Title: **Development and Application of Technical Key Performance Indicators (KPIs) for Smart Water Cities (SWCs) Global Standards and Certification Schemes**

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Subject: **SWC Assessment for Busan Eco-delta City, Republic of Korea**

The assessment of the water system in the Busan Eco Delta Smart City occurred between March and June 2023, encompassing two key phases: a self-assessment and result verification for both technical and governance components. The collected data aimed to provide specific insights into BEDC. However, due to BEDC being part of the larger Busan municipality, at times the available information pertains to the municipality in its entirety, and not exclusively to BEDC. The report acknowledges and addresses this aspect by making references to the broader municipal context within the text.

For Technical pillar, various data sources have been utilized to gather the data needed for the smart water city evaluation. The urban water data for BEDC was obtained from the information presented on the K-water website. The rest of the information was gathered from either the surrounding districts of BEDC (Gangseo, Sasang and Buk districts), or from Busan Metropolitan city data. In the Republic of Korea, the majority of the data necessary for the smart water city evaluation can be accessed online. The national agencies that facilitate the collection of these data include the Korea Water Resources Corporation (K-water), Korea Meteorological Administration (KMA), National Institute of Environmental Research (NIER), National Groundwater Information Management and Service Center (GIMS), Korea Statistics Ministry, Ministry of Environment (MOE) and the Korea Environment Corporation (KECO). City-scale data was also collected from the Busan Metropolitan City government, Busan Water Authority, and Busan Environmental Corporation (BECO). Data information sources were also utilized, such as the Water Resources Management Information System (WAMIS), Water Environment Information Center, Integrated Groundwater Information Services, Busan Open Data Portal, Korea Public Data Portal, Busan Metropolitan City Urban Flood Integrated Information, National Drought Information Portal, National Water Supply Information System, Korea Water Resources Water Information Portal, Water Information Portal, National Water Supply Information System and the Korea Statistical Information Services (KOSIS).

1. Urban water cycle

1.1 Precipitation

URBAN WATER CYCLE - Precipitation	
Indicator 1.1.a Coverage extent of precipitation observation stations (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Precipitation station area density (km^2/station) = Total urban area (km^2) / Number of precipitation stations within the city	
Operation of at least one rain gauge per 5 km^2	
Operation within 5 – 10 km^2	
Operation within 10 – 20 km^2	**2**
Rain gauge coverage is more than 20 km^2	
City has no data on rainfall station coverage density, or no rainfall measurements are performed	
Not applicable. This indicator is not considered.	
Quantitative Analysis: **Show the calculation process and provide data supporting the justification.** Gangseo-gu, Sasang-gu, Buk-gu total surface area = 179.05, 35.84, 38.30 km^2 Number of rainfall stations: MOE = 2, KMA AFSO = 4, KMA AWS = 7.	

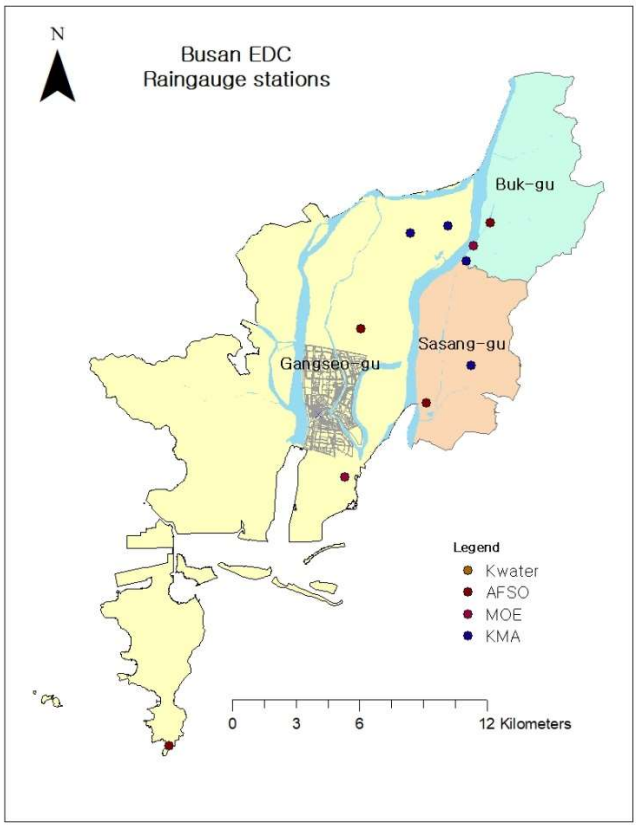


Figure. Total number of precipitation stations for Busan EDC

Calculation:

$$\text{Precipitation station area density} = \frac{\text{Total urban surface area}}{\text{No. of rainfall stations within the city}}$$

$$\text{Precipitation station area density}_{\text{Busan EDC}} = \frac{253.19\ \text{km}^2}{13} = \mathbf{19.5}\ \text{km}^2/\text{station}$$

Source: Korea Meteorological Administration Open Data Portal (data.kma.go.kr) > Data > Weather Observation > Ground

URBAN WATER CYCLE – Precipitation	
Indicator 1.1.b Monitoring and recording frequency of the precipitation observation stations (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Precipitation is recorded at 1-minute interval	4
Recorded at least 10-minute interval	
Recorded at least 30 min interval	
Recorded at hourly or more than hourly interval	

City has no data on rainfall monitoring frequency, or no rainfall measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

지점	지점명	일시	1분 강수량(mm)	강수유무(유무)
904	사상	2023-02-27 0:01	0	0
904	사상	2023-02-27 0:02	0	0
904	사상	2023-02-27 0:03	0	0
904	사상	2023-02-27 0:04	0	0
904	사상	2023-02-27 0:05	0	0
904	사상	2023-02-27 0:06	0	0
904	사상	2023-02-27 0:07	0	0
904	사상	2023-02-27 0:08	0	0
904	사상	2023-02-27 0:09	0	0
904	사상	2023-02-27 0:10	0	0
904	사상	2023-02-27 0:11	0	0
904	사상	2023-02-27 0:12	0	0
904	사상	2023-02-27 0:13	0	0
904	사상	2023-02-27 0:14	0	0
904	사상	2023-02-27 0:15	0	0
904	사상	2023-02-27 0:16	0	0
904	사상	2023-02-27 0:17	0	0
904	사상	2023-02-27 0:18	0	0
904	사상	2023-02-27 0:19	0	0
904	사상	2023-02-27 0:20	0	0

Figure. Busan Metropolitan City AWS (Automated Weather Station) real-time sample data (1-min interval)

Source: Korea Meteorological Administration Open Data Portal (data.kma.go.kr) > Data > Weather Observation > Ground > Synoptic Meteorological Station

URBAN WATER CYCLE - Precipitation	
Indicator 1.1.c Precipitation error and missing data (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of missing data (precipitation) (%) = (Number of missing values / Total number of precipitation observations) * 100	
Percentage of missing and error precipitation data is less than 6 %	4
Percentage is within 6 to 10 %	
Percentage is within 10 to 20 %	
Percentage is more than 20 %	

City has no information on rainfall observation error and missing data, or no rainfall measurements are performed	
Percentage of missing and error precipitation data is less than 6 %	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Busan Metropolitan city rainfall observation information data:

Rainfall station	Duration of observation	Total number of rainfall observations	Total number of recorded observations	Total percentage of missing data
Gupo	2006-present	6274	6225	0.78

Computation:

$$\text{Precipitation missing data percentage} = \frac{\text{Total number of missing data}}{\text{Total number of observations}} \times 100\%$$

$$\text{Precipitation missing data percentage}_{\text{Busan EDC}} = \mathbf{0.78\%}$$

Source: Water Resources Management Information System (wamis.go.kr) > Hydrometeorological data > Rainfall data

URBAN WATER CYCLE - Precipitation	
Indicator 1.1.d Precipitation data automation and data quality assurance (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
The city implements the automation and quality assurance methods criteria mentioned above	
At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the automation and calibration of precipitation monitoring instruments	

Rainfall observation method and quality assurance
✓ Real-time and automated recording of rainfall
✓ Existence of auto-calibration function within the rainfall instrument or system
✓ Regular calibration of the rainfall instrument
✓ Recorded rainfall data quality assurance

Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

System (ASOS) and Automated Weather Stations (AWS) are all recorded automatically and in real-time. Hence, **100%** of the observation stations records automated and real-time precipitation data.

Figure. Busan Metropolitan City ASOS (Busan Rainfall Synoptic Station) and AWS (Sasang AWS) stations.

Source: Korea Meteorological Administration Open Data Portal (data.kma.go.kr) > Data > Weather Observation > Ground > Synoptic Weather Stations > View branch details

According to "Meteorological Instrument Test Regulations" under Meteorological Administration Oder No. 734 (law.go.kr/LSW): meteorological instruments, including precipitation measuring instruments, are subject to inspections by the Korea Meteorological Agency (KMA) under Article 14 of Standardization of Weather Observation Act.

Rainfall observation devices are routinely calibrated at least 10 times per year, to determine the suitability by comparing with performance, structure, type, condition, etc. and issued a "verification certification" for the instrument to be suitable for meteorological observation.

Reference: National Legislation Information Center (2012). Accessed in law.go.kr/LSW 04 May 2023.

URBAN WATER CYCLE – Precipitation
Indicator 1.1.e Observed precipitation data collection process (Busan) (Choose one of the following options that better describes the current circumstances in city)

	Rainfall observation ICT-based technologies
✓	Automated weather stations (AWS), Automated synoptic observation system (ASOS), IoT rainfall instruments, Sensor rain gauges
✓	Ground-based doppler radar, Microwave radiometers
✓	Regional-scale satellite data, GIS
✓	Numerical weather prediction, AI-based rainfall prediction systems, Machine learning

The city utilizes all of the ICT-based rainfall monitoring instruments criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the application of ICT in rainfall monitoring, or city does not apply ICT in rainfall monitoring	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

The Korea Meteorological Agency utilized radar and satellite images to perform weather observations for Busan Metropolitan City.

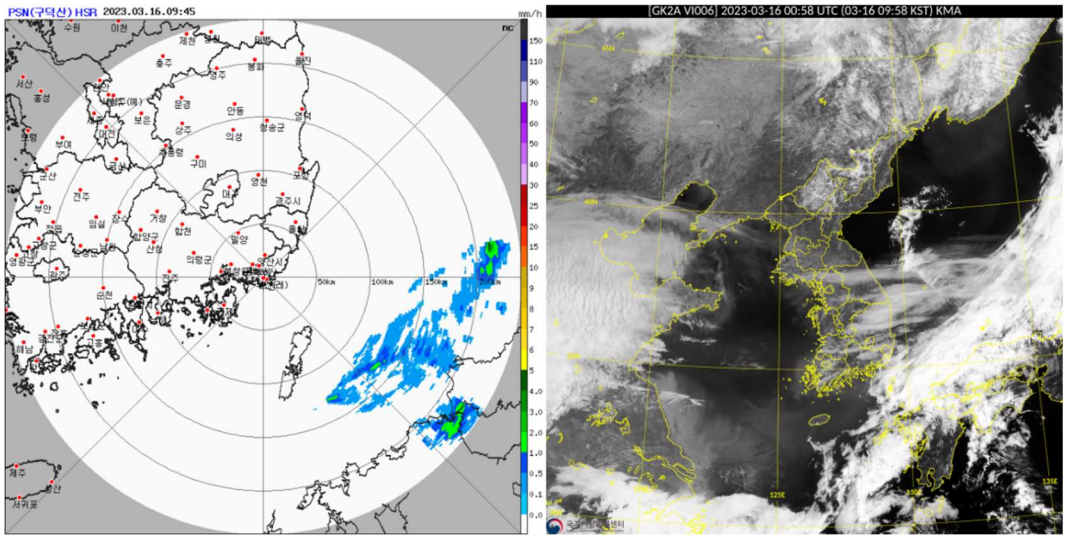


Figure. Realtime radar and satellite observations covering Busan Metropolitan City

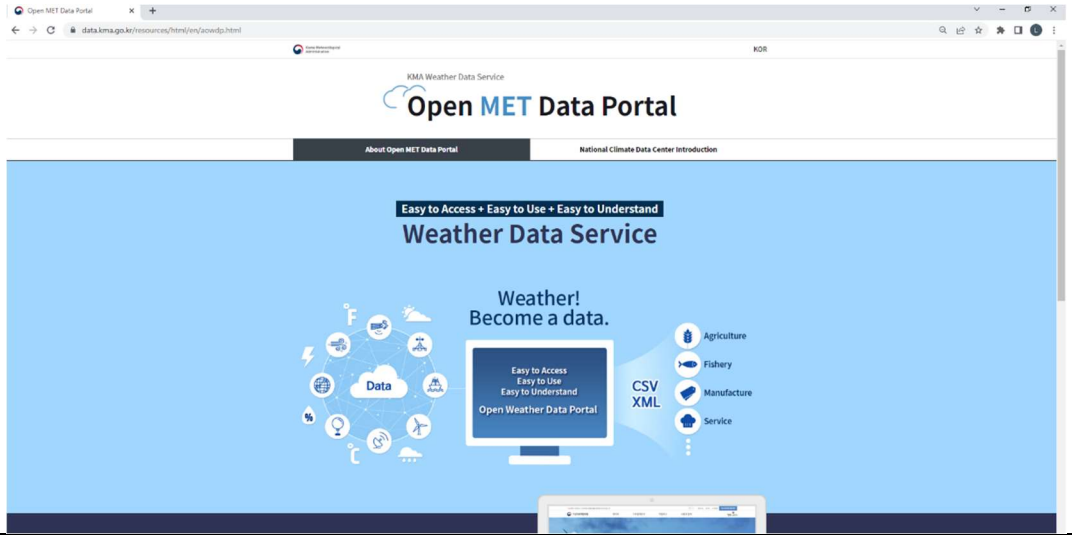
Source: Korea Meteorological Administration (web.kma.go.kr) > Weather Chart Images > Satellite / Radar Images

URBAN WATER CYCLE - Precipitation
Indicator 1.1.f ICT-based precipitation data accessibility (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)

Open online access of complete observed precipitation data	4
Open online access of partial or incomplete precipitation data	
Manual retrieval of precipitation data (i.e. official letter request, direct request to the office in charge)	
Restricted access to precipitation data (i.e. data only available within intergovernmental agencies)	
City has no information on precipitation data accessibility, or data is not available to public access	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

Based on the access of precipitation data from KMA website (data.kma.go.kr), observed data are complete and open access. Therefore, the score for this indicator is full-score.



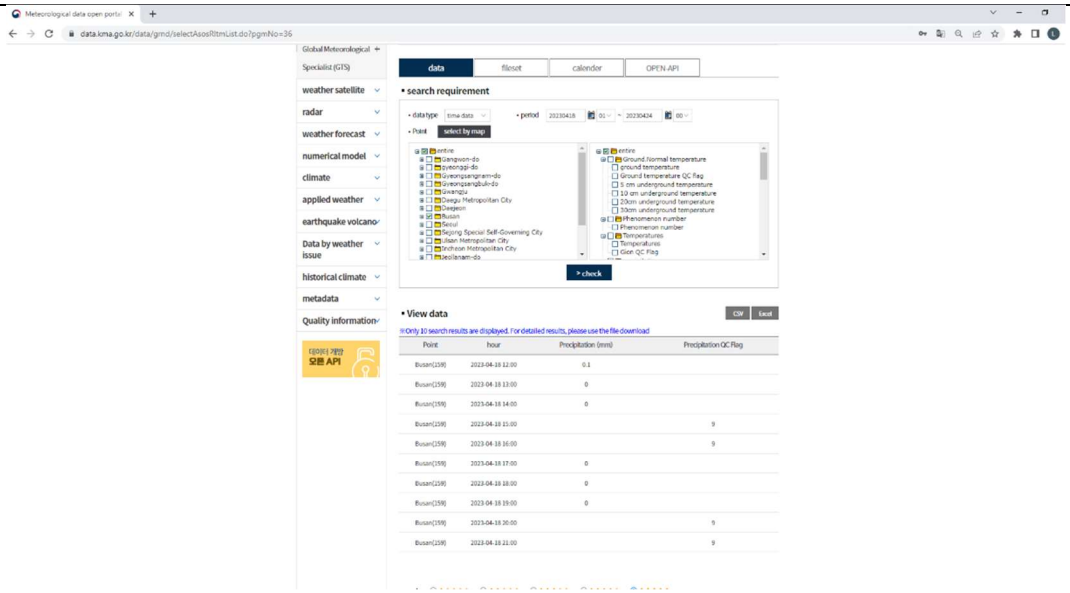


Figure. KMA open access website

Source: Korea Meteorological Administration (data.kma.go.kr) > data > meteorological observations

1.2 Surface water

URBAN WATER CYCLE – Surface water	
Indicator 1.2.a Percentage of impervious surface (EDC) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of impervious surface (%) = Total impervious surface area (km^2) / Total urban area (km^2) * 100	
The percentage coverage of impervious surface area compared to the city total area is less than 70%	
Percentage is within 70 to 75%	3
Percentage is within 75 to 80%	
Percentage coverage is more than 80%	
City has no data on impervious surface information	
Not applicable. The indicator is not considered.	
Quantitative Analysis: **Show the calculation process and provide data supporting the justification.** According to Korea Water Resource Corporation, the total pervious area (Parks and Grasslands) for Busan Eco Delta City are 0.66 km^2 and 2.36 km^2 respectively.	

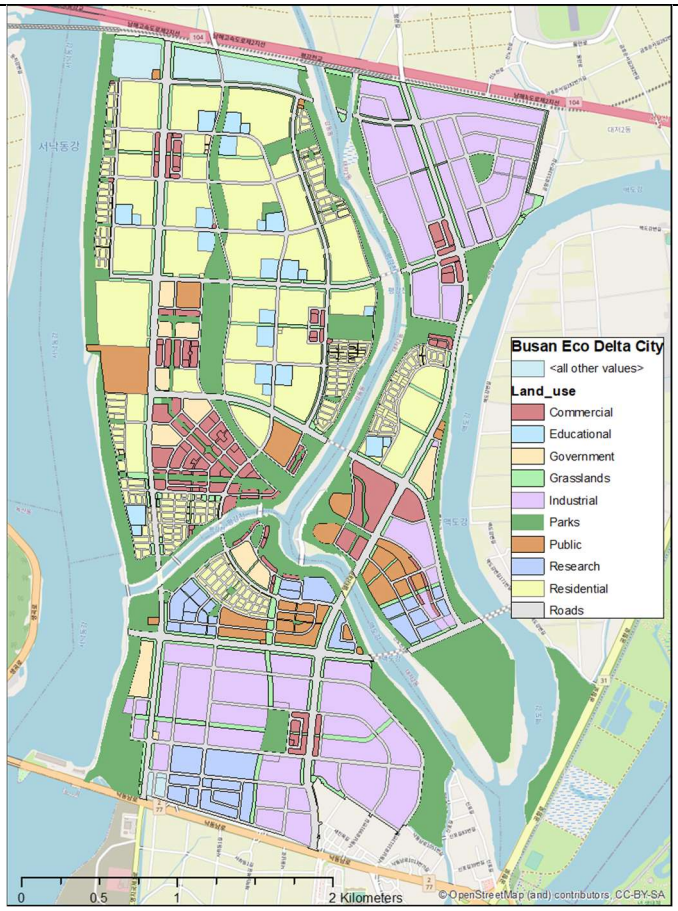


Figure. Busan Eco Delta City land use

The total impervious surface percentage is therefore computed as:

$$\text{Impervious surface percentage} = \frac{\text{Total urban area} - \text{Total pervious surface}}{\text{Total urban area}} \times 100$$

$$\text{Impervious surface percentage}_{\text{Busan EDC}} = \frac{11.89 - 3.02\ \text{km}^2}{11.89\ \text{km}^2} \times 100 = \mathbf{74.6\%}$$

Source: Korea Water Resource Corporation: (kwater.or.kr/website/ecodeltacity)

URBAN WATER CYCLE – Surface water	
Indicator 1.2.b Green space ecosystem protection (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of natural conserved area (%) = Total surface area dedicated for nature conservation (km^2) / Total urban area (km^2) * 100	
The percentage of the natural conserved area within the city is more than 20%	
Percentage is from 15 to 20%	**3**

Percentage is from 10 to 15%	
Percentage is less than 10%	
City has no data on nature conserved area information	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to Korea Water Resource Corporation, the total green space area assigned for nature conservation for Busan Eco Delta City is 2.36 km^2.

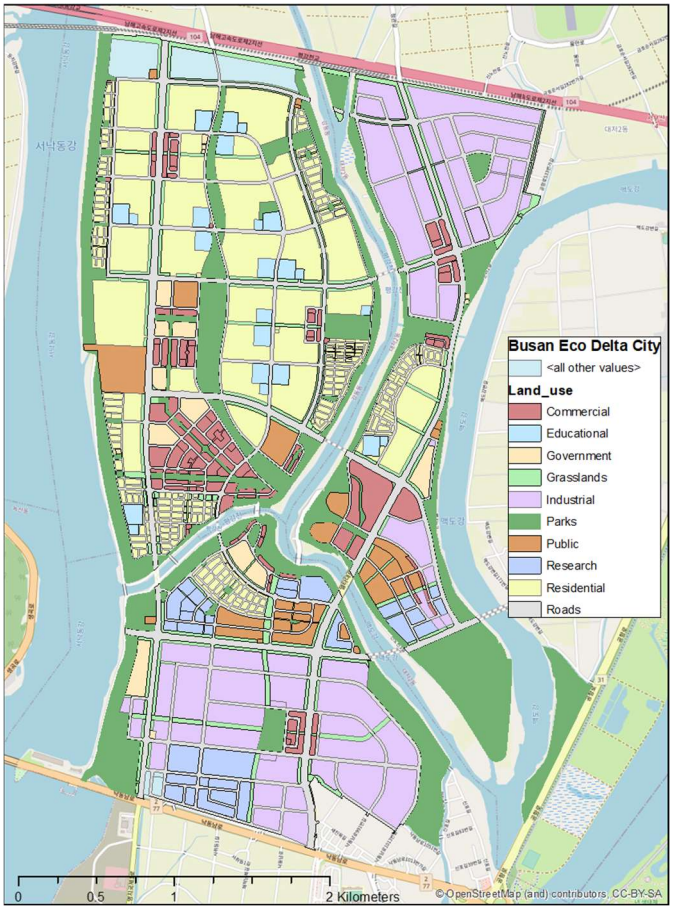


Figure. Busan Eco Delta City land use

The percentage of conserved area for BEDC is:

$$\text{Conserved area percentage} = \frac{\text{Total natural conserved area}}{\text{Total urban area}} \times 100$$

$$\text{Conserved area percentage}_{\text{Busan Eco Delta City}} = \frac{2.36\ \text{km}^2}{11.89\ \text{km}^2} \times 100 = \mathbf{19.8\%}$$

Source: Korea Water Resource Corporation: (kwater.or.kr/website/ecodeltacity)

URBAN WATER CYCLE – Surface water	
Indicator 1.2.c Urban waterfront facilities (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Waterfront purposes ✓ Recreation, leisure, parks and green spaces, cycling and walking trails, cultural entertainment ✓ Environmental conservation ad protection, ecological habitat, wetland restoration, storm water management ✓ Commercial, industry ✓ Transportation, ferry terminal, water-based public transits	
The city waterfront and water spaces satisfy all the waterfront purpose criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
None of the criteria is satisfied, or the city has no information on waterfront management, or no waterfront /water space areas within the city	

Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

Busan Metropolitan city constructed the Busan North Port as international marine tourism, serve as a gateway for Eurasian continent, as a leisure waterpark and revitalize local economy.

Figure. Busan North Port waterfront area

Source: Busan Metropolitan City (busan.go.kr) > City government > Key projects

URBAN WATER CYCLE – Surface water	
Indicator 1.2.d Application of LID and green infrastructures (Busan) (Choose one of the following options that better describes the current circumstances in city)	
LID surface area percentage (%) = (LID and green infrastructures total surface area coverage (km^2) / Total urban area) * 100	
The percentage of urban surfaces with LID and green infrastructures is more than 15 %	4
Percentage is between 10 to 15 %	
Percentage is between 5 to 10 %	
Percentage is less than 5 %	
City has no data on LID and green infrastructures, or city has no application of LID and green infrastructures	

Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Green infrastructure distribution for Busan Metropolitan city

Category	Total area (km^2)	LID and Green Infrastructure			
		Green area	Wetland	Combined	
				Area (km^2)	Percentage (%)
Residential	147.4	22.4	0.6	23.0	15.6
Commercial	26.2	1.8	0.2	2.0	7.6
Industrial	60.1	6.5	0.2	6.7	11.1
Green belt	533.8	390.8	31.0	421.9	79.0
Unassigned area	10.2	0.4	-	0.4	3.9
Total	777.6	421.9	32.0	453.9	58.4

The total percentage of LID and green infrastructure surface for Busan Metropolitan City is 58.4%.

Source: Yeo et al. (2021). A study on enhancing response to climate change using spatial analysis of green infrastructure. Busan Development Institute. Accessed in bdi.re.kr on 30 Jun 2023.

1.3 Urban stream water level

URBAN WATER CYCLE – Urban stream water level	
Indicator 1.3.a. Extension extent of water level observation stations (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Stream water level station coverage extent (km/station) = Total river extent (km) / Number of stream water level stations within the city	
Operation of more than 5 stream gauges per 10 km river extent	
More than 3 stream gauges per 10 km extent	3
More than 1 stream gauge per 10 km extent	
Equal to or less than 1 stream gauge per 10 km extent	
City has no data on stream water level extent coverage, or no stream water level measurements are performed	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Busan Metropolitan City major rivers and corresponding total extension (Source: river.busan.com)

Major river	Length (km)
Oncheoncheon	14.13
Suyeong-gang	19.2
Dongcheon	4.85
Daecheoncheon	5.5
Jisacheon	9.2
Kamjeoncheon	2.9
Hakjangcheon	5.35
Choryangcheon	1.6

According to Busan Metropolitan City major river water level information (data.busan.go.kr), there are a total of 18 stream gauge stations within the city river streams, therefore:

Computation:

$$\text{Stream gauge station per extent} = \frac{\text{Total river extension (km)}}{\text{No. of stream gauge stations within the city}}$$

$$\text{Stream gauge station per extent}_{\text{Busan Metropolitan City}} = \frac{62.73\ \text{km}}{18} = \mathbf{3.49\ km/station}$$

Sources:

river.busan.com >view major streams
Busan Open Data Portal (data.busan.go.kr) > Busan Metropolitan City River Current Status

URBAN WATER CYCLE – Urban stream water level	
Indicator 1.3.b. Water level monitoring frequency (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Water level measurements are performed at interval of equal to or less than 10-minute	4
Water level is measured at least 30-minute interval	
Water level is measured at least hourly interval	
Water level is measured at more than hourly interval	
City has no data on stream water level monitoring frequency, or no stream water level measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the official data website for Busan Metropolitan City, regional water level stations record real-time water level data at 10-min interval.

