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Analysis of Hydropower Generation and Water Supply Capability Changes in Multipurpose Dam According to Climate Change Scenarios

Jaeung Yi , Changwon Choi

The effects of climate change on hydropower generation and water supply capability is analyzed for multipurpose reservoirs. The A2 and B2 climate change scenarios with a reservoir simulation model are used for this analysis. The five scenarios, which are 2011-2040 and 2051-2080 runoffs obtained from A2 scenario, 2011-2040 and 2051-2080 runoffs obtained from B2 scenario, and the historical runoff, are applied to two multipurpose reservoirs, Soyang Reservoir and Chungju Reservoir, located in the Han River, South Korea. Since the inflow to Soyang Reservoir decreases according to both A2 and B2 climate change scenarios, the outflow also decreases, and ultimately the power generation and water supply decreases about 10-15%. However, since the inflow to Chungju Reservoir increases according to climate change scenarios, the outflow also increases, ultimately the power generation increases about 10-15%. Therefore, the suitable strategy for each reservoir corresponding to climate change is required for reservoir operation and management.

1 Introduction

Climatic change has huge effects on both humans and nature, such as natural disasters and environmental problems. Climatic change has become a global issue that should attract the attention of international societies. Internationally, WMO (World Meteorological Organization) and UNEP (United Nations Environmental Programme) have organized IPCC (Intergovernmental Panel on Climate Change) to focus on climatic change. According to the IPCC (2002), the average temperature of the earth has increased by about 0.6°C over the last 100 years. Climatic change directly affects human lives because it could greatly change not only the temperature, but also the rainfall, evaporation, etc.

The purpose of this study is to investigate the effects of climatic change on the water resources and hydropower generation of a river basin. To accomplish this, the multipurpose reservoirs used for supplying water, generating hydropower, controlling floods, etc. on the Han River in Korea were evaluated. By using runoff data due to long-term rainfall obtained by the greenhouse gas emissions scenario of IPCC, a simulation model was formulated to show reservoir operations as realistically as possible.

2 Climatic Change Scenarios

Emission scenarios have been written by IPCC (2002) to assess the uncertainty of the future's climate. The recently published SRES scenarios qualitatively show demographic, social, economic, technological, ecological, and political futures. These scenarios can be divided into four types, A1, A2, B1, and B2, which have different aims. This study used the flows of the Han River in Korea in 2011 to 2040 and in 2051 to 2080, from the A2 scenario as a pluralistic scenario and the B2 scenario as a region-coexisting type scenario. Five types of data about the amount of water flow, including four kinds of flow (A2 in 2011 to 2040, A2 in 2051 to 2080, B2 in 2011 to 2040, B2 in 2051 to 2080) and historical flow data, were applied to Chungju Reservoir and Soyang Reservoir, multipurpose reservoirs on the Han River, to investigate changes in water resources and hydroelectric power generation.

Lately, the effects of climatic change on water resources and hydroelectric power generation have been actively studied. Lehner et al. (2005) presented a model-based approach for analyzing the possible effects of global change on Europe's hydropower potential at a country scale. They indicated that following moderate climate and global change scenario assumptions, severe future alterations in discharge regimes have to be expected, leading to unstable regional trends in hydropower potentials. Cieto (2008) et al. presented an assessment of the impacts on the Portuguese energy system due to climate change induced water availability variation. They showed that water availability decreases in particular for the power sector using a bottom-up technology based linear optimization model. Kosnik (2008) introduced one approach to more actively switch to renewable technologies in the production of electricity in order to reduce greenhouse gas emission from the burning of fossil fuels.

3 Model Formulation

3.1 Reservoir System

The Han River is located in the middle of Korean peninsula (Fig. 1). The basin area is 26,219 km² and the river length is 481.7 km making it the largest river in Korea. The Han River consists of the South Han River and the North Han River. The Korea Water Resources Corporation is responsible for operation and management of multipurpose reservoirs, such as Soyang Reservoir and Chungju Reservoir, and Korea Hydro & Nuclear Power Corporation is responsible for operation and management of generation-driven reservoirs, such as Hwacheon

Reservoir, Chuncheon Reservoir, Euiam Reservoir, Cheongpyeong Reservoir, and Paldang Reservoir. The characteristics of multipurpose reservoirs are presented in Table 1.

