition Change according to Climate Change (Flood/Drought Frequency Variation) 8
1.3.1 Flood Disaster 8
1.3.2 Drought Damage 11

2. CHAPTER II - Integrated Water Resources Management (IWRM) 12
2.1 General Concept of IWRM 12
2.2 IWRM Realization System 12
2.2.1 Technologies of Water Information Investigation/Management Analysis 13
2.2.2 Technologies of Water Resources Management Forecast/Operation 13
2.2.3 Technology of Water Resource Maintenance and Safety Management 14
2.2.4 Water Quality Management at Basin/River/Reservoir 14
2.3 Flood/Drought Mangement 15
2.3.1 Dam Construction and River Maintenance 15
2.3.2 Construction of Dams 16
2.3.3 Multi-functional Weir (Low-head Dam) 20
2.3.4 Multi-regional Water Supply System and Industrial Waterworks 21
2.3.5 Comprehensive Plan for Land Water Welfare 25
2.4 Facility Operation Policies in Flood/Drought 25
2.5 Procedures of Dam Operation and Forecast/Warning (Technical Procedures) 27
2.5.1 Precipitation Forecast in Dam Upstream According to Weather Forecast 27
2.5.2 Flood Discharge Analysis 28
2.5.3 Establishment of Flood Control/Adjustment Plan 28
2.5.4 Simulating Reservoir Operation and Decision-making of Flood Control 28
2.5.5 Flood Forecast/Warning and Delivery 30
2.5.6 Case of Flood Adjustment 31

3. **CHAPTER III - Stable Water Supply** 33
3.1 Total Water Cycle System 33
3.2 Technology for Each Treatment Process 33
3.2.1 Managing the Water Supply 33
3.2.2 Water Purification and Treatment 34
3.2.3 Supply Management 34
3.2.4 Wastewater Treatment 35
3.2.5 State-run Multi-regional Water Supply System 35
3.2.6 Management of the Local Water Supply (Smart Water Management Technology) 36

4. **CHAPTER IV - Smart Technology for Adapting to Climate Change** 37
4.1 Integrated Water Resources Operations Center 37
4.1.1 Special Water Management Conditions in South Korea 37
4.1.2 Imbalance in Regional Water Resources Due to Climate Change 39
4.1.3 Smart Water Resources Management System 40
4.1.4 Future Tasks 46
4.2 Metropolitan Integrated Operations Center of Multi-regional Water Supply Systems 47
4.2.1 Background 47
4.2.2 History and Current Status 47
4.2.3 Advanced Water Treatment 48
4.2.4 Multi-regional Water Supply System Integrated Operations Center 48
4.2.5 Network Inter-connection 48
4.2.6 Future plans 50
4.3 Revenue Water Ratio Improvement Project 51
4.3.1 Revenue Water Ratio Improvement Procedure 51
4.3.2 Case of the Revenue Water Ratio Improvement 51
4.3.3 Smart Technology 52
4.4 Smart Water Grid 52
4.4.1 Solution to Drought 53

Bibliographic References 54
Appendices 55

LIST OF TABLES

TABLE 1: River regime coefficient comparison among major rivers in the world (K-water, 2017b) 4

TABLE 2: Trend of population and water use (MOLIT, 2016) 6

TABLE 3: Major hydraulic structures and water supply potential 7

TABLE 4: Yearly ground water use in Korea 8

TABLE 5: Flood events and damages in Korea (MPSS, 2016) 9

TABLE 6: Drought damages in past 40 years 11

TABLE 7: Dams in South Korea 15

TABLE 8: Function of multipurpose dam (K-water, 2017b) 17

TABLE 9: Multipurpose dam details located on major rivers in Korea (Integrated Water Resources Management Department of K-water, 2016) 19

TABLE 10: List of multi-functional weirs (low-head dams) 20

TABLE 11: Status of multi-regional water supply system operated by the central government (K-water, 2017a) 21

TABLE 12: The capacity of the multi-regional water supply system in South Korea 23

TABLE 13: The area without stable water supply in South Korea (K-water, 2017b) 25

TABLE 14: The number of rainfall stations in Korea (MOLIT & K-water, 2017) 27

TABLE 15: The number of water stage gauging stations in Korea 27

TABLE 16: The reservoir operation rules (Shin, C. K. and Cho, W. H., 2017) 29

TABLE 17: Flood release from Namgang multipurpose dam in 2012 33

TABLE 18: Extreme precipitation deviations by region (June - August 2017) 40

LIST OF FIGURES

FIGURE 1: Annual precipitation of major countries of the world 1

FIGURE 2: Annual precipitation history of Korea (1905-2015) (MOLIT, 2016) 2

FIGURE 3: Seasonal distribution of precipitation of Korea (1986-2015) (OECD, 2017) 2

FIGURE 4: Regional precipitation distribution 3

FIGURE 5: Water use in Korea 5

FIGURE 6: Trend of population and water use (MOLIT, 2016) 6

FIGURE 7: The concept of IWRM (K-water, 2017b) 12

FIGURE 8: IWRM concept diagram (K-water, 2015) 13

FIGURE 9: Ratio chart of dams divided by operational purpose in Korea (K-water, 2017b) 16

FIGURE 10: Major dams and low-head dams in Korea (Kim, H. Y., 2016) 18

FIGURE 11: The distribution map of multi-regional water supply system 22

FIGURE 12: Water management systems (Shin, C. K. and Cho, W. H., 2017) 26

FIGURE 13: Procedure of flood prevention in Korea (Shin, C. K. and Cho, W. H., 2017) 31

FIGURE 14: The path of Typhoon Sanba and rainfall radar image in 2012 31

FIGURE 15: The example of flood control using Flood Analysis System in Namgang multipurpose dam in 2012 32

FIGURE 16: Comparison of rainfall between Korea and global average 37

FIGURE 17: Seasonal rainfall distribution in Korea 38

FIGURE 18: Comparison of river regime coefficient 38

FIGURE 19: Frequency of drought occurrence in Korea (Kim, H. S., 2017) 39

FIGURE 20: Status of rainfall during summer 2017 in Korea 40

FIGURE 21: Function of Integrated Water Resources Operation Center in K-water 41

FIGURE 22: Decision-making support system in water resources 41

FIGURE 23: Conceptual map of RHDAPS 42

FIGURE 24: The procedure of precipitation forecasting optimized with dams 43

FIGURE 25: Flood forecasting procedure 44

FIGURE 26: Optimization of reservoir operation in view of water supply 45

FIGURE 27: Generation Integrated Operation System 45

FIGURE 28: Hazards of urban flooding in Korea 46

FIGURE 29: Metropolitan multi-regional water supply pipeline networks 47

FIGURE 30: Sungnam Water Treatment Plant (786 m3/d) (K-water, 2015) 48

FIGURE 31: Integrated operational system composition 49

FIGURE 32: Integrated operational control center for multi-regional water supply system 49

ACRONYMS AND ABBREVIATIONS

2-MIB	2-Methylisoborneol
BOD	Biochemical Oxygen Demand
DP	Dynamic Planii
FAO	Food and Agriculture Organization
FAS	Flood Analysis System
GIOS	Generation Integrated Operation System
GIS	Geographic Information System
HMI	Human Machine Interface
ICT	Information and Communications Technology
IDB	Inter-American Development Bank
IRBM	Integrated River Basin Management
IRBP	Integrated River Basin Planning
iWater	Real-time Standard Water Operation System
IWM	Integrated Watershed Management
IWRM	Integrated Water Resources Management
KEMS	K-water Earthquake Monitoring System
K-HIT	K-water Hydro Intelligent Toolkit for IWRM
KHNP	Korea Hydro & Nuclear Power
KMA	Korea Meteorological Administration
KRC	Korea Rural Community Corporation
KSMBRK	K-water Wastewater Treatment Technology with Membrane Bio–Reactor
K-water	Korea Water Resources Corporation
LAC	Latin America and the Caribbean
LDR	Linear Decision Rule
LP	Linear Planning
MOE	Ministry of Environment
MOLIT	Ministry of Land, Infrastructure and Transport
NGO	Non-governmental Organization
O&M	Operation and Maintenance
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PFS	Precipitation Forecast System
RHDAPS	Real-time Hydrological Data Acquisition and Processing System
RO	Reverse Osmosis
ROK	The Republic of Korea
ROM	Reservoir Operation Model
RWIS	Real-time Water Information System
RWSS	Reservoir Water Supply System
SOE	State-owned Enterprise
SRC	Spillway Rating Curve
SRD	Scheduled Release Discharge
SS	Suspended Solids
SURIAN	Integrated Water Quality Forecasting System
SWM	Smart Water Management
WAMIS	Water Resources Management Information System
Water-INFOS	Local Water Supply Integrated System
Water-NET	Water Supply Network Diagnosis, Operational Management System
WRSMS	Water Resources Safety Management System
WSA	Water and Sanitation
WTP	Water Treatment Plant

1. CHAPTER I
Features and Usage of South Korean Water Resources

1.1 Features of Water Resources

1.1.1 Comparison in Precipitation

Annual precipitation in South Korea, measured by 654 rainfall stations (419 of which are affiliated with the Ministry of Land, Infrastructure, and Transport; 74 of which are under Korea Meteorological Administration; and 161 of which are under K-water), is 1,299.7 mm (1986-2015). Although that value is 1.6 times the global average (813 mm), high population density reduces the per capita annual precipitation rate to 2,546 m3, only 1/6 of the global average (15,044 m3). (K-water, 2017b).

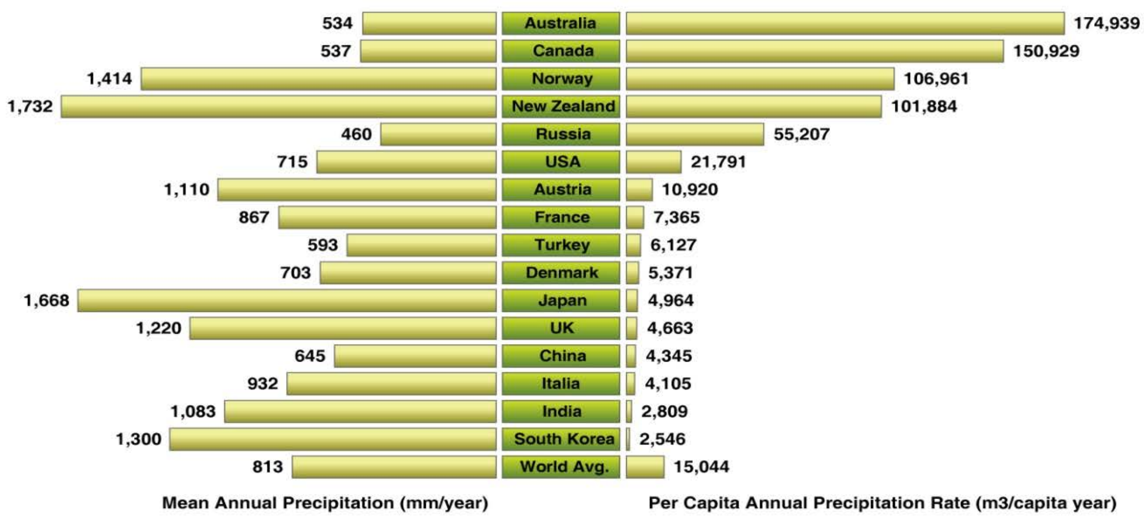

FIGURE 1: Annual precipitation of major countries of the world[1] (MOLIT, 2016)

1.1.2 Temporal Variation of Precipitation

Modern meteorological observation began in South Korea in 1905. Reviewing records of annual precipitation since then, it can be noticed that the variation range of (annual) precipitation has been increasing gradually. The value fluctuated rapidly from 754 mm (1939) to 1,756 mm (2003), and the incidence of extreme drought and flood events is increasing (MOLIT, 2012).

[1] Source of mean annual precipitation: Food and Agriculture Organization of United Nations (FAO) AQUASTAT Database (2013-2017) and annual precipitation rate per capita were calculated in Water Resources in Japan (MLIT, 2015).

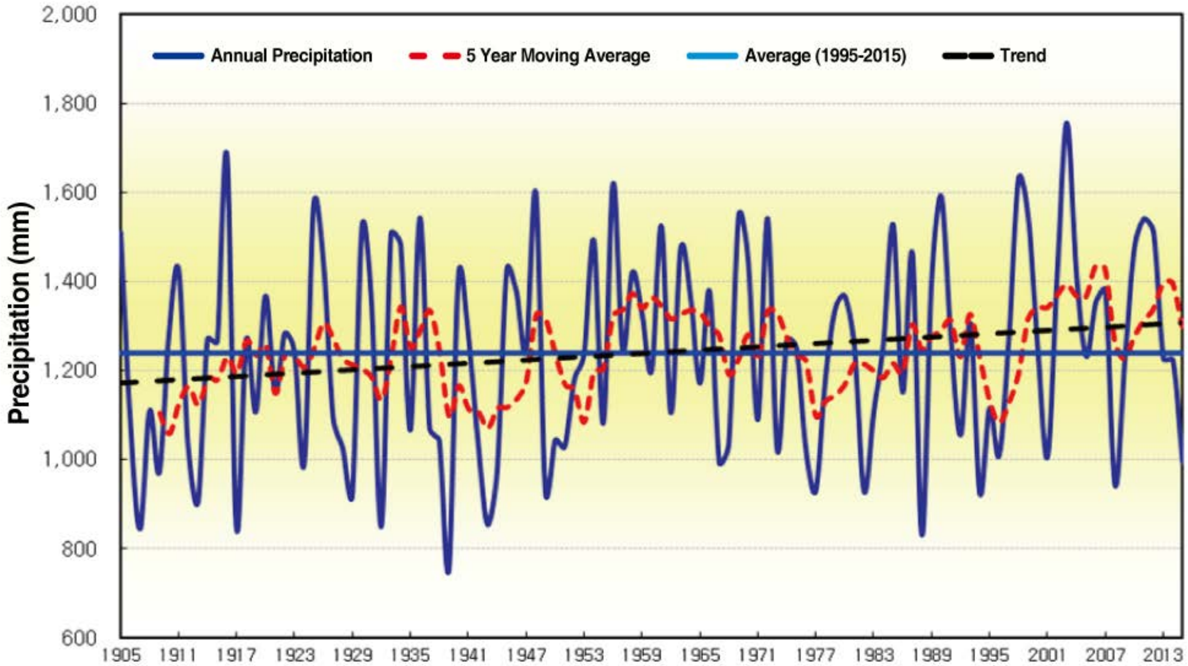

FIGURE 2: Annual precipitation history of Korea (1905-2015) (MOLIT, 2016)

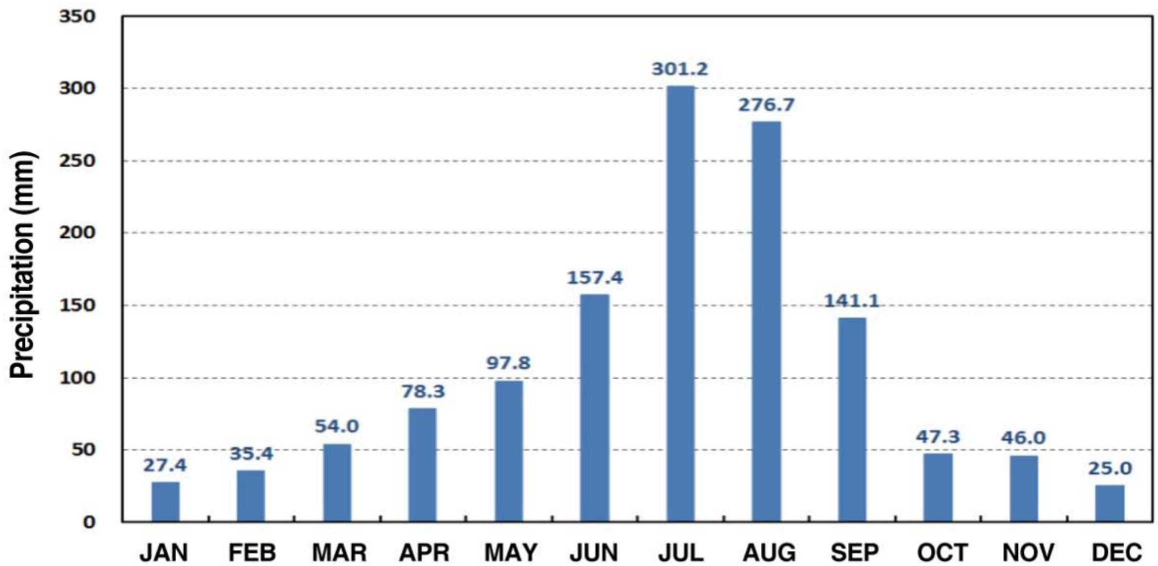

FIGURE 3: Seasonal distribution of precipitation in Korea (1986-2015) (OECD, 2017)

Also, 68% of total precipitation is concentrated in the flood period (June-September), and large precipitation deviation by region/estuary makes the rainfall state vulnerable with respect to drought/flood management (MOLIT, 2016). For example, annual precipitation in the area during the past three decades shows severe deviation, too: up to 1,729 mm (Jeju Island and Ulleng Island), and down to 1,240 mm (Geumgang River area).

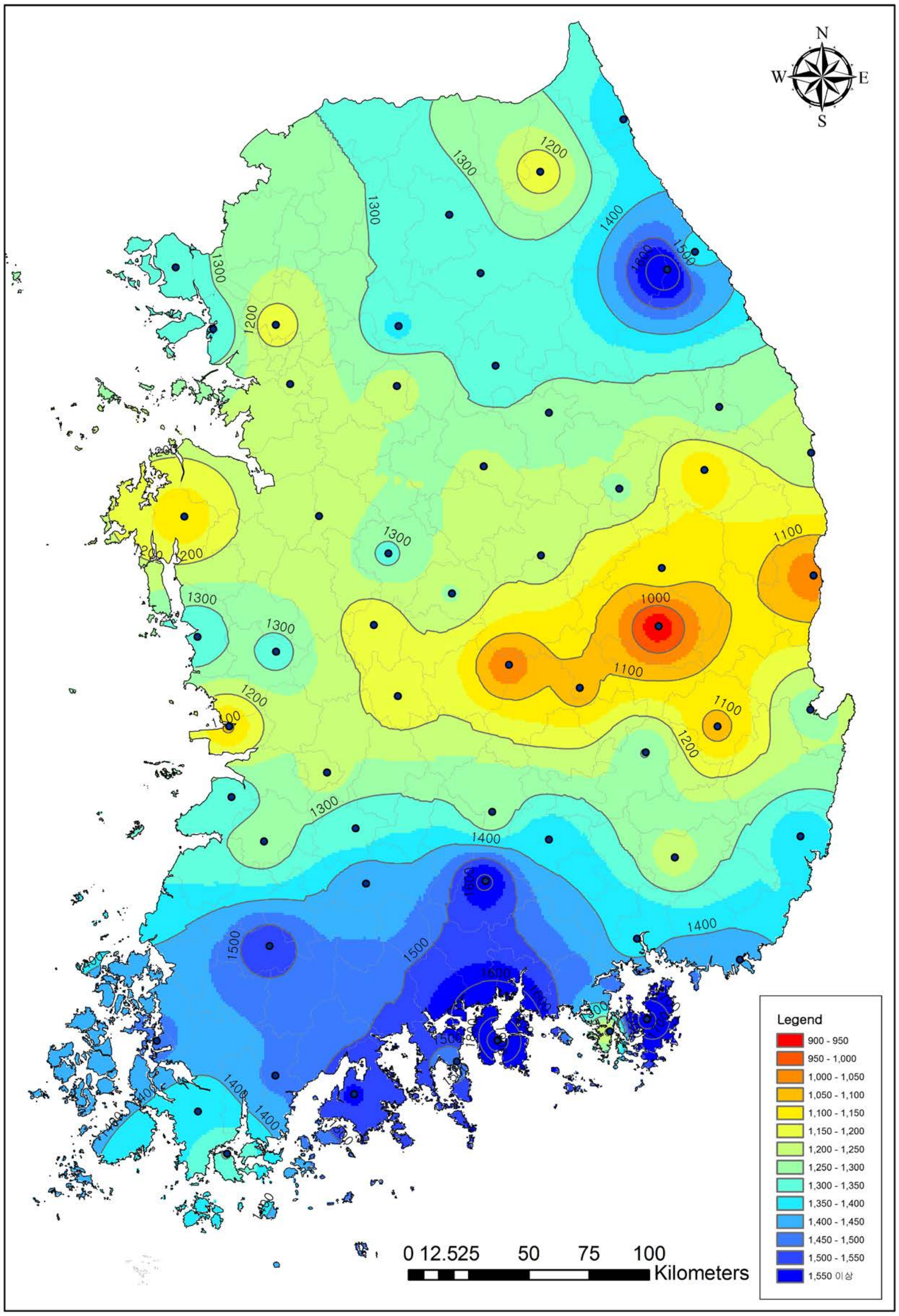

FIGURE 4: Regional precipitation distribution

1.1.3 Features of Topography and Stream Flow

The steep topographical characteristics of the Korean Peninsula make it difficult to manage water resources. About 65% of South Korea's is mountainous, and high-east/low-west geography, with steep streams, make flooding common. Most of Korea's major rivers originate at mountains in the east and flow to the west, and they have very steep slopes. Steep geographical conditions and concentrated floods lead to fast outflows during the flood period, while the discharge is very low in the water shortage season. Those features are a disadvantage for drought and flood management.

The river regime coefficient (ratio of annual maximum flow and annual minimum flow in a year) in South Korean rivers is approximately 71-272. These values have been improved with dam construction, but are still considerably larger than other countries, which means it is relatively harder to manage water resources.

TABLE 1: River regime coefficient comparison among major rivers in the world (K-water, 2017b)

River (point)	River Regime Coefficient			River (Country)	River Regime Coefficient
	Before Dam Construction*	1980-1990**	1995-2014***		
Hangang River (Hangang Bridge)	390	90	115	Ōyodo River (Japan)	110
Nakdonggang River (Jindong)	372	260	101	Seine (France)	34
Geumgang River (Gongju)	300	190	71	Nile (Egypt)	30
Seomjingang River (Songjeong)	390	270	272	Rhine (Germany)	16
Yeongsangang River (Naju)	320	130	214	River Thames (UK)	8

【Note】* Source: Hangang River (1919-1943), Nakdonggang River (1919-1927), Geumgang River (1918-1927), Seomjingang (1919-1964), Yeongsangang River (1916-1975).
** Source: "An Analysis of the Effect of Damming on Flow Duration Characteristics of Five Major Rivers in Korea" (Journal of the Korean Society of Civil Engineers, 13(3), 1993.)
*** Material from the Korea Annual Hydrological Report (1995-2014) was used to calculate each point's river regime coefficient.

1.2 Status of Water Resource Usage

1.2.1 Total Amount of Water Resources and Renewable Water Resources

Annual renewable water resources in South Korea total 76 billion m3, or 57% of the total amount of water resources (132 billion m3). The remainder is lost by evapotranspiration or other causes. Total water use consists of river maintenance water (12.1 billion m3), domestic water (7.6 billion m3), industrial water (2.3 billion m3), and agricultural water (15.2 billion m3), which is equal to 61% of water intake usage.

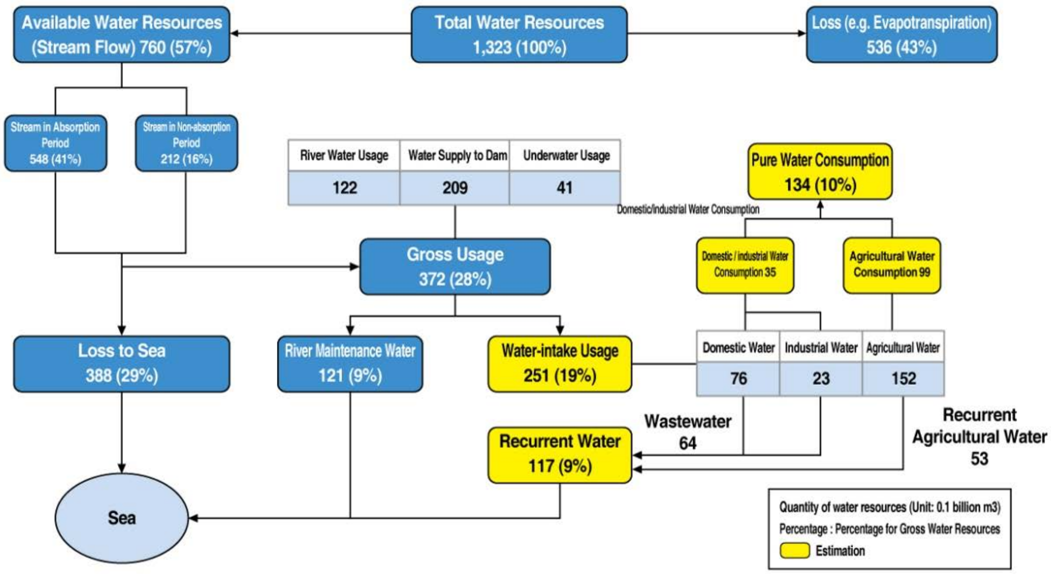

FIGURE 5: Water use in Korea

1.2.2 Variation of Water Use

Though the use of domestic/industrial/agricultural water increased five times, from 5.1 billion m3 (1965) to 25.1 billion m3 (2014), the amount has been gradually decreased or seldom varied since 2003. Comparing this fluctuation with population change (from 28.7 million in 1965, to 50.7 million in 2014), water use is growing rapidly.

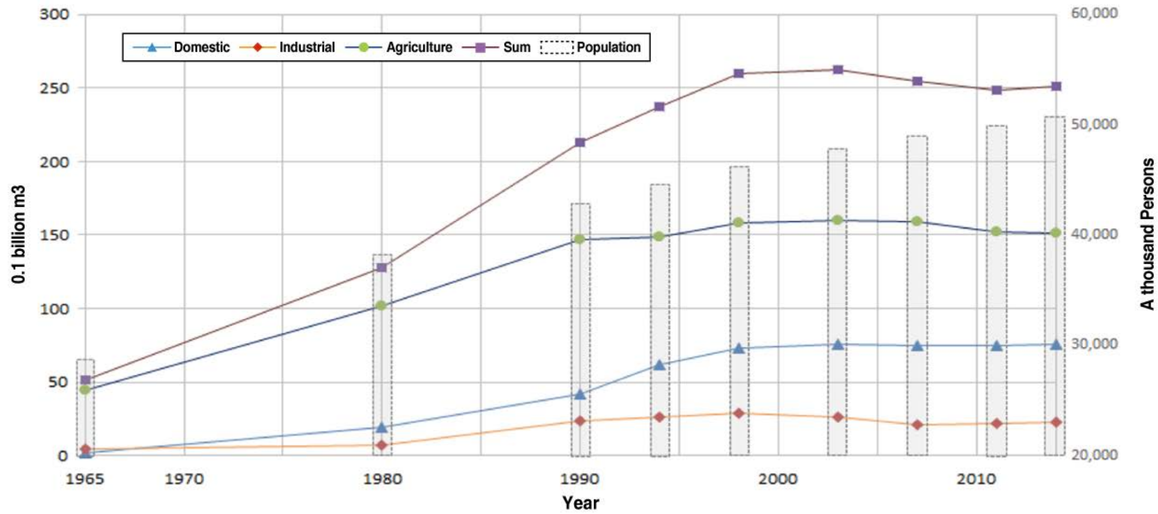

FIGURE 6: Trends of population and water use (MOLIT, 2016)

TABLE 2: Trends of population and water use (MOLIT, 2016)

(Unit: 0.1 billion m^3)

Water Use	1965	1980	1990	2003	2007	2014
Domestic	2	19	42	76	77	76
Industrial	4	7	24	26	28	23
Agricultural	45	102	147	160	154	152
Sum	51	128	213	262	259	251
Population (1,000 persons)	28,705	38,124	42,869	47,892	49,055	50,747
[lpcd*]	[n/a]	[n/a]	[n/a]	[347]	[340]	[335]

【Note】* Definition: Liter per capita, per day; Source: Drinking Water Statistics of Korea (MOE, 2016)
** Based on Drinking Water Statistics published by the Ministry of Environment of Korea (published annually since 1999)

1.2.3 Water Supply to Dam, Reservoir, and Weir

Total amount of water supply for existing water resource facilities, including dams, reservoirs, and weirs, is 20.9 billion m^3 per year.

TABLE 3: Major hydraulic structures and water supply potential

(Unit: million m^3/year)

Classification	Total Water Storage Capacity	Valid Water Storage Capacity	Water Supply Capacity	Flood Control Capabilities	Notes
SUM	23,113.7	14,629.7	20,922.3	5,772.4	-
Multipurpose Dam*	12,923.0	9,111.0	11,220.2	2,295.7	21 spots including Soyanggang Dam
Power Generation Dam	1,844.0	992.8	1,335.0	276.8	15 spots including Hwacheon Dam
Domestic/industrial Water Dam	609.0	536.3	880.5	23.5	54 spotsincluding Gwangdong Dams
Estuary Weir, Freshwater Lake	1,259.3	807.1	2,930.0	-	12 spots including Asan Lake
Agricultural Reservoir***	3,142.4	3,009.1	4,093.0	19.0	117,401 spots including Seongju Lake
Multifunctional Weir	626.3	173.4****	463.6	445.7	16 spots
Flood Control Dam, Regulating Reservoir	2,709.7			2,711.7	4 Spots including Dam of Peace

* Yeongju Dam (completed in 2016) and effect from connecting Andong and Imha (23.7 million m3/year) are added.
** On basis of quantities or effective storage capacity as noted in the basic dam plan.
*** Source: Statistical Yearbook of Land and Water Development for Agriculture, 2015.
**** Storage capacity between weir water level and underground water constraint level.

1.2.4 Underground Water Usage

Amount of underground water usage is approximately 4.1 billion m^3 (2015). Though the usage has been increasing constantly every year, the increase range has been decreasing since 2013.

TABLE 4: Yearly ground water use in Korea

(Unit: million m^3/year)

Classification	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Whole country	3,096	3,210	3,468	3,749	3,678	3,717	3,725	3,784	3,807	3,807	3,907	3,990	4,071	4,085	4,094

1.3 Condition Change According to Climate Change (flood/drought frequency variation)

1.3.1 Flood Disasters

Large-scale flood damage in South Korea, measured in terms of human casualties (dead and missing), has been decreasing since 1959, while property damage has also been gradually decreasing since 2002. These trends are a result of water resources policies that enhanced flood control ability and secured stream discharge capacity through multipurpose dam construction and stream maintenance for flood prevention. Thus, it is very important to secure water resource infrastructure, including dam and stream irrigation facilities.

Nevertheless, excessive flooding does occur due to changing rainfall patterns that are caused by climate change. These changing patterns include increased precipitation, decreased days of precipitation, and a rise in short-term, localized heavy rain. According to the Korea Meteorological Administration, the frequency of localized heavy rain with 30 mm per hour or more[2], surged 37%, from 60 times in the 1980s to 82 times since 2000. Between July 26th and July 28th, 2011, for example, localized heavy rain in the metropolitan area (113mm per hour on the morning of the 27th in Gwanak-gu, Seoul; 449.5mm per day in Dongducheon; and 322.5 mm per day in Moonsan) inundated the most populated downtown neighborhoods in Seoul, including Gangnam Station and the Gwanghwamun district. Meanwhile, a large-scale landslide caused by localized heavy rain in the Mt. Woomyeonsan district and Gangwon Chuncheon resulted in numerous casualties, including 57 deaths and 12 missing people.

These flood damage cases are caused primarily by a change in rainfall characteristics due to climate change. The danger of floods is estimated to be rising, according to the examination of maximum precipitation fluctuation for 12-hours of a 100-year frequency based on an RCP 8.5 climate change scenario. Compared to the past three decades (1976-2005), future 100-year frequency maximum precipitation by region is predicted to increase more than two-fold. More efforts to prevent flood damage are required.

[2] Localized heavy rain is generally defined as rainfall of 30 mm per hour or more. (Korea Meteorological Administration)

- Average precipitation for 100-year frequency in seven major domestic points compared to the past three decades (1976-2005): a 14.8% increase in the early 21st century (2011-2040), a 17.1% increase in the middle of the 21st century (2071-2100), and an 11.4% increase in the late 21st century (2071-2100).
- A significant deviation in fluctuations by point: maximum 126.3% increase in Mokpo point (2041-2070), while 6.1-7.4% decreases in Pohang point.
- Spatial distribution of maximum precipitation for 100-year frequency changes very differently with past, and range of limit value for maximum precipitation is extended more.
- It is estimated that the increased range of maximum precipitation for 100-year frequency will be relatively larger along the southern/southwest coast, in Gangwon-do, and along the northwest coast.

TABLE 5: Flood events and damage in Korea (MPSS, 2016)

Disaster	Period	Severely Damaged Area	Maximum Daily Rainfall	Human Fatalities (persons)	Property Loss (mil.USD)
Great flood in Eulchuk	Jul. 18–Sep. 7, 1925	Central area	-	517	0.9
Typhoon Sarah	Sep. 15-17, 1959	Yeongdong, Yeongnam, Honam	168.1 mm (Jeju)	849	662
Flood in Anyang/Siheung District	Aug. 19-20, 1927	Seoul, Gyeonggi, Gangwon, Chungbuk	313.6 mm (Suwon)	550	265
Typhoon Judy	Jul. 28-29, 1989	Geyongnam, Jeonnam	221.0 mm (Geoje)	20	1,192
Heavy rain	Jul. 21-23, 1980	Chungbuk, Chungnam, Gyeonggi, Gangwon	217.0 mm (Jeju)	180	1,255
Great flood in 1984	Aug. 31-Sep. 4, 1984	Seoul, Gyeonggi, Gangwon	314.0 mm (Sokcho)	189	1,643
Typhoon Thelma	Jul. 15-16, 1987	Namhae, Donghae	216.8 mm (Goheung)	345	3,913
Heavy rain in central area	Jul. 21-23, 1987	Central area	517.6 mm (Buyeo)	167	3,295
Typhoon Gladys	Aug. 22-26, 1991	Busan, Gangwon, Gyeongbuk, Gyeongnam	439.0 mm (Busan)	103	2,357
Typhoon Janis and heavy rain	Aug. 19-30, 1995	Seoul, Gyeonggi, Gangwon, Chungnam, Chungbuk	361.5 mm (Boryeong)	65	4,562
Heavy rain in Gyeonggi, Gangwon, and northern area	Jul. 26-28, 1996	Gangwon, Gyeonggi	268.0 mm (Chelwon)	29	4,275
Heavy rain in Seoul, Gyeonggi, Chungcheong	Jul. 31-Aug. 18, 1998	Seoul, Gyeonggi, Gangwon, Chungbuk, Chungnam	481.0 mm (Ganghwa)	324	12,478
Typhoon Olga and heavy rain in Gyeonggi and Northern Gangwon	Jul. 23-Aug. 4, 1999	Gyeonggi, Gangwon, Gyeongnam, Jeonnam, Jejujingo	280.3 mm (Cheolwon)	67	10,490
Typhoon Prapiroon and localized heavy rain	Aug. 23-Sep. 1, 2000	The whole country	645.0 mm (Gunsan)	28	2,520
Typhoon Rusa	Aug. 30-Sep. 1, 2002	The whole country	870.5 mm (Gangreung)	246	51,479
Typhoon Maemi	Sep. 12-13, 2003	The whole country	453.0 mm (Namhae)	131	42,225
Typhoon Megi	Aug. 17-20, 2004	Gangwon, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam	322.5 mm (Gwangju)	7	2,508

Disaster	Period	Severely Damaged Area	Maximum Daily Rainfall	Human Fatalities (persons)	Property Loss (mil.USD)
Heavy rain	Aug. 2-11, 2005	Gyeonggi, Chungbuk, Jeonbuk, Gyeongbuk, Gyeongnam	382.0 mm (Gwangju)	19	3,316
Typhoon Ewiniar	Jul. 9-29, 2006	The whole country	264.5 mm (Namhae)	62	18,344
Typhoon Nari	Sep. 13-18, 2007	The whole country	300.0 mm (Namhae)	16	1,591
Heavy rain	Jul. 26-29, 2011	Seoul, Busan, Incheon, Gyeonggi, Gangwon	449.5 mm (Dongducheon)	67	3,768
Typhoons Bolaven and Tembin	Aug. 25-30, 2012	Jeju, Jeolla, Chungcheong	244.0 mm (Jindo)	11	6,365
Typhoon Sanba	Sep. 15-17, 2012	Jeju, Jeonnam, Gyeongsang, Gangwon	405.2 mm (Jeju)	2	3,657
Heavy rain (Jul. 11th-15th, 18th)	Jul. 11-15, 18, 2013	Gapyeong (Gyeonggi), Chuncheon/Hongcheon/Pyongchang/Inje (Gangwon)	459 mm (Chuncheon)	1	940
Heavy rain (Jul. 22nd-23rd)	Jul. 22-23, 2013	Icheon/Yeoju (Gyeonggi)	353 mm (Yeoju)	3	625
Typhoon Gladys	Aug. 22-26, 1991	Busan, Gangwon, Gyeongbuk, Gyeongnam	439.0 mm (Busan)	2	1,342
Heavy rain (Aug. 25th)	Aug. 25, 2014	Geumjeong/Gijeong (Busan), Changwon/Goseong (Gyeongnam)	248 mm (Changwon)	65	4,562

TABLE 6: Drought damages in past 40 years

Year		Damage	Note (Source)
1967-1968	1967	Drought area: 420,547ha, Damage cost: 626.6 bn KRW	Drought Record Investigation Report (Ministry of Construction and Transportation, June 2002)
	1968	Drought area: 470,422ha, Damage cost: 700.9 bn KRW	
1981-1982	1981	Drought area: 145,457ha, Damage cost: 216.7 bn KRW	
	1982	Drought area: 470,422ha, Damage cost: 700.9 bn KRW	
1994-1995		Drought area: 173,269 ha in 86 cities/counties	Drought Record Investigation Report (Ministry of Construction and Transportation, December 1995)
1967-1968	1967	Drought area: 420,547ha, Damage cost: 626.6 bn KRW	Drought Record Investigation Report in 2001 (Ministry of Construction and Transportation, June 2002)
	1968	Drought area: 470,422ha, Damage cost: 700.9 bn KRW	
2008-2009		1,227 towns in 77 cities/counties Limited water supply for 228,068 persons, Transported water supply for 51,800 persons	2008-2009 Drought-Overcoming Promotion Result Report (Central Disaster and Safety Countermeasure Headquarters, National Emergency Management, 2009)
2014-2015		51,241 households in 26 cities/counties Limited water supply for 6,365 persons Transported water supply for 111,107 persons	Drought Record Investigation in 2015 (Ministry of Construction and Transportation, 2016)

1.3.2 Drought Damage

Extreme drought due to climate change occurred in 2015 as precipitation that year was recorded as being the third lowest amount of precipitation since meteorological observation began in 1973 (1st rank in Seoul, Gyeong-gi, Gangwon, and Chungbuk). Cumulative precipitation that year was only 984 mm, or 72% of the average year. This drought dropped the water reserve rate of the Boryeong Dam to an all-time low level (18.9%, in November 2015), and the dam in charge of West Chungnam area experienced water scarcity despite its water supply position. Although water supply reliability generally determines facility size so that multipurpose dam allow for a drought once every 20-30 years, and that particular water supply dam allows for a drought once every 10 years, the drought that Boryeong Dam experienced in 2015 was for a 200-year frequency. Since 1970, South Korea has suffered from drought over a period of five to seven years, and local drought is becoming an increasingly serious concern, with increasing rainfall deviation across multiple regions.

