Water Management Policy of the City of Seoul

Date 2015-07-31 **Category** Water Supply (Arisu) **Updater** scaadmin

Writer

Young-Jun Choi

Affiliation

Waterworks Research Institute

Date

2015-07-31

Last Update

2017-02-10

Water Management Environment & A Changing Paradigm

The concept of water management has existed since prehistoric times. When states were formed, water management became one of the most important pillars of government power.

While water is a resource that people cannot live without, it can also bring irreparable damage. It thus has to be kept in check as well as managed for human use. Reservoirs or embankments would normally be used to maintain water flow but were ineffective as a means to control water during floods (Joongang Daily, 2001).

Until modern times, water management was linear in a sense, and its sole purpose was to manage supply and make the most effective use of it. In other words, people would intervene through social and economic means to utilize and manage the water from the rain that flows

into the rivers and lakes, after which the water would once again be released into the ocean.
Today, water management has to be cyclic in nature in order to meet increasing demands, not simply due to climate change or economic considerations. Water needs to be managed in a sustainable way through the generations because this is what is required by the times. To that end, it is necessary to develop the relevant policies.

While Seoul realized compressed economic growth in a relatively short period of time, its water management system (including waterworks and sewer lines) has also improved dramatically. We will examine Seoul's policy changes and experiences and what lessons can be learned.

Status

Introduction

Seoul sources all its water from the Han River. After treatment, it is piped to taps all over the city.

The raw water the city uses comes from intake points located in Seoul (Gangbuk, Jayang, Pungnap, Amsa) and the City of Namyangju (Gangbuk). As of 2013, the total capacity was 7,120,000 m^3/day. Seoul has 6 purification centers (Arisu Purification Centers) with a daily processing capacity of 4,350,000 m^3, and average production around 3,166,000 m^3/day.
Tap water produced at the purification centers is supplied through a network of pipes to residents, the final users, and the length of those pipes total 13,792 km – greater than the Earth's diameter (12,756.2 km). The key facilities for tap water supply are pumping stations and distribution stations, the latter of which number 104, with a total distribution capacity of 2,418,000 m^3. Even if the water production and supply facilities were to encounter an emergency, everyone would be supplied with water at a normal rate for 17 hours. Facilitating the supply are 196 pumping stations: 4.6% of these are manned, while the rest are unmanned.
As of 2014, the flow rate was 95.4%, one of the best in the world. Leakage is kept very low, within the 3% range.

To respond effectively to algae and new types of unregulated harmful substances, Seoul has been working to introduce advanced purification facilities since 2007, with installation to be complete at all purification centers by 2015.

While the city has one of the world's best tap water production and supply systems, many residents are not confident about the quality of the tap water. Increasing the public's trust through communication remains one of the most important tasks for Seoul. The water flow rate is very low compared to cities in the US or Europe, and is a major detriment to the financial health of the waterworks system, as well as to ensuring its safety and security.

Access to the sewer system in Seoul stands at 100%. As of 2013, 3.16 million m^3/day of sewage water can be processed at 4 water treatment centers, with 3 other facilities dedicated to processing solid human waste (10,500 m^3/day).

Sewer pipes in Seoul were installed with a secondary purpose of draining stormwater (to prevent incidents/accidents) and were used as part of the combined sewer system by connecting to the drainage pipes for domestic wastewater. This, however, resulted in a number of issues such as drainage. From 1992, the city took measures to restore the intended functions of the sewer pipes – the fundamental infrastructure of the city. An internal investigation of its sewer pipes by zone was completed in 2001 to learn more about the conditions, and maintenance was carried out on a systematic basis to replace pipes that were deteriorating, damaged or otherwise unable to properly perform their draining function.

Flooding from heavy rain is largely caused by insufficient sewer pipe and stormwater pumping station capacity. Moreover, climate change is expected to increase the occurrence and severity of torrential rains, while urbanization increases the impervious surface area, exacerbating the potential for flood damage.

In a quantitative sense, Seoul's waterworks and sewer systems are sufficient. One of the policies the government should prioritize for the future is development of an integrated water management system that will improve quality and sustainability. South Korea has enjoyed dramatic quantitative growth and has achieved qualitative stability. Now that Seoul has the waterworks and sewer infrastructure in place, it needs to focus more on improving the effectiveness of operation and management of the facilities. At this juncture, it is imperative that Seoul carefully review the potential for an integrated management system.

Geographic Conditions & Overview

Located in the central west section of the Korean peninsula, Seoul is divided through its center by the Han River. On the northern end of the city is the administrative district called Dobong-dong (Dobong-gu); on the eastern end is Sangil-dong (Gangdong-gu); the southern end is

Wonji-dong (Seocho-gu); and the western end is Ogok-dong (Gangseo-gu). The city is comprised of 25 administrative *gu*-districts, with 423 *dong*-districts. As of December 2014, the population was 10,103,000, or 19.7% of the nation's population 51,328,000. Seoul is 605.41 km² in area, or about 0.28% of the Korean Peninsula (0.61 % of South Korea), and is 30.3 km-long from north to south, and 36.78 km-long from east to west.
When the Joseon Dynasty was founded in 1394, Seoul became the kingdom's capital, which it has remained ever since. It is now the center of politics, economics, industry, society, culture and transportation.
The administrative zone increased to 593.75 km² in January 1963, and by March 1973, encompassed 605.30 km². In the 1970s, rapid urbanization sent developers to the south of the Han River, and through the Asian Games in 1986 and the Olympics in 1988, Seoul entered the world stage.
In 1991, local governments were granted more power to govern themselves through a policy of local autonomy. The year 1994 was the 600th anniversary of Seoul as the capital city.

Seoul is located at 37.34 N latitude and 126.59 E longitude, is divided by the river system of the Han River and 4 streams (Cheonggye, Jungnang, Tan, and Anyang), and surrounded by mountains on all 4 sides. To the north is Bugak Mountain, to the east is Nak Mountain, to the south is Nam Mountain, and to the west is Inwang Mountain. On the outer edge are Bukhan Mountain (north), Deogyang Mountain (west), Gwanak Mountain (south), and Yongma Mountain (east), together forming a double basin.

The city center is at 25–40m altitude, with some 40% of the total area at or below 30m; 27% is above 70m, precluding development as a city area; 27% is at the middle range; and 6% is occupied by the river systems.
To the east, the average altitude is within the 35m range, both north and south of the Han River. In Jongno, Jung-gu, Seongbuk, Seodaemun (all north of the Han) in the center, the average altitude is higher, at around 50m, with a similar situation in the Gwanak and Dongjak areas south of the river. Mapo, west of the Han, and Yongsan to the north are relatively low, at 25m.

River & Water Systems

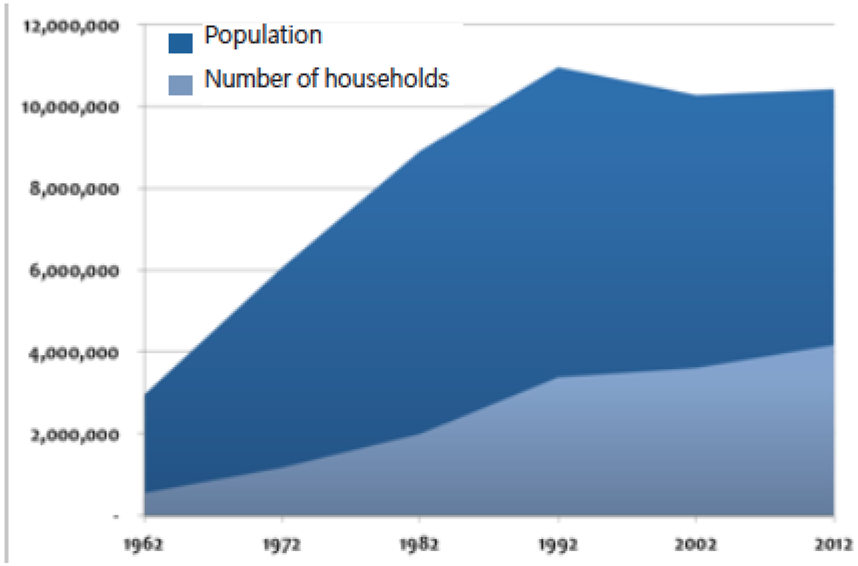
The Han River is formed by the Namhan and Bukhan rivers that converge 35 km upstream to the northeast of Seoul. The river cuts through the center of Seoul from east to west, joining the Imjin River before flowing into the West Sea to the north of Incheon.

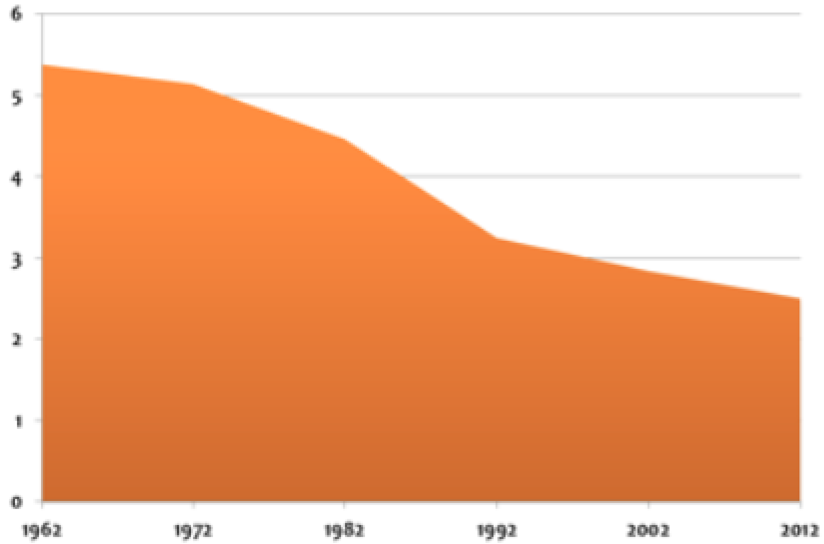
The total length of the Han is 494.44 km, which has a drainage area of 25,953.6 km^2. The effective basin width is 47.19 km, with a shape factor of 1.95. It is a combination of dendritic and fan shapes. The river winds and meanders and is quite wide compared to its length, making it difficult to utilize and manage. Because the river is shorter than might be expected due to the size of its drainage area, the peak flow is high, resulting in considerable flood damage. This phenomenon is concentrated on the gently sloped Namhan River and the main stream. The channel slope is the 1/250 point upstream of convergence, and at the 1/5,000 point of the main stream.
Within Seoul, 36 small and medium streams flow into the Han, with total length of the streams in aggregate being 247.99 km. Stream planning has been divided into zones: Jungnang (Cheonggye Stream, Jungnang Stream), Tan Stream (Tan Stream, Yangjae Stream), Nanji (Bulgwang Stream, Hongje Stream), and Seonam (Anyang Stream).