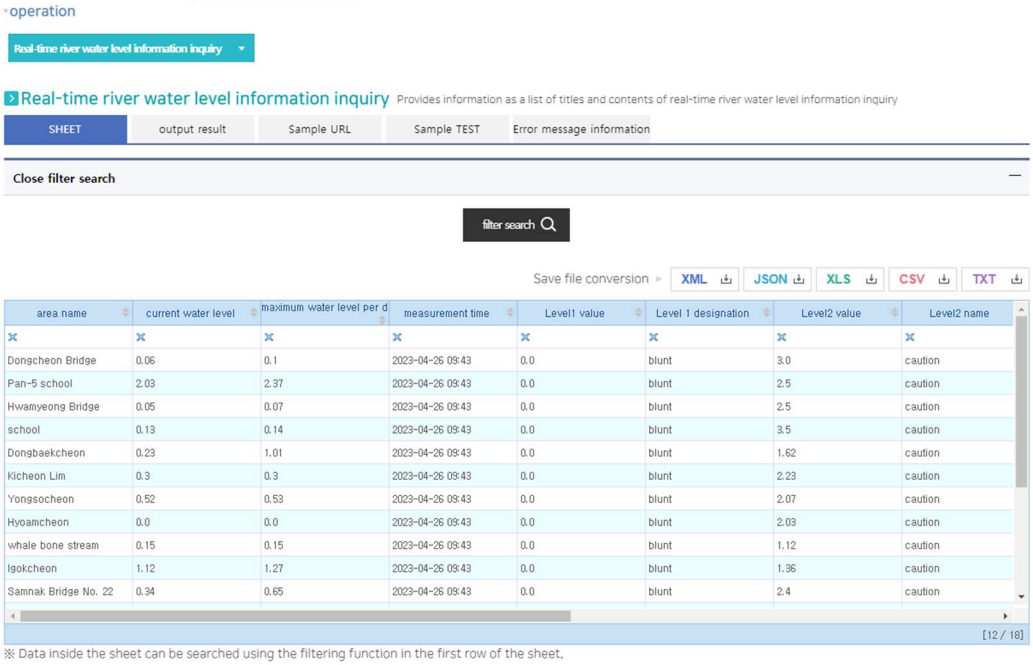


Figure. Water level data for Busan City

Source: Busan Open Data Portal (data.busan.go.kr) > Real-time river water level Information Inquiry

URBAN WATER CYCLE – Urban stream water level	
Indicator 1.3.c Water level error and missing data (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of missing data (water level) = (Number of missing values / Total number of water level observations) * 100	
Percentage of missing and error water level data is equal to or less than 5 %	4
Percentage is within 5 to 10 %	
Percentage is within 10 to 20 %	
Percentage is more than 20 %	
City has no information on stream water level observation error and missing data, or no stream water level measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Busan Metropolitan city Nakdong river water level station data (Source: WAMIS):

Water level station	Duration of observation	Total number of water level observations	Total number of recorded observations	Total percentage of missing data
Gupo Bridge	1987-present	13060	12836	1.72%

$$\text{Water level missing data percentage} = \frac{\text{Total number of missing data}}{\text{Total number of stream level observations}} \times 100\%$$

$$\text{Water level missing data percentage}_{\text{Busan EDC}} = \mathbf{1.72\%}$$

Source: Water Resource Management Information System (wamis.go.kr) > Hydrometeorological data > Water level data

URBAN WATER CYCLE – Urban stream water level

Indicator 1.3.d Water level data automation and quality assurance (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Stream water level observation method and quality assurance
✓ Real-time and automated recording of stream water level
✓ Existence of auto-calibration function within the water level instrument or system
✓ Regular calibration of the water level instrument
✓ Recorded water level data quality assurance

The city implements all of the stream water level automation and calibration criteria mentioned above	
At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the implementation of automation and calibration or the city does not implement automation and calibration in stream water level monitoring	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to Water Resources Management Information System (wamis.go.kr), all stream gauge monitoring stations are recorded automatically and in real-time. Therefore, the score for this indicator is full score.

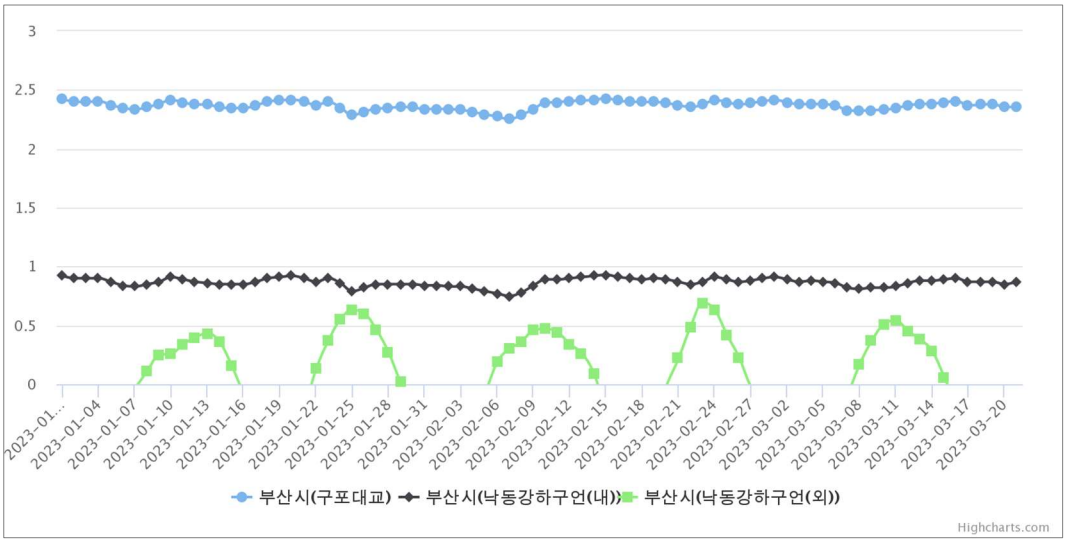


Figure. Observed real-time transmission stream water level data from Busan Metropolitan City

Source: WAMIS (wamis.go.kr) > hydrometeorological data > water level data > Water level correlation data by river

URBAN WATER CYCLE – Urban stream water level	
Indicator 1.3.e ICT-based observed water level data collection process (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Stream water level observation ICT-based technologies ✓ Water level sensors (ultrasonic, radar, acoustic doppler, pressure transducers etc.)-based stream gauges ✓ Solar panel generation, system controller, etc., data transmission and monitoring instrument ✓ Numerical analysis, Water level prediction, machine learning, etc., water level analysis ✓ Remote sensing-based instruments, IoT sensors, Image recognition, cctv etc.	
The city utilizes all of the ICT-based stream water level monitoring instruments criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	

At least one of the criteria is satisfied	
City has no information on the application of ICT in stream water level monitoring, or city does not apply ICT in stream water level monitoring	
No river or urban stream within the city boundaries	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to WAMIS, stream gauge flow is measured using ICT-based real-time automatic data collection method (Telemetry, ADCP- Acoustic Doppler current profiler, ADVM- Acoustic Doppler velocity meters, Propeller flow meter, etc.). Therefore, the score for this indicator is full-score.

Figure. Stream gauge monitoring in for Busan Metropolitan City

Source: WAMIS (wamis.go.kr) > hydrometeorological data > water level data > Station specifications

URBAN WATER CYCLE – Urban stream water level	
Indicator 1.3.f ICT-based water level data accessibility (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Open online access of complete observed stream water level data	4
Open online access of partial or incomplete stream water level data	
Manual retrieval of stream water level data (i.e. official letter request, direct request to the office in charge)	
Restricted access to stream water level data (i.e. data only available within intergovernmental agencies)	
City has no information on stream water level data accessibility, or data is not available to public access	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

Based on the access of water level data from WAMIS website (wamis.go.kr) and Busan Open Data website (data.busan.go.kr), observed data are complete and open access. Therefore, the score for t his indicator is full-score.

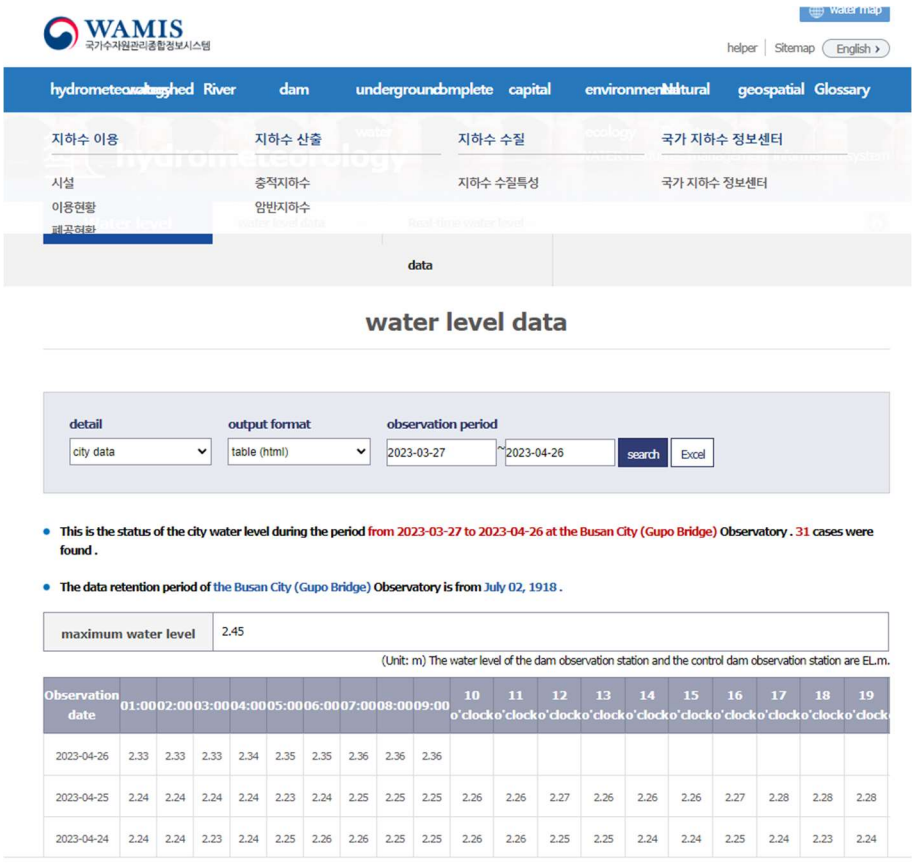


Figure. Open-source real time water level data for Busan stream gauge station (wamis.go.kr)

Source: WAMIS (wamis.go.kr) > hydrometeorological data > water level data

1.4 Urban stream water quality

URBAN WATER CYCLE – Urban stream water quality	
Indicator 1.4.a Coverage extent of water quality observation points (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Stream water quality station density (km/station) = Total river extent (km) / Number of stream water quality stations within the city	
At least one stream water quality inspection within 10 km river extent	
At least one inspection within 20 km extent	3

At least one inspection within 30 km extent	
At least one inspection within more than 30 km extent	
City has no data on stream water quality monitoring coverage, or no stream water quality measurements are performed	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Gangseo-gu, Sasang-gu, Buk-gu total river extent = 20.2 km, 18.8 km, 7.2 km
No. of stream quality stations = 8

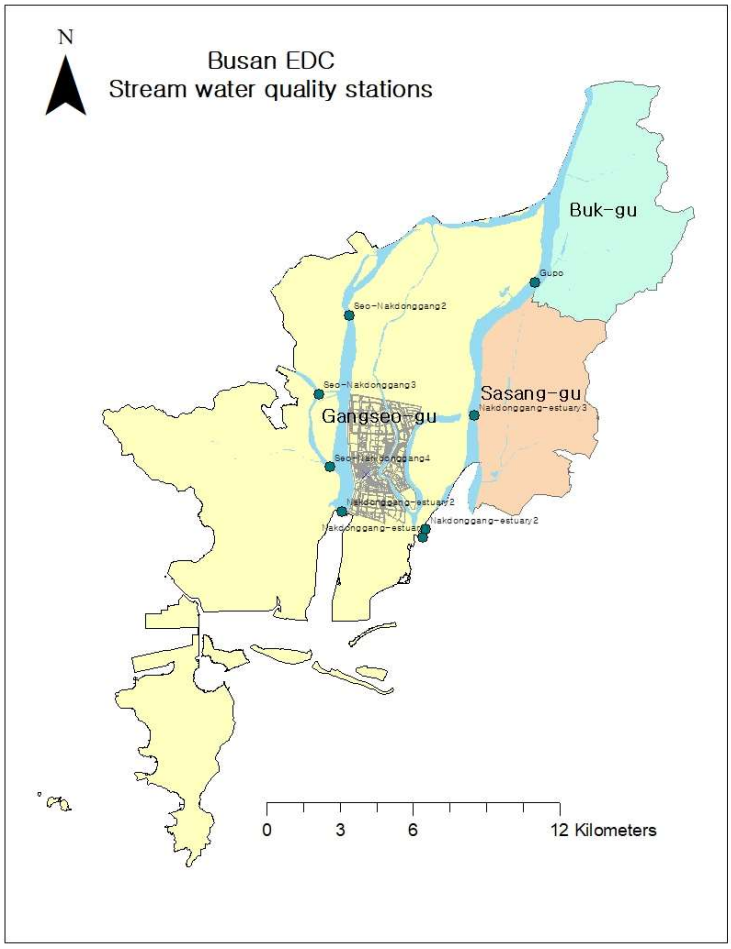


Figure. Total number of stream water quality stations within Gangseo, Sasang and Buk District, Bus an Metropolitan City

Computation:

$$\text{Stream water quality station area density} = \frac{\text{Total river extent}}{\text{No. of stream water quality stations}}$$

$$\text{Stream water quality station area density}_{\text{Gangseo-gu,Busan}} = \frac{88.7\ km}{8} = \mathbf{11.1}\ \text{km/station}$$

Source: Korea Water Resource Corporation

URBAN WATER CYCLE – Urban stream water quality	
Indicator 1.4.b Urban stream water quality monitoring frequency (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Stream water quality monitoring is conducted at least hourly interval	4
Monitoring is conducted at semi-daily interval (3-, 6-, 12-hourly)	
Monitoring is conducted at least once a day	
Monitoring is conducted more than once a day	
City has no data on stream water quality monitoring frequency, or no stream water quality measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Based on Busan open data (data.busan.go.kr), stream water quality parameters such as temperature, electric conductivity, dissolved oxygen, pH, salinity, turbidity, etc. are measured at hourly interval.

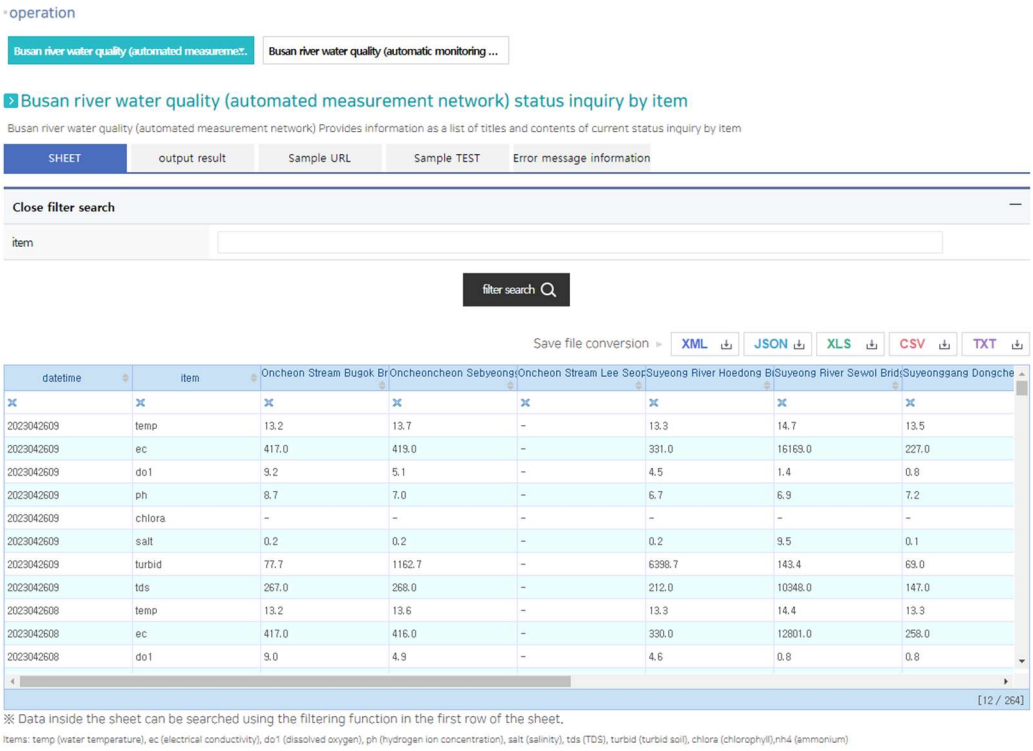


Figure. Real-time stream data water quality data collected hourly (data.busan.go.kr)

Source: Busan Open Data Portal (data.busan.go.kr) > Busan Metropolitan City River Water Quality Information (Automated Measurement Network)

URBAN WATER CYCLE – Urban stream water quality	
Indicator 1.4.c Urban stream water quality error and missing data (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of missing data (urban stream water quality) = (Number of missing and error stream quality data / Total number of observations) * 100	
Percentage of missing urban stream water quality data is less than 5 %	
Percentage is within 5 to 10 %	
Percentage is within 10 to 15 %	
Percentage is more than 20 %	1

City has no information on stream water quality missing and error data, or no stream water quality measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Stream water quality station	Duration of observation	Total number of water quality observations	Total number of recorded observations	Total percentage of missing data
Eulsukdo	1989-1994	72	72	0%
Geumgok	2002-present	240	140	41.7%
Gupo	1989-present	396	296	25.2%
Nakdong Estuary 1	2008-present	168	80	52.4%
Nakdong Estuary 2	2008-present	168	80	52.4%
Seobusan	1992-1994	36	36	0%
Seonakdong 1	1992-present	360	260	27.8%
Seonakdong 2	1992-present	360	260	27.8%
Seonakdong 3	1992-present	360	260	27.8%
Seonakdong 4	2007-present	180	92	48.9%
Suyeonggang 5	2007-present	180	92	48.9%

$$\text{Stream water quality missing data percentage} = \frac{\text{Total number of missing data}}{\text{Total number of stream quality observations}} \times 100\%$$

$$\text{Water quality missing data percentage}_{\text{Gangseo-gu,Busan}} = \mathbf{32.1\%}$$

Source: Water Resource Management Information System (wamis.go.kr) > Environmental Ecology > Water quality network > River water

URBAN WATER CYCLE – Urban stream water quality

Indicator 1.4.d Urban stream quality standard and pollution level (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Pollutant	Residential		Commercial		Combined	
	Average	Recommended	Average	Recommended	Average	Recommended
BOD (mg/l)	10	≤5	9.3	≤5	7.8	≤5
COD (mg/l)	73	≤20	57	≤20	65	≤20
TP (μg/l)	260-380	325	200-340	200	160-840	290

Measurements of BOD, COD and TP are within the recommended values established by EPA (1999) or measurements are satisfied based on city standards	4
Majority of measurements are within the recommended values	

Measurements between average and recommended values	
Measurements are below average values	
City has no data on stream water quality measurements, or no stream water quality measurements are performed	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

Table. Measured average pollutants for Busan Metropolitan City stream water and recommended st ream water quality from EPA

Pollutant	Urban stream average	EPA recommended	Measured average
BOD	7.8	≤5	3.2
COD	65	≤20	5.62
TP	0.16-0.84	0.29	0.26

The average measured BOD, COD and TP for Busan urban stream satisfies the EPA recommended values.

Source: Korea Water Resources Corporation

URBAN WATER CYCLE – Urban stream water quality

Indicator 1.4.e Water quality data automation and quality assurance (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Stream water quality observation method and quality assurance
✓ Real-time and automated recording of stream water quality
✓ Existence of auto-calibration function within the water quality instrument or system
✓ Regular calibration of the water quality instrument
✓ Recorded water quality data quality assurance

Stream water quality data are recorded fully-automated and in real-time; and calibrations are performed to the measuring instruments	
Data are recorded partially automated; calibrations are performed	3
Data are recorded partially automated; no calibrations are performed	
Data are recorded manually; calibrations are performed	
City has no information on the automation and calibration of stream water quality measuring instruments; or no calibrations are performed to the measuring instruments	

Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to Busan Metropolitan City river water quality information, river water quality is measured by:

Division	Manual measuring network	Automatic measuring network	Total
Busan Health and Environment Research Institute	22	0	22
Nakdong River Basin Environmental Office	2	0	2
Nakdong River Water Environment Research Institute	3	0	3
Busan Institute of Health and Environment	37	13	50

River water quality is measured with combination of manual and automated measurements.

Source: Busan Metropolitan City (busan.go.kr) > Information by Sector > Environmental Protection > Water > River water quality > Measuring network overview

URBAN WATER CYCLE – Urban stream water quality

Indicator 1.4.f ICT-based observed water quality data collection process (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Stream water quality observation ICT-based technologies
✓ Stream water quality sensors (multi-, single parameter sensors, etc.)
✓ Automatic water samplers
✓ Spectrophotometers, microbial detection equipment
✓ Data loggers and telemetry system, Communication systems, environmental monitoring software, system controller, etc., data transmission and monitoring instrument

The city utilizes all of the ICT-based stream water quality monitoring instruments criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the application of ICT in stream water quality monitoring, or city does not apply ICT in stream water quality monitoring	

Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

River water quality is tested with combination of manual and automated procedures.

Figure. River water quality sample collection and instrument laboratory analysis

Real-time water quality index is measured through the following **ICT-based instruments/methods:**

River water quality parameter	Instrument/Method
Temperature	Thermistor
pH	Glass and reference electrode
DO	Electrode
EC	Electrode
TOC	Non-dispersive infrared detection
TN	Ultraviolet absorbance spectrophotometry
turbidity	Turbidimeter

Source: Water Environment Information Center (water.nier.go.kr) > Operational Status > Water quality measurement network

URBAN WATER CYCLE – Urban stream water quality	
Indicator 1.4.g ICT-based water quality data provision and accessibility (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Open online access of complete observed stream water quality data	4
Open online access of partial or incomplete stream water quality data	
Manual retrieval of stream water quality data (i.e. official letter request, direct request to the office in charge)	
Restricted access to stream water quality data (i.e. data only available within intergovernmental agencies)	

City has no information on stream water quality data accessibility, or data is not available to public access	
Open online access of complete observed stream water quality data	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to Busan open data (data.busan.go.kr), stream water quality parameters such as temperature, electric conductivity, dissolved oxygen, pH, salinity, turbidity, etc. are provided real time and open source at the website.

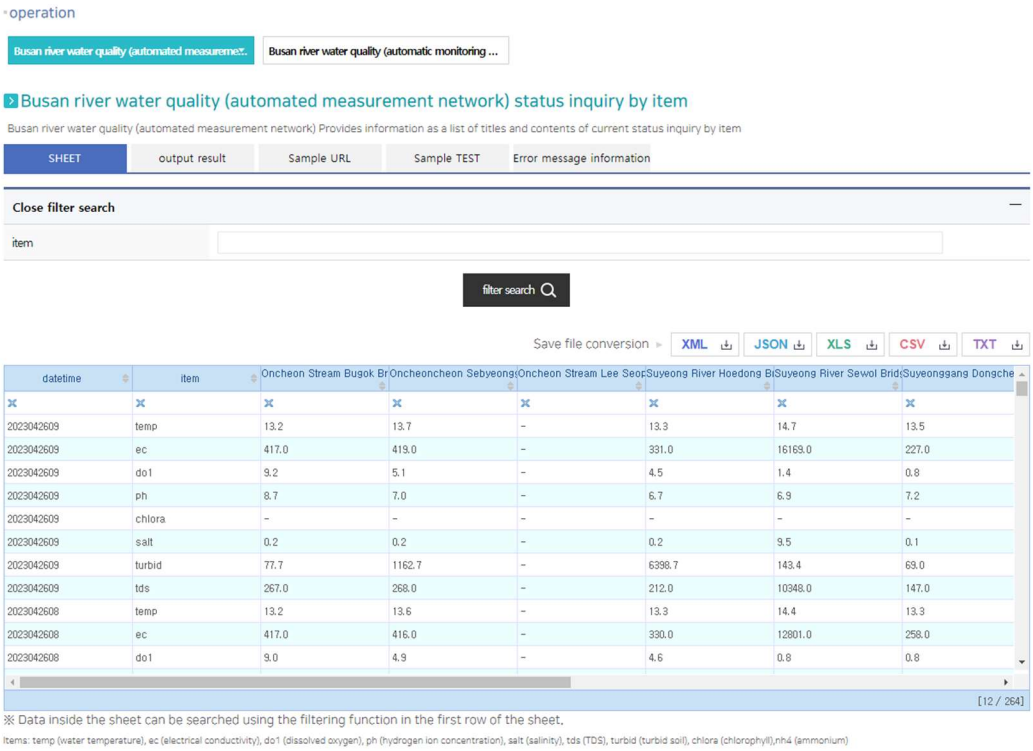


Figure. Real-time stream data water quality data provided at the city official data website (data.busan.go.kr)

Source: Busan Open Data Portal (data.busan.go.kr) > Busan Metropolitan City River Water Quality Information (Automated Measurement Network)

1.5 Groundwater level

URBAN WATER CYCLE – Groundwater level
Indicator 1.5.a Coverage extent of groundwater level observation stations (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)
Groundwater station density (km^2/station) = Urban area (km^2) / Number of groundwater observation stations and storage networks

The ratio of groundwater level monitoring station coverage within the city is one station per 10 km^2	
Operation of at least one station per 10 to 40 km^2	3
Operation of at least one station per 40 to 100 km^2	
Operation of at least one station per more than 200 km^2	
City has no information on groundwater level monitoring coverage, or no groundwater level measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Busan Gangseo District surface area = 179.05 km^2
Total number of groundwater level monitoring stations (National and Regional groundwater level observation stations) (Source: gims.go.kr) = 8

$$\text{Groundwater level station area density} = \frac{\text{Total urban surface area}}{\text{No. of groundwater observations}}$$

$$\text{Groundwater level station area density}_{\text{Busan EDC}} = \frac{179.05\ \text{km}^2}{8} = \mathbf{22.4\ km^2/station}$$

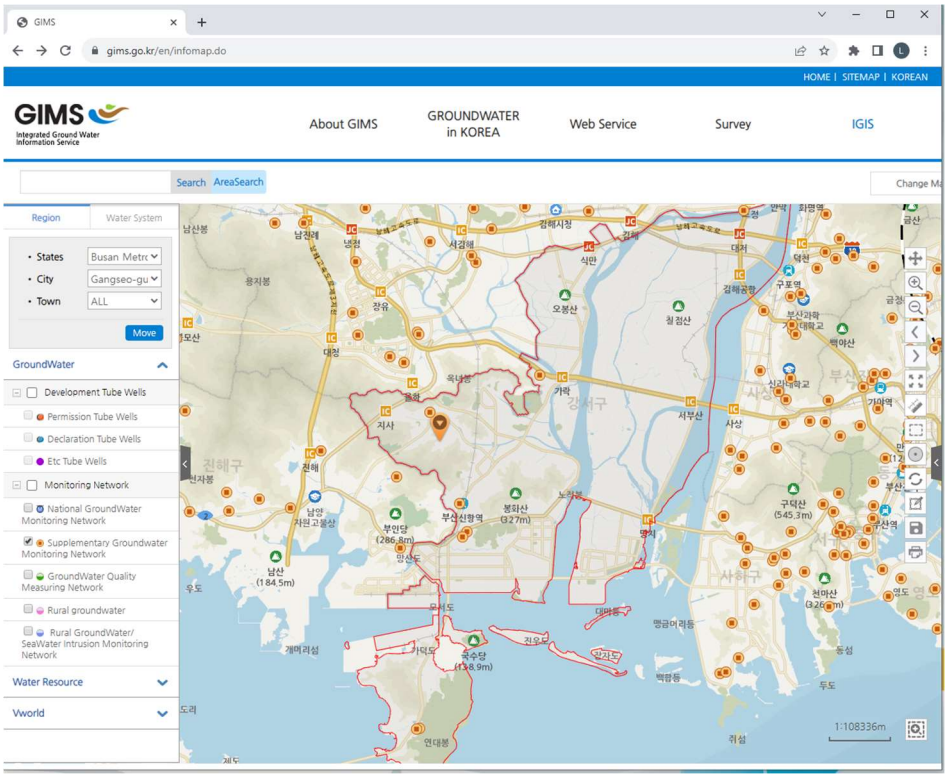


Figure. Ground water quality monitoring distribution map for Busan Metropolitan City

Source: National Groundwater Information Center (gims.go.kr) > Groundwater Information Map > Go to map

URBAN WATER CYCLE – Groundwater level	
Indicator 1.5.b Groundwater level monitoring frequency (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Groundwater level observations are performed at more than hourly interval	4
Observations at daily interval	
Observations at monthly interval	
Observations are performed more than monthly interval	
City has no information on groundwater level monitoring frequency, or no groundwater level measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the National Groundwater Monitoring Center (gims.go.kr), groundwater level monitoring for the city of Busan, recording rainfall amount and corresponding ground water level, are performed at an hourly interval.