The drought issue is related to the stability and equity of the regional water supply. Thanks to the continuous water supply project promoted by the government, water supply rate in the whole country hit 96.1% in 2014, but low-populated regions, such as rural areas, still demonstrate vulnerability to water use. Forty-nine cities/counties located in chronically drought-stricken areas have suffered water scarcity more than three times since 1990, and the stability and equity of the water supply are lacking in those regions. Stable water use is available in regions within the water supply service range, but sources of water supply in unsupplied regions could dry out if the droughts last for a long time. Regions with water sources of underground water and middle/small sized streams tend to suffer more serious damages.

2. CHAPTER II
Integrated Water Resources Management (IWRM)

2.1 General Concept of IWRM

Integrated Water Resources Management (IWRM) is defined as water management in a unit of a basin. Considering the whole basin as an organic body leads to maximized synergy in terms of efficiency, impartiality, and sustainability. IWRM manages water within a basin as an organic body through an integrated view from upstream to downstream, and considers all the human and natural activities that influence water at the basin.

- **Efficiency:** Improve availability before development and prioritize prevention before restoration.
- **Impartiality:** Share residual water and take care of rural areas as well as urban areas, and tributaries as well as mainstreams.
- **Sustainability:** Operate with an eye on present and future generations, and for nature and humans.

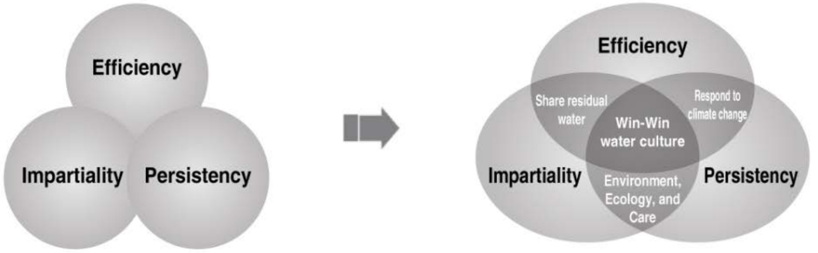

FIGURE 7: The concept of IWRM (K-water, 2017b)

The UN defines IWRM as a process 'to manage water resources more efficiently in consideration of all the water resource uses,' which is not a mean or a goal, but a process. IWRM's approaches vary according to water environment by country. The term is often used interchangeably with Integrated Watershed Management (IWM), Integrated River Basin Management (IRBM), and Integrated River Basin Planning (IRBP).

2.2 IWRM Realization System

Implementing IWRM requires correct integrated management at the basin level, which efficiently manages the entire hydrological cycle process, including precipitation flow into the river/basin.

In the case of South Korea, four kinds of technologies are utilized for integrated water resources management: (1) technology for water information investigation/management/analysis; (2) technology for forecast/operation of water resources management; (3) technology for maintenance and safe management of water resources facilities; and (4) technology for integrated water quality management of basins and rivers.

These technologies have been developed through water management over the past 50 years. South Korea has introduced cutting-edge ICT to the water resources management decision- making process, establishing itself as a leader in smart water resources management. Figure 8 presents a conceptual diagram that includes technologies by area of IWRM.

2.2.1 Technologies of Water Information Investigation/Management Analysis

The government of South Korea collaborated with expert organizations such as K-water to secure research capabilities across all areas, including floodgate, basin, and underground water. As a result, all water-related information is collected in real-time and is publicized to people through the ITC-based real-time portal site (WAMIS: Water Management Integrated System) and the Drought Management System. It is also utilized for policy-making related to national water resources and the identification of new projects.

2.2.2 Technologies of Water Resources Management Forecast/Operation

The South Korean government has been tireless in its efforts to develop technologies for precipitation forecasting and decision-making for efficient water resources management to overcome tough conditions in the Korean Peninsula. Such conditions include extreme floods accompanying typhoons, frequent critical droughts, and significant seasonal/regional deviations in rainfall. The technologies developed by the South Korean government were packaged for customized water resources management.

K-water, as a public corporation that conducts development and management of water resources on behalf of the government, is utilizing above water resource management technologies to operate basin-integrated intelligent decision-making (in the form of the K-water Hydro Intelligent Toolkit), packaged real-time monitoring, and more than five individual water management technologies.

The following are technologies included in the toolkit:

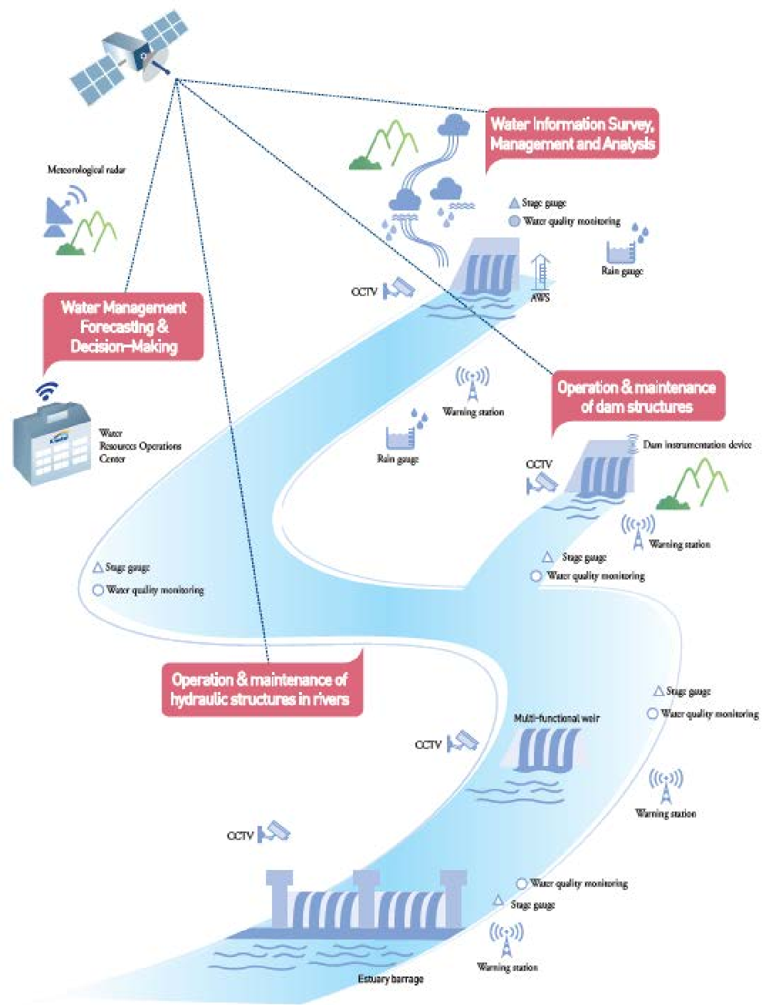

FIGURE 8: IWRM concept diagram (K-water, 2015)

- RHDAPS (Real-time Hydrological Data Acquisition and Processing System): A user-customized portal system that produces and provides high-quality hydrologic data through real-time data acquisition/delivery/saving/processing on a Web-hosted database. By collecting and displaying hydrologic data and video data (such as stage of dam/weir, inflow, and discharge) in real-time, this system facilitates efficient decision-making and enhances disaster planning capabilities. This system is now applied to and operated by water resources facilities in South Korea under governmental management, including 14 multipurpose dams, 14 water-supplying dams, and 16 weirs.
- PFS (Precipitation Forecast System): This system divides the entire area of the Korean Peninsula into a 3 km x 3 km grid to produce quantitative long-term/short-term precipitation forecast information. The system is optimized for the unique characteristics of the physical environment, such as detailed topography around the dam.
- FAS (Flood Analysis System): This system supports decision-making through real-time hydrologic information and basin-integrated flood analysis based on precipitation forecasts.
- RWSS (Reservoir Water Supply System): This integrated system was developed to maximize the use of water resources facilities, such as dams, weirs, and agricultural reservoirs in connection to natural rivers for integrated water resources management. It decides release discharge for multi-dam conjunctive operation based on inflow/demand by the water system, and applies the discharge to a water budget analysis model and water quality model to analyze the operational effects.
- GIOS (Generation Integrated Operation System): The IWRM Center remotely observes and controls all facilities necessary for new and renewable energy production. These facilities include nine large hydropower generators installed in multipurpose dams, 16 small hydropower generation plants installed in weirs, the Sihwa Lake Tidal Power Station, and electric power transmission/transformation facilities. With data gathered through the system, a comprehensive picture of power generation and statistical analysis are provided.

2.2.3 Technology of Water Resource Maintenance and Safety Management

Water resources facilities not only naturally show signs of decrepitude as time goes by, but they are also under various external threats, including overflow due to floods, sliding on slopes, and earthquakes. To enhance the safety of water resources facilities, the South Korean government is conducting the 'Flood Control Capability Improvement Project', re-evaluating multi-purpose dams' flood control ability and adding new spillways. Furthermore, the government introduced Water Resources Safety Management System and a dam danger analysis evaluation, which incorporates real-time measurement and earthquake observation, aimed at prevention-oriented scientific facility management. Core technologies for safety management are as follow:

- WRSMS (Water Resources Safety Management System): System for organized safe management of water resources facilities against various safety threats, such as recent abnormal weather conditions and worn-out dams. This system takes measures at dams using 22 types of instruments in real-time, and alarms facility managers if measures' target values (e.g. displacement, settlement, and leaks) are missed or exceed the managerial standards specified by the early alarm system.
- KEMS (K-water Earthquake Monitoring System): K-water's system to respond to recent earthquake issues and to strengthen the safety of national facilities under management by K-water. This system conducts earthquake monitoring in real-time, and immediately spreads alarms to relevant authorities in the event of abnormalities.

2.2.4 Water Quality Management at Basin/River/Reservoir

A real-time water quality forecast and monitoring system is used to preserve healthy hydro-ecosystems where humans and nature co-exist. Connecting models of meteorology, basin, dam, and river, this system observes pollution sources and predicts reservoirs' water quality to suggest the best scenario, to guard against water quality accidents, and to minimize the influence of water quality changes to the ecosystem.

- Integrated Water Quality Forecast System (Super-computer-based River Analysis Network): By integrating models of meteorological forecast, basin, river, and reservoir, this system provides precise water quality forecast data and helps enhancement of response to water quality accidents and fast decision-making. This system has various scenarios to apply to water quality forecasting.

2.3 Flood/Drought Management

Climate change is estimated to make floods and other weather-related disasters more frequent. As for the danger of flood, the amount of localized heavy rain (defined as 100 mm or more of daily precipitation) is predicted to increase by 2.7 times. Embankments designed to endure a flood of 100-year/200-year frequency will lose half of its flood control ability, because flood discharge of 100-year frequency will increase 20%. Localized heavy rain will increase sediment disasters such as landslide and avalanches as well. Water leakage to the earth will rise in the future, while the underground water recharge rate will decline.

Floods and droughts due to climate change will be more frequent, and droughts are estimated to be especially more severe in spring and winter. In the case of fall typhoons (September-November), even if there is no appreciable change in the frequency, they will be more intense.

The danger of drought will rise as well, as more years will register less rain. Drought periods will be 3.4 times longer than in the past. Temperature rise will bring greater demand and short supply in all sectors, not only domestic/industrial/agricultural water, but also river maintenance water. Moreover, as the rainy season will extend from June-August to July-September, there will be decreased precipitation in June, when demand for agricultural water is high; this, in turn, will lead to low agricultural production.

Climate change affects water quality and river environments, too. The rise of water temperature and hypoxia on river/lake bottoms will create harmful effects on hydro-ecosystems, such as mass stranding of fishes. Increased water turbidity and decreased water quality will also result.

In order to prepare for the increasing severity of floods and droughts, there is a need for structural countermeasures, such as dam/waterworks construction, and non-structural countermeasures, such as the improvement of operational methods.

2.3.1 Dam Construction and River Maintenance

The fundamental structural countermeasure against floods and droughts has to do with the making of a bowl, which means dams or reservoirs.

TABLE 7: Dams in South Korea

<table>
<tr><th>Classification</th><th>Sum</th><th>Multipurpose Dam</th><th>Domestic/Industrial Water Supply Dam</th><th>Hydropower Generation Dam</th><th>Agricultural Water Supply Dam</th></tr>
<tr><td>Number of Facilities</td><td>17,491</td><td>21</td><td>54</td><td>15</td><td>17,401</td></tr>
<tr><td rowspan="2">Effective Storage (million m^3)</td><td rowspan="2">13,649.2</td><td>9,111.0</td><td>536.3</td><td>992.8</td><td>3,009.1</td></tr>
<tr><td>66.8%</td><td>3.90%</td><td>7.30%</td><td>22.0%</td></tr>
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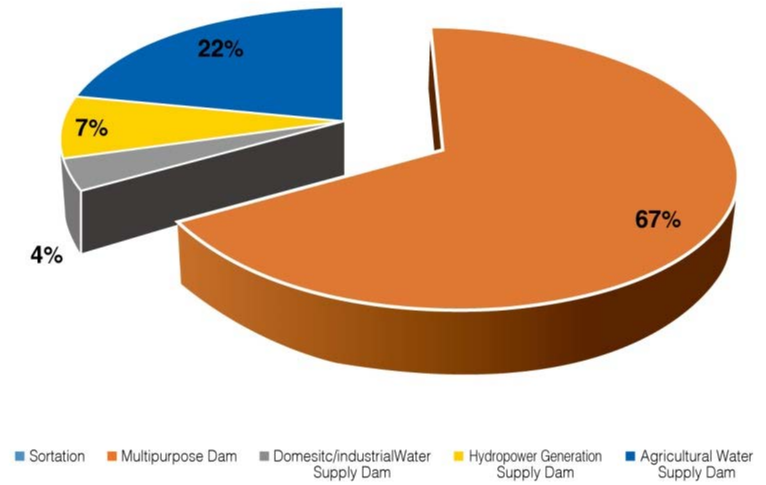


FIGURE 9: Ratio chart of dams divided by operational purpose in Korea (K-water, 2017b)

Two interventions are crucial with respect to flood damage prevention: (1) detain flood discharge as much as possible to decrease the peak discharge, and (2) divert flood discharge as much as possible to the sea. Dams must be constructed to raise flood detainment ability, while river maintenance is essential to enhancing flood exclusion ability.

To prepare for droughts, it is important to keep water for supply confined as long and as much as possible. However, that is not enough to solve the drought issue because regional rainfall deviations have become significant due to recent climate change. This means that water shortages are experienced somewhere, despite the existence of a sufficiently big water bowl. Therefore, it is imperative to distribute imbalanced water resources evenly.

The South Korean government has been efficiently responding to those problems so far, building dams and utilizing a multi-regional water supply system.

2.3.2 Construction of Dams

As of late 2016, South Korea had a total of 17,491 dams/reservoirs, including dams under construction. Among the total, there are 21 multipurpose dams with 66.8% of gross effective storage, which is about two times the storage capacity of other dams. Also, to prepare for rapid climate change, five flood control dams (Dam of Peace, Gunnam Flood Regulating Reservoir, Damyang Flood Regulating Reservoir, Hwasoon Flood Regulating Reservoir, and Hantangang Flood Regulating Dam) are in operation. South Korea's rainfall is concentrated in three summer months, and tends to produce floods. Water on rivers mainly goes fast to the sea in those months due to steep slopes, while droughts occur during the rest of the year. These unique conditions are the reason that the South Korean government adopted multipurpose construction for flood prevention, water supply, and power generation.

Multipurpose dams adjust to prevent water-related disasters in flood periods, releasing discharge to supply domestic/industrial/agricultural water and river maintenance water in normal/dry/drought period. Multipurpose dams also provide clean energy through hydropower generation. Additionally, waterside spaces around the dams contribute to the local economy. Despite the importance of multipurpose dams, social conflicts about dam construction have been occurring recently. These include controversies about environmental protection, backlash against submergence of existing residential districts, and property rights concerns.

Because of these controversies, the South Korean government abandoned the unilateral promotion method and established the "Improvement Plan of Dam Project Procedures (June 2013)," which involves building consensus among relevant stakeholders, including experts, NGOs, and residents of areas where projects are planned. Because of the plan, the government works only on dams that receive the approval of the Dam Pre-review Council and which have completed an opinion gathering process in conjunction with the local community. Recently the government has been implementing diverse systems, including the 'Dam Construction Application System', so that only necessary dam projects are promoted where local communities want them.

The gross storage capacity of all multipurpose dams in South Korea was approximately 12.7 m3 as of 2016. Those dams are equipped with the power generation capacity of approximately 1.05 million kW, with approximately 2.2 billion m3 of flood control capability and approximately 11 m3 of annual water supply capability.

In dam-to-dam comparison, Soyanggang Dam has the biggest storage capacity (2.9 billion m3), with 1.2 m3 of annual water supply capability, which is smaller than Chungju Dam (3.4 m3). As for power generation capacity, Chungju Dam is the highest (0.41 million kW).

TABLE 8: Function of multipurpose dam (K-water, 2017b)

Stabilizing Water Supply	• Precipitation in South Korea is 1.6 times of the world average, but per capita precipitation is only 1/6 of the world average due to population density. Because of mountainous topography representing 65% of the total national land, deviation of precipitation by region is large. Furthermore, the precipitation is concentrated into a flood period. These conditions are disadvantages for water resources use in the country. Thus, South Korea needs to decrease seasonal imbalances of water resources. It is also essential to stably secure water resources to satisfy demands, which have increased mainly in urban areas where the population is concentrated. • Multipurpose dams are very important social overhead capital facilities, and take more than 10 years to build. A lack of preparation for dam construction leads to huge increases in social costs, and may become the biggest obstacle for economic development, which is why multipurpose dam building requires sufficient opinion gathering and planning in advance.
Efficient Flood Damage Reduction	• Flood outflows take approximately 41% of gross water resources in South Korea. Dams detain that much water to decrease flood damage and utilize the saved water if necessary, which is why dams are a representative water control facility in East Asia with a monsoon climate like South Korea. • Recent frequent large-scale localized heavy rain underscores the necessity of multipurpose dam construction. Multipurpose dams are also useful to share flood discharge in basin with river bank.
Creation of Sound River Environment	• Dams provide river maintenance water equally throughout the year to prevent dry stream phenomenon, to improve water quality, and to enhance auto purification ability, which helps prevent water pollution accidents and inhabitation of fish resources. • Before the multipurpose dam was introduced to South Korea, rivers had very large gaps between maximum and minimum flows. The quantity of river flow was stabilized as river maintenance water was provided constantly after dam construction. • Also, based on the increased desire of people for sound water environments, the role of the dam to provide waterfront amenities is increasing, as in the example of the Cheonggyecheon Stream restoration.
Contribution to Local Economy	• Historically, dam construction has emphasized the functional aspect of water resources. Current models, however, should comprehensively consider effects on ecological environment and society, including tourism, leisure, local community development, fish preservation, river environment management, developing diverse aspects of the dam, and to make dams contribute to regional development and be welcomed by people and the local community.

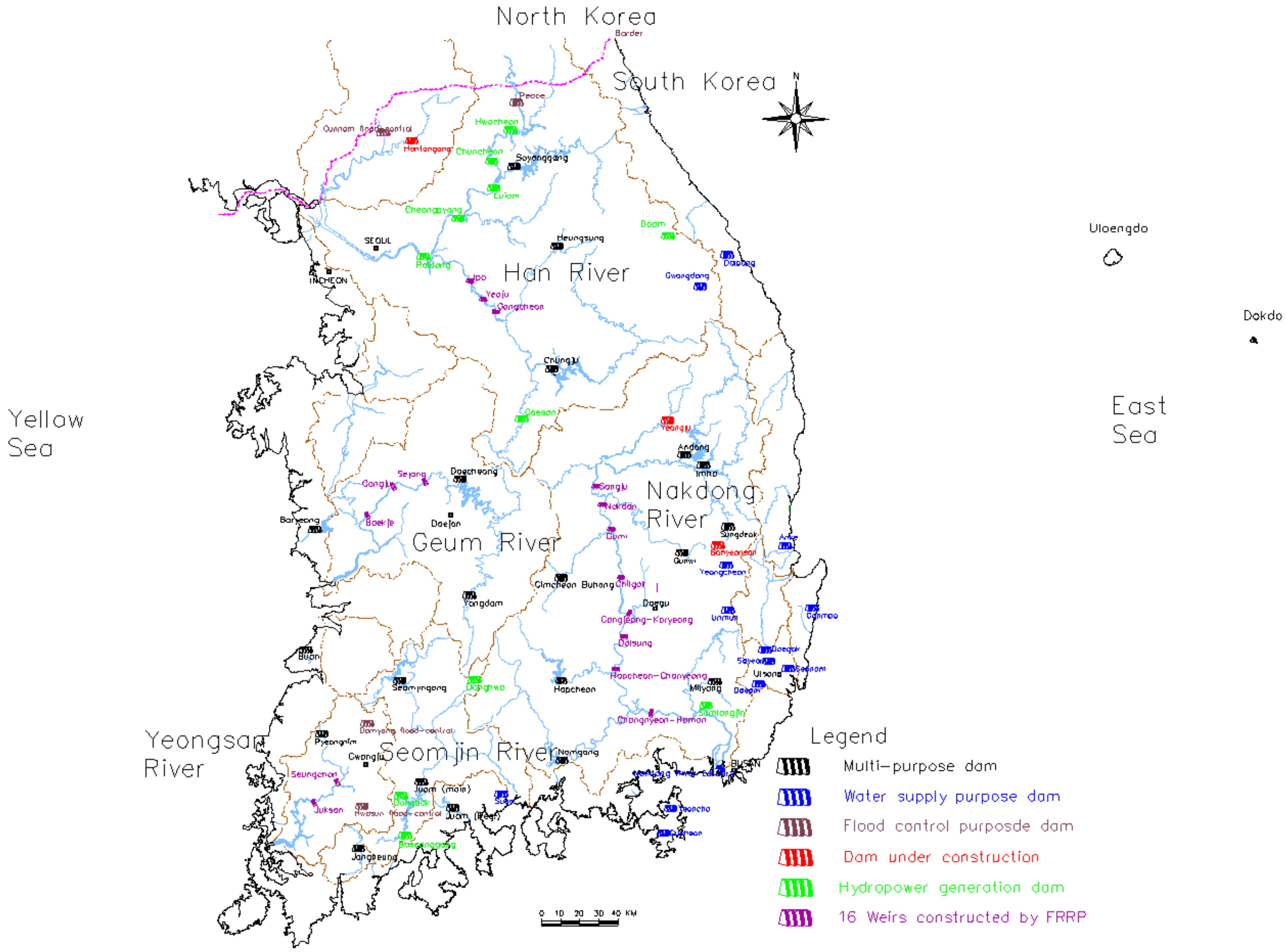


FIGURE 10: Major dams and low-head dams in Korea (Kim, H. Y., 2016)

TABLE 9: Multipurpose dam details located on major rivers in Korea (Integrated Water Resources Management Department of K-water, 2016)

Water System	Dam	Area of Basin (km^2)	Dimension		Total Storage (million m^3)	Effective Storage (million m^3)	Power Generation Capacity (thousand kW)	Effect of Project		Construction Period
			Height (m)	Length (m)				Flood Control (million m^3)	Water Supply (million m^3/year)	
Sum		22,511			12,742	8,951	1051.8	2,221	10,993	
Hangang River	Soyanggang Dam	2,703	123	530	2,900	1,900	200	500	1,213	1967-1973
	Chungju Dam	6,648	97.5	447	2,750	1,789	412	616	3,380	1978-1986
	Hoengseong Dam	209	48.5	205	86.9	73.4	1.3	9.5	119.5	1990-2002
Nakdonggang River	Andong Dam	1,584	83	612	1,248	1,000	91.5	110	926	1971-1977
	Imha Dam	1,361	73	515	595	424	51.1	80	591.6	1984-1993
	Hapcheon Dam	925	96	472	790	560	101.2	80	599	1982-1989
	Namgang Dam	2,285	34	1,126	309.2	299.7	14	270	573.3	1987-2003
	Miryang Dam	95.4	89	535	73.6	69.8	1.3	6	73	1990-2002
	Seongdeok Dam	41.3	58.5	274	27.9	24.8	0.2	4.2	20.6	2002-2015
	Gunwi Dam	87.5	45	390	48.7	40.1	0.5	3.1	38.3	2000-2011
	Gimcheonbuhang Dam	82	64	472	54.3	42.6	0.6	12.3	36.3	2002-2014
	Gimcheonbuhang Dam	32.6	58.5	250	22.1	17.9	0.2	3.5	14.9	2010-2015
Geumgang River	Daecheong Dam	3,204	72	495	1,490	790	90.8	250	1,649	1975-1981
	Yongdam Dam	930	70	498	815	672	26.2	137	650.4	1990-2005
Seomjingang River	Seomjingang Dam	763	64	344	466	370	34.8	32	350	1961-1965
	Juam Dam	1,010	58	330	457	352	1.4	60	271.7	1984-1992
	Juam Regulating Reservoir	134.6	99.9	562.6	250	210	22.5	20	218.7	1984-1992
Jiksocheon Stream	Buan Dam	59	50	282	50.3	35.6	0.2	9.3	35.1	1990-1996
Ungjincheon Stream	Boryeong Dam	163.6	50	291	116.9	108.7	0.7	10	106.6	1990-2000
Tamjingang River	Jangheung Dam	193	53	403	191	171	0.8	8	127.8	1996-2007

2.3.3 Multi-functional Weir (Low-head dam)

The South Korean government implemented the Four River Restoration Project between 2009 and 2013. This project secured additional water resources through weir construction, dredging, mid-scale/small-scale dam construction, and embankment raising for agricultural reservoirs. Also, the project created ecology parks, bicycle roads, and camping sites for leisure space and to contribute to the quality of life and national culture. Table 10 shows the list of multi-functional weirs constructed by this project.

TABLE 10: List of multi-functional weirs (low-head dams)

Basin	Weir	Area of Basin (km^2)	Specification (m)		Type of gate (Number of gates)
			Height	Length	
Sum		158,813			
Hangang River	Gangcheon Weir	10,972	8	440	Rising sector type (7EA)
	Yeoju Weir	11,115	8	513	Shell type (12EA) Turning type (1EA)
	Ipo Weir	11,803	6	521	Shell type (6EA)
Geumgang River	Sejong Weir	6,942	2.8-4.0	348	Turning type (3EA)
	Gongju Weir	7,408	7	280	Truss type (3EA) Turning type (3EA)
	Baekje Weir	7,976	5.3	311	Shell type (3EA)
Yeongsangang River	Seungchon Weir	1,327	7.5	512	Truss (4EA)
	Juksan Weir	2,359	3.5	184	Shell type (4EA)
Nakdonggang River	Sangju Weir	7,407	11	335	Shell type (2EA)
	Nakdan Weir	9,221	11.5	286	Truss type (1EA)
	Gumi Weir	9,557	11	374	Shell type (3EA)
	Chilgok Weir	11,040	11.8	400	Shell type (2EA) Turning type (2EA)
	Gangjeong Goryeong Wire	11,667	11.5	954	Rising sector type (2EA)
	Dalseong Weir	14,248	9.5	580	Rising sector type (3EA)
	Hapcheon Changryeong Weir	15,074	11.5	328	Truss type(3EA) Turning type (2EA)
	Changryeong Haman Weir	20,697	10.7	549	Rising sector type (3EA)

As Figure 10 shows, multi-functional weirs were installed at large rivers that penetrate the national land, and water storage and water level the weirs newly secured are helpful for stable agricultural/domestic water supply even in droughts. These multi-functional weirs are equipped with small hydropower stations, utilizing heads of water to contribute to clean energy production.

2.3.4 Multi-regional Water Supply System& Industrial Waterworks

The South Korean government started building industrial waterworks in the 1960s, after the Korean War. The first industrial waterworks were made to stabilize the water supply to national industrial complexes in Ulsan and Changwon. Until the early 1970s, those waterworks were built to supply water to industrial complexes for national economic development. Since then, construction of multi-regional water supply system projects has been promoted in a unit of a branch: from phase 1 of Metropolitan Multi-regional Water Supply System in 1973 to Geumsan-Muju Multi-regional Water Supply System in 2013.

Imbalances of water resources occur because there is no water bowl that is adequate for an area. In a geographical context with flat land and low rainfall, it is hard to install a proper water resources facility. Although 70% of the country is mountainous, South Korea has water resource imbalance issues. As a means to solve the imbalanced interregional water supply problem, the South Korean government has been operating a multi-regional water supply system, which is a system that supplies tap water to local governments. A multi-regional water supply system is planned/built/operated only by the central government, unlike other water supply systems in South Korea, and is considered excellent for integrated basin management and drought prevention.

TABLE 11: Status of the multi-regional water supply system operated by the central government (K-water, 2017a)

Class	Water Intake Facilities		Water Treatment Facilities	
	Number of Facilities	Capacity	Number of Facilities	Capacity
Sum	48	17,553.4	42	8,532
Multi-regional water supply system	35	13,859.9	34	6,892
Industrial Waterworks	13	3,693.5	8	1,640

FIGURE 11: The distribution map of the multi-regional water supply system

TABLE 12: The capacity of the multi-regional water supply system in South Korea

Classification	Source of water supply (Water-intake Point)	Facility Capacity ($10^3 m^3/d$)	Project Period	Water Supply Recipient City
Sum	-	17,553.40	-	113 cities/counties
Multi-regional water supply system	**-**	**13,859.90**	**-**	**105 cities/counties**
Metropolitan Area I-VI	Soyanggang Dam, Chungju Dam (Paldang Dam, Hangang River)	8,285.00	'73~'08	Seoul and 26 cities
Ilsan Area	Chungju Dam (Hangang River)	250	'89~'96	Goyang
Taebaek Area	Gwangdong Dam, Dalbang Dam (Gwangdong Dam, Dalbang Dam)	110	'85~'90	Taebaek, Samcheok, Donghae, Jeongseon
Wonju Area	Hoengseong Dam (Hoengseong Dam)	100	'99~'03	Wonju, Hoengseong
Changju Dam Water System	Chungju Dam (Namhangang River)	250	'94~'01	Icheon and 6 cities/counties
Daecheong Dam Water System I, II	Daecheong Dam (Daecheong Dam, Daechoeng Balancing Reservoir Dam)	1,010.00	'84~'03	Cheongju, Cheongwon, Cheonan, Asan, Sejong
Geumgang Rive Water System	Daecheong Dam (Geumgang River)	[170]	'76~'84	Nonsan, Buyeo
Boryeong Dam Water System	Boryeong Dam (Boryeong Dam)	285.2	'92~'98	Boryeong and 7 cities/counties
Central Chungnam Area	Daecheong Dam, (Daechoeng Balancing Reservoir Dam)	163	'04~'09	Gongju, Nonsan, Buyeo
Jeonju Area	Yongdam Dam (Yongdam Dam)	700	'93~'04	Jeonju and 5 cities/counties
Seomjingang River Water System	Dongjingang River (Dongjingang River)	90	'88~'96	Gimje, Jeongeup
Buan Dam Water System	Buan Dam (Buan Dam)	87	'94~'98	Gochang, Buan, Yeonggwang
Donghwa Dam Water System	Donghwa Dam (Donghwa Dam)	52	'96~'02	Namwon, Jangsu, Imsil, Gokseong
Juam Dam Water System I, II	Juam Dam (Juam Dam)	596	'89~'99	Gawngju, Mokpo, Naju, Hwasun
Western Jeonnam Area	Pyeongrim Dam (Pyeongrim Dam)	30	'01~'10	Damyang, Hanpyeong, Yeonggwang, Jangseong
Southern Jeonna Area	Jangheung Dam (Jangheung Dam)	150	'01~'08	Mokpo and 8 counties
Gumi Area I, II	Imha Dam (Nakdonggang River)	400	'80~'97	Gimcheon, Gumi, Chilgok
Pohang Area	Imha Dam (Imha Dam)	161.2	'96~'01	Pohang, Gyeongju
Gampo Dam	Gampo Dam (Gampo Dam)	4.5	'02~'06	Gyeongju
Geumhogang River Water System	Unmoon Dam (Unmoon Dam)	370	'85~'96	Daegu, Gyeongsan, Yeongcheon, Cheongdo

Classification	Source of water supply (Water-intake Point)	Facility Capacity ($10^3m^3/d$)	Project Period	Water Supply Recipient City
Inner Yeongnam Area	Andong Dam (Nakdonggang River)	44	'04~'08	Daegu, Goryeong, Seongju
Ulsan Area	Daegok Dam, Sayeon Dam (Sayeon Dam)	220	'99~'05	Ulsan
Miryang Dam Water System	Miryang Dam (Miryang Dam)	150	'95~'01	Miryang, Yangsan Changneyong
Namgang Dam Water System I, II	Namgang Dam (Namgang Dam)	325	'85~'05	Jinju and 6 cities/counties
Geumsan-Muju Area	Yongdam Dam (Yongdam Dam)	27	'05~'13	Geumsan, Muju, Jinan
Industrial Waterworks	**-**	**3,693.50**	**-**	**19 cities/counties**
Asan I, II	Asan-ho Lake, Daecheong Dam (Asan-ho, Daechoeng Balancing Reservoir Dam)	421	'94~'02	Pyeongtaek, Asan, Seosan, Dangjin
Gunsan	Daecheong Dam (Geumgang River Estuary)	130	'89~'94	Gunsan
Yeocheon Gwangyang	Sooer Dam, Juam Dam, Seomjingang (Sooer Dam, Somejingang, Regulating Reservoir Dam)	1,080.00	'74~'08	Yeosu, Gwangyang, Suncheon, Goheung, Boseong
Daebul	Yeongsangang River (Yeongsangang River)	57.5	'90~'94	Yeongam
Gumi	Imha Dam (Nakdonggang River)	64	'01~'06	Gumi
Pohang	Yeongcheon Dam, Hyeongsangang River (Yeongcheon Dam, Hyeongsangang River)	295	'68~'80	Pohang, Gyeongju, Yeongcheon
Ulsan I, II	Hapcheon Dam, Daeam Dam (Nakdonggang River, Daeam Dam)	1,325.00	'62~'96	Ulsan, Yangsan
Changwon	Hapcheon Dam (Nakdonggang River)	285	'66~'81	Changwon
Geoje	Gucheon Dam, Yeoncho Dam (Gucheon Dam, Yeoncho Dam)	36	'77~'87	Namwon, Jangsu, Imsil, Gokseong

2.3.5 Comprehensive Plan for Land Water Welfare

In regions where existing water supply methods (e.g. dam and surface water) fail to solve water shortage problems, substitutive water source development through water source diversification is an attractive option. This practice is being actualized in areas out of water supply range and areas with unstable water sources.
Rural areas, mountain villages, islands, and coastal areas are especially vulnerable to water supply shortages during drought periods, if multi-regional/local waterworks systems even reach them. In the case of areas dependent on singular small-scale water sources, water shortage occurs in spring with low rainfall and winter freezing times due to cold snaps.

