3. Present Situation of Water Resources and Countermeasures for Drought in Korea

Soon Hyuk LEE[1]

1. Introduction

In Korea, there are relatively less plains and more steep mountain regions. It has a mean annual precipitation of 1,283mm, two third of which is concentrated in three summer months - June, July, and August. Due to topography and climate conditions, Korea's river flow considerably varies throughout the year, which repeatedly causes serious natural disasters such as flood damage and drought and loss of lives and property. In addition, rapidly expanding industrial activities have significantly raised the national standard of living over the last few decades. Thus, the social demand for city water, agricultural water, and factory water has substantially increased. Likewise, several water-related natural disasters over the last few years, e.g., drought in the southern and central regions between July 1994 and April 1995, flood in the central region in August 1995, winter drought that started in October 1995, flood in Kyungki and Kangwon provinces in 1996, severe drought in the central region in 2001 and heavy flood in the central and northern regions in 2002 have aroused the whole nation's greatest concern. This paper mainly discusses the present situation of water resources, relevant tasks, and some countermeasures for droughts in Korea.

2. Present Situation of Water Resources

2.1 Characteristics of Water Resources

Korea is located in a temperate monsoon zone. A major portion of its annual precipitation consists of concentrated heavy rainfall that comes during a relatively short

[1] Department of Agricultural Engineering, Chungbuk National University, Cheongju, 361-763, Republic of Korea

period in the summer. For about six months of the year particularly in winter and spring, arid climate persists. Due primarily to this seasonal and regional disproportionate distribution of its precipitation, it is very difficult to preserve water and avoid the frequent flood and drought problems.

Korea has a mean annual precipitation of 1,283mm, which is 1.3 times that of the world average. Therefore, its precipitation cannot be considered insufficient. However, the annual average precipitation per person is 2,705m^3. This represents a mere 10% of the world average of 26,800 m^3.

A more important factor to consider is Korea's seasonal and regional distribution. Its precipitation distribution varies from 754mm to 1683mm. In terms of season, two-thirds of the total annual precipitation is concentrated between June and September. On the other hand, only one-fifth of the annual precipitation comes in from November to April. Therefore, Korea suffers from frequent cases of flood and drought compared to other countries with evenly distributed annual precipitation.

Since the 1960s, Korea's annual precipitation has been increasingly fluctuating. This has resulted in more frequent floods and droughts, reflecting the poor state of water supply facilities and flood prevention. In terms of region, Jeju and the southern coastal region experience much rainfall with more than 1,500mm annual precipitation. Conversely, inland Kyungbuk region only has 1,000mm annual precipitation. Thus, annual precipitation by region greatly varies.

Similarly, a large portion of the precipitation, about 600mm –700mm in Korea is lost during evaporation and transpiration. They do not add to the river flow. Thus, available precipitation is more or less than 500mm compared to the 1,283mm mean annual precipitation. As such, annual precipitation that is less than its mean presents a strong possibility for drought in Korea.

In addition to the climate factor, the topographical condition should also be taken into account. Unlike Europe that has several large plains, 65% of the national land in Korea is mountainous. Naturally, the inclination of its rivers is largely steep. When a heavy rainfall comes, overland flow velocity is a very high speedy. Thus, substantial floods outflow in a very short span of time in comparison with the watershed area and precipitation. Consequently, the coefficient of the river regime increases to more than 300, which is actually ten times the global average (Table 1).

Table 1. Coefficient of river regime in Korea and foreign country

River (Stations), Korea	Coefficient of river regime	River (country)	Coefficient of river regime
Han (Indogyo)	390	Missouri (U.S.A)	75
Geum (Gongju)	300	Thames (U.K)	8
Nakdong (Jindong)	260	Rhine (Germany)	16
Yeongsan (Naju)	320	Donau (Germay, Estuary)	30
Seomjin (songjeong)	390	Seine (France)	34

Source: Water and Health, Water Resources Corporation, Mar 2001.

Therefore, most rivers in Korea have drainage areas with somewhat large width to allow easy and safe flood drainage. During the normal and dry seasons, rivers are generally in a state of dry wash. Thus, the natural water environment is not very advantageous for the efficient use of small lands in Korea.