Changes in Urban Development & the Water Reclamation System

The population of Seoul began growing in earnest in the 1960s when urban development began to take off, and continued to grow until the early 1990s. This growth decreased somewhat in the 1990s but stabilized within the 10 million range in the 2000s (Figure 1).

<Figure 1> Population & Household Changes in Seoul / <Figure 2> Changes in People/Household in Seoul





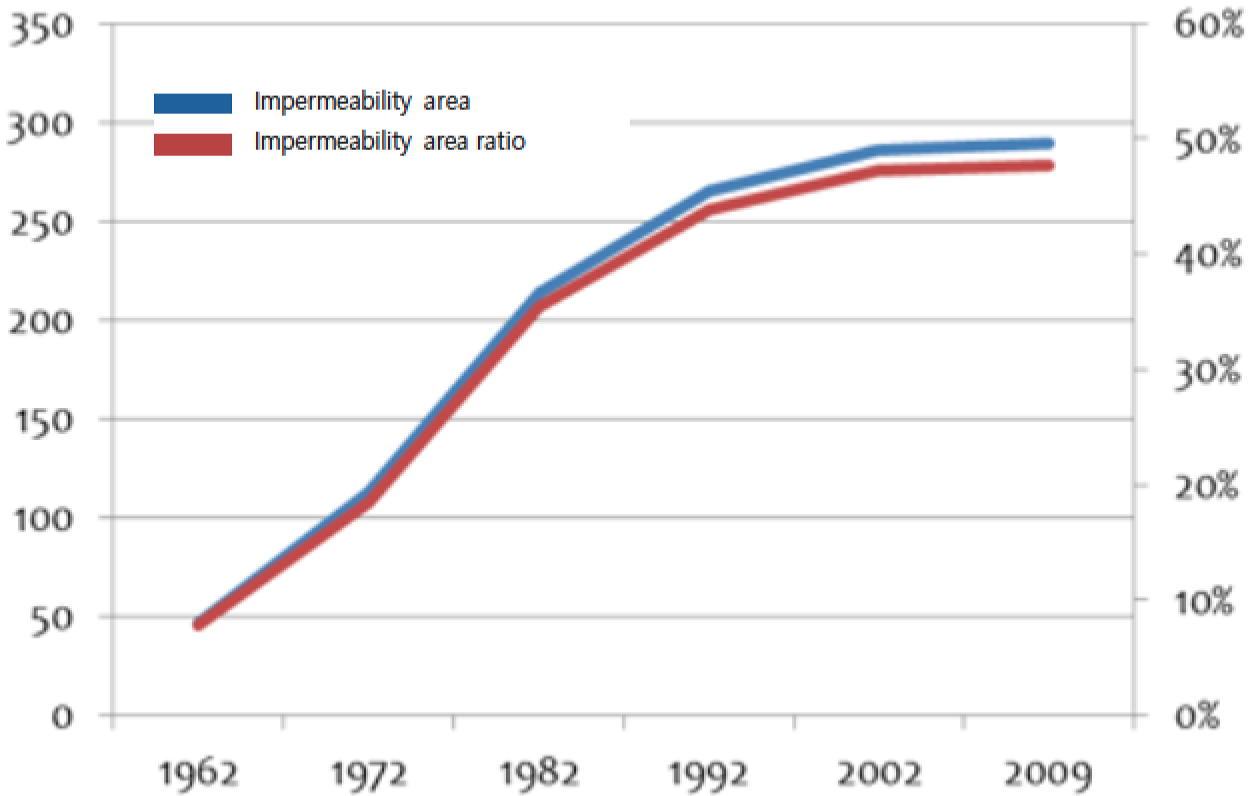
	Population	No. of Households	People/Household	Population Density
1962	2,983,324	554,136	5.38	5,001
1972	6,076,143	1,182,655	5.14	9,912
1982	8,916,481	2,000,678	4.46	14,370

	Population	No. of Households	People/Household	Population Density
1992	10,969,862	3,383,169	3.24	18,121
2002	10,280,523	3,623,929	2.84	16,978
2012	10,442,426	4,177,970	2.50	17,255

The noticeable demographic change during this period is the number of persons per household, which fell dramatically from 5.4 in the 1960s to 2.5 by 2012 (Figure 2). In 2014, the percentage of single-person households exceeded 25%, a trend which is likely to become more dominant in the future. These demographic changes are important factors that affect the pattern of water use and the water reclamation system, and should be taken into account in Seoul's water management policies (Table 1).

Seoul's urbanization began in earnest in the 1960s. Before that time, urbanization policies were mostly focused on restoring the social infrastructure that had been destroyed in the Korean War.
From the 1960s to 2012, the city's population grew 3.5 times, from 3 million to 10 million. The number of households went up 7.5 times, from 550,000 to 4.17 million. However, growth was not confined to population or household. The migrant population and urban concentration accelerated, aided by development of the export industry complex in Guro-dong (1964) and construction of the expressways (late 1960s).
Such a drastic increase in population and urbanization brought about hydraulic changes in the city. One example is the increase of impervious surface area, adversely affecting the water reclamation system (Figure 3).

<Figure 3> Impervious Surface & Percentage of Seoul



The impervious surface area as a percentage of Seoul was 7.8% in 1962 and 47.1% by 2002, an approximately six-fold increase. During the rainy season, surface runoff that had equaled 502,000 m^3/day (1962–1971) had also increased six fold to 2,990,000 m^3/day (1995–2004). The total runoff in the dry season was 375,000 m^3/day between 1962 and 1971, but had fallen to 183,000 m^3/day between 1995 and 2004, a decrease of about 49% (Kim Yeong-ran 2012).

The increase in impervious surface area due to urbanization also brought the peak flow up during heavy rainfall while reducing natural flow,

causing streams to run dry on clear days.
Seoul's population density grew 3.5 times, from 5,001 persons/km^2 in 1962 to 17,472 persons/km^2 as of 2010 (Kim Yeong-ran 2012). The amount of daily floating population from the surrounding satellite cities also jumped. The rising population and density caused many issues in water management such as reduction of the natural flow and increased stream intake, use of groundwater, expelled stormwater and wastewater, incidence of dry stream beds, ecological risks, and urban pollution.

Water Volume & Quality Management

The total volume of water resources in Seoul is 940 million m^3/year, with 690 million m^3/year available for use (Seoul Development Institute, 2011). Water use equaled 13.4 billion m^3/year as of 2009, and is steadily increasing. The water resources reserve accounts for 70.3% of total water use, 12.6 billion m^3/year (94.1%) of which is supplied from outside, while only 78 million m^3/year (5.9%) is sourced internally. The city depends heavily on the outside for its water. This is detrimental not only to overall supply but also to the sustainability of water reclamation in the long term.
With the launch of the Comprehensive Han River Development Plan, more sewage treatment centers were built in the 1980s. The quality of water began to improve thanks to continued construction of septic tanks and sanitation facilities and strengthening of regulations on wastewater discharge facilities. From 1994 however, droughts began to occur in the winter while more domestic wastewater was drained upstream of the Han River from large apartment complexes. The situation was made worse by the increasing number of restaurants and accommodation facilities near the protected reservoir area, degrading water quality again. This degradation continued until 1997 (Seoul

Metropolitan Government, 2014).
The improvement of water quality after 1997 was largely due to action at the government level, including: i) institutional support such as development of the Special Water Quality Management Plan for Paldang Reservoir and the Han River System (1998), enactment and promulgation of the Act on the Improvement of Water Quality & Support for Residents of the Riverhead of the Han River System (1999), and designation of the Jamsil Water Reservoir Protection Area (1995) and Waterfront Areas (1999); and ii) continued efforts to improve water quality by strengthening guidelines and regulations on wastewater discharge facilities (Seoul Metropolitan Government, 2014).

Upstream of the Han, water quality is maintained at a higher level (BOD 1.6 mg/L or lower) than midstream and downstream, where BOD levels are between 2.1 and 2.2 mg/L.
In Jamsil, BOD was 2.6 mg/L in 1997, but from the following year, this began steadily decreasing to 1.7 mg/L in 2004 and 1.4 mg/L in 2005, thanks to measures taken to improve water quality at the upstream reservoir. Since 2006, BOD levels have remained between 1.1 and 1.9 mg/L – 'Good (I b)' – for reasons that include introduction of non-point source pollutants in the dry season and changes in the precipitation and discharge rate from Paldang Dam. At Gayang Point, the level was 5.5 mg/L in 1997, falling to 2.9 mg/L in 2005 and remaining between 2.5 and 4.5 mg/L ('Fair (III)') between 2006 and 2010. After 2010, quality improved again and is normally 2.2 mg/L.
As for the tributaries, the BOD level depends on the quality of the upstream water. Those with higher levels were the Tan (6.9), Jungnang (14.1), and Anyang streams (5.0) (Table 2).

<Table 2> Water Quality Improvement Goals & Performance for the Han River & Major Tributaries in Seoul (Seoul Metropolitan Government, 2014)

	2010	Performance	2011	Performance	2012	Performance	2013	Performance
Jamsil	1.6	1.5	1.5	1.1	1.5	1.2	1.5	1.3
Gayang	3.0	3.1	3.0	2.6	3.0	2.5	3.0	2.2
Jungnang Stream	11.0	8.8	8.0	4.5	7.5	5.8	7.5	14.1
Tan Stream	20.0	10.7	15.0	6.6	13.0	6.4	11.0	6.9
Anyang Stream	8.0	6.9	7.0	4.5	6.5	4.1	6.0	5.0

<Table 3> Han River Water Quality by Point & Parameter in 2013 (Seoul Metropolitan Government, 2014)