Seawater desalination has recently been in the spotlight as a water source diversification method. Since three sides of the Korean Peninsula are surrounded by sea, it is easy to access seawater. Moreover, most cities near the coast are benefiting from water supply services. Considering these circumstances, the South Korean government established a plan to develop seawater desalination facilities and to supply freshwater in shortage areas. As part of the plan, a project is being promoted to run a seawater desalination plant with 0.1 million ton per day scale in Daesan Seaside Industrial Complex on the west coast, and then to supply RO water (reverse osmosis water). By establishing operation plans connecting a substitute water source to a present water source or a purification plant to other ones, it is possible to consider a water supply customized to certain local governments/areas.

TABLE 13: The areas without a stable water supply in South Korea (K-water, 2017b)

Classification	Region	Population (10^3 Persons)	Note
Sum		612	
Local water supply system	All parts of Sokcho-si ('06, '11, '15)	80	Dry-out in Ssangcheon Underground Water Dam
	All parts of Taebaek-si (2009)	17	Decreased water reserve rate in Gwangdong Dam
Multi-regional water supply system	8 cities/counties in Chungnam, including Boryeong-si (2015)	480	Decreased water reserve rate in Boryeong Dam
	All parts of Taebaek-si (2009)	35	Decreased water reserve rate in Gwangdong Dam

2.4 Facility Operation Policies in Flood/Drought

A dam has to fulfill two functions at the same time. On the one hand, a dam secures water to be used in the future, filling its water bowl. On the other hand, a dam needs to empty the water bowl to control floods. In the case of multifunctional weirs, it needs inter-facility conjunctive operation in consideration of situations that include flow into a river, discharge from an upstream dam, and a river's water quality.

The Ministry of Environment (MOE), , the department in charge of water resources management in South Korea, built a close mutual assistance system with related water management organizations, such as the Korea Meteorological Administration, and is conducting scientific and systemic water management, introducing a super-computer that provides a customized and detailed precipitation forecast system of dam/weir basins. To actively respond to these water management circumstances, K-water, a water expert public corporation, launched a special water resource management department, 'Water Resources Operations Center,' in 2002, extending the Comprehensive Water Resource Management Situation Room.

K-water's water resource management is conducted by an integrated dam database. The database acquires meteorological forecast data from the Precipitation Forecasting System (PFS), which includes observation at floodgates (e.g. precipitation, water stage) and analysis by super-computer. Real-time observation data gathered from the whole country (RHDAPS, Real-time Hydrological Data Acquisition and Processing System) and data from Generation Integrated Operation System (GIOS) go to K-water, too. All these materials are collectively managed by the database of K-water.

The information in the database is analyzed by various systems, such as the intelligent decision support toolkit (K-HIT, K-water Hydro Intelligent Toolkit for Integrated Water Resources Management Decision Support), Flood Analysis System (FAS), and Reservoir Water Supply System (RWSS), and the result is applied to decision-making for optimal water resource management, such as flood control and stable water supply.

Thus, water resources management in South Korea is conducted based on foundation techniques including hydrologic data observation, data acquisition, and water control and irrigation management that are implemented by using the data.

The overall flow of water resource management is visualized in the following figure:

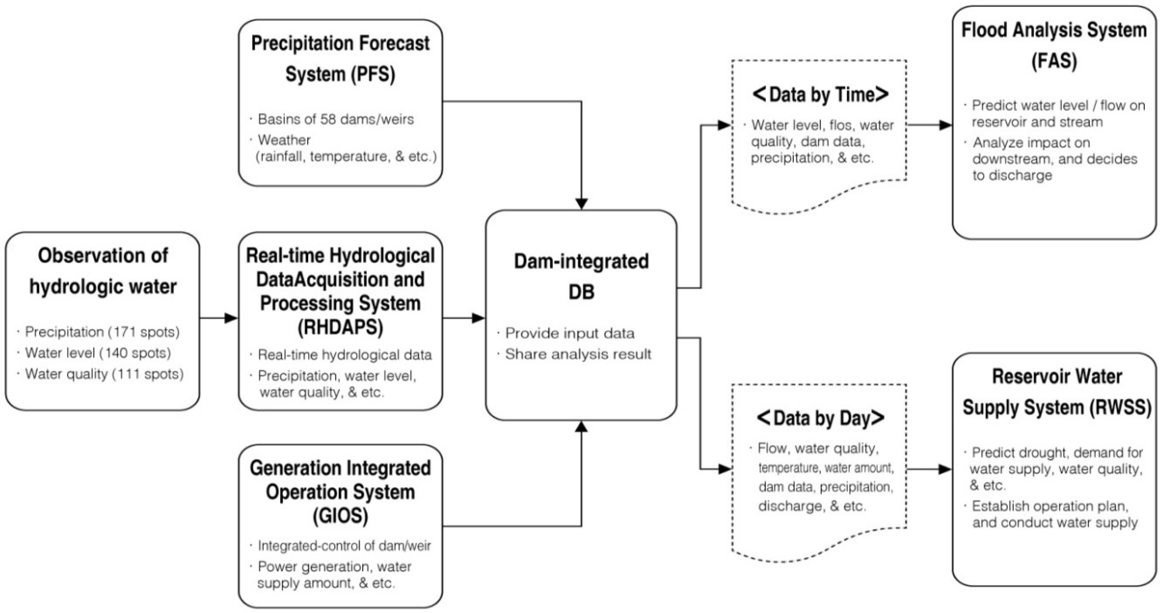


FIGURE 12: Water management systems (Shin, C. K. and Cho, W. H., 2017)

During a drought period, facility operation is essential to solve interregional imbalances of water resources. In case of continuous drought, conjunctive operation connects dams, weirs, and reservoirs. Each facility switches its operation method to a secure available water quantity and sends it into a river's maintenance flow, which enables a more stable water supply (e.g. agricultural water from the river in a drought period). For example, if downstream of a dam has a sufficient quantity of water for river maintenance water and agricultural supply, it is possible to allow the dam to reserve water.

2.5 Procedures of Dam Operation &ForeCast/Warning (Technical Procedures)[3]

The detailed process of flood adjustment utilizing connections within the water resource management systems is as follows:

2.5.1 Precipitation Forecasts in Dams Upstream according to Weather Forecast

Hydrologic data is observed and gathered in real time by the Ministry of Environment (MOE), K-water, the Korea Meteorological Administration (KMA), Korea Hydro & Nuclear Power (KHNP), Korea Rural Community Corporation (KRC), and other entities. There are 693 rainfall stations and 629 water stage gauging stations in total across the country.

The measured hydrologic data is verified following national authorization procedures, and then provided to all people through the Water Resources Management Information System (WAMIS). The precipitation data and hydrologic data gathered at water stage gauging stations are utilized as basic material to establish water resources plans or land-relevant plans.

K-water's comprehensive water resources situation room saves data for water resources management (e.g. rainfall, water stage, and hydrologic data related to dam operation) in its server by using satellites. RHDAPS plays a data management role. Also, K-water shares more than 1,000 kinds of hydrologic, real-time data with related organizations such as MOLIT and KMA. After strengthening monitoring functions according to dam operators' convenience, the hydrologic data is provided to people in real-time.

TABLE 14: The number of rainfall stations in Korea (MOLIT & K-water, 2017)

SUM	Ministry of Land, Infrastructure, and Transport	K-water	Korea Meteorological Administration	Korea Hydro & Nuclear Power
693	422	171	93	7

TABLE 15: The number of water stage gauging stations in Korea

SUM	Ministry of Land, Infrastructure, and Transport	K-water	Korea Hydro & Nuclear Power	Korea Rural Community Corporation	Ministry of Environment
629	476	140	7	4	2

A super-computer based PFS was built and is operated to strengthen K-water's own precipitation forecasting system. PFS divides the whole country in a unit of 3 km X 3km grids and produces quantitative 120-hour precipitation forecasting information that is optimized to the physical environment, such as detailed geography around the dam basin. Each basin receives precipitation forecasting information by utilizing this system.

[3] This section was modified by the author; the original is from 'Flood Forecasting Analysis Procedure in Korea (Shin, C. K. and Cho, W. H., 2017)'.

2.5.2 Flood Discharge Analysis

Administrators in the Water Resources Management Center consider hydrologic data and precipitation forecasting data to conduct flood analysis. Flood analysis distributes the predicted rainfall on an axis of time and space to simulate inflow to the flood control dam and hydrological curve. If it is expected that the flood discharge would overflow and cause damage, proper dam operation is needed for safe flood adjustment.

To do this, it is necessary to determine quantity and time of discharge release from an upstream dam, while keeping the dam safe, and not allowing water stages at principal points downstream (mainly near urban areas) to exceed embankments.

2.5.3 Establishment of Flood Control/Adjustment Plan

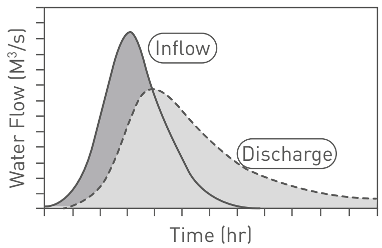
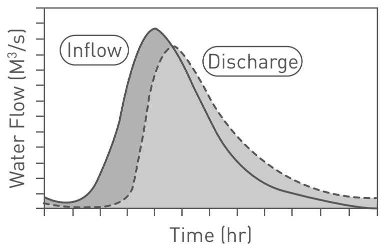
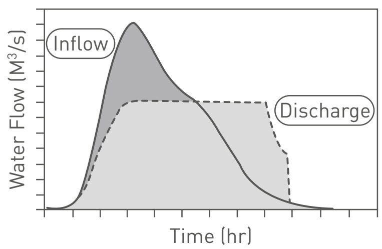
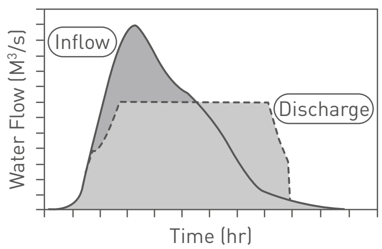
In decision-making for flood control, conjunctive dam operation sets water flow limits at river control points and appoints flow tolerances on control points to flood retention dams. For smooth flood adjustment by water resources facilities, a Flood Analysis System (FAS) is utilized. FAS conducts flood analysis by using precipitation forecasting data from PFS and hydrologic information acquired from RHDAPS. FAS is able to interwork with a real-time database to automatically collect the super-computer's precipitation forecasting data. This system not only supports an automated office environment, but also requires simple training for conducting analyses.

2.5.4 Simulating Reservoir Operation and Decision-making of Flood Control

Simulation of reservoir operation is conducted based on flood analysis as the result of precipitation forecast. Through simulation utilizing a trial and error method, a reservoir operation plan is established to minimize flood damage, both upstream and downstream. Reservoir conjunctive operation analysis is also conducted to minimize peak flood discharge downstream and to prevent flood damage. Using an optimization method, this analysis decides the quantity of discharge by reservoir, and then conducts simulated operations to establish a release plan in consideration of field constraints. Hydraulic modeling by a dam release scenario applies the reservoir operation plan and sea level at the end of rivers and helps to determine the overflow at major river points, which leads to the establishment of the final release decision-making plan.

An optimal dam-weir operation plan is established through these processes. Once the plan is made, the Flood Control Office affiliated with MOE, the competent ministry of the South Korean government, examines appropriateness of the dam operation and the impacts to upstream/downstream one more time, before authorizing the flood adjustment plan.

TABLE 16: The reservoir operation rules (Shin, C. K. and Cho, W. H., 2017)

Classification	Conceptual Diagram	Features & Strengths/Weaknesses
Auto ROM		• A method that fully opens gates when reservoir level is higher than goal level. • Not able to utilize flood adjustment space in a multipurpose dam. • Over-discharge releasing in flood period may lead to increased flood damage at dam downstream.
SRC ROM		• Applied with no relation to flood hydrograph forecast. • Discharge is decided by using spillway rule curve, a gate operation method that keeps reservoir level lower than flood level, and that releases discharge only by adjusting reservoir level.
Rigid ROM		• Releases discharge a fixed rate until predicted inflow hits the peak, and then releases fixed quantity of flow after peak point. • When after-peak fixed discharge is equal to inflow, reservoir level reaches flood level. It is then available to utilize flood adjustment capacity at maximum range. • Flood of 200-year frequency is generally set as default flood.
Technical ROM		• Synchronize total quantity of flood detention during releasing period with flood adjustment capacity of reservoir, after reaching restricted level in flood period. • A method to decide discharge that is able to utilize flood adjustment capacity as much as possible. • Hard to apply unless inflow forecast is accurate, because of perfect input hydrograph prediction.

The Water Resource Management Center's reservoir operation techniques are as follows: In the flood period, reservoir operation basically aims at decreasing flood damage downstream by using the reservoir's detention space between the restricted water stage in flood season and the design flood level to adjust flood, and at securing sufficient water storage for stable water supply in preparation of post-flood period, which refers to drought season. When examining flood adjustment capacity and adjustment methods, it is necessary to compare each scenario's cost of flood adjustment capacity to its damage abatement downstream. By comparison, it is needed to examine various methods (e.g. setting flood adjustment capacity higher than normal high water level and setting restricted water level).

The Water Resource Management Center's reservoir operation techniques are as follows: In the flood period, reservoir operation basically aims at decreasing flood damage downstream by using the reservoir's detention space between the restricted water stage in flood season and the design flood level to adjust flood, and at securing sufficient water storage for stable water supply in preparation of post-flood period, which refers to drought season. When examining flood adjustment capacity and adjustment methods, it is necessary to compare each scenario's cost of flood adjustment capacity to its damage abatement downstream. By comparison, it is needed to examine various methods (e.g. setting flood adjustment capacity higher than normal high water level and setting restricted water level).

As for reservoir operation, there are two types: the optimization method and the simulation method. The former is used mainly for long-term operation and includes linear planning (LP) and dynamic planning (DP). The latter is often adopted for real-time reservoir operation method due to a simple theory and ease of access in practical work.

The simulation method includes, as in the above table, Auto Rom, an operation based on the Spillway Rating Curve (SRC), Rigid ROM, Technical ROM, LDR, SRD, etc. K-water examined simulation methods generally adopted by domestic multipurpose dams, comprehensively considering the forecast level of input flood, availability of floodgate control, water storage capacity and discharge release ability, flood control effect, and features in operation and maintenance. As a result, K-water has adopted the fixed-quantity release method (Technical ROM) and the Scheduled Release Discharge (SRD) ROM for maximum utilization of flood retention capacity.

Auto ROM is used for one to two years following dam construction in consideration of uncertainty of basin hydrologic data. Rigid ROM is used for the next two to three years, and then Technical ROM is adopted since the time forecast of hydrologic data in the basin is enabled. In the case of the fixed release method, it is hard to be applied unless inflow prediction is accurate because the method predicts perfect input hydrograph. On the other hand, SRD (Scheduled Release Discharge) ROM is applied to actual flood control practices. According to this method, the dam operator decides optimal discharge, release time, and release period in person, continuing simulated dam operation in consideration of current precipitation forecasts and constraints downstream.

Modified Technical ROM is being used because it is most effective to simulate. Similar to the rough water level drawdown curve, it is calculated by comparing decrease of discharges in long dam-operation history in case that similar rainfall comes down to the dam basin. This comparison is possible only if plenty of experimental data is accumulated.

2.5.5 Flood Forecast/Warning and Delivery

Water resource managers adjust discharge within authorized discharge limits in consideration of floodgate conditions in real-time to conduct flood management. Before releasing discharge, the manager notifies relevant authorities, local governments, and residents, allowing them to prepare for the discharge in advance. The manager needs to patrol the area constantly to investigate flood damage situations.

If flood discharge is too large and threatens the safety of a dam, there is no choice but to increase discharge, which may lead to overflow. In the event that the water level of downstream embankment is expected to be compromised, an evacuation order needs to be sent to the flood risk area to decrease damage in terms of lives and properties. The flow of water resource management described above is represented in Figure 13.

2.5.6 Case of Flood Adjustment

This chapter discusses a case of the Namgang Dam operation during the 2012 flood period. The 2012 rainy season began with low rainfall (a scenario which is referred to as the 'dry rainy season') in the early phase. Although the full-scale rainy season came after June 29th, it ended earlier than normal, with a seasonal rain front that advanced to Manchuria fast due to Typhoon Khanun. After seasonal rain, troughs passed through continuously and three typhoons struck the Korean Peninsula, which led to much more rain than in the average year. The continuous strike by the three typhoons (Typhoon No.15 Bolaven, Typhoon No.14 Tembin, and Typhoon No.16 Sanba) after mid-August due to expanded North Pacific anticyclone is the first phenomenon of its type since meteorological observation commenced, and which required a more fully focused disaster response.

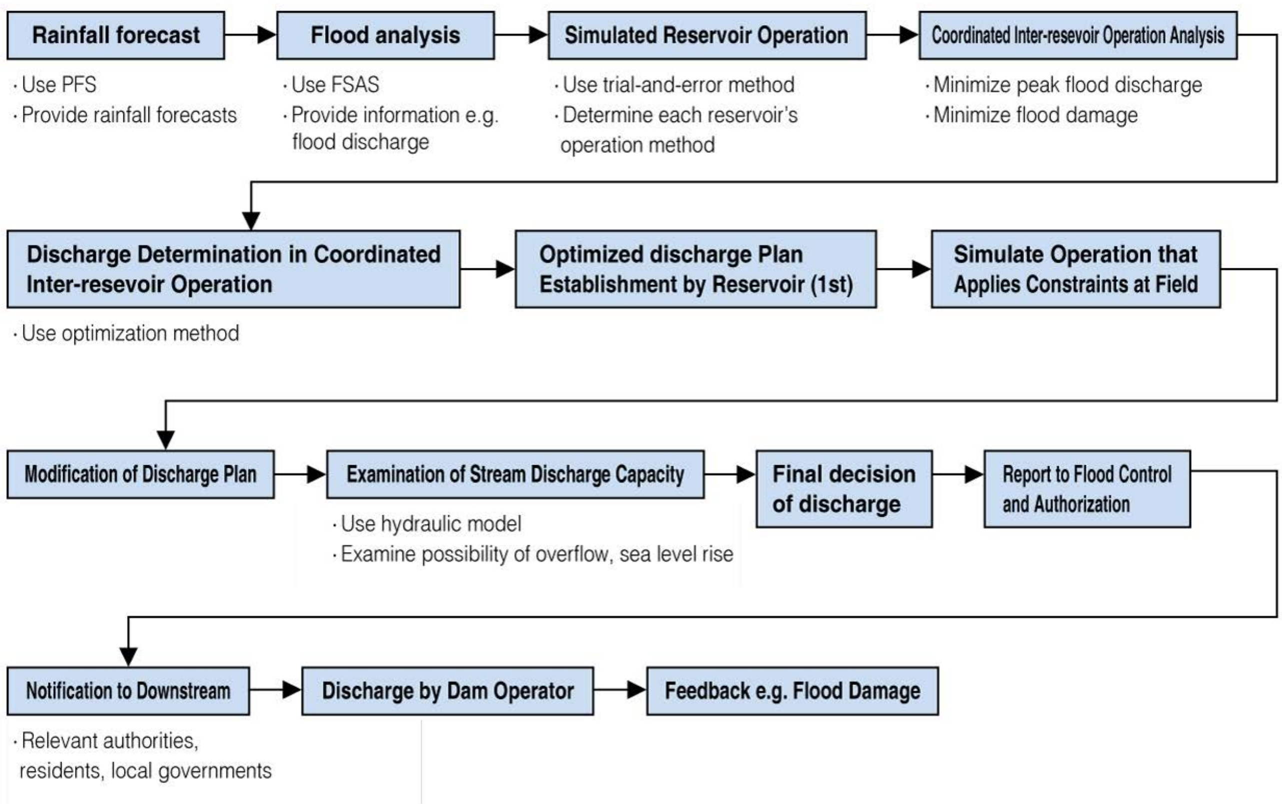


FIGURE 13: Flood prevention procedures in Korea (Shin, C. K. and Cho, W. H., 2017)

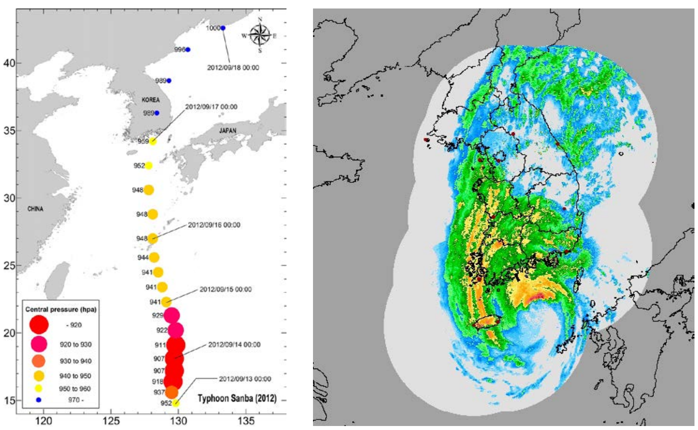


FIGURE 14: The path of Typhoon Sanba and rainfall radar image in 2012

Bolaven and Tembin hit South Korea in quick succession in 2012, which was recorded as the first time that two typhoons struck the Korean Peninsula within 43 hours. Bolaven struck the peninsula first, as Tembin moved slowly in the unusual course of an 'α shape' due to the Fujiwhara Effect. Bolaven was the strongest typhoon among those that advanced to the West Sea since 2000. Then, Sanba struck from the South Sea at around 12:00, September 17th. From the morning of the 17th, the typhoon dropped localized heavy rain on the inland area of Gyeongnam, where Namgang Dam is located. A total of 267 mm of precipitation fell into Namgang Dam basin between the 15th and 17th, and the maximum rainfall during 24 hours was 230 mm.

K-water, in preparation for Sanba's strike, conducted runoff analysis and simulated reservoir operation by applying FAS based on forecast data calculated by PFS. As a result, from September 13th (two days before the typhoon was expected to impact the area), K-water released discharge to lower water level at a rate of 300 m^3 per second, which is within a discharge range that is not harmful to the downstream area. Thus, K-water secured 142 million m^3 of additional flood adjustment capacity.

As the typhoon's full impact began to be felt, 14,100 m^3/s of water surged into Namgang Dam, exceeding the dam's designed flood discharge capacity (10,400 m^3/s). However, the dam secured the flood adjustment capacity in advance, releasing discharge downstream at a rate of 2,510 m^3/s (maximum), which is far lower than the designed discharge rate (4,050 m^3/s). 14,100 m^3/s inflow is almost equal to 14,818 m^3/s, the largest inflow from Typhoon Rusa in 2002. The efficient response to the flood was made through conjunctive utilization of diverse water resources management systems: flood adjustment capacity securement by pre-releasing discharge; hydrologic data (e.g. rainfall, water level, water flow) monitoring by using RHDAPS; rainfall forecast by using PFS; real-time flood analysis by using FAS; and discharge adjustment. Thus, it was possible to minimize flood damage by Sanba, although the discharge downstream was 2,510 m^3/s, which was only 42% of 5,911 m^3/s in the case of Rusa.

As described above, utilization of various systems, including RHDAPS, PFS, FAS, and GIOS, enabled efficient dam operation, helping decision-making and adjustment of discharge through runoff analysis and downstream impact analysis.

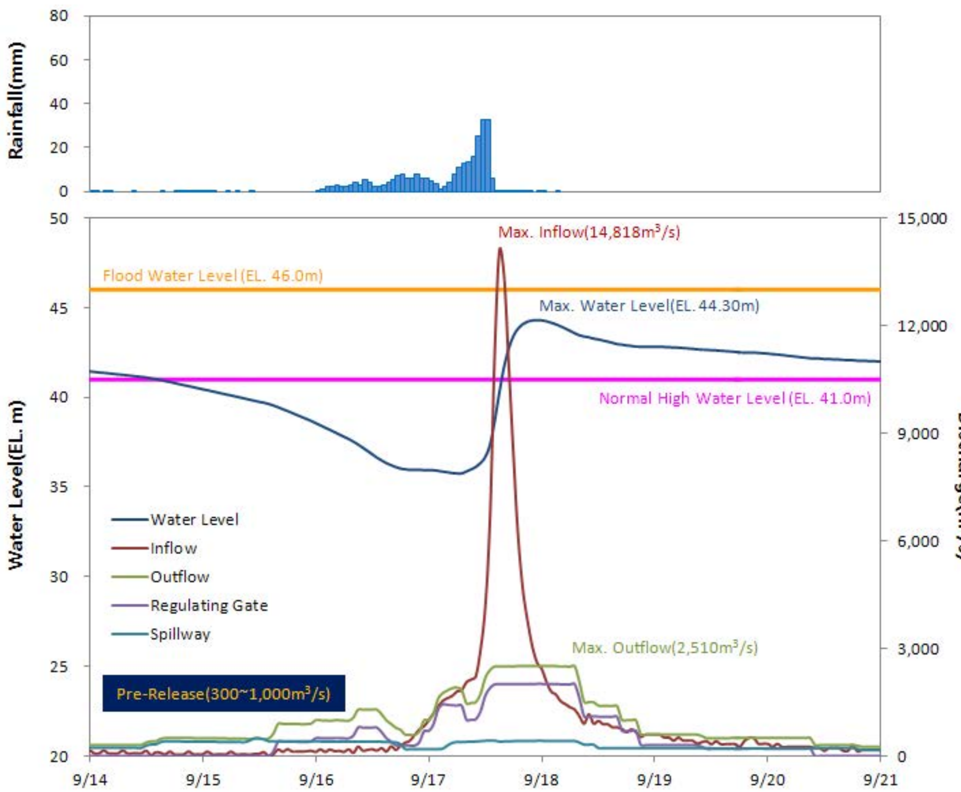


FIGURE 15: Example of flood control using the Flood Analysis System in Namgang multipurpose dam in 2012

The maximum water level when Sanba struck was EL.44.3m at 23:00, September 17th, by which 1.7m of residual height was secured in comparison to the designed flood level (EL. 46.0m). Namgang Dam's flood adjustment rate for Sanba was 82.2%, and it was analyzed that the flood adjustment by Namgang Dam lowered the water level at Jinju point in the dam's downstream area to 0.23m, decreasing flood damage.

TABLE 17: Flood release from Namgang multipurpose dam in 2012

Date	Discharge
September 13th, 17:00	80 m^3/sec
September 14th, 14:00	500 m^3/sec
September 15th, 16:00	900 m^3/sec (at check gate: 400 m^3/sec)
September 16th, 00:00	1,000 m^3/sec (at check gate: 500 m^3/sec)
September 16th, 09:00	1,300 m^3/sec (at check gate: 800 m^3/sec)
September 17th, 13:00	2,500 m^3/sec (at check gate: 2,000 m^3/sec)

Thus, K-water's water management system minimized flood damage downstream by determining optimal discharge in optimal time based on scientific analysis that involved cutting-edge ICT.

3. CHAPTER III Stable Water Supply

3.1 Total water cycle system

The Korean government operates an integrated water supply management system, which provides a total solution for the entire water supply process. This process begins at the district water supply and ends at a water faucet in the consumer's house. In addition, the government supplies industrial water tailored for companies and operates the wastewater treatment system to protect the source water. Through these efforts, the government has made the water cycle system stable and efficient, and it has provided a healthy water supply to the public.

3.2 Technology for each treatment process

3.2.1 Managing the Water Supply

Traditionally, surface water, lake water, and underflow water have been primary water supply sources. However, severe climate change has caused big fluctuations in the flow rate and there has been too much dependence on rainfall, so it is no longer possible to secure a stable water source using surface water only. For this reason, diversifying the water source has been discussed, and potential alternatives to surface water are riverbank filtration, underground water, and desalinated seawater.

As a measure to establish a preventive water quality safety management system, a forecasting system that can monitor and predict the occurrence of algae and odorous substances has been developed. There is also a real-time gauging system that detects algae and odorous substances as well as an online gauging system to check for algal toxin levels that are in operation. These systems enable the government to pre-emptively respond to abnormal water quality conditions such as algae in the water supply.

- SURIAN (Integrated Water Quality Forecasting System): This system utilizes the water quality modeling technique to predict the algae odor concentration for five days in advance, and automatically generates forecasts every day. By using weather, water flow rate, and water quality data, the system can forecast algae and odorous substance levels, so that decisions can be made scientifically and the water quality can be maintained at an optimal level.

3.2.2 Water Purification and Treatment

In order to reinforce the system that produces clean water that everyone can trust, the government is running two programs—water safety management and water purification and treatment diagnosis. In addition, the government is making efforts to adopt an advanced water supply system. Utilizing the new concept of vertical water purification technology, water purification facilities can be distributed closer to consumers. Also, the government has successfully developed and is using the water purification and treatment diagnosis program, the water treatment control logic program, and the pilot plant development technology.

- **Intelligent Water Purification Facility Diagnosis Program (Dr. water+):** This program has been developed to diagnose the water purification and treatment process. By deducing performance-limiting factors, the program provides efficient ways to manage the water purification and treatment process.
- **Integrated Water Treatment Control Logic Program:** This smart water treatment monitoring and control program utilizes both classical control methods and data mining methods to monitor and control the water purification and treatment process (chemicals, sterilization) as well as the discharged water treatment process.
- **Vertical Water Purification Process and Distributed Water Supply System:** This compact new concept, vertical structure water purification design, allows water purification facilities to be installed near consumers. This advanced water supply system is safe and stable. Since water purification facilities are distributed, emergency water supplies can also be procured.

3.2.3 Supply Management

The Korean government is developing a water management system that can monitor and control the entire water cycle process, from the water supply to the water faucet. This is made possible by using information communications technology (ICT). In addition, the collected data are analyzed so the intelligent pipeline management system can manage the water quantity, water quality, and energy. As a result, uninterrupted water service can be provided, and practical facility improvement ideas can be identified. The following specialized programs and packages allow the government to successfully provide a healthy water supply:

- **Water-NET (Water Supply Network Diagnosis, Operational Management System):** This GIS-based water supply network diagnosis system can collect real-time data from the water supply network and manage the water quantity, water quality, risks, and energy.
- **iWater (Real-time Standard Water Operation System):** This standardized human machine interface (HMI) system can remotely monitor and control facilities such as the water supply, water purification plant, booster station, pipelines, water reservoir, and water faucets, all from the integrated operations center.
- **RWIS (Real-time Water Information System):** This system checks water-related operations data every minute in real-time and provides the information to the user.

- **Water-INFOS (Local Water Supply Integrated System):** GIS-based integrated solution to manage facilities, customers, billing, and customer complaints for the local water supply system.
- **Flowmeter Calibration and Performance Testing Technology:** Advanced technology for precision calibration of flowmeters that supports the fluid and flow performance testing of the water meter, valve, and other core parts and exports.
- **Rehabilitation Technology of Medium- to Large-diameter Water Pipe:** Provides cleaning for large diameter water pipes (D500-D1,650mm) using polygon-shaped oil pressure cylinder frame equipment. Along with the cleaning, it uses spray lining rehabilitation technology to prolong the life of the water pipes and lower the improvement costs.

K-water has raised its competitiveness by utilizing the water treatment method and efficiently managing facilities to lower the production costs for industrial water. Also, by operating in conjunction with the multi-regional water supply system network, K-water is providing a stable supply of industrial water, which is produced to meet companies' demands. Recently, K-water has produced water using seawater desalination via reverse osmosis (RO), and this water has been used for petrochemical processing. In addition, K-water is conducting research and development with technology to create pure water and ultra-pure water used in the semiconductor cleaning process.

3.2.4 Wastewater Treatment

Water is brought from the district water supply and goes through the purification process before being supplied to consumers. Once the water has been used, it goes back to nature via river. Properly treating the used water before it returns to nature is a very important final step of the water treatment process.

The Korean government has built sewer systems in the upper reaches of a river before the dam to improve river water quality and enhance public sanitation. This, in turn, improves the public living environment. In addition, the government has participated in private investment projects such as a large-scale sewage system project in an effort to create a clean, stable, high-quality water cycle system. To support this cause, K-water has developed advanced technology for wastewater treatment and a water treatment management system, which includes:

KS-MBR Process: Technology using the aeration/non-aeration parallel alternate reaction vessel and precision filtration film, maximizing the efficiency of organism use to treat wastewater.

Self-Diagnostic Wastewater Operation System (Dr. Wastewater): Wastewater management and process monitoring system that can predict the water quality of the inflow and outflow in real-time.

3.2.5 State-run Multi-regional Water Supply System

The Korean government has built 48 metropolitan water supply and industrial water supply systems across the country. These provide water to 22 million residents across the country via 42 water purification plants and water pipelines that extend a total of 5,265km, amounting to 48% of the national water supply. This means that the central government is responsible for the water. Because most of the water sources are large multi-purpose dams or large rivers, water can be supplied stably even in the midst of a severe drought. In the recent droughts, the multi-regional water supply system did not have to enforce restrictive rationing, but the local water supply facilities had to ration water usage.

In addition, about 20% of the country's total population lives near the Seoul metropolitan area. To smoothly provide water to the Seoul metropolitan area, an integrated metropolitan operation system is being used. K-water has built and operated the multi-regional water supply system on behalf of the government. The water is supplied from large dams and large rivers, which are stable water supply sources. The water is then purified and then sent to various local governments near the metropolitan area. The water supplied in this manner is then sent to each household via the local government's water facilities—a water purification facility, water reservoir, water pipes, etc.

As such, the central government-run multi-regional water supply system can solve the disparity in water supply between cities and rural areas due to heavy dependency on rainfall. By providing water from a stable water supply, the local governments outside the city district can receive the water from the central government. This policy is unique to South Korea and it can fundamentally resolve the water supply problem.

There could be some difficulties establishing new water policies to address water imbalances between regions with abundant sources and cities that want to secure water due to lack of resources. Historically, most modern cities and communities have developed as local autonomous systems. The first challenge is the topographical features like huge ranges and big rivers, which divide communities. This was finally settled to a self-governing system. Although people could not overcome these natural obstacles in the past due to a lack of technology, they can sufficiently handle these problems nowadays, thanks to advanced construction technologies like large dams, tunnels, and long pipelines.

There are other potential challenges involved in introducing a new policy. For instance, during the negotiation process to establish new water policies, we could encounter debating among central and local governments and NGOs regarding governing systems, financing, construction, and operation and maintenance. Most of these conflicts are related to financial issues. However, the biggest problem is determining that the operation and maintenance (O&M) system of these infrastructures is sustainable and sound. O&M is integral, requiring a legal support system of the government. Based on South Korea's experiences, we strongly recommend the establishment of a public enterprise like K-water in South Korea, which is run by the central government and is charged with conducting planning, construction, and operation and maintenance of water resources facilities, such as multi-regional water supply systems as well as multi-purpose dams.

This policy, where the central government, instead of the local government, takes ownership of developing the water source and supplying the water from these sources, is definitely worth considering for countries that want to build infrastructure and a system to develop the water resources and water supply system.

3.2.6 Management of the Local Water Supply (Smart Water Management Technology)

The local government is responsible for the local water supply system; therefore, the local governments build and operate their own water supply systems. As mentioned above, many local governments near metropolitan areas do receive water from the central government-operated multi-regional water supply system because its water source is more stable.

Compared to the multi-regional water supply system, the local water supply systems are smaller in size, but they do have complex pipeline networks. The local government has a very important role to play in providing water to the end-users, so they have to manage water pipes with small diameter as well as the water meters at each household.

One of the areas of concern for the local water supply system is the accounted water rate. Because water pipeline networks are very complicated, it is extremely difficult to locate where the leak is happening and lowering the operational cost efficiency. It is just as difficult to repair the water leaks.