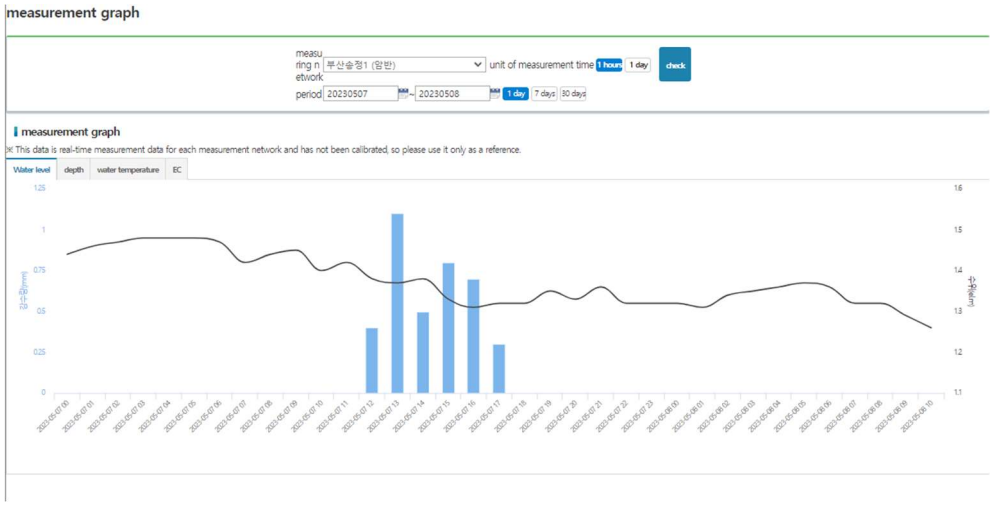


Figure. Groundwater monitoring frequency in one of Busan City monitoring wells

Source: National Groundwater Information Center (gims.go.kr) > Groundwater monitoring network > National Groundwater Management and Measurement Network > Measuring Network Status and Graph

URBAN WATER CYCLE – Groundwater level

Indicator 1.5.c Groundwater level error and missing data (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of missing data (groundwater level) = (Number of missing and error values / Total number of groundwater level observations) * 100	
Percentage of missing and error groundwater level data is less than 5 %	
Percentage is within 5 to 10 %	
Percentage is within 10 to 20 %	
Percentage is more than 20 %	1
City has no information on groundwater level missing and error data, or no groundwater level measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Busan Metropolitan City Groundwater level stations

	Busandaeshin District	Busangeumsong District Aquifer 1	Busandeumsong District Aquifer 2	Busangooseo District Aquifer 1	Busangooseo District Aquifer 2	Busanjangan District
Operation date	19980516-present	20151201-present	20151201-present	20171201-present	20171201-present	20031231-present
Number of data record	8933	2734	2734	1489	1489	7081
Number of missing data	103	2305	2583	1489	1489	365
Missing data percentage	1.1	84.3	94.5	90.8	90.8	5.14

The average missing groundwater level data percentage for Busan Metropolitan City is 61.1%.

Source: National Groundwater Information Center (gims.go.kr) > Groundwater monitoring network > National Groundwater Management and Measurement Network > Measuring Network Status and Graph

URBAN WATER CYCLE – Groundwater level
Indicator 1.5.d Groundwater level data automation and quality assurance (Busan) (Choose one of the following options that better describes the current circumstances in city)

Groundwater level observation method and quality assurance
✓ Real-time and automated monitoring of groundwater level
✓ Existence of auto-calibration function within the groundwater monitoring instrument or system
✓ Regular calibration of the groundwater instrument
✓ Recorded groundwater level data quality assurance

The city implements groundwater level monitoring automation and calibration criteria mentioned above	
At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the implementation of automation and calibration or the city does not implement automation and calibration in groundwater level monitoring	
The city implements groundwater level monitoring automation and calibration criteria mentioned above	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the Integrated Groundwater Information Service, groundwater level, temperature and electric conductivity are measured **automatically** at an hourly interval in the installed aquifer and alluvial wells.

Source: Integrated Groundwater Information Services (gims.go.kr/en) > Survey > Monitoring Network

URBAN WATER CYCLE – Groundwater level

Indicator 1.5.e ICT-based observed groundwater level data collection process (Gangseo-gu, Sasang-gu , Buk-gu)
(Choose one of the following options that better describes the current circumstances in city)

Groundwater level observation ICT-based technologies
✓ Groundwater level sensors (acoustic, optical), pressure transducers, piezometer, etc., based groundwater gauges
✓ Automated data loggers, Real-time wireless communication, Telemetry, system controller, etc., data transmission and monitoring instrument
✓ Numerical analysis, Groundwater prediction, machine learning, etc., groundwater level analysis
✓ Remote sensing-based instruments, IoT devices

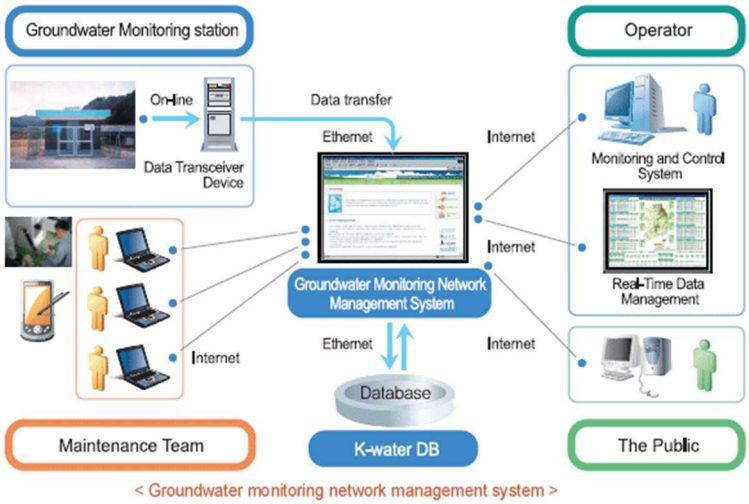
The city utilizes all of the ICT-based groundwater level monitoring instruments criteria mentioned above	4
At least three of the criteria are satisfied	

At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the application of ICT in groundwater level monitoring, or city does not apply ICT in groundwater level monitoring	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to the National Groundwater Information Service, monitoring networks in Korea are composted of automatic and manual observational wells conducted by Ministry of Land, Infrastructure and Transport, Korea Water Resource Corporation, Ministry of Environment, Korea Environment Corporation and the regional municipalities.

Figure. Busanjangan automated aquifer groundwater level measuring well



< Groundwater monitoring network management system >

Figure. Groundwater level monitoring and analysis through ICT

Source: Integrated Groundwater Information Services (gims.go.kr/en) > Survey > Monitoring Network

URBAN WATER CYCLE – Groundwater level	
Indicator 1.5.f ICT-based groundwater level data provision and accessibility (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Open online access of complete observed groundwater level data	4
Open online access of partial or incomplete groundwater level data	
Manual retrieval of groundwater level data (i.e. official letter request, direct request to the office in charge)	
Restricted access to groundwater level data (i.e. data only available within intergovernmental agencies)	
City has no information groundwater level data accessibility, or data is not available to public access	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

The National Groundwater Information Center provides open access information to the groundwater monitoring well over Korea, including the city of Busan.

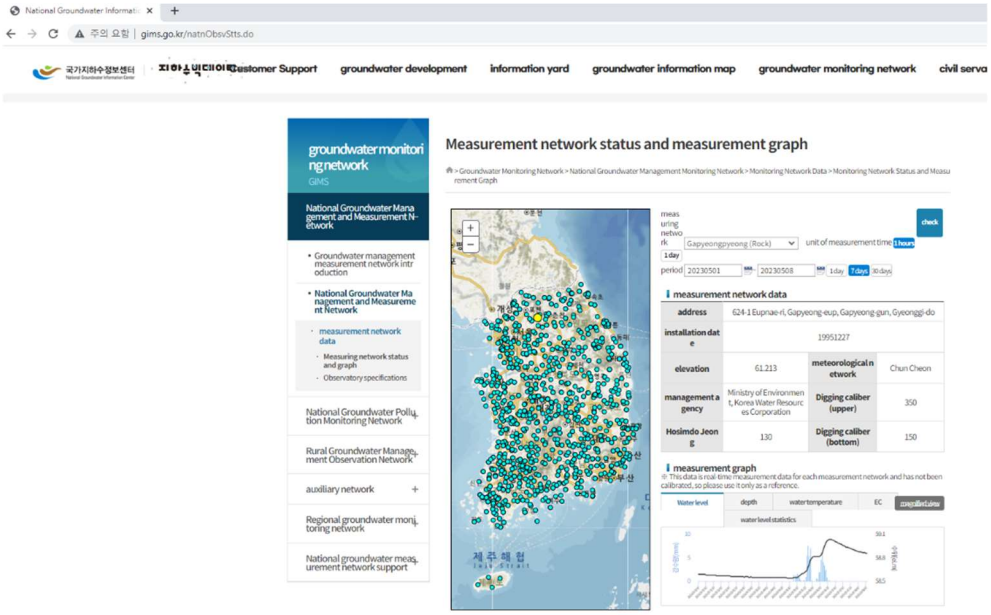


Figure. Groundwater level open access data (gims.go.kr)

Source: National Groundwater Information Center (gims.go.kr)

1.6 Groundwater quality

URBAN WATER CYCLE – Groundwater quality	
Indicator 1.6.a Coverage extent of groundwater quality observation stations (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Groundwater quality station density (km²/station) = Total urban area (km²) / Number of groundwater quality monitoring wells within the city	
Ground water quality inspection with area coverage less than 10 km²	
Inspections within 10 to 40 km²	3
Inspections within 40 to 100 km²	
Inspections within more than 100 km²	
City has no data on groundwater quality monitoring coverage, or no groundwater quality measurements are performed	

Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Busan Metropolitan City surface area = 770.91 km^2
Total number of groundwater quality monitoring stations (National, Water quality and pollution monitoring) (gims.go.kr) = 158

$$\text{Groundwater quality station area density} = \frac{\text{Total urban surface area}}{\text{No. of groundwater quality observations}}$$

$$\text{Groundwater quality station area density}_{\text{Busan EDC}} = \frac{179.05\ km^2}{9} = \mathbf{19.9\ km^2/station}$$

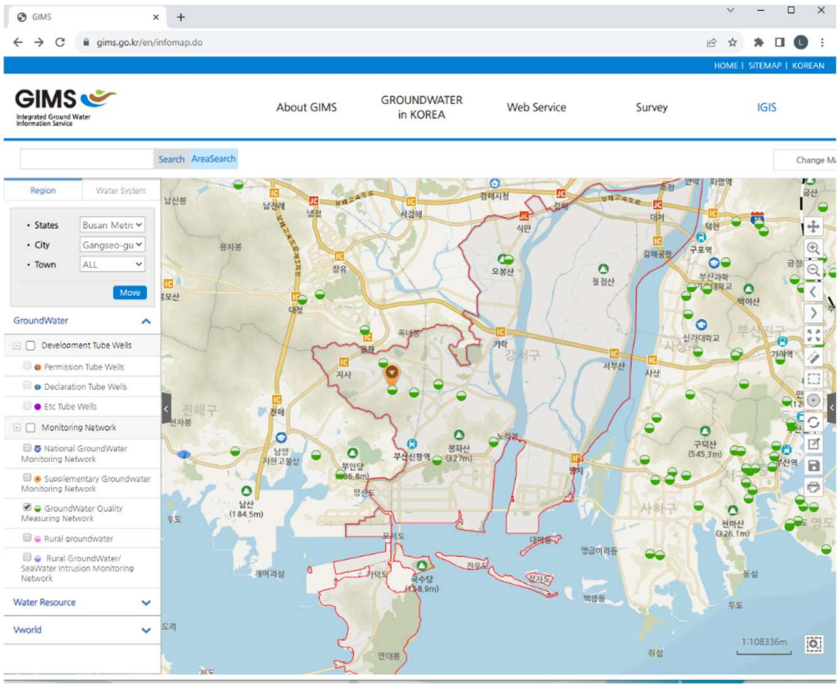


Figure. Groundwater quality monitoring distribution map for Busan Gangseo District

Source: National Groundwater Information Center (gims.go.kr) > Groundwater Information Map > Go to map

URBAN WATER CYCLE – Groundwater quality	
Indicator 1.6.b Groundwater quality monitoring frequency (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Groundwater quality monitoring is performed at least weekly interval	
Monitoring is performed at least monthly interval	3
Monitoring is performed at least quarterly interval	
Monitoring is performed at more than quarterly interval	

City has no data on groundwater quality monitoring frequency, or no groundwater quality measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Average total number of groundwater quality observations per year (1996-2022) = 2004
Total number of groundwater quality observation wells = 158

$$\text{Groundwater quality monitoring frequency} = \frac{\text{Total number of inspections per city}}{\text{Total number of observation wells per city}}$$

$$\text{Groundwater quality monitoring frequency}_{\text{Busan Metropolitan City}} = \frac{2004}{158} = \mathbf{12.7\ inspections\ per\ year}$$

Source: National Groundwater Information Center (gims.go.kr) > Reports > Groundwater annual reports

URBAN WATER CYCLE – Groundwater quality	
Indicator 1.6.c Groundwater quality error and missing data (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of missing data (groundwater water quality) = (Number of missing and error groundwater quality data / Total number of observations) * 100	
Percentage of missing groundwater quality data is less than or equal to 5 %	**4**
Percentage is within 5 to 10 %	
Percentage is within 10 to 15 %	
Percentage is more than 20 %	
City has no information on groundwater quality missing and error data, or no groundwater quality measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Number of groundwater quality inspections per year (1996-2022). (No. of groundwater quality stations within the city = 158).

Year	Total inspection	Inspections/year	Year	Total inspection	Inspections/year
2022	1397	8.8	2008	1933	12.2
2021	1556	9.8	2007	1111	7.0
2020	1399	8.9	2006	2146	13.6
2019	1856	11.7	2005	1166	7.4
2018	1776	11.2	2004	1189	7.5
2017	1240	7.8	2003	2632	16.7
2016	2192	13.9	2002	3359	21.3
2015	1286	8.1	2001	2834	17.9
2014	1583	10.0	2000	2457	15.6
2013	2062	13.1	1999	2165	13.7
2012	606	3.8	1998	3949	25.0
2011	1243	7.9	1997	3211	20.3
2010	2239	14.2	1996	2956	18.7
2009	2554	16.2	Total	54097	342.4

The total number of inspections per year for Busan Metropolitan city is 12.7 inspections per year, the total groundwater quality inspections from 1996-2022 should be 342.9. Therefore:

$$\text{Groundwater missing data percentage}_{\text{Busan Metropolitan City}} = \frac{\text{Expected no. of inspections} - \text{Total inspections}}{\text{Target no. of inspections}} \times 100$$

$$\text{Groundwater missing data percentage}_{\text{Busan Metropolitan City}} = \frac{342.9 - 342.4}{342.9} \times 100 = \mathbf{0.15\%}$$

Source: National Groundwater Information Center (gims.go.kr) > Reports > Groundwater annual reports

URBAN WATER CYCLE – Groundwater quality	
Indicator 1.6.d Groundwater quality compliance (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Groundwater quality compliance based on regional/city-scale regulatory law and standards for groundwater quality	4
Groundwater quality compliance based on national regulatory law and standards for groundwater quality	
Groundwater quality measured is not fully complied with the regulatory standards	

City does not follow any groundwater regulatory standards	
City does not have information on groundwater quality standards, groundwater quality monitoring is not performed	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

Table shows the National Groundwater quality inspection results from the annual report:

Year	Total inspection	Passed	Failed	Pass percentage (%)
2022	1397	1322	75	97
2021	1556	1462	94	94
2020	1399	1332	67	95
2019	1856	1743	113	94
2018	1776	1632	144	92
2017	1240	1162	78	94
2016	2192	2057	135	94
2015	1286	1197	89	93
2014	1583	1409	174	89
2013	2062	1947	115	94
2012	606	540	66	89
2011	1243	1152	91	93
2010	2239	1982	257	89
2009	2554	2178	376	85
2008	1933	1531	402	79
2007	1111	958	153	86
2006	2146	1902	244	89
2005	1166	909	257	78
2004	1189	977	212	82
2003	2632	2404	145	91
2002	3359	3175	164	95
2001	2834	2543	281	90
2000	2457	2263	131	92
1999	2165	1872	281	86
1998	3949	3076	776	78
1997	3211	2596	612	81
1996	2956	2542	414	86
Average	2003.6	1772	220	89

Based on the National standards for groundwater quality for Korea, Busan Metropolitan City have an average compliance of 89% (27-year data).

Source: National Groundwater Information Center (gims.go.kr) > Reports > Groundwater annual reports

URBAN WATER CYCLE – Groundwater quality	
Indicator 1.6.e Groundwater quality data automation and quality assurance (Busan) (Choose one of the following options that better describes the current circumstances in city)	

Groundwater quality observation method and quality assurance
✓ Real-time and automated monitoring of groundwater quality
✓ Existence of auto-calibration function within the groundwater monitoring instrument or system
✓ Regular calibration of the groundwater instrument
✓ Recorded groundwater quality data quality assurance

The city implements groundwater quality monitoring automation and calibration criteria mentioned above	
At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the implementation of automation and calibration or the city does not implement automation and calibration in groundwater quality monitoring	
The city implements groundwater quality monitoring automation and calibration criteria mentioned above	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the National Groundwater Information Center, groundwater quality is measured based on the following methods.

Section	National Groundwater Management Network	National Groundwater Monitoring Network	Auxiliary Groundwater Level Monitoring Network	Auxiliary Groundwater Quality Monitoring Network
Implementing Agency	K-water	K-eco / Regional Environmental Office	Municipality	Municipality
Measured parameter	Water level, temperature, EC, water quality	Water level, temperature, EC, water quality	Water level, temperature, EC	Water quality
Method	Automatic / manual monitoring	Automatic / manual monitoring	Automatic / manual monitoring	Manual monitoring

Source: National Groundwater Information Center (gims.go.kr) > Information board > Report storage > Groundwater information

URBAN WATER CYCLE – Groundwater quality

Indicator 1.6.f Observed groundwater quality data collection process (Gangseo-gu, Sasang-gu, Buk-gu)
(Choose one of the following options that better describes the current circumstances in city)

Groundwater quality observation ICT-based technologies
✓ Groundwater quality sensors (Multi- and single-parameter groundwater quality sensors, water quality meters, biosensors, etc.)
✓ Automatic groundwater samplers
✓ Automated data loggers, Real-time wireless communication, environmental monitoring software, system controller, etc., data transmission and monitoring instrument
✓ Remote-sensing based instruments, ~~GIS~~

The city utilizes all of the ICT-based groundwater quality monitoring instruments criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the application of ICT in groundwater quality monitoring, or city does not apply ICT in groundwater quality monitoring	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to the National Groundwater Information Service, monitoring networks in Korea are composted of automatic and manual observational wells conducted by Ministry of Land, Infrastructure and Transport, Korea Water Resource Corporation, Ministry of Environment, Korea Environment Corporation and the regional municipalities.

Figure. Busanjangan automated aquifer groundwater quality measuring well

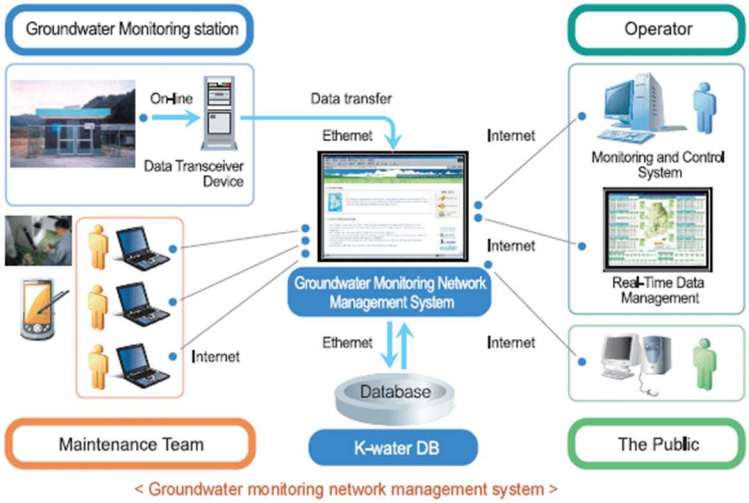


Figure. Groundwater quality monitoring and analysis through ICT

Source: Integrated Groundwater Information Services (gims.go.kr/en) > Survey > Monitoring Network

URBAN WATER CYCLE – Groundwater quality
Indicator 1.6.g ICT-based groundwater data accessibility (Busan) (Choose one of the following options that better describes the current circumstances in city)

Open online access of complete observed groundwater quality data	4
Open online access of partial or incomplete groundwater quality data	
Manual retrieval of groundwater quality data (i.e. official letter request, direct request to the office in charge)	
Restricted access to groundwater quality data (i.e. data only available within intergovernmental agencies)	
City has no information groundwater quality data accessibility, or data is not available to public access	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

The National Groundwater Information Center provides open access information to the groundwater monitoring well over Korea, including the city of Busan.

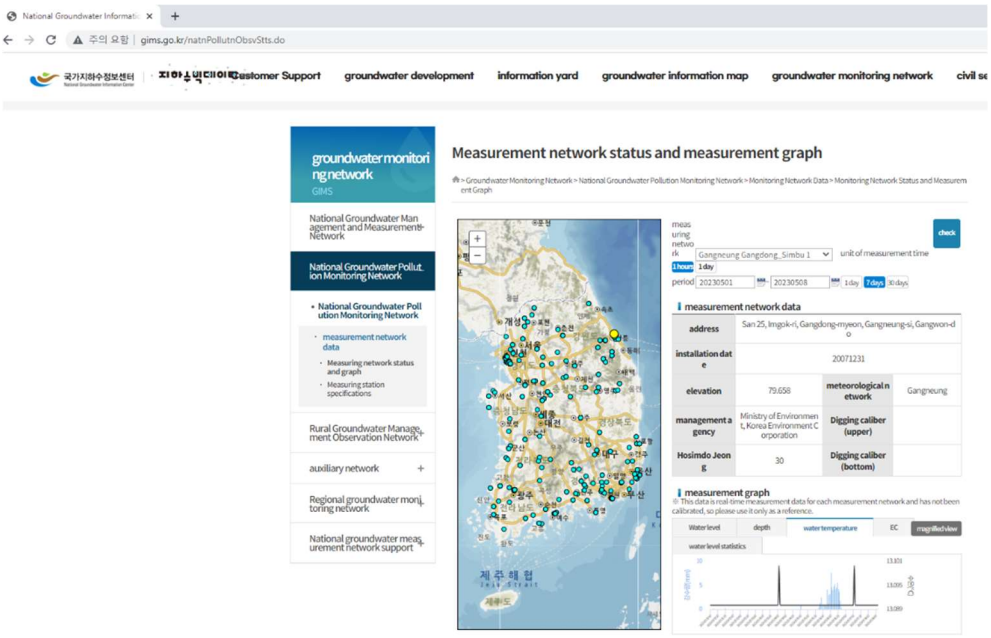


Figure. Groundwater quality open access data (gims.go.kr)

Source: National Groundwater Information Center (gims.go.kr)

2. Water Disaster Management

2.1 Flood

WATER DISASTER MANAGEMENT – Flood

Indicator 2.1.a. Flood casualty index (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)	
No casualties related to urban flood events occurred in the past 10 years	
No casualties related to urban flood events occurred in the past 5 years	3
No casualties related to urban flood events occurred in the past 3 years	
No casualties related to urban flood events occurred in the past year	
Casualties relating to urban flooding have occurred	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Casualties related to flood from 2011 – 2020 (Source: WAMIS)

	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Busan	0	0	0	0	0	1	0	0	0	0

Flood-related deaths have been recorded for the city since 2011.

Source: Water Resource Management Information Service (wamis.go.kr) > Natural Disasters > Flood > Past flood damages > Casualties

WATER DISASTER MANAGEMENT – Flood	
Indicator 2.1.b. Flood property damage index (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Flood property damage index = Total flood property damage amount (residential, commercial, industrial, agricultural) / Total Gross Regional Domestic Product (GRDP) * 100	
Calculated Flood Property Damage Index is less than 0.01	4
Index is within 0.01 to 0.05	
Index is within 0.05 to 0.1	
Index is more than 0.1	
City has no data on flood-related property damage	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Total flood damage amount for all districts in Busan Metropolitan city per year

Year	Total flood damage amount (KRW)
Recent 10 years	135,314,113,000

According to the Korea Statistics Ministry, the Busan regional gross domestic product (GDP) 2021 = 91,698,334,000,000 KRW. The 10-year average flood damage ratio is therefore:

$$\text{Flood damage index}_{\text{Busan Metropolitan City}} = \frac{\text{Total annual flood damage amount (10 year)}}{\text{City GDP}} \times 100$$

$$\text{Flood damage index}_{\text{Busan Metropolitan City}} = \frac{135{,}314{,}113{,}000 \text{ KRW}}{91{,}698{,}334{,}000{,}000 \text{ KRW}} \times 100 = \mathbf{0.001}$$

Source: Korea Statistics Ministry
Water Management Information System (wamis.go.kr)

WATER DISASTER MANAGEMENT – Flood	
Indicator 2.1.c. Flood risk area index (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)	
Flood risk area index = (Total surface area that are vulnerable to flooding based on historical events (km^2) / Total urban area (km^2)	
Calculated flood risk area index is less than 0.01	4
Index is within 0.01 to 0.05	
Index is within 0.05 to 0.1	
Index is more than 0.1	
City has no data on flood risk area, or no flood risk assessments are performed	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Total flooded area per year

Year	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Flooded area (km^2)	0	0	0	0	0	0	0	0	0	0.07

Maximum recorded flooded area for recent 10-year data is 0.07 km^2.

$$\text{Flood risk index}_{\text{Busan Metropolitan City}} = \frac{\text{Flood risk area}}{\text{Total urban area}} = \frac{0.07\ \text{km}^2}{181.5\text{km}^2} = \mathbf{0.0004}$$

Source: Water Resource Management Information Service (wamis.go.kr) > Natural Disasters > Flood > Past flood damages > Flooded areas

WATER DISASTER MANAGEMENT – Flood	
Indicator 2.1.d. Levee structure maintenance percentage (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Levee structure percentage (%) = (Total extent of constructed levee for flood prevention (km) / Total urban river extent (km)) * 100	
The percentage of constructed and maintained levee structures for flood protection is more than 80 %	
Percentage is between 60 to 80 %	3
Percentage is between 40 to 60 %	
Percentage is less than 40 %	
City has no data on levee structure or flood prevention measures	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. 2023 Busan Metropolitan City current status of rivers and streams.