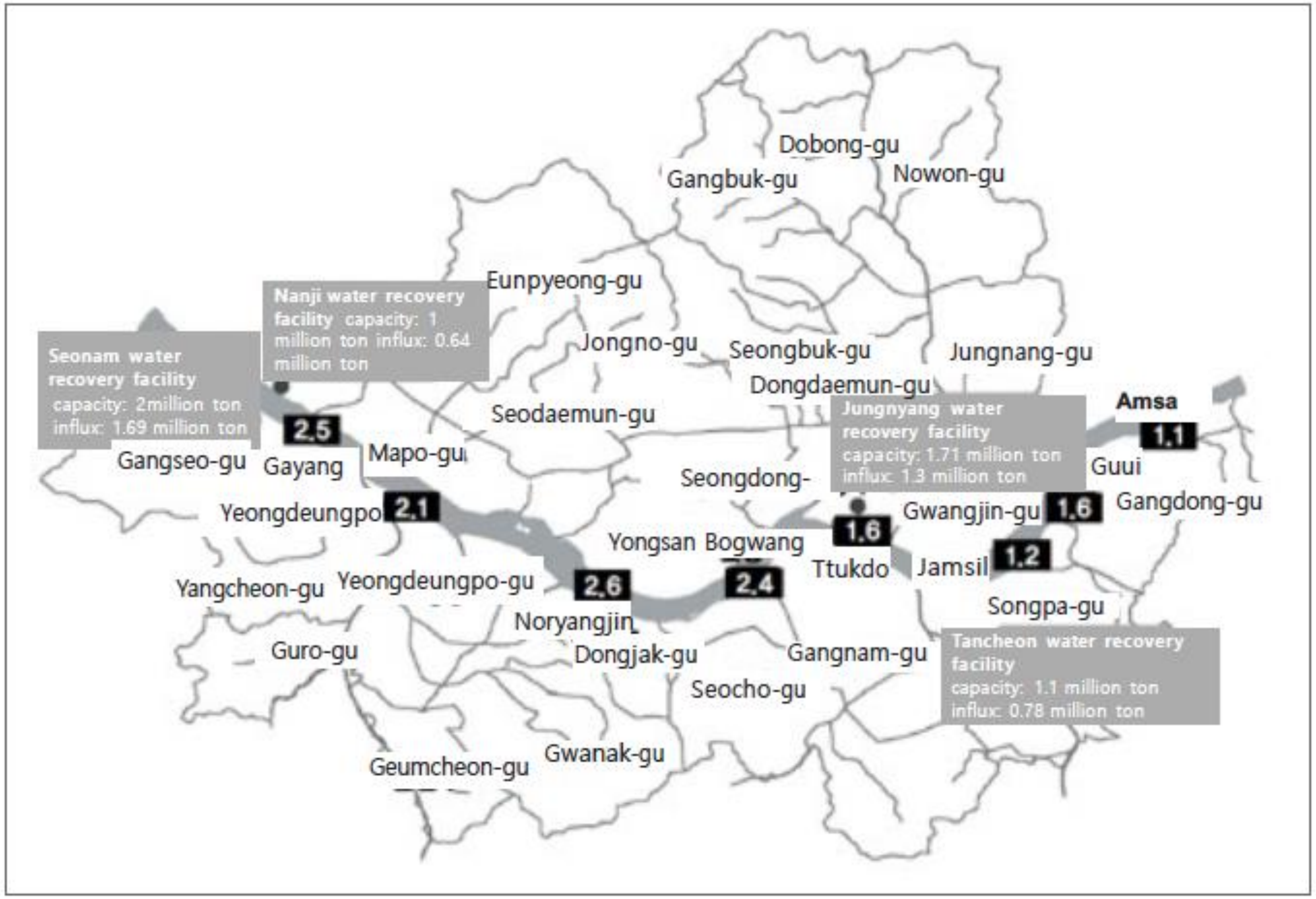
	Item	Amsa	Gueui	Jamsil	Ttukdo	Bogwang	Noryangjin	Yeongdeungpo	Gayang

Environmental (Standards Target)	II	II	II	II	II	II	II	III
Temperature	13.2	13.6	13.2	13.3	13.4	14.0	14.1	14.8
pH	7.9	8.0	7.9	7.6	7.5	7.6	7.4	7.6
DO	11.7	12.0	12.1	11.8	11.5	10.3	10.8	11.0
BOD	1.2	1.4	1.3	1.6	2.1	2.1	2.1	2.2
COD	3.4	3.9	3.6	3.9	4.3	4.7	4.7	4.6
SS	5.9	6.7	6.4	6.9	6.7	8.5	7.4	10.7
Total Coliform Count	10,675	1,346	12,845	24,473	92,482	68,290	53,364	34,461
Fecal Coliform Count	33	163	159	668	3,330	8,862	1,262	1,578
Total Nitrogen	2.156	2.262	2.277	2.649	3.029	3.412	3.481	3.409

Total Phosphorus	0.053	0.035	0.027	0.037	0.069	0.138	0.124	0.118
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND
Cyanide	ND	ND	ND	ND	ND	ND	ND	ND
Lead	ND	ND	ND	ND	ND	ND	ND	ND
6 Chromium VI	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	ND	ND	ND	ND	ND	ND	ND	ND
ABS	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	ND	ND	ND	ND	ND	ND	ND	ND

<Figure 4> Water Quality at Major Points Along the Han River (BOD mg/L) & Water Renewal Facilities

(㎥/day)



Stream water quality has been measured by the city and provincial institutes of public health & environment since 1974. The Ministry of Environment built an online national network in 1992 to collect the data on a regular basis. As of 2013, there were 443 points for water quality measurement on the Han River system. On the river segments in Seoul, there are 8 points on the main river and 19 points on the tributaries (Figure 4). A total of 36 parameters are measured at regular intervals (monthly, quarterly, or yearly) (Table 3).

Upstream Reservoir & Stream Management Policies

So far, policies implemented to preserve water quality of the Han River have focused on installation of sewage treatment facilities in urban areas and management of the sources of pollution. However, quality management of Han River water is only of limited scope without management of non-point source pollution inside the city. Many development projects (industrial complexes, site development, farmland and forest management, roads, parking lots, etc.) have been pursued without much consideration for non-point source pollution. As pollution from such city sources continues to affect the Han, a new approach is imperative that takes non-point source pollution into account.

Foundation for Basic Environmental Protection Facilities

The 4 water treatment centers of Jungnang, Nanji, Tancheon, and Seonam were processing a total 3.16 million m^3/day as of the end of 2013, an amount which covers all wastewater produced in Seoul. Facilities capable of processing 1.75 million m^3/day will be installed at the 4 centers to comply with stronger discharge water quality standards and the assigned total maximum daily load.

Stronger Management of Wastewater Discharge Facilities

Wastewater discharge facilities subject to guidance and inspections are provided with continued guidance and inspected by the SMG. They are encouraged to replace any deteriorating facilities and improve their efforts to prevent industrial wastewater from contaminating the water supply (Seoul Metropolitan Government, 2014).

Citizens Environment Watch

To monitor for and stop pollution, a Citizens Environment Watch was organized in 2004 and is a collaborative organization involving regulatory authorities, local residents, and private entities. Designed to jointly address pollution, it will lead to the establishment of a private-public environmental watch network which will enhance transparency and effectiveness of the guidance and inspection of pollutant discharging facilities while ensuring that the environmental watch and preservation activities are led by the private sector.

Water Pollution Alert

The Water Pollution Alert system was initiated in 1998 in response to dead fish found in the Han River and its tributaries and has been in practice ever since to respond to other such incidents.

Automatic Monitoring System

A full-time monitoring system was introduced to prevent water pollution from the introduction of harmful chemicals into the streams, sewer pipes, and receiving waters at the water renewal facilities, while minimizing damage should such contamination occur. The system is designed to monitor for and track unauthorized discharges.

The automatic system looks at 14 parameters, including cyanide, at 9 points on the main river (6 at the upstream reservoir and 3 at the streams themselves) and at 3 points along the tributaries. The water is monitored at 8 points for the presence of any of sixteen harmful chemicals, including the receiving water at the treatment center. Furthermore, oil fences and oil absorbents are available to handle oil spills, and emergency simulation training is held at the Han River every year.

<Table 4> Protection of Han River Water Source (Seoul Metropolitan Government, 2014)

Category	Paldang Reservoir Protection Area	Special Paldang Reservoir Preservation Area	Nature Preservation Zone	Jamsil Reservoir Protection Area	Waterfront Area
Date Designated	July 9, 1975	July 19, 1990	December 31, 1982	March 20, 1995	September 30, 1999

Legal Basis	Article 5, Water Supply & Water-works Installation Act	Article 22, Frame-work Act on Envi-ronmental Policy	Article 6, Seoul Metropolitan Area Readjustment Planning Act	Article 5, Water Supply & Water-works Installation Act	Article 4, Act on the Improvement of Water Quality & Support for Residents of the Riverhead of the Han River System
Area	159	2,102	3,831	6.45	191.3
Jurisdiction	4 cities and *gun* counties in Gyeo-nggi Province	61 *eup/myeon* districts in 7 cities and *gun* counties in Gyeonggi Province	3 *gun* counties in 5 cities and *gun* counties in Gyeo-nggi Province	Upstream of Jamsil Reservoir, Gwang- jin-gu, Songpa-gu, Gangdong-gu, and nearby riverside areas	6 cities and *gun* counties in Gyeo-nggi Province, 2 cities in Gangwon Province, Chungju in North Chungc-heong Province

Description	Restrictions on fishing, car washing, and other potentially polluting activities in the protected area	Special compre–hensive plan for preservation of upstream reservoir (installation of basic environ–mental protection facilities, special pollution source management, change of intended use in certain districts)	Restrictions on de–velopment of sites, industrial lots, and tourist attractions that increase the population	Restrictions on fishing, boating, car washing, and other potentially polluting activities in the protected area	Restrictions on installation of accommoda tions, public bath facilities, and facilities that gen–erate general and livestock wastewa–ter

Total Maximum Daily Load

The water systems are divided into unit zones by total maximum daily load, with each zone assigned a water quality target and a total maximum allowed production of pollutants to maintain that target. Existing regulations on concentrations are limited, considering the unique environmental characteristics and concentration of pollutant sources for each zone. This new system was introduced to adopt a more effective, scientific approach, assigning more responsibility to the involved parties.

The maximum load system was made mandatory for the Han River system, as for the Nakdong, Geum, Yeongsan, and Seomjin rivers, after revision of the Act on the Improvement of Water Quality & Support for Residents of the Riverhead of the Han River System on May 31, 2010. Accordingly, Seoul established a Framework Plan on Total Maximum Daily Load. An Action Plan on Total Maximum Daily Load was also established for unit zones where the target set by the Minister of Environment is exceeded. The system went into full effect in June 2013.

The Water Use Fee System

Water use fees are charged to areas downstream of the Han River system to finance the assistance that goes to residents and organizations living and operating in the upstream reservoir protected area and are under various restrictions due to measures to protect the water source. Installation and operation of basic environmental protection facilities and the purchase of land that may have a serious impact on the quality of the upstream water are also eligible for financial assistance from the water use fee system. This system was introduced to promote the prosperity of both the upstream and downstream regions of the Han. A certain amount is charged to final users who use water from the upstream source.