On the other hand, Europe's precipitation shows a well proportionate annual distribution and relatively constant flow rate due to the west coast oceanic climate or the Mediterranean climate. The variation of the flow rate is generally low during flood or drought. Therefore, Europe does not urgently require countermeasures such as embankment and multi-purpose dam for flood and drought compared to Korea.

Other water resources-related problems in Korea include its considerable regional imbalance of available water resources and the serious problem on ground water development. In Korea, the annual amount of its ground water is estimated at 13 – 14 billion m^3. However, a major portion is supplied to the river flow during the dry season. Likewise, the development of the aquifer strata is poor. Thus, large-scale exploitation of ground water is very difficult.

2.2 Amount of Water Resources and Current State of Utilization

Figure 1 shows that Korea's water resources as of 1998 total 12.76 billion m^3, which was derived by multiplying the mean annual precipitation of 1,283 mm and total

South Korean land area of 99,450 km^2. Subtracting the lost amount of 54.5 billion m^3 (43%) caused by evapotranspiration and infiltration from the total amount of water resources yields a total river discharge of 73.1 billion m^3 (57%). About 40 billion m^3 (31%) of the total river discharge flows to the sea. The remaining 33.1 billion m^3 (69%) is utilized as water through rivers, dams, and ground water. For the ground water in particular, the total annual utilizable amount is estimated at 13.5 billion m^3. However, current utilization amounts to only 3.7 billion m^3. As of 1998, the total utilized amount of water in terms of utilization area is composed of life water 7.3 billion m^3 (22%), factory water 2.9 billion m^3 (9%), agricultural water 15.8 billion m^3 (48%), and sustainable river flow 7.1 billion m^3 (21%).

(Unit: 10^8m^3/year)

