Hydrological Survey

KIHS 한국수자원조사기술원
Korea Institute of Hydrological Survey

United Nations Educational, Scientific and Cultural Organization

i-WSSM
International Centre for Water Security and Sustainable Management

Hydrological Survey

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UNESCO United Nations Educational, Scientific and Cultural Organization

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History of the Hydrological Survey in Korea

Hydrological Survey

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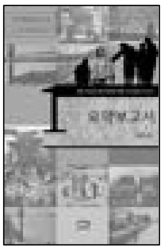
i-WSSM

Aims & Objectives

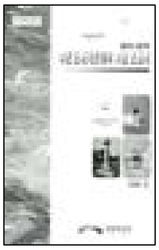
- The aims of the course are to:
  (1) Introduce the necessity of the hydrological survey and the historical trend of the hydrological survey in Korea
  (2) Explain the current status of the hydrological survey in Korea and the master plan
  (3) Propose a sustainable international cooperation plan and an ideal direction of the hydrological survey based on hydrological technologies and experience in Korea

- At the conclusion of the course, trainees will be able to:
  (1) Understand the historical flow of the hydrological survey
  (2) Establish the master plan strategy of the hydrological survey
  (3) Find the ideal future direction of the hydrological survey

References



History and Future of the Hydrological Survey in Korea (MLTM, 2001)



Master Plan of Hydrological Survey(2010~2019) (MLTM, 2008)

National Network of Hydrological Survey (MLTM, 2010)

Hydrological Survey Report (ME, 2019)

Korea Annual Hydrological Report(ME, 2018)

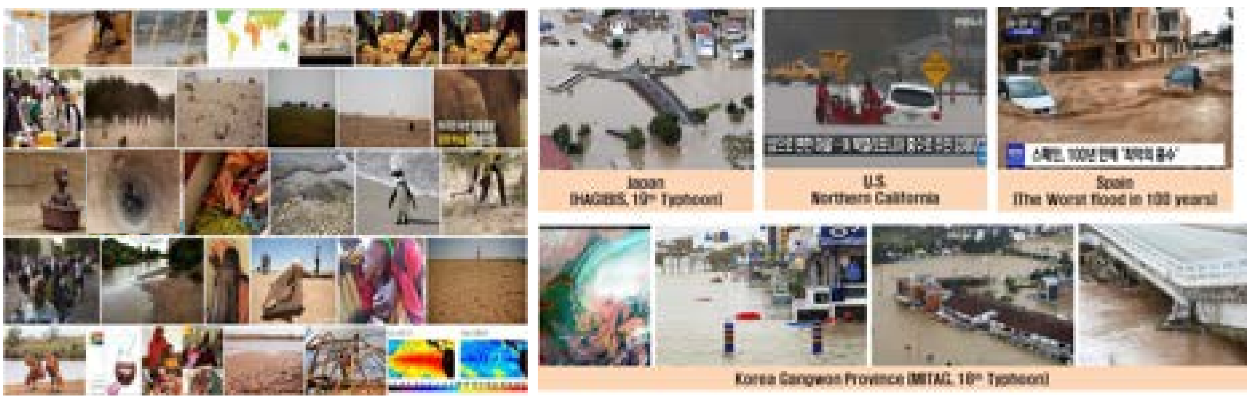
Contents

1. Introduction

1.1 Hydrological Survey
1.2 History of the Hydrological Survey

1.1 Hydrological Survey

- World Water Problem
  - The World is suffering from Water Problems such as drought, flood, water supply, etc.

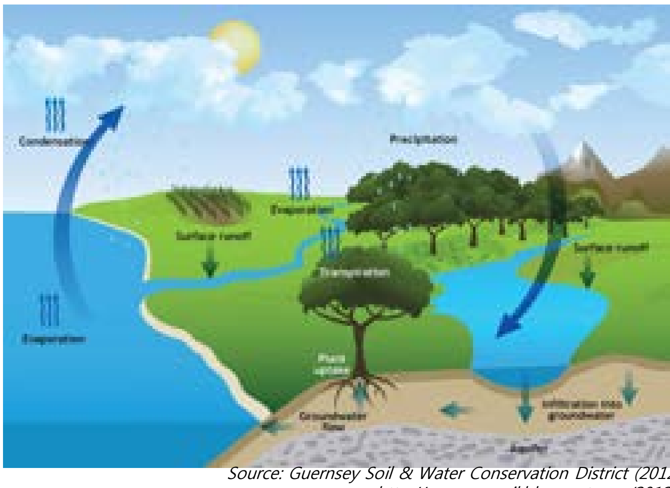


Source : MBC NewsToday, Yonhapnews agency, https://www.youtube.com/watch?v=R03syLwnmIg, etc.

"Hydrology" is the science that deals with the occurrence and distribution of waters of the Earth, including their chemical and physical properties and their interaction with the environment. (Guide to Hydrological Practices, WMO No.168)

1.1 Hydrological Survey

- **Water Cycle & the Hydrological Survey**
  - Water cannot be made or removed; it is only constantly circling and turning in the Earth's space.
  - It is important to know the amount of water circulating to use water efficiently.
  - *A hydrological survey* is the measurement and analysis of the amount of water that is constantly circulating, including the amount of rain falling from the sky, the amount that evaporates or transpirates, the amount that seeps into the ground, and the amount that flows into the river and sea.



Source: Guernsey Soil & Water Conservation District (2012), Your Backyard Woods - the water cycle
http://guernseysoil.blogspot.com/2012/07/your-backyard-woods-water-cycle.html

1.2 History of the Hydrological Survey

- **Importance of History**
  - What is important in a hydrological survey is history--that is, the time period of measurement.
  - For example, to predict the amount of rain falling in the sky, we need accurate information about recent rain patterns.
  - Changes in nature cannot be grasped in a day or two. To grasp the changes in the present and predict the future, measurements of nature must be made over a long period of time.
  - Therefore, it is important to continue the hydrological survey.

- **History of the Hydrological Survey in Korea**
  - 1441: The invention of the rain gauge and the beginning of rainfall measurement

    The invention of SuPyo and the beginning of water level measurement as flood warning

Hydrological Survey of the Joseon Dynasty(1441~1910)
- The history of hydrological surveys in Korea can be largely divided into pre- and post-1441, when Cheukwoogi and SuPyo were installed.

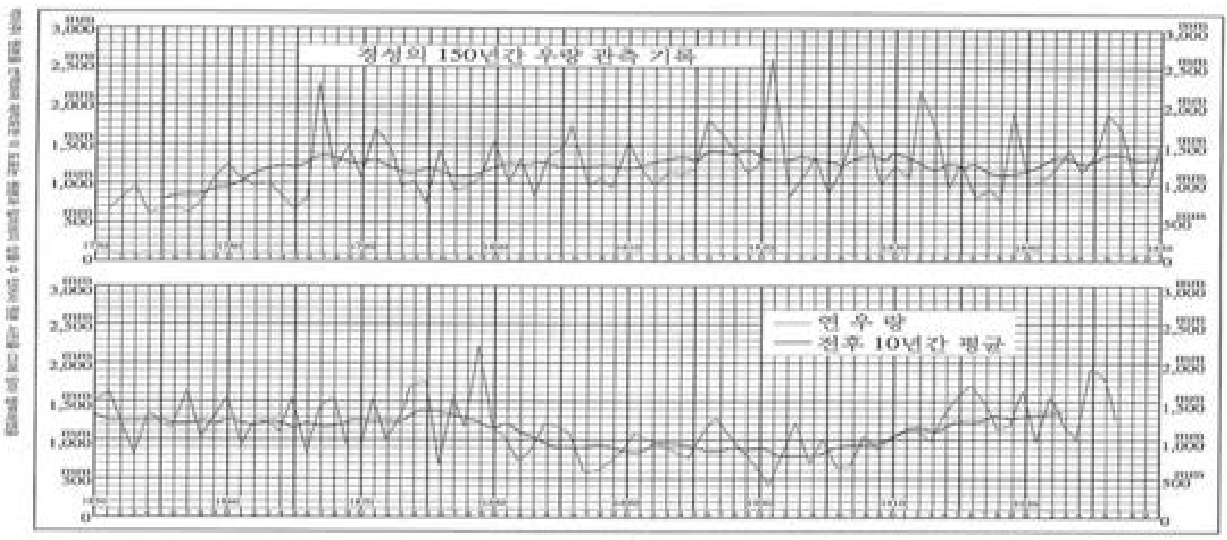

Rain gauge (Cheukwoogi)


Water level gauge (SuPyo)

1.2 History of the Hydrological Survey

▪ Hydrological Surveys in Korea

- Annual rainfall in Seoul 1771~1927



Source: Ministry of Environment

1.2 History of the Hydrological Survey

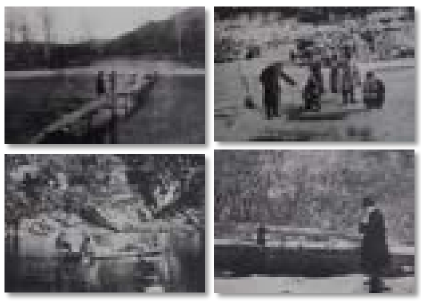
▪ History of the Hydrological Survey in Korea

- 1904) : The beginning of measuring modern rainfall in Korea
- 1911) : The beginning of measuring modern stage and streamflow

Modern Hydrological Survey(1911~1945)
- The modern hydrological survey can be said to be in 1911 when the water level and streamflow began to be measured by modern measuring equipment and methods.
- In particular, it can be said that it is a big turning point that the streamflow of the river was measured by the current meter introduced in the West and the amount of water flowing into the river was measured in conjunction with the survey result of the river section.
- In addition, during this period, observation networks for rainfall, water level, and streamflow were established nationwide, and evaporation was also measured.

rainfall measurement

Yeongsanpo stage station

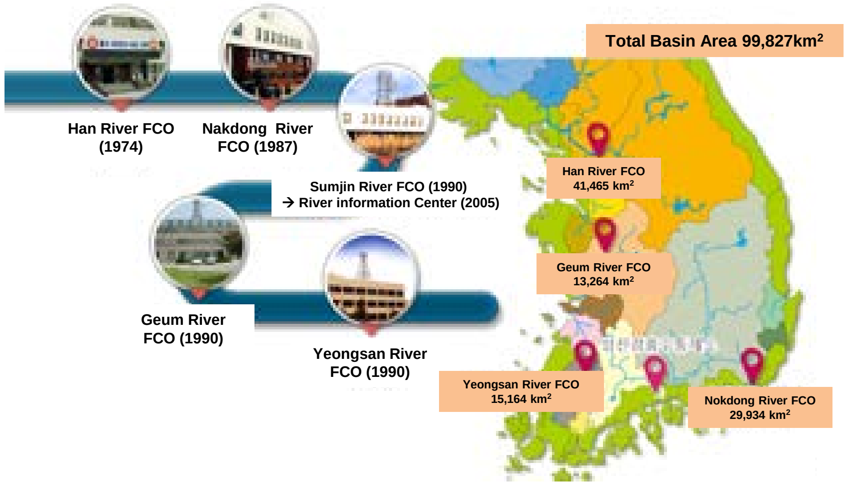


streamflow measurement

1.2 History of the Hydrological Survey

▪ History of the Hydrological Survey in Korea

- 1974.7: Hangang River Flood Control Office was opened and flood forecasting, warning system started.
- 2005.5: River information center was newly established.



1.2 History of the Hydrological Survey

▪ History of the Hydrological Survey in Korea

- Hydrological observation had been performed by different engineering companies, which produced low-quality hydrological data caused by a lack of expert and equipment, insufficient experience, & old-fashioned tech etc.
- The foundation of the professional institute for the hydrological survey was necessary to solve those problems and improve the poor measurement system in Korea.

HSC (Hydrological Survey Center [2007]) was the first special organization in Korea to produce high-quality hydrological data with advanced techniques and professional staff.
※ It is based on the government Ministry of Land, Infrastructure and Transport plan.

The Korea Institute of Hydrological Survey (KIHS) was designated as the exclusive authority for the hydrological survey in 2017.

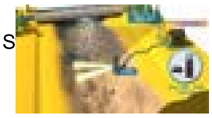
1.2 History of the Hydrological Survey

▪ History of the Hydrological Survey in Korea

- Working Area in KIHS

Authority Dedicated Organization to Hydrological Survey in Korea

Hydrological Survey
- Education and Training
- Certification of Measuring Instruments
- Investigation of River Basin
- Investigation of Damage by Flood
- Flow Discharge
- Automatic Discharge Measurement S (IRDIMS)
- Sediment Load
- Soil Moisture and Evapotranspiration



Project designated by the government

Data Provision & Policy Support
- Provision of Hydrological data to related agency FCO, K-water, etc.
- Policy support for national Hydrological Survey

International Cooperation
- WMO RA II WGHS
- Typhoon Committee
- Educational Support to Hydrological Survey (ODA)

Others (R&D)
- Improvement of Standardization and Manuals
- Establishment of National Decade Plan of Hydrological Survey
- Establishment of Network of Hydrological Survey
- Monitoring of riverbed change
- Development of Technique and Software for Hydrological Survey

2. Hydrological Survey in Korea

2.1 Status
2.2 Master Plan
2.3 National Network
2.4 Hydrological Survey

2.1 Status of the Hydrological Survey

▪ Organization of the Hydrological Survey

- Ministry of Environment: Four River Flood Control Office, National Institute of Environmental Research, Korea Meteorological Administration, K-water, KIHS
- Other Public Institutions: Korea Rural Community Corporation, Korea Hydro & Nuclear Power Co., etc.

Division	Ministry of Environment					Local Government	Other Public Institutions	
	FCO	KIHS	K-water	NIER	KMA		KRC	KHNP
Type of Org.	Government Agency	Public Institution	Public Enterprise	Government Agency	Government Agency	Local Government	Public Enterprise	Public Enterprise
Scope	National, Local Rivers	National, Local Rivers	Upstream of a Dam, Etc.	National, Local Rivers	National	Local Stream	Upstream of a Reservoir, Etc.	Upstream of a Dam
Items of Observation	Precipitation Water Level	Water Level Discharge Sediment SM, ET	Precipitation Water Level Discharge Sediment SM, ET	Discharge	Precipitation Etc.	Precipitation Water Level Discharge	Precipitation Water Level Discharge	Precipitation Water Level Discharge
Purpose	Comprehensive River and Water Resources Management		Water Resources Development And Dam Operations	Water Quality Control	Weather Observation And A Forecast	Disaster And Water Quality Management	Agricultural Water Management	Hydroelectric Power

2.1 Status of the Hydrological Survey

▪ Status of the Hydrological Survey

- Reference: Annual hydrological report (2018) and research of ME (2019)

Type of Observation		Total	Ministry of Environment			K water	KRC	KHNP
			FCO	NIER	KMA*			
Precipitation		715	**425**		80	189		21
Water level (Stage)		775	**552**			167	49	7
Discharge	**Manual**	448	**154**	262		28		4
	Automatic	62	**62**					
Sediment		52	**44**			8		
Evapotranspiration		12	**10**			2		
Soil Moisture		8	**2**			6		

→ * KMA AWS (Automatic Weather System) Exclusion

→ KIHS (Consignment from ME FCO)

2.2 Master Plan of the Hydrological Survey

- **Background**
  - The master plan addresses
    - The increasing importance of water management according to global warming and climate change
    - The increasing importance of hydrological surveys on resource use and management, such as water supply, water control, and river environment
    - The acquisition of systematic water information for the future

Article 17 Practicing Hydrological Survey by RIVER ACT

(4) The Minister of Land, Transport and Maritime Affairs shall formulate and execute a ten-year unit long-term master plan of hydrological survey as prescribed by the Presidential Decree for systematic and efficient development of the survey. *<Amended Apr. 1, 2009>*

2.2 Master Plan of the Hydrological Survey

- **Strategy (main contents) and objective**
  - Strengthening the foundation of the hydrological survey
  - Improving water information reliability
    Advancing standardization, QC, and R&D of the hydrological survey
  - Expanding ubiquitous water information computing (Provision of personalized hydrological information)
  - Advancing the hydrological survey system

The provision of water information (at any time and place; whenever and wherever)

The production of sufficient and accurate water information

2.2 Master Plan of the Hydrological Survey

■ Progress, 2010~2019

Present		Long-term master plan
Hydrological survey network focusing on flood control	→	• Construction of hydrological survey network considering water supply, water control, water quality, etc.
Intermittent stream bed profile survey	→	• Systematic and continuous stream bed profile survey
Measurement by the conventional equipment	→	• Development and adoption of advanced equipment
Unmeasured items of hydrological survey	→	• Sediment load survey • Survey of soil moisture and evapotranspiration
The lack of social recognition about hydrological survey	→	• Holding a centennial celebration of the modern hydrological survey • Strengthening public relations
Low quality of hydrological information	→	• Establishment of QC system and R&D of hydrological survey
Insufficient transmission of hydrological information	→	• Construction of water information sharing system
Insufficient budget and institution of hydrological survey	→	• Efforts to ensure sufficient budget • Foundation of specialized institution

2.2 Master Plan of Hydrological Survey

■ 2nd Master Plan, 2020~2029

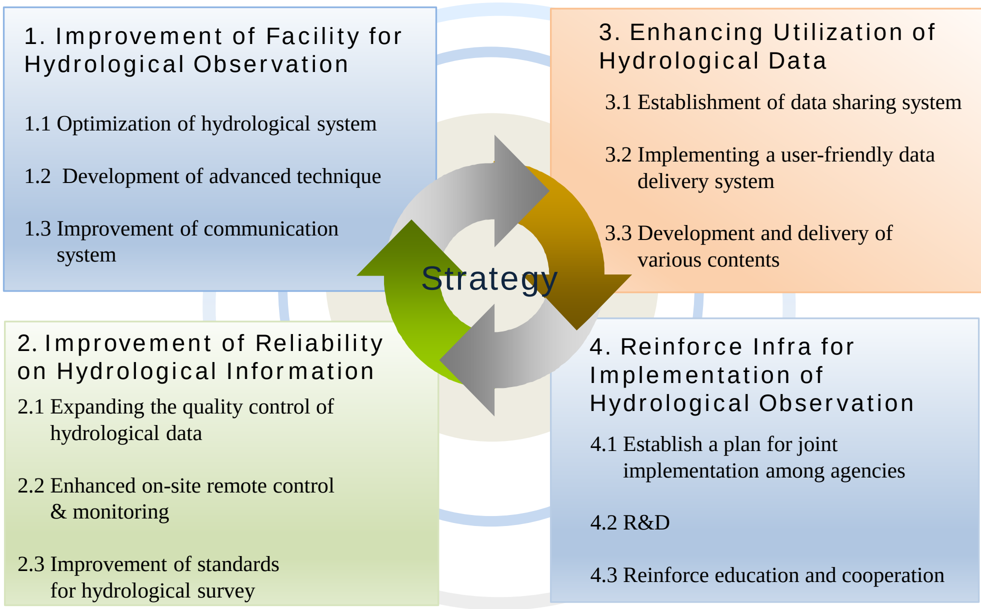
Vision	Creating a shared value of water resources through internal stability of water information
Target	Internal stability of the production and utilization of fundamental data for the management of water resources

Strategy

1. Improvement of Facility for Hydrological Observation
2. Improvement of Reliability of Hydrological Information
3. Enhancing Utilization of Hydrological Data
4. Reinforcing Infra for Implementation of Hydrological Observation

2.2 Master Plan of the Hydrological Survey

▪ 2nd Master Plan, 2020~2029



2.3 National Network of the Hydrological Survey

▪ Introduction

- National Network of Hydrological Survey
- Hydrological network of nationwide scale for national water resources management of Korea

Source: Ministry of Land, Infrastructure and Transport

2.3 National Network of the Hydrological Survey

▪ Status

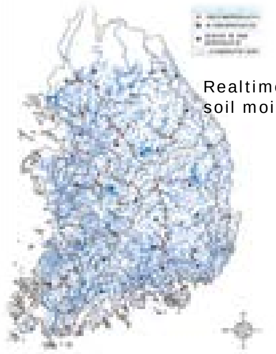
Division	Water level	Streamflow	Realtime streamflow	Sediment load	Soil Moisture	Evapotranspi ration
Number of sites	645	380	97	138	25	25

Final NHSN is planned to finish by 2020 (Currently 80% completed and managed [2012])

※ The rain gauge stations : **715** **[ME: 425** / K-water: 189 / **KMA: 80** (AWS: 585 Operating separately) / KHNP:21]

Korea Annual Hydrological Report(2018)

National water level network

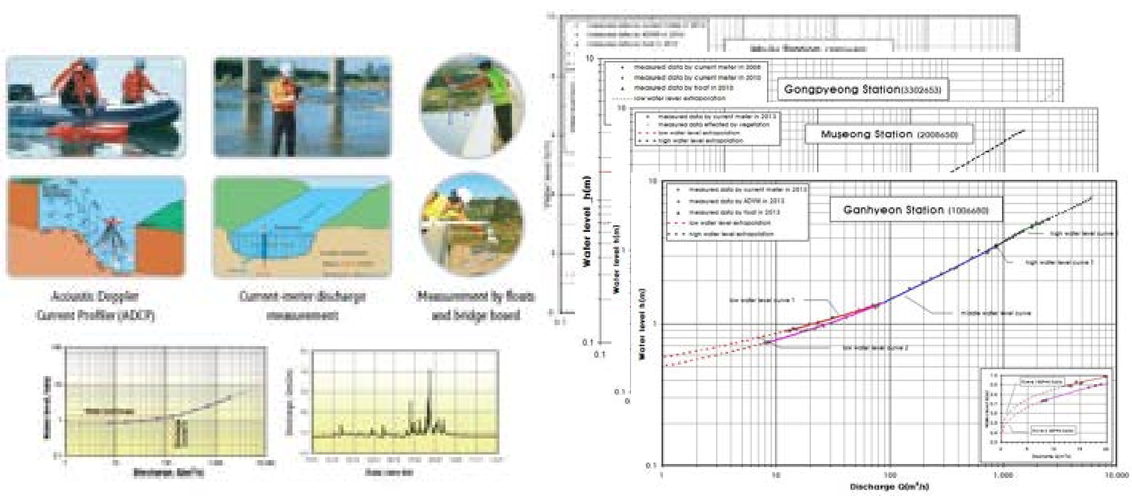


Realtime streamflow, sediment load, soil moisture, evapotranspiration network

2.4 Hydrological Survey

▪ Discharge Measurement

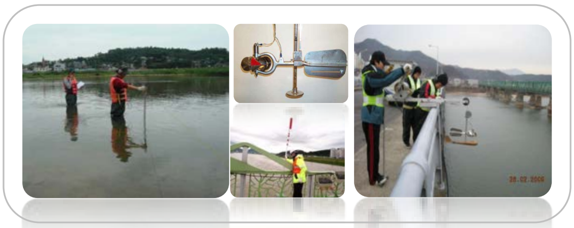
- Product discharge data by H-Q rating curve
- Discharge measurement data to develop relation between H and Q
- Development of H-Q in various conditions by weir operation, vegetation growth, riverbed change, etc.



2.4 Hydrological Survey

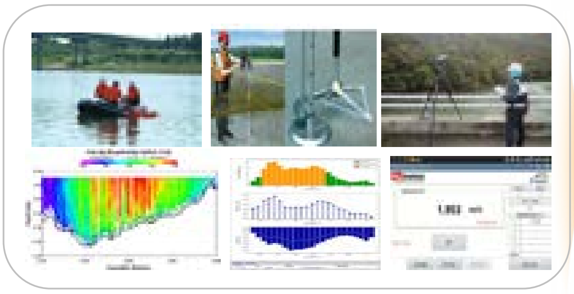
▪ Discharge Measurement

1. PAST

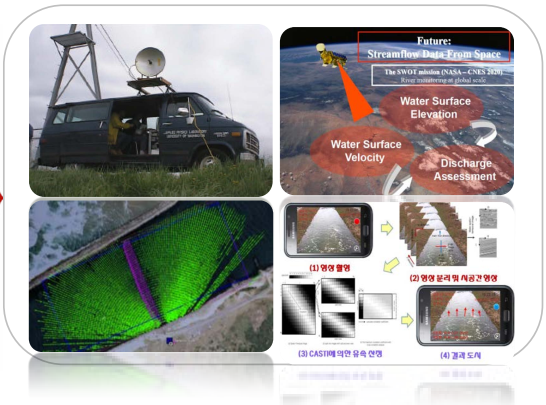


year	Rate of usage by equipment (%)				
	Price AA	ADCP	ADV	Float	etc.
2009	55.2	18.7	3.6	21.7	0.8
2019	0.5	59.2	37.1	1.1	2.1

2. PRESENT



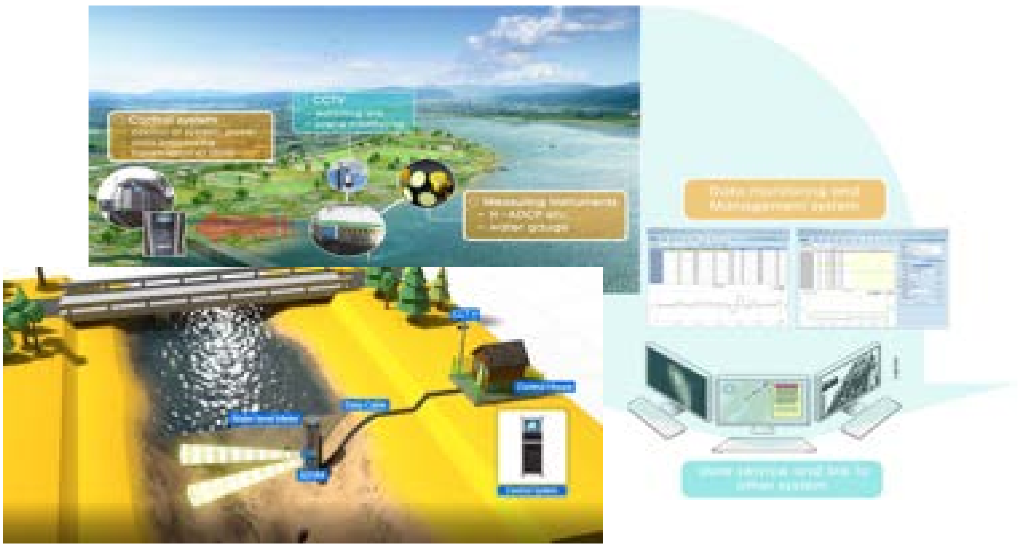
3. FUTURE



2.4 Hydrological Survey

▪ Construction and operation of IRDIMS

- IRDIMS: Integrated Real-time Discharge Measurement System
- Discharge measurement system using H-ADCP
- Real-time discharge measurement under conditions for which a H-Q rating cannot be developed
- IRDIMS consists of measuring instruments, control system, and data monitoring and management system



2.4 Hydrological Survey

▪ Construction and operation of IRDIMS

- IRDIMS is widely used to measure real-time discharge in Korea.
- IRDIMS mainly has been installed in difficult stations to measure discharge due to backwater or tidal effect and key stations-to-flood forecast.
- 63 stations have been constructed and are being operated, and it will be extended to more than 100.

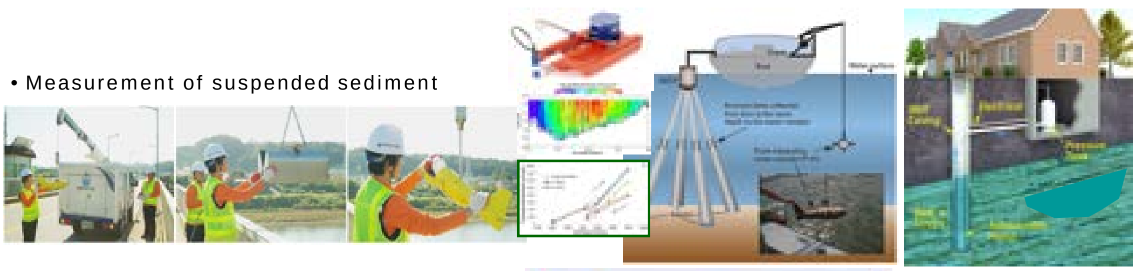
Total	Han River	Nakdong River	Keum River	Yeongsan River
62	19	23	10	10

2.4 Hydrological Survey

▪ Measurement of Sediment Load

- Measurement of Suspend Sediment: 44 sites (2019)
  * Total sediment load is calculated by the relation between suspend-sediment and discharge.
- Development of new techniques to measure suspended sediment
  * Laser In-Situ Scattering and Transmisometery, ADCP, Auto sampler

• Measurement of suspended sediment



• Collecting bed material

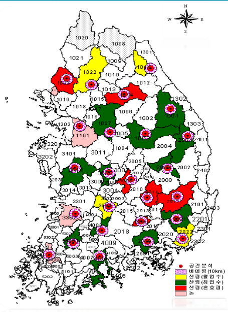
2.4 Hydrological Survey

▪ Soil Moisture & Evapotranspiration

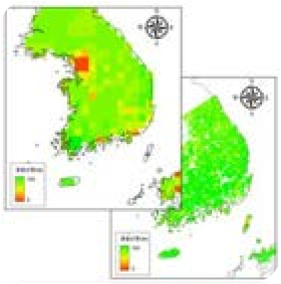
- Real-time evapotranspiration/soil moisture measurement and monitoring

Org.	No.	Method	Period (min)	Item
FCO	6	eddy covariance method	30	ET
KIHS	2		30	ET
K-water	2		30	ET
RDA	1		30	CO2, CH4
KFS	6		30	CO2, CH4
NCAM	6		30	CO2, CH4, ET
NIMS	2		30	CO2, CH4, ET

Org.	No.	Method	Period (min)	Item
FCO	6	TDR	30	SM
KIHS	2	TDR	120	SM
K-water	6	TDR	30	SM
RDA	67	TDR, FDR	60	SM
KMA	11	TDR	60	SM
NCAM	6	TDR	30	SM



NHSN, SM · ET (25 stations)



mapping calibration of satellite (MODIS) data

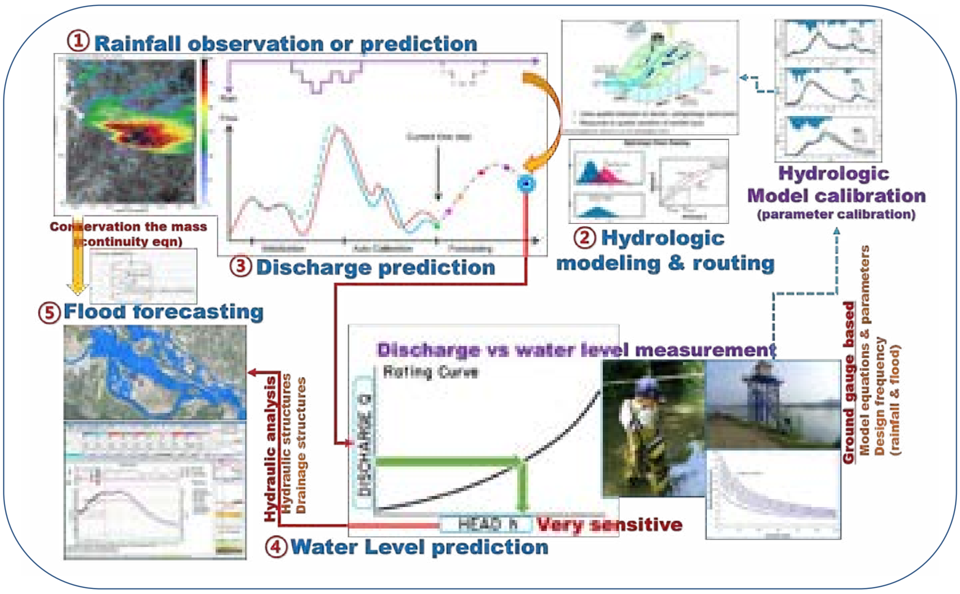
Soil moisture measuring equipment

☞ Evapotranspiration monitoring tower

2.4 Hydrological Survey

▪ Rainfall Radar Observation

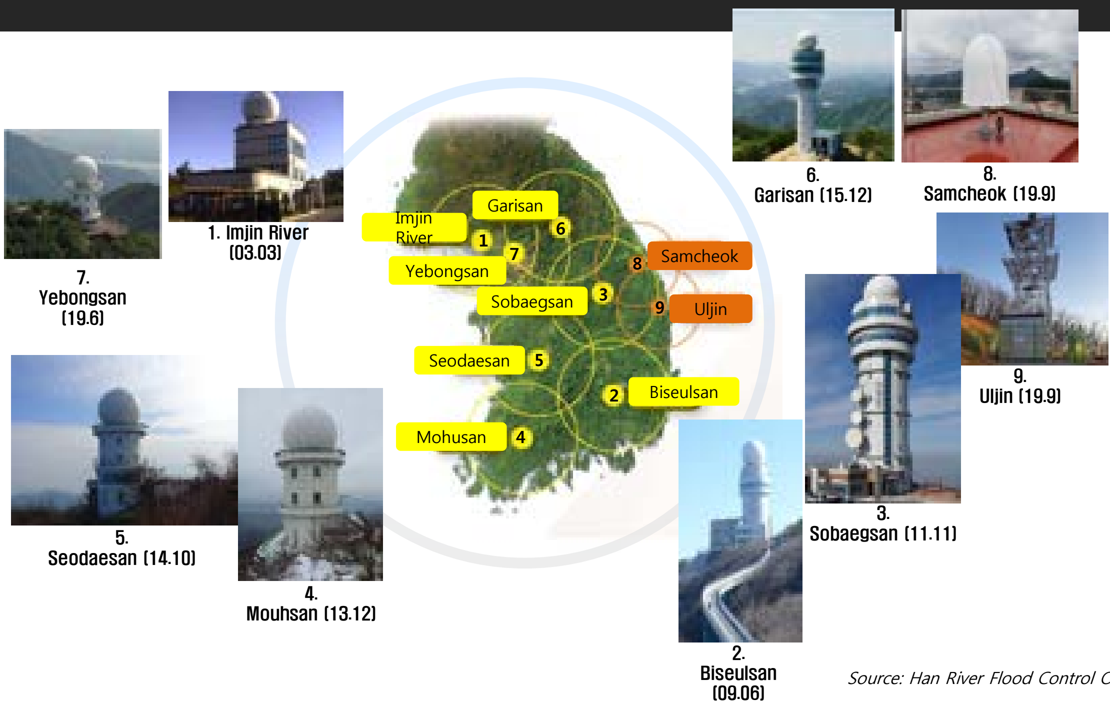
- Status of rainfall radar observation and the enhancement of flood forecasting system



Source : HRFCO_KICT

2.4 Hydrological Survey

▪ Rainfall Radar Observation Status



Source: Han River Flood Control Office

2.4 Hydrological Survey

▪ Hydrological Data Quality Control

- QC/R&D for securing high-quality hydrological data

	Data quality management system	Measurement	remark
Training	training of discharge measurement method and for fields condition	Cultivation of an expert and prevention of accident	1 / year
Fields investigation	Preparation of table and checklist for fields investigation	Fields investigation and establish of measurement plan	1 / year
Measurement & Calculation	Standardization of measurement criterion and calculation of discharge	Measurement and calculation of discharge with standard process	1 / each data
Estimation of meas.process	estimation of observance for measurement and calculation process and feedback for uncertainty of data	Modification and complement	1 / each data
Test and Verification of data	Overall test and verification of measured data	Analysis of failure data	1/(half/quarter year)
Definition of data	Estimation and definition of data used to development h-Q relation	Development of h-Q relation	1/(half and a year)
Distribution of data	Distribution and service of data	Publication of annual/half report	1/(half and a year)

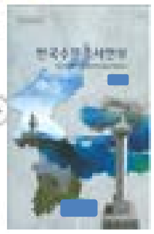
2.4 Hydrological Survey

▪ Quality Control of Hydrological Data

- Collection, provision, and utilization of hydrological data

HDIMS(Hydrological Data Information Management System)

WINS(Water management Information Networking System)


Annual Report

WAMIS (Water Management Information System)

A portal system based on the internet, built for providing service including water resource information scientifically collected, created, and processed for water-related organizations.
(Hydro/Meteorology, Basin, River, Dam, Ground Water, etc.)

http://www.wamis.go.kr/ENG/

2.4 Hydrological Survey

▪ Certification of Measuring Instruments of Hydrological Observation

- Test and calibration of water-gauge, rainfall/snow gauge in field and lab
- 5,910 gauges have been certified by KIHS since 2009.

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
No. of Certifications	98	333	572	539	359	682	690	573	811	655	649

Instruments of hydrological survey	The term of validity (year)
Rain/snow gage	3
Water gage	3
Hydrometer	2
Sediment	5
Soil moisture	5
Evapotranspiration	5


Field certification


Indoor (Lab.) certification

2.4 Hydrological Survey

- Standardization of Hydrological Observation
  - Education & training of hydrological surveyors on treatment and utilization of the data
  - Methods and criteria of hydrological survey
  -

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
No. of completion	180	84	90	87	84	96	131	109	166	138	138

3. Prospects & Conclusion

3. Prospects and Conclusion

▪ Sustainable International Cooperation

- Hydrological survey Symposium (Every 2 years)
- ISE/IAHR (2010~)
- 2nd Asia-Pacific Water Summit (Thailand, 2013)
- WMO RAII Asia WGHS (2014~)
- The 7th WWF (2015)
- ESCAP/WMO TC
- KOICA(ODA) (2014~)
- Mekong Water Data Experts meeting (2019)
- WMO CSI Workshop (2019)

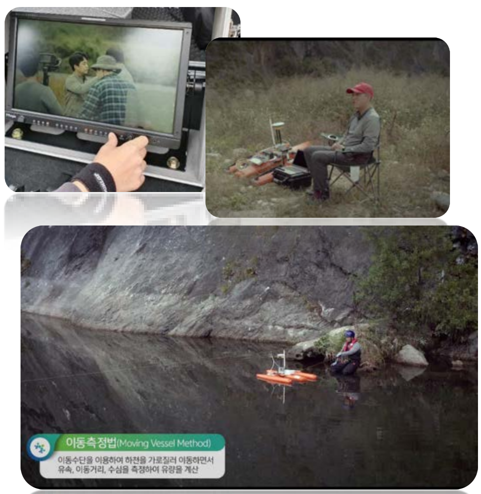
Increasing importance of hydrological observation and data
Increasing demand and request for sharing and transfer of technical know-how
→ **Step**-by-step preparation

3. Prospects and Conclusion

▪ International Education/Training Program

- Manuals and guidelines on hydrological observation for various river conditions
- Production of educational contents for the practice of hydrological observation (Video)

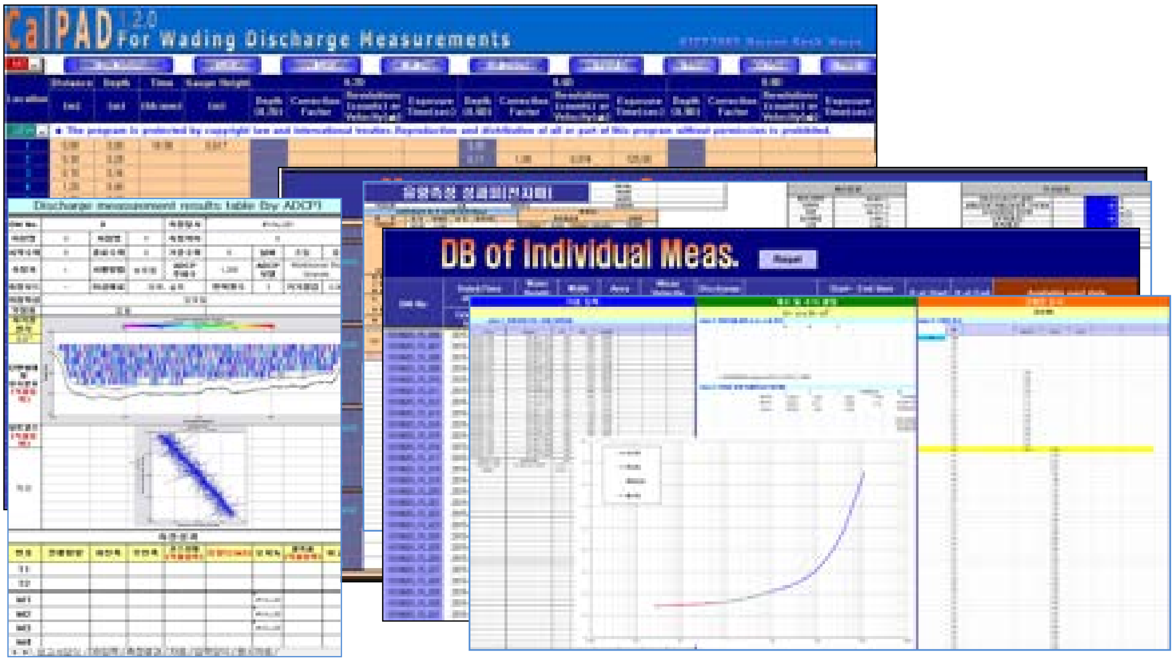
Manual and Guidelines



Educational Video Production

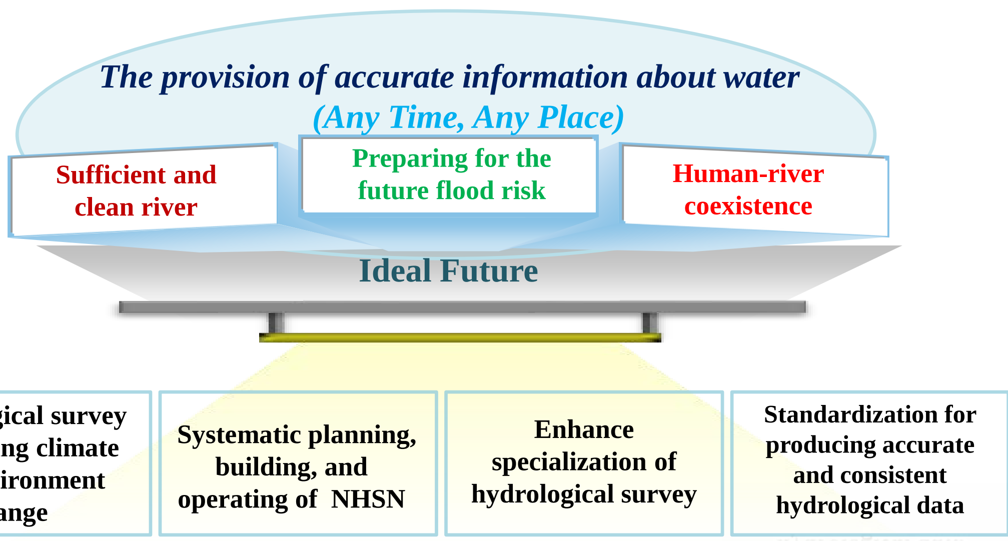
3. Prospects and Conclusion

- **International Education/Training Program**
  - Development of various software tools for data processing, Q/C



3. Prospects and Conclusion

- **Ideal Direction of the Hydrological Survey**




Thank you very much

MEMO

Hydrological Survey Introduction

Hydrological Survey Introduction

Aims & Objectives

- The aims of the course are to:
  - (1) Promote among trainees a good understanding of the basic concepts of the hydrological survey
  - (2) Ensure that trainees have knowledge of each hydrological survey method and status
- At the conclusion of the course, the trainee will be able to:
  - (1) Explain the water circulating process
  - (2) Describe water resources of earth
  - (3) Recognize water resources conditions in Korea
  - (4) Apply each hydrological survey method
  - (5) Utilize hydrological survey data and anticipate its effect

References

- Hydrological survey basic plan (Ministry of Environment, 2019)
- Hydrological survey manual (KIHS, 2017)
- Hydrological survey guideline(KIHS, 2017)
- Long-term master plan of water resources (Ministry of Environment, 2016)

Contents

1. Basic Concepts of the Hydrological Survey

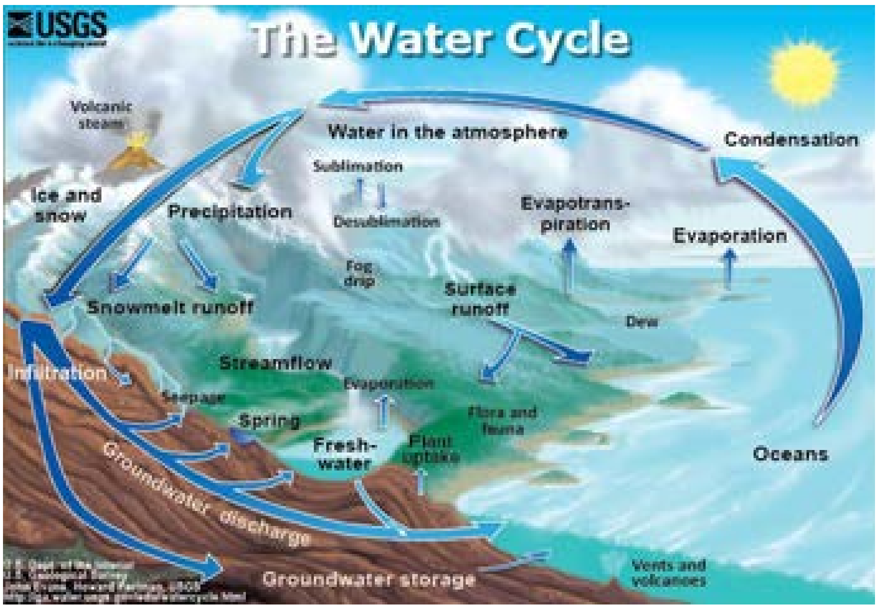
1.1 Introduction

1.2 Water Resources on Earth

1.3 Water Resource Condition in Korea

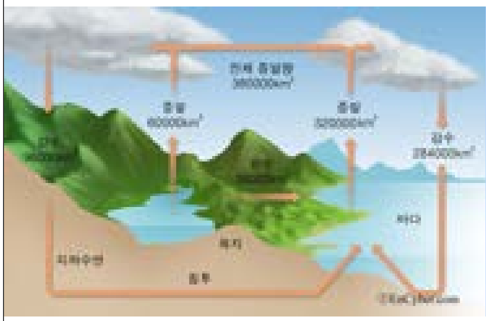
1.1 Introduction

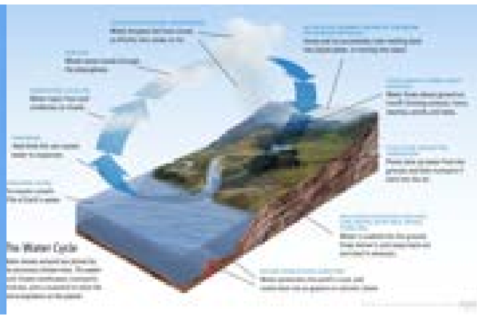
- **Water circulation**
  - The water on Earth is constant, but it always moves and circulates



1.1 Introduction

- **Water circulation (1)**
  - Water is constantly circulated on Earth.
    - ✓ Precipitation-river/underground-evaporation-sea runoff-vapor-condensation-cloud- precipitation
  - The total amount of water does not change--only the state does.





1.1 Introduction

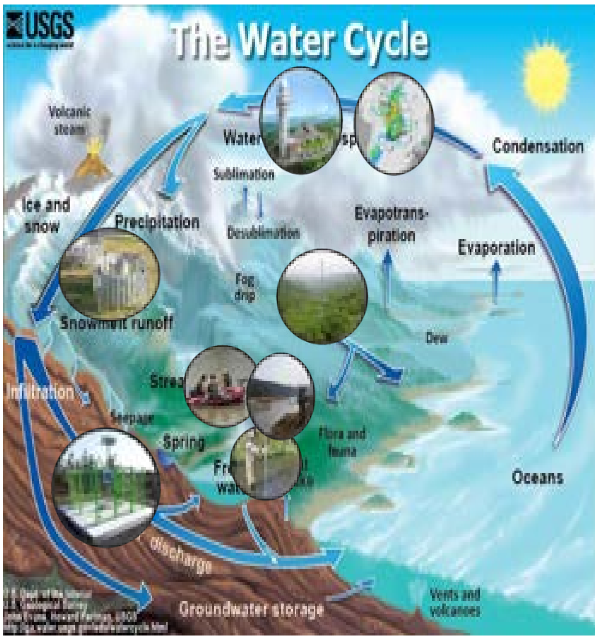
- **Water circulation (2)**
  - The major effects of water circulation on ecosystem:
    - ✓ It is purified in the water circulation process.
    - ✓ It absorbs and condenses surrounding energy during evaporation and releases energy when it is watered, which affects the climate.
    - ✓ Transfer to inorganic matter
    - ✓ Fresh water supply to life on Earth
    - ✓ Changes in topography and geography
      - E.g., erosion, creeping, deposition, soil change, etc.




1.1 Introduction

Hydrological survey definition

Hydrologic surveys observe and measure water circulation factors to quantify the water circulation process on Earth.



1.2 Water Resources on Earth

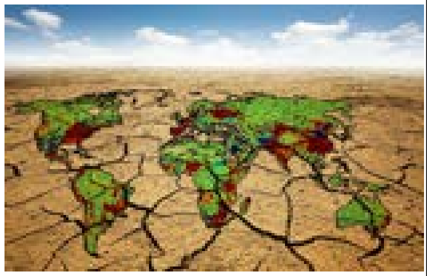
- The total amount of water on Earth is 1.4 billion ㎦ **and covers the surface of the Earth by the ocean in a depth of 2.7 km.**
- Very little of this water can be used by humans.
  - ✓ 97% sea water, 3% fresh water
  - ✓ The readily available index of surface water is 0.3%
  - ✓ In general, the water available to living organisms is about 0.006% of the total amount
- The amount of water that life can consume is about 3,200 liters per person in the world
  - ✓ Comparison of water supply per capita in Korea, the amount can be used in 10 days approximately.

➢ Though the total amount of water on Earth is abundant, the usable water is a small percentage only.

1.2 Water Resources on Earth – Global Water Shortage

- **The amount of water each person needs to live through the day**
  - ✓ 20~50 liters for drinking, cooking and cleaning per day (UN)
- **One in six people in the world is not getting safe water (WHO etc.)**
  - ✓ 2.5 billion people, including 1 billion children, do not receive basic public health benefits
  - ✓ Every 20 seconds, a child dies due to this lack of benefits.
  - ✓ 1.5 million deaths per year result from poor water sanitation.



1.2 Water Resources on Earth – How Do We Tackle the Water Shortage?

- **We need skills and wisdom to meet the water.**

① Identification of water circulation: an accurate and precise hydrologic survey is essential.

② Saving water: education to change public perception of water consumption, development of water-saving equipment, adjustment of water price, etc.

③ Wastewater reuse: recycling water, reducing water leakage rate, etc.

④ Development & efficiency technology for water supply and preservation: Agricultural-related water systems, technologies related to dams and reservoirs, etc.

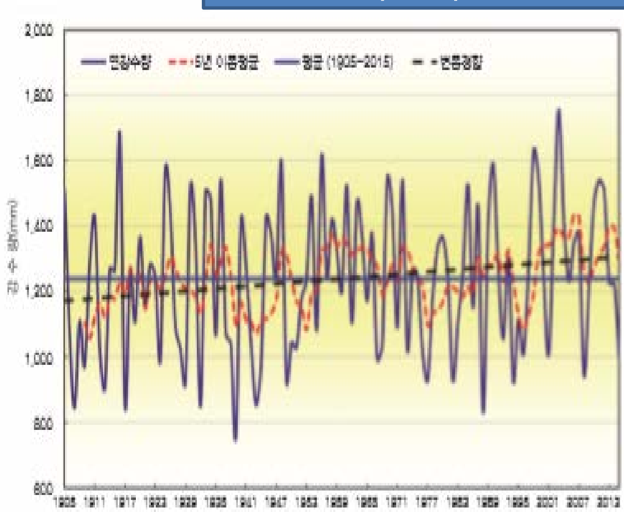

1.3 Water Resources in Korea

① The annual precipitation varies greatly, and extreme drought and flood frequency increased.

② The annual precipitation is about 1,300 mm

- 1.6 times more of the global average, and the precipitation per capita is 1/6 of the global average.

Annual precipitation trend (1905~2015)



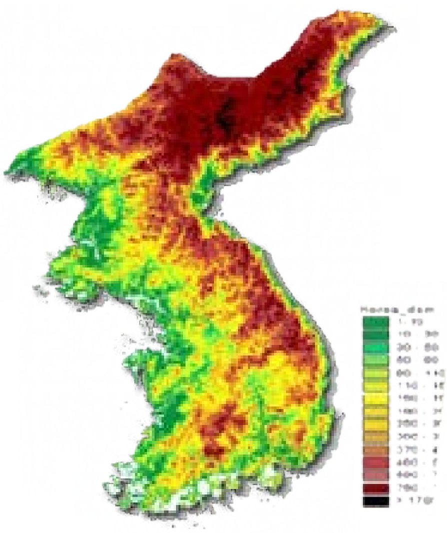
Year	Annual precipitation (mm)	Description
1939	754	Minimum No.1 in history
1988	830	No.2 in history
1907	844	No.3 in history
2003	1,756	Maximum No.1 in history
1916	1,683	No.2 in history
1998	1,630	No.3 in history

1.3 Water Resources in Korea

③ Concentration of precipitation during the year (70%), severe variation by region (catchment)

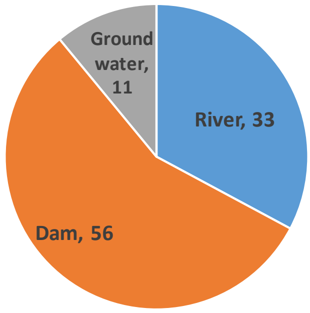
④ High flow deviation (65% mountainous region, rapid river slope, rapid flood discharge)

70% concentration of annual rainfall



1.3 Water Resources in Korea

- **Current status of total water resources**
  - ✓ Total water resources: 130 billion tons/year
  - ✓ Among them, approximately 37 billion tons are being used (28%)
    - (2016, long-term master plan of water resources)
  - ✓ Water resources in Korea account are sourced about 90% from rivers (dam + river) and 10% from underground water.



2. Hydrological Survey Methods and Application

2.1 Hydrological Survey Methods

2.2 Hydrological Survey Data Application

2.1 Hydrological Survey Methods

- **Purposes of the hydrological survey are**

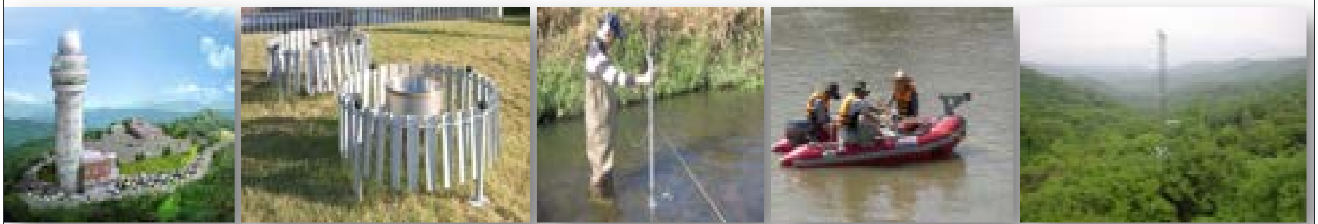
  By measuring and analyzing all information on water circulation--

  ① To provide the people with the water they need

  ② To mitigate the damage caused by drought and flood

  ③ To maintain good quality of clean and fresh water

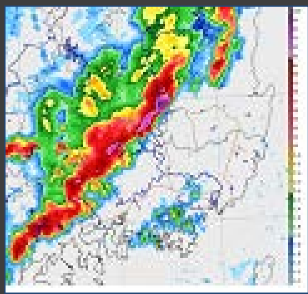
  In other words, the survey is performed to provide basic data for the management of national water resources.

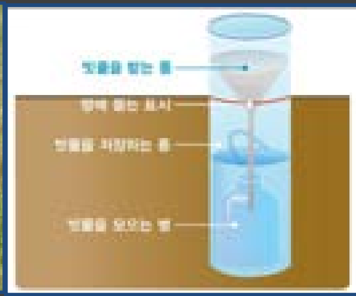


2.1 Hydrological Survey Method: Precipitation

- **Definition**
  - ✓ Rain or snow, hail, etc.
  - ✓ Survey the amount of water that fell to the ground from the atmosphere
- **Measuring equipment**
  - ✓ Rainfall radar, invert precipitation gauge, normal rain gauge, etc.

2.1 Hydrological Survey Method: Precipitation





2.1 Hydrological Survey Method: Precipitation

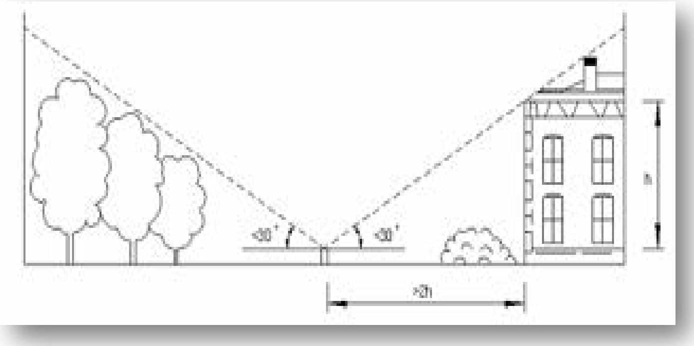
- **Trend of precipitation gauge**
  - ✓ Standards for measuring instruments officially used in Korea (2018, Korea Hydrological Annual Report)
  - ✓ Invert precipitation gauge takes up 99% or more.

전도형 강수량계(DC전원)

전도형 강수량계(AC전원)

2.1 Hydrological Survey Method: Precipitation (Location)

- **Optimal location to measure precipitation accurately**
  - ✓ To be installed on smooth land with no obstacles around it
    - Position suggested 4 times the height of the obstacle (minimum 2 times)
  - ✓ A place where there is no fear of water gathering
  - ✓ To avoid places with unusual wind speed and directions
  - ✓ An easy place to maintain and safe to use



2.1 Hydrological Survey Method: Precipitation(Location/False Case)

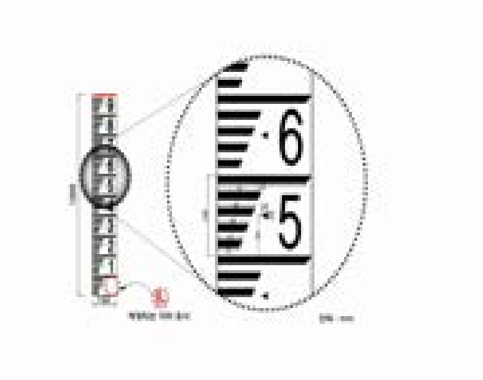
2.1 Hydrological Survey Method: Precipitation(Location/False Case)

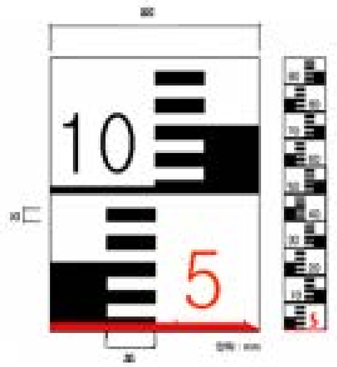
2.1 Hydrological Survey Method: Water Level

- **Definitions:** measuring the height of water surface against the reference plane
- **Measurement equipment:** water level staff + automatic measurement device
- **Automatic measurement device:** float type: 65%, radar type: 30%, pressure type: 5%
  - ✓ A gradual increase in radar type

2.1 Hydrological Survey Method: Water Level(Water Level Staff)

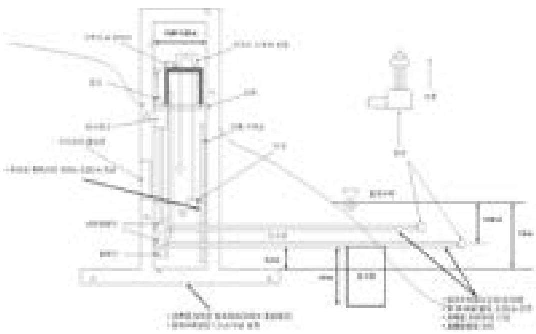
- **Measurement mark with direct eye for water level observation**
  - ✓ The most basic standard measurement method for water level monitoring stations
  - ✓ Mainly used for the error correction of automatic water level gauges
  - ✓ Correct installation and maintenance so that the accurate elevation can be known through the zero-elevation test point





2.1 Hydrological Survey Method: Water level (Float type)

Division	Principle	Installation	Maintenance	Character
-Float -Bridge attachment type -Embankment installation type	-Observation well = water level change =float location change	-Observation well, conduct water pipe, etc., -The initial installation cost is relatively high.	-Blockage problems caused by ingress soil occur in a river with a lot of soil flow. -The device itself is simple -Ease of response in case of failure	-Long-term stability -Critical (major) point is recommended. (only if there are no maintenance issues)

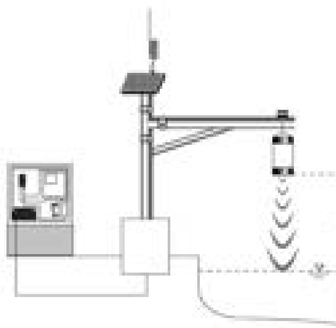


2.1 Hydrological Survey Method: Water level (Radar type)

Division	Principle	Installation	Maintenance	Character
-Radar ✓ Germany ✓ Japan ✓ America	-Converting the measured time of microwave reflection to water surface into water level	-Bridge, etc. facilities installation and movement convenience	-Access for maintenance and convenience	-Very little temperature impact -Requires jamming radio waves or interference checking -Contactless advantage -Gradually expanding trend -Observation well available

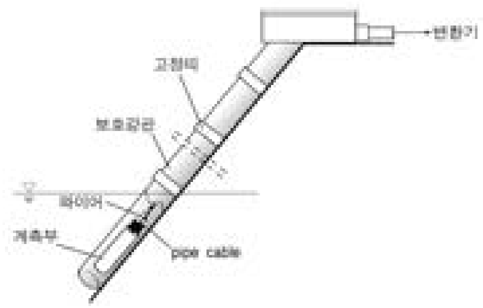
2.1 Hydrological Survey Method: Water level (Ultrasonic type)

Division	Principle	Installation	Maintenance	Character
Ultrasonic	-Converting the measured time of ultrasonic reflection to water surface into water level	-Same as radar type	-Same as radar type	-Exterior environmental impact existence (temperature, fog, rainfall, etc.) Contactless advantage



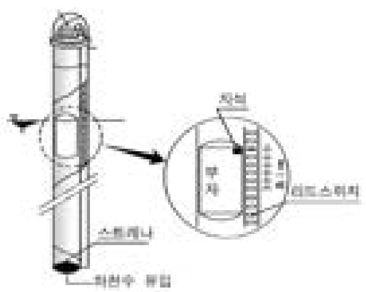
2.1 Hydrological Survey Method: Water level (Pressure type)

Division	Principle	Installation	Maintenance	Character
-Pressure	-Principle of proportional water depth and pressure	-Relatively simple -Can be installed in small areas or in small well	-Maintenance of soil inflow to well is required -Caution of error due to increase in flow rate (Requires stationary flow)	-Relatively economical -Simple to install, which is often applied to temporary stations -Well is required for long-term operation



2.1 Hydrological Survey Method: Water level (etc.)

Division	Principle	Character
Image type	Image analysis	-Maintenance of water level staff and image equipment is important. -Difficult to secure stability in check surface recognition
Lead type	Record the float location as the lead switch recognizes it	-Maintenance problem, water level recognition error occurred -Operational difficulties such as freezing problems, device failure problems, etc.



2.1 Hydrological Survey Method: Discharge

- **Definition:** Survey on the amount of water passing through a river section per second

$$Q = A \times V$$

2.1 Hydrological Survey Method: Discharge

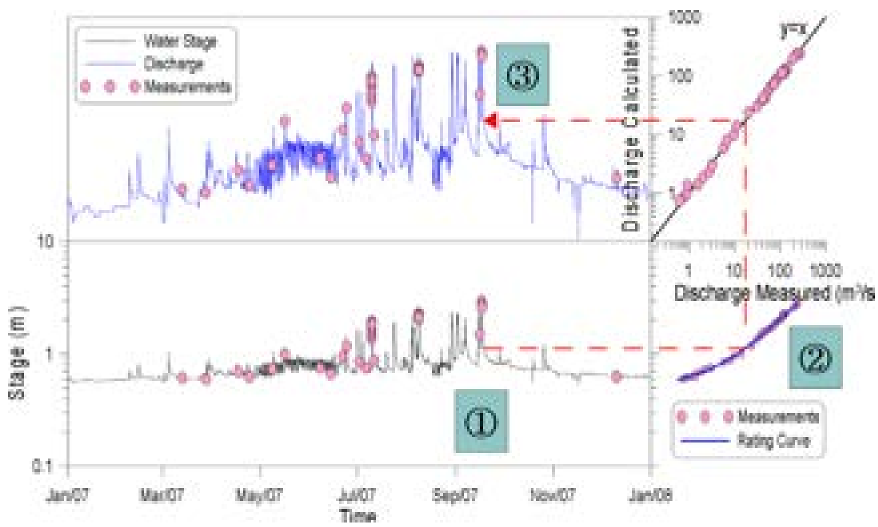
- **Concept of discharge calculation**
  - Water level is easy to be measured continuously using the gauge.
  - Continuous measurement of discharge is very difficult. (Automatic flow facility operation with some conditions is available)
  - Therefore, the calculation of general discharge is
    - To measure the discharge more than 36 times a year (1)
    - To develop a formula for measuring level and discharge (2)
    - To convert to discharge by substituting it for continuously measured water level (3)

※ Why can't all discharge stations be automatically measured?

- Restrictions on site conditions (always stay above a certain depth)
- Automatic flow measurement facilities also need to be directly calibrated every year.

2.1 Hydrological Survey Method: Discharge

- The first site or the site of the frequent river change: more than 36 times a year
- Stable site: improve the existing formula by measuring only 8-24 times a year

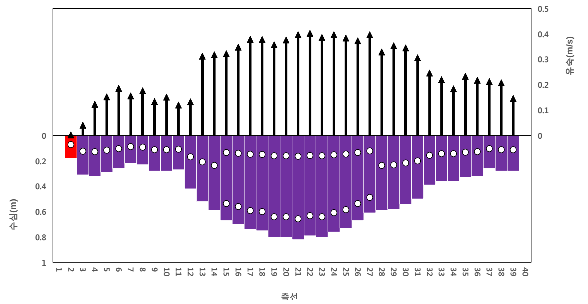


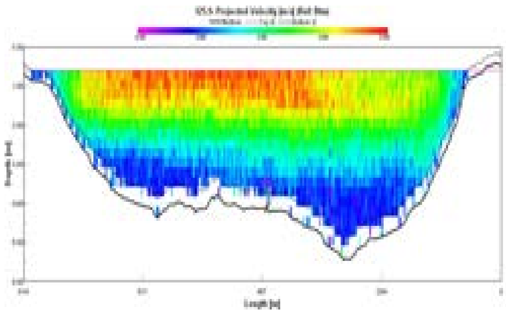
2.1 Hydrological Survey Method: Discharge

procedure	Main content
Education	Hydrologic survey method suitable for site condition Safety education
Pre-survey	Historical data collecting and analyzing and field characteristic Establish a measurement plan of the location, method, frequency, etc. Safety planning
Measurement & Calculation	Compliance with survey criteria Calculation using standard calculation SHEET
Data evaluation	Compliance with measurement data standards, reviewing hydrological characteristic, and evaluating uncertainty Analysis and review of methods and errors in calculation
Data complement	Analysis and complementation of cause of error according to data evaluation results Apply on future measurements
Data confirmation	Confirmation of data through re-evaluation
Data management & distribution	Data management through HDIMS Provision of provisional and final data through WINS, etc. Published in the annual hydrological report of Korea

2.1 Hydrological Survey Method: Discharge

- **Discharge measurement method**
  - ➢ Discharge is multiplied by the average flow velocity and the cross-section area.
  - ➢ Therefore, the average flow velocity and cross section area are measured in the field.
  - ➢ Divided into low, normal, and flood season according to timing (water level)
    - Low, normal season: flow current meter
    - Flood season: float, microwaves type etc.





2.1 Hydrological Survey Method: Discharge

- **Procedure**
  - ➢ Water level/surface width/water depth measurement/flow velocity measurement/discharge calculation

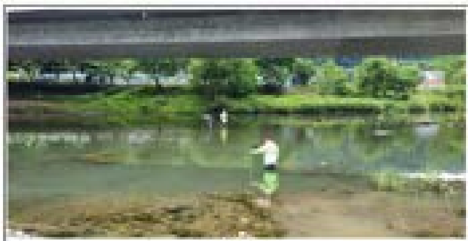
측정절차	측정내용	측정 사진
수위관측	측정 시작수위, 종료수위 관측 → 유량측정 평균수위 산정	
수면폭 측정	하천 수면폭 측정 및 유속측선수 구분	
수심측정	구분된 측선에서 수심 측정	
유속측정	수심에 따른 하천 도플유속 측정	
유량계산	현장에서 측정된 성과를 이용하여 유량계산 → 유속(㎧) × 단면적(㎡) = 유량(㎥/s)	

2.1 Hydrological Survey Method: Discharge

- **Utilization trend of discharge meter**
  - ✓ In the past, mechanical and float type were mainstream
  - ✓ The accuracy and efficiency of the latest devices are improving.
  - ✓ Gradual expansion into ADV, ADCP, microwave, etc

2.1 Hydrological Survey Method: Discharge

- Discharge measurement methods



Wading method

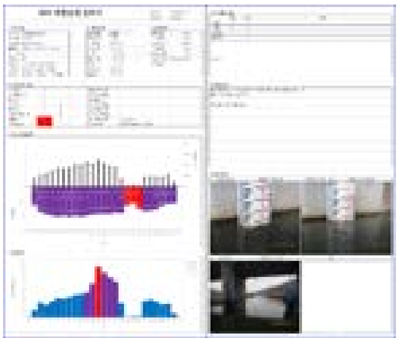
Lateral line method

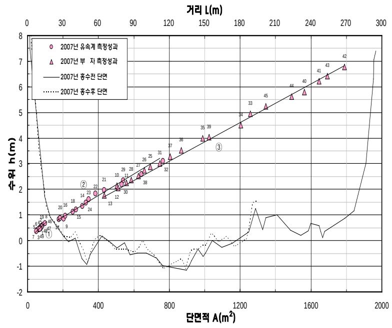
Boat method

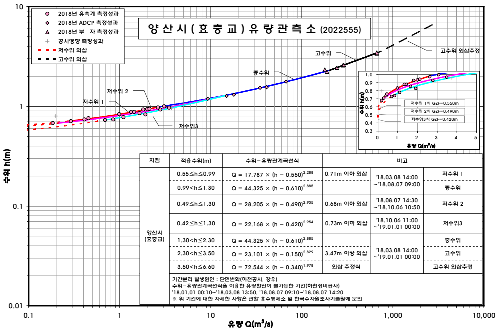
Bridge method

2.1 Hydrological Survey Method: Discharge

- **Rating curve development procedure**
  - ✓ Measurement results in quality control.
  - ✓ Result analysis:
    - Water level cross section , level-flow velocity, upper and lower runoff review
  - ✓ Curve development:
    - Period/section separating etc., curve precision

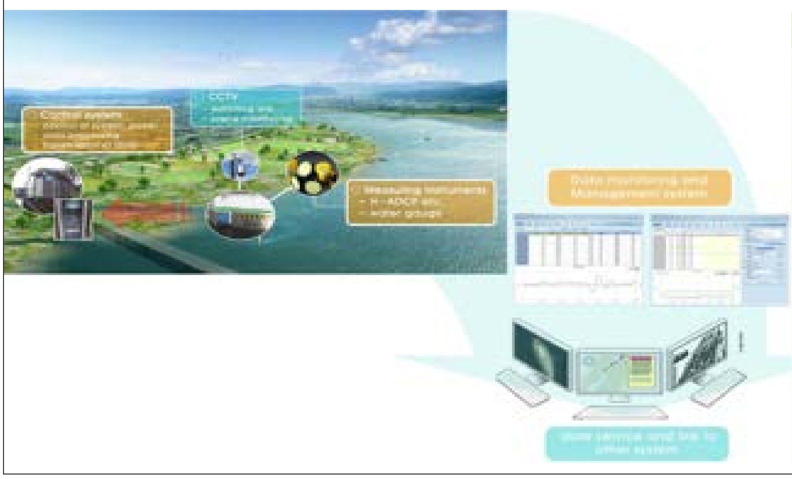




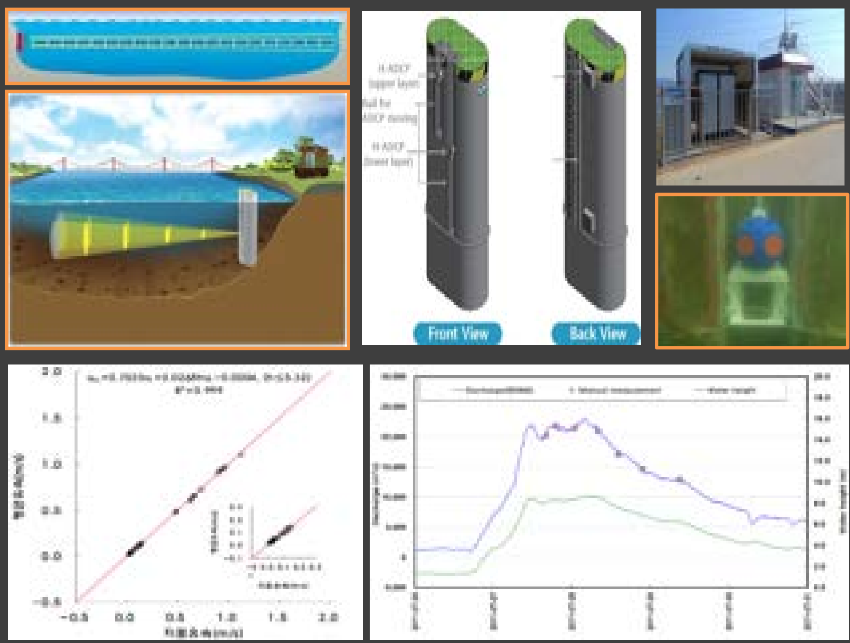


2.1 Hydrological Survey Method: Discharge

- **Automatic discharge measurement system**
  - ✓ IRDIMS (Integrated Real-time Discharge Information Measurement System)
  - ✓ Sensor type: ADVM, UVM
  - ✓ ADVM type is more applicable in Korea.



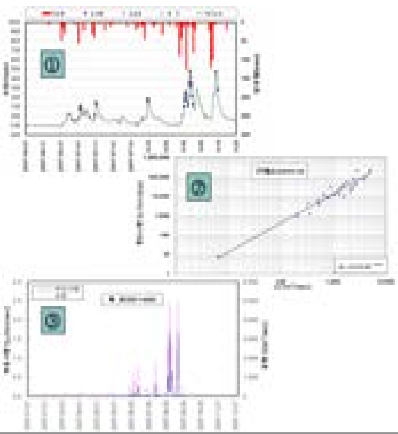
2.1 Hydrological Survey Method: Discharge



Calibration is required every year to produce reliable real-time discharge data through field measurement

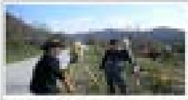
2.1 Hydrological Survey Method: Sediment Discharge

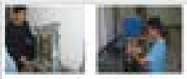
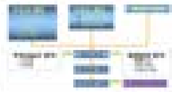
- **Definition**
  - Survey on the amount of sediment passing through a river section per second
- **Procedure**
  - Measure and analyze more than 15 times a year (1)
  - Make rating curve from the data on the measurement of discharge –sediment (2)
  - Calculate the amount of sediment for the desired discharge (3)



2.1 Hydrological Survey Method: Sediment Discharge

- **Sediment discharge measurement and analysis method**
  - ✓ Section measurement/bed material collection/water level measurement
  - ✓ Suspended sediment measurement/analysis the sample/calculation sediment

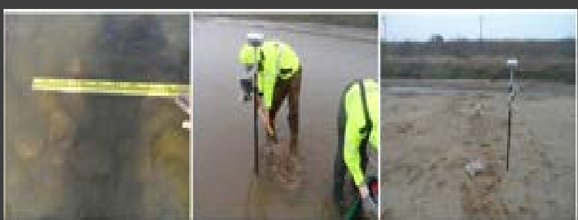
측정절차	측정내용	측정 사진
단면측량	홍수 전후 단면측량 실시 → 홍수 전후 평균단면적 사용	
하상토 채취	부유사 측정단면에서 하상토 채취 → 부유사 미측정 구간의 소류사량 추정	
수위관측	측정 시작수위, 종료수위 관측 → 유사량 측정 평균수위 산정	
측선배치	부유사량 측정 측선 배치	

측정절차	측정내용	측정 사진
부유사량 측정	채취기를 이용한 부유사량 측정 → 수심적분법, 점적분법	
시료분석	채취된 하상토 및 부유사량 분석 → 입도분포 및 부유사 농도분석	 하상토 분석 부유사 농도
유사량 산정	유량과 유사농도를 이용하여 산정 → 유량 × 유사 농도 = 유사량	

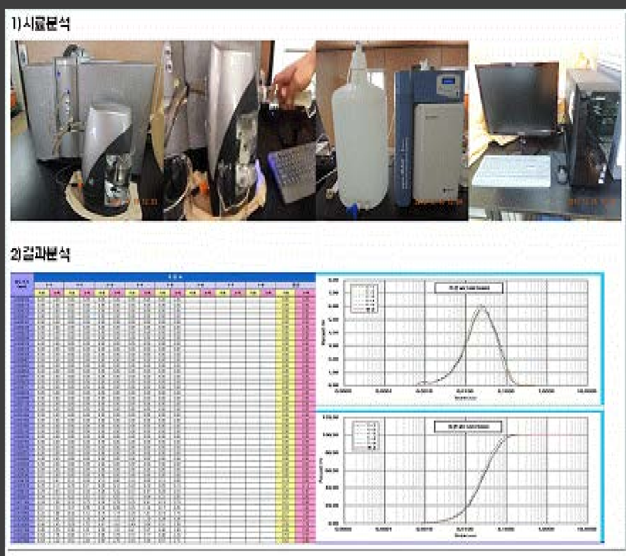
2.1 Hydrological Survey Method: Sediment Discharge

• Measurement of suspended sediment

• Collecting bed material



• Particle size analysis



2.1 Hydrological Survey Method: Soil Moisture

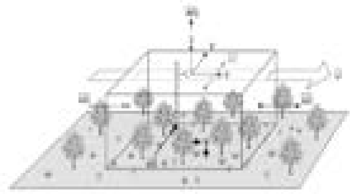
- **Definition**
  - Measurement of the amount of moisture contained in the soil
- **Measurement method**
  - FDR
    - According to dielectric constant in the soil using high frequency wave
    - Conversion of capacitance in a measuring circuit
  - TDR
    - Dielectric constant conversion according to the reflective wave in soil using ultra high frequency wave
  - Other Cosmic-Ray Method, etc

2.1 Hydrological Survey Method: Soil Moisture

2.1 Hydrological Survey Method: Evapotranspiration

- **Definition**
  - The sum of evaporation from water surfaces, soil, and transpiration from vegetation
- **Major factor**
  - Micrometeorological: radiation, temperature, wind, humidity, precipitation, etc.
  - Surface: vegetation, soil moisture, etc.
- **Measurement device (for Eddy Covariance Method)**
  - Evapotranspiration tower: 3D wind speed & direction meter + gas analyzer etc.

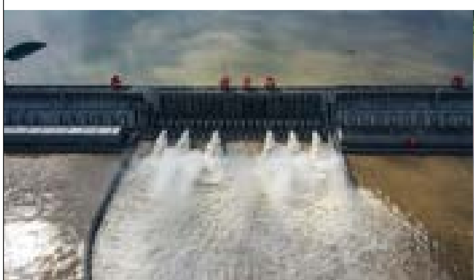




2.2 Hydrological Data's Application (1)

- **Water regulation:** water resources planning and management/water supply/ dam design & operation/ conflict over right to water and its solution/ water resource concept arrangement and assignment in international river etc.

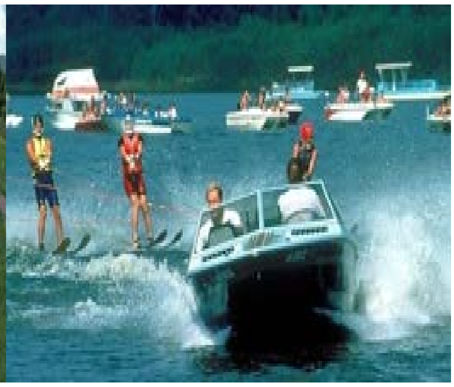
- **Water control:** flood warning/water control planning/bank design/ design & operation of water control facilities / bride and convert design etc.



2.2 Hydrological Data's Application (2)

- **Water environment:** river maintenance flow/river environment design & management/water pollution management
- **Others**: water leisure (river side activity, water-ski, fishing etc.)/ water circulation research(long-term water resource variation, climate change etc.)





2.2 Hydrological Data's Application: Valuation

- **Results of valuation study of hydrological data**
  - ✓ Benefit cost ratio(B/C ratio: benefit/cost)
  - ✓ The hydrologic survey provides 1.5 to 21.2 times higher profit values economically.
  - ✓ More than the project cost
  - ✓ About 10 times in Korea

권역	국가수문관측망					
	수위	유량		유사량	지하수위	증발산량
		유량	자동유량			
합계	645	380	97			
한강	200	133	32			
낙동강	206	115	29			
금강	148	79	22			
섬진강	44	27	3			
영산강	47	26	11			


Summary (2)

1) **Precipitation:** conductive rainfall gauge, rainfall radar

2) **Water level:** float, radar, pressure type etc.

3) **Discharge:** measurement for a rating curve, mechanical/ADV/ADCP, float type etc.
Automatic discharge: real-time discharge measurement using ultrasonic sensor such as ADVM etc.

4) **Sediment:** suspended sediment and bed martial measurement & analysis
Soil moisture: electronic resistance sensor(TDR, FDR)
Evapotranspiration: Eddy Covariance Method (3D wind speed & direction meter + gas analyzer)

Summary (2)

5) Application of Hydrological Data
- Essential basic data of national water management
  (water regulation, water control, water environment, water leisure etc.)

6) Value of Hydrological Data
- Economic value is difficult but according to relative research
- B/C 1.5~21


Thank you very much

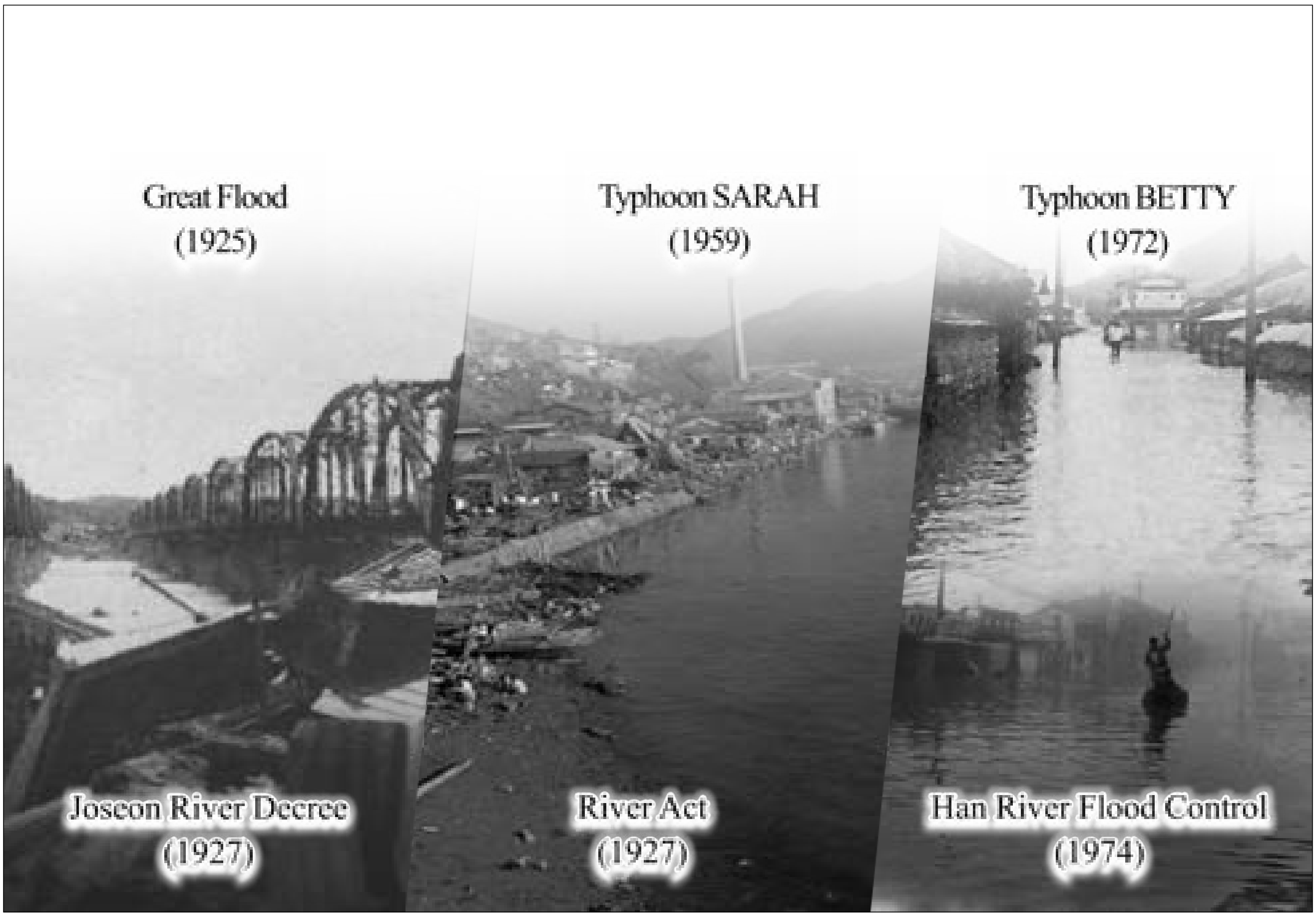
MEMO

2nd Master Plan for Hydrological Investigation

Hydrological Survey

Improving the Reliability and Usability of Hydrological Data: The 2nd Master Plan of Hydrological Investigation (2020~2029)

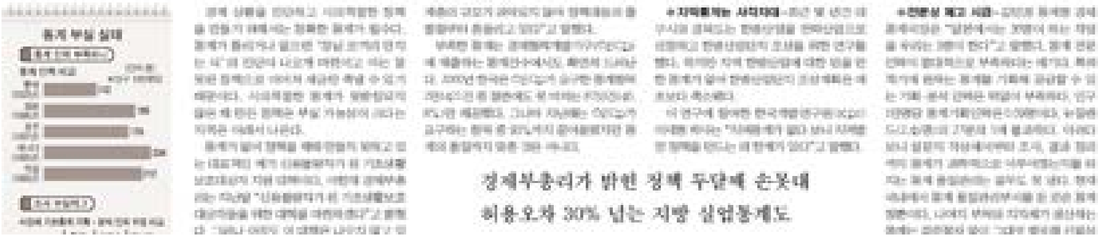
KIHS 한국수자원조사기술원
Korea Institute of Hydrological Survey



Expanding Management from Flood to Water

1st Period (1974~1986) | 2nd Period (1987~2004) | 3rd Period (2005~)

No Statistics, only investigation for several months…
Missed the time to establish a policy

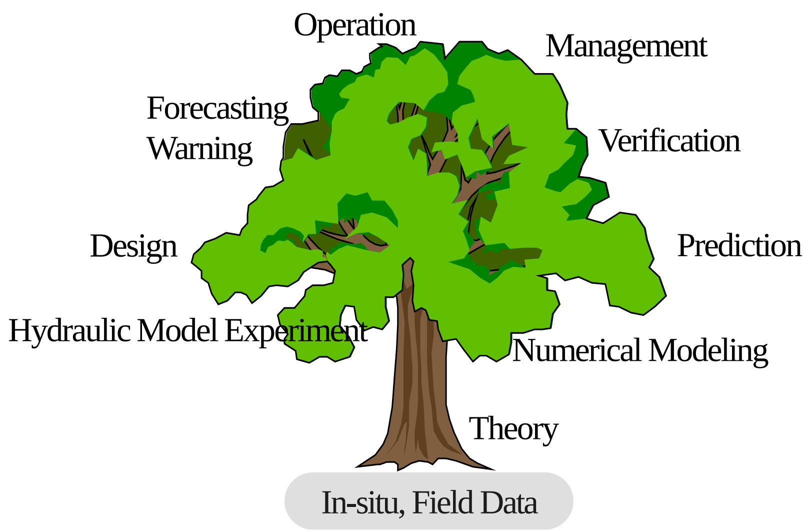

경제부총리가 밝힌 정책 두달째 손못대
취용오차 30% 넘는 지방 실업통계도

It is necessary to review again from the origin of the Hantan River Dam construction

임진강 유역 치수대책으로 정부가 1999년부터 추진했던 한탄강댐 건설사업은 기본홍수량 등 기초 자료가 부실한 상태에서 객관적 근거 없이 사업이 추진됐다는 감사결과가 나왔다.

First implementation of the total pollution control system in Gyeonggi-do

Models can be bought, but data cannot



The 1st Master Plan of Hydrological Investigation (2010–2019)

- Increase Professionalism of Hydrological Investigation!

System Improvement	River Law, Regulations	Water Resources Law, Regulation Updating Quality Control (QC), Data Certified
Diversification & Modernization	Precipitation, Stage, Discharge, Analogue, Manual Measurement	Evaporation, Evapotranspiration Soil Moisture, Sediment Acoustic, Rainfall Radar Automatic Measurement
Organizational Specialization	Water Information Center Hydrological Survey Center	Water Resources Information Center Korea Institute of Hydrological Survey

The 2nd Master Plan of Hydrological Investigation (2020–2029)

- Increase Usability of Hydrological Investigation!

Expansion of Hydrological Survey Network	National Hydrological Survey Network (ME, K-water)	→	National Hydrological Survey Network (Joint Use, unique task for each institution)
Enhancement of Reliability and Usability	Certification of Annual Data of Precipitation, Stage, Discharge, QC	→	Expansion of the Number of Certification and QC Items
Strengthening the Execution System	Master Plan, Prevention of Duplicate Execution	→	Institutional Joint Annual Implementational Plan, Work Support and Evaluation System

Contents

1. Basic Concept

Purpose of the Investigation: Comprehensive Planning and Management

Natural State → Expected State

“Setting what is most desirable state, starting from the natural and social status”

“Finding out what functions can be expected when placed in their natural state”

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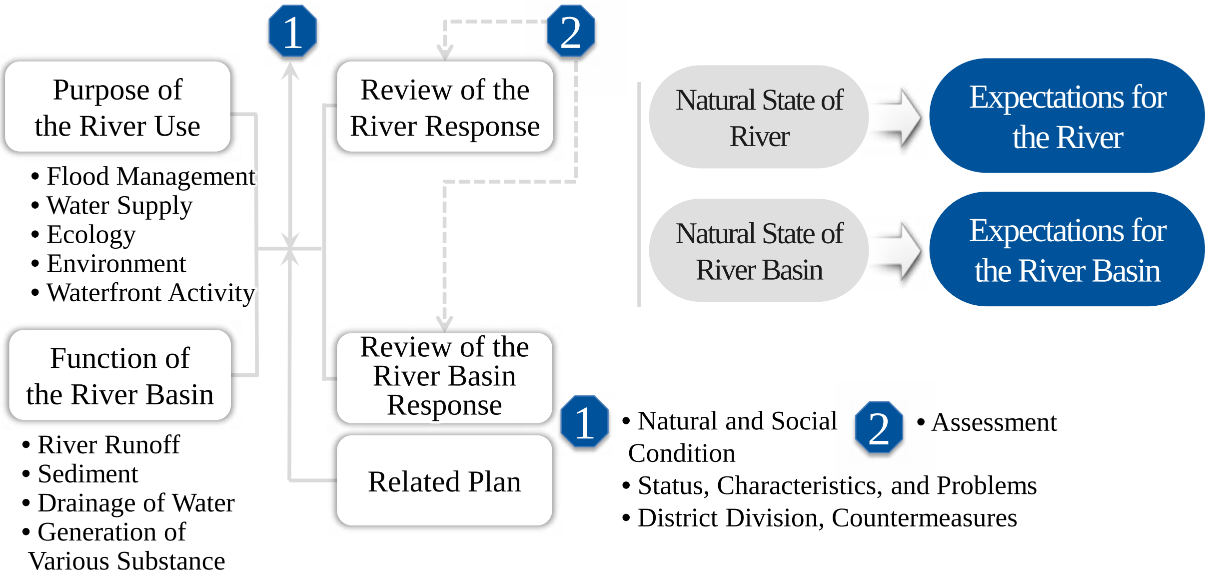
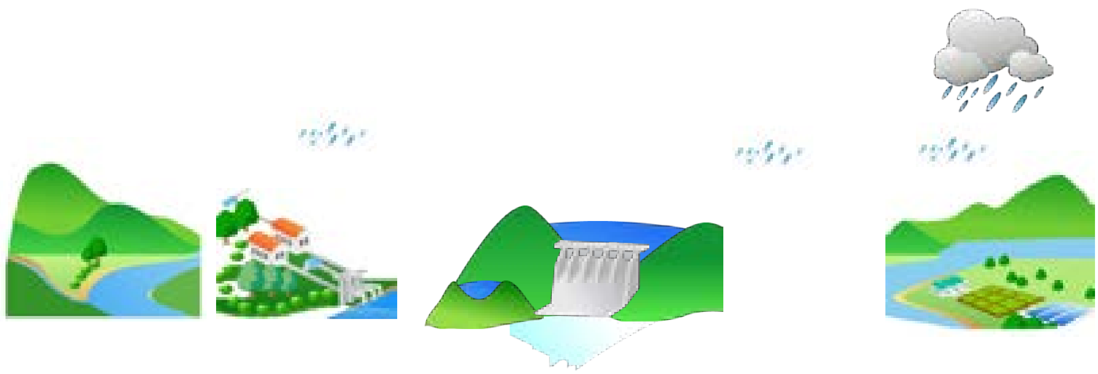
Significance of the Investigation: Comprehensive Assessment



Traditional Water Management Method

Waterway | Storage | Infiltration



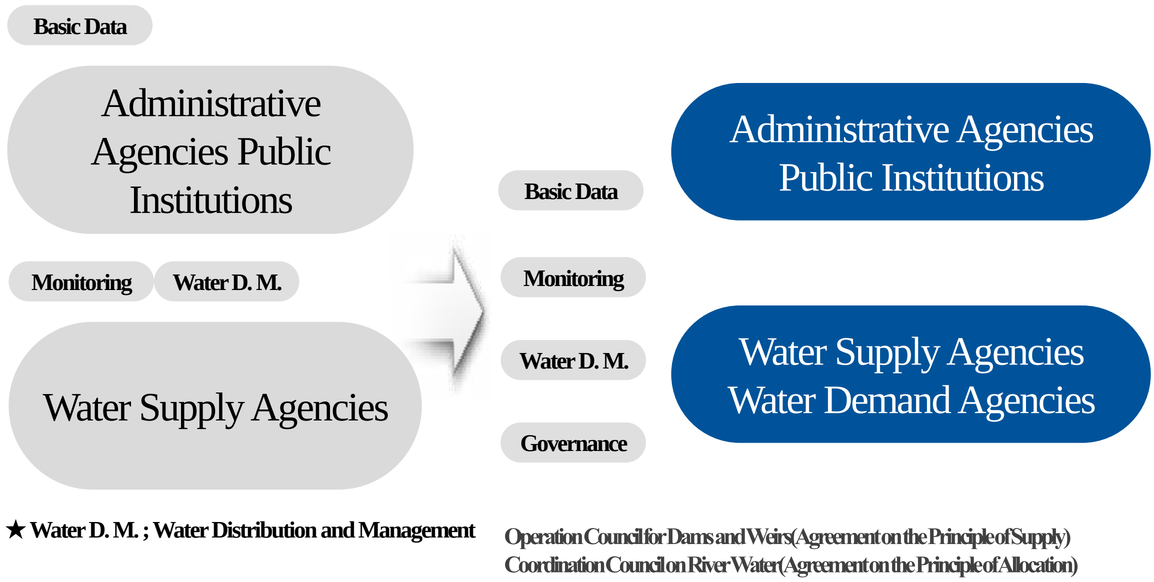
Direction of the Flood Management (1/2)

Target of Defense		Target of Isolation	Target of Defense
People, Property	⇨	People, Property	
Target of Isolation		Target of Isolation	
Flood		Flood	

Direction of the Flood Management (2/2)

Div.	Current Direction		Improvement Direction
Goal	· Isolating the Flood from Targets of Defense		· Isolating Targets of Defense from the Flood
Major Means	· Large-Scale Structural Measures · River Maintenance · Bottom Repairment	⇨	· Small-Scale Structural Measures · Dam Operation Improvement · Flood Forecasting · Increasing and Adjusting the Water Resistance of Land
Causes & Sol.	· Exceeding of the Design Flood due to Climate Change · Recognition of "Absolutely Safe"	⇨	· Preparing for the Occurrence of Residual Flood Risk · Increasing Water Resistance · Reducing Adverse Impact on the Environment

Direction of the Water Use Management



2. The 2nd Master Plan of Hydrological Investigation (2020-2029)

Background

▪ Establishment of the 2nd Master Plan that comprehensively considers environmental conditions such as intensifying climate change and policy changes such as the unified water management

- Necessary to improve the safety of the people from the increasing risk of climate change

Increasing frequency of torrential rain: (Rainfall over 50mm/hour) 2013 yr 18 times → 2018 yr 35 times, about twice as much
damage caused by typhoons and heavy rains in the last 10 years: about 4 trillion dollars, 146 deaths, 210,000 victims

- Difficult to cope with disasters with traditional measures such as dam construction

Difficult to continuously promote structure-oriented policies such as dam construction and river maintenance due to environmental impacts
Preparing the smart system using advanced ICT and equipment to promote non-structural measures

- Increased public demand for water management policies due to the unified water management

Need to relieve the public anxiety over water safety
Increasing demand for information from the public, such as provision of living information related to water for waterside leisure

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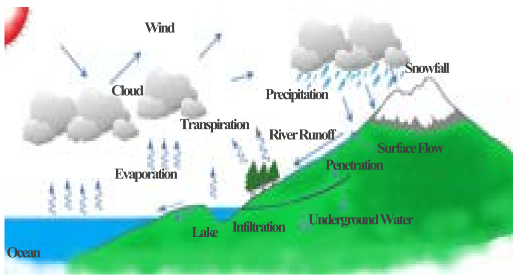
Significance

▪ National Strategy for Direction and Implementation for Systematization and Efficiency of Hydrological Investigation

- Legal Basis: 10-year Master Plan under Article 9 of the Water Resources Act
- Planning Period: 2020 to 2029 (10 years)
- Contents: Status & Evaluation, Network, Technology Development, Provision & Use of Data
- Survey Item: Water Level and Flowrate of River and River Water Use and Supply Facilities
  Precipitation, Evapotranspiration, Soil Moisture, etc. in River Basin

Purpose of the Investigation (Article 9 of the Act)
1. Understanding the structure of water cycle in river, basins, lakes, and swamps
2. Establishing a plan for water resources
3. River maintenance, installation of river facilities, and design of various structures
4. Use and management around rivers
5. Flood and drought forecast, etc.
6. Other matters necessary for water resources management



Outcomes, Limits, and Suggestions of the 1st Master Plan (1/2)

- Expansion of the National Hydrological Investigation Network (NHIN)
- Establishment of QC Standards Suitable for Institutional Characteristics
- Strengthening the basis for Information Sharing and Utilization

Outcomes

- Securing the foundation for hydrological investigation by operating the NHIN

  Operating 9 rainfall radars and 1,213 hydrological gaging stations
- Enhancing the reliability of data through scientific investigation and advanced technology

  Rate of automatic discharge gaging station 25 %, Utilization rate of ADCP 87 % in discharge investigation
- Strengthen disaster reduction support by providing customized flood information

  Operating 409 stations for providing flood risk information(interest, caution, alert, serious) to governmental agencies, etc.

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Outcomes, Limits, and Suggestions of the 1st Master Plan (2/2)

Limits and Suggestions

- Necessary to establish a dense NHIN that includes the work of all agencies

  (As-Is) Ministry of Environment → (To-Be) + local government, public institutions, etc.
- Insufficient QC, linkage and utilization of hydrological data produced by each institution

  Necessary to manage hydrological data of the water supply and use facilities at the national level systematically
- Compared to the introduction of advanced equipment, applied R&D is insufficient

  Need for research to improve the field applicability of advanced equipment like rainfall radar (large 7, small 2), satellite, and ADVM, etc.

Policy Change

1911 Start of modern hydrological investigation (Sancheong station, Precipitation 1904, Stage 1911, Discharge 1911)
1999 Newly establishment of the River Law Article 18 (Conducting Hydrological Investigation)
2001 Revision of Article 18 (Conducting River Basin Investigation), Including hydrological Investigation in River Basin Investigation
2007 Newly establishment of the River Law Article 17 (Conducting Hydrological Investigation)
2017 Enactment of Law on Investigation, Planning, and Management of Water Resources

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Propulsion Direction (1/2)

- Goal: Producing high quality hydrological data and enhancing shared value
- Strategy: ① Enhancement of reliability of hydrological data through establishment of investigation base and innovation, ② Providing customized hydrological data and strengthening the usability of hydrological data

Detailed Goal	Propulsion Task
1. Innovation of the National Hydrological Investigation Network (NHIN)	1.1. Qualitative and Quantitative Reinforcement in NHIN 1.2. Modernization of Hydrological Investigation 1.3. Improvement of Hydrological Data Transmission System
2. Enhancement of Reliability of Hydrological Data	2.1. Customized QC Suitable for Each Organization 2.2. Improvement of Hydrological Data QC System 2.3. Improvement of Hydrological Investigation Standards

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Propulsion Direction (2/2)

Detailed Goal	Propulsion Task
3. Improving the Usability of Hydrological Data	3.1. Enhancing the Provision of User-Friendly Information 3.2. Establishing the Joint Utilization System of Data 3.3. Strengthening the Basis for Water Information Utilization
4. Strengthening the Execution Base	4.1. System Improvement in Consideration of Changes in Water Management Conditions 4.2. Revitalizing R&D 4.3. Strengthening Education and International Cooperation

Unified Water Management

National Satisfaction Survey on Environmental Policy (2019.12., 700 people)

- 10 policies (overall satisfaction 60.1 points), water management 8th (63.9 %) in popularity, 2nd (60.3 points) in satisfaction
- Reason for dissatisfaction: Lack of response to change circumstances (33.3 %), consistency (28.2 %), tangible policy effects (20.5 %), etc.

Integrated Water Management by Ministry of Environment

- Establishment of water management system, securing water safety, supply of clean water, value creation and management innovation

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Future in 10 years

	Now (As-Is)	10 years later (To-Be)
1. NHIN 2. Reliability	Centered on the Ministry of Environment	Including All Agencies
3. Usability	Provider-Oriented Utilization	User-Oriented Real-Time Data Sharing
4. Execution Base	Management System for Each Institution	Customized Joint Management System

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Goal 2029

8,460 Stations	3 Ministries 16 Cities and Provinces	100 %	Sharing of Various Real-Time Data
NHIN	**NHIN Operating Organization**	**Data QC**	**Usability**
· Joint Utilization Network (3,573) · Institution-Specific Purpose Network(4,887)	+ Including 9 Public Organizations	· Customized Hydrological Data QC for All Agencies	· Real-Time Collection · Sharing of Water Information · Water Management Support
↑	↑	↑	↑
· NHIN (1,213 Stations)	· Ministry of Environment · K-water	· QC for Data Produced by Ministry of Environment	· Collection of Data by Each · Complex Sharing System

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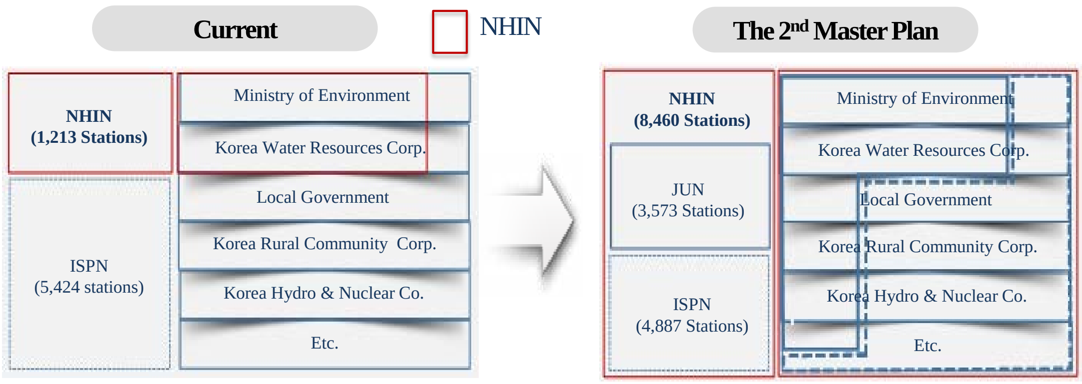
Propulsion Task (1-1)

■ Innovation of the NHIN

1-1. Qualitative and Quantitative Reinforcement in NHIN

Expansion of the NHIN (Joint Utilization Network +Institution-Specific Purpose Network)



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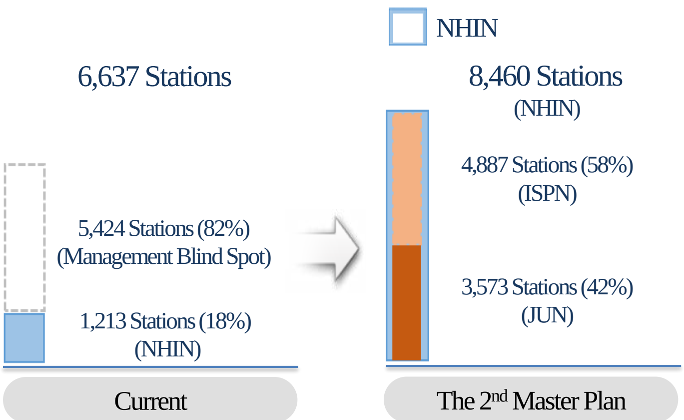
Propulsion Task (1-1)

■ Innovation of the NHIN

1-1. Qualitative and Quantitative Reinforcement in NHIN

Expansion of the NHIN (Joint Utilization Network +Institution-Specific Purpose Network)



NHIN

Division	Current	The 2nd Master Plan Sum	JUN	ISPN
Sum	1,213	8,460	3,573	4,887
Precipitation	-	3,326	1,619	1,707
Water Level	645	3,168	1,073	2,095
Flowrate	380	1,489	519	970
Sediment	138	146	146	-
Soil Moisture	25	210	110	100
Evapotranspiration	25	121	106	15

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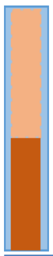
Propulsion Task (1-1)

■ Innovation of the NHIN

1-1. Qualitative and Quantitative Reinforcement in NHIN

Reinforcement of Hydrological Investigation in Island Regions

NHIN



164 Stations (NHIN)

67 Stations (58%) (ISPN)

97 Stations (42%) (JUN)

Division	Sum	JUN	ISPN
Sum	164	97	67
Precipitation	60	60	-
Water Level	62	25	37
Flowrate	34	4	30
Sediment	4	4	-
Soil Moisture	2	2	-
Evapotranspiration	2	2	-

Jeju Island

Short Term (within 1 year)

Implementation plan, installation and operation in Jeju island

Middle Term (2~3 years)

Establishment of installation and operation plan for island regions based on the case of Jeju island

Long Term (after 4 years)

Continuous expansion of island regions by year
Establishment of operating system for the entire country

Propulsion Task (1-2)

■ Innovation of the NHIN

1-2. Modernization of Hydrological Investigation

Expanding Application of the Advanced Technology Suitable for Measurement Types
Development of Automation Technology for Flow and Sediment Measurement

- Rain Radar Installation and Operation — **To improve the accuracy of urban flood prediction**
  - Large 7 + Small 2 → Large 7 + Small 19 [7 (21 vulnerable urban rivers), 10 (shielding supplement)
- Equipment Verification System (2023) — **Laboratory level test, Comparative Measurement, Test river operation**
  - Rain & Stage Gage, Flow Meter → + Flow Meter such as ADCP, Evapotranspiration Meter, Soil Moisture Meter, etc.
- Multipurpose Observatory (Pilot, 2022) — **Stage, Flow + Sediment, Water Temp., Electric Conductivity**
- Water Resources Disaster Observation Satellite — **Flood, Drought, Green Algae Monitoring (2025)**
- Automatic Measurement Technology Development — **Non-Contact Flow Meter, Sediment Measurement Using ADVM (2021)**

Propulsion Task (1-2)

▪ Innovation of the NHIN

1-3. Improvement of Hydrological Data Transmission System

Establishment and Operation of Various Transmission Systems Suitable for Each Organizations

- Diversification of Communication Networks — **To secure a disaster information transmission system**
  - Terrestrial Network
    Commercial Satellite
    → Disaster-only Korean geostationary orbit communication satellite (2027)
    Establishment of redundancy plan (2026)
    Establishment of satellite network utilization system for all gaging stations (2029)
- Optical Communication-Based Network — **Building an intelligent network for collection and utilizing hydrological information including video, etc.**
  - Use of Dedicated Line at Some Stations
    → Establishment of the comprehensive network plan (2022)
    Pilot operation (2026)

Propulsion Task (2-1)

▪ Enhancement of Reliability of Hydrological Data

2-1. Customized QC Suitable for Each Organizations

Establishment of Instructions and Systems for Quality Control of Hydrological Data
Capacity building of Hydrological Investigation Organizations

- Customized Instructions — **Establishing instructions (standards) according to JUN and ISPN**
  - Instruction on Installation Environment and Maintenance of Hydrological Investigation Facilities and Standards for QC of Hydrological Data
    → Differentiating standards and giving grades (high, medium, low)
    JUN: Authorization of data, Confirmation of annual statics
    ISPN: Data confirmation through quarterly evaluation
- Establishment of Quality Management System — **Quality management System, Capacity building**
  - Establishing a Data Quality Management System for Each Organization
    → Support for expanding data quality management to all organizations
    Support for reinforcing capacity for quality management of hydrological data in charge of local governments and public institutions

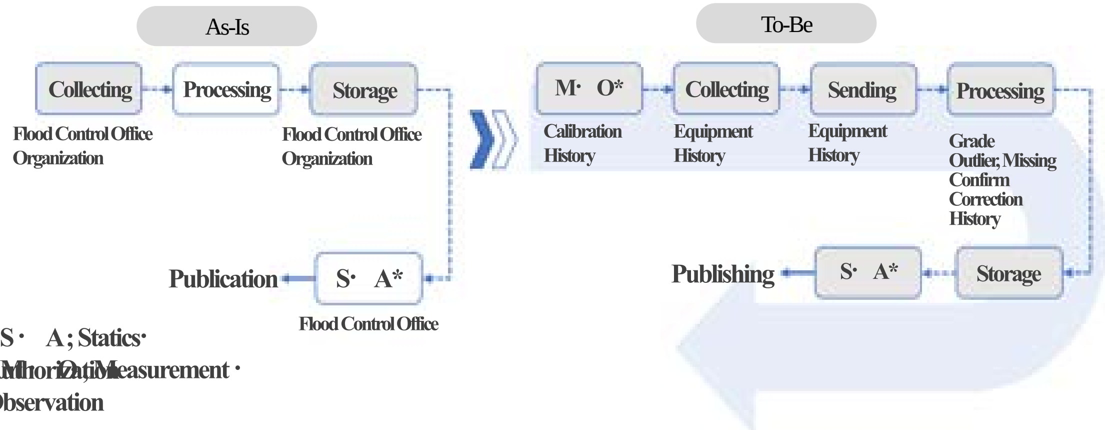
Propulsion Task (2-2)

▪ **Enhancement of Reliability of Hydrological Data**

2-2. Improvement of Hydrological Data QC system

For the Entire Process

· Integrated Management of the Entire Process **From field measurement to data production**



* S· A ; Statics· Authorization · M· O ; Measurement · Observation

Propulsion Task (2-2)

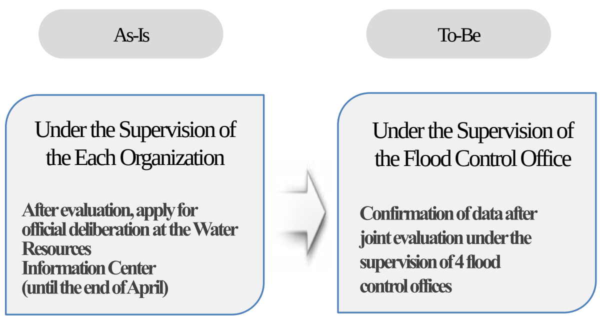
▪ **Enhancement of Reliability of Hydrological Data**

2-2. Improvement of Hydrological Data QC system

For Self-Assessment and Official Approval

· Establishment of an Integrated Evaluation System

It takes one year to finalize the data for the publication of the Korean Annual Hydrological Report, because it takes a long time for the self-evaluation and official approval process



- After conducting self-evaluation by region and quarterly, the completed data is distributed with the evaluation result
- Operate joint evaluation system of hydrological investigation organization in the jurisdiction of 4 flood control offices under the supervision of flood control offices
- Adjust the function of the Deliberation Committee for official approval of hydrological data from the data deliberation to the consulting and deliberating on evaluation results, implementation plans, and handling of pending issues.
- Through self-evaluation pilot operation (until 2021), promote the establishment of an integrated management system (until 2025)

Propulsion Task (2-3)

■ Enhancement of Reliability of Hydrological Data

2-3. Improvement of Hydrological Investigation Standards

Linkage of Various Regulations

· Organic Linkage of Regulations for each Organizations

Review of standards, regulations, and guidelines (2021)
Improvement plan, Revision of regulations, etc. (2023)

· Ministry of Land, Infrastructure and Transport → River Design Standard

· Ministry of Environment → Hydrological investigation business regulation
Regulations on the installation and maintenance of hydrological investigation facilities and quality control of hydrological data
Regulation on the official approval, storage, distribution, and use of hydrological data

· Korean Agency for Technology and Standards → Korean Standard

Propulsion Task (3-1)

■ Improving the Usability of Hydrological Data

3-1. Enhancing the Provision of User-Friendly Information

Format, Providing, and Utilization of Data

· Establishment of the Customized Information Providing System

For professional use of hydrological data

· Providing of guidelines for utilization of hydrological data for calculation of basic hydrological data such as design flood (2025)
· Establish a provision system for providing big data so that it can be used in conjunction with various information in the watershed in consideration of tasks for each users

Data Type

Precipitation	Flow velocity	H-Q	Q-Sediment	Avapro-transpiration	Dam· Reservoir	Instream flow
Stage	Flow rate	Sediment	Soil moisture	Intake· Drainage	Basin data	Etc.