To overcome this problem, the block system is set up to divide the water supply network into various zones. Then, the accounted water rate is calculated for each zone and the water leak detection and repair work is performed. At the same time, old pipes need to be replaced. This type of project requires tremendous technical skills and manpower.

Twenty-three local governments in South Korea have requested K-water to improve the efficiency in operating their water supply system. This is because K-water has the experience of managing and operating the multi-regional water supply system and it also has applied information communications technology to manage the water supply system scientifically. As a result, the accounted water rate in 23 local governments, including Nonsan water supply system, has shown 10-20% improvement. K-water's involvement has contributed significantly to solving the water-related problems for local governments. This was a good example that showed how the stable water source from the multi-regional water supply system and the management of the complex local water supply network can utilize IT to enable smart water management.

Countries that do not have sufficient water sources and are planning to build a water supply system to bring the water from a long distance can consider South Korea's multi-regional water supply system and the local water supply system as a good example. If they can create the block system from the construction phase, and adopt the water leak management system, billing system, and other systems in a bundle, it should produce a big synergistic effect.

4. CHAPTER IV Smart Technology for Adapting to Climate Change

4.1 Integrated Water Resources Operations Center[4]

4.1.1 Special Water Management Conditions in South Korea

Water management conditions in South Korea are more difficult than in any other country in the world. The adverse conditions are caused by the seasonal rainfall characteristics and the geographical characteristics already discussed at length in this document. First, the meteorological characteristics need to be examined. The average annual rainfall in South Korea is 1,277mm while the global average is 807mm. South Korea gets 1.6 times more rainfall than the global average. However, due to the high population density, the amount of water available per person is only 17% of the global average. To make matters worse, two-thirds of the annual rainfall is concentrated during the flood season, which is between June and September. During the rest of the year, rainfall is very low.

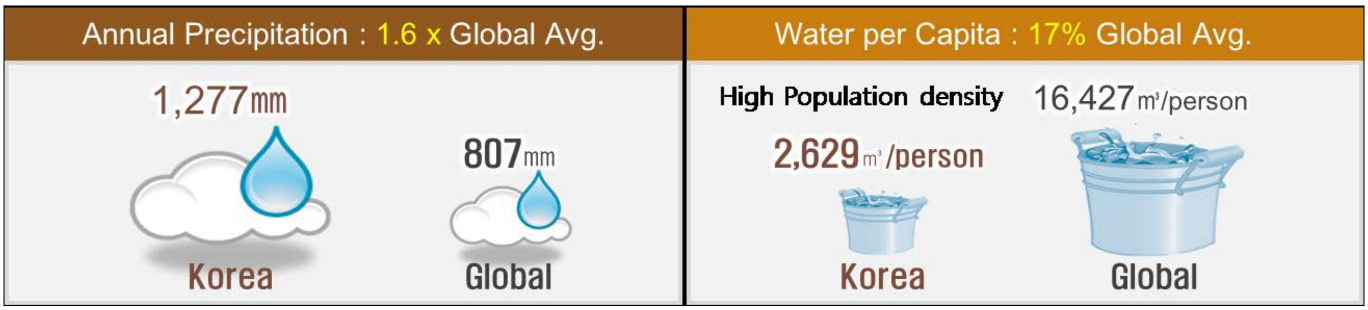


FIGURE 16: Comparison of rainfall between Korea and global average

Such conditions led South Korea to build and operate multi-purpose dams rather than single-purpose dams. The multi-purpose dams allow the country to prepare for both the dry season and the rainy season.

Other useful comparisons include examining river regime coefficients. The river regime coefficient for the Seine and Rhein River are 34 and 18, respectively, which are extremely small compared to the ones in Korea (see Chapter 1.1). The index value for the Mississippi River in the United States is only 3. This shows that the rainfall is very consistent, and the river flow rate does not vary much throughout the year. Therefore, it is evident that the conditions in South Korea are not favorable when it comes to managing water resources.

4 The author referred the material of 1st Asian International Water Week (Kim, H. S., 2017).

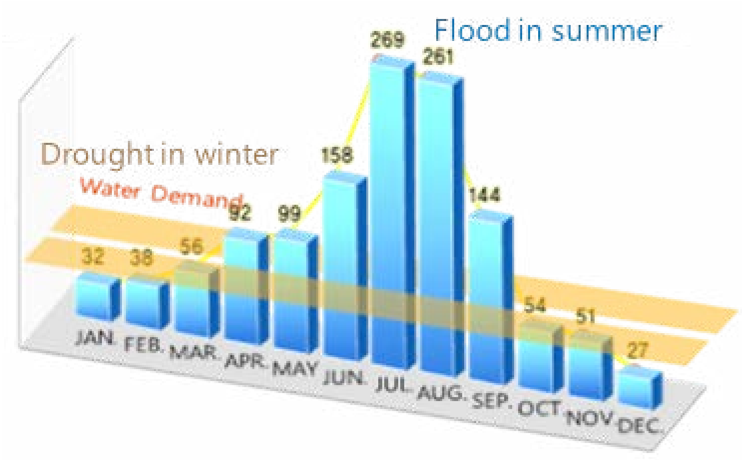


FIGURE 17: Seasonal rainfall distribution in Korea

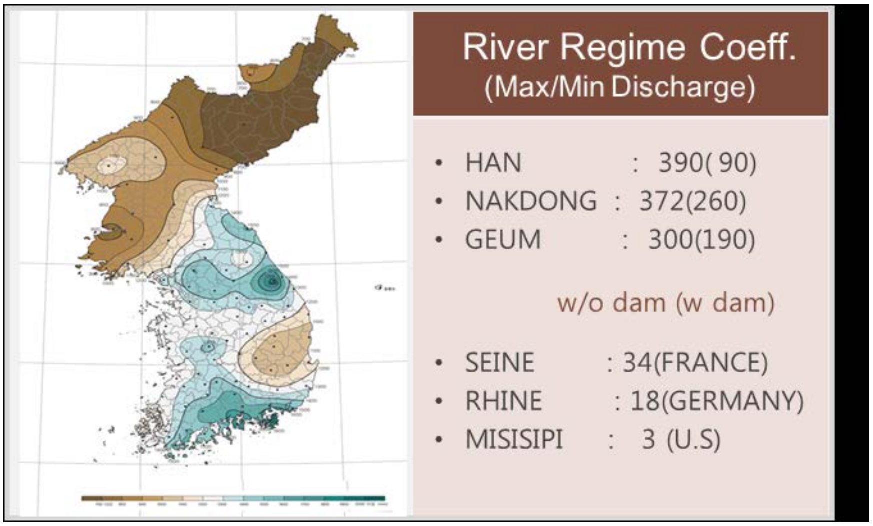


FIGURE 18: Comparison of river regime coefficients

Furthermore, water-related disasters are occurring more frequently due to climate change, which poses another threat element in water resources management. The damage due to flooding is especially greater in regions where a heavy torrential rainfall is concentrated over a small area. For South Korea, damage due to flooding in the 2000s has been 5.3 times greater than in the 1980s. Like flooding, droughts are occurring more frequently than before. In the 1970s, a drought occurred once every five to seven years. But in the 2010s, droughts are more frequent, occurring every two to three years.

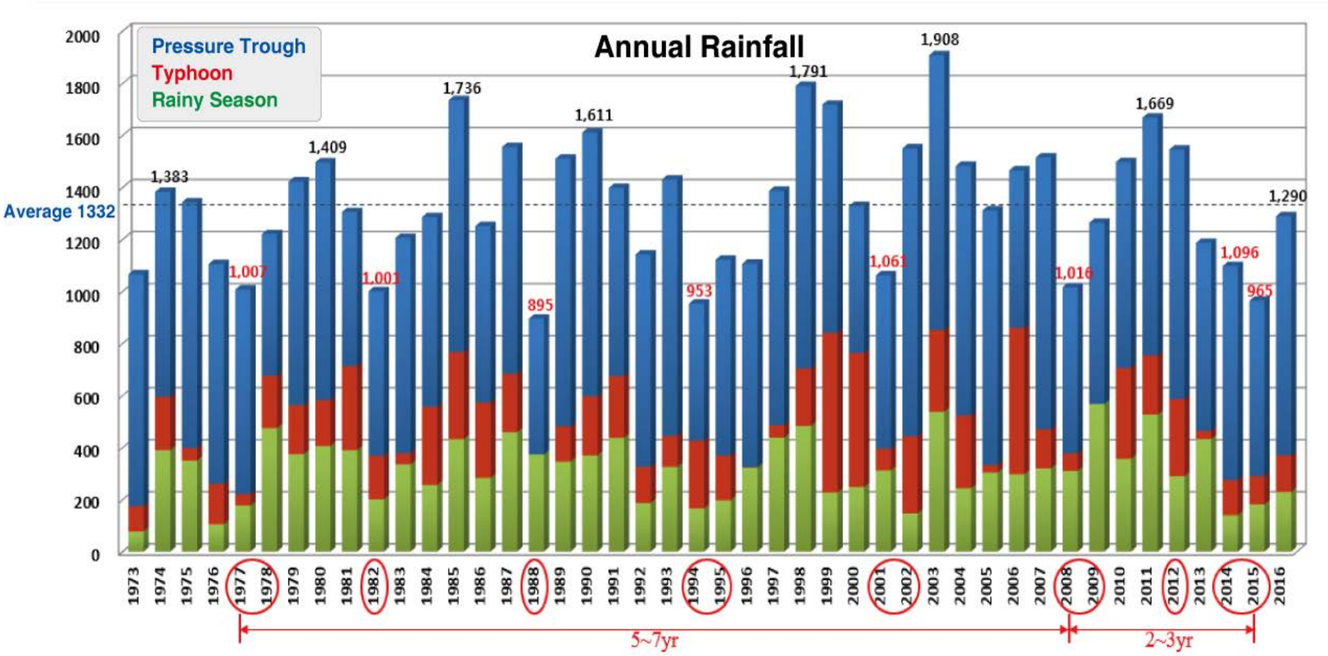


FIGURE 19: Frequency of drought occurrence in Korea (Kim, H. S., 2017)

4.1.2 Imbalance in Regional Water Resources Due to Climate Change

South Korea is experiencing extreme rainfall imbalance by region due to climate change. For instance, look at the rainfall data between June and August of 2017. The Han River basin, in which Seoul is located, is the largest area among all river basins in the country. During this period, substantial rainfalls in this region caused flooding, and the aggregate rainfall during this period reached 120% of the normal precipitation.

However, Nakdong river basin, the second largest river basin, located in the southeastern part of the country, recorded precipitation which was less than 70% of what it is normally. Sumjin river basin also had a similar result. So, even though South Korea is much smaller than the South American continent, both drought and flooding occurred in this small territory.

Two large-scale multi-purpose dams in Han River basin, Soyanggang dam and Choongju dam, had to release water to control the flooding. However, actions were taken to over the drought near the Nakdong river basin and Sumjin river basin areas. In Daegu Metropolitan City, located in the center of Nakdong River, it is feared that drought will lead to a water shortage. As a result, emergency water canals are being constructed to prepare for the worst.

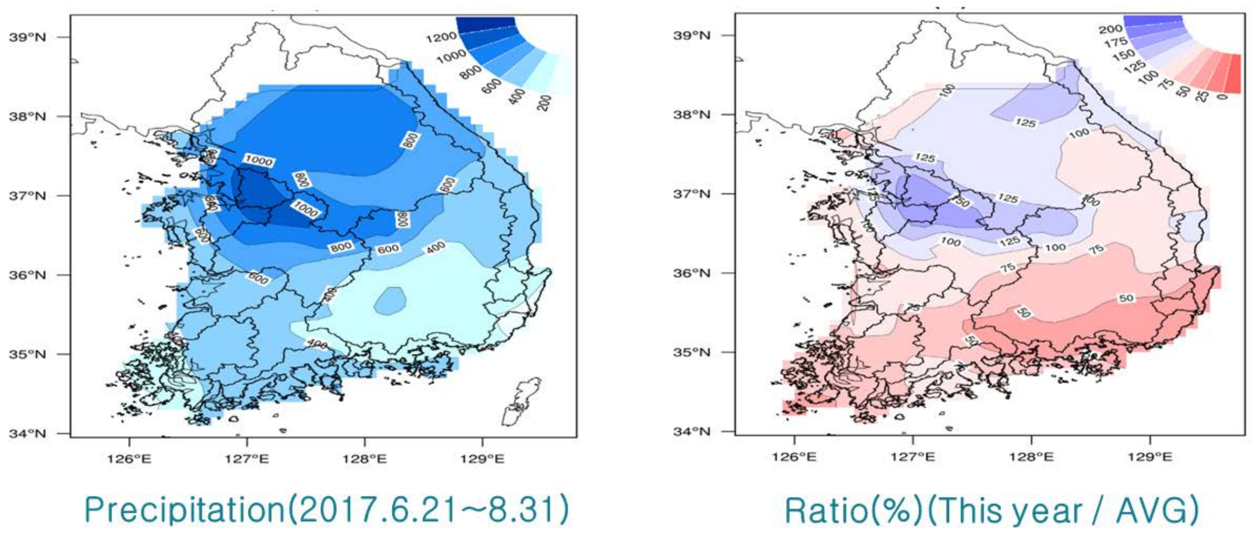


FIGURE 20: Status of rainfall during summer 2017 in Korea

TABLE 18: Extreme precipitation deviations by region (June - August 2017)

Basin	Basin [2017]	Ratio [2017/AVG.]	Remarks
Han River	784	120%	Flood
Nak-dong River	417	68%	Drought
Sumjin River	478	69%	Drought

4.1.3 Smart Water Resources Management System

To overcome flood and drought crisis conditions, the Korean government has developed the Smart Water Management System to effectively respond to threats posed by water-related disasters. The 'Integrated Water Resources Operations Center' is located at K-water's headquarters. Its regional operation centers are located at each river basin, and branch offices are located at individual dams.

These centers operate a total of 54 dams, which are located across the seven major river basins: 37 dams, 16 weirs, and 1 barrage. The centers perform all the tasks necessary to manage water, including forecasting rainfall, real-time monitoring of the rainfall, water level, and flow rate, flood control, water supply, hydropower generating, and developing technology (Integrated Water Resources Management Department of K-water, 2016).

The operation center makes necessary decisions on issues related to water resources based on the real-time data gathered from each dam and river basin. K-water has developed and is utilizing an intelligent, integrated toolkit called K-HIT (K-water Hydro Intelligent Toolkit) to assist with its decision-making process. This toolkit consists of five main modules: (1) RHDAPS (Real-time Hydrological Data Acquisition and Processing System); (2) PFS (Precipitation Forecasting System); (3) FAS (Flood Analysis System); (4) RWSS (Reservoir Water Supply System); and (5) GIOS (Generation Integrated Operation System).

Utilizing these modules systematically will enable seamless operation of the centers to make decisions about flood prevention, water supply control, and adjusting the amount of power generated.

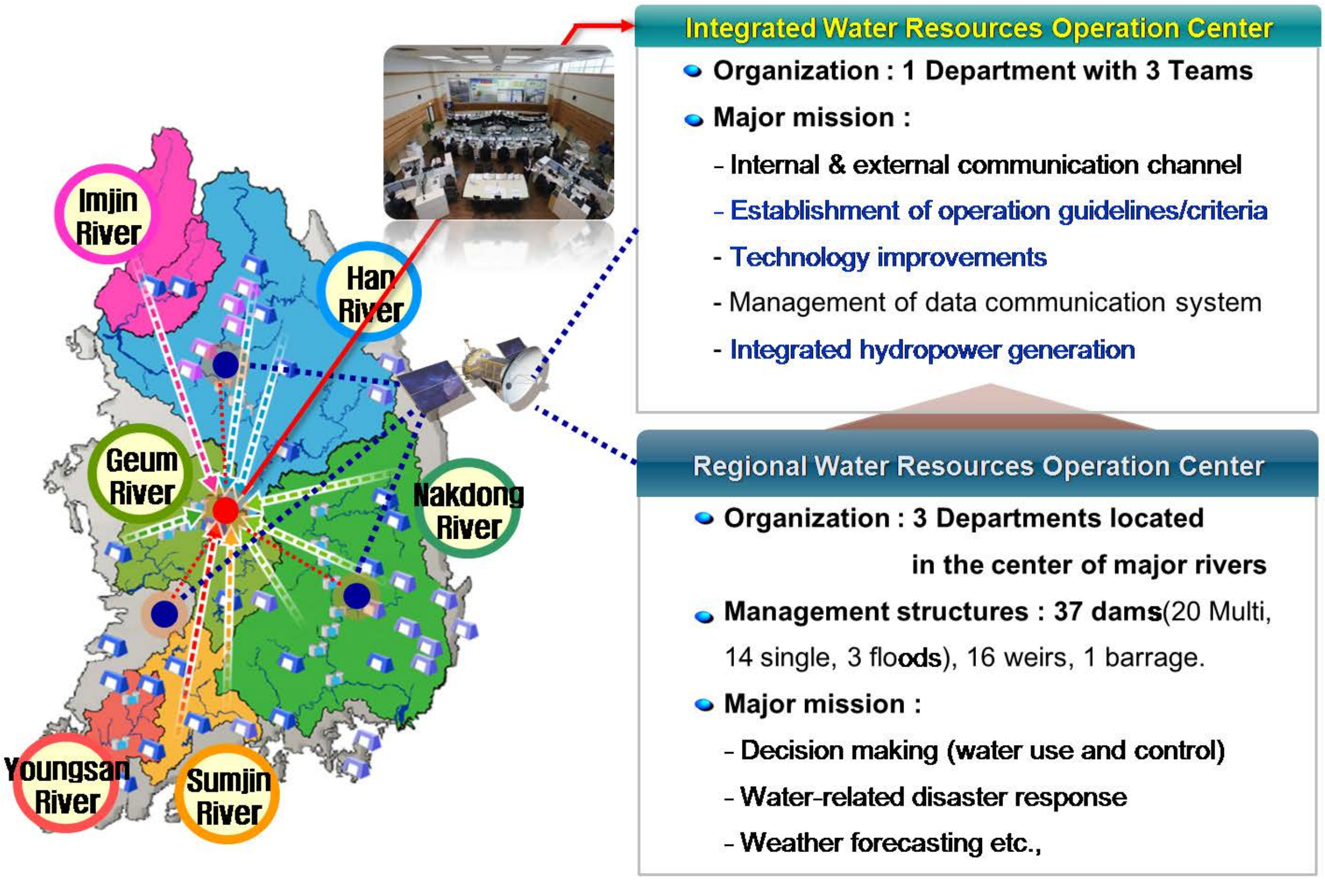


FIGURE 21: Function of Integrated Water Resources Operation Center in K-water

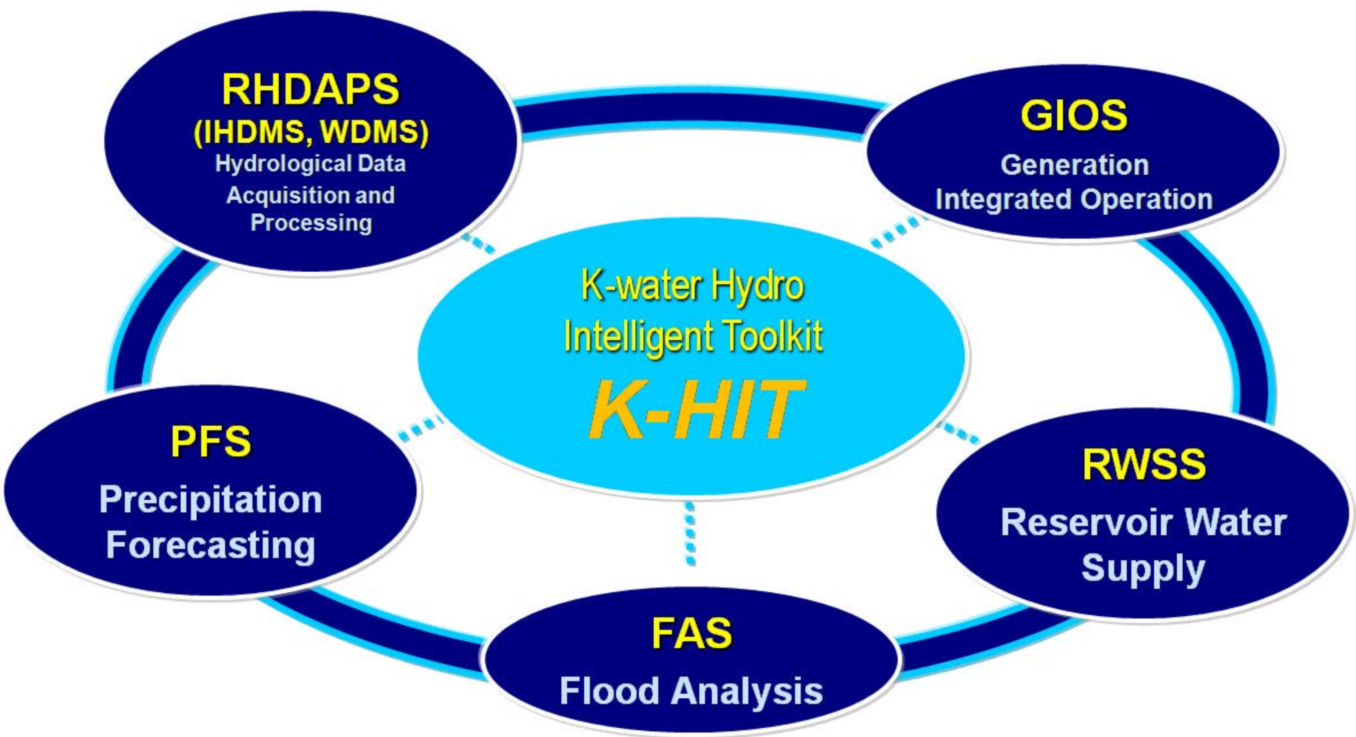


FIGURE 22: Decision-making support system in water resources

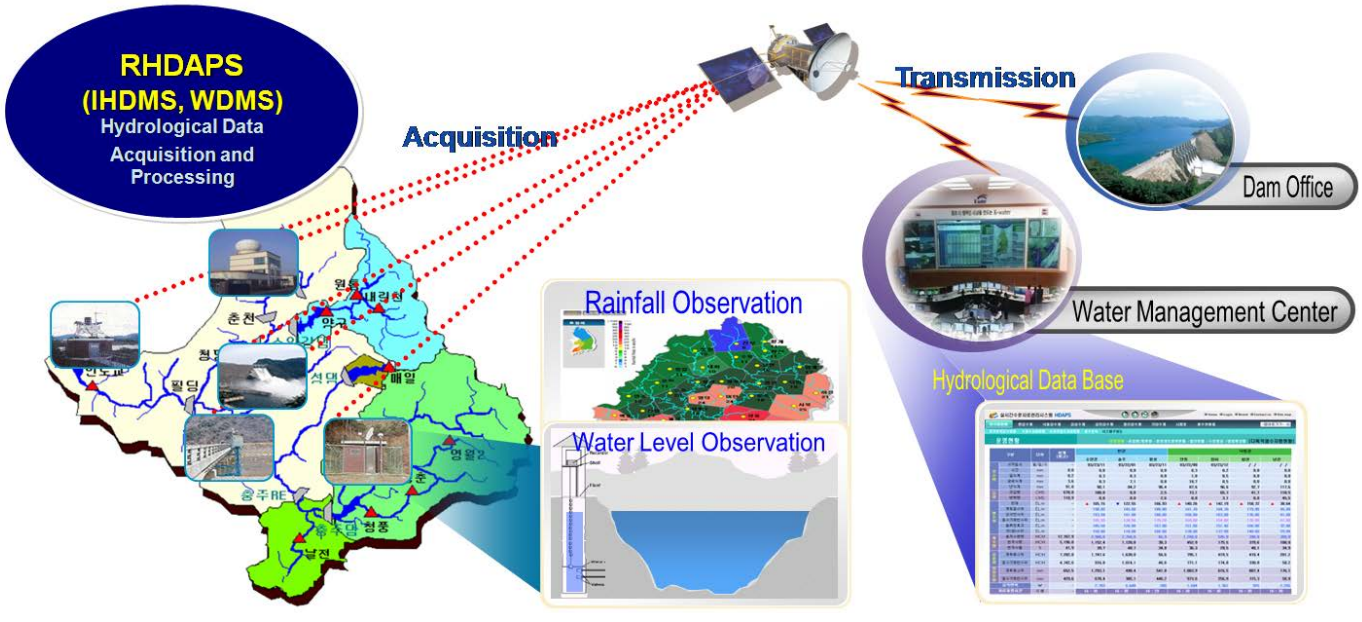


FIGURE 23: Conceptual map of RHDAPS

- RHDAPS (Real-time Hydrological Data Acquisition and Processing System): This system gathers the real-time floodgate data and processes them. The system collects data such as the rainfall, water level of the rivers, discharge flow rate, and water quality from 417 gauging stations that are spread across 54 dams and weirs. All data is sent to the dam operations offices and control centers via redundant communications networks (satellite or mobile networks). The collected data are processed every 1, 10, 30, and 60 minutes and stored in a relational database, and they are fundamental to all kinds of floodgate analysis.

4.1.3.1 Rainfall forecasting for the dam regions

The most important and fundamental phase of the water resources management is rainfall forecasting. K-water utilizes various data such as rainfall radar from the Korea Meteorological Administration. K-water also uses data from NOAA (National Oceanic and Atmospheric Administration) and Japan Meteorological Agency to forecast rainfall data. The collected data include climate information such as temperature, humidity, and wind speed. These data are run through a super-computer four times a day to predict rainfall amount five days in advance. The rainfall data map to individual 3 km x 3 km grid areas on a high-resolution display and cover the entire Korean peninsula. These rainfall data are then generated for each dam region to help with the flood analysis as well as forecasting and warning.

- PFS (Precipitation Forecasting System): This system divides the entire Korean peninsula into 3km x 3km grid areas and generates short- and long-term quantitative rainfall prediction data which are optimized to the natural environments and the geographical conditions of each grid area.

4.1.3.2 Flood Control

When a flood occurs, engineers from the water resources management center forecast the amount and flow rate of the water that will flow into the reservoir. This prediction is made using the real-time gauged data and the rainfall prediction data generated by the precipitation forecasting system. Using the amount of water inflow and the flow rate as input data, the engineer runs a reservoir operation simulation based on the scenario. If the simulation results show that the amount of the water inflow is greater than the reservoir capacity, then discharging water into the spillway is considered. In this case, the engineers also need to analyze the water levels in the lower reaches of the river, which will be impacted by the spillway discharge.

Based on the analysis results and prior to discharging the water, the water resources management center must inform residents of the affected areas, the central and local governments, and related agencies regarding the impacts of the spillway discharge according to the flood forecasting and warning procedure. Such prevention efforts can save the lives and properties of residents in the lower reaches of the river.

- FAS (Flood Analysis System): This system assists with decision-making using integrated flood analysis for the affected region based on real-time floodgate conditions and rainfall forecasts.
- RWSS (Reservoir Water Supply System): This system aims to maximize the utilization of water resource facilities such as dams, weirs, and agricultural reservoirs. By linking the natural rivers with these facilities, the system allows the integrated management of water resources. Based on the amount of water inflow and water consumption for each river system, the system operates various dams seamlessly and determines the amount of water discharged. Furthermore, by applying the amount of the discharged water as an input to the water balance analysis and the water quality model, this system can analyze the effects and benefits of the water resource management operations.

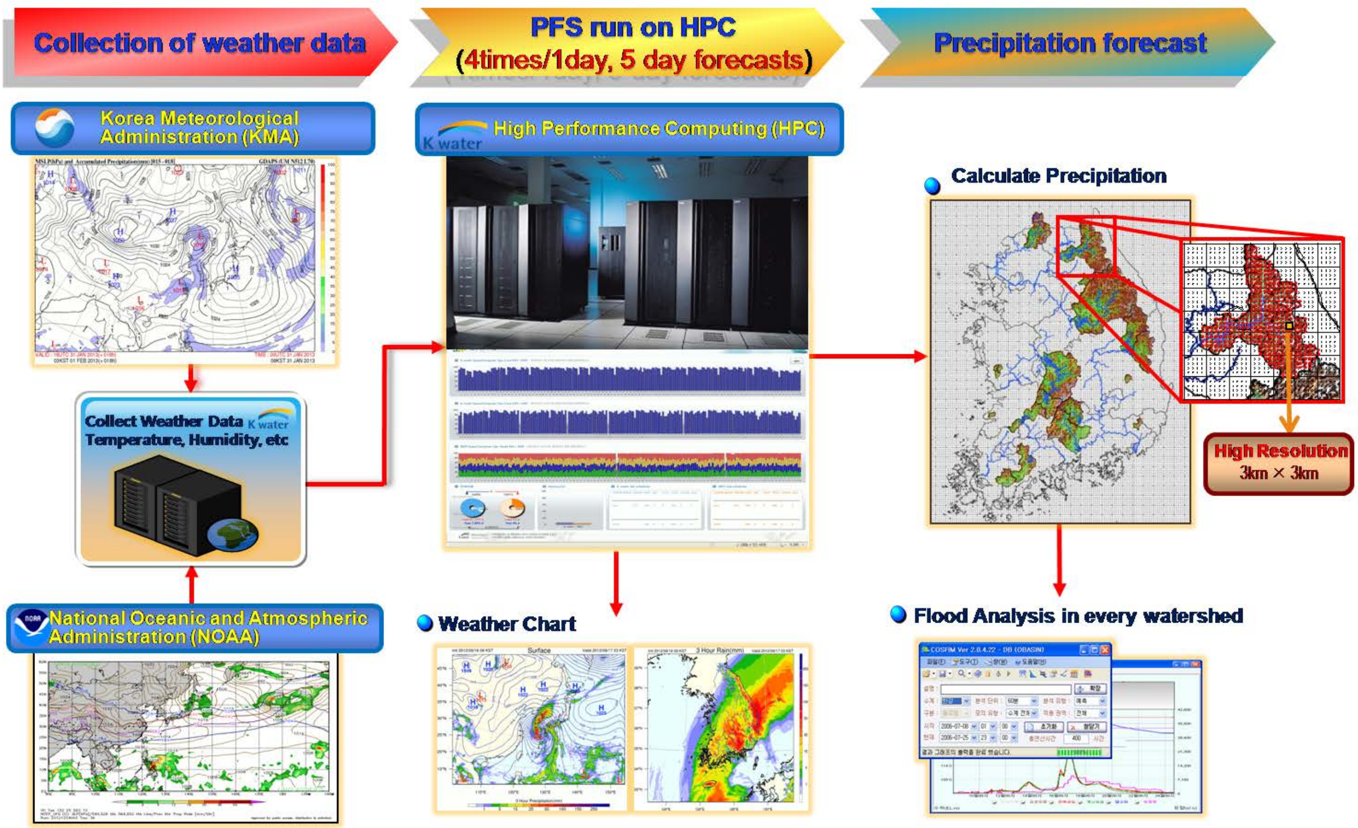


FIGURE 24: The procedure of precipitation forecasting optimized with dams

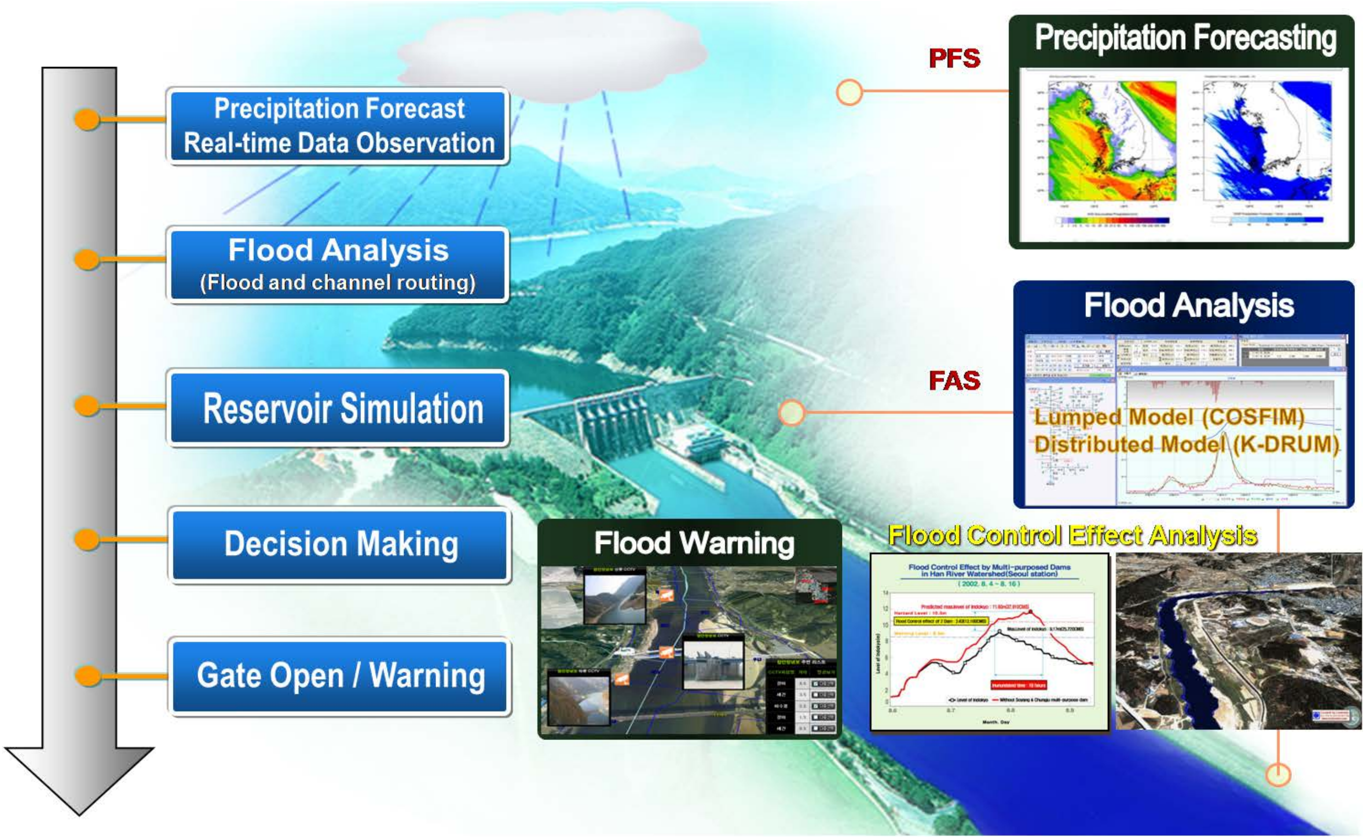


FIGURE 25: Flood forecasting procedure

4.1.3.3 Water Supply

In addition to the aforementioned flood control, another important function of multi-purpose dams is water supply control. This section introduces the analysis procedure for the water supply function. By estimating the long-term water outflow volume per river basin, it becomes possible to assess the amount of water resources available. Afterward, water system managers investigate the amount of water consumption. Then, considering the water quality level, they estimate the reservoir water supply and analyze the water balance. Finally, they optimize reservoir operation by ensuring there is sufficient water supply while maintaining satisfactory water quality.

4.1.3.4 Hydropower Generation

In South Korea, K-water is the number one company in the field of new and renewable energy generation. As water is discharged, the hydroelectric power generators at dams and weirs operate to generate power. The Integrated Water Resources Management Center remotely operates 87 power generators installed at dams and weirs, and they make business transactions in the electricity market. In addition, four staff members at the Integrated Water Resources Management Center handle the work that needs to be performed at 25 power generating facilities, demonstrating great work efficiency and cost savings.