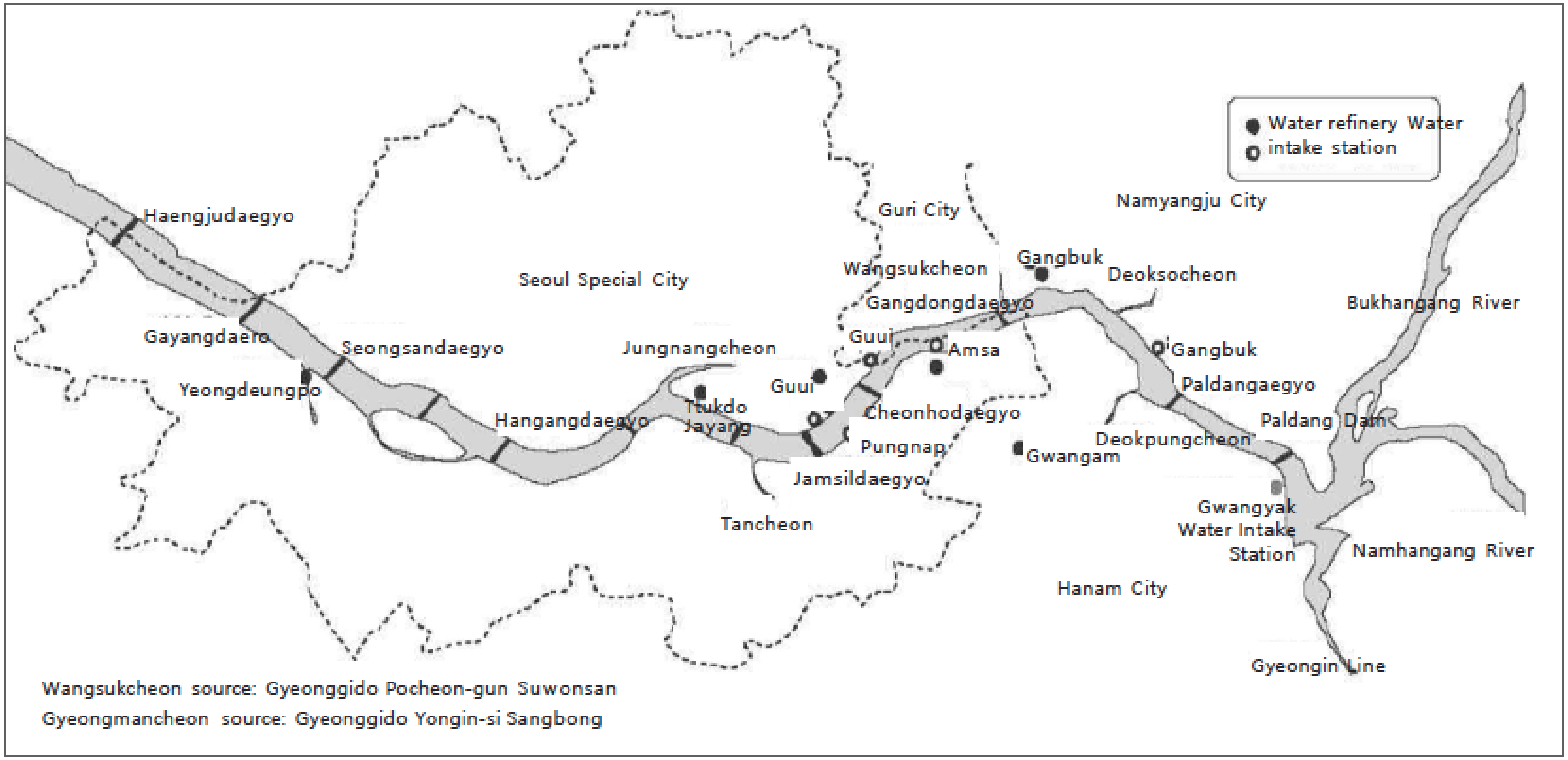
The collected fees are used in the following ways: purchasing of land in the water reservoir protection and waterfront area; resident assistance programs; as a proportion of local contributions for installation/operation of basic environmental protection facilities by local governments in the upstream reservoir area; operation of the Han River Watershed Management Committee; assistance for environmentally-friendly programs; and other programs launched as per the presidential decree towards improvement of the water quality of the upstream reservoir.

Changes in Waterworks Policies

Modern waterworks service began in Seoul when two Americans, Henry Collbran and Harold Bostwick, obtained permission from Korea's Emperor Gojong to operate waterworks facilities and built a purification center in Ttukdo, which was completed on September 1, 1908, to supply water. At the time, the production capacity was 12,500 m^3/day, with water supplied to 125,000 people.

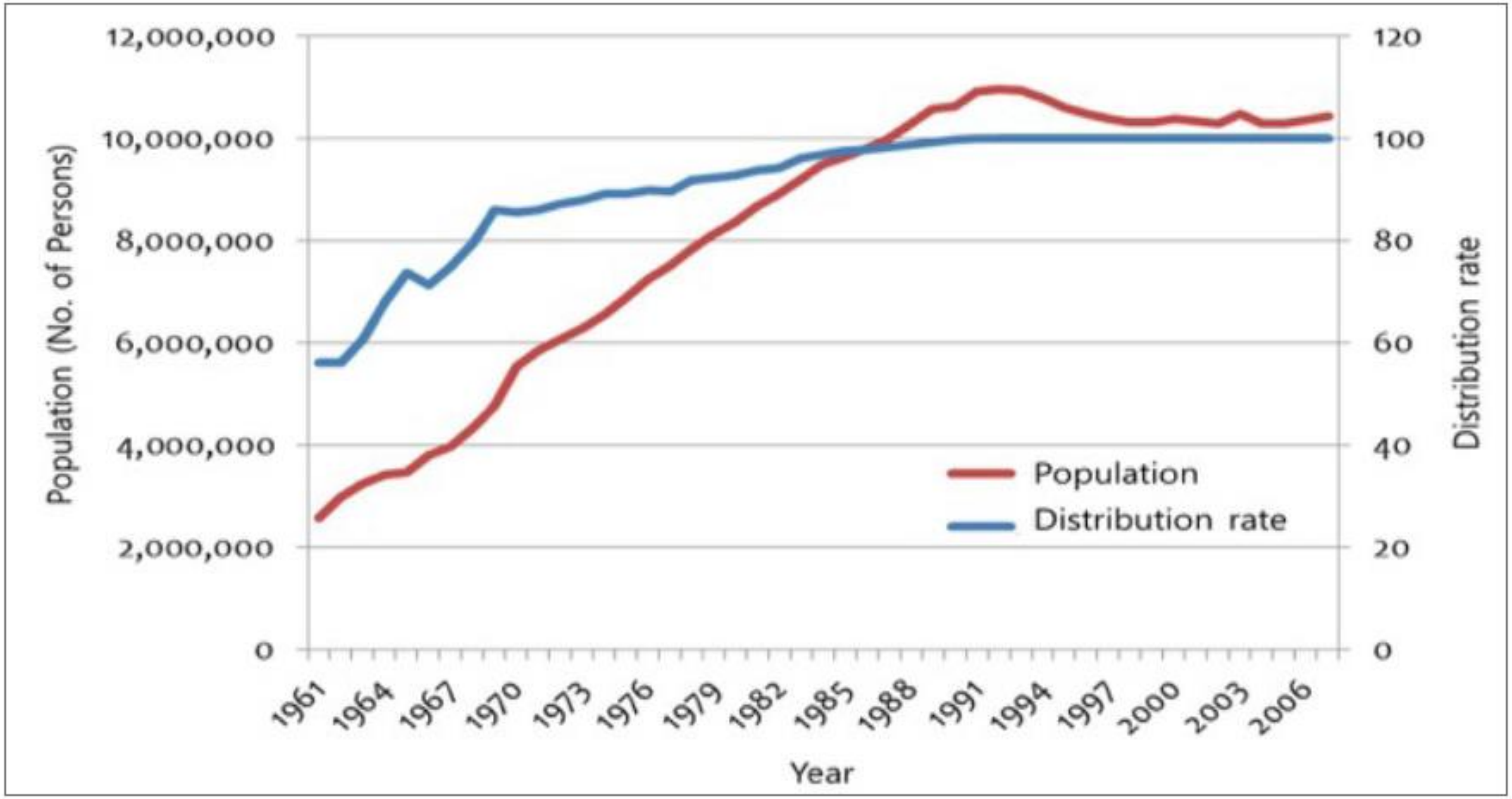
In 1946, 3 purification centers were built, a number which grew to 5 by 1977. By 2004, some parts of the aging Gueui Purification Center and the purification centers in Noryangjin, Shinwol, Seonyu and Bogwang were closed. Today, there are 6 purification centers (Gwangam, Amsa, Gueui, Ttukdo, Yeongdeungpo, and Gangbuk) (Figure 5). As of the end of 2013, production capacity was 4.35 million m^3/day, and the waterworks service rate is 100%, meaning all citizens have access to the waterworks.

<Figure 5> Intake Points in Seoul (Seoul Metropolitan Government, 2014)



As mentioned, in 1908 the purification capacity was 12,500 m^3 of water per day, supplied to 125,000 people. As of the end of 2013, the capacity was 4.35 million m^3/day, giving access to some 10.38 million people, representing and 348-fold increase in facility capacity and an 83-fold increase in the number of people with access.

<Figure 6> Waterworks Service Rate in Seoul



Until 1992, facility capacity was insufficient for water demand, and there were difficulties with operation and supply. After 1998 however, the facilities reached sufficient capacity, ensuring stability of supply (Figure 6). In 2013, 11.6 billion m^3 of tap water was used in Seoul, with the daily average being about 3.19 million m^3.

Introduction of Advanced Purification Facilities

From the 1960s to the 1980s, the major focus of waterworks policy was on quantitative expansion, but thereafter, policies began targeting the assurance of water quality and stability of supply.
Into the 2000s, the city's waterworks system improved in both quantitative and qualitative terms, and the policies focused on providing taste-free, safe tap water to residents.
Alongside these changes, there was a growing need for countermeasures to potential degradation of water quality at source and pollution due to climate change and urbanization. Accordingly, more advanced purification facilities were introduced. With the Ttukdo Arisu Purification Center as the last target in 2015, all purification centers will have installed these advanced purification systems. The currently-installed system is primarily focused on controlling odor- and taste-generating particles from algae, but also seeks to respond to the potential for issues to be caused by new trace particles. When these new facilities are completed in 2015, the citizens of Seoul will have access to cleaner, safer tap water.