River name	Total river extension(km)	Repaired extension (km)	Stream	Total river extension(km)	Repaired extension (km)
Nakdong	34.74	20.28	Seokdae	16.38	14.2
West Nakdong	28.22	3.24	Jomin	8.5	4.62
Pyeonggang	24.86	0.26	Jisa	16.54	16.54
Maekdo	14.2	0	Songjeong	2.3	0.5
Suyeong	19.87	15.68	Haeban	0.97	0.97
Goejeong	10.74	5.97	Hogye	3.65	3.65
Hakjang	11.72	11.72	Shina	0.85	0.85
Deokcheon	7.4	3.67	Hyoam	9.06	1.8
Daeri	3.38	2.96	Jangan	15.06	10.96
Daecheon	10.88	2.9	Yongso	8.68	6.13
Bosu	6.06	6.06	Jwagwang	18.47	16.87
Gudeok	1.22	1.22	Deokseon	4.94	4.94
Choryang	3.22	3.22	Dongbaek	4.42	2.6
Busan	3.6	0	Ilkwang	10.86	6.16
Dong	11	7.57	Jukseong	8.86	4.23
Jeonpo	5.34	5.34	Manhwa	5.19	3.69
Hogye	3.22	3.02	Seobu	4.53	3.15
Bujeon	8.38	8.38	Songjeong	11.02	6.01
Gaya	5.5	5.5	Cheolman	17.8	17
Nam	5.14	5.14	Guchil	3.4	0.31
Chun	7.94	7.94	Igok	3.6	1
Udong	3.98	3.98	Songjeong	3.67	3.67
Suyeong	44.28	34.44	Ilgi	2.1	0
Oncheon	26.48	26.48	Samrak	9.2	7
Dongrae	1.94	1.94	Gamjeon	5.8	3.63

The total river extension and the total repaired river extension are 499.2 km and 327.4 km, respectively. The percentage of levee maintenance is:

$$\text{Levee maintenance percentage}_{\text{Busan Metropolitan City}} = \frac{\text{Total repaired river extension}}{\text{Total river extension}} \times 100$$

$$\text{Levee maintenance percentage}_{\text{Busan Metropolitan City}} = \frac{327.4\ \text{km}}{499.2\ \text{km}} \times 100 = \mathbf{65.8\%}$$

Source: Public data portal (data.go.kr) > Busan Metropolitan City River Current status

WATER DISASTER MANAGEMENT – Flood

Indicator 2.1.e. Urban flood hazard mapping (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Criteria for smart water city flood hazard mapping

✓ Application of advanced numerical techniques on city-scale flood hazard mapping (i.e., numerical modeling, hydro-dynamic, rainfall-runoff, physical-based, AI-based, Machine learning)	
✓ Application of integrated flood hazard mapping that includes urban flood, storm surge/coastal flood, riverine flood, climate change projected flood risk etc.	
✓ Application of city-scale flood hazard mapping using conventional approach, based on historical return-period flood data, field survey, etc.	
✓ Application of high-resolution flood hazard maps (< 10 m)	

The city satisfied all of the criteria for flood hazard mapping mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the city-scale flood hazard mapping, or the city does not apply urban flood hazard mapping	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

Busan Metropolitan City flood hazard maps based on historical return period flooding accessible to safecity.busan.go.kr.

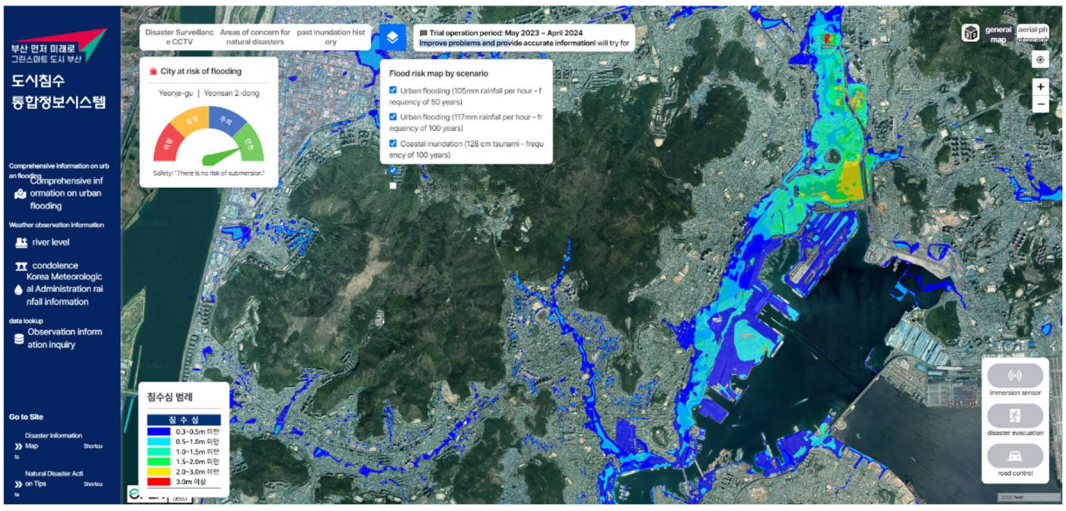


Figure. Return period urban flood hazard map provided from Busan integrated flood information center (safecity.busan,go.kr)

Source: Busan Metropolitan City Urban Flood Integrated Information (safecity.busan.go.kr)

WATER DISASTER MANAGEMENT – Flood	
Indicator 2.1.f. Application of ICT in flood information management (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)	

Criteria for smart water city disaster information strategies
✓ Establishment of city-scale information system
✓ Utilization of ICT-based technologies in disaster information transmission.
✓ Existence of integrated disaster information management (flood, drought)
✓ Interdepartmental communication between monitoring agencies and disaster mitigation agencies

The city satisfied all of the criteria for integrated disaster management mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the integrated disaster management or the city does not app ly integrated disaster management	
Not applicable	

Qualitative Analysis:
Provide evidence that justifies the choice made.

Busan Metropolitan city integrated disaster information system utilizes ICT-based information for monitoring, safety and disaster recovery.

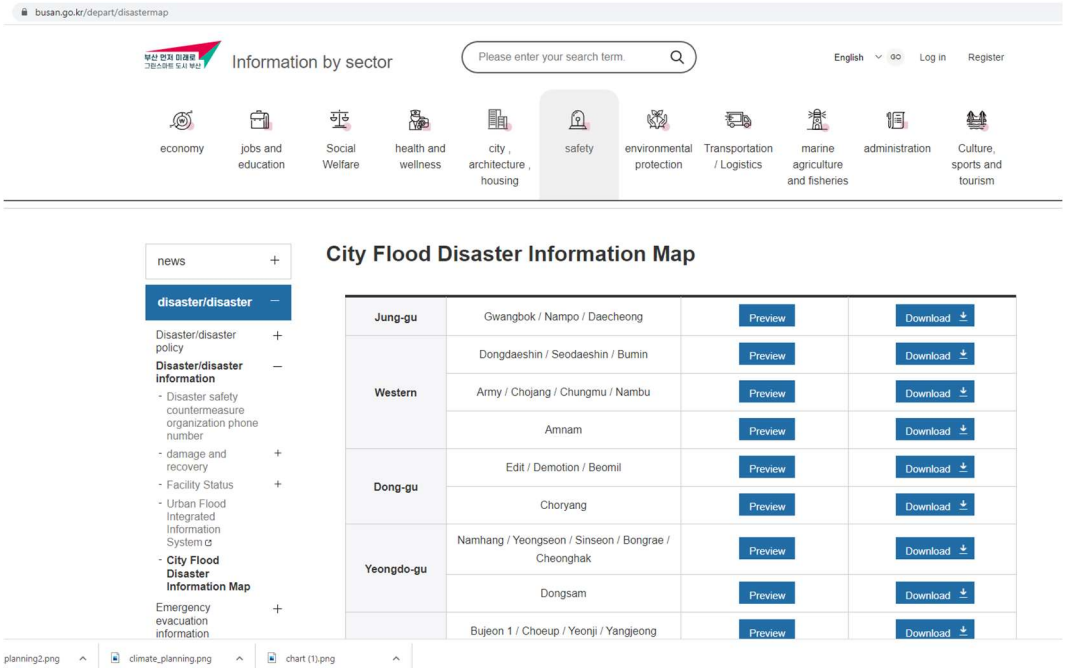


Figure. District-scale flood disaster information accessible to safecity.busan.go.kr, providing real-time weather

and traffic information, dissipating disaster text message services etc.

Source: Busan Metropolitan City (busan.go.kr) > Information by Sector > Safety

WATER DISASTER MANAGEMENT – Flood	
Indicator 2.1.g. Urban flood prediction and early warning (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)	
The city satisfied all of the criteria for the urban flood prediction and early warning system mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the flood prediction and early warning or the city does not apply flood prediction and early earning	
Not applicable	

Criteria for smart water city flood prediction and early warning
✓ Establishment of city-scale urban flood prediction
✓ Establishment of flood early warning center
✓ Application of ICT-based technologies in city flood prediction and early warning system
✓ Application of ICT-based technologies in flood information communication

Qualitative Analysis:
Provide evidence that justifies the choice made.

The Integrated flood disaster information center also provides real-time information on river water level and heavy rainfall alert necessary for flood forecast and mitigation.

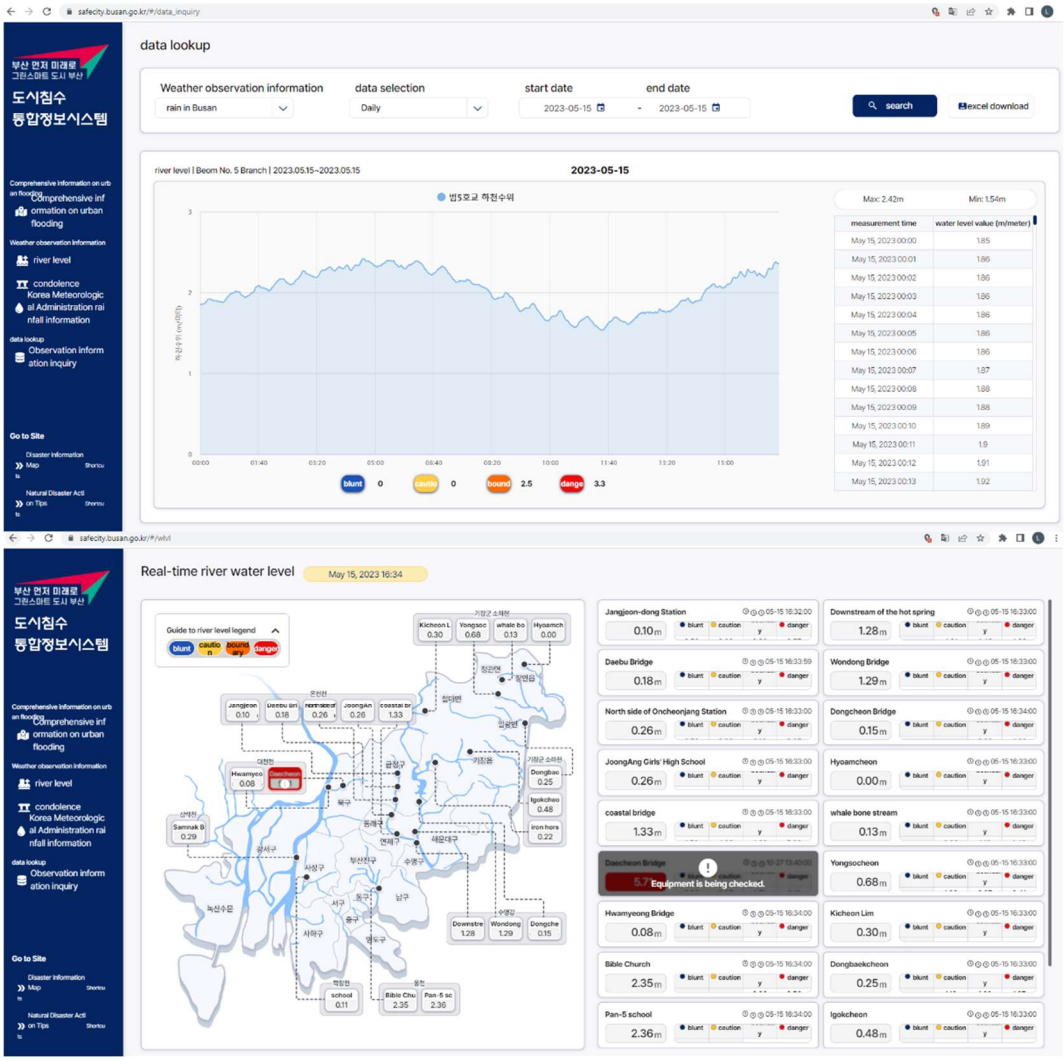


Figure. Real-time water level information for flood prediction and early warning (safecity.busan.go.kr)

Source: Busan Metropolitan City Urban Flood Integrated Information (safecity.busan.go.kr) > Comprehensive Information on Urban Flooding > River level

2.2 Drought

WATER DISASTER MANAGEMENT – Drought
Indicator 2.2.a. Drought damage index (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)
Drought damage index = Number of population affected by the water service interruption, limited supply etc. / Total number of populations

Calculated Drought damage index is less than 0.01	4
Index is within 0.01 to 0.05	
Index is within 0.05 to 0.1	
Index is more than 0.1	
City has no data on drought-related limited water supply population	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the National Drought Information portal, the total number of populations affected by drought occurrences for recent 10-years is zero.

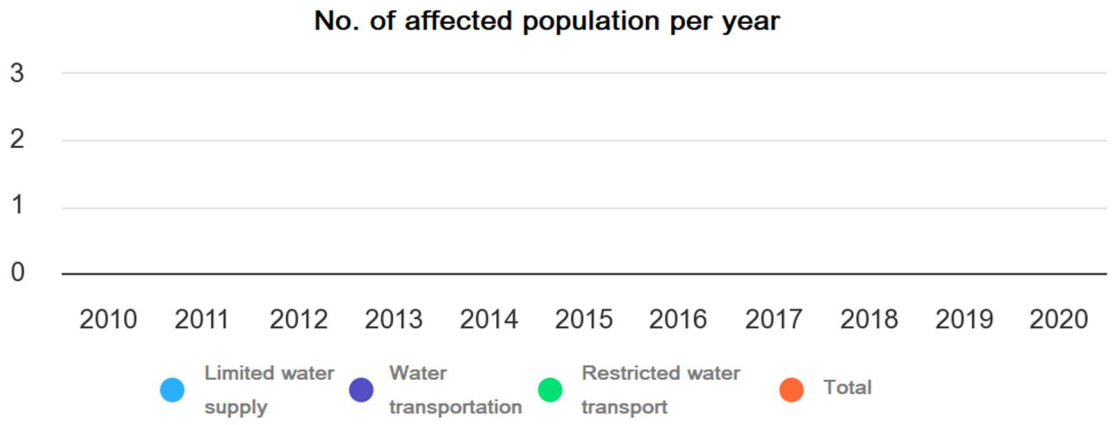


Figure. Gangseo district, Busan Metropolitan City number of drought-affected population per year (drought.go.kr)

Source: National Drought Information Portal (drought.go.kr) > National Drought Information > One Map > Drought Damage Status > Drought Damage Statistics

WATER DISASTER MANAGEMENT – Drought	
Indicator 2.2.b. Recent drought occurrence frequency (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Occurrence of drought event within the last 10 years	
Occurrence of drought event within the last 5 years	
Occurrence of drought event within the last 3 years	2

Occurrence of drought event within the last year	
City is susceptible to drought events	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

The Drought frequency analysis from the National Drought Information portal shows occurrence of drought events in Busan for 2022 and 2017.

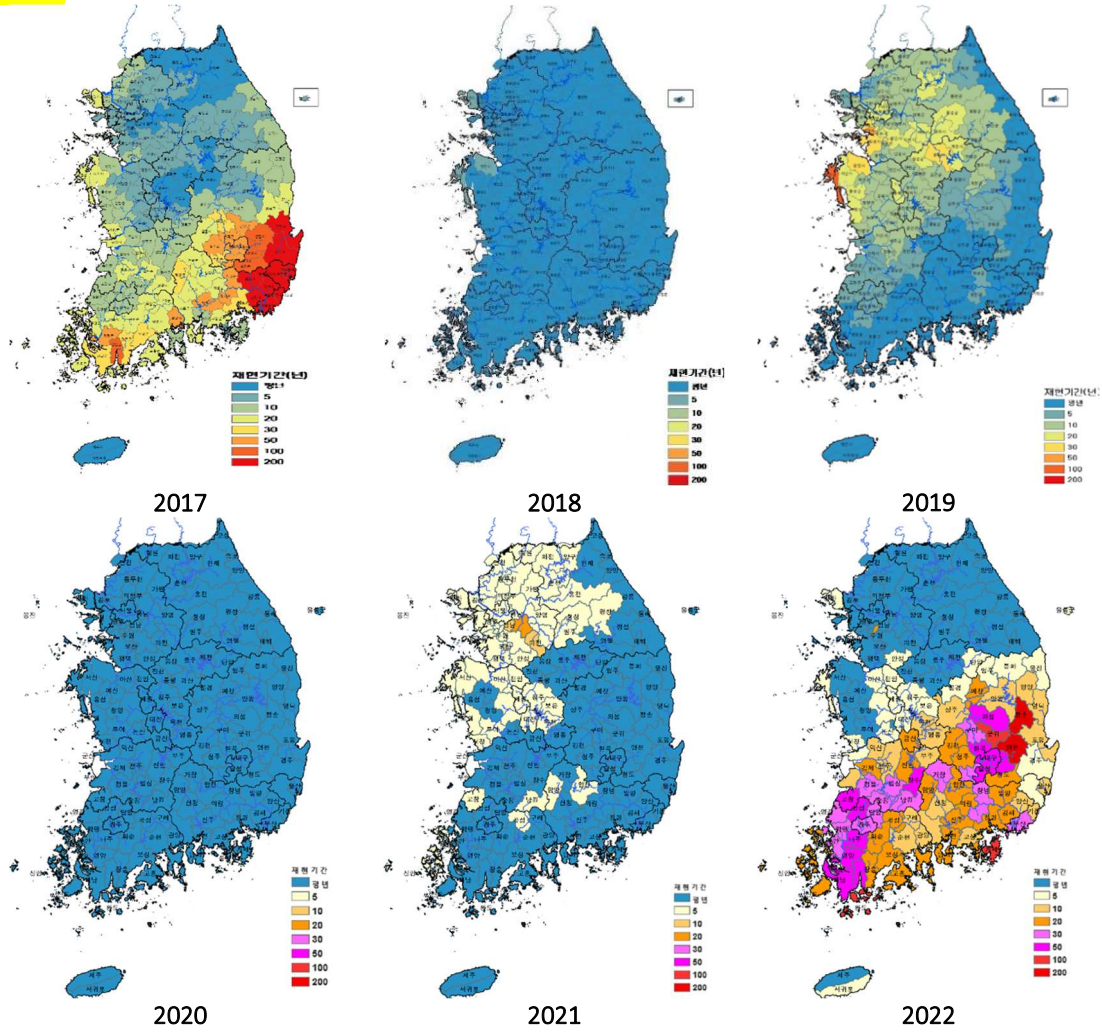


Figure. Occurence of drought events in Busan Metropolitan City in 2022 (50-year return period) and 2017 (200-year return period).

Source: National Drought Information Portal (drought.go.kr) > Drought Information Analysis > Drought Frequency > Drought Frequency Analysis Result

Indicator 2.2.c. ICT-based drought mapping (Gangseo District)
(Choose one of the following options that better describes the current circumstances in city)

Criteria for smart water city drought hazard mapping
✓ Application of drought hazard mapping based on calculation of Standard Precipitation Index (SPI), Hydrological drought indices, Normalized Vegetation or Soil moisture Index, etc.
✓ Application of drought forecasting models, or climate projected drought models
✓ Application of drought impact assessment
✓ Application of drought hazard mapping using historical drought data

The city satisfied all of the criteria for drought hazard mapping mentioned above	
At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the city-scale drought hazard mapping, or the city does not apply drought hazard mapping	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

The National Drought Information Portal provides city-scale drought index information based on SGI (Standard Groundwater Index), SPI (Standard Precipitation index), PDSI (Palmer Drought Severity Index), MSWSI (Modified Surface Water Supply Index) and SMI (Soil Moisture Index). These indices are mapped through GIS using observed hydro-meteorological data.

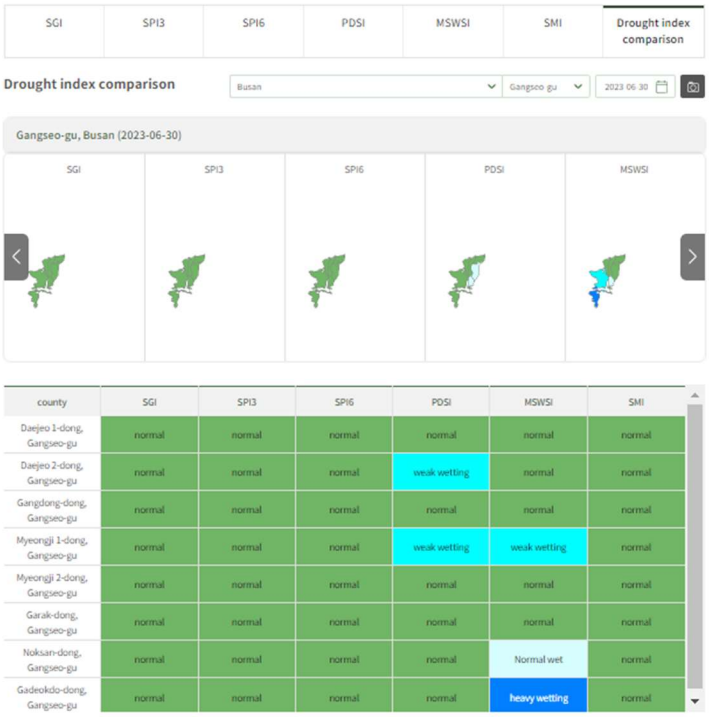


Figure. Kanseo district, Busan Metropolitan City Drought index information

Source: National Drought Information Portal (drought.go.kr) > Drought Information Analysis > Drought Index

WATER DISASTER MANAGEMENT – Drought	
Indicator 2.2.d. Drought information and emergency water supply facilities (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)	
Criteria for smart water city drought information	
✓ Application of city-scale drought monitoring and information	
✓ Availability of drought information (hazard map, forecasts) to public (website, television, etc.)	
✓ Availability of emergency water supply facilities in the event of water supply shortage due to drought	
✓ Application of ICT in drought data collection and monitoring	
The city satisfied all of the criteria for drought information and emergency water supply mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	

City has no information on the city-scale drought information, or the city does not apply drought information	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

The National Drought Information portal provides city-scale drought information and emergency water supply related information on drought.go.kr.

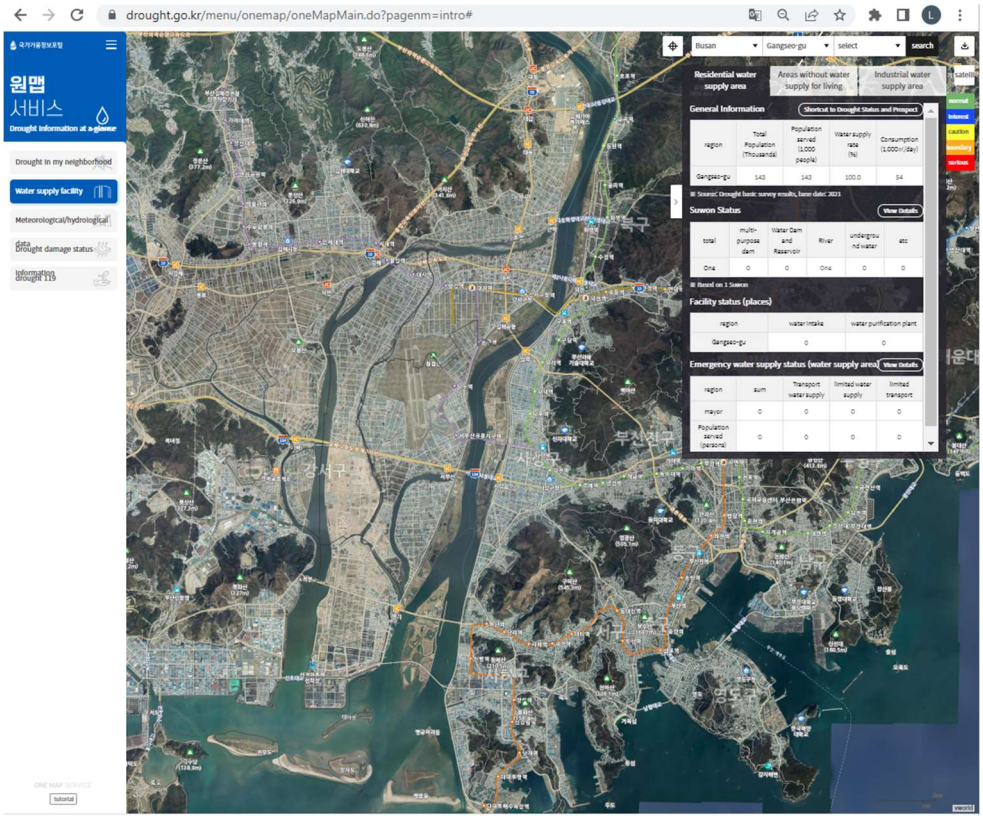


Figure. Gangseo District, Busan Metropolitan City drought and emergency water supply information

Source: National Drought Information Portal (drought.go.kr) > Easy to see Drought > Drought on the map

WATER DISASTER MANAGEMENT – Drought

Indicator 2.2.e. Drought prediction system (Gangseo District)
(Choose one of the following options that better describes the current circumstances in city)

	Criteria for smart water city drought prediction system
✓	Application of drought model for drought forecasting
✓	Application of ICT in drought early warning systems
✓	Application of remote-sensing instruments for drought monitoring
✓	Application of ICT in drought forecast information dissipation

The city satisfied all of the criteria for drought prediction system mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the city-scale drought prediction system, or the city does not apply drought prediction system	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

City-scale drought forecast information are provided by the National Drought Information portal at drought.go.kr.

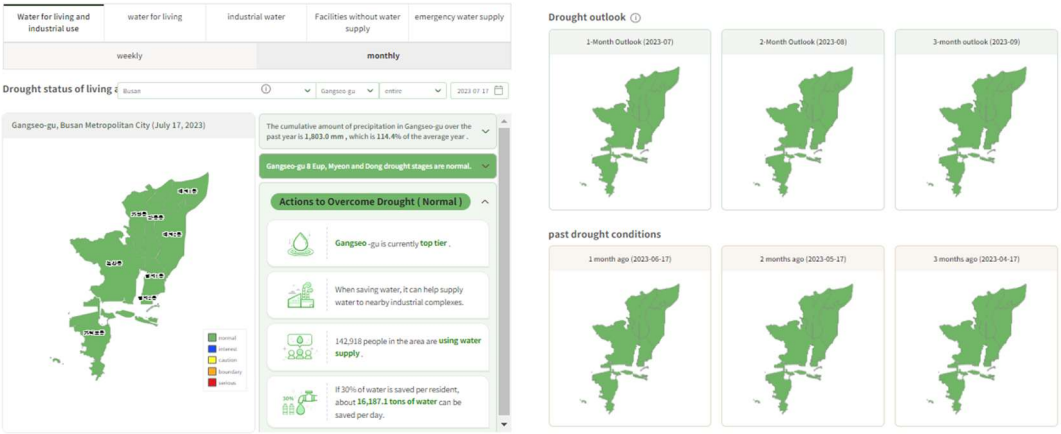


Figure. Gangseo District, Busan Metropolitan City Drought forecast information

Source: National Drought Information Portal (drought.go.kr) > Drought Information Analysis > Status and Prospect

2.3 Climate change

WATER DISASTER MANAGEMENT – Climate change
Indicator 2.3.a. Climate adaptation planning (Busan) (Choose one of the following options that better describes the current circumstances in city)

	Criteria for smart water city climate adaptation planning
✓	Establishment of climate change adaptation measures and planning guidelines for the city
✓	Use of climate models and climate-projected hazard maps
✓	Assessment and analysis of climate risk areas

✓ Establishment of capacity building and community climate education	
The city satisfied all of the criteria for climate change adaptation planning mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the city-scale climate change adaptation, or the city does not apply climate change adaptation planning	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

South Korea Metropolitan Cities urban climate adaptation strategies according to Lee and Kim (2018).