Data Processing

Basic data for river basin	Hydrological data (before and after QC)	Officially approved data
Data of related organizations	Statistical processing	

Propulsion Task (3-1)

■ Improving the Usability of Hydrological Data

3-1. Enhancing the Provision of User-Friendly Information

Format, Providing, and Utilization of Data

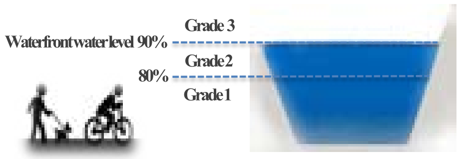
Providing data

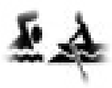
Data processing stage	Raw data	Provisional data	Confirmed data	Statistic data
Data format standardization	Text	File	Analysis tool	Input data
How to provide data	Portal	Mobile app.	Annual report	Report

· Water-friendly activity index, statistical data **To support people's leisure and water-friendly activities**

Non-enter type: Safety (waterfront water level), Comfort (DO, Turbidity, Chl-a)

Enter type: Safety (flow velocity, flow rate), Comfort (fecal coliform bacteria, DO, Temp., pH, Turbidity, Chl-a)





Index	Ref. Flow Velocity (m/s)	Ref. Flow Rate (㎥/s)
Grade 1	< 0.3	< 800
Grade 2	< 0.5	< 1,400
Grade 3	≥ 0.5	≥ 1,400

Propulsion Task (3-2)

■ Improving the Usability of Hydrological Data

3-2. Establishing the Joint Utilization System of Data

Guidelines for using data when establishing various plans
Improvement of the official approval system of data

· Establishment of Joint Utilization System of Hydrological Data

Systematization of data analysis, processing, providing types, and procedure (2021~)

- Inappropriate use in legal plans
- No history management of shared data

Establishment of guidelines for using data (2021)
Establishment of a history management system for real -time data providing by 15 organizations (2021~)

· Improvement of the Evaluation System of Hydrological Data

Improvement of self-assessment for each hydrological investigation organizations (2021~)

- Operation of self-assessment committee for each organizations
- Operation of deliberation committee for official approval of data

Operating joint evaluation system under the supervision of 4 flood control offices

Propulsion Task (3-3)

▪ Improving the Usability of Hydrological Data

3-3. Strengthening the Basis for Water Information Utilization

Improvement of collection system for water intake and drainage data

· Improving the Collection System of River Water Use

For real-time water intake data collection (2021 ~)

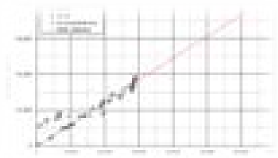
· Report on water intake data by water users
· Need to secure reliability of measurement data

Establish measurement standards to secure reliability
Improvement of the agricultural water collection system, which accounts for 60% of the total water consumption

Linkage between systems
· waterworks and sewerage Office, factory, etc.
· connection of management system

Flow measurement
· pumping station, weir for water intake, factory, etc.
· flow meter (ADVM, ADCP, etc.)

Operation time, amount of electricity
· pumping station
· relationship between flow rate and wattage



Propulsion Task (3-3)

▪ Improving the Usability of Hydrological Data

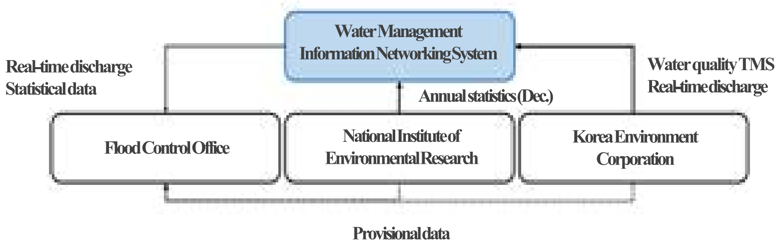
3-3. Strengthening the Basis for Water Information Utilization

Improvement of collection system for water intake and drainage data

· Improving the System for Sharing Discharged Water to Rivers

Improvement of distribution system of discharge data such as sewage treatment facilities (2021~)

· Promotion of distribution system improvement for sharing and utilization of production data for each stage from real time data
(raw data → provisional data → confirmed data → statistic data)
· About 950 facilities capable of real-time monitoring through the remote water quality monitoring system among about 18,200 sewage and wastewater treatment facilities nationwide



Propulsion Task (4-1)

■ Strengthening the Execution Base

4-1. System Improvement in Consideration of Changes in Water Management Conditions

Building the execution base for operation of the NHIN

· System Improvement to Implement the 2nd Master Plan

Establishment of the basis for implementation considering the situation of each hydrological organizations (2021)

- **Improvement of systems related to investigation methods, instrument test, investigation environment, and quality control**
- **Establishment of the Rain Radar Control Center to provide user-friendly information on flash floods in cities, mountains, etc.**
- **Revision of related regulations to prepare the basis for verification of advanced equipment such as ADCP**
- **Standardization of terms in the fields of water resources and water environment, publication of a glossary, and suggestions for use**

· Establishment of Joint Action Plan of Hydrological Investigation Organizations

Annual action plan incorporating each plans (2023~)

- **Establishment of an annual action plan incorporating the plans of organizations for use of data and prevention of duplication**

Propulsion Task (4-2)

■ Strengthening the Execution Base

4-2. Revitalizing R&D

Promotion of research and development to improve the reliability of data linked to various fields

· Improving Reliability of Hydrological Data

- **Improving the reliability of real-time data for flood forecasting**
- **Linkage with water management improvement**
- **Reinforcement of linkage among investigation items**
- **Improving on-site measurement method**
- **Operation of a pilot basin to improve the water balance**

· Remote Sensing, Communication Technology Development

- **Water resources satellite payload development and launch (~2025)**
- **Development of geostationary orbit satellites for communication purpose (~2027)**

Propulsion Task (4-3)

■ Strengthening the Execution Base

4-3. Strengthening Education and International Cooperation

Hydrological investigation training
Domestic and foreign technical support

- Hydrological Investigation Training Improvement
  - **Development of online and offline education program and textbook**
  - **New curriculum for each investigation category**
  - **Establishment of maintenance training course**
  - **Establishment of company training course**

- Technical Support for Domestic and Foreign Hydrological Investigation
  - **Support for regional customized capacity building**
  - **Support for establishing HIN in developing countries**
  - **Establishment of HIN for shared rivers between South and North Korea**
  - **Technical cooperation with member countries of WMO and TC**

Milestone & Budget of the Plan (1/4)

■ Innovation of the NHIN

’20 ~ ’29　577.52 billion won (525.02 million dollar)

1-1. Qualitative and Quantitative Reinforcement in NHIN		**44.93 (40.85)**
· Expanding of the NHIN (JUN + ISPN)	**’20~**	**331.12 (301.02)**
· Reinforcement of Hydrological Investigation Island Region	**’21~**	**6.40 (5.82)**
1-2. Modernization of Hydrological Investigation		
· Expanding Application of the Advanced Technology Suitable for Measurement Types	**’20 ~ ’28**	**55.40 (50.36)**
· Development of Automatic Technology for Flow and Sediment Measurement	**’21 ~ ’26**	**4.00 (3.64)**
1-3. Improvement of Hydrological Data Transmission System		
· Establishment and Operation of Various Transmission Systems Suitable for Each Organizations	**’20 ~ ’29**	**8.70(7.91)**
· Optical Communication-Based Network	**’22~**	**43.70(39.73)**

Milestone & Budget of the Plan (2/4)

▪ Enhancement of Reliability of Hydrological Data

2-1. Customized QC Suitable for Each Organizations		10.20 (9.27)
· Establishment of Instructions and Systems for Quality Control of Hydrological Data	'21~	3.00 (2.73)
· Capacity Building of Hydrological Investigation Organizations	'20~	1.20 (1.09)
2-2. Improvement of Hydrological Data QC System		
· Integrated Management of the Entire Process	'20~	2.60 (2.36)
· Establishment of an Integrated Evaluation System	'20~	-
2-3. Improvement of Hydrological Investigation Standards		
· Organic Linkage of Regulations for each Organizations	'21~	1.20 (1.09)
· Strengthening the Connection between KS and ISO	'20~	2.20 (2.00)

Milestone & Budget of the Plan (3/4)

▪ Improving the Usability of Hydrological Data

3-1. Enhancing the Provision of User-Friendly Information		8.90 (8.09)
· Establishment of the Information Providing System for Professional Use of Hydrological Data	'21~	3.10(2.82)
· Providing Index and Statistical Data for Supporting People's Life	'21~	-
3-2. Establishing the Joint Utilization System of Data		
· Establishment of Joint Utilization System of Hydrological Data	'21~	2.00(1.82)
· Improvement of the Evaluation System of Hydrological Data	'21~	-
3-3. Strengthening the Basis for Water Information Utilization		
· Improving the Collection System of River Water Use	'21~	2.80(2.55)
· Improvement the System for Sharing Discharged Water to Rives	'21~	1.00(0.91)

Milestone & Budget of the Plan (4/4)

▪ Strengthening the Execution Base

4-1. Improving Systems that Reflect Change of Water Management Conditions		109.10 (99.18)
· System Improvement to Implement the 2nd Master Plan	'21~	-
· Establishment of Joint Action Plan of Hydrological Investigation Organizations	'23~	-
4-2. Revitalizing R&D		
· Improving Reliability of Hydrological Data	'21~	4.90(4.45)
· Remote Sensing, Communication Technology Development	'20~ '27	103.00(93.64)
4-3. Strengthening Education and International Cooperation		
· Hydrological Investigation Training Improvement	'21~	1.20(1.09)
· Technical Support for Domestic and Foreign Hydrological Investigation	'21~	-

Thank for your attention

MEMO

Measurement of rainfall stage

Hydrological Survey

Observation of Rainfall and Water Level

KIHS 한국수자원조사기술원 Korea Institute of Hydrological Survey

Aims & Objectives

- The aims of the course are to:

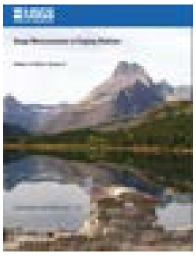
  Promote among trainees a good understanding of the purpose of rainfall, stage observation, and the methodology the trainees can apply to measuring them

- **At the conclusion of the course, trainees will be able to:**

  (1) Explain how a raindrop is formed
  (2) State types of observation equipment that can observe rainfall
  (3) Describe components of water-level observation facility and type of the sensor

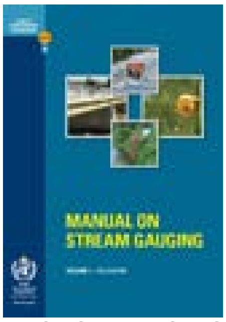
References

Guide to Instruments and Methods of Observation, Volume1 & 2 (WMO, 2018)

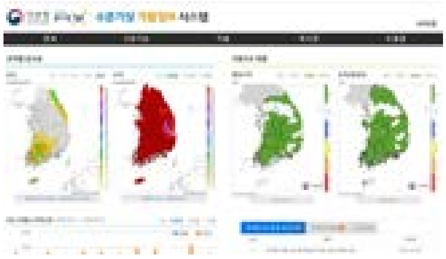


Stage Measurement at Gaging Stations (USGS, 2010)
https://www.aihydrology.org/index.php?option=com_content&view=article&id=55:stage-measurement-at-gaging-stations&catid=23:newsroom&Itemid=140

https://www.water.or.kr/



MANUAL ON STREAM GAUGING, Volume 1 - fieldwork (WMO, 2010)



http://hydro.kma.go.kr/front/intro.do

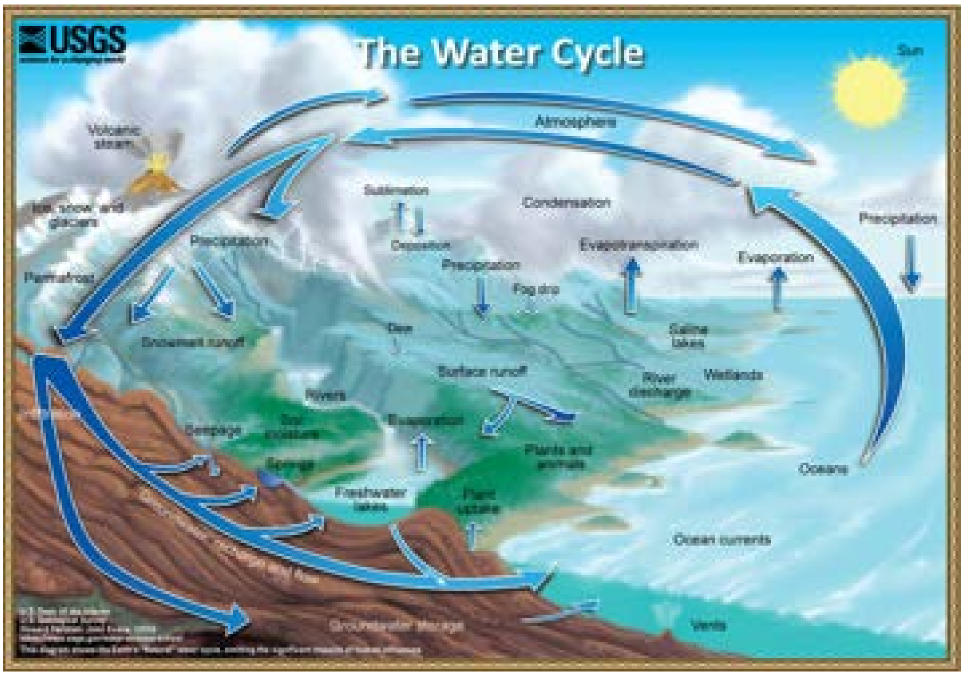
Report (KIHS, 2019)

Contents

1. Introduction

1.1 The Water Cycle
1.2 The Budget of Water
1.3 Generation of a Raindrop

1.1 The Water Cycle



Source: https://www.usgs.gov/media/images/water-cycle-natural-water-cycle

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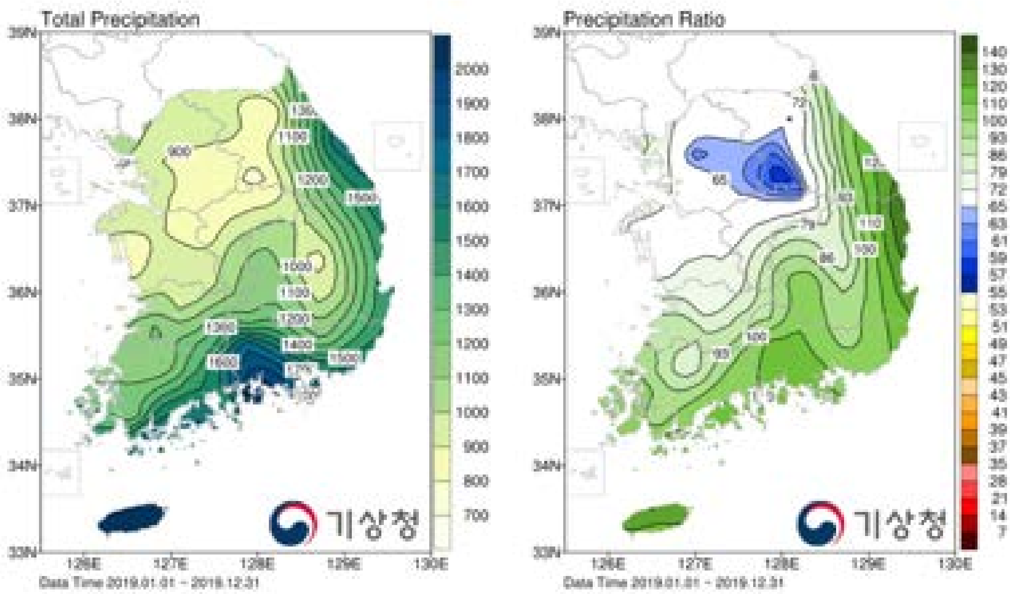
1.2 Water Information in Korea



Source: https://hydro.kma.go.kr

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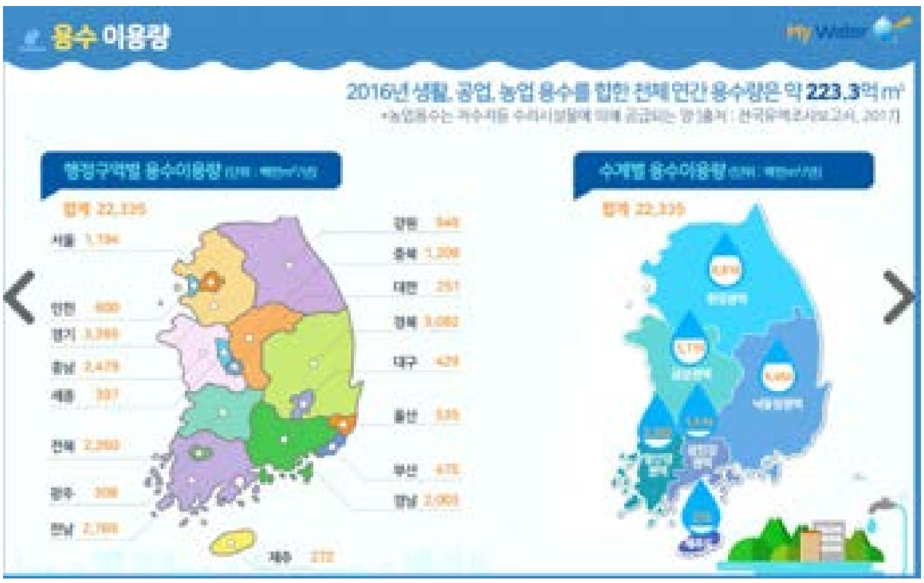
1.2 Water Information in Korea



Source: https://www.water.or.kr/wstatic/easy/easys030101.do?seq=1002&p_group_seq=53&menu_mode=1

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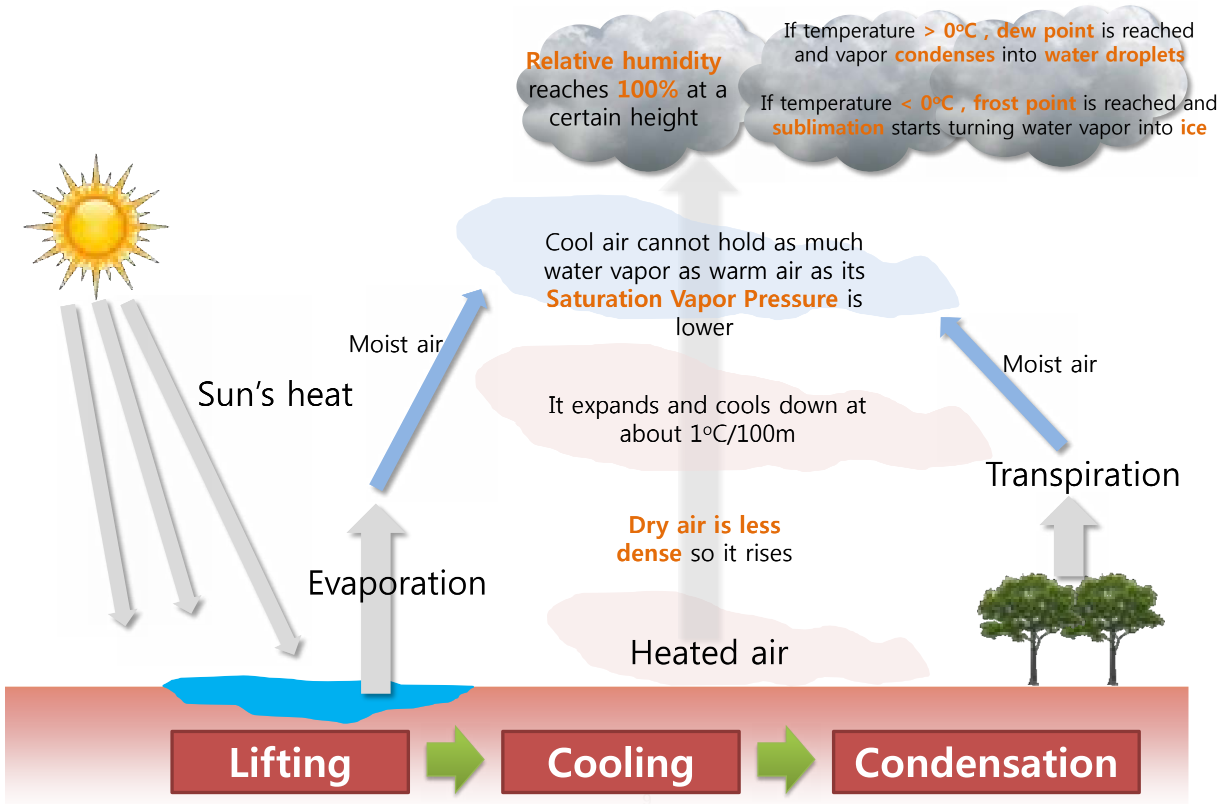
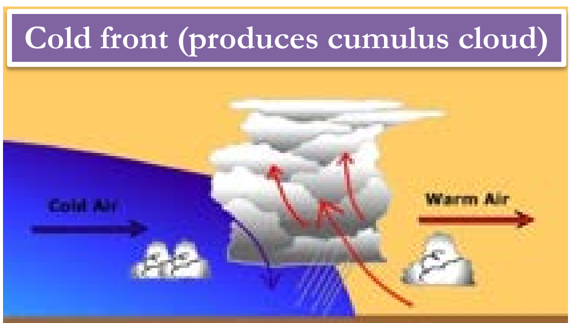
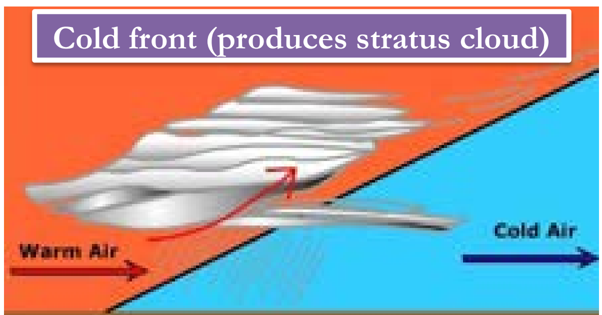
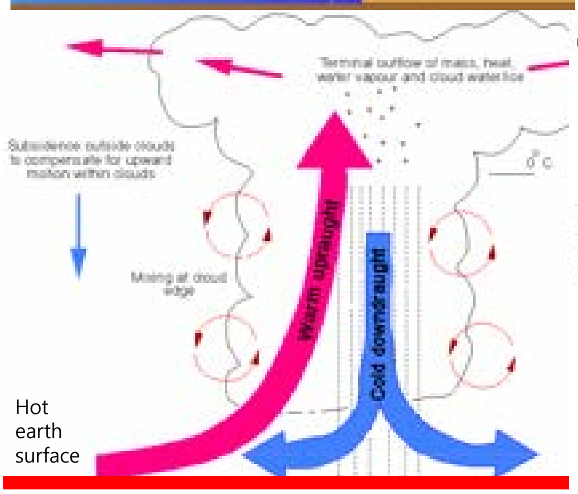
1.3 Generation of a Raindrop

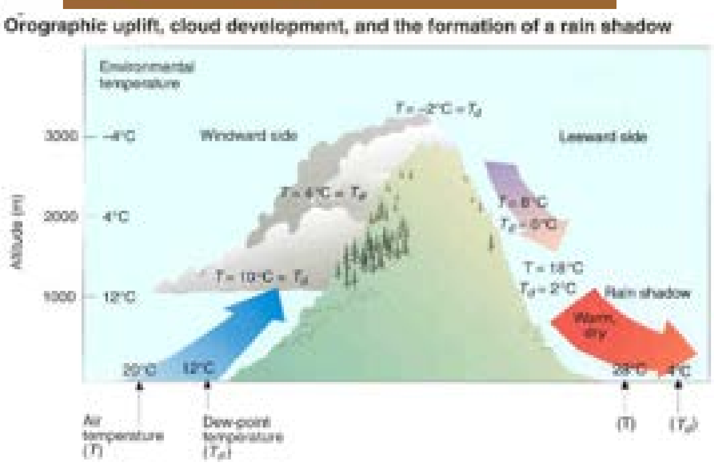


1.3 Generation of a Raindrop

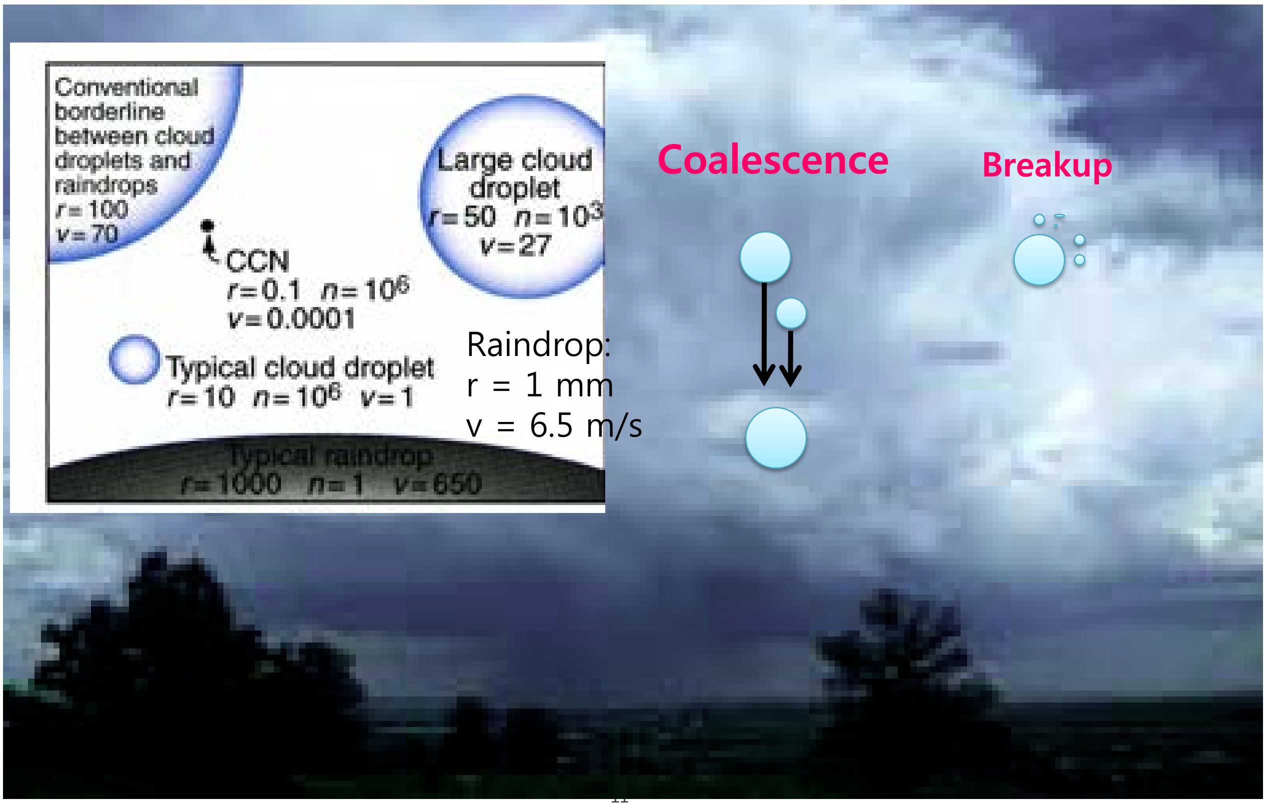






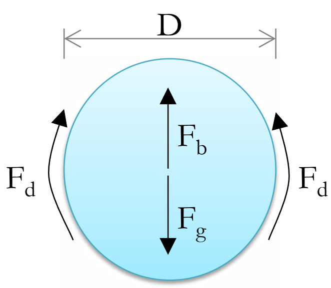


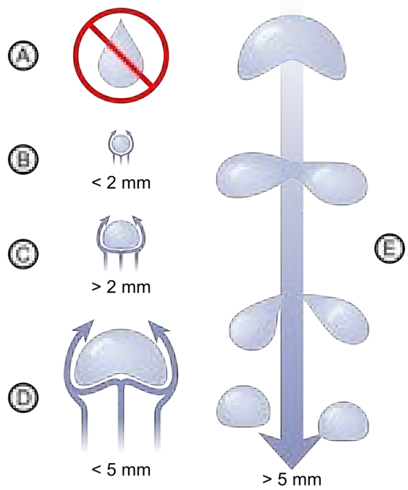
1.3 Generation of a Raindrop



1.3 Generation of a Raindrop

- **Three forces acting on the raindrop**
  - Gravity force due to weight
  - Buoyancy force due to displacement of air
  - Drag force due to friction with surrounding air





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2. Rainfall Measurement

2.1 Introduction
2.2 Instrumentation
2.3 Errors in Rain Gauges

2.1 Introduction

- **History of Rain Observation**
  - 5 B.C.: The ancient Greeks are first known to have recorded rainfall.
  - 4 B.C.: Rainwater was measured in an ancient Indian round jar.
  - 2 B.C.: The ancient Jews measured the amount of rainwater using a bowl.
  - 1441: The rain gauge was invented and used in the Joseon Dynasty of Korea.
  - 1639: Castelli invented the rain gauge in Italy.
  - 1780: Systematic weather observations were initiated by the European Meteorology Society.
  - 1848: Weather forecasting began to be published in British newspapers.
  - 1854: Weather charts issued, and weather forecasting began in France.
  - 1904: The weather station was first deployed in Mokpo, Korea

Source: Gwacheon National Science Museum

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2.1 Introduction

- **Purpose**

  -To obtain representative samples of the fall over the area to which the measurement refers

The primary aim of any method of precipitation measurement is to obtain representative samples of the fall over the area to which the measurement refers. There is a critical need in hydrology for accurate measurement of precipitation. Therefore, for raingauges the choice of site, the form and exposure of the measuring gauge, the prevention of loss by evaporation, and the effects of wind and splashing are important considerations. More complex methods such as the use of weather radar and satellites require detailed understanding of error characteristics. This chapter discusses the facets of precipitation measurement that are most relevant to hydrological practice. A more general discussion of the topic can be found in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8).

Source: WMO-No.168, "Guide to Hydrological Practices Volume1" Chapter 3. Precipitation Measurement

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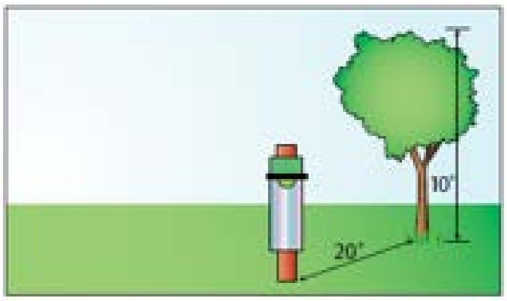
2.1 Introduction

- **Rain-Gauge Location: where the site is little influenced by wind**

  - The effects on the gauge itself
  - The effects of the site on the wind trajectories

Where possible, the gauge site should be protected from wind movement in all directions by objects, such as trees and shrubs, of as nearly uniform height as possible. The height of these objects above the orifice of the gauge should be at least half the distance from the gauge to the objects, but should not exceed the distance from the gauge to the objects (to avoid interception of precipitation that should reach the gauge). The ideal situation is to have the angle from the top of the gauge to the top of the encircling objects between 30° and 45° to the horizontal (Figure I.3.1).



Source: WMO-No.168, "Guide to Hydrological Practices Volume1" Chapter 3. Precipitation Measurement

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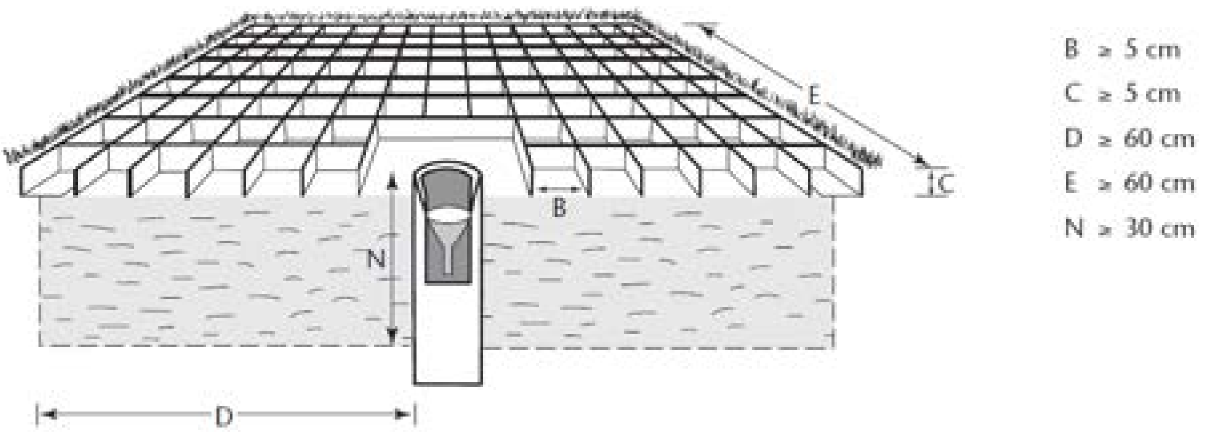
2.1 Introduction

- **Ideal Site for a Rain Gauge**



Pit gauge for the measurement of liquid precipitation

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Source: WMO-No.168, "Guide to Hydrological Practices Volume1" Chapter 3. Precipitation Measurement

2.2 Instrumentation

- **Gauge type**
  - Manual rain-gauge
  - Tipping-bucket gauge
  - Weighing gauge
  - Float gauge
- **Disdrometer**
  - JW disdrometer
  - POSS
  - Parsivel
  - 2DVD
- **Remote sensing**
  - Radar
  - Acoustic type

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2.2 Instrumentation

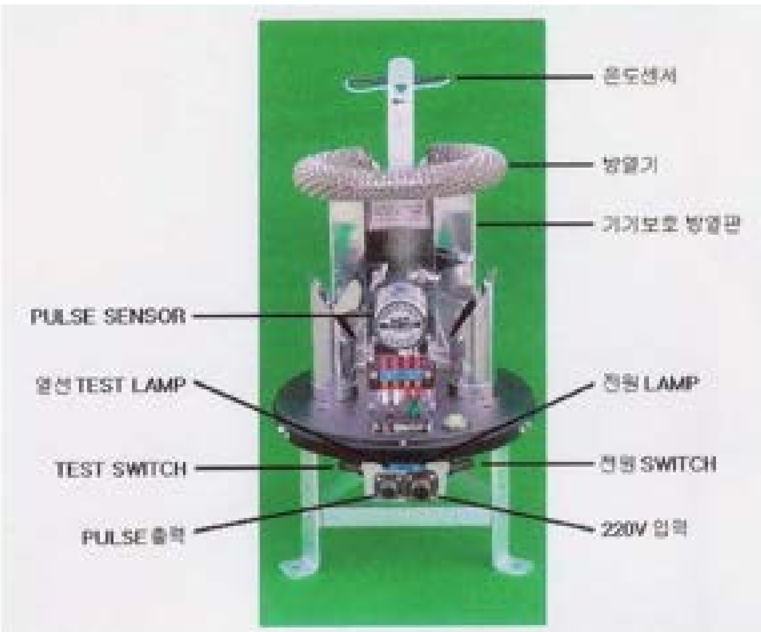
▪ Gauge type: Manual rain-gauge

Source: http://www.hysc.kr/mall/m_mall_detail.php?ps_goid=16287 19

(Meteorological Service of Canada)

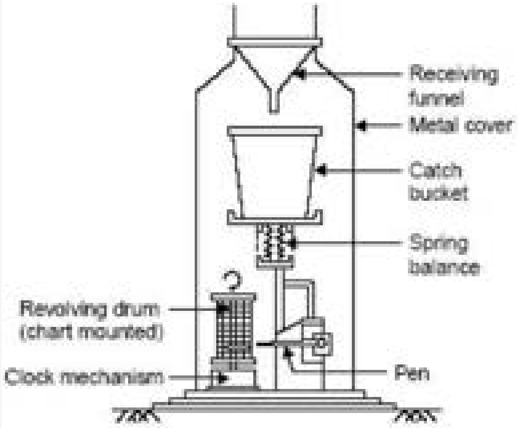
2.2 Instrumentation

▪ Gauge type: Tipping-bucket gauge



2.2 Instrumentation

▪ Gauge type: Weighing gauge



Source: https://geologyscience.com/applied-geology/hydrogeology/elements-of-the-hydrologic-cycle-1/

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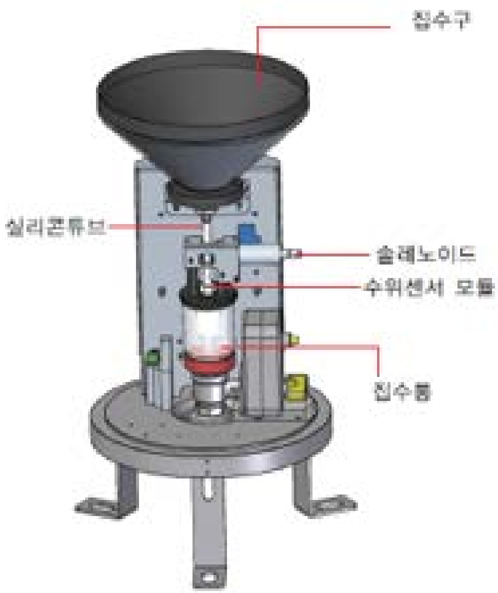
2.2 Instrumentation

▪ Gauge type: Float gauge



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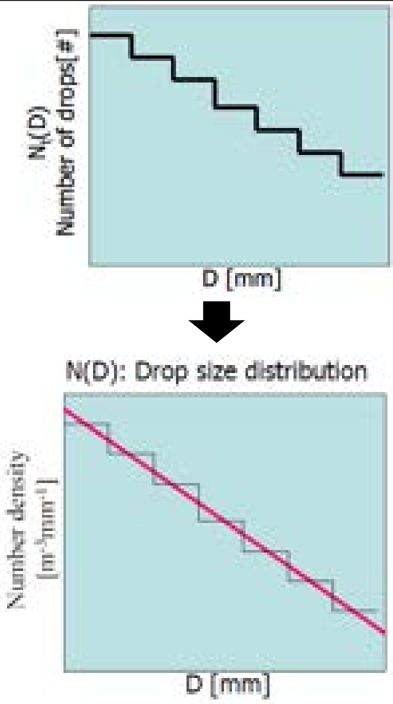
Source: Prof. Lee presentation

2.2 Instrumentation

▪ Disdrometer: JW disdrometer

Joss and Waldvogel (1970s)
Impact disdrometer



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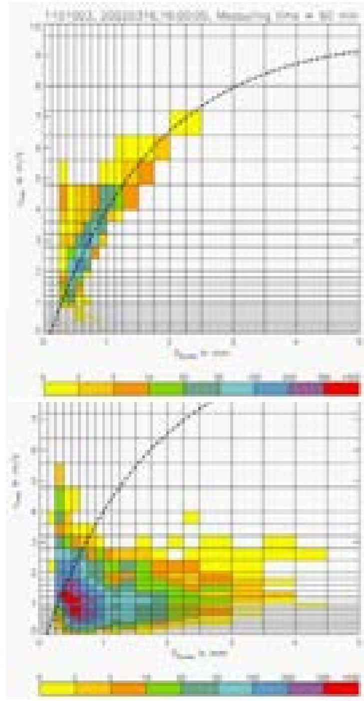
2.2 Instrumentation

▪ Disdrometer: Parsivel

Laser-based optical disdrometer
for simultaneous measurement
of PARticle SIze and VELocity
of all liquid and solid precipitation



Source: https://www.ott.com/download/ott-parsivel-white-paper/

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2.2 Instrumentation

▪ POSS: the Precipitation Occurrence Sensor System

- This is a bistatic, X-band, Doppler radar, designed by Environment Canada.
- The POSS measures a signal whose frequency is proportional to the raindrop Doppler velocity and whose amplitude is proportional to the raindrop diameter.
- The volume of sampling for the three instruments is very different.
- However, their observations are all consistent to each other.

Source: http://www.radar.mcgill.ca/facilities/poss.html

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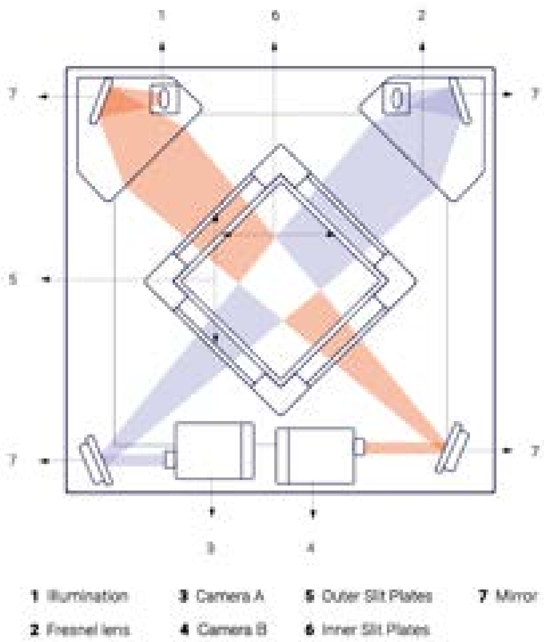
2.2 Instrumentation

▪ Disdrometer: 2DVD (2-Dimensional Video Disdrometer)



Source: https://www.distrometer.at/2dvd/

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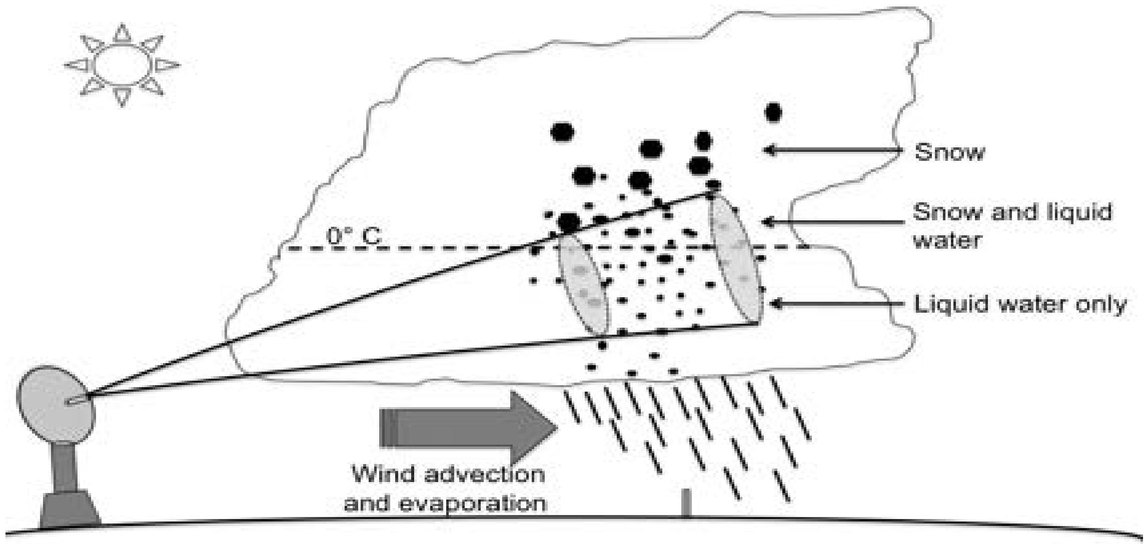
2.2 Instrumentation

▪ Radar (RAdio Detection And Ranging)



Source: R. Cifelli and V. Chandrasekar (2010)

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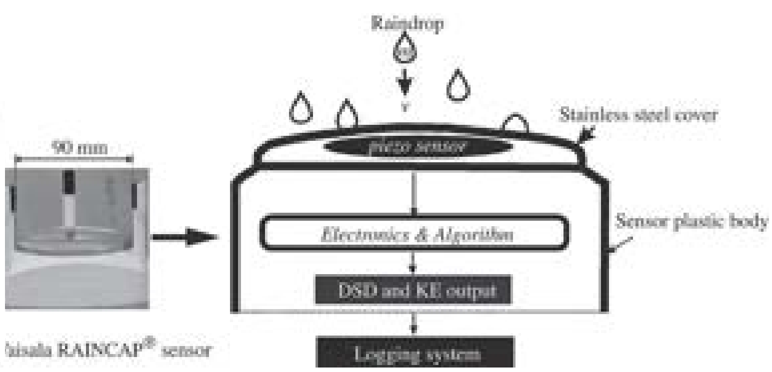
2.2 Instrumentation

▪ Acoustic type



Vaisala WXT531 Acoustic rain gauge

Source: https://www.bellflowsystems.co.uk/vaisala-wxt531-acoustic-rain-gauge.html

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2.3 Errors in Rain Gauge

Table I.3.1. Main components of the systematic error in precipitation measurement and their meteorological and instrumental factors listed in order of general importance

$$P_k = kP_c = k(P_g + \Delta P_1 + \Delta P_2 + \Delta P_3 \pm \Delta P_4 - \Delta P_5)$$

where P_k is the adjusted precipitation amount, k is the correction factor, P_c is the precipitation caught by the gauge collector, P_g is the measured precipitation in the gauge, and P_1 to P_5 are corrections for components of systematic error as defined below:

Symbol	*Component of error*	*Magnitude*	*Meteorological factors*	*Instrumental factors*
k	Loss due to wind field deformation above the gauge orifice	2–10% 10–50%*	Wind speed at the gauge rim during precipitation and the structure of precipitation	The shape, orifice area and depth of both the gauge rim and collector
$\Delta P_1 + \Delta P_2$	Losses from wetting on internal walls of the collector and in the container when it is emptied	2–10%	Frequency, type and amount of precipitation, the drying time of the gauge and the frequency of emptying the container	The same as above and, in addition, the material, colour and age of both the gauge collector and container
ΔP_3	Loss due to evaporation from the container	0–4%	Type of precipitation, saturation deficit and wind speed at the level of the gauge rim during the interval between the end of precipitation and its measurement	The orifice area and the isolation of the container, the colour and, in some cases, the age of the collector, or the type of funnel (rigid or removable)
ΔP_4	Splash-out and splash-in	1–2%	Rainfall intensity and wind speed	The shape and depth of the gauge collector and the kind of gauge installation
ΔP_5	Blowing and drifting snow		Intensity and duration of snow storm, wind speed and the state of snow cover	The shape, orifice area and depth of both the gauge rim and the collector

* Snow

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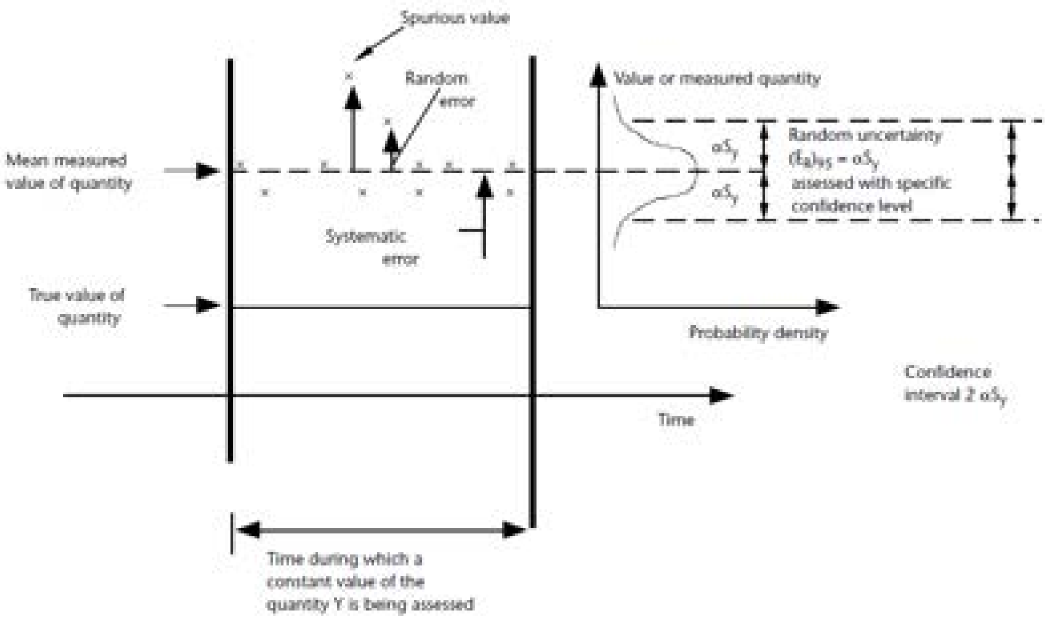
Source: WMO-No.168, "Guide to Hydrological Practices Volume1" Chapter 3. Precipitation Measurement

2.3 Errors in Rain Gauge

▪ **Errors (Systematic Error and Random Error)**



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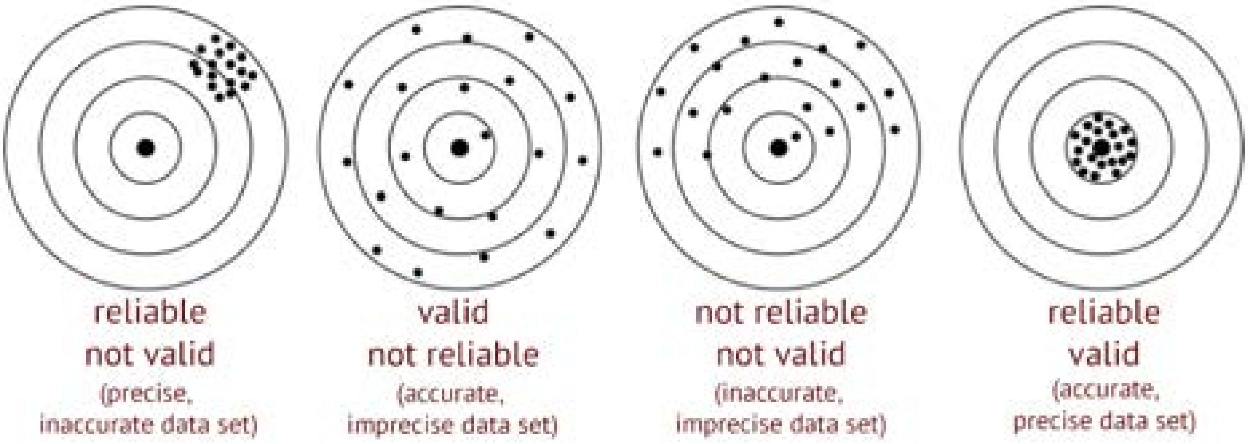
Source: WMO-No.168, "Guide to Hydrological Practices Volume1" Chapter 2. Methods of Observation

2.3 Errors in Rain Gauge

- **Errors (Accuracy and Precision)**



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Source: WMO-No.168, "Guide to Hydrological Practices Volume1"
Chapter 3. Precipitation Measurement

3. Stage Measurement

3.1 Introduction and Purpose
3.2 Stage-Accuracy Requirements
3.3 Gage Structures
3.4 Instrumentation

3.1 Introduction and Purpose

- **Stream stage**
  - Useful in the design of structures (bridges, embankments, levees, or the use of flood plains)

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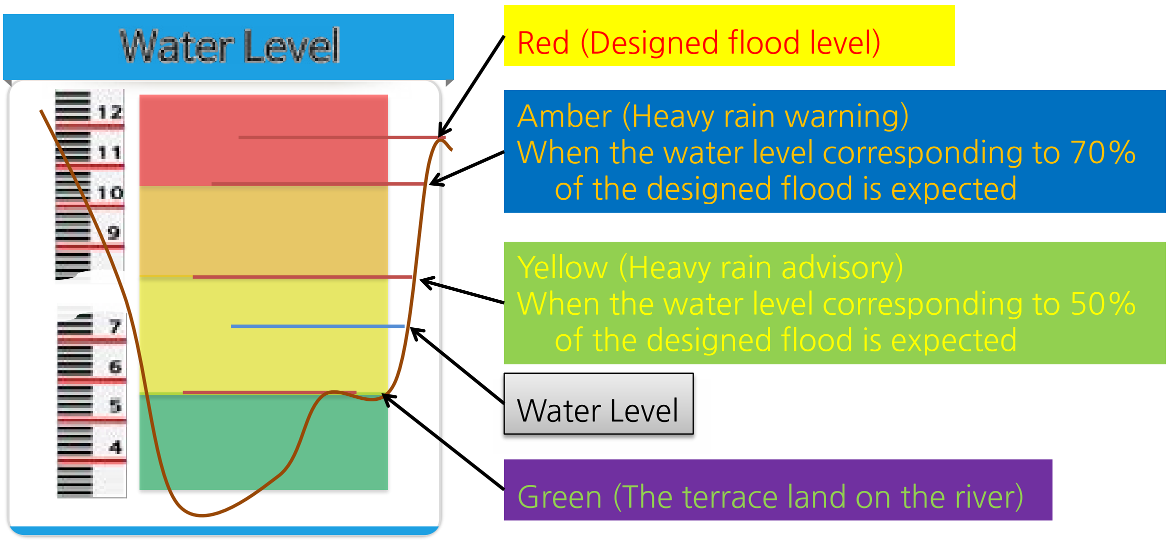
3.1 Introduction and Purpose



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3.2 Stage-Accuracy Requirements

- Gage-reading errors
- Stage-sensor errors
- Water surface to sensor to recorder errors
- Hydraulically induced errors
- Recorder errors
- Retrieval or Communication errors

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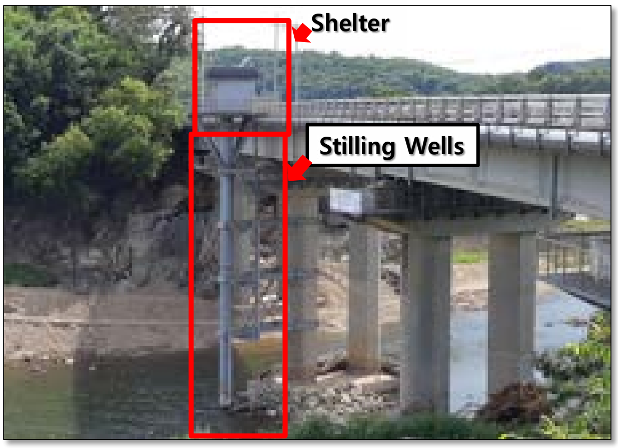
3.3 Gage Structures

- Stream and reservoir gages require
  - Instrument shelter
  - Gages and Sensors
  - Stilling Wells
  - Communication equipment



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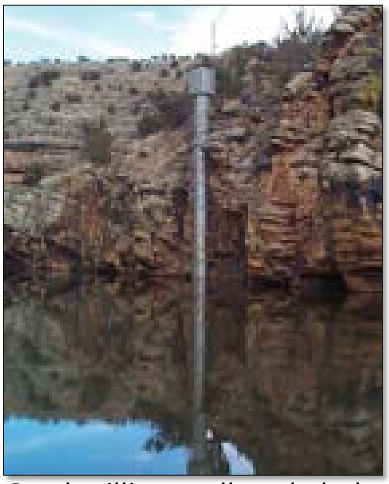
3.3 Gage Structures

- **Stilling Wells**
  - Protects the float and dampens the fluctuations in the stream caused by wind and turbulence.

Concrete pipe stilling well and shelter



Steel stilling well and shelter

Source: U.S. Geological Survey, Reston, Virginia, "Stage Measurement at Gaging Stations" 2010

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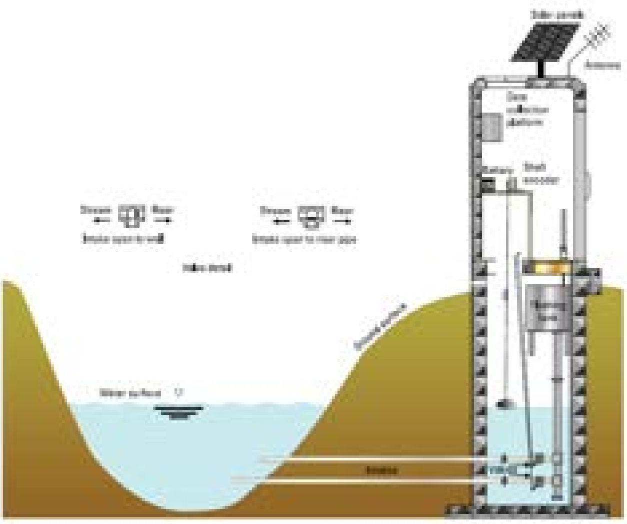
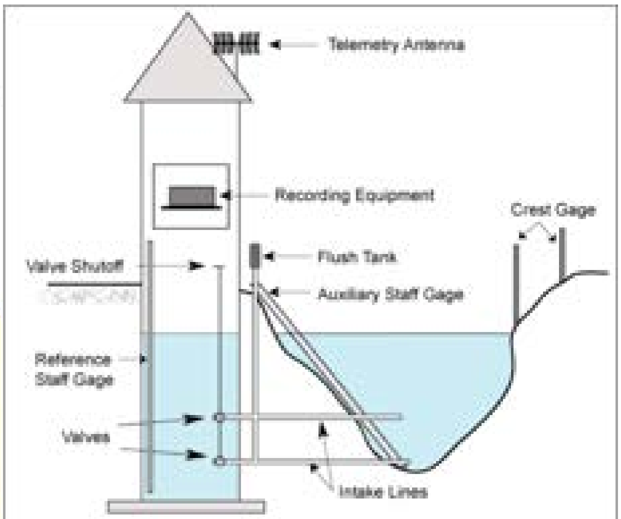
3.3 Gage Structures

- **Schematic of Stilling Wells**



Schematic of a typical flushing system for intakes.



Typical components of a stilling well

Source: U.S. Geological Survey, Reston, Virginia, "Stage Measurement at Gaging Stations" 2010.

Source: https://kacv.net/brad/nws/lesson4.html

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3.3 Gage Structures

- Shelter

Instrument shelter located on a bridge abutment

Instrument shelter located on a stream bank

Instrument shelter located on a concrete stilling well

Source: 환경부, 한국수자원조사기술원, "수문조사시설 개선 및 설치기준 체계화 연구(2차)" 2019

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3.4 Instrumentation

- **Nonrecording Gages**
  - Staff Gages
  - Electric-Tape Gages
- **Recording Gages**
  - Contact Water-Level Sensors
    - Float-Driven Sensors
    - Reed Gages
    - Submersible Pressure Transducers
    - Bubble Gages
  - Noncontact Water-Level Sensors
    - Acoustic (sonic or ultrasonic waves)
    - Radar
    - Optical system

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3.4 Instrumentation

▪ Staff Gages

Vertical-Staff Gages

Inclined-Staff Gages

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3.4 Instrumentation

▪ Electric-tape gages & Wire-weight gages

Electric-tape gage

Wire-weight gage

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3.4 Instrumentation

▪ Float-Tape Gages

Float-tape gage

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Source: U.S. Geological Survey, Reston, Virginia, "Stage Measurement at Gaging Stations" 2010

3.4 Instrumentation

▪ Recording Gages

- Contact Water-Level Sensors
    - Float-Driven Sensors
    - Reed Gages
    - Submersible Pressure Transducers
    - Bubble Gages
- Noncontact Water-Level Sensors
    - Acoustic (sonic or ultrasonic waves)
    - Radar
    - Optical system

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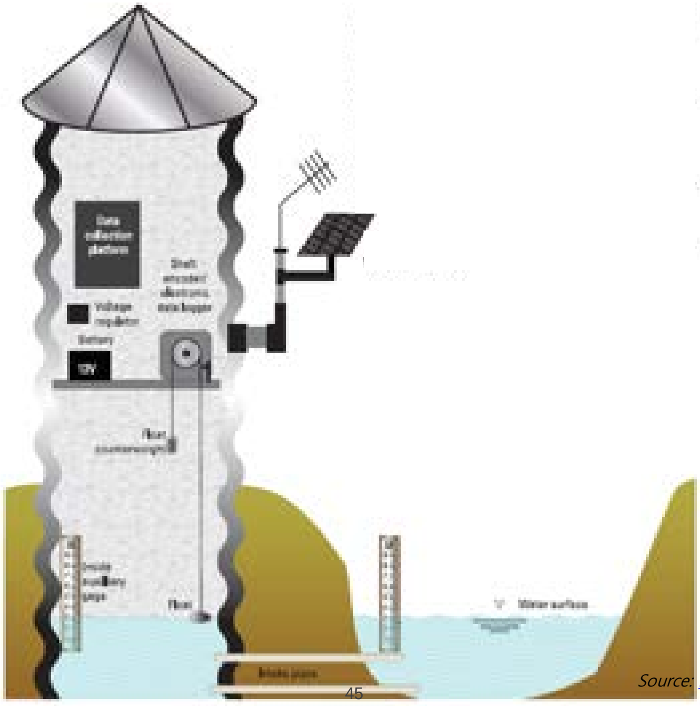
Source: 환경부, 한국수자원조사기술원, "수문조사시설 개선 및 설치기준 체계화 연구(2차)" 2019

3.4 Instrumentation

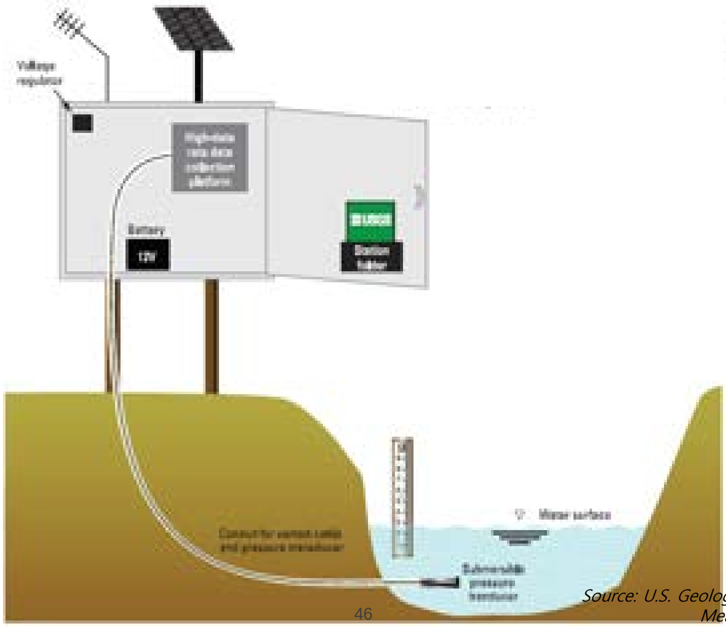
▪ Float Sensor and Reed Gage



Source: https://kacv.net/brad/nws/lesson4.html

3.4 Instrumentation

▪ Submersible Pressure Transducers



Source: U.S. Geological Survey, Reston, Virginia, "Stage Measurement at Gaging Stations" 2010

3.4 Instrumentation

▪ Bubble Gages

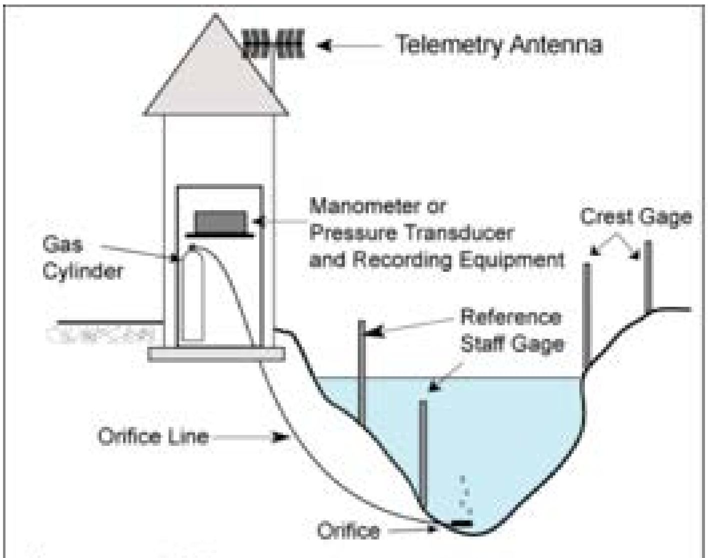


Figure 4.19. Bubble gage or gas-purge gaging station components.

Schematic of Bubble Gage

Source: https://kacv.net/brad/nws/lesson4.html

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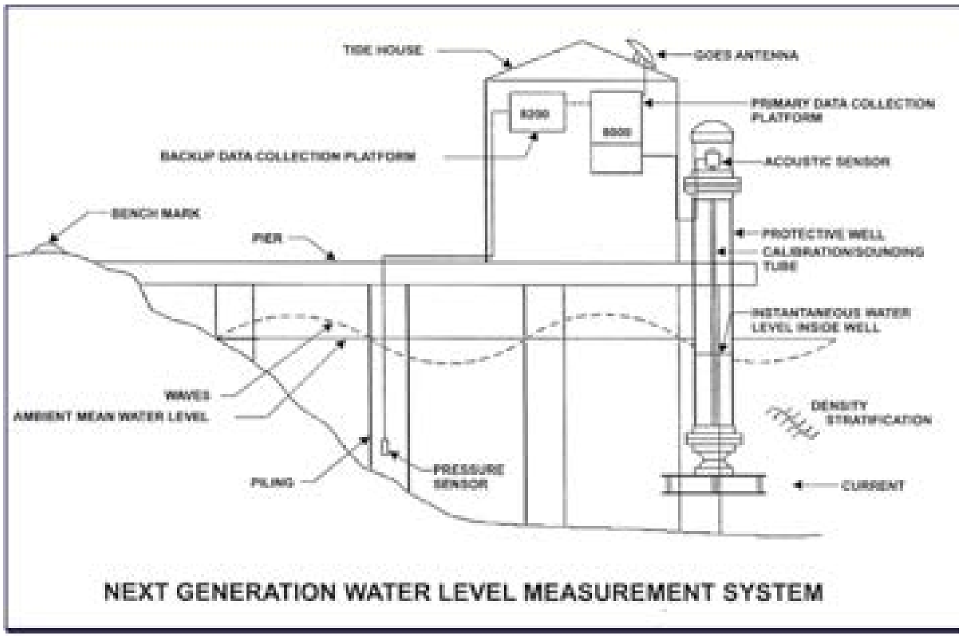
3.4 Instrumentation

▪ Acoustic Sensors



Source: John D. Boon, Robert M. Heitsenrether, Mark Bushneil, Microwave-acoustic water level sensor comparisons: Sensor response to change in oceanographic and meteorological parameters 2009

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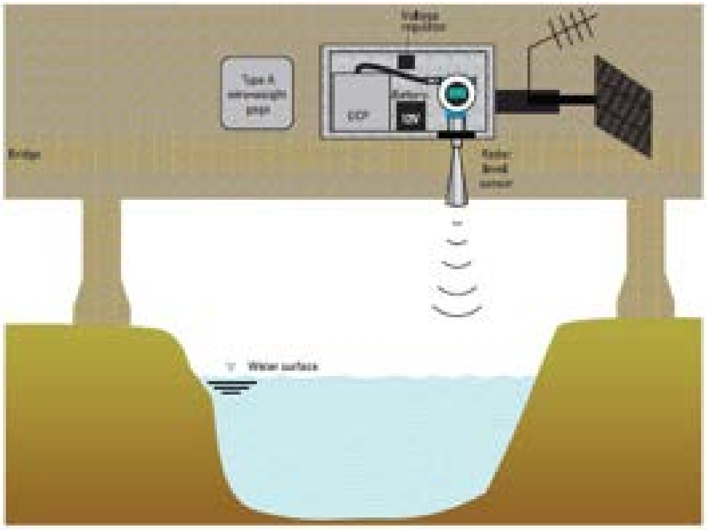
3.4 Instrumentation

▪ Radar Sensors



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Source: U.S. Geological Survey, Reston, Virginia, "Stage Measurement at Gaging Stations" 2010

3.4 Instrumentation

▪ Optical Sensors

Optical stage height monitoring system

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Source: https://kacv.net/brad/nws/lesson4.html

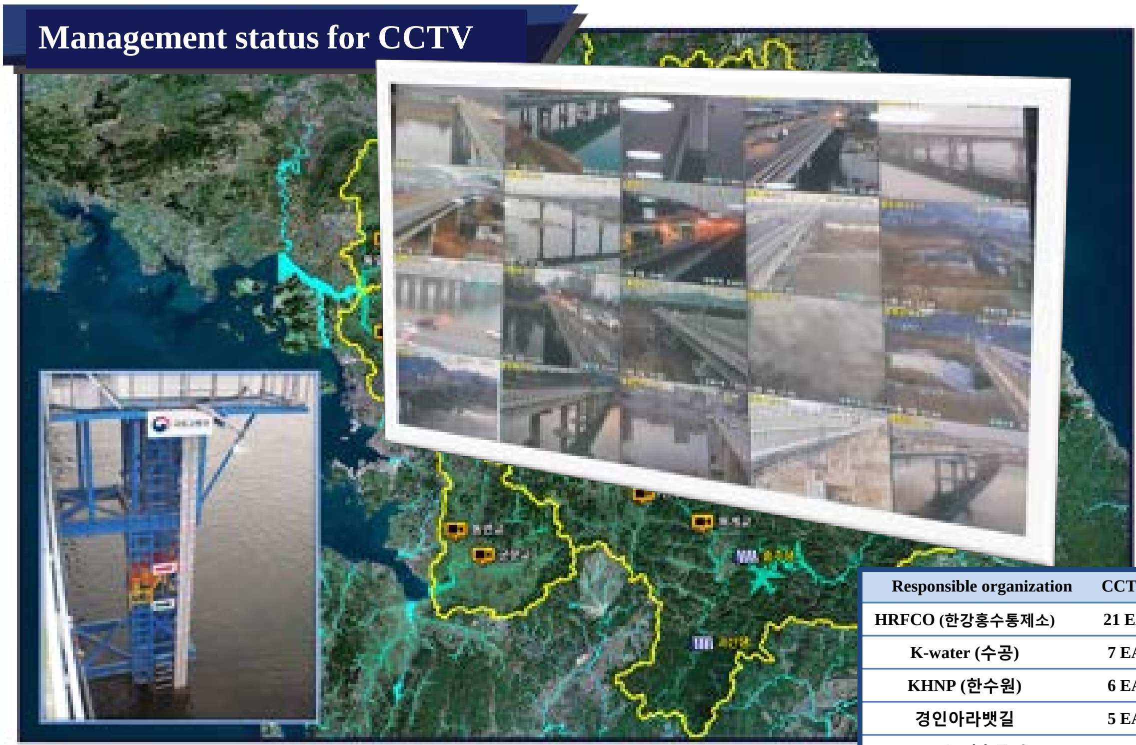
4. Hydrologic Instrumentation Facility of HRFCO

4. Hydrologic Instrumentation Facility of HRFCO

Overview of measurement stations by basin area of Hangang River

4. Hydrologic Instrumentation Facility of HRFCO

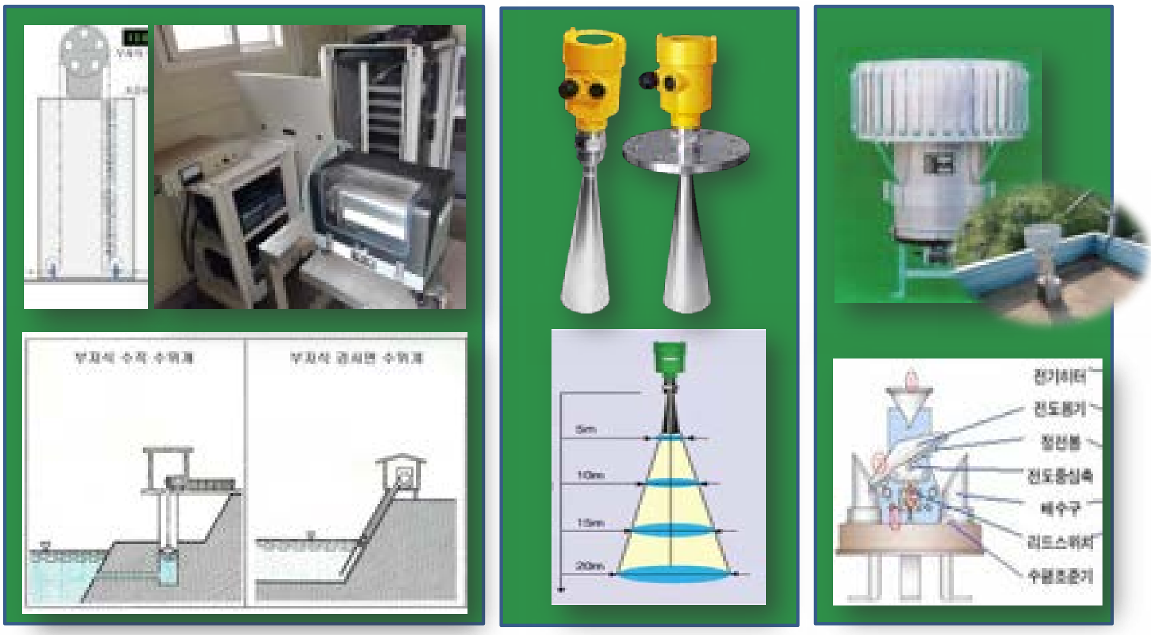
Management status for CCTV



Responsible organization	CCTV
HRFCO (한강홍수통제소)	21 EA
K-water (수공)	7 EA
KHNP (한수원)	6 EA
경인아라뱃길	5 EA
KRC (농어촌공사)	4 EA

4. Hydrologic Instrumentation Facility of HRFCO

▪ Instrumentation of HRFCO



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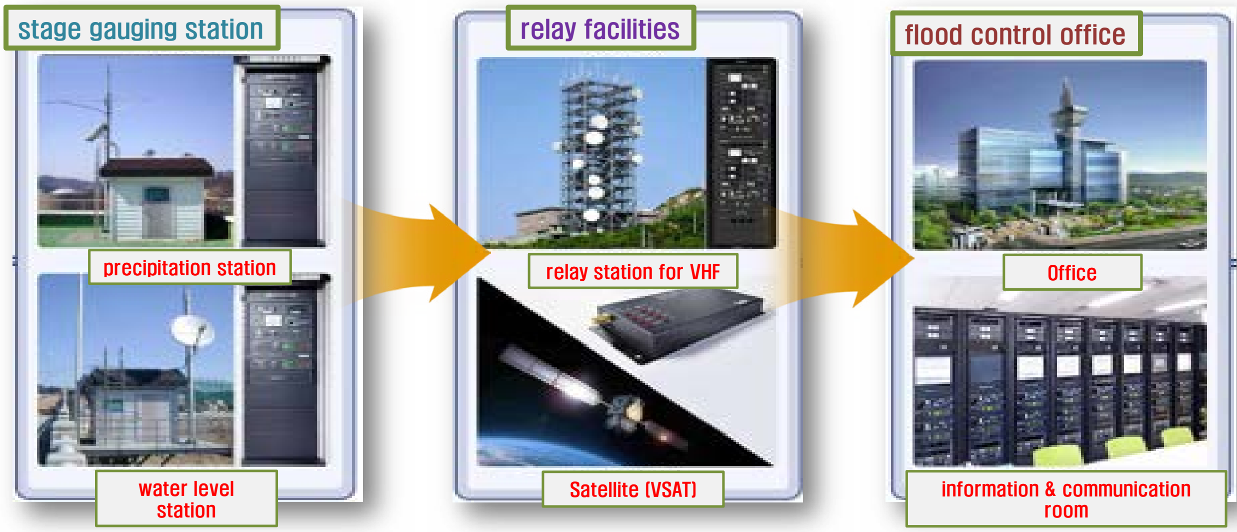
4. Hydrologic Instrumentation Facility of HRFCO

▪ Block Diagram Of Gathering Water Level Information

▣ **Measured data of water level &precipitation are transmitted to the flood control office per 10 minutes.**



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Thank you very much

Radar Observation and Its Application

Hydrological Survey

Radar Observation and Its Applications

KIHS 한국수자원조사기술원 Korea Institute of Hydrological Survey

i-WSSM

Aims & Objectives

- The aims of the course are to:

  Promote among trainees a good understanding of the reason for observing rainfall using rain gauge and rain radar.

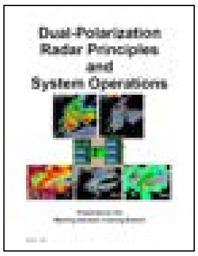
- At the conclusion of the course, trainees will be able to:

  (1) Understand the principle of rainfall estimation using rain radar.

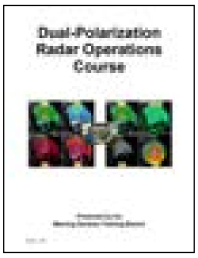
  (2) The sources of errors in quantitative precipitation estimation in terms of radar observation.

  (3) Use of radar observation in hydrological applications.

References

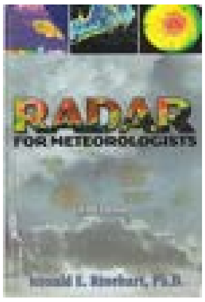


https://training.weather.gov/wdtd/courses/dualpol/documents/DualPolRadarPrinciples.pdf



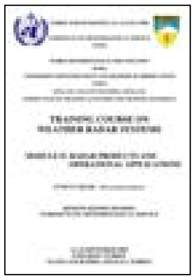
https://training.weather.gov/wdtd/courses/dualpol/documents/DualPolOpsStudentGuide.pdf

http://radar.kma.go.kr/main.do



Radar for Meteorologists, fifth edition (R. E. Rinehart, 2004)

Guide to Instruments and Methods of Observation, Volume1 & 2 (WMO, 2018)



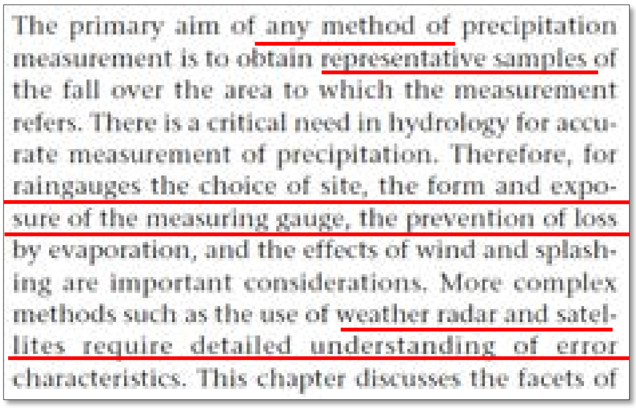
https://www.wmo.int/pages/prog/www/IMOP/publications/IOM-88_TM-Radars/IOM-88_Module-D.pdf

Contents

1. Introduction
2. Radar Variables
3. Data Processing
4. Quality Control
5. Quantitative Precipitation Estimation (QPE)
6. Applications
7. Radar Networks

1. Introduction

- **The Guide to Hydrological Practices (WMO No.168)**
  - Volume I: Hydrology – From Measurement to Hydrological Information
    - Chapter 3. Precipitation Measurement
      - 3.1 General Requirements: Accuracy and Precision
  - Volume II: Management of Water Resources and Application of Hydrological Practices



The primary aim of any method of precipitation measurement is to obtain representative samples of the fall over the area to which the measurement refers. There is a critical need in hydrology for accurate measurement of precipitation. Therefore, for raingauges the choice of site, the form and exposure of the measuring gauge, the prevention of loss by evaporation, and the effects of wind and splashing are important considerations. More complex methods such as the use of weather radar and satellites require detailed understanding of error characteristics. This chapter discusses the facets of

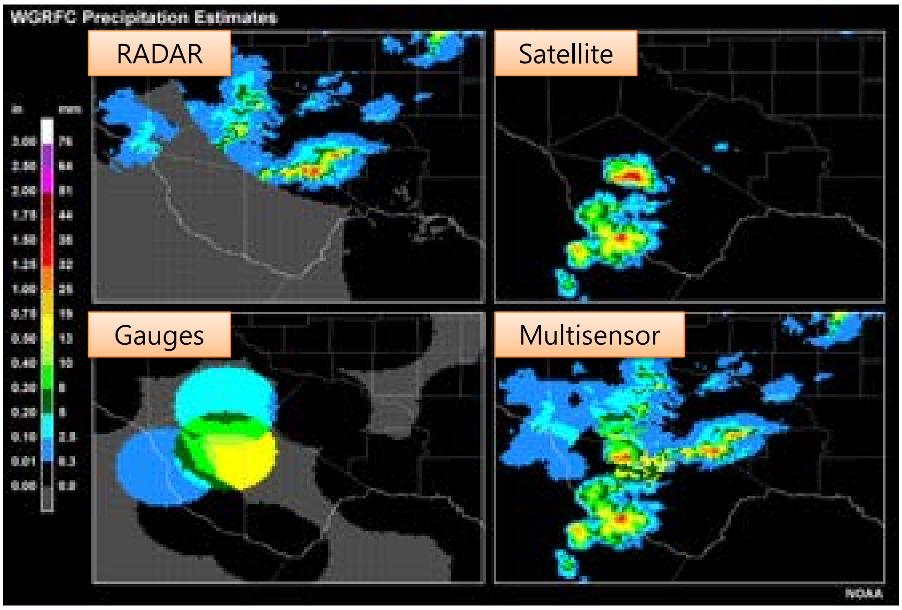
The purpose of rainfall observation:
Collecting representative precipitation samples

What is required for radar observation:
The understanding of error characteristics

6

1. Introduction

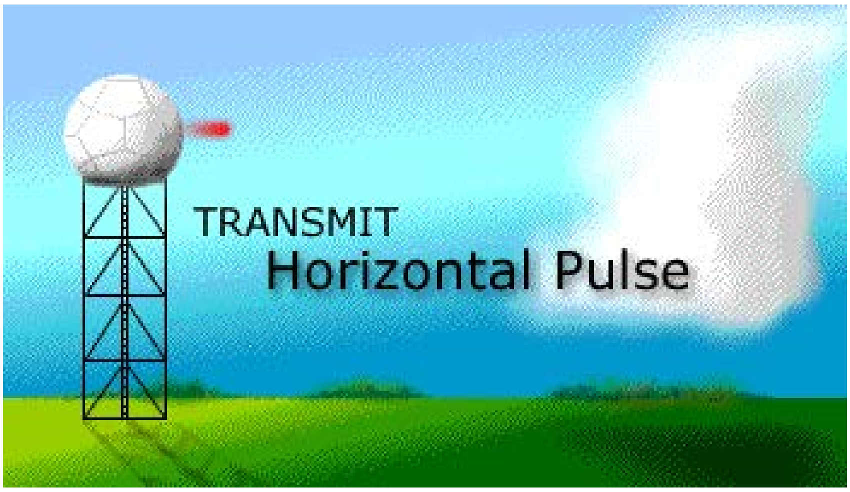
▪ Multi-Sensor Precipitation Estimator (MPE)



http://stream1.cmatc.cn/pub/comet/QPF-QPE/PrecipitationEstimatesPart2Analysis/comet/hydro/precip_est/part2_analysis/print.htm

1. Introduction

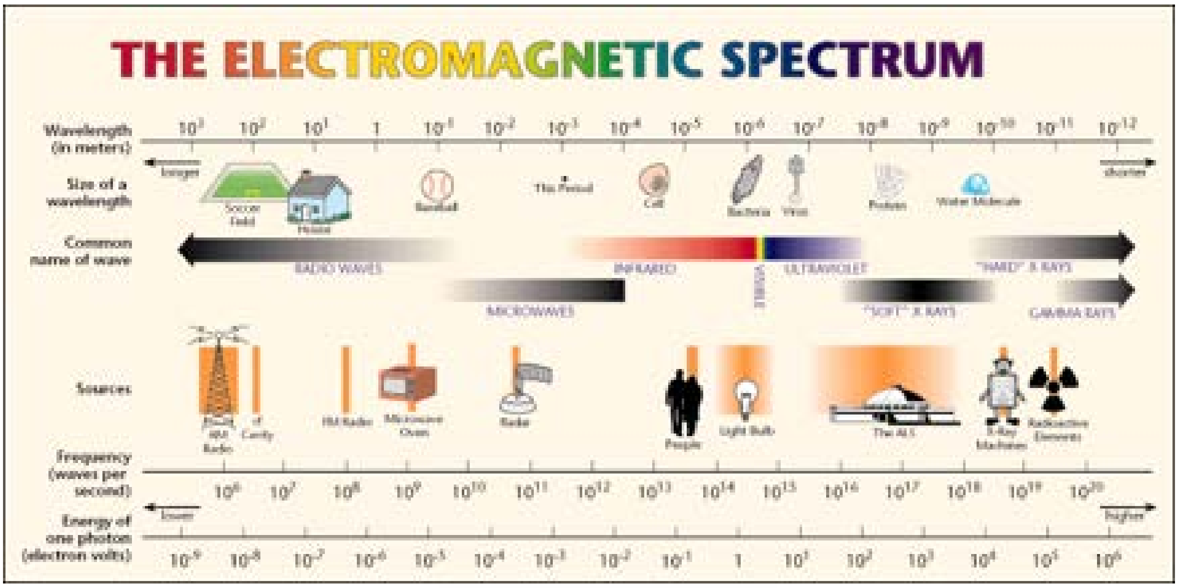
▪ RADAR (RAdio Detection And Ranging)



https://www.weather.gov/bmx/radar_dualpol

1. Introduction

▪ The Electromagnetic Spectrum

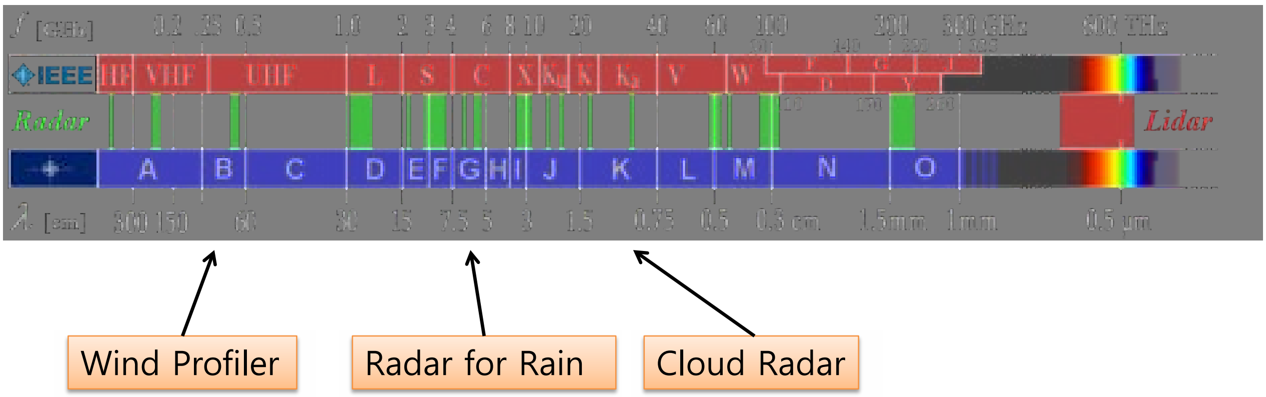


RADAR Frequency

https://marine.rutgers.edu/cool/education/class/josh/em_spec.html

1. Introduction

▪ Weather Radar Band



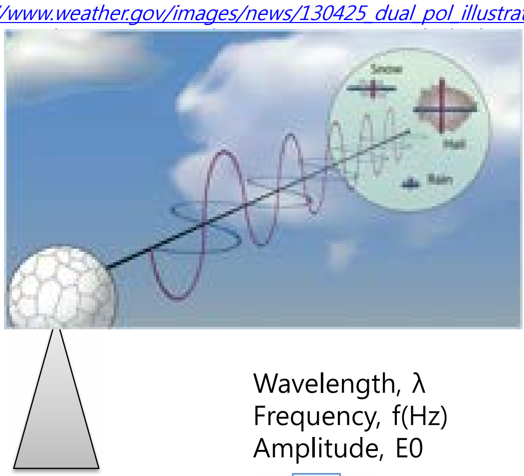
https://www.radartutorial.eu/07.waves/Waves%20and%20Frequency%20Ranges.en.html

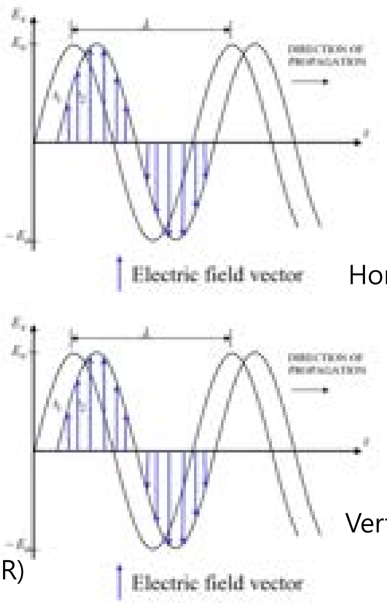
2. Radar Variables

2. Radar Variables

▪ Single or Dual Polarization Radar

https://www.weather.gov/images/news/130425_dual_pol_illustration.jpg





Horizontal Channel

Vertical Channel

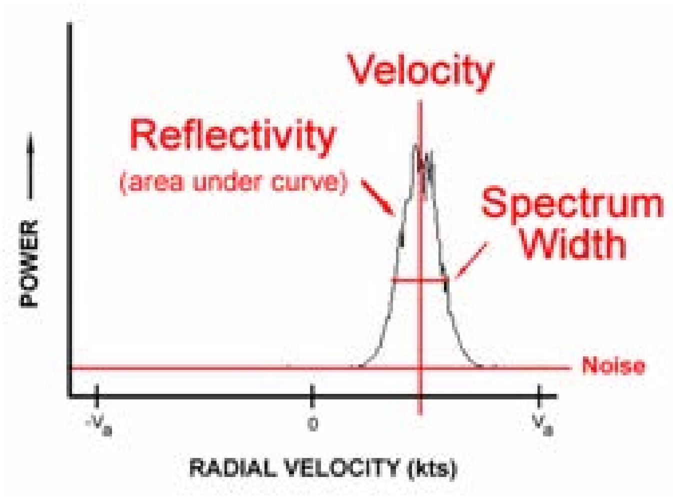
Wavelength, λ
Frequency, f(Hz)
Amplitude, E0

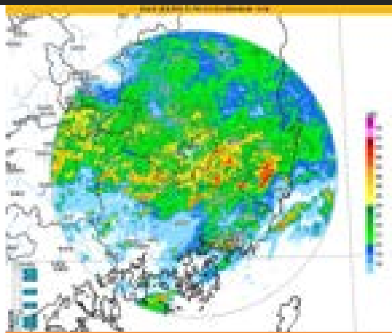
- Reflectivity (Z)
- Radial Velocity (Vr)
- Spectrum Width (W)

- Differential Reflectivity (ZDR)
- Differential Phase (Phidp)
- Specific Differential Phase (KDP)
- Cross Correlation (RhoHV)

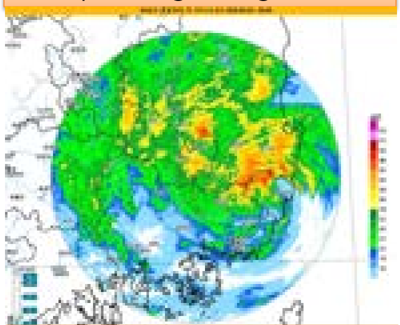
2. Radar Variables

▪ Reflectivity, Velocity, and Spectrum Width





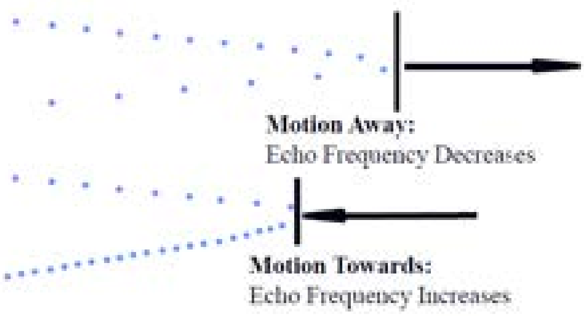
Example image: Jangma Front

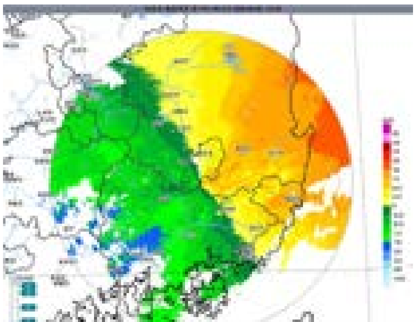


Example image: Tyhoon

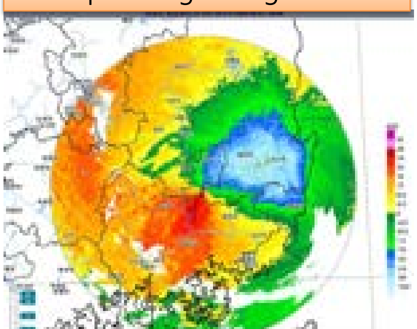
2. Radar Variables

▪ Velocity: Doppler Velocity





Example image: Jangma Front



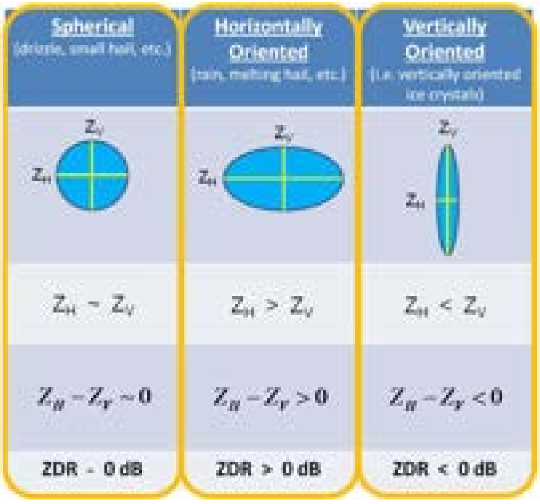
Example image: Tyhoon

2. Radar Variables

▪ Dual-Polarization Variables

- Differential Reflectivity

$$ZDR = Z_H - Z_V$$



Major Axis Diameter (mm)	Image	ZDR (dB)
< 0.3 mm		~ 0.0 dB
1.35 mm		~ 1.3 dB
1.75 mm		~1.9 dB
2.65 mm		~2.8 dB
2.90 mm		~3.3 dB
3.68 mm		~4.1 dB
4.00 mm		~4.5 dB

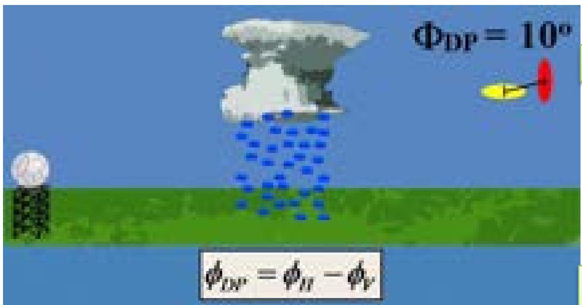
Dual-Polarization Radar Operations Course

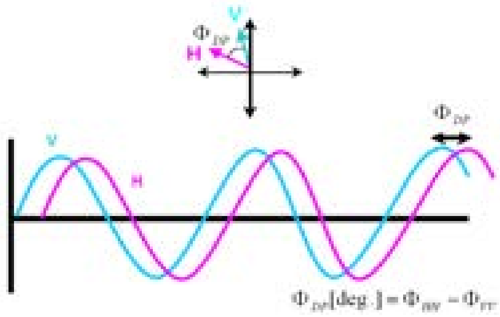
Source: *Dual-Polarization Radar Principles and System Operations*

2. Radar Variables

▪ Dual-Polarization Variables

- Differential Phase (PhiDP)



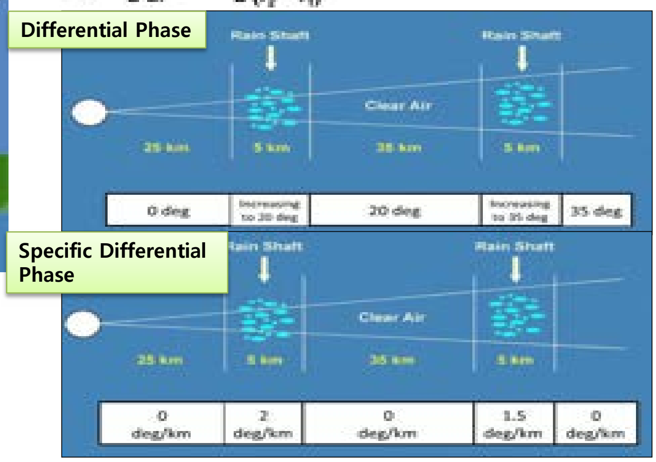


- Specific Differential Phase

(Unit: degree/km)

$$K_{DP} = \frac{d\phi_{DP}}{2\,dr} \approx \frac{\phi_{DP}(r_2) - \phi_{DP}(r_1)}{2(r_2 - r_1)}$$

r1, r2: Distance from radar

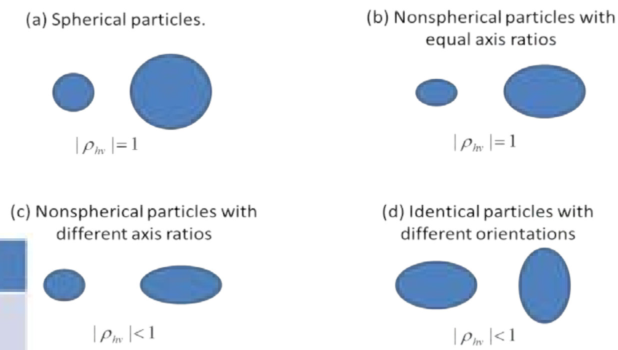


- As this is the phase information, there is little effect of the partial beam blocking.
- As the number of raindrops grows, the specific differential phase increases.

2. Radar Variables

▪ Dual-Polarization Variables

- Cross Correlations



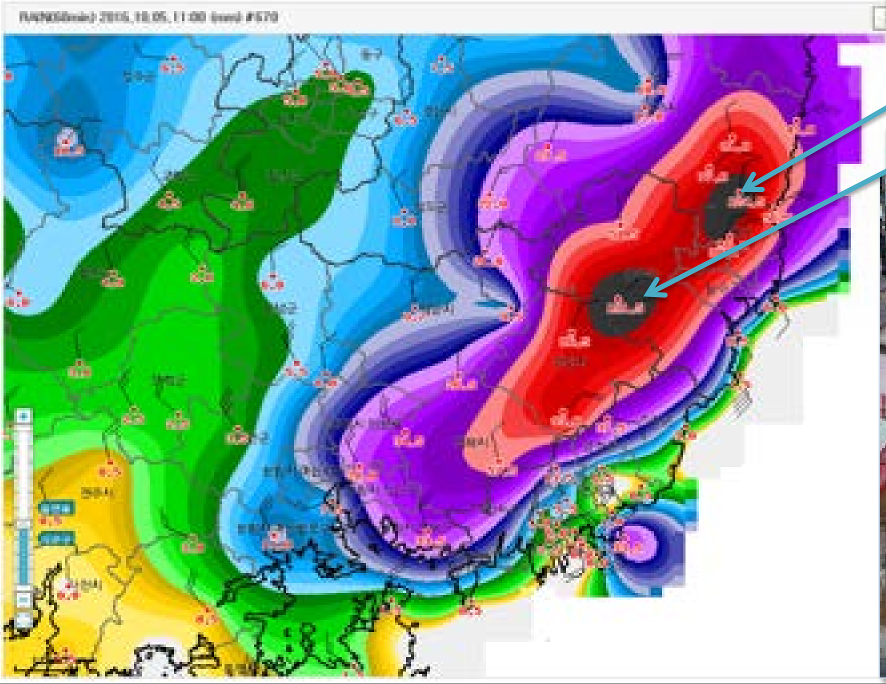
Non-Meteorological (birds, insects, etc.)	Metr (Non-Uniform) (hail, melting snow, etc.)	Metr (Uniform) (rain, snow, etc.)
	Hail Wet Aggregates	
Complex scattering from pulse-to-pulse. Horizontal and vertical pulses change in different manners from pulse-to-pulse	Somewhat complex scattering from pulse-to-pulse. Moderate differences from pulse-to-pulse for the horizontal and vertical pulses	Well-behaved scattering from pulse-to-pulse. Little differences from pulse-to-pulse for the horizontal and vertical pulses
Low CC (< 0.7)	Moderate CC (0.80 to 0.97)	High CC (> 0.97)

Source: A. Ryzhkov lecture (2012)
Dual-Polarization Radar Operations Course

2. Radar Variables

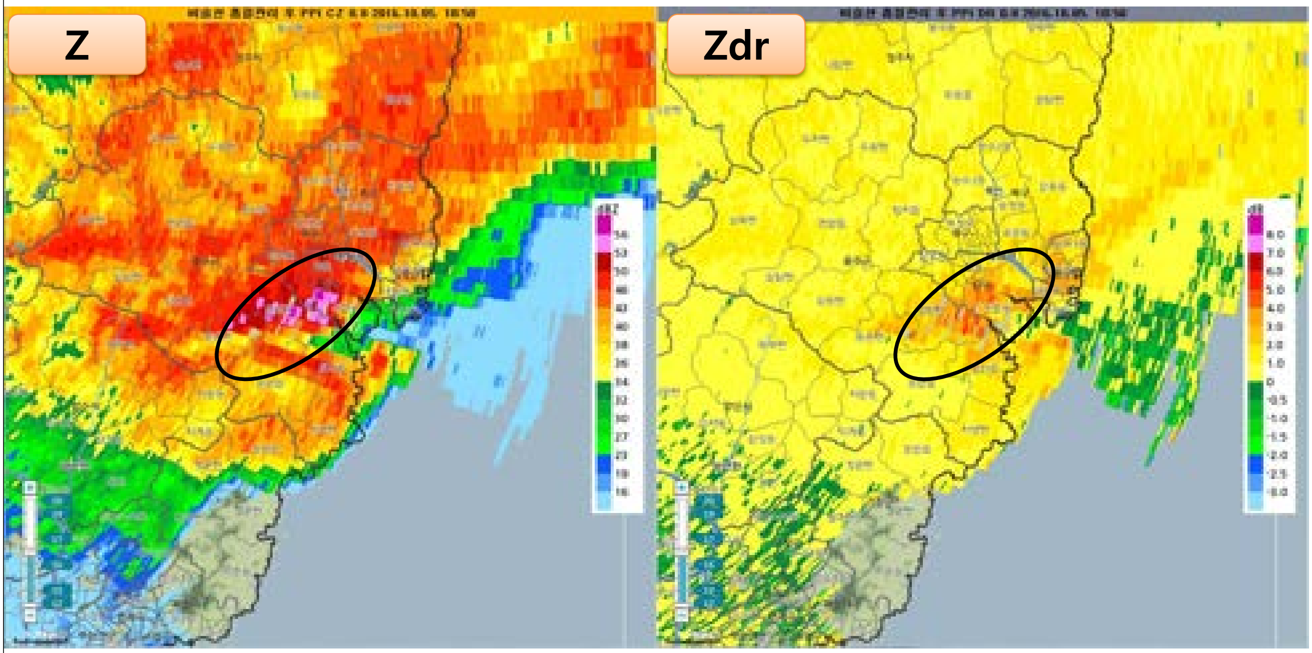
▪ Example Images for Heavy Rainfall

1h Accumulated rainfall (10~11LST, 2016.10.05)



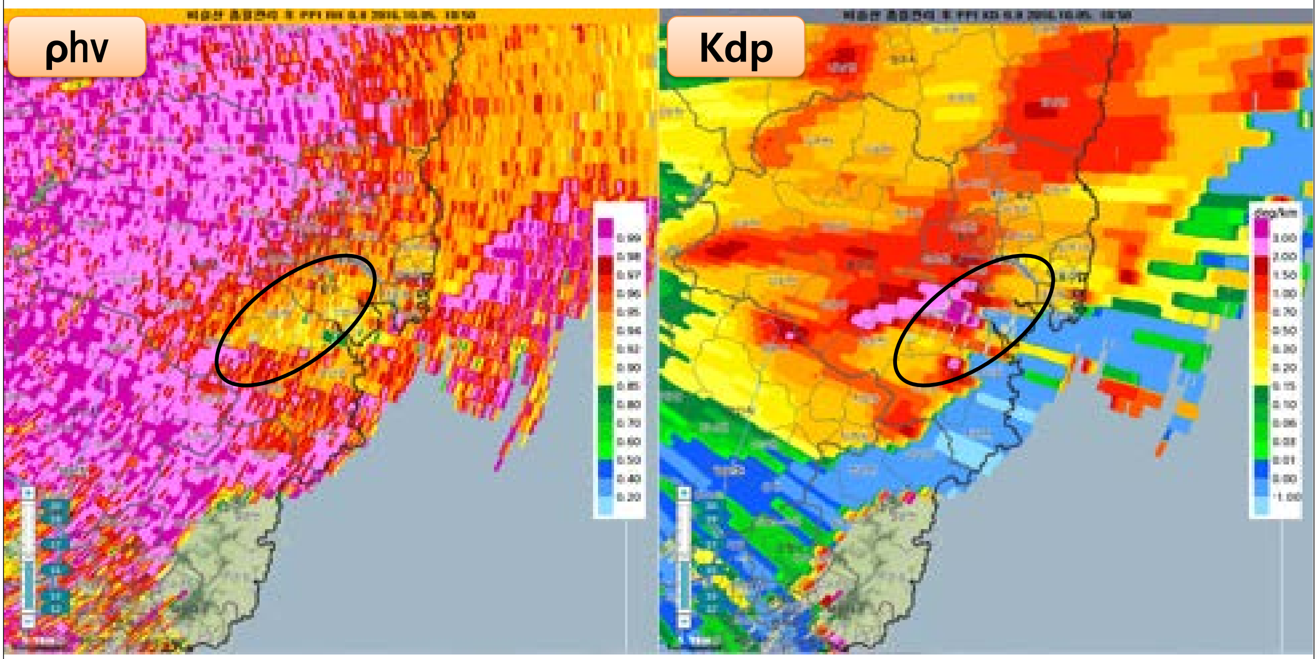
2. Radar Variables

▪ Example Images for Heavy Rainfall



2. Radar Variables

▪ Example Images for Heavy Rainfall

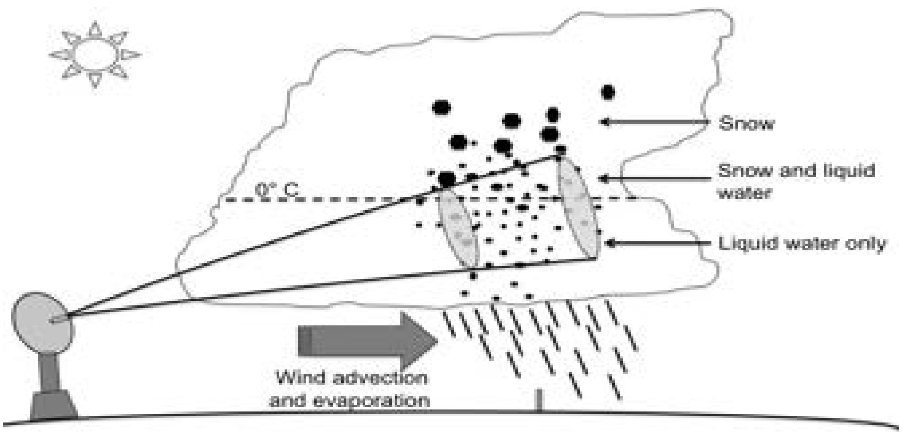


3. Data Processing

Source: R. Cifelli and V. Chandrasekar (2010)

3. Data Processing

▪ Schematic Diagram of Radar Observation



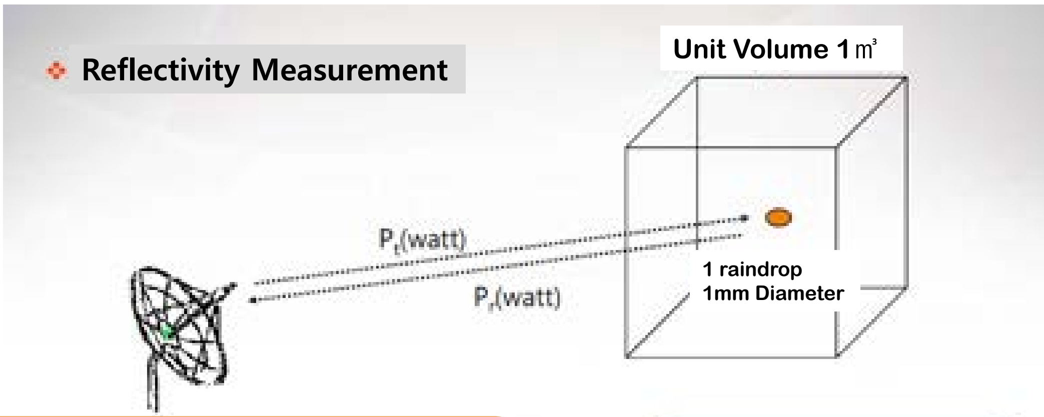
Radar Equation

Z-R relationship

Observation → Radar Variables (Reflectivity, Velocity, Spectrum Width, Differential Reflectivity, etc.) → Quality Control → QPE → Areal precipitation → Application

3. Data Processing

▪ RADAR Equation



Radar equation: $P_r = \frac{P_t C K^2}{r^2} Z_e$

Reflectivity factor: $Z_e(mm^6/m^3) =$ ㅃ N더D덕D^6

Reflectivity: Z더dBZ덕 $= 10log_{10}Z_e$

Reflectivity

$Z_e = \sum N(D)D^6 = 1mm^6/m^3$

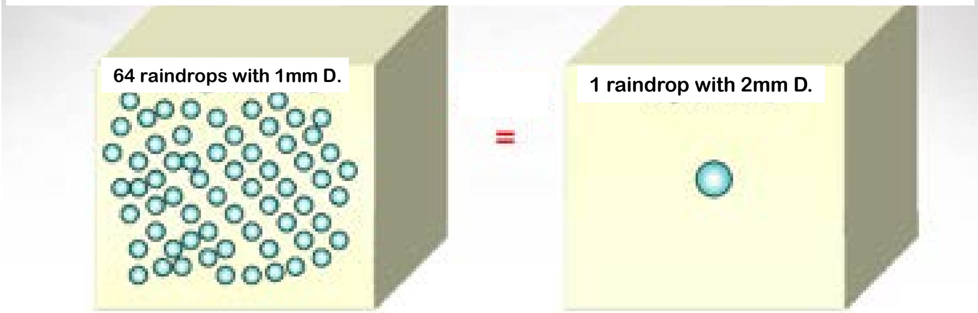
Z(dBZ) = $10log_{10}Z_e$ = 0dBZ

Source: Presentation by WRC, KMA

3. Data Processing

▪ RADAR Equation

64 raindrops with 1mm diameter vs. 1 raindrop with 2 mm diameter in unit volume in terms of radar reflectivity



Reflectivity

$Z_e = \sum N(D)D^6 = 64 \times 1^6 = 64\ mm^6/m^3$

Z(dBZ) = 10log64 = 18dBZ

=

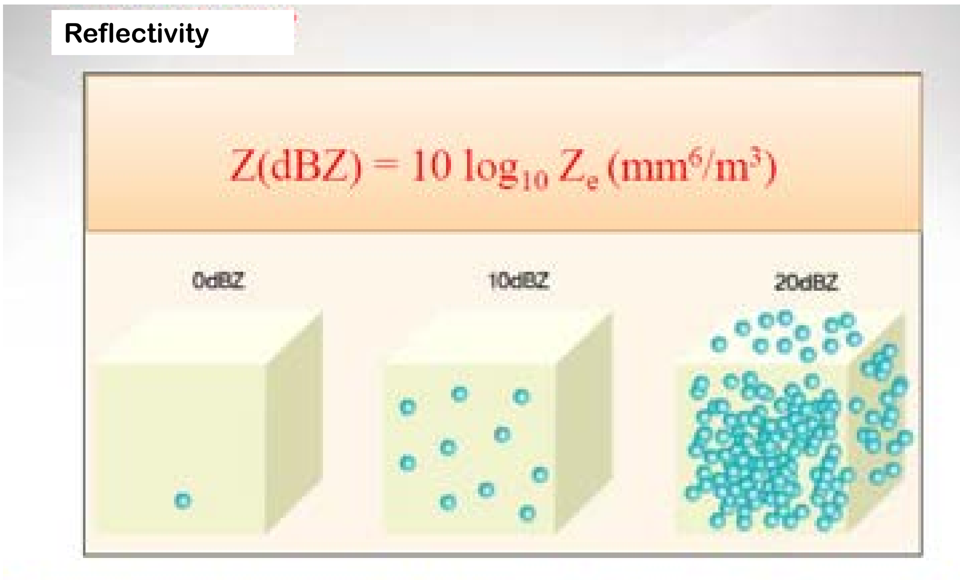
$Z_e = \sum N(D)D^6 = 1 \times 2^6 = 64\ mm^6/m^3$

Z(dBZ) = 10log64 = 18dBZ

Source: Presentation by WRC, KMA

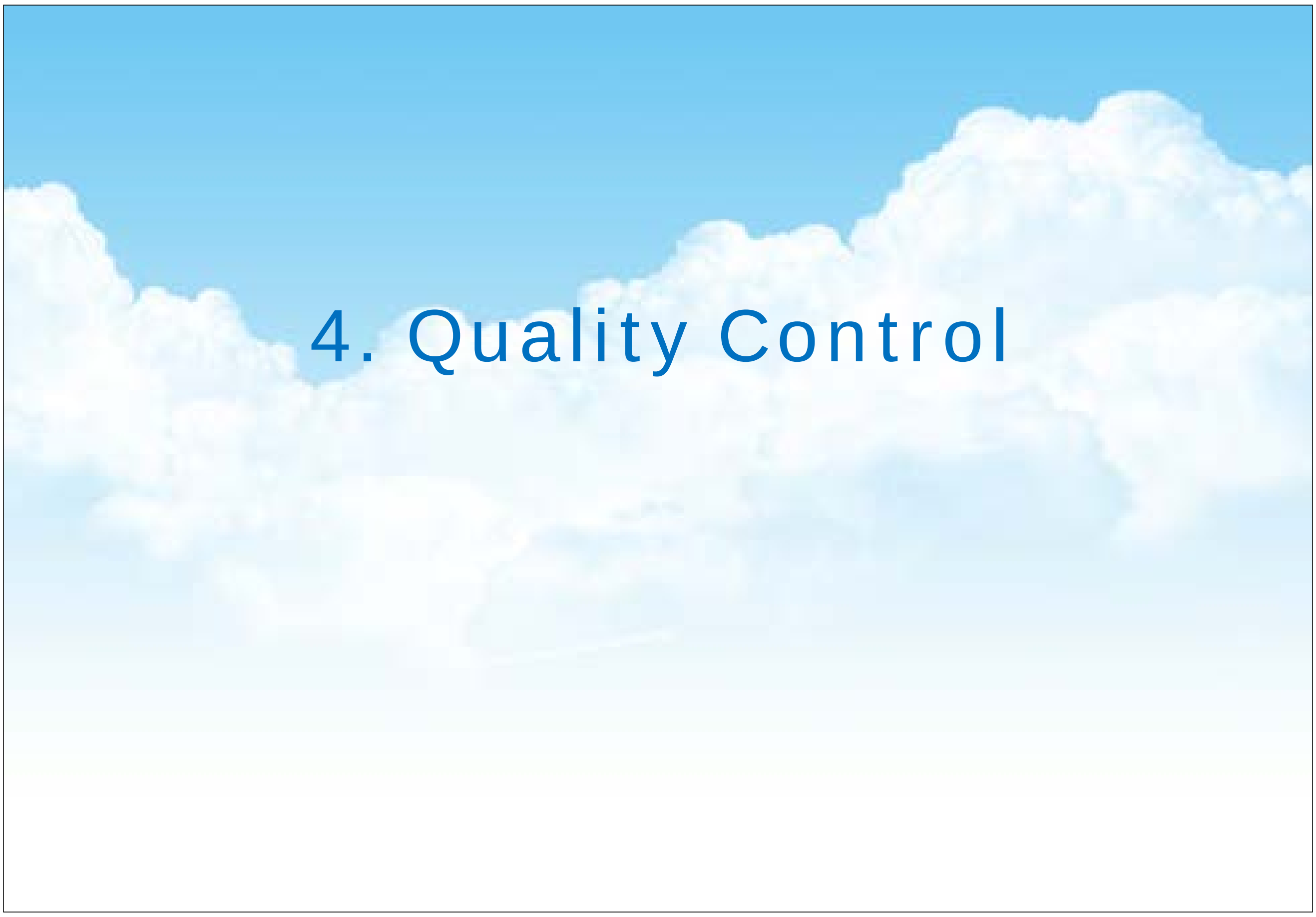
3. Data Processing

▪ **RADAR Equation**



Raindrop with 1mm diameter in unit volume: #1 → 0 dBZ, #10 → 10 dBZ, #100 → 20 dBZ

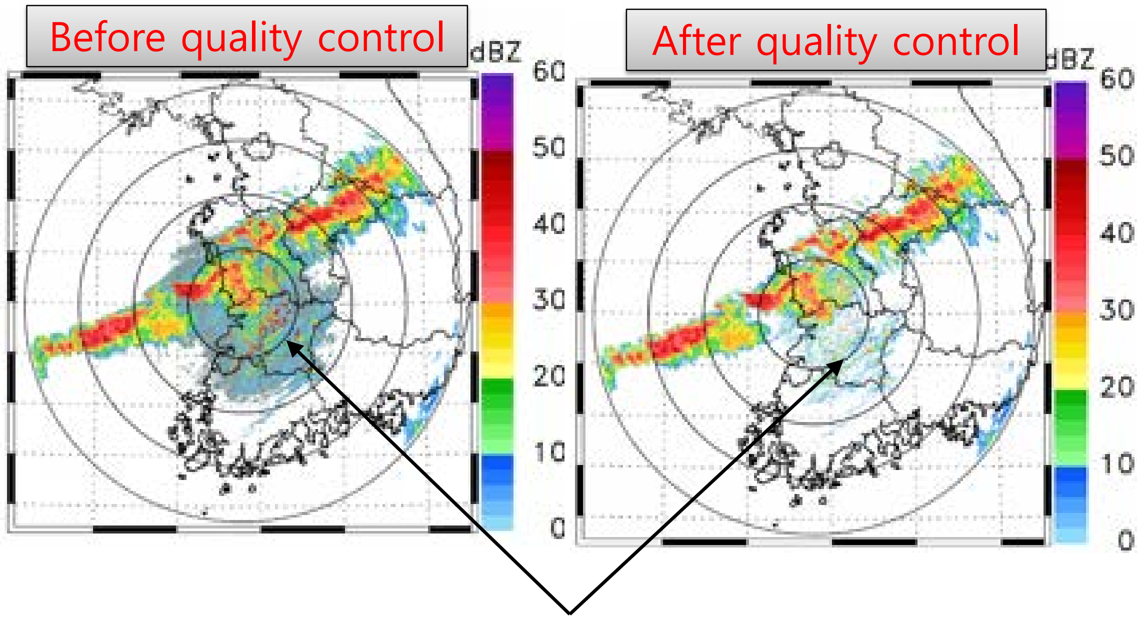
Source: Presentation by WRC, KMA



4. Quality Control

Yo-Han Cho et al.(2016): Identification and Removal of Ground Echoes and Anomalous Propagation Using the Characteristics of Radar Echoes. J. Atmos. Oceanic. Technol, 23, 1206-1222.