Flow Rate Improvement

When the Seoul Metropolitan Government's Office of Waterworks was launched in 1989, the flow rate in Seoul was 55.2%. By 2000, it had jumped to 72.0%, and by 2014 to 95.1% – a level of success unprecedented in the world. Flow rate refers to the amount collected in fees as a percentage of the tap water produced and supplied by a purification center. For instance, the flow rate is 90% if 100 m^3 of tap water is supplied to users and fees collected amount to the cost of producing 90 m^3 of tap water. The higher the flow rate, the lower the outside funding necessary for production and supply (e.g., raw water acquisition, purification chemicals, power, etc.), thereby improving the financial health of waterworks management. From 1989 to 2013, the flow rate improved by 39.2% (55.2% [1989] → 94.4% [2013]); in financial terms, this is equivalent to savings of KRW 4.665 trillion (by unit price) since the launch of the Office of Waterworks.
Seoul has been able to improve flow rate in several ways: continuing to repair old, leak-prone pipes; securing distribution stations; and

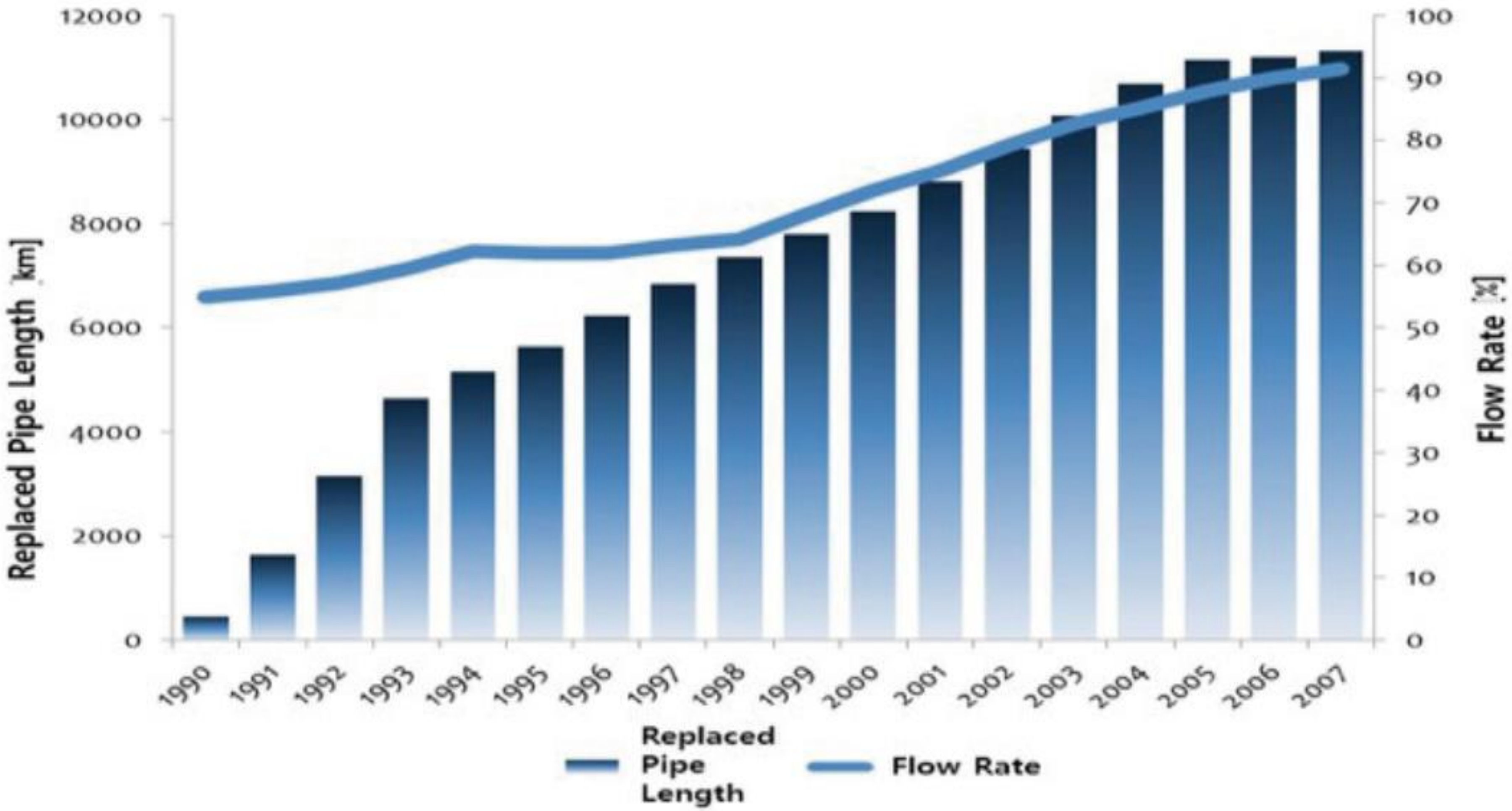
switching to a run-of-river type to stabilize the water pressure and prevent related leaks. In addition, a flow monitoring system was adopted to monitor the flow and water pressure in real time. An effective leak detection method was employed as well. Seoul was divided into 2,037 small blocks and systematic leak detection carried out to quickly identify leaks and take appropriate action. Medium blocks (100 as of 2013) were also set up to analyze and manage flow rate at the medium block level.

By 2017, Seoul aims to increase flow rate to 96.5% and will work to find the latest technologies that will improve and lead to its better management.

Distribution System Management

There were 13,721 km of distribution pipes installed in Seoul as of 2014. To improve water quality and flow rate in the process of distribution, Seoul replaced deteriorating piping (13,192 km of all 13,728 km) between 1984 and 2013. By 2018, all deteriorating pipes will be replaced (Figure 7).

<Figure 7> Improved Flow Rate After Pipe Replacement

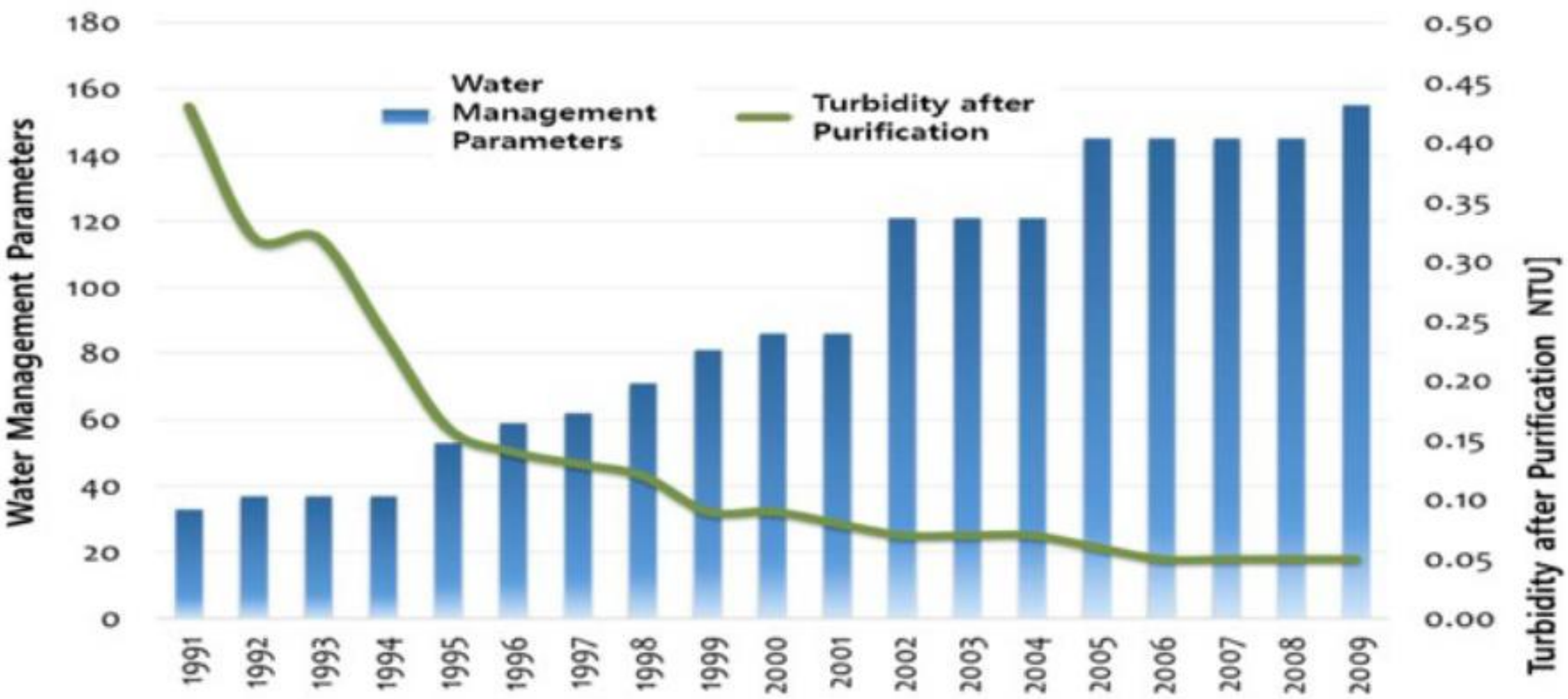


The distribution stations are capable of processing 2.42 million m^3 of water, equal to about 13.9 hours of supply in case of an emergency. The capacity will be increased to 2.48 million m^3 by 2030, to provide about 15 hours of emergency supply. This will enable constant and direct supply that does not require water tanks at the customers' end. The stability of water supply will be considerably enhanced, not to mention higher water quality during the process of distribution.

Water Quality Management

In 1990, South Korea had 28 water quality inspection parameters. The number of parameters has gradually increased, and as of 2013, there were a total of 85 – 59 statutory and 26 general monitoring parameters. As of 2012, Seoul conducted regular inspections according to 164 parameters (59 statutory and 105 parameters set by the city [including parameters from the Ministry of Environment]) (Figure 8).