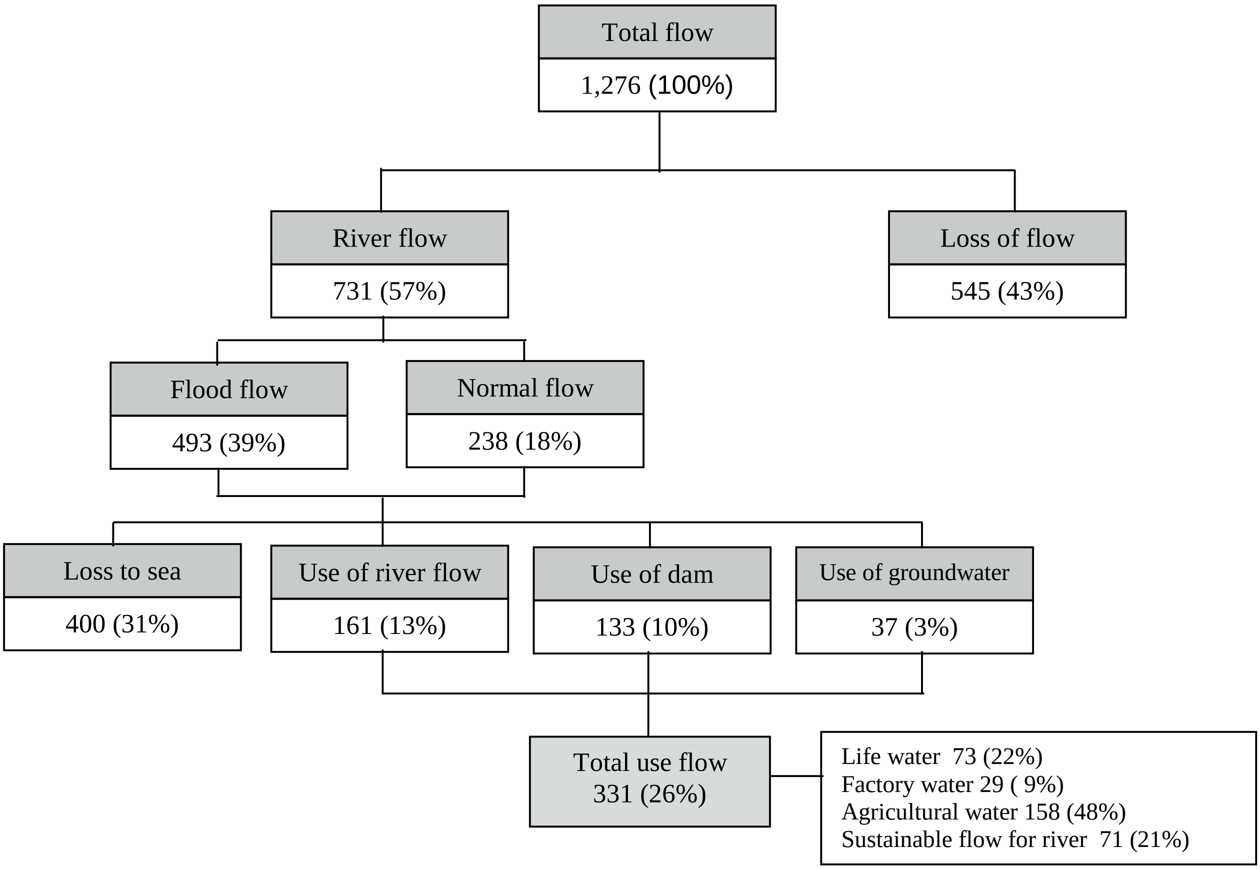

Figure 1. Present conditions for use and total flow of water resources in Korea.

Source: MOCT, Korea, 1998

3. Urgent Water Resources-Related Problems

3.1 Worsening Water Shortage

In order to secure a stable supply of water, Korea has constructed and is currently operating 13 multi-purpose dams and 31 multi-regional water supply systems including factory water supply systems. Nonetheless, some regions almost routinely suffer from water shortage. Likewise, 15% (7 million people) of the whole Korean population experiences the annual interruption of city water supply. Droughts of varying scales have occurred eight times over the last decade. Moreover, 28 cities and counties throughout the nation are not equipped with a stable water intake system. They consistently suffer from droughts when dry seasons persist. This situation is expected to worsen in the future due to population increase, expansion of city water supply, and economic growth, which will all ultimately lead to the mounting demand for water. Despite several large-scale facilities currently under construction, water shortage is still expected to hit the whole nation from 2006 onwards. Likewise, the 2 billion m^3 of water will not meet the water demand in 2011. In order to cope reasonably with this water shortage problem, the Korean government is seeking to maximize 5.1 billion m^3 of new water resources including several multi-purpose dams by stages. As such, it plans to increase the water reserve rate from 7.7% in 1994 to 8.5% in 2011. The successful implementation of this plan is expected to solve the water shortage in Korea.

3.2 Inadequacy of the Integrated Water Management

Uncertainty in information on the amount of utilizable water and the quantity of water utilized, as well as the inadequacy in management and information supply have cast doubts on the prospects of the demand for water and water shortage. The independent operation of multi-purpose dams and single-purpose dams with the same river system bring about serious inability to supply water and control flood through the combined management of dams.

3.3 Difficulty in Securing Water Requirement and Supplying Water

In Korea, there is a severe imbalance in terms of renewable water resources per person (annual average natural river flows/whole population) among regional watershed basins. As a result, some regions have serious difficulty in securing water resources. In such situation, the development of water resources via the construction of dams poses social and political problems due to the enhanced environmental consciousness of the general public, loss of life base in submerged districts, ecological changes, massive constraints in the development of dam peripheral areas, and lack of appropriate areas for dam construction. Moreover, the competitive distribution process of limited water among different regions in the upper stream and lower reach of rivers and deterioration of water quality have critically hampered the supply of water.

4. Current State of Drought and Countermeasures

4.1 Current State of Drought

Since the 1960s, a relatively serious drought has taken place in Korea every 5-6 years, e.g., 1968, 1977, 1982, 1988, and 1994. The most recent and by far the most distressing drought hit Korea between March and June 2001, with precipitation of only 79.9 mm. This was a pitiful 54.1% of 147.6mm during the same period last 2000, and 27.1% of the established average of 294.3mm. In particular, the rate of storage in the case of reservoir for agricultural water was only 69% of the established average. Moreover, 359,000 people in 84 cities and counties nationwide were subjected to controlled or transported water supply on 16 June 2001. Sufficient supply of agricultural water was virtually impossible at that time.