▪ Removing of Non-Precipitation Echo

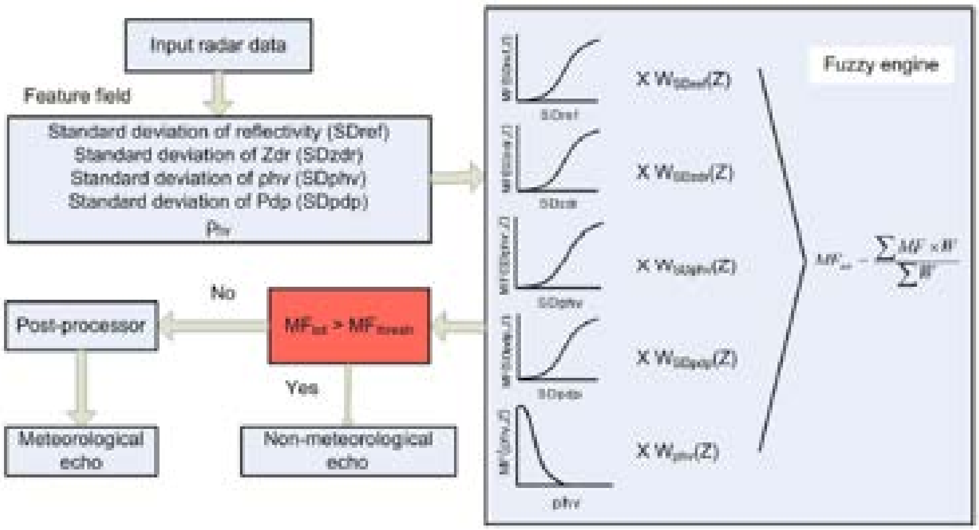


4. Quality Control

Yo-Han Cho et al.(2016): Identification and Removal of Ground Echoes and Anomalous Propagation Using the Characteristics of Radar Echoes. J. Atmos. Oceanic. Technol, 23, 1206-1222.

▪ Removing of Non-Precipitation Echo

- Diagram of QC

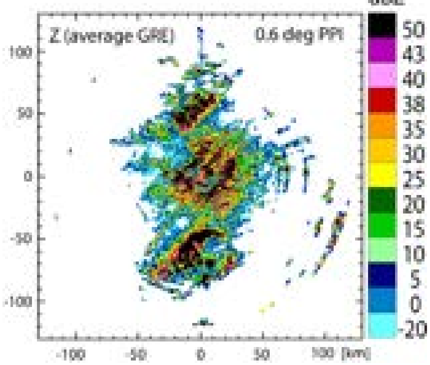


4. Quality Control

Yo-Han Cho et al.(2016): Identification and Removal of Ground Echoes and Anomalous Propagation Using the Characteristics of Radar Echoes. J. Atmos. Oceanic. Technol, ***23****, 1206-1222.*

▪ Removing of Non-Precipitation Echo

Average ground echo map



Non-precipitation echoes :

Given the observation of an echo on **clear** situation, then it is

1. **Normal GRE** if "$Z_{AverageGroundMap}$ >0 dBZ"
2. **AP** if "$Z_{AverageGroundMap}$ = nodata"

Precipitation echoes:

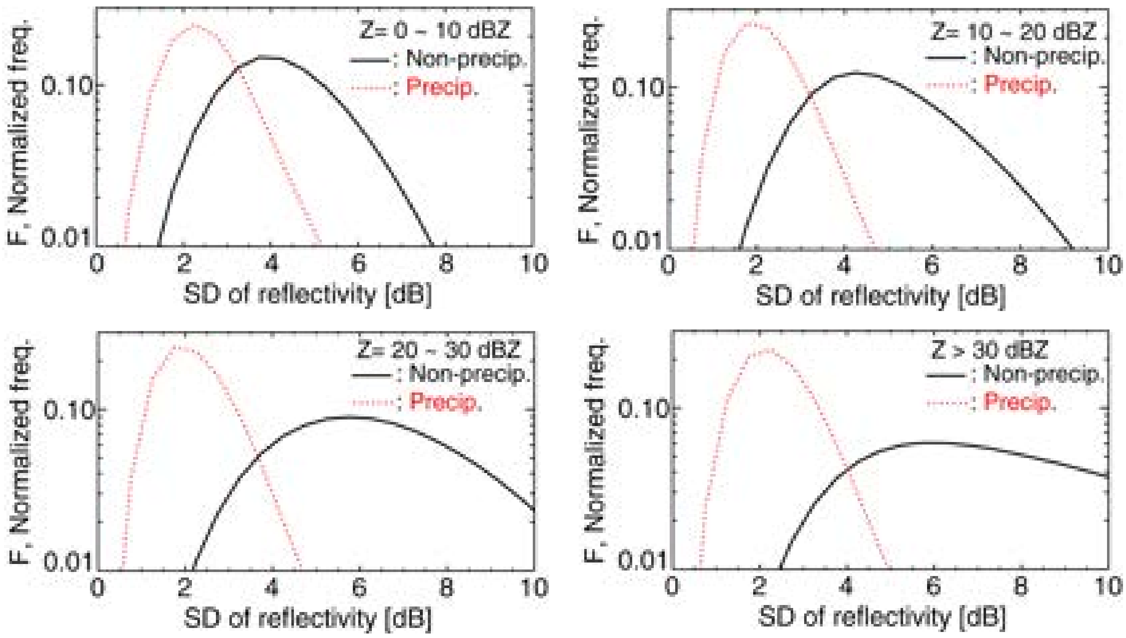
Given the observation of an echo on **rainy** situation, then it is

Precipitation if "$Z_{AverageGroundMap}$ = nodata"

4. Quality Control

Yo-Han Cho et al.(2016): Identification and Removal of Ground Echoes and Anomalous Propagation Using the Characteristics of Radar Echoes. J. Atmos. Oceanic. Technol, ***23****, 1206-1222.*

▪ Removing of Non-Precipitation Echo



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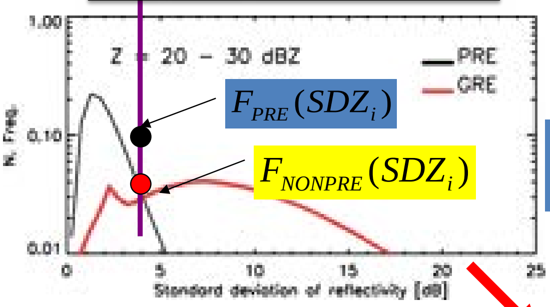
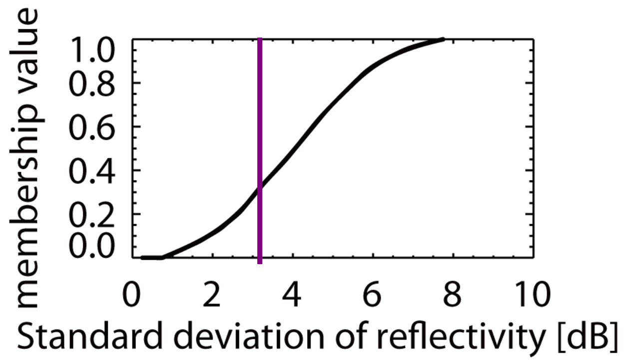
▪ Removing of Non-Precipitation Echo

Frequency distributions



$$MF_{NONPRE}(SDZ_i) = \frac{F_{NONPRE}(SDZ_i)}{F_{NONPRE}(SDZ_i) + F_{PRE}(SDZ_i)}$$

Membership function



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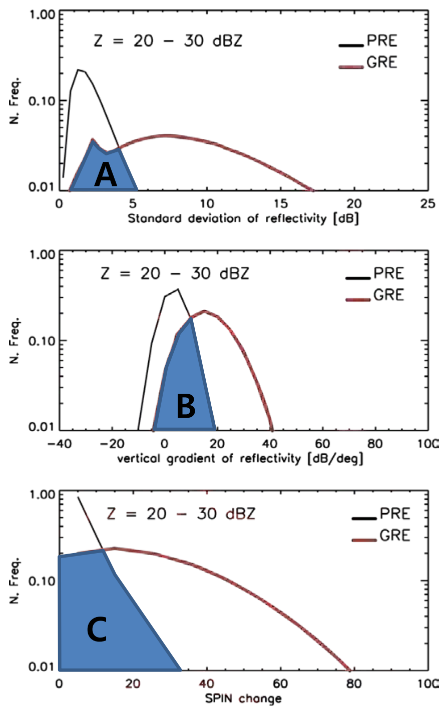
▪ Removing of Non-Precipitation Echo



$$W_{SDZ} = \frac{1}{AD}$$

$$W_{VGZ} = \frac{1}{BD}$$

$$W_{SPIN} = \frac{1}{CD}$$

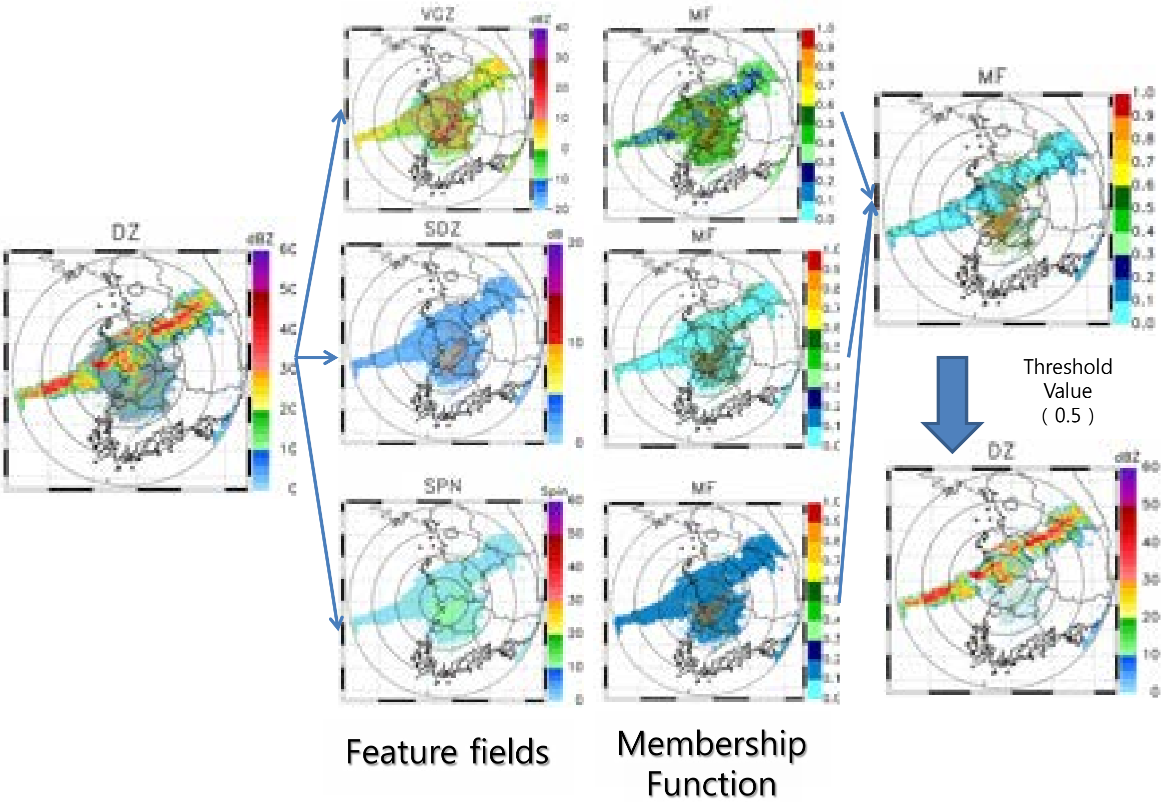
$$D = \frac{1}{A} + \frac{1}{B} + \frac{1}{C}$$

Weighting Function

dBZ	SD(Z)	VG(Z)	SPIN change
Z > 30	0.43	0.39	0.18
30 > Z > 20	0.39	0.38	0.23
20 > Z > 10	0.30	0.48	0.23
10 > Z > 0	0.36	0.35	0.28
Z < 0	0.69	–	0.31

4. Quality Control

*Yo-Han Cho et al.(2016): Identification and Removal of Ground Echoes and Anomalous Propagation Using the Characteristics of Radar Echoes. J. Atmos. Oceanic. Technol, **23**, 1206-1222.*



5. Quantitative Precipitation Estimation (QPE)

5. QPE

Marshall, J. s., and W. Mck. Palmer, 1948: The Distribution of Raindrops with Size, J. Meteorol., 5, 165-166.

▪ QPE

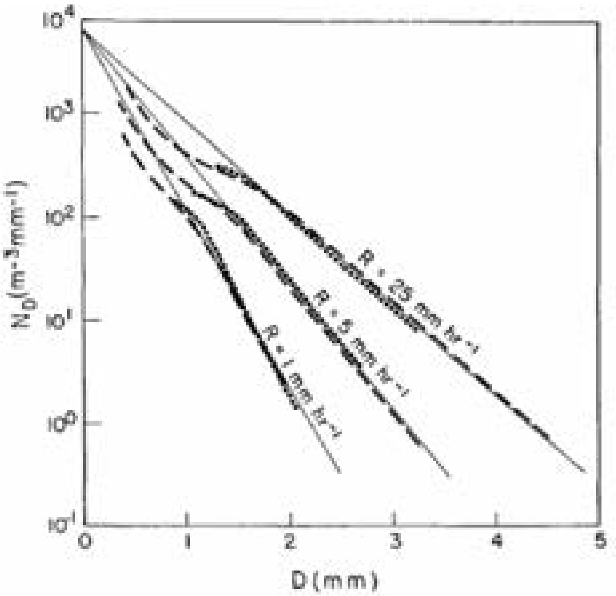
- J. S. Marshall and W. McK. Palmer (1948) measured raindrop size spectra at Ottawa.
- Found exponential size distribution of the form:

$$N_D = N_0\, e^{-\lambda D}$$

where N_0 = 8000/(m^3 mm),
D : droplet diameter (mm)
λ : shape parameter

$$\lambda = 4.1\, R^{-0.21}$$

where R is rain rate in mm/h



5. QPE

https://vlab.ncep.noaa.gov/web/wdtd/-/surface-precipitation-rate-spr-?selectedFolder=9234881

▪ QPE

- To convert radar measurable Z to hydrologically useful parameter R, we need a relationship to convert between these.
- A convenient and empirical relationship is a power-law relationship:

$$Z = AR^b$$

Table 1.2: Typical Z-R relationship recommended for WSR-88D

Name	Relationship	Optimum for:
Marshall-Palmer	Z=200R1.6	General stratiform precipitation
WSR-88D Convective	Z=300R1.4	Summer deep convection (non-tropical convection)
Rosenfeld	Z=250R1.2	Tropical convection systems
East-Cook Stratiform	Z=130R2.0	Winter stratiform precipitation in the US (east of continental divide)
West-Cook Stratiform	Z=75R2.0	Winter stratiform precipitation in the US (west of continental divide)

5. QPE

▪ QPE

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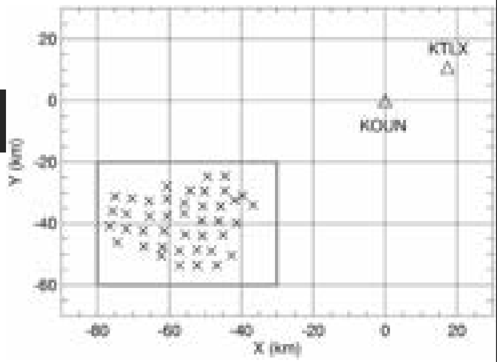

Rainfall Estimation with a Polarimetric Prototype of WSR-88D

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Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, Norman, Oklahoma

(Manuscript received 26 April 2004, in final form 3 October 2004)

ABSTRACT

As part of the Joint Polarization Experiment (JPOLE), the National Severe Storms Laboratory conducted an operational demonstration of the polarimetric utility of the Norman, Oklahoma (KOUN), Weather Surveillance Radar-1988 Doppler (WSR-88D). The capability of the KOUN radar to estimate rainfall is tested on a large dataset representing different seasons and different types of rain. A dense gauge network—the Agricultural Research Service (ARS) Micronet—is used to validate different polarimetric algorithms for rainfall estimation. One-hour rain totals are estimated from the KOUN radar using conventional and polarimetric algorithms and are compared with hourly accumulations measured by the gauges. Both point and areal rain estimates are examined. A new "synthetic" rainfall algorithm has been developed for rainfall estimation. The use of the synthetic polarimetric algorithm results in significant reduction in the rms errors of hourly rain estimates when compared with the conventional nonpolarimetric relation: 1.7 times for point measurements and 3.7 times for areal rainfall measurements.

5. QPE

▪ QPE

TABLE 1. List of different polarimetric algorithms used for rainfall estimation.

	a	b	c	Assumptions	Source
		$R(K_{DP}) = a\|K_{DP}\|^b \text{sign}(K_{DP})$			
1	50.7	0.85		Simulated DSD, equilibrium shape	BC01
2	54.3	0.806		Measured DSD (FL), Brandes' shape	BZV02
3	51.6	0.71		Simulated DSD, Goddard's shape	IB02
4	44.0	0.822		Measured DSD (OK), equilibrium shape	NSSL
5	50.3	0.812		Measured DSD (OK), Bringi's shape	NSSL
6	47.3	0.791		Measured DSD (OK), Brandes' shape	NSSL
		$R(Z, Z_{DR}) = a Z^b Z_{dr}^c$			
7	6.70×10^{-3}	0.927	−3.43	Simulated DSD, equilibrium shape	BC01
8	7.46×10^{-3}	0.945	−4.76	Measured DSD (FL), Brandes' shape	BZV02
9	7.11×10^{-3}	1.0	*	Simulated DSD, Goddard's shape	IB02
10	1.42×10^{-2}	0.770	−1.67	Measured DSD (OK), equilibrium shape	NSSL
11	1.59×10^{-2}	0.737	−1.03	Measured DSD (OK), Bringi's shape	NSSL
12	1.44×10^{-2}	0.761	−1.51	Measured DSD (OK), Brandes' shape	NSSL
		$R(K_{DP}, Z_{DR}) = a\|K_{DP}\|^b Z_{dr}^c \text{sign}(K_{DP})$			
13	90.8	0.93	−1.69	Simulated DSD, equilibrium shape	BC01
14	136	0.968	−2.86	Measured DSD (FL), Brandes' shape	BZV02
15	52.9	0.852	−0.53	Measured DSD (OK), equilibrium shape	NSSL
16	63.3	0.851	−0.72	Measured DSD (OK), Bringi's shape	NSSL

* Here, $c = -8.14 + 1.385 Z_{DR} - 0.1039 Z_{DR}^2$.

5. QPE

▪ QPE

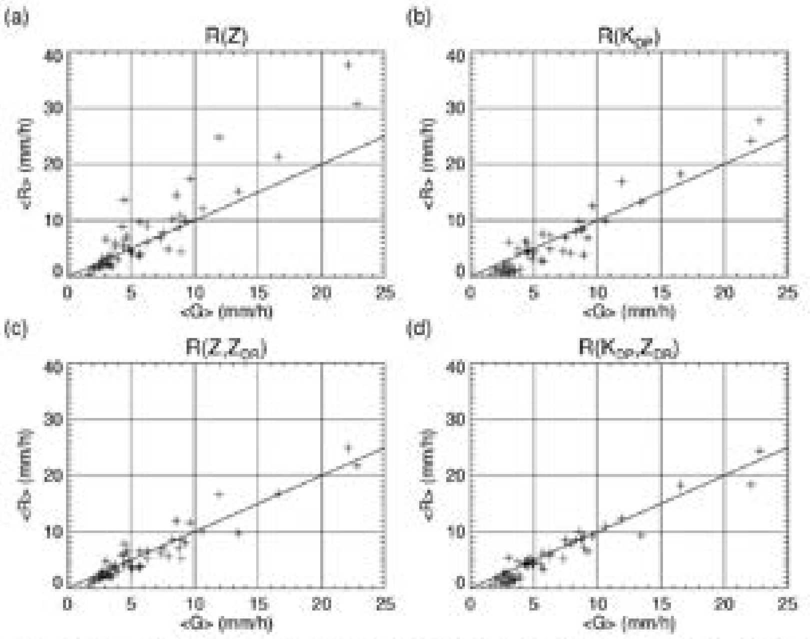


FIG. 4. Mean areal rain rates from gauges ⟨G⟩ vs their estimates ⟨R⟩ from different radar-rainfall algorithms (24 rain events, 50 h of observations). The $R(K_{DP})$, $R(Z, Z_{DR})$, and $R(K_{DP}, Z_{DR})$ relations are the best in each category (algorithms 4, 10, and 14 in Table 1, respectively).

5. QPE

▪ QPE

R(Z): Z-R relationship(Convective Rain)

$R = 1.7 \times 10^{-2} \times Z_H{}^{0.714}$

R(Z,Zdr): WRC, KMA(2015)

$If\ \ Z_H \geq 35dBZ$

$R = 6.16 \times 10^{-3} \times Z^{0.95} Z_{DR}{}^{-5.55}$

$else$

$R = 1.7 \times 10^{-2} \times Z_H{}^{0.714}$

R(Z,Zdr,Kdp): Ryzhkov et al.(2005)

$R(Z_H) = 1.7 \times 10^{-2} \times Z_H{}^{0.714}$

$If\ R(Z_H) < \ 6\, mm/h$

$R = (1.7 \times 10^{-2} \times Z_H{}^{0.714})/(0.4 + 5.0|Z_{DR} - 1|^{1.3})$

$If\ 6\ \leq R(Z_H) < 50\ mm/h$

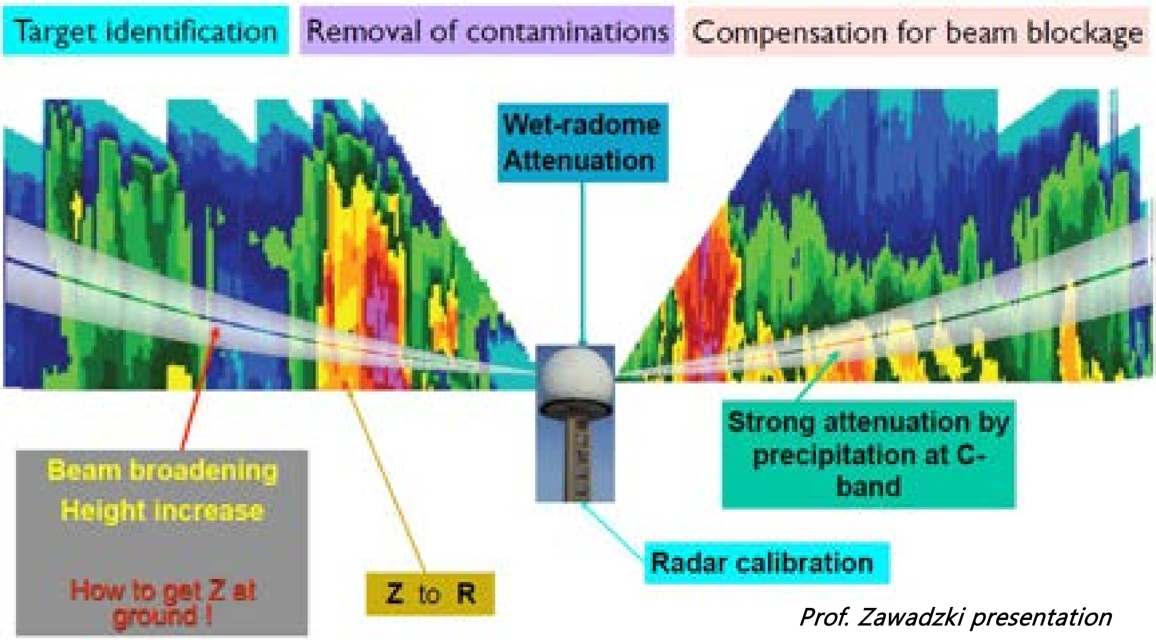
$R = (44.0|K_{DP}|^{0.822} sign(K_{DP}))/(0.4 + 3.5|Z_{DR} - 1|^{1.7})$

$If\ R(Z_H) \geq 50\ mm/h$

$R = 44.0|K_{DP}|^{0.822} sign(K_{DP})$

5. QPE

▪ **Considerations Necessary to Derive a QPE Product**



Prof. Zawadzki presentation

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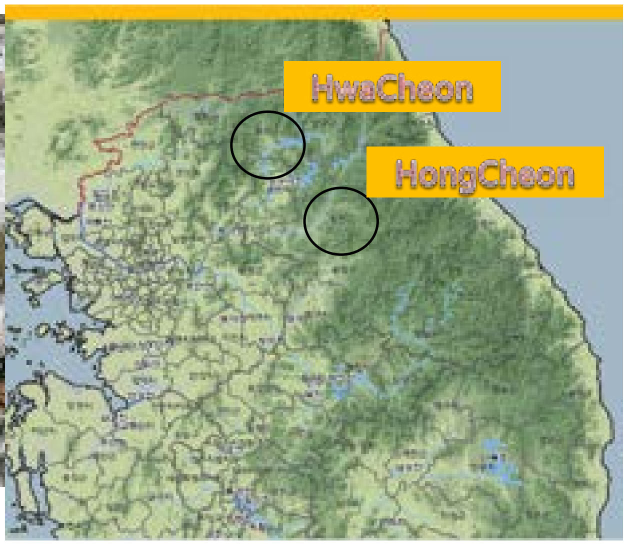
6. Application

6. Application

- **Severe Weather Monitoring and QPE**
  - Detection of hail signatures or heavy rainfall
  - QPE
- **Quantitative Precipitation Forecasting**
  - Short-term range (0~6 hours) rainfall forecasting
- **Hydrological Application**
  - Flood Forecasting
  - Flash Flood Forecasting

6. Application

- **Hail Signatures (13:45 LST on Sep. 1, 2016 Mt.Gari)**

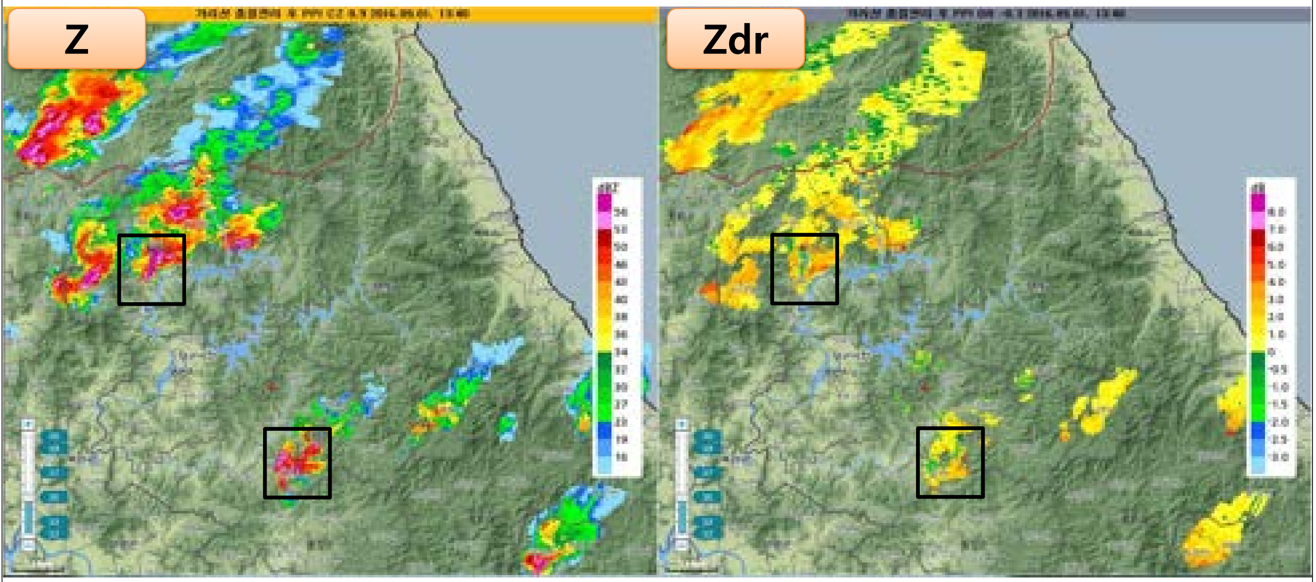


❖ Yonhap news

- 13:30 ~13:50 LST
- Size: 0.5 ~ 3 cm

6. Application

■ Hail Signatures (13:45 LST on Sep. 1, 2016 Mt.Gari)



6. Application

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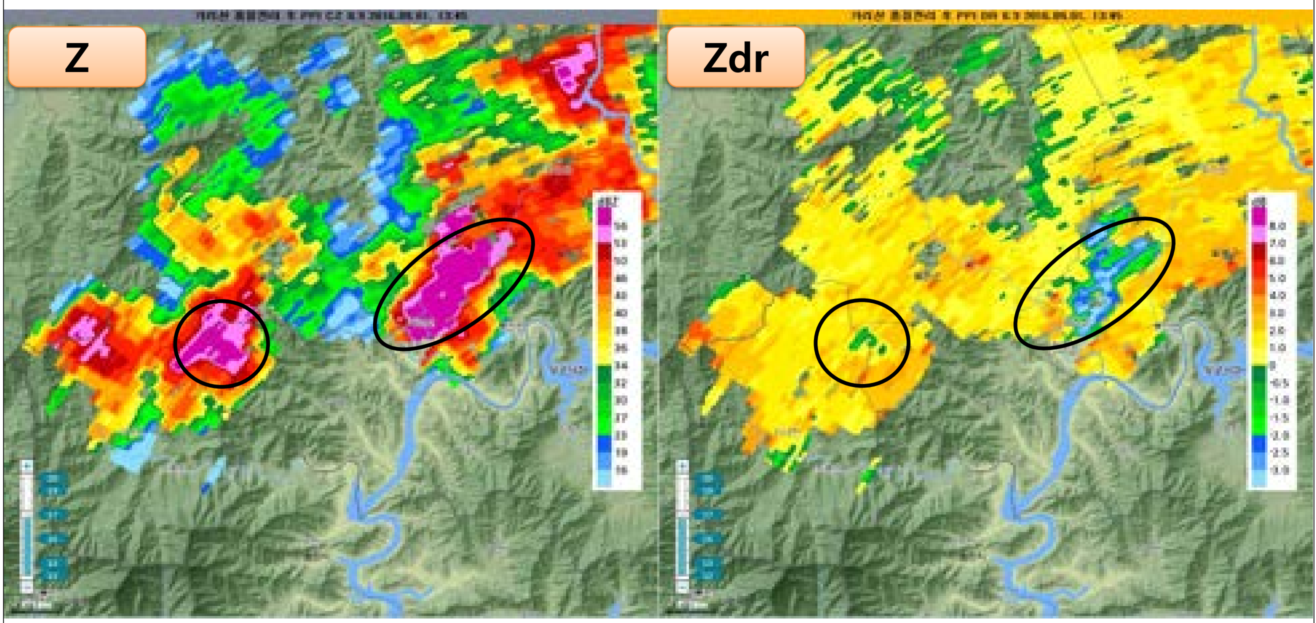

6. Application

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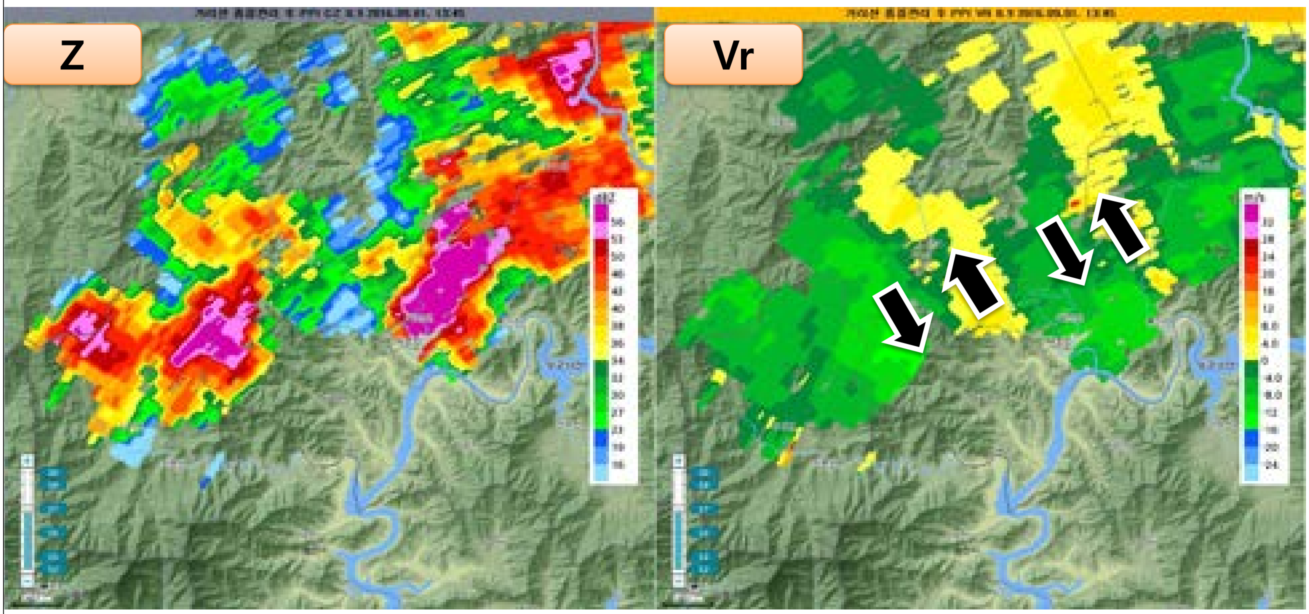

6. Application

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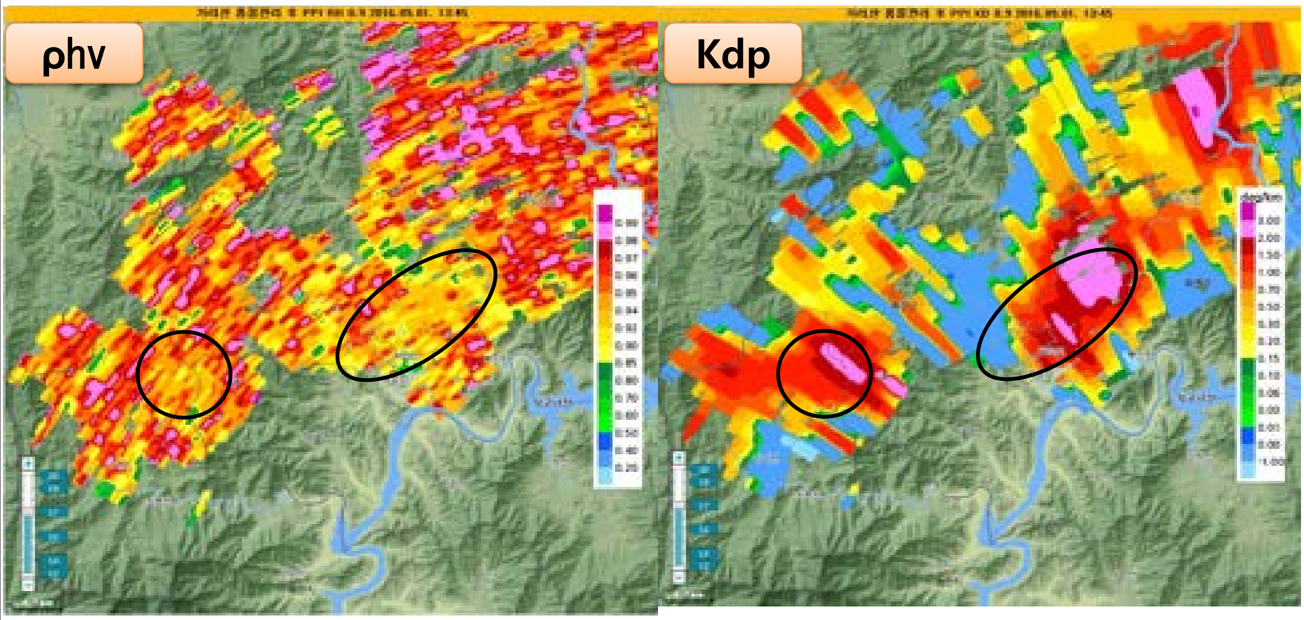
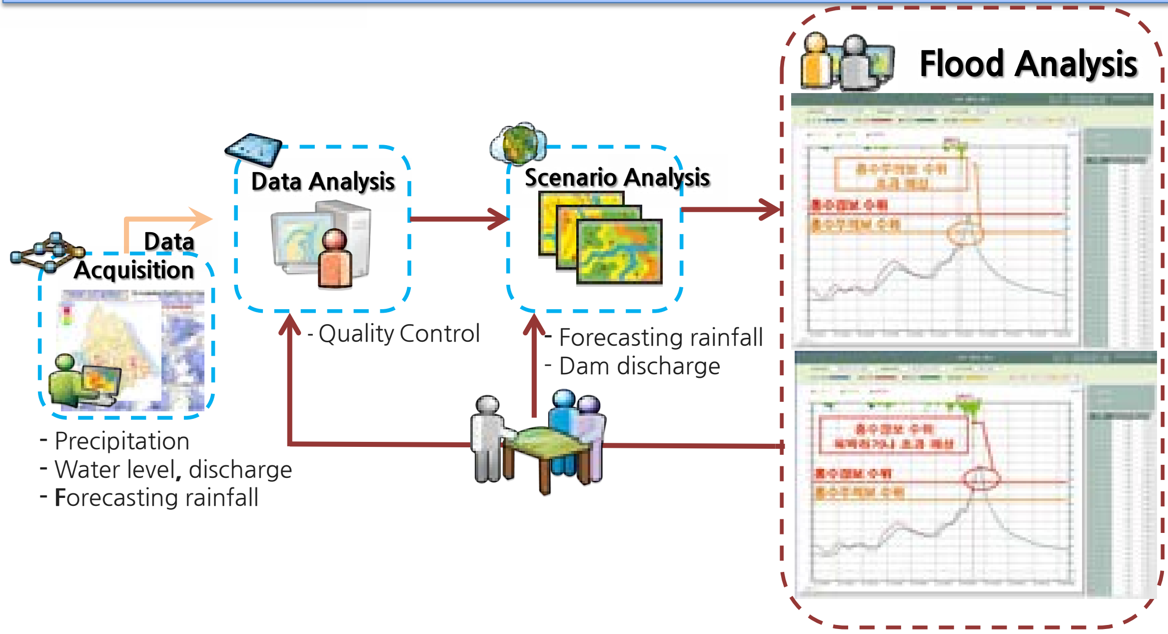


6. Application

▪ Hydrological Application

Flood Forecasting



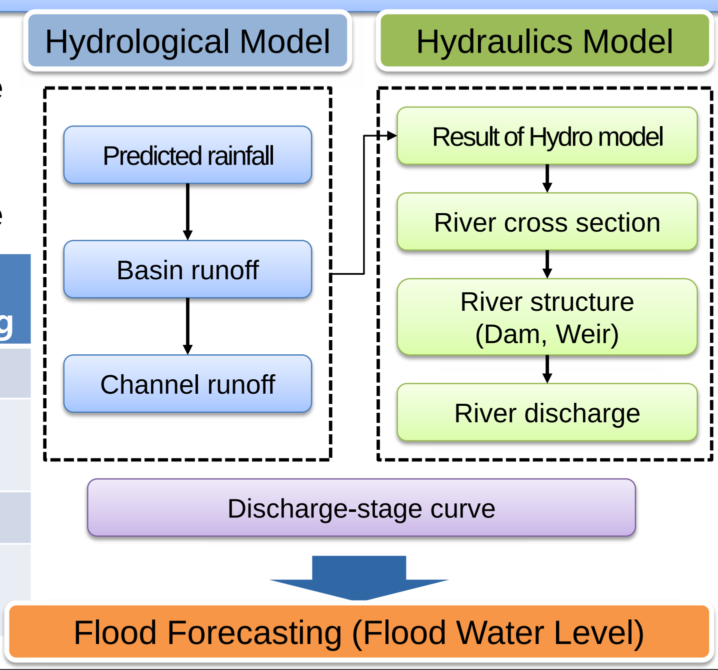
6. Application

▪ Hydrological Application

Flood Forecasting

- Flood Watch
  - 50% of design flood discharge
- Flood Warning
  - 70% of design flood discharge

Basin	# of Flood Forecasting
Hangang River	16
Nakdonggang River	17
Geumgang River	9
Yeongsangang River	13

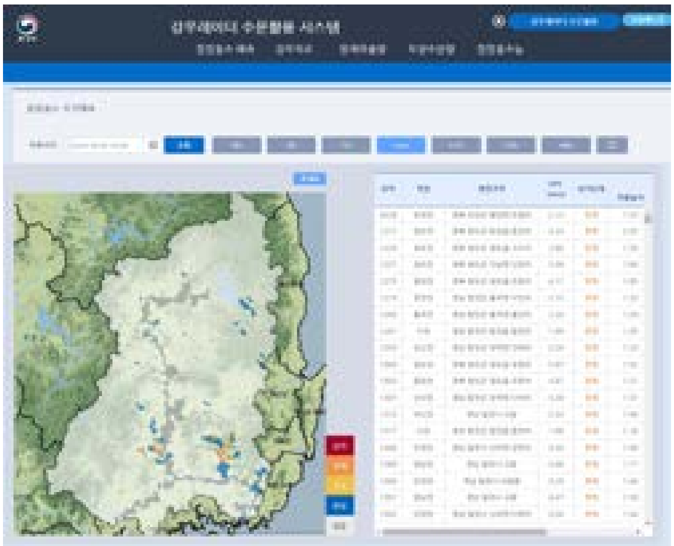


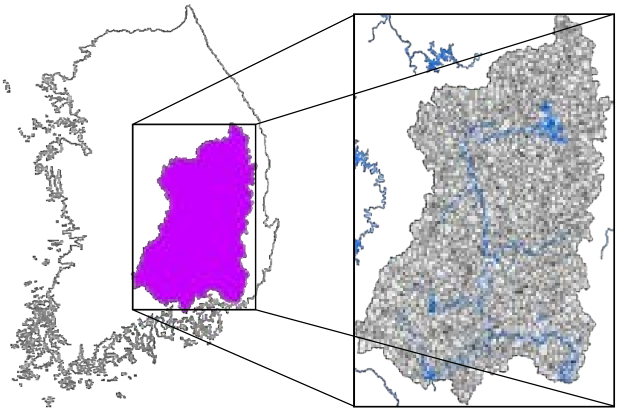
6. Application

▪ Hydrological Application

Flash Flood Forecasting System for Nak-dong River Watershed

✓ Divide Nak-dong River Watershed into 1,784 Sub-basin

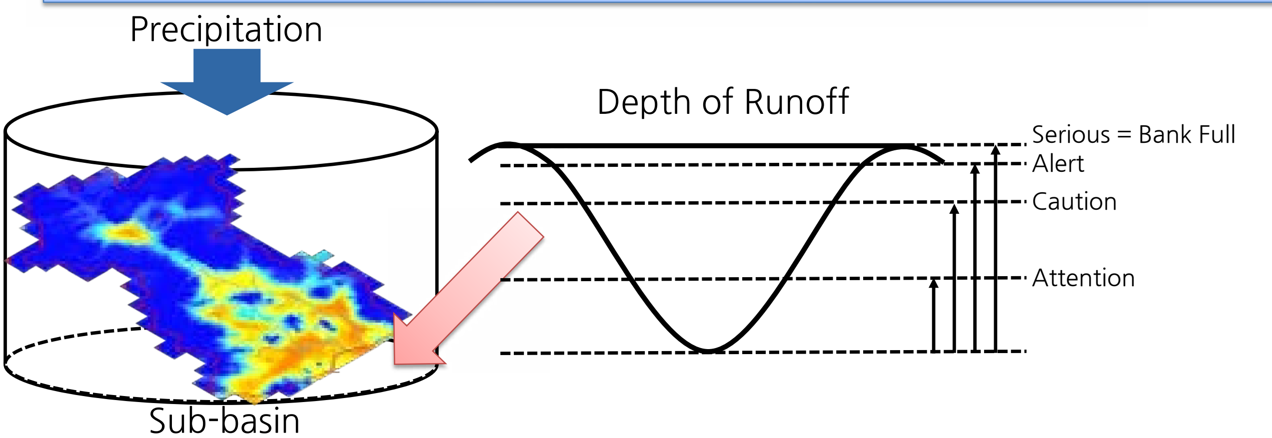




6. Application

▪ Hydrological Application

Flash Flood Forecasting System for Nak-dong River Watershed



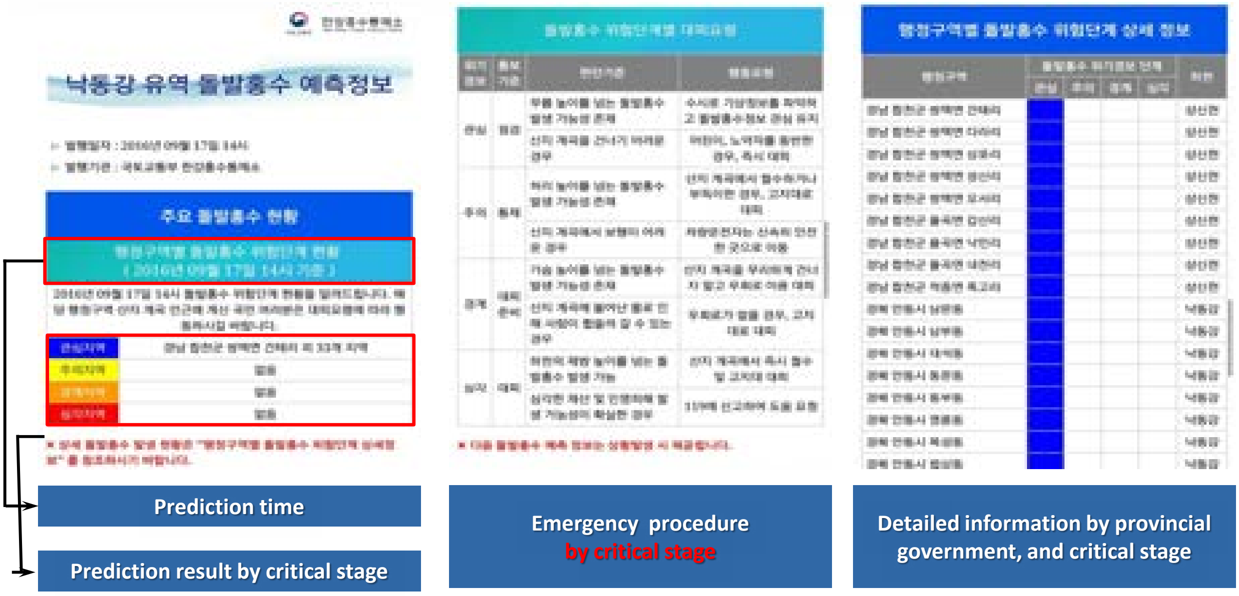
✓Flash Flood Forecasting by Critical Stage

Stage	Attention	Caution	Alert	Serious
depth	0.5m (knee)	1.0m (waist)	1.2m (chest)	Overflow(levee)

6. Application

▪ Hydrological Application

Flash Flood Forecasting System for Nak-dong River Watershed

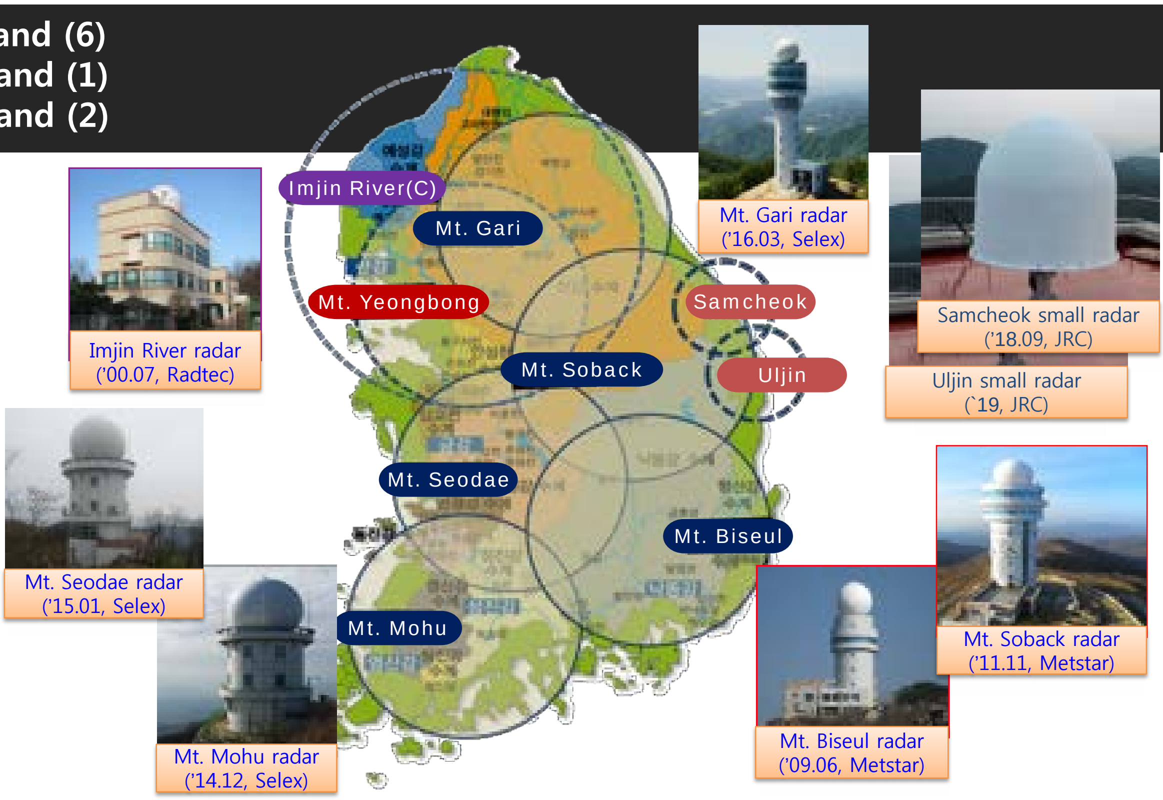


7. Radar Networks

7. Radar Networks

(Operated by Ministry of Environment)

- S-band (6)
- C-band (1)
- X-band (2)



Thank you very much

Discharge Measurement and Computation

Hydrological Survey

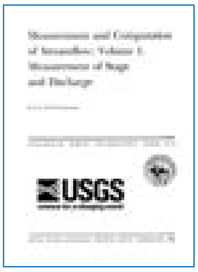
Discharge Measurement and Computation

Aims & Objectives

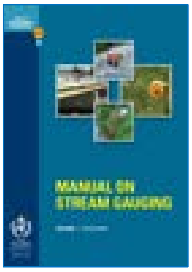
- The aims of the course are to:
  - (1) Promote among trainees a good understanding of the basic principles of discharge measurement
  - (2) Introduce and understand trainees of various equipment and method for discharge measurement in the field

- **At the end of the course, trainees will be able to:**
  - (1) Understand the objectives and necessity of discharge measurement
  - (2) Apply methods of discharge measurement with field condition
  - (3) Compute discharge data

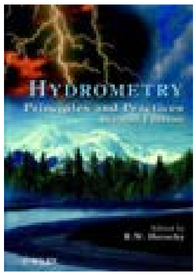
References



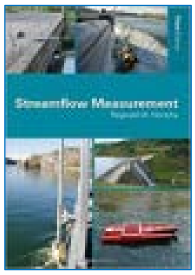
USGS Measurement and Computation: vol1. (S.E. RANTZ and others, 1982)



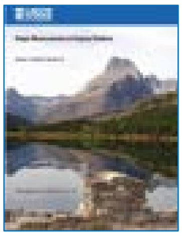
Manual on Stream Gauging 1 (WMO-1044, 2010)

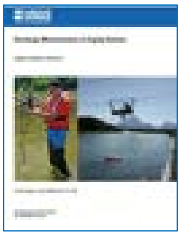


Hydrometry principal and Practices (R.W. Herschy and others, 1978)



Streamflow Measurement (R.W. Herschy, 1978)





USGS TWRI 3-7A, 3-8A (2010)

Hydrological Survey Report (ME, 2010~2019)

Manual on Discharge Streamflow measurement (KIHS, 2018)

Guideline of discharge measurement, etc. (KIHS, 2018)

Contents

1. Introduction

1.1 Background
1.2 Streamflow (or Discharge)
1.3 Discharge Measurement

1.1 Background

- Streamflow, or channel runoff, is the flow of water in streams, rivers, and other channels and is a major element of the water cycle.
- It is one component of the runoff of water from the land to water bodies, the other component being surface runoff.
- "Streamflow" refers to the amount of water flowing in a river.
  → How much water is flowing in the river (stream)?

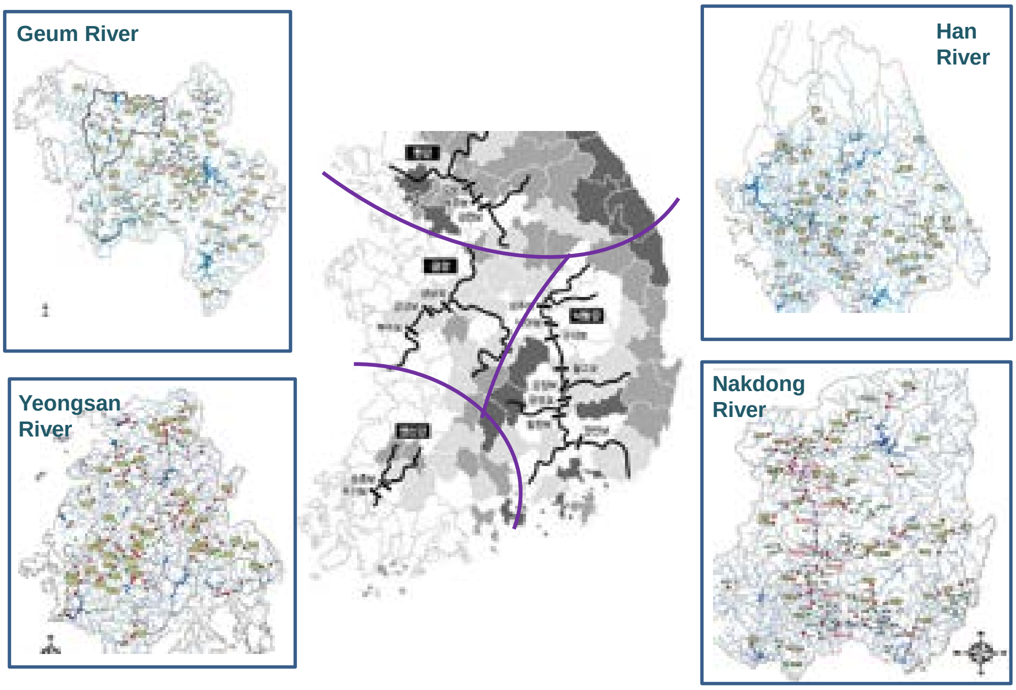
Seomjin River in Korea

Han River in Korea

Source: Ko.wikipedia

1.1 Background

▪ Hydrological Survey in Korea (KIHS)

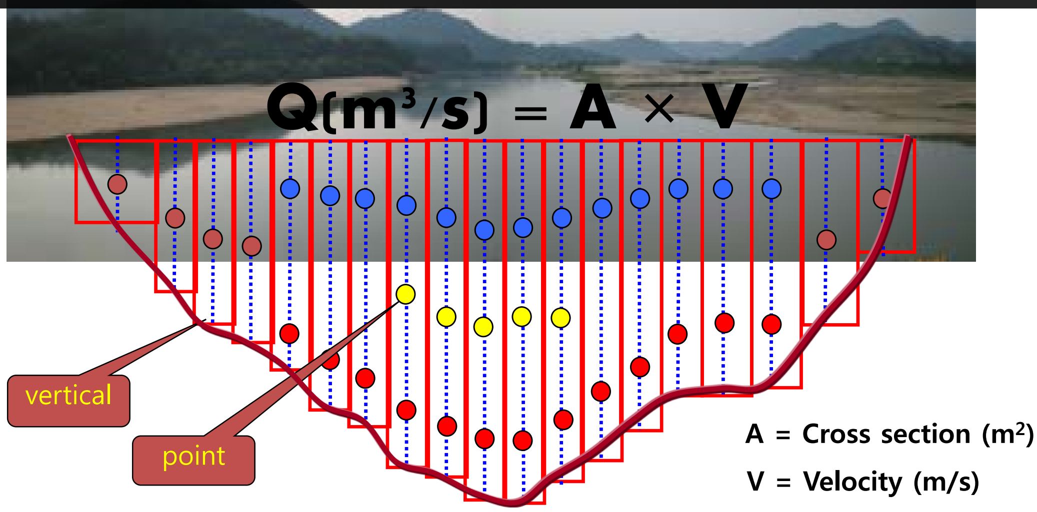


Source: ME_KIHS, “Hydrological Survey report” 2019

1.2 Streamflow (or Discharge)

▪ Definition of Streamflow or Discharge

- Streamflow, or discharge, is defined as the volumetric rate of flow of water (volume per unit time) in an open channel, including any sediment or other solids that may be dissolved or mixed with it, adhering to the Newtonian physics of open channel hydraulics of water.
- “Streamflow measurement” or “discharge measurement” is generally applied to the final result of the calculations.

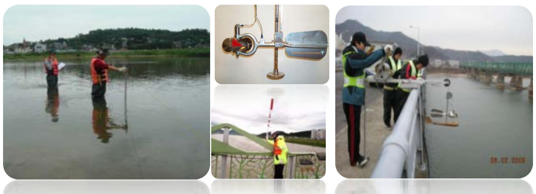


Source: USGS, “Techniques and Methods 3–A8” 2010

1.3 Discharge Measurement

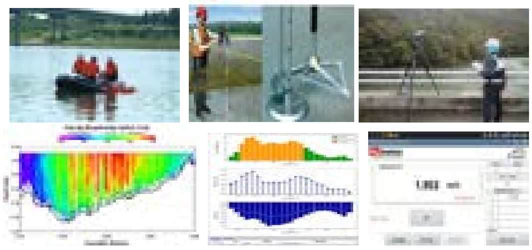
▪ **Discharge measurements are made by the several methods.**

1. Past

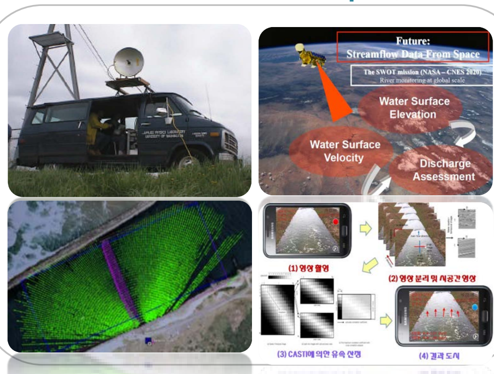


year	Ratio of equipment used for discharge measurement (%)				
	Price AA	ADCP	ADV	Float	etc
2009	55.2	18.7	3.6	21.7	0.8
2018	9.4	48.8	33.5	6.4	1.9

2. Present



3. Future (Advanced Techniques)



2. Discharge Measurement

2.1 General Procedures

▪ General Procedures of Discharge Measurement

	Major Procedure	Main Contents
Pre-investigation and field measurement	Pre-Investigation	• Collecting of past material, pre-investigation for field measurement • Planning for hydrological survey considering the field conditions
	Streamflow measurement and calculation	• Standards compliance and decision of measuring method, measurement location considering the field conditions • Calculation using standard-calculation sheet
Discharge computation and analysis	Evaluation of data	• Compliance with standards about measured data, uncertainty evaluation • Error review of the survey method and calculation
	Quality Control (QC)	• Error analysis and supplementation according to the results of valuation of data • Reflecting on future measurement
	Confirmation of data	• Confirmation of data through the data revaluation
	Evaluation of rating curve	• Development of rating curve • Accuracy evaluation of rating curve • Runoff analysis etc.

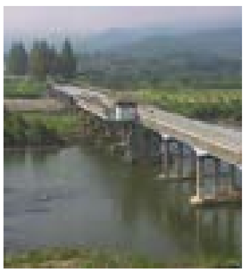
Source: KIHS, "Manual on Hydrological Survey " 2017

2.2 Selection of Gaging Station Sites

▪ The ideal gage site satisfies the following criteria, many of which are defined in ISO 1100-1:

- The general course of the stream is straight for about 10 times the stream width, upstream and downstream from the gage site.
- The total flow is confined to one channel at all stages, and no flow bypasses the site as subsurface flow.
- The stream-bed is not subject to scour and fill and is relatively free of aquatic vegetation.
- The gauge site is far enough upstream from the confluence with another stream or from the tidal effect to avoid any variable influence the other stream or the tide may have on the stage at the gauge site.
- The site is readily accessible for ease in installation and operation of the gauging station.

Han River Flood Control Office



[The Gaging Stations in Korea]

2.3 Selection of Measurement Site

- **The first step in making a current-meter measurement is to select a measurement cross section of desirable qualities.**
- **If the stream can be waded or the measurement can be made from a boat, the hydrographer looks for a cross section with the following characteristics, as described in ISO 748 (2007, in publication):**
  - The channel at the measuring site should be straight and of uniform cross section and slope to minimize abnormal velocity distribution.
  - Flow directions for all points on any vertical across the width should be parallel to one another and at right angles to the measurement section.
  - A stable streambed, free of large rocks, weeds and obstructions that would create eddies, slack water and turbulence
  - The measurement section should be clearly visible across its width and unobstructed by trees, aquatic growth, or other obstacles.

[Selection of measurement cross section]

2.3 Selection of Measurement Site

- A measurement section that is relatively close to the gaging station control to avoid the effect of tributary inflow between the measurement section and the control
- Avoiding the effect of channel storage between the measurement section and the control during periods of changing stage
- The site should be easily accessible at all times with all necessary measurement equipment
- Sites should be avoided where there is converging or diverging flow
- Sites displaying vortices, reverse flow or dead water should be avoided
- Good conditions for discharge measurements at all stages

2.3 Selection of Measurement Site

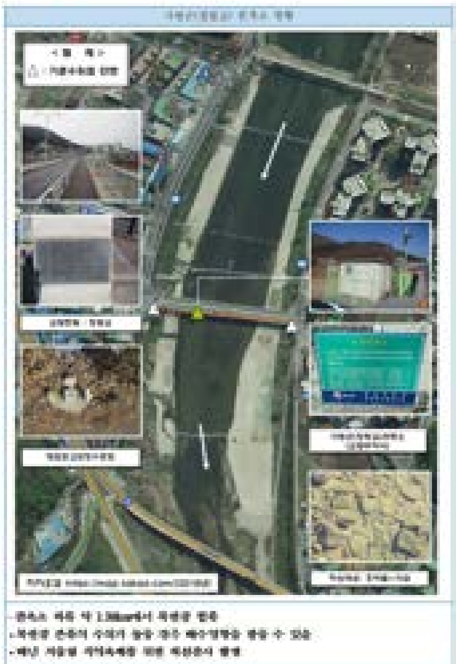
- It is very difficult to meet all the standards so far in natural (open-channel) rivers.
- Therefore, the researcher should choose the location that meets as many criteria as possible.

2.4 Pre-Investigation

- **Collection and Analysis of the Past Hydrological Survey Data**

- Location
- Status of gaging station
- Basin characteristics
- Information of river
- Check the importance of station

Prediction and contrast of changes in the environment through field investigation

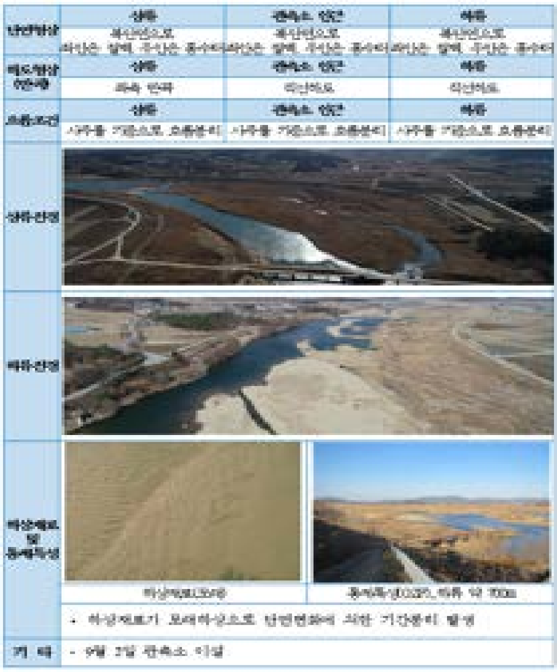


Source: KIHS, “hydrological Survey Report” 2019

2.4 Pre-Investigation

▪ Field Investigation Before Measurement

- ✓ The Possibility of measurement
- ✓ Review of topographic conditions, cross-sectional characteristics, etc.
- ✓ Flow condition in the measuring section
- ✓ Characteristics of runoff
- ✓ Investigation of other observatory(station) maintenance status, usability, etc.



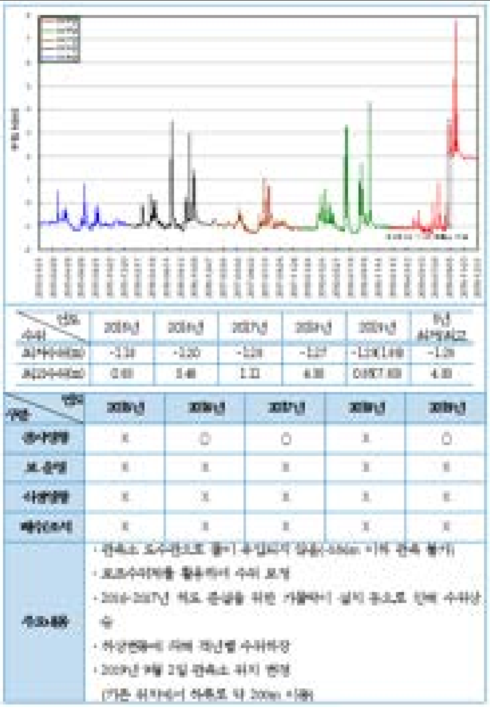
Source: KIHS, "hydrological Survey Report" 2019

2.4 Pre-Investigation

▪ Collection and Analysis of the Past Hydrological Survey Data

- ✓ Check the past water level data
- ✓ Characteristics of station (construction, weir, vegetation, backwater, etc.)
- ✓ Annual cross-section data of station
- ✓ Annual variability of rating curve

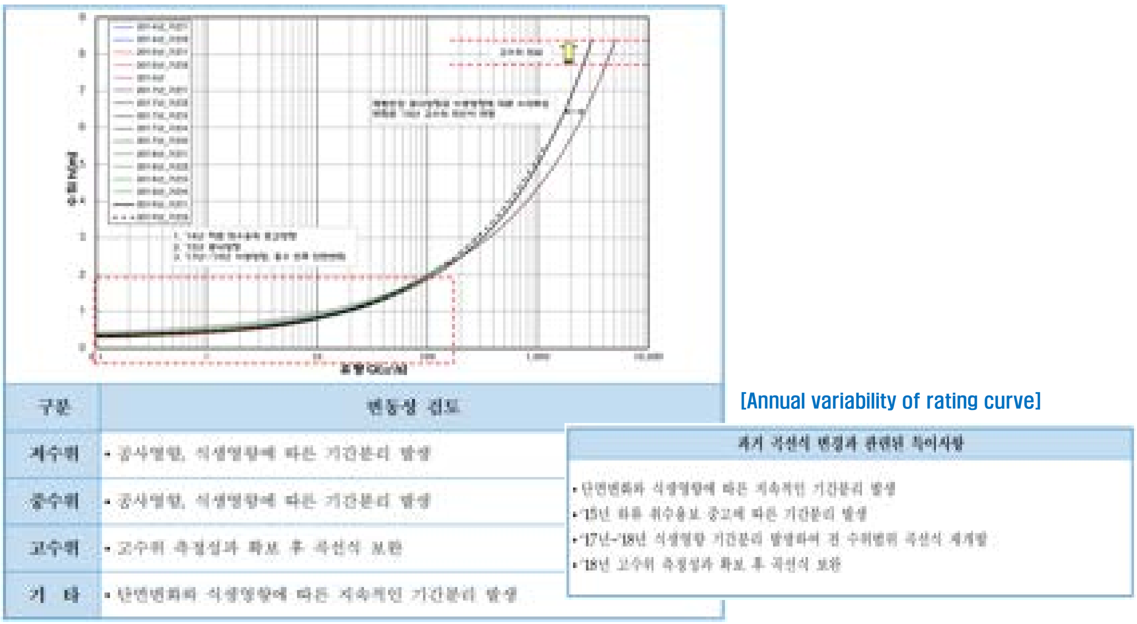
[Annual cross-section data of station]



Source: KIHS, "hydrological Survey Report" 2019

2.4 Pre-Investigation

- Collection and Analysis of the Past Hydrological Survey Data



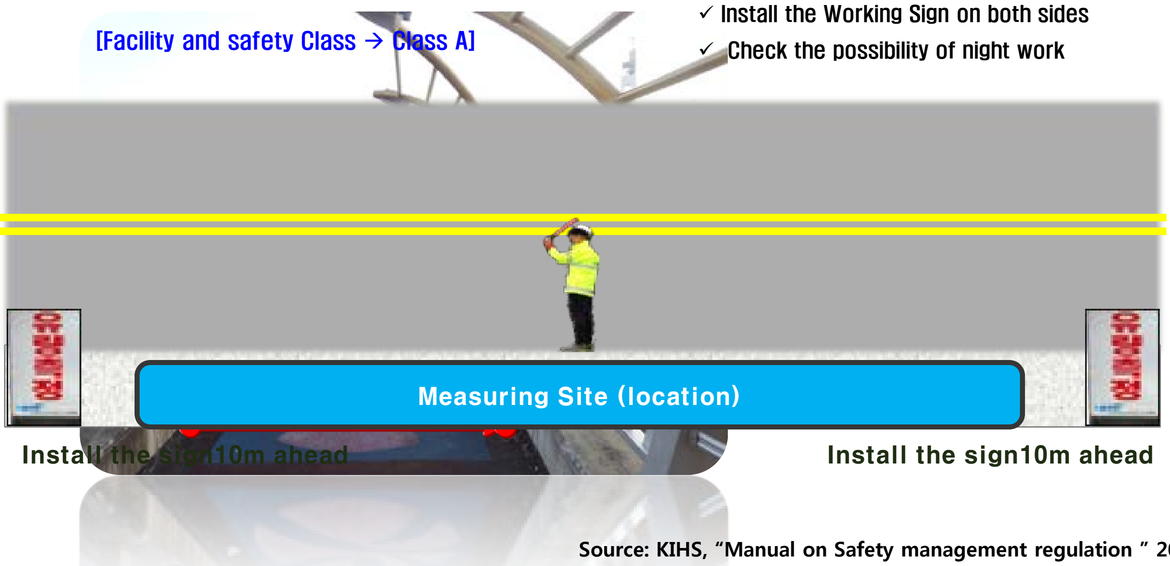
[Annual variability of rating curve]

Source: KIHS, “hydrological Survey Report” 2019

2.4 Pre-Investigation

- Safety should be a primary consideration when working at gaging stations
- Even when working with other people, one’s personal safety and the safety of others should be of paramount importance

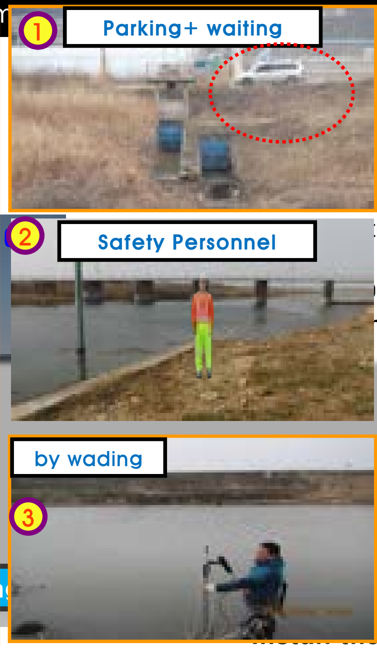
✓ Classification according to the installation of Sidewalk, railing, fence
✓ Install the Working Sign on both sides
✓ Check the possibility of night work



Source: KIHS, “Manual on Safety management regulation ” 2019

2.4 Pre-Investigation

▪ **Safety Management Regulation of KIHS**



o the installation of

n both sides

night work

sign for working

Source: KIHS, “Safety management regulation in KIHS” 2019

3. Methods of Discharge Measurement

3.1 Introduction

3.2 Conventional Current Meters

3.3 Floats

3.4 ADCP

3.5 Others

3.1 Introduction

- Discharge measurements are made at each gauging station to determine the discharge rating for the site.

3.1 Introduction

- Initially the discharge measurements are made at various stages at the station to define the discharge rating.
- Measurements are then made at periodic intervals, usually monthly, and also during extreme events such as floods or droughts to verify the rating, extend the rating, or to define any changes in the rating caused by changes in stream-channel conditions.
- Discharge measurements are made by the several methods.

[Various Methods of discharge measurement on sites]

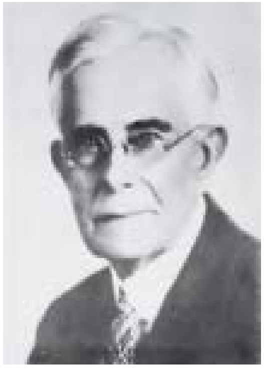
Source: photos by KIHS

3.2 Discharge Measurement by Conventional Current Meter Methods

- **Development of the Current Meter**
- **Complete Modern Current Meter**
  - Europe (horizontal axis currentmeter, German Ott, Ott currentmeter, 1881 – present)
  - United States (vertical axis currentmeter, German Price, Price currentmeter, 1882 – present)

[Ott Current meter]

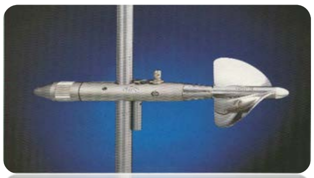
[Price AA Current meter]



Source: KICT, SWRRC TR 2004-01, "Streamflow Measurement Manual" 2004

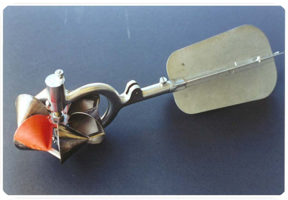
3.2 Discharge Measurement by Conventional Current Meter Methods

- **A current meter is a precision instrument calibrated to measure the velocity of flowing water.**
- **Several types of current meters are available for use, including rotating-element mechanical meters, electromagnetic meters, acoustic meters and optical meters.**
  - The original prototype for this kind of current meter was designed and built in 1882 by W.G. Price while working with the Mississippi River Commission
  - Acoustic Doppler velocimeters (ADVs) are a class of acoustic meter that measures a point velocity and can thus be used to make measurements with a wading rod



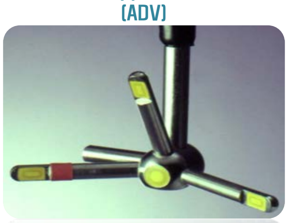
[Ott Current meter]

[Price AA Current meter]



[Electromagnetic current meter]

[Acoustic Doppler Velocimeter (ADV)]

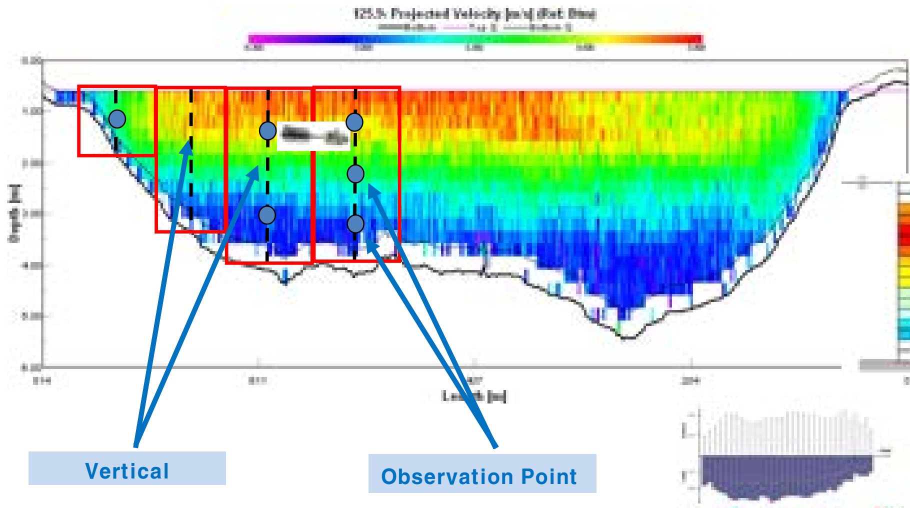


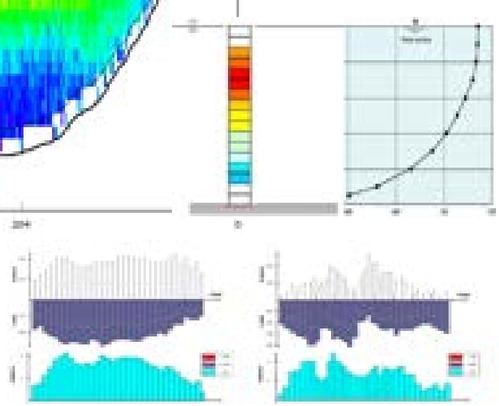
Source: KICT, SWRRC TR 2004-01, "Streamflow Measurement Manual" 2004

3.2 Discharge Measurement by Conventional Current Meter Methods

▪ The Selection of Vertical and Observation Point

- The first and last edges are placed as short as possible
- In the midsection method, there is an area that excludes the edges when calculating discharge
- The verticals are arranged at the same ratio of discharge, not at equal intervals





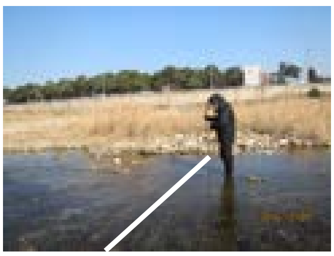
The ratio of discharge section by section, KIHS

3.2 Discharge Measurement by Conventional Current Meter Methods

▪ The first measurement made in a discharge measurement is usually the determination of horizontal stationing (width) in the cross section being measured.

- Width needs to be measured using the proper equipment (tapes and tag line reel) and procedures that apply to the type of measurement.

[Kevlar tag line]



Source: WMO-No. 10445, "Manual on stream gauging" 2010

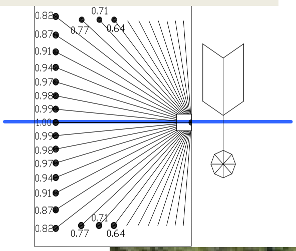
3.2 Discharge Measurement by Conventional Current Meter Methods

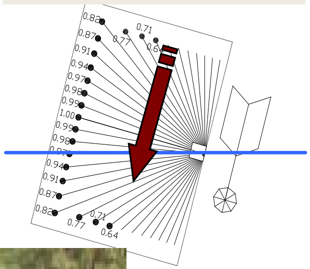
▪ Direction of Flow Measurement

- Consider the direction of flow because the component of velocity normal to the measurement section is that which must be determined by both mechanical and acoustic Doppler point-velocity current meters
- Generally, for the mechanical meter, the relation for velocity components not normal to the measuring section can be visualized and should be corrected using the cosine of alpha

Correction factor: 1

Correction factor: 0.97





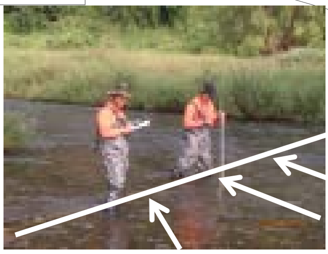
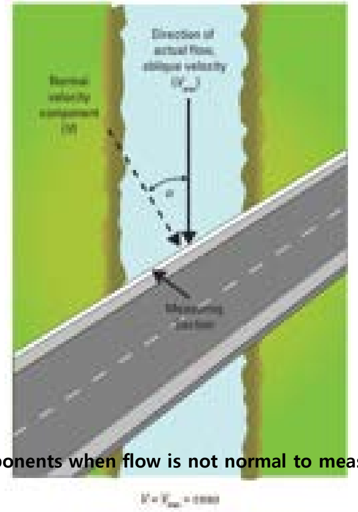


Photo by KIHS



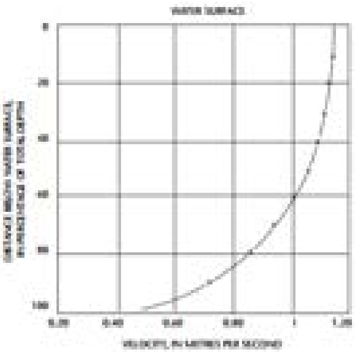
[Velocity components when flow is not normal to measuring section]

Source: USGS, "Techniques and Methods 3–A8" 2010

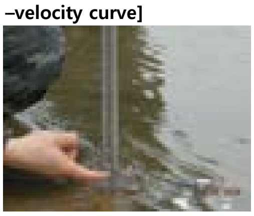
3.2 Discharge Measurement by Conventional Current Meter Methods

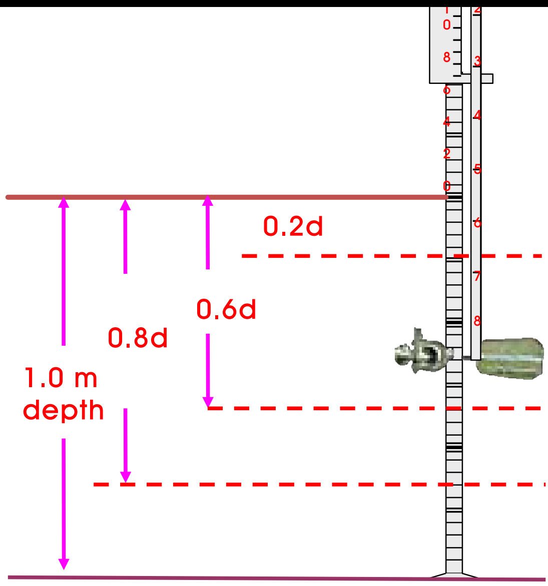
▪ Current meters generally measure stream velocity at a point for various depth.

- The mean velocity in a vertical is obtained from velocity observations at several points in that vertical (ISO 748).



[Typical vertical –velocity curve]





Source: WMO-No. 10445, "Manual on stream gauging" 2010

3.2 Discharge Measurement by Conventional Current Meter Methods

- **Current Meter Measurement by Wading**
  - Use the type AA, pygmy, or ADV meter for wading measurements
  - Table lists the type of meter and velocity method to use for wading measurements at various depths Table in USGS

[Wading measurement using a top-setting rod]

Depth, in feet	Current meter	Velocity method
2.5 and greater	Price Type AA	0.2 and 0.8
1.5 - 2.5	Price Type AA	0.6
0.3 - 1.5	Price Pygmy	0.6
1.5 and greater	Price Pygmy	0.2 and 0.8
0.3 - 1.5	ADV	0.6
1.5 and greater	ADV	0.2 and 0.8

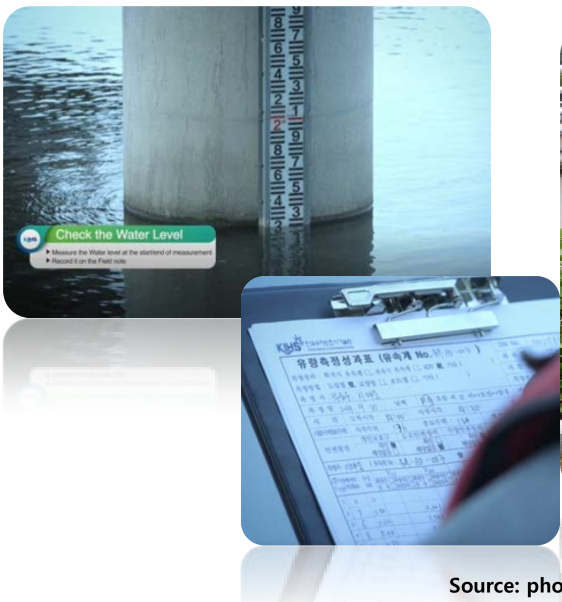
Current meter and velocity-measurement method for various depths

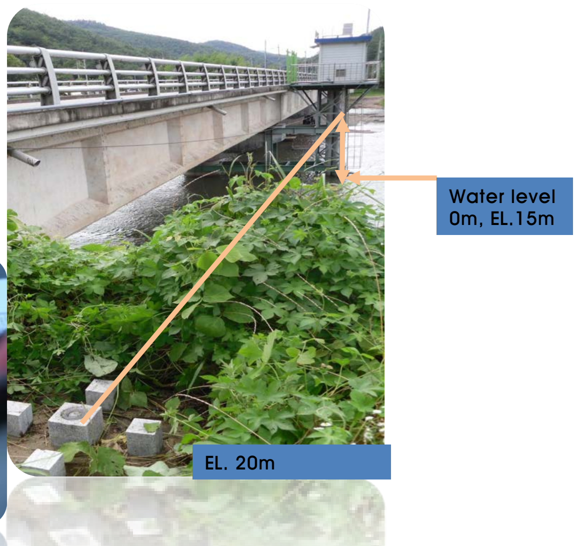
- **In General, in Korea (KIHS), the 3-point method is used based on 0.6m for wading measurement**
- **The 3-point method consists of observing the velocity at 0.2, 0.6 and 0.8 of the depth, thereby combining the two-point and 0.6-depth methods**

Source: USGS, “Techniques and Methods 3–A8” 2010

3.2 Discharge Measurement by Conventional Current Meter Methods

- **Field Consideration during Discharge Measurement**
  - The water level should be checked at the beginning and end of the discharge measurement
  - Record the water level on the field note

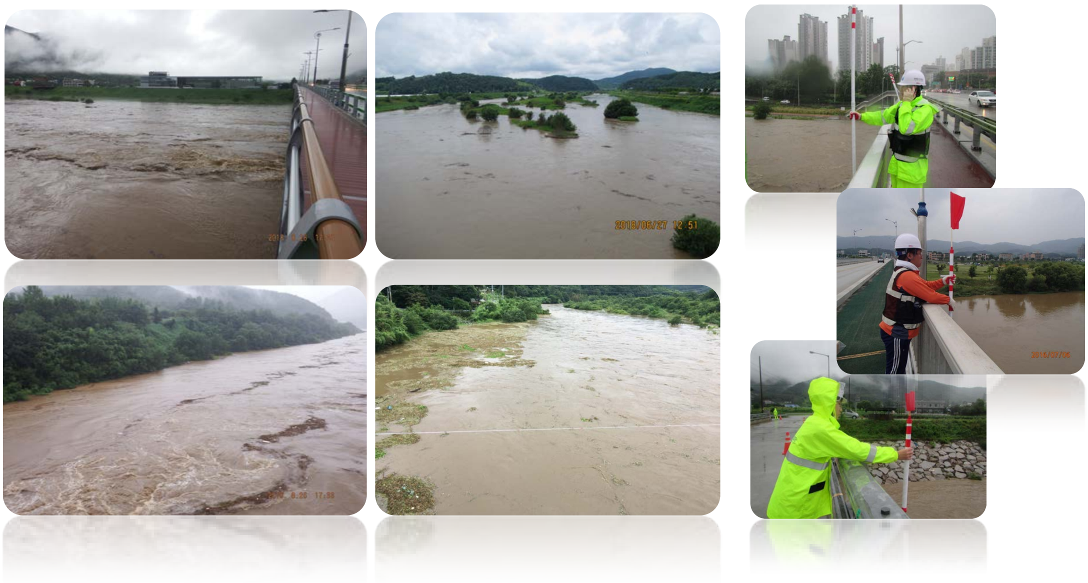




Source: photo by KIHS, “Record of water level at the gauging station”

3.3 Discharge Measurement by Floats

- **The float method is used in the measurement of streamflow where excessive velocities, depths, and floating drift prohibit the use of a current meter.**

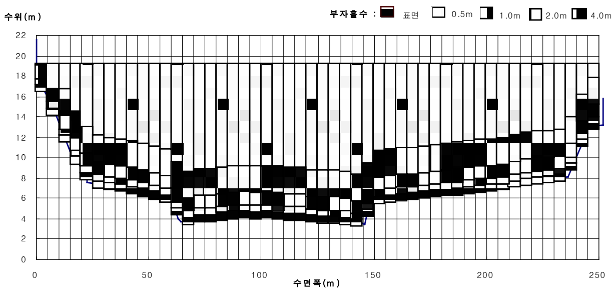


Source: photo by KIHS, "Discharge Measurement by floats"

3.3 Discharge Measurement by Floats

- **Float and Additional Equipment for Measurement**

Depth (m)	Less than 0.7	0.7~1.3	1.3~2.6	2.6~5.2	5.2 or more
Draft of floats	Surface floats	0.5m	1.0m	2.0m	4.0m



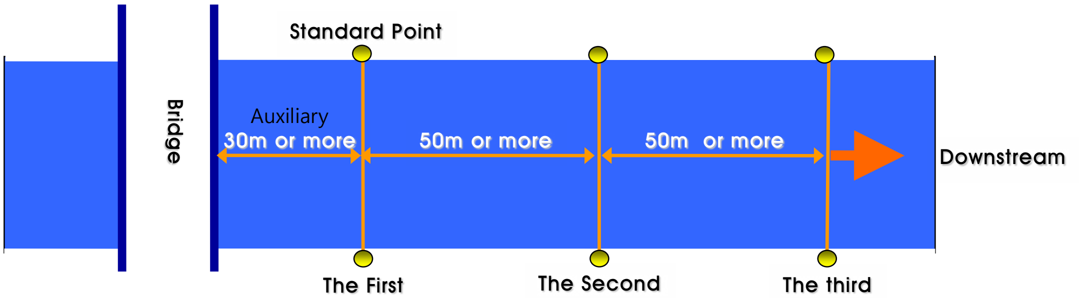
[Table of floats draft]

[Additional Equipment]

Source: KIHS, "guideline of Discharge Measurement by floats" 2018

3.3 Discharge Measurement by Floats

- **The method consists essentially of observing the time required for a float to traverse a course of known length and noting its position in the channel.**



Division		Distance
Auxiliary section	Zero to Upstream(Standard)	At least more than 30m
Measuring Section	From upstream to Downstream	① At least 50m or more ② Max Velocity(㎧)×20sec

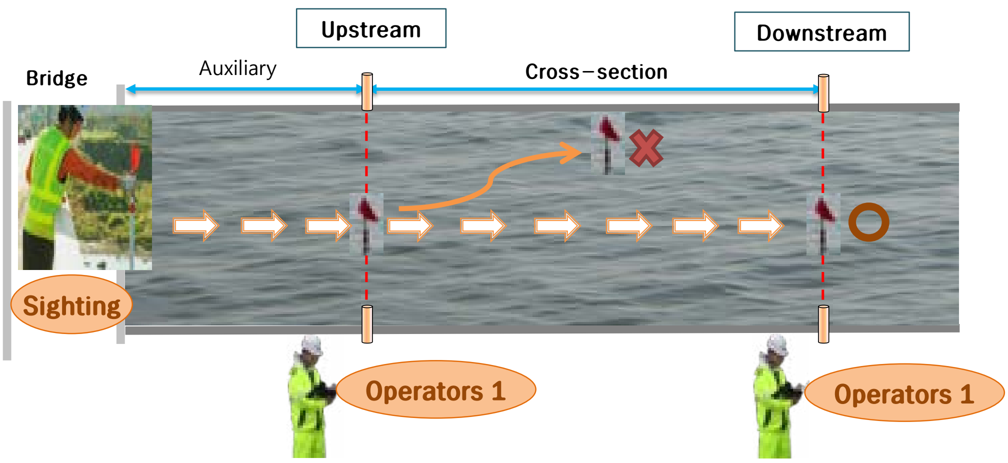
[The standard of KIHS]

Distance(m)	Less than 50	50~100	100~200	200~400	400~800	800 or more
General	6	8	10	12	14	16
Rapid change of stage	3	4	5	6	7	8

[Standard of ISO] 5 or more (At least 3) segment

3.3 Discharge Measurement by Floats

- **The position of a float in the river may be found as follows:**
  - In making a float measurement the floats are placed in the stream so that they are distributed across the stream width
  - The position of each float with respect to the distance from the bank or zero point is noted
  - The stopwatch is used to time their travel between the end cross-sections of the reach

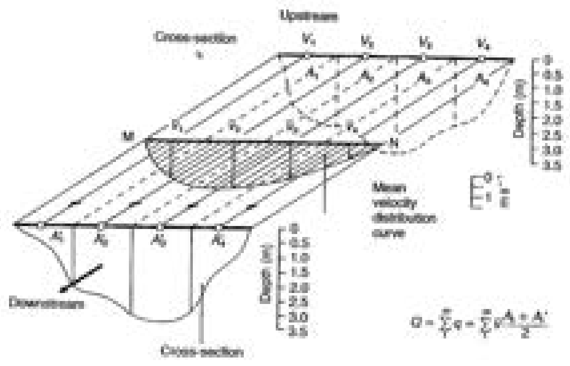


Source: photo by KIHS, "Discharge Measurement by floats"

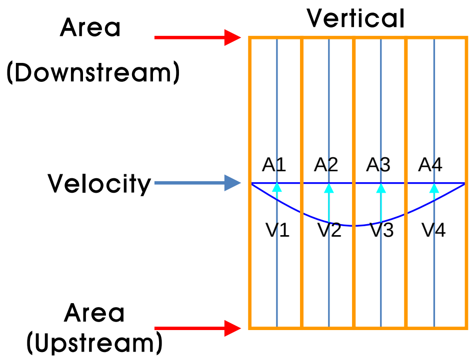
3.2 Discharge Measurement by Floats

▪ Computation of Discharge

$Q = \sum(\text{Mean Velocity} \times (\text{UpArea} + \text{DownArea})/2)$



[Computation of discharge from float measurement]



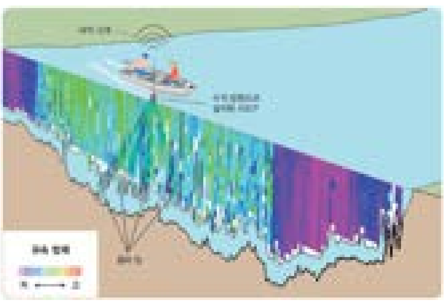
A1V1 + A2V2 + A3V3 + A4V4

= Total Discharge (Q)

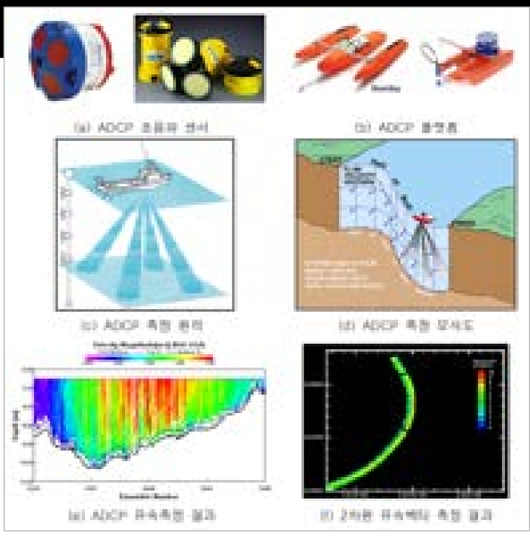
Source :Reginald W. Herschy " Streamflow Measurement-Third Edition" 2009

3.4 The ADCP Methods of Discharge Measurement

- **Acoustic Doppler Current Profiler (ADCP)**
- **The ADCP collects measurements of velocity depth and position as it passes across the measuring section.**
  - The ADCP measures velocity magnitude and direction using the Doppler shift of acoustic energy reflected by material suspended in the water column, providing essentially a complete vertical profile of velocity



[ADCP User' s Guideline, KICT 2015, KIHS 2018]



Source: KIHS, ADCP user's Guideline, 2018

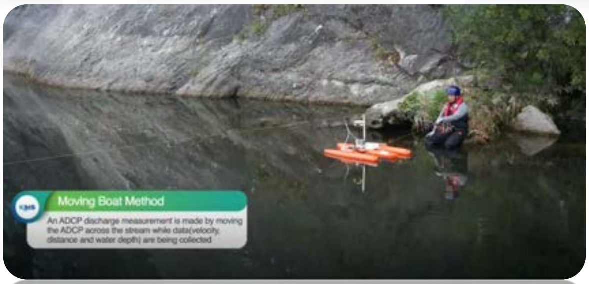
3.4 The ADCP Methods of Discharge Measurement

- **Advantages of ADCP over Velocity-area Methods (Streamflow Measurement, Reginald W. Herschy)**
  - normally quicker than existing current meter methods
  - the largest of the world's rivers may be measured as well as the smallest floods may be more conveniently measured
  - may be used to check existing methods easily transported from site to site

Moving unmanned boat method

Moving boat method on the bridge

Moving boat method with pilot



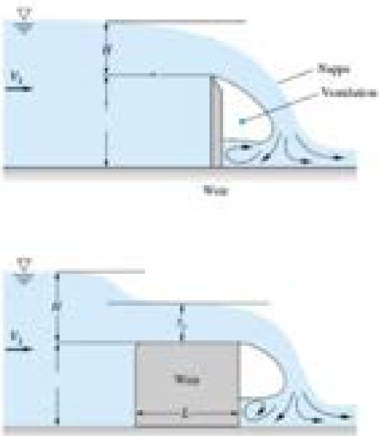
Moving boat method with tagline

Source: photo by KIHS, "ADCP methods of discharge measurement", 2019

3.5 Other Methods of Discharge Measurement

- **Weir and Flumes**
  - For open-channel flow measurement, a change in depth of flow at some point is typically measured and correlated with water flow rate
  - On small rivers, it is often convenient to measure flow by means of weir or flume

[Sharp-crested and broad-crested weir]



[Weir]

[Venturi Fumes]

Source: Mohsin Siddique-PPT Slide "Open Channel Hydraulics", 2020
https://www.slideshare.net/yourmohsin/part-iii-open-channels
http://mpac.ie/environmental-solutions/venturi-flumes/
https://www.quora.com/Who-invented-weirs

3.5 Other Methods of Discharge Measurement

▪ Microwave Water Surface Current Meter for Low and High Flows

- Microwave water surface current meter (MWSCM) can measure river surface velocities easily without contacting water

[Illustration of velocity measurement principle with MWSCM]

Source: K-water Research Institute, Korean Journal of Ecology and Environment 47(3):225-231, 2014
KIHS, discharge measurement guideline of Microwave water surface current meter, 2020

3.5 Other Methods of Discharge Measurement

▪ Surface Image Velocimetry

- real-time surface image velocimeter (SIV) using an Android smartphone.
- It can measure river surface velocity by using its built-in sensors and processors

Source: Yu, Kwonkyu, "등록특허 10-1512690, 2015]
Yu, Kwonkyu, J. Korea Water Resour. Assoc. Vol. 49, No. 6 (2016), pp. 469-480

4. Calculation and Analysis of Discharge

4.1 Recording Field Notes
4.2 Calculation and Analysis of Discharge
4.3 Hydrological Data Quality Control

4.1 Recording Field Notes

- **Field notes for a discharge measurement may be recorded on standard paper note sheets (Ex: KIHS Field note form)**

[Standard paper field note form, KIHS]

[Current Meter, ADV discharge measurement]

[ADCP discharge measurement]

[ADCP discharge measurement]

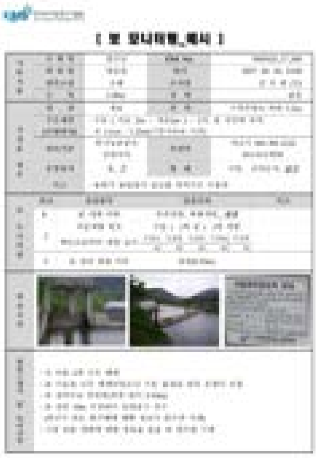
[float discharge measurement]

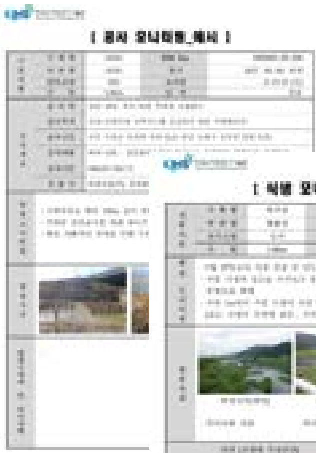
Source: KIHS form, “Standard paper field note”

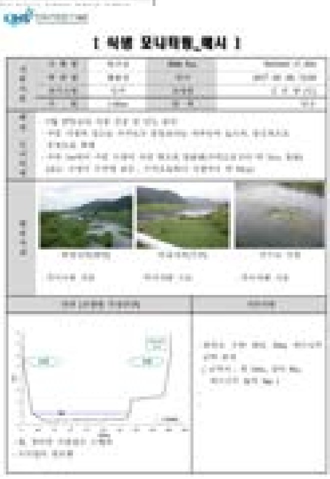
4.1 Recording Field Notes

- **Field notes for a discharge measurement may be recorded on standard paper note sheets (Ex: KIHS Field Monitoring Notes form)**

[Current Meter, ADV discharge measurement]







[Field Monitoring Note]

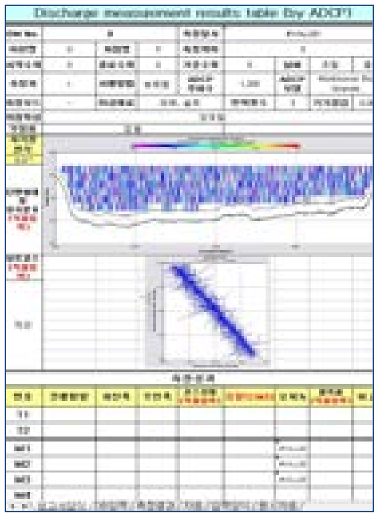
Source: KIHS form, “Standard paper field note”

4.2 Calculation and Analysis of Discharge (Streamflow)

- **Calculation of Discharge Data Using Standard Calculation Sheet**
  - Software tool to calculate of field discharge data

CalPAD
(measured by current meter)

FloatPAD
(measured by float)



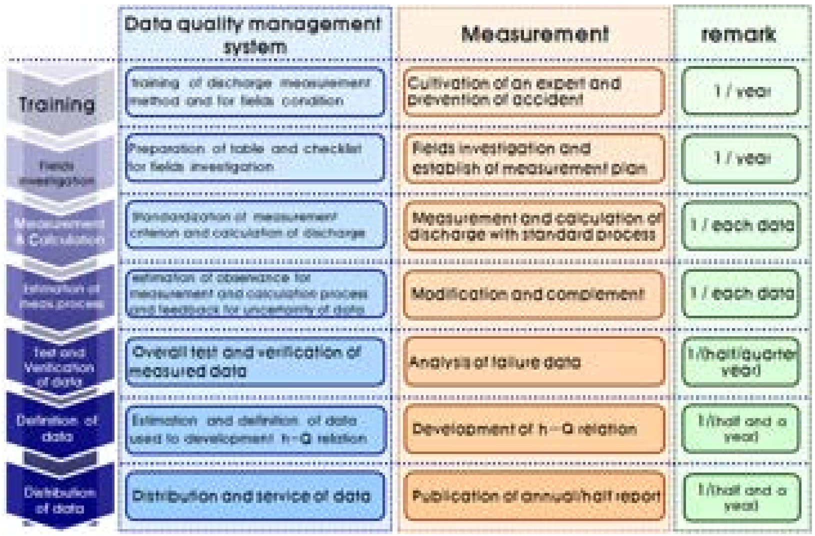
ADVM sheet
(measured by ADCP)

Source: KIHS, “Standard calculation sheet(Software tool)”, 2020

4.3 Hydrological Data QC

- QC and R&D for Securing Hydrological Data of High Quality
- Hydrological Data Quality Management System (HDQMS)
- QC/QA Activity and Feedbacks throughout the Process

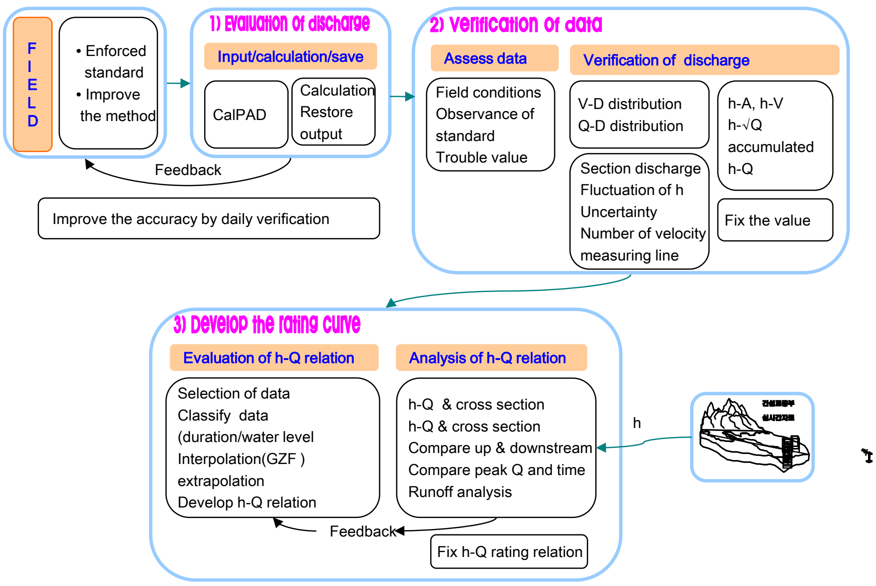
Process of HDQMS



Source: KIHS, “Hydrological Survey Hydrological survey data QC regulation” 2019

4.3 Hydrological Data QC

- Analysis and Review of Discharge Data
- HDQMS



Source: KIHS, “Hydrological Survey Report” 2019

4.3 Hydrological Data QC

▪ Analysis and Review of Discharge Data

- Verification of discharge (DB Sheet: DM No., h-A, h-Q, H-V, Ration of discharge (%), Uncertainty (%) Change of water level, Compliance of measurement standards)

Source: KIHS, "Hydrological Survey Report" 2019

4.3 Hydrological Data QC

▪ Analysis and Review of Discharge Data

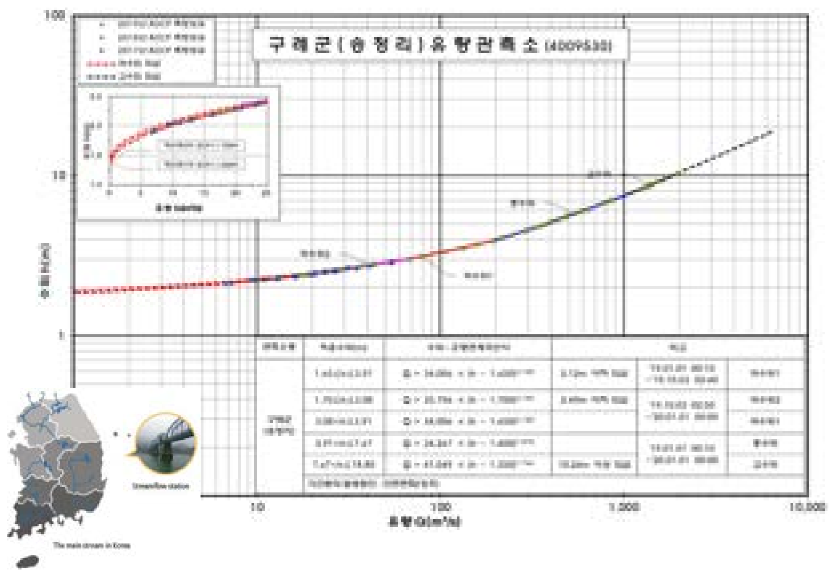
- Development of rating curve (analysis of stage-discharge relations)
- Review and correction of water level data
- Conversion of discharge and results comparison
- Review of annual and cumulative runoff
- Trend analysis of runoff last 5 years

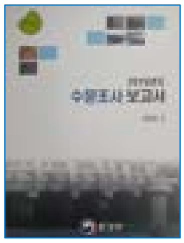
Source: KIHS, "Hydrological Survey Report" 2019

4.3 Hydrological Data QC

▪ Publication of Hydrological Survey Report

- KIHS (in Korea) is develop and provide the quarterly rating report and annual report, and publishes Hydrological Survey report (KIHS, ME) and Korea Annual Hydrological report (HRFCO, ME)





Hydrological Survey Report (ME, 2010~2019)

Korea Annual Hydrological Report (ME, 2018)

Source: KIHS, "Hydrological Survey Report" 2019

4.3 Hydrological Data QC

▪ Collection and Distribution of Hydrological Data

- **HDIMS** System for collecting and managing the measured hydrological data
- **W**ater management **I**nformation **N**etworking **S**ystem (WINS)
  System for distribution to various organization and using the collected hydrological data

Source: HDIMS and WINS System


Thank you very much

MEMO

Stage Discharge Ratings

Hydrological Survey

Stage-Discharge Ratings with Various River Conditions in Korea

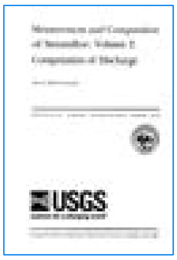
KIHS 한국수자원조사기술원 Korea Institute of Hydrological Survey

Aims & Objectives

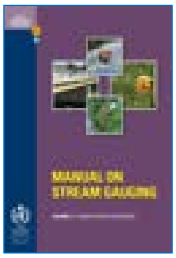
- The aims of the course are to:
  (1) Promote among trainees a good understanding of the basic theory to develop of rating curve with stage-discharge relations
  (2) Practice and develop rating curve based on the field data using a software tool
  (3) Understand discharge rating effect with field conditions

- **At the end of the course, trainees will be able to:**
  (1) Understand the stage-discharge relations at gaging station
  (2) Control and shift discharge rating
  (3) Explain development and graphical plotting of rating curve

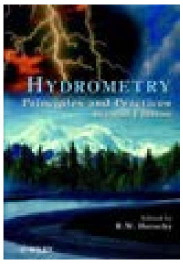
References



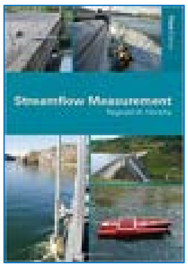
USGS Measurement and Computation: vol2. (S.E. RANTZ and others, 1982)



Manual on Stream Gauging 2 (WMO-1044, 2010)

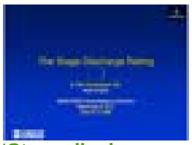


Hydrometry principal and Practices (R.W. Herschy and others, 1978)



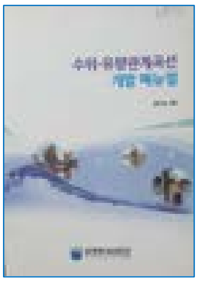
Streamflow Measurement (R.W. Herschy, 1978)

'Hydrological Basics' Training, 2011



'Stage discharge ratings'(USGS-FERA, 2006)

Hydrological Survey Report (ME, 2010~2019)



Manual on development of stage-discharge rating (HSC, 2014)

Manual on Discharge Streamflow measurement (KIHS, 2018)

Contents

1. Introduction
2. Stage–Discharge Controls and Shift Ratings
3. Graphical Plotting of Rating Curve
4. Effect of Discharge Ratings with Various River Conditions

1. Introduction

1.1 Background
1.2 Computation of Discharge Data
1.3 Stage-Discharge Relations

1.1 Backgrounds

- Continuous records of discharge at gauging stations are computed by applying the discharge rating for the stream to records of stage.
- Discharge ratings may be simple or complex, depending on the number of variables needed to define the stage-discharge relation.
- Discharge ratings for gauging stations are usually determined empirically by means of discharge measurements made in the field.