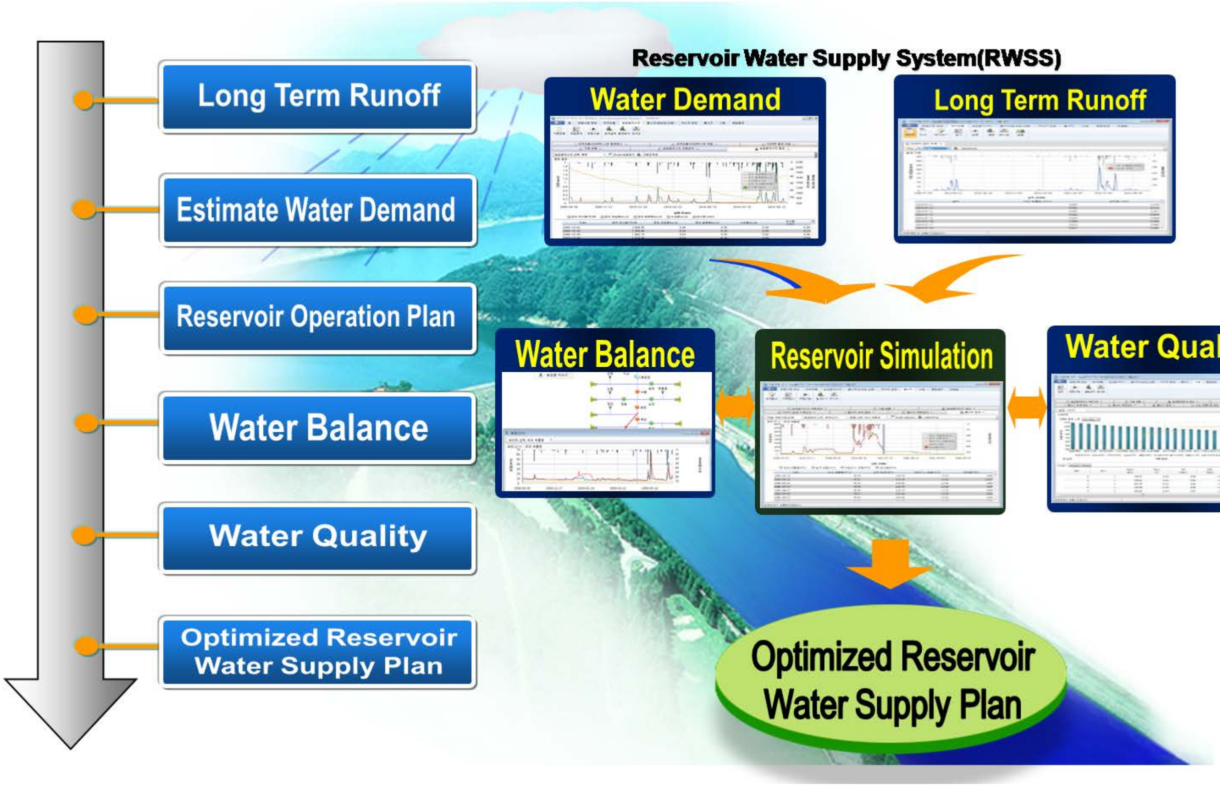


FIGURE 26: Optimization of reservoir operation in view of water supply

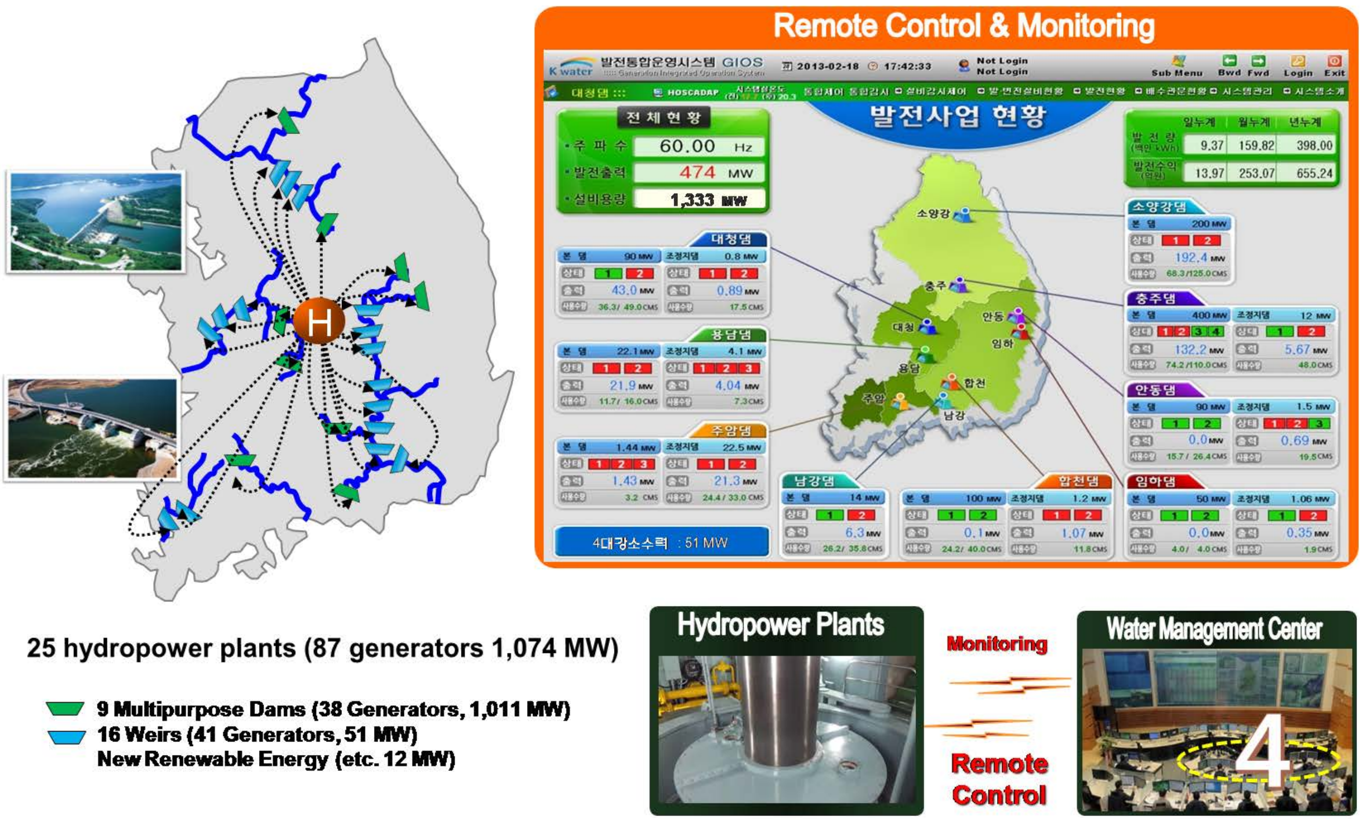


FIGURE 27: Generation Integrated Operation System

To make this efficiency possible, K-water has developed the Generation Integrated Operation System. K-water has also obtained the technology for water turbine performance testing, so it can continually improve power generation technology.

- GIOS (Generation Integrated Operation System): This system allows the Integrated Water Resources Management Center to remotely monitor and control all facilities needed to generate new and renewable energy. These facilities include nine large hydropower generators installed at multi-purpose dams, 16 small hydropower generators installed at weirs, a power generation facility at the Sihwa tidal power plant, and power transmission and transformer facilities.
- Water Turbine Performance Testing Technology: By making a small-scale version of the real water turbine, and creating test environments to measure the flow rate, pressure, and rotational speed according to the test standard, this technology enables K-water to perform various water turbine performance tests such as efficiency, cavitation, axial thrust, pressure ripples, non-constrained, air flow injection, Winter-Kennedy, and current observation.

4.1.4 Future Tasks

If heavy rainfall is focused in an urban area that is in the upper reaches of a river and there is no dam in the river, the result can be catastrophic. In October 2016, Typhoon Chaba destroyed the levees in the Taehwa River and six nearby tributaries in South Korea, as well as damaging numerous houses and vehicles. It was determined that this flood was a 200-year flood. In July 2017, a torrential rainfall of 98mm/hr lasted for three hours in Chungju-si, resulting in four casualties and over 500 houses being flooded. As such, water-related disasters due to climate change can occur anywhere, even close to where we live.

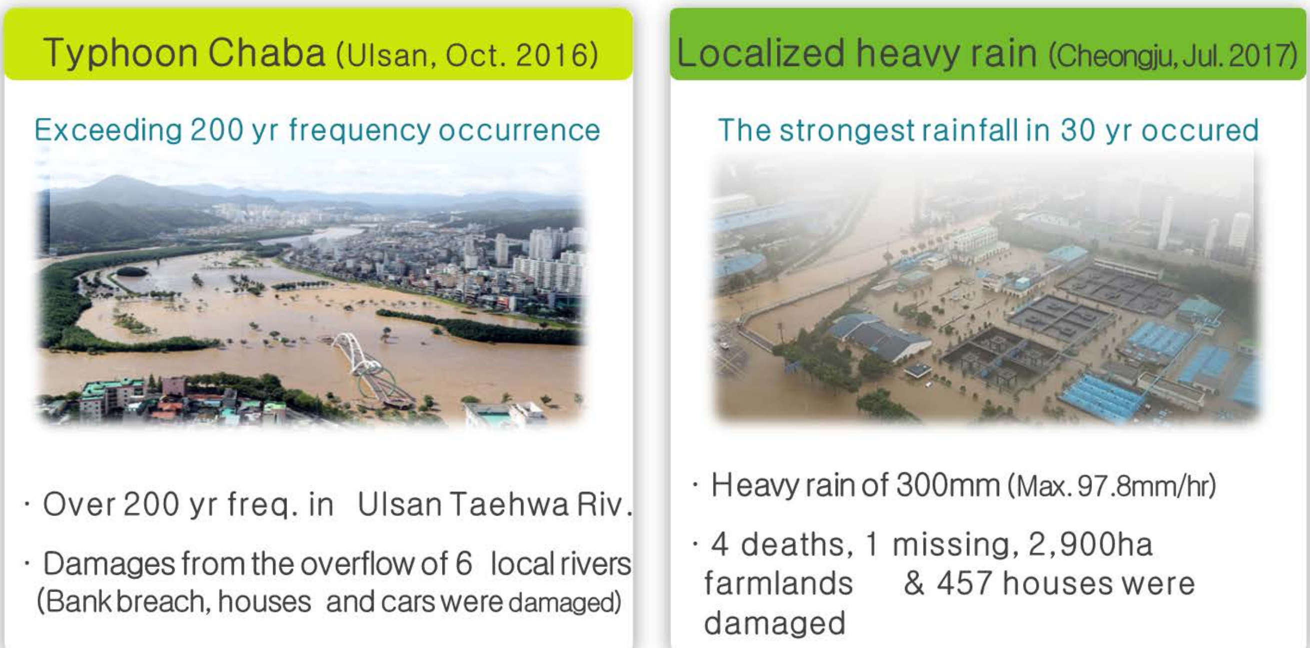


FIGURE 28: Hazards of urban flooding occurred in Korea

4.2 Metropolitan Integrated Operations Center of Multi-regional Water Supply Systems

4.2.1 Background

As Korea started to be developed and industrialized rapidly in the 1960's and 1970's, people began to move to Seoul and the Metropolitan area seeking decent jobs and better opportunities for their future. As a result, huge infrastructure investment, including water supply, was required for the industrialization and centralizing population. Seoul had Han River, passing through the center of the city. It had abundant water of acceptable quality to meet the city's own needs, but not enough to supply satellite cities. Therefore, the government decided to supply multi-regional water to the cities where water was not quantitatively and economically available, and took the role to K-water (Korea Water Resources Corporation), an SOE (State-Owned Enterprise) in charge of water resources development and management. The multi-regional water supplies managed by K-water cover approximately 50% of the country's whole water supply.

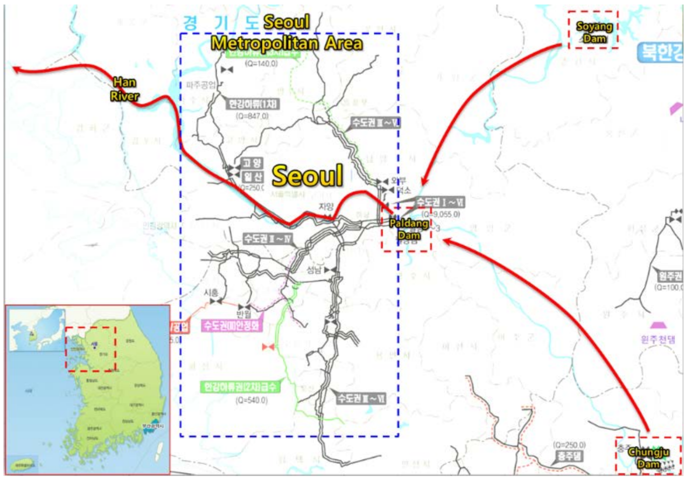


FIGURE 29: Metropolitan Multi-regional Water Supply Pipeline Networks

4.2.2 History and current status

The total capacity is 8,535,000 m3/day with five intakes, nine WTPs, thirteen pumping stations, and large-scale pipelines of 1,092 km. The whole system was developed in six phases, with phase I beginning in 1979 and phase VI rolling out in 2008, with intermediate phases occurring based on construction timing and depending on needs. All five intakes are located near the Paldang dam, where two rivers meet and the flow is also controlled by upstream dams. The multi-regional water is supplied to 27 satellite cities and a total of about 13 million citizens, and the quantity and quality (treated or raw) of the water are decided in the planning stage, depending on the needs of the cities. The tariff is the same throughout the country, but varies depending on the water quality (treated or raw). It is partly subsidized by the central government and is strictly controlled by stakeholders, including NGOs.

4.2.3 Advanced Water Treatment

The raw water quality for this water supply is relatively excellent (BOD 1.2ppm, SS 9.3 ppm, Chlorophyll-A 16.0 ppm) and is strictly controlled by several agencies, including the central government. Therefore, all the WTPs depended on the conventional treatment; that is, sedimentation, for rapid filtration and disinfection. However, public complaints about the taste and odor were raised repetitively and those issues turned out to be based on the Geosmin and 2-MIB. K-water conducted research over the course of several years to select the best technology with several combinations of pilot plants of the raw water, selecting the ozone and GAC in-between filtration and disinfection as the best one. The first design project started in 2006; currently, most of the WTPs supplying drinking water are equipped with advanced treatment, resolving the taste and odor issues caused by Geosmin and 2-MIB.

FIGURE 30: Sungnam Water Treatment Plant (786 m3/d) (K-water, 2015)

4.2.4 Multi-regional Water Supply System Integrated Operations Center

All the facilities were operated and controlled separately, therefore efficient O&M was not possible, nor was immediate action in the event of emergencies. Customers began to require improved service with immediate actions. Therefore, K-water completed the integrated operation center in 2007, and the whole systems are monitored and controlled at this center, with the least number of operators required at each facility. As an SOE, this approach was more for public satisfaction rather than decreasing costs.

All the facilities are databased through GIS, with real-time data collection, automatic detection for leakage, and an alarm system. Therefore, immediate detection and action are now possible for any possible threat to the water supply. In addition, water flow and pressure data are constantly collected and simulated to predict future accidents. This simulation also supports the decision-making for replacement or rehabilitation of facilities.

4.2.5 Network inter-connection

In Korea, all major activities are centralized into Seoul and satellite cities with a population of approximately 20 million, which is almost half of the country, even though the central government recently moved to a new town located in the center of South Korea. Therefore, the failure of water supply creates real chaos in everyday life and also to the industry, resulting in tremendous economic loss. Since the first phase was constructed in the late 1970s, operators began to worry about unexpected accidents due to deterioration.

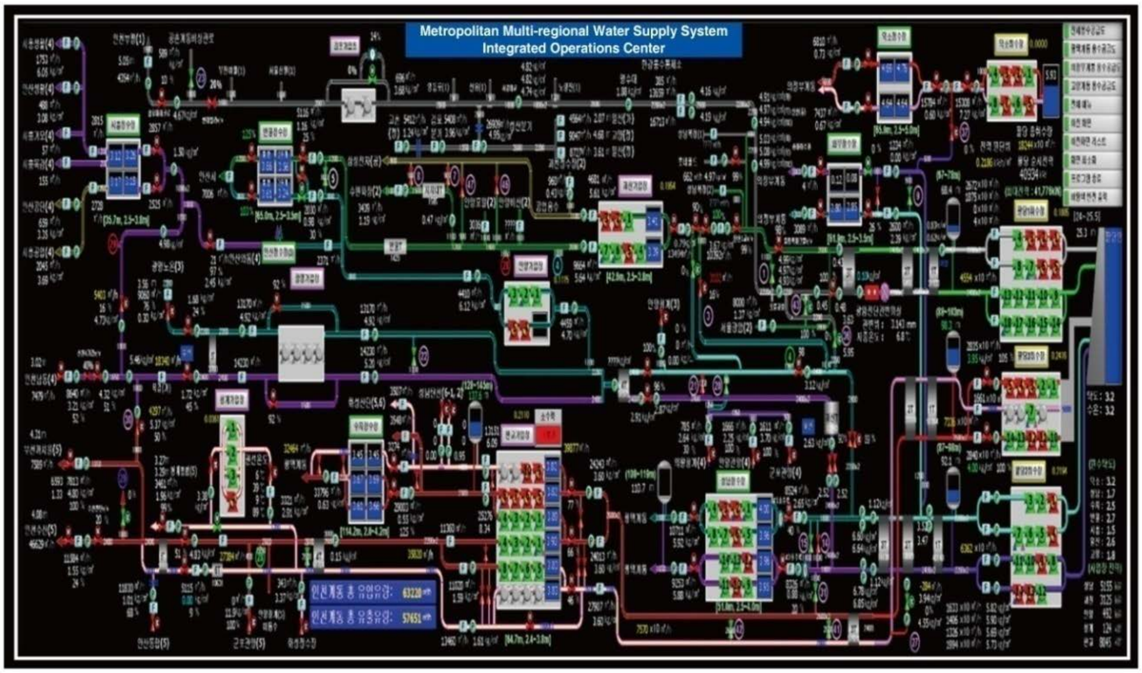


FIGURE 31: Integrated operational system composition

FIGURE 32: Integrated Operational Control Center for the Multi-regional Water Supply System

In some cases, a dual line was suggested, but it was estimated to be too early for such a large investment, including compensation for additional land and civil complaints. Instead, K-water decided to interconnect the network, where geographically possible, from phase I to phase VI. In this way, albeit imperfectly, K-water could minimize the water shut-down even during maintenance and unexpected accidents in the network.

4.2.6 Future plans

4.2.6.1 Dual Pipelines

Water quality is already highly acceptable, thanks largely to the introduction of advanced water treatment. However, most of the water supplier's concerns are water shut-down due to deteriorated pipelines. Network inter-connection has been a good solution, but it is not perfect. Therefore, a dual pipeline system is inevitable as a means of avoiding shut-down. At present, dual pipelines represent 20% of the entire pipeline system, and 72 inter-connections have been installed to prevent water shut-down. Using these facilities, alternate water paths can be found on the network, even though unexpected accidents, such as leakages, occur on 80% of the pipelines. Constant diagnosis and simulation are performed to make decisions about priorities. A dual pipeline system will soon be constructed to cover the other 20% of the pipeline system. From the point of a water supplier based on a cost-benefit analysis, this is not economically viable; however, as an SOE, this approach is inevitable if best public benefit is to be achieved.

4.2.6.2 Healthy Water Supply

In the 1970s, the major purpose of waterworks was to ensure sufficient water supply for people and industry. However, because of deteriorated raw water quality partly due to the industrialization, the paradigm shifted to safe water supply in the 1980s and 1990s. As of 2000, customers desire for water that is free of taste and odor has been taken care of, thanks to the successful introduction and operation of the advanced treatment process.

K-water monitors the water quality for 300 variables, despite the fact that national criteria include only 86 criteria. However, the tap water drinking ratio is just around 5%, while other OECD countries, such as the USA, Canada, and Japan mark around 50%. As a multi-regional water supplier, cooperation with local governments is required to increase this figure. K-water is trying to supply water with the best quality, with healthy substances such as minerals, and controlling the chlorine concentration in the network.

4.2.6.3 Smart Water Supply

The integrated operation center is a state-of-the-art ICT-based smart water system. However, it is limited to the point of a supplier and an operator of the facilities for efficient O&M. Some part of the extremely low ratio of the direct tap-water drinking is due to invisible distrust on the water supply system. Therefore, K-water is trying to open water supply information to the public through electronic displays on the street and/or via smartphone application. A pilot project based on a concession agreement with a local government successfully increased the ratio from approximately 1% to 25% by a similar approach.

4.2.6.4 Sharing Experiences and Best Practices

K-water has been in charge of the multi-regional water supply system for more than 40 years, and more than 10 years for the concession project, including distribution pipelines, with medium-sized cities having populations of approximately 100,000 people. As a result, K-water has experienced trials and errors, accumulating a huge amount of experience in practice and research/education. K-water, as an SOE, is quite open to external agencies even from foreign countries to share its troubleshooting and best practices. Therefore, any official visit for bench-marking K-water will be highly welcomed.

4.3 Revenue Water Ratio Improvement Project

Revenue water ratio is simply a rate of the amount of water supplied by the water reservoir to the water meter reading at the end of the pipeline network. A high revenue water ratio means there is little loss due to a water leak. Since it is tied to the water service provider's revenues, it can also indicate the company is in good financial condition.

In Korea, the revenue water ratio improvement projects used to be carried out by the local governments that managed the local water supply systems. But unfortunately, some of the water supply systems run by local governments had very low revenue water ratios and the local governments were seeking a solution. K-water proposed a revenue water ratio improvement project to some of these districts as part of the operation efficiency improvement project. In 2017, 22 local water supply systems showed dramatic improvements.

4.3.1 Revenue Water Ratio Improvement Procedure

The first step in improving the revenue water ratio is locating where the water is leaking. There are three approaches to locating a water leak, and the involve searching the 1) area, 2) line, and 3) point. First, a complex network of water supply pipelines needs to be categorized into zones and the water supply amount and the water meter readings need to be sorted. Then, the zone with the lowest revenue water ratio is identified. This is called the "area" approach. Once the area with the greatest water loss is found, then the pipelines need to be investigated to identify the pipeline with the biggest water loss. In this investigative process, water valves need to be closed sequentially. This is called the "line" approach. Lastly, to locate the water leak on a pipeline, various devices are used to determine the water leak location.

Once the point of water leak has been determined, the ground in this section is dug up and the water leak is verified. Afterward, the pipeline is fixed and the process is repeated in the same zone. Once the repair work is complete for the zone, workers move on to the zone with the second worst revenue water ratio and repeat the entire process.

Normally, when a leak is repaired on a pipeline, the water pressure inside the pipeline increases and it is prone for another weak spot in the zone to start leaking. Therefore, when a water leak is fixed, a pressure reducing valve needs to be installed at the entry point of the zone. This procedure can prevent additional water leaks. However, if water leaks continue to occur in the zone, then these pipelines are determined to be too deteriorated and it is time to plan for pipeline replacement.

4.3.2 Case of the Revenue Water Ratio Improvement

Most of the old cities have a large proportion of deteriorated pipelines because these cities adopted a water supply system early on. It is natural, then, to have many areas with low revenue water ratio. On the other hand, these cities have become central and the complexity of the water supply networks have increased. Therefore, it is difficult to perform pipeline repair work or replacement work.

Most of the Central and South American countries have historical, old cities. One of these cities is Talca, which is located in Chile. The Korean government and K-water have performed a beta revenue water ratio improvement project in Talca, and the result was 16-20% improvement. If the revenue water ratio projects become full-fledged in the future, the financial condition of the water service provider should improve significantly.

For a case in South Korea, we would like to introduce Nonsan city in Chungcheongnam-do Province. Nonsan was the first city where K-water undertook the water supply system operation efficiency improvement project. In 2004, when K-water took over the operation, the accounted water rate was a mere 54.9%. At the end of 2016, the accounted water rate was 84.6%. That is an improvement of 29.7%.

4.3.3 Smart Technology

To maintain the improved revenue water ratio, continuous monitoring is required, and smart water management technology can be applied for this purpose. Let's take a look at an example of how to set up a given district. First, a flow meter needs to be installed at the entry point of the water supply system in the district. This flow meter gauges how much water is supplied to the district. In addition, the water pressure may need to be lowered at times, so pressure reducing valves need to be installed. Water pressure at the entry point and the exit point need to be measured. These data need to be transmitted to the water supply system networks' operations center, so communications equipment needs to be installed at the entry point of the district. Now, the water supply amount for the district can be measured.

It would be ideal for monitoring purposes to get the water meter reading from every household in the district. It would not be economical to install a smart meter at every household, however, so smart meters can be selectively installed at households where water usage is high. Using these data, the trend of the revenue water ratio can be monitored. Also, the pressure reducing valves can be adjusted to maintain the highest water pressure in the district at an appropriate level. To do so, the operations center needs to monitor the water pressure at important points.

It is practical to install the electronic version of the aforementioned devices, so the various conditions of the water supply system can be monitored and controlled from the operations center. By using smart meters and by linking these meters to the water pipe networks' operation system or the water leak detection system, the operations center can perform telemetering and telecontrol. The technology which enables this system is called "Smart Water Management."

The smart water management technology has been applied in the 23 local water supply systems previously mentioned, as well as all multi-regional water supply system facilities.

4.4 Smart Water Grid

The origin of the Smart Water Grid traces back to the field of power generation. Electricity generating power plants are located in various locations and these facilities are interconnected in the form of a network. If one of these power plants has a problem, the electricity generated at a different power plant can be rerouted to consumers. As a result, the customers do not experience a power outage. This type of network is called a power grid.

Applying the same concept, a smart water grid diversifies the water sources and the supply pipelines so that end users will receive a continuous water supply. Recent climate change events have affected both surface water reserves and rainfall amount significantly, so the existing water sources may not provide a sufficient water supply. In addition, as the economy grows and new cities are built, new water sources are constructed. By inter-connecting these water sources to the existing water supply network, the water source can be switched to another one in the event of an emergency. A smart water grid thus ensures a stable water supply.

In addition, places like the Middle East, which has very little rainfall and almost no fresh water resources, depend on desalinated seawater and underground water as their main water source. In some parts of Europe, a mixture of surface water, underground water, and desalinated seawater is used to supply water. These are also examples of a smart water grid.

4.4.1 Solution to Drought

The Korean government has made provisions to cope with changes in regional water consumption over time and to prepare for emergency water supply situations. By inter-connecting water pipelines near the multi-regional water supply systems, water supply can be re-routed in the event of an emergency, thereby increasing the reliability of the water supply system.

This plan was spearheaded by the central government as part of the national plan, and K-water, which is the main operator of the multi-regional water supply system, has implemented the plan and is currently operating the system. Over the past three years, the western region of Chungcheongnam-do Province has experienced severe drought. As a result, Daesan Imhae industrial district was in danger of running low on water for industrial use. To overcome this problem, the water supply was pulled from a different water source, Lake Asan, and re-routed to Lake Daeho. This was possible because there were interconnected pipelines that were constructed during the water system modification project.

Due to climate change, rainfall is very low in the regions where the existing multi-purpose dam is located. It was predicted that normal water supply cannot be provided. To resolve this problem, the water was supplied from a different river system, Geum River, to the upper reaches of the multi-purpose dam. This waterway was constructed in 2015 when there was a severe drought in the area. A total of 70 billion won was invested so water could be supplied over a 60-meter height by applying pressure. This facility is operated only during emergency situations, and it is an example of a smart water grid.

We can look at several recent examples related to drought. Boryung multi-purpose dam, located in the western part of the Korean peninsula, has recorded a 19% water reserve rate. This is the lowest level since the dam was built. As a result, restrictive water rationing was enforced for 135 days. Only after constructing an emergency waterway, the Korean government was able to supply sufficient water from the nearby Geum River basin. This type of project is only possible during an emergency. However, when looking at this in a broad sense, this is also an example of a smart water grid.

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APPENDICES

Index of Appendices

Category	Technology	Subsystem / Title	Appendix
IWRM Projects			
Water information survey, management and analysis	RHDAPS(Real-time Hydrological Data Acquisition and Processing System)		A-1
	Riverflow Measurement Technology(RMT)		A-2
	M-WAS(Mobile Water Analysis System)		A-3
	HOPTC(Hydrological Observation Performance Test Center)		A-4
Water management forecasting & decision-making	K-HIT(K-water Hydro Intelligent Toolkit)		A-5
	PFS(Precipitation Forecasting System)	K-PPM(K-water Precipitation Prediction Model)	A-6
		CAM(Community Atmosphere Model)	A-7
	FAS(Flood Analysis System)	COSFIM(Coordinated Operation System for Flood Control in Multi-reservoirs)	A-8
		K-DRUM(K-water Distributed Rainfall Runoff Model)	A-9
	RWSS(Reservoir Water Supply System)		A-10
	GIOS(Generation Integrated Operation System)		A-11
	K-FAT(K-water Frequency Analysis Tool)		A-12
Operation & maintenance of dam structures	WRIS(Water Resource Integration System)		A-13
	WRSMS(Water Resources Safety Management System)		A-14
	KEMS(K-water Earthquake Monitoring System)		A-15
	D-SMART		A-16
	Large Geotechnical Centrifuge		A-17
	SMART-TM		A-18
Operation & maintenance of hydraulic structures in rivers	SURIAN (Supercom-based River Analysis Network)		A-19
	K-water GATe Water Combine(K-water Green-Algae-Tide Water Combine to remove algal blooms)		A-20
Water Supply Projects			
Quality management of water sources	MDSS(MIB Control Decision Support System)		B-1
Technology of water treatment system optimization	Dr.Water+(Knowledge-Based WTP Diagnosis Program)		B-2
	ICLP-WTP(Integrated Control Logic Program for WTP)		B-3
	KMWTP(K-water Mobile Water Treatment Plant)		B-4
	Decentralized Water Supply System		B-5
	Water & Sewage Demonstration Plant		B-6
Smart piping & operation technologies	water-NET(Diagnosis, Operation and Management System for Water Distribution Networks)		B-7
	iWater 5(SE)(Standard Water Operating Systems)		B-8
	RWIS(Real-time Water Treatment Information System)		B-9
	Water-INFOS(Integrated Waterworks Information System)		B-10
	FCPTT(Flowmeter Calibration & Performance Testing Technology)		B-11
	SCSL(Smart Cleaning & Spray-On Lining Technology)		B-12
Efficient wastewater treatment & operation technology	KSMBR(K-water Advanced Wastewater Treatment Technology with Membrane Bio-Reactor)		B-13
	Dr. Wastewater(Self-Diagnosis & Management System for WWTP)		B-14
Clean Energy Projects			
Hydropower generation	WTPTT(Water Turbine Performance Testing Technology)		C-1
Solar Photovoltaic Power	SOLATUS(Tracker-type Floating Solar Power Generation System)		C-2

RHDAPS

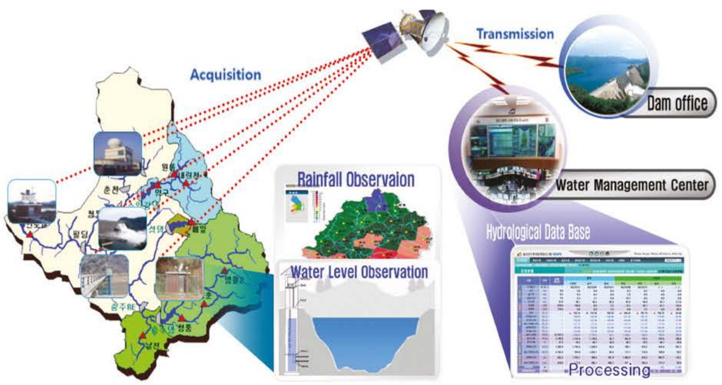
Real-time Hydrological Data Acquisition & Processing System

A-1

Overview

RHDAPS is a customized portal system based on web-DB to acquire, transmit, store and process real-time hydrological data (e.g., precipitation, water level, inflow, etc.), and thereby produce & supply quality data, including basic data for flood analyses and other visual data. This system is also equipped with the function of alarming against any emergency situations (e.g., a sudden rise in water level) via SMS, pop-up window, etc.

Configuration



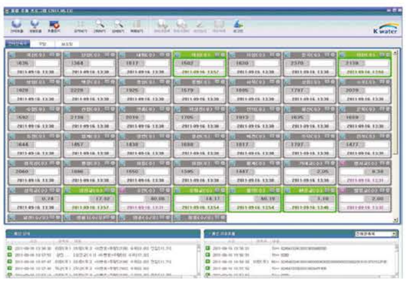
Features

- Acquires & produces real-time hydrological data
  - Ensures stable operation with wide range satellite communication technologies
  - Collects hydrological data for relevant organizations
- Stores & processes DB about dams & weirs
  - Stores hydrological data into DB
  - Enables the quality management of hydrological data
- Displays & provides hydrological data
  - Displays hydrological data for decision-making support
  - Provides real-time data about the status of dams & weirs, including image data

Functions

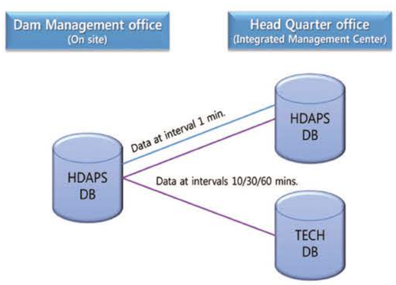
Functions to acquire & produce real-time hydrological data

- Calls & processes hydrological data
- Allows interface among different kinds of systems and processes data



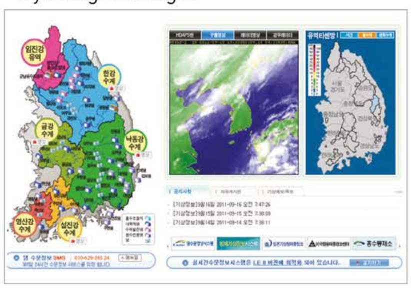
Functions to store & process hydrological data

- Collects & processes data at intervals of 1/10/30/60 minutes
- Calculates dam-related data and provide a transmission module



Functions to display & provide hydrological data

- Provides hydrological data about the status of dams & weirs around the country
- Provides a situational alarm along with hydrological images



Effects

- Possible to acquire quality data through improving the stability of system operation
- Possible to enhance capacity for disa ster management through ensuring the real-time analysis of hydrological data (e.g, water level, precipitation, etc.) and providing efficient decision-making supports

Applications

- 2003 : Applied to the operation of nationwide dams & weirs based on web-DB
- 2010 : Applied to the integration of image data and the improvement of display functions
- 2013 : Applied to the provision of status data about weir gates and the improvement of operator-specific functions
- Applied to the operation of K-water's hydraulic facilities & structures, including 17 multi-purpose dams, 14 dams dedicated to water supply, 16 weirs, etc.

A-2

Riverflow Measurement Technology

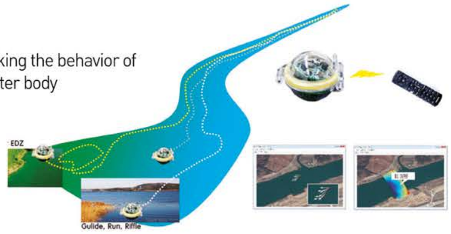
RMT

Overview

RMTs, which include multi-depth flowmeters, microwave surface velocity meter and gyro ball, are technologies to acquire reliable basic water resource data, and thereby perform relevant surveys in a timely manner

Configuration

Gyro ball for tracking the behavior of water body



Microwave surface velocity meter

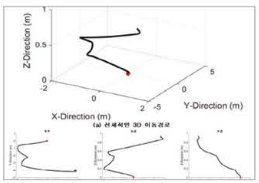
Multi-depth flowmeter

Features

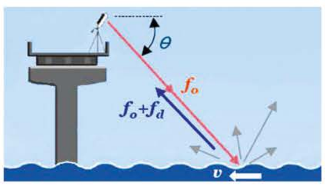
- Gyro ball
  Calculates 3-D flow velocity and travel distance, compare between gyroball flow velocity and measured flow velocity, and determine correlations among depth, temperature and flow velocity
- Microwave surface velocity meter
  Measures flow velocity on water surface from a difference between signals (Doppler frequency) sent and received from flow movement on water surface
- Multi-depth flowmeter
  Measures 3-point flow velocity at any given time through securing equal-ratio water depth based on the pulley principle

Functions

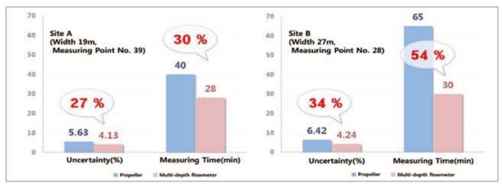
| Gyroball |



| Microwave surface velocity meter |



| Multi-depth flowmeters |



- Gyro ball : Functions to calculate 3D velocity and relative travel distance by calculating & integrating the accelerations of each axis, and post-process and visualize data with GUI
- Microwave surface velocity meter : Functions to resolve problems (that come from the risk of damages against rotational flowmeters, errors in measuring flow velocity with floats, a need to mobilize multiple personnel, etc.) through non-contact measurement methods, which, in turn, will make it possible to conveniently measure flow velocity even in case of flood
- Multi-depth flowmeter : Functions to save measuring time and reduce uncertainty by applying a simultaneous 3-point flow velocity measurement method

Effects

- Gyroball : Possible to track a river's 3D flow velocity, identify the point of flow stagnation, and thereby predict the point of water pollution
- Microwave surface velocity meter : Possible to regularly monitor flood discharge with an unmanned real-time flood measurement system
- Multi-depth flowmeter : Possible to save measuring time by 33~50%, and reduction uncertainty by up to 54%

Applications

- Applied to the measurement of flow velocity in a river (K-water, university labs, government organizations, etc.)