<Figure 8> Changes in Water Quality Management (Parameters) & Purified Water Quality (Turbidity)

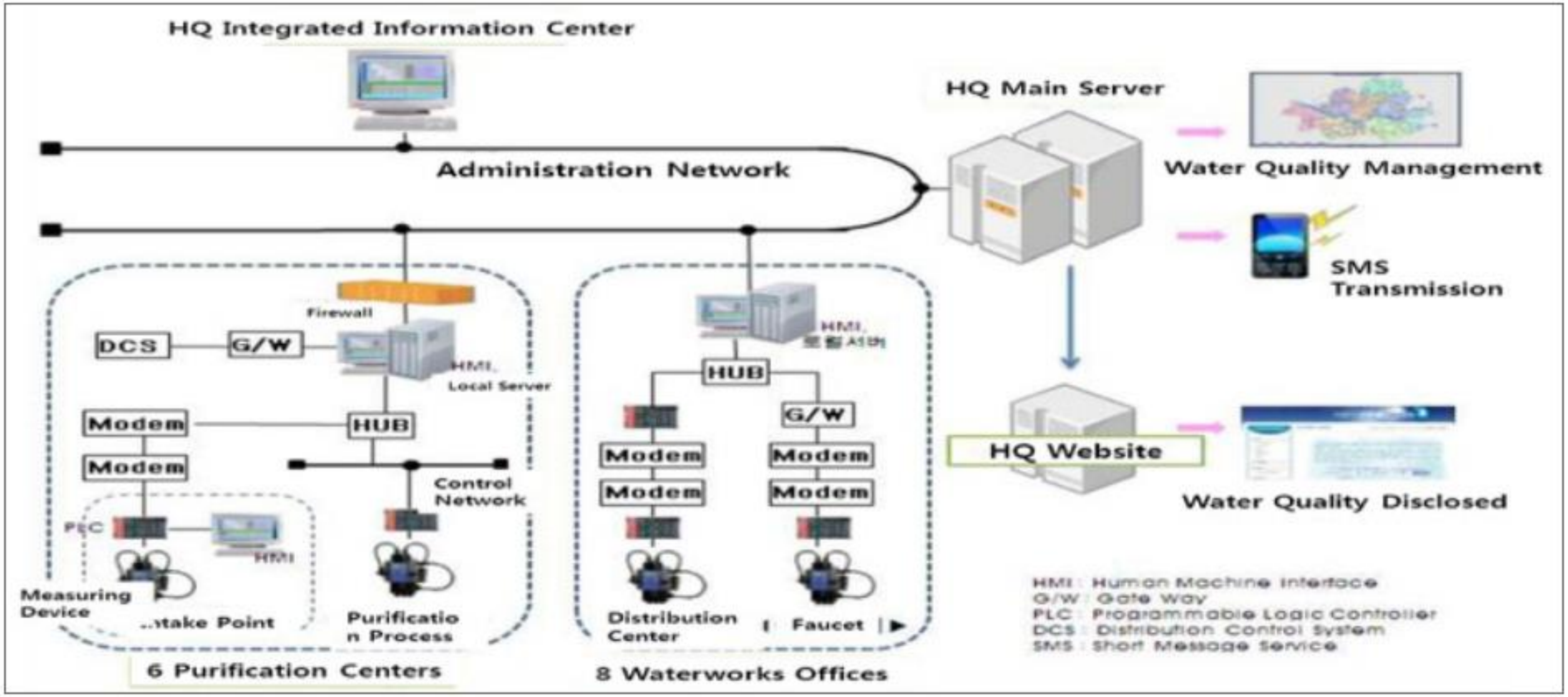


Seoul Water-Now System

The Seoul Water-Now System monitors water quality in real time 24 hours a day, from source to faucet. Monitors are installed at 200 locations: intake points, purification centers, distribution stations, pumping stations, parks, and faucets (during the supply process) (Figure 9). The water quality thus monitored is disclosed to the public in real time to enhance transparency and reliability of waterworks administration. The

Seoul Water-Now System has been recognized by the international community for its excellence in providing administrative services to satisfy residents' right to know and to protect their health. Along with Arisu Quality Certification, it won the grand prize at the UN Public Service Awards (UNPSA) on June 23, 2009.

<Figure 9> Seoul Water-Now System



During the Joseon Dynasty, sewage flowed on street surfaces or in low-lying areas, passing through low ditches and flowing into the streams or underground. There were virtually no facilities or efforts at management. However, Cheonggye Stream, one of Seoul's major streams, had undergone dredging and other related works. In the 12th year of King Taejong (1412), full construction works were carried out at Cheonggye Stream and other streams so as to prevent them from flooding.

During the years of the Korean Empire (1897-1910), a 6,832 m-long culvert was built as part of the city sewer project, making it the nation's first modern sewer pipe. Since then however, there is no record of maintenance or management.

The modern concept of a sewer system was applied when the 225 km-long main and branch sewer lines were installed over 4 occasions, from 1921 to 1945, after Korea was forcibly annexed by Japan. This system was constructed to prevent pollution from urban flooding and wastewater and to process fecal material that was being discharged without control.

Until the 1960s, the main purpose of the sewers was to expel stormwater from the city, and lines were built in efforts to improve the street environment. After that decade, South Korea began experiencing dramatic economic growth accompanied by rapid industrialization and urbanization, improved quality of life, and change of method in treatment of fecal material, amplifying the pollution load from wastewater. Accordingly, people began to take interest in the construction of sewage treatment facilities and a separate sewer system.

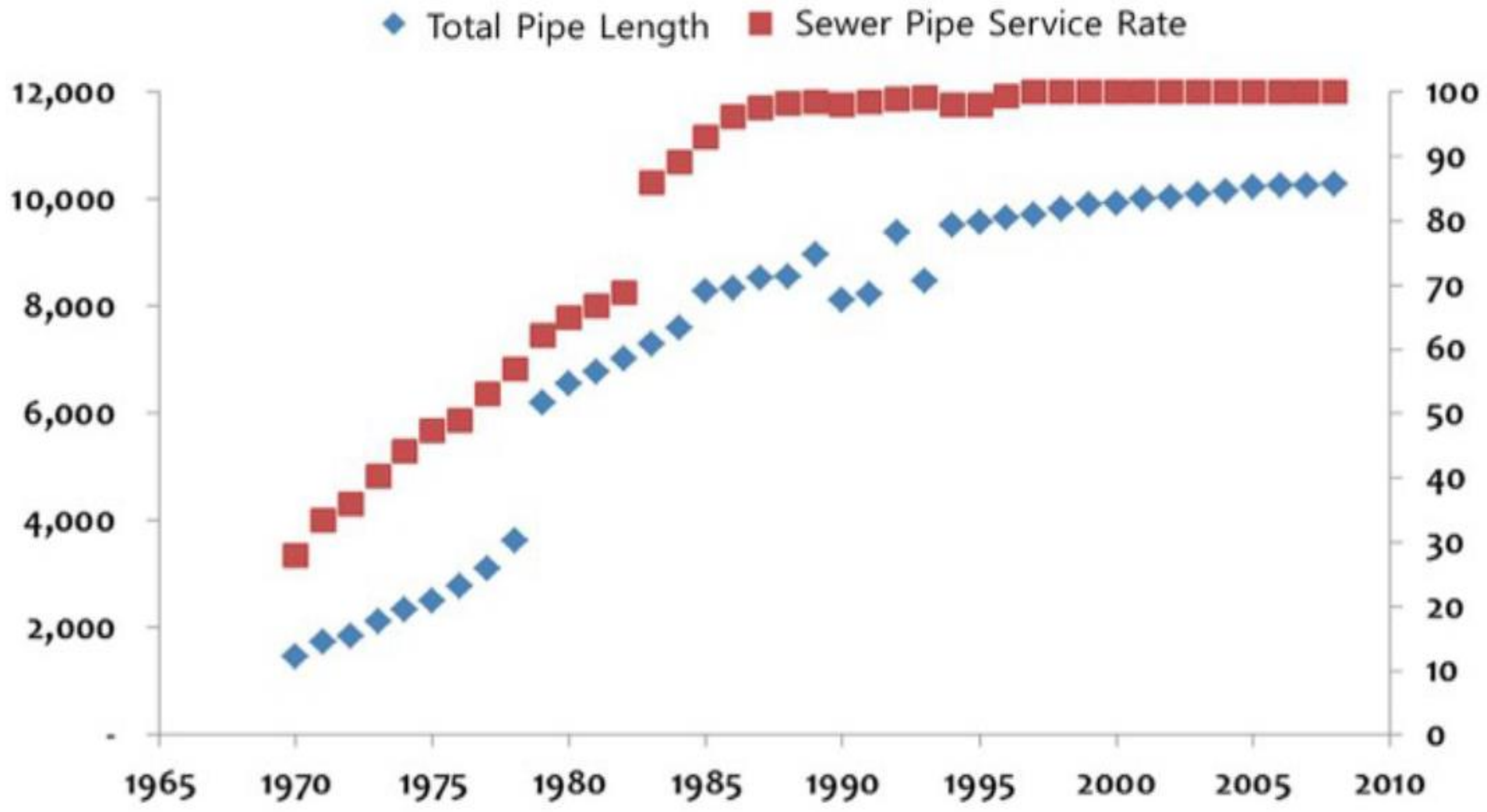
The sewer system as we know it began, thanks to international aid South Korea received since 1954 for post-war restoration.

In 1959, the first construction to cover Cheonggye Stream began. In 1966, the Sewerage Act was passed, and the Cheonggye Stream Wastewater Treatment Center (150,000 m^3/day) began construction with a USAID loan, and was completed in 1976. The early 1960s were politically challenging for South Korea, but this did not stop the government from pursuing the sewage system project. Consequently, the pre-1961 sewer pipe network more than doubled in length from 631 km to 1,462 km (Figure 10).

The 1970s was a decade of sewer expansion: the existing sewer system was actively repaired while new facilities were built and renovated with fervor.

From 1987, the number of wastewater treatment facilities jumped, mainly to prepare for the Olympics in 1988. Between 1986 and 1999, sewerage capacity grew 39 times, from 150,000 m^3/day to 5.81 million m^3/day.

<Figure 10> Sewer Pipe Length & Service Rate in Seoul



In 2005, the purpose and concept of wastewater treatment were clearly defined. To ensure that the system remains sustainable and ready for future climate changes, the facilities, usually referred to as wastewater treatment facilities, were called water treatment centers.

In line with higher standards on water discharged from water treatment centers, an advanced treatment system was introduced. In 2007, the new system, which had a capacity of 460,000 m^3/day, was applied to Jungnang Water Treatment Center; by 2012, the system was also installed at 4 other centers, representing a total capacity of 3.91 million m^3/day. At Jungnang and Seonam water treatment centers, the system was installed while some of their facilities were incorporated into the underground system. The aboveground space was modernized and transformed into a park for local residents (Table 5).