Step1)
Measurement of Water level

Step2)
Discharge measurement

Step3)
Development of H-Q rating curve

Source: WMO, "Manual on stream Gauging (MWO-no.1044)" 2010

1.2 Computation of Discharge Data

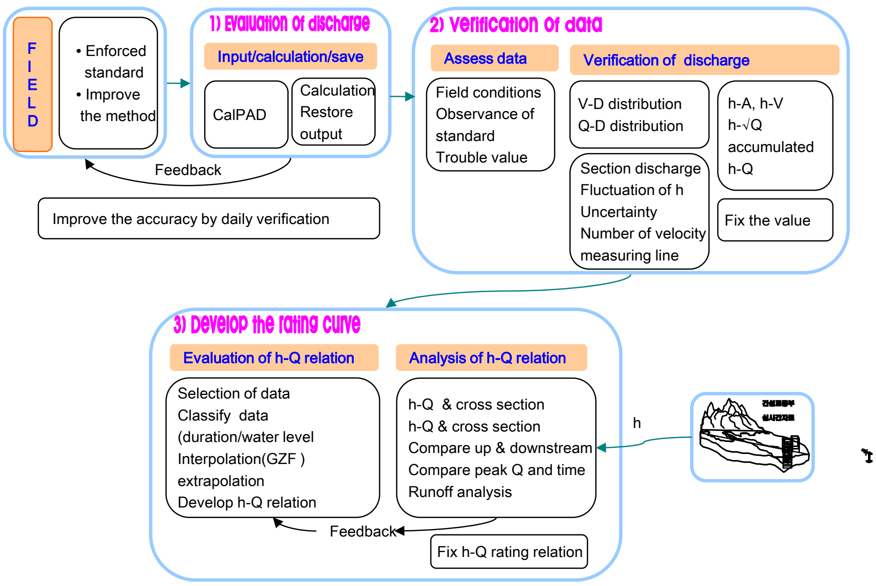
▪ The Procedure of Streamflow (Discharge) Measurement

Major Procedure	Main Contents
Pre-Investigation	• Collecting of past material, pre-investigation for field measurement • Planning for hydrological survey considering the field conditions
Streamflow measurement and calculation	• Standards compliance and decision of measuring method, measurement location considering the field conditions • Calculation using standard-calculation sheet
Evaluation of data	• Compliance with standards about measured data, uncertainty evaluation • Error review of survey method and calculation
Quality control (QC)	• Error analysis and supplementation according to results of valuation of data • Reflected on future measurement
Confirmation of data	• Confirmation of data through the data revaluation
Evaluation of rating curve	• Development of rating curve • Accuracy evaluation of rating curve • Runoff analysis etc.

Source: KIHS, "Procedure of streamflow measurement"

1.2 Computation of Discharge Data

▪ The Procedure of Streamflow (Discharge) Measurement
▪ Hydrological Data Quality Management System (HDQMS)



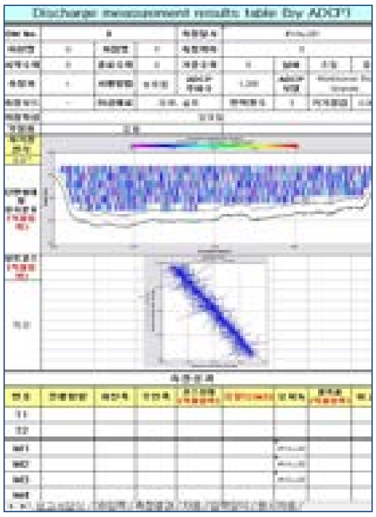
Source: KIHS, "Manual on development of stage discharge rating curve," 2014

1.2 Computation of Discharge Data

▪ Calculation of Discharge Data Using Standard Calculation Sheet

CalPAD
(measured by current meter)

FloatPAD
(measured by float)



ADVM sheet
(measured by ADCP)

Source: KIHS, "Standard calculation sheet," 2020

1.2 Computation of Discharge Data

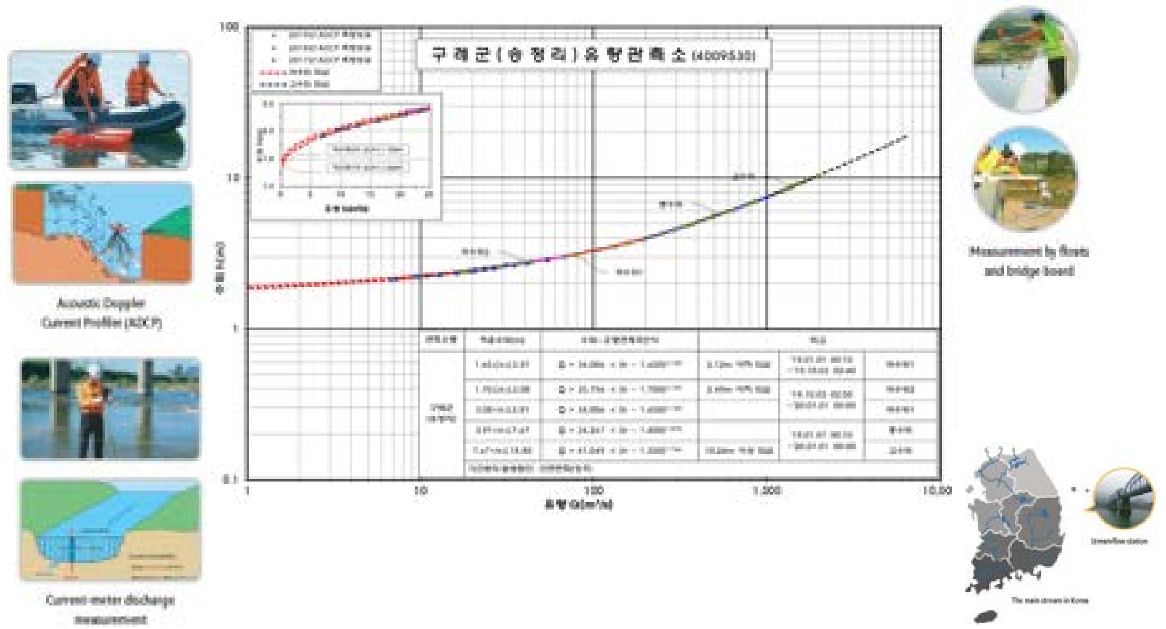
▪ Calculation of Discharge Data Using Standard Calculation Sheet

[DB]Pad]

Source: KIHS, "Standard calculation sheet," 2020

1.3 Stage-Discharge Relations

- **Discharge measurements must be made throughout the entire (or wide enough) range of stage to accurately define a rating curve.**
- **Stage-discharge relationship is called a rating curve.**



1.3 Stage-Discharge Relations

- **Stage-Discharge Rating Curve (Rating)**
  - determined empirically by means of discharge measurements made in the field, fitting a **stage-discharge equation**
- **Rating curve is expressed as**

$$Q = a(h-e)^b$$

Q is discharge

h is gauge height of the water surface

e is the gauge height of zero flow for a control of regular shape, or of effective zero flow for a control of irregular shape; is sometimes indicated as h_0

$h - e$ is the depth of water on the control

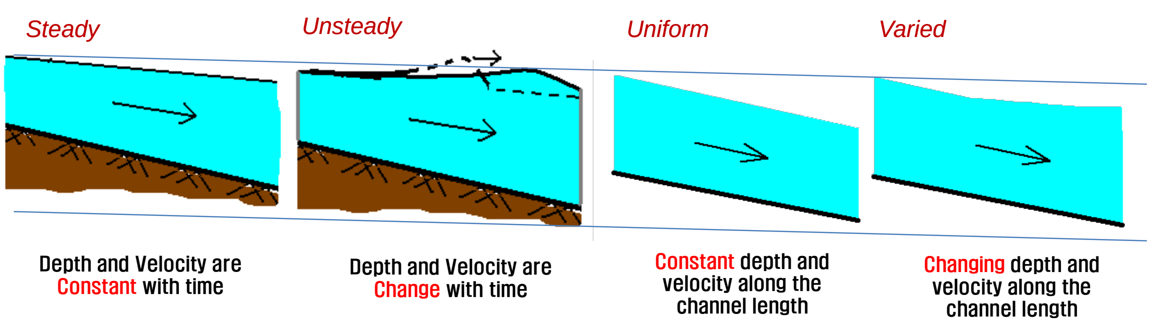
Source: 2nd IAHR-WMO Course on Stream gauging, 2012

2. Stage-Discharge Controls and Shift Ratings

2.1 Open-Channel Flow
2.2 Stage-Discharge Controls
2.3 Shift Ratings

1.2 Open-Channel Flow

- **Types of Flow**
- **Temporal Flow Classification**
  - Steady and unsteady flow-time as the criterion. Flow in an open channel is "steady" if the depth of flow does not change, or if it can be assumed to be constant during the time interval under consideration. The flow is unsteady if the depth changes with time (Chow, 1959).
- **Spatial Flow Classification**
  - Uniform flow and varied flow-space as the criterion: Flow in an open channel is "uniform" if the depth of flow is the same at every section of the channel.
  - Flow is "varied" if the depth of flow changes along the length of the channel (Chow, 1959).



Source: USGS-FERC, "The Stage-Discharge Rating," 2006

2.2 Stage-Discharge Controls

- The stage-discharge relation for open-channel flow at a gauging station is governed by channel conditions downstream from the gauge, referred to as a control.

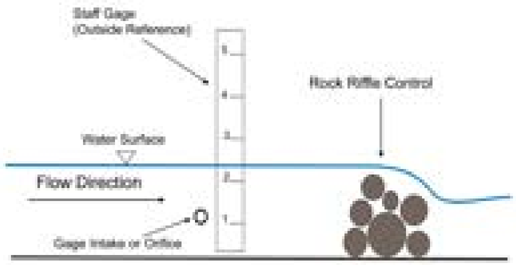
- Two types of controls can exist, depending on channel and flow conditions. Low flows are usually controlled by a section control whereas high flows are usually controlled by a channel control.
  Medium flows may be controlled by either type of control.

Source: WMO-No.1044, "Manual on Stream Gauging Vol.2," 2010

2.2 Stage-Discharge Controls

- **The Section Control**
  - A section control is a specific cross-section of a stream channel, located downstream from a water level gauge that controls the relation between gauge height and discharge at the gauge
  - A section control can be a natural feature such as a rock ledge, a sand bar, a severe constriction in the channel or an accumulation of debris. Likewise, a section control can be a manmade feature such as a small dam, a weir, a flume, or an overflow spillway (WMO-No. 1044).

The rock riffle is acting as a section control



Source: 2nd IAHR-WMO Course on Stream gauging, 2012

2.2 Stage-Discharge Controls

- **The Channel Control**
  - A channel control consists of a combination of features throughout a reach downstream from a gauge.
  - These features include channel size, shape, curvature, slope, and channel roughness.



–(ISO 1100–2, 1998)

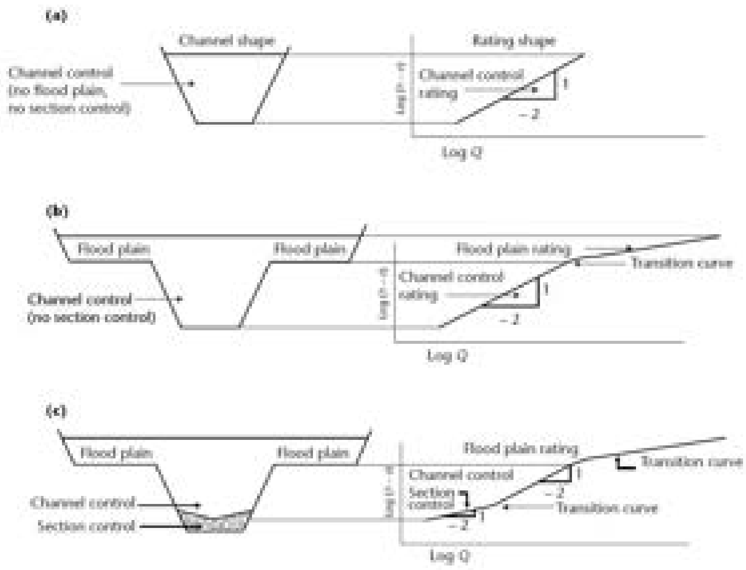
- **The Combination and Compound Controls**
  - At some stages, the stage-discharge relation may be governed by a combination of section and channel controls, sometimes referred to as compound controls.
  - This usually occurs for a short range in stage between section-controlled and channel controlled segments of the rating.

Transition zone


Source: WMO-No.1044, "Manual on Stream Gauging Vol.2," 2010

2.2 Stage-Discharge Controls

- **Relation of Channel and Control Properties to Rating Curve Shape**
  - Examples of a hypothetical rating curve showing the logarithmic plotting characteristics for channel and section controls and for cross-section shape changes



Source: WMO-No.1044, "Manual on Stream Gauging Vol.2," 2010

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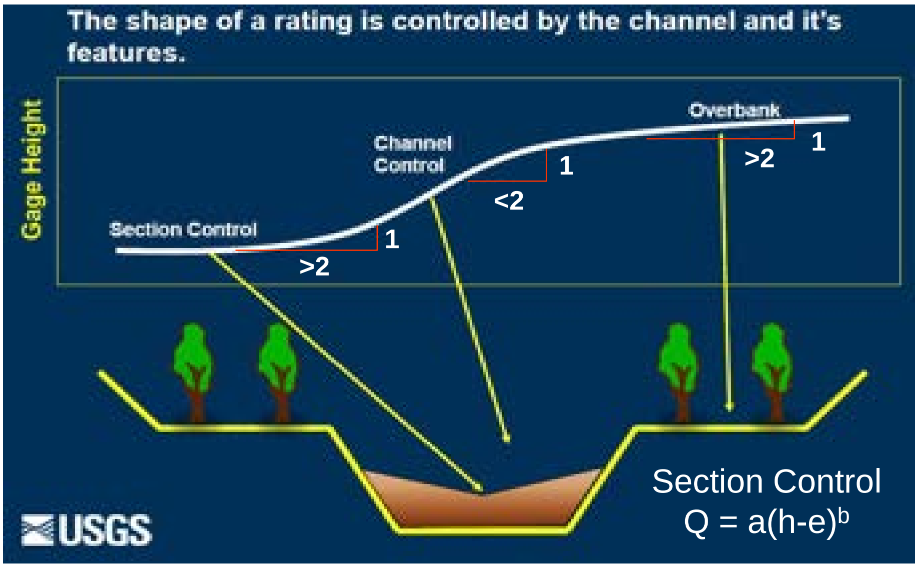
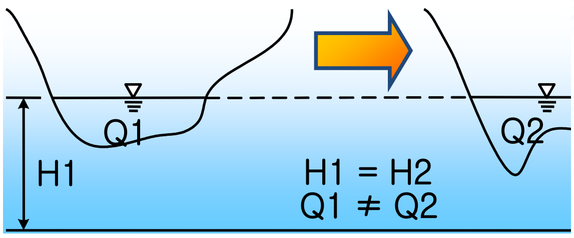
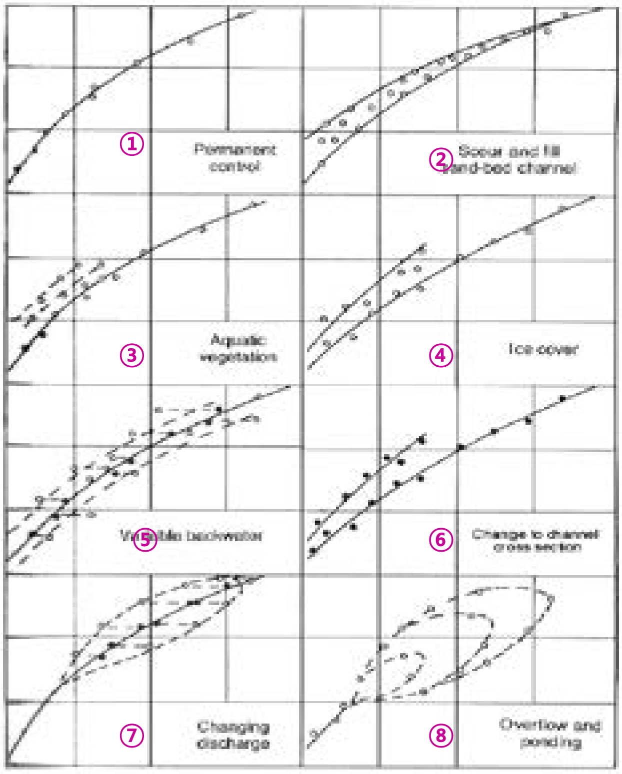


Source: USGS-FERC, "The Stage-Discharge Rating," 2016
WMO-No.1044, "Manual on Stream Gauging Vol.2," 2010

2.3 Shift Ratings

- **Shifts in the Discharge Rating**
  - reflect the fact that stage-discharge relations a
    gradually or abruptly, because of changes in th
    station
- **Shift is a temporary rating.**
- **Generally used for a temporary cha**



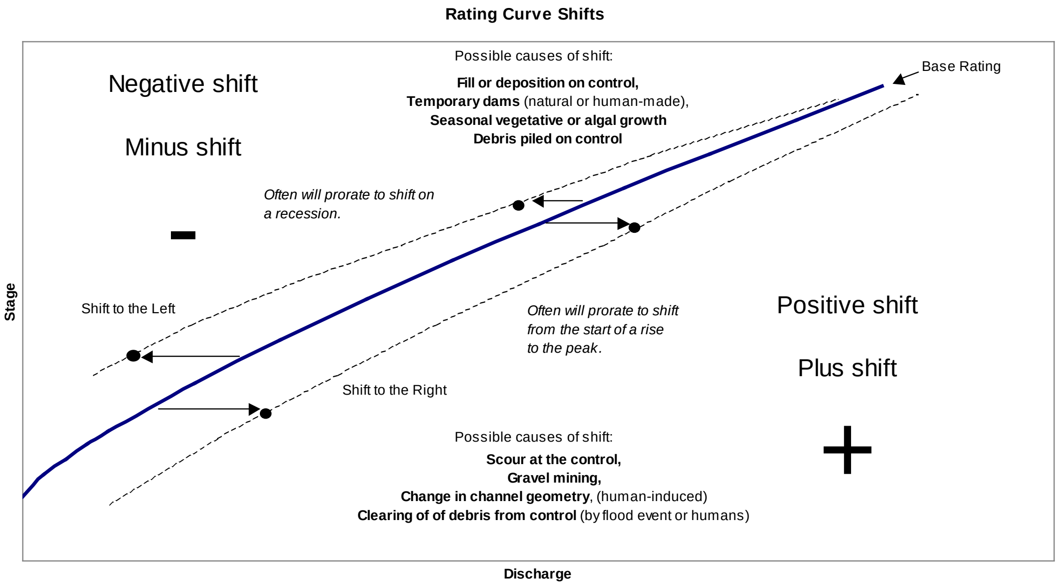


Various rating curve shapes

Source: WMO-No.1044, "Manual on Stream Gauging Vol.2," 2010
Manual on hydrological survey, 2011

2.3 Shift Ratings

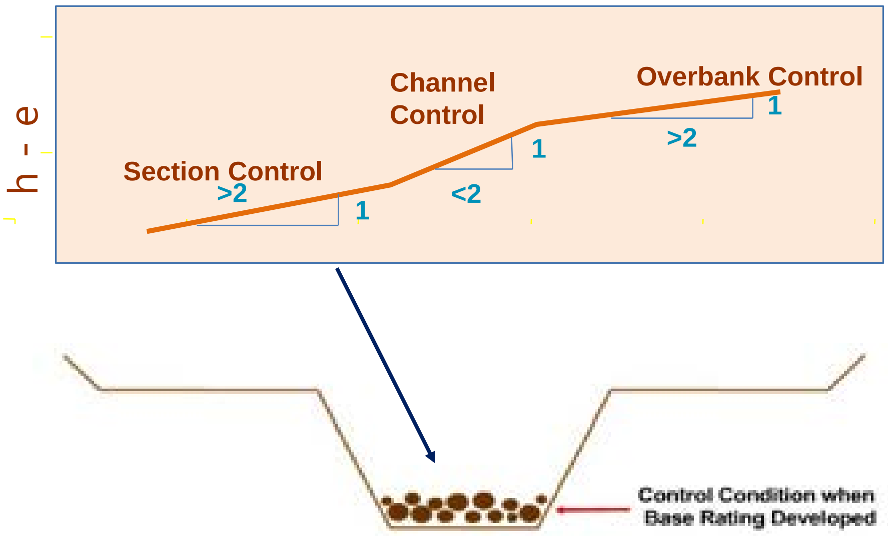
▪ Shifts Rating Curve Shape



Source: USGS-FERC stream gauging Seminar, The stage-Discharge Rating, 2006

2.3 Shift Ratings

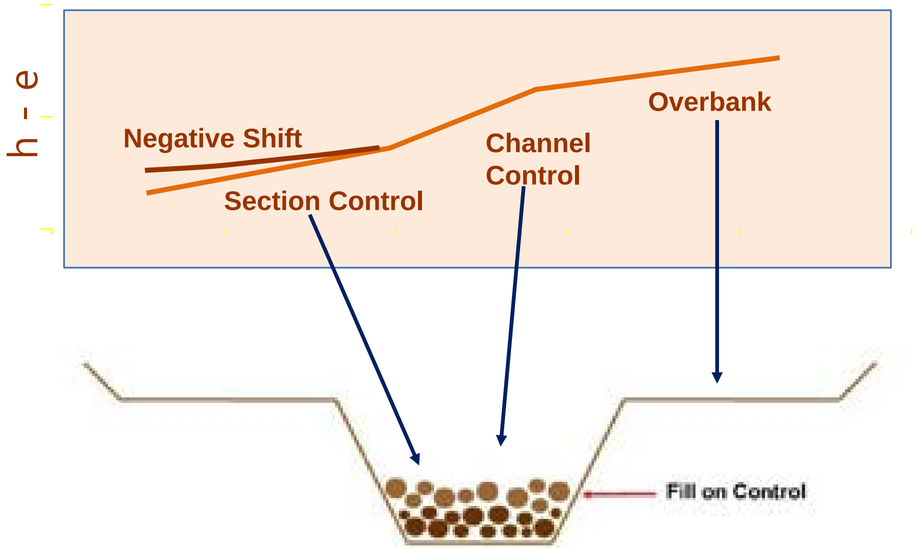
▪ Shifts Rating Curve Shape



Source: USGS-FERC, “The Stage-Discharge Rating," 2016

2.3 Shift Ratings

- Shifts Rating Curve Shape
- (-) Shift
  - Fill of deposition on control, temporary dams (natural or artificial), seasonal vegetative or algal growth



Source: USGS-FERC, "The Stage-Discharge Rating," 2016

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- Shifts Rating Curve Shape
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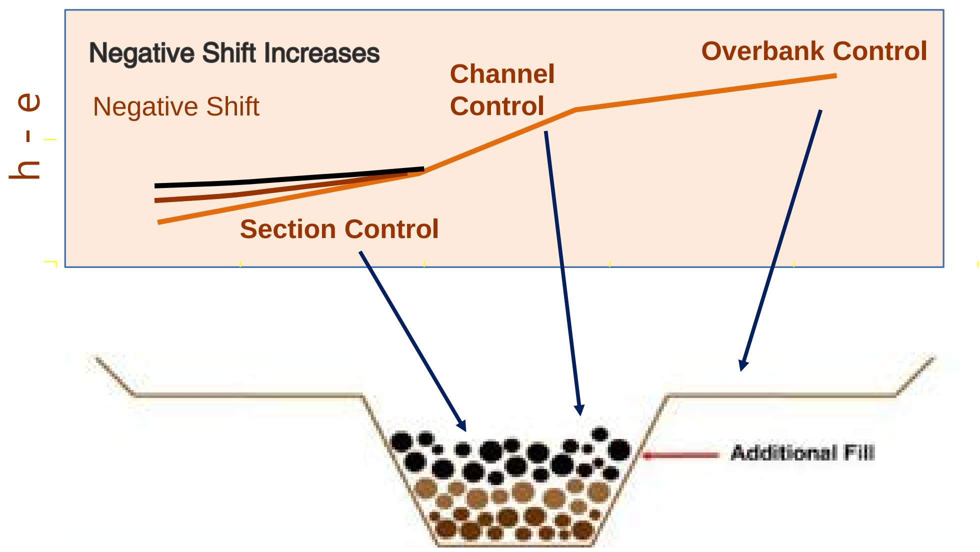


Source: USGS-FERC, "The Stage-Discharge Rating," 2016

3. Development Of Rating Curve

3.1 Development Of Rating Curve Using Regression Analysis

3.2 Graphical Plotting Of Rating Curve

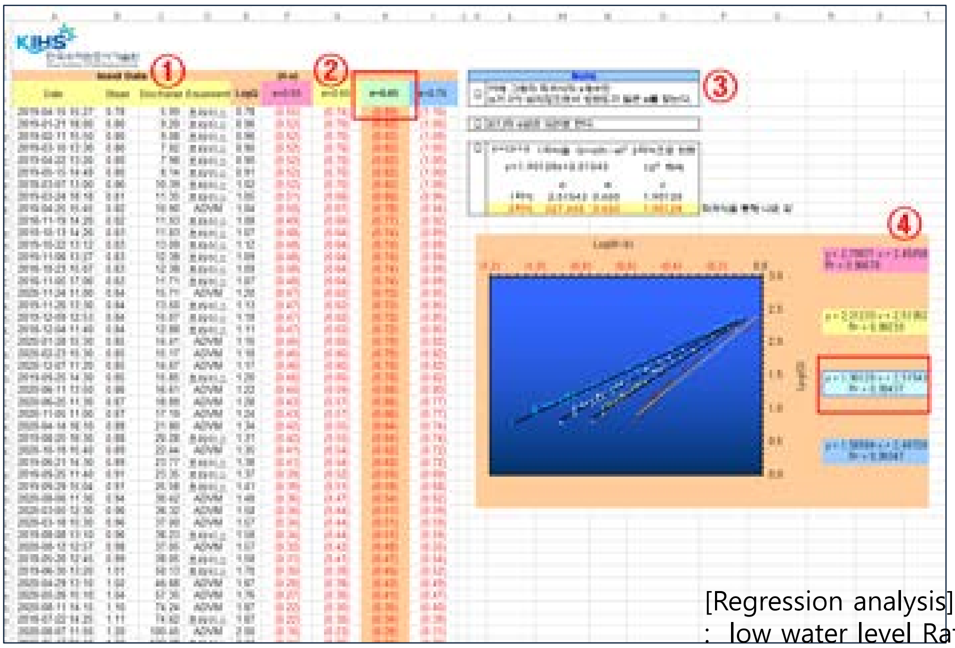
3.1 Development of Rating Curve Using Regression Analysis

- **Development of Rating Curve Using Field Discharge Data**

Source: KIHS, “Rating regression analysis and plotting sheet," 2020

3.1 Development of Rating Curve Using Regression Analysis

▪ Development of Rating Curve Using Field Discharge Data

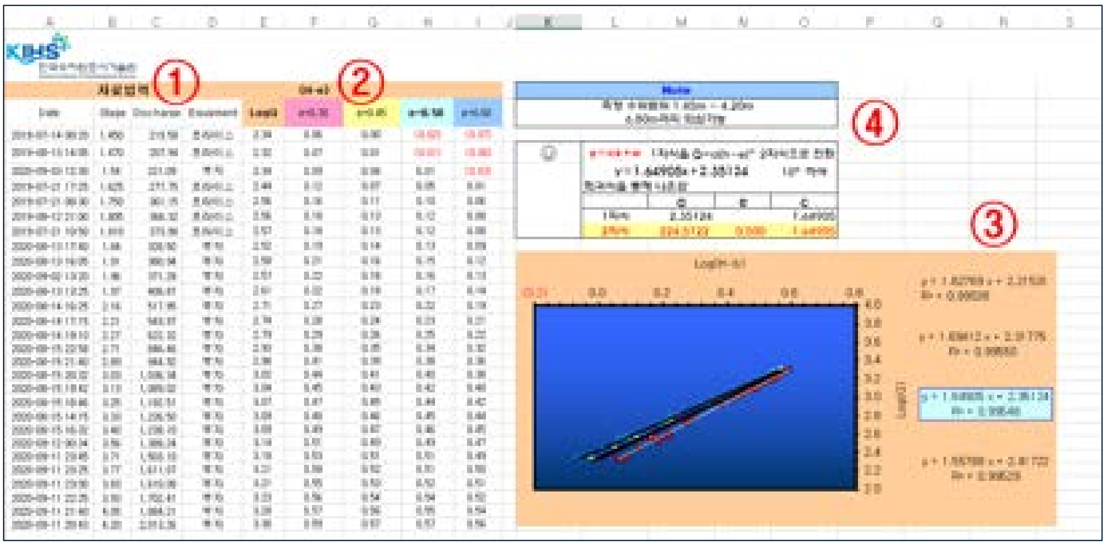


[Regression analysis]
: low water level Rating Equation

Source: KIHS, “Rating regression analysis and plotting sheet," 2020

3.1 Development of Rating Curve Using Regression Analysis

▪ Development of Rating Curve Using Field Discharge Data

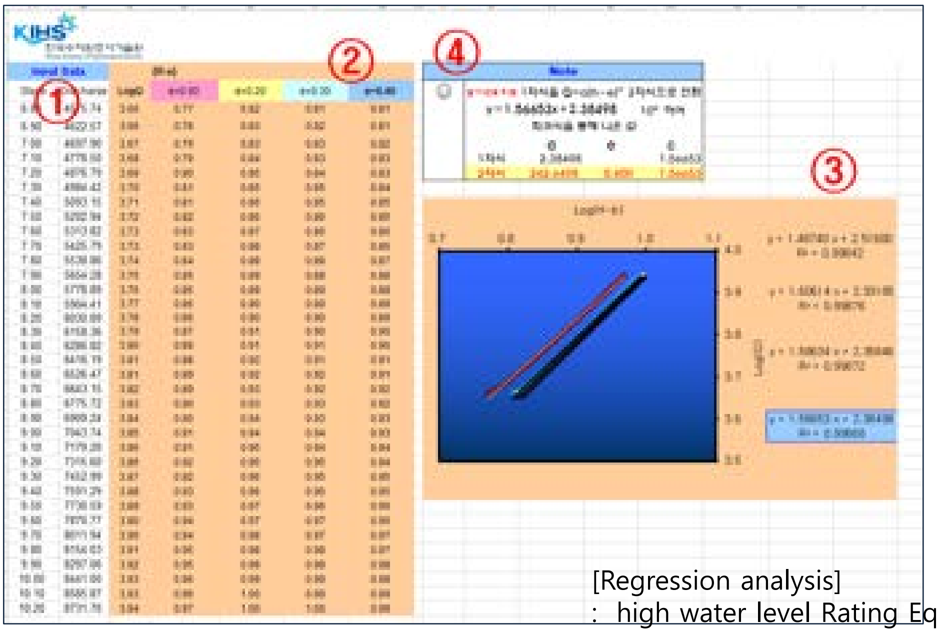


[Regression analysis]
: middle water level Rating Equation

Source: KIHS, “Rating regression analysis and plotting sheet," 2020

3.1 Development of Rating Curve Using Regression Analysis

▪ Development of Rating Curve Using Field Discharge Data



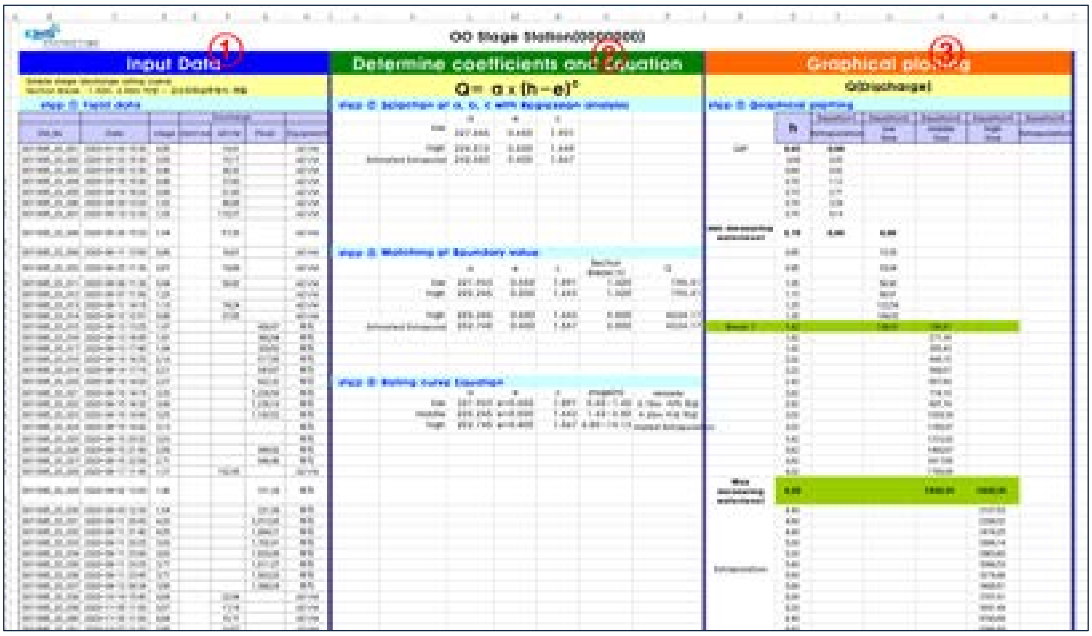
[Regression analysis]
: high water level Rating Equation

Source: KIHS, "Rating regression analysis and plotting sheet," 2020

3.1 Development of Rating Curve Using Regression Analysis

▪ Development of Rating Curve Using Field Discharge Data

- Determine coefficients and rating curve equation

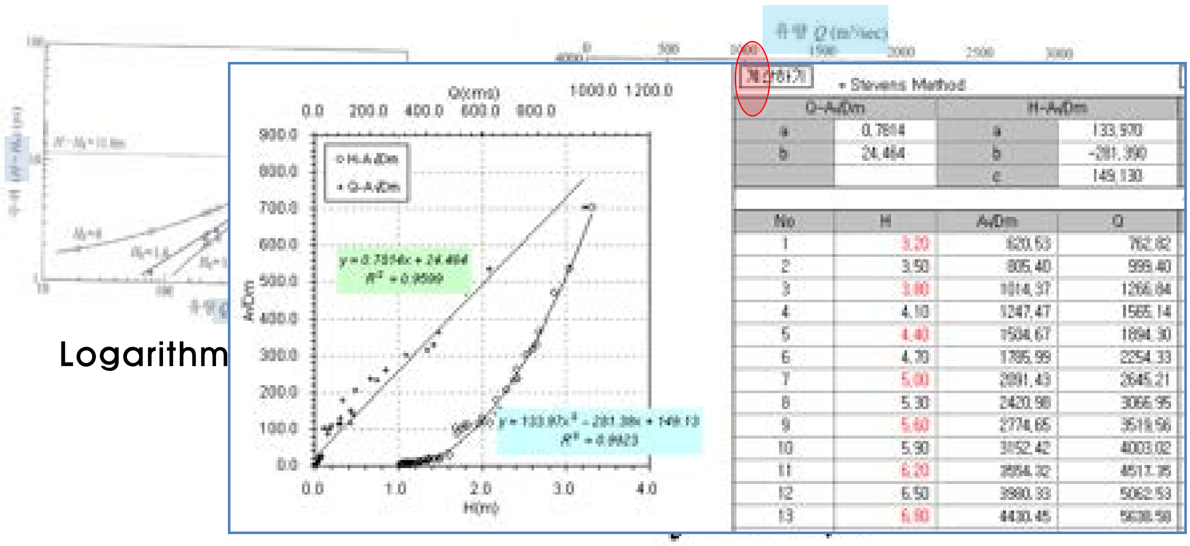


Source: KIHS, "Rating regression analysis and plotting sheet," 2020

3.1 Development of Rating Curve Using Regression Analysis

▪ Development of Rating Curve Using Field Discharge Data

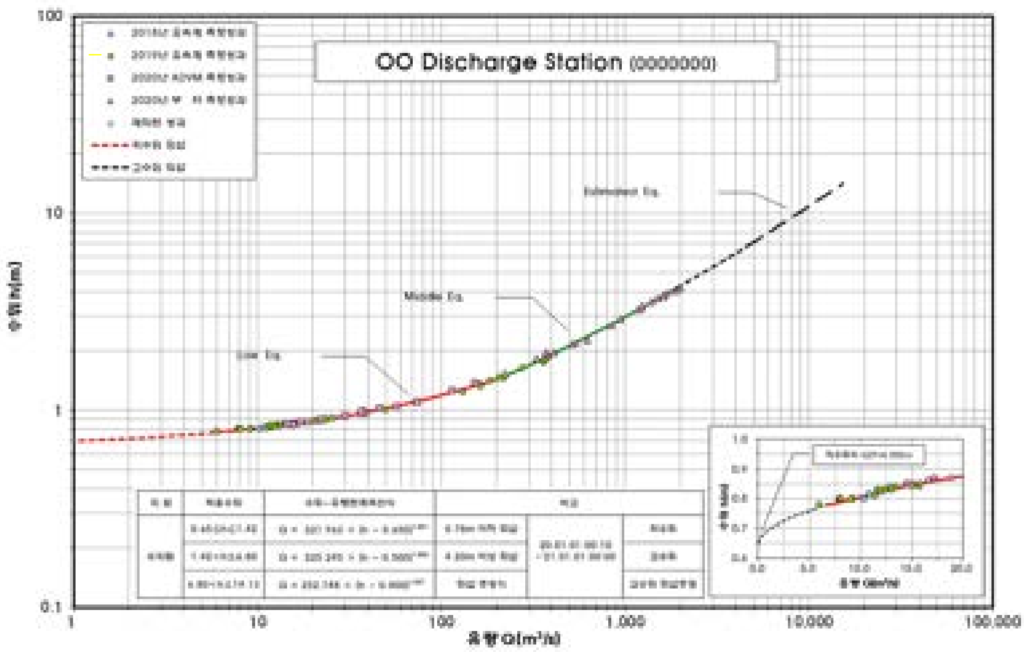
- High flow extrapolation: logarithmic method, Stevens method, velocity-slope method, slope-area method, etc. (Jaesoo Lee, 2006)



Source: KIHS, "Rating regression analysis and plotting sheet," 2020

3.2 Graphical Plotting of Rating Curve

▪ Graphical Plotting of Rating Curve



Source: KIHS, "Rating regression analysis and plotting sheet," 2020

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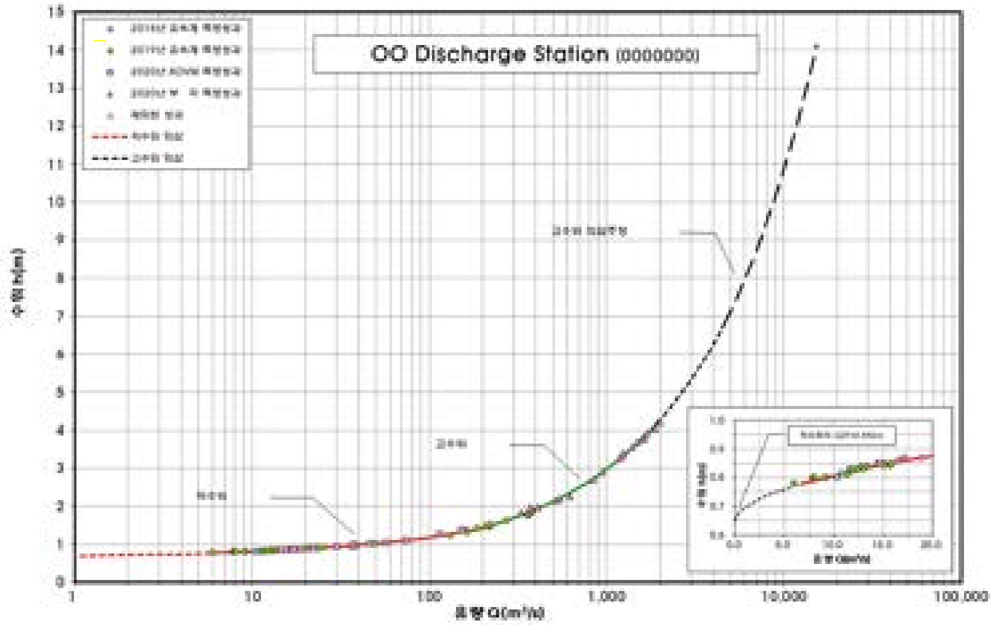

Source: KIHS, “Rating regression analysis and plotting sheet," 2020

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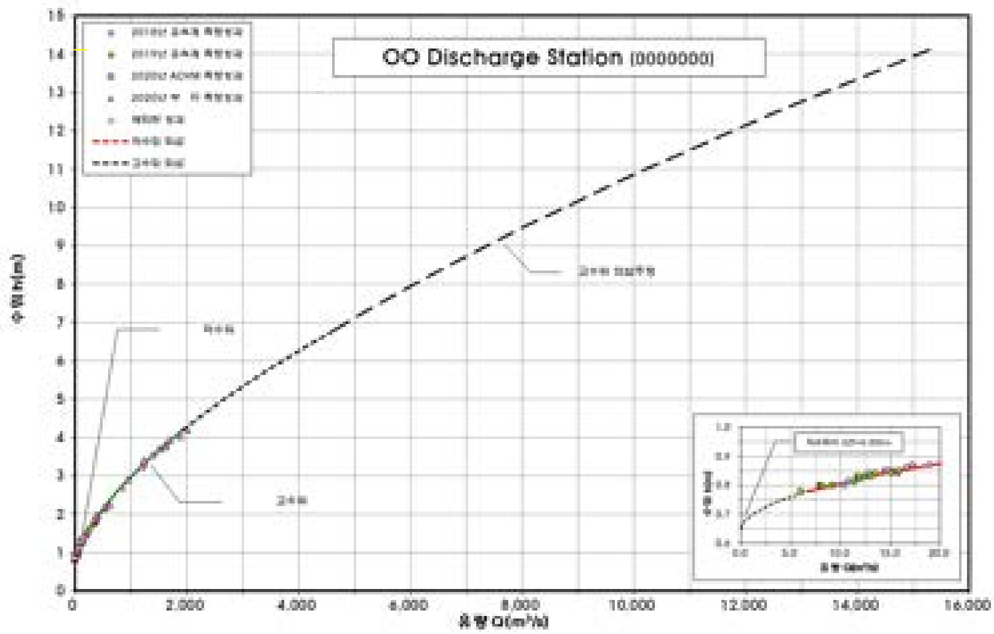


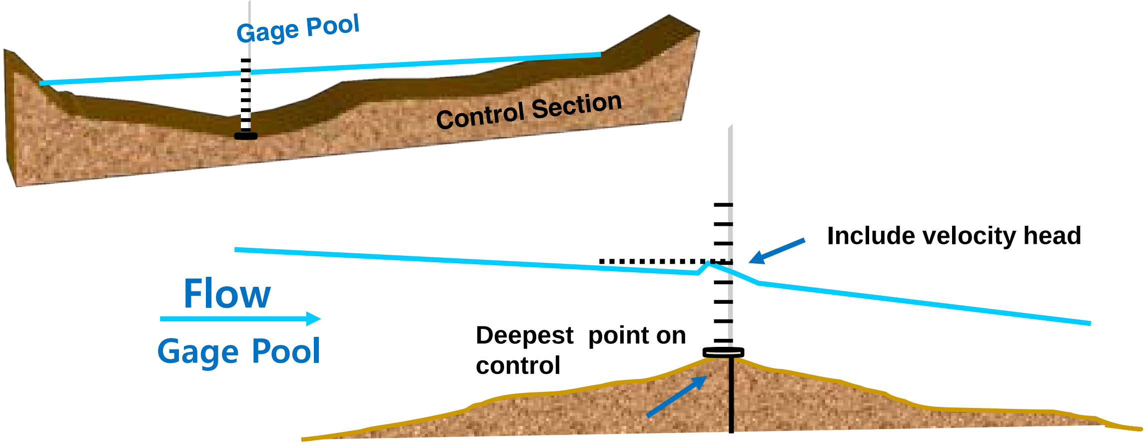
Source: KIHS, “Rating regression analysis and plotting sheet," 2020

4. Effect Of Discharge Ratings With Various River Conditions In Korea

4.1 Gage Height Of Zero Flow (GZF)
4.2 Sand Channel Streams
4.3 Vegetation Growth
4.4 Weir

4.1 Gage Height of Zero Flow

- The stage that would occur at a gaging station if the discharge were infinitesimal is the gage height of zero flow (GZF).
- It is also defined as the gage height of the point of zero flow (PZF).



Control section perpendicular to flow

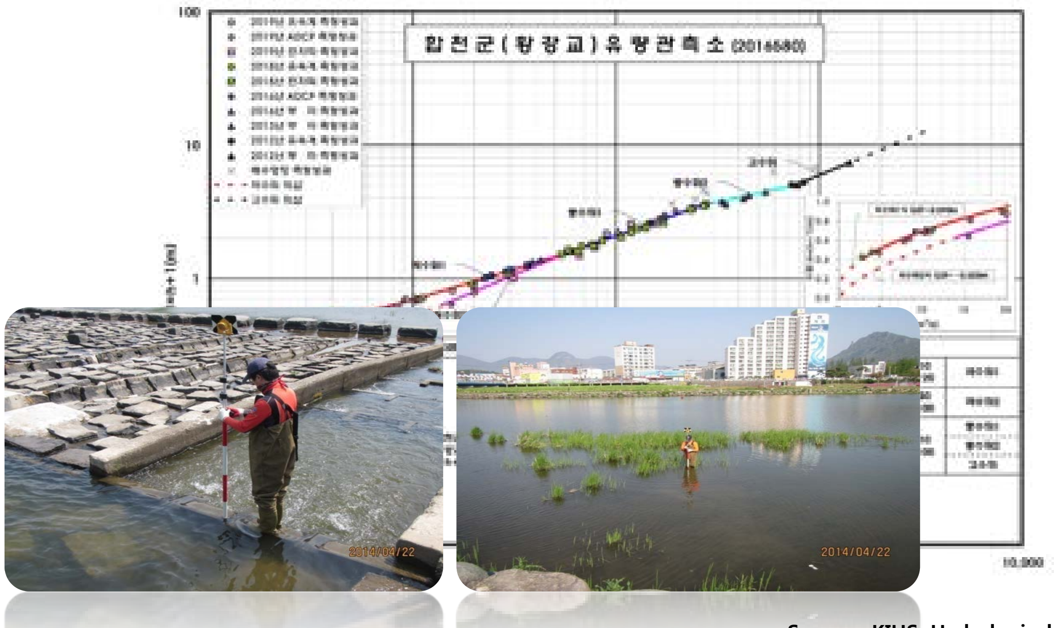
(The PZF is the physical location of the deepest point on the control)

Source: USGS, twri_3-A10, DISAHRGE RATING AT GAGING STATIONS/ Hydrological Basics Training, 2011

4.1 Gage Height of Zero Flow

▪ The Effect of Discharge Ratings with GZF

- River construction

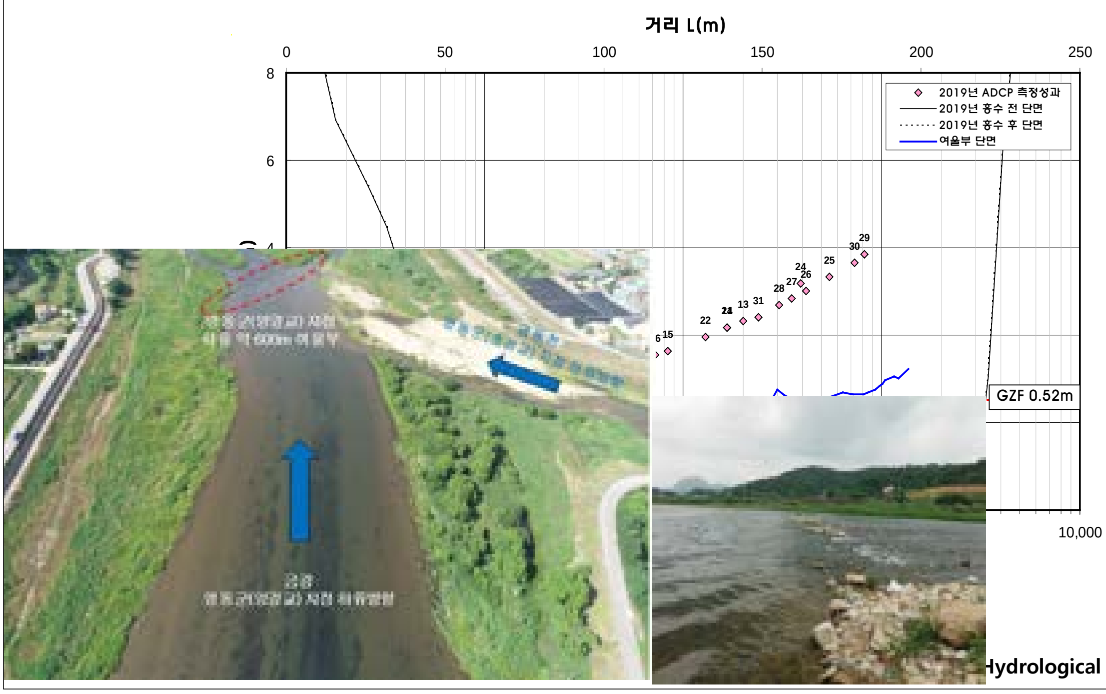


Source: KIHS, Hydrological Survey Report, 2019

4.1 Gage Height of Zero Flow

▪ The Effect of Discharge Ratings with GZF

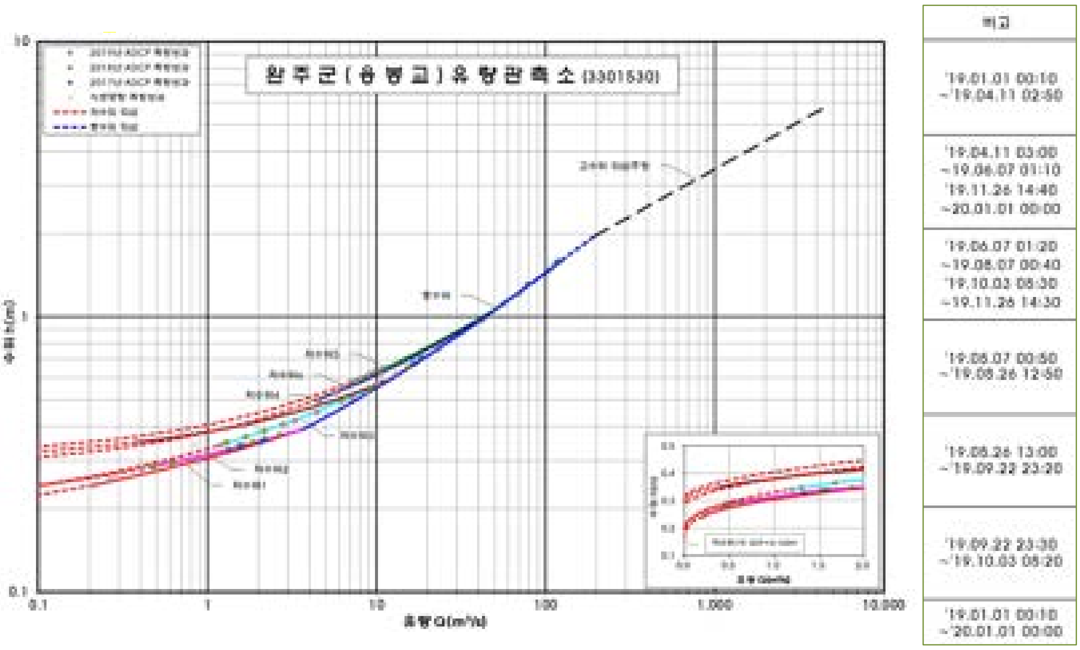
- Field survey and monitoring of GZF
- Controlled by a riffle located 600m downstream



Hydrological Survey Report, 2019

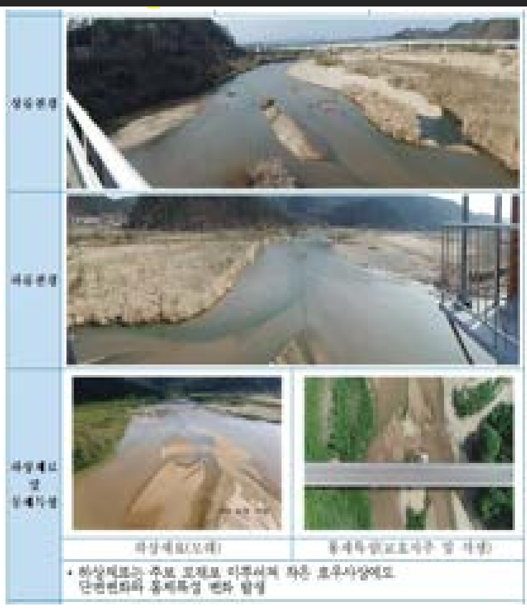
4.1 Gage Height of Zero Flow

- **The Effect of Discharge Ratings with GZF**
  - The periodic growth of river vegetation



4.2 Sand Channel Streams

- **In sand channel streams, stage-discharge relations are continually changing with time because of scour and fill and because of changes in the configuration of the channel bed.**

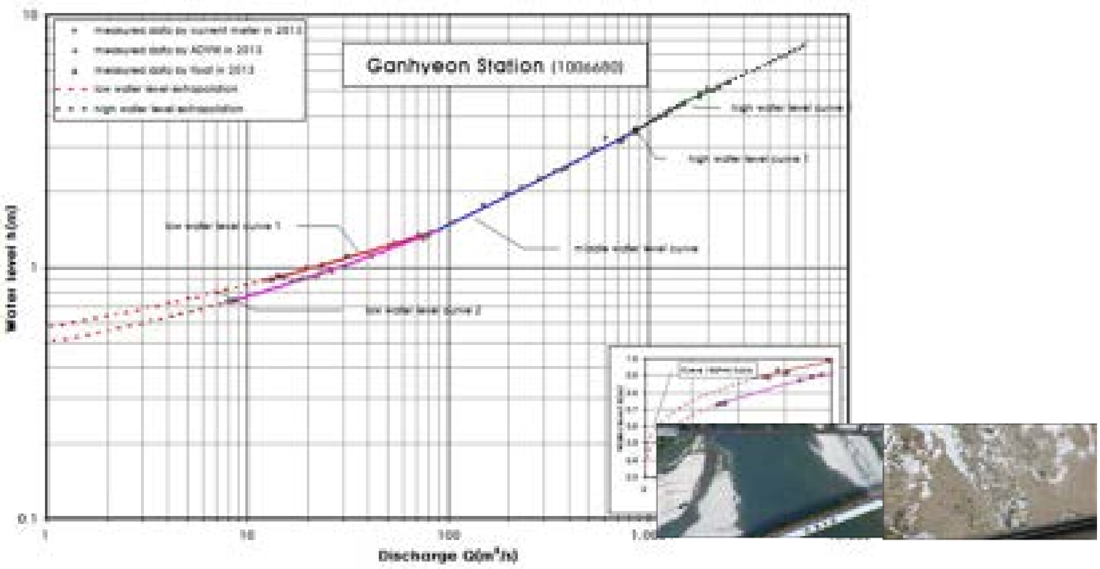


These changes cause the shape and position of the stage-discharge relation to vary from time to time, and it becomes very difficult to explain it

Source: KIHS, Hydrological Survey Report, 2019

4.2 Sand Channel Streams

- **In sand channel streams, stage-discharge relations are continually changing.**
  - Sand channel stream (Separation by before and after the flood bed change)
    ①01/01 00:00-07/20 18:40 ②07/20 18:50-12/31 23:50 (Scour of session)



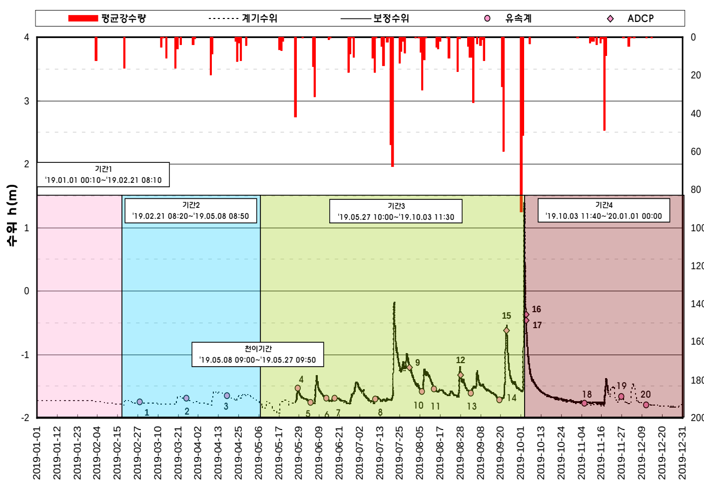
Source: KIHS, Hydrological Survey Report, 2013

4.2 Sand Channel Streams

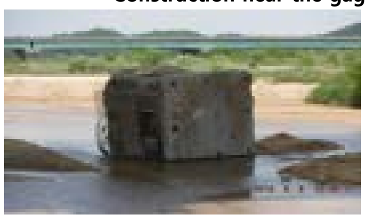
- **The Case Study in Sand Channel Streams**

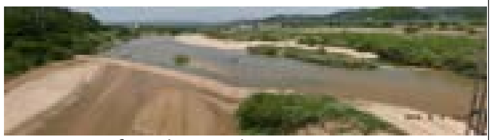
Nakdong River basin Yecheon-fun (Gopyeong bridge)

✓ The Shift of rating due to the station construction and sand stream



Construction near the gaging station





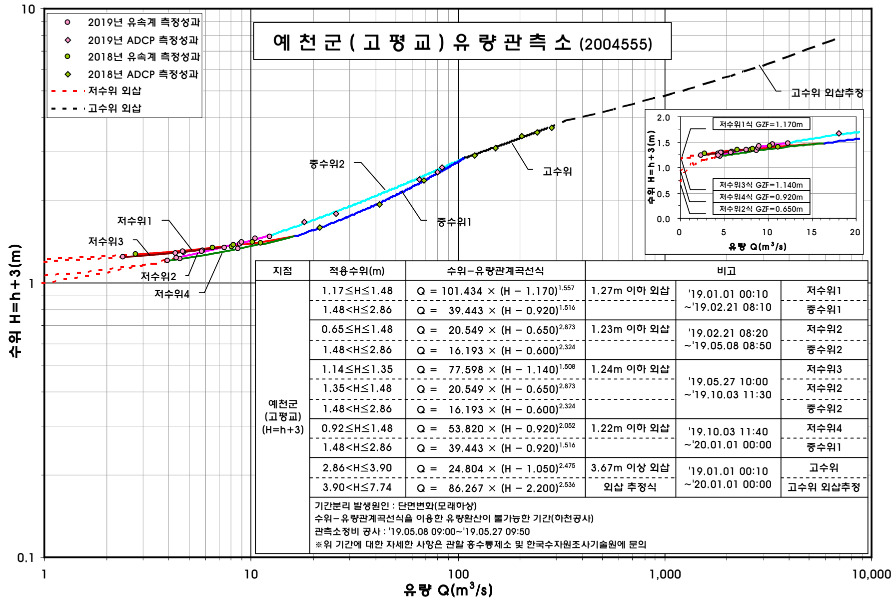
Upstream of gaging station

Source: KIHS, Hydrological Survey Report, 2019

4.2 Sand Channel Streams

▪ The Case Study in Sand Channel Streams

Nakdong River basin Yecheon-fun (Gopyeong bridge)



지점	적용수위(m)	수위-유량관계곡선식	비고		
예천군 (고평교) (H=h+3)	1.17≤H≤1.48	$Q = 101.434 \times (H - 1.170)^{1.557}$	1.27m 이하 외삽	'19.01.01 00:10 ~'19.02.21 08:10	저수위1
	1.48<H≤2.86	$Q = 39.443 \times (H - 0.920)^{1.516}$			중수위1
	0.65≤H≤1.48	$Q = 20.549 \times (H - 0.650)^{2.873}$	1.23m 이하 외삽	'19.02.21 08:20 ~'19.05.08 08:50	저수위2
	1.48<H≤2.86	$Q = 16.193 \times (H - 0.600)^{2.324}$			중수위2
	1.14≤H≤1.35	$Q = 77.598 \times (H - 1.140)^{1.508}$	1.24m 이하 외삽	'19.05.27 10:00 ~'19.10.03 11:30	저수위3
	1.35<H≤1.48	$Q = 20.549 \times (H - 0.650)^{2.873}$			저수위2
	1.48<H≤2.86	$Q = 16.193 \times (H - 0.600)^{2.324}$			중수위2
	0.92≤H≤1.48	$Q = 53.820 \times (H - 0.920)^{2.052}$	1.22m 이하 외삽	'19.10.03 11:40 ~'20.01.01 00:00	저수위4
	1.48<H≤2.86	$Q = 39.443 \times (H - 0.920)^{1.516}$			중수위1
	2.86<H≤3.90	$Q = 24.804 \times (H - 1.050)^{2.475}$	3.67m 이상 외삽	'19.01.01 00:10 ~'20.01.01 00:00	고수위
	3.90<H≤7.74	$Q = 86.267 \times (H - 2.200)^{2.536}$	외삽 추정식		고수위 외삽추정

기간분리 발생원인 : 단면변화(모래하상)
수위-유량관계곡선식을 이용한 유량환산이 불가능한 기간(하천공사)
관측소정비 공사 : '19.05.08 09:00~'19.05.27 09:50
※위 기간에 대한 자세한 사항은 관할 홍수통제소 및 한국수자원조사기술원에 문의

✓ The Shift of rating due to the station construction and sand stream

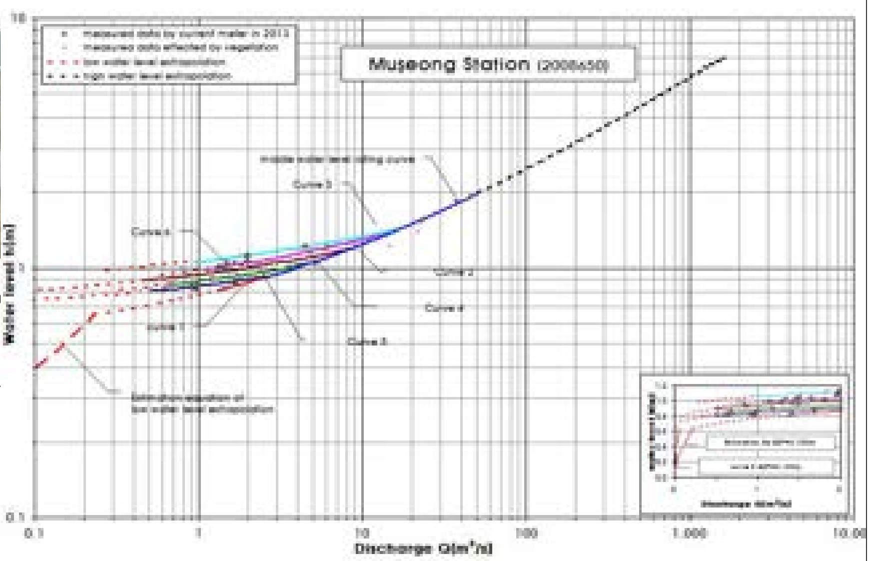
Source: KIHS, Hydrological Survey Report, 2019

4.3 Vegetation Growth

▪ Stage-discharge relations are continually changing with time because of vegetation growth.

✓**Example of vegetation growth monitoring**

- Separation of period by growth (circulation) of vegetation

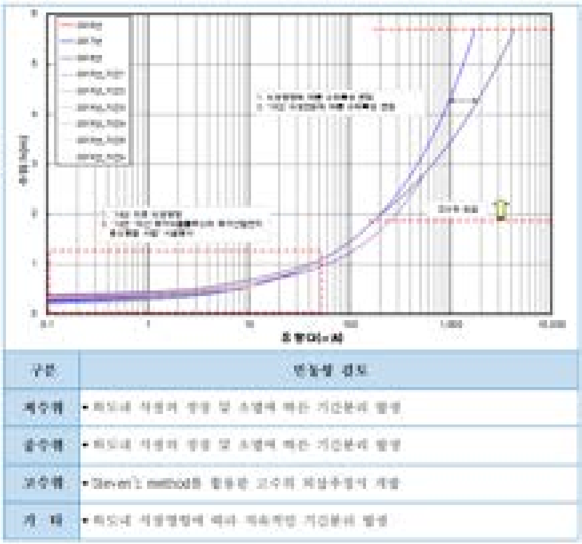


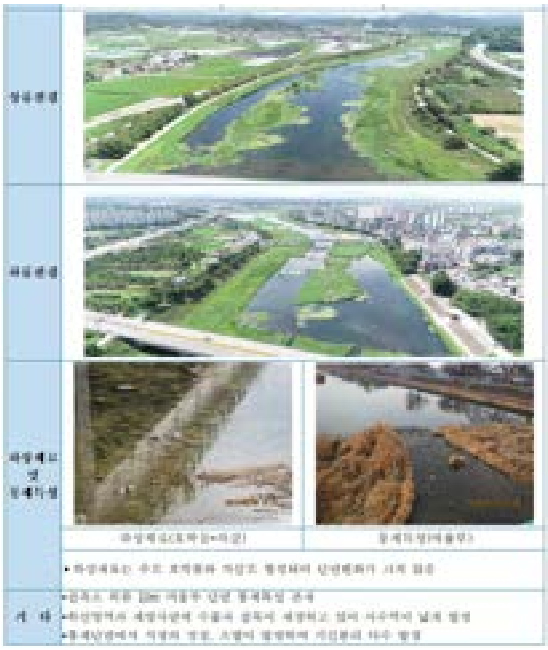
① Little effect of V
②~④ The growth
⑤~⑦ The extincti

4.3 Vegetation Growth

- **Stage-discharge relations are continually changing with time because of vegetation growth.**

Youngsan River Basin Wanjugun (Yongbonggyo)





4.3 Vegetation Growth

- **Stage-discharge relations are continually changing with time because of vegetation growth.**
- **Field monitoring of vegetation**

Youngsan River Basin Wanjugun (Yongbonggyo)

[Period 1_1.1-04.11]

[Period 2_4.11-6.7]

[Period 3_ 6.7-8.7]

[Period 4_ 8.7-8.26]

[Period 5_8.26-9.22]

[Period 6_9.22-10.3]

[Period 7_10.3-11.26]

[Period 7_11.26-12.31]

Source: KIHS, Hydrological Survey Report, 2019

4.3 Vegetation Growth

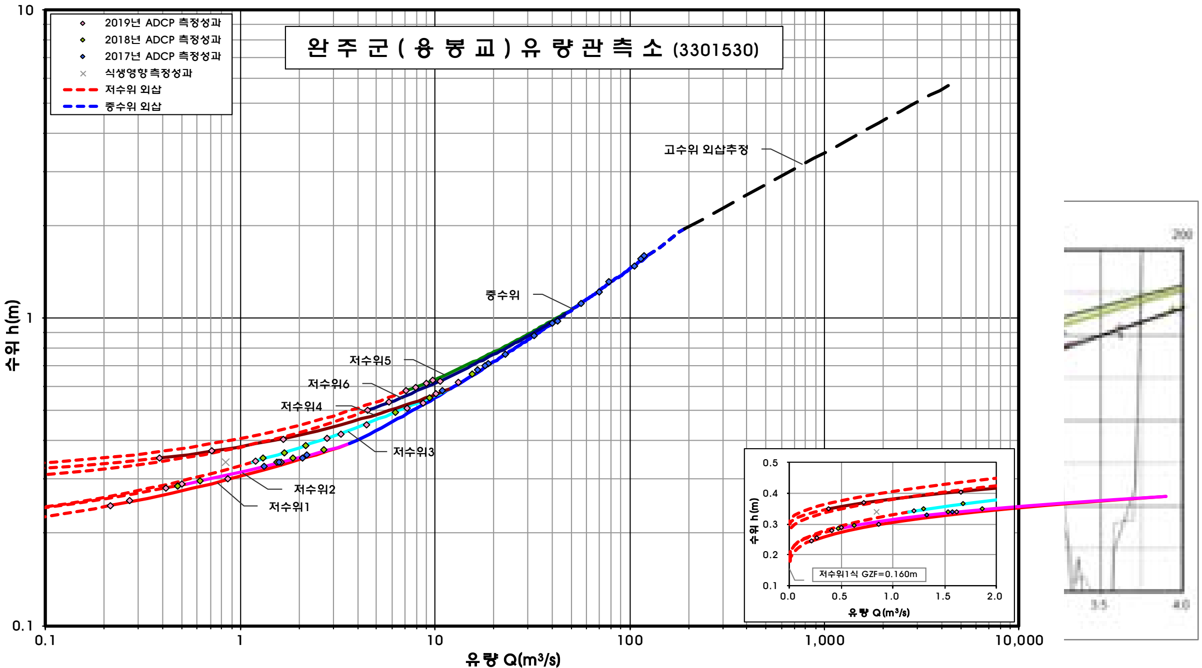
▪ **Stage-discharge relations are continually changing with time because of vegetation growth.**

Youngsan River Basin Wanjugun (Yongbonggyo)

Source: KIHS, Hydrological Survey Report, 2019

4.3 Vegetation Growth

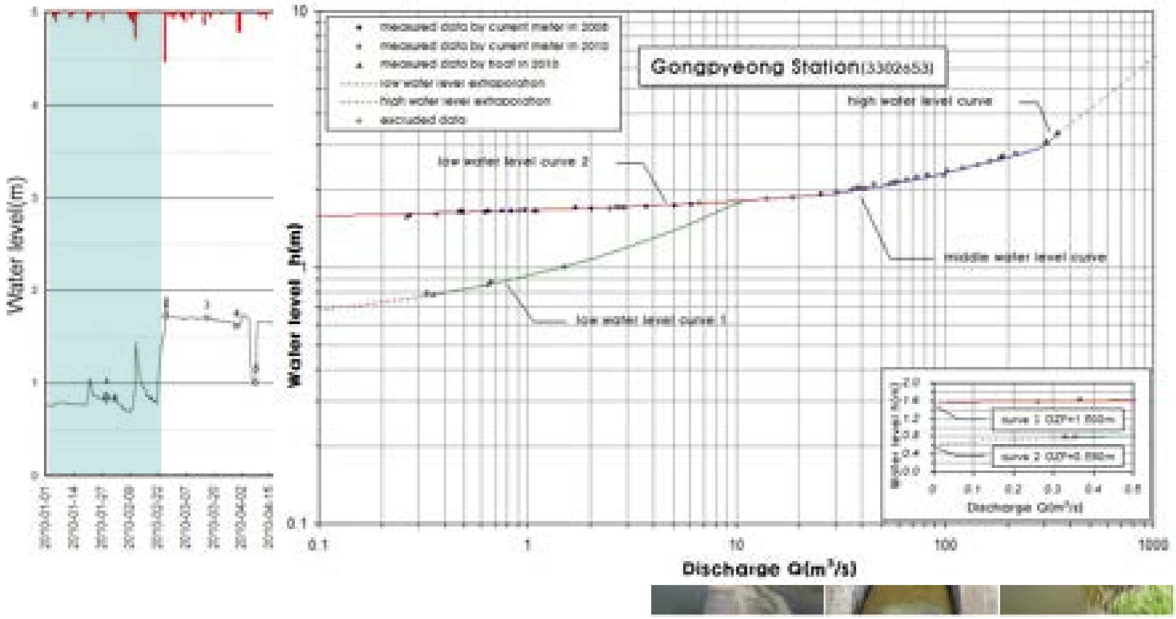
▪ **The Case Study of Vegetation Growth**



Source: KIHS, Hydrological Survey Report, 2019

4.4 Weir

▪ **Stage-discharge relation is changed according to the weir operation.**



Source: KIHS, Hydrological Survey Report, 2010

4.4 Weir

▪ **Stage-discharge relation is changed according to the weir operation.**

– Han River Basin Hongcheongun (Yongseongyo)

Continuous changing of stage discharge relation in 2010 to 2019

Source: KIHS, Hydrological Survey Report, 2019

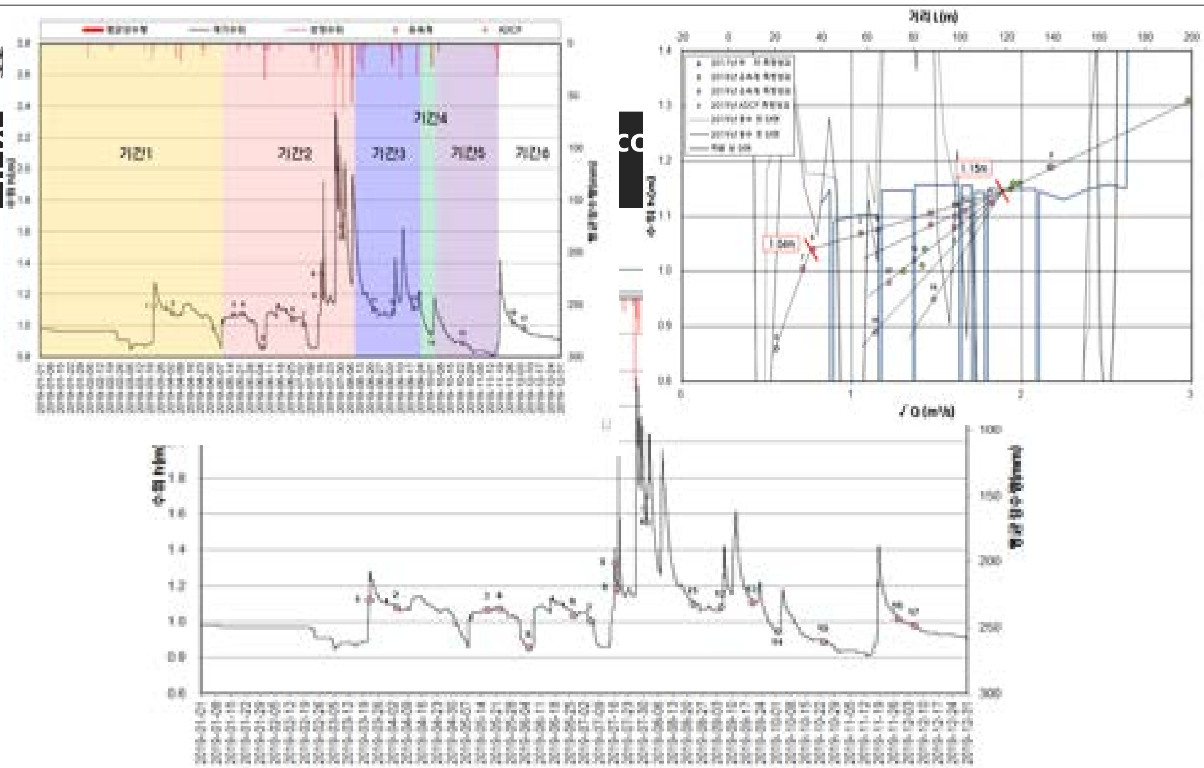
4.4 Weir

- Stage-discharge relation is changed according to the weir operation.
- Field monitoring of weir effect

Han River Basin Hongcheongun Yongseongyo

원 인	특성	구분	기간
가동보	부분개방1	기간1	'19.01.01. 00:10~'19.05.07. 20:20
	부분개방2	기간2	'19.05.08. 06:40~'19.08.07. 23:00
	부분개방3	기간3	'19.08.07. 23:10~'19.09.23. 14:40
	부분개방4	기간4	'19.09.23. 14:50~'19.10.04. 07:40
	부분개방5	기간5	'19.10.04. 07:50~'19.11.15. 19:10
	부분개방6	기간6	'19.11.16. 19:10~'20.01.01. 00:00

Source: KIHS, Hydrological Survey Report, 2019

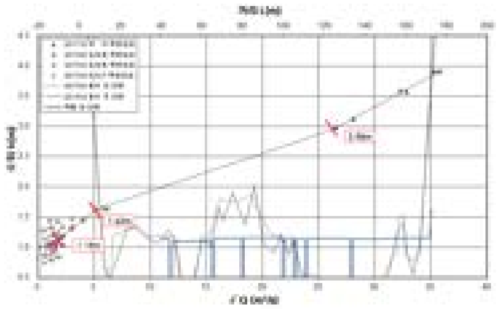


Discharge measurement and Weir operation monitoring in 2019

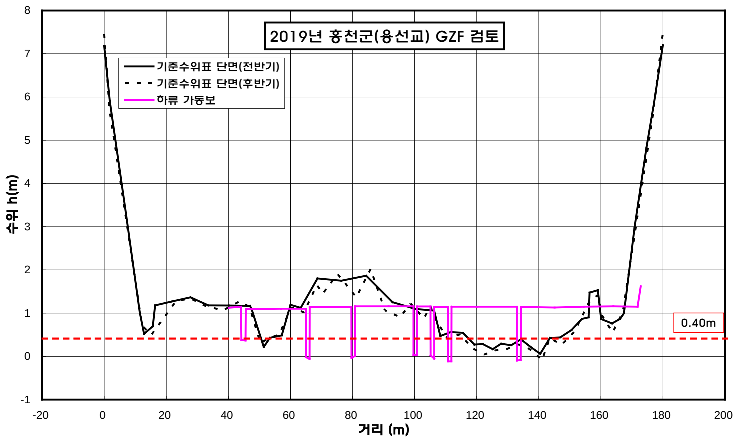
Source: KIHS, Hydrological Survey Report, 2019

4.4 Weir

- Stage-discharge relation is changed according to the weir operation.
- Field Survey of GZF



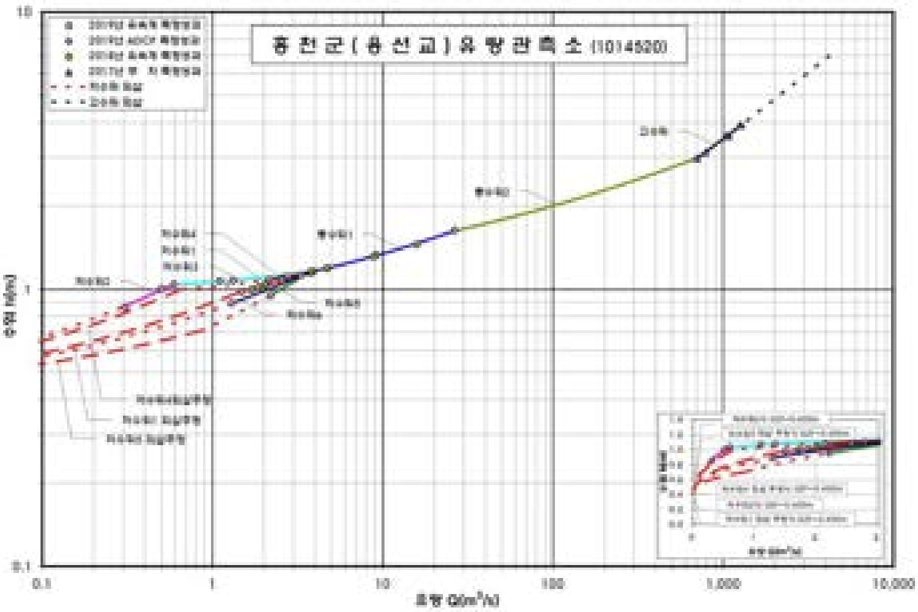
Han River Basin Hongcheongun (Yongseongyo)



Source: KIHS, Hydrological Survey Report, 2019

4.4 Weir

- Stage-discharge relation is changed according to the weir operation.
- Field monitoring of weir effect



Source: KIHS, Hydrological Survey Report, 2019


Thank you very much

Advanced Discharge Measurement Techniques

Hydrological Survey

Advanced Discharge Measurement Techniques

KIHS 한국수자원조사기술원 Korea Institute of Hydrological Survey

i-WSSM

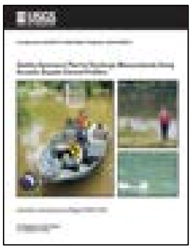
Aims & Objectives

- The aims of the course are to:
  - (1) Introduce the meaning of the advanced discharge measurement and how to measure
  - (2) Help trainees to understand the principles and methods of discharge measurement using acoustic doppler current profiler (ADCP) and to develop the abilities to produce high-quality data
  - (3) Present the maintenance methods for stable operation of ADCP

- At the conclusion of this course, trainees will be able to:
  - (1) Understand the advanced discharge measurement
  - (2) Explain the principle and method of discharge measurement using ADCP
  - (3) Perform the quality control for producing high-quality data

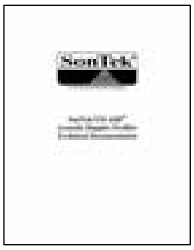
References

Discharge Measurements Using a Broad-Band Acoustic Doppler Current Profiler (USGS, 2001)

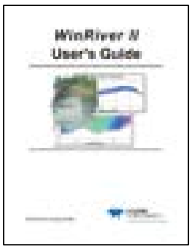


Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers (USGS, 2005)

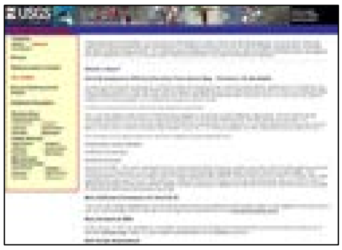
Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat (USGS, 2013)



Acoustic Doppler Profiler(ADP) Principles of Operation(SoTek/YSI, 2000)



WinRiver II User's Guide (TRDI, 2016)



OSW Hydroacoustics website (https://hydroacoustics.usgs.gov/)

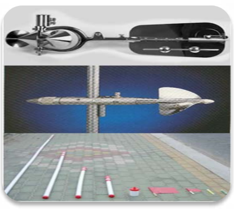
Contents

1. Introduction

1.1 Advanced Discharge Measurement
1.2 Types of Method

1.1 Advanced Discharge Measurement

- What is Advanced Discharge Measurement?
  - Traditional discharge measurement refers to the analog method of measuring point flow velocity information only using mechanical current meter, etc.
  - Advanced discharge measurement refers to a digital method of measuring various information, such as 2D- or 3D-flow velocity distribution, using advanced technologies such as ultrasonic (acoustic) waves and imaging.



Traditional discharge measurement equipment

- Mechanical (rotating-element) current meter, magnetic current meter, etc.
- little type and quantity of information
- point flow velocity, discharge
- analog method

Advanced discharge measurement equipment

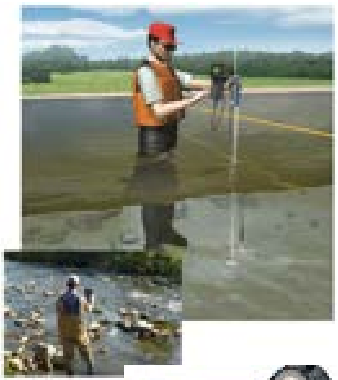
- ADV (Acoustic Doppler Velocimeter), ADCP (Acoustic Doppler Current Profiler), UVM(Ultrasonic Velocity Meter), LSPIV(Large Scale Particle Image Velocimetry), LDV(Laser Doppler Velocimetry) , etc.
- large type and quantity of information
- flow velocity distribution, turbulence flow, flow velocity vector, suspended sediment concentration, discharge, etc.
- digital method

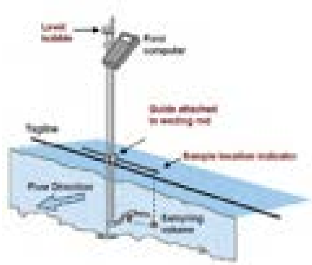
1.2 Types of Method

▪ Acoustic Doppler Velocimeter (ADV)

- ADV is designed to record instantaneous velocity components at a single-point with a relatively high frequency.
- Measurements are performed by measuring the velocity of particles in a remote sampling volume based upon the Doppler shift effect.

FlowTracker (sontek): most commonly used



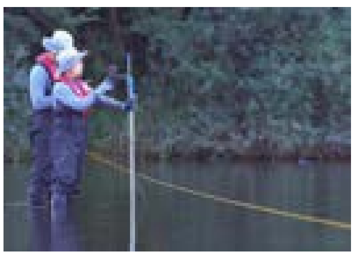


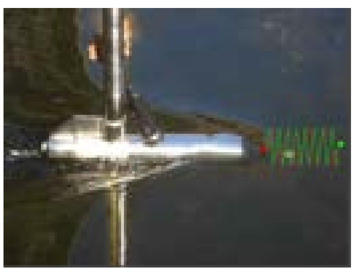
1.2 Types of Methods

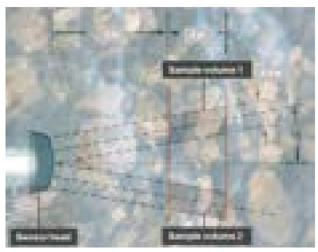
▪ ADV

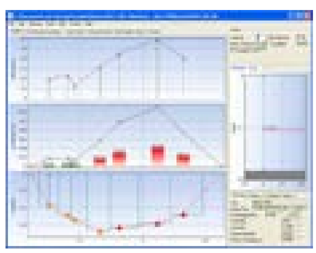
- ADV is designed to record instantaneous velocity components at a single-point with a relatively high frequency.
- Measurements are performed by measuring the velocity of particles in a remote sampling volume based upon the Doppler shift effect.

ADC(OTT): most commonly used









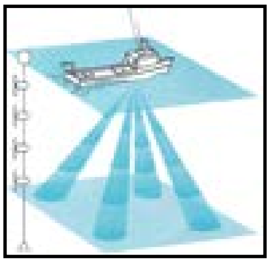
1.2 Types of Methods

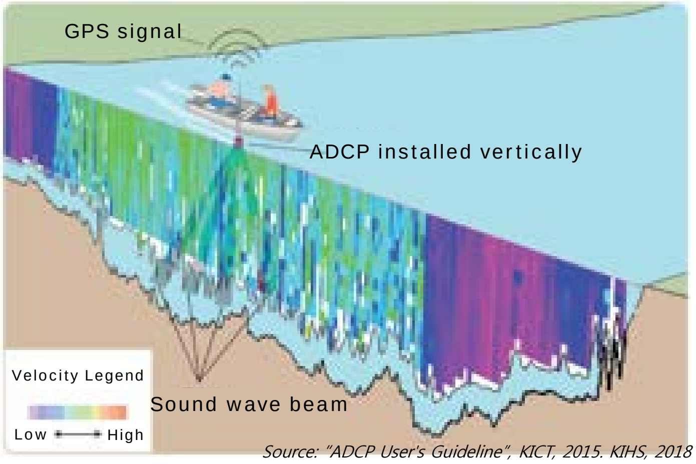
▪ ADCP

- ADCP is a hydroacoustic current meter similar to sonar, used to measure water current velocities over a depth range using the Doppler effect of sound waves scattered back from particles within the water column.

• Acoustic - sound waves and the
• Doppler - Doppler shift are used to measure
• Current - water velocity
• Profiler - profiles

Equipment that calculates discharge by measuring the 2D-flow velocity distribution of a cross section while crossing a river





Source: "ADCP User's Guideline", KICT, 2015. KIHS, 2018

1.2 Types of Methods

▪ ADCP most commonly used

[TRDI] StreamPro
Frequency 2,000㎑ (4-beam) ADCP, manual setting possible, used at a water depth of 0.10m to 6m

[TRDI] RiverPro
Frequency 600㎑ (vertical beam)/1,200㎑ (4-beam) ADCP, manual/automatic setting possible, used at a water depth of 0.20m to 25m

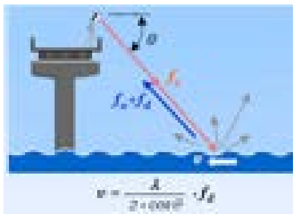
[SonTek] RiverSurveyor S5
Frequency 1,000㎑ (vertical beam)/3,000㎑ (4-beam) ADCP, automatic setting possible, used at a water depth of 0.30m to 5m

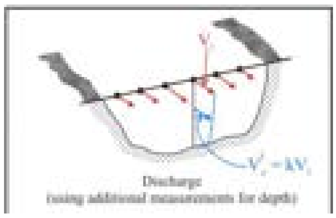
[SonTek] RiverSurveyor M9
Frequency 500㎑ (vertical beam)/3,000㎑&1,000㎑ (dual 4-bean) ADCP, automatic setting possible, used at a water depth of 0.30m to 40m

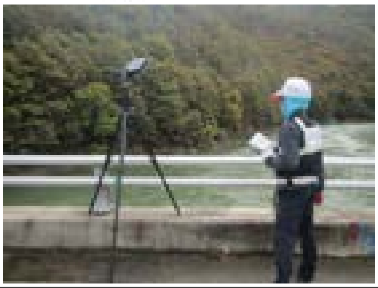
1.2 Types of Method

▪ Electromagnetic Wave Surface Velocimeter (EWSV)

- EWSV measures the surface flow velocity by using the Doppler effect of the reflected wave when electromagnetic waves are radiated to the flowing water surface.







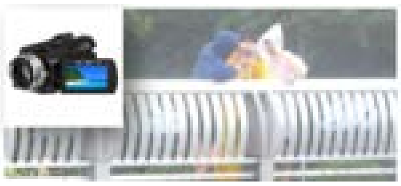
Source: K-water, "EWSV User's Guideline"

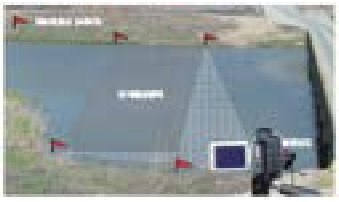
1.2 Types of Methods

▪ Large Scale Particle Image Velocimetry (LSPIV)

- LSPIV is a technique that can be applied to real rivers by expanding the existing particle image velocimetry technique to calculate the velocity vector of the target area by tracking particles in the recorded image.

Calculation of surface flow velocity by analyzing the flow of the water surface using a video recording device such as a camcorder, etc.



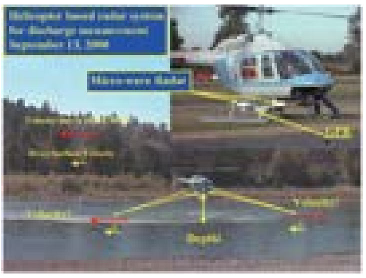


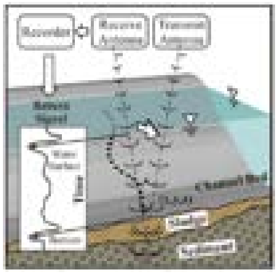
Source: Yu, Kwonkyu, "등록특허 10-1512690, 2015]
Yu, Kwonkyu, J. Korea Water Resour. Assoc. Vol. 49, No. 6 (2016), pp. 469-480

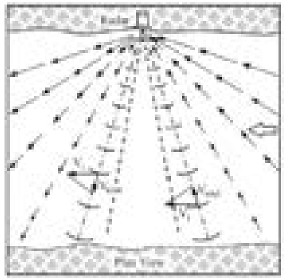
1.2 Types of Methods

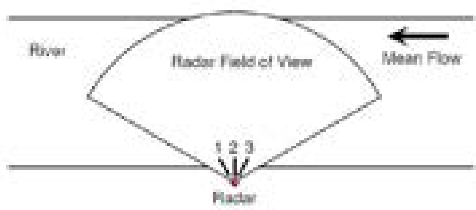
▪ **Ground-Penetrating Radar & Surface Velocity Radar (GPR & SVR)**

- GPR & SVR is a method of installing a GPR and SVR on a helicopter or a fixed installation of an SVR on a river and acquiring river cross section data and surface velocity data using GPR.







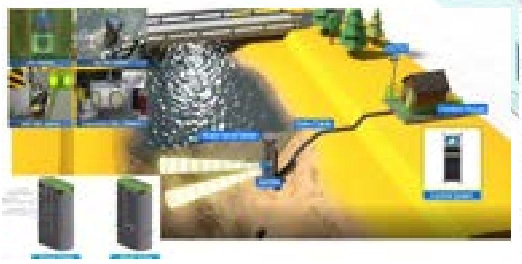


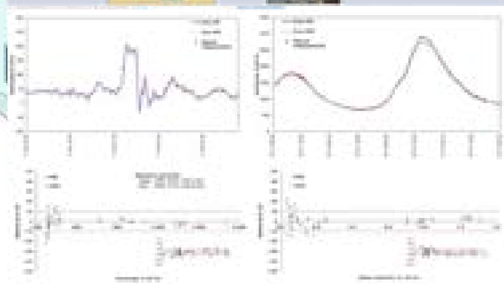
SOURCE: (1)Ralph T. Cheng, "Present and Future Plans of Streamgaging at the USGS" 2003
(2)C. Teague, et al., "Initial River Test of a Monostatic RiverSonde Streamflow Measurement System" 2003
(3) Marian Muste, "Experimental Hydraulics: New Views of the Rivers" 2013

1.2 Types of Methods

▪ **Real-time discharge measurement using ADVM**

- Discharge measurement system using ADVM(Side-looking, Up-looking, Moving type(up & down, rotation))
- Side-looking types are mostly used for discharge measurement.
- Real-time discharge measurement under back water or tidal conditions that H-Q rating cannot be developed
- This method is widely used to measure real-time discharge in Korea.





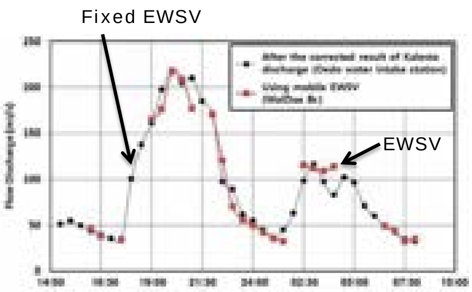
1.2 Types of Methods

▪ Real-time discharge measurement using fixed EWSV

- Fixed EWSV measures the real-time water surface velocity and water level in a non-contact method.
- This method is mainly used to measure real-time discharge in mountain streams in Korea.

Installation of bridge

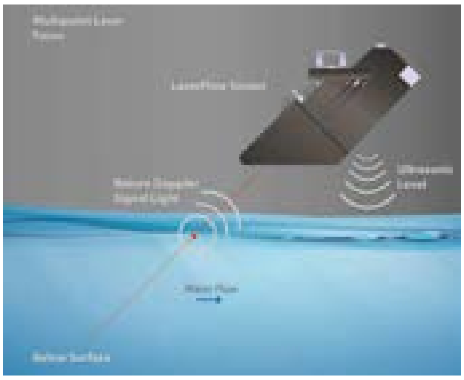
Installation of riverbank

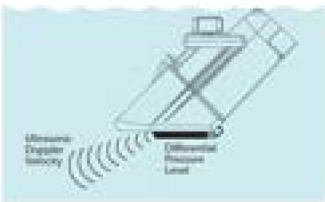


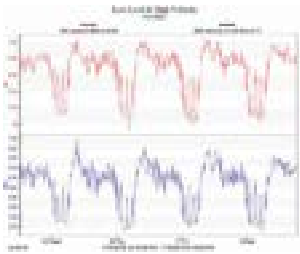
1.2 Types of Methods

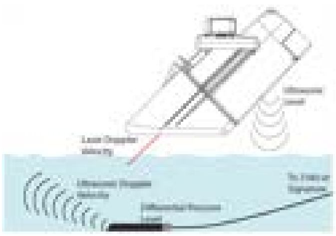
▪ Real-time discharge measurement using LDV

- LDV is a method of measuring water velocity using the Doppler effect of a laser, and it can be installed and operated in the same way as fixed EWSV.
- This method is easy to install in small and medium-sized rivers, waterways, and pipelines.





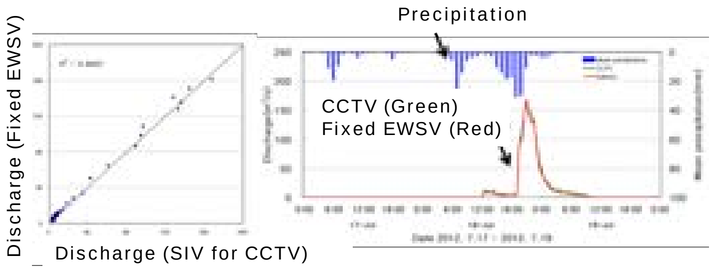




SOURCE: TELEDYNE ISCO, LaserFlow AV Sensor Broche, etc.

1.2 Types of Methods

- **Real-time discharge measurement using fixed camcorder**
  - This method calculates the discharge by using SIV method on the recorded video (or image) of a fixed camcorder such as a river CCTV for disaster monitoring.
  - Although there are limitations in poor environments (nighttime, heavy rain, etc.), it is being improved by applying infrared photography, machine learning, and AI.



2. Discharge Measurement using ADCP

2.1 ADCP Features

- **Necessity**
  - Measurement of flow velocity distribution over the cross section
  - No need to assume the log vertical flow velocity distribution
  - Rapidly measurement: within 10 min per measurement -> measurable for large rivers, tidal rivers, etc.
  - Measurement of flow velocity vector -> measurable for bi-directional flow

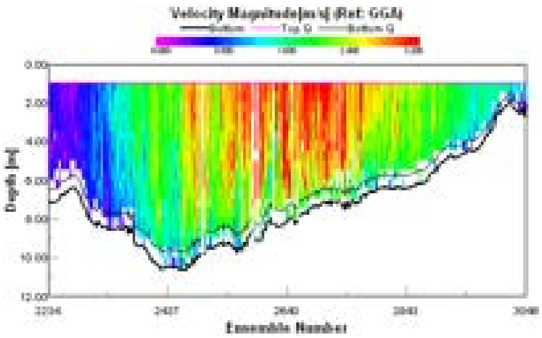


Fig. Rapidly measurement for large rivers

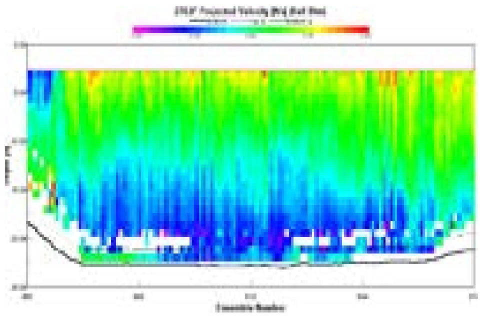


Fig. Measurement for Bi-directional flow

2.1 ADCP Features

- **Necessity**
  - Measurement of vertical flow velocity distribution, discharge, turbulence flow, suspended sediment load, etc.
  - Provides flow velocity data combined with geographic information based on precise positioning such as global navigation satellite system
  - Verification of 2D-flow model

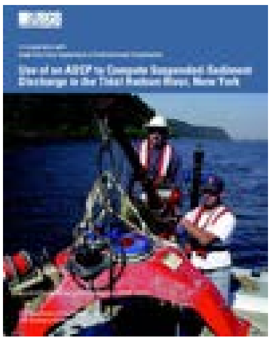


Fig. Measurement of suspended sediment load

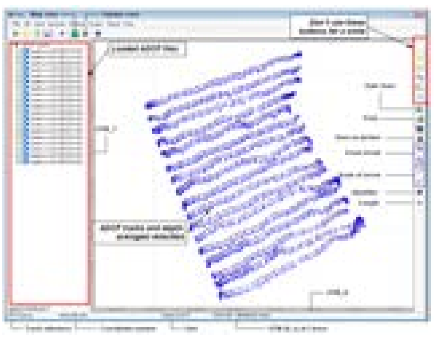


Fig. Measurement of 2D flow velocity

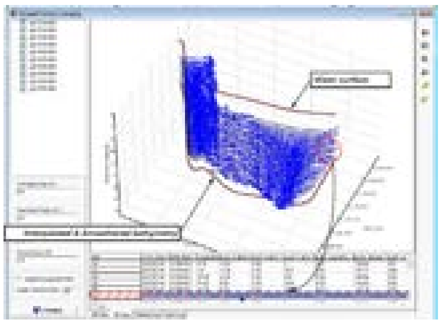


Fig. Verification of flow model

SOURCE: USGS OSW, "A quick tutorial for using VMS(ADCP Velocity Mapping Software)" 2009

2.1 ADCP Features

▪ Principle of ADCP

- Sound wave: To vibrate the eardrum in the form of a sect by partially changing pressure on the medium (air) in which the vibration of an object was uniform.

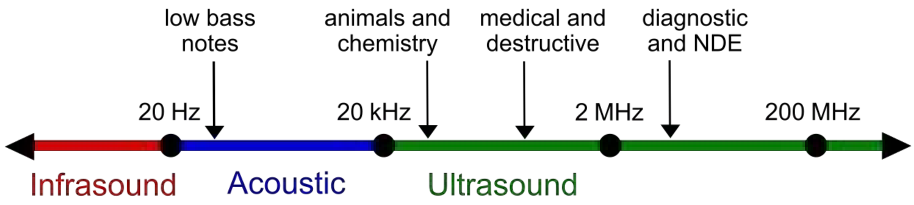


Fig. Types of sound wave

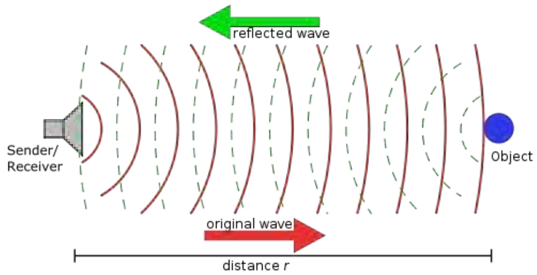


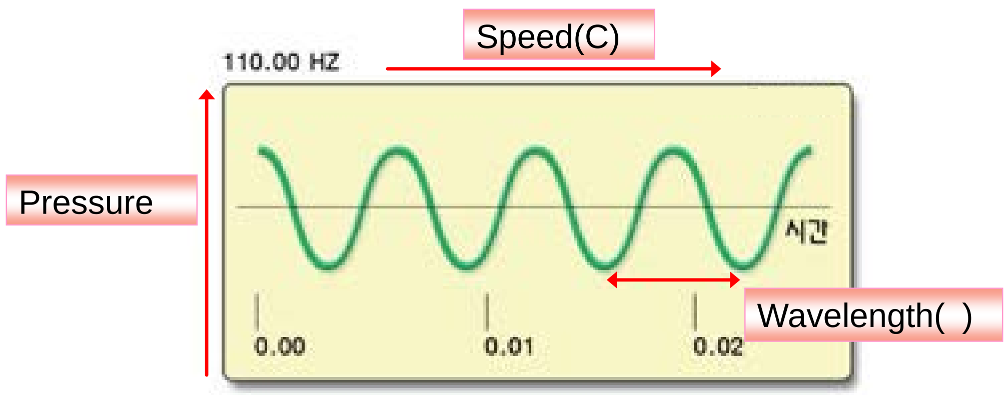
Fig. Transmission and reception of underwater sound waves

SOURCE: WIKIPEDIA(“Ultrasound”)

2.1 ADCP Features

▪ Principles of ADCP

- General characteristics of sound waves
  Frequency(f): number of sound waves passing over a period of time



2.1 ADCP Features

▪ Principles of ADCP

- Speed of transmission underwater sound waves

· The most important thing in measuring flow velocity using sound waves is the transmission speed of sound waves (C), and it is a function of water temperature (T), water depth (d), and salinity (S).

· The water temperature is 3㎧ per 1℃, and the salinity causes a change in sound velocity of 1.2㎧ per 1ppt, and the speed of sound wave at a total water temperature of 20℃ is 1,481㎧.

· In rivers, the water depth is usually around 20m and the vertical change of water temperature is not large, so it is hardly considered. However, salinity should be measured in case of tidal rivers and its effect should be considered.

$$C = 1449.2 + 1.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.01T)(S - 35) + 0.0016d$$

Water temperature	Speed of sound wave(m/s)
0	1,402
10	1,447
20	1,482
30	1,509
40	1,529
In water containing salt, the speed of sound is about 50㎧ faster	

SOURCE: ISO 6416, 2017

2.1 ADCP Features

▪ Principle of ADCP

- Doppler effect of sound waves

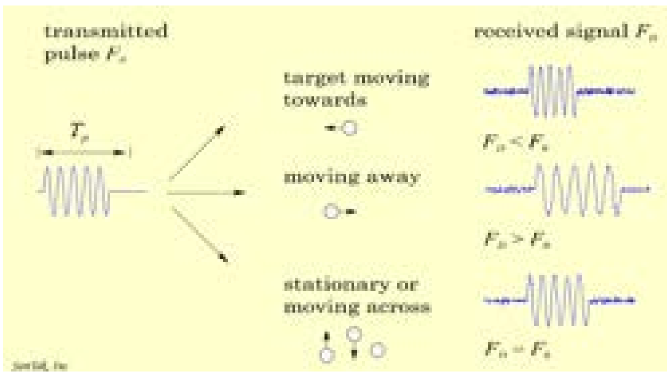
· The Doppler effect of sound waves is the change in frequency that occurs when sound waves generated from a sound source move away or close to the observer (the person listening to the sound wave).

· Using the Doppler effect, ADCP measures the flow velocity by transmitting ultrasonic waves of a certain frequency in the water and collecting the echoes that are scattered and returned by the floating particles.

· Frequency shift (F_{shift}) is a function of the frequency (F_{source}) and relative speed (V) of the transmitted sound wave, and the speed of sound waves (C) in water.