M-WAS

Mobile Water Analysis System

A-3

Overview

M-WASs are multi-purpose river Hydrological survey vehicles used to conveniently accommodate and transport such river survey equipment or instruments as flowmeters, suspended load samplers, S-boats, etc.

Configuration

Features

- Timely produces outputs by mobilizing mid-to-high speed flowmeters and suspended load samplers with a crane
- Possible to accurately moves & adjusts survey equipment with special devices (e.g., weight sensor, winch, etc.)
- Easy to accommodate relevant survey equipment thanks to a sliding platform
- Equipped with a portable refrigerator to prevent any pollution and alteration in specimen for water quality analysis

Functions

| Relevant equipment & tools |

[Medium-high speed flowmeter]

[Microwave surface velocity meter]

[ADCP]

[suspended load sampler]

| Storage of speciment for water quality analysis |

| Status view of surveys performed using a crane |

Effects

- Possible to improve the applicability & safety of survey equipments under various river conditions
- Possible to improve the storage & utilization of various survey equipment
- Possible to save traveling & measuring time
- Convenient to perform surveys at night time thanks to water depth and water surface detection sensors
- Possible to appropriately store samples as per a water pollution process test method.

Applications

- Applied for hydrological surveys required to operate K-water's dams and weir
- Applied to survey the status of salt damages, riverbed variation, etc.

A-4

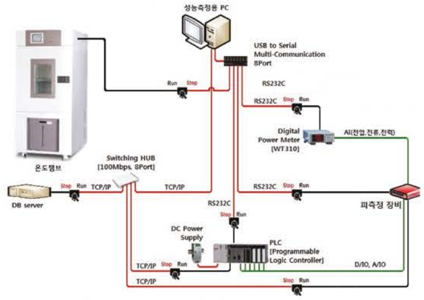
HOPTC

Hydrological Observation Performance Test Center

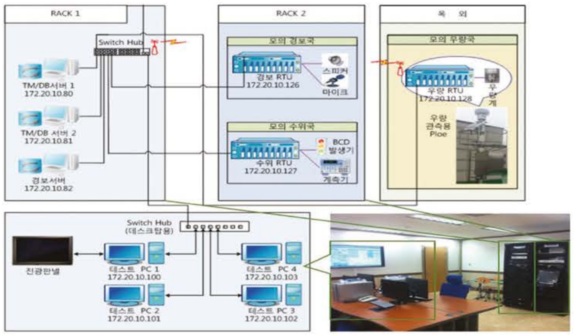
Overview

HOPTC is a proven performance test center with capabilities to perform overall performance tests on hydrological monitoring systems in terms of their performance, compatibility, applicability, reliability, etc.

- Develops a standard verification system through standard guidelines to performance tests
- Conducts the calibration of rainfall gauge and stage meters
  - Builds a world-class scientific facility management system
  - Supports the building of integrated flood disaster management system



Configuration



Features

Components	Performance tests
Gauging system	· Determine the measurement uncertainty of rainfall gauges, stage meters, etc.
Communications system	· Satellite, LAN, WiFi, Zigbee, etc.
Warning system	· Sound pressure test, sound collection test, etc.
R T U	· Protocol, applicability of new systems, etc.
Server	· CPU, memory service rate · Compatibility tests with other models
S / W	· Applicability, installment procedure
Miscellaneous	· Solar photovoltaic power, battery charge/discharge tests · Limit tests on facilities (data, environment)

Functions

Functions to monitor performance tests on a real-time basis

- Monitors real-time test data with a performance test program and builds DB

Functions to calibrate rainfall gauges

- Calibrates rainfall gauges in a calibration room or on an onsite basis / issues an onsite calibration certificate

Functions to calibrate stage meters

- Calibrates stage gauges in a calibration room / issues an onsite calibration certificate

Effects

- Contributes to the improvement of data reliability
- Used for the development of next-generation water management infrastructure markets & role models
- Allows the building of feedback system: Technical supports, training supports, PR activities, etc.

Applications

- Applied to the in-depth examination of the central control center for satellite communications network (HQ, Gunnam) (2013 to 2014)
- Applied to the analysis of RTU electricity consumption and limit temperature tests (2014)
- Applied to the calibration of gauges at 177 lots, including Inje Rainfall Gauging Station in the Soyang R. Dam (once every 3 years)

K-HIT

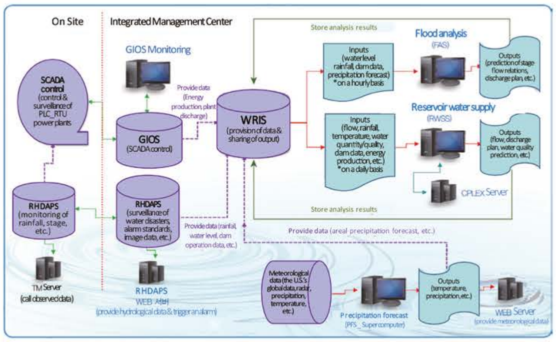
K-water Hydro Intelligent Toolkit

Overview

K-HIT is a decision support package converged with advanced ICTs and linked with individual water management technologies, which will ensure flood control & reliable water supply and monitoring of real-time data

- RHDAPS (Real-time Hydrological Data Acquisition and Processing System)
- PFS (Precipitation Forecasting System) : K-PPM (for short-term predictions), CAM (for long-term predictions)
- FAS (Flood Analysis System) : COSFIM (Coordinated dams analysis), K-DRUM (Distributed Rainfall Runoff Model)
- RWSS (Reservoir Water Supply System)
- GIOS (Generation Integrated Operational System)

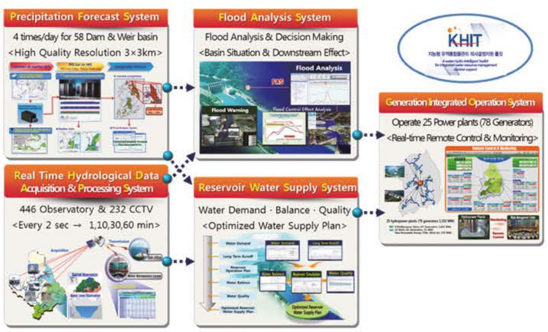
Configuration



Features

- IWRM (Integrated water resource management) technology based on know-how accumulated by K-water through 40 years of water management development and application practices
- Allows scientific analyses and predictions with ICTs for rainfall prediction, hydrological data management, disaster alarm, flood analysis, water supply, electricity generation, etc.

Functions



- RHDAPS
  Remote call & control of hydrological data, development of DB with real-time hydrological data, web-based monitoring of real-time hydrological data
- PFS
  Long- and short-term weather forecasting for target dam & weir watersheds
- FAS
  Hydrological flood analysis, multi-dimensional rainfall-runoff analysis, integrated hydraulic & hydrological analysis
- RWSS
  Estimation of rainfall & runoff, linked operation of dams & weirs, river flow analysis, river water quality analysis
- GIOS
  Real-time remote surveillance & control

Effects

- Rainfall prediction → data acquisition & management → flood control & water supply → integrated management of hydraulic structures & facilities (e.g., dam, weir, flood control reservoir)
- Contributes to improve the reliability of water supply through minimizing flood and drought damages with scientific water management practices
- Allows the linked operation of dams & weirs
- Allows the production of quality, clean energy

Applications

- Applied to the operation of K-water's hydraulic facilities & structures, including 17 multi-purpose dams, 14 dams dedicated to water supply, 16 weirs, etc.
- Applied to integrated flood disaster management projects for municipal & provincial governments (Namweon, Muju, Gunsan etc.)
- Scheduled to develop & build integrated dam operation system in Algeria

A-6

K-PPM

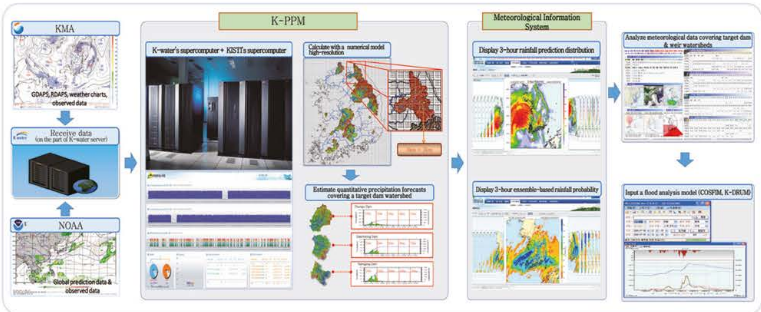
K-water Precipitation Prediction Model

Overview

K-PPM is a short-term precipitation prediction model to produce long- and short-term quantitative precipitation prediction data optimized for physical environment (e.g., detailed topography of the target dam watershed) by subdividing the nation into lots of grids with a size of 3㎞ × 3㎞, which compared with a long-term precipitation prediction model, CAM

- Produces 5-day (120-hour) prediction data 4 times per day with a 3km x 3km high-resolution model, which is composed of 10 ensembles
- Provides quantitative precipitation prediction data for 58 areas (including dams, weirs, etc.) nationwide
- Provides 10 kinds of real-time input data (including precipitation, temperature, humidity, etc.) required for water quality & hydraulic prediction models

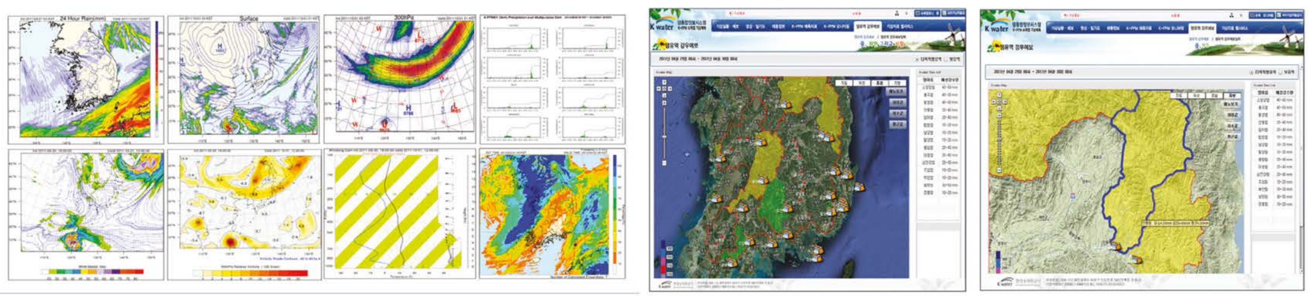
Configuration



Features

- Improves accuracy considering the complex topography of specific dam watersheds (covering mountains, valleys, etc.) through developing a 3㎞x3㎞ high resolution model
- Timely produces data easy to use through building a supercom-based automation system
- Remedies uncertainty in weather prediction data through simultaneously operating 10 models as per an atmospheric physical equation

Functions



- Functions to query 5-day weather prediction data at different altitudes at intervals of 3 hours
- Functions to produce & analyze GIS-based 5-day precipitation prediction data
- Functions to predict some 60 meteorological variables, including precipitation, temperature, humidity, air pressure, insolation, etc.

Effects

- Contributes to the maximization of power generation revenues &, storage through helping make a decision about the proactive, flexible operation of target dams with 5-day precipitation prediction data
- Minimizes flood damages through helping making a decision about dam discharge in a timely, accurate way
- Improves the accuracy of 5-day precipitation prediction data through installing ultra-short-term & data assimilation modules

Applications

- Applied to the meteorological prediction of 58 basins nationwide, including 17 multi-purpose dams, 14 dams dedicated to water supply, 16 weirs, etc. managed by K-water
- Applied to the "Proposal of Thailand Weather Prediction System in the integrated water management module of Thailand IWRM Project"
- Applied to the real-time production and provision of input data for flood & water quality analysis models

CAM

Community Atmosphere Model

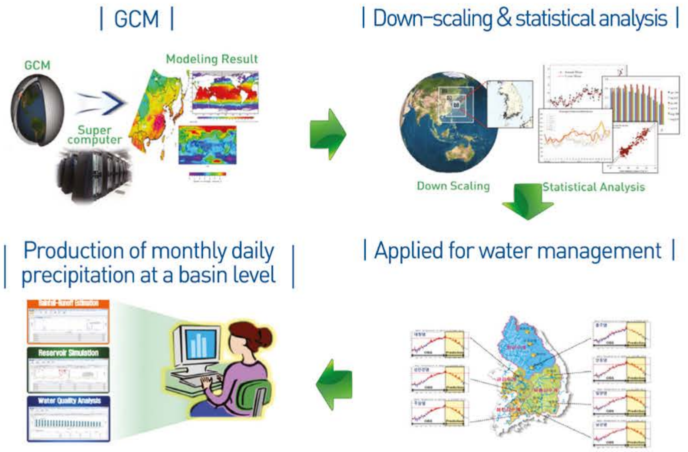
A-7

Overview

CAM is a global weather prediction system to quantitatively predict 1-month precipitation on a daily basis for each of target basins and produce 3-month seasonal weather forecasts required to formulate a reliable water management & supply plan

- Produces & provides 3-month quantitative precipitation prediction data
- Produces & provides 1-month quantitative precipitation prediction data from down-scaled 50㎞x50㎞ data (consisting of 10 ensembles)

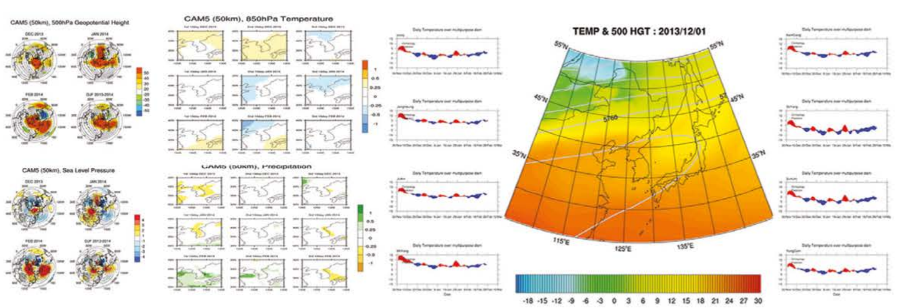
Configuration



Features

- Produces 3-month prediction data with a horizontal resolution of 50km and 30 stories in vertical level using CAM as developed by the U.S. NCAR
- Produces 1-month daily precipitation data using SSM (Slice Step Method), which is a combination of the down-scaling and statistical methods
- Reduces uncertainty in meteorological predictions by applying mean values as estimated from trying a model 10 times based on a time difference

Functions



Upper and Lower Level Fields

Temperature and Precipitation

- Functions to produce a deviation degree of monthly, quarterly upper-level circulation, precipitation and temperature
- Functions to produce monthly precipitation and temperature estimates for multipurpose dams
- Functions to produce 3-month weather forecast charts covering East Asia
- Functions to produce 36 global meteorological variables, including precipitation, temperature, etc.

Effects

- Contributes to the prevention of damages from algal bloom, flood and drought through providing quantitative precipitation prediction data by basin
- Maximizes power generation and water supply using long-term precipitation prediction data
- Secures infrastructure to develop offshore projects through verifying outputs and advancing the system

Applications

- Applied to the production of quantitative precipitation prediction data by basin to formulate a reliable water management & supply plan
- Applied to the production of seasonal precipitation prediction data (Korea Meteorological Administration's Long-term Prediction Experts Conference)
- Applied to the production of summer weather prediction data (Korea, China and Japan Long-term Prediction Experts Conference)

A-8

COSFIM

Coordinated Operation System for Flood control In Multi-reservoirs

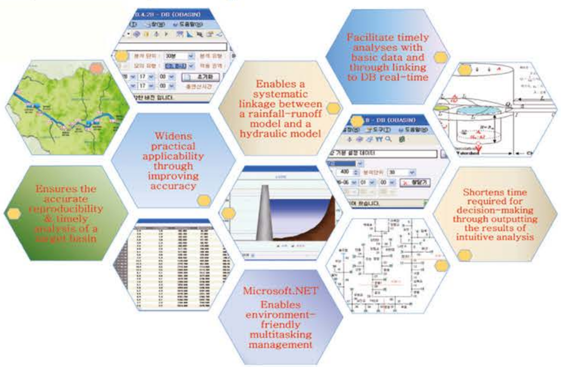
Overview

COSFIM is a basin-wide integrated flood analysis & decision support system to track hydrological status and predict precipitation on a real-time basis, which is compared K-DRUM is a distributed basin-wide runoff analysis model

- Timely produces basic data through ensuring real-time linkage to DB
- Helpful in improving accuracy and applicability
- Helpful in saving time required for decision-making by intuitively displaying analysis results
- Intellectual properties : COSFIM

Configuration

| COSFIM(Coordinated Operation System for Flood control In Multi-reservoirs) |



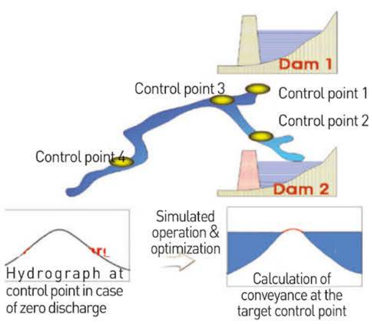
Features

- Equipped with functions to perform a hydrological flood analysis with a storage function method and a simulated operation of dams and weirs
- Equipped with functions for a hydraulic analysis of river and reservoir surface shape through automating linkage with hydrological analysis results
- Helps make a decision about discharge through evaluating impacts on the upper and lower river on a real-time basis (real-time linkage to DB)

Functions

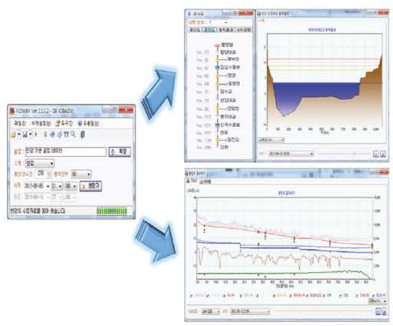
| Hydrological flood analysis |

- Estimates floods & reviews reservoir operation
- Analyzes the effects of linkage among flood, dams and weirs in terms of flood control



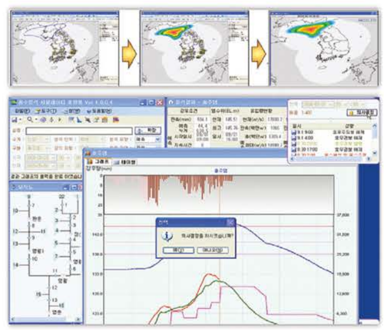
| Hydraulic flood analysis |

- Analyzes the impacts of flood on the lower river in case of dam discharge
- Performs a flood routing analysis considering tidal level at an estuary



| Simulated flood analysis |

- Performs a flood analysis of virtual meteorological data
- Make an objective evaluation of flood analysis results



Effects

- Contributes to reduce social, economic flood damages by lowering FWL through the linked operation of dams and weirs
- Contributes to the minimization of flood damages in the upper & lower river through ensuring the efficient linked operation of dams and weirs within a river system

Applications

- Applied to the development of an analysis model for target dams, weirs and basins and flood management practices
- Applied to the provision of technical supports for Algeria, the Philippines, etc. (as through building a flood analysis model and a simulation system)
- Applied to the provision of technical supports for municipal and provincial governments' integrated flood disaster management projects (as through developing a flood analysis model and monitoring standards)

K-DRUM

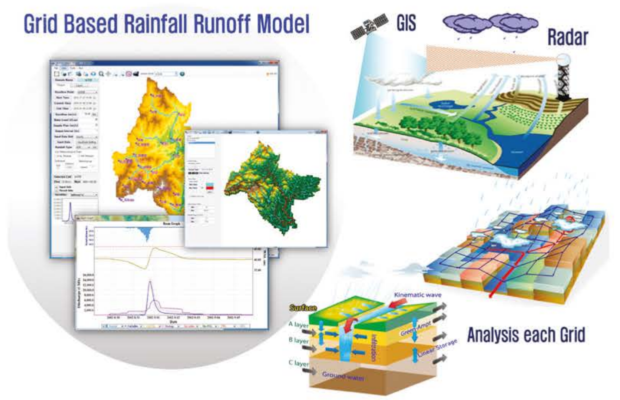
K-water Distributed Rainfall Runoff Model

Overview

K-DRUM is a distributed runoff model based on physically subdivided grids to survey and analyze basin runoff, suspended sediments and other water quality parameters

- Divides a specific basin into multiple grids, apply various physical characteristics (e.g., topography, soil. vegetation, etc.), and then calculate infiltration (from rainfall and other basin circumstances), surface flow, groundwater flow, evapotranspiration, snow-melt, sediments, water quality, etc. with a numerical analysis method
- Estimates normal runoff with an automated system to use meteorological prediction data

Configuration

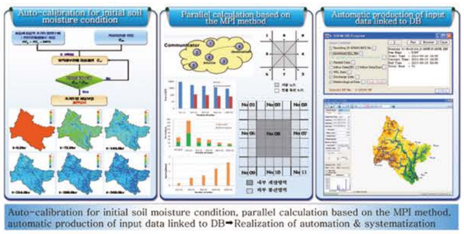


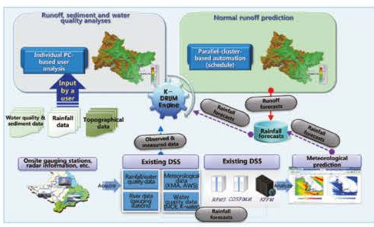
Features

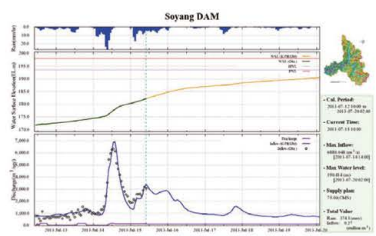
- Possible to build a completely automated system with the application of physical parameters and the initial soil moisture auto-calibration method
- Possible to perform a run-off analysis on an unmeasured basin with high accuracy
- Possible to perform a long-term runoff analysis on a large-scale basin with application of the MPI-based parallel computing method
- Possible to consider localized stormwater through inputting point rainfall data and high-resolution spatial distribution rainfall data
- Possible to analyze the behavior of sediments considering rainfall and flow energy

Functions

- Auto-calibration method (automation, systemization), PC-based analysis method (user-friendly GUI), server-specific system (normal runoff prediction system)







Effects

- Possible to perform short- and long-term rainfall-runoff & sediment analyses and save simulation time with a parallel computing technique
- Leads integrated basin analysis & prediction automation technologies
- Possible to acquire quality runoff data with high accuracy through improving a basinwide rainfall processing method
- User-friendly thanks to linkage to K-water's DB
- Equipped with evaluation technologies for unmeasured basins and newly developed basins

Applications

- Applied to the operation of a normal runoff prediction system linked to K-PPM (17 multi-purpose dams and 14 dams dedicated to water supply)
- Applied to the estimation of runoff and sediments required to survey dam sediments
- Applied to the development of one-stop water management system linked with KMA's LDAPS
- Introduced into the Pakistan Patrind HPP Project (long-term runoff pattern analysis); and applied to the estimation of evapotranspiration and soil moisture content (2014) in the target sub-basins of the Yongdam Dam watershed

A-10

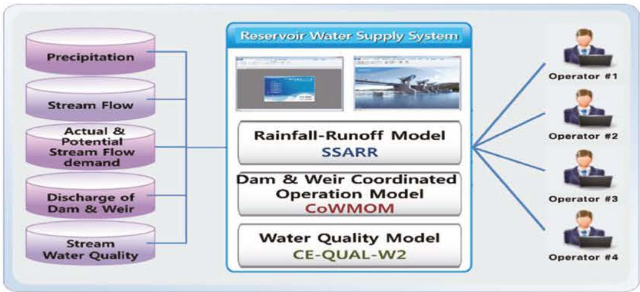
RWSS

Reservoir Water Supply System

Overview

RWSS is an integrated water resource management system to estimate optimal discharge for ensuring linkage among target rivers, dams and weirs considering expected flow into each of them and water demand within the same water system, and thereafter apply the optimal discharge estimates to a water budget analysis model and a water quality analysis model for estimating discharge availability at the event of water pollution and analyzing the effects of water quality improvement.

Configuration

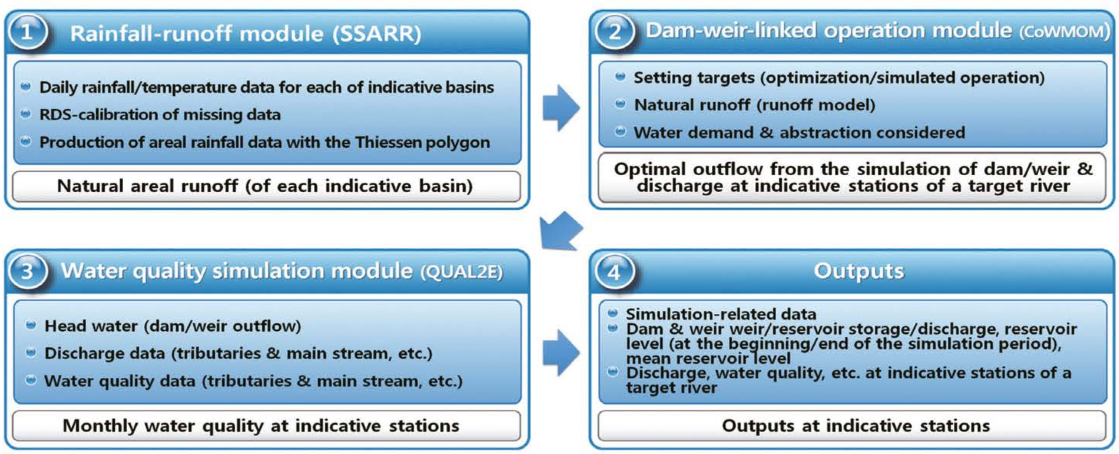


Features

- Serves as an integrated solution in which various water supply analysis models are combined
  - Consists of rainfall-runoff model, irrigation reservoir-linked module, water budget analysis model, water quality analysis model, etc.
- Controls inputs and outputs through developing a user-friendly phased GUI by each model
- Allows real-time linkage among meteorological data, river discharge data, dam or weir operation data, water quality data, etc.

System Connection

| Procedure for the integrated, linked simulation of water supply system |



Functions

| Integrated simulation environment |
- Provides user-friendly integrated simulation environment

| Dam-weir-linked operation mode |
- Performs a simulated dam-weir operation and an optimization analysis

| Rainfall-runoff model |
- Estimates runoff for each of typical basins with a long-term runoff analysis

| River water quality analysis |
- Simulates river water quality with the presence of dams or weirs

Applications

- Applied to the development of a dam-weir-linked operation plan for each water system considering expected flow into hydraulic structures and irrigation reservoirs in target river systems and water demand
- Applied to the estimation of available discharge capacity in case of water quality threats and algal bloom and the analysis of the effects of water quality improvement

GIOS

Generation Integrated Operation System

Overview

GIOS is an integrated operation system used for the real-time remote supervisory control of dam & weir generation, transmission and distribution systems and gates, and the production & provision of relevant data covering overall operation status and other statistical analysis data

- Ensures efficient water management decision making supports through providing data about the status of power generation and other statistical data
- Multiplexes major servers and networks to improve system reliability
- Manages malfunction logs for each of target facilities & structures, allows real-time alarm monitoring, and ensures data linkage among systems

Configuration

| Powerhouse |

- Surveillance & control of onsite facilities
- Configuration of RTU for control & data acquisition

| Water Resources Operations Center |

- Integrated operation, surveillance and control of target facilities & structures
- Data monitoring & analysis

9 multipurpose dams & 16 weirs (HPPs)

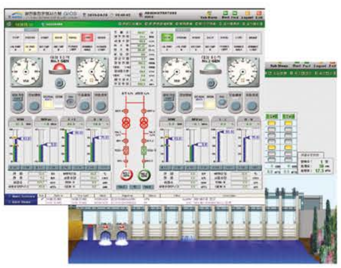
Features

- Dualizes surveillance control and data storage
  - Minimizes data loss and maintain surveillance & control functions through automatic switchover at the event of any failure or malfunction
- Develops a multiplexed communications network
  - Multiplexes WAN zones (2 wired/1 wireless)
  - Dualizes LAN zones (dualized structure of router & switch)
- Applies a standard connection method
  - Select major information communications infrastructure
  - Periodically inspect & address system weaknesses
  - Develops a cyber attack response system
- Certificed as GS (Good Software) by TTA

Functions

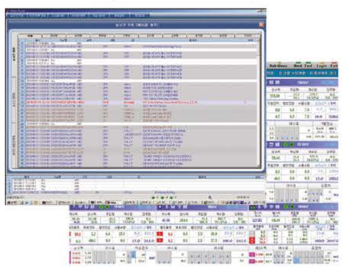
| Real-time surveillance & control |

- Integrated remote surveillance & control of generation & substation facilities and gates in 9 multipurpose dams nationwide and generation & substation facilities in 16 multifunctional weirs



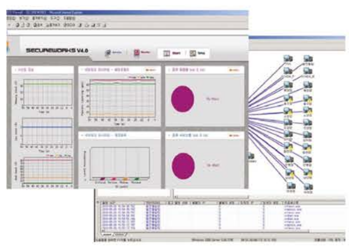
| Malfunction monitoring |

- Triggers an audio visual alarm when an alarm is needed
- Transmits an SMS message by level and manages alarm history



| System security |

- Prevents virus & cyber intrusion with Anti-Virus, IP(AMC), firewall, resource management system, one-way transmission device, integrated log-in management system, etc.



Effects

- Helpful in improving productivity through the optimal control of energy generation
- Helpful in saving production costs through ensuring unmanned remote generation surveillance & control
- Possible to improve the reliability of facilities thanks to a remote surveillance & control system

Applications

- Applied to the development of integrated operation system for 9 multipurpose dams (large hydropower) (April 2012)
- Applied to the remote integrated operation of 16 weirs (small hydropower) (May 2012)
- Applied to the remote integrated operation of Sihwa Tidal Power Plant (January 2013)
- Applied to linkage between the integrated mid- and small-scale dam operation system to HQ (December 2014)

A-12

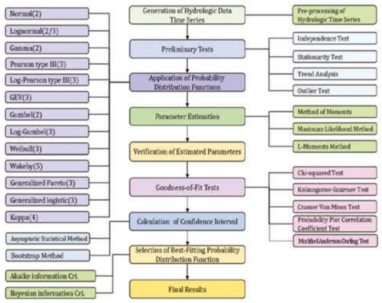
K-FAT

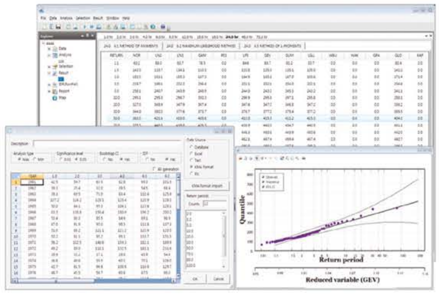
K-water Frequency Analysis Tool

Overview

K-FAT is a tool with which it's possible to acquire & preprocess hydrological data online and make frequency analyses of flood and drought through estimating 14 types of probability distributions, perform a goodness-of-fit test and determining an optimal probability distribution.

Configuration





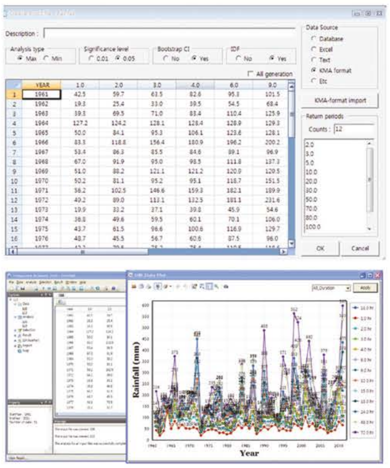
Features

- Capable for the batch processing of hydrological data at various points
- Pre-processes raw data of various types
- Provides GIS-based visualization functions at multiple analysis points

Functions

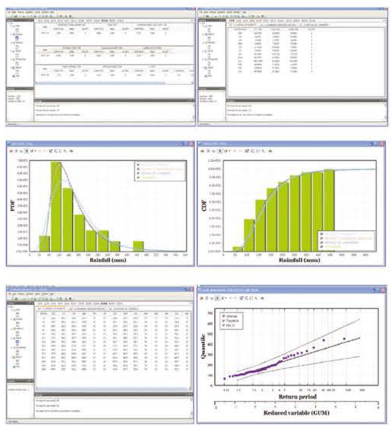
Functions to pre-process raw data

- Functions to pre-process K-water's own DB, Excel data, text data, KMA's raw data, etc.
- Functions to visually display outputs before and after preprocessing (e.g., graph or chart)



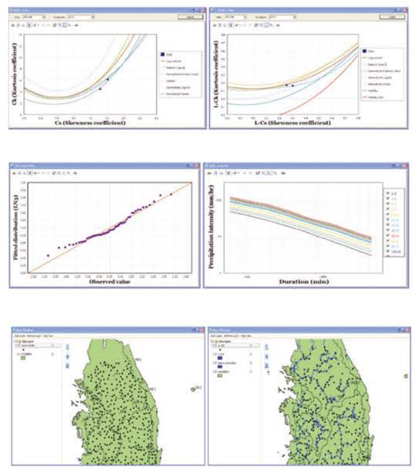
Functions to perform a flood & drought frequency analysis

- Functions to perform calculations with a frequency analysis module
- 14 probability distribution models; estimation of 3 parameters; 5 goodness-of-fit tests; calculation of uncertainty, etc.



Functions to display various analysis results

- Functions to select an optimal probability distribution model with MRD, LMRD, etc.
- Functions to produce histogram, IDF curve, etc.
- Functions to display multi-point analysis results on GIS



Effects

- Possible to use 14 types of probability distribution models and a frequency analysis timely and accurately
- Possible to perform a simultaneous analysis of hydrological data at multiple points with high efficiency

Applications

- Applied to the development of design & operation standards for various kinds of hydraulic infrastructure assets (e.g., dams, river banks, storm sewers, etc.)

WRIS

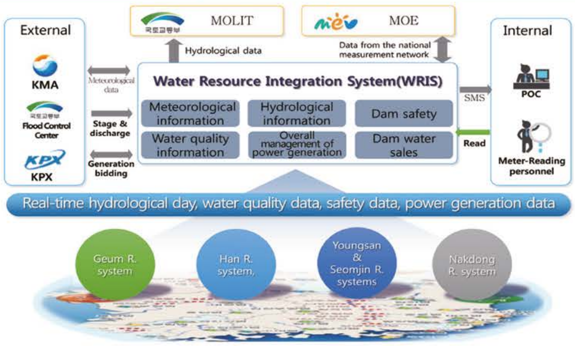
Water Resource Integration System

A-13

Overview

WRIS is a system to support & ensure the integrated operation & maintenance of dams and weirs using 6 kinds of data, including meteorological data, hydrological data, water quality data, dam water management data, dam safety management data, and power generation data.

Configuration



Features

- Provides relevant services (e.g., rainfall prediction, weather chart covering specific dam watersheds, etc.) with K-water's own meteorological prediction models
- Supports the integrated management of water resource operation information about target dams & weirs
- Shares operational status data through linking among real-time measured data about target dams & weirs & supports decision-making
- Shares data among relevant organizations (e.g., MOLIT, MOE, KPX, etc.)

Functions

| Meteorological information |

- Provides『meteorological information』(e.g., weather chart, rainfall prediction, etc.)

| Hydrological information |

- Supports overall decision-making through collecting『hydrological information』(e.g., inflow, discharge, energy production, storage, water level, rainfall, etc.)

| Water quality information |

- Manages pollutants and other environmental factors that affects『water quality』

| Dam safety |

- Ensures the『safety management』of various hydraulic infrastructure assets

| Dam water sales |

- Manages『dam water sales』for water supply plan, contract management, monthly reading, billing,, etc.

| Overall management of power generation |

- Supports the overall management of『power generation practices』related to power generation plan, bidding process (KPX), power operation, etc.