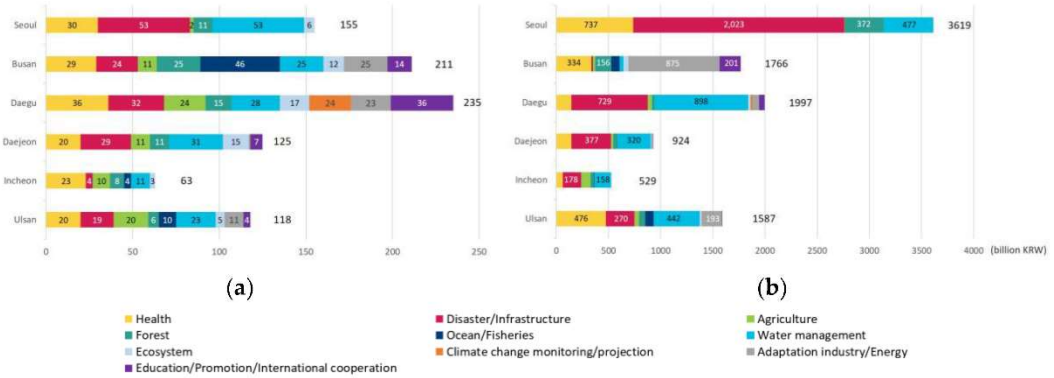


Figure. (a) Number of adaptation programs and (b) allocated budget of Planned climate change adaptation measures for Korea Metropolitan Cities, including Busan (Lee and Kim, 2018).

Source: Lee, J. and Kim, J. (2018). Assessing Strategies for Urban Climate Change Adaptation: The Case of Six Metropolitan Cities in South Korea. *Sustainability* 10(6), 2065.

WATER DISASTER MANAGEMENT – Climate change
Indicator 2.3.b. Application of renewable energy (Busan) (Choose one of the following options that better describes the current circumstances in city)

Criteria for smart water city renewable energy application
✓ Carbon footprint reduction, zero emission devices, e-transportations
✓ Energy saving strategies
✓ Eco-friendly facilities, green infrastructures, rainwater harvesting

✓ Alternative power source (hydropower, solar, wind, geothermal etc.)	
The city satisfied all of the criteria for renewable energy application mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the city-scale renewable energy application, or the city does not apply renewable energy application	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to Baek et al. (2016), 1.68% of Busan's electricity consumption was provided from renewable energy.

Category	Plan	Executing organization
Local energy plan	Energy education	Industry Technology
	LED traffic light supply	Traffic Planning
	Power-saving street light	Road Planning
	Micro-cooperation system	Busan National University
Equipment supply plan	PV generation supply for Deksan filtration plant	Water supply
	PV generation supply for Noksan sewage plant	Korea Environment Corporation
	Ocean thermal generation plant supply	Korea Maritime Ocean University
	Green home supply business	Industry Technology

Source: Baek, S. et al (2016). Optimal renewable power generation systems for Busan Metropolitan city in South Korea. *Renewable energy* 88, 517-525.

3. Water supply and treatment

3.1 Water source

WATER SUPPLY AND TREATMENT – Water source	
Indicator 3.1.a. Water quality monitoring frequency (Gangseo District) (Choose one of the following options that better describes the current circumstances in city)	
Raw water quality observations are performed at hourly or less than hourly interval	4
Observations performed at daily interval	

Observations performed at weekly interval	
Observations performed at more than weekly interval	
City has no data on raw water quality monitoring frequency, or no water source quality measurements are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the Busan water authority, raw water quality from water source reservoir dam for Gangseo District, Busan Metropolitan City is measured every 5 minutes.

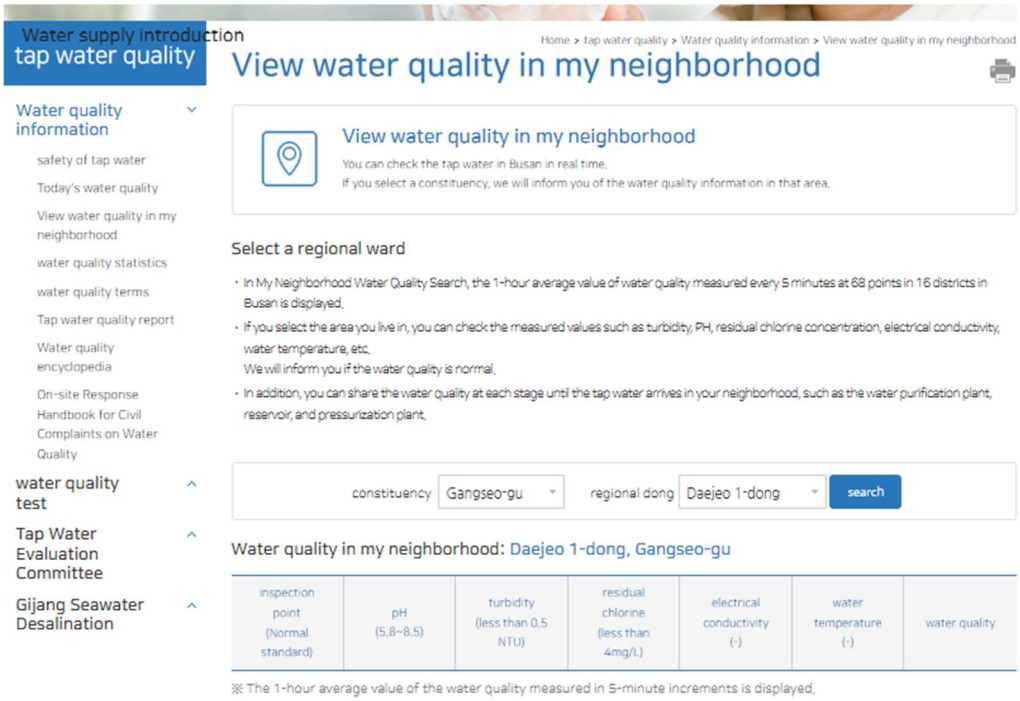


Figure. Gangseo District, Busan Metropolitan City raw water quality monitoring frequency

Source: Busan Water Authority (busan.go.kr) > Tap water quality > Water quality information > Water quality statistics

WATER SUPPLY AND TREATMENT – Water source	
Indicator 3.1.b. Water source availability (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Water reliability index = (Volume of available water (m^3) / total volume of water consumption (m^3)) * 100	
Calculated water reliability index is more than 100 %	**4**

Index is between 90 to 100 %	
Index is between 80 to 90 %	
Index is less than 80 %	
City has no data on water availability and water consumption	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

The water source availability is computed as follows:

Year	Annual water intake volume (m^3)	Annual water supply consumption (m^3)	Water assurance percentage (%)	Year	Annual water intake volume (m^3)	Annual water supply consumption (m^3)	Water assurance percentage (%)
2021	423058474	423058474	100.0	2013	386233106	386233106	100.0
2020	416544543	416544543	100.0	2012	386052300	386052300	100.0
2019	425676748	425676748	100.0	2011	391511531	374006896	104.7
2018	422010281	422010281	100.0	2010	384524839	370533182	103.8
2017	401303260	401303260	100.0	2009	386291528	386291528	100.0
2016	390193772	390193772	100.0	2008	403989795	403989795	100.0
2015	382937950	382937950	100.0	2007	410170798	410170815	100.0
2014	381863032	381863032	100.0	2006	418015500	418015500	100.0

The average annual water assurance percentage for Busan Metropolitan City is **100.5%** based on annual water intake volume and water supply consumption data from 2006 to 2021.

Source: National Water Supply Information System (waternow.go.kr) > Water supply information > Water supply statistics > Key Indicators > Current water intake status

WATER SUPPLY AND TREATMENT – Water source

Indicator 3.1.c. Raw water quality data automation and quality assurance (Gangseo District)
(Choose one of the following options that better describes the current circumstances in city)

Water source observation method and quality assurance	
✓	Real-time and automated recording of water source
✓	Existence of auto-calibration function within the water source monitoring instrument or system
✓	Regular calibration of the water source monitoring instrument
✓	Recorded water source data quality assurance

The city utilizes all of the water source monitoring automation and calibration criteria mentioned above	

At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the water source monitoring automation and calibration, or city does not apply automation and calibration in water source quality monitoring	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the Kwater water Information portal (water.or.kr), Gangseo District, Busan Metropolitan City receive majority of their water source from Nakdong River. The following are the number of observation stations and parameters measured.

Stream water source quality stations	1. Estuary bank pier 8 2. Estuary bank pier 10 3. Upstream gate 4. Eulsukdo bridge P3 5. Eulsukdo bridge P20 6. Nakdong river estuary 7. Nakdong bridge 8. Right bank drainage gate 9. Hakjang stream junction 10. River maximum depth point station 11. River bank station 12. Gangseo Nakdong bridge
Parameters measured	Water depth, salinity, temperature and electric conductivity
Realtime measuring stations	All

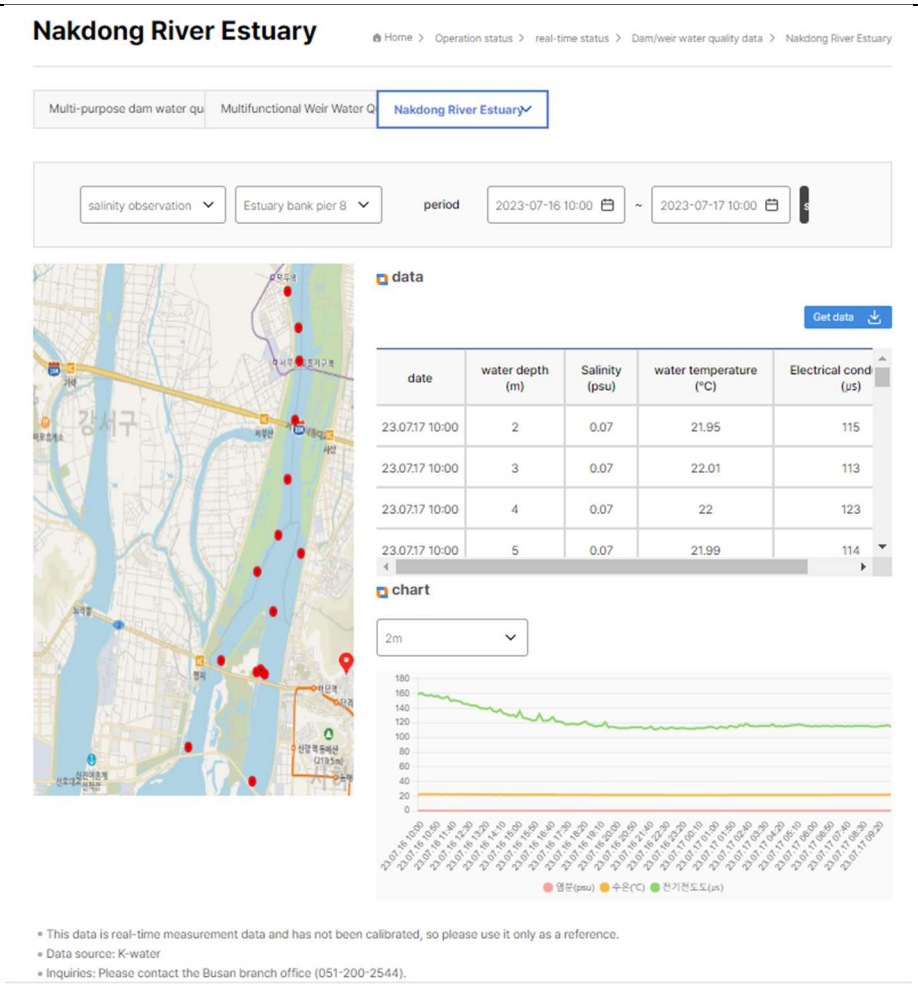


Figure. Water source quality automation status for Gangseo District, Busan stream

Source: Korea Water Resource Water Information Portal (water.or.kr) > Operation status > Real-time status > Dam/weir water quality data

WATER SUPPLY AND TREATMENT – Water source	
Indicator 3.1.d. ICT-based water source data collection process (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Water source quality observation ICT-based technologies	
✓ Multi-, single-parameter water quality sensors, Spectrophotometers, Turbidimeters, Conductivity meters, pH meters, Analyzers	
✓ Automated data loggers, Telemetry	
✓ Real-time wireless communication, Alert systems	
✓ Remote sensing-based instruments, GIS	
The city utilizes all of the ICT-based water source quality monitoring instruments criteria mentioned above	4

At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the application of ICT in water source quality monitoring, or city does not apply ICT in water source quality monitoring	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to the Busan Metropolitan city Water Purification Results Report 2016, the city utilizes real-time measuring instruments in water source monitoring.

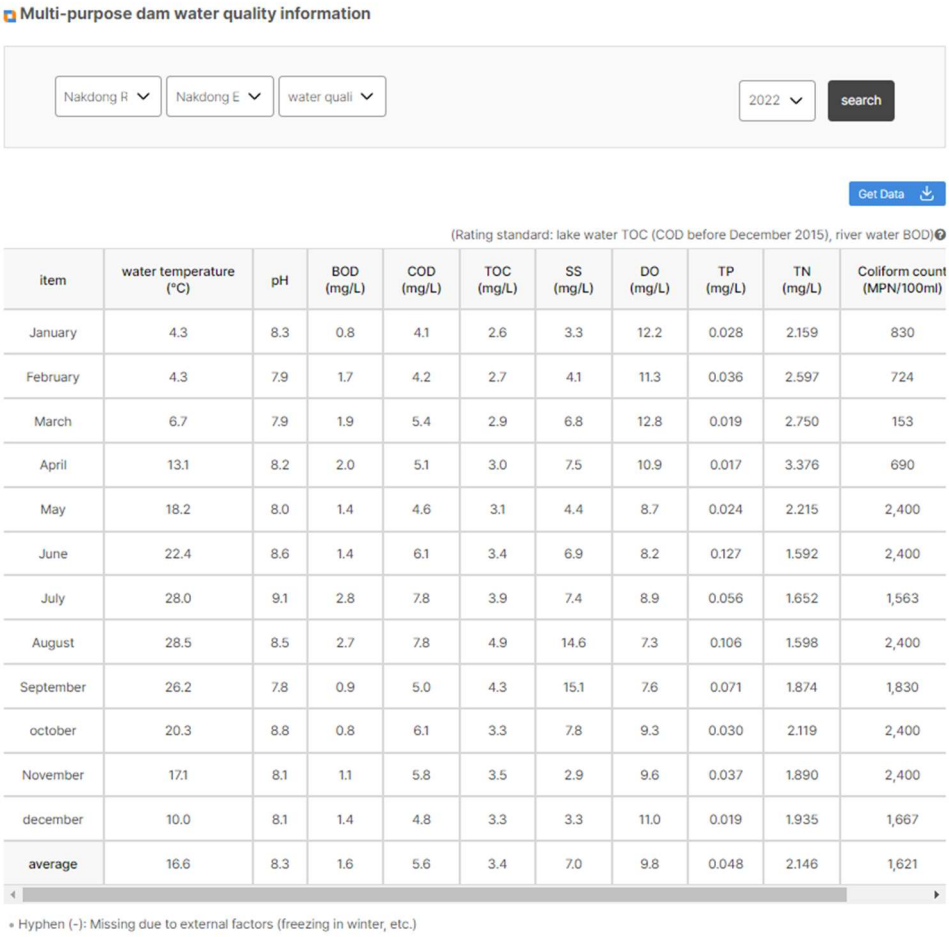
Figure. Water source real-time intake monitoring instruments (Maeri water reservoir, Busan)

Source: Busan Metropolitan City (busan.go.kr) > Waterworks division [Correction and treatment requirements]

WATER SUPPLY AND TREATMENT – Water source	
Indicator 3.1.e. Water source data accessibility (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Open online access of complete observed water source data	4
Open online access of partial or incomplete water source data	
Manual retrieval of water source data (i.e. official letter request, direct request to the office in charge)	
Restricted access to water source data (i.e. data only available within intergovernmental agencies)	
City has no information water source data accessibility, or data is not available to public access	
Not applicable. The indicator is not considered.	
Quantitative Analysis:	

Show the calculation process and provide data supporting the justification.

The water source quality data for Busan Metropolitan City is accessible to various government open source websites such as Water Information Portal (water.or.kr), Water Environment Information System (water.nier.go.kr) and Busan Open Data Portal (data.busan.go.kr).



(Rating standard: lake water TOC (COD before December 2015), river water BOD)

item	water temperature (°C)	pH	BOD (mg/L)	COD (mg/L)	TOC (mg/L)	SS (mg/L)	DO (mg/L)	TP (mg/L)	TN (mg/L)	Coliform count (MPN/100ml)
January	4.3	8.3	0.8	4.1	2.6	3.3	12.2	0.028	2.159	830
February	4.3	7.9	1.7	4.2	2.7	4.1	11.3	0.036	2.597	724
March	6.7	7.9	1.9	5.4	2.9	6.8	12.8	0.019	2.750	153
April	13.1	8.2	2.0	5.1	3.0	7.5	10.9	0.017	3.376	690
May	18.2	8.0	1.4	4.6	3.1	4.4	8.7	0.024	2.215	2,400
June	22.4	8.6	1.4	6.1	3.4	6.9	8.2	0.127	1.592	2,400
July	28.0	9.1	2.8	7.8	3.9	7.4	8.9	0.056	1.652	1,563
August	28.5	8.5	2.7	7.8	4.9	14.6	7.3	0.106	1.598	2,400
September	26.2	7.8	0.9	5.0	4.3	15.1	7.6	0.071	1.874	1,830
october	20.3	8.8	0.8	6.1	3.3	7.8	9.3	0.030	2.119	2,400
November	17.1	8.1	1.1	5.8	3.5	2.9	9.6	0.037	1.890	2,400
december	10.0	8.1	1.4	4.8	3.3	3.3	11.0	0.019	1.935	1,667
average	16.6	8.3	1.6	5.6	3.4	7.0	9.8	0.048	2.146	1,621

• Hyphen (-): Missing due to external factors (freezing in winter, etc.)

Figure. Busan Metropolitan City water source quality data (water.or.kr)

Source: Water Information Portal (water.or.kr), Water Environment Information System (water.nier.go.kr) and Busan Open Data Portal (data.busan.go.kr)

3.2 Drinking water treatment

WATER SUPPLY AND TREATMENT – Drinking water treatment	
Indicator 3.2.a. Drinking water quality compliance (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Water standard compliance percentage (%) = (Number of compliance water quality standards / Total number of inspections) * 100	
Percentage compliance of city water quality inspection for drinking water quality standards is 100 %	4

Compliance percentage is between 97 to 99 %	
Compliance percentage is between 95 to 97 %	
Compliance percentage is less than 95 %	
City has no data on water quality compliance inspections, or no water quality inspections are performed	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Busan metropolitan city status compliance of Drinking water purification plants (2023 Data)

Purification plant		pH	Ammonium nitrogen	Turbidity	Trihalomethane	Residual chlorine	Potassium Permanganate
Standard		5.8-8.5	< 0.5 mg/L	<0.5 NTU	< 0.1 mg/L	< 4mg/L	< 10mg/L
Deoksan	Ave	7.2	0	0.08	0.022	0.7	1.6
	Max	7.4	0	0.12	0.035	0.75	2.3
	Min	6.9	0	0.05	0.011	0.63	1.2
Hwamyeong	Ave	7.09	0	0.08	0.027	0.64	1.7
	Max	7.4	0	0.12	0.036	0.68	2.7
	Min	6.8	0	0.05	0.022	0.6	1.4

According to the data, all of the Water Purification plants have complied to the standard requirements for pH, ammonium nitrogen (NH3), turbidity, trihalomethane (THMs), residual chlorine and potassium permanganate (KMnO4).

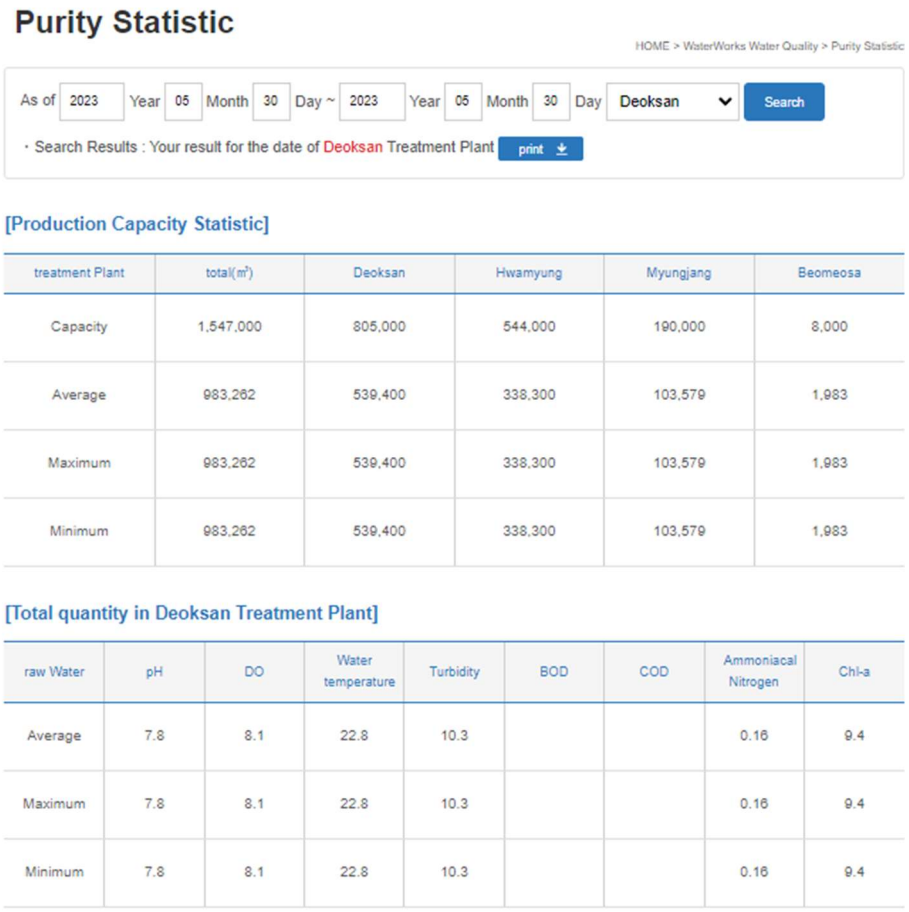
Source: Busan Water Authority (busan.go.kr.water_en) > Water supply water quality > Water Purity Statistics

WATER SUPPLY AND TREATMENT – Drinking water treatment	
Indicator 3.2.b. Drinking water quality measurement frequency (Busan) (Choose one of the following options that better describes the current circumstances in city)	
The quality of drinking water from water purification plants are being monitored at an hourly or less than hourly interval	
Monitoring at daily interval	3
Monitoring at weekly interval	
Monitoring at more than weekly interval	
City has no data on drinking water quality data frequency, or no drinking water quality inspections are performed	

Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the Busan Water Authority, drinking water purification plants performs quality performance observations at least once a day.



Purity Statistic

HOME > WaterWorks Water Quality > Purity Statistic

As of 2023 Year 05 Month 30 Day ~ 2023 Year 05 Month 30 Day Deoksan Search

· Search Results : Your result for the date of Deoksan Treatment Plant print

[Production Capacity Statistic]

treatment Plant	total(㎥)	Deoksan	Hwamyung	Myungjang	Beomeosa
Capacity	1,547,000	805,000	544,000	190,000	8,000
Average	983,262	539,400	338,300	103,579	1,983
Maximum	983,262	539,400	338,300	103,579	1,983
Minimum	983,262	539,400	338,300	103,579	1,983

[Total quantity in Deoksan Treatment Plant]

raw Water	pH	DO	Water temperature	Turbidity	BOD	COD	Ammoniacal Nitrogen	Chl-a
Average	7.8	8.1	22.8	10.3			0.16	9.4
Maximum	7.8	8.1	22.8	10.3			0.16	9.4
Minimum	7.8	8.1	22.8	10.3			0.16	9.4

Figure. Drinking water purification quality measurement frequency

Source: Busan Water Authority (busan.go.kr.water_en) > Water supply water quality > Water Purity Statistics

WATER SUPPLY AND TREATMENT – Drinking water treatment

Indicator 3.2.c. Drinking water purification data automation and quality assurance (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Drinking water observation method and quality assurance	
✓	Real-time and automated observation of drinking water quality
✓	Existence of auto-calibration function within the water quality monitoring instrument or system
✓	Regular calibration of the drinking water quality monitoring instrument
✓	Recorded drinking water quality data quality assurance

The city implements drinking water quality monitoring automation and calibration criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria are satisfied	
The city has no information on the drinking water quality monitoring automation and calibration, or the city does not implement automation and calibration in drinking water quality monitoring	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the Busan Metropolitan city Water Purification Results Report 2016, energy management, intelligent alarm and mobile process management has been fully automatized through intelligent integrated management system.

Source: Busan Metropolitan City (busan.go.kr) > Waterworks division [Correction and treatment requirements]

WATER SUPPLY AND TREATMENT – Drinking water treatment	
Indicator 3.2.d. Drinking water data accessibility (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	

Drinking water quality observation ICT-based technologies
✓ Water quality sensors (residual chlorine, turbidity),
✓ Conductivity and pH meters, Flow meters (turbine, magnetic)
✓ Analyzers (residual disinfectant, TOC)
✓ Spectrophotometers

The city utilizes all of the ICT-based drinking water quality monitoring instruments criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the application of ICT in drinking water quality monitoring, or city does not apply ICT in drinking water quality monitoring	

Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

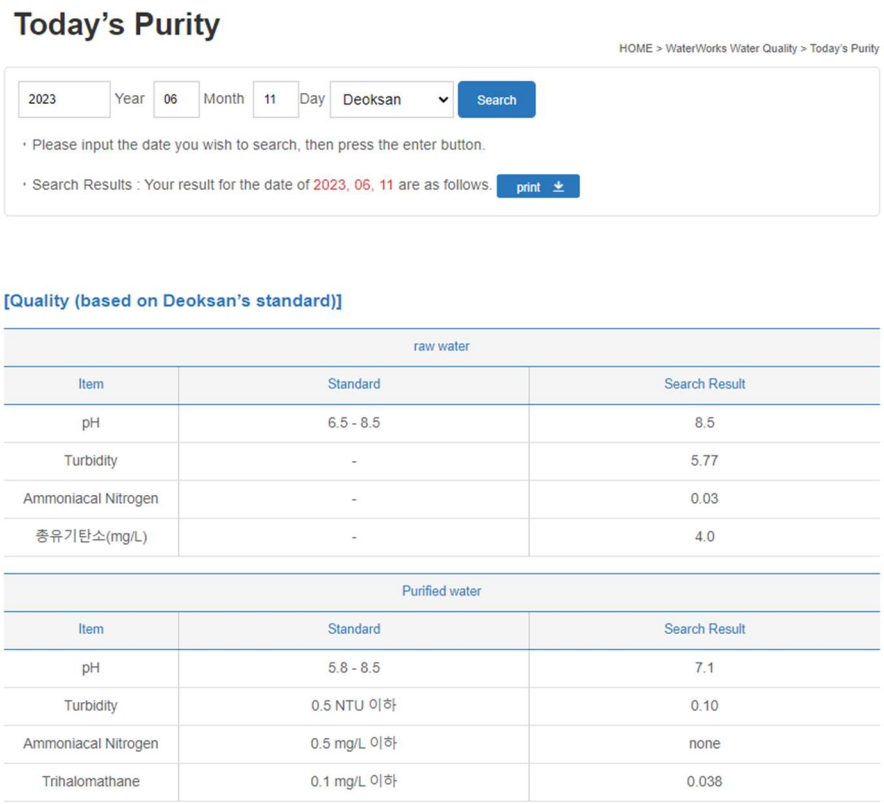
According to Korea Water Resources Corporation, drinking water treatment facilities provides clean water using innovative water management technologies, digitalized management system using artificial intelligence (AI) and big data. These integrated solutions provide real time information in water plant management and smart water treatment plants.