· The higher the frequency (F_{source}) of the transmitted sound wave, the larger the frequency change (F_{shift}), so the high frequency ADCP can measure the flow velocity more accurately.

$$F_{shift} = -2F_{source}\frac{V}{C}$$



SOURCE: SonTek/YSI, "Acoustic Doppler Profiler Technical Documentation" 2000

2.1 ADCP Features

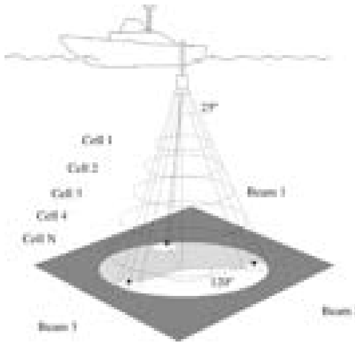
▪ Principle of ADCP

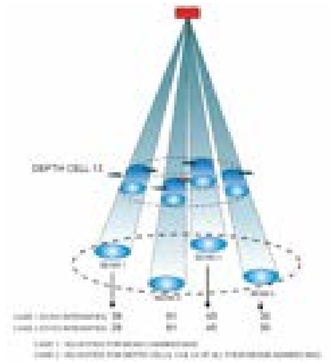
- Measurement of 3D flow velocity

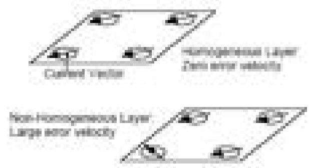
· ADCP usually has 3 to 4 transceivers to generate sound waves in various directions and measure the 3D flow velocity component through this.

· Sound waves are collected primarily by individual transceivers, through which the beam velocity is measured.

· The beam velocity can be converted into a flow velocity of various coordinate systems depending on the measurement purpose, and the coordinate systems usable in ADCP include beam coordinate system, rectangular coordinate system, boat coordinate system, earth coordinate system, etc.







SOURCE: *(1)Ray Kostaschuk, et al., "Measuring flow velocity and sediment transport with an acoustic Doppler current profiler", Geomorphology, Volume 68, Issues 1–2, 15 May 2005, Pages 25-37*
(2)TELEDYNE RD INSTRUMENTS, "ADCP Coordinate Transformation" 2008
(3)TELEDYNE RD INSTRUMENTS, "QA/QC Parameters for ADCP" 2006

2.1 ADCP Features

▪ Principle of ADCP

- Measured current

· ADCP measures the flow velocity while crossing a river, so the relative velocity (V) includes the velocity of water and boat velocity expressed as a vector component.

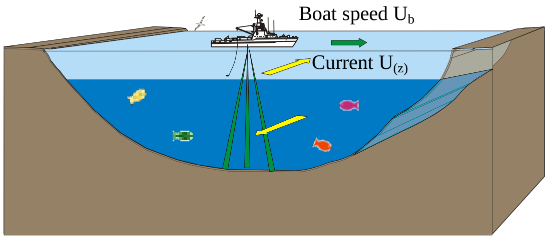
· To calculate the discharge, it is necessary to extract the flow velocity vector in the direction of the normal to the path crossing the river, and the boat speed and direction are important.

· Determining boat speed and path using sound waves reflected from the riverbed is called bottom-tracking.

· If the boat speed is faster than the water velocity, the error is likely to increase in the water velocity measurement, especially when the water velocity is slow, the error increases.

· Bottom tracking assumes that the riverbed is fixed and does not move, so measurement should be made in consideration of the moving bed condition when the sand particles of the riverbed continue to move as in a sand-bed stream.

Measured Current: $U_m = U_b + U_{(z)}$



2.1 ADCP Features

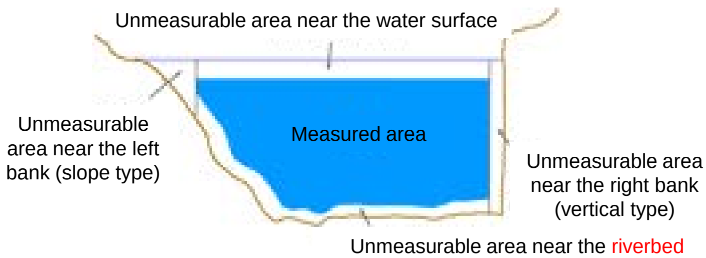
▪ Principle of ADCP

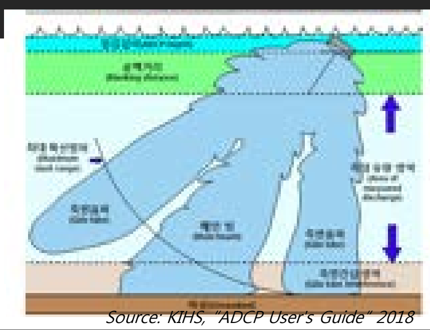
- ADCP & sound wave frequency
 · (High frequency) Depth cell size and blanking distance, minimum measurement depth and maximum measurement depth are small, and the flow velocity resolution is high, so it is suitable for shallow and slow flow rate rivers.
 · (Low frequency) Opposite to high frequency, suitable for deeper and faster flow velocity rivers.
- Transducer offset, Transducer draft, ADCP depth
 · Distance from the center of the transducer surface to the water surface when placing the ADCP below the water surface.
 · The ADCP transducer surface must be submerged in water as sound waves can be transmitted and received normally.
 · If air bubbles are generated around the ADCP due to waves or swirls during movement, the accuracy of the measurement is reduced due to cavitation.

2.1 ADCP Features

▪ Principle of ADCP

- Blanking distance
 · The depth of the sensor directly below which ADCP cannot measure
- Beam angle, Slant angle
 · ADCP usually has 3 to 4 transceivers, and the spreading angle (15-30°) with respect to the vertical axis of the ADCP is called the slant angle.
- Side lobe effect
 · A phenomenon in which the ADCP sound wave(side-lobe) transmitted at an abnormal angle rather than the slant angle hits the riverbed and acts as a noise of the strong reflected wave, disturbing the flow velocity measurement near the riverbed.
- Measured & Unmeasured area
 · (Measured area) Area in which ADCP can directly measure the flow velocity in the cross section.
 · (Unmeasured area) Since direct flow velocity measurement is not possible, the area in which the flow velocity and discharge are indirectly estimated using the measured flow velocity.



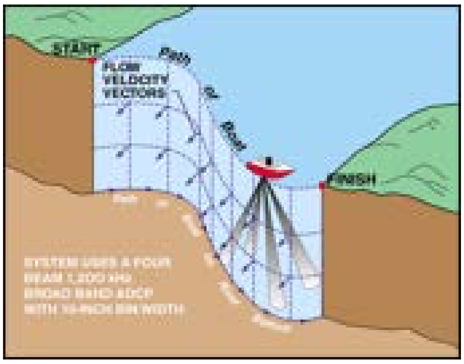


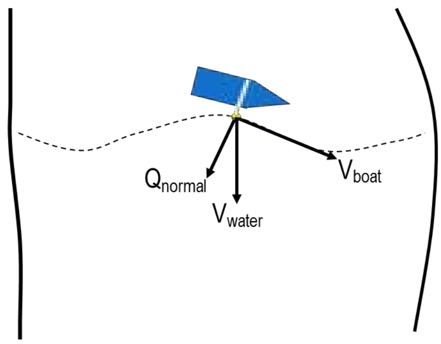
Source: KIHS, "ADCP User's Guide" 2018

2.2 Discharge measurement

▪ Moving Vessel Method

- The discharge is calculated from the flow velocity, distance, and depth measured while moving ADCP across the river using a means of transportation such as a boat.
- Discharge measurement regardless of the boat's crossing path
  · ADCP measures both boat speed and discharge
  · Only the flow velocity component perpendicular to the boat's travel direction is used for discharge calculation.



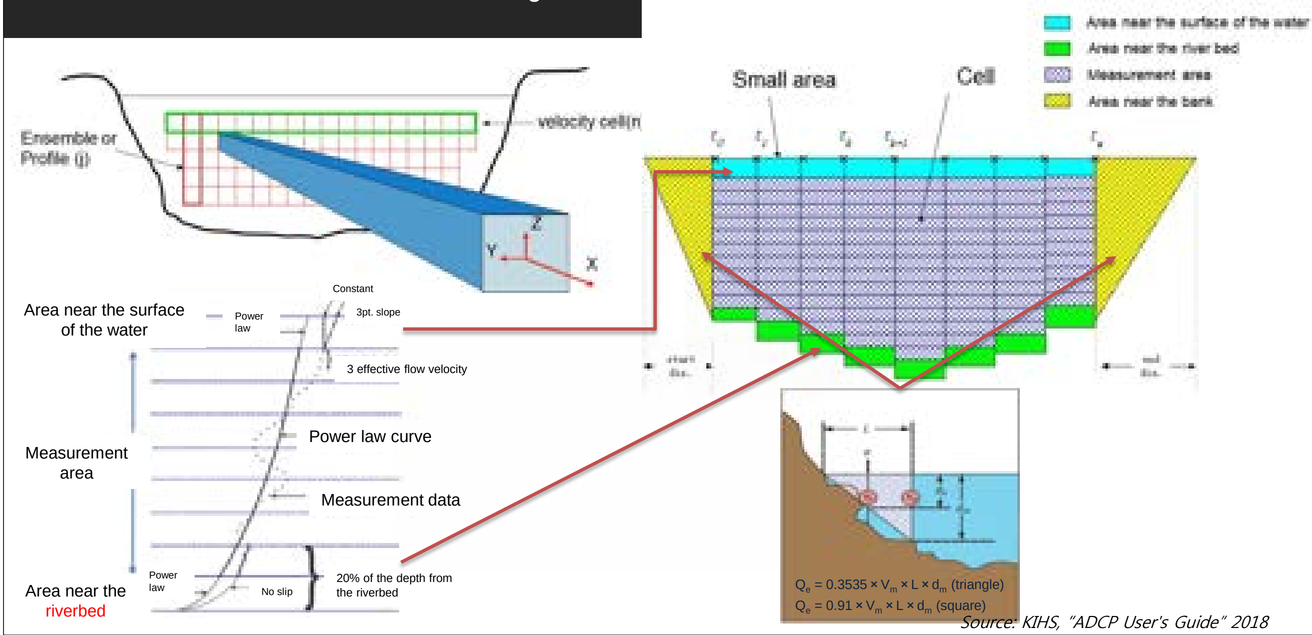


Source: KIHS, "ADCP User's Guide" 2018

2.2 Discharge measurement

▪ Moving Vessel Method

- Calculation of discharge in the measurement area
  · ADCP calculates the discharge for each depth cell in the measurement area and then sums it all in the transverse direction to calculate the discharge.



Source: KIHS, "ADCP User's Guide" 2018

2.2 Discharge measurement

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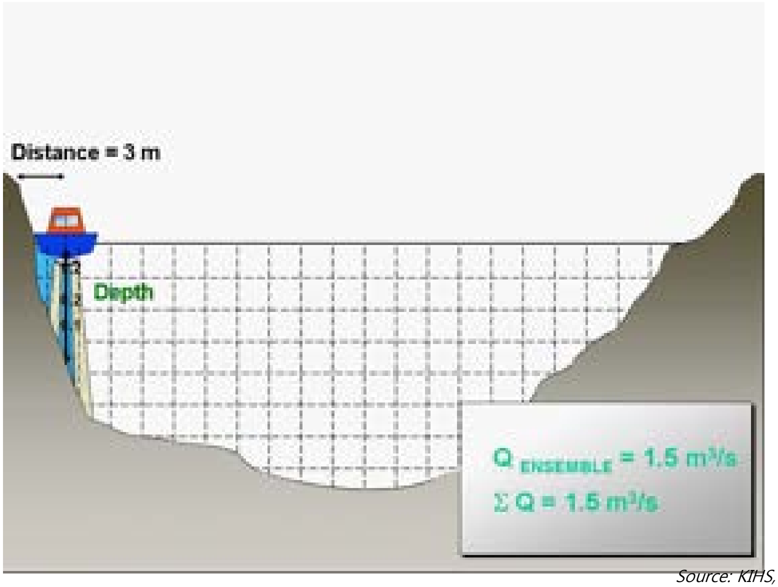


Source: KIHS, "ADCP User's Guide" 2018

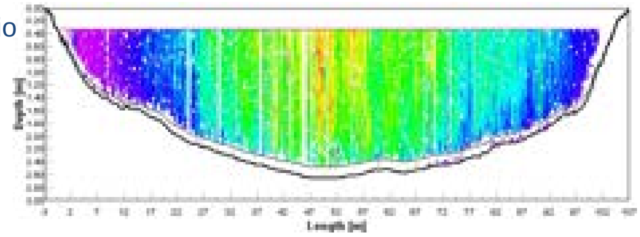
2.2 Discharge measurement

▪ Moving Vessel Method

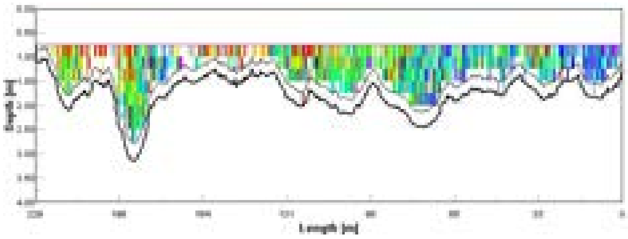
- Relative size of measurement area and unmeasured area according to cross-sectional shape

Measurement area/Total area ratio

about 85%



about 55%

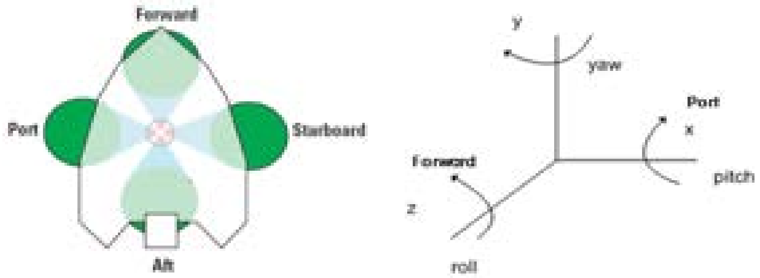


2.3 Precautions

▪ **ADCP Installation**

- Arrangement of ADCP(when using a boat)
  - When measuring by connecting ADCP to a boat, it can be placed in front of and behind the boat, on both sides and in the center of the boat, usually placed on both sides of the boat.

· Easy to deploy
· Easy to measure ADCP depth
· There is a possibility that deflection in the direction of movement may occur in the measured discharge.
· Possibility to be adjacent to other elements of ferrous metal (engine) or electromagnetic field
· There is a possibility of damage to ADCP from floating objects or obstacles.
· ADCP depth is sensitive to deflection due to roll.



2.3 Precautions

▪ **Number of Transect Measurements**

- In the case of steady flow

· Perform 4 repeated measurements

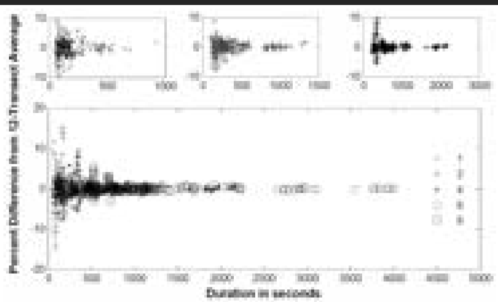
· If any one of the four measurement results exceeds 5% of the coefficient of variation of discharge, four additional measurements are made.

- When the water level changes

· In case of rapid change in flow, one transect measurement can be used as the discharge, but the reason should be recorded.

▪ **Total Transect Measurement Time**

- For at least two repeated measurements, it is recommended that the total transect measurement time be 500 seconds or more or the average boat crossing speed is 50% or less of the mean velocity.



SOURCE: USGS, 2011

2.3 Precautions

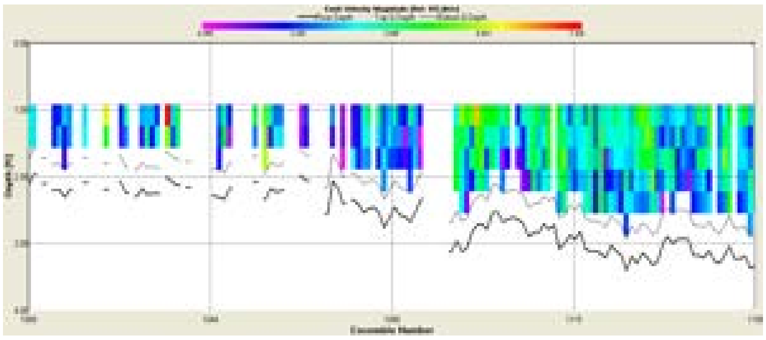
- % of measured discharge
  - The ratio of the discharge in the measurement area to the transect measurement discharge is at least 40%.
- % of edge (near the bank) discharge
  - It is recommended to ensure that the ratio of the discharge in the edge area combined with the left and right edge is within a maximum of 10%.
- Coefficient of Variation Width & Cross-Sectional Area
  - In the case of two or more cross-sectional measurements, it is recommended that the coefficient of variation of the average water surface width and cross-sectional area be at least 10% for any of the measurement results.

3. Review of ADCP Measurement Cases

3. Review of ADCP Measurement Cases

- Inappropriate measurement case for sections with very irregular beds

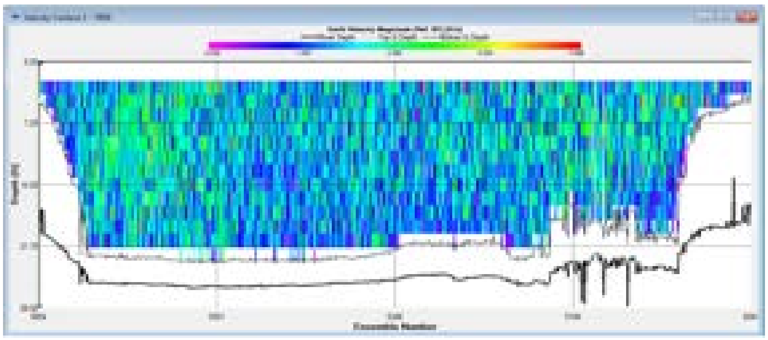
  - (Key Point) Excessive areas of the unmeasurable area near sleep, excessive missing profiles, and bias
  - (Solution) Measurement of deep and smooth cross-section, using high frequency ADCP for low depth



3. Review of ADCP Measurement Cases

- Inappropriate measurement case of section with vertical edge

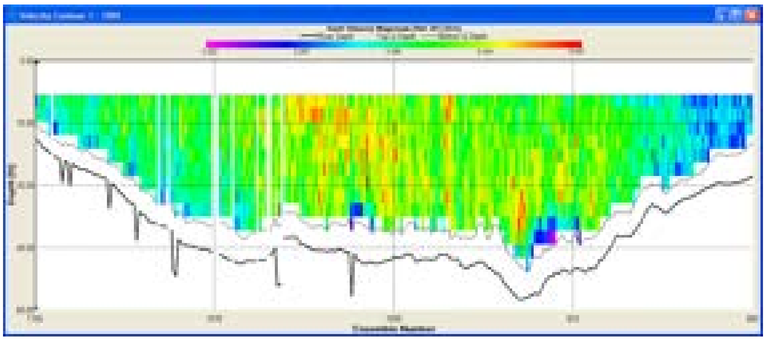
  - (Key Point) Acquisition of abnormal water depth and flow velocity profile due to side-lobe effect is too close to the vertical edge position.
  - (Solution) Change the left and right edge start and end positions to a position where there is no side-lobe effect, and clear vertical edge treatment in the edge setting



3. Review of ADCP Measurement Cases

▪ Measurement cases in which a number of false measurements of water depth occurred-1

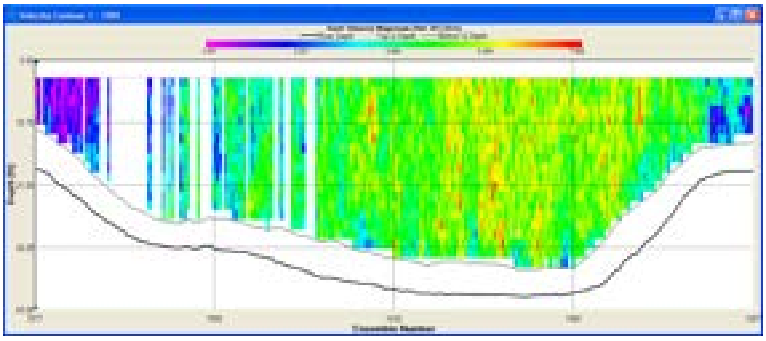
- (Key Point) Many false measurement of water depth occurs.
- (Solution) Post-processing of changing the average depth calculation method setting and applying depth filtering



3. Review of ADCP Measurement Cases

▪ Measurement cases with many missing profiles

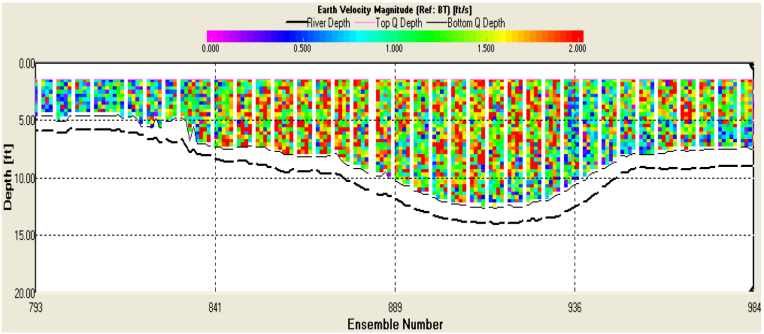
- (Key Point) Communication errors or many missing profiles due to very high crossing speeds
- (Solution) Confirmation of communication quality deterioration factors in the surrounding environment or after interpolation of low-speed traversing and missing profiles



3. Review of ADCP Measurement Cases

- Measurement cases with periodic missing due to communication problems

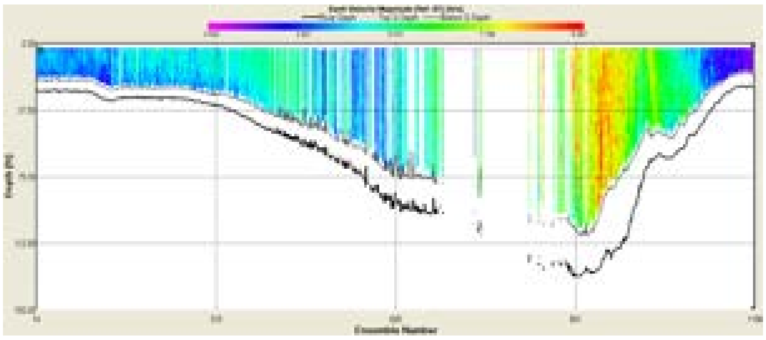
- (Key Point) Periodic missing of flow velocity profile due to the communication error
- (Solution) Battery replacement to maintain proper voltage, missing profile interpolation post-processing



3. Review of ADCP Measurement Cases

- Cases of missing information due to high-concentration suspended-sediment load during the flood season

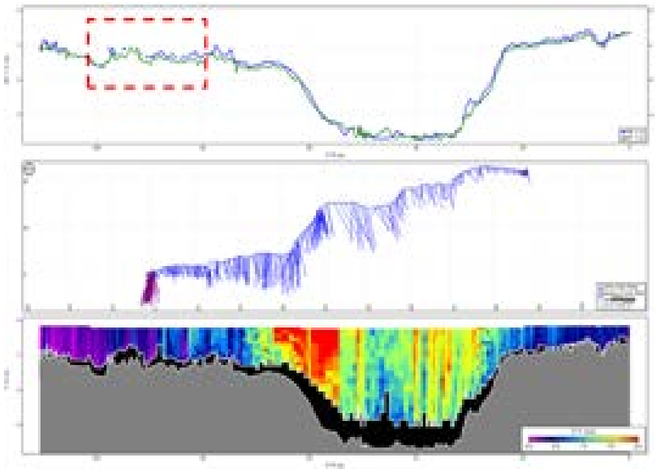
- (Key Point) Profile missing is concentrated in areas where high-concentration suspended-sediment load flow occurs.
- (Solution) Using an acoustic sounding device or a low-frequency vertical beam, using a low-frequency ADCP for flow velocity measurement, and post-processing the missing profile (however, if the missing rate is over 25%, it is necessary to determine whether to use the data)



3. Review of ADCP Measurement Cases

- A measurement case in which vegetation caused miscalculation during flooding of the high-water site

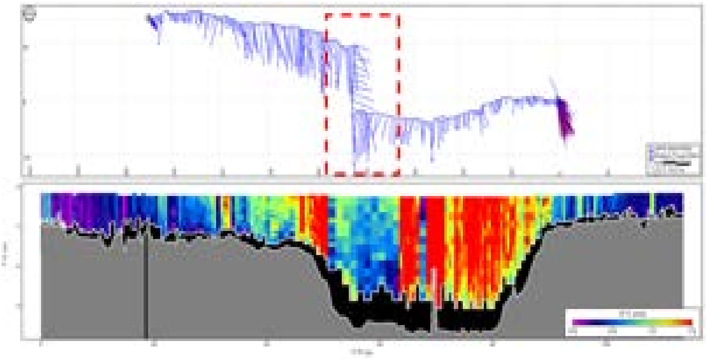
- (Key Point) When measuring the flooded section of the high-water site, errors in the depth and flow velocity profile occur due to the influence of vegetation.
- (Solution) It is necessary to determine whether or not it is possible to measure by considering the height of the vegetation in the flooded section of the high-water site, and post-processing of the false profile. (however, it is necessary to determine whether data is used or not.)



3. Review of ADCP Measurement Cases

- A measurement case in which an error occurred due to the rapidly change of the ADCP's travel path

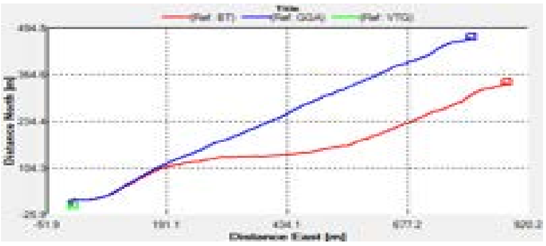
- (Key Point) Flow velocity profile error occurs due to the rapidly change of ADCP's travel path.
- (Solution) Smooth movement of ADCP minimizes false profile.

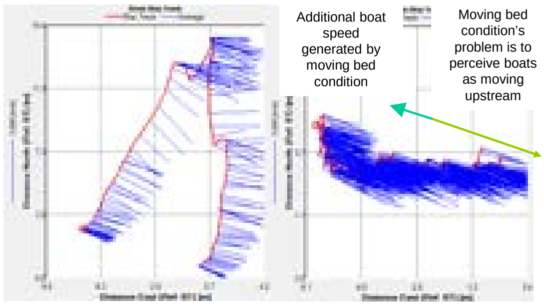


3. Review of ADCP Measurement Cases

▪ Measurement example with moving bed condition

- (Key Point) As a moving bed condition occurs, ADCP appears to move upstream, resulting in deviation of the measured discharge.
- (Solution) Using tracking by GNSS, discharge correction using moving bed testing

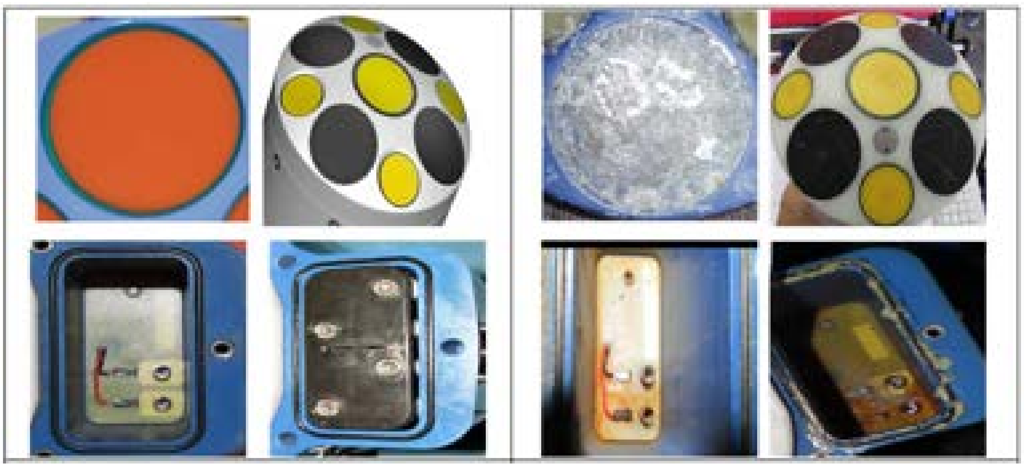




4. ADCP Maintenance

- **Appearance Inspection**

  - Transducer, temp., sensor, battery compartment & holder



Good Bad

4. ADCP Maintenance

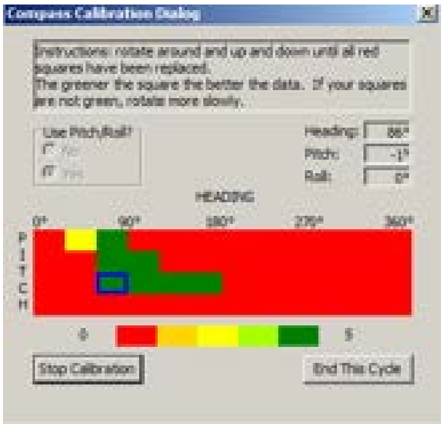
- **Appearance Inspection**

  - Cable & connector: corrosion, O-ring, etc.

4. ADCP Maintenance

▪ Compass Calibration

- Performed according to the compass calibration program and procedure provided by each manufacturer

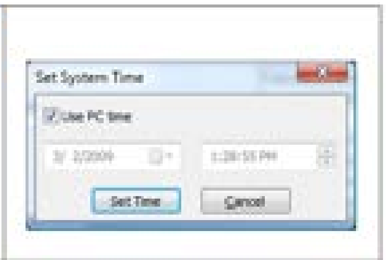


4. ADCP Maintenance

▪ Diagnostic Test

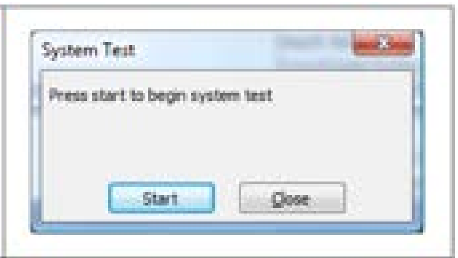
- Serial communication connection check, ADCP time check and synchronization
- ADCP system test: Check signal processing and communication board, recorder, voltage, temperature sensor, beam, etc.

TRDI WinRiver II



SonTek/Xylem RiverSurveyor Live

TRDI WinRiver II

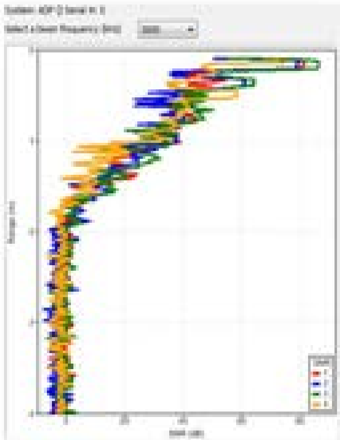


SonTek/Xylem RiverSurveyor Live

4. ADCP Maintenance

■ **Water Tank Test**

- Beam check, temperature check, zero velocity check, tracking check



SOURCE: USGS, “About the USGS Hydrologic Instrumentation Facility (HIF)” 2018

4. ADCP Maintenance

■ **Quality Assurance Test Requirements**

- Comparative measurement is a field flow measurement that can obtain flow data that can be compared and verified in a general water level-discharge relationship (H-Q) using a verified ADCP of the same or other types.

Table 5. Quality-assurance test requirements for acoustic Doppler current profilers (ADCPs).

Instrument situation	Quality-assurance test: Beam alignment test*	Quality-assurance test: Transformation matrix check	Quality-assurance test: Comparison measurement
New	Required		Required
Transducer repair or replacement	Required		Required
Non-transducer hardware repair or upgrade		Required	Required
Required, recommended, or allowed firmware change		Required	
Unapproved or testing firmware change		Required	Required
At least once within a 3-year period			Required

*See detailed description of beam alignment for applicability to specific ADCPs.

SOURCE: USGS, 2014


Thank you very much

MEMO

Introduction of IRDIMS

Hydrological Survey

Introduction of the Integration River Discharge Measurement System

KIHS 한국수자원조사기술원 Korea Institute of Hydrological Survey

Aims & Objectives

- The aims of the course are to:
  (1) Introduce the **principal and practical operation** of integration river discharge measurement system (IRDIMS)
  (2) Improve trainees' understanding of the **need of measurement facilities** such as IRDIMS

- **At the conclusion of the course, trainees** will be able to:
  (1) Use and operate the **automatic discharge measurement system**
  (2) Describe all procedures for IRDIMS operation **from installation to data processing**

References

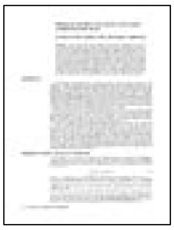
CONSTRUCTION & OPERATION of IRDIMS (Roh, 2015)

Computation of Discharge Using IVM in Tidally Affected Area (USGS, 2005)

Acoustic Doppler Current Profiler (RDI, 2011)

Argonaut-SL System Manual (SonTek/YSI, 2009)

Computing Discharge Using the Index Velocity Method (USGS, 2012)



Maximum and Mean Velocities and Entropy in Open-Channel Flow (Chiu et al., 1995)

Report of Hydrological Data (MOLIT, 2007~2018)

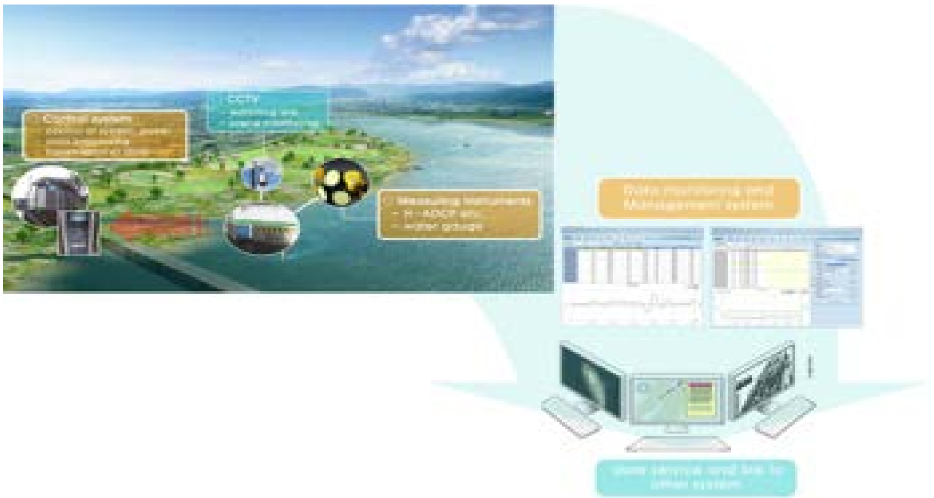
Contents

1. Introduction

1.1 Introduction of IRDIMS
1.2 Status of IRDIMS

1.1 Introduction of IRDIMS

- **IRDIMS**
  - Discharge measurement system using H-ADCP
  - Real-time discharge measurement under backwater or tidal conditions that H-Q rating cannot be developed
  - IRDIMS consists of measuring instruments, a control system, and a data monitoring and management system

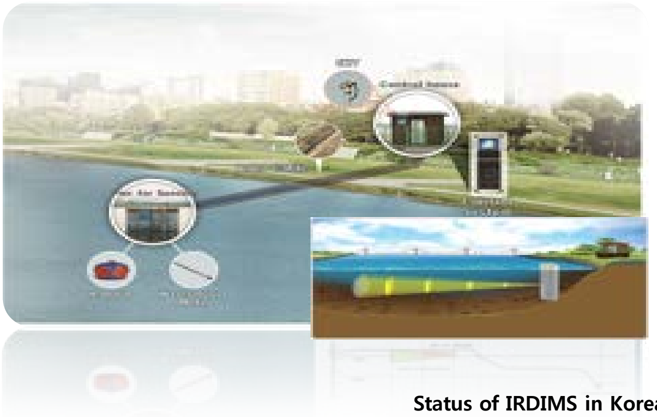


Introduction of IRDIMS systems (Roh, 2016)

1.2 Status of IRDIMS in Korea

- **Construction and operation of IRDIMS**
  - IRDIMS is widely used to measure real-time discharge in Korea.
  - IRDIMS has been mainly installed in stations with difficult-to-measure discharge due to the backwater or the tidal effect and key stations to forecast floods.
  - 63 stations have been constructed and are operating now, and it will be extended to more than 100 stations.

Total	Han River	Nakdong River	Keum River	Yeongsan River
62	19	23	10	10



Status of IRDIMS in Korea (Roh, 2015)

2. Principle of Measurement

2.1 Types of Acoustic Velocity Meter
2.2 Principles of Acoustic Doppler Velocity Meters
2.3 Discharge Calculation

2.1 Types of Acoustic Velocity Meters

▪ Measurement of velocity using characteristics of acoustic waves

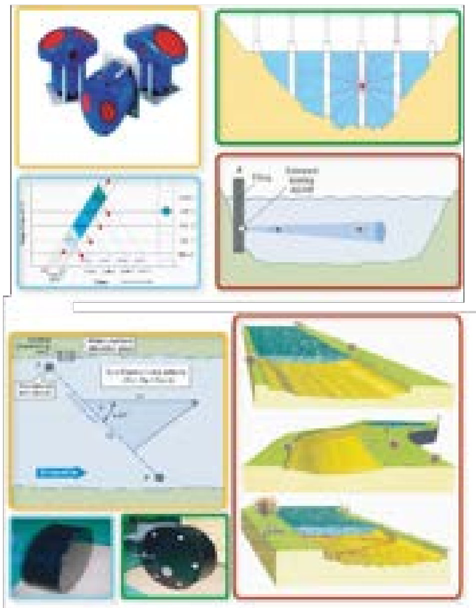
- Acoustic Doppler Velocity Meter (ADVM) and ultrasonic velocity meter (UVM) are the most widely used to measure discharge.

ADVM (Acoustic Doppler Velocity Meter)

- Measurement of velocity using '**Doppler effect**' of acoustic pulse having specific frequency
- Velocity within acoustic beam(cells) is determined on the basis of the change in the frequency of acoustic pulse
- Side-looking type of H-ADCP(Horizontal Acoustic Doppler Current Profiler) is the most used

UVM (Ultrasonic Velocity Meter)

- Measurement of velocity using travel time difference of acoustic pulse between upward and downward direction of flow
- Flow velocity is proportional to time travel difference
- 2 T/T transducers are installed at angle of 30~60º in the flow direction
- Single and multi-layer path, cross path, respond path are available for flow condition



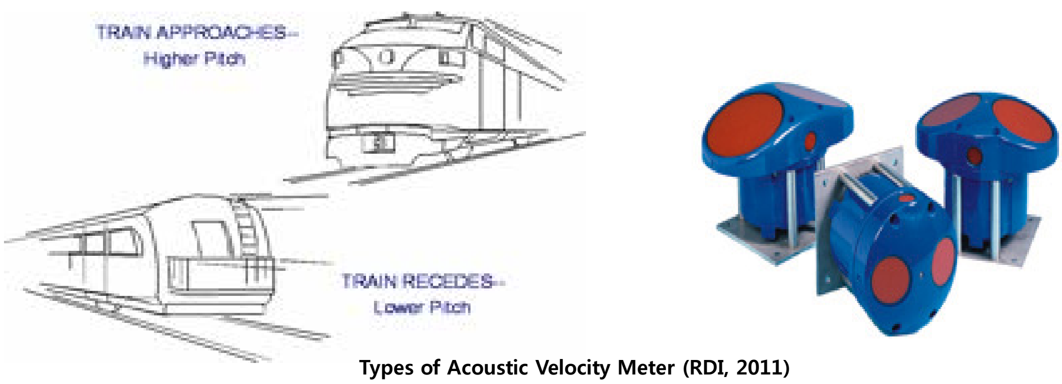
Types of Acoustic Velocity Meter (Roh, 2015), USGS (2005)

2.2 Principle of ADVM

▪ H-ADCP measurement using Doppler effect

- An acoustic pulse of a specific frequency from H-ADCP is transmitted into the water column along the acoustic beam.
- A fraction of acoustic pulse is reflected by small particles in the water, returning to the transducer at a frequency that has been shifted due to the Doppler effect
- The frequency of transmitted *(F_s)* and reflected(F_d) has a relation with velocity (*V*) based on Doppler effect

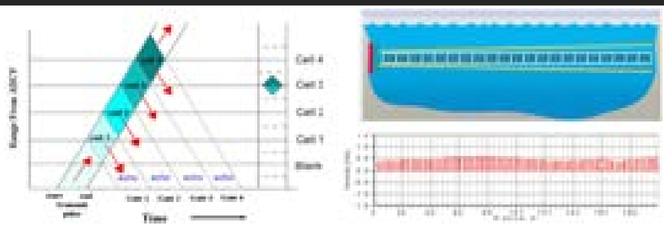
  $F_d = 2F_s(V/C)$, *C*: speed of acoustic pulse
- H-ADCP has 2~4 transducers and can measure a 2~3D velocity vector depending on the number of transducers.



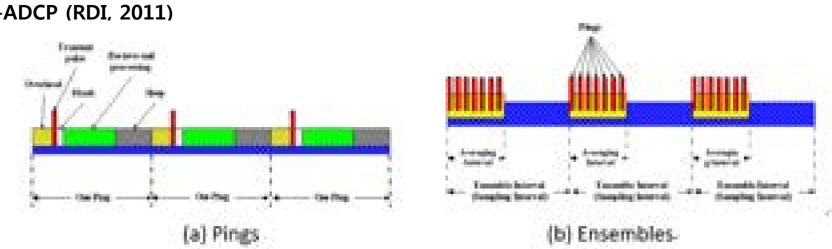
Types of Acoustic Velocity Meter (RDI, 2011)

2.2 Principle of ADVM

- **H-ADCP measurement using Doppler effect**
  - A transducer acquires velocity vector in 100~128 cells at regular interval.
  - The number of cells and their size can be determined depending on the type of the model, and once the number of cells is settled, the size of cells can be determined depending on maximum range of measurement.
  - The velocity of an individual cell is computed by averaging data with an interval of ensemble composed of several pings.



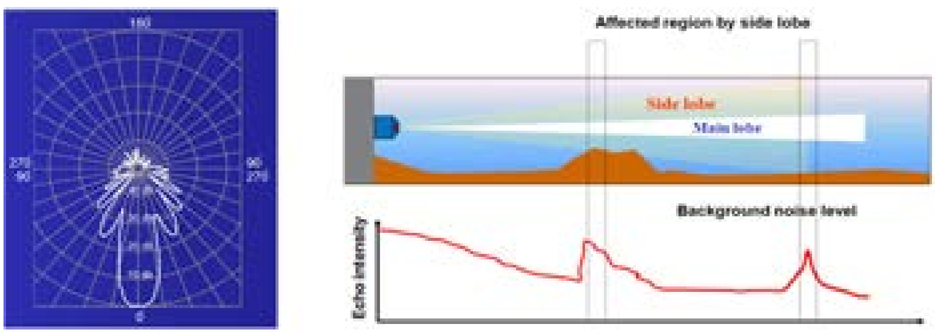
Velocity measurement in cell of H-ADCP (RDI, 2011)



Measurement interval of ADVM (RDI, 2011)

2.2 Principle of ADVM

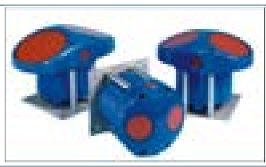
- **Limitation of range of H-ADCP measurement**
  - Energy (signal intensity) of an acoustic pulse is decayed when traveling in water because of spreading loss and attenuation loss, so the available range of ADVM should be shorter as it moves away from the transducer.
  - If an acoustic pulse reaches the bed or water surface (including side-lobe) and signal intensity will be significantly increased, the available measurement should be determined within the range that shows the regular decay of signal intensity.



Characteristics of acoustic pulse (USGS, 2011)

2.2 Principle of ADVM

▪ H-ADCP models and specifications

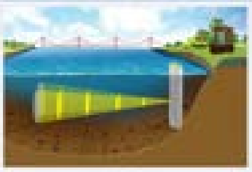
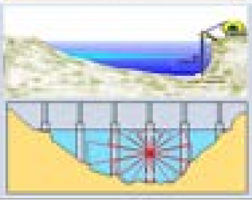
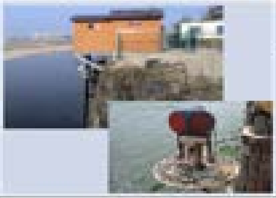
	Specifications							
Models	Channel Master			ADP-SL		ARG-SL		
								
Manufacturer	RD Instruments			SonTek				
Frequency(kHz)	300	600	1,200	250	500	500	1,500	3,000
Maximum range (m)	300	90	20	180	100	120	20	5
Range of velocity (m/s)	default ±5, max. ±20			±10		±6		
Accuracy(%, cm/s)	±0.5%(±0.2cm/s)			±1%(±0.5cm/s)		±1%(±0.5cm/s)		
Resolution(cm/s)	0.1			0.1		0.1		
No. of cells	128			100		10		
Size of cell(m)	1~16	0.5~8	0.25~4	1~20	1~12.0	1.5~30	0.4~8	0.2~4
Beam angle(°)	2.2	1.5	1.5	1.6°		1.5°		
Blanking distance(m)	1	0.5	0.2	1.5	1.0	1.5	0.2	0.1
Aspect Ratio(R:H)	35:1			20:1		20:1		

2.2 Principle of ADVM

▪ Installation of H-ADCP

- Side-looking types are mostly used for discharge measurement

(Roh, 2015)

Types	Measurements	Examples	Remarks
Up-looking			- Installed at the channel bed and measures vertical velocity profile - Suitable for small river and waterway - Problem of sedimentation
Side-looking			- Installed at the both side or center of channel - Measures horizontal velocity profile - Limitation of range depending on depth and shape of cross-section
Moving type up and down /rotation			- Moving ADCP to measure velocity in wider area in cross-section - Device to move ADCP is required - Problems of maintanance

2.2 Principle of ADVM

- **Installation of side-looking type**

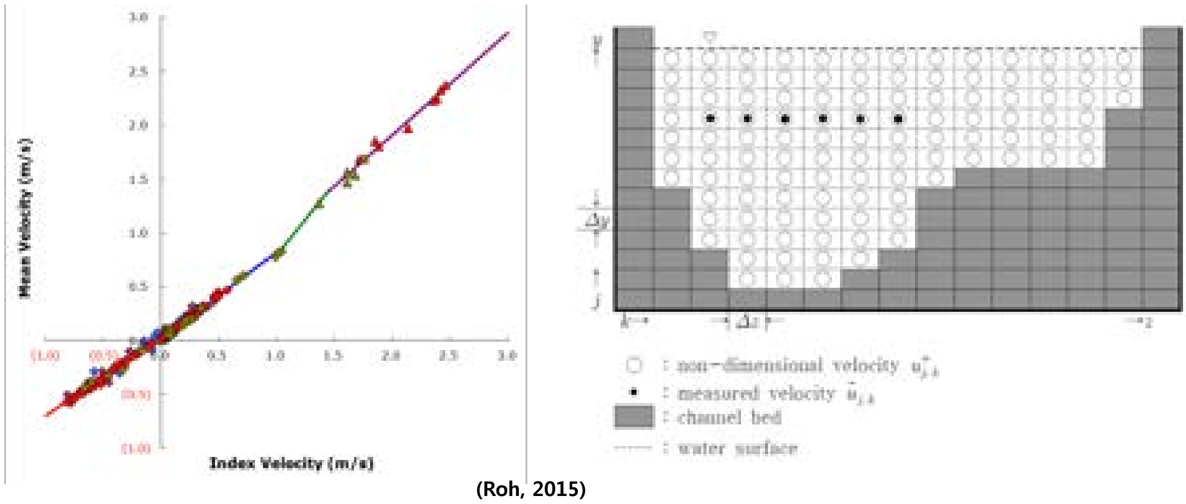
(Roh, 2015)

3. Discharge Calculation

3.1 Types of the Calculation
3.2 Index Velocity Method
3.3 Velocity Profile Method
3.4 Use of the S/W tools

3.1 Types of the Calculation

- **Index Velocity Method (IVM)**
  - Calculating mean velocity by relationship between mean- and index velocity from H-ADCP
- **Velocity Profile Method (VPM)**
  - Velocity distribution of the cross-section is estimated by applying a theoretical velocity profile.



(Roh, 2015)

3.2 Index Velocity Method

- **IVM**
  - Using the relationship between mean and index velocity measured by H-ADCP at a fixed position
  - Several individual discharge measurements are needed to develop the relationship between index and mean velocity throughout the expected range in stage or mean velocity

Procedure of IVM

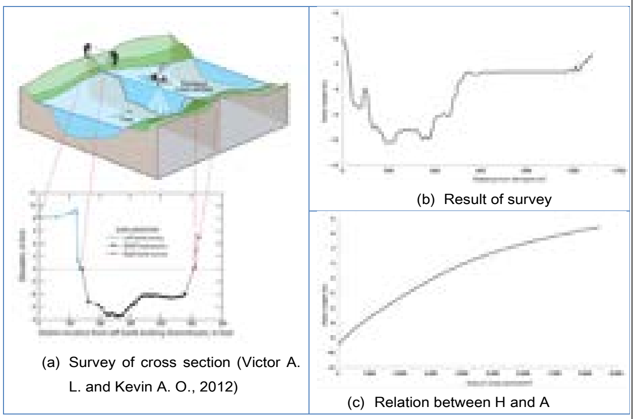
① Discharge measurements to get mean velocity

② Development of relationship between water height (H) and area of cross-section (A)

③ Definition of mean and index velocity

④ Development of relationship between mean and index velocity

⑤ Discharge calculation using index velocity by relationship of H-A and V_i-V_m



(a) Survey of cross section (Victor A. L. and Kevin A. O., 2012)

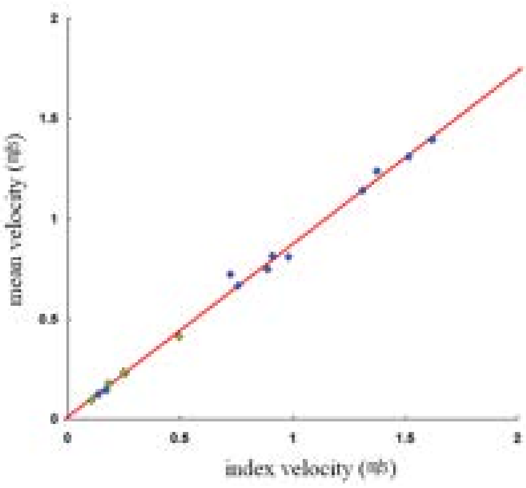
(b) Result of survey

(c) Relation between H and A

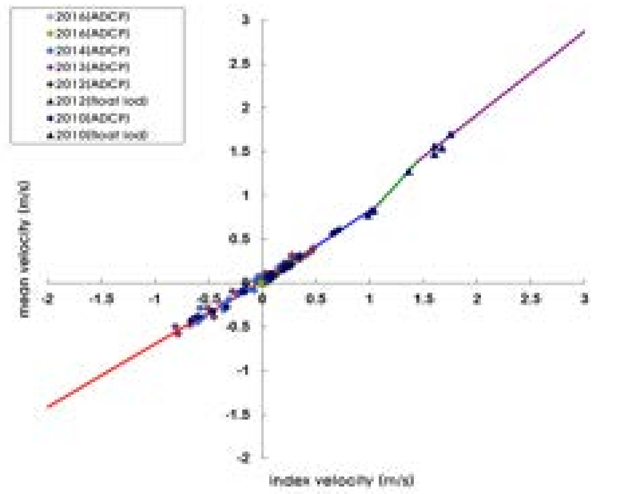
Development of relation between water height and area (USGS, 2011)

3.2 IVM

- **Development of relationship between mean and index velocity**
  - It is necessary to measure enough and well-distributed discharge data in the various velocity range.
  - It could be a single linear equation or 2~3 equations with infection points depending on the variation of the relation.



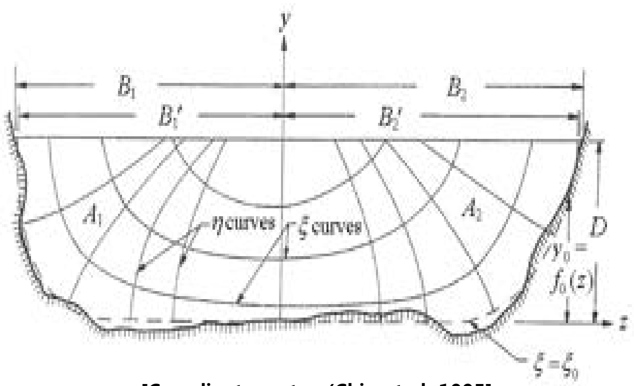
Single linear index rating (USGS, 2011)



Complex index rating (Roh, 2015

3.3 Velocity Profile Method

- **VPM**
  - Chiu (1989)`s 2D distribution based on entropy theory



[Coordinate system(Chiu et al, 1995]

Transformation of ξ − η coordinate system

$$\xi = Y(1-Z)^{\beta_i}\exp(\beta_i Z - Y + 1)$$

$$Y = \frac{y+\delta_y}{D+\delta_y+h} \quad Z = \frac{|z|}{B_i+\delta_i}$$

Chiu`s 2D velocity distribution

$$\frac{u}{u_{max}} = \frac{1}{M} ln\left[1 + (e^M - 1)\frac{\xi - \xi_0}{\xi_{max} - \xi_0}\right]$$

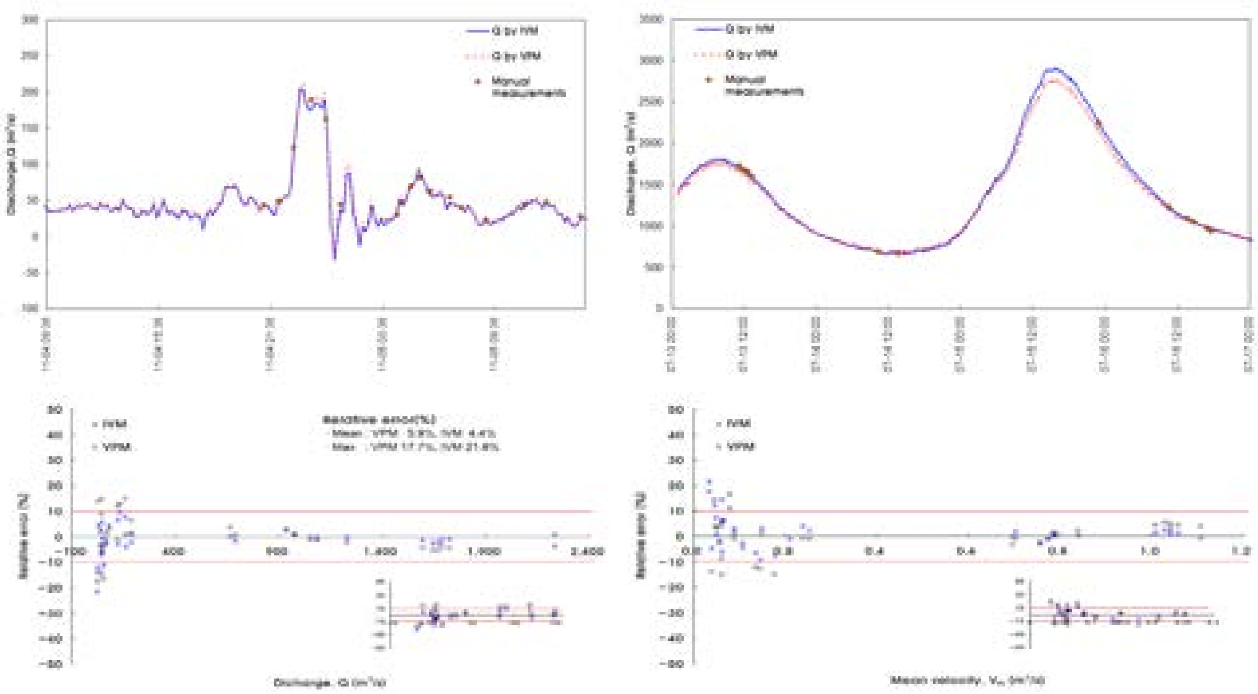
$$\phi(M) = \frac{\bar{u}}{u_{max}} = e^M(e^M - 1)^{-1} - \frac{1}{M}$$

Parameters

- h/D, z/B : Position of Max velocity(in depth and width)
- β_L,β_R : parameters related to shape of iso-vel ξ curve
- entrophy parameter M

3.3 Velocity Profile Method

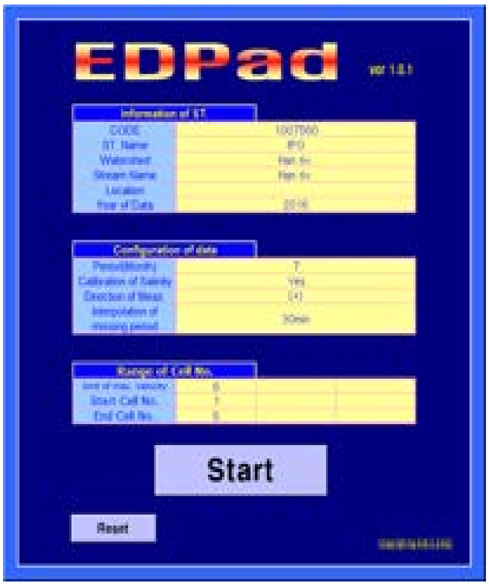
▪ Comparison between IVM and VPM

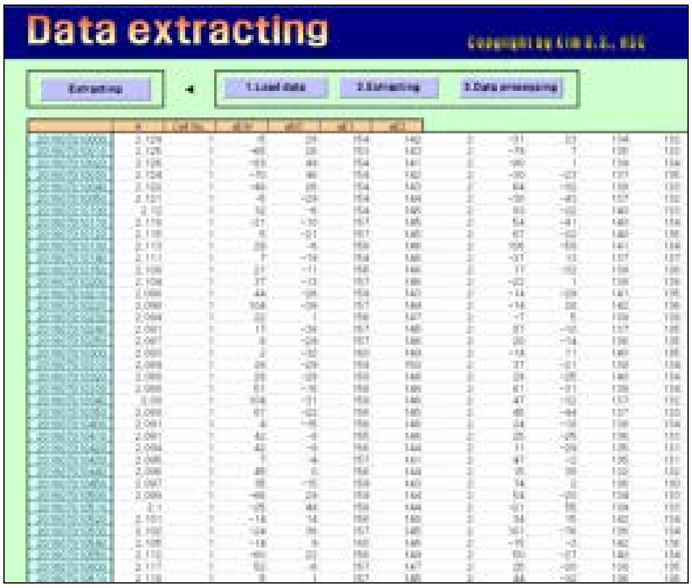


3.4 Use of the Software Tools

▪ EDPad to data extracting from ADVM

- Data handling of index velocity measured by H-ADCP

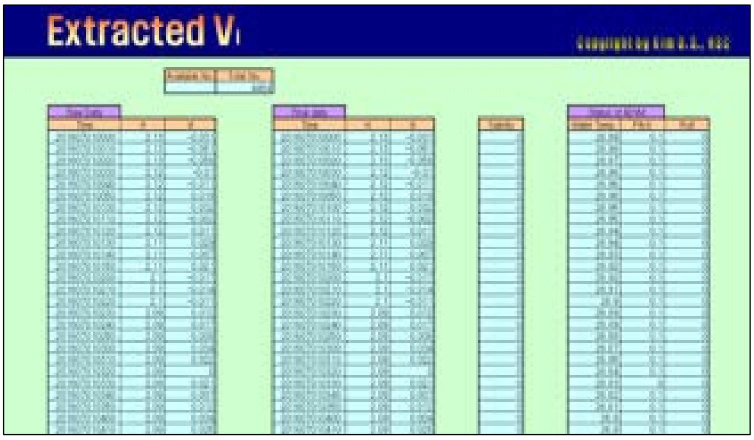


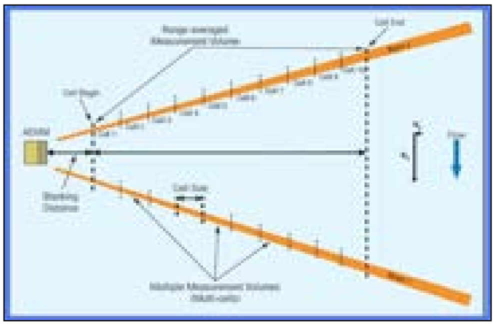


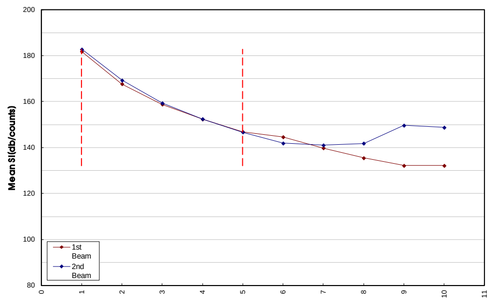
3.4 Use of the Software Tools

▪ **EDPad to data extracting from ADVM**

- Data handling of index velocity measured by H-ADCP



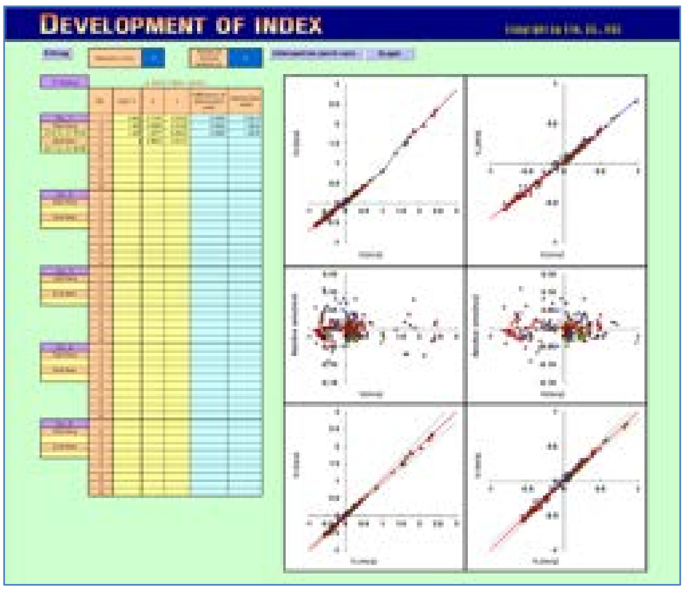




3.4 Use of the Software Tools

▪ **MCDPad to develop index rating**

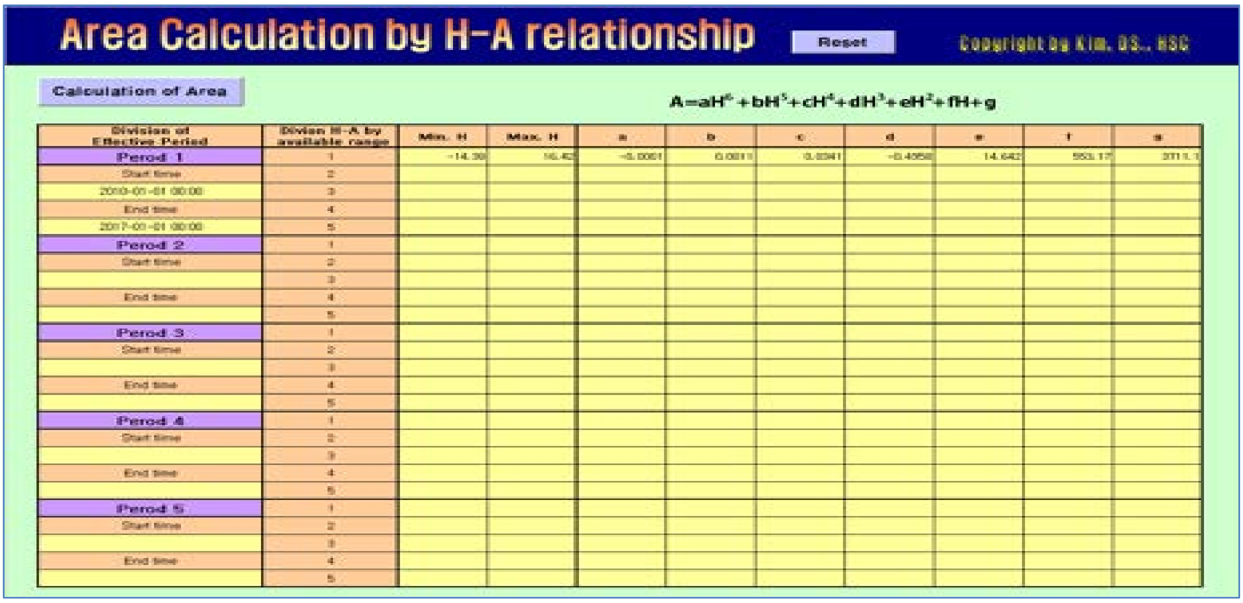
- Providing all procedures for developing index rating and discharge calculation



3.4 Use of the Software Tools

▪ MCDPad to develop index rating

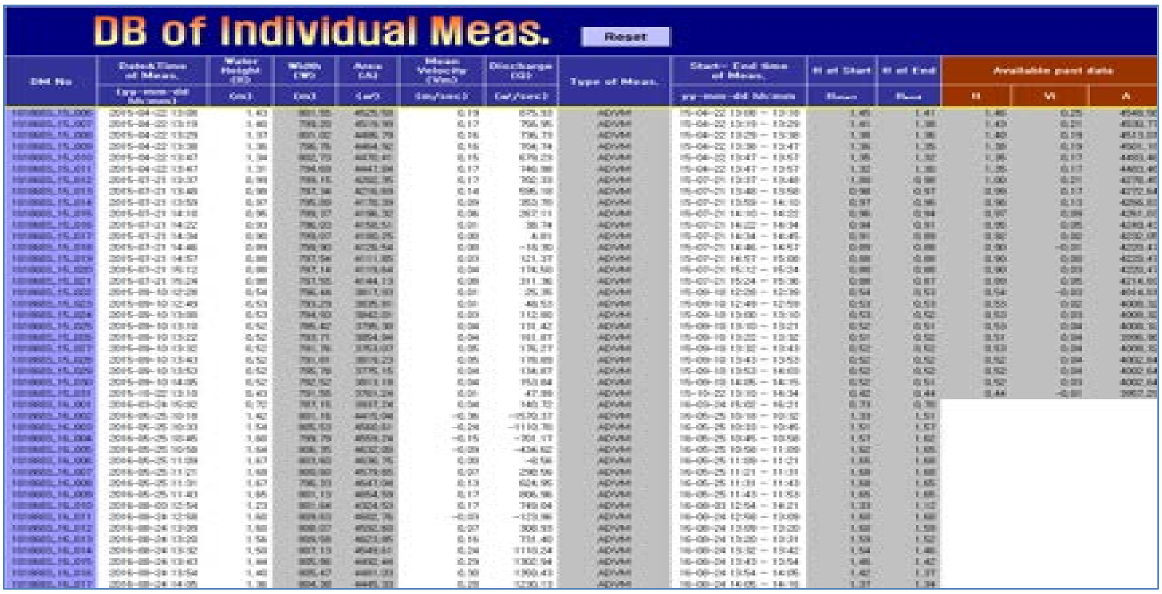
- Development of H-A relation to calculate area of cross section



3.4 Use of the Software Tools

▪ MCDPad to develop index rating

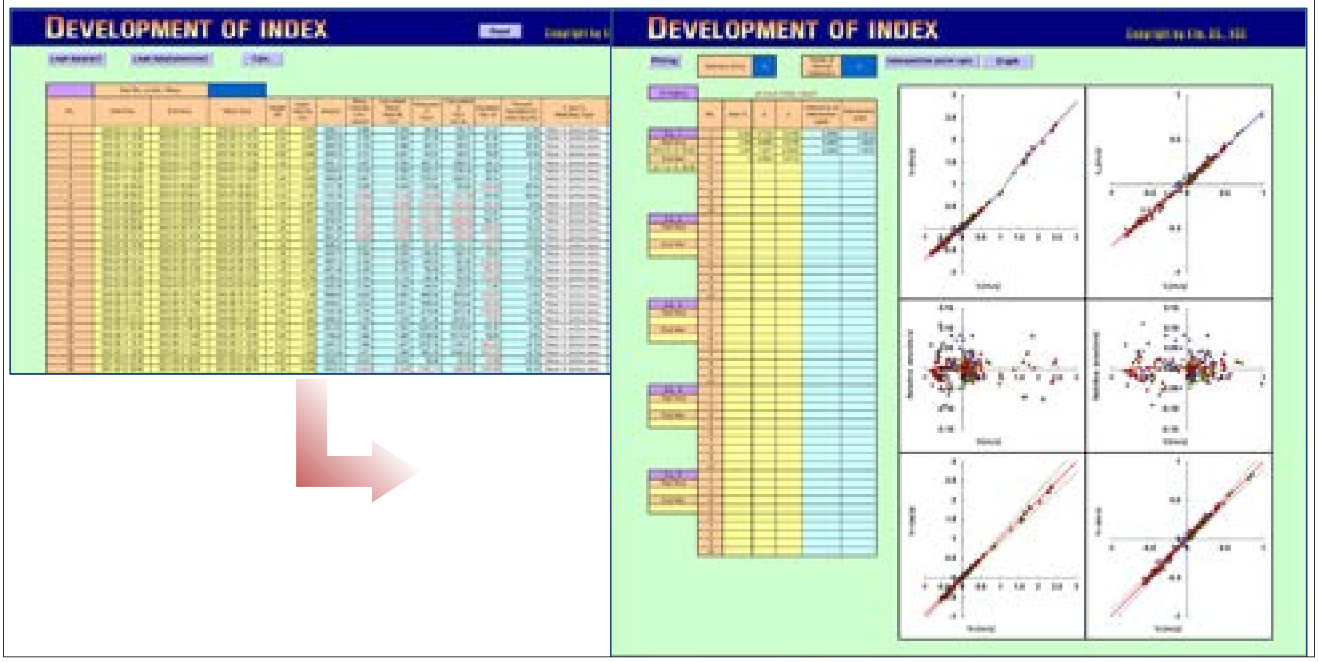
- Mean velocity from individual discharge measurements



3.4 Use of the Software Tools

▪ MCDPad to develop index rating

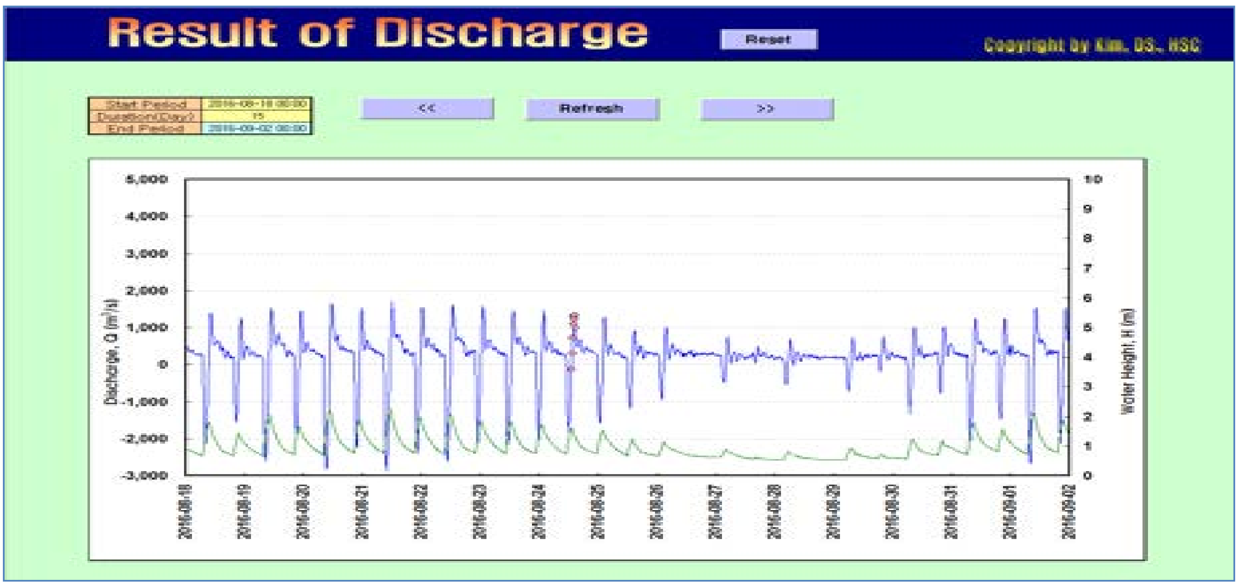
- Development of relationship between mean and index velocity



3.4 Use of the Software Tools

▪ MCDPad to develop index rating

- Calculation of continuous discharge by the index rating from index velocity measured by H-ADCP



4. Examples of Measurement

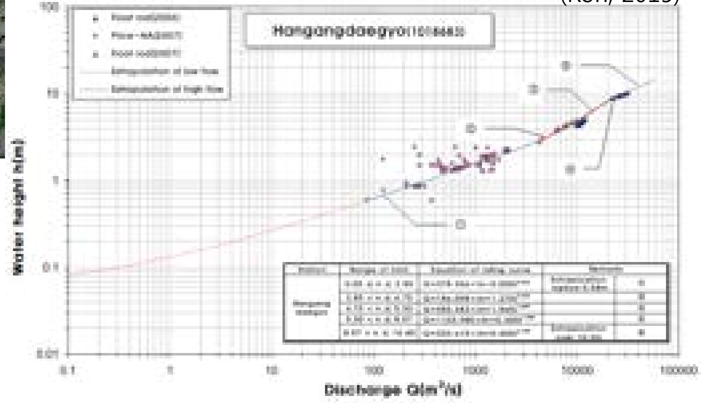
4.1 Tidal Flow Condition
4.2 Backwater Condition
4.3 Comparison Annual Runoff

4.1 Tidal Flow Condition

- **Measurement in tidal effect**
  - The location influenced by tidal changes from the Yellow Sea

Map by Google Earth

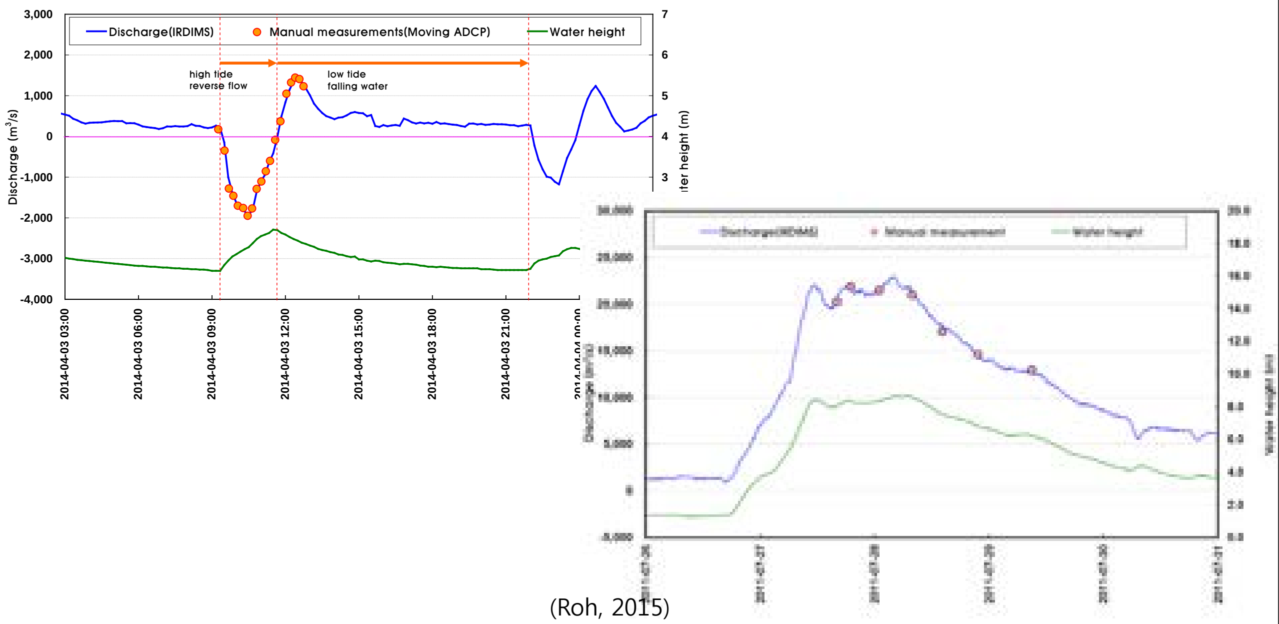
(Roh, 2015)



4.1 Tidal Flow Condition

▪ Measurement in tidal effect

- The location influenced by tidal changes from the Yellow Sea



(Roh, 2015)

4.2 Backwater Condition

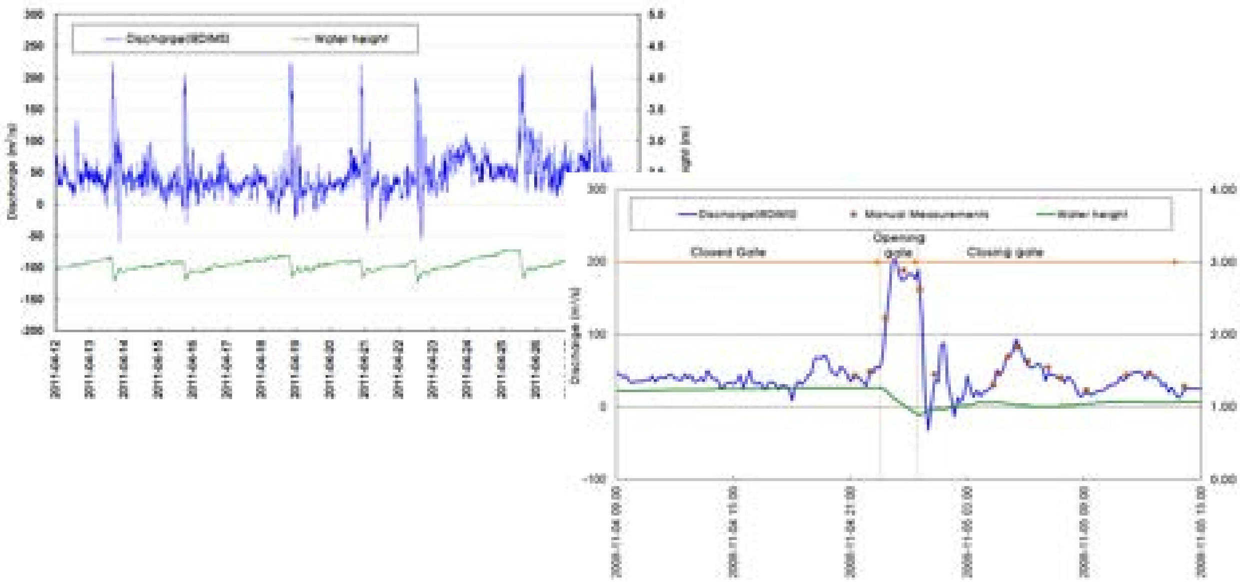
▪ Measurement in backwater condition by the hydraulic structure

- The location affected by backwater from sea dike sluice

Map by V world

4.2 Backwater Condition

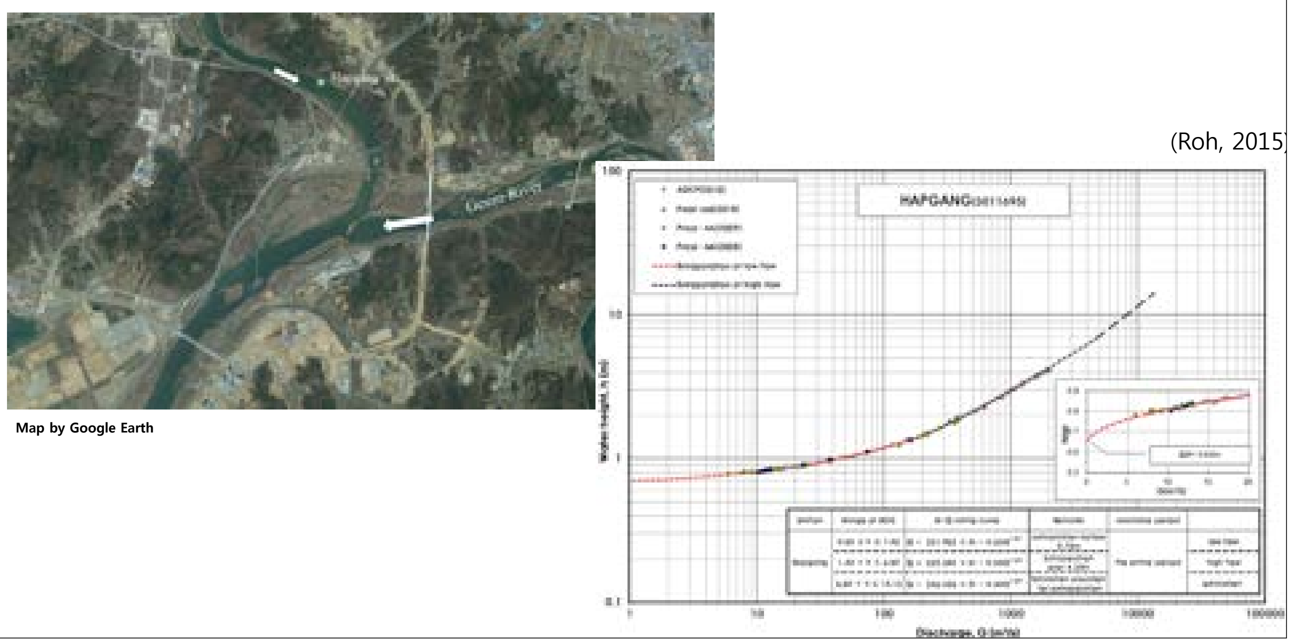
- **Measurement in backwater condition by the hydraulic structure**
  - The location affected by backwater from sea dike sluice



(Roh, 2015)

4.2 Backwater Condition

- **Measurement in backwater condition in a flow junction**
  - The location nearby a flow junction

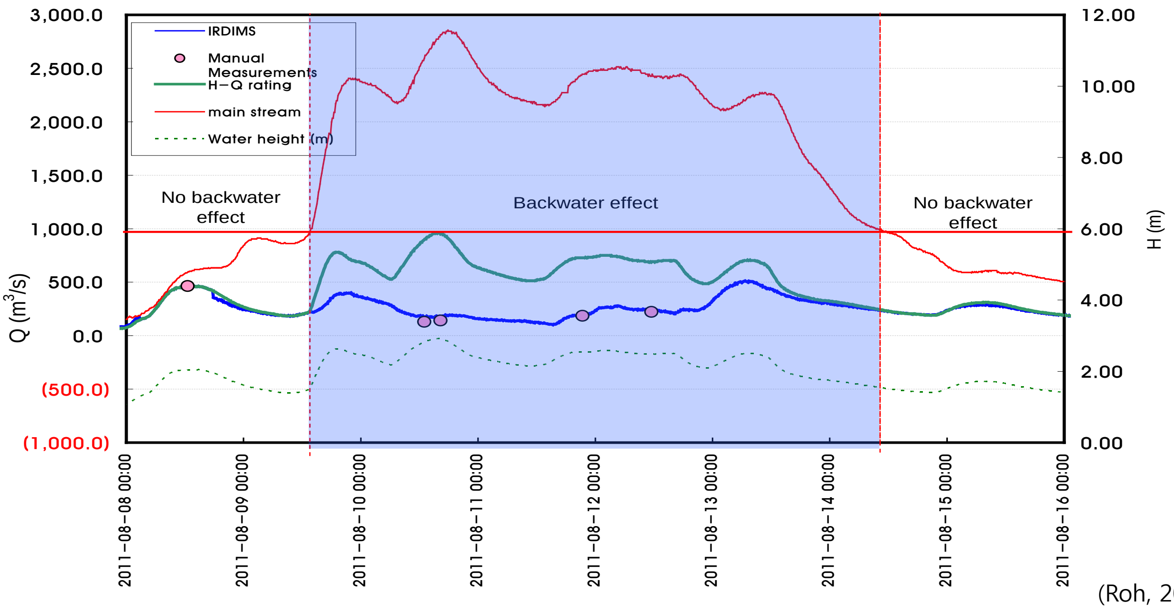


Map by Google Earth

(Roh, 2015)

4.2 Backwater Condition

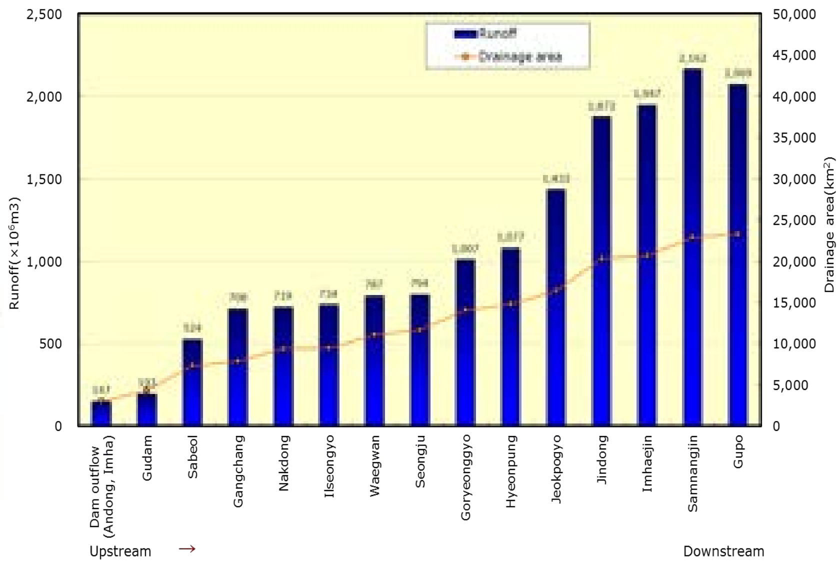
- **Measurement in backwater condition in flow junction**
  - The location nearby a flow junction



(Roh, 2015)

4.3 Comparison Annual Runoff

- **Comparative analysis on runoff of IRDIMS stations**
  - Runoff calculated using the data from 14 IRDIMS stations from up and downstream in the Nakdong River



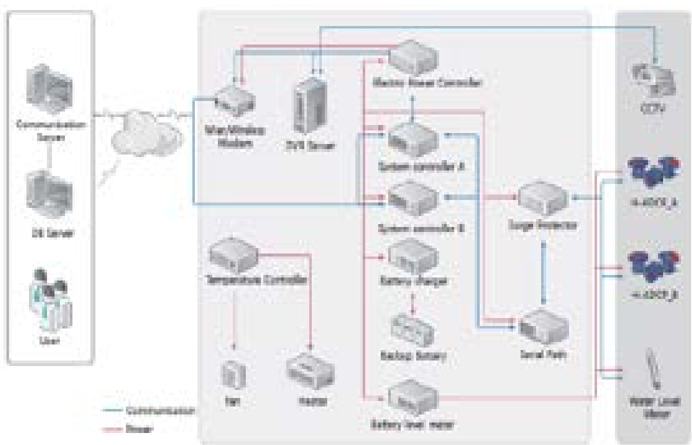
(Roh, 2015)

5. Control System

5.1 Function of the Control System
5.2 Monitoring and management system

5.1 The Function of the Control System

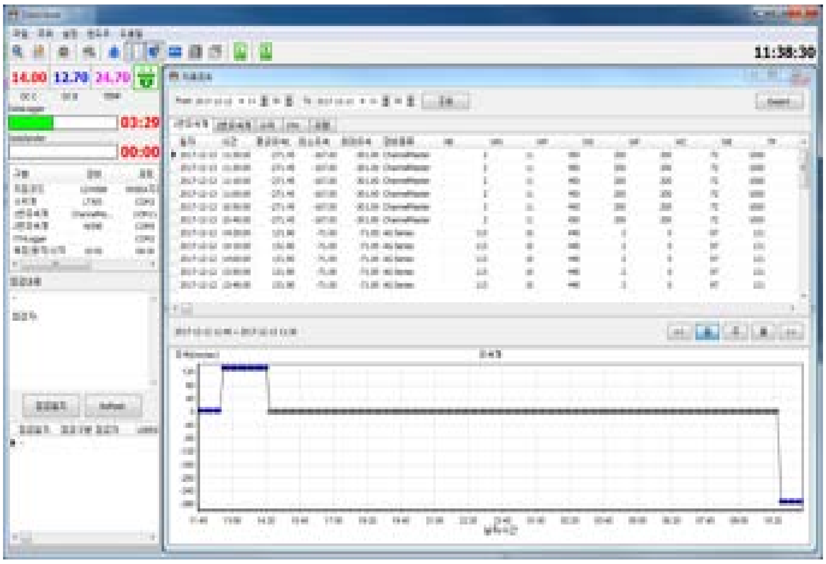
- **The Function of the Control System**
  - Operation and control of all Instruments
  - Data collection, data processing, and real-time data transfer
  - Real-time monitoring and remote control
  - Protection from all damages



5.1 The Function of the Control System

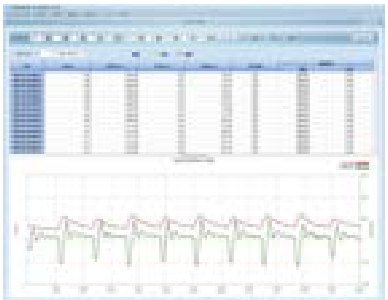
▪ Operation of the Control System

- Data Logger
- Data Sender
- Data Viewer

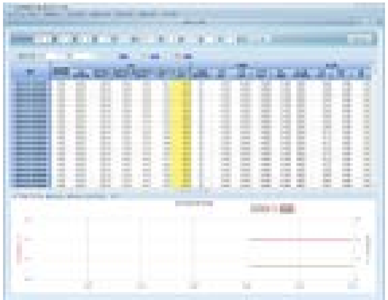


5.2 Monitoring and Management System

▪ Monitoring and management system for real-time operation

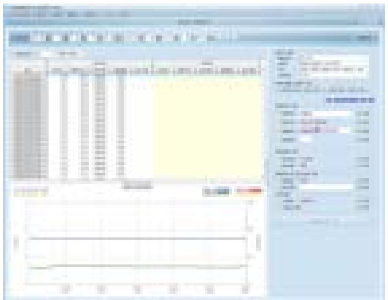


Data monitoring



Monitoring of operational conditions

Analysis of velocity profile



Data Q/C

Management of cross-section

Management of field maintenance

5.2 Monitoring and Management System

▪ Data Code for QC

Div.	code	State of real-time data	Remarks
Real-time	0100	Normal	
	0990	Missing by trouble of data communication	
	0991	Missing by trouble of field system within 30 minute	
	0992	Missing by trouble of field system over 30 minute	
Post-processing	0200	Abnormal data	
	0221	Corrected data by using H-Q curve	
	0222	Corrected data by using linear interpolation	
	0223	Corrected data by using curved interpolation	
	0224	Corrected data by using data of up- and down station	
	0229	Corrected data by using other methods	
	0300	Missing data	
	0321	Corrected data by using H-Q curve	
	0322	Corrected data by using linear interpolation	
	0323	Corrected data by using curved interpolation	
	0324	Corrected data by using data of up- and down station	
	0329	Corrected data by using other methods	
	0500	Abnormal data that is impossible to correct	
	0600	Missing data that is impossible to correct	
	0700	Abnormal data due to the measuring condition of the station	
	0800	Abnormal data by unknown cause	
	0900	Unidentified data	

6. Conclusions

6. Conclusion

- Advanced methods such as IRDIMS are needed to improve the efficiency and accuracy of the discharge measurement under various flow conditions.
- This system is increasing in utility to overcome the limitations of existing measurement methods.
- It is important to determine the installation location and type of H-ADCP considering the flow conditions.
- The accuracy of the calculation depends on the appropriate H-ADCP position and the proper calculation method according to the H-ADCP position.

Thank you very much

Sediment Survey

Hydrological Survey

Sediment Survey:
Suspended and Bed Load Discharge

Aims & Objectives

- The aims of the course are to:

  (1) Promote among trainees a good understanding of the basic measurement principle of sediment
  (2) Enable trainees to improve the measurement method of suspended and bed load
  (3) Have trainees cultivating the technology to calculate total sediment discharge and develop the ability to use sediment data

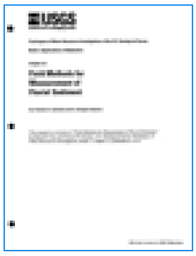
- At the conclusion of this course, trainees will be able to:

  (1) Identify the necessity of sediment discharge survey
  (2) Perform methods of suspended and bed load survey
  (3) Explain methods of calculating suspended discharge and estimating total sediment discharge

References

Suspended-sediment concentration, load, total suspended solid and particle-size fraction (USGS Report, 2013)

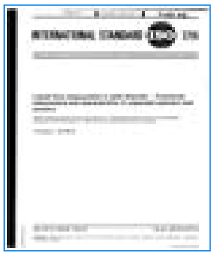
Fluvial Sediment concept, Chapter C1 (USGS Report,)



Field methods for measurement of fluvial sediment, chapter C2 (USGS Report)

Computation of fluvial sediment discharge, chapter C3 (USGS Report)

Laboratory theory and methods for sediment analysis, chapter C1 (USGS Report)



Liquid flow measurement in open channels-functional requirements of suspended sediment load sampler (ISO 3716)

Contents

1. Introduction
2. Sediment sampling equipment and method
3. Laboratory analysis
4. Computing suspended and total sediment discharge

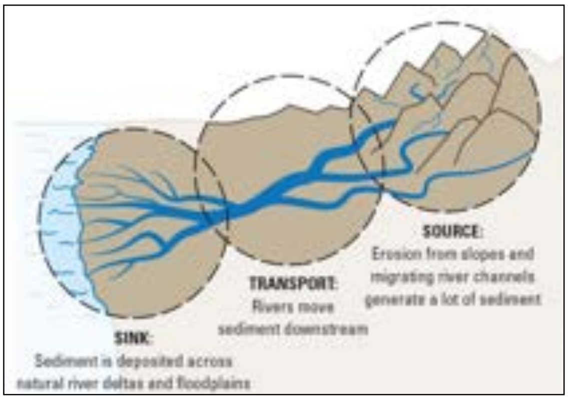
1. Introduction

1.1 A Basic Knowledge

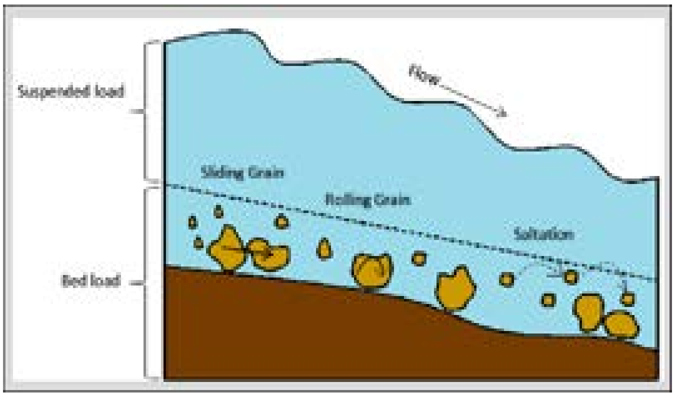
1.1 A Basic Knowledge

- **What is Sediment Load?**

  - **Sediment** is a naturally occurring material that is broken down by processes of weathering and erosion and is subsequently transported by the action of wind, water, or ice or by the force of gravity acting on the particles. For example, sand and silt can be carried in suspension in river water and on reaching the seabed deposited by sedimentation.



Source: https://www.usgs.gov/media/images/sediment-diagram-source-sink



Source: https://www.researchgate.net/figure/Sediment-motion-in-river-morphology_fig1_315977429

1.1 A Basic Knowledge

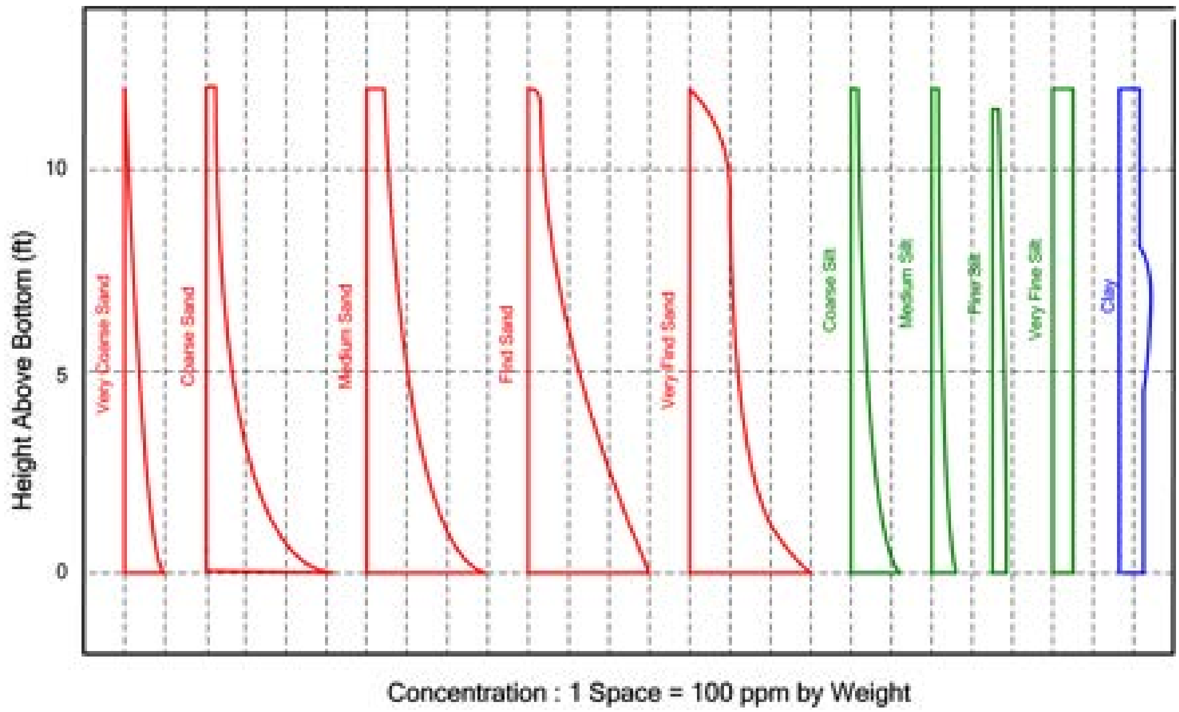
▪ How is River Sediment Classified?

- **Classification of Sediment Load**
  - River sediment load is classified according to the transport form, relationship with hydraulics, and the measurement limit.
  - Suspended load consists of sediment particles that are mechanically transported by suspension within a stream or river.
  - Bed load is the component of fluvial sediment load that moves in a rolling, sliding, and saltating mode.

<table>
<tr><th>Classification</th><th colspan="2">Transfer form</th><th>Relationship with Hydraulics</th><th>Measurement Limit</th></tr>
<tr><td rowspan="4">Sediment Load</td><td colspan="2" rowspan="2">Suspended Load</td><td>Wash Load</td><td rowspan="2">Sampled Load</td></tr>
<tr><td rowspan="3">Bed Material [Sediment] Load (Suspended Load + Bed Load)</td></tr>
<tr><td rowspan="2">Bed Load</td><td>Saltation Load</td><td rowspan="2">Unsampled Load</td></tr>
<tr><td>Contact Load</td></tr>
</table>

1.1 A Basic Knowledge

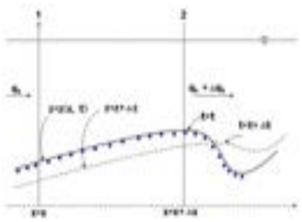
▪ How are River's Sediment Classified?

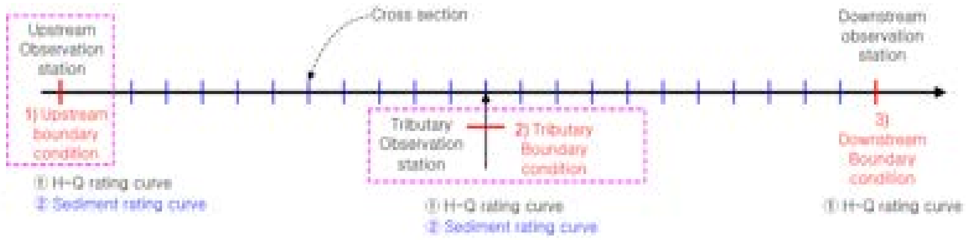


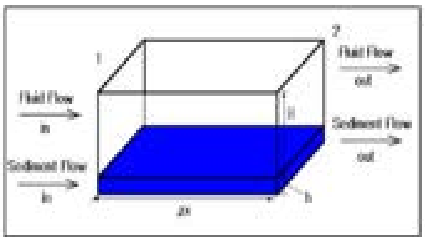
1.1 A Basic Knowledge

▪ Why Do We Measure Sediment Load?

- **<Four elements>** Watershed management, river management, river facility management, dam and reservoir management
- Establishment of river stabilization countermeasures due to artificial river change
- Simulation of riverbed change in the future
- Sediment balance analysis







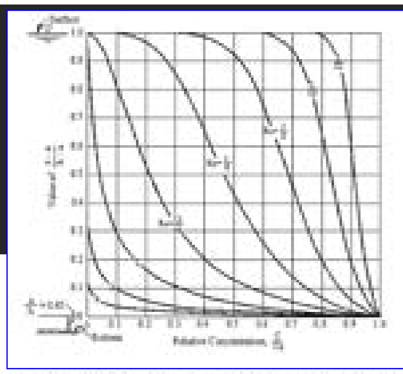
1) Water continuity equation $\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0$

2) Sediment equation $\frac{\partial h}{\partial t} + \frac{1}{\gamma_s} \frac{1}{(1-\lambda)} \frac{\partial q_s}{\partial x} = 0$

1.1 A Basic Knowledge

▪ Characteristics of River Sediment Load

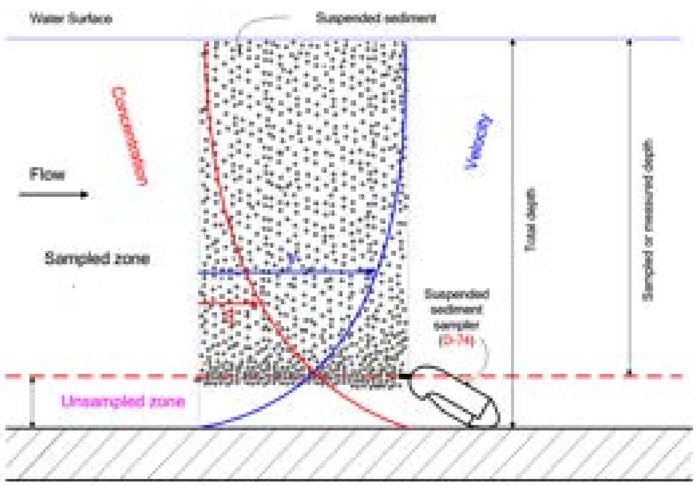
- The concentration of the river's sediment load is large near the riverbed and smaller toward the water surface.
- The flow velocity of the river is lower as the water depth is deeper, and it is higher near the water surface.

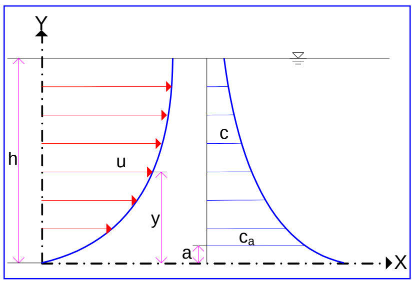


Rouse concentration distribution equation

$$\frac{C}{C_a} = \left[\left(\frac{h-y}{y}\right)\left(\frac{a}{h-a}\right)\right]^z$$

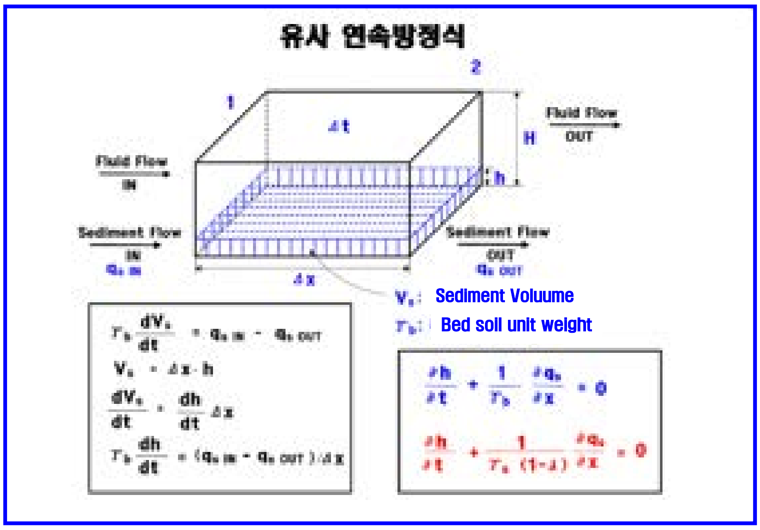
$z = \frac{w_s}{\beta \kappa u_*}$ (Rouse Number)

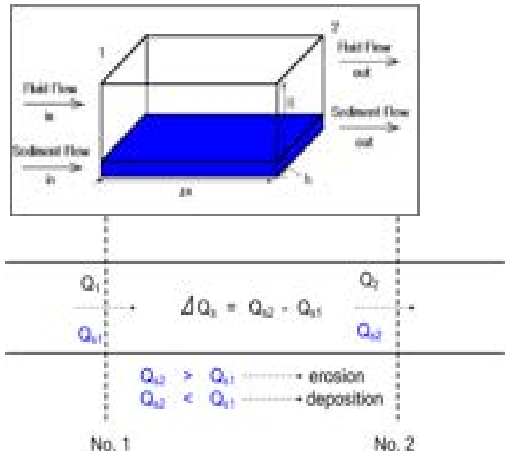




1.1 A Basic Knowledge

▪ Characteristics of River Sediment Load

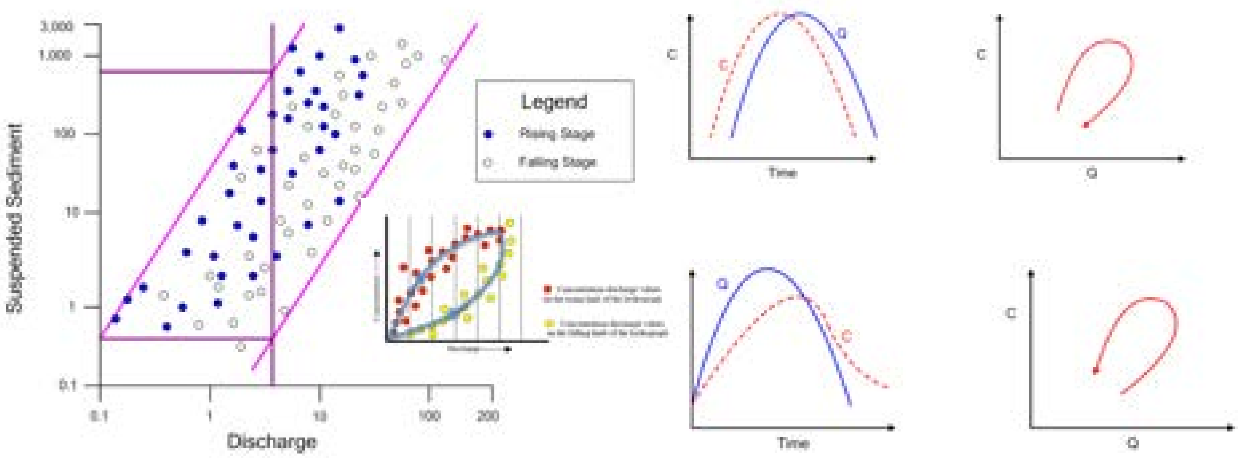




1.1 A Basic Knowledge

▪ Characteristics of River Sediment Load

- The concentration of suspended load is large in the rising part and small in the descending part.
- In general, natural rivers show clockwise characteristics.
- Rivers that are artificially controlled show counterclockwise characteristics.



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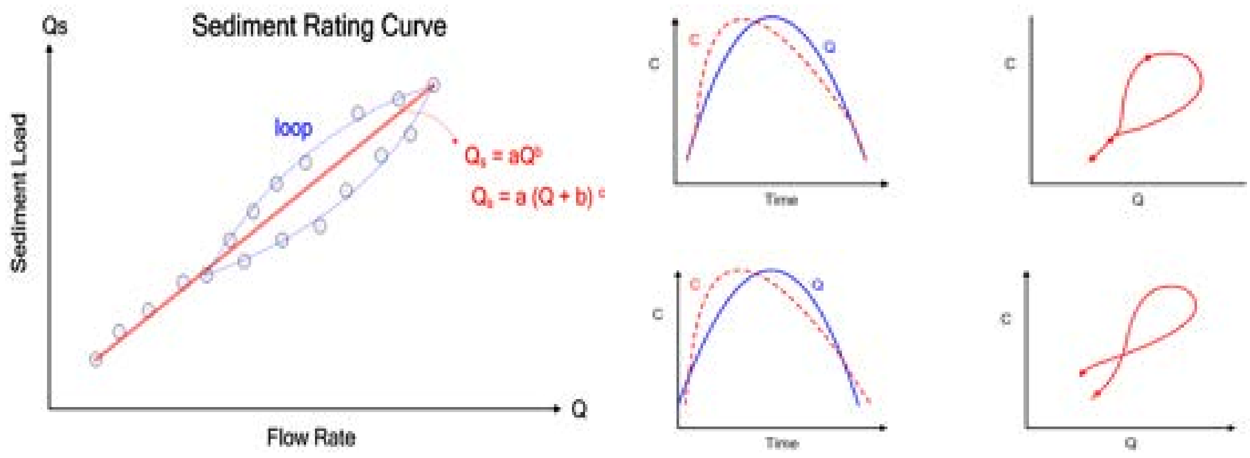
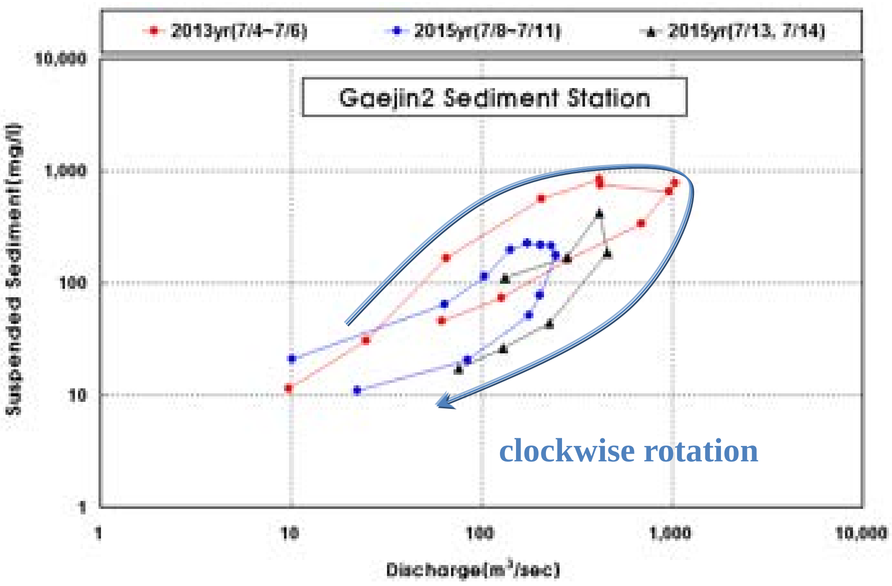


1.1 A Basic Knowledge

▪ Loop Characteristics

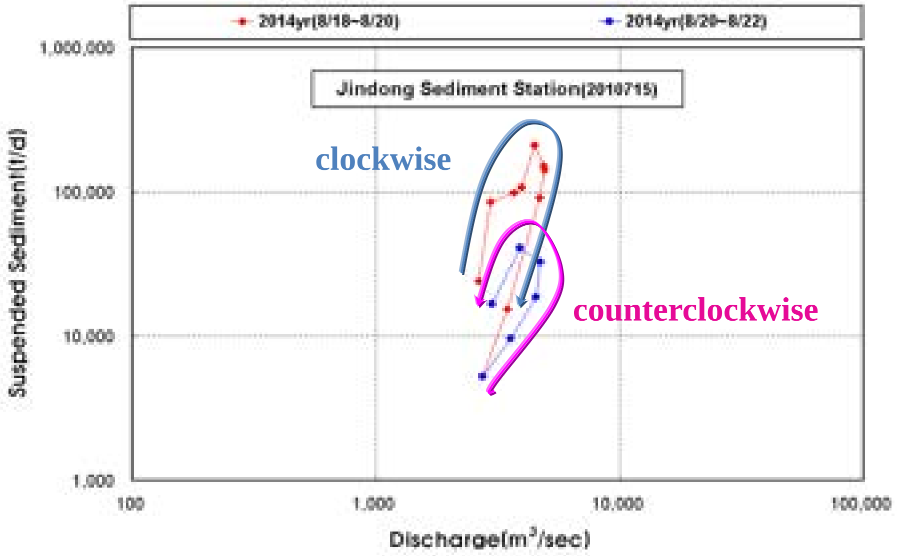
- Loop characteristics of suspended sediment in the Gaejin2 station
- Gaejin2 station showed the characteristics of clockwise rotation.