4.2 Drought Countermeasures

4.2.1 Development of Technique for Estimating Demand for Water and Establishment of a Systematic Plan for the Supply and Demand of Water

Designing a systematic, stable, and integrated plan for the supply and demand of water nationwide or regionally requires objective and reliable information on the total amount of water demand, using an accurate and practical estimation model of calculating water demand. The surplus or deficiency of water is calculated by analyzing the water balance through the river system. The deficiency will only be resolved through a long-term integrated plan for securing water resources. In the late 1996, the Korean government proposed a long-term integrated plan (1997 - 2011) for securing water resources. While the plan included prospects for the supply and demand of water all over the country, it was based only on the standard of the normal time. Therefore, the plan should consider the amount of water demand and shortage caused by unpredictable droughts. Only then can Korea have scientific and practical prospects and corresponding countermeasures for water shortage.

4.2.2 Construction of Small and Medium Multi-Purpose Dams and Small Water-Exclusive Dams and Expanded Development of Multi-Regional Water Supply System

Table 2 shows the 13 existing multi-purpose dams in Korea, e.g., Soyanggang Dam, Chungju Dam, Heongseong Dam in the Han River, Andong Dam, Namgang Dam, Hancheon Dam, and Imha Dam in the Nakdong River, Daecheong Dam and Yongdam Dam in the Geum River, Seomjingang Dam and Juam Dam in the Seomjin River, and Milyang Dam and Buan Dam in other rivers. The water supply capacity of these dams is approximately 10.641 billion m^3, with their flood control capacity at about 2.18 billion m^3. In addition, annual flood control capacity of the ten power generation dams is 276 million m^3. In terms of the annual effective storage water capacity, 16 water-exclusive dams including Youngcheon and Unmun maintain 767 million m^3. On the other hand, 29 agricultural water reservoirs including Jangseong and Damyang secure more than ten million m^3 and 5 river mouth dams in the Nakdong River and the Geum River have an annual water supply capacity of 3,363 million m^3.

In the future, there is a need to continuously develop and secure water resources to satisfy the expected demand for water in this millennium. As such, there is a need to investigate for several candidate areas where small and medium multi-purpose dams and small water-exclusive dams can be constructed. Implementation of this plan should ensure minimal destruction of animal and plant habitats and avoid environmental devastation and disruption of the ecosystem between the upper stream and the lower reaches, which are caused by submergence and dam construction. Thus, it is important to formulate a plan for environment-friendly dam construction. In addition, the plan for dam construction should consider the residents living within the vicinity. The government should extend assistance to residents concerned by upholding their welfare and including income-generating activities for them.

Table 2. Present conditions of multipurpose dam. (Unit: $10^6 m^3$/year)

River	Dam	Watershed area (Km^2)	Size (m)		Storage capacity	Useable storage capacity	Power generation (10^3KW)	Effect of project		Period
			Height	Length				Flood control	Water supply	
Total					12,272.5	8,522.9	1,041.4	2,179.3	10,641.3	
Han	Soyanggang	2,703	123	530	2,900	1,900	200	500	1,213	`67-`73
	Chungju	6,648	98	447	2,750	1,789	412.0	616	3,380	`78-`86
	Heongseong	209	48.5	205	86.9	73.4	1	9.5	111.6	`91-`00
Nakdong	Andong	1,584	83	612	1,248	1,000	90	110	926	`71-`77
	Imha	1,361	73	515	595	424	50	80	592	`84-`93
	Hapcheon	925	96	472	790	560	101.2	80	599	`82-`89
	Namgang	2,285	34	1126	309	299.7	14	269.8	573.3	`87-`99
Milyang	Milyang	95.4	89	535	73.6	69.8	1.3	6	73	`91-`01
Geum	Gaecheong	4,134	72	495	1,490	790	90	250	1,649	`75-`81
	Yongdam	930	70	498	815	672	24.4	137	650.4	`91-`01
Seomjin	Seomjingang	763	64	344	466	347	34.8	32	350	`60-`65
	Juam	1,010	58	330	707	562	22.5	80	489	`84-`92
Gikso	Buan	59	50	280	42	36	0.2	9	35	`91-`96

Source: Water Vision 2020, Water Resources Corporation, Korea, 2001.12

Currently, the Korean government shoulders 20,000–30,000 million won in korean currency of the business expenses for peripheral region arrangement per dam construction. It aims to promote regional economic development in the dam peripheral area, prepare a housing site and agricultural land, and realize flood control works. Likewise, the government shoulders 800 million won – 1 billion won of the assistance business expenses for peripheral regions upon completion of the dam construction. The funds are normally used for the construction of farm roads, expansion and pavement of roads, small water supply systems, and village halls.