Source: Korean Herald Business (2021). K-water paves the way for Net-zero and the innovative water industry on the global stage. Herald.com/en/2021/04/30.

WATER SUPPLY AND TREATMENT – Drinking water treatment	
Indicator 3.2.e. Drinking water purification data accessibility (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Open online access of complete observed drinking water data	4
Open online access of partial or incomplete drinking water data	
Manual retrieval of drinking water data (i.e. official letter request, direct request to the office in charge)	
Restricted access to drinking water data (i.e. data only available within intergovernmental agencies)	
City has no information on drinking water data accessibility, or data is not available to public access	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Drinking water data information can be easily accessed through the Busan Water Authority website.



Today's Purity

HOME > WaterWorks Water Quality > Today's Purity

2023 Year 06 Month 11 Day Deoksan Search

· Please input the date you wish to search, then press the enter button.

· Search Results : Your result for the date of 2023, 06, 11 are as follows. print

[Quality (based on Deoksan's standard)]

raw water		
Item	Standard	Search Result
pH	6.5 - 8.5	8.5
Turbidity	-	5.77
Ammoniacal Nitrogen	-	0.03
총유기탄소(mg/L)	-	4.0

Purified water		
Item	Standard	Search Result
pH	5.8 - 8.5	7.1
Turbidity	0.5 NTU 이하	0.10
Ammoniacal Nitrogen	0.5 mg/L 이하	none
Trihalomathane	0.1 mg/L 이하	0.038

Figure. Drinking water quality data information from open-access website

Source: Busan Water Authority (busan.go.kr/water) > Tap water quality > Water quality information > Today's water quality

Source: Busan Metropolitan City (busan.go.kr) > Waterworks division [Correction and treatment requirements]

WATER SUPPLY AND TREATMENT – Drinking water treatment

Indicator 3.2.f. Advanced water purification treatment process (Gangseo-gu, Sasang-gu, Buk-gu)
(Choose one of the following options that better describes the current circumstances in city)

Advanced water purification treatment process criteria	
✓	Granular or activated carbon, Ozonation
✓	Packed tower aeration
✓	Reverse osmosis, water oxidation, Chemical precipitation and coagulation
✓	Membrane filtration, Biofiltration, Desalination, UV Disinfection

The city utilizes all of the advanced water purification treatment criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the application of water purification advanced water treatment, or city does not apply advanced water treatment	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to Busan Water Authority (busan.go.kr/water_en/WaterSafety), the city's drinking water treatment plants utilizes methods such as deposition, filtration, ozonation and active carbon to eliminate in removing germs, foul taste and odors.

Figure. Busan Metropolitan city drinking water purification process (busan.go.kr)

Table. Busan Metropolitan City purification plant water source and treatment methods (Busan National Water Supply Information System)

Purification plant	Water source	Water treatment method
Deoksan	River	Rapid filtration method
Myeongjang	Lake	Advanced treatment method
Beomeosa	Lake	Slow filtration method
Hwamyeong	River	Advanced treatment method

Source: Busan Water Authority (busan.go.kr) > Public Information Section > Tap water production process
Source: National Water supply Information System (waternow.go.kr) > Water supply information > Water facility status > Water purification facility

3.3 Water distribution

WATER SUPPLY AND TREATMENT – Water distribution	
Indicator 3.3.a. Water supply network distribution (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage extent of water supply pipe distribution (%) = (Number of population with access to water supply / Total number of population) * 100	
Percentage of with access to water supply distribution network is 100 %	4
Percentage is within 95 – 100 %	
Percentage is within 90 – 95 %	
Percentage is within less than 90 %	
City has no data on population with access to water supply	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the National Water supply Information System (waternow.go.kr), the number of districts in Busan Metropolitan City that has access to water supply per year are as follows:

Year	Total number of districts	Number of districts without access to water supply	Year	Total number of districts	Number of districts without access to water supply
2021	205	0	2013	210	0
2020	205	0	2012	212	0
2019	206	0	2011	214	0
2018	206	0	2010	214	0
2017	205	0	2009	214	0
2016	205	0	2008	217	1
2015	206	0	2007	227	1
2014	210	0	2006	226	2

Since 2009, there are no district in Busan that do not have access to centralized water supply.

Source: National Water supply Information System (waternow.go.kr) > Water supply information > Water supply statistics > Key Indicators > General Information

WATER SUPPLY AND TREATMENT – Water distribution
Indicator 3.3.b. Status of aging water supply pipes (Busan) (Choose one of the following options that better describes the current circumstances in city)

Percentage of aging pipe lines (%) = (Extension of pipelines installed more than 30 years ago / Total pipeline extent) * 100	
The percentage of water supply pipelines that are installed more than 30 years ago is less than 5 %	
Percentage is from 5 to 10 %	3
Percentage is from 10 to 15 %	
Percentage is greater than 15 %	
City has no data on aging water supply pipelines	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the 2006-2021 data of Waterworks Supply Status from the Ministry of Environment, the total water supply pipe extension for Busan Metropolitan City is 4,253,477 m, while the total extension of aging pipelines is 409,626 m. Therefore, the percentage of aging water supply pipelines is computed as:

$$\text{Aging water supply pipes percentage}_{\text{Busan Metropolitan City}} = \frac{\text{Total extension of aging pipelines (m)}}{\text{Total water supply pipe extension (m)}} \times 100$$

$$\text{Aging water supply pipes percentage}_{\text{Busan Metropolitan City}} = \frac{409{,}626\ \text{m}}{4{,}253{,}477\ \text{m}} \times 100 = \mathbf{9.6\%}$$

Source: Korean Statistical Information Service (kosis.kr) > Central Administrative Agency > Ministry of Environment > Water supply statistics > Waterworks pipeline status (2006-2021)

WATER SUPPLY AND TREATMENT – Water distribution	
Indicator 3.3.c. Revenue water percentage (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of revenue water (%) = (Amount of total water consumption (m^3) / Total amount of water supplied from the treatment plant (m^3)) * 100	
The percentage of revenue water is more than 95 %	
Percentage is between 85 to 95 %	3
Percentage is between 80 to 85 %	
Percentage is less than 80 %	

City has no data on water consumption and water revenue	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table: Annual water supply leakage percentage / non-revenue water

Year	Total water supply leakage percentage (%)	Year	Total water supply leakage percentage (%)
2021	4.7	2013	4.1
2020	3.3	2012	4.0
2019	4.6	2011	5.0
2018	2.9	2010	5.1
2017	3.6	2009	7.5
2016	3.7	2008	7.5
2015	4.4	2007	10.2
2014	4.0	2006	12.3

The average annual non-revenue water from 2006 to 2021 is 5.4%. Therefore, the average percentage of revenue of Busan Metropolitan City is about **94.6%.**

Source: waternow.go.kr > Water supply information > Water supply statistics > Key Indicators > Quantity management

WATER SUPPLY AND TREATMENT – Water distribution	
Indicator 3.3.d. Water storage effective capacity (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Reservoir effective storage capacity (%) = (Maximum daily water supply (m^3) / Maximum water storage capacity (m^3)) * 100	
The effective reservoir storage capacity percentage is less than 70 %	4
Percentage is between 70 to 75 %	
Percentage is between 75 to 80 %	
Percentage is greater than 80 %	
City has no data on daily and maximum storage capacity	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Busan Metropolitan city drinking water purification facilities' daily storage capacity and maximum water supply performance (2006-2020).

Year	Maximum water supply performance (m^3/day)	Purification plant storage capacity (m^3/day)	Year	Maximum water supply performance (m^3/day)	Purification plant storage capacity (m^3/day)
2020	1313898	2913800	**2012**	1377960	2913800
2019	1368351	2913800	**2011**	1352038	2913800
2018	1361853	2913800	**2010**	1309930	2913800
2017	1298115	2913800	**2009**	1359830	2913800
2016	1298115	2913800	**2008**	1414080	2913800
2015	1417562	2913800	**2007**	1433320	2914800
2014	1427907	2913800	**2006**	1447380	2914800
2013	1265000	2913800	**Ave**	**1363023**	**2913933**

According to the National Water Supply Information System data, the average storage capacity and maximum daily water supply performance of Busan purification plants are 2,913,933 m^3 and 1,363,023 m^3, respectively. Therefore, the facility effective storage capacity is:

$$\text{Effective facility storage capacity}_{\text{Busan Metropolitan City}} = \frac{\text{Max. water supply performance } (m^3/\text{day})}{\text{Storage capacity } (m^3/\text{day})} \times 100$$

$$\text{Effective facility storage capacity}_{\text{Busan Metropolitan City}} = \frac{1{,}363{,}023\ m^3/\text{day}}{2{,}913{,}933\ m^3/\text{day}} \times 100 = \mathbf{46.8\%}$$

Source: National Water Supply Information System (waternow.go.kr) > Water supply information > Water supply statistics > Key Indicators > Current water intake and water purification status

WATER SUPPLY AND TREATMENT – Water distribution

Indicator 3.3.e. Water distribution data automation and quality assurance (Gangseo District)
(Choose one of the following options that better describes the current circumstances in city)

Water supply observation method and quality assurance	
✓	Real-time and automated monitoring of water supply
✓	Existence of auto-calibration function within the water supply monitoring instrument
✓	Regular calibration of the water supply monitoring instrument
✓	Recorded water supply data quality assurance

The city implements the water supply monitoring automation and calibration criteria mentioned above	
At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	

At least one of the criteria is satisfied	
The city does not have information on the water supply automation and calibration, or the city does not apply automation and calibration in water supply monitoring	
Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Busan districts utilization of automated remote water meter reading.

District	Remote metering percentage (%)	District	Remote metering percentage (%)
Dongrae-gu, Geumjeong-gu, Yeonje-gu	10.6	Buk-gu, Sasang-gu	9.6
Jung-gu, Dong-gu	10.9	Haeundae-gu	8.9
Seo-gu	9.0	Saha-gu	9.0
Yeondo-gu	4.7	**Gangseo District**	**96.8**
Busanjin-gu	10.7	Kijang-gun	82.1
Nam-gu, Suyeong-gu	9.6	Total	19.3

The city utilizes **partially automated system** to monitor water supply distribution.

Source: Busan Water Authority > Fees / Civil service > Remote meter reading system > Remote meter reading system status

WATER SUPPLY AND TREATMENT – Water distribution

Indicator 3.3.f. Water supply pipe maintenance system (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Water supply pipe maintenance system ICT-based technologies criteria
✓ Real-time pipe sensors for leak detection, pressure and valve gauges
✓ Remote sensing-based technologies, GIS, Drones, Robotics, CCTV
✓ Machine learning predictive analysis, IoT (Internet of Things)
✓ AI-based maintenance systems, Early warning leakage devices

The city utilizes all of the ICT-based technologies in water pipe maintenance system criteria mentioned above	4
At least three of the criteria are satisfied	
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the ICT-based technologies in water pipe maintenance system, or city	

does not apply ICT-based technologies in water pipe maintenance system	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to Busan Water Authority (busan.go.kr), the city coordinates with pipe leak specialists and maintenance companies to address issues in water supply pipe lines leakages and damages. These companies facilitate maintenance issues including high-tech equipment pipe leak detection, water proof construction, piping maintenance, repair, plumbing, etc.

Source: Busan Water Authority (busan.go.kr) > Fee/Civil Service > Free Inspection > Water Related Company

WATER SUPPLY AND TREATMENT – Water distribution	
Indicator 3.3.g. Application of smart water metering (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of smart metering (%) = (Total number of smart water meter installation in the city / Total number of water meter installations) * 100	
The percentage of smart water meter installations in the city is greater than 30 %	4
Percentage is within 20 to 30 %	
Percentage is within 10 to 20 %	
Percentage is less than 10 %	
City has no information on smart water meter installations, or no application of smart water reading in the city	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to the Busan Water Authority, the city utilizes remote smart metering system based on Internet of Things (IoT) that checks meter status information every hour.

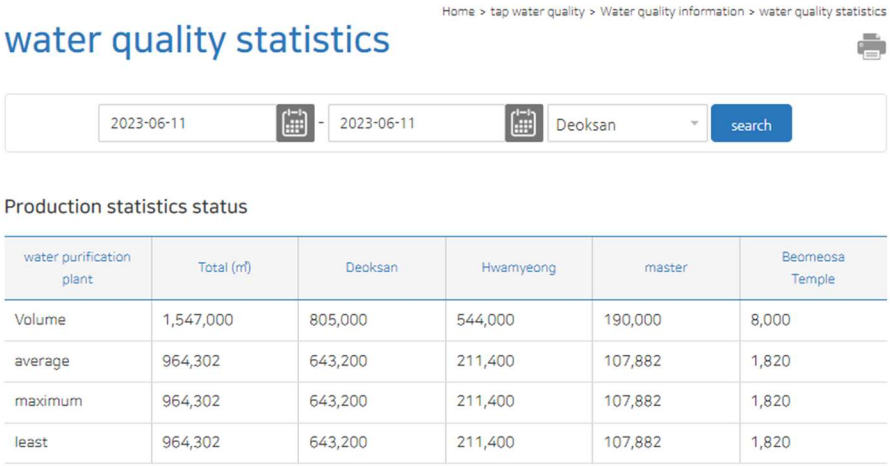
Figure. Busan City digital water meter and remote meter reading terminal

Source: Busan Water Authority (busan.go.kr/water) > Fee / civil service > Remote meter reading > Check digital water meter and remote meter reading terminal

WATER SUPPLY AND TREATMENT – Water distribution	
Indicator 3.3.h. ICT-based water distribution data accessibility (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Open online access of complete observed water supply data	4
Open online access of partial or incomplete water supply data	
Manual retrieval of water supply data (i.e. official letter request, direct request to the office in charge)	
Restricted access to water supply data (i.e. data only available within intergovernmental agencies)	
City has no information water supply data accessibility, or data is not available to public access	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

For Busan Metropolitan city, daily water supply volume can be accessed on the website, however, real-time water distribution data is not available.



water purification plant	Total (㎥)	Deoksan	Hwamyeong	master	Beomeosa Temple
Volume	1,547,000	805,000	544,000	190,000	8,000
average	964,302	643,200	211,400	107,882	1,820
maximum	964,302	643,200	211,400	107,882	1,820
least	964,302	643,200	211,400	107,882	1,820

Figure. Water production statistics for Busan Metropolitan City

Source: Busan Water Authority (busan.go.kr) > Tap water quality > Water quality information > Water quality statistics

3.4 Waste water treatment

WATER SUPPLY AND TREATMENT – Waste water treatment	
Indicator 3.4.a. Sewage network distribution (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of urban population with access to sewage network (%) = (Number of population with access to sewage network / Total number of populations) * 100	
Percentage of urban population with household connected to city sewage network system is 100 %	
Percentage is between 95 to 99 %	3
Percentage is between 90 to 95 %	
Percentage is less than 90 %	
City has no data on population with access to sewage network	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table. Busan metropolitan city total population and population that has access to centralized sewage facility (1998-2021).

	Total population	Total population with access to sewage treatment		Total population utilizing septic tank	Population with no access to sewage treatment
		Within treatment facility	Outside treatment facility		
Busan	3389800	3375331	10314	4155	0

Sewage network population access percentage is then computed as:

$$\text{Sewage network population}_{\text{Busan Metropolitan City}} = \frac{\text{Population with access to sewage facility}}{\text{Total population}} \times 100$$

$$\text{Sewage network population}_{\text{Busan Metropolitan City}} = \frac{3{,}385{,}645}{3{,}389{,}800} \times 100 = \mathbf{99.88\%}$$

Source: Korean Statistical Information Service (kosis.kr) > Central Administrative Agency > Ministry of Environment > Sewage statistics > Sewage distribution status

WATER SUPPLY AND TREATMENT – Waste water treatment	
Indicator 3.4.b. Status of aging sewer pipes (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of aging sewage pipes (%) = (Extension of aging sewage pipes (m) / total extension of the urban sewage pipes (m)) * 100	
The percentage of sewage pipes lines that are more than 30 years old is less than 5 %	4
Percentage is from 5 to 10 %	
Percentage is from 11 to 15 %	
Percentage is greater than 15 %	
City has no data on aging sewage pipelines	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the 2021 Sewage network statistics, the total sewage pipe network for Busan Metropolitan City is 10,149.8 km. On a 2020 Report by the Ministry of Environment, the total extension of aging sewage pipes for the city is 420 km. The percentage of aging sewer pipe network is:

$$\text{Aging sewer pipe percentage}_{\text{Busan Metropolitan City}} = \frac{\text{Total extension of aging pipes}}{\text{Total pipe extension}} \times 100$$

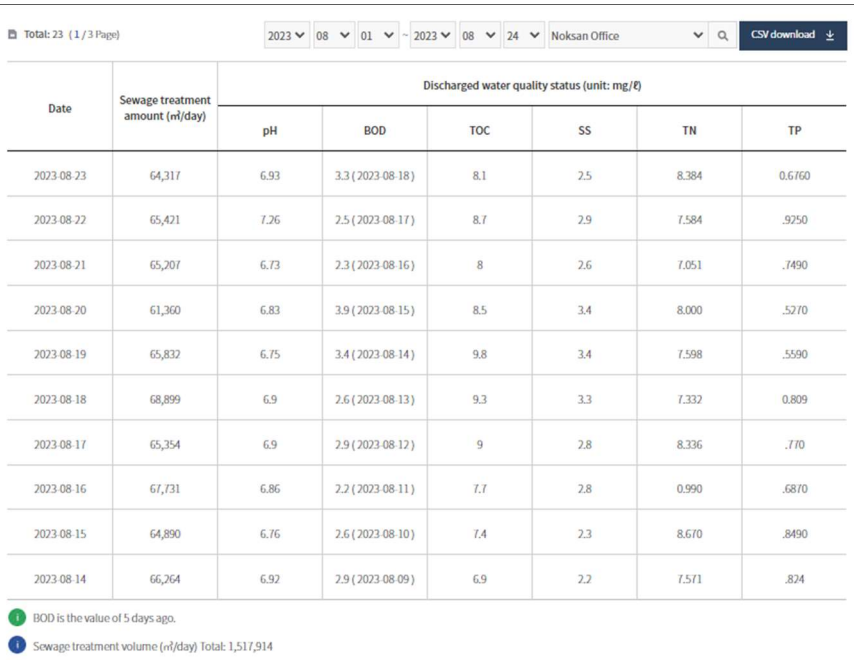
$$\text{Aging sewer pipe percentage}_{\text{Busan Metropolitan City}} = \frac{420\ \text{km}}{10{,}149.8\ \text{km}} \times 100 = \mathbf{4.1\%}$$

Sources:
Ministry of Environment (me.go.kr) > Disclosure > Prior information announcement > water supply and sewage > 2021_Sewer_Statistics.txt
Ministry of Environment via Construction Technology Telecommunication System (codil.or.kr) > 2020 Final report "Development of an automated repair robot capable of precision diagnosis of old sewage pipes by applying ICT-based maintenance technology and emergency repair by observing ground subsidence"

WATER SUPPLY AND TREATMENT – Waste water treatment	
Indicator 3.4.c. Sewage treatment monitoring frequency (Gangseo-gu, Sasang-gu, Buk-gu) (Choose one of the following options that better describes the current circumstances in city)	
Sewage treatment monitoring is performed on a daily basis	4
Monitoring is performed at least weekly interval	
Monitoring is performed at least monthly interval	
Monitoring is performed less than monthly interval	
City has no data on sewage water treatment monitoring frequency, or no sewage water treatment monitoring are performed	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to the Busan Environmental Corporation, the Busan Metropolitan City monitors waste water quality in the waste water facilities on a daily basis.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Date	Sewage treatment amount (㎥/day)	Discharged water quality status (unit: mg/ℓ)					
		pH	BOD	TOC	SS	TN	TP
2023-08-23	64,317	6.93	3.3 (2023-08-18)	8.1	2.5	8.384	0.6760
2023-08-22	65,421	7.26	2.5 (2023-08-17)	8.7	2.9	7.584	.9250
2023-08-21	65,207	6.73	2.3 (2023-08-16)	8	2.6	7.051	.7490
2023-08-20	61,360	6.83	3.9 (2023-08-15)	8.5	3.4	8.000	.5270
2023-08-19	65,832	6.75	3.4 (2023-08-14)	9.8	3.4	7.598	.5590
2023-08-18	68,899	6.9	2.6 (2023-08-13)	9.3	3.3	7.332	0.809
2023-08-17	65,354	6.9	2.9 (2023-08-12)	9	2.8	8.336	.770
2023-08-16	67,731	6.86	2.2 (2023-08-11)	7.7	2.8	0.990	.6870
2023-08-15	64,890	6.76	2.6 (2023-08-10)	7.4	2.3	8.670	.8490
2023-08-14	66,264	6.92	2.9 (2023-08-09)	6.9	2.2	7.571	.824

BOD is the value of 5 days ago.

Sewage treatment volume (㎥/day) Total: 1,517,914

Figure. Waste water treatment quality monitoring frequency

Source: Busan Environmental Corporation (beco.or.kr) > Environment corporation information > Operational status

WATER SUPPLY AND TREATMENT – Waste water treatment	
Indicator 3.4.d. Sewage water treatment data automation and quality assurance (Gangseo-gu, Sasang -gu, Saha-gu) (Choose one of the following options that better describes the current circumstances in city)	
Wastewater observation method and quality assurance	
✓ Real-time and automated monitoring of wastewater	
✓ Existence of auto-calibration function within the wastewater monitoring instrument or system	
✓ Regular calibration of the wastewater monitoring instrument	
✓ Recorded wastewater data quality assurance	
The city implements wastewater monitoring automation and calibration mentioned above	
At least three of the criteria are satisfied	3
At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
The city has no information on the wastewater automation and calibration, or the city does not implement automation and calibration in wastewater monitoring	

Not applicable	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

An automatic system that measures and controls dissolved oxygen and microbial concentration is developed by Busan Environment Corporation, installed in Subyeon sewage treatment plant (Saha-gu) and Nam sewage treatment plant (Nam-gu).

Figure. Subyeon Waste Water Treatment Plant Automatic water quality measuring instrument, Saha-gu, Busan

Source: Korea Environment Corporation (keco.or.kr)
Source: The World Daily > "Acquired patent for automatic water quality measurement device Busan Environment Corporation", 2010

WATER SUPPLY AND TREATMENT – Waste water treatment	
Indicator 3.4.e. Separated sewage network status (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of separated sewer system (%) = (Extension of separated sewer system (m) / total extension of urban pipe lines (m)) * 100	
The percentage of separated sewage and storm pipe system is more than 70 %	
Percentage is between 65 to 70 %	
Percentage is from 60 to 65 %	
Percentage is less than 60 %	1

City has no data on separated sewage system	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

Table shows separated and combined sewage network for Korea based on 2021 Korea sewer statistics data.

Metropolitan City	Pipe network (km)				Separated sewer percentage (%
	Total	Combined sewage network	Separated network		
			Storm water	Waste water	
Seoul	2,628,833.5	2,493,945.5	45,275.0	89,613.0	5.1
Busan	216,211.0	132,975.0	21,928.0	61,308.0	38.5
Daegu	1,919,800.0	1240910	360350	318540	35.4
Incheon	406,668.9	271943.3	26997.9	107727.7	33.1
Gwangju	269,295.1	112903.4	77720.1	78671.6	58.1
Daejeon	76,186.0	43993	13393	18800	42.3
Ulsan	283,253.5	0	37248.3	246005.2	100
Sejong	18,223.5	0	2510	15713.5	100

The separated sewage network percentage for Busan Metropolitan City is:

$$\text{Separated sewage network percentage}_{\text{Busan Metropolitan City}} = \frac{\text{Separated network (km)}}{\text{Total pipe network (km)}} \times 100$$

$$\text{Separated sewage network percentage}_{\text{Busan Metropolitan City}} = \frac{83{,}236\ \text{km}}{216{,}211\ \text{km}} \times 100 = \mathbf{38.5\%}$$

Source: Ministry of Environment (me.go.kr) > Laws and policies > Environmental policy > Water supply and sewage > 2021 Sewage statistics

WATER SUPPLY AND TREATMENT – Waste water treatment

Indicator 3.4.f. Sewage pipe maintenance system (Busan)
(Choose one of the following options that better describes the current circumstances in city)

Sewage pipe maintenance system ICT-based technologies criteria
✓ Real-time sewage pipe sensors for leak detection, pressure and valve gauges
✓ Remote sensing-based technologies, GIS, Drones, Robotics, CCTV
✓ Machine learning predictive analysis, IoT (Internet of Things)
✓ AI-based maintenance systems, Early warning leakage devices

The city utilizes all of the ICT-based technologies in waste water pipe maintenance system criteria mentioned above	4
At least three of the criteria are satisfied	

At least two of the criteria are satisfied	
At least one of the criteria is satisfied	
City has no information on the ICT-based technologies in waste water pipe maintenance system, or city does not apply ICT-based technologies in waste water pipe maintenance system	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to Busan sewer 911, the city utilizes equipments such as high-pressure washing machine, dredging vehicle and pipe endoscope cameras to monitor and maintain sewage system.