1.1 A Basic Knowledge

▪ Loop Characteristics

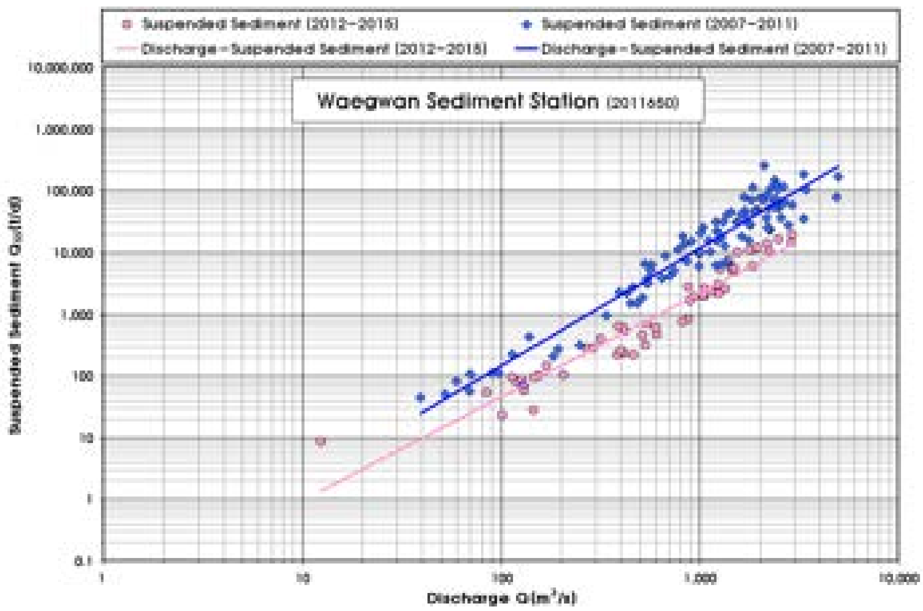
- Loop characteristics of suspended sediment in the Jindong station
- Jindong station showed the characteristics of clockwise and counterclockwise.



1.1 A Basic Knowledge

▪ Suspended Sediment Characteristics

- Effect according to the dredging and multiple-function weir construction
- Characteristics of suspended sediment by Four Major Rivers Project in Korea



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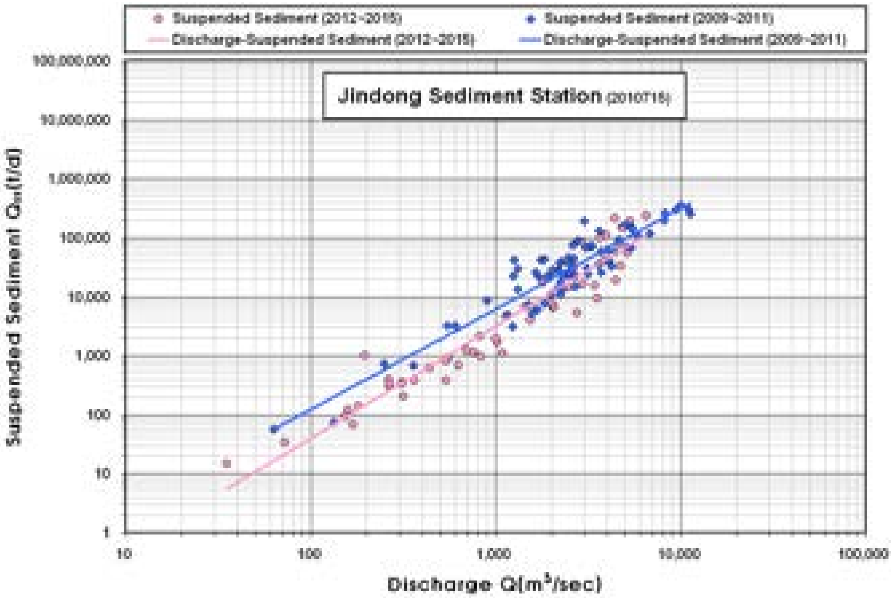
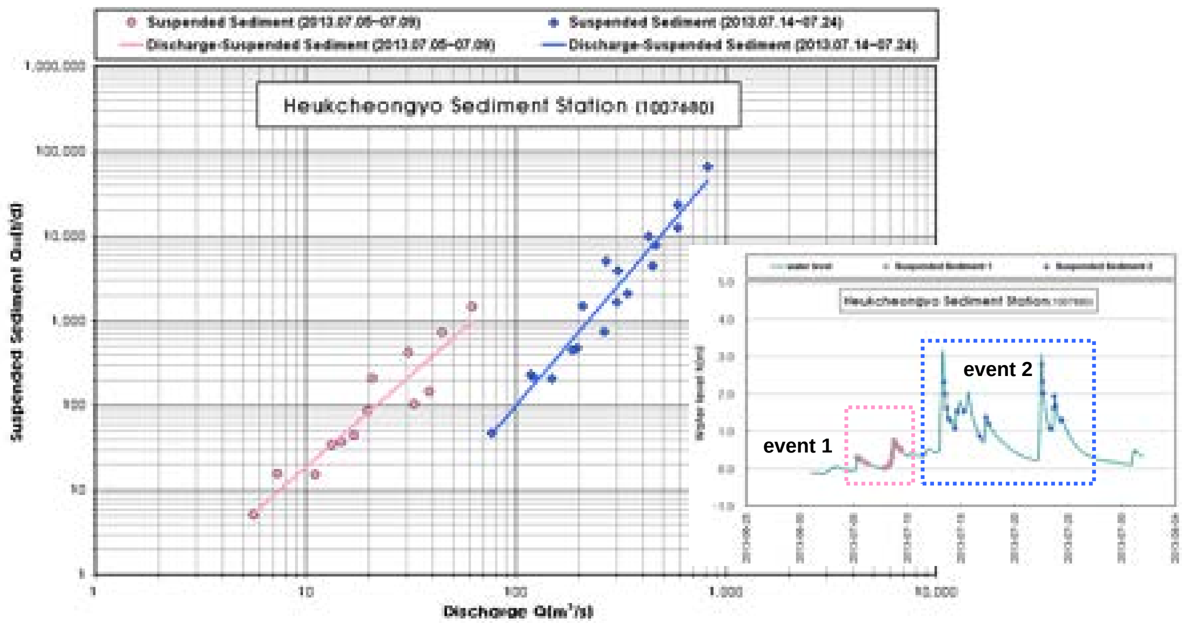


1.1 A Basic Knowledge

▪ Suspended Sediment Characteristics

- Suspended sediment characteristics according to the rainfall events
- A comparative analysis of suspended sediment by the sequence of the rainfall events



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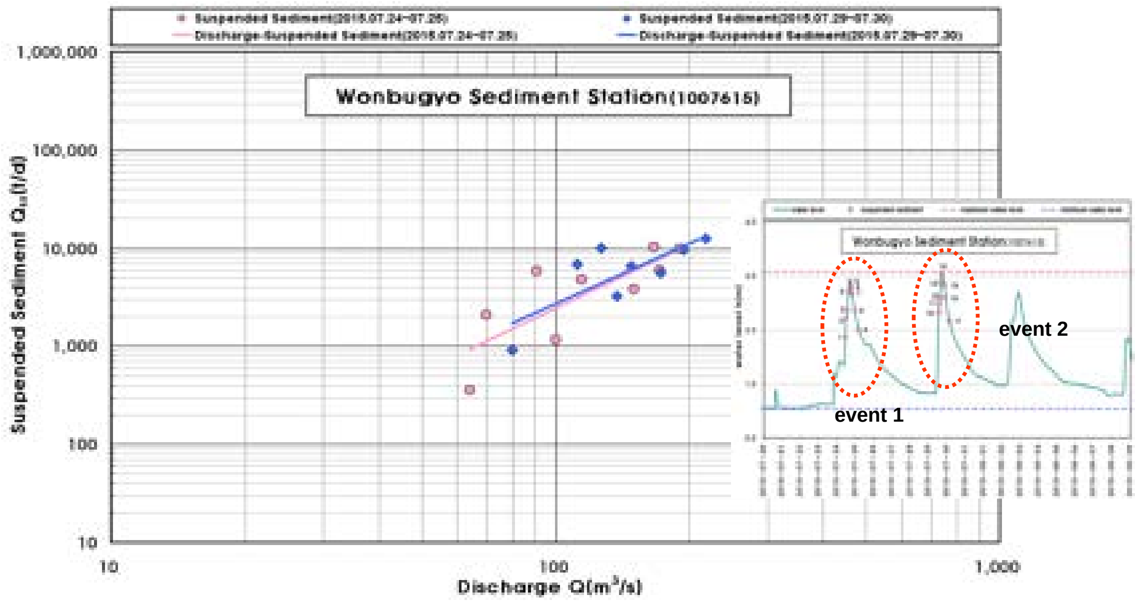


2. Sediment Sampling Equipment and Method

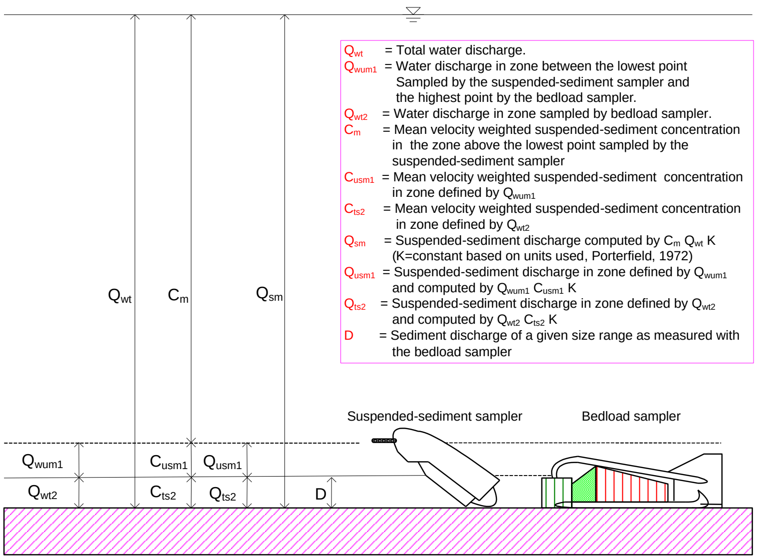
2.1 Sampling Equipment

2.2 Sampling Method

2.1 Sampling Equipment (Suspended load)

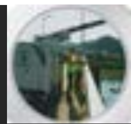
▪ Total Sediment Measurement (Hubbell, 1961)

- In order to measure the river sediment discharge, both the suspended load and the bed load must be measured at the same time.
- Total Sediment = Suspended load (D-74) + Bed load (Helley-Smith)



2.1 Sampling Equipment (Suspended load)

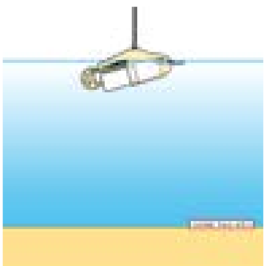
▪ Depth-Integrating Method



- A depth-integrating sampler is designed to iso-kinetically and continuously accumulate a representative sample from a stream vertical while transiting the vertical at a uniform rate.
- (Depth-Integrating sampler) DH-48, DH-59, DH-74, DH-81, **D-74**, D-77

* D (depth integrating), H (hand-held by rod or line)

* D-74 sampler is widely used worldwide.



2.1 Sampling Equipment (Suspended Load)

▪ Point-Integrating Method

- The Point-Integrating sampler usually has **a valve that is operated by electricity.**
- This equipment can take samples from any location in the water depth.
- (Point-Integrating sampler) P-61, P-63, P-72
  * P (Point-Integrating), 61 (the year of manufacture)
- (P-61 sampler) It weighs 48 kg (105 lbs.) and streamlined.
  * D-74 sampler is widely used worldwide.

P-61 Point Integration Sampler

P-72 Point Integration Sampler

2.2 Sampling Equipment (Bed material)

▪ Bed Material Equipment

- Bed material samplers: ① grab sampler, ② dredge sampler, ③ **scoop sampler**, ④ core sampler
- Grab, dredge, and scoop sampler are equipment that collects samples from the bed surface.
- The core sampler uses hydraulic pressure or vibration to drive a tube into the bed and collect it.
- When the sampler is dropped onto the bed, the open bucket closes, and the bed material is collected.
- (Grab sampler) Shipek
- (Dredge sampler) Van Veen sampler
- **(Scoop sampler) BM-54, BMH-60, BMH-80**
  * BM-54 is the most widely used in Korea (sampler length 56 cm, sampler weight 45 kg)
- (Core sampler) Phleger sampler, Alpine sampler, Benthos sampler

• US BMH-60

• US BM-54

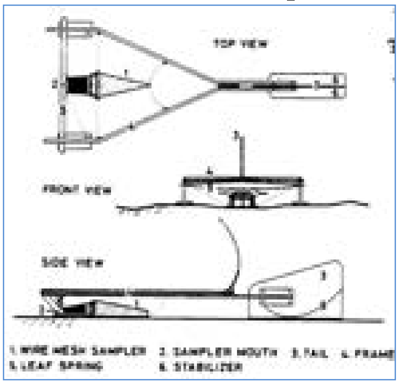
US BMH-53

2.2 Sampling Equipment (Bed load)

Bed Load Sampler)

- Bed load samplers is divided into two types: ① Mechanical collection type, ② Bed type tracking method
- (Mechanical collection type) ① Box or basket type, ② Pan or tray type, ③ Pressure difference type, ④ Slot or pit type
- (Representative bed load sampler) Arnhem sampler, **Helley-smith sampler**
- (Arnhem bed load sampler) It is equipment to collect bed load by descending a sampler with a fine wire mesh to the bed.
- (Helley-Smith sampler) This sampler was first developed in 1971 and is an improved Arnhem sampler.
  * Helley-Smith sampler consists of nozzle, a collection bag, and a collector body

Arnhem sampler



Helley-Smith sampler

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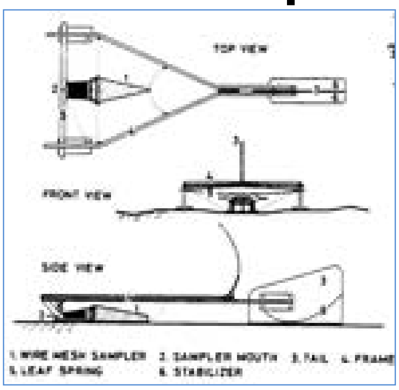
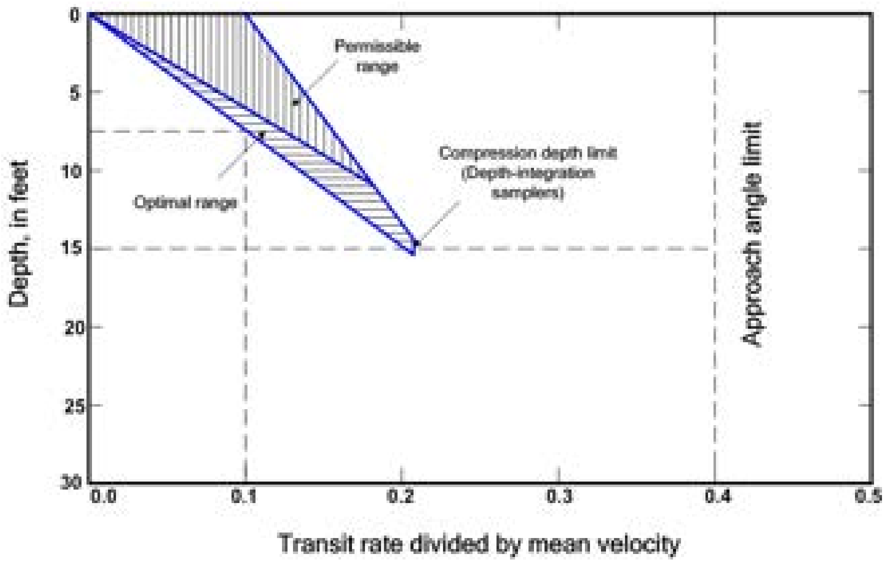


Helley-Smith sampler

2.2 Sampling Method

▪ Measurement Condition of Sediment Load

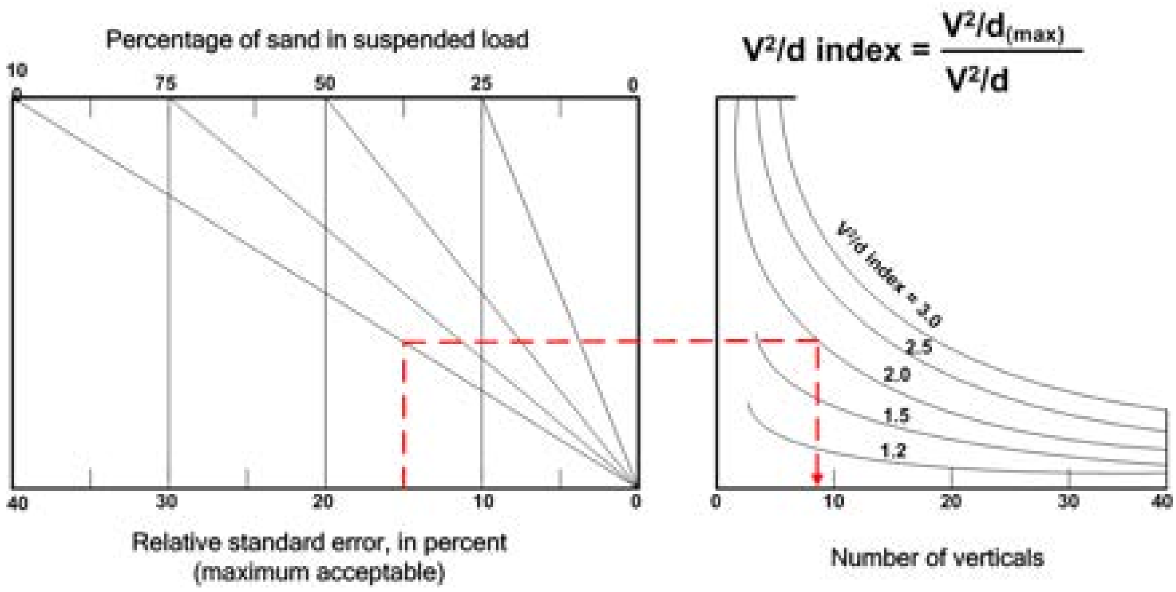
- Variation of range of transit rate to mean velocity ratio versus depth relative to nozzle size for pint-size sample container.
- Related to depth and transit rate



2.2 Sampling Method

▪ Determination of Sampling Vertical Number

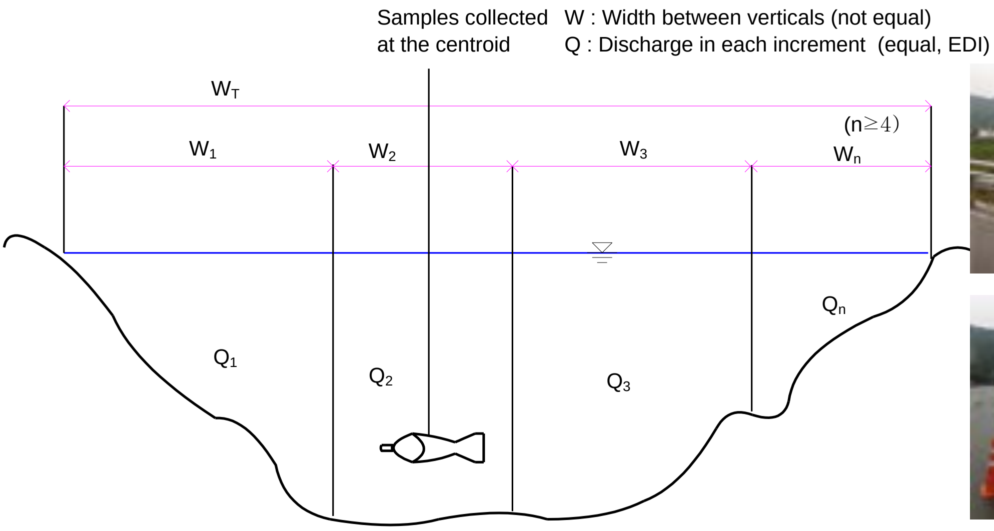
- Nomo-graph to determine number of sampling verticals required to obtain results within an acceptable relative standard error



2.2 Sampling Method (Suspended load)

▪ Equal-Discharge-Increment (EDI)

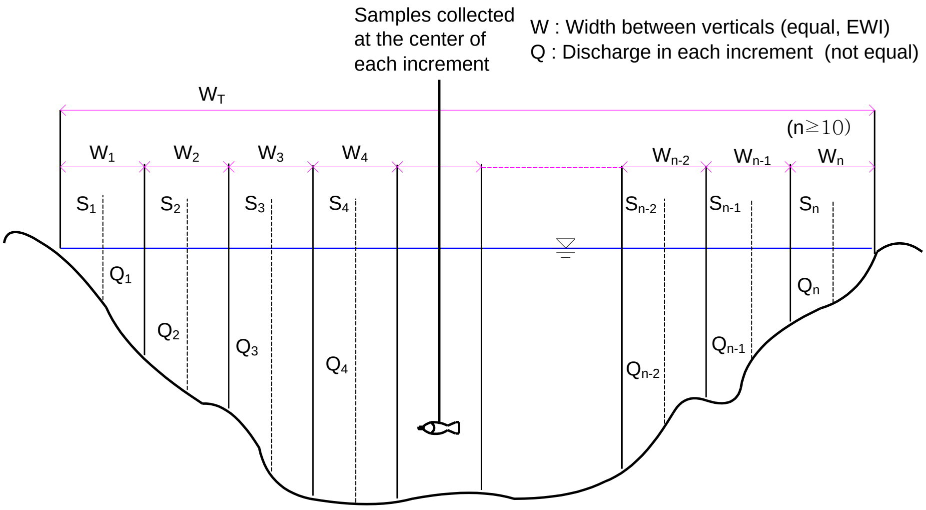
- Samples are collected at the centroids of flow each increment.
- Divide the measurement line so that the section flow rate is the same.



2.2 Sampling Method (Suspended load)

▪ Equal-Width-Increment (EWI)

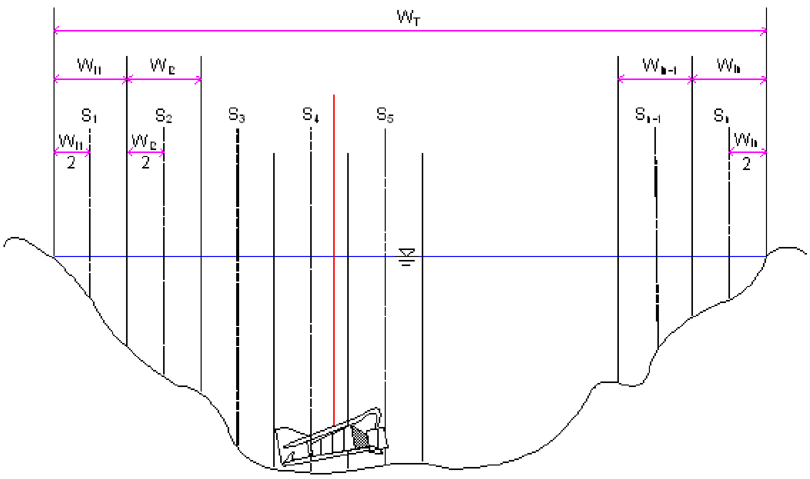
- This equal spacing between the verticals (EWI) across the stream and the sampling at an equal transit rate at all verticals yields a gross sample volume proportional to the total streamflow.
- Measurement lines should be set at the same interval.



2.2 Sampling Method (bed load)

▪ Single EWI

- The measurement lines are at the same interval and the measurement time is the same for each line.
- About 20 samples should be taken from each measuring line.



1) Width of Increments

$W_{i1} = W_{i2} = \quad = W_{in} = \frac{W_T}{n}$

2) Time on Bottom

$t_1 = t_2 = \quad = t_n$

3) S_i = Station of Sample Vertical $_i$

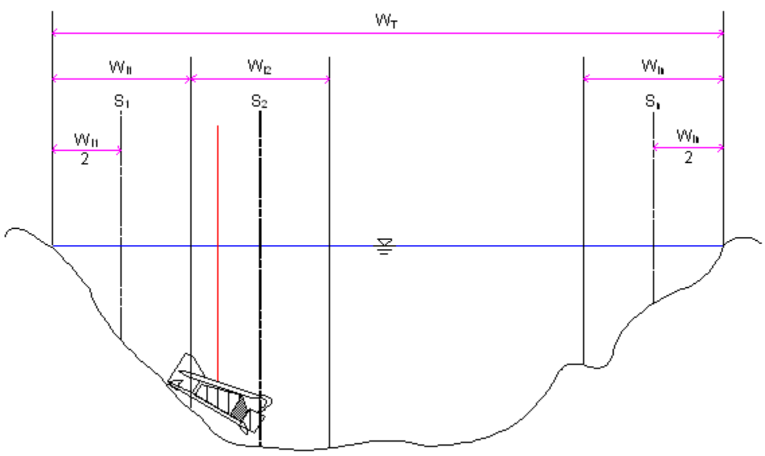
4) Number of Verticals

n = 20

2.2 Sampling Method (bed load)

▪ Multiple EWI

- Measurement lines are set at the same interval, and measurement time is applied differently.
- The measurer should repeat it about 5 times from each measuring line and collect about 20 samples.



1) Width of Increments

$W_{i1} = W_{i2} = \quad = W_{in} = \frac{W_T}{n}$

2) Time on Bottom

$t_1 \neq t_2 \neq \quad \neq t_n$

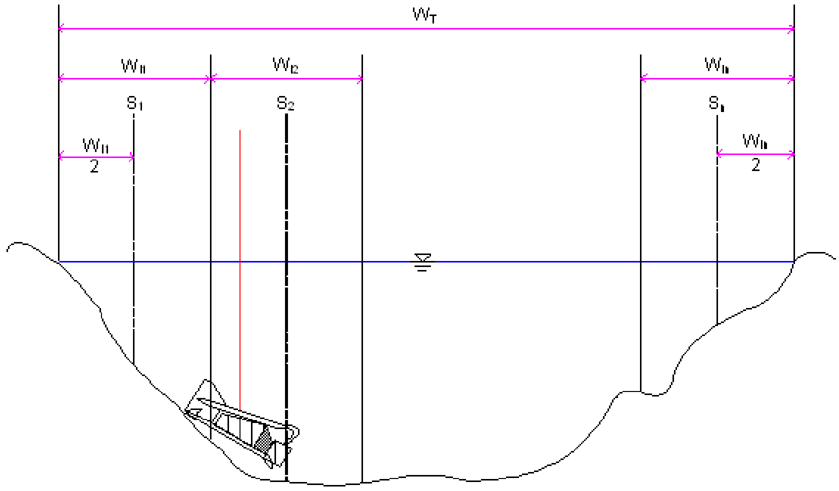
3) S_i = Station of Sample Vertical $_i$

4) Number of Verticals

n = 4~5

2.2 Sampling Method

- **Unequal-Width-Increment**
  - The measurement line and the measurement time are applied differently.
  - The measurer should repeat it about 5 times from each measuring line and collect about 20 samples.



1) Width of Increments

$W_{v1} \neq W_v \neq \quad \neq W_{vn}$

2) Time on Bottom

$t_1 \neq t_2 \neq \quad \neq t_n$

3) S_i = Station of Sample Vertical $_i$

4) Number of Verticals

n = 4~5

3. Laboratory Analysis

3.1 Concentration Analysis
3.2 Particle Size Analysis

3.1 Concentration Analysis

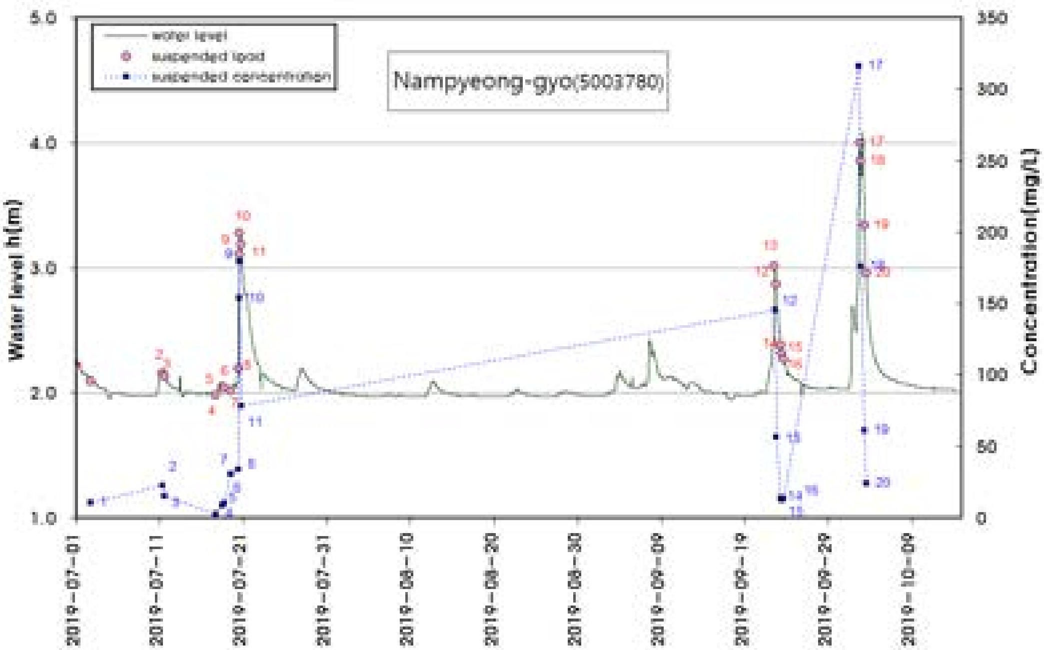
▪ Analysis of Suspended Concentration

- Filtration Method
  - Shorter analysis time when analyzing low concentration samples
  - Suitable for samples less than 10 g/l
  - Not suitable for high concentration samples
  - Filter paper hole is clogged
- Evaporation Method
  - Suitable for high concentration samples
  - Suitable for samples over 10g/l
  - If the amount of organic matter is large, correction is required

3.1 Concentration Analysis

▪ Example of Nampyeong-gyo Observatory

- In general, the concentration of suspended load increases as the flow rate increase.

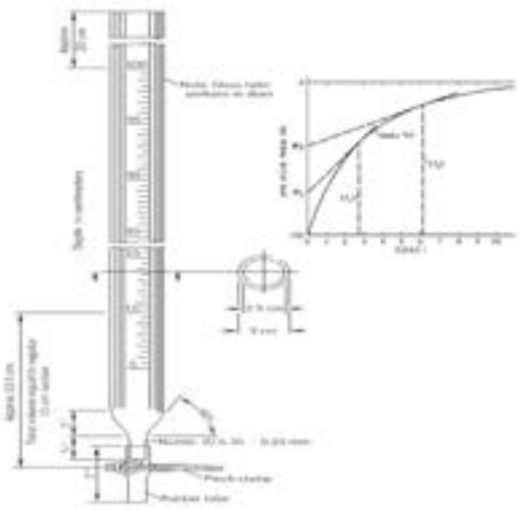


3.2 Particle Size Analysis

▪ Methods of Particle Size Analysis

- Among the five methods below, the BW tube method is widely used for suspended load concentration.
- The BW tube method uses the sedimentation velocity of particles, and the heavier the particles, the faster they sink to the floor.
- Sieve analysis method is widely used in bed material analysis.

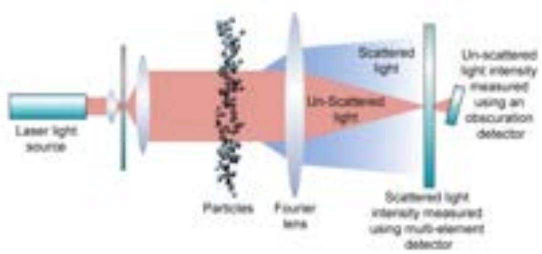
Analysis method	Particle-size (mm)	Concentration range (mg/l)	Sample quantity (g)
Sieve analysis	0.062~32	-	0.05
VA tube	0.062~2.0	-	0.05~15.0
Pipette	0.002~0.062	2,000~5,000	1.0~5.0
BW tube	0.002~0.062	1,000~3,500	0.5~1.8
Hydrometer	0.002~0.062	25,000~50,000	20~200

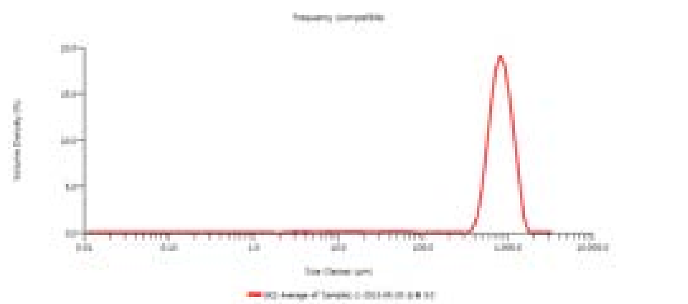


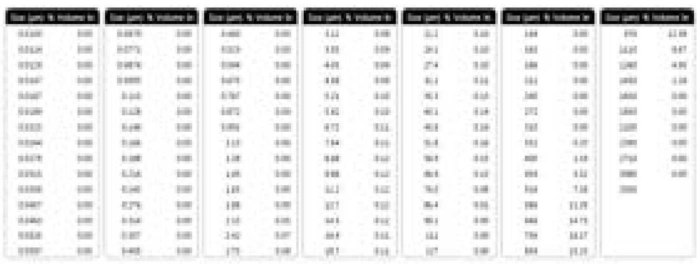
3.2 Particle Size Analysis

▪ Particle Analyzer

- The particle analyzer measures the particle size using the principle of laser diffraction.







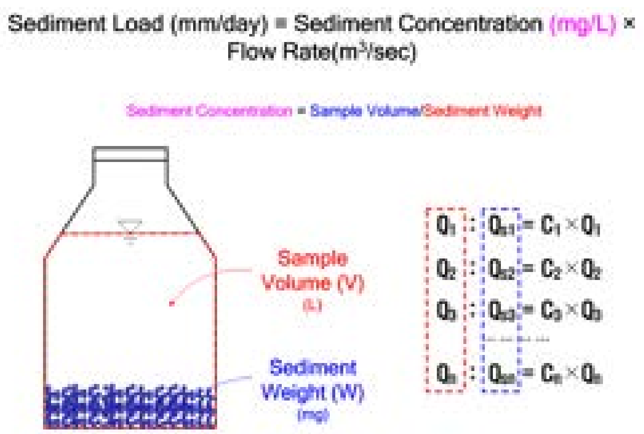
4. Computing Sediment Discharge

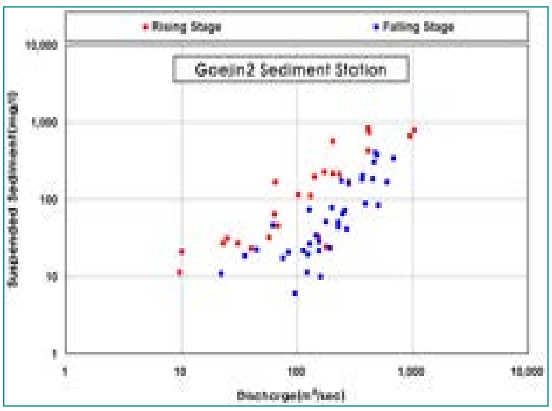
4.1 Suspended Discharge
4.2 Total Sediment Discharge
4.3 ADCP-Based Sediment Measurement

4.1 Suspended Discharge

▪ **Definition of Suspended Discharge**

- Suspended discharge is calculated by multiplying the flow rate by the concentration of suspended load.

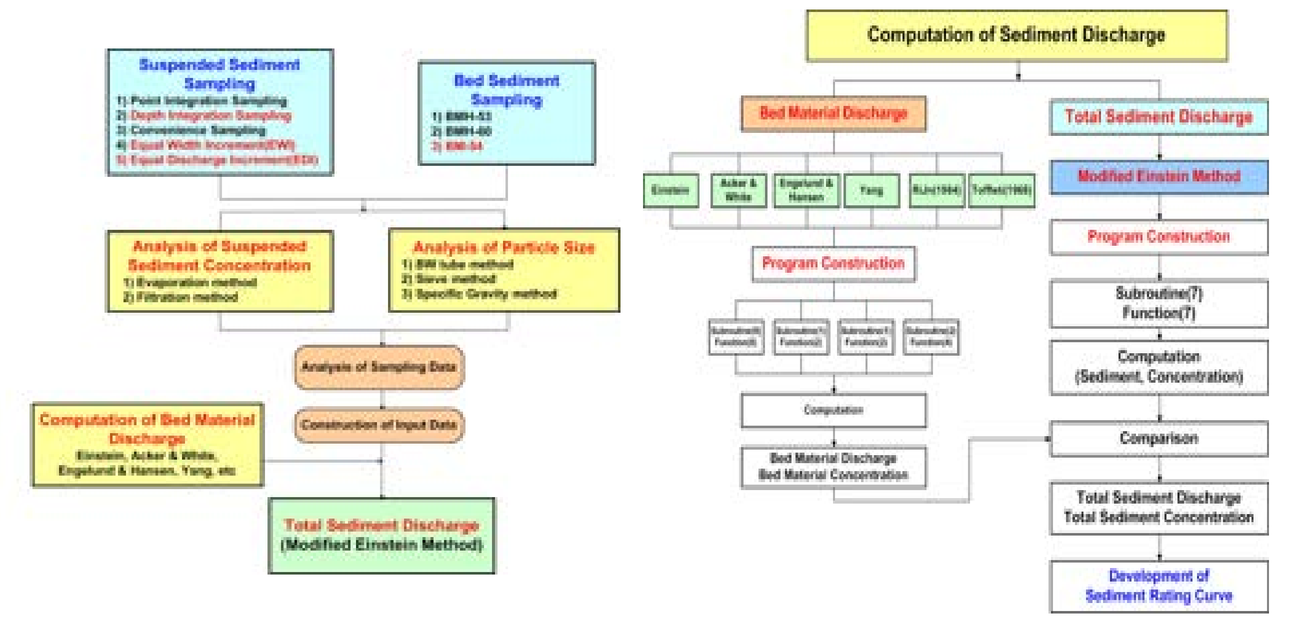




4.2 Total Sediment Discharge

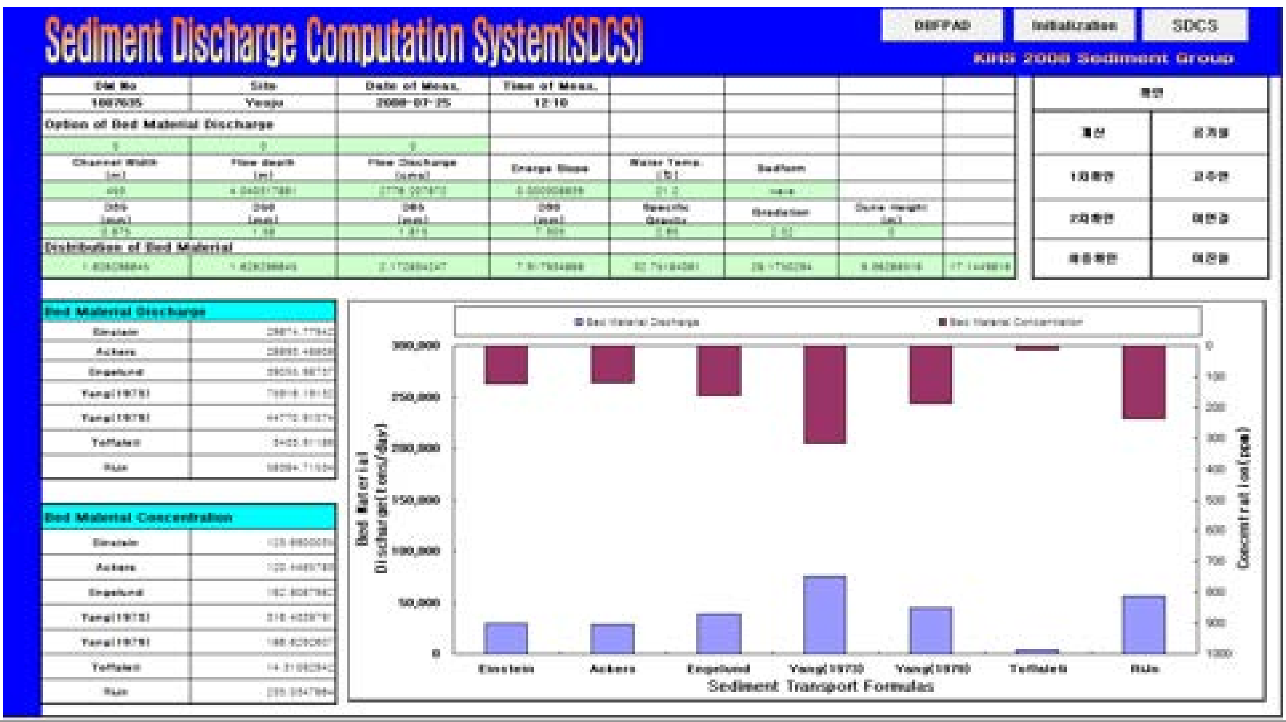
▪ Structure of Sediment Discharge Computation System

- Bed material discharge (Einstein, Acker & White, Engelund & Hansen, Yang, RiJn, Toffaleti, etc)
- Total sediment discharge (Modified Einstein Method)



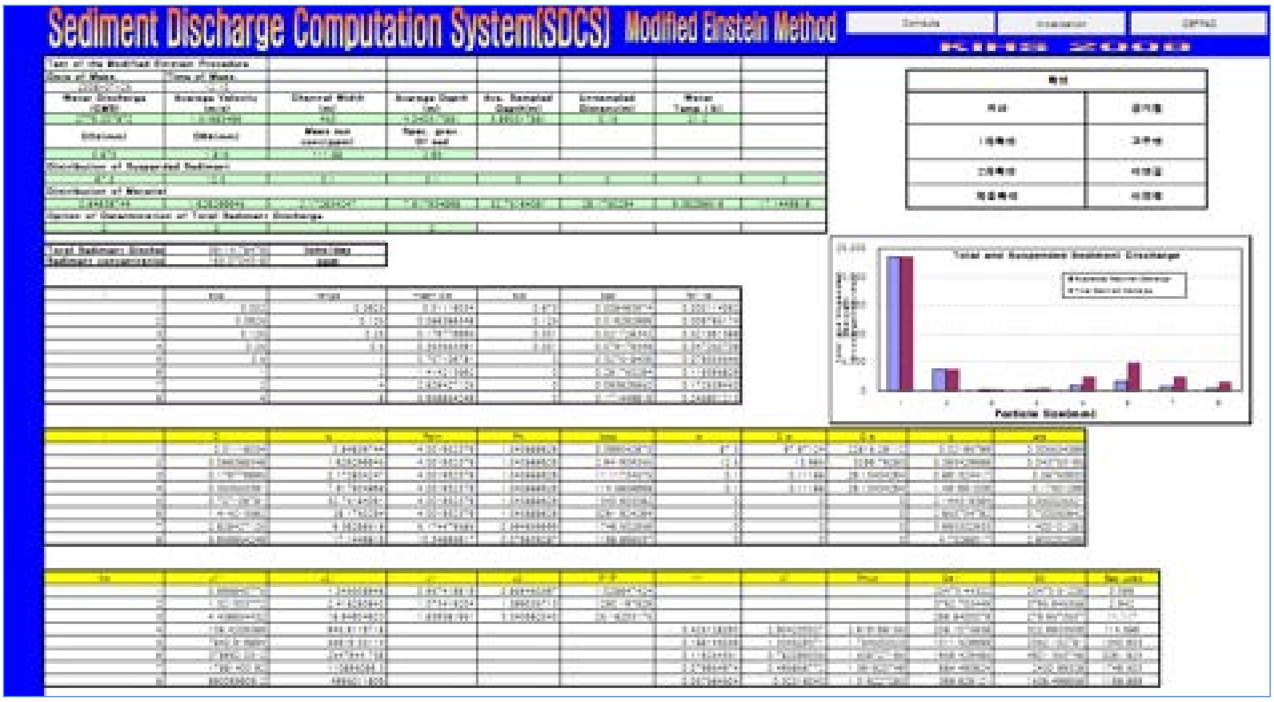
4.2 Total Sediment Discharge

▪ Module of Bed Material Sediment Discharge



4.2 Total Sediment Discharge

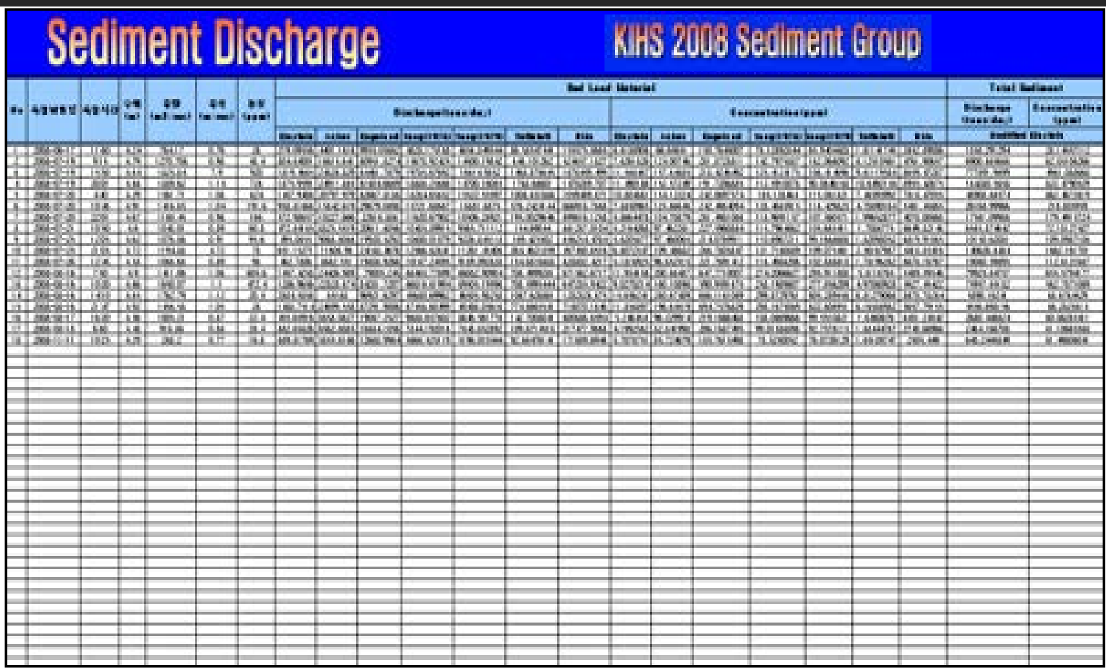
▪ Module of Modified Einstein Method



4.2 Total Sediment Discharge

▪ DB Pad for SDCS

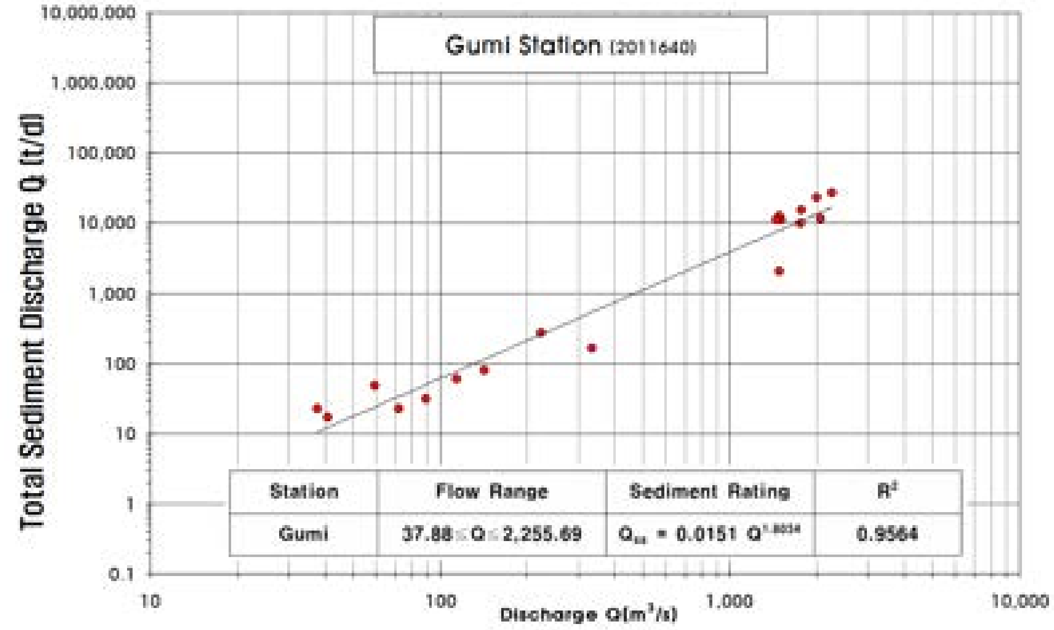
- The DB PAD can store and manage information on the bed load material and total sediment discharge



4.2 Total Sediment Discharge

▪ Development of Sediment Rating Curve

- In general, relational expressions are developed exponentially.

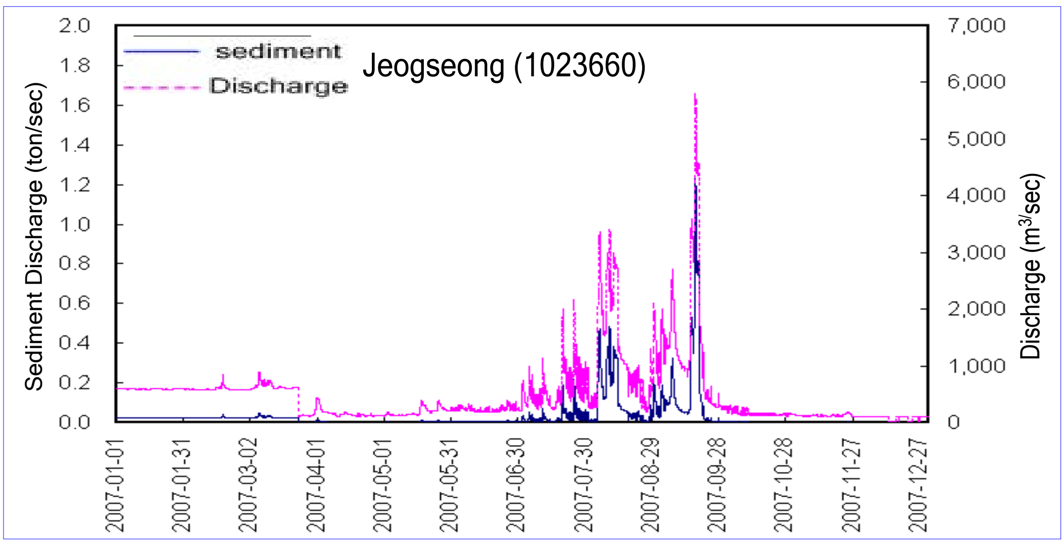


Station	Flow Range	Sediment Rating	R^2
Gumi	$37.88 \le Q \le 2,255.69$	$Q_{ss} = 0.0151\ Q^{1.8034}$	0.9564

4.2 Total Sediment Discharge

▪ Sediment Flow Rate

- The sediment flow rate is calculated by substituting the flow rate in the sediment rating curve.
- Calculation of sediment flow rate is the final goal of the sediment survey, which is used for multiple purposes in river management.

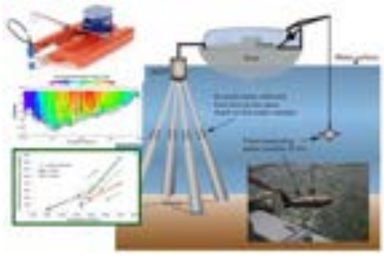


4.3 ADCP-Based Sediment Measurement

▪ ADCP-Based Sediment Measurement

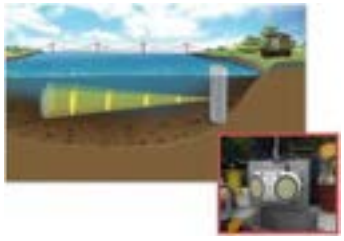
- Corporations and institutes in Korea, especially KIHS, are pursuing a study on calculating the sediment discharge based on ADCP.
- In addition, we review the applicability of various sediment survey techniques and apply them to various rivers.

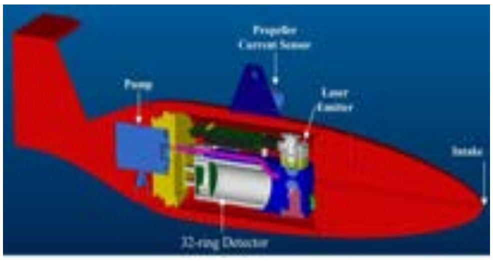
Principle of V-ADCP



Source: USGS, "Scientific Investigations report"

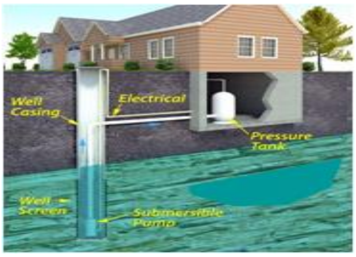
Principle of H-ADCP





LISST

Source: Sequoia



Pumping method

Thank you very much

Observatory Operations
Soil Moisture

Hydrological Survey

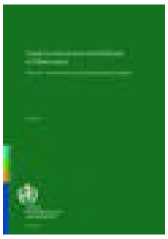
Observatory Operations: Soil Moisture

Aims & Objectives

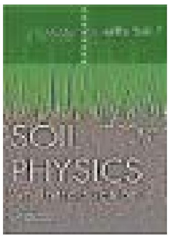
- The aims of the course are to:
  (1) Promote among trainees a good understanding of the basic measurement principle of soil moisture
  (2) Ensure that trainees can set up a soil moisture observatory and operate it stably
  (3) Utilize appropriate quality control to develop trainees' ability to produce good data

- At the end of this course, trainees will be able to:
  (1) Install the soil moisture observatory
  (2) Carry out the maintenance of soil moisture observatory
  (3) Utilize the quality control for producing good data

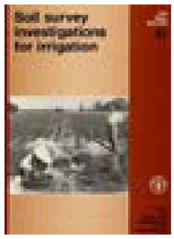
References



Guide to instructions and methods of observation (WMO)

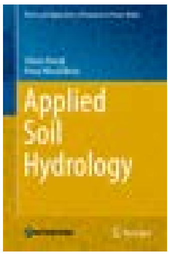


Soil Physics: An Introduction (Shikla, 2013)

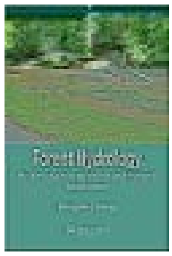


Soil survey investigations for irrigation (FAO)

METER Group
User guide and webinar
(METER Group)



Applied Soil Hydrology (Springer)



Forset Hydrology (Chang, 2006)

Contents

1. Introduction

1.1 A Basic Knowledge
1.2 Type of Method

1.1 A Basic Knowledge

- What is soil moisture?
  - **Micro: s**oil moisture is the water that is held in the spaces between soil particles.
  - **Macro: s**oil moisture is a critical land surface parameter that exerts a strong control on land-atmosphere exchanges of water, energy, and carbon over large areas of the Earth.

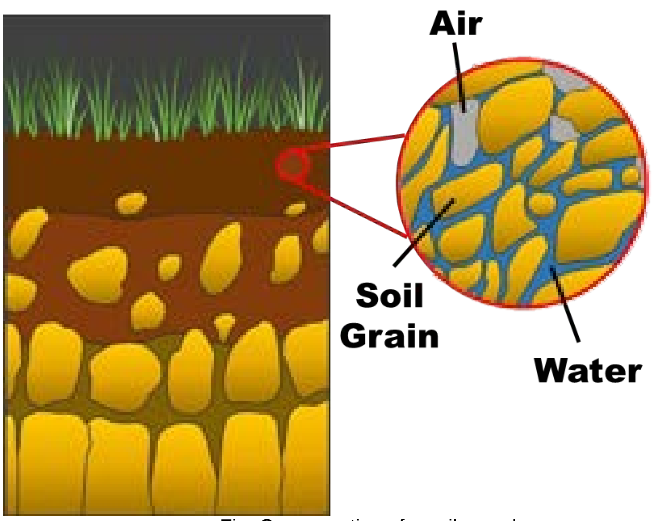


Fig. Cross-section of a soil sample

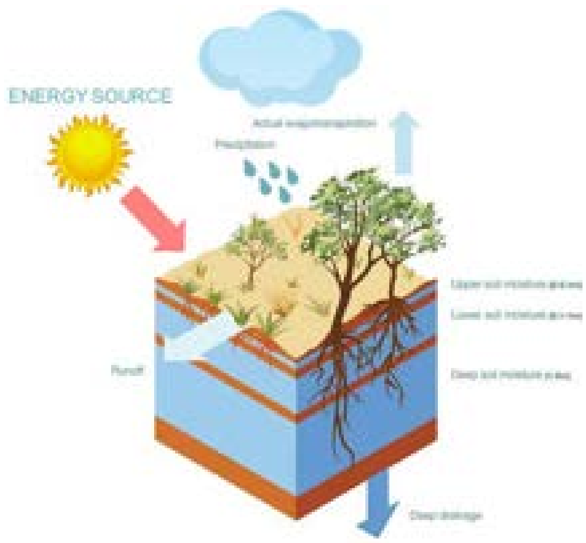


Fig. Water flow in and out of the soil

1.1 A Basic Knowledge

▪ Why measure soil moisture?

- **Agriculture:** Assessing plant water requirement and scheduling irrigation work
- **Forestry:** Plant water uptake and consumptive use
- **Hydrology:** Water storage capacity of soil
  Rate and quantity of water movement
- **Others:** Plan disaster prevention measures (drought, land slide, soil loss, etc.)

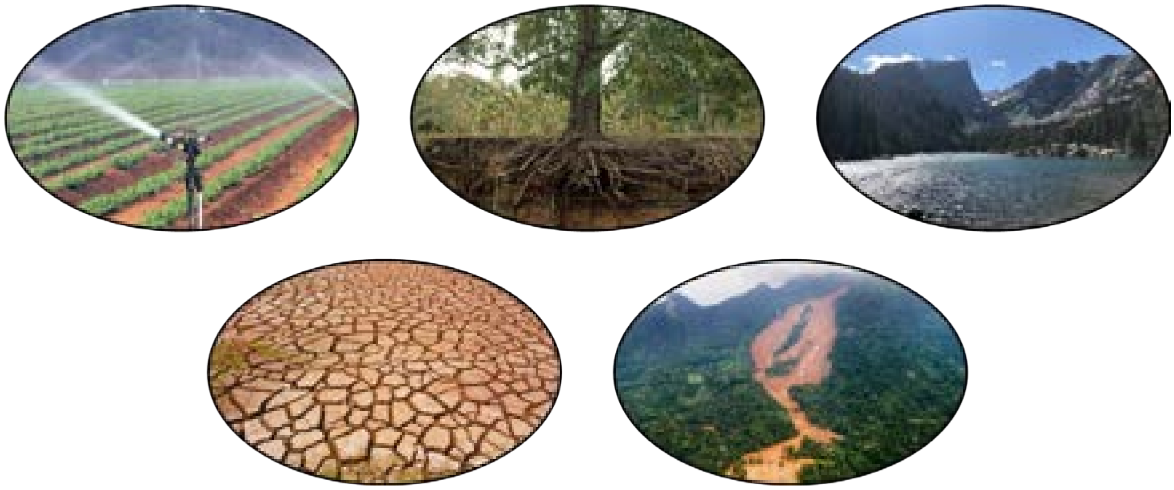


Fig. Measurement application example

1.1 A Basic Knowledge

▪ How to measure soil moisture?

- **Gravimetric method:** Mass of water (g) per mass of soil (g)
  - · The mass of soil varies depending on the shape and composition of the soil, making it more complex to use.
  - · Gravimetric water content is used to develop calibrations and validate readings of most volumetric water content measurements that are sensed either in situ or remotely.
- **Volumetric method:** Volume of water (cm^3) per total volume (cm^3)
  - · The amount of water in the soil is measured regardless of soil characteristics.

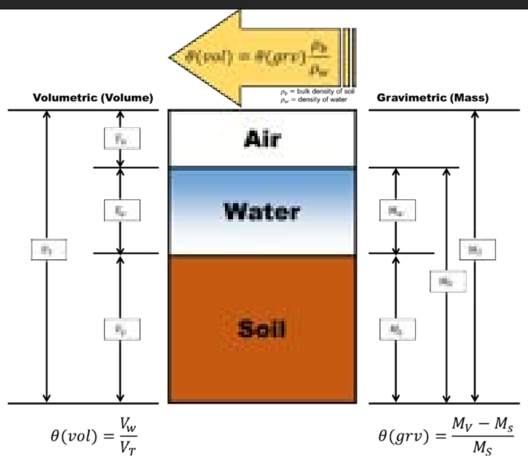
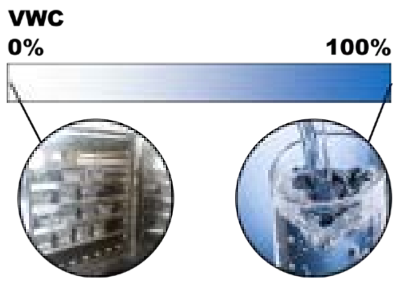


Fig. Soil as a three-phase System



- Oven dry soil = 0% VWC by definition
- 100% VWC = fully saturated soil?
  No, this is pure water
- VWC at saturation is dependent on soil type

Fig. Volumetric Water Contents meaning

1.2 Method Type

- **Direct Method**
  - **Pros:** Simple, principles measurement, Inexpensive
  - **Cons:** Destructive, does note account for temporal variability, time consuming, requires precision process
- **Indirect Method**
  - **Pros:** Time series, less instructive
  - **Cons:** Needs for calibration, relatively expensive

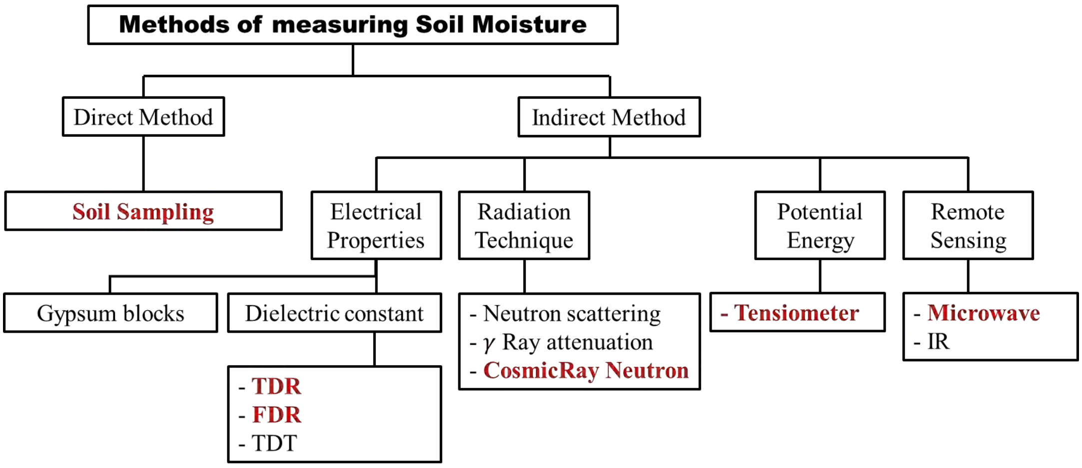


Fig. Methods of measuring Soil Moisture

1.2 Method Type

- **Soil Core Sampling (Volumetric)**
  - **The moist weight is determined by weighing the soil sample at the time of sampling, and the constant dry weight is obtained after drying the soil sample in an oven at 105℃ for 24 hours.**

Gravimetric water content = (wet soil weight – dry soil weight)/dry soil weight

Volumetric water content = Gravimetric * bulk density

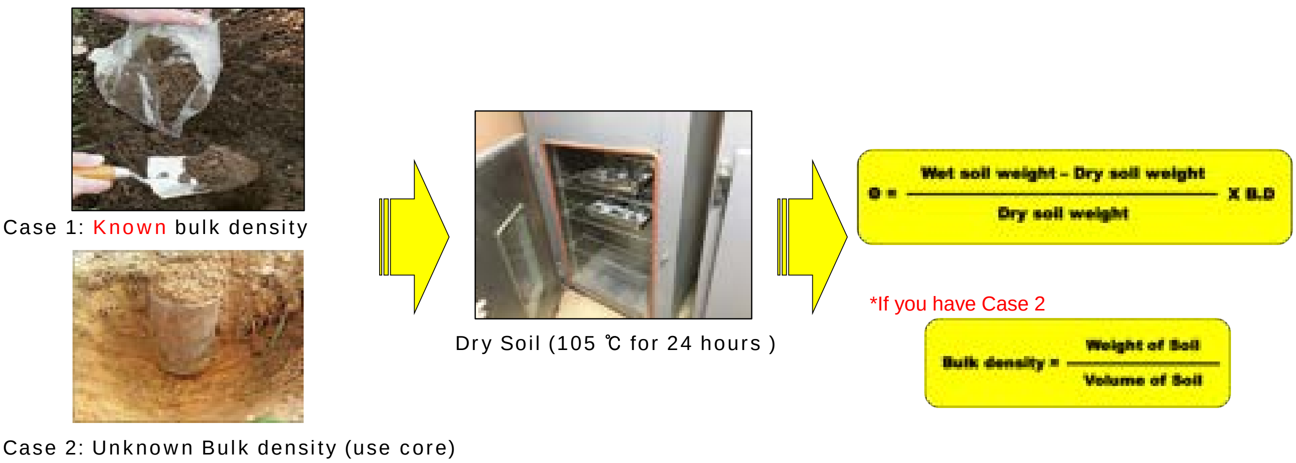


Fig. Sampling Process

1.2 Method Type

- **Dielectric permittivity (TDR, FDR)**
  - **Dielectric soil moisture sensors determine the soil moisture by measuring the dielectric constant of the soil, an electrical property that is highly dependent on the moisture constant.**
  - **TDR: Using pulse echo time**
  - **FDR: Using pulse Frequency**

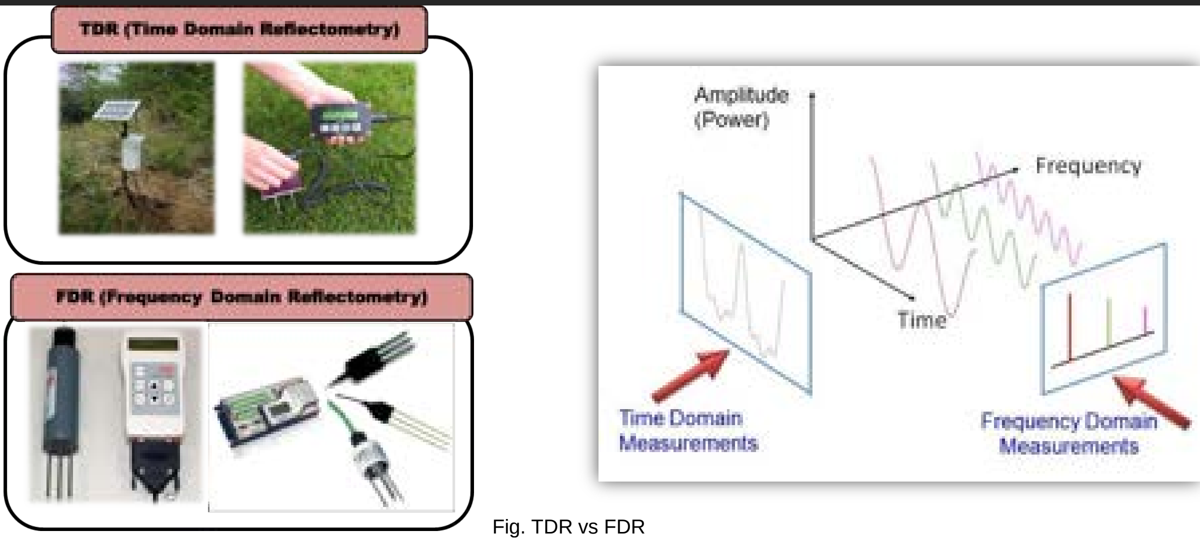


Fig. TDR vs FDR

1.2 Method Type

- Cosmic-Ray neutron probe
  - Fast neutrons are produced by nuclear interactions between the incoming cosmic rays and elements of the Earth's atmosphere. When they reach the soil surface, they penetrate to a certain depth and are scattered back into the atmosphere. Since fast neutrons are mainly moderated by hydrogen, the fast neutron intensity at a near-ground-level is negatively correlated with the near-surface soil moisture

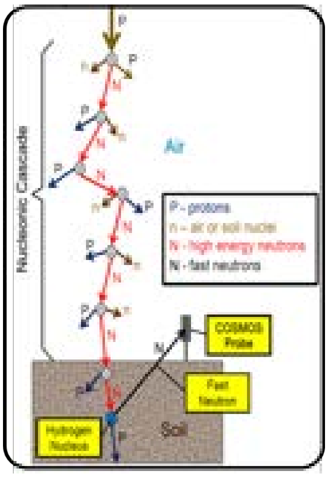


Fig. Cosmic-Ray Movement

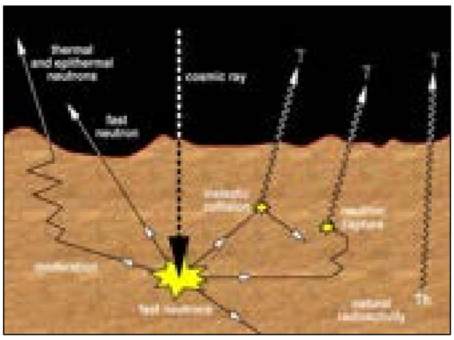


Fig. Cosmic-Ray Collision Process
(source: Turnbull et al., 2011)

Fig. Cosmic-Ray Probe site

1.2 Method Type

- **Tensiometer**
  - Water flow from a higher energy state to a lower until they reach equilibrium
  - g + m + p + o
    (total = gravitational + matric + pressure + osmotic)

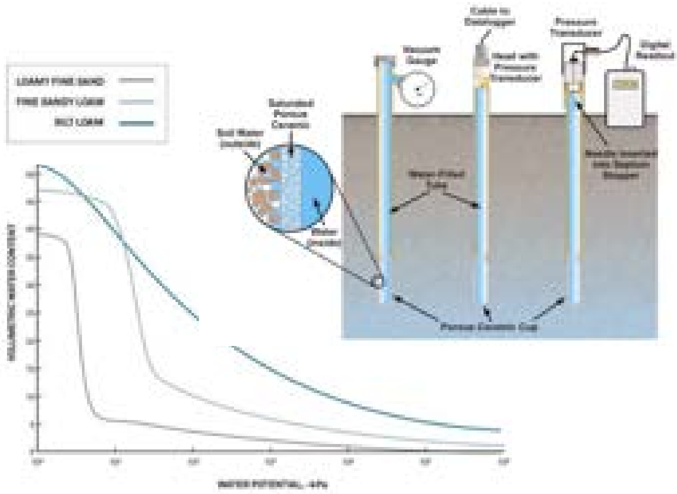


Fig. Relation of VWC to potential
(source: METER group, “https://www.metergroup.com”, and Or et al., 2003)

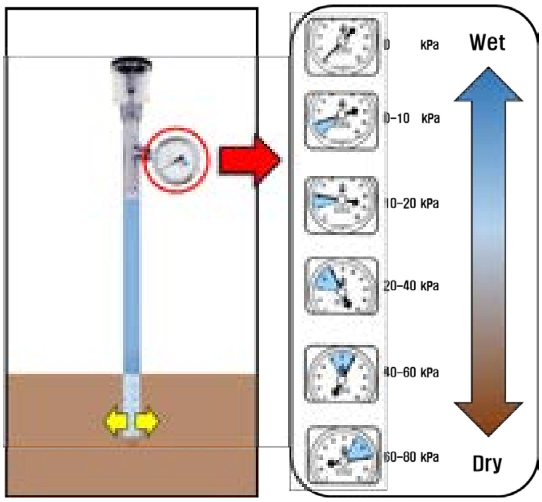


Fig. Tensiometer unit

1.2 Type of Method

- **Microwave (Active, Passive)**
  - Wide range and ungauged basin of measurements possible
  - All-weather, all-day measurement capability
  - Very sensitive to soil water content below relaxation frequency of water (<10GHz)
  - **Radar** measures the energy scattered back from the surface
  - **Radiometers** measures the self-emission of the Earth’s surface

Active Sensors

Passive Sensors

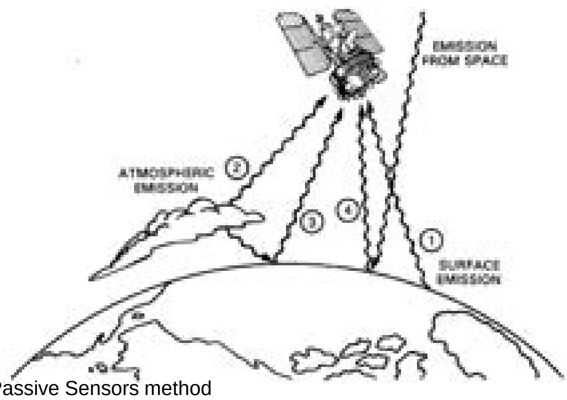


Fig. Active and Passive Sensors method
(source: Wagenr PPT slide “Soil Moisture Measurements from Space and Application to Operational Hydrology”)

2. Observatory Installation:
Dielectric Constant

2.1 Site selection
2.2 Sensor Installation
2.3 Precautions

2.1 Site selection

▪ About what?

- According to the WMO “Guide to Meteorological Instruments,” there is no standard depth or measurement interval at which soil moisture observations are taken, since this strongly depends on the **research objectives** for which the sensors are installed.

Example focus on research objectives

· **Agriculture:** drought, crop growth
· **Forestry:** plant roots, hygroscopic property
· **Hydrology:** Water storage capacity of soil
Rate and quantity of water movement

▪ Factors to Consider

- Depth
- Time interval
- Arrangement

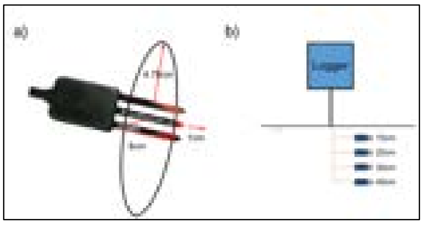


Fig. METER group 5TM sensor properties

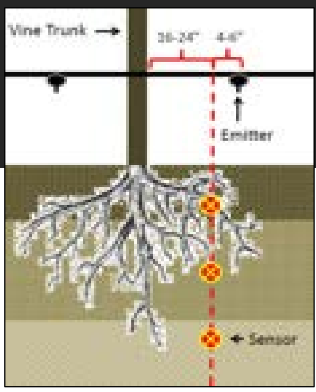


Fig. Depth of sensor
(source: Virtual Viticulture Academy, “Use of soil & plant data for irrigation decisions”)

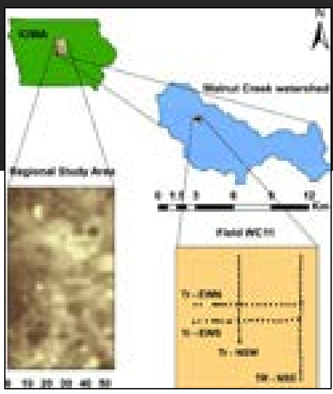


Fig. SMEX02 Arrangement of sensor
(source: Joshi et al., 2010)

2.2 Sensor installation

▪ Pre-field testing

- Set up the instrumentation and test it BEFORE you go to the field.
  · Mounting hardware
  · Power supply & charging
  · Data acquisition
  · Logger program
  · Data delivery
- Ensure you have all necessary equipment for the installation.

Fig. Examine the environment using drone

Fig. Analysis of soil property

2.2 Sensor installation

▪ Choose the right site

- Topographic, Slope, Aspect
- Soil Texture, Organic Metter
- Vegetation and Canopy types (LAI, NDVI ...)
- Weather pattern (Precipitation, Radiation …)
- Flow of water

Fig. Examine the environment using drone

Fig. Analysis of soil property

2.2 Sensor Installation

▪ Installation Process

- Dig at the location you want to observe (minimize site disturbance)
- Install a wave guide in position and depth you are interested in.
- Do your best to pack back to the original density.
  (Backfill the soil to the approximate depth from which you excavated it.)
- Set up the logger and the battery.
- Collect the sample of the surrounding soil.
- Meta measurement (GPS location, elevation, etc.)

▪ Field check

- Confirm proper data acquisition
- Confirm successful data transfer
- Confirm system power supply & charging

Fig. Wave guide installation

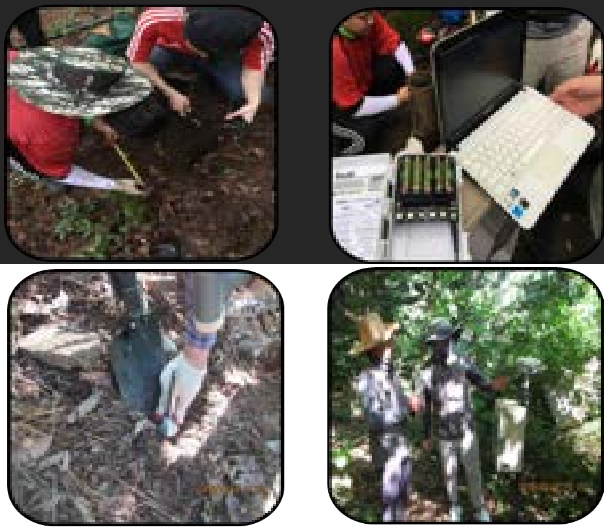
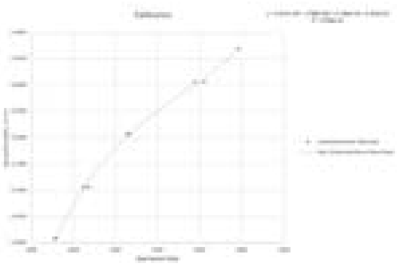


Fig. Installation Process

2.2 Sensor Installation

▪ Probe calibration

- Not all soils have identical electrical properties
- Need the calibration of variations in soil bulk density, mineralogy, texture, and salinity, the generic mineral
- Not required, but recommended
- Increase in accuracy of 1~2% can be expected.



Material	Parameters of the calibration equations
Mineral soil	$\theta = 4.3\times10^{-6}\varepsilon_a^3 - 5.5\times10^{-4}\varepsilon_a^2 + 2.92\times10^{-2}\varepsilon_a - 5.3\times10^{-2}$
Potting soil	$\theta = 2.25\times10^{-5}\varepsilon_a^3 - 2.06\times10^{-3}\varepsilon_a^2 + 7.24\times10^{-2}\varepsilon_a - 0.247$
Rockwool	$\theta = 1.68\times10^{-3}\varepsilon_a^2 + 6.36\times10^{-3}\varepsilon_a + 0.0286$
Perlite	$\theta = -1.07\times10^{-3}\varepsilon_a^2 + 5.25\times10^{-2}\varepsilon_a - 0.0045$

Fig. The parameter value of the soil moisture content calculation formula suggested by Meter Group
(source: METER group, https://www.metergroup.com)

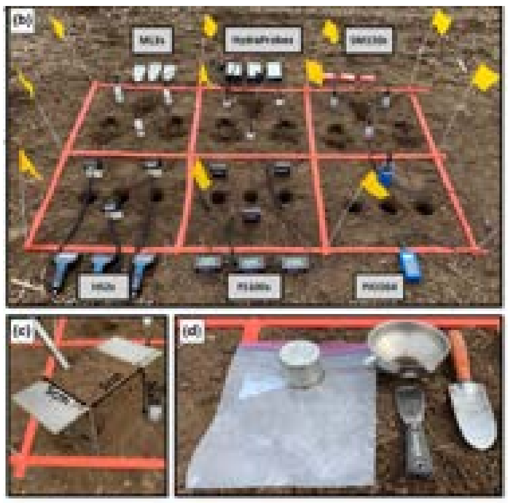


Fig. Calibration sampling work in field
(source: Kim et al., 2019)

2.3 Precautions

- In-soil properties
  - Avoid rocks and vegetation roots in a location adjacent to the probe.
  - In coarse soil, it can cause noise.
  - Noise can occur in areas where uneven bio-pore, such as fallen leaves or soil fauna, is made.
  - Large amounts of organic matter and clay layers may cause distortion of observations.

Fig. The accuracy of the position sensor (source: sensoterra, "https://www.sensoterra.com")

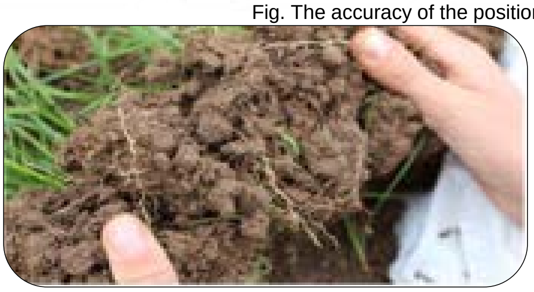


Fig. Development of Porosity due to Soil aggregation

Fig. Pore development due to soil animals

2.3 Precautions

- Environmental destruction
  - **Avoid compression of soil by footprints**
    -Causes distortion of observed values
  - **Protect against cable damage**
  - **It is important to mark the location of the probe and install an approach barrier**

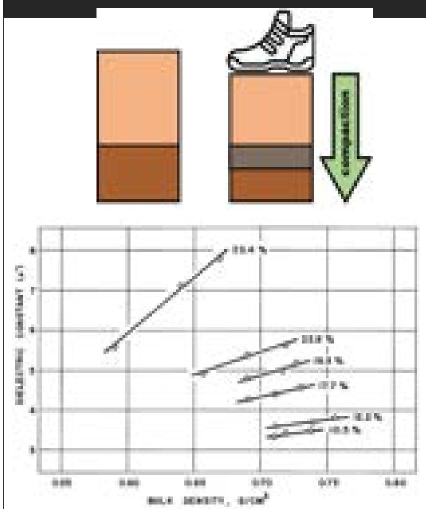


Fig. Dielectric change due to volume density difference (source: Nelson, 1979)

Fig. Installation location indication

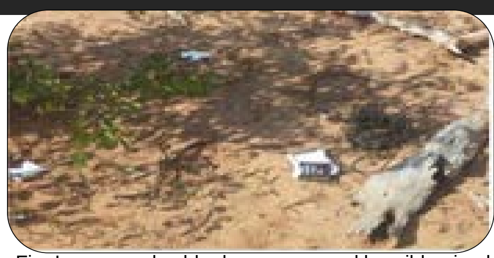


Fig. Logger and cable damage caused by wild animals (source: METER group, https://www.metergroup.com)

Fig. Case of protective tube installation

2.3 Precautions

- **Topographic influence**
  - **It is recommended to install it in a relatively sloped flat position.**
  - **Avoid installing probes in areas where soil erosion or flow is crucial.**
- **Soil freezing**
  - **In the event of soil freezing, separate quality control and probes damage should be checked**

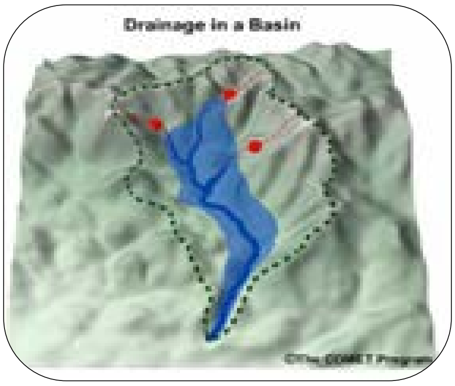


Fig. Flows along the slopes of the basin
(source: The Comet Program, "Drainage in a basin")

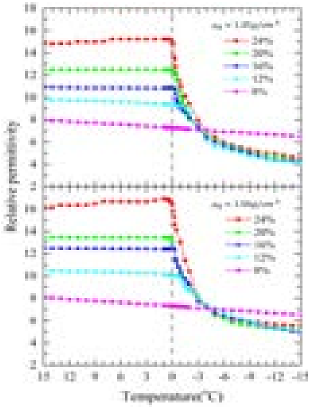


Fig. dielectric constant change according to soil temperature
(source: Guo et al., 2018)

3. Maintenance

3.1 Field Inspection

3.1 Field inspection

- Inspection cycle)

- The inspection cycle is set according to the weather conditions and the characteristics of the device
- Always fill out an inspection log

- Check list)

Routine Inspection
- Check logger
 operation station, storage memory)
- Battery capacity
- Related facilities
- Probe fixed state
- Check data
back-up data, missing or noise data)

Emergency Inspection
Weather conditions)
- Lightning event
- Torrential rain event
- Typhoon event
Data conditions)
- Case of detect the data error

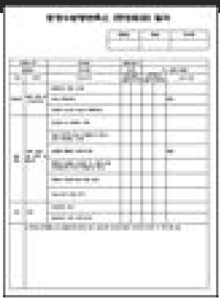


Fig. Inspection log

Fig. Carry out inspection

4. Data Handling

4.1 Data Management Process
4.2 Quality Control
4.3 Analysis and Database

4.1 Data Management Process

- **Process**
  - Perform monthly quality control
- **Review of measurement data**
  - It has included an error in the data collected from the field to review the series with rainfall.
  - If the error occurs continuously, an emergency inspection is taken place.
- **Suspected data**
  - Excessively high or low measurement (Spike)
  - Drastic change in tendency (Brake)
  - Inconsistent with rainfall trends
  - Continuous noise

Quality control and data management procedure

Data Collection	Data Check	Quality-Control	Data Management
1. Data Download 2. Count data sample 3. Data normality Check(in field)	1. CSV to Excel 2. Data normality Check 3. Inter-comparison with rainfall	1. Spike 2. Break 3. CHV, CLV 4. Gap-filling	1. Database (1) Daily (2) Monthly (3) Yearly 2. Statistical Analysis

Fig. Date Management control process

4.2 Quality Control

- **Process**
  - Perform monthly quality control.
- **Review of measurement data**
  - It has included an error in the data collected from the field to review the series with rainfall.
  - If the error occurs continuously, an emergency inspection is taken place.
- **Suspected data**
  - Excessively high or low measurement (Spike)
  - Drastic change in tendency (Brake)
  - Inconsistent with rainfall trends
  - Continuous noise

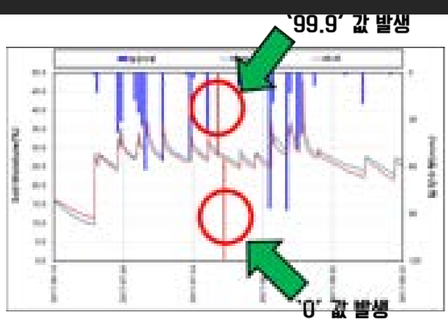


Fig. Outlier data example

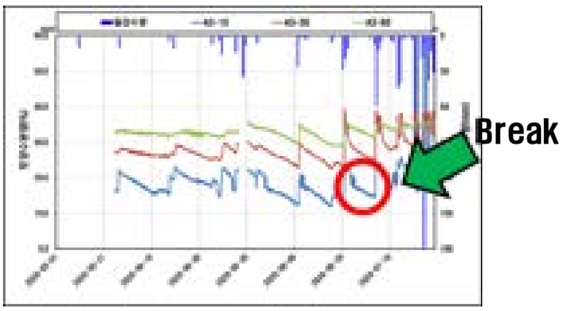


Fig. Break data example

4.2 Quality Control

- **Spike detection**

  - Spikes are different from noise as they typically occur only one time step and are unpredictable with respect to their magnitude.

- **Break detection**

  - With breaks, we typify sudden increases (jumps) or decreases (drops) in the registered soil moisture value, usually from one time unit to the next.

- **CHV, CLV detection**

  - A constant high (Low) signal may be registered when the soil moisture content exceeds the upper limit of sensitivity of the sensor.

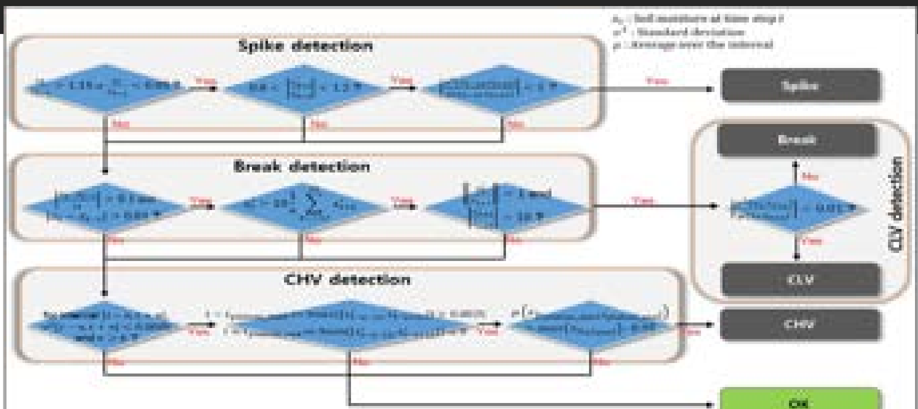


Fig. Quality Control Algorithm (source: Dorigo, 2011)

4.3 Analysis and Database

- **Soil Moisture Data**

  - Analysis of pattern by year through time series analysis of soil moisture

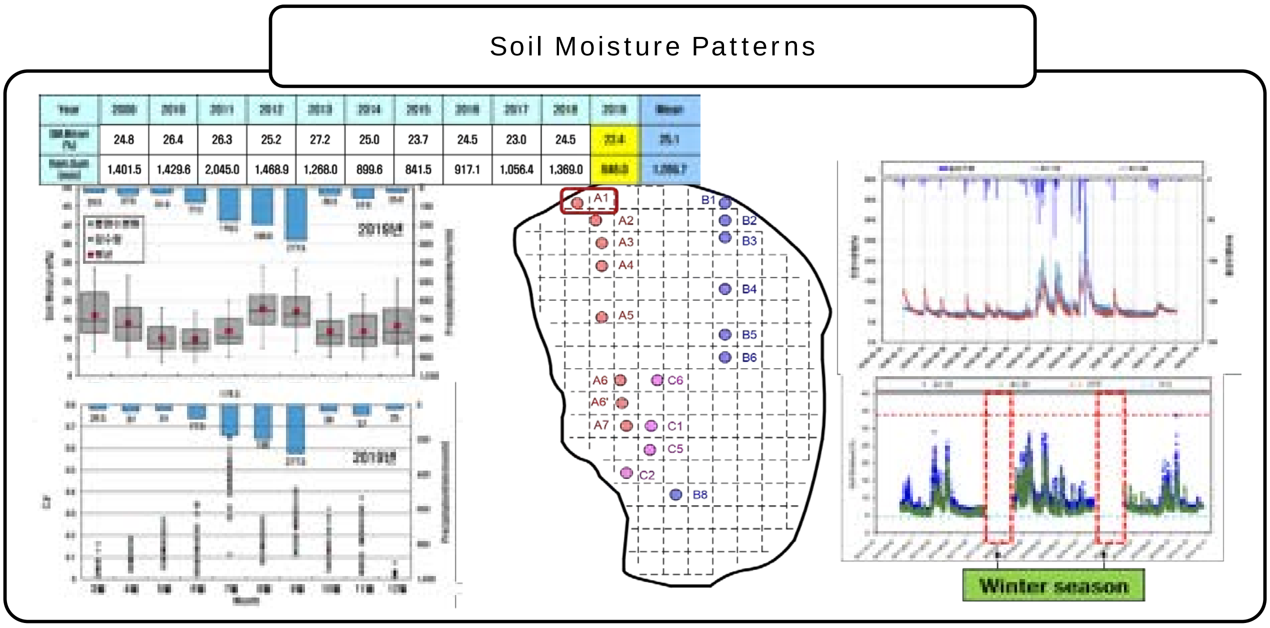


Fig. Various soil moisture data graph


Thank you very much

Observatory Operations Evapotranspiration

Hydrological Survey

Observatory Operations: Evapotranspiration

Aims & Objectives

- The aims of the course are to:

(1) Promote among trainees a good understanding of the basic measurement principle of evapotranspiration

(2) Enable trainees to set up an evapotranspiration observatory and operate it stably

(3) Improve the trainees' abilities to utilize appropriate quality control for high quality data

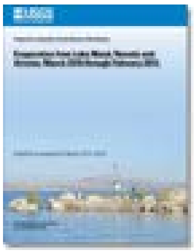
- At the conclusion of the course, trainees will be able to:

(1) Install an evapotranspiration observatory

(2) Carry out the maintenance of the evapotranspiration observatory

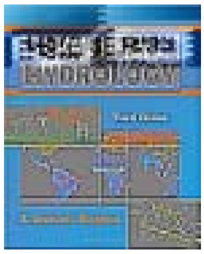
(3) Utilize quality control for producing good data

References



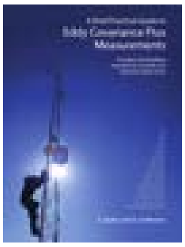
Evaporation from Lake Mead, Nevada and Arizona (USGS Report, 2013)

FAO irrigation and drainage paper (FAO-56)



Physical hydrology (Dingman)

Eddy Covariance: A Practical Guide to Measurement and Data Analysis (Springer)



Eddy covariance Flux Measurement (G. Burba and D. Anderson)

Campbell Scientific User Manual (Campbell Scientific)

Contents

1. Introduction

1.1 A Basic Knowledge
1.2 Type of Method

1.1 A Basic Knowledge

- What is Evapotranspiration?
  - **Evaporation**
    - · Process by which the phase of water is changed from a liquid to a gas
    - · In the hydrological cycle, evaporation moves in the vertical direction of the spatially averaged water vapor
  - **Transpiration**
    - · Process in which liquid water from plants is converted to vapor and released into the atmosphere
  - **Factors**
    - · radiation, temperature, wind, humidity, pressure, etc.

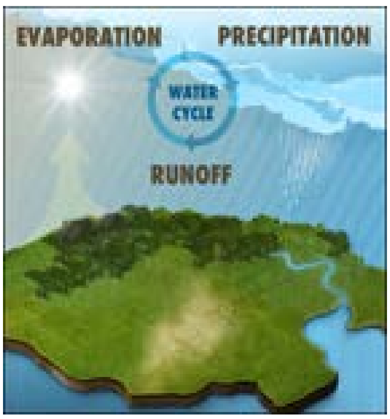


Fig. Hydrology cycle
(source: The climate reality project)

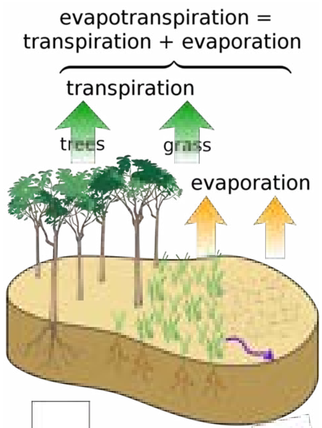


Fig. Evapotranspiration
(source: Wikipedia, “Evapotranspiration”)

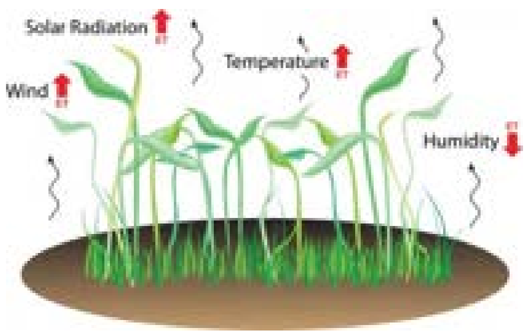


Fig. Evapotranspiration Factors
(source: Campbell scientific)

1.1 A Basic Knowledge

- **Why do we measure Evapotranspiration?**
  - **Agriculture** Assessing plant water requirement and scheduling irrigation work
  - **Forestry** Plant water uptake and consumptive use
  - **Hydrology** Water management, basin analysis
  - **Others** Plan disaster prevention measures (drought, climate changes, dust, etc.)

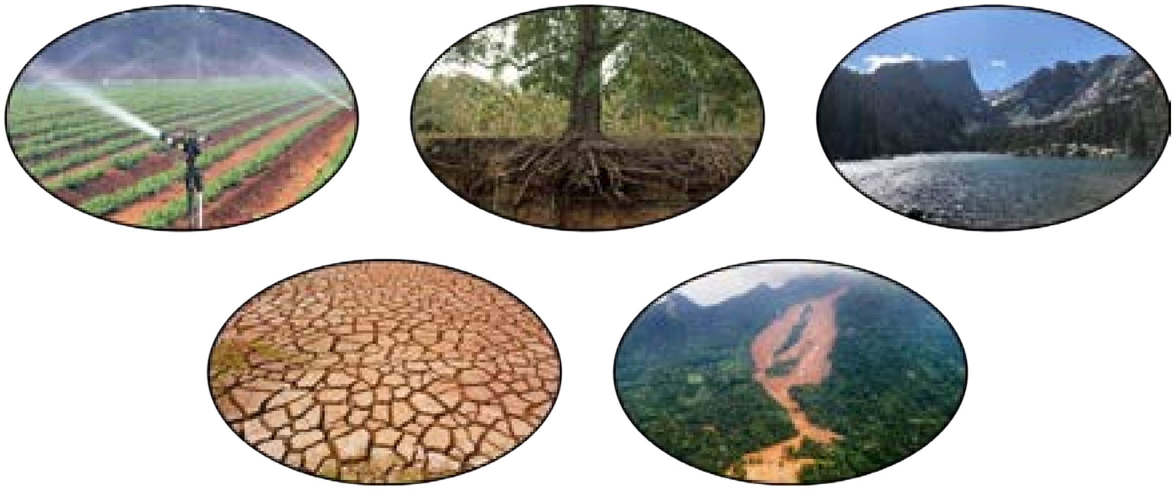


Fig. Measurement application example

1.1 A Basic Knowledge

- **How to measure Evaporation?**
  - **Latent heat of vaporization**
    - · During the phase change, the liquid will not increase in temperature, as all the heat added is used (absorbed) to overcome the latent heat of vaporization
    - · Liquid changes to gas
    - · Energy need to change 1kg of water to steam (without temperature change) = 2.26×10^{6} J kg^{-1}

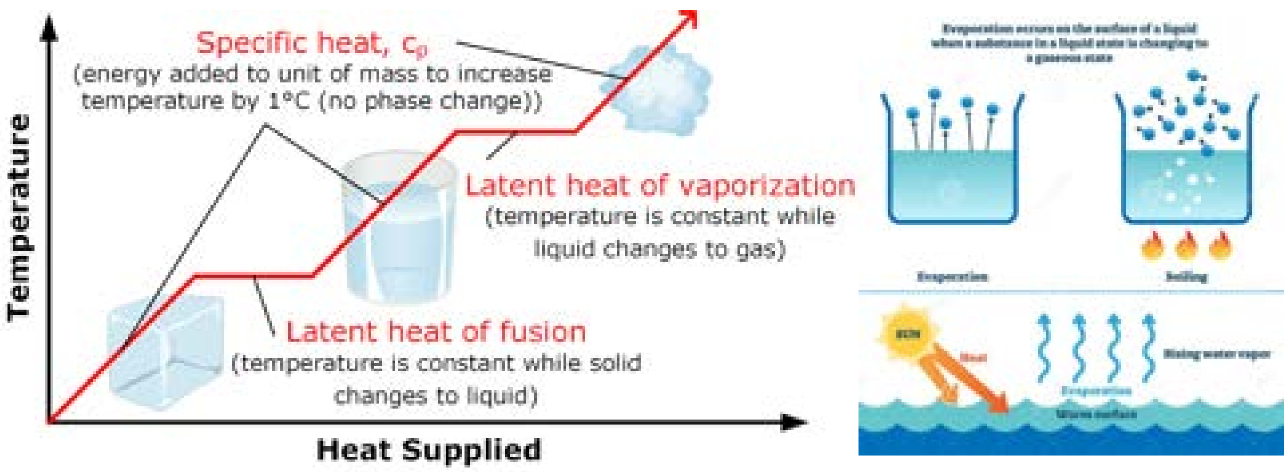


Fig. The concept of evaporation
(source: shutterstock, https://www.shutterstock.com)

1.2 Method Type

- **Water Budget Method**
  - These measurements deduce ET as a loss of liquid water by measuring or estimating all the other components in a water budget.
- **Water Vapor Transfer Method**
  - This measures the flow of water vapor into the atmosphere using meteorological sensors mounted above the surface.
- **Empirical & Analytical Equation**
  - It is easy to calculate but different from the actual ET (potential or reference ET)

Methods of measuring Evapotranspiration

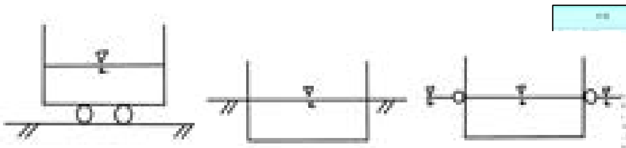
Water Budget Measurement	Water Vapor Transfer method	Components of Evaporation	Empirical & Analytical Equation	Large scale Evaporation
Evaporation Pan	Bowen Ratio Energy Budget	Soil Evaporation	(FAO)Penman-Monteith	Remote sensing
Water balance of basin	Eddy Covariance	Sap-flow	Priestley-Taylor	Scintillometer
Lysimeter	Mass transfer	Rainfall-interception loss	Meyer’s	LIDAR

Fig. Methods of measuring ET

1.2 Method Type

- **Evaporation Pan Method**
  - An evaporation pan is used to hold water during observations for the determination of the quantity of evaporation at a given location. Such pans are of varying sizes and shapes, the most used being circular or square
  - Pros: Simple, inexpensive, and long-term global datasets are available
  - Cons: Uncertainties in magnitude and timing, contains errors (splashing, solar heating of the pan, wind effect), freezing condition limit use, often poorly sited and maintained, must determine pan coefficient, always fill water (no actual evaporation)

Fig. Evaporation Pan
(source: Wikipedia, “Evapotranspiration”)



$$E = \Delta Z_W^* k_P$$

ΔZ_W^*= the change in daily water levels

k_P= Pan coefficient

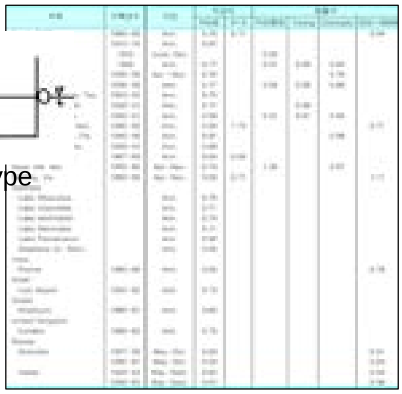


Fig. Evaporation pan coefficient
(source: 이재수 저, “수문학”)

1.2 Method Type

▪ Water Balance of Basin

- Evaporation is calculated as the residual of the water balance input terms (precipitation P, surface inflow Q_{in}, groundwater inflow G_{in}) and output term (Surface runoff Q_{out}, groundwater outflow G_{out}, diversion and withdrawals D) and change in water level ΔZ_W
- Pros: Accounts for evaporation over the entire reservoir, thus, complex shapes and locations that do not meet meteorological-based fetch requirements can be measured
- Cons: All the water balance terms must be accurately measured (seldom possible), therefore, large errors can accumulate in the E estimation.

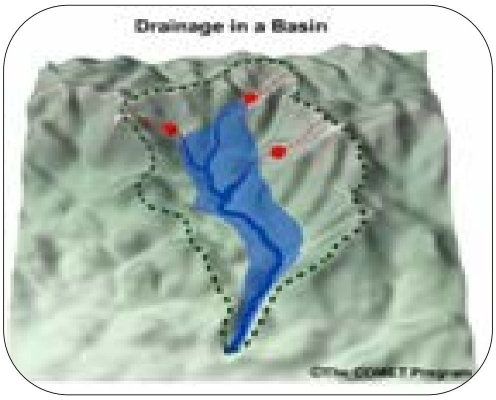


Fig. Basin
(source: The COMET program, "Drainage in a basin")

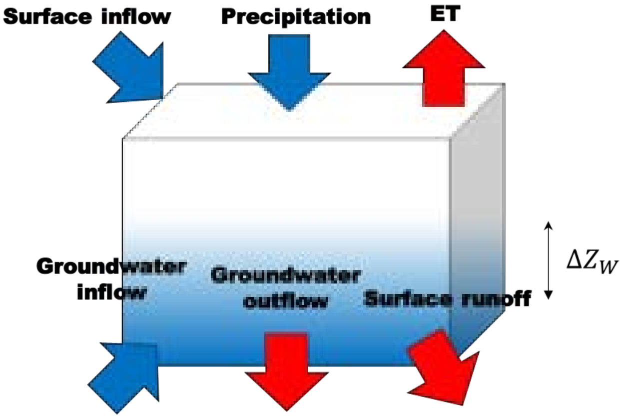


Fig. The concept of water balance

1.2 Method Type

▪ Lysimeter

- The amount of water lost by evapotranspiration can be worked out by calculating the difference between the weight before and after the precipitation input
- Pros: most accurate when vegetation is grown in a large soil tank, which allows the rainfall input and water lost through the soil to be easily calculated
- Cons: Expensive and poor representation of conditions outside of a laboratory (for tree)

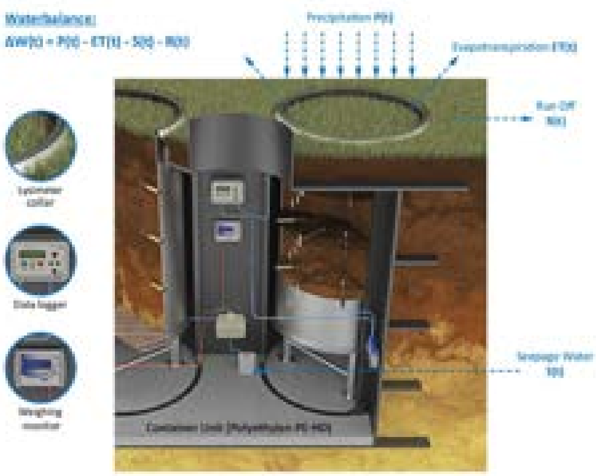


Fig. Soil cross section with lysimeter installed
(source: MEMECO, https://memecosales.com/)

Fig. Lysimeter Type

1.2 Method Type

- **FAO Panman-Monteith**
  - The panel of experts recommended the adoption of the Penman-Monteith combination method as a new standard for reference evapotranspiration and advised on procedures for calculation of the various parameters
  - Pros: Grass, together with alfalfa, is a well-studied crop regarding its aerodynamic and surface characteristics and is accepted worldwide as a reference surface
  - Cons: May require local calibration of the wind function to achieve satisfactory results

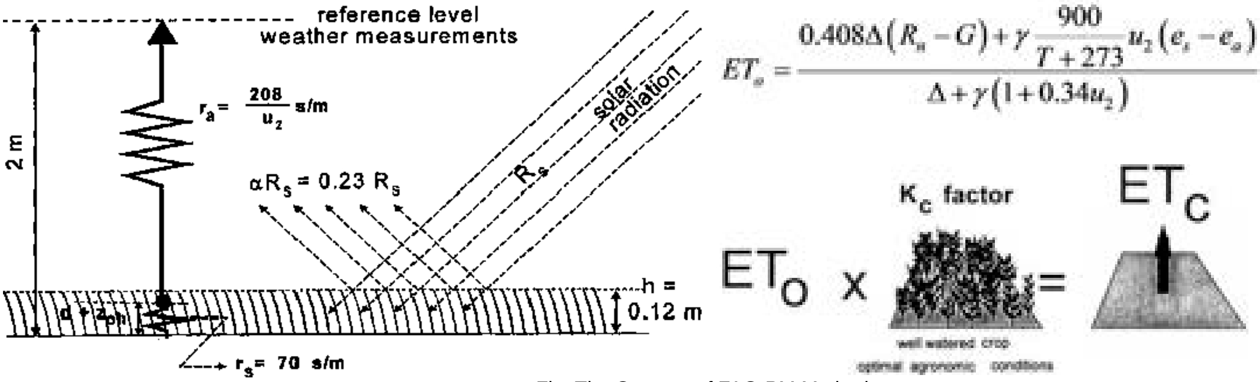


Fig. The Concept of FAO-PM Method
(source: FAO, "FAO-56 Drainage and Irrigation paper")

1.2 Method Type

- **Bowen Ratio Energy Budget**
  - Vertical gradients in air temperature and humidity are used to determine the Bowen ratio β, which is then combined with the surface energy balance equation
  - Pros: Has been applied with success over small reservoirs where the heat storage term J_T can be accurately measured
  - Cons: Difficult to accurately measure the heat storage term over large or complex reservoirs

Fig. BREB Station
(source: EMS Brno, "http://www.emsbrno.cz")

$$\lambda E = \frac{R_n - G}{1 + \beta}$$

$$E = \frac{1}{\lambda_v \rho_w} \frac{R_n - G}{1 + \beta}$$

$$\beta = \gamma\left(\frac{T_2 - T_1}{e_2 - e_1}\right)$$

$$\gamma = \left(\frac{c_p P}{0.622\lambda_v}\right)$$

Primary inputs		Relative constants
R_n	[W m^{-2} or Jm^{-2}day^{-1}]	$\lambda_v = 2.501 \times 10^6 - 2370\,T$ J kg^{-1}
G	Often neglected	γ = 66.8 Pa/°C for typical conditions
T_1, T_2	[°C]	p = 10^5 Pa
e_1, e_2	[Pa]	c_p = 1005 J kg^{-1} °C^{-1}

1.2 Method Type

- **Eddy covariance**
  - Evaporation is calculated from high-frequency (typically 10Hz) measurements of the deviation of specific humidity and vertical wind speed relative to a time-averaged mean
  - Pros: Theoretically simple with measurement at one height above the water surface
  - Cons: Instruments are relatively expensive, adequate fetch is required; several well-known corrections should be applied to the raw data; assumptions are included

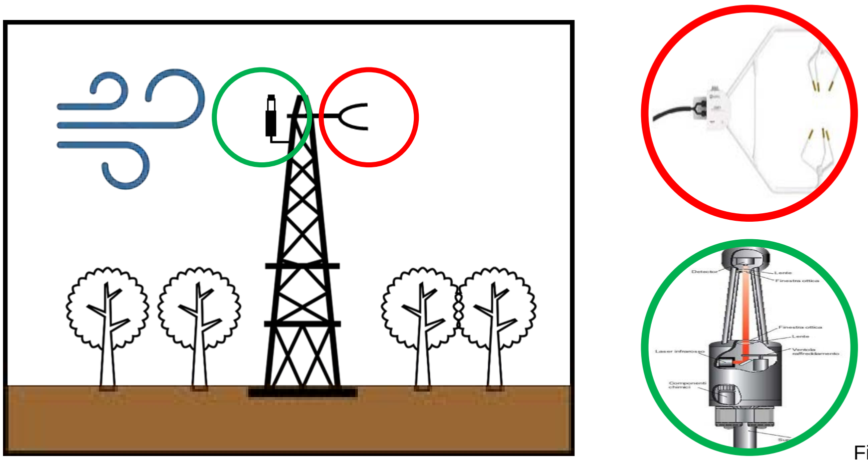


Fig. Flux Tower and Sensors

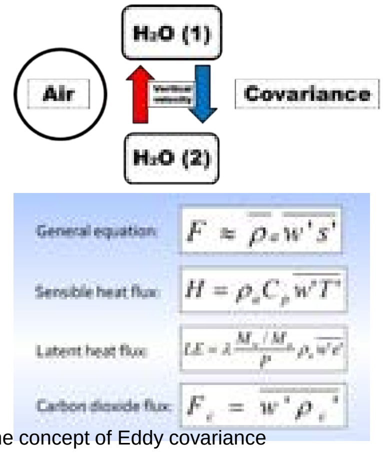


Fig. The concept of Eddy covariance
(source: Li-cor, "Eddy covariance manual")

2. Observatory Installation

2.1 Site Selection
2.2 Sensor Installation

2.1 Site Selection

▪ Flux Tower Site

- The best location has points that represent the weather and atmospheric conditions, the characteristics of the vegetation distribution, the soil characteristics, etc. in the region or basin you want to observe because they are affected by a wide variety of conditions, including physical factors such as temperature, water, wind, and humidity; atmospheric conditions; type of vegetation; and distribution density.