In particular, securing the stable supply of water in the seaside and some regions where the dam cannot be constructed require medium-term and long-term plans for multi-regional water supply systems. The systematic implementation of this plan will allow the supply of water to reach almost all farming and fishing villages. The multi-regional water supply system transcends a single river system or an administrative district, thereby achieving the systematic integration of several cities that have difficulty securing their own water resources regionally. As of 1994, the multi-regional water supply systems have a supply rate of about 82%. Thus, a long-term plan for its expansion is critical.

4.2.3 Development of Ground Water, Groundwater Dam, Wastewater Reclamation and Reusing System, and Sea Water Desalination as Supplementary Water Resources

Korea primarily needs a scientific and systematic ground water development. The annual amount of ground water utilization has been gradually increasing, i.e., 2.6 billion m^3 in 1994, 2.9 billion m^3 in 1996, and 3.7 billion m^3 in 1998. Nonetheless, the utilization rate is much lower (about 10% of the total amount of water utilization) compared to the United States (20%) and France (19%). As such, a measure for efficient ground water development and management is necessary. This chiefly requires accurate investigation on the amount of natural ground water resources, condition of its utilization, and current state of water quality pollution.

In addition, Korea needs to construct groundwater dams. The groundwater dam is referred to as a curtain wall that allows utilization of the riverbed and ground waters. This is an undercurrent dam basically constructed underground. This dam has several advantages compared to the general reservoir, e.g., prevents evaporation loss, eliminates possibilities for environmental damage, poses no problems with residents living nearby, and incurs relatively less compensation cost for residents concerned. However, it has some disadvantages such as higher maintenance cost and difficulty for getting a large amount of water at the same time. In 1983, a groundwater dam was constructed as a model project for the supply of agricultural water for the first time in Korea. A total of

20 groundwater dams have been built since then, with 0.3 million m^3 of the total pumping water. In the future, Korea needs to investigate for several appropriate areas for the construction of groundwater dams and continue such construction.

Moreover, Korea needs to install several wastewater reclamation and reusing systems. The wastewater reclamation system is designed to produce water for flush toilet, cleaning, sprinkling, car washing, and factory through the treatment of used water. Introducing this system may reduce the amount of tap water utilization and the amount of sewerage, which will consequently result in cost reduction for the construction of filtration and sewage treatment plants and water treatment. Likewise, this system will also contribute to the prevention of water quality pollution. As of late 1997, Korea has 59 existing wastewater reclamation and reusing systems in several building sites including Lotte World in Seoul, Samsung Electronics in Suwon, Main Office of POSCO in Seoul, and apartment complexes. This system needs to be installed in more areas.

Finally, Korea needs seawater desalination. The production unit cost of desalinated water per m^3 is 1500-3000 won. This is 3-6 times higher than the production unit cost of tap water, 499 won. Its higher production cost notwithstanding, the seawater desalination system should be built in many seaside areas and islands. Similarly, the technique to reduce production cost should be developed. Korea currently has 26 existing seawater desalination systems, 22 of which are used for city water with a supply capacity of 3 m^3-500 m^3 per day. The remaining four are used for factory water with a supply capacity of 4,800 m^3- 70,000 m^3. The Korean government plans to build 41 additional seawater desalination systems.

4.2.4 Combined Management of Dams within River Systems and Development and Operation of Water Resources Information System

Multi-purpose dams are used for the supply of various kinds of waters, flood control, and hydraulic power generation. Similarly, agricultural water and hydraulic power generation dams have their own single purposes. However, agricultural water and hydraulic power generation dams within a single river system should be converted into multi-purpose dams during drought. They should be operated through combined management in order to increase the amount of water supply.

In addition, various water-related information should be easily available in real time through the development of an integrated water resources management system. This will enable the improvement of water utilization in the upper stream and lower reaches of rivers. The proposed integrated water resources management system should include the computerization of drought-related information, supplementary development of the flow model for the dry season, and development and management of a drought forecast model.

4.2.5 Implementation of Policies for Water Saving

Various measures should be applied for controlling water utilization. As such, Korea needs relevant official policies. In fact, the implementation of proper policies for the management of the demand for water is equally important as the development of new water resources to cope with the demand for water. In particular, such policies are known to have a highly positive effect during the dry season.