Effects

- Improves data reliability through ensuring the integrated management of water resource information & supports timely decision-making
- Shares meteorological data among relevant organizations (e.g., KMA, GFS etc.) and ensure proactive risk response through K-water's own meteorological prediction system
- Ensures efficient water quality management through managing pollutants and ecological environment
- Monitors safety threat factors to hydraulic infrastructure
- Ensures the systematic management of dam water supply

Applications

- Applied to the provision and utilization of hydrological data covering 17 multipurpose dams, 14 dams dedicated to water supply, and 16 weirs
- Applied to the development & operation of real-time surveillance system through linking among embedded gauges in 31 dams and 16 weirs nationwide
- Applied to the testing of 41 kinds of water quality items for each of 109 water quality measurement points and the utilization of the outputs

WRSMS

Water Resources Safety Management System

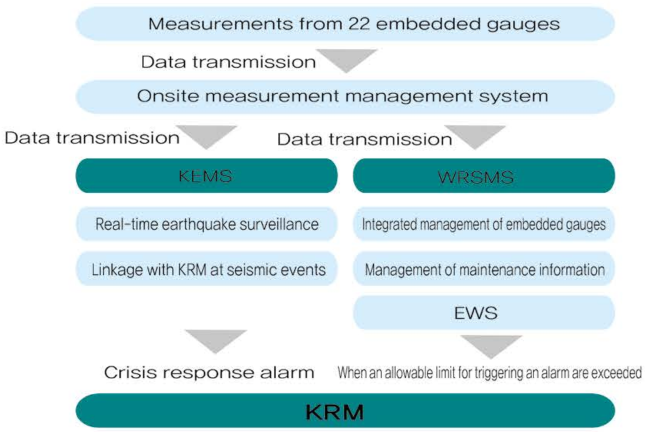
A-14

Overview

WRSMS is a system to trigger an early warning against any emergency situation through monitoring & analyzing information about the maintenance records of hydraulic infrastructure assets (in terms of regular inspection, repair and reinforcement) and nation-wide seismic events, and thereby ensure their safety management

- EWS (Early Warning System)
- WRSMS (Water Resources Safety Management System)
- IESS (Integrated Earthquake Surveillance System)

Configuration

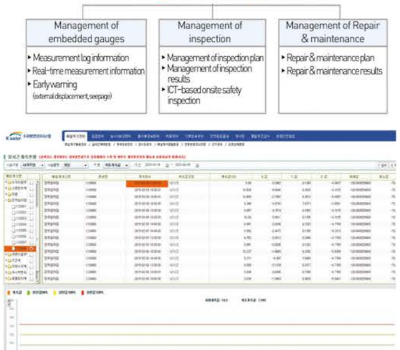


Features

- WRSMS
  - Manages embedded gauges
  - Manages repair & maintenance plans and results
  - Monitors real-time measured data
- EWS
  - Functions to build a timely onsite inspection system when any abnormal readings are detected
- IESS
  - Allows the real-time monitoring of seismic events

Functions

Water resource safety management system



Early warning system

Integrated earthquake surveillance system

Ensures the real-time monitoring of seismic events and the sharing of status data among relevant organizations

Effects

- Used to assess mid- & long-term dam stability through accumulating basic data
- Possible to systematically manage hydraulic structures & facilities through providing space dedicated to safety management
- Contributes to the improvement of the safety management of dam structures with remote monitoring & automation technologies against natural disasters and dam aging

Applications

- Applied to the operation of K-water's various hydraulic structures & facilities, including 17 multipurpose dams, 14 dams dedicated to water supply, 16 weirs, etc.

KEMS

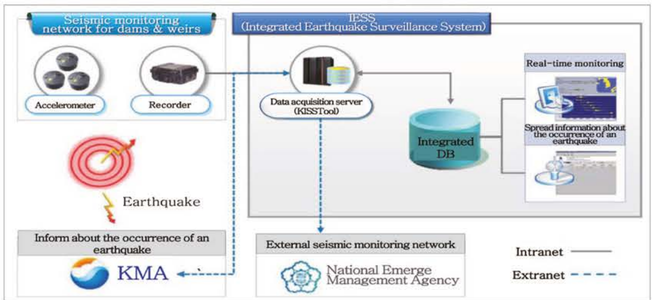
K-water Earthquake Monitoring System

Overview

KEMS is a system with which it's possible to receive & analyze real-time information about seismic event through ensuring the integrated management of seismometers at hydraulic structures (dams and weirs) and spread & share information about any emergency situation in a timely manner

- Status of installed seismometers
  - Installed in 17 multipurpose dams, 14 dams dedicated to water and 16 weirs, Nakdong R. Estuary Barrage, Gyeongin Ara Waterway, Sihwa Tidal Power Plant, etc., and monitored on a real-time basis
- Supports timely crisis response (Inland M4.0, Ocean M4.5) through automating linkage to K-water's KRM
  - Response procedure : Inform about the outbreak of an earthquake → Emergency inspection (within 3 hours) → Confirmation inspection (within 6 hours) → In-depth inspection (within 24 hours, if required)

Configuration

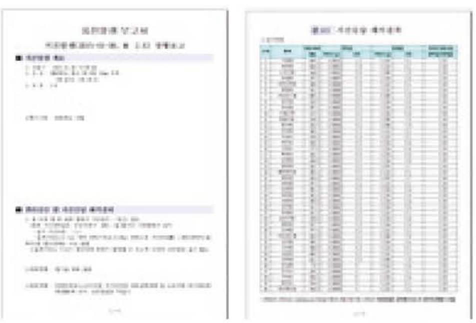


Features

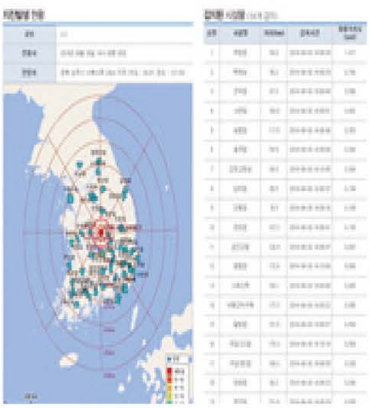
- Ensures the integrated management of seismometers:
  - Integrated management of information from seismometers (location, quantity) installed at all sites
  - Manages inspection history (initial inspection, regular inspection)
  - Transmits SMS messages to POCs automatically when any abnormal readings are detected
- Informs about earthquake information:
  - Timely informs applicable facility managers about the outbreak of an earthquake through ensuring linkage to KMA

Functions

- Automates linkage with KRM
- Creates a damage status report at seismic events
  - Automatic creation of seismic response analysis results



- Surveillance of all relevant sites at seismic events



- Real-time monitoring (seismic wave form, etc.)

Effects

- Possible to identify the status of earthquake damages an early stage of earthquake through enabling the timely detection of its outbreak
- Possible to share earthquake information among relevant organizations through ensuring linkage to the MPSS

Applications

- Applicable to national critical infrastructure (e.g., reservoirs, dams, gas utilities, nuclear utilities (KHNP), express railroads), substations, etc.) and other facilities or structures where seismometers are installed as per Article 5 of the Enforcement Ordinance of the Earthquake Disaster Response Act

A-16

D-SMART

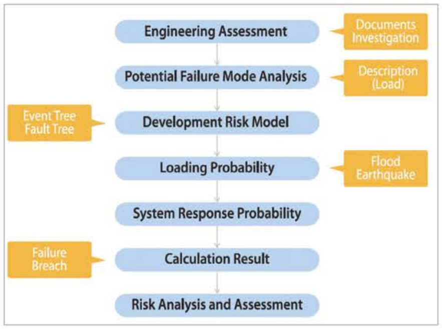
Evaluation tool for risk-based dam safety management

Overview

D-SMART is a DSS (decision support system) to determine risk factors in which the uncertainty of flood, earthquake, aging, etc. are reflected, present the quantitative results of failure probability, and thereby prioritize repair & reinforcement plans for the improvement of dam stability prioritize

- Hydrological, geotechnical analysis module ：Used to calculate the probability of potential failure mode accompanied by flood, earthquake, etc. against hydraulic structures
- Risk assessment tool ： Functions to design a risk analysis model, assess possible risks under different scenarios at a potential failure, and compare the effects of risk mitigation

Configuration

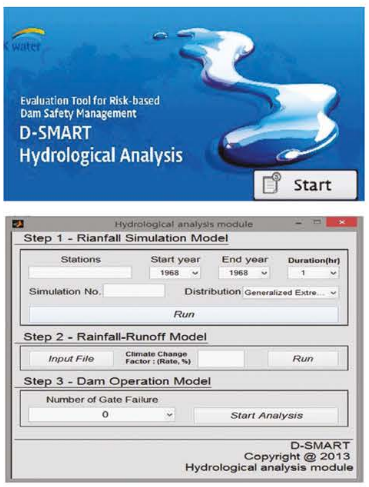


Features

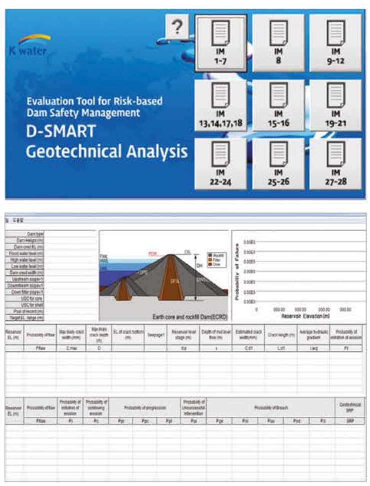
- Risk analysis module
  - Engineering assessment, history management of potential failure mode
  - Hydrological analysis module for climate change
  - Geotechnical analysis module for failure characteristics
- Risk assessment tool
  - Management of central server data & uses
  - Function of risk model wizard
  - Function of analyzing results to compare alternatives

Functions

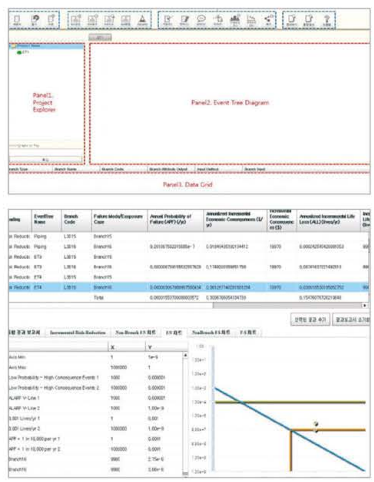
| Hydrological analysis module |



| Geotechnical analysis module |



| Risk assessment tool |



Effects

- Manages the history of dam risk factors & monitors inspection results
- Manages dam analysis data & improvement of data reliability thorough their control management
- Enables proactive responses through self-application & competitiveness improvement
- Produces quantitative, scientific results
- Produces optimal alternative by comparing among alternatives

Applications

- Applied to the risk analysis & assessment of target dams
  - Soyang R. Dam, Sueo Dam, Gwangdong Dam, Yeongcheon Dam
- Applicable to projects to stabilize aged reservoirs operated by municipal governments
- Introduced into a R&D project for disaster safety management driven by the MPSS (Ministry of Public Safety & Security)

Large Geotechnical Centrifuge

LGC

A-17

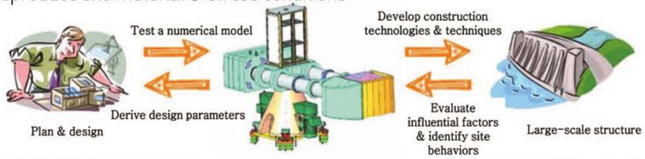
Overview

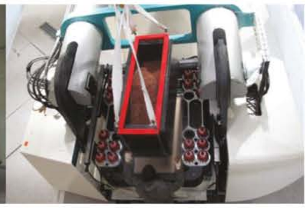
LGC is the world's largest modeling equipment used for the empirical safety performance evaluation of such critical water resource infrastructure assets as dams, multi-purpose weirs, water works, etc.

- Centrifugal model test
  - CMT (centrifugal model test) is a technique to simulate the behavioral characteristics of structures equivalent to the corresponding ones at an actual site through complementing incompleteness accompanied by scaling in scale model tests on geotechnical structures. With this technique, it's possible to represent similar material & geometrical characteristics and structural behaviors as shown in the structures at the actual site and identify a failure mechanism by applying various load conditions, which is why the technique has commonly been used as one of the most reliable geotechnical tests.
- Utilization of centrifugal model test
  - Used to evaluate the design appropriateness of large-scale structures and their stability against or their vulnerability to extreme natural events (e.g, flood, earthquake, etc.)
  - Used to identify the damage & failure mechanism of structures and evaluate the viability of any countermeasures

Configuration

Reproduce site material & stress conditions

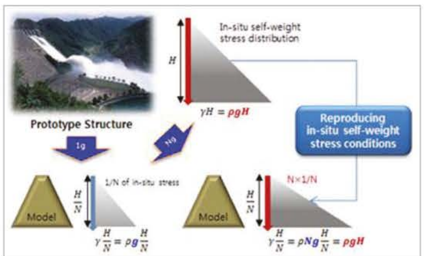




Features

- Reliable safety assessment technique in which the same material & geometrical characteristics as shown in large structure at an actual site are considered
- Used as an empirical validation tool for the safety of large-scale critical hydraulic structures whose design, construction, operation or checkup is underway

Functions



- Utilization of the world's largest centrifugal model tester (radius of gyration : 8m, accelerated 150 times as fast as gravity)
- Functions to identify the behavioral characteristics of dams, multi-purpose weirs, conduits, etc.
- Possible to evaluate the seismic performance of large structures using seismic simulation system

Effects

- Advances a process to validate and evaluate the safety performance of hydraulic structures against such extreme events as climate change, earthquake, etc.
- Resolves the constraints of numeric analysis method
  - Realistic modeling of structures & improvement of the geotechnical behaviors of ground materials in terms of reliability

Applications

- Applied to evaluate the appropriateness of long-term settlement estimates and the forced replacement method design for the construction of a guide bank training dyke as par of a project to expand a drainage gate for the Nakdong R. mouth weir (2013)
- Applied to evaluate dam responses to and safety against an extreme earthquake (0.94g) (in the seismic performance tests on the Philippine Angat Dam in 2014)
- Applied to evaluate the safety & behavioral characteristics of aged reservoir levee body at the event of storm water and reservoirs (Kangwon National University) and the seismic response of ocean wind power foundation (Kongju National University)

A-18

SMART-TM

HMI - based integrated package program for disaster management

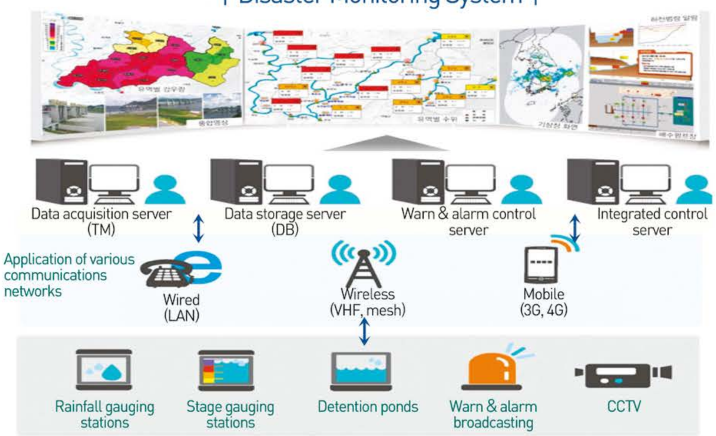
Overview

SMART-TM, an HMI-based integrated package program developed by K-water with its own flood disaster prevention technology, is a standard information delivery platform optimized for ensuring the effective acquisition & sharing of relevant data among different disaster management agencies and the remote control of relevant systems & facilities and developing disaster management systems

- With SMART-TM as an integrated package program, it's possible to monitor and control the whole status of a specific disaster (e.g., extreme flood) at a level of a single system.
- Composed of standardized information delivery systems (equipped with the integrated functions of data acquisition & storage, warning and integrated control), SMART-TM has been optimized to effectively share relevant information among different disaster management agencies and develop disaster management systems.

Configuration

| Disaster Monitoring System |

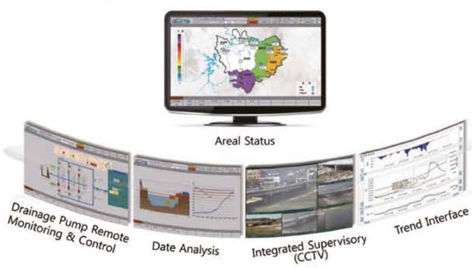


Features

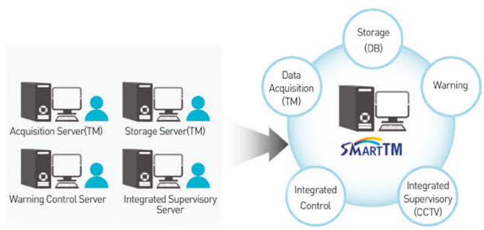
- Real-time monitoring & hydrological analysis
  - Acquisition of reliable data
  - Provision of real-time video monitoring functions
  - Provision of alarm as monitoring standards
  - Supervisory control of drainage pump station and detention pond
- Standard information delivery system
  - Standard platform for system integration
  - Possible to communicate among different models of systems
  - Sharing of hydrological among relevant agencies
- System integration
  - Equipped with the integrated functions of data acquisition & storage and warning
- Certified as Good Software by TTA

Functions

- Functions of integrated & supervisory control, data analysis, and video monitoring



- Integrated functions of data acquisition & storage, warning, integrated control, etc.



Effects

- Possible to maximize flood damages in small- and mid-scale rivers through building a customized flood disaster management system for flood-prone areas
- Possible to save costs for building & operating a disaster management system for municipal & provincial governments
- Possible to achieve flood-free land through linking to the national disaster response system

Applications

- Applied to the development & building of flood disaster management system for Namweon City (2011), Muju Country(2013), Gunsan City(2014)
- Applied to the development & building of customized flood disaster management system for each of municipal & provincial governments
- Applied to the development of overseas integrated flood disaster management projects

SURIAN

Supercom-based River Analysis Network

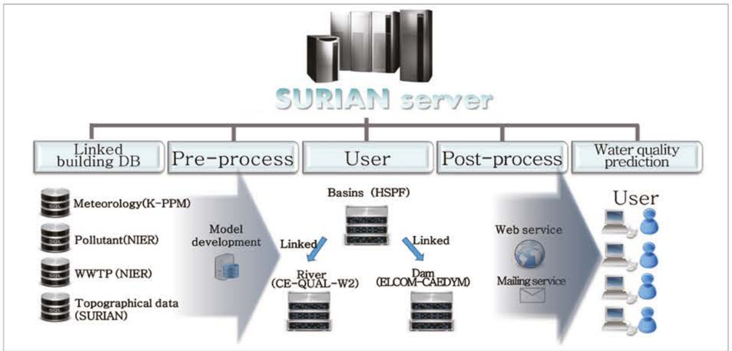
A-19

Overview

SURIAN is a system to provide more accurate water quality prediction data, improve capabilities to respond to water pollution accidents and facilitate decision-making through linking to K-PPM, HSPF, CE-QUAL-W2, and ELCOM-CAEDYM

- Real-time forecasting system
  - Real-time forecasting system to provide 5-day water quality prediction data every day through mailing and web services (containing temperature, BOD, TN, TP, SS, Chl-a, Geosmin, 2-MIB, etc.)
- Timely forecasting system
  - Timely forecasting system operated at a manual mode to flexibly respond to various water quality prediction scenarios and providing various post-processing functions, including user-friendly automatic modeling system and 3-D visual graphs

Configuration



Features

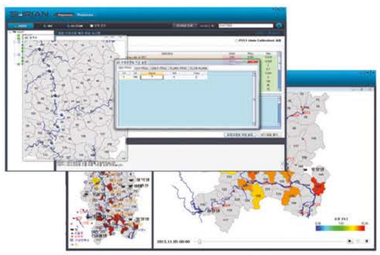
- Improvement of model driving velocity (by some 15 times) through building a server dedicated to model driving and applying parallelization (openMP)
- Provision of various post-processing functions (including automatic modeling system) through developing DB with model input data
- Building & Application of modules for advanced users (as through linking among models and applying PEST and BMPrac)

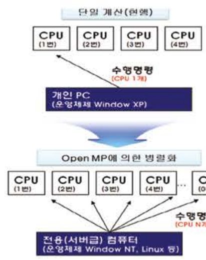
Functions

- Real-time water quality prediction system
- Automated driving of water quality model & provision of web services

- At-any-time mode (possible to apply different scenarios for different models)
- Maximization of accessibility to water quality model

- Improvement of the velocity of a 3-D reservoir model (ELCOM-CAEDYM)
- Building of a server dedicated to model driving & application of parallelization (openMP)





Effects

- Possible to timely and effectively to respond to water pollution accidents using water quality prediction data
- Improves accuracy through linking among models and applying automated correction program
- Possible to predict water quality based on various water quality scenarios
- Improves model driving velocity through server building & parallelization

Applications

- Applied to the reinforcement & utilization of water treatment process through predicting water quality for 19 rivers and 8 dams
  - Provides water quality prediction information for Daejeon Waterworks Headquarters (2013 to 2014)
- Water turbidity forecasting services covering Imha Dam, Hapcheon Dam, Nam R. Dam, Soyang R. Dam (2012 to 2014)
- Applied to the utilization of real-time water quality prediction data to manage agal bloom (February 2014)
- Applied to the prediction of odoriferous matters through a correlation analysis among Chl-a and Geosmin (2-MIB) (Bukhan River)

K-water GATe Water Combine

K-water Green-Algae-Tide Water Combine to remove algal blooms

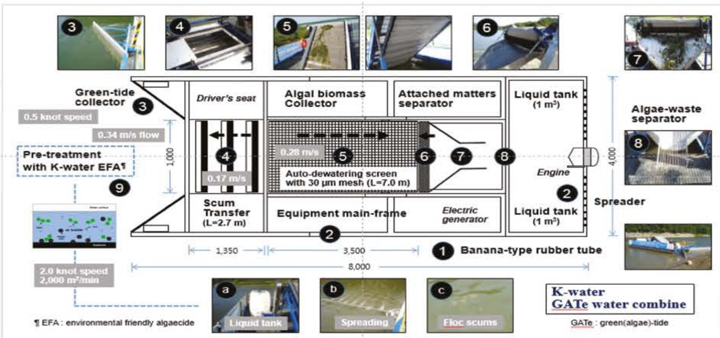
A-20

Overview

K-water GATe Water Combine is a technology to timely and directly remove algal blooms present in rivers and reservoirs through coagulating and floating them with physical and chemical methods

- With this technology, it's possible to remove & control agal blooms over wide areas, including a specific river system by coagulating and floating them using an agal remover, and then selectively removing them using an agal removal unit.

Configuration



Features

- Highly lightweight assembly type and very good in terms of mobility and applicability (possible to carry this combine with one 5-ton vehicle)
- No separate need for berthing facilities
- Excellent in terms of readiness (possible to carry this combine where agal blooms happen within 3 hours, and then remove them within 4 hours since)
- Possible to control & remove over wider areas and excellent in terms of economic feasibility and environment-friendliness

Functions

| Mobilize & carry |

- Improvement of mobility (timely mobilization)

| Assemble |

- Shortening of disassembly & assembly time to some 2 hours (from 3 hours)

| Spray chemicals |

- Spraying of chemicals evenly & improvement of the spraying system and the nozzles

| Remove agal blooms |

- Improvement of stripping device to separate off collected agal blooms and other impurities

Effects

- Develops onsite practical technologies to proactively respond to agal blooms, and thereby resolve the problem of agal blooms in large rivers and reservoirs
- Develops & provides next-generation pollution purification technologies by changing waters where agal blooms happen to a brand-new concept of resource production base
- Used as a tool to manage water pollution beforehand through onsite practical optimization, and improve the environment of waterfronts (amenities)
- Advances basin & water quality management practices through applying BT and ET convergence technologies
- Development of environment-friendly technologies to control agal blooms → Development of K-water's own source technologies to relevant on-shore & off-shore markets

Applications

- Applied to the removal of agal blooms in the mainstream of Hapcheon & Changnyeong Weirs and its tributaries (some 1.7 tons)
- Applied to the monitoring of where agal blooms occur at Nakdong R. Bonpo Intake Station & removal of pollutants flowing in the tributaries (0.9 ton)
- Applied to the removal of agal blooms in Chuso-ri Waters of Daecheong Dam (2.9 tons)
- Utilized as response technology to agal blooms in large river basins

MDSS

MIB Control Decision Support System

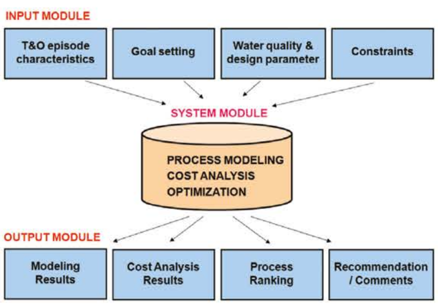
B-1

Overview

MDSS is a system to help decision makers optimize water treatment processes considering water quality conditions and design parameters, and thereby control MIB, a main cause of taste and odor in drinking water.

- Allows users to determine optimal water treatment system from the integrated results of the cost analysis and the simulation of seven water treatment processes (PAC, GAC, BF, O_3, UV+H_2O_2, and NF) so as to cost-effectively control the cause of taste and odor (MIB) in drinking water
- Provides information on the design of optimal processes, establishment of water treatment strategies, and achievement of optimal process operation in new and existing water treatment plants.

Configuration

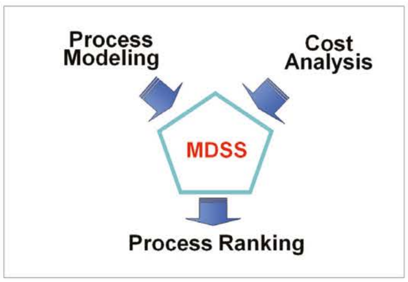


Features

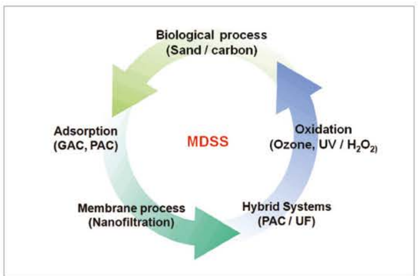
- Consists of three modules
  - Input module : 4 categories
  - System modules : Process modeling, cost analysis, and optimization
  - Output module : Modeling results, cost analysis results, process ranking, and recommendation/comments
- Ranking and Scenario Evaluation : Comparing processes in line with relative O&M, capital, and total cost to determine the priority of processes

Functions

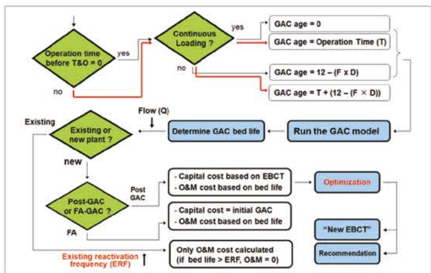
| Main Functions |



| Applicable Processes |



| Algorism of GAC |



Effects

- Evaluates processes in terms of the ability to control MIB and Geosmin
- Develops algorithm models characterized by processes to control taste and odor in drinking water
- Based on algorithms, developing a decision support system to provide a proper guidance for taste and odor control at water treatment plants in line with raw water quality

Applications

- 7 advanced WTPs in Metropolitan Area

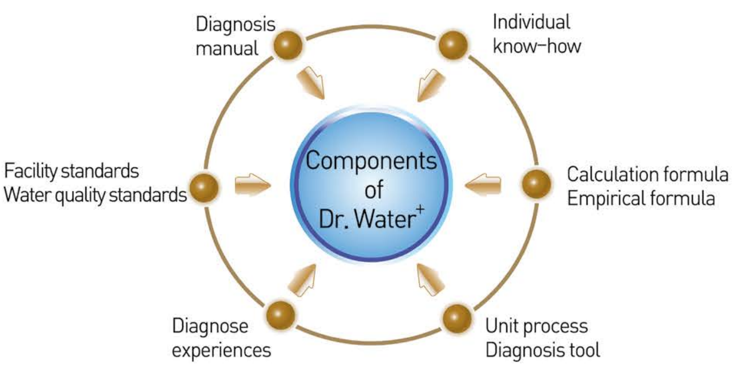
Dr.Water+

Knowledge-Based WTP Diagnosis Program

Overview

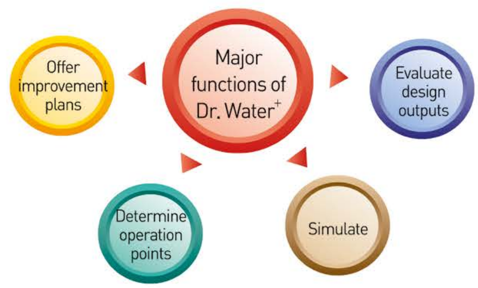
Dr. Water+ is a program dedicated to the technical inspection of WTPs (water treatment plants) and their water treatment processes. This program functions to derive any constraints in the performance of the water treatment processes, and thereby develop an operation & maintenance plan for ensuring efficient water treatment

Configuration



Features

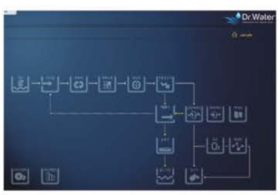
- Evaluates the design & operation and economic feasibility of each process to identify optimal operation points
- Derives optimal process design and operation factors



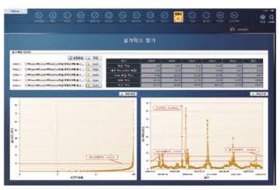
Functions

- Contains a list of 51 diagnostic items in 9 water treatment processes.
  - 9 processes : Gauging well, Chemical treatment, Distribution channel, Mixing, Coagulation, Sedimentation, Filtration, Disinfection, and Effluent treatment
  - 51 diagnostic items : Evaluating the appropriateness of hydraulic structure for each process, the characteristics of filter medium, and others
- Includes a Guidebook for the Technical Diagnosis of Water Treatment Plants (e-book)
- Includes an Ozone Simulator to diagnose ozone process

Main screen



Process analysis Graph drawing



Process analysis Hydraulic evaluation

Guide book for technical diagnoses

Effects

- Provides an effective tool for technical diagnosis
- Ensures the objectivity of results from computer-aided diagnosis approach
- Contributes to effective operation and maintenance of water supply system

Applications

- The technical diagnosis of municipal and industrial water supply systems (2011 ~ 2014)

ICLP-WTP

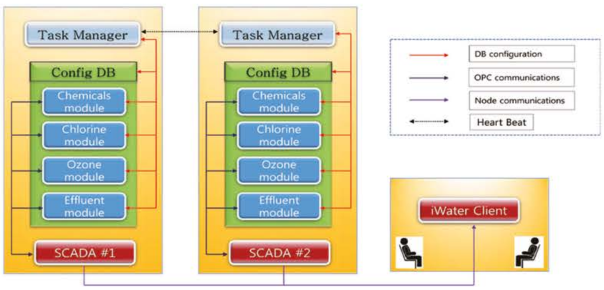
Integrated Control Logic Program for WTP

Overview

ICLP-WTP is a program for the smart monitoring of water treatment processes using a conventional control method and a data mining technique (to ensure the supervisory control of major water treatments (e.g., chlorination) and effluent treatment processes)

- Integrated Control Logic Program for Water Treatment
  - Up-to-date control method is used to ensure stable water production and standardize water treatment control logic.
  - Contains a core process automation software technique for the control logic of production technology-dependent main water treatment processes.
- Integrated Control Logic Program for Effluent Treatment
  - Implements a continuous integration system of effluent treatment process to increase sludge treatment capacity and to meet the legal effluent quality standards
  - Analyzes realtime material balance to monitor sludge for each section, and control retention time/schedule and change effluent structure/facility to ensure flexibility.

Configuration

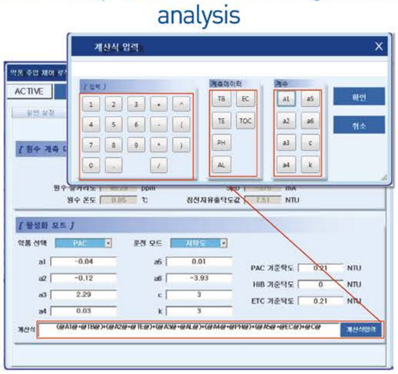


Features

- Application-based control logic
- Determine scientific feed rate on data mining
- Analyzes realtime sludge material balance of effluent process
- Controls retention time to meet legal effluent water quality standards
- OPC communication and tag mapping provide expansibility
- Certified Good Software

Functions

Chemical process control in regression analysis



Realtime material balance analysis of effluent processes

Main Algorithms

- Integrated Control Logic Algorithms for Water Treatment
  - Chemical : Multiple Regression Equation
  - Disinfection : Multiple Loop Control
  - Ozone : Multi-point Operational Formula
- Integrated Control Logic Algorithms for Effluent Treatment
  - Sequence, estimated sludge production, and retention time control

Effects

- Determines scientific feed rate corresponding to a given water treatment condition to enhance the stability of drinking water
- Implements a continuous integration effluent system to increase treatment capacity and to meet the legal effluent quality standards
- Reduces costs related to the extension to application-based program and ensuring versatility
- Secures core software technologies and creating value-added technologies

Applications

- Pilot implementation of an integrated control logic program for water treatment processes (2010-2012)
  - Cheongju WTP (chemical and disinfection), and Seongnam WTP (ozone)
- Expansion of integrated control logic program for water treatment processes (2012-2014)
  - Ilsan WTP, Deokso WTP, Gogryeong WTP, and Bansong WTP
- Pilot implementation of an integrated control logic program for effluent processes (2014-2015)
  - Boryeong WTP

B-4

KWMTPs

K-water Mobile Water Treatment Plants

Overview

KMWTP is a relocatable water treatment plant to evaluate and select an optimal water treatment process when there is a change in the quality of raw water accompanied by climate change or small modicums of pollutants flow in (newly)

- Mobile water treatment plants (KMWTPs) allow on-site evaluation of BAT (Best Available Technology Economically Achievable) to timely respond to new trace pollutants in water and changes in raw water quality due to climate change.
- The MWTP is used to identify threshold concentration and operating parameters for the treatment of polluted water on site so as to determine technological solutions ensuring water safety against new pollutants and quickly responding to water pollution incidents

Configuration

- (Unit 1,100㎥/day) Coagulation → DAF → Microfiltration (MF) → AOP → Ozone → Activated Carbon → UV, etc.
- (Unit 2,100㎥/day) Microfiltration (MF) → Nano (NF)

Features

- Implements actual water treatment processes in a mobile plant
- Focuses on quick response to unusual water quality due to new pollutants and water pollution incidents

Functions

| Trailer-mounted MWTP for immediate mobility |

| Wing opening truck body for increased work space |

Effects

- Carries out on-site evaluation and optimization of water treatment processes for each intake source
- Identifies parameters for design and operation of new and rehabilitated water treatment plants to appropriately respond to new pollutants and climate change

Applications

- Applied to the evaluation of the efficiency of treating
  - Tate & odor attributable to blue-green algae (anabaena spiroides) in the Han R. system (2013)
  - Clogging of filtration pond attributable to diatom in the Nakdong R. system (2014)
  - Pollutants in Asan Lake (2014)
  - Hardness substances at Danyang WTP (2014)

Decentralized Water Supply System

DWSS

B-5

Overview

DWSS is a safe, reliable advanced water supply system to ensure the distributed relocation of water treatment plants around customers and secure emergency water using a vertical-type water treatment technology (which is a brand-new concept of compact vertical-structured water treatment design technology)

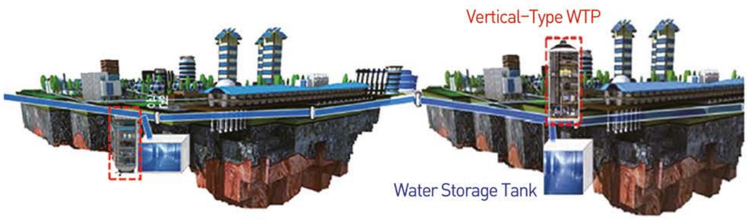
- Vertical-type Water Treatment Technology

  A tankless water treatment system, including membrane filtration and pressure-type advanced water treatment (ozone and activated carbon), shall be installed in vertical structure to considerably reduce the installation area to 1/3 of that for the existing design technology.

- Decentralized Water Supply System

  A vertical-type water treatment technology shall facilitate a customer-oriented safe and stable water supply system of the future by decentralizing water treatment plants and securing auxiliary water sources and emergency water supply.

Configuration

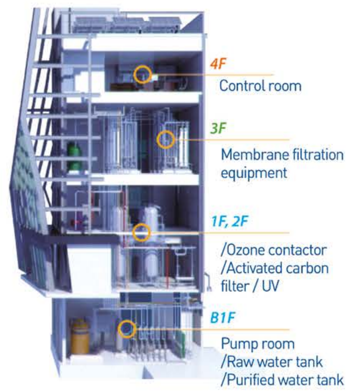


Features

- Small-sized vertical water treatment plants facilitate decentralization of water supply system within the city.
- Decentralized water supply system, combined with auxiliary water sources and emergency water supply storage using storage tanks and deep tunnels, ensures a safe and stable water supply.