  · A place that represents the weather, topography, soil, vegetation, etc. of the surrounding area
  · A place not affected by individual obstacles such as trees and buildings
  · Easy to install, maintain, and manage observation facilities
  · A place where irrigation, soil characteristics (texture, soil layering, general type), watershed slope, vegetation cover, etc. can represent the surrounding area (target watershed)

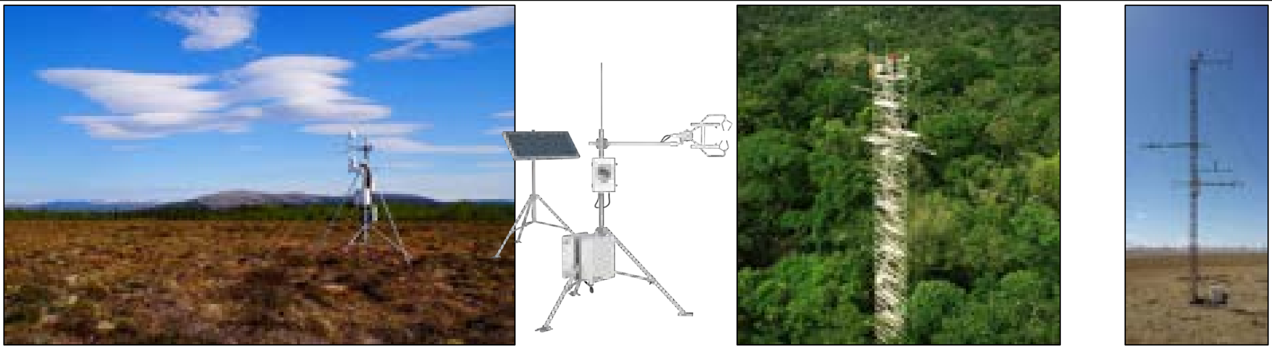


Fig. Flux tower Type
(source: Fluxnet, Campbell scientific)

2.2 Sensor Installation

▪ Flux Tower Installation Standard

- Several installation criteria are required for the accuracy of observation.
- The tower should not distort the wind.

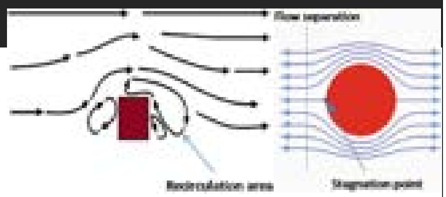


Table and Fig . Flux tower installation standard (source: Munger et al., 2012)

Index	Detailed criteria
Endurance	Wind Speed: Less then 40 m/s , Humidity: 0～100%, Temperature:-50～50℃ salt air, Freezing: 12.7mm, Snow: 5.1m/yr, Rainfall: 0-6.35m/yr
Wobble	Movement of less than 1mm per 1m in height (at wind speeds lower than 20m/s) Prohibited vibration occurs in 1~20Hz
Sensor Height	Grassland, Shrubland: $h_m = 6$m (Note, $h_m >$ 뎐$Z_d + 4$뎌$h_c - Z_d$뎍뎟 and $h_c \leq 1.75$) Forest, Mixed forest:: $h_m \approx Z_d + 4$뎌$h_c - Z_d$뎍 (Note, Change height every time vegetation grows with $h_m \leq Z_d + 3.4$) Crops within 3m: 8m
Size	Tower Installation of towers with a height of at least 5뎌$h_c - d$뎍 as the vegetation continues to grow Area Tower base area less than 4m^2 (Note: it can be wider when the water pipe is wide, but minimization is recommended)

3. Maintenance

3.1 Data Monitoring
3.2 Field Inspection
3.3 Device Check

3.1 Data Monitoring

- Daily monitoring
  - Make sure if each observation device is working properly, and then record the inspection log. (Logger status => Volt 12V < , temp, measurement samples 10Hz =18,000, major meteorological data)
  - Make reports after the daily inspection is completed once or twice a day.
  - Determine whether an emergency field inspection is being made.

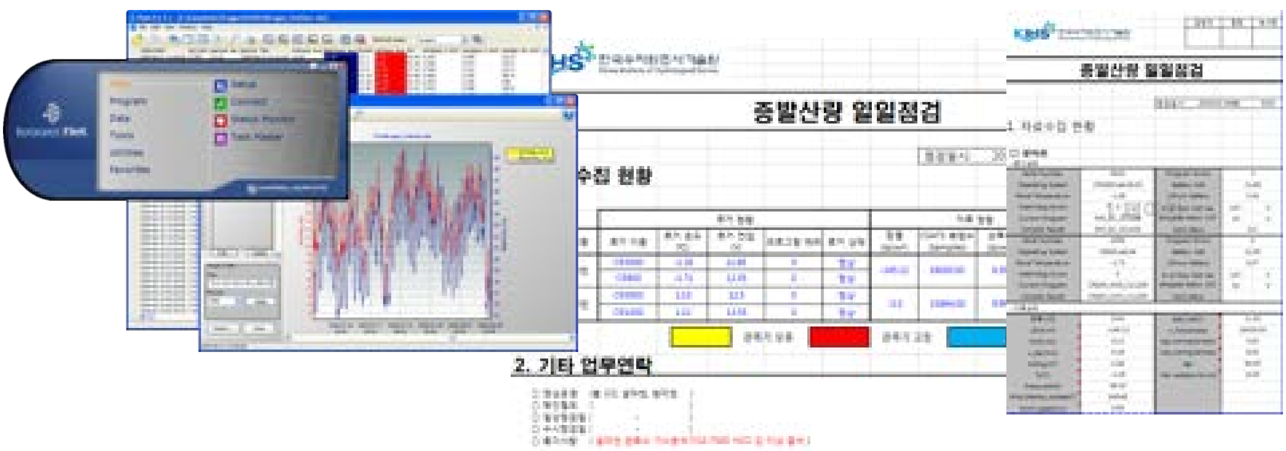


Fig. Flux data status using Loggernet

Fig. Daily monitoring Log

3.2 Field inspection

- **Inspection cycle**
  - The inspection cycle is set according to the weather conditions and the characteristics of the device.
  - Always fill out an inspection log.

- **Check list**

Routine Inspection
- Check logger
 (operation station, storage memory)
- Battery capacity
- Related facilities
- Check Sensor (cleaning, change filter)
- Check data
 (back-up data, missing or noise data)

Emergency Inspection

Weather condition
- Lightning event
- Torrential rainfall event
- Typhoon event

Data conditions
- Detect the data error

Number of visits		1월	2월	3월	[illegible]	5월	6월	7월	8월	9월	10월	11월	12월
Site 1	Plan	2(2)	2(2)	2(2)	[illegible]	-	-	-	-	-	-	-	-
	Acc	2(2)	4(4)	6(6)	[illegible]	-	-	-	-	-	-	-	-
	%	8.3 (8.3)	16.7 (16.7)	25.0 (25.0)	[illegible]	-	-	-	-	-	-	-	-
Site 2	Plan	2(2)	2(2)	2(2)	[illegible]	-	[illegible]	-	-	-	-	-	-
	Acc	2(2)	4(4)	6(6)	[illegible]	-	[illegible]	-	-	-	-	-	-
	%	8.3 (8.3)	16.7 (16.7)	25.0 (25.0)	[illegible]	-	-	-	-	-	-	-	-
Total	Acc	4(4)	8(8)	12(12)	[illegible]	-	[illegible]	-	-	-	-	-	-
	%	8.3 (8.3)	16.7 (16.7)	25.0 (25.0)	[illegible]	-	-	-	-	-	-	-	-

Fig. Inspection Log

Fig. Inspection in Field

3.3 Device check

- **Inter-comparison check**
  - Cross-check with auxiliary weather equipment
  CSAT3 vs AWS (Wind Velocity, Direction, Temp)

- **Time series check**
  - Check measurements with time series characteristics (It is not an absolute value but for reference only)

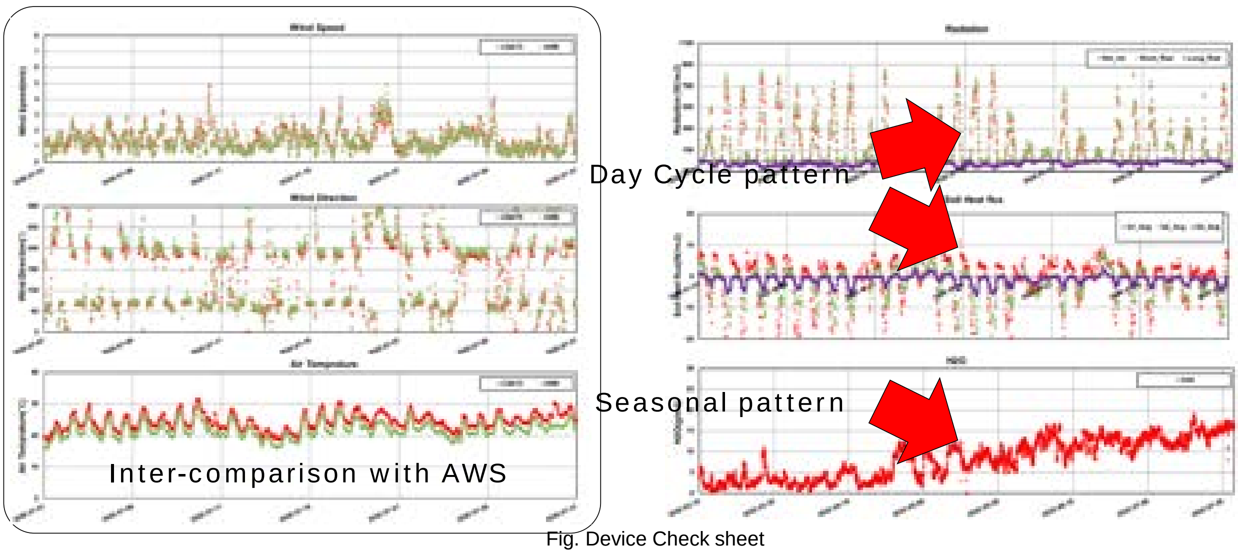


Fig. Device Check sheet

4. Data Handling

4.1 Data Management Process
4.2 Quality Control
4.3 Analysis and Database

4.1 Data Management Process

- Process
  - Perform monthly quality control

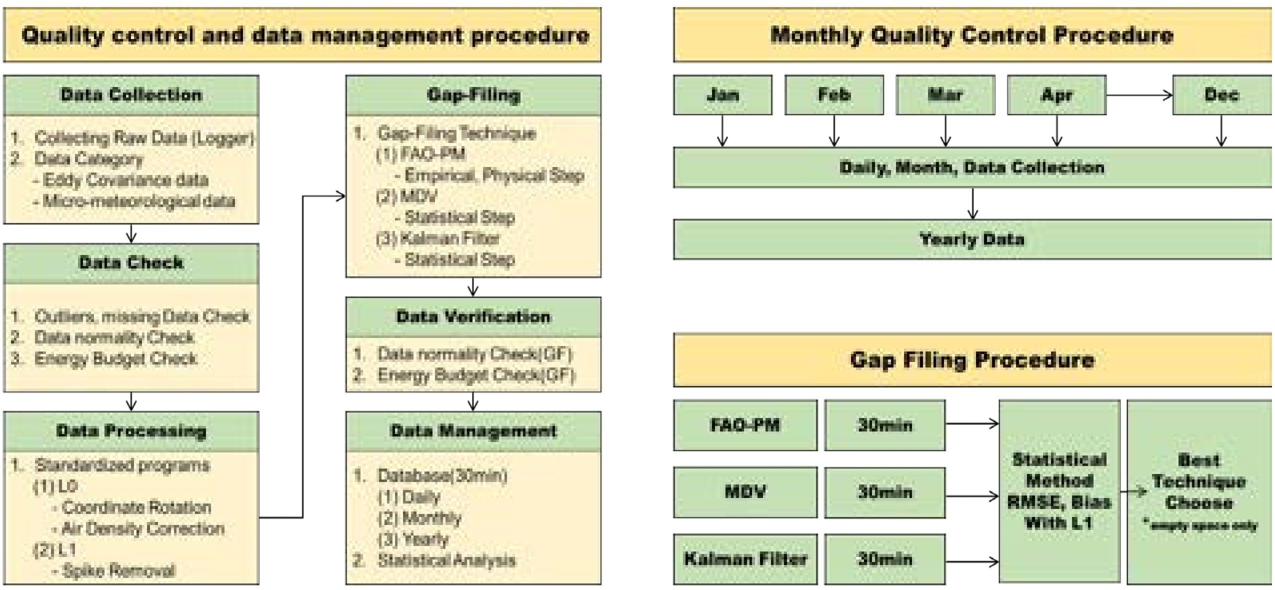


Fig. Data processing flow chart

4.2 Quality Control

▪ **Standardized Data** Raw to L0, L1

- The method of measuring eddy covariance has many assumptions.
  (The terrain is horizontal and uniform; the average fluctuation of w' is zero; air density fluctuation, flow convergence, and divergence are negligible)
- Quality data calculation through standardized process
- Coordinate Rotation (PFR), Density Correction (WPL), Spike Removal

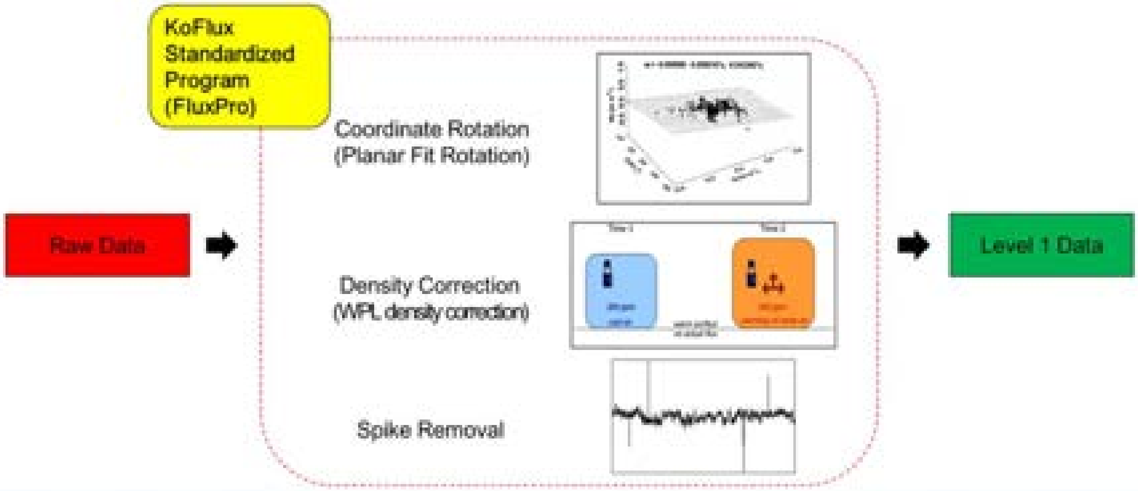


Fig. Data standardization process

4.2 Quality Control

▪ **Gap-filling Method** L1 to L2

- Hydrological data continuity
- Compensation of missing data through statistical and physical methods

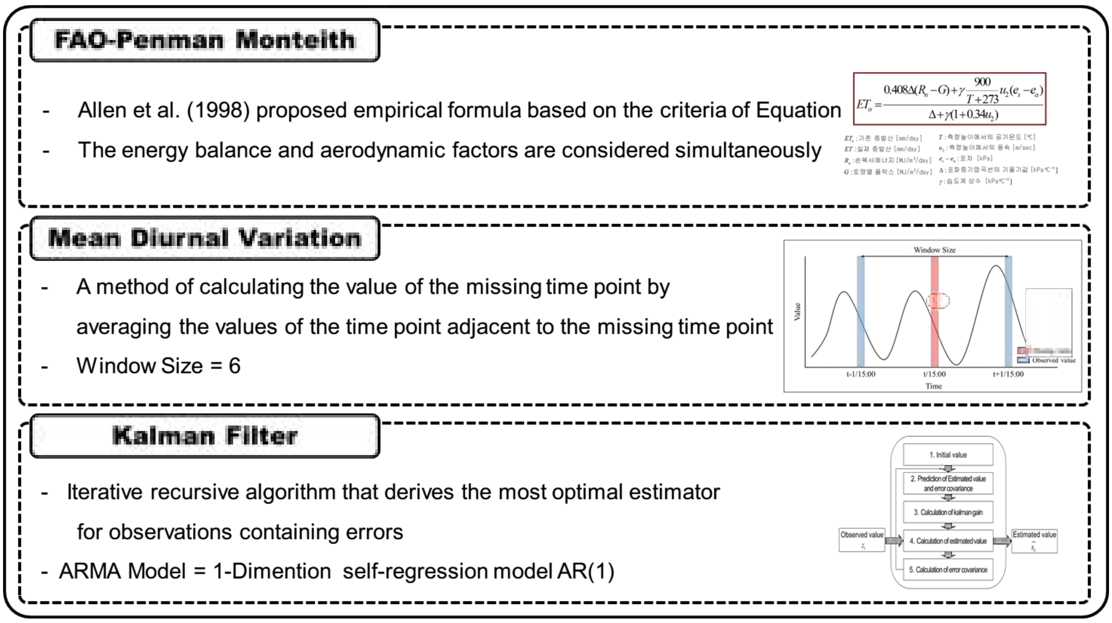


Fig. Gap-filling Method

4.3 Analysis and Database

- **Evapotranspiration Data**
  - Analysis of pattern by year through time series analysis of evapotranspiration

Evapotranspiration Patterns

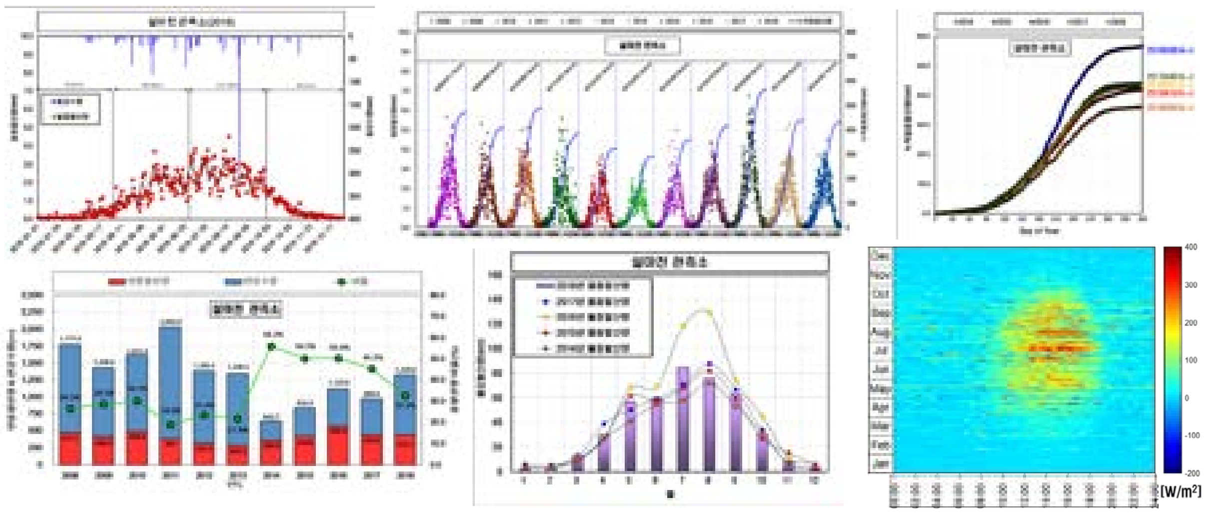
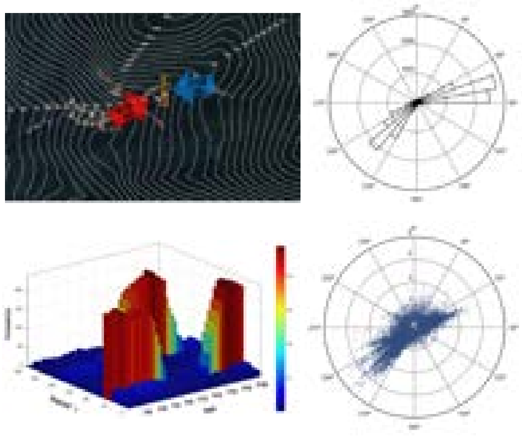


Fig. Various evapotranspiration data graph

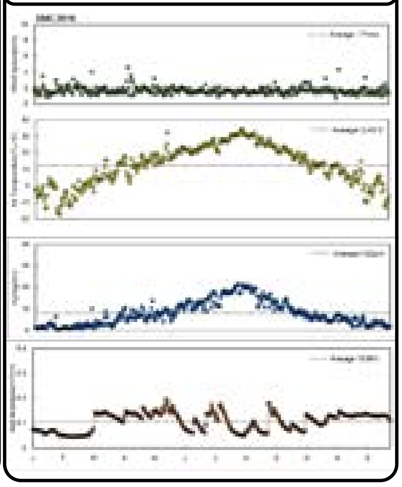
4.3 Analysis and Database

- **Micro-Meteorological Data**
  - Collecting topographic and meteorological data near the station for the analysis of evapotranspiration
- **Observation Rate**
  - Record issues for accurate analysis

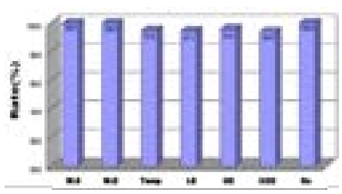
Wind and topographical characteristics



Micro-meteorological characteristics



Observation rate



Site Observation Rate(%)			
Jan	97.1	Jul	96.4
Fer	97.2	Aug	95.7
Mar	95.0	Sep	97.3
Apr	94.9	Oct	96.9
May	89.6	Nov	95.7
Jun	95.7	Dec	95.5

Fig. Micro-meteorological graph and Observation rate


Thank you very much

MEMO

Discharge Computation

Hydrological Survey

Discharge Computation

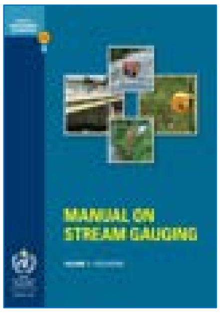
Aims & Objectives

- The aims of the course are to:
  - (1) Promote among trainees a good understanding of the basic principles of discharge measurement
  - (2) Introduce various equipment and enable trainees to understand method for discharge measurement in the field

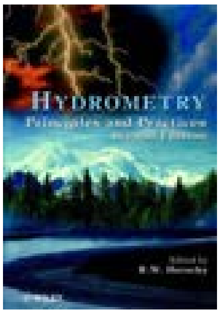
- At the conclusion of this course, trainees will be able to:
  - (1) Explain the objectives and necessity of discharge measurement
  - (2) Apply the methods of discharge measurement with field condition
  - (3) Perform the computation of discharge data

References

USGS Measurement and Computation: vol1. (S.E. RANTZ and others, 1982)

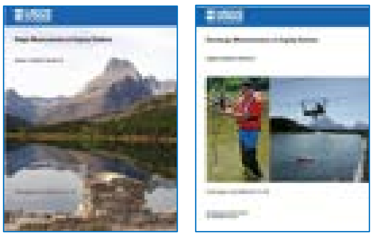


Manual on Stream Gauging 1 (WMO-1044, 2010)



Hydrometry principal and Practices (R.W. Herschy and others, 1978)

Streamflow Measurement (R.W. Herschy, 1978)



USGS TWRI 3-7A, 3-8A (2010)

Hydrological Survey Report (ME, 2010~2019)

Manual on Discharge Streamflow measurement (KIHS, 2018)

Guideline of discharge measurement, etc. (KIHS, 2018)

Contents

1. Introduction

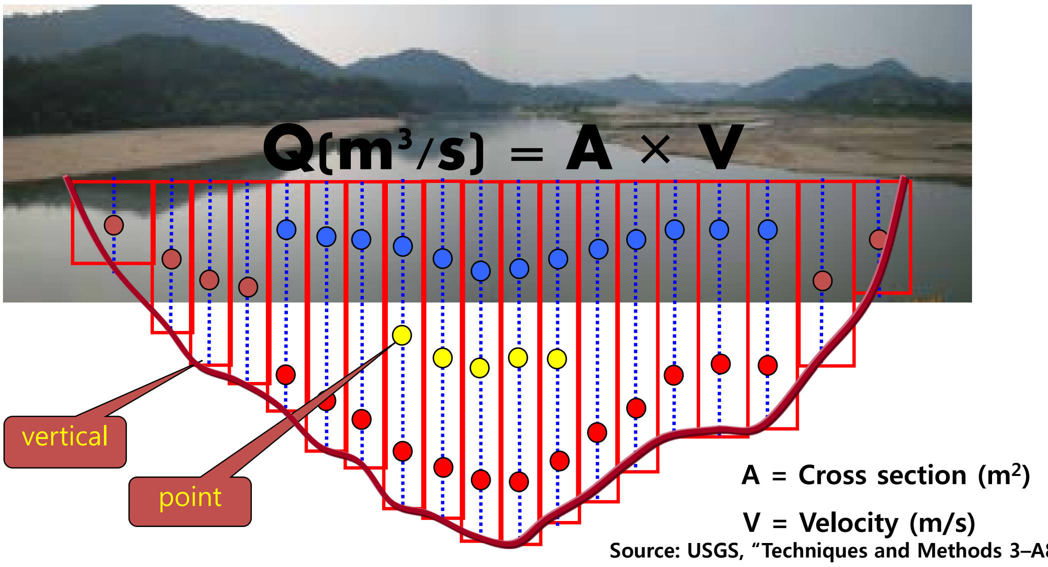
1.1 Background
1.2 Discharge Calculation Software (CalPAD)

1.1 Background

▪ **Streamflow Measurement**

1.1 Background

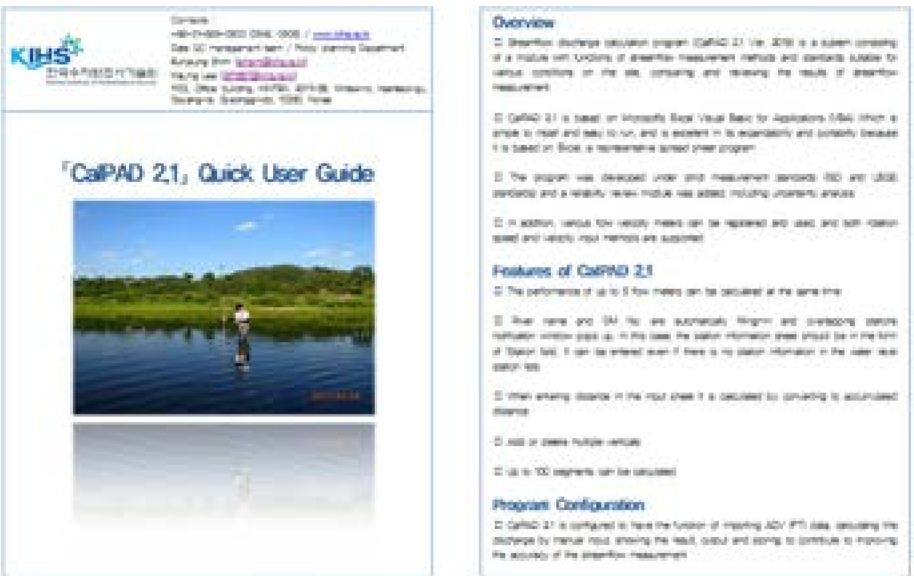
- **Definition of Streamflow or Discharge**
  - the volumetric rate of flow of water (volume per unit time) in an open channel, including any sediment or other solids that may be dissolved or mixed with it that adhere to the Newtonian physics of open channel hydraulics of water
  - "streamflow measurement" or "discharge measurement" is generally applied to the result of the calculations.



Source: USGS, "Techniques and Methods 3–A8" 2010

1.2 Discharge Calculation Software (CalPAD)

- **Development of software tool to calculate discharge for all kinds of point velocimetry (price meter, ADV, etc.) using the midsection method**



Source: KIHS, "「Calpad 2.1 Quick User Guide」" 2019

1.2 Software Tool to Calculate Discharge (CalPAD)

▪ Overview of CalPAD 2.1

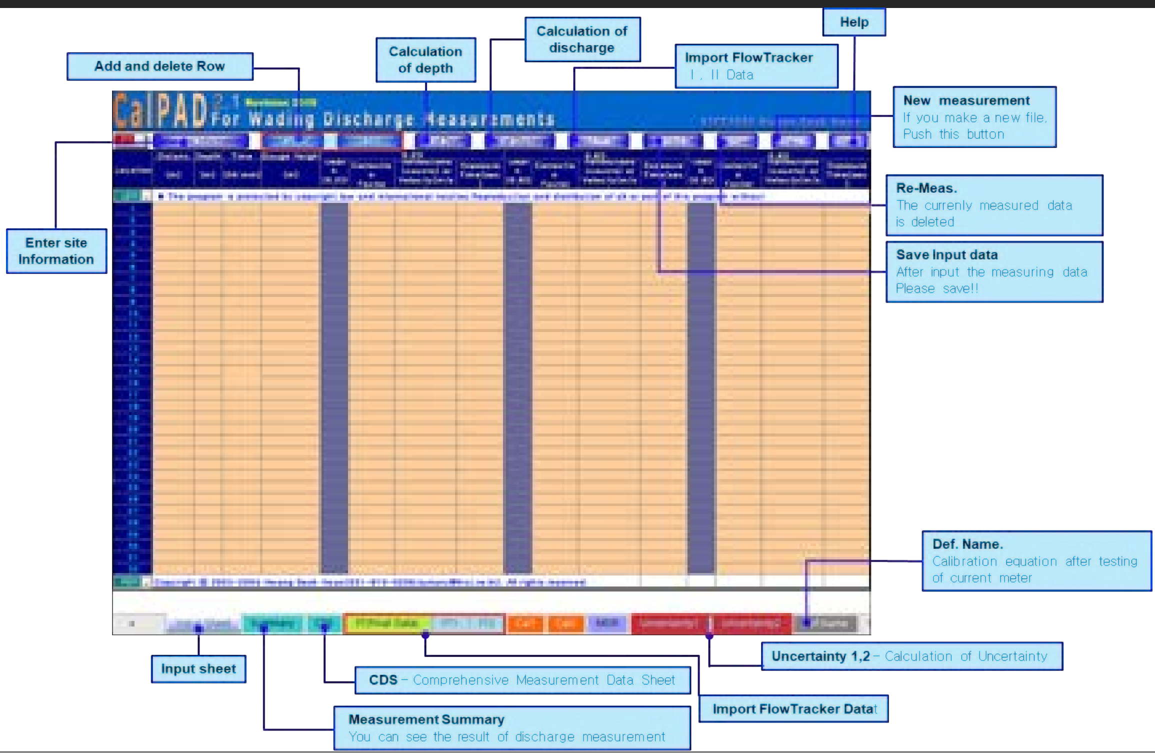
- The streamflow discharge calculation program (CalPAD) is a system consisting of a module with the functions of streamflow measurement methods and standards suitable for various conditions on the site, comparing and reviewing the results of streamflow measurement.
- CalPAD 2.1 based on Microsoft's Excel Visual Basic for Applications, which is simple to install and easy to run, and is excellent in its expandability and portability because it is based on Excel, a representative spreadsheet program.
- The program was developed under strict ISO and USGS measurement standards and a reliability review module was added, including uncertainty analysis.
- In addition, various flow velocity meters can be registered and used, and both rotation speed and velocity input methods are supported.

▪ Features

- The performance of up to 5 flow velocity meters can be calculated at the same time.
- River name and DM No. are automatically filled-in and, in the case of overlapping stations, a notification window pops up.
- In this case, the station information sheet should be in the form of “station lists.”
- On the input sheet, distance is calculated by converting to the accumulated distance.
- Add or delete multiple verticals.
- Up to 100 segments can be calculated.

1.2 Software Tool to Calculate Discharge (CalPAD)

▪ Main Sheet of CalPAD 2.1

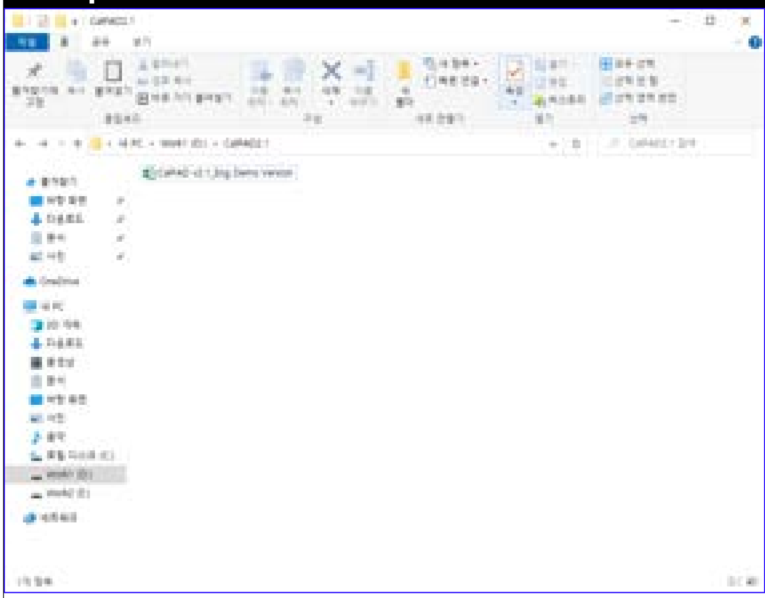


2. CalPAD

2.1 Calculating Procedures

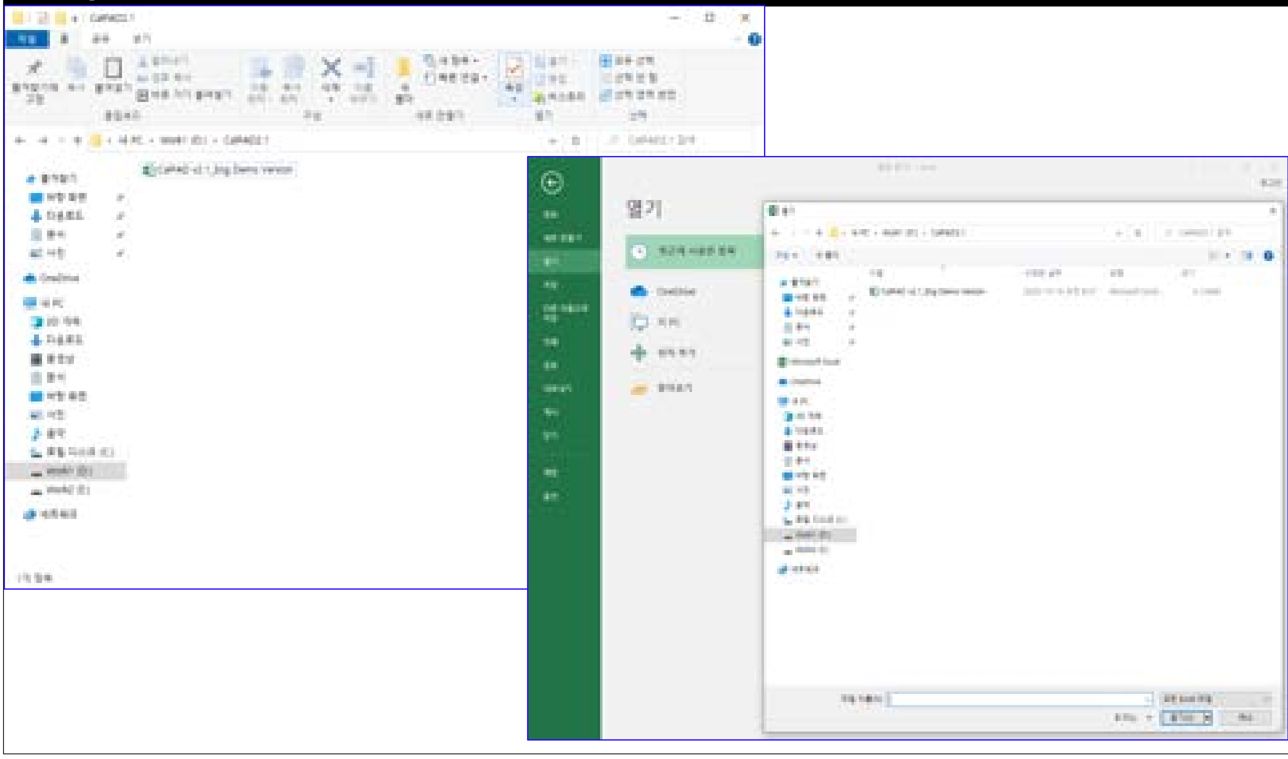
2.1 Calculating Procedures

- **Open the CalPAD 2.1**



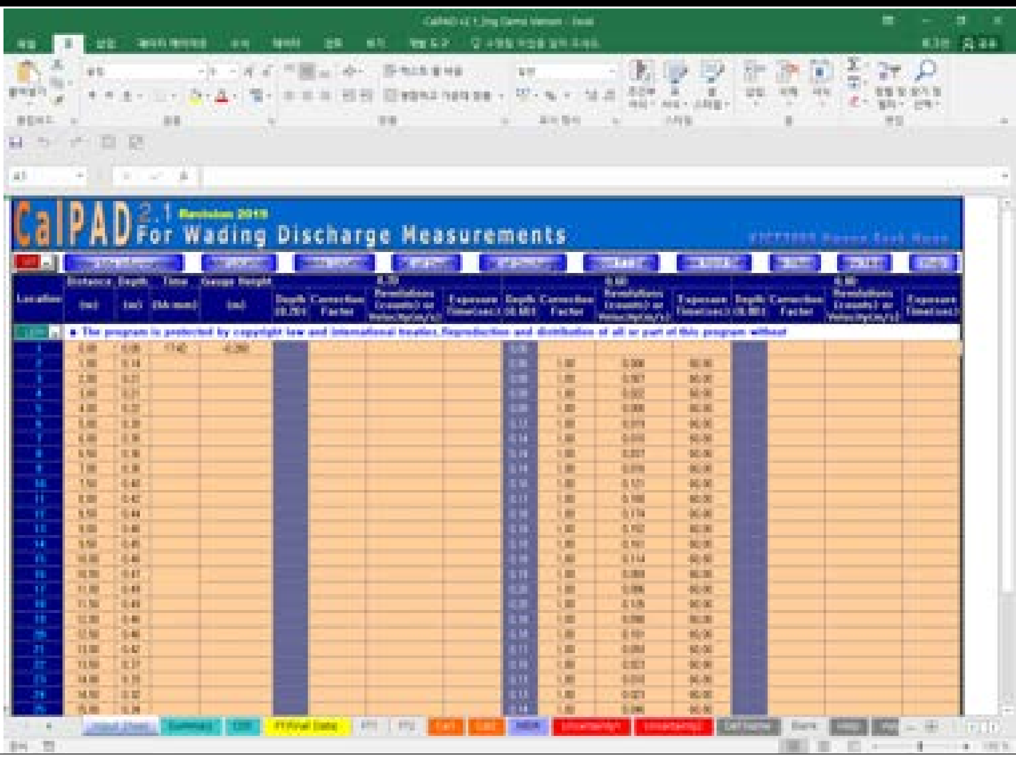
2.1 Calculating Procedures

▪ **Open the CalPAD 2.1**



2.1 Calculating Procedures

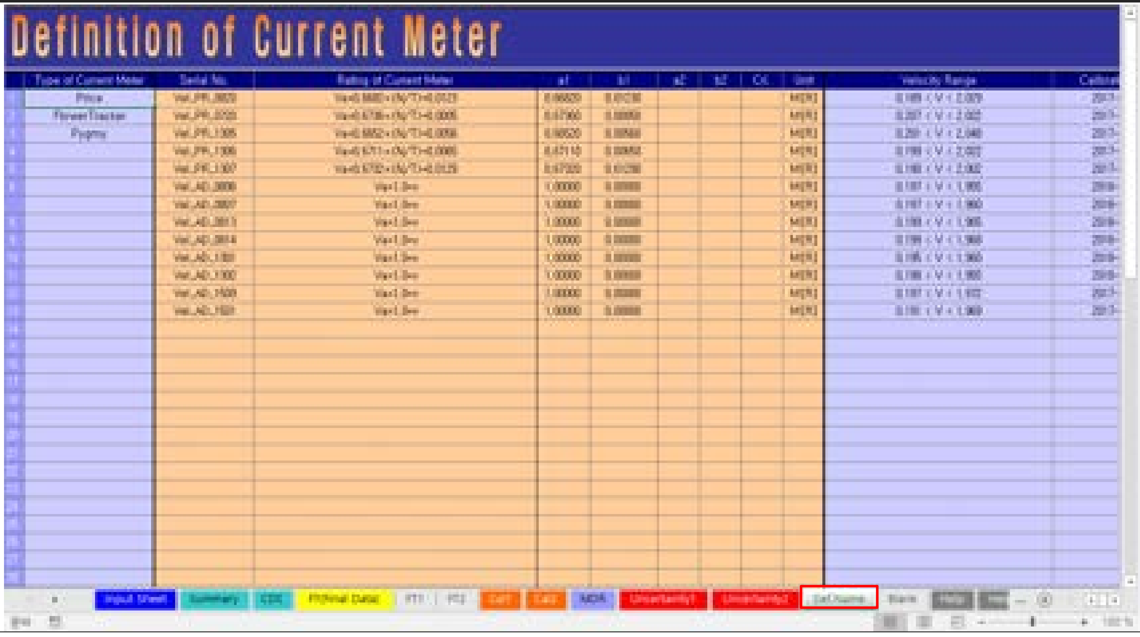
▪ **Open the CalPAD 2.1**



2.1 Calculating Procedures

▪ Input the Definition of Current Meter

- Enter the information of current meter into the Def.Name sheet.
  Input the type of current meter, rating of current meter, velocity range, and method of measurement.



2.1 Calculating Procedures

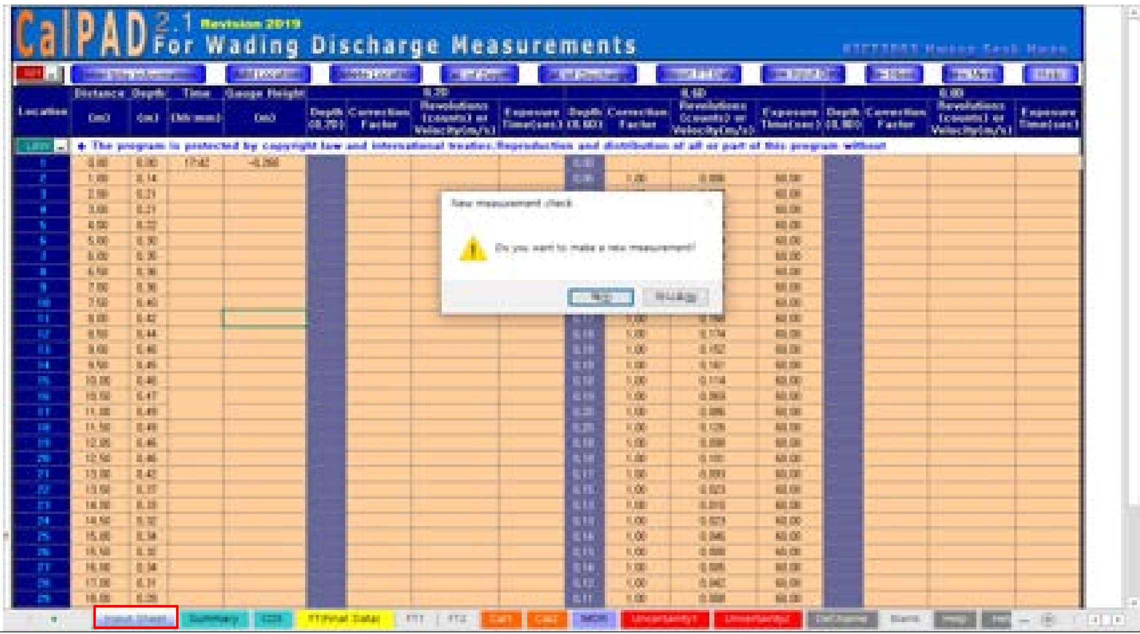
▪ Input the Definition of Current Meter

- Enter the information of current meter into the Def.Name sheet.
  Input the type of current meter, rating of current meter, velocity range, and method of measurement.

2.1 Calculating Procedures

▪ New Measurement

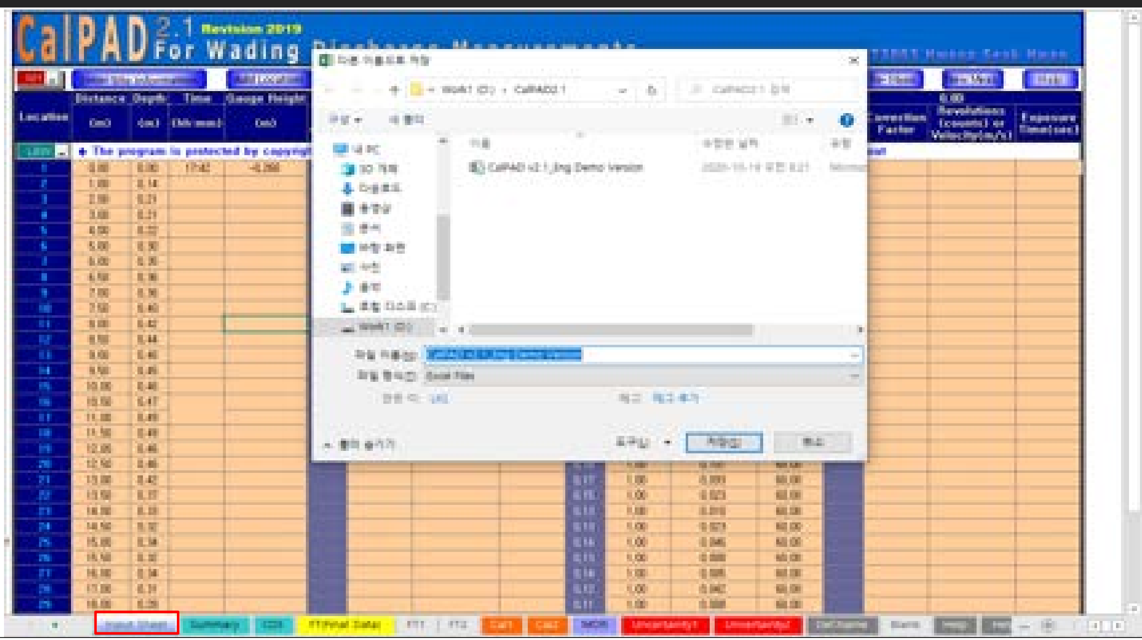
- If you want to make a new measurement file, click the new measurement button.
- Answer Yes to the pop-up question.



2.1 Calculating Procedures

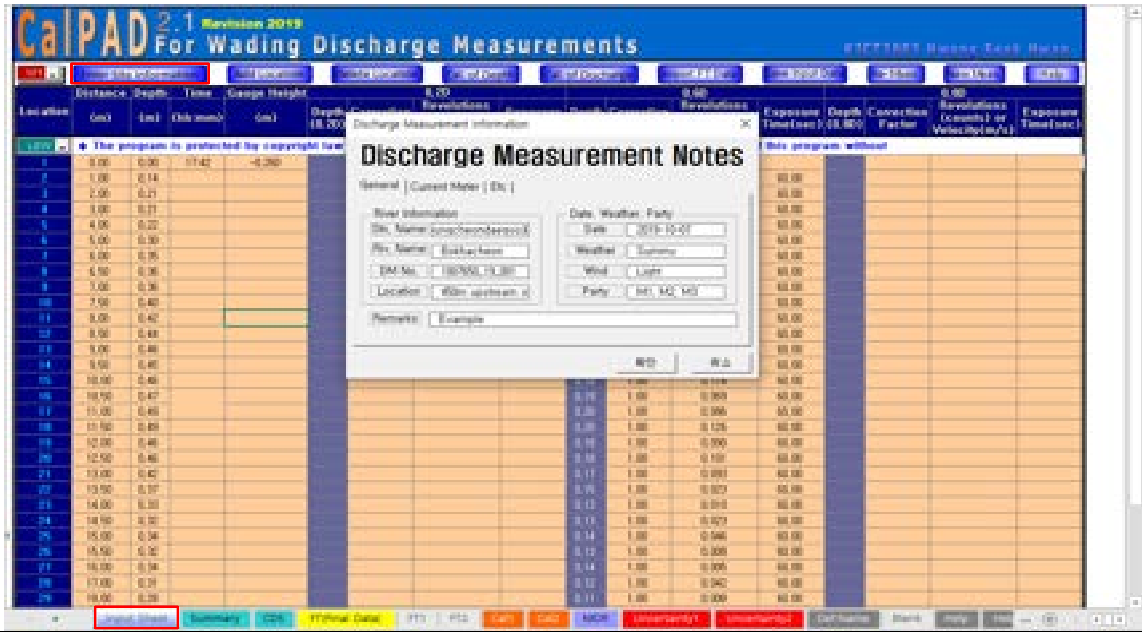
▪ Save File as

- You can specify folders and file names to Reset all sheets without saving on cancel.
- Ex: Station Name_DM_Year_No → Imjingyo_1021580_16_017



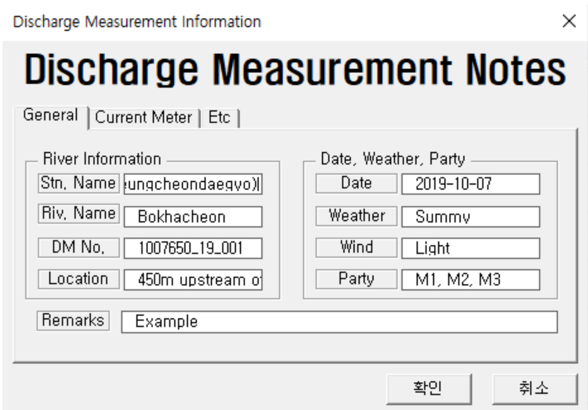
2.1 Calculating Procedures

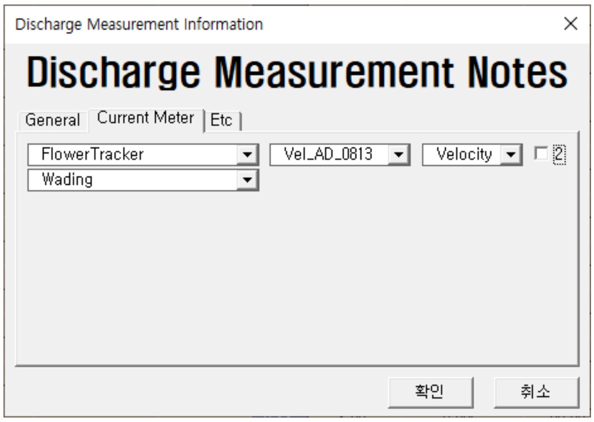
- **Input the Station Information**
  - Enter site information → discharge measurement, current meter, etc.



2.1 Calculating Procedures

- **Input the Station Information**
  - Enter site information → discharge measurement, current meter, etc.

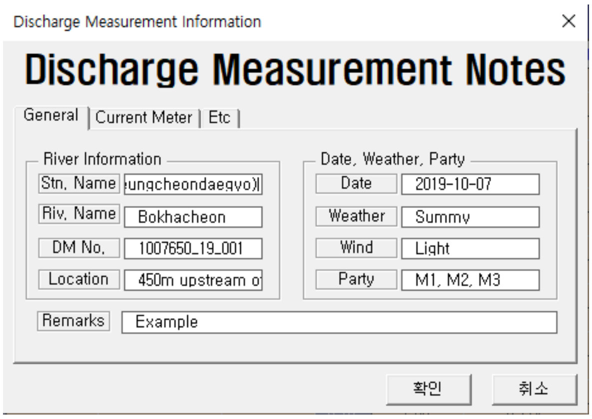


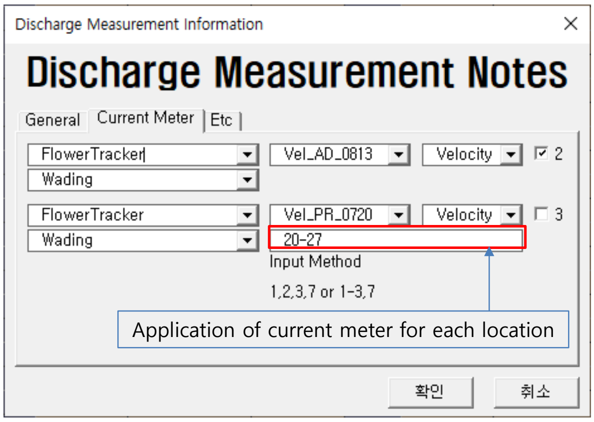


2.1 Calculating Procedures

▪ Input the Station Information

- Enter site information → discharge measurement, current meter, etc.





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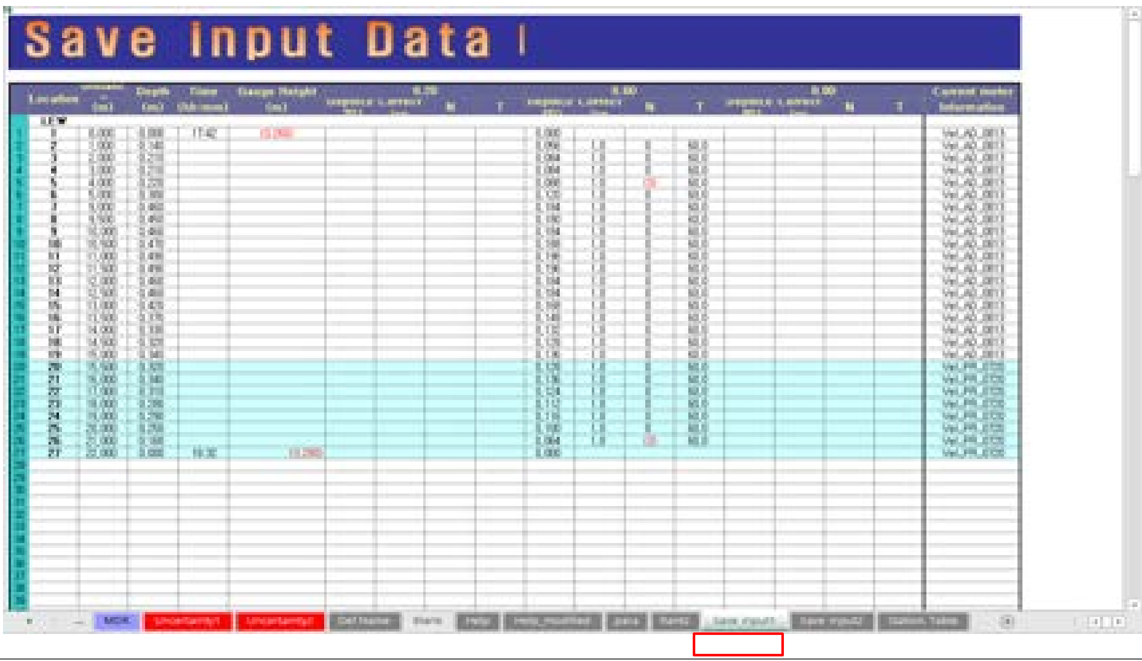
▪ Input the Station Information

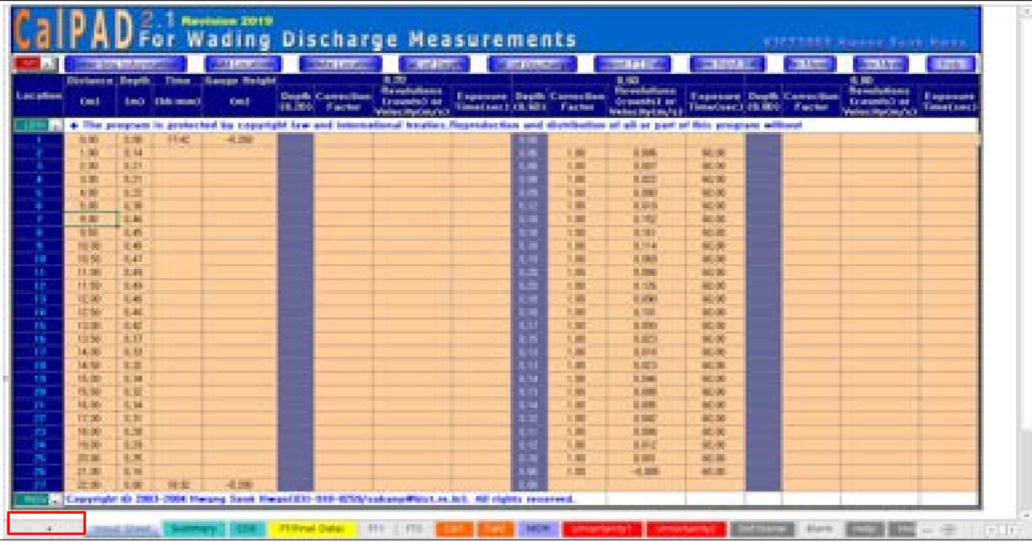
- Enter site information → discharge measurement, current meter, etc.



2.1 Calculating Procedures

▪ Input the Measuring Data (Manual)

1. Distance and depth of cross section
2. Starting and ending time
3. Number of revolutions of hydrometer(current meter) with measuring time
4. Input the correction factor. (1.00)
5. Click the calculation of depth.
6. Selection option (once or twice)



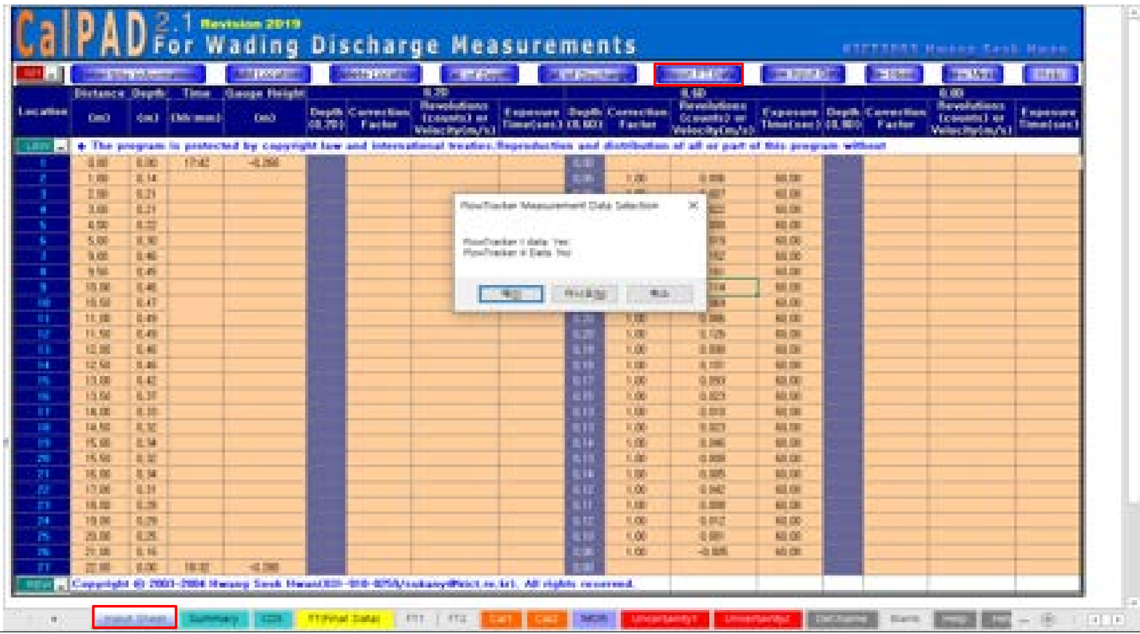
2.1 Calculating Procedures

▪ Input the Measuring Data (Import FlowTracker Data)

1. Distance and depth of cross section
2. Starting and ending time
3. Click 'Import FT Data.'
4. Select 'FlowTracker' type
5. Enter the number of 'FlowTracker.' (1 or 2)
6. Enter the last measuring distance between instruments if two units are used
7. Select dis file. (Please select Left → Right in order.)
8. Input the organized data in "Input Sheet."
9. Input the correction factor (1.00)
10. Click the calculation of depth
11. Selection option (once or twice)

2.1 Calculating Procedures

▪ Input the Measuring Data (Import FlowTracker Data)



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▪ Input the Measuring Data (Import FlowTracker Data)

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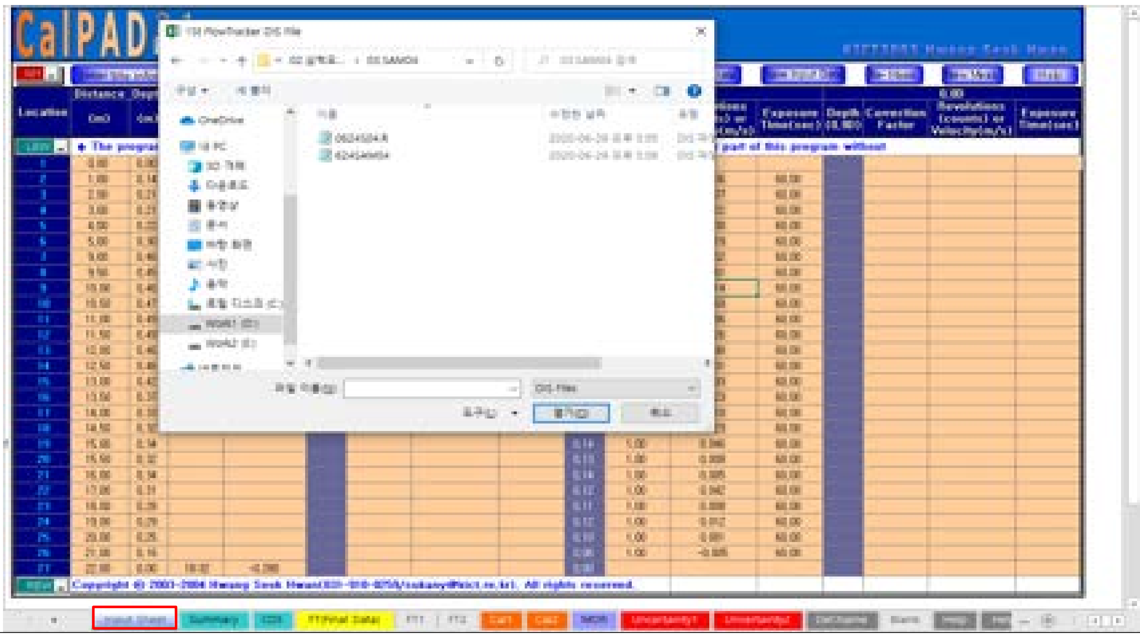

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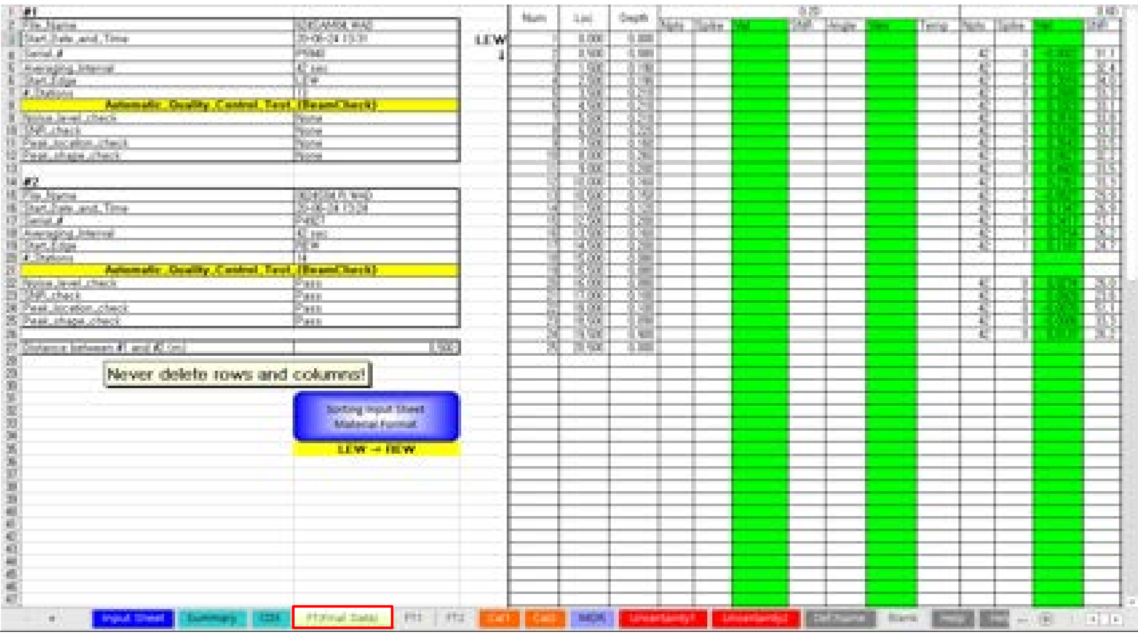
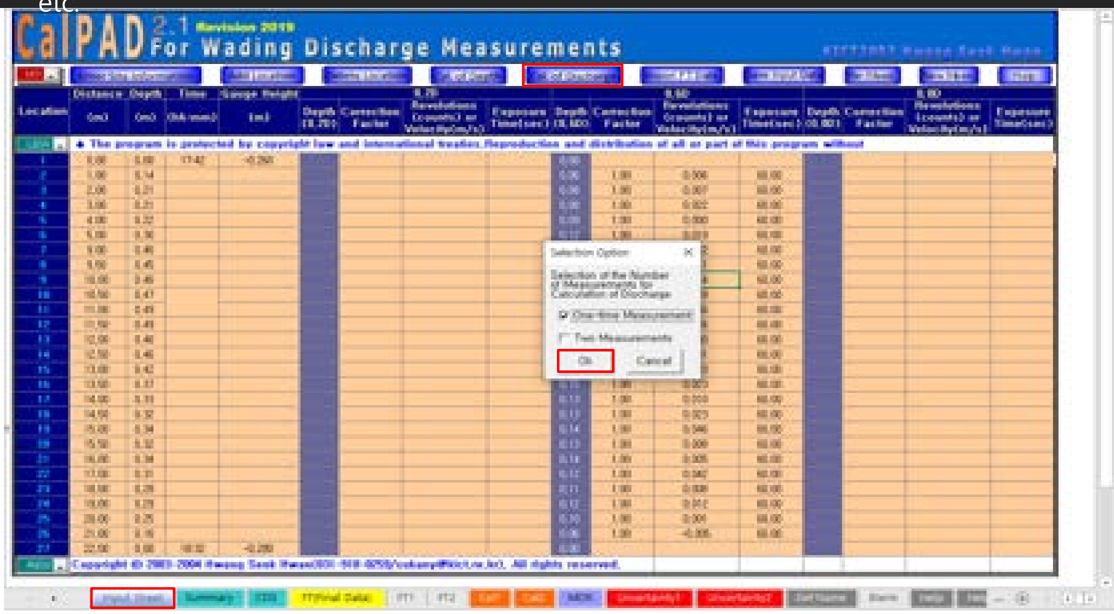


2.1 Calculating Procedures

▪ Calculation of Discharge

1. Click the cal. of discharge button
2. Make a selection for number of measurements (one-time of the number select)
3. After calculation, you can see the results of measurement in the pop-up window.
4. Ex: Width (m), total discharge (m3/s), mean water level (gauge height)(m), mean velocity (m/s) etc.



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- **Calculation of Discharge**
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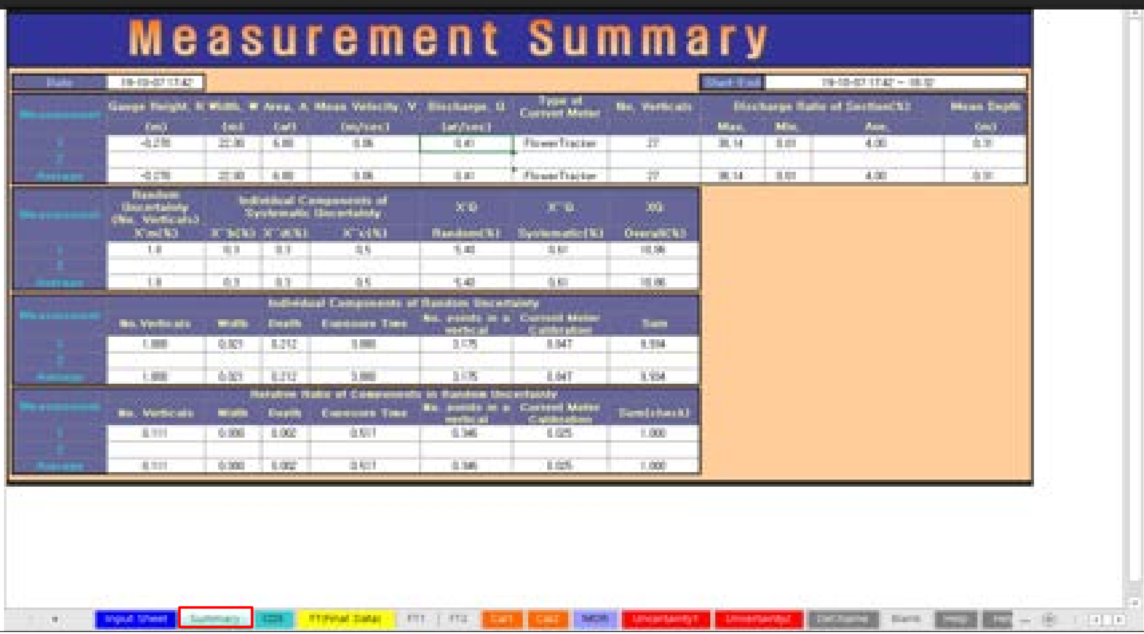
2.1 Calculating Procedures

- **Results of Measurement**
  - Results of measurement ☞
    Summary, comprehensive measurement data sheet, calculation of uncertainty, measurement difference and ratio, etc.



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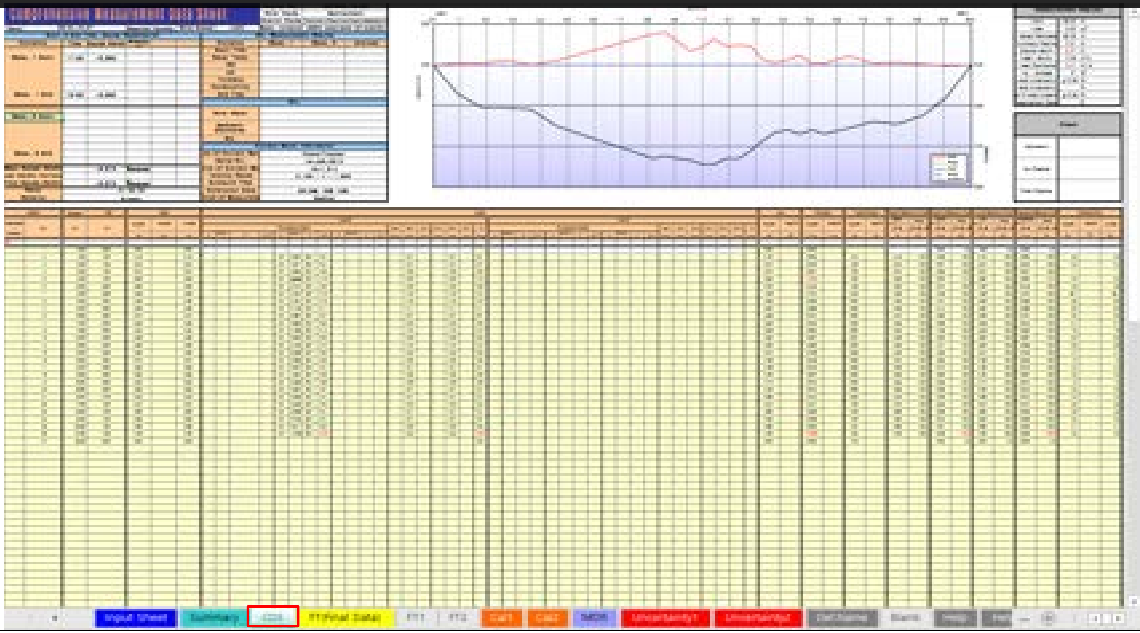

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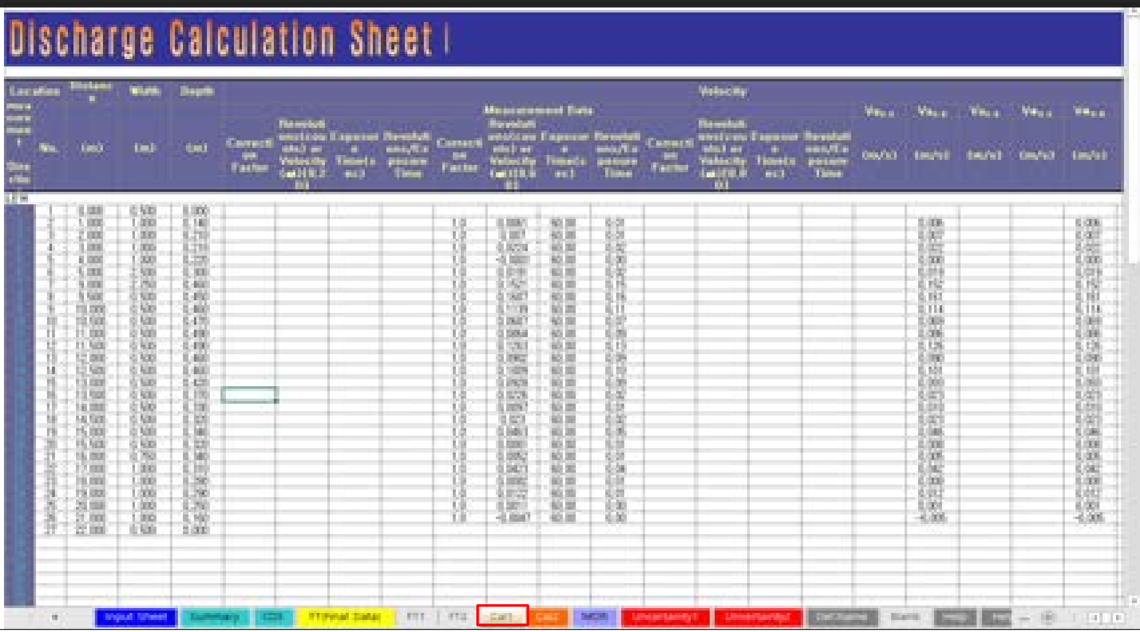

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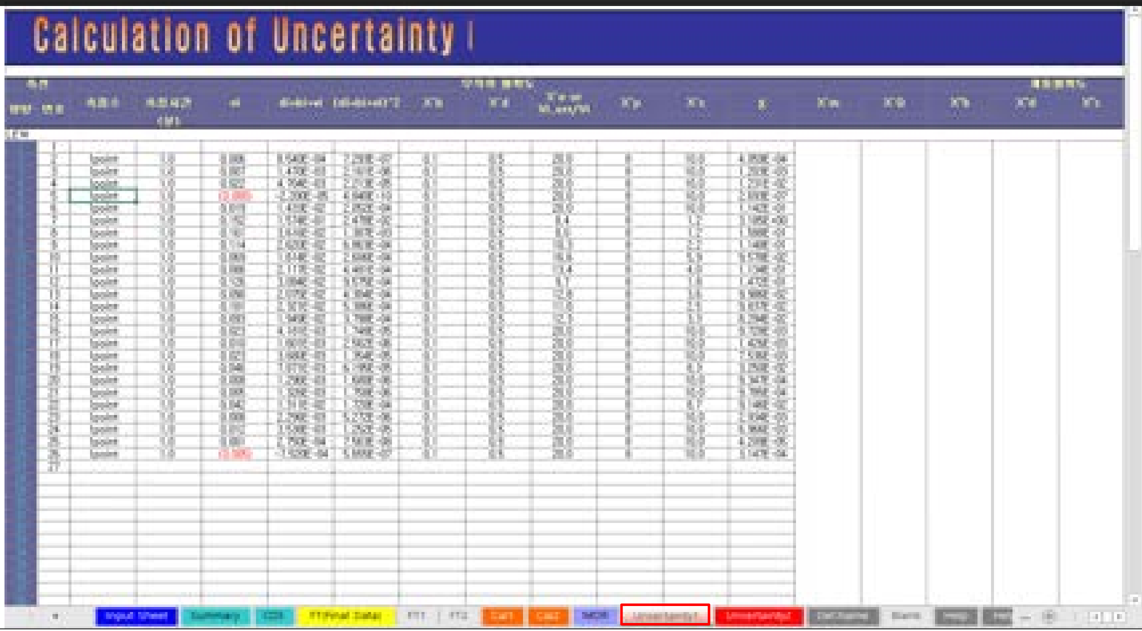

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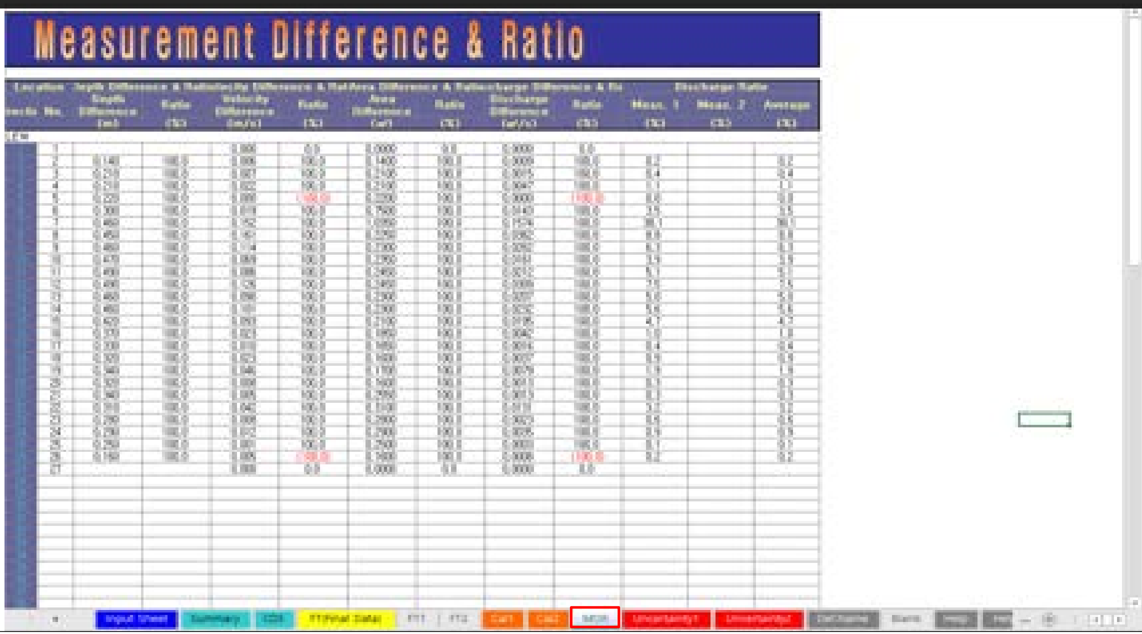



Thank you very much

MEMO

Introduction of Flood Forecasting in Korea

Hydrological Survey

Introduction of Flood Forecasting in Korea

KIHS 한국수자원조사기술원
Korea Institute of Hydrological Survey

Aims & Objectives

- The aims of the course are to:
  (1) Introduce the Korean flood forecast system, the spread of flood information, and plans for the future

- At the end of the course, trainees will be able to:
  (1) Recognize and illustrate the flood forecast strategy in Korea

Contents

1. Introduction

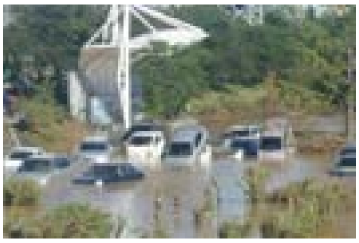
1. Introduction

▪ Definition and Type of Flooding

- A natural disaster that causes overflowing water of rivers and damage to the surrounding area due to heavy rainfall.

River flooding

Urban flooding



Flash flooding

1. Introduction

▪ Flood Mitigation and Management Measures

- **Flood Forecast**

- Predicts the flow rate in the stream and gives notification of the possibility of flooding in advance

Structural Measures

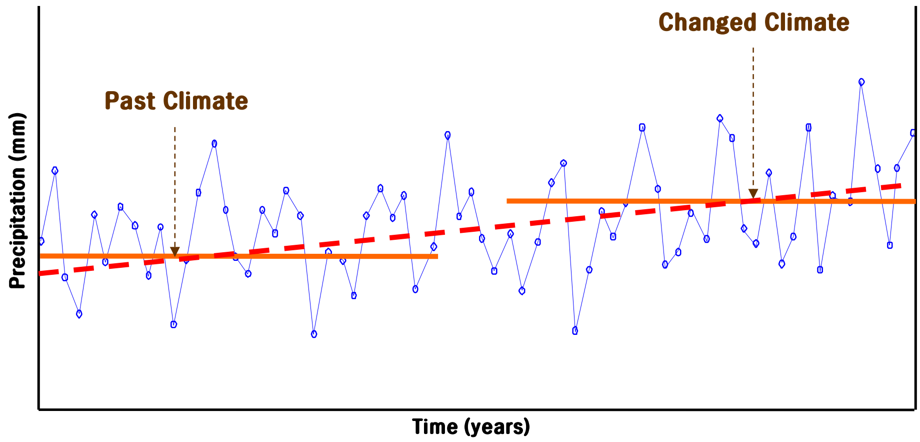
- River Improvement
  - dikes and flood walls
  - channel improvements
  - flood diversion / floodway
- Retention / Retardation of Runoff
  - reservoirs, retarding ponds
  - rainfall retention facilities
  - conservation of upper watershed through regulations on development and afforestation

Non-Structural Measures

- Flood Plain Management
  - land use regulation
  - flood proofing of facilities
  - flood insurance
- Flood Warning and Evacuation
  - flood forecasting and warning system
  - information and education campaign
  - flood hazard map
  - flood rescue & disaster relief

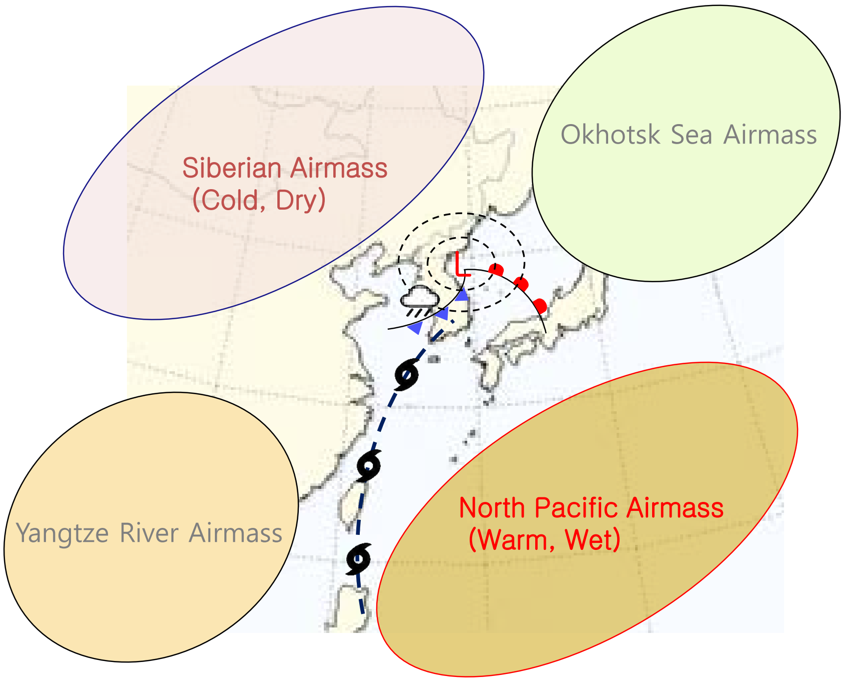
1. Introduction

▪ **Climate Shift**
- Variation of Precipitation Trends



2. Water Resources in Korea

▪ Weather Condition in Korea



2. Water Resources in Korea

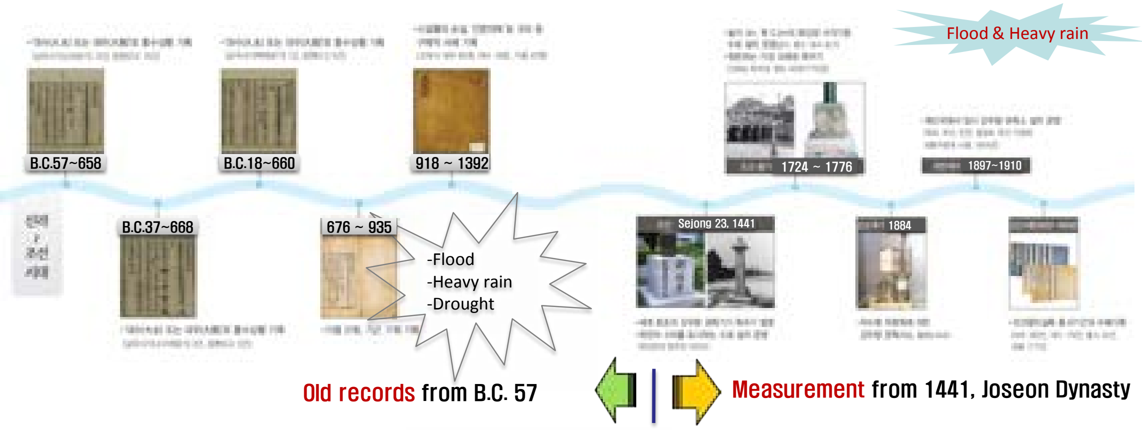
▪ Tasks for Water Resource Management

- ❖ Hydrological survey
- ❖ River flow management
- ❖ Water resources informatization
- ❖ Improvement of flood & low flow management technique
- ❖ International and domestic cooperation

365 days !

2. Water Resources in Korea

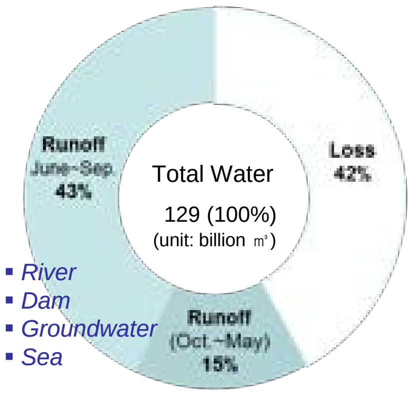
▪ Historical Issues, Flood, and Drought

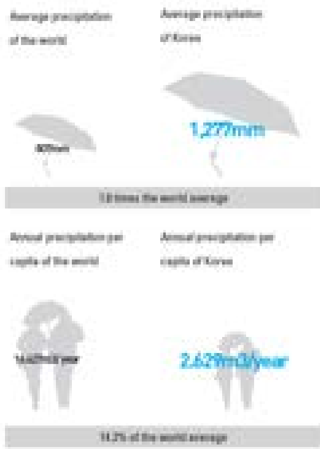


Great King Sejong
(1397~1450)

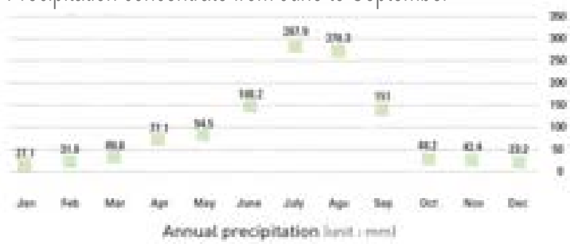
2. Water Resources in Korea

▪ Water Resources in Korea





Precipitation concentrate from June to September



Mountain area 70%

3. Flood Forecast in Korea

3. Flood Forecast in Korea

▪ Location of Flood Control Offices in Korea

❖ Total Basin Area: 99,827.26㎢

Han River FCO (since 1974)

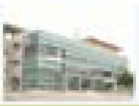
Basin area: 41,464.89㎢

2005. 5. River Information Center (RIC) Organized for specialization

⇒ 2016. 3. RIC reorganized as a Water Resources Information Center (Strengthen its task, especially river flow management)

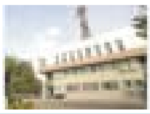
Geum River FCO (since 1990)

Basin area: 13,264.25㎢



Yeongsan River FCO (since 1991)

Basin area: 15,163.83㎢

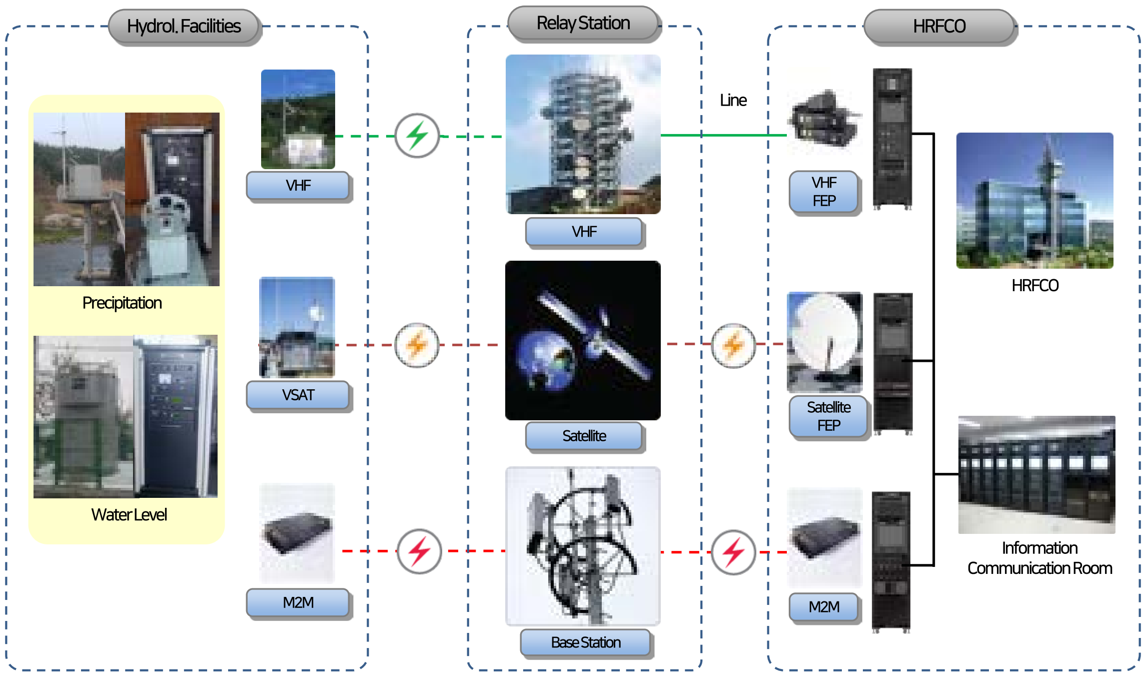


Nakdong River FCO (since 1987)

Basin area: 29,934.29㎢

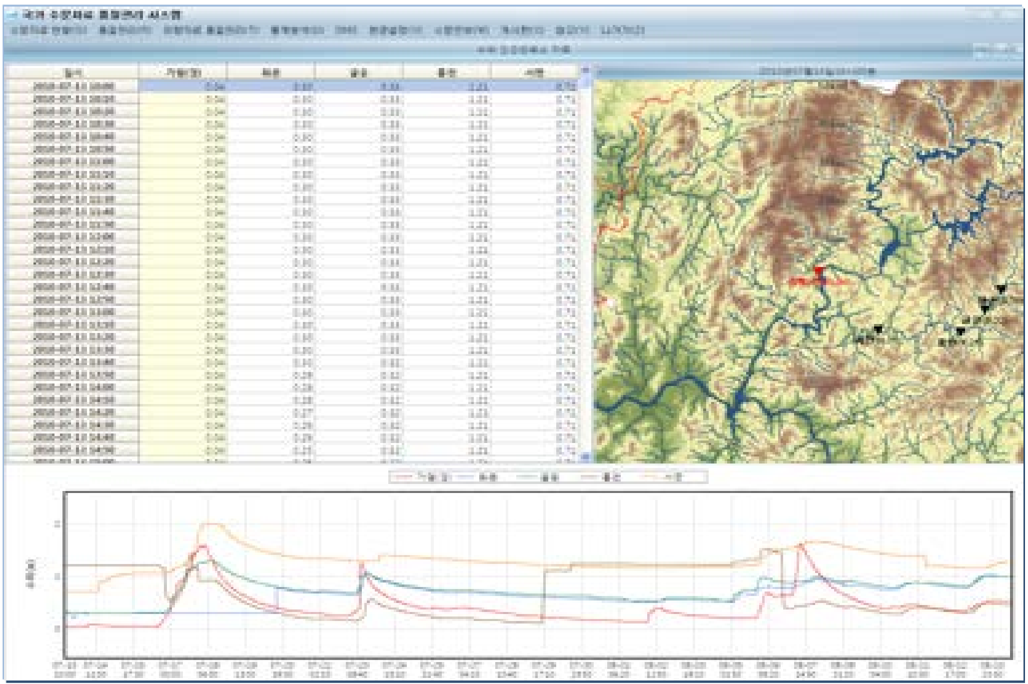
3. Flood Forecast in Korea

▪ Hydrological Data Collection



3. Flood Forecast in Korea

▪ FCO Hydrological Data Quality Control System



3.1 Legal Basis for Flood Forecasting

▪ Act on the investigation, planning, and management of water resources

Flood Forecasting

When a flood is expected to cause damage to human life and property, a flood warning shall be issued to prevent or reduce such damage.

▪ Enforcement regulation of water resources

Flood Forecasting

A flood warning shall be issued when a flood is expected in the river and nearby area.

▷ Including information

- Inundation information for riverside roads, railways, and important facilities
- Forecast information of water level in riverside and close area
- Flood hazard information in the hydrophilic zone
- Other information necessary to prevent or reduce flood damage

Flood Bulletin

When a flood is expected to cause serious damage to human life and property, special attention shall be required to the flood, or a flood watch or flood warning must be issued.

3. Flood Forecast in Korea

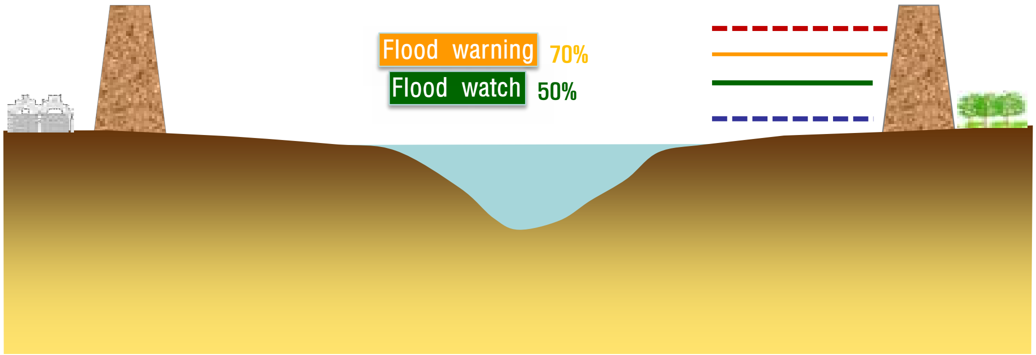
▪ Mission for Flood Forecasting

Duty Director

Flood Forecasting Team	General Coordination Team	Quality Control Team	Public Relations Team
• Dam discharge approval and monitoring • Flood forecasting • Inundation forecasting	• Situation report • Flood warning issue (Webpage, SMS, CBS)	• Hydrological data monitoring • Field action • Display panel control	• Providing the information to the public (Facebook, Twitter)

3.2 Standard for Flood Forecast and Bulletin Sites

- Dividing criteria into 4 level (Attention, Watch, Warning, Severe)
- Designating 65 sites for flood forecast of the whole country

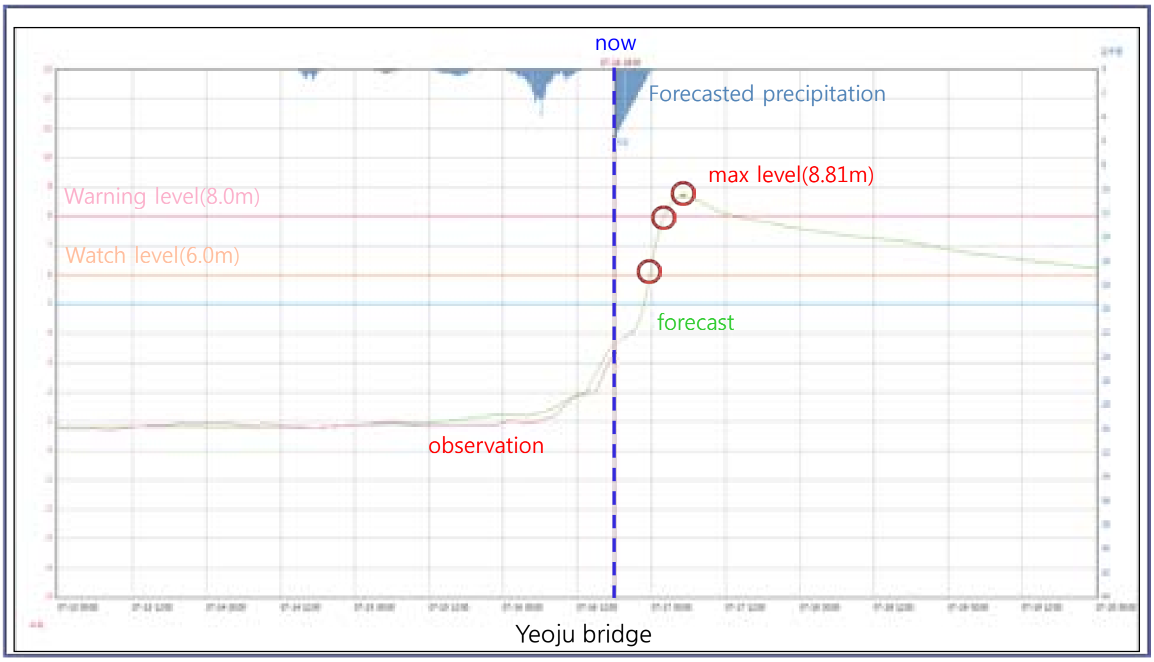


	number of Site	Han River FCO	Nakdong River FCO	Geum River FCO	Youngsan River FCO
Bulletin Site	65	19	20	11	15

	2017 year	2018 year	2019 year	2020 year
Bulletin Site	50	55	60	65

3. Flood Forecast in Korea

- **Flood Forecast Model Results**



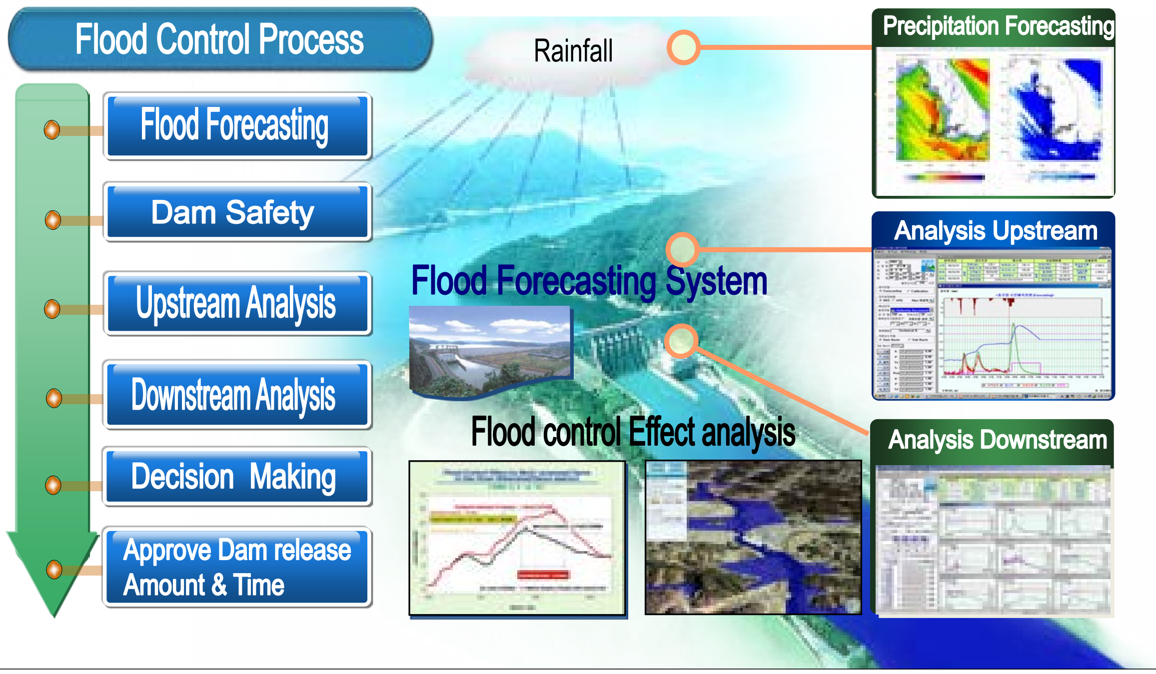
3. Flood Forecast in Korea

▪ **Flood Forecast Information Displays**

3.3 Dam Control during the Flood Season

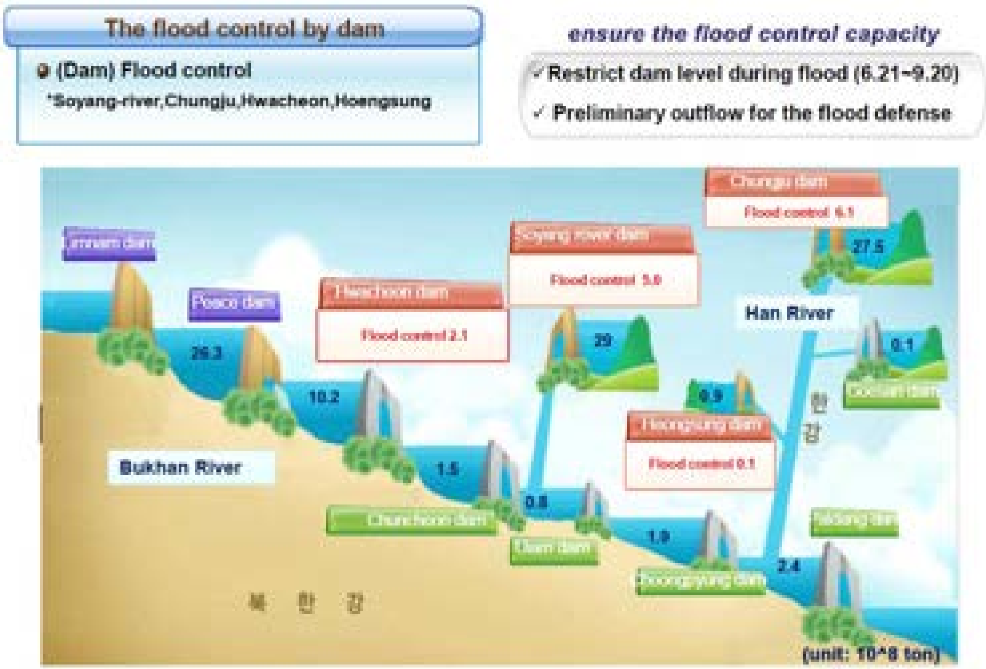
▪ **Different Dam Operator**

- Multipurpose dam (K-Water), power generation dam (KHNP), etc



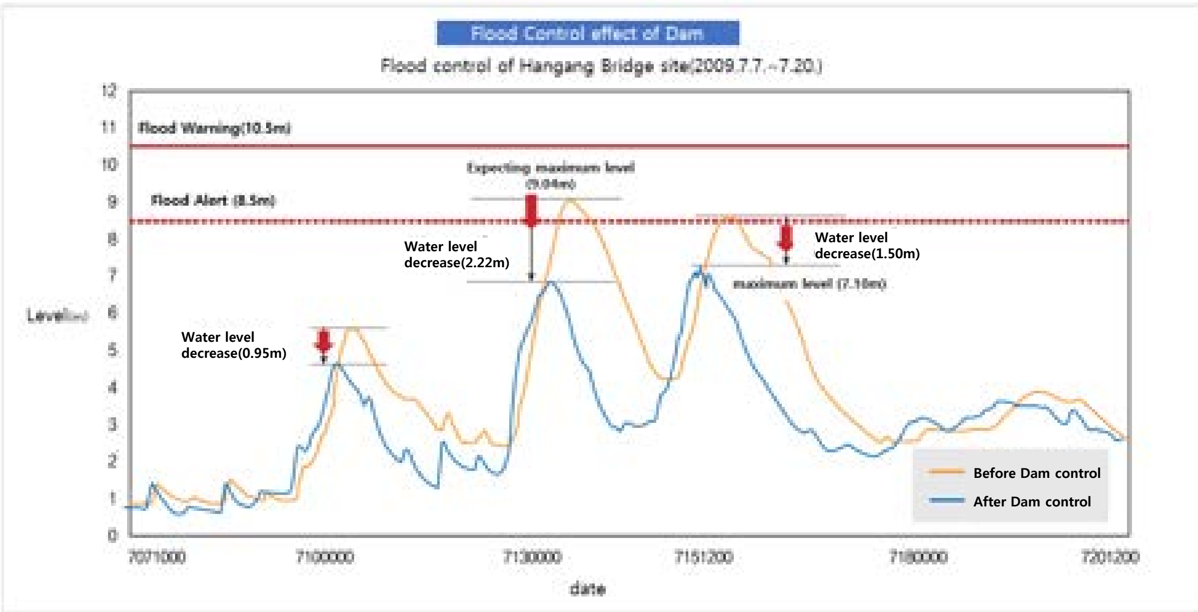
3. Flood Forecast in Korea

▪ Flood Defense Through Dam Operation



3. Flood Forecast in Korea

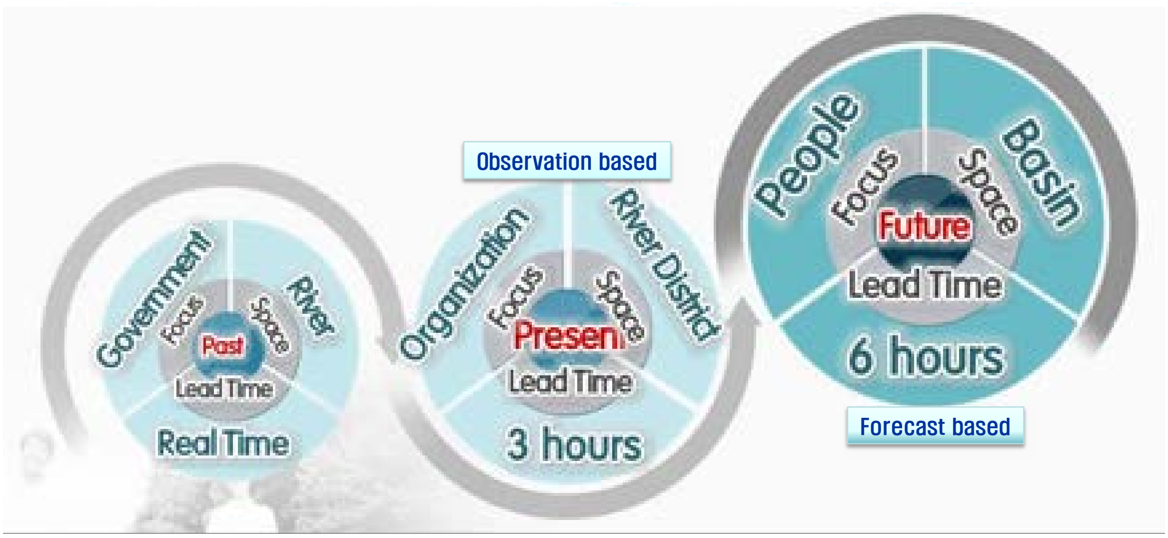
▪ Effect of Dam Operation



4. Flood Forecast Master Plan

4. Flood Forecast Master Plan

▪ Flood Forecast Paradigms are Changing



Changing Focused on People's Life !

4. Flood Forecast Master Plan

▪ Expanding from River to Basin

4. Flood Forecast Master Plan

▪ Securing Lead Time for Flood Response

4. Flood Forecast Master Plan

▪ **Focusing on People's Life**

- Improving Information Providing System for Easy Delivery
  - Pass Directly to the People with Smart Phone and Internet
- Providing Flood Information Customized People' s Life
  - Leisure, Waterfront Activities, Cultural Performing
- Strengthening Cooperation with Related Organizations
  - Joint Training and Workshops about Hydrological, Weather, Disaster Reduction with Related Organizations

5. Conclusions

5. Conclusions

▪ Flood Countermeasure of FCO

Infrastructure for hydrological survey and data management

- Station, rain radar, data quality management system
- Hydrological data assessment commitment

Establishing a dam supply plan with related agencies

- Plan through the council that considers the authorities, the local government, and many stakeholders
- Water conflict management with the operational council

Discharge approval of dam to control flood

- Downstream safety is a top priority when the approval is given.