For one, the water rates should be adjusted to a realistic level. This is a practical way of preventing excessive water utilization and preparing funds for the construction of water-related facilities. Currently, the price of water is set at 70% - 74% of production costs. Water is unnecessarily wasted due to such low price. Likewise, related social expenses are increasing.

Table 3 shows that the average charge of household water in the city as of 30 December 1999 is 240 won per m^3, which is 1/2-1/8 of that of most countries. Such low water charge is due to the public concern about the negative impact of water charge increase on the prices of goods. In reality, this concern is basically unfounded. A 1% increase in water charge is expected to bring about only a negligible 0.0007% additional expense (13 won) to the monthly household expenditure. While the low price of water is favorable to the general consumers, it results in the insufficient recovery of the production cost. Thus, the ensuing outcomes are very undesirable, e.g., delay in the capital infusion for the renovation of old facilities, difficulty in the improvement of water quality, and deterioration of the competitiveness of tap water. In turn, these will result in the lack of confidence of the general public on government policies and public utility businesses.

Table 3. Comparative table of water rate according to nation (Based life water)

(Unit: won/m^3)

Division	Korea	Italia	U.S.A	Australia	Japan	U.K	France	Germany
Water rate	240.4	584	664	871	1,374	1,638	1,710	1,936
Comparative (Ratio)	1	2.4	2.8	3.6	5.7	6.8	7.5	8.1

Source: '98 Water supply statistics, MOE, Korea, 1999. 1$=1,145.4 won (Dec. 30, 1999)

Likewise, equipment for water saving should be developed and extensively supplied. Such equipment include tap, showerhead, toilet bowl, washing machine, and dishwasher. Towards this end, relevant housing and construction laws and regulations should be revised. Other measures include improvement of the rate of water utilization through the early replacement of old water pipes; promotion of the importance of water and water saving to the general public; the improvement of the withdrawal rate of factory water; construction of a system for the re-use of agricultural water; and official policies that seek the high utilization of water through the re-use of return flow.

5. Conclusion

While Korea has produced many positive results in the development, utilization, and management of water resources, it has faced quantitative and qualitative water-related crises. Specifically, it faces problems of water shortage and deterioration of the quality of river water resulting from the explosive increase in the demand for water. Such increase in the demand for water is caused by population expansion, rapid urbanization, and industrialization.

For years, water-related international organizations have pointed out that water shortage and global warming are two of the most critical environmental problems in the global society for this millennium. Over the last two decades in particular, many countries including Korea, Japan, the United States, Australia, and several countries in Africa have suffered from severe droughts. Likewise, there are widespread worries of the entire globe suffering from water crisis during the early period of this millennium. A huge number of people are expected to experience disastrous water shortage. Korea is also expected to face severe water shortage in the near future.

Given the negative water-related prospects and reality, Korea should fully prepare to secure enough water resources and overcome droughts. Towards this end, the aforementioned systematic plan and practices should be established and pursued.

References

Kim, S. and Woo, H.S (1996). Study of Permanent Drought Measures in Water Resources Planning and Management, Korea Institute of Construction and Technology.

Kim, W. K. (2001). Disaster and Measures of the Flood and Drought in Korea, Symposium for the prevention of Flood and Drought, Korea Society of Soil and Environment.

Korea Water Resources Corporation, Korean Federation of Water Science and Engineering Society (2000). 21 Century's Water.

Korea Water Resources Corporation (2001). Water and Health.

Korea Water Resources Corporation (2001). Investigation Report of Drought in Korea.

Lee, S. H. (1995). Several suggestion for the Prevention of Drought, Journal of Korea Society of Agricultural Engineers, Vol.37, No.1.

Lee, S H. (2002). Development and Utilization of Water Resources in Korea, Supreme Manager Course for the Professional Workers, Chungbuk National University.

Lee, H. N. (2002). Supply Measures of Water Resources for Drought Disaster, Symposium 2002 for Drought Disaster Prevention, Yeongnam University, Daegu, Korea.

Ministry of Construction and Transportation (2001). Water Vision 2020, Korea .

Won, I. H. (2000). Development and Policy for the Water Resources of Korea, Symposium 2000 for Water Science, Korean Federation of Water Science and Engineering Society.