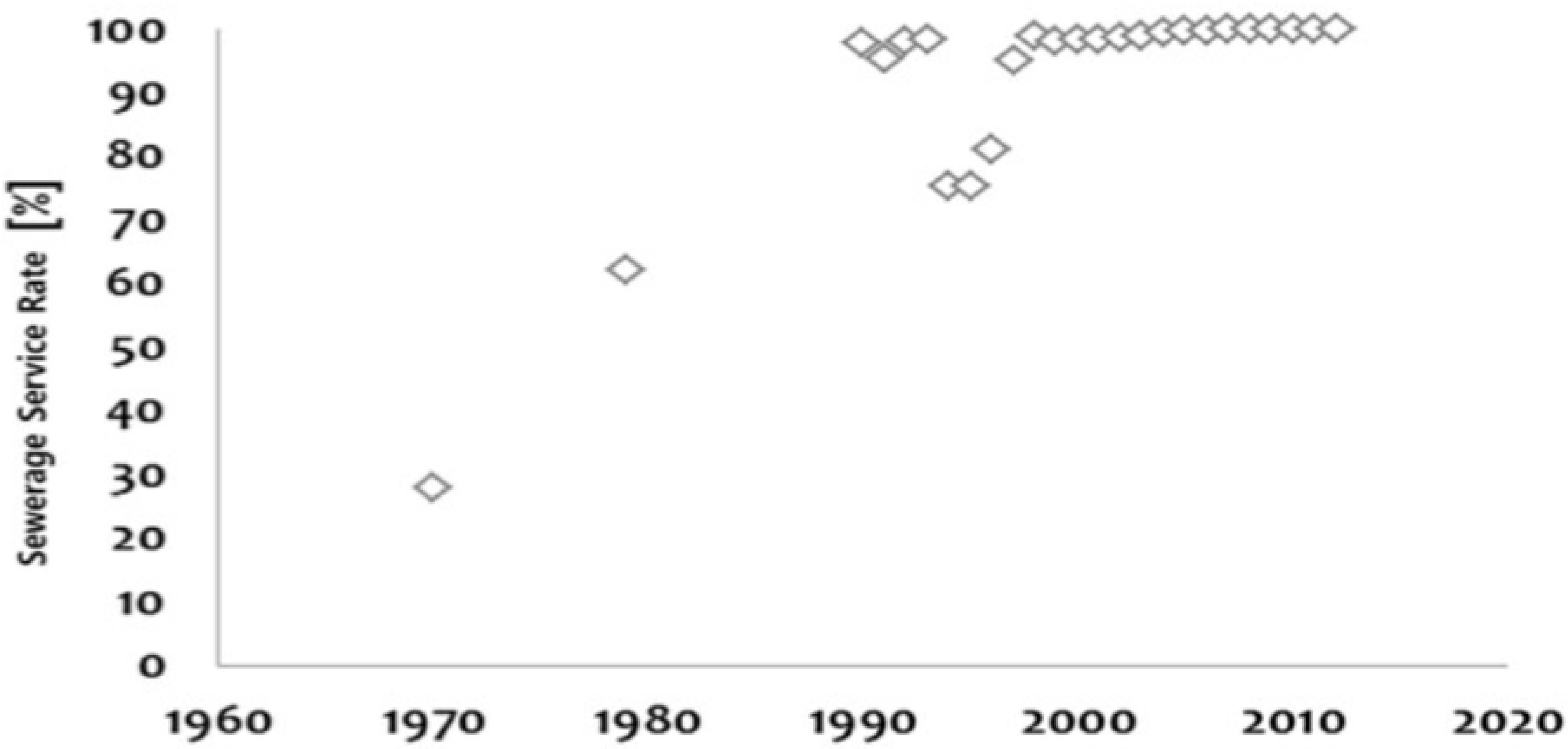
<Table 5> Introduction of Advanced Treatment System in Seoul

Category		Total	Jungnang	Nanji	Tancheon	Seonam
Capacity	Advanced Treatment	391	88	86	90	127
	Facility Modernization	61	25	–	–	36
Cost		774,717	327,220	48,120	93,377	206,000

Category	Total	Jungnang	Nanji	Tancheon	Seonam
Construction Period	2009/1 – 2018/12	2009/2 – 2016/12	2009/7 – 2013/4	2009/1 – 2013/5	2009/11 – 2018/12

As mentioned earlier, focus was placed on quantitative expansion of sewerage capacity in the late 1980s. Sewer pipes were added and improved as well. The total length of the sewer network, which was 6,559 km in 1980, had increased 1.4 times to 9,122 km by 1990. In each year since, 200 km of piping has been improved.

<Figure 11> Sewer Service Rate in Seoul (Ministry of Environment, 2015; Seoul Metropolitan Government, 2010)



In the 1990s, projects were implemented to restore the functions of sewer pipes as they are fundamental urban facilities that protect the environment. From 1992 to 2001, the network was examined by zone to replace deteriorating and damaged pipes in a systematic manner (Table 5).

By 2007, all citizens had access to the sewer system. From then on, Seoul placed more focus on quality management of the system, user satisfaction, and policy tasks designed to ensure safety (Figure 11).
Such change and policy direction for the future are well represented in the 2020 Seoul Sewerage Vision. The policy directions as seen in the Vision are as follows:

- Enhanced capabilities to prevent potential disasters caused by climate change;
- Efficient and systematic repair and maintenance of deteriorating pipes;
- Improved living environment and services to the public;
- More realistic water billing to secure sufficient financing;
- Advanced sewage treatment and modernization;
- People-friendly water treatment centers;
- Reduced energy consumption at water treatment centers;
- Operational efficiency at water treatment centers;
- Launch of renewable energy programs.

Restoration of the Environment & Ecosystem

Restoration of the environment and ecosystem, one of Seoul's water management policies, and policy indicators and objectives are well described in the Seoul Water Quality and Ecosystem Preservation Plan 2014-2018 (Seoul Metropolitan Government, 2014). The vision of this plan is to create a "City with a Healthy Water Environment for Peaceful Cohabitation of People and Nature" so as to restore the balance of the city's aquatic ecosystem. The Plan includes 5 strategies and 12 programs (Figure 12)

<Figure 12> The Seoul Water Quality & Ecosystem Preservation Plan: Strategies & Programs (Seoul Metropolitan Government, 2014)

Vision: City with a Healthy Water Environment for Peaceful Cohabitation of People & Nature

Strategy	Revise Management goals in line with changes in water environment	Restore aquatic ecosystem health	Build a sustainable water circulation system	Reduce discharge of pollutants into stream and river systems	Build a watershed Management oriented system
Program	1. Go from BOD-Orientation to a COD and T-P focused management system 2. Improve advanced treatment facilities to reduce T-P and non-degradable organic compounds	1. Expand natural eco-system and river system restoration programs 2.Develop/preserve waterfront wetlands and restore the ecosystem 3.Aquatic ecosystem inspections and assessments	1.Improve water reuse and circulation system 2.Preserve instream flow of the river ecosystem	1.Repair sewer pipe system and overflows 2.Manage the Combined Sewer Overflows	1.Maintain a measuring network for effcient management 2.Assess total maximum daily load and monitor water quality 3.Strengthen watershed management by involving local residents

Plan Indicator

- Expand river ecosystem, restoration, and maintenance programs
- Increase percentage of segments rated "Fair" or higher in the aquatic ecosystem health assessment to 23% or higher (Diatom Index(1D Fair))
- Improve BOD (Biochemical Oxygen Demand) ratio to 71.4% or higher

Besides steps to preserve water quality and the ecosystem, the Plan also includes action and strategies that encompass the entirety of the sustainable water reclamation system.

This is significant in that it changes the policy paradigm from water quality management to preservation and maintenance of a healthy aquatic ecosystem through various means, such as restoring stream and river ecosystems to their natural, healthy state, and conducting assessments and inspections of those ecosystems (Table 6)

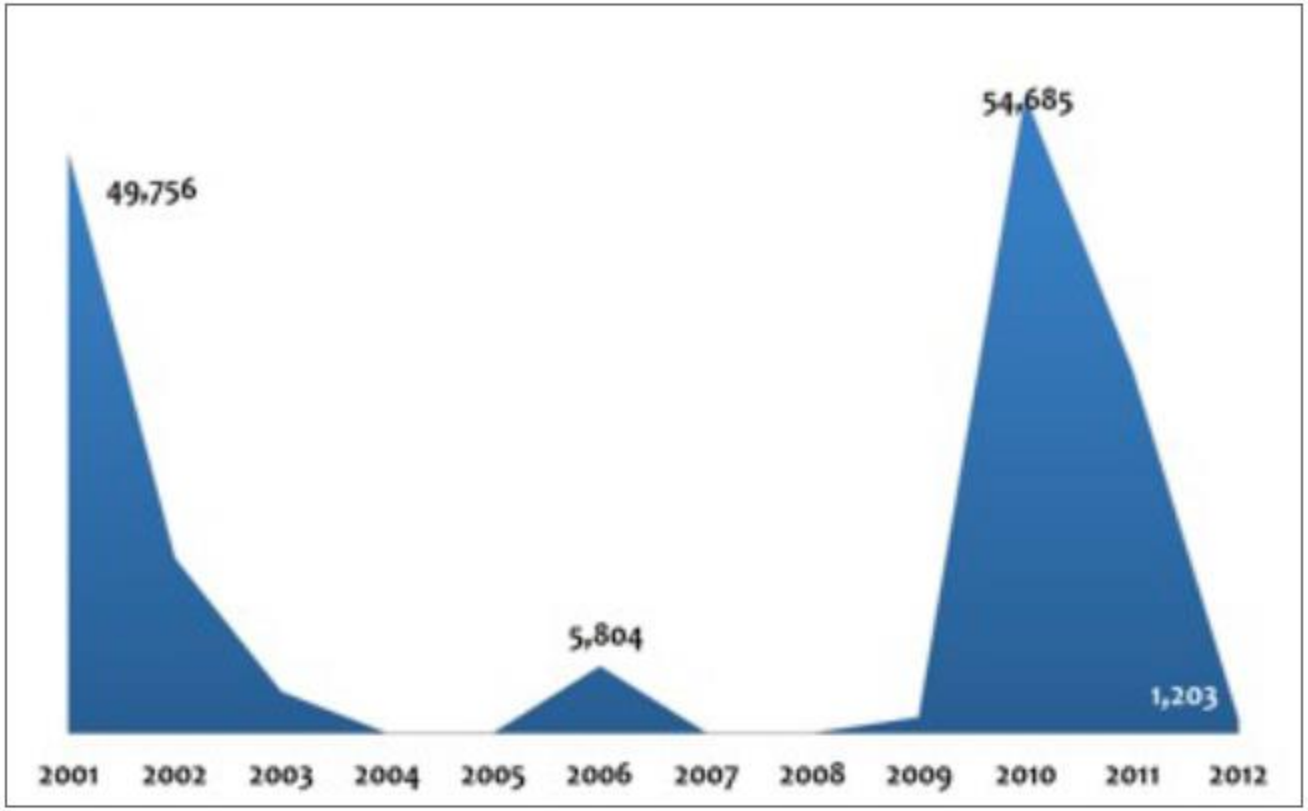
<Table 7> Water Quality Targets from the Seoul Water Quality & Ecosystem Preservation Plan (Seoul Metropolitan Government, 2014)

Area	2012 Water Quality [mg/L]			2018 Target Water Quality [mg/L]		
	BOD	COD	T-P	BOD	COD	T-P
Jungnang Stream Area (Downstream)	5.800 (Slightly Poor)	12.300 (Very Poor)	1.267 (Very Poor)	5.000 (Fair)	8.600 (Slightly Poor)	0.649 (Very Poor)
Tan Stream Area (Down-stream)	6.400 (Slightly Poor)	9.600 (Poor)	0.598 (Very Poor)	5.000 (Fair)	7.000 (Fair)	0.200 (Fair)
Anyang Stream Area (Downstream)	4.100 (Fair)	8.400 (Slightly Poor)	0.211 (Slightly Poor)	4.000 (Fair)	7.000 (Fair)	0.159 (Fair)
Hongje Stream Area (Hongje Stream)	3.000 (Slightly Good)	5.100 (Fair)	0.080 (Slightly Good)	3.000 (Slightly Good)	4.800 (Slightly Good)	0.070 (Slightly Good)
Han River (Haengju Bridge Point)	4.100 (Fair)	6.800 (Fair)	0.290 (Slightly Poor)	3.800 (Fair)	5.000 (Slightly Good)	0.141 (Fair)

Reducing Flood Risk

In the past decade, Seoul's annual average rainfall has been 1,550 mm, 70% or more of which comes in the torrential rains occurring during the summer months (June–August). The city suffered major damage in 1987, 1990, 1998, 2001, 2010, and 2011. Every decade or so, Seoul sees 2 or 3 major floods. Most of the damage has been to buildings and facilities, crippling urban functions (blocking traffic, causing blackouts, suspending communications etc.) (Figure 13).