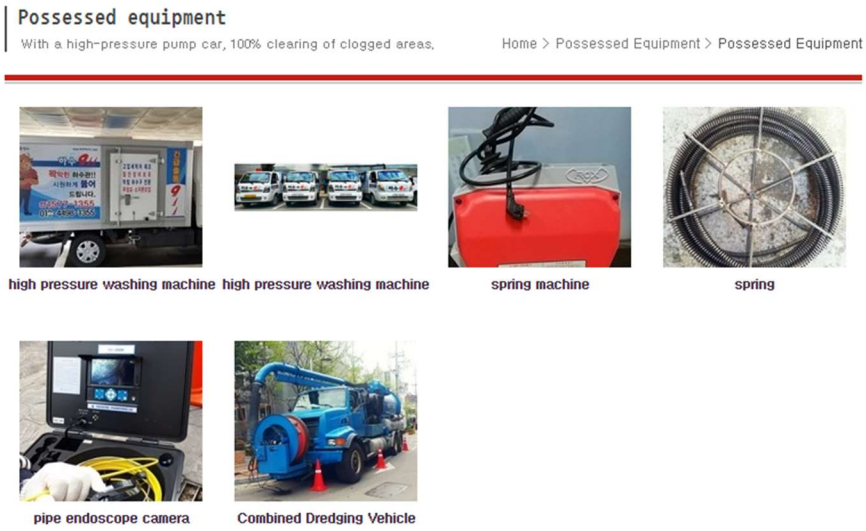

Figure. Equipments used for sewer maintenance, that includes ICT-based technologies

Source: Busan sewer 911 (busansewer911.com) > Possessed equipment

WATER SUPPLY AND TREATMENT – Waste water treatment
Indicator 3.4.g. Advanced sewage water treatment process (Busan) (Choose one of the following options that better describes the current circumstances in city)

	Advanced water purification treatment process criteria
✓	Preliminary treatment (screening, grit removal, comminution, equalization)
✓	Primary treatment (solid waste removal, sedimentation, separation)
✓	Secondary treatment (bacterial decomposition, ozonation, oxidation processes)
✓	Tertiary treatment (membrane, ultra and nano-filtration, disinfection, activated carbon-absorption)

The city waste water facilities process until tertiary level of waste water treatment	4
Process until secondary level of waste water treatment	
Process until primary level of waste water treatment	
Process only until preliminary waste water treatment	
City has no information on the process of advanced waste water treatment, or city does not implement advanced waste water treatment	
Not applicable. The indicator is not considered.	
Qualitative Analysis: Provide evidence that justifies the choice made. According to Korea Statistical Information Service (kosis.kr), Busan Metropolitan City waste water facilities perform physical (primary), biological (secondary) and advanced (tertiary) treatment for sewage waste water. About 91.4% of the population benefits from advanced level waste water treatment method. Source: Korean Statistical Information Service (kosis.kr) > Central Administrative Agency > Ministry of Environment > Sewage statistics > Sewage distribution status	

3.5 Water reuse

WATER SUPPLY AND TREATMENT – Waste water reuse	
Indicator 3.5.a. Reused and recycled waste water (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of recycled water (%) = Volume of urban water undergoing recycling and reuse (m^3) / Total volume of water usage in the city (m^3) * 100	
The percentage of reuse of recycled water for the city is more than 60 %	4
Percentage is from 55 to 60 %	
Percentage is from 50 to 55 %	
Percentage is less than 50 %	
City has no data on recycled and reused waste water, or no waste water recycling are implemented	
Not applicable. The indicator is not considered.	

Quantitative Analysis:
Show the calculation process and provide data supporting the justification.

According to the Korea Statistical Information Service (KOSIS), the total amount of Sewage facility water inflow and discharge per day for Busan Metropolitan City (1991-2021 data) are 1,423,906.3 m^3 and 1,338,228.7 m^3, respectively. The percentage of treated water to be reused is assumed to be:

$$\text{Percentage of recycled water}_{\text{Busan Metropolitan City}} = \frac{\text{Facility water discharge } (m^3)}{\text{Sewage facility intake water } (m^3)} \times 100$$

$$\text{Percentage of recycled water}_{\text{Busan Metropolitan City}} = \frac{1{,}338{,}228.7\ m^3}{1{,}423{,}906.3\ m^3} \times 100 = \mathbf{94\%}$$

Source: Korea Statistical Information Service (kosis.kr) > Environment > Sewage statistics > Sewage water treatment status summary

WATER SUPPLY AND TREATMENT – Waste water reuse	
Indicator 3.5.b. Percentage resource recovery of sewage solid waste (Busan) (Choose one of the following options that better describes the current circumstances in city)	
Percentage of recycled sludge materials = (Volume of waste water sludge materials being recycled (agriculture, construction, etc.) / Total sludge material byproducts) * 100	
The percentage of recycled sludge materials is more than 90 %	
Percentage is from 80 to 90 %	
Percentage is from 70 to 80 %	
Percentage is less than 70 %	1
City has no data on sludge material recycling, or no solid waste recycling are implemented	
Not applicable. The indicator is not considered.	

Qualitative Analysis:
Provide evidence that justifies the choice made.

According to KOSIS, the amount of total and recycled sludge output for Busan Metropolitan City (2001-2014 data) is as follows:

Total (ton/year)	Recycled (ton/year)		
	Renewable energy	Fertilizer	Others (Cement plastic etc.)
215,236.5	120,250.3	1,387.0	9,782.5

The percentage of recycled sludge materials is therefore:

$$\text{Sludge reuse percentage}_{\text{Busan Metropolitan City}} = \frac{\text{Total recycled solid waste}}{\text{Total solid waste}} \times 100$$

$$\text{Sludge reuse percentage}_{\text{Busan Metropolitan City}} = \frac{131{,}719.8\ \text{ton}}{215{,}236.5\ \text{ton}} \times 100 = \mathbf{61.06\%}$$

Source: Korea Statistical Information Service (kosis.kr) > Environment > Sewage statistics > Sewage sludge (2001-2014)

4. Busan Eco-delta City evaluation results on Technical Pillar

4.1 Urban water cycle

Indicator 1.1a Coverage extent of precipitation monitoring stations

For Busan Metropolitan City, which includea the Busan Eco Delta City (BEDC), the agency that is responsible for rainfall monitoring is the Korea Meteorological Administration (KMA). BEDC is located within the scope of Gangseo, Sasang and Buk districts. Within these boundaries, a total of 13 rainfall stations are in operation (2 from the Ministry of Environment [MOE] and 11 from KMA). Considering the total surface area of the districts at 253.19 km^2, the rainfall station coverage for BEDC is therefore 19.5 km^2 per station. The BEDC rainfall station coverage density satisfies WMO recommended densities for meteorological stations for urban areas, which is 10-20 km^2 per station.

Score assigned	2

Indicator 1.1b Monitoring and recording frequency of precipitation instruments

The KMA rainfall stations located within the vicinity of Busan Eco Delta City (Gangseo, Sasang and Buk districts) records rainfall intensity (mm) at a 1-minute interval. The recommended temporal variability for rainfall observations, in order to properly analyze the small-scale hydrological processes such as the channel flows in sewer and storm drains, should be less than 10-minute interval.

Score assigned	4

Indicator 1.1c Percentage comparison of missing and error of observed precipitation data to the total observed data

The nearest rainfall station in the Busan Eco Delta City is Gupo station. Based on the data gathered from the Water Resources Management Information System (WAMIS), the station records rainfall since 2006, logging a total of 6,225 rainfall observations. The calculated missing and error rainfall data for this station is 0.78%. According to literature, a minimum value of 0.5-5.4% of missing and error rainfall data must be implemented in order to limit the effect of missing data in climate parameter estimations.

Score assigned	4

Indicator 1.1d Quantity of observed precipitation data that is recorded electronically and the calibration status of precipitation recording instruments

The KMA rainfall stations within close proximity of Busan Eco Delta City, namely the Synoptic and Automated Weather Stations (ASOS and AWS) are all recording automatically and in real-time. In addition, according to the "Meteorological Instrument Regulations" under Meteorological Order No. 734, rainfall observation devices are subject to inspections and routine calibrations at least 10 times annually. This is to determine the suitability by comparing the performance, structure, condition, etc. of meteorological observation.

Score assigned	3

Indicator 1.1e Process of precipitation data collection using ICT-based technologies

The Korea Meteorological Administration utilizes radar and satellite data to perform rainfall observations for the city of Busan, which includes the BEDC. Included in the ICT-based instruments used by the Agency for rainfall monitoring are automated weather stations (AWS), sensor rain gauges, ground-based doppler radars, regional-scale satellite data and numerical weather predictions.

Score assigned	4

Indicator 1.1f Status of public accessibility to precipitation data records

The rainfall data for Korea are accessible to the public through the Korea Meteorological Administration website (data.kma.go.kr), including the observed data for the stations located in Gangseo, Sasang and Gu districts, around the vicinity of BEDC. The observed data are complete and open access by registering using an active email address.

Score assigned	4

Indicator 1.2a Percentage comparison of impervious surface to the total surface area

Based on the land use data provided by the Korea Water Resource Corporation (K-water), the total surface area and total pervious surface area (Parks and Grasslands) of the Busan Eco Delta City are 11.89 km^2 and 3.02 km^2, respectively. The total impervious surface area for BEDC is therefore 8.87 km^2,

amounting to about 74.6% of the total surface area. The percentage of impermeability is an important factor in the natural water balance, higher percentage can have a negative effect to urban flooding and groundwater recharge.

Score assigned	3

Indicator 1.2b Percentage comparison of the nature conservation area to the total surface area as related to the status of urban stream biodiversity

The Busan Eco Delta city land use data gathered from K-water (kwater.or.kr/website/ecodeltacity) indicates that 2.36 km^2 of the area is dedicated to nature conservation green spaces, which equates to 19.8% of the total surface area. Artificial alterations initiated by the city management to conserve the natural state of the surface is an indicator of smart water city.

Score assigned	3

Indicator 1.2c Establishment of urban waterfront or water space facilities

The Busan Metropolitan city, which includes the Busan Eco Delta city, constructed the Busan North port to serve as international marine tourism, gateway for the Eurasian continent, as a leisure water park and revitalize the local economy. The establishment of man-made waterfront facilities and structures can serve in various purposes, including transportation, commerce, recreation, environmental protection, storm water management and city aesthetics.

Score assigned	4

Indicator 1.2d Percentage comparison of applied Low Impact Development (LID) and Green infrastructure area and total surface area

Based on the “Study on enhancing response to climate change using spatial analysis of green infrastructure” by the Busan Development Institute, the LID, and green infrastructures with the residential, commercial, industrial, greenbelt and unassigned area within the city is 23.0 km^2, 2.0 km^2, 6.7 km^2, 421.9 km^2 and 0.4 km^2, respectively. The total percentage of LID and green infrastructures in the city is 58.4%. LID and green infrastructures are practices that mimic the natural process of the urban hydrological cycle with the purpose of preserving the quality of urban water and the associated

ecological habitat.

Score assigned	4

Indicator 1.3a Coverage extent of urban stream and coastal water level monitoring stations

Busan Metropolitan city has a total of 62.73 km river extent of the major rivers within the city (Oncheon stream, Suyeong River, Dong stream, Daecheon stream, Jisa stream, Kamjeon stream, Hakjang stream and Choryang stream). According to the Busan Metropolitan City Major River Water Level Information, there are a total of 18 stream gauge stations along the river pathways. Therefore, the coverage extent of water level stations within the city is 3.49 km extent per station. These water level stations are important for flood control and early warning, water flow measurements and proper water resource management.

Score assigned	4

Indicator 1.3b Monitoring and recording frequency of water level instruments

According to the official data portal of the Busan Metropolitan city, the regional water level stations record real-time water level data at 10-min intervals. Continuous and frequent water level monitoring is critical in providing prior early warning in case of flood events.

Score assigned	4

Indicator 1.3c Percentage comparison of missing and error of observed water level data to the total observed data

The nearest water level station within the vicinity of Busan Eco Delta city is the Gupo Bridge water level station. This station has been recording water levels since 1987, having a total number of 12,836 recorded data over 13,060 observation period. The total percentage of missing data for this station is therefore 1.72%. Research suggests that a missing value of <5.0% is considered acceptable and can be categorized as homogeneous data.

Score assigned	4

Indicator 1.3d Quantity of observed water level data that is recorded electronically and the calibration status of water level recording instruments

Based on the data gathered from the Water Resources Management Information System (WAMIS), all stream gauge monitoring stations within the vicinity of Busan Metropolitan City are recording automatically and in real-time. Automated and real-time monitoring allows for efficient water management, disaster preparedness and over all stream sustainability.

Score assigned	3

Indicator 1.3e Process of water level data collection using ICT-based technologies

The stream flows within the Busan Metropolitan city are measured using ICT-based real-time and automatic data collection methods, such as Telemetry, ADCP (Acoustic Doppler Current Profiler), ADVM (Acoustic Doppler Velocity Meters), Propeller flow meter, etc. The usage of modern ICT-based technologies in water level monitoring is an indicator of a smart water city.

Score assigned	4

Indicator 1.3f Status of public accessibility to water level data records

The complete river and stream water level data for Busan Metropolitan city can be accessed from WAMIS website (wamis.go.kr) and the Busan Open Data website (data.busan.go.kr). The ease of access to water level data promotes transparency in urban water management, allowing the public to have access to important information that is crucial in decision making during flood events.

Score assigned	4

Indicator 1.4a Coverage extent of urban stream water quality monitoring stations

Busan Eco Delta city is located within the areas of Gangseo, Sasang and Buk Districts, having a total surface area of 253.19 km^2. According to the Korea Water Resources Corporation, there are a total of 8 water quality monitoring stations along the urban stream and rivers located within the districts. Therefore, the calculated stream water quality station coverage density is about 31.6 km^2 per station. These water quality stations are important in keeping track of the health of the water bodies, monitoring

its impact on public health and aquatic ecosystem.

Score assigned	3

Indicator 1.4b Monitoring and recording frequency of stream water quality sampling instruments

The water quality of urban streams needed to be frequently tested in order to identify prospective issues that might affect the health of the urban stream ecosystem. According to the Busan Open data, the stream water quality parameters such as temperature, electric conductivity, dissolved oxygen, pH, salinity, turbidity, etc. are measured at an hourly interval.

Score assigned	4

Indicator 1.4c Percentage comparison of missing and error of observed water quality data to the total observed data

According to the data gathered from Water Resources Management Information Sy, the 8 water quality monitoring stations within the city are Eulsukdo, Geumgok, Gupo, Nakdong Estuary 1 and 2, Seobusan, Seonakdong 1,2,3,4 and 5 water quality stations. The percentage of missing water quality data for each station are 0.0%, 41.7%, 25.2%, 52.4%, 52.4%, 0.0%, 27.8%, 27.8%, 27.8%, 48.9% and 48.9%, respectively. The average water quality percentage of missing data is 32.1%. A large percentage of missing data can lead to biases in performing water quality trends or modeling.

Score assigned	1

Indicator 1.4d Standard quality of urban stream water

According to data from the Korea Water Resource Corporation, the Busan Metropolitan city stream water measured pollutant levels for BOD (biochemical oxygen demand), COD (chemical oxygen demand) and TP (total phosphorus) are 3.2 mg/l, 5.62 mg/l and 0.26 µg, respectively. These measurements satisfy the Environmental Protection Agency (EPA) recommendations for BOD, COD and TP pollutant levels, which are ≤5 mg, ≤ 20 mg, and 0.29 µg, respectively.

Score assigned	4

Indicator 1.4e Quantity of observed water quality data that is recorded electronically and the calibration status of water quality recording instruments

For Busan Metropolitan City, the river water quality measurements are performed through manual measuring networks by the Busan Health and Environment Research Institute (22 stations), the Nakdong River Basin Environmental Office (2 stations), the Nakdong River Water Environment Research Institute (3 stations), while automated monitoring is performed by the Busan Institute of Health and Environment (37 manual and 13 automated monitoring). No information on instruments calibrations is gathered.

Score assigned	3

Indicator 1.4f Process of water quality data collection using ICT-based technologies

According to the Water Environment Information Center, the city utilizes real-time water quality indices through ICT-based instruments or methods such as thermistor, glass and reference electrode, non-dispersive infrared detection, ultraviolet absorbance spectrophotometry and turbidimeter. The usage of these technologies in water quality monitoring increase data quality, maintains cost effectiveness, larger scale coverage, and more.

Score assigned	4

Indicator 1.4g Status of public accessibility to water quality data records

According to the Busan open data (data.busan.go.kr), stream water quality parameters such as temperature, electric conductivity, dissolved oxygen, pH, salinity, turbidity, etc. are provided in real-time through the website. The accessibility of this information allows the public to constantly monitor the quality of the urban river, enabling the community to be vigilant of potential threats.

Score assigned	4

Indicator 1.5a Coverage extent of groundwater level monitoring stations

The groundwater data for the Republic of Korea is being managed by the National Groundwater Information Center. Busan Eco Delta City is located within the Gangseo District. According to the Center, the total number of groundwater monitoring wells within the District of Gangseo (total surface area of

(179.05 km^2) is 8 stations. The groundwater level monitoring coverage density is about 22.4 km^2 per station.

Score assigned	3

Indicator 1.5b Monitoring and recording frequency of groundwater level instruments

The groundwater monitoring frequency should be enough to detect the short-term and seasonal fluctuations of groundwater level in the effect of hydrological stresses. According to the National Water Information Center, the groundwater level monitoring for the city of Busan is being conducted at an hourly interval.

Score assigned	4

Indicator 1.5c Percentage comparison of missing and error of observed groundwater level data to the total observed data

According to the data gathered from the National Groundwater Information Center, the missing data percentage among 6 groundwater level stations within the city are 1.1%, 84.3%, 94.5%, 90.8%, 90.8% and 5.14%. The average missing data percentage is 61.1%. A higher missing data percentage is not recommended in maintaining the accuracy and reliability of groundwater level datasets.

Score assigned	1

Indicator 1.5d Quantity of observed groundwater level data that is recorded electronically and the calibration status of ground water level recording instruments

According to the Integrated Groundwater Information Services, the groundwater level, temperature, and electric conductivity are measured automatically at an hourly interval in the installed aquifer and alluvial wells. The automation and calibration of groundwater level monitoring instruments play an important role in managing groundwater source for public water supply.

Score assigned	3

Indicator 1.5e Process of groundwater level data collection using ICT-based technologies

The groundwater monitoring networks for the republic of Korea are composed of automatic and manual observations, conducted by the Ministry of Land, Infrastructure and Transport, Korea Water Resource Corporation, Ministry of Environment, Korea Environment Corporation, and the regional municipalities. The ICT-based groundwater level monitoring instruments located within the districts of Gangseo, Sasang and Buk includes data transceiver device, monitoring and control system, real-time data management and ethernet database.

Score assigned	4

Indicator 1.5f Status of public accessibility to groundwater level data records

Open access to groundwater level data is crucial in effective groundwater management, research, and decision-making. The National Groundwater Information Center provides open access to the groundwater monitoring wells all over Korea, including the city of Busan.

Score assigned	4

Indicator 1.6a Coverage extent of groundwater quality monitoring stations

The district of Gangseo, where the Busan Eco Delta City is located, has a total of 9 groundwater quality observation wells covering a total of 179.05 km^2 of surface area. Therefore, the groundwater quality station coverage density is 19.9 km^2 per station. The spatial density of groundwater quality monitoring stations is important in understanding the current and past status of the quality of groundwater within the city.

Score assigned	4

Indicator 1.6b Monitoring and recording frequency of groundwater quality sampling instruments

High-resolution groundwater quality timeseries data is necessary for water resource management and understanding the changes in subsurface water quality. According to the National Groundwater Information Center, the average total number of groundwater quality observation per year for the city of Busan (1996-2022) is 2004, while the total number of groundwater observation wells within the city is 158. The groundwater quality monitoring frequency for Busan Metropolitan city is therefore 12.7 groundwater quality inspections per year.

Score assigned	3

Indicator 1.6c Percentage comparison of missing and error of observed groundwater quality data to the total observed data

Based on the groundwater quality data gathered from the National Groundwater Information Center, the total number of inspections from 1996 to 2022 is 54097, resulting to roughly 342.4 groundwater quality inspections annually. Since the target inspection 12.7 inspections per year, the total groundwater quality inspections should be 342.9. Therefore, the percentage of missing data for groundwater quality monitoring is 0.15%.

Score assigned	4

Indicator 1.6d Standard quality of urban groundwater water

The groundwater quality standards indicate the maximum permitted contaminant concentration amount that can be acceptable for water supply. According to the Groundwater Annual report by the National Groundwater Information Center, the average passing percentage of the groundwater quality compliance for Busan Metropolitan City from 1996 to 2022 is 89%. The groundwater monitoring for the city follows the compliance standard for the city of Busan.

Score assigned	4

Indicator 1.6e Quantity of observed groundwater quality data that is recorded electronically and the calibration status of groundwater quality recording instruments

According to the National Groundwater Information Center, the groundwater quality for the city performed by the Korea Water Resources Corporation, K-eco Regional Environment Office and the municipality of Busan conduct a combination of manual and automatic monitoring. Automation in groundwater quality observations ensures the consistency and accuracy of data collection, reducing opportunities for error in recording.

Score assigned	3

Indicator 1.6f Process of groundwater quality data collection using ICT-based technologies

Monitoring of groundwater quality in Korea are composed of automatic and manual observation wells conducted by the Ministry of Land, Infrastructure and Transport, the Korea Water Resources Corporation, Ministry of Environment, the Kore Environment Corporation, and the regional municipalities. For Busan Metropolitan City, the observation wells utilize ICT-based technologies such as online data transceiver devices, real-time data management, and monitoring and control system.

Score assigned	4

Indicator 1.6g Status of public accessibility to groundwater quality data records

Limitations in the public's access to groundwater data can present issues in water resource management hindering effective public communication. For the city of Busan, the National Groundwater Information Center provides open access information to groundwater quality monitoring. Some of the groundwater quality parameters that can be accessed are electric conductivity, pH levels, total chloroform and nitric acid nitrogen, chlorine ion, cadmium, arsenic, mercury, lead and more.

Score assigned	4

4.2 Water disaster management

Indicator 2.1a Flood casualty index as an indicator of the city population's vulnerability to life-threatening flood events

Reducing flood-related casualties is an essential aspect in city disaster preparedness and mitigation. According to the Water Resource Management Information Service, flood-related casualties have occurred in Busan Metropolitan city in 2016.

Score assigned	3

Indicator 2.1b Flood damage index as an indicator of the city's vulnerability to property damages caused by urban flood events

Flood damage index refers to the potential risk of flood damage of the city as referred to the relationship between the cost of damage resulted from flood events and the city's gross domestic product (GDP).

According to the Korea Statistics Ministry and the Water Management Information System, Busan Metropolitan City's most recent GDP and the 10-year averaged flood damage amount (2011-2020) are 91,698,334,000,000 KRW and 2,882,926,460,000 KRW, respectively. The computed flood damage index for Busan Metropolitan city is therefore 0.0003.

Score assigned	4

Indicator 2.1c Percentage comparison of the flood-prone areas to the total surface area

Flood risk area index pertains to the portion of the urban area susceptible to recurrent flooding. For Gangseo district in Busan Metropolitan city, the maximum recorded flooded area for the recent 10-year data is 0.07 km^2 (Water Resource Management Information Service). Given the district's total surface area of 181.5 km^2, the flood risk area index is therefore 0.0004. An index of less than 0.1 is considered a good indicator for reduced risk of the city relating to flood events.

Score assigned	4

Indicator 2.1d Percentage comparison of completed stream levee structures to the total stream extent

There are a hundred rivers and streams within the Busan Metropolitan city, the largest ones being the Suyeong River, Nakdong river, West Nakdong river and Oncheon stream. Based on the data gathered from the Busan Metropolitan city current river status from the public data portal, the total river extension and the total repaired river extension are 499.2 km and 327.4 km, respectively. The computed levee maintenance percentage is 65.8%. Levee maintenance refers to the restoration of rivers and urban streams to prevent riverine flooding through construction of dikes, levees, artificial retentions, etc.

Score assigned	3

Indicator 2.1e Application of city-scale flood hazard maps

This indicator refers to the city's application of city-scale flood hazard mapping for the municipal flood mitigation strategies. According to the Busan Metropolitan city Integrated Urban Flood Information, the city implements flood hazard maps based on historical return period flooding. These high-resolution flood hazards include rainfall-induced flooding (50- and 100-year return period rainfall), coastal flooding (tsunami) and river flooding.

Score assigned	4

Indicator 2.1f Implementation of city-scale integrated disaster information system and application of ICT-based technologies in flood management

The Gangseo district flood disaster information can be accessed to safecity.busan.go.kr. The website provides real-time weather and traffic information, in addition to dissipation of disaster text messages, etc. The Busan Metropolitan city integrated disaster information system utilized ICT-based information for monitoring, safety protocols and disaster recovery.

Score assigned	4

Indicator 2.1g Operation of urban flood prediction system and advanced real-time alarm services

The Busan Metropolitan city integrated flood disaster information center also provides real-time information on river water level and heavy rainfall alert, and other ICT-based technologies such as disaster surveillance CCTVs, necessary for flood forecast and mitigation. These early warning systems are key elements for flood disaster risk reduction, minimizing potential casualties and damage due to flooding.

Score assigned	4

Indicator 2.2a Drought damage index as an indicator in identifying the city's vulnerability to drought events based on the percentage of population affected by drought-related limited water supply

The urban drought damage index refers to number of people affected by the control measures during drought periods, including water service interruptions, limited water supply, etc. in relation to the total number of city's population. According to the National Drought Information Portal, there is zero drought-affected population within the Gangseo district for 2010 to 2020. This score can be attributed to the preparedness of the city on the limitations in the city's water supply during drought events.

Score assigned	4

Indicator 2.2b Recent drought occurrences affecting water supply and distribution

This indicator pertains to the occurrences of drought events in recent years that had affected the water supply and distribution in the city. According to the National Drought Information Portal, drought frequency analysis shows occurrence of drought events in Busan for 2017 (200-year return period) and 2020 (50-year return period).

Score assigned	2

Indicator 2.2c Application of ICT-based drought mapping

Drought risk assessment and mapping is critical in city-scale drought management in identifying drought risk areas allowing for planning, preparation, and mitigation strategies for the impact of drought in the city. The National Drought Information portal provides district-scale information and drought forecasting for Gangseo district based on standard ground index (SGI), standard precipitation index (SPI), Palmer drought severity index (PDSI), modified surface water supply index (MSWSI) and soil moisture index (SMI). These indices are mapped for the cities and districts through geographic information system using observed hydro-meteorological data.

Score assigned	3

Indicator 2.2d Operation of city-scale emergency water supply facilities and drought information system

The National Drought Information portal provides drought information and emergency water supply related information for Gangseo district, and other districts in Korea, accessible to drought.go.kr. The information provided by the drought portal includes current and past status of drought in the city and districts, showing drought normal status, states of interest, warning, precaution, and severe warning.

Score assigned	4

Indicator 2.2e Operation of drought advanced warning system and advanced information services

The application of advanced drought warning and information services are important in decreasing potential risk. The drought information for Gangseo district can be accessed in the National Drought information portal drought.go.kr, including neighborhood drought information, emergency water supply facilities, meteorological and hydrological data, and drought damage status. In addition, drought forecasts and warnings are provided on the website, identifying potential drought risks within 1-month,

2-month and 3-month outlook.

Score assigned	4

Indicator 2.3a Application of city-scale climate change adaptation planning

City-scale climate change planning and adaptation is crucial in addressing climate-induced vulnerabilities. According to the South Kore Metropolitan Cities urban climate adaptation strategies, climate adaptation programs and budgets for planned climate change adaptation measures for Busan Metropolitan city is established. Highlighted in the planning are climate change monitoring and projection, industry and energy adaptation, agriculture, and fisheries.

Score assigned	4

Indicator 2.3b Application of renewable energy and energy-saving strategies

According to the Optimal Renewable Power Generation systems for Busan Metropolitan city in South Korea 2016, about 1.68% of the city's electricity consumption is derived from renewable energy. Among the renewable power strategies include power saving streetlights, LED traffic lights, PV generation supply for Drinking water treatment and Wastewater treatment facilities, ocean thermal generation plant and green home supply businesses.

Score assigned	4

4.3 Water supply and treatment

Indicator 3.1a Monitoring and recording frequency of water source monitoring instruments

The water source quality monitoring system aims to detect levels of pollution in the water source, enabling adequate actions to prevent the effect to public consumption. According to the Busan Water Authority, the water source quality monitoring at reservoir dam for Gangseo district, Busan is conducted on a 5-min interval, with averaged value computed at hourly interval. Finer temporal measurement scales are preferable to reduce the possibility of uncertainty and allows capture of transient events.

Score assigned	4

Indicator 3.1b Water source availability based on the total volume of available water and consumed water

According to the National Water Supply Information Center, the Busan Metropolitan city water source availability data obtained from the data from annual water intake volume and annual water supply consumption from 2006 to 2011 is 100.5%. A water source reliability value of more than 100% assures the sufficiency of water supply to the city's consumers.