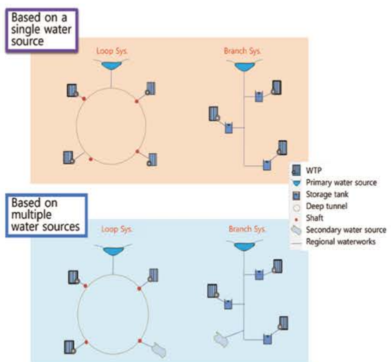
Functions

| Vertical Water Treatment System |



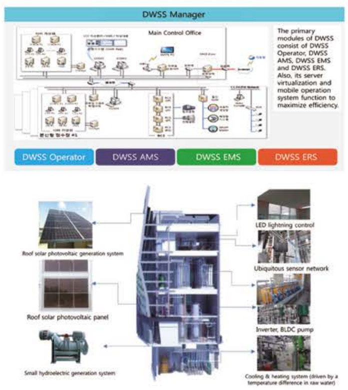
- Pressure-type process package
- A compact tankless system

| Decentralized Water Supply System |



- Optimal location methodology
- Direct, indirect, and hybrid water supply systems

| Clean & Low Energy Technologies |



- Clean energy (small hydropower, water temperature difference and solar power)
- Low energy design

Effects

- Ensures customer-oriented safe and stable water supply in the future
- Aims to make zero cutting-off water supply and increase a direct water supply rate from the current level of 5% to 30%
- Used in other water supply systems, for example, high quality industrial water supply
- Energy saving from clean energy

Applications

- The vertical water treatment demonstration plant in the K-water Cheongju Water Treatment Plant (1,000㎥/day)
- The introduction of the decentralized water supply system in the Saemangeum development project is currently underway.

B-6

Water & Sewage Demonstration Plant

WSDP

Overview

WSDP is a technology to enable the methodical, systematic performance of relevant researches by installing a demonstration plant for validating each of various water treatment processes and capacities, and ensure the timely provision of onsite supports with test beds

- Demonstration plants (Installed Capacity 1,000㎥/day · line × 2 lines)
  - (Line 1) Pre-ozone-Coagulation-Sedimentation-Filtration-Post-ozone-Activated carbon
  - (Line 2) Coagulation-Sedimentation (Inclined plate)-Filtration-Activated carbon
  - 1 unit of each dissolved air flotation (DAF) and non-powered coagulation and sedimentation, and 1 set of effluent water basin
- Pilot Plants (5 processes, 235㎥/day)
  - Optimization of existing processes : Coagulation/sedimentation tank, filtration basin, and underdrains
  - Membrane filtration (UF/MF/NF/RO)
  - Advanced treatment (ozone and activated carbon) : Ozone generator, and activated carbon column
  - Sewage treatment : Reactor (6 ea), inflow storage tank, and settling basin
  - Pipelines : Corrosion test facilities, storage tank test equipment, and pipe physical properties test facilities

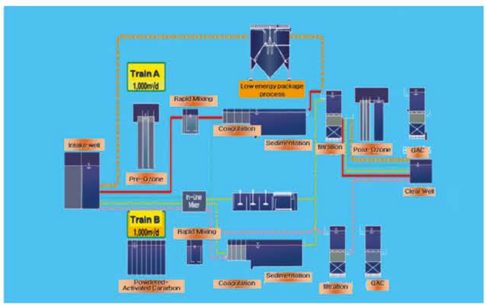
Configuration

Features

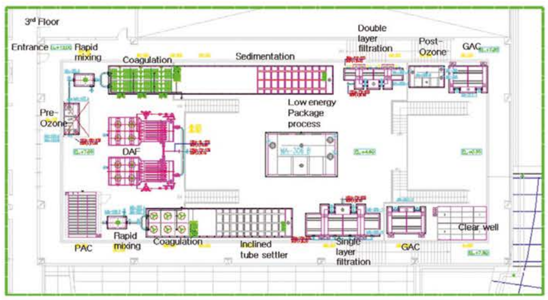
- Demonstration plant
  Resolves problems with the demonstrative operation of water treatment processes proposed in the model plant and checks the effects of the treatment processes
- Model plant
  Compares among different unit treatment processes and enables the selection of optimal processes

Functions

| Plant Schematic |



| Lay - out |



Effects

- Provides training programs for local experts and foreigners (ODA/ADB) in water treatment
- Presents rapid solutions to water treatment issues
- Provides membrane module certification and certified flowmeter calibration services
- Implements a test-bed for verification of technologies resulted from small business innovation research projects

Applications

| Education Study Tour |

Year	2010	2011	2012	2013	2014
Event	36	39	28	34	22
Person	696	787	542	587	461

| Membrane Module Certification and Flowmeter Calibration |

Year		2010	2011	2012	2013	2014
Membrane Module Certification	Event	4	7	6	5	4
	Revenue USD	81,748	123,770	134,000	78,656	37,214
Flowmeter Calibration	Event	2,447	2,929	3,414	2,990	3,373
	Revenue USD	549,872	733,061	725,115	926,021	993,155

water-NET

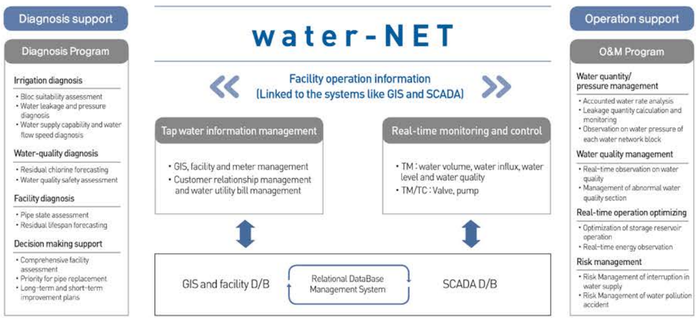
Water Network Diagnosis, Operation & Maintenance System

B-7

Overview

water-NET is a water network operation system to support the optimal operation & maintenance of water networks through analyzing, diagnosing and evaluating operational DB with an IT-based work process system covering all works processes (including survey, diagnosis, facility improvement, operational improvement, maintenance, etc.)

Configuration



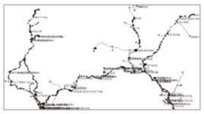
Features

- Dr.Pipe
  - Integrated diagnosis tool for hydraulic integrity, water quality, and physical conditions in WDS
  - Dr.Pipe consist of 4 main modules, including integrity diagnosis, water safety (water quality) assessment, physical condition assessment, and integrated decision support tools for rehabilitating or replace aged water pipes.
- Net.Operation
  - Optimal O&M support system based on a real-time monitoring and control system
  - Net.Operation consist of real-time monitoring system and analysis system to monitor flow, pressure, WQ, energy, etc. in water distribution networks. The monitored data are used for the optimal O&M of water leakage, water quality, energy, etc. with various analysis tools.

Functions

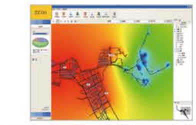
| Dr.Pipe |

Builds a water pipe network model



- Build a pipe network analysis model
- Functions to automate the calibration & correction of errors in pipe network and the allocation of water demand

Inspects hydraulic integrity



- Analyzes water pipe networks considering water pressure, flow velocity, etc.
- Assesses hydraulic integrity & block appropriateness
- Derive alternatives to the improvement of water supply system

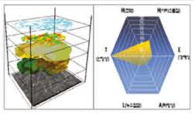
Inspects water quality

- Assesses WQ variations
- Assesses WQ safety
- Analyze the damping capacity of residual chlorine

Inspects the safety of target infrastructure

- Assesses the physical conditions of water pipes
- Predicts pipes' remaining service life with a physical, economic model

Supports decision-making



- Analyzes inspection results & makes decisions about each of alternatives
- Makes an overall performance assessment
- Formulates short- & long-term improvement plans

| Net.Operation |

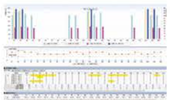
Functions to analyze water pipe networks

- Analyzes pipe networks based on measured data

Manages water quantity

- Monitors water leakage by block
- Analyzes revenue water ratio by block & gross water quantity

Manages energy



- Analyzes pump capacity & energy loss

Manages water quality (WQ)

- Monitors WQ on a real-time basis
- Predicts residual chlorine through water pipe network analysis

Manages water crises

- Valve operation tool in emergency situation
- Predicts expected water supply cut-off areas

Predicts water demand

- Predicts daily & hourly water demand
- Predicts reservoir level through simulating inflow variations

Effects

- Dr.Pipe
  - Enables the saving of inspection & analysis time by 90% and improves reliability of diagnosis
- Net.Operation
  - Enables scientific, efficient operation & maintenance

Applications

- Dr.Pipe
  - Applied to the technical inspection of water pipe networks, along with the transfer of relevant technologies to engineering companies, etc.
- Net.Operation
  - Applied to the building & operation of 16 provincial waterworks and 12 regional waterworks

B-8

iWater 5(SE)

Standard Water Operating System

Overview

iWater 5(SE) is a standardized HMI system for the supervisory control of all relevant facilities (including intake stations, water treatment plants, booster stations, pipelines, distribution reservoirs, water taps, etc.) at a remote integrated center.

① iWater (standard water treatment operating system)
Serves as K-water's standard HMI to remotely monitor waterworks on a real-time basis

② SiS (smart iWater system)
Monitors WTPs with mobile units anywhere

③ IWS+ (smart warning management system)
Functions as an accident prediction & alarm system

④ Optimal pump operating system
Functions as an automated pump operating system (that functions to monitor pump performance on a real-time basis

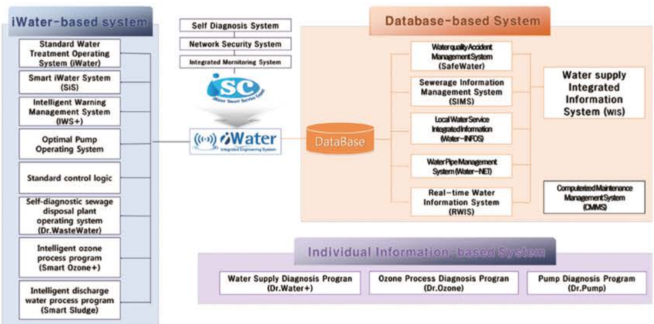
⑤ Standard control logic
Automatically determines chemical/chlorine injection rate in accordance with a specific intelligent algorithm

⑥ Dr.Wastewater (self-diagnosis & management system for WWTP)
Ensures the real-time monitoring & prediction of inflow & discharge in terms of water quality

⑦ Smart Ozone+ (smart ozone process program)
Ensures real-time response & optimal operation depending on changing water quality in ozone processes

⑧ Smart Sludge (smart effluence process program)
Provides the functions of real-time effluence balance analysis and continuous/automatic operation

Configuration



Features

- Possible to be equipped with an application software optimized for each water treatment process based on the functions of monitoring & control that are provided by iWater engine software
- Standardizes display structure, components, monitoring control procedure and system application standards, etc.

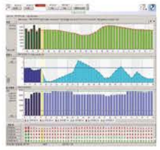
Functions

Real-time monitoring

Movement monitoring

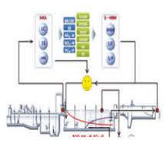
Alarm triggering

Optimal pump operation

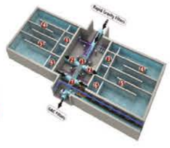


Automatic injection of chemicals

Wastewater treatment management



Optimal ozone management



Automatic operation of effluent

Effects

- Reduces work-shift loads on operators through introducing a standardized water treatment system
- Shortens system building period by providing standard displays, water treatment symbols, etc. for building water treatment system
- Leads standards for the development of key water-related S/W's

Applications

- Applied to Chungcheong (1 site), Jeonnam (4 sites), Gyeongbuk (1 site), Gyeongnam (6 sites) in 2014
- Will be applied to Gangweon (2 sites), Gyeongbuk (4 sites) in 2015

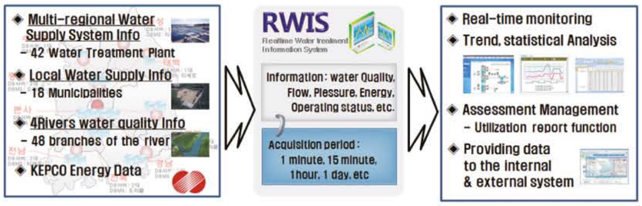
RWIS

Real - time Water Information System

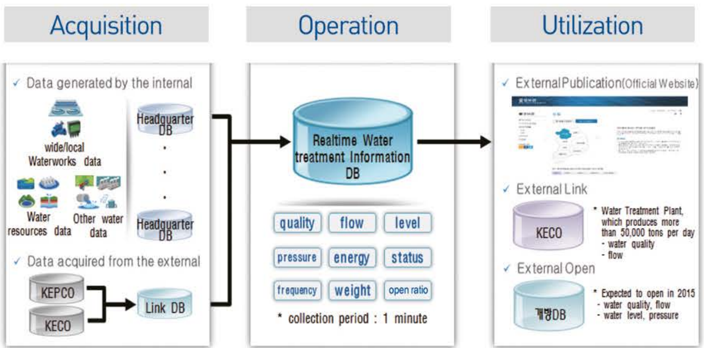
Overview

RWIS is a system to query & supply real-time operational data about regional and provincial & municipal waterworks, including their business management information, sale operation, facility operation, water quality, annual reports, etc. every one minute.

- Data acquisition & transmission
  Acquires & transmit data about regional and provincial & municipal waterworks, KEPCO's meter readings, including operation data about wastewater works & dams dedicated to water supply, schematic diagrams for water supply, status of pump operation, etc.
- Data calibration & correction
  Calibrates & corrects data every 15 minutes and 1 hour through trending analyses, report configuration, etc.



Configuration

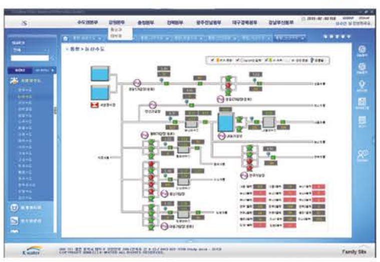


Features

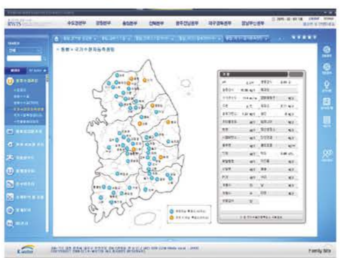
- Acquires data about water quality and volume of water supply over the entire process of water supply ranging from water sources to end users, and links them to an internal system and external entities.
- Acquires & transmits data about the operation of waterworks (water quality, flow, water level, pressure, etc.) per every one minute.

Functions

| Schematic diagrams for water supply |



| Water quality information |



| Trending analysis |

Effects

- Improves the operation of waterworks & supports decision-making with one-minute real-time data
- Builds a foundation for the analysis & application of data about waterworks

Applications

- Sharing of 18,000 data through 21 internal & external systems
  - Providing water quality information for users on MOE's web-site, application to water resources and supply facilities management

B-10

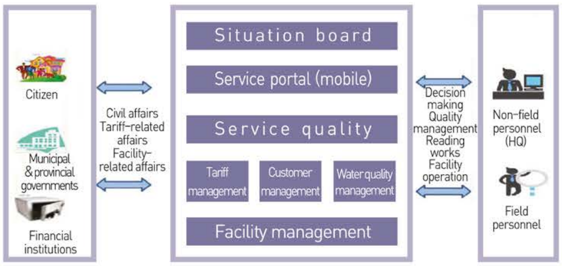
Water-INFOS

Integrated Waterworks Information System

Overview

Water-INFOS is an integrated waterwork solution for the management of municipal or provincial waterworks, customer management, determination of tariff policy, handling of waterwork-related civil complaints, etc.

Configuration

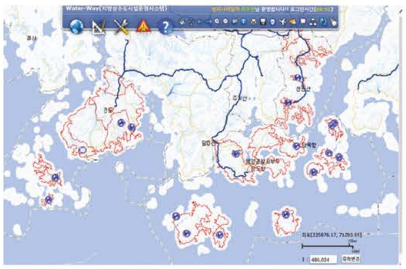


Features

- The excellence of system quality certified by the Good Software (GS) from the TTA
- Integrated solution for local waterworks
- Provides mobile services for billing check, civil complaints, and billing settlement before moving out

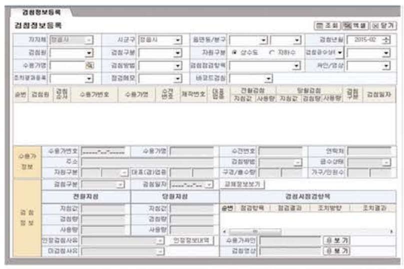
Functions

| Facility Management (Water-Way) |



GIS-based management information on pipeline network and water supply facilities (workplaces and valves)

| Billing Management (Water-Bills) |



Billing procedures, including water meter reading, adjustment, notice, receiving, and late payment

| Customer Management (Water-CRM) |

Customer-based complaints handling and notification services

| Water Quality |

Daily, weekly and monthly water quality at waterworks, and households

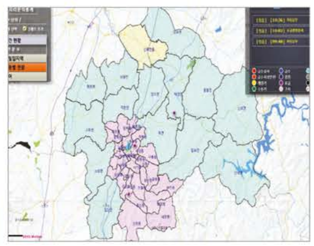
| Service Portal (Water-POS) |

e-customer services, such as billing information, on the Internet

| Service Quality (SQI) |

Four SQIs, including water meter reading and visiting complaints handling

| Digital Information Display |



GIS-based realtime statistical information of civil complaints and water quality

Effects

- Integrating information from seven sectors to provide one-stop waterwork services
- Implementing GIS-based effective facility management
- Introducing SQI (Service Quality Index) to improve customer service quality

Applications

- 21 Local Waterworks
  - Metropolitan : Dongducheon, Yangju, Paju, and Gwangju
  - Chungcheong Province : Nonsan, Seosan, Geumsan, and Danyang
  - Jeolla Province : Jeongeup, Naju, Hampyeong, Wando, Jindo, and Jangheung
  - Gyeongsang Province : Yecheon, Goryeong, Bonghwa, Geoje, Sacheon, Tongyeong, and Goseong

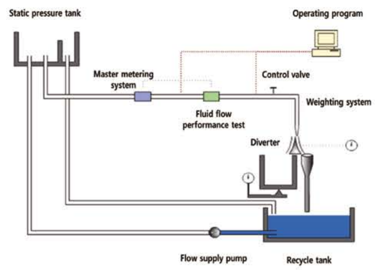
FCPTT

Flowmeter Calibration & Performance Test Technology

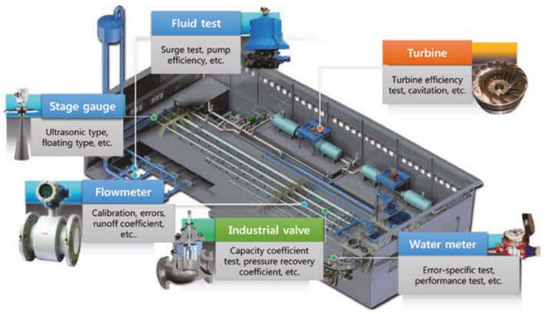
Overview

FCPTT is a world-class technology to help with fluid flow performance tests on watermeters, valves, etc. through the precision correction of flowmeters (CMC: 0.08%)

- Fluid supplied to test pipe from a hydrostatic tank at a stable flow passes through a test flowmeter to enter into a collecting tank
- The mass flow of fluid entered into a collecting tank over a certain period of time is converted into volume flow, which will then be compared with flowmeter reading.



Configuration



Features

- Introduces double acting hydraulic cylinder and triggering/photo sensor detection techniques to build a high-precision diverter system
- Air valve, strainer and regulating bypass valve shall be installed in a test pipe to stabilize the test flow rate.
- A high-precision load cell shall be introduced to improve measurement method (compressive → tensile), and in turn to improve weight unbalance.

Functions

| Flowmeter Calibration |

High-precision calibration service ameasurement capability (CMC) of 0.08% at the advanced level

| Water Meter Performance Test |

Water meter performance test corresponding to a given installation setup (15~50mm)

| Valve and Fluid Flow Performance Test |

Precision control value and fluid flow performance test (capacity factor, pressure recovery coefficient, and water hammer)

Effects

- Manages under-registration rate for water meters to improve revenue water ratio in waterworks
- Secures advanced technologies for flow measurement and valve/fluid flow performance test
- Tests the performance of national core products/exports developed by small business

Applications

- 3,000 units tested annually (revenue of KRW 1 billion)
- Tested the performance of the high-precision control valve for liquid oxygen in the Korea's first carrier rocket Naro
  - Contributing to the localization of core parts, and the market advance to space industry of KRW 210 trillion
- Tested the performance of International Thermonuclear Experimental Reactor (ITER)[1] shield block for cooling
  - Securing technologies for manufacturing core parts of nuclear fusion reactors, equivalent to about KRW 61.8 billion in money terms

1) ITER is the largest international R&D project in history, carried out jointly by the USA, EU, Japan, China, Russia, Japan and Korea to scientifically and technologically demonstrate the commercial feasibility of nuclear fusion energy.

B-12

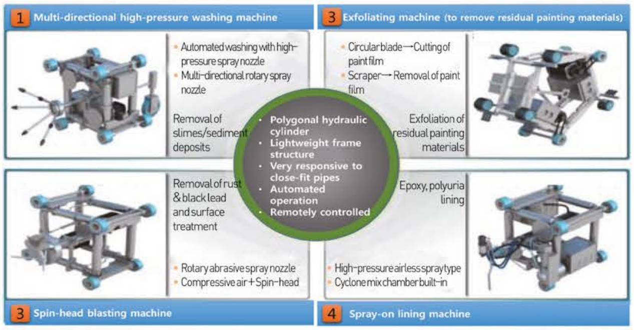
SCSL

Smart Cleaning & Spray-on Lining technology

Overview

SCSL is a cleaning & spray lining rehabilitation technology for large-diameter water pipes (with D500mm to D1,650mm in diameter) that requires the use of equipment having a structure of polygonal hydraulic cylinder frame

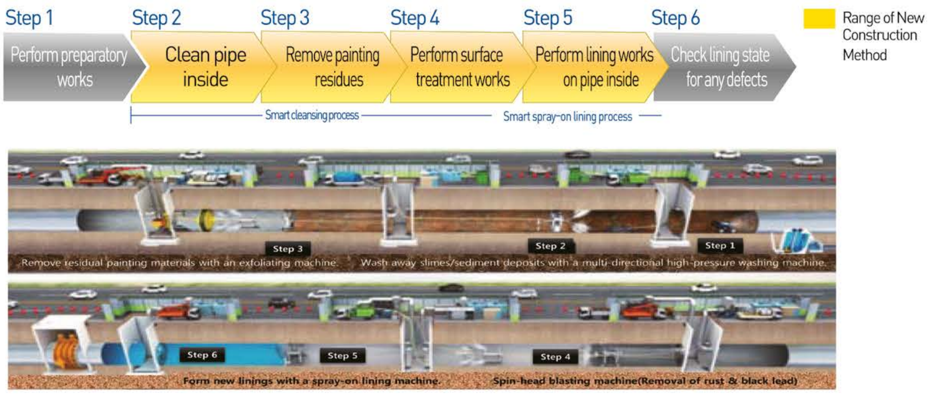
Configuration



Features

- Common features of main apparatuses
  - Structured with multi-joint hydraulic cylinder frame and possible to adhere closely to the pipe inside, bend a pipe spirally, and perform stable construction works
  - Applicable to long-distance construction with the help of high-efficiency batteries (low energy) and through an unmanned remote control (without any separate worker) and possible to monitor construction processes on a real-time basis
- Quality standards for main processes
  - Cleaning : Surface treatment grade SSPC SP-10, surface roughness Over 50 ㎛Rz
  - Lining adhesive strength – Over 10 MPa

Functions




Before cleansing


After cleansing


After lining

Effects

- Used to restore the functions of existing aged pipes or extend their service life without any separate excavation or replacement
  - Green technology to reduce CO_2 produced in the process of producing new pipes or from construction wastes, which are accompanied together with non-excavation rehabilitation
- Used to cost-effectively restore hydraulic, water-quality and physical functions and ensure reliable water supply
  - Possible to reduce 40% of construction costs per meter when compared with construction costs for the installation of new pipes (based on D1,500 mm)
- Advances pipe rehabilitation technology and secures quality competitiveness
  - Applicable to oil transportation pipes, gas pipes and other agricultural/industrial water distribution pipes

Applications

- K-water's conveyance pipelines in Changweon
  - Cultural asset protection areas, some sections buried under traffic lane (congested with traffic load at ordinary time)
  - Steel D1,100 mm, L= 1.2 km
- Seoul municipal waterworks
  - Seoun-ro (sections where it's hard to excavate)
  - Steel D900 mm, L= 1.2 km

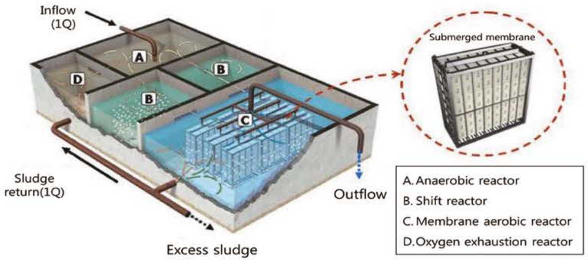
KSMBR

K-water Advanced Wastewater Treatment Technology with Membrane Bio - Reactor

Overview

KSMBR is an advanced wastewater treatment technology to maximize the utilization efficiency of organic matters with an aeration/ non-aeration parallel swing reactor and a microfiltration membrane

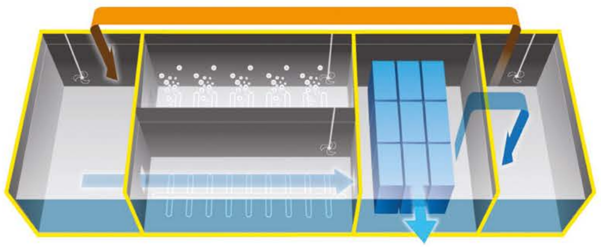
Configuration



Features

- The application of a polyolefin hollow fiber microfiltration membrane module developed by domestic technology contributes to the reduction of initial investment and maintenance cost.
- Facilitates the response to low C/N ratio and the change in organic matters and nitrogen loads in inflow to ensure stable water quality of the recycled water

Functions



Anaerobic reactor	Shift reactor	Membrane aerobic reactor	Oxygen exhaustion reactor
Phosphorous emissions	NAN process, flexible to various inlet conditions, equipped with the function of simultaneous nitrification & denitrification	Residual nitrogen & phosphorus intake, membrane for solid-liquid separation, etc.	Optimizes a shearing process through reducing dissolved oxygen (DO) (Concentration of DO: 0.2 to 0.4mg/l)

- Intermittent aeration process facilitates the reduction of internal recycling energy.
- Minimizes sludge generated with the operation of high-concentration MLSS & long SRT
- Flow analysis is used to minimize under-aeration and to equalize fluid flow.
  - Minimizes membrane pollution and the need for chemical cleaning and cleaning air supply to reduce maintenance cost
- Improved membrane packing density, particulate solids removal capability, and permeability reduce the power cost for suction pump.
  - There are no settling, filtration and disinfection processes needed.
- The short HRT facilitates compact-sized treatment facility, and increases the treatment efficiency in the existing facilities.

Effects

- Uses a hollow fiber microfiltration membrane developed by domestic technology to enhance the cost competitiveness
- Improved membrane packing density and diffuser reduce the area of aerobic tank and air supply rate to less than 40% and 50%, respectively.
- Enables the saving of maintenance costs over the existing MBR process

Applications

- 181 sewage and wastewater treatment plants in Korea (362,000㎥/day)
  - Gongchon STP (65,000㎥/day), and Okchon STP (18,000㎥/day)
- Korea's first project for recycling treated wastewater
  - Treated wastewater reused as industrial water supply in the Daegu Dalseong Industrial Complex (15,000㎥/day)
  - KRW 2.2 billion was saved annually over the existing water supply

Dr. Wastewater

Self-Diagnosis & Management System for WWTP

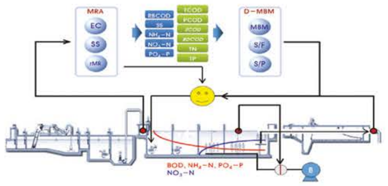
B-14

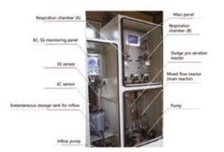
Overview

Dr.Wastewater is a web-based self-diagnosis wastewater operation & maintenance system with which it's possible to predict the water quality of inflow and outflow on a real-time basis, and thereby manage wastewater treatment processes

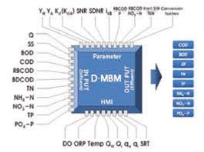
- Self-diagnosis system built in deductive diagnosis methodology (DDM)
- Web-based management system for sewage treatment plants facilitates the integration with TMS (Tele-Monitoring System)

Configuration





MRA

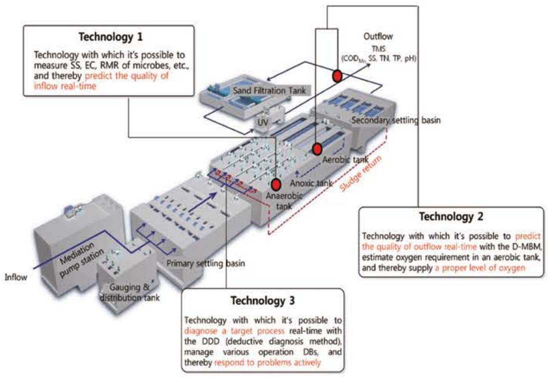


D-MBM

Features

- A Microbial Respiration Analyzer (MRA) is used to collect the realtime pollutant data from inflow (11 items) at 5~10 minutes interval.
- A Dynamic-Mass Balance Model (D-MBM) is used to predict the effluent quality in 8~10 hours based on MRA and monitoring results.
- MRA and D-MBM are used to appropriately control air supply rate in aeration tank for an economic operation.
- DDM is used to identify solutions.

Functions



- Realtime inflow prediction module : Realtime inflow analysis (11 items)
- Realtime effluent prediction module : Realtime effluent prediction (8 items)
- Self-diagnosis and realtime optimization module : Diagnostic procedure specialized in main effluent items
- A web-based version facilitates accessibility to and integration with existing systems, and increases security.
- The software allows the customization of core technologies, including prediction, calculation and diagnosis.

Effects

- Routinely monitors effluent quality to meet the criteria in sewage treatment plants
- Increases pollutant removal efficiency (improved by 13.3% for BOD)
- Controls air supply rate for an economic operation : 35% reduction in air supply rate
- Self-diagnosis and process optimization decrease the risk rate.
- Verifies the normal operation of instruments
- Acquires advanced data, including realtime inflow data and behavioral characteristics of pollutants in reactors

Applications

- Oaegwan STP (A_2O, 22,000m³/day) (2009~2013)

WTPTT

Water Turbine Performance Testing Technology

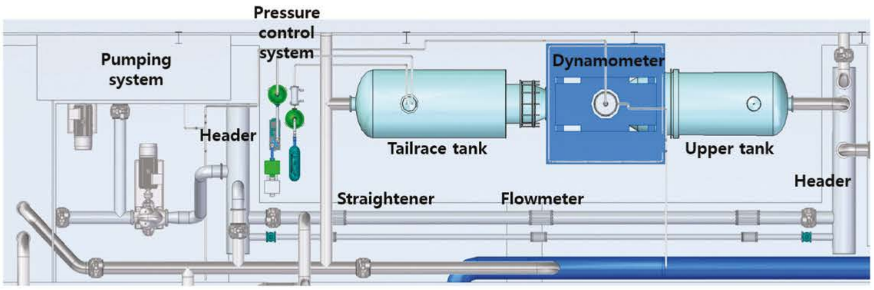
C-1

Overview

WTPTT is a technology used to perform turbine generator performance tests (including efficiency test, cavitation test, axial thrust test, pressure fluctuation test, runaway speed test, air injection test, Winter-Kennedy test, flow pattern test, etc.) on a scale model of turbine under preset testing conditions (flow, pressure, rotational speed, etc.) as per generally accepted test standards (e.g., IEC 60193)

- Test capability : Less than 100kW full-sized turbine and reaction turbine model
- Test item : 8 items required by the IEC

Configuration



Features

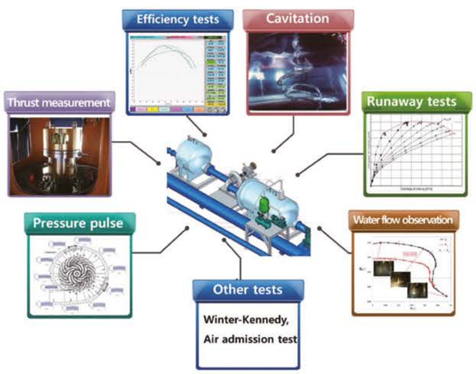
- Installed area : 300 m²
- Max. head : 40 m
- Max. flow : 1.0 m³/s
- Revolution : 2,500 rpm
- Test item : Efficiency, Pressure pulsation, Runaway, Cavitation, and Axial thrust

Functions

Performance tests on a full-scale turbine and a scaled-down model

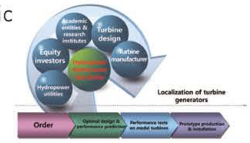
| Test items |

- Small-scale model test : Efficiency test, Cavitation test, Runaway speed test, Pressure fluctuation test, Winter-Kennedy test, etc.
- Forces characteristic test : Axial thrust test, Radial thrust test, Guide vane torque test and Runner blade torque test of Kaplan turbine
- Flow pattern observation and inner flow measurement for hydraulic machinery



Effects

- Encourages the localization of hydraulic equipment for national strategic projects
- 50 hydraulic equipment were tested



Applications

- Carried out the experimental performance test of turbine developed by the small business for the small hydropower generation system in Yongdam Dam (May 2014)
- Assigned R&D for the standardization of turbine performance testing technologies (←Korea Energy Management Corporation, July 2014)

C-2

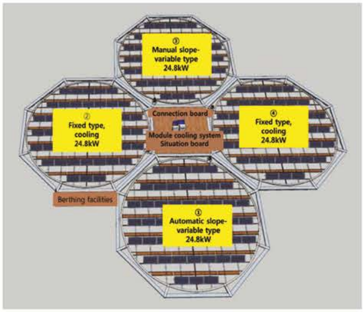
SOLATUS

Tracker-type Floating Solar Power Generation System

Overview

SOLATUS is a tracker-type floating solar photovoltaic system to maximize energy production by changing the inclination & azimuthal angle of its solar photovoltaic array according to the route of the moving sun, functioning to combine a sun-tracking technique and a floating structure along with mooring device on the water surface above the dam and reservoir

Configuration



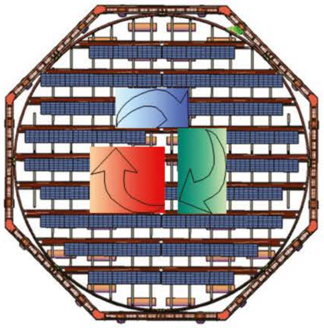
- Installed capacity : 100kW
- Structure: 4 sets of 25kW
- Fixed (cooling system) : 2 sets
- Automatic sun-tracking : 1 set
- Manual sun-tracking : 1 set
- Area occupied : 2,662㎡

Features

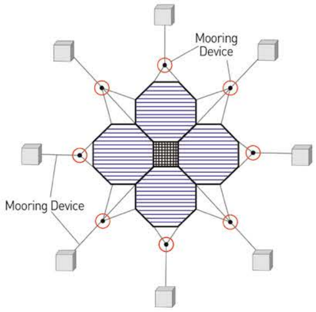
- Tracks the azimuthal angle fluctuation
- Cooling module is used to increase power generation
- Wireless sensor network is supported
- Component technology ensures Easy Install and Easy Maintenance
- Its octagonal structure provides expansibility.

Functions

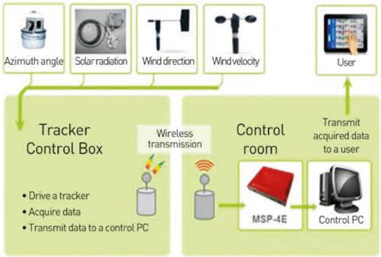
Azimuthal Angle Tracking Horizontal Revolution Mechanism



Water Level Response Mooring Device



Overview of structural system



Effects

- Develops proprietary technologies to achieve technical dominance
- Encourages the mutual growth of solar power industry
- Increases the efficient use of land
- Six floating solar power plants are expected to produce the power generation revenue of KRW 7,814 million annually.
- The power generation is 23% higher than that of a fixed-type floating solar power plants

Applications

- The floating solar power plant in Hapcheon Dam started operation on December 2013.
- 1,200MW floating solar power plants will be developed in 12 dams, including Sihwa Lake, by 2022.

IDB
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K water