Developing measures to improve water management

- Standard manual, continuous education, and training

Thank you very much

Introduction of National Water Resources Information Strategy in Korea

Hydrological Survey

Introduction of National Water Resources Information Strategy in Korea

KIHS 한국수자원조사기술원 Korea Institute of Hydrological Survey

United Nations Educational, Scientific and Cultural Organization · i-WSSM International Centre for Water Security and Sustainable Management

Aims & Objectives

- The aims of the course are to:

  (1) Introduce Korean national water resources information strategy and the future plans

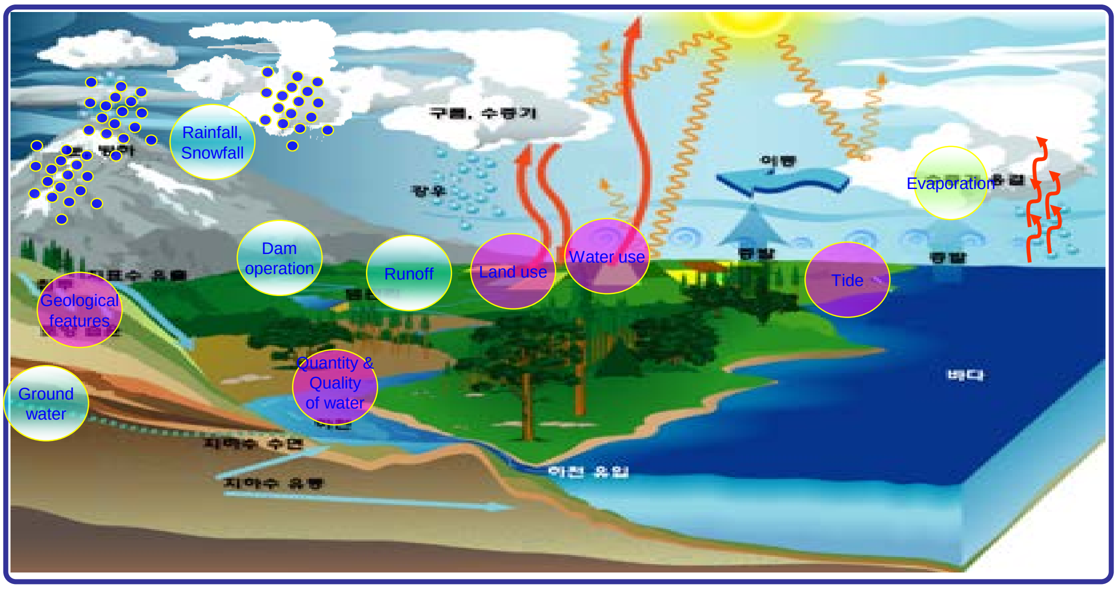
- At the conclusion of the course, trainees will be able to:

  (1) Recognize the representative water resources information system in Korea

Contents

1. Basic Concept

- Water Cycle (Atmosphere → Rainfall → Runoff → Evaporation)



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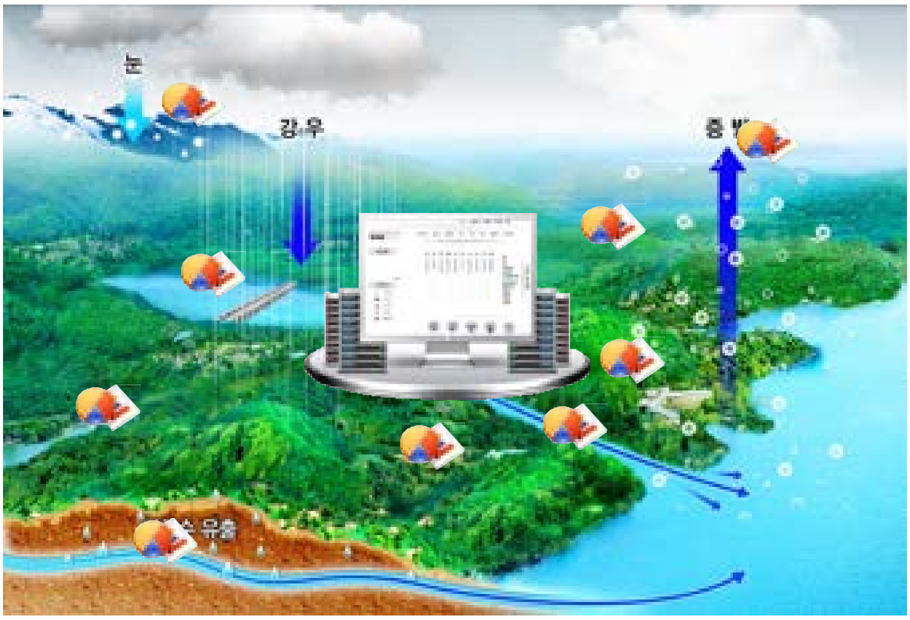
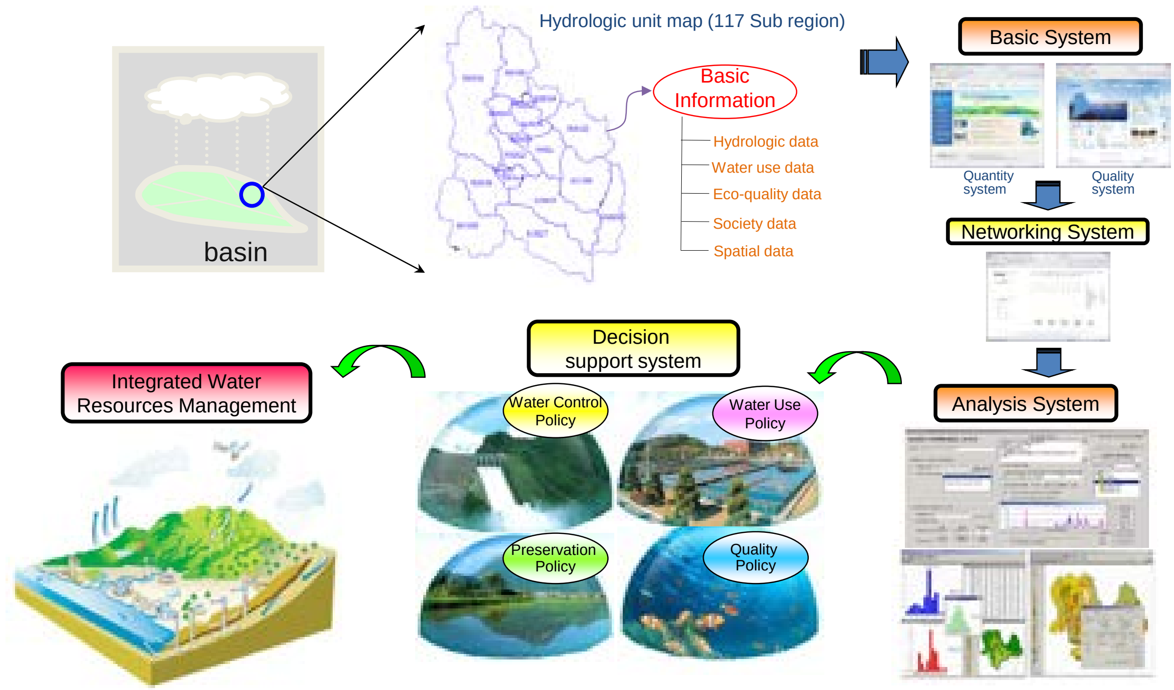


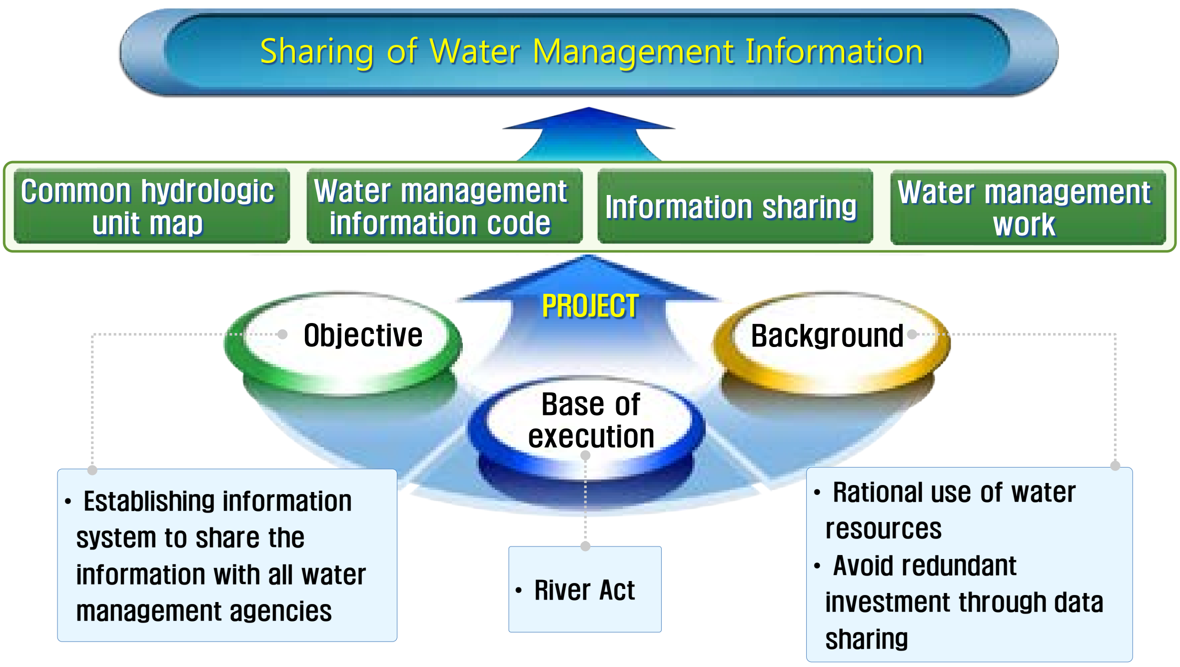
1. Basic Concept

▪ Illustration of Concept for Integrated Water Resources Management



1. Basic Concept

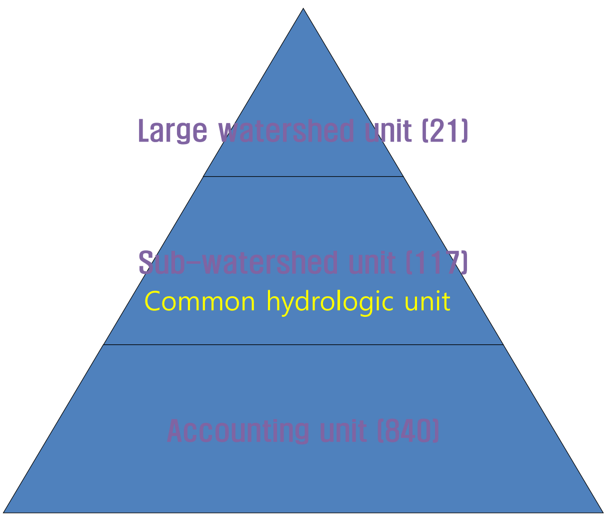
▪ Motivations and Objectives



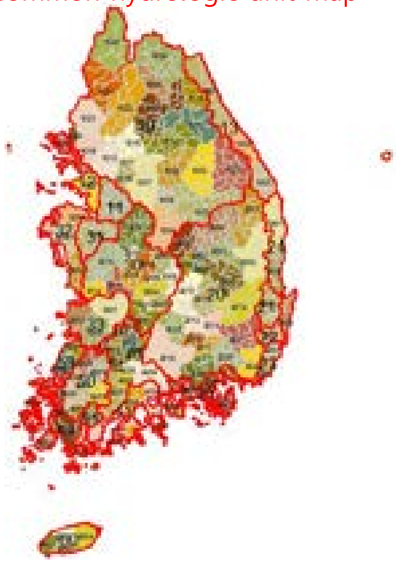
2. Water Management Information Standards

2. Water Management Information Standards

- **Development of Hydrologic Unit Map (2004)**
  - Space standard for collecting, analyzing, and managing basic information on water

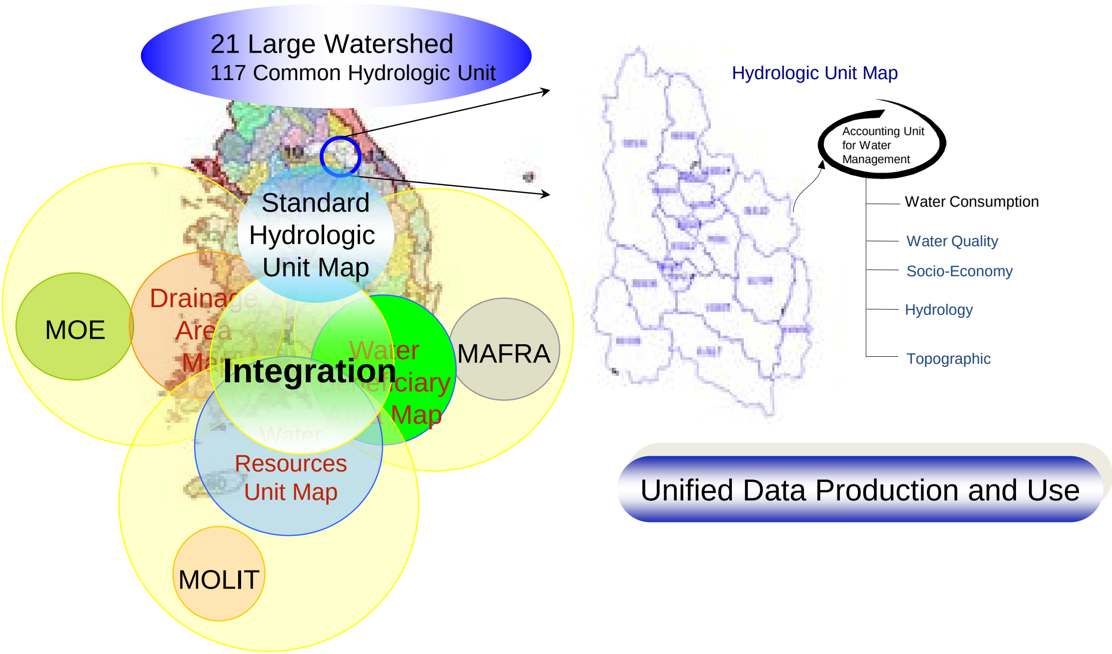


Common hydrologic unit map



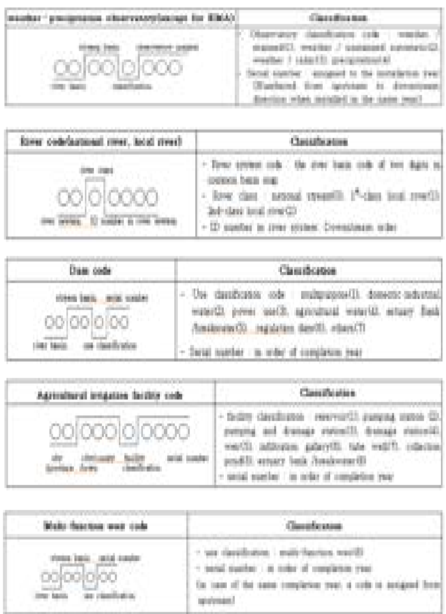
2. Water Management Information Standards

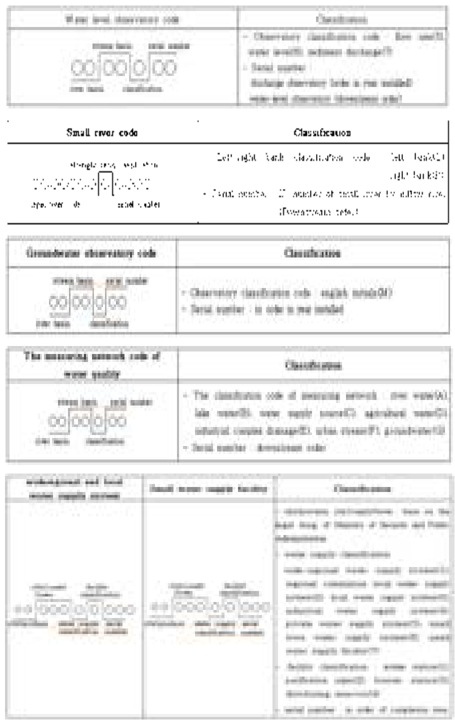
▪ Common Hydrologic Unit Map



2. Water Management Information Standards

▪ Water Management Information Code





Source: MOLIT, “Water Management Information Standards” 2013

2. Water Management Information Standards

- **Information Sharing**
- The needs for the operation system standards of water management information
  - The information system environments established independently by each organization are manifold by factors such as IT technology, budget, and bid system by year.
  - A technical standard needs to be applied within the scope to achieve the purpose of information exchange among the relevant organizations.
- The operation system standard principles of water management information
  - The operation system standards of water management information set the interoperability securing as the target of standardization, because the interoperability securing is important in terms of the information operation system standards among the relevant organizations.
  - It is a principle to accept the "Information System Deployment And Operation Technology Guidelines" of the National Computerization Agency as a higher standard to the interoperability securing as the operation system standards of water management information.
- The application of interoperability securing guidelines
  - The application principle in a security field includes standards, guidelines, models, and frameworks related to the information security from the data storage, transmission, and processing in an automated system and applies the criteria that meet the requirements in the interoperability securing guidelines from the National Information Society Agency.

2. Water Management Information Standards

- **Water Management Work**

  - The work area of water management through the work area analysis is categorized into 11 categories as follows

Work area	Water management work
1. Hydrometeorology	- rainfall observation, water level observation, discharge observation, weather chart, temperature, evaporation, etc.
2. Basin	- basin characteristics, humanities and social, basin environment, infrastructure
3. River	- river shape, river facility, river management, weir operation
4. Dam	- dam facility, reservoir, dam operation
5. Groundwater	- groundwater hydrological water quality, groundwater development · use
6. Water utilization	- domestic water, agricultural water, industrial water, water right, return flow, water transport characteristics
7. Water supply	- water supply facility, operation management, water quality management
8. Water environment, ecology	- river water quality, lake water quality, basin pollution, sewerage, environmental infrastructure, ecology
9. Natural disaster	- flood management, drought, typhoon
10. Geographic space	- base map, water resources thematic map, basin thematic map, environmental thematic map, imagery data, ocean space information
11. Marine water quality environment and tide	- marine environment, tide and marine weather observation

2. Water Management Information Standards

- **Water Management Work**
  - The characteristic classification of water management data is subdivided into 4 categories

Division	Subdivision	Contents
1. Observation data	11 measurement data	data measured automatically / manually by observation equipment, data measured manually, data measured by observer’s eyes
	12 recording paper data	data automatically recorded on the paper from magnetic device
	13 numeric data	numeric data received from TM equipment
	14 analogue data	continuous data shown on screen by measurement equipment
2. Survey data	21 survey data	field survey data
	22 statistical data	data aggregating, analyzing survey contents
	23 analysis materials	observation data, data processing survey contents via the analysis process
	24 plan data	business plan, facility plan data
3. Operation data	31 facility data	data about facility data
	32 water data	water supply data
	33 performance data	performance data to a plan
	34 licensing data	licensing a status data
4. Spatial data	41 drawing data	drawing data such as a blueprint of not having coordinates
	42 image data	photography, scanning data
	43 satellite image data	processing data received from the satellite office
	44 numeric map data	numeric map data having a geodesic coordinate
	45 point data	point data having a geodesic coordinate
	46 line data	line data of segment having a geodesic coordinate
	47 plane data	closed polygon(polygon) data having a geodesic coordinate

3. Water-Related Information Systems

3. Water-Related Information Systems

▪ **Information System**

WAMIS	WAter Management Information System	•Standard Unit (watershed) •Meteohydrology
WINS	Water management Information Networking System	•Water quality & Ecology •Water Use
RIMGIS	RIver Management Geographic Information System	•Standard Unit (river) •River Administration

http://www.wamis.go.kr

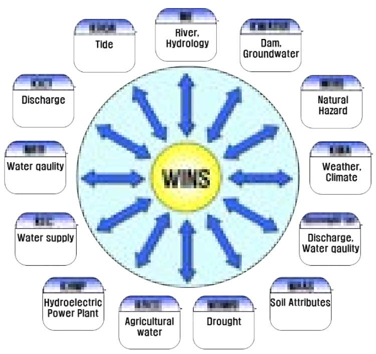
http://www.wins.go.kr

http://www.river.go.kr

3. Water-Related Information Systems

▪ **Water Management Information Networking System**

- WINS (Water management Information Networking System) (http://www.wins.go.kr)
  - Provides water management information on-line to the water-related agencies
  - Based on the national water management information standard (2004), 13 agencies, including the Ministry of Environment; Ministry of Agriculture, Food and Rural Affairs; Ministry of the Interior and Safety; and Korea Meteorological Administration, etc. share water management information data
  - The Water Management Executive Committee is held annually.



3. Water-Related Information Systems

- **WINS**
  - 82 items, such as hydrometeorology, dam operation, environmental ecology, ground water, water use, river, basin, soil, geographic space, and natural disaster, are shared through WINS.

3. Water-Related Information Systems

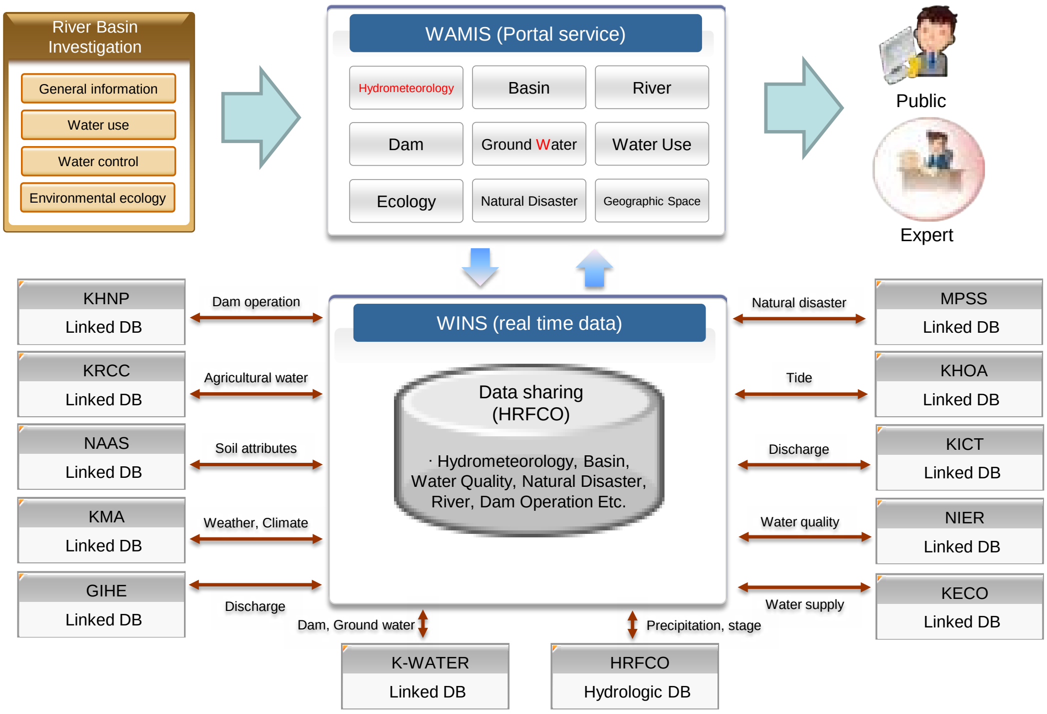
- **WINS**

3. Water-Related Information Systems

▪ WINS

3. Water-Related Information Systems

▪ Relationship between WAMIS & WINS



3. Water-Related Information Systems

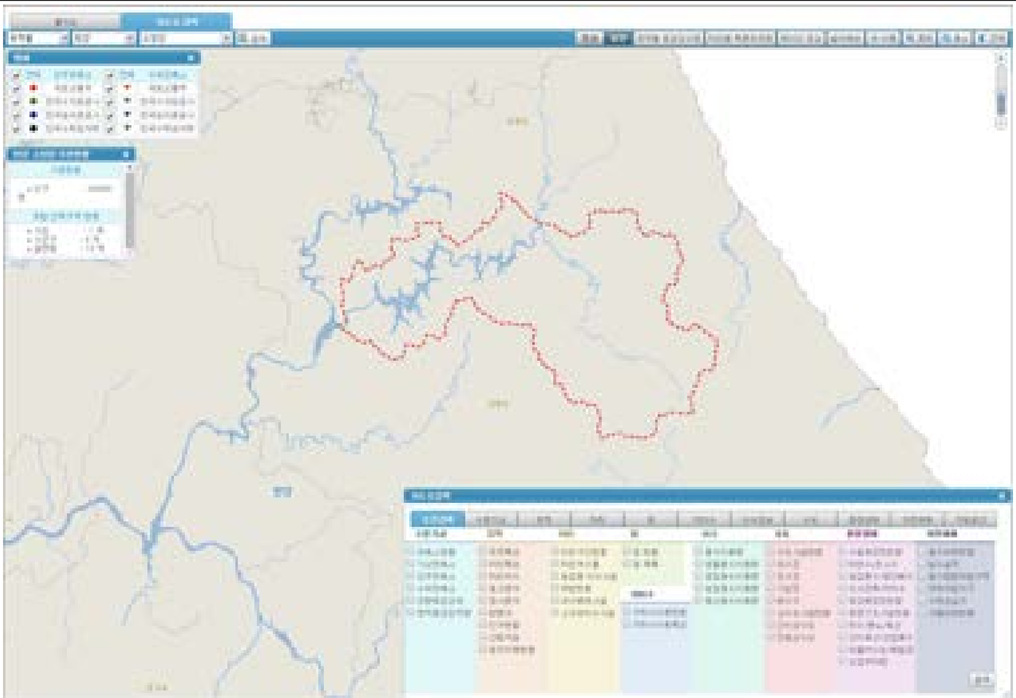
- **Water Resources Management Information System**
  - WAMIS (WAter resources Management Information System) (http://www.wamis.go.kr)
    - Scientifically collects, processes, and analyzes water resource information, which is distributed nationwide
    - Provides 300 basic data items in 10 categories based on a common hydrologic unit map (117 unit), local government (256 unit) and river (national and regional grade)

3. Water-Related Information Systems

- **WAMIS**
  - Stage, precipitation, dam operation – hourly, daily, monthly data service
  - Water use, water supply, natural disaster, ecology – 1year periodic data service
  - Basin, river, geographic space – 5- or 10-year periodic data service

3. Water-Related Information Systems

- **WAMIS**



Source: http://www.wamis.go.kr

3. Water-Related Information Systems

- **WAMIS**
  - **Water Now map**

    - presents a state of river outflow to figure out the current condition of outflow visually compared to previous data using the quartile reference value (25%, 75%) derived by the statistical process from th past data.

    - Users can recognize the state of water supply and demand, noticing the situation of the quantity of flo across the nation at a glance.

Source: http://www.wamis.go.kr

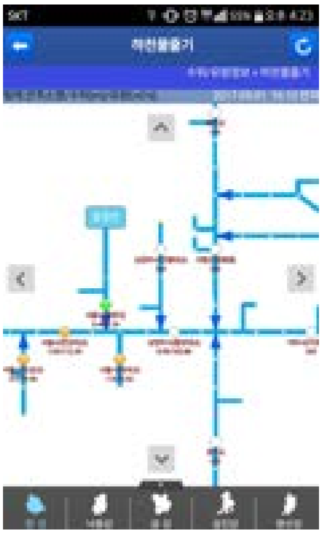
3. Water-Related Information Systems

- **WAMIS**
  - Mobile services



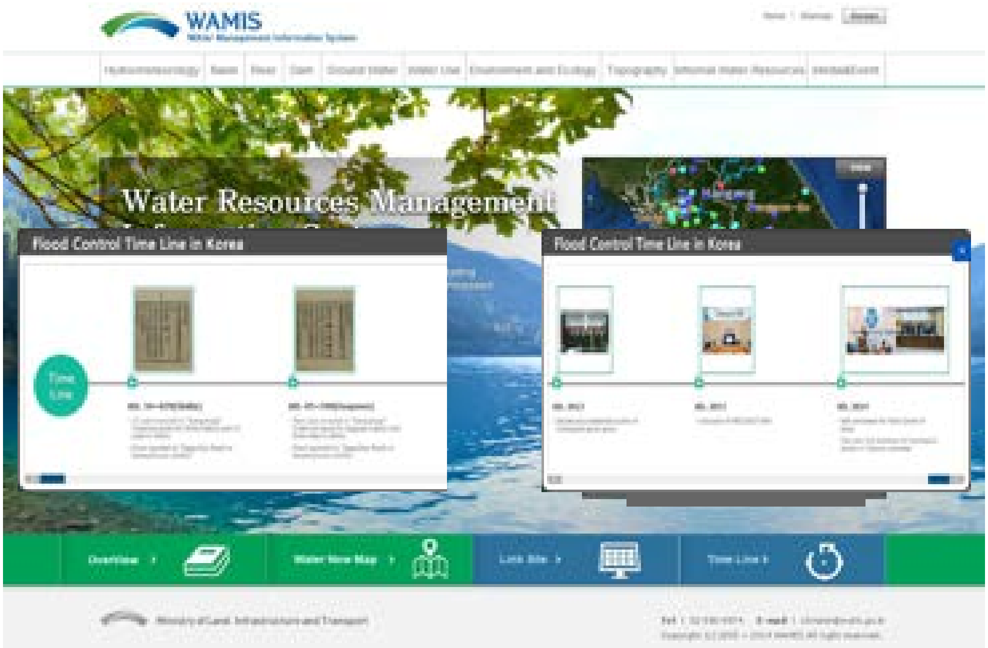
3. Water-Related Information Systems

- **WAMIS**
  - Mobile services



3. Water-Related Information Systems

▪ **WAMIS**
- Official Website of WAMIS

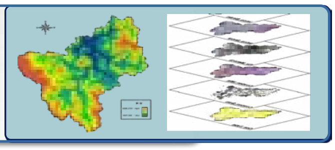


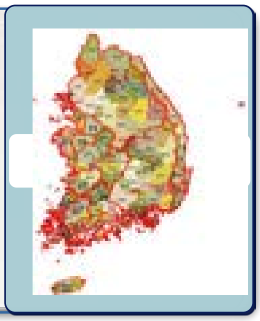
4. River Basin Investigation

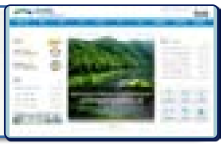
4. River Basin Investigation

▪ Overview

Time span	• Period: 1965 ~ present
Contents	• General conditions of basin • Hydraulic & Hydrologic characteristics • Water utilization & flood control • Ecosystem & environment
Provision	• Building basic data for WAMIS



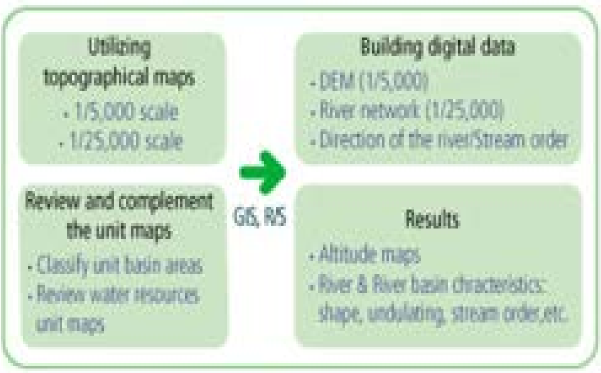


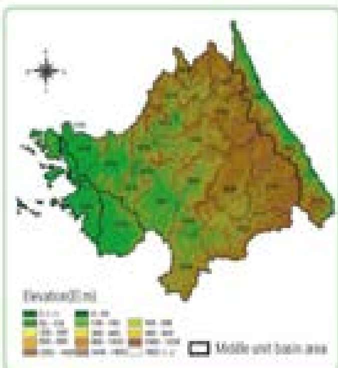


4. River Basin Investigation

▪ Characteristics of the River Basin

- Investigate and obtain digital information on the rivers based upon unit maps using the GIS, R/S techniques.

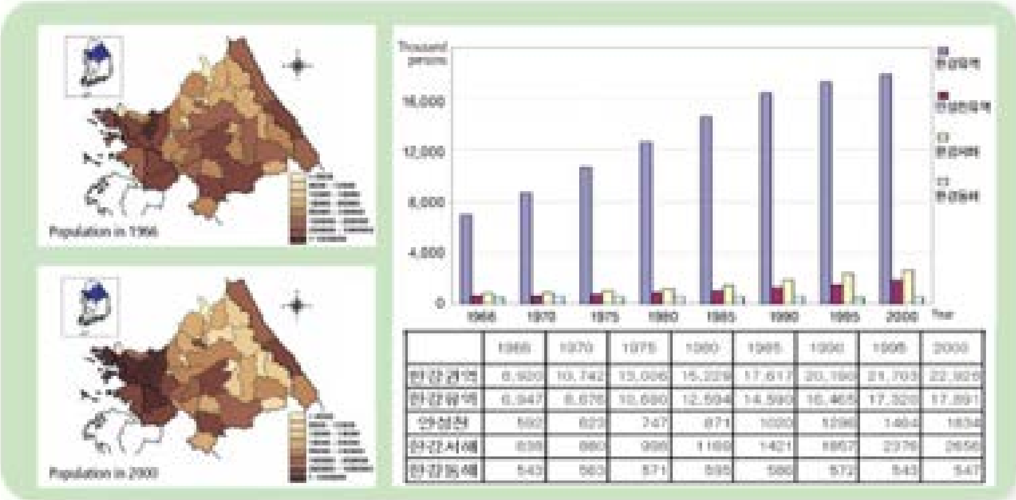




Source: MOLIT, K-water “River Basin Investigation in Korea” 2018

4. River Basin Investigation

- **Population Industry and Economy**
  - Convert data by administrative district into a river basin—based format
  - Build various database on the population, culture, history, industry, and economy



Source: MOLIT, K-water "River Basin Investigation in Korea" 2018

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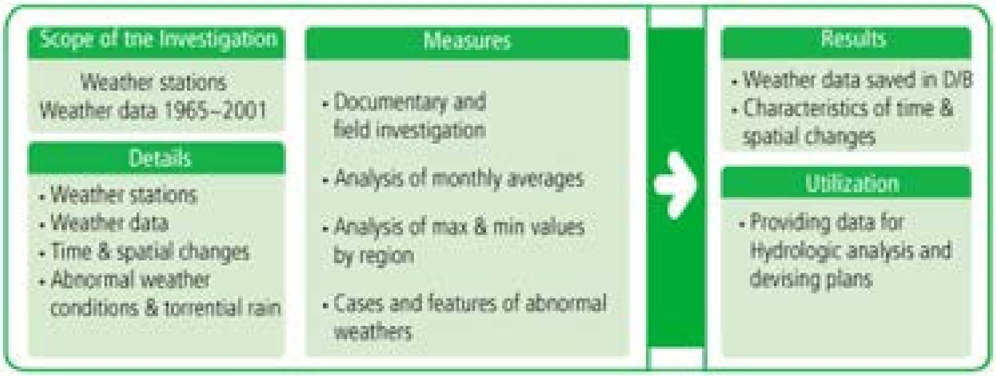
4. River Basin Investigation

- **Climate and Weather**
  - Investigate the features of the weather by examining the time & spatial status of the data



Source: MOLIT, K-water "River Basin Investigation in Korea" 2018

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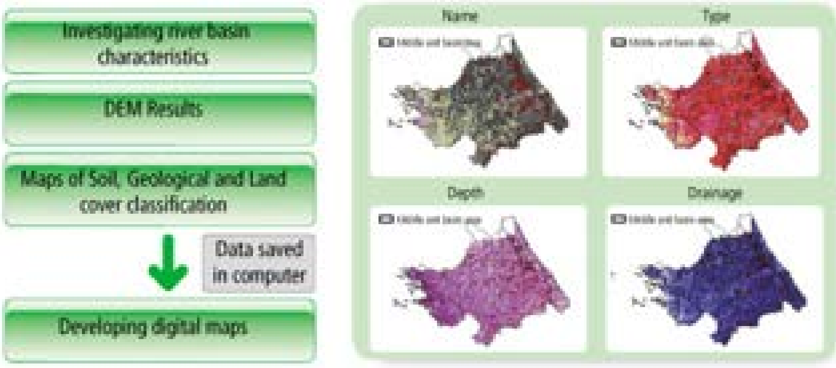
4. River Basin Investigation

- **Topography, Geography, Soil, and Geology**
  - Study the inclination of river basin, soil, lineal structure, fault, geological features and runoff curve index (CN) utilizing the digital maps (DEM, soil map, geological map)



Source: MOLIT, K-water "River Basin Investigation in Korea" 2018

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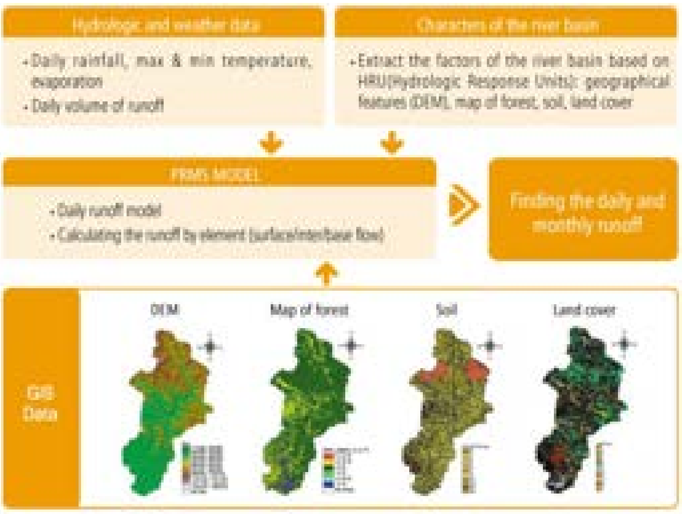
4. River Basin Investigation

- **Hydraulic & Hydrologic Investigation**
  - Provide the basic information required to analyze the hydraulic & hydrologic properties by investigation of surveying network, stream flow, sediment quantity, the river mouth, etc.

- **Simulation of Long-Term Runoff**

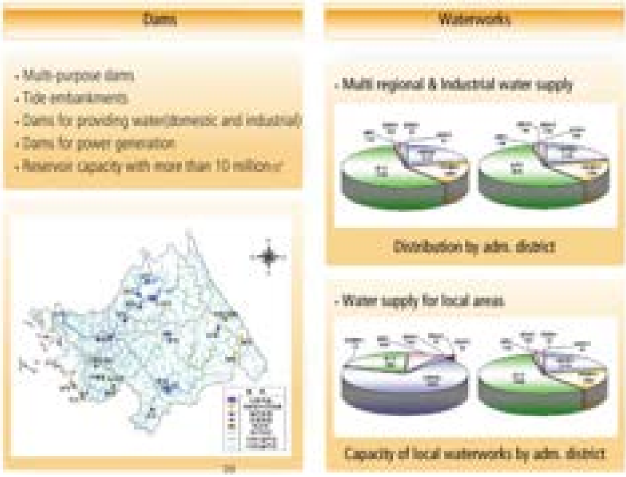


Source: MOLIT, K-water "River Basin Investigation in Korea" 2018

4. River Basin Investigation

- **Investigation of Water Utilization**
  - Provide the basic information required to understand the status of water utilization and estimate future demand by investigating water use by type (domestic, industrial, agricultural) and various facilities for water utilization.

- **Investigation on the Facilities for Water Utilization**



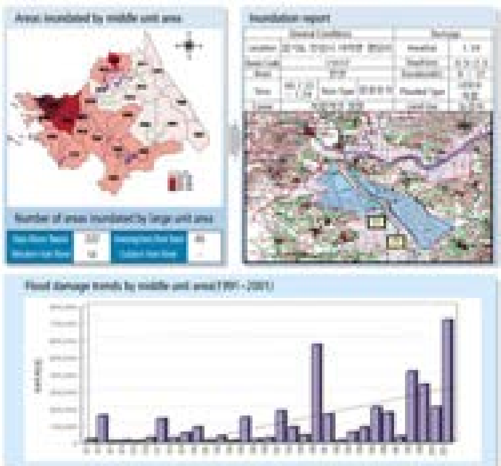
Source: MOLIT, K-water "River Basin Investigation in Korea" 2018

4. River Basin Investigation

- **Investigation of the Flood Control**
  - Provide information for the flood control plans by investigating damages from floods and operation system of facilities

- **Investigation on the Flood Damage by Event**

Approach: Major flood events that caused large-scale damages
- Damages due to flood (by detailed category), Causes of the inundation
- Writing a report on inundation by investigating actual events

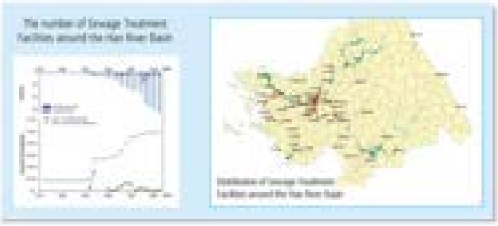


Source: MOLIT, K-water "River Basin Investigation in Korea" 2018

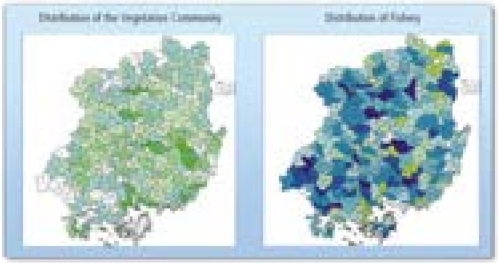
4. River Basin Investigation

- **Investigation of the Environment**
  - Provide information for overall river basin development and its preservation and management considering the environment through investigation of environmental facilities, water quality, eco environment, soil pollution, etc.

- **Environmental Infrastructures**



- **Eco Environment (Vegetation, Fisheries, etc.)**

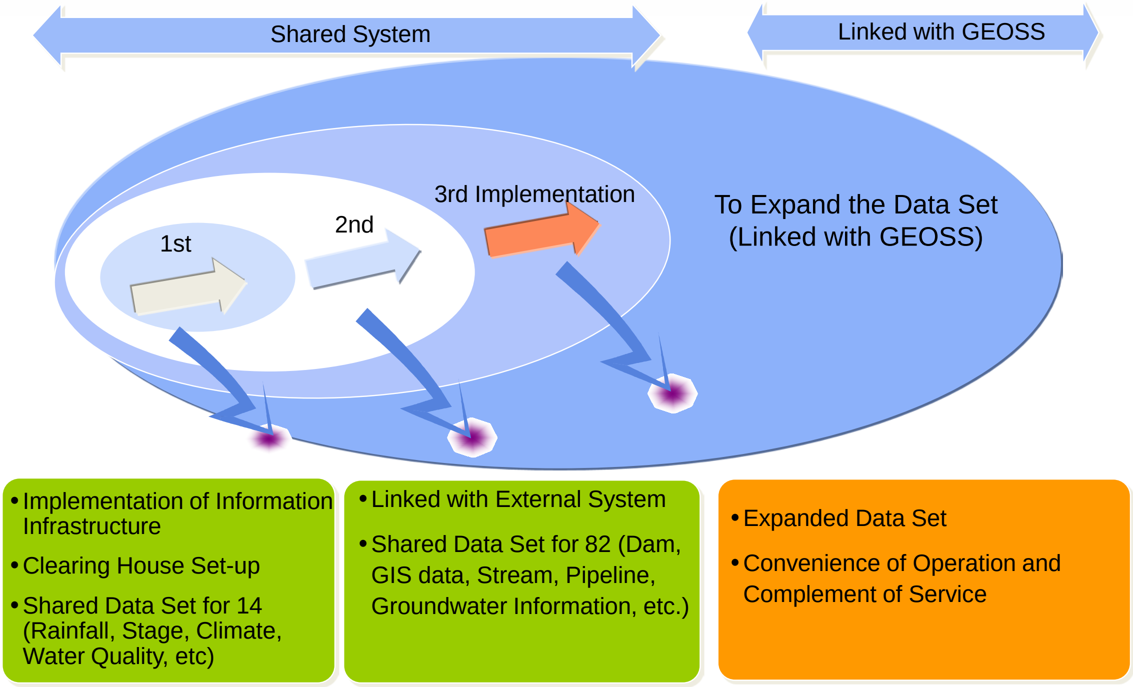


Source: MOLIT, K-water "River Basin Investigation in Korea" 2018

5. Plans For Future

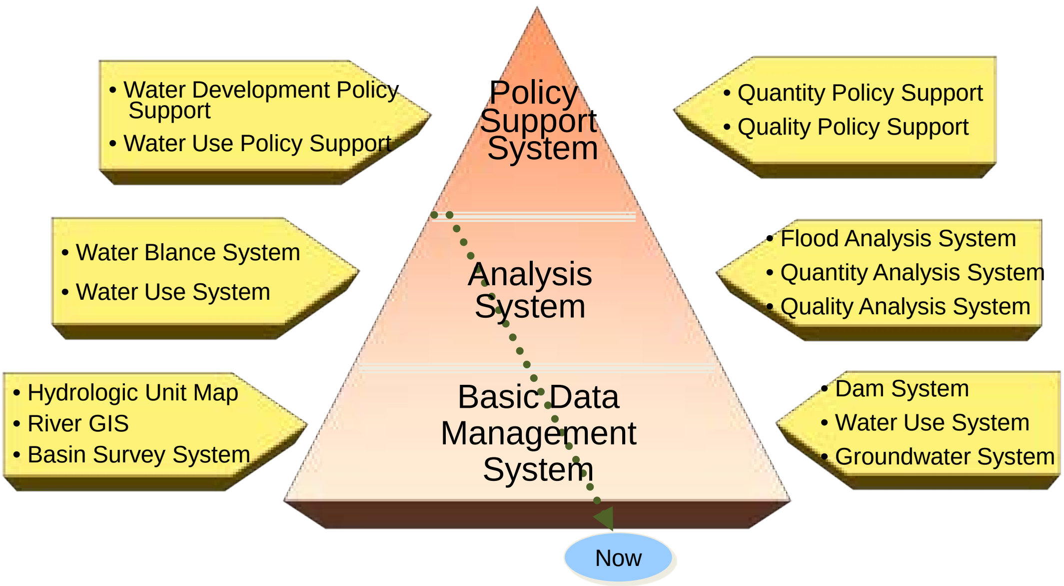
5. Plans for Future

▪ Future Information Strategy Planning for Sharing Data of Water Resources



5. Plans for Future

▪ Future Plans for Water Resource Data System




Thank you very much

National Quality Control System and Standardization for Hydrological Data

Hydrological Survey

National Quality Control System and Standardization for Hydrological Data

Aims & Objectives

- The aims of the course are to:

  (1) Promote among trainees a good understanding of the hydrological data quality control process
  (2) Help trainees to consider the plan for improving the data quality system

- At the conclusion of this course, trainees will be able to:

  (1) Explain data quality control process
  (2) Apply methods of the data correction
  (3) Recognize the importance of the national data quality control system establishment

References

http://www.law.go.kr/LSW/eng

TECHNICAL REGULATIONS

TECHNICAL REGULATIONS

(WMO,2006)

Contents

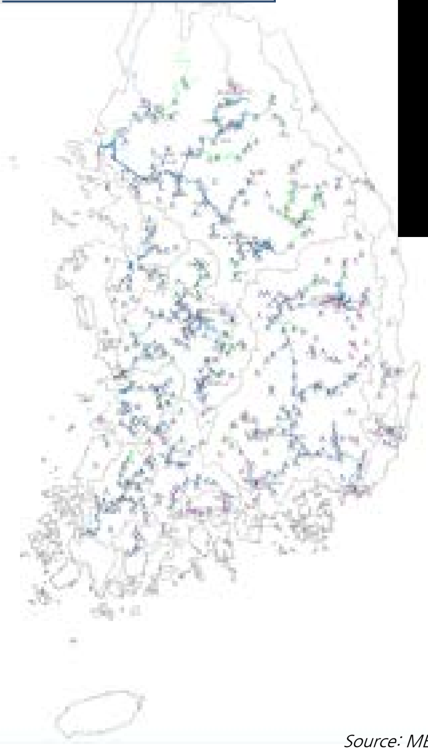
1. Introduction
2. Standardization
3. Data Correction Method
4. National Quality Control System
5. Screenshot of S/W
6. Conclusions

1. Introduction

1.1 Hydrological Observations of Korea

Precipitation Stations

Water Stage Stations



☐ Annual Hydrological Report of Korea
(ME, 2019)
- ○ 634 Precipitation Stations
- ○ 809 Water Stage Stations
  (215 Discharge Measurement)
- ○ 50 Sediment
  8 Soil Moisture contents
  12 Evapotranspiration
- ○ ME, K-water, KHNP, KRC

Source: ME, "Annual Hydrological Report of Korea" 2019

1.2 Korean Laws Related to the Data Quality Control

- **Act on the investigation, planning, and management of water resources and its enforcement decrees**
  - Matters for efficient conservation and use of water resources, development, and prevention of disaster reduction
  - Definitions, principles, establishment, and management of plans
  - Hydrological observation includes Article 9 in the law

Definition of Hydrological Observation

. It refers to observation, measurement, investigation, and analysis in a scientific way about the following contents:

⇒ **water level**, **flow rate** (including the amount of water intake and discharged water), and sediment in rivers, lakes, and swamps

⇒ **precipitation**, evapotranspiration, and soil moisture content in basins

1.3 World Meteorological Organization (WMO)

- **WMO Technical Regulations Vol. III Hydrology (2006)**
  - to facilitate cooperation in meteorology and hydrology
  - to meet, in the most effective manner, specific needs in the various fields of application of meteorology and hydrology in the international sphere
  - to ensure adequate uniformity and standardization in the practices and procedures

Composition of Hydrological Observation

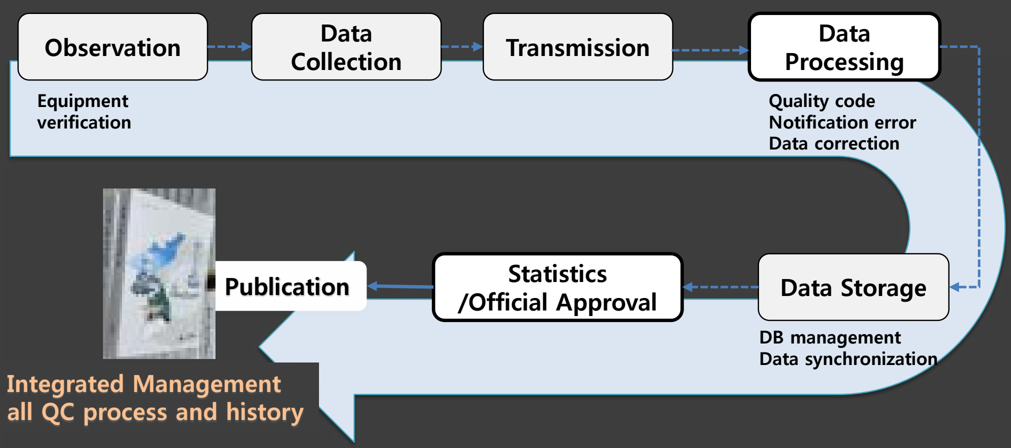
. At a hydrometric station, observations can be made of some or all of the following elements

⇒ River, lake or reservoir **stage, stream flow,** sediment

⇒ Temperature and other physical properties, characteristics and extent of ice cover of the water of river, lake, or reservoir

⇒ Chemical and biological properties of the water of river, lake, or reservoir

1.4 Data Quality Control Process



Although data quality control (QC) process starts from observing the data at site and includes all the process to confirmation and publication, it has been focused on the data processing and publication, in aspect of contents, precipitation and water level.

1.5 Characteristics of Hydrological Data

Content	Industrial Products	Hydrological Data
Production	Artificial	Natural
Control	Controllable and reproducible	Out of Control and reproduce
Accuracy	Measurable	Impossible to measure
Handling defective products	Disposal	Maintain
Customer	Public	Expert and Public
Error propagation period	Immediate, sporadic	Long-term, multiple
Socio-economic Effect	Private	Nation-wide
Quality control	Easy, simple	Hard, complex

2. Standardization

2.1 Regulations-Related Standardization

(1) Standards for Installation environment and maintenance of hydrological observation facilities and quality control of hydrological data (ME, 2018)

- conditions of the facilities installation site, maintenance, data quality control

Conditions Installation site	Layout and location, equipment selection, and redundancy, facility code
Maintenance	Establishment of the maintenance plan, inspection, record of management, installation of the signboard
Data Quality Control	Objectivity, clarity, accuracy

(2) Standards for storage, distribution, application and authorization of hydrological data (ME, 2018)

3. Data Correction Method

focused on the water stage and rainfall

3.1 Rainfall Data Correction Method

(1) Reciprocal Distance Squared (RDS)-weighted method

- A method of interpolating by the weight of the missing rainfall data using the distance between the measured rainfall stations and the missing rainfall station

3.2 Rainfall Data Correction Method

(2) By relation equation with nearly stations' data

- Simple linear regression analysis is among the observation stations near the 4th quadrant with the corresponding station.
- Correcting the data by a simple regression formula between the data of near station
- Multiple linear regression analysis at two or more nearby precipitation stations

(3) Arithmetic mean by nearby stations

- Complement the precipitation data of the corresponding precipitation station by the simple arithmetic average of the data from nearby stations

3.2 Rainfall Data Correction Method

(4) By observed, paper recorded, data logger recorded values

- To correct and supplement missing data caused by problems in data transmission

(5) Coefficient of Correction Weighting Method

- A method using the coefficient of correlation between the station and the nearby station data, not the distance factor as the weight of the missing rainfall point

3.3 Stage Data Correction Method

(1) By observed, paper recorded, data logger recorded values

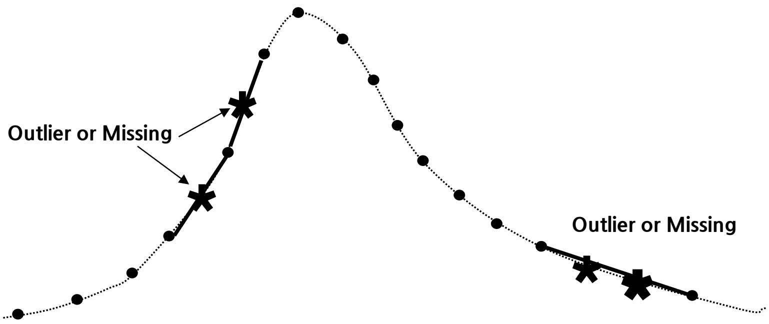
- Observed water stage by station visit or discharge measurement, etc.
- Checking the shape of the time series of rainfall & river water stage
- Comparing with the time series of up & downstream stations

3.3 Stage Data Correction Method

(2) Linear interpolation

- For the interval regarded as a straight line of water stage time series
- Not proper for the interval including the peak or inflection point

Applicable case for LI

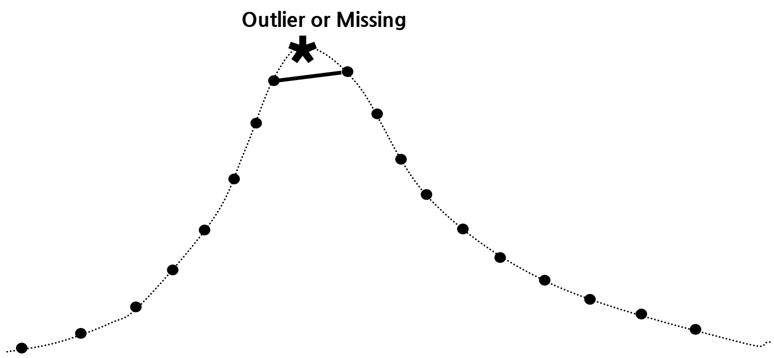


[The Potential Leakage Points]

3.3 Stage Data Correction Method

(2) Linear Interpolation (cont'd)

Improper case for LI



Recommend to consider other methods

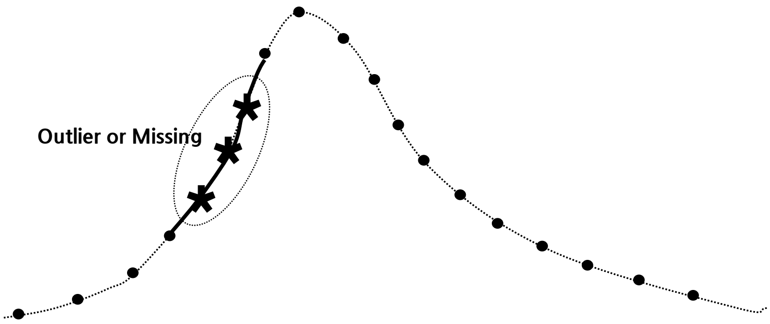
[The Potential Leakage Point]

3.3 Stage Data Correction Method

(3) Cubic spline interpolation (CSI)

- For the interval with smooth change of water stage time series
- Some good & smooth curve data outside the interval are necessary.

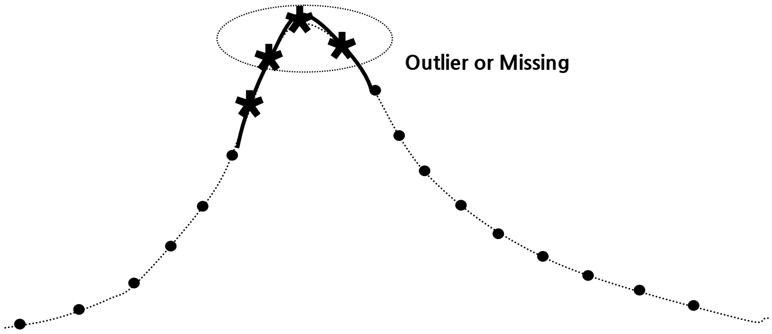
Applicable case for CSI



The Potential Leakage Points

3.3 Stage Data Correction Method

(3) CSI (cont'd)



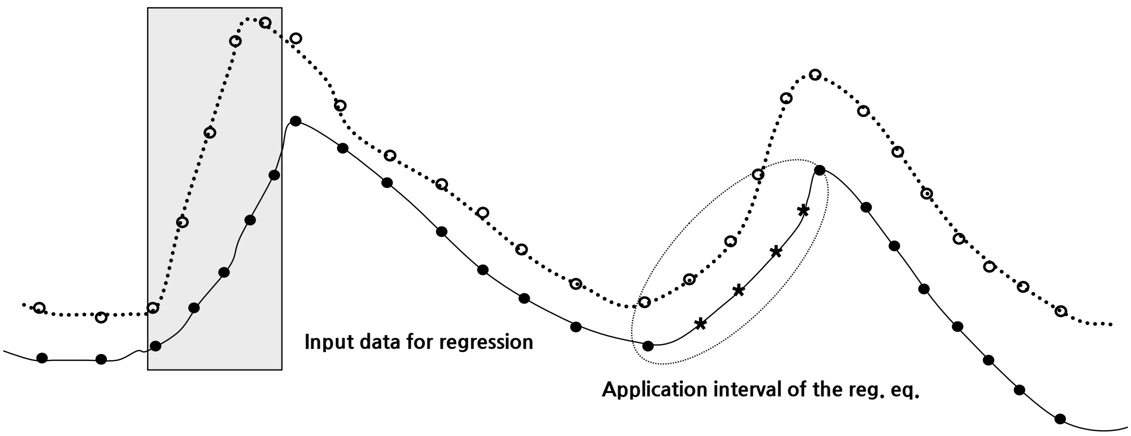
Applicable case for CSI - judgment needed to publish or not

[The Potential Leakage Point]

3.3 Stage Data Correction Method

(4) By relation equation with nearly stations' data (caution needed)

- Applying relation equations by simple or multiple linear regression analysis
- Selecting the interval of similar shape for the water stage time series of up or downstream stations
- Not recommended for a long-term data modification



4. National QC System

4.1 Background and project proceedings

- **Establishment of a system to improve the overall quality of national hydrological data**

Period	Project Title and Main Subjects	
2007-2011	Establishment of NQCS for Hydrological Data* - Consistent methods and procedures for QC - Construction of the systems for 4 FCOs - Practical use and improvement of the NQCS	
2012-2020	Improvement and Distribution of NQCS for Hydrological Data* - System functions for more data types - Distributing the NQCS to related agencies - Continuous improvement of the NQCS	

"Ministry of Environment(ME)"

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4.2 Main Concepts and Characteristics

- **Main Concepts of the NQCS**

✓ Site inspection - Automatic QC - Manual QC

- **Characteristics of the NQCS**

✓ Semi-automatic system (AQC-SMS warning-MQC)

✓ Various functions for monitoring & correcting the data

✓ Providing the quality codes after each step of AQC, MQC

✓ Various reporting forms and statistical analysis

✓ Effectively publishing the Annual Hydrological Report of Korea

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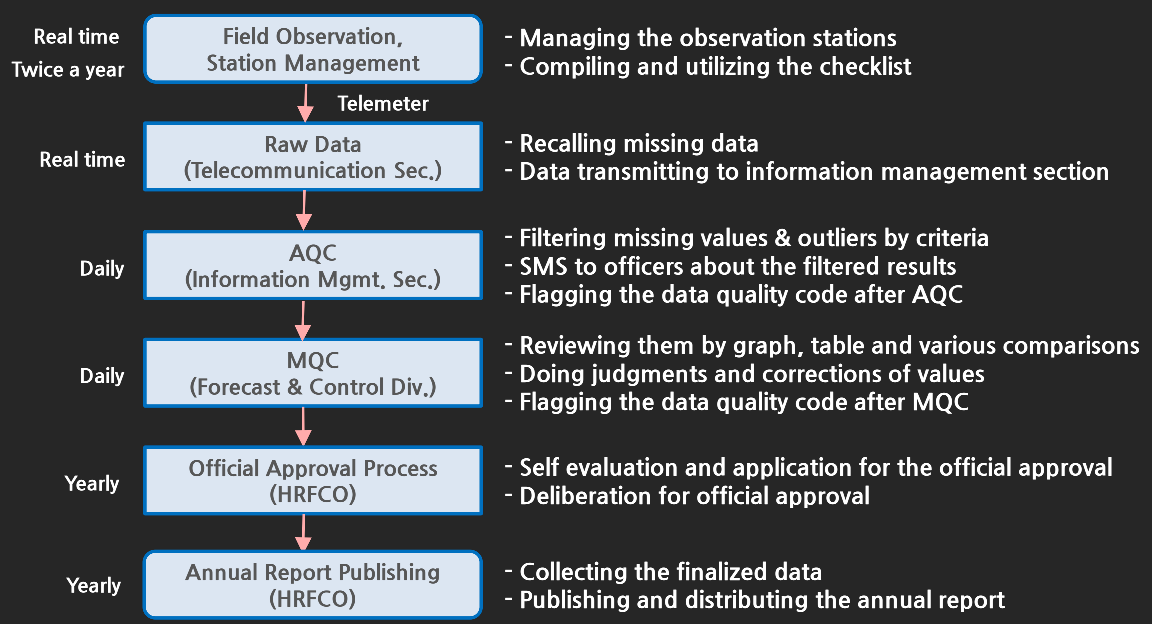
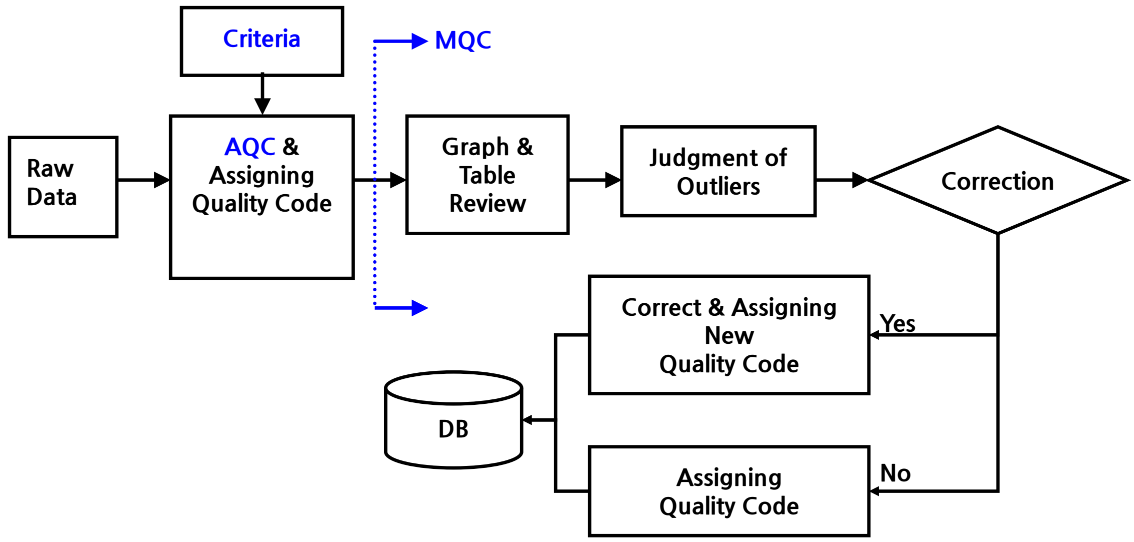
4.3 Process of the Hydrological Data Management



4.4 System Configuration

- **Process from observed raw data to database storage**



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4.5 Quality Codes

- **Rating quality codes according to the data status automatically**

Quality Code		Data status and correction method			Remarks
0100		Good quality data of continuous time-series			
02 (020)	11	Corrected Outliers (Raw data)	Rainfall	Corrected by observed, paper recorded, data logger recorded values	Outlier Handling
	12			Corrected by RDS method	
	13			Corrected by the arithmetic mean of nearby stations	
	14			Corrected by relation equation with nearby stations' data	
	19			Corrected by the judgment of the person in charge (reason of judgment, the correcting method should be written.)	
	21		Water Stage	Corrected by observed, paper recorded, data logger recorded values	
	22			Corrected by linear interpolation	
	23			Corrected by cubic spline interpolation	
	24			Corrected by relation equation with nearby stations' data	
	29			Corrected by the judgment of the person in charge (reason of judgment & correcting method should be written)	
	31		Rainfall	Corrected by RDS method	"-" Rainfall or related
	41		Water Stage	Corrected by the water stage value of one-time step earlier	Too high value

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4.5.1 Quality Codes (con't)

▪ **Rating quality codes according to the data status automatically**

<table>
<tr><th colspan="2">Quality Code</th><th colspan="3">Data status and correction method</th><th>Remarks</th></tr>
<tr><td rowspan="2">03
(030)</td><td>11 - 19</td><td rowspan="2">Corrected
Missing Data
(Raw data)</td><td>Rainfall</td><td rowspan="2">Methods in the 2?? codes applied to missing data</td><td rowspan="2">Missing data
Handling</td></tr>
<tr><td>21 - 29</td><td>Water
Stage</td></tr>
<tr><td rowspan="2">04</td><td>1</td><td rowspan="2">Corrected
by other methods</td><td>Rainfall</td><td>Other methods or judgments applied to rainfall data modification</td><td rowspan="2">Comments needed</td></tr>
<tr><td>2</td><td>Water
Stage</td><td>Other methods or judgments applied to water stage data modification</td></tr>
<tr><td colspan="2">05</td><td colspan="3">Outliers that cannot be corrected</td><td>No change</td></tr>
<tr><td colspan="2">06</td><td colspan="3">Missing data that cannot be corrected</td><td>No change</td></tr>
<tr><td colspan="2">07</td><td colspan="3">Lack of consistency in data for some reasons (ex: field situation change)</td><td>No change
(reasons need to be written)</td></tr>
<tr><td colspan="2">08</td><td colspan="3">Bad quality data with unknown reason</td><td>Unknown reason</td></tr>
</table>

4.5.1 Quality Codes (con't)

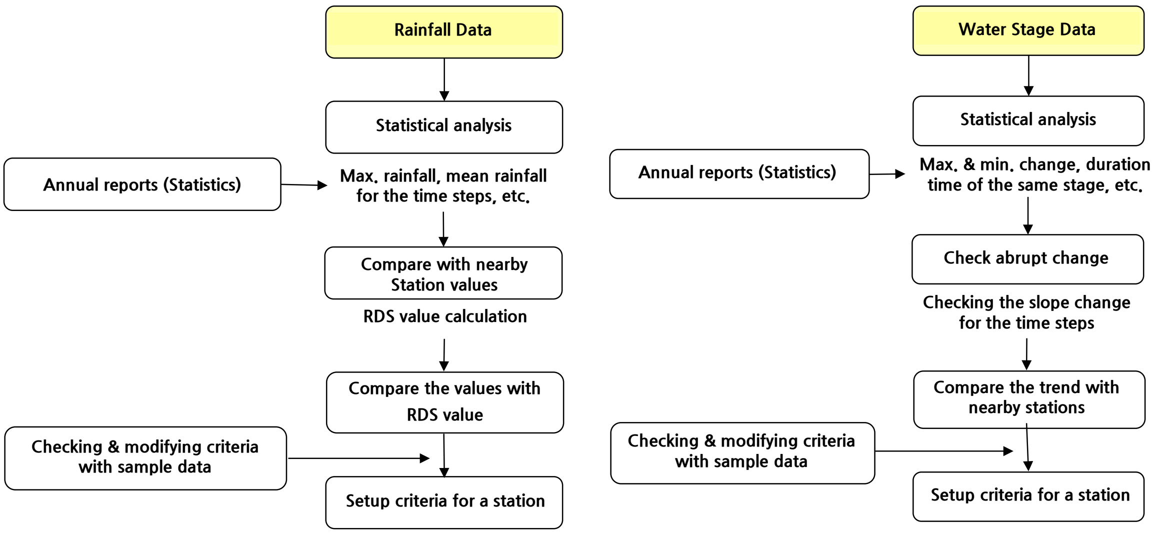
▪ **Rating quality codes according to the data status automatically**

<table>
<tr><th colspan="2">Quality Code</th><th colspan="3">Data status and correction method</th><th>Remarks</th></tr>
<tr><td rowspan="16">09
(090)</td><td>00</td><td rowspan="16">AQC result
(MQC needed with caution)</td><td rowspan="7">Rainfall</td><td>Not suitable for current AQC criteria</td><td rowspan="3">Too large rainfall value</td></tr>
<tr><td>11</td><td>Too large value (level 1: 40~80 mm / 30 min.)*</td></tr>
<tr><td>12</td><td>Too large value (level 2: more than 80 mm / 30 min.)</td></tr>
<tr><td>21</td><td>Observed value is more than the 300 % of the RDS value</td><td rowspan="2">Spatial Inconsistency</td></tr>
<tr><td>22</td><td>Observed value is less than the 40 % of the RDS value</td></tr>
<tr><td>31</td><td>Observed value is less than zero</td><td></td></tr>
<tr><td>91</td><td>Missing data</td><td>Not recorded</td></tr>
<tr><td>50</td><td rowspan="9">Water
Stage</td><td>Not suitable for current AQC criteria</td><td rowspan="5">Abrupt change</td></tr>
<tr><td>51</td><td>Abrupt zero value</td></tr>
<tr><td>52</td><td>Slope is more than 3 times of the slope for previous two time steps</td></tr>
<tr><td>53</td><td>Slope is more than -2 times of the slope for previous two time steps</td></tr>
<tr><td>54</td><td>Change of water stage is more than 0.3 m for one time step</td></tr>
<tr><td>61</td><td>Constant water stage for more than 24 hours</td><td>Constant value</td></tr>
<tr><td>71</td><td>More than the highest value ever</td><td>Too large</td></tr>
<tr><td>72</td><td>Less than the lowest value ever</td><td>Too small</td></tr>
<tr><td>92</td><td>Missing data</td><td>Not recorded</td></tr>
</table>

* Blue parts are different station by station.

4.6 Criteria for Automatic Data Filtering

▪ AQC Criteria for automatic data filtering: station by station



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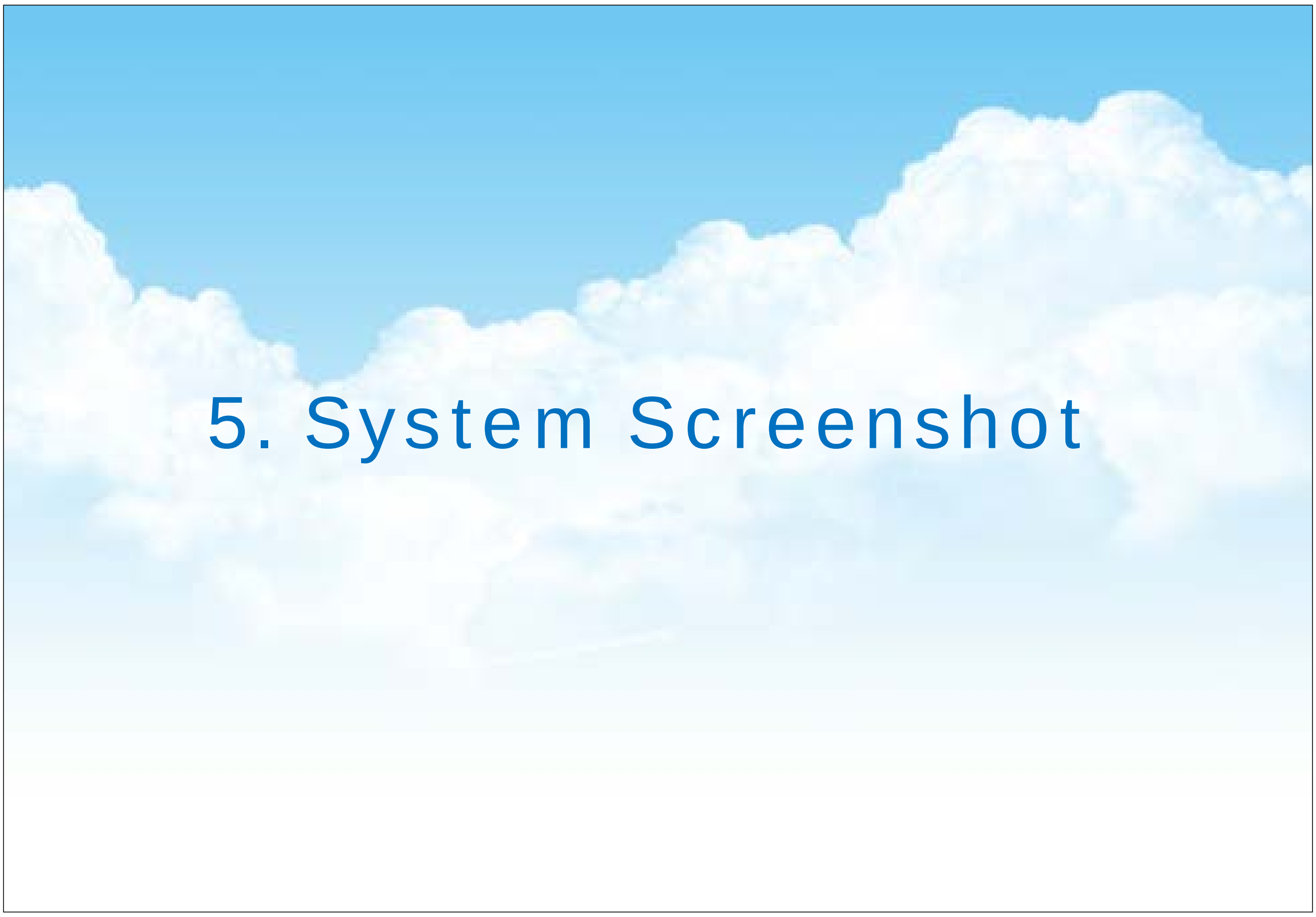
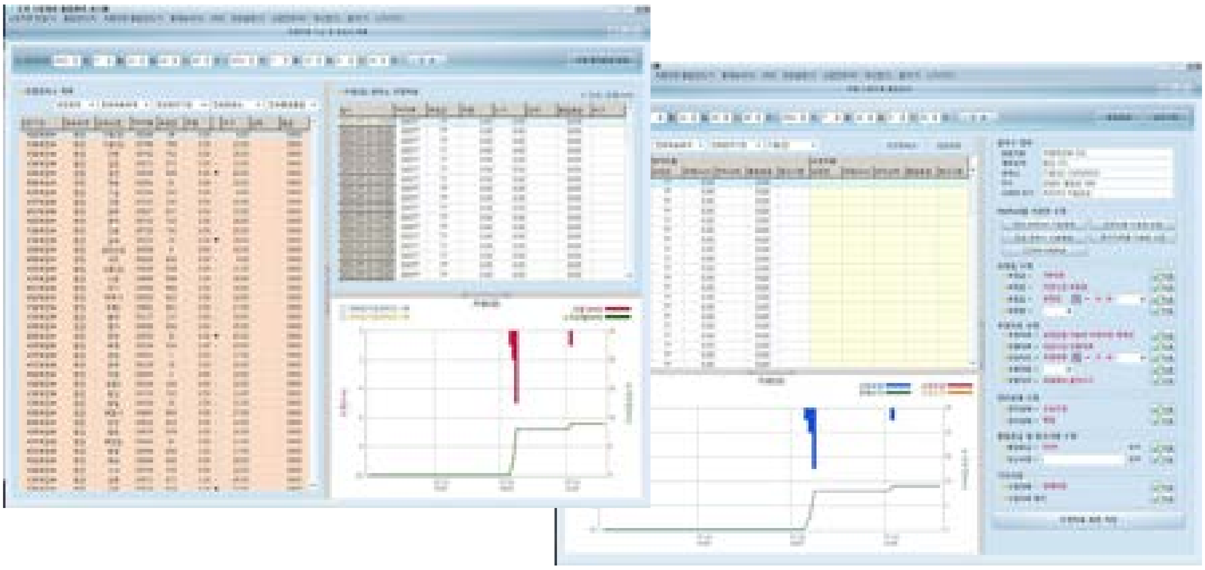


5.1 National Quality Control System for the Hydrological Data

- Check the data with table and graph (rainfall data)



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5.1 National Quality Control System for the Hydrological Data

- Check the data with table and graph (water level data)

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6. Conclusion

6. Conclusion

- Hydrological data quality control is important for ensuring the reliability and for enhancing the data utilization.
- In Korea, hydrological data QC is accomplished using the national system and related law and standards.
- The system needs to maintain consistency by practical use and share with related public organizations or companies.
- Efforts to expand the hydrological observation contents and to apply the new technology based on the QC system must go on.

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Thank you very much

MEMO

New Challenges on Hydrological Data Application

Hydrological Survey

New Challenges on Hydrological Data Application

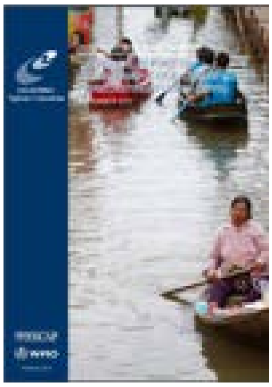
Aims & Objectives

- The aims of the course are to:
  - (1) Promote among trainees a good understanding of the new challenges in the concepts of the measurement, data management, application
  - (2) Help trainees to have a plan of new challenges considering their hydrological works condition

- The objectives are that trainees will be able to:
  - (1) Recognize new challenges in various aspects, measurement, data management and application
  - (2) Understand the importance of the hydrological data quality improvement

References

https://public.wmo.int/en/water/dynamic-water-resources-assessment-tool



TECHNICAL REPORT ON DEVELOPMENT OF EXTREME FLOOD FORECASTING SYSTEM (EFFS)

(TC,2017)

Contents

1.Introduction

1.1 Importance of Hydrological data

- Han River Flood Control office has led the international cooperation project in ESCAP/WMO Typhoon Committee since 2004

1st Phase	2nd Phase	3rd Phase	
Performance Evaluation & Improvement of Flood Forecasting Model (2004~2007)	Assessment System of Flood Control Measures on Socio-economic Impacts (2008~2011)	Extreme Flood Management in TC Regions (2012~2017)	?
DSS-FOP(Decision Support System for Flood forecasting system Operation & Planning)	Assessment System of Flood Control Measures & Technical Report	Extreme Flood Forecasting System & Guideline for Extreme Flood Management	

- According to the members requests, Han River Flood Control office accomplishes the project which is aimed to improve the hydrological data quality similar with own QC system

Without useful data, the model is useless!!!

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1.2 What Is the New Challenge?

What kind of challenge I will take begins with evaluating my current situation

No Concern
- O Do not observe and collect the Data
- O Have no concern about the situation

Chaos
- O One-time observation
- O Several organizations without standard

System Making
- O Continuous Observation
- O Collection and storage by governing Office
- O Utilization increase
- O Quality evaluation

Completion
- O Improved and documented process
- O Statistical analysis
- O Developed evaluation
- O Quality verification
- O Publication

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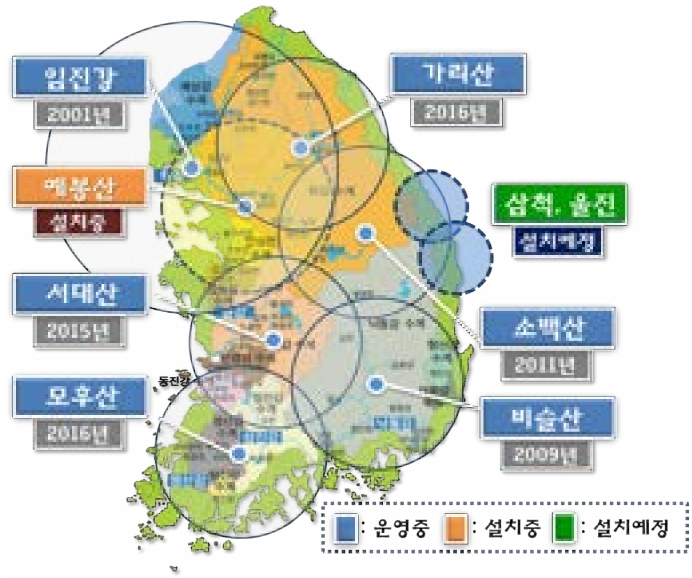
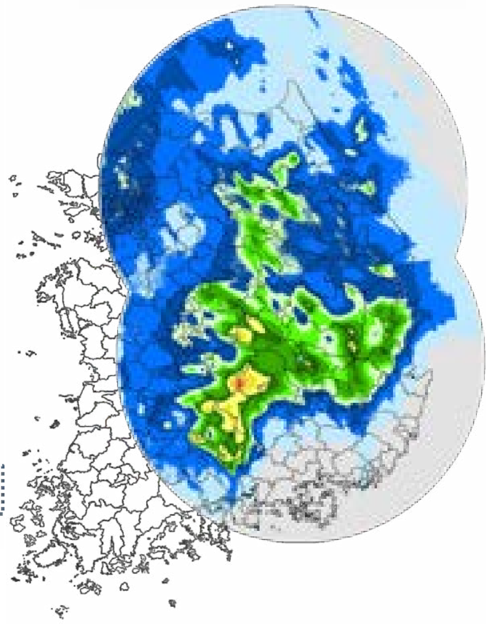
2. Measurement Techniques Development

2.1 Rainfall Measurement, Expansion from Point to Area

▪ **Rain Radar Station operated by ME**



RADAR COMPOSITE MAP



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2.2 Discharge Measurement, Automatic and Unmanned

▪ **Automatic Discharge Measurement Station**

(Integrated Real-time Discharge Measurement System)

Real-time, Remote control and Automatic measure and acquisition

Total	Han River	Nakdong River	Geum River	Yeongsan River
64	19	23	10	12

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2.3 Discharge Measurement, Contactless

- **Surface image velocimetry**
  - ✓ Measure in point or line
  - ✓ Proper to narrow stream
  - ✓ Difficulty in low flow velocity
  - ✓ Need the bridge or riverbank
  - ✓ For long time monitoring
- **Drone image velocimetr**
  - ✓ Measure in area
  - ✓ Proper to wide river
  - ✓ Available in low flow velocity
  - ✓ Need the flight approval
  - ✓ For short time monitoring



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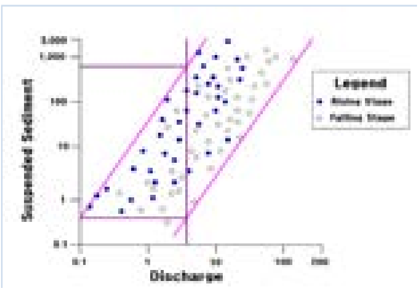
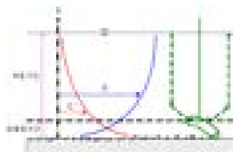
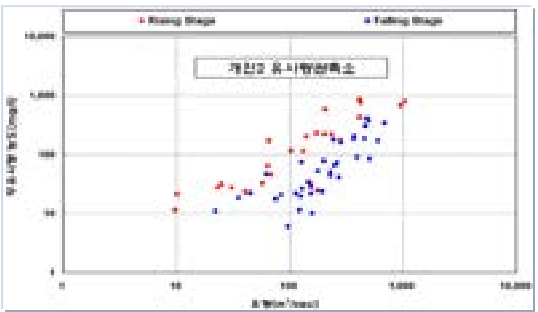
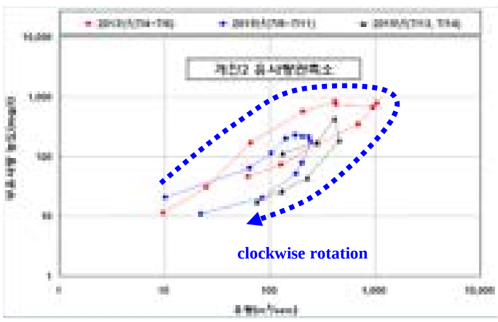
2.4 Research for Expansion of Contents

- **Sediment**

Research of characteristics of rising and falling parts and roof characteristics



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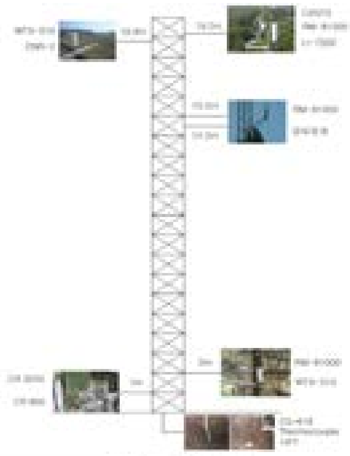
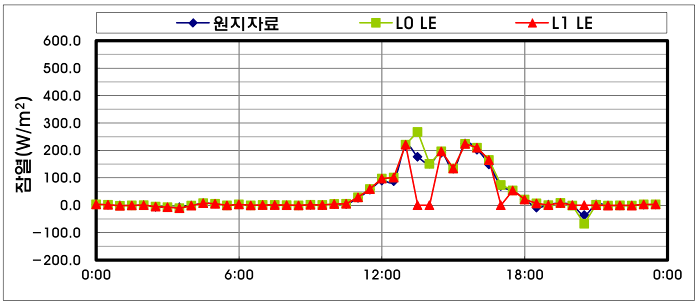
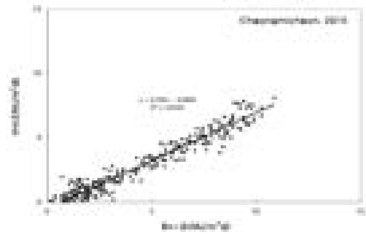
2.4 Research for Expansion of Contents

- **Evapotranspiration**

Research of checking outlier and gap filling method







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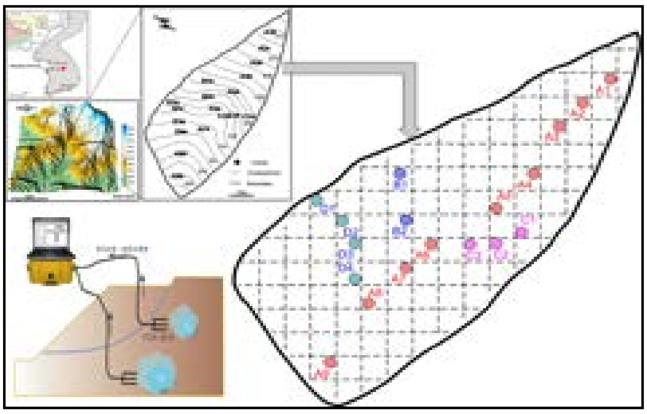
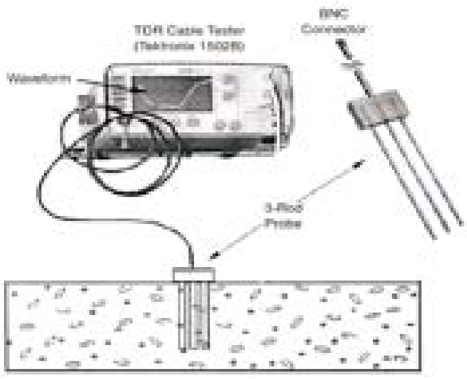
2.4 Research for Expansion of Contents

- **Soil Moisture Contents**





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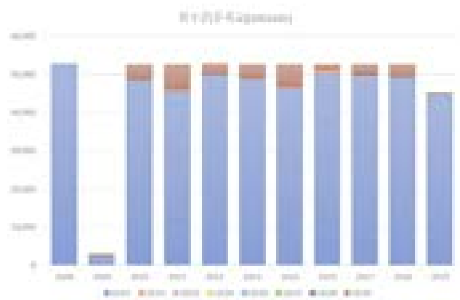
3. Data Management

3.1 Improvement of Data Quality Control

- **Setting the automatic QC criteria by statistical analysis**
  - Recent 3 ~ 5 years QC cases analysis
  - considering characteristics and situation of site
  - Grant of prerequisites (allowed change per unit time)
- **Reducing manual QC works and automation**
  - Applying Indicator of automatic QC criteria
  - Introducing AI algorithm(local search algorithm)

< QC codes grunt cases analysis>



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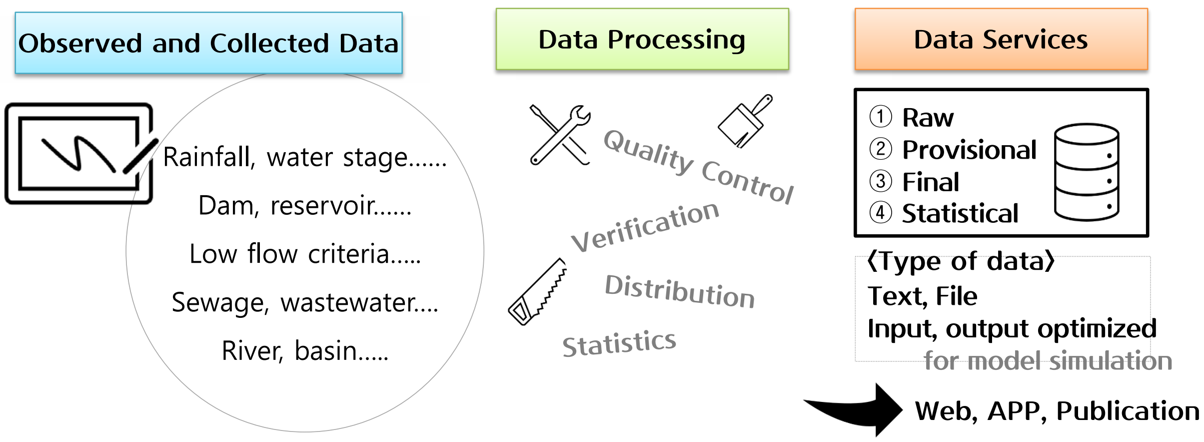
3.2 Improvement of Data Management System

- System for providing big data so that it can be used by citizens and experts
- Raw, provisional, final, statistical data as current 10-minute, 1-hour, and daily series
- Data service not only real time observed data but also statistical data and



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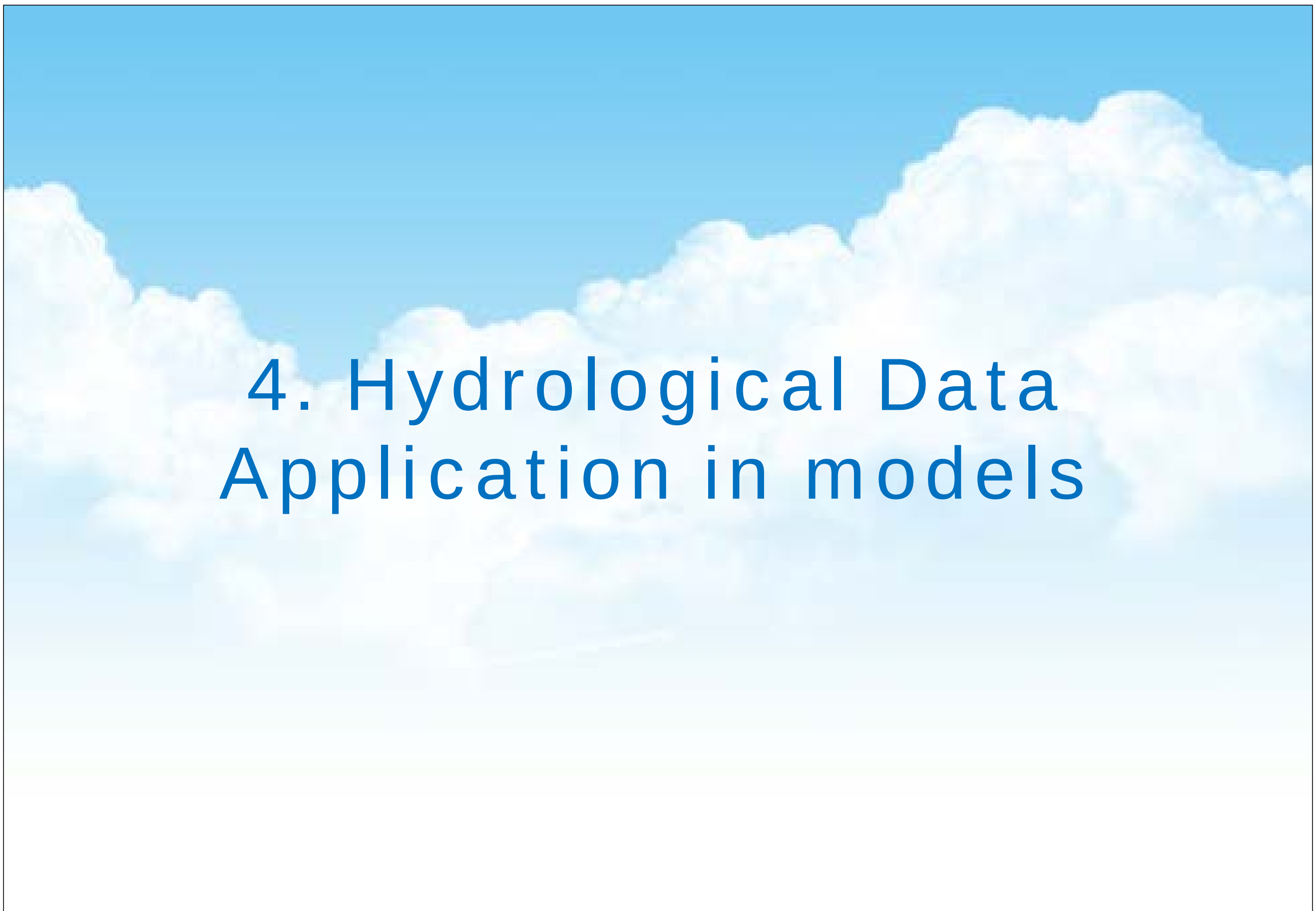

4.1 Models You Can Use..

- **Extreme Flood Forecasting system(EFFS)**
  - including flood forecasting methods and technologies for Asia-Pacific countries

Extreme Flood Forecasting System

Apply Step by Step system Based on the Flood Forecasting Capacity

Level 1	**Simple Statistic Model**
Level 2	**Rainfall-Runoff Model (Storage Function Model)**
Level 3	**Flood Forecasting using the Radar**
Level 4	**Establishment of Dam, Reservoir EAP (Emergency Action Plan)**

- **Level 1 : Relationship of** Stage-Stage, Rainfall-Stage, Stage-Discharge, Discharge-Discharge
- **Level 2 : Relationship** between the runoff and storage at basins and channels with the equation of flood wave motion to estimate a continuity equation to decide the flood runoff
- **Level 3 : Input the Radar data** connected to Level 2, Rainfall-Runoff Model
- **Level4 : EAP Flow Chart** and Simulation module of extreme flood (e.g. dam break scenario, bank collapse, etc.) using **FLDWAV**

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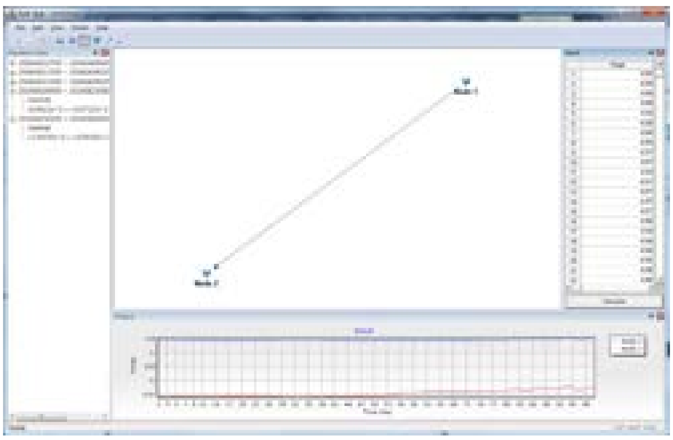
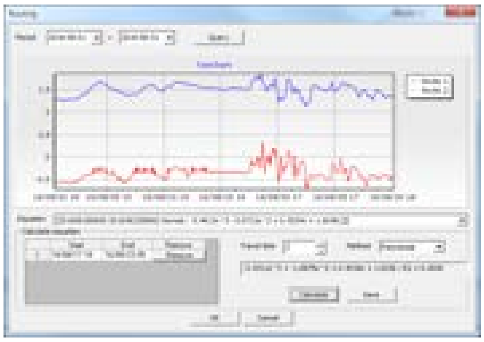
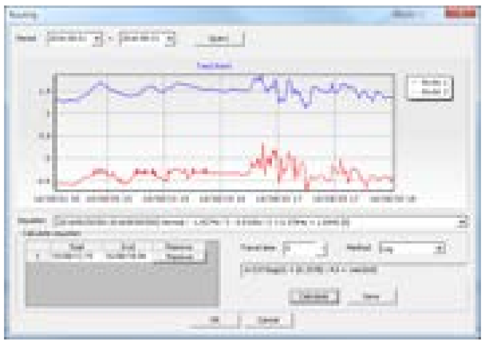
4.1 Models You Can Use..

- **Screen shot of EFFS**







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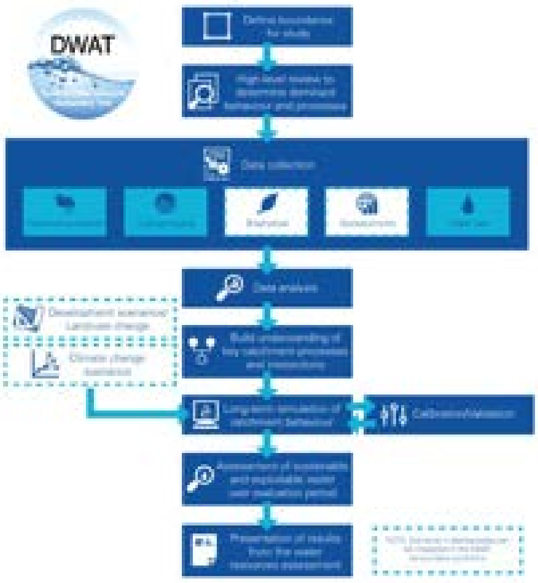
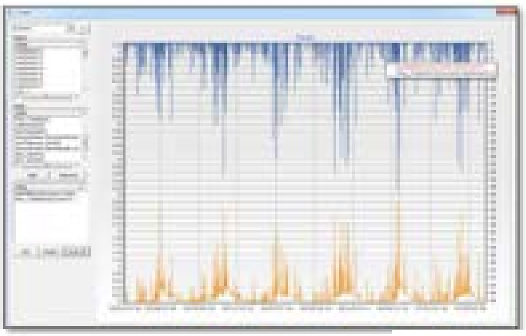
4.1 Models You Can Use..

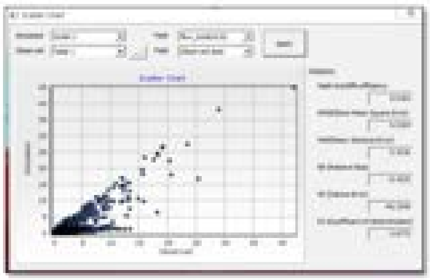
▪ Dynamic water resources assessment tool

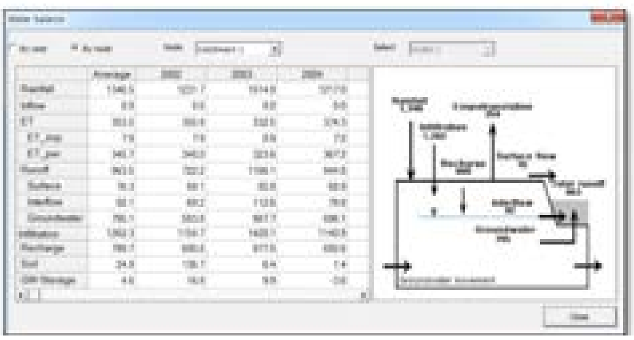


A distributed conceptual scheme for water cycle analysis and contains sub-algorithms, such as evapotranspiration, infiltration, watershed runoff, groundwater movement, and channel routing

4.2 Screen Shot of DWAT







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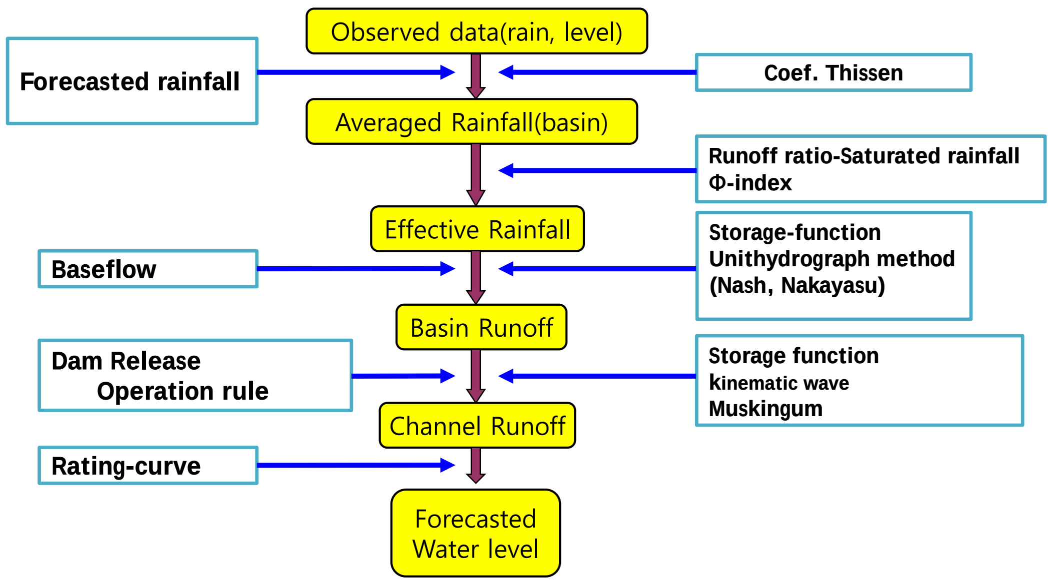
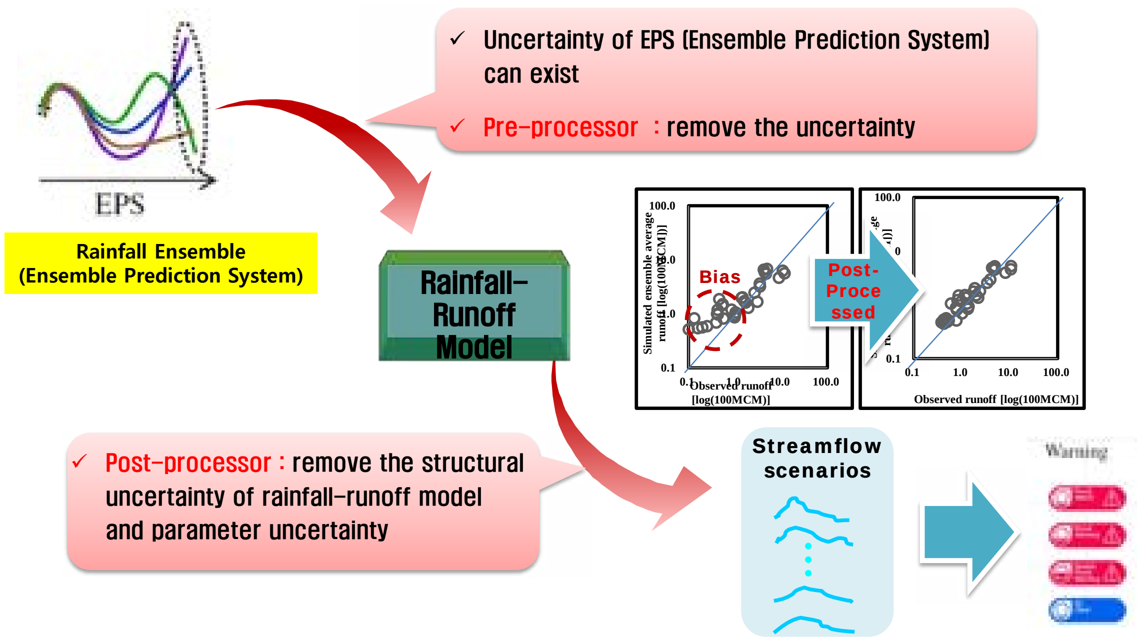
4.3 Hydrological Flood Forecast Model in Korea

■ The process needs the manual calibration by experts



4.4 Stochastic Forecast Model

■ Ensemble model



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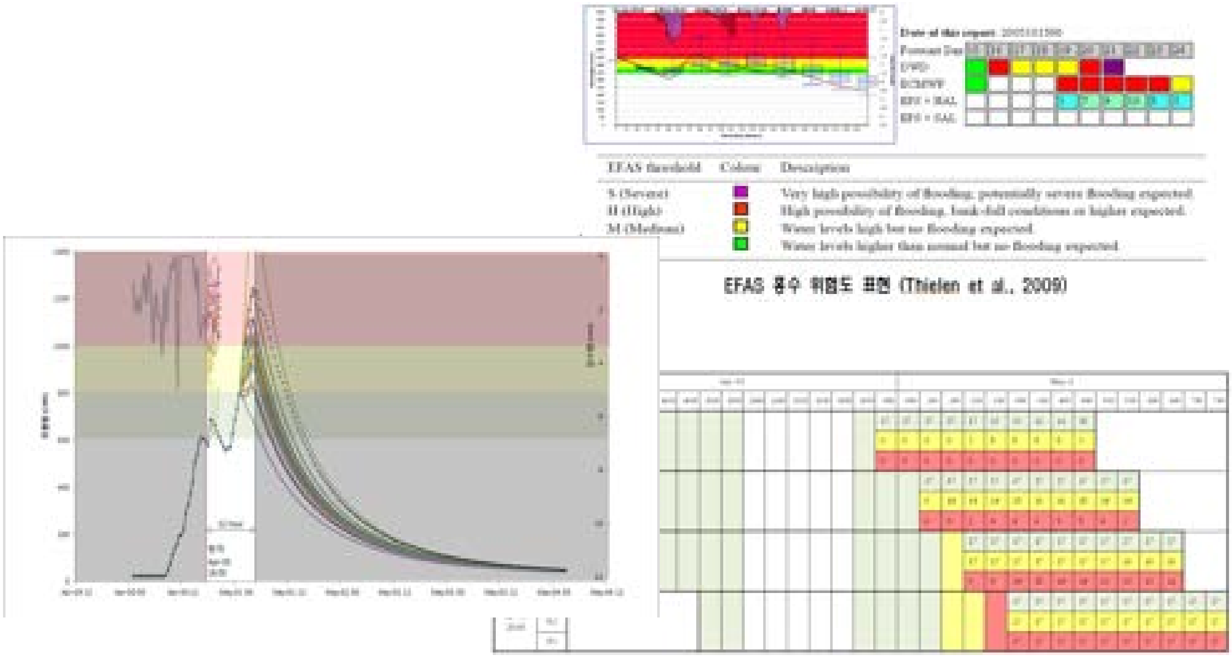
4.4 Stochastic Forecast Model

▪ **Results of stochastic flood forecasting**



EFAS 홍수 위험도 표현 (Thielen et al., 2009)

※ R1: 600 cms ~ 800 cms, R2: 800 cms ~ 1000 cms, R3: 1000 cms ~

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4.4 Stochastic Forecast Model

▪ **Transfer function noise model**

Modeling dynamic relationship between input and output

☞ suitable for real-world applications in various fields

Model Identification

- *empirical approach*
- *Haugh and Box identification*
- *Box and Jenkins method*

Parameter Estimation

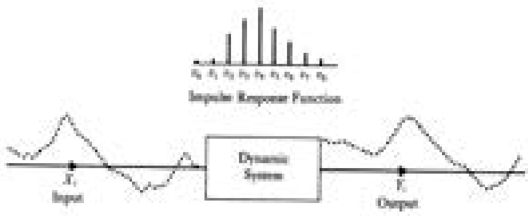
- *based on maximum likelihood method*
- *noise term follow ARMA process*

Diagnostic Checking

- *check* a_t *independently distributed*
- *residual autocorrelation coefficient*

$$Y_t - \mu_y = \overbrace{v(B)\,(X_t - \mu_x)}^{\text{Dynamic Component}} + \overbrace{N_t}^{\text{Noise}}$$

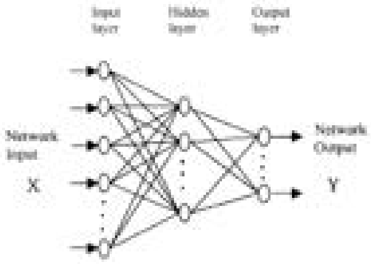
$$= \frac{\omega(B)}{\delta(B)} B^b (X_t - \mu_x) + \frac{\theta(B)}{\phi(B)} a_t$$



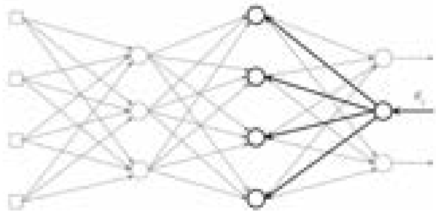
4.5 Deep Learning Model(or Data Driven)

- **ANN(Artificial Neural Network)**

  Learning neurons resembling human brain networks



<backpropagation process>



- Stochastic Gradient Descent

$$\hat{y}_k = f_0\left[\sum_{j=1}^{n} w_{kj} f_h\left(\sum_{i=1}^{m} w_{ji}x_i + w_{jb}\right) + w_{kb}\right]$$

$$E = \sum_{p=1}^{P} E_p = \sum_{p=1}^{P}\sum_{k=1}^{n}\left(y_{pk} - \hat{y}_{pk}\right)^2$$

Initial weight

↓

Calculating error

Repeat process

↓

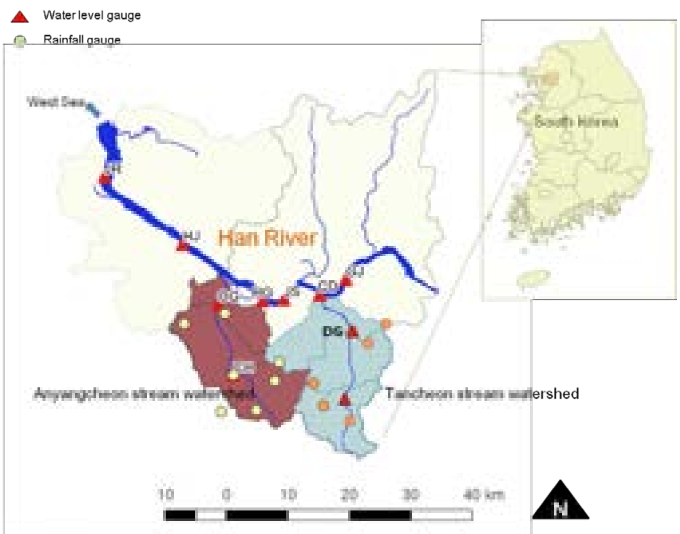
Updating weight $\Delta w_{ij} = \alpha e_i x_j$

↓

Adjusting weight $w_{ij} \leftarrow w_{ij} + \Delta w_{ij}$

4.6 Comparison Case Flood Forecast Result(SFM, TFN, ANN)

- Select data from 2007 to 2017 *considering flood events*



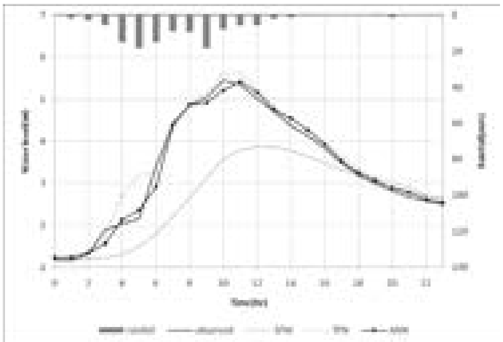
- Input : Hourly Rainfall from 2007~2017
- output : Hourly River water level (ANN)

  River discharge(TFN)
- Rain predic.: MAPLE 2016

✓ Training and testing
  - TFN : 2007~2012 / 2013~2016
  - ANN: 2007~2013 / 2014~2016

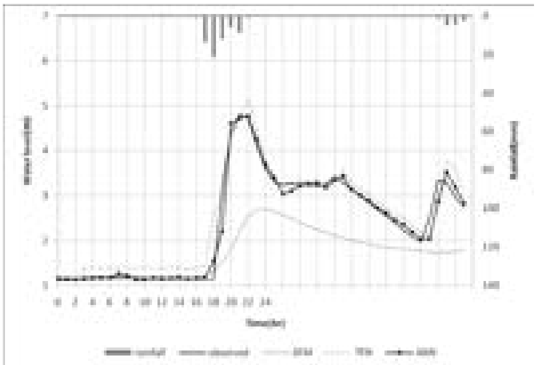
4.6 Comparison Case Flood Forecast Result(SFM, TFN, ANN)

▪ Flood forecast result (2013.7.12 ~7.13) in Anyangcheon stream



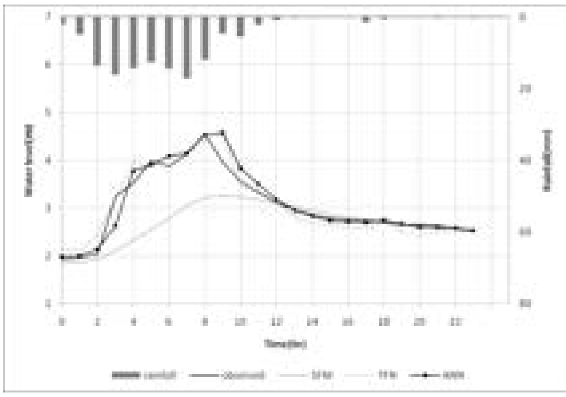
TFN		ANN	
RMSE	NSE	RMSE	NSEC
0.2088	0.9232	0.1574	0.9564
0.3282	0.9614	0.2038	0.9667

Flood forecast result (2013.7.21 ~7.22)

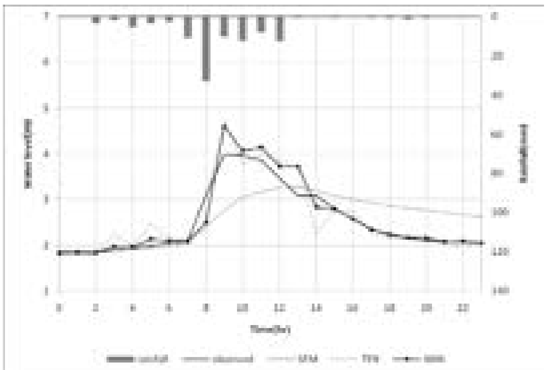


4.6 Comparison Case Flood Forecast Result(SFM, TFN, ANN)

▪ Flood forecast result (2016.7.21 ~7.22) in Tancheon stream



TFN		ANN	
RMSE	NSE	RMSE	NSEC
0.2157	0.9010	0.2070	0.9089
0.2631	0.8290	0.2057	0.8955



5. Conclusion

5. Conclusion

- New challenges are on going in hydrological works in aspect of measurement technology, data management, and hydrological models.
- Among these various challenges, you have to grasp your status and decide which challenge to choose.
- First step for improving hydrological works is to enhance the reliability of hydrological data, and model application is the next.
- If enough data is secured, your model produces the better results.
- In addition to models introduced here, you can consider a lot of models for simulating the hydrological situation.
- The most important thing is that you need reliable data to run a good model.

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Thank you very much