Score assigned	4

Indicator 3.1c Quantity of observed water source data that is recorded electronically and the calibration status of water source recording instruments

Gangseo district, Busan Metropolitan city receives the majority of their water source from Nakdong river. According to Korea Water Resource Corporation water information portal, all of the stream water source monitoring stations (Estuary bank pier 8, 10, Upstream gate, Eulsukdo bridge P3, 20, Nakdong river estuary, Nakdong bridge, etc.) along this river records in real-time. The application of real-time information in water source monitoring is necessary for prompt and adequate actions for prevention in water pollution.

Score assigned	3

Indicator 3.1d Process of water source data collection using ICT-based technologies

This indicator assesses the application of ICT-based technologies in water source monitoring. According to the Busan Metropolitan city Water Purification Results Report 2016, the city utilizes real-time ICT-based measuring instruments in water source monitoring in Maeri water reservoir, Busan. The types of water parameters measured include water depth, salinity, temperature, and electric conductivity.

Score assigned	4

Indicator 3.1e Status of public accessibility to water source data records

The water source quality data for Busan Metropolitan city is accessible to various government open-source websites such as the Water Information Portal (water.or.kr), Water Environment Information

System (water.nier.go.kr) and the Busan Open Data Portal (data.busan.go.kr). These water quality data include water temperature, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), and more.

Score assigned	4

Indicator 3.2a Drinking water quality compliance with the established drinking water quality standards

The standard for drinking water quality compliance is important in preventing the consumption of contaminated tap water. Based on the Busan Metropolitan city compliance status of Drinking water purification plants (2023 data), the drinking water facilities that supply drinking water to Gangseo, Sasang and Buk districts (Daeoksan and Hyangyeong plants) all complied to the standard requirements for pH, ammonium nitrogen (NH3), residual chlorine, turbidity, trihalomethane (THMs) and potassium permanganate (KMnO4).

Score assigned	4

Indicator 3.2b Monitoring and recording frequency of water quality monitoring instruments in Water purification treatment plants

According to the Busan Water Authority, the drinking water purification plants operating within the city perform quality performance observations at least once a day. High frequency of drinking water monitoring can reduce the associated risk in the chemical balance, compliance with the environmental regulation, improving reliability and public safety.

Score assigned	3

Indicator 3.2c Quantity of observed drinking water treatment data that is recorded electronically and the calibration status of drinking water recording instruments

Automation and quality assurance application in Drinking water quality monitoring can assist in the early prevention of unexpected occurrences. According to the Busan Metropolitan City Water Purification Results Report 2016, the energy management, intelligent alarm, and mobile process management has been fully automatized through intelligent integrated management system.

Score assigned	3

Indicator 3.2d Process of drinking water treatment data collection using ICT-based technologies

According to Korea Water Resources Corporation, drinking water treatment facilities provides clean water using innovative water management technologies, digitalized management system using artificial intelligence (AI) and big data. These integrated solutions provide real time information in water plant management and smart water treatment plants, especially applied to Busan Eco Delta City drinking water management.

Score assigned	4

Indicator 3.2e Status of public accessibility to drinking water treatment data records

The availability of drinking water quality data to the public embodies transparency, accountability and informed decision making. For Busan Metropolitan city, drinking water data information can be easily accessed through the Busan Water Authority website (busan.go.kr/water). On the website, information such as the standard and the measured values of purified water parameters such as pH, turbidity, ammonium nitrogen, etc. can be accessed.

Score assigned	4

Indicator 3.2f Application of advanced water purification treatment process in the Drinking water treatment facilities

According to the Busan Water Authority, the city's drinking water treatment plants utilize treatment methods such as deposition, filtration, ozonation, and active carbon to eliminate germs, foul taste, and odors. These water treatment facilities, namely Deoksan, Myeongjang, Beomeosa and Hwamyeong apply slow and rapid filtration methods and advanced treatment methods to purify the drinking water for the city.

Score assigned	4

Indicator 3.3a Percentage extent of water supply distribution based on the number of populations with

access to water supply

The extent to which the water supply distribution benefits the majority of the urban population, receiving adequate water supply services is an indicator of a smart water city. According to the National Water Supply Information System, there is no district in Busan that does not have access to centralized water supply network since 2009. Therefore, 100% of the city's population have access to drinking water services.

Score assigned	4

Indicator 3.3b Percentage of aging and deteriorating water supply pipelines

According to the 2006-2011 data of Waterworks Supply Status data from the Ministry of Environment, the total water supply pipe extension for Busan Metropolitan city is 4,253,477 m, while the total extension of pipelines installed more than 30 years ago is 409,626 m. Therefore, the percentage of aging pipelines for Busan Metropolitan city is 9.6%. Aging pipelines introduce potential for water breaks and leakages, which can result in huge water loss and expensive maintenance.

Score assigned	3

Indicator 3.3c Percentage of revenue and non-revenue water

For the annual water supply leakage percentage for 2006 to 2021, the average non-revenue water for Busan Metropolitan city is 5.4%. Therefore, the city's average percentage of revenue water is 94.6%. According to literature, an estimated average water loss in water network is about 5% for well maintained pipes. Small percentage loss indicates good maintenance of water supply network.

Score assigned	3

Indicator 3.3d Water storage effective capacity of water treatment facilities

The water storage effective capacity pertains to the stability of water supply, can be calculated based on the water treatment facility's maximum daily water supply and the maximum daily storage capacity. Based on the National Water Supply Information System data (2006-2020), the average daily storage capacity and maximum daily water supply performance for Busan purification plants are 2,913,933 m^3

and 1,363,023 m^3, respectively. Therefore, the city's computer effective storage capacity percentage is 46.8%.

Score assigned	4

Indicator 3.3e Quantity of observed drinking water quality data that is recorded electronically and the calibration status of water quality recording instruments

Real-time monitoring and automation in water supply network monitoring allows immediate actions in times of leak detection, pressure variations and other issues. Based on the data gathered from the Busan Water Authority, automated remote water meter monitoring is utilized for all of Busan city districts, where Gangseo district has the highest percentage (96.8%) of automated remote reading.

Score assigned	3

Indicator 3.3f Implementation of water supply pipe maintenance system

According to the Busan Water Authority, the city coordinates with pipe leak specialists and maintenance companies to address issues in water supply pipeline leakages and damages. These companies facilitate maintenance issues including high-tech pipe leak detection equipment, waterproof construction, piping maintenance, repair, plumbing etc. Pipe maintenance ensures continuous and sustainable water service provision, preventing decline of pipe quality leading to greater water loss and contamination.

Score assigned	4

Indicator 3.3g Application of smart water meter reading

Busan Metropolitan city utilizes remote smart meter system that is operated by IoT (Internet of Things) technology. These smart meters provide status information on an hourly basis. According to Busan Water Authority, about 96.8% of meter reading in Gangseo district, Busan is automated and run remotely. The application of smart water reading in water consumption constituent key component in water management, allowing more mindful water consumption and efficient usage.

Score assigned	4

Indicator 3.3h Status of public accessibility to drinking water treatment data records

For the drinking water treatment facilities in Busan Metropolitan city, including Deoksan, Hwamyeong, Beomeosa and Myeongjang, the daily water supply volume can be accessed in the Busan Water Authority website (busan.go.kr). Public access to water supply data enables consumers to monitor their water consumption which can initiate water saving strategies.

Score assigned	4

Indicator 3.4a Percentage extent of sewage service distribution based on the number of populations with access to sewage system

Sewage network population access percentage refers to the coverage of sewage pipe network distribution, wherein a larger percentage shows a well-managed sanitation system. According to the Busan Metropolitan city total population and the population with access to centralized wastewater facilities (1998-2021) are 3,398,000 and 3,385,645. Aside from the 0.12% of the population using individual septic tanks, 99.88% of the city's population benefits from wastewater services.

Score assigned	3

Indicator 3.4b Percentage of aging and deteriorating sewage pipelines

According to the 2021 Sewage network statistics facilitated by the Ministry of Environment, the total sewage pipe network for Busan Metropolitan city is 10,149.8 km. On a 2020 Final report by the Ministry of Environment, the total extension of aging sewage pipes in the city is about 420 km. Therefore, for Busan Metropolitan city, the percentage of aging sewage pipe network is 4.1%.

Score assigned	4

Indicator 3.4c Monitoring and recording frequency of wastewater monitoring instruments in the Wastewater Treatment facilities

For the Gangseo, Sasang and Buk districts in Busan Metropolitan city, the quality of wastewater in the sewage treatment facilities is being monitored on a daily basis, according to the data obtained from the Busan Environmental Corporation. High frequency monitoring would allow higher probability of early

detection of failure events within the treatment facilities.

Score assigned	4

Indicator 3.4d Quantity of observed sewage data that is recorded electronically and the calibration status of wastewater recording instruments

The Busan Environment Corporation developed an automatic system that measures and controls dissolved oxygen and microbial concentration, installed in Subyeon sewage treatment plant (Saha district) and Nam sewage treatment plant (Nam district). Real-time and automated monitoring during the wastewater treatment process is necessary in addressing and handling potential problems that might occur during the operation.

Score assigned	4

Indicator 3.4e Application of separated wastewater and storm water network

Separated sewer system operates individual pipe networks for wastewater and storm water flow. Based on the 2021 Korea sewer statistics data, the total combined sewage, storm water, and wastewater network total extent for Busan Metropolitan city are 132,975.0 km, 21,928.0 km, and 61,308.0 km, respectively. The separated sewage network percentage for the city is therefore 38.5%.

Score assigned	1

Indicator 3.4f Implementation of sewage network maintenance system

The application of maintenance procedures in sewage networks are needed in order to identify problems in wastewater collection and transportation. Busan Metropolitan city utilizes modern equipment such as high-pressure washing machines, dredging vehicles and pipe endoscope cameras to monitor and provide maintenance for the sewage network.

Score assigned	4

Indicator 3.4g Application of advanced sewage treatment process in the Wastewater treatment facilities

According to the Korea Statistics Information Service, Busan Metropolitan city wastewater facilities perform physical (primary), biological (secondary) and advanced (tertiary) treatment processes for sewage wastewater. About 91.4% of the city's population benefits from advanced level wastewater treatment results. Advanced wastewater treatment offers advantages in more effectively removing pollutants and contaminants, producing high-quality treated water, and minimizing negative impacts to the environment.

Score assigned	4

Indicator 3.5a Percentage of reused and recycled wastewater

Based on the Sewage water treatment status summary (1991-2021) published by the Korea Statistical Information Service, the total amount of daily water inflow and discharge for Busan Metropolitan city are 1,423,906.3 m^3 and 1,338,228.7 m^3, respectively. The percentage of recycled treated wastewater for the city is 94.0%. Reusing treated wastewater promotes conservation of water resources, reducing demand for fresh water supplies and promotes sustainability.

Score assigned	4

Indicator 3.5b Percentage of recycled sewage solid waste materials

Reuse of sewage treatment facilities' solid byproducts foster a more sustainable and environmentally friendly approach to wastewater management. For Busan Metropolitan city, the amount of total and recycled sludge materials according to a 2001-2014 data by the Korea Statistical Information Service, are 131,719.8 ton (91.3% for biomass energy, 1.05% for fertilizers and the remaining to cement or plastic production) and 215,236.5 ton, respectively. The percentage of recycled sludge materials for the city is computed as 61.1%.

Score assigned	1

5. Technical Pillar Assessment and Recommendation (Busan Eco Delta City)

The smart water city evaluation for Busan Eco Delta city, as part of the Busan Metropolitan city, is presented for each category in Figures X. The horizontal axis pertains to the individual key technical key performance indicators, while the vertical axis describes the final scoring for each KPIs. Black bars

represent the KPI evaluations that are focused on the urban water characteristics of the Busan Eco Delta City, while the colored bars represent the KPI evaluations that used the urban water data provided by Busan Metropolitan city.

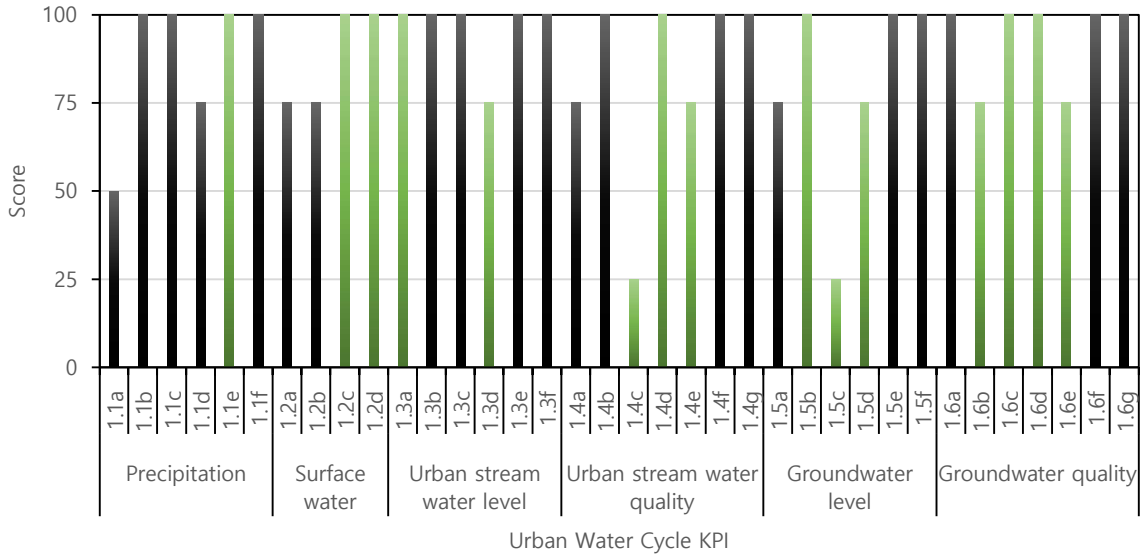

Figure. Busan Eco Delta City smart water evaluation scores on Technical Pillar urban water cycle category

For the urban water cycle category, Busan Eco Delta City obtained full score in several smart water city indicators, including the observation station monitoring coverage density for stream water level and groundwater quality; monitoring frequency for rainfall, stream water level, stream water quality and ground water level; percentage of missing or error data for rainfall, stream water level and groundwater quality; ICT-based data collection process for rainfall, stream water level, stream water quality, groundwater level and groundwater quality; data accessibility for rainfall, stream water level, stream water quality, groundwater level and groundwater quality; establishment of waterfront facilities, application of LID and green infrastructures; and water quality standards for stream and groundwater. This implies that the Busan Eco Delta city, and Busan Metropolitan city, exhibit smart water management in facilitating and monitoring of urban water data. Due to the effort of the responsible agencies on the thorough spatial and temporal observation of the hydrological parameters, application of ICT in the observation and accessibility to data, the community can become well aware of the current status of the city's urban water hydrology. The excellent scoring for stream water quality and groundwater quality standards suggests that the current level of pollutants in the water sources are within the acceptable limit, indicating the good health of the urban water. In addition, the high percentage of the application

of nature-based solutions in the construction of pathways, retention facilities, etc. indicates the city's efforts to preserve the quality of urban water through natural procedures.

According to the evaluation, it can be perceived that the city needs improvement in limiting the missing data information specifically for stream water level and groundwater level data. Missing hydrological data can lead to biases in model simulations, leading to erroneous data interpretations that can affect the forecasts of future water level trends. In addition, the number of installed rain gauge stations within the city needed to be improved to properly monitor the changes in the spatial distribution of rainfall in high-dense population areas.

For the administration of water disaster management in Busan Eco Delta City (and Busan Metropolitan City), the effectivity of the city's disaster preparation and mitigation strategies is apparent based on the full score obtained in the following aspects: including the flood property index, flood risk area index, flood hazard mapping, integrated disaster information system, urban flood prediction and early warning, drought damage index, drought information and availability of emergency water supplies, drought prediction system, as well as the implementation of city-scale climate adaptation planning, the usage of renewable energy and implementation of energy saving strategies. The results signify that the city's smart water management performed exceptionally in the prediction and mitigation of localized flood events. This disaster management involves the utilization of modern technologies in flood hazard mapping, application of integrated water disaster information system, city-scale flood and drought forecasting, and flood early warning. The city also facilitates climate preparatory strategies by taking initiatives in climate change actions, adaptation measures, and prioritizing the application of alternative renewable energy sources in public activities. Because of these measures, the city managed to maintain low risks in flood damage and flood-susceptible areas. The efforts conducted by the city to reduce these hazard risks are significant indicators of smart water management.

The analysis emphasized the vulnerability of the city to climate risk events, pertaining to the records of drought events and flood-related casualties occurred in the city in recent years. Even though the city managed well in majority of the water disaster management indicators, some deficiencies are also observed, such as in the relatively low percentage of completed flood preventive structures, as well as the usage of advanced drought forecasting and impact assessment in drought hazard mapping. The construction of levees and dams to prevent river overflow during flood events aids in reducing the risk to urban residents. In addition, modern procedures used in drought hazard development ensure the accuracy and efficiency of drought prediction.

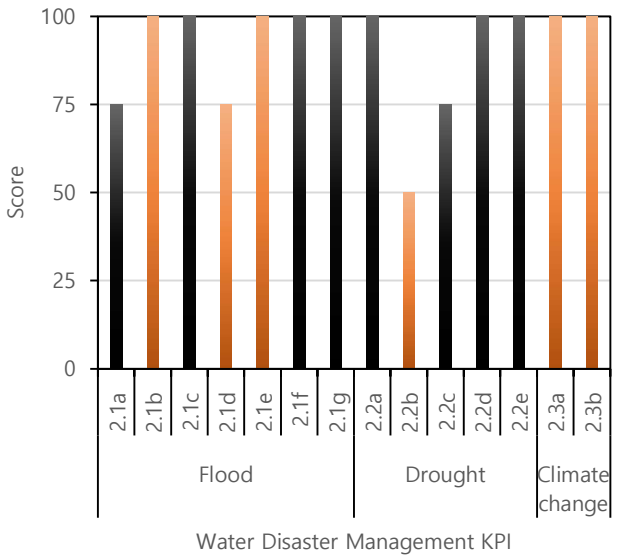

Figure. Busan Eco Delta City smart water evaluation scores on Technical Pillar water disaster management category

Lastly, the city managed to obtain exceptional points in the water supply and treatment management, specifically in the monitoring frequency of water source and waste water; in the application of ICT-based technologies in collection process of water source and drinking water treatment data; in the availability of consumable water and capacity of water treatment plants; in the compliance in the standards of safe drinking water; in the extent of service coverage of water supply distribution; in the accessibility to water source, drinking water treatment and water supply distribution data; in the application of advanced technologies in treating drinking water and waste water; in the maintenance of water supply and sewage pipelines; in the installation of smart meters; in the acceptable quantity of aged pipelines; and in the high percentage of treated waste water that is being recycled. These results demonstrate that the city exhibits smart water city characteristics in the proper management of water supply, drinking water treatment and wastewater treatment. Due to the efforts conducted by the respective agencies facilitating the water supply, citizens can guarantee the safety of drinking water and the extent of services the facilities can make. These indicators also ensure the efficiency of water distribution, minimizing non-revenue water that is critical in water conservation.

However, relatively lower scores are obtained in the application of separated sewage network and recycling of wastewater sludge materials. The implementation of separated storm and sewage system ensures the consistency of storm water flow during flood events, while the application of biowaste recycling helps in the reduction of wastewater byproducts that can affect the health of the ecosystem,

if not disposed properly.

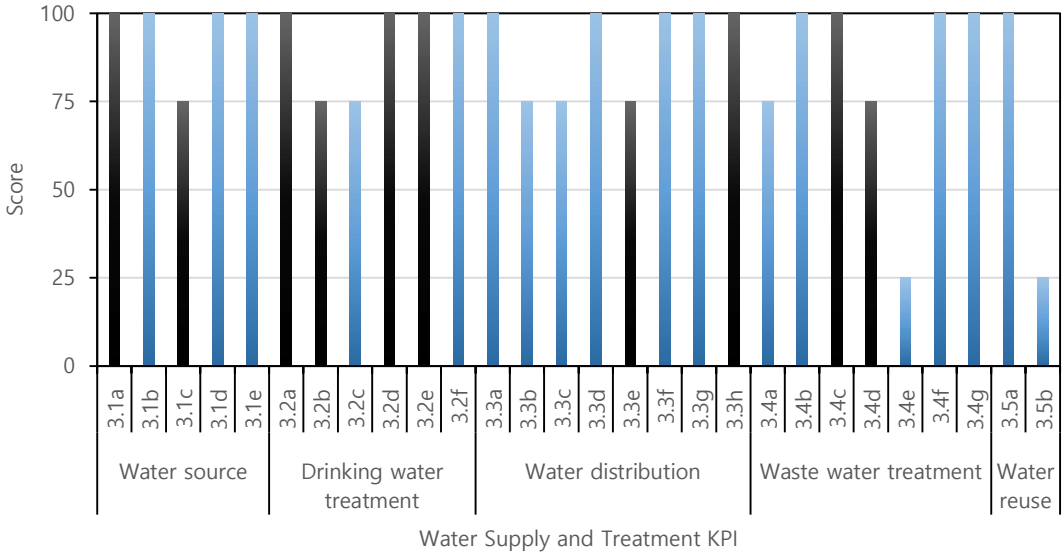

Figure. Busan Eco Delta City smart water evaluation scores on Technical Pillar water supply and treatment category

The overall smart water city assessment of Busan Eco Delta city in all categories of the technical pillar is shown in Table X and Figure X. The overall scoring of the technical evaluation is computed by weighing the Sustainability and Smartness scores.

Table. Busan Eco Delta city smart water city technical evaluation scores

Category	Subcategory	Sustainability score (%)	Smartness score (%)
Urban water cycle	Precipitation	80.0	90.0
	Surface water	82.5	100.0
	Stream water level	100.0	90.0
	Stream water quality	78.8	90.0
	Groundwater level	75.0	90.0
	Groundwater quality	93.8	90.0
Disaster management	Flood	86.3	100.0
	Drought	75.0	92.5
	Climate change	100.0	100.0
Water supply	Water source	100.0	90.0

and treatment	Drinking water treatment	92.5	92.5
	Water distribution	88.8	92.5
	Waste water treatment	87.5	77.5
	Water reuse	100.0	25.0
Technical evaluation total score		88.9	

For the Sustainability aspect, the city scored exceptionally well in Stream water level, Climate change, Water source and Wastewater reuse. This implies that the city is effective in implementing sustainable management in adequately monitoring the stream water level directly affecting the water resource, through the adequate number of installed water level stations, recording frequency, and negligible amount of error data; its initiatives to take climate change actions and adaptation strategies; monitor and manage the city's primary water sources through high monitoring frequency and reliability of water source; and the ability of the city in effectively recycle treated waste water. Under the Smartness category, the indicators under the Surface water, Flood and Climate change achieved full score. This is due to the city's application of low impact development and green infrastructures in naturally aiding the urban hydrological flow, the utilization of advanced flood hazard mapping, integrated disaster information center, and urban flood forecasting and early warning during flood events; and lastly, the city's efforts to maximize the usage of renewable energy and energy saving strategies. The application of these efforts shows the qualification of Busan Eco Delta city to be labelled as a smart water city.

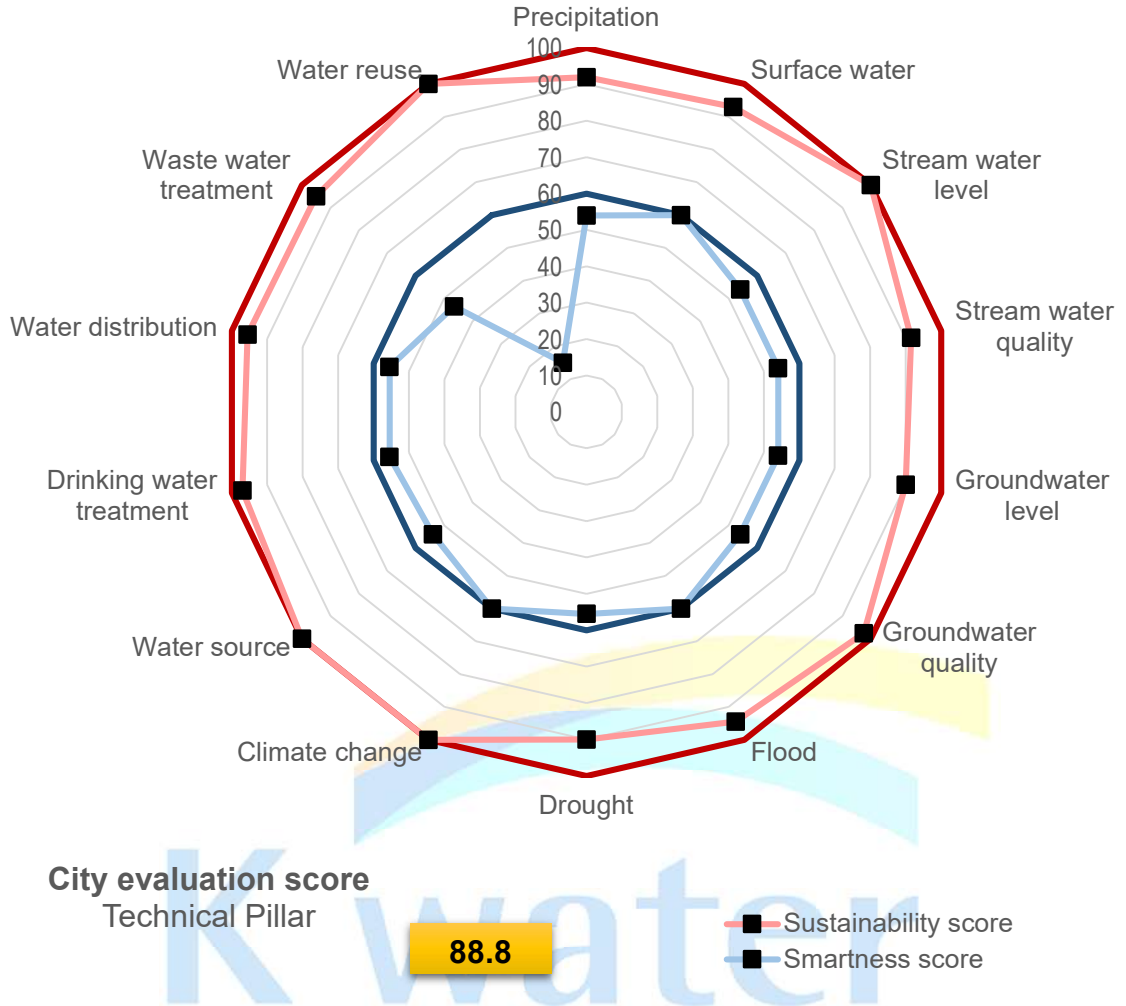

Figure. Busan Eco Delta City final scoring on Technical Pillar

Based on the overall evaluation, the technical assessment of the Busan Eco Delta City highlights the application of smart water city technologies and strategies in the management of its urban water. Smart water cities leverage the usage of advanced technologies and smart water management techniques to optimize the urban water management, ensuring the consistent monitoring, efficient water usage, ensuring the health of the population and the environment. Further improvement can be suggested on the following areas:

Reducing the quantity of errors or missing data in stream water quality and groundwater level observation, through consistent instrument calibration and performing data quality control. Moving forward, it is also advised to provide priority in the installation of separated storm water and sewage water pipelines to prevent flood water contamination in segregating sanitary wastewater and storm

water runoff. It is recommended to find more ways to increase the amount of sludge materials being recycled, such as use as fertilizers in agriculture, use as ingredients in cement making in construction, etc. Lastly, it is advisable to install more rainfall monitoring stations within the city to ensure the accurate recording of rainfall distribution that is critical for city-scale weather forecasting and flood early warning.

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