<Figure 13> Losses in Seoul from Flooding (Unit: KRW 1 million)



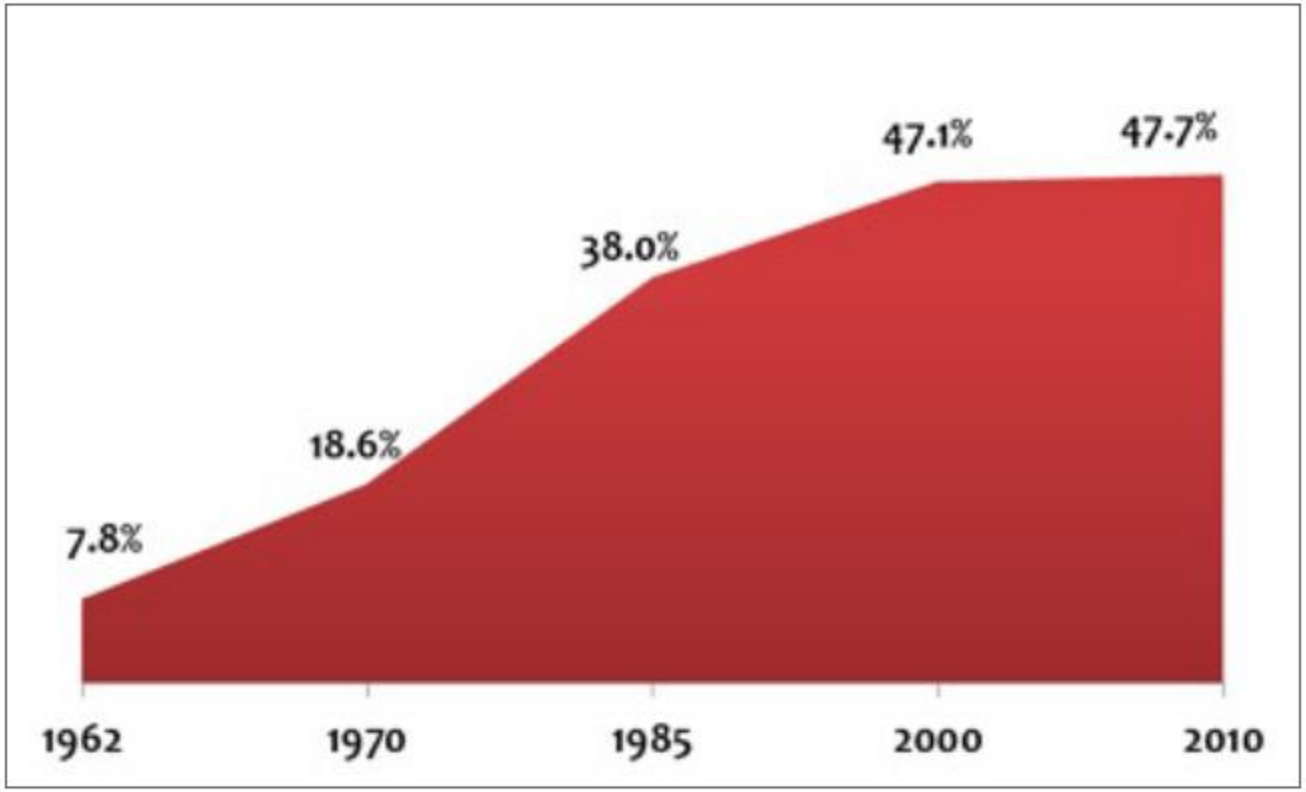
For the past 30 years (1971–2001), rainfall has steadily increased from 1,344 mm to 1,550 mm. Analysis of the relationship between rainfall (hourly maximum and daily maximum) and financial damage in the years when flood damage was serious (1987, 1990, 1998, 2001, 2010, and 2011) shows no clear tendency but generally, the greater the volume or intensity of rainfall, the greater the property damage. The extent of flood damage was determined largely by the climate, particularly in the amount of rain.

Flood damage occurs usually in flat, low-lying areas with poor drainage, especially to semi-underground housing, underground spaces (underground arcade, etc.), and roads. In some parts of the city however, the nature of the flood damage is rather complex, a combination of both inland and river (e.g., overflows) floods caused by heavy rain and the antecedent conditions of precipitation.

Seoul has for some time worked on improving its stream systems, sewer systems, inland flood control facilities, and other facilities designed to prevent water-related disasters (sewer pipes, rainwater pumping stations, reservoirs, etc.). These facilities are at a relatively advanced level, and yet storm and flood damage have not abated, owing to global climate change and the effects of urban development. The Basic Sewage Improvement Plan of 2009 is a response to climate change and heavy rainfall that reinforces the recurrence interval standards for sewer pipes from 5 years (main) and 10 years (branch) to 10 years and 30 years, respectively. Of the 9,380 km of sewage line, 476 km (5.1%) have interruptions in their flow due to old designs. Considering the reinforced recurrence interval in the future (30 years for main pipes, 10 years for branches), 618 km (6.6%) are estimated to be inadequate. To better prevent inland flooding, flood-prone zones should be selected for repair and maintenance of any inadequate or deteriorating pipes on a continual basis, while upgrading the capacity of some rainwater pumping stations that have reached their capacity limits.

While the urbanization of Seoul has helped expand built-up areas, it has also increased the impervious surface area. This reality gives rise to urban flooding, urban heat islands, and other forms of undesirable natural phenomena, undermining healthy water reclamation and destroying the natural habitats. According to urban ecosystem research done in 2010, 47.6% of Seoul's surface area was impervious (Figure 14).

<Figure 14> Impervious Surface Area in Seoul



Green belts and open spaces with an impervious surface rate of less than 10% accounted for 43.6%; areas with an impervious surface rate of 90% or more accounted for 37.2%; areas with an impervious surface rate of between 70% and 89% made up 11.1%. Since the 2000s, the most noticeable change in the impervious surface rate was a reduction of the areas with a 90% or higher or 10% or lower rate and an increase in the areas in the 30%–90% range. While reduction of the areas with an impervious surface rate of 90% or more is desirable, the change in the impervious rate fluctuates greatly across the city. Reduction of the areas with an impervious surface rate of 90% or more seems to have been caused by redevelopment and improvement that aimed to secure sufficient green space for a more natural ecosystem. However,

areas in the 70%–90% range have increased due to the development of roads and commercial and business districts, hindering overall improvement. It is therefore necessary to devise a way to reduce the impervious surface rate in development projects undertaken.
Safety management to prevent urban disasters can be divided into 4 strategies: 1) reinforcing preventive action; 2) enhancing disaster response; 3) developing a complete restoration system; and 4) making improvements through participation and communication.

The tasks designed to prevent water-related disasters are as follows:

- Make improvements in 29 flood-prone zones
- Prevent the loss of human life in the river systems
- Strengthen management of basement housing units in flood-prone areas
- Integrate management of disaster prevention facilities by basin
- Improve street level drains
- Encourage residents in vulnerable areas to buy insurance
- Increase rainwater management capacity 8-fold by 2020 (from 5.6 mm to 46.5 mm)

Seoul's Water Management Policy: Challenges

Seoul's water management policies have achieved remarkable development in a relatively short period of time. The spectrum of the city's technical and policy experience and performance is broad. However, policy challenges include finding new resolutions towards creating a safer and more pleasant city for residents.

Of primary importance is that any policy approach be based on the understanding that raw water and water sources must be managed more stringently to ensure the Han River system is clean and safe. While such efforts are already in place and have had some success, more emphasis is needed that management at the source must be as strict as during the supply and treatment process. We do not have to refer to US or European cases to understand the necessity. Management at the source is indeed one of the most crucial elements of integrated water management policies (WHO).

Another challenge is to be prepared for new trace particles. PPCPs and CEC's (contaminants of emerging concern) are now detected at low concentrations but must nevertheless be monitored and managed because they affect health and the aquatic ecosystem (EPA, 2011). Most such substances are not yet regulated but are on the increase every year, both in amount and type. It is especially important that the relevant departments work together closely to address the issue.

The Han River is the only source of water for Seoul. Climate change and urbanization have increased the possibility of water pollution, making it critical to find other sources for the sake of economics and safety. Development of sources beyond surface water would include passive methods (groundwater and rainwater) as well as more proactive means (reuse of wastewater).

Rainwater in particular can be utilized through rainwater management facilities, which can help circulate water in and out of dry seasons. Policies can also consider reducing base flow by pumping in water to maintain the streams.

Effective management of rainwater and groundwater is increasingly important, not just from the perspective of water resource management, but also with an eye to preventing disasters (e.g., road collapses, floods) and safety. Policies should pay attention to increasing surface permeability in the city to increase groundwater levels, and to developing artificial groundwater replenishment technology.

Due to climate change and urbanization, Seoul sees more torrential rain flooding, landslides, and other storm and undesirable water-related events, as well as an increase in their severity. Structural measures – improvements to disaster prevention facilities – as well as an integrated approach to built-up areas are necessary. Urban planning and management of construction is also crucial. Other necessary measures include: a warning system and provision of relevant information for prevention; upgrades to the emergency response system to minimize damage and

loss of life; and consideration of regional characteristics to refine response and approach.
Countermeasures against flooding should consider direct impact on buildings and other structures but should also take on a more dimensional approach toward urban planning, housing, improvement of the residential environment, and green parks. It should also be noted that urban planning and the residential environment should include flood-related safety measures.

For the future, a more integrated water management system should be included in Seoul's water management policies. This integrated system would involve integrated management of all water resources including rainwater and groundwater, as well as technology and policies regarding the waterworks and the sewer system. This system should address the technical and policy challenges in a way that assures the sustainable use and reuse of water and other energy resources.

As we have examined the changes in Seoul's water management policies, especially in relation to waterworks and sewers, the city, with a system built in the midst of rapid urbanization and quantitative growth, will now need to focus on stability and quality so as to develop an integrated system that will provide the foundation for sustainable water management in the future.