Multipurpose reservoirs have a flood control capability by maintaining limited water levels during the rainy season of June to September. In this study, multipurpose reservoirs in the Han River basin, Chungju Reservoir and Soyang Reservoir, were analyzed in relation to the changes in the hydroelectric power generation and water supply by using the historical inflow data and inflow data computed by the climatic change scenarios. Monthly historical inflow data for 15 years from 1986 to 2000 were used. Also, monthly inflow data in 2011 to 2040 and in 2051 to 2080, as computed by climatic change scenarios A2 and B2 were used.

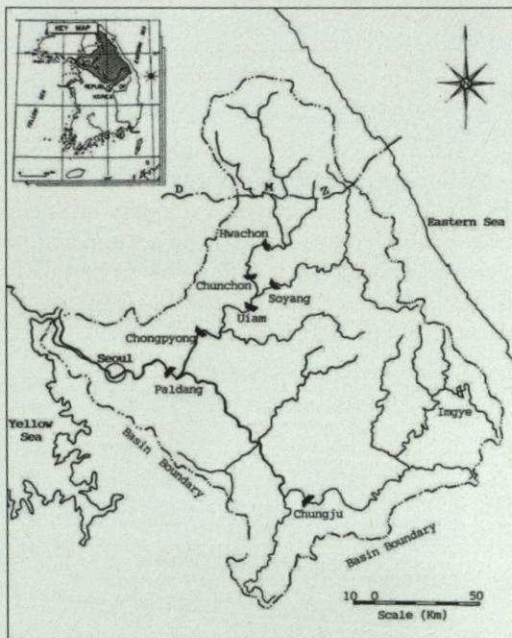


Fig. 1 Han River Basin

Table 1 Characteristics of Soyang and Chungju Reservoirs

	Unit	Soyang Reservoir	Chungju Reservoir
Watershed			
Drainage basin	km ²	2,703	6,648
Dam			
Dam structure	-	Earth core rock fill dam	Concrete Gravity dam
Dam crest elevation	EL.m	203.0	147.5
Volume	10 ³ m ³	9,590	902
Reservoir			
Flood elevation	EL.m	198.0	145.0
Full reservoir level	EL.m	193.5	141.0
Gross reservoir capacity	10 ⁶ m ³	2,900	2,750
Flood control storage	10 ⁶ m ³	500	616
Power generation			
Firm supply	m ³ /s	46.4	107.2
Generation capacity	10 ³ kW	200	400
Annual generation	GWh	353	764.6

3.2 Inflow Data

The average annual rainfall in Korea is approximately 1,274 mm; however, most of this rainfall occurs in rainy season. Two thirds of the annual rainfall occurs in rainy period, from June to September. This extremely unbalanced rainfall produces poor results in relation to hydroelectric power generation. Table 2 shows the monthly average and annual average inflows for five scenarios, including the historical data, 2011 to 2040 in scenario A2, 2051 to 2080 in scenario A2, 2011 to 2040 in scenario B2, and 2051 to 2080 in scenario B2.

Table 2 Yearly Average Inflow according to Scenario A2, B2

Soyang Reservoir	Scenario A2	Scenario B2
1986-2000(historical inflow)	71.2	71.2
2011-2040	60.5 (-15.0 %)	57.1 (-19.8 %)
2051-2080	57.5 (-19.2 %)	60.1 (-14.9 %)
Chungju Reservoir	Scenario A2	Scenario B2
1986-2000(historical inflow)	163.9	163.9
2011-2040	245.0 (+49.5 %)	222.0 (+35.5 %)
2051-2080	222.2 (+35.6 %)	227.0 (+38.5 %)

The historical annual average inflow of Soyang Reservoir in 1986 to 2000 was 71.2 m³/s. The annual average inflow of Soyang Reservoir based on climatic change scenario A2 was 60.5 m³/s in 2011 to 2040 and 57.5 m³/s in 2051 to 2080, decreasing by 15.0 % and 19.2 %, respectively, compared to the historical

inflow. The annual average inflow of Soyang Reservoir based on climatic change scenario B2 was 57.1 m³/s in 2011 to 2040 and 60.1 m³/s in 2051 to 2080, decreasing by 19.8 % and 14.9 %, respectively, compared to the historical inflow. Most of the monthly average inflows in climatic change scenarios A2 and B2 decreased compared to the historical data.

The historical annual average inflow of Chungju Reservoir in 1986 to 2000 was 163.0 m³/s. The annual average inflow of Chungju Reservoir based on climatic change scenario A2 was 245.0 m³/s in 2011 to 2040 and 222.2 m³/s in 2051 to 2080, increasing by 49.5 % and 35.6 %, respectively, compared to the historical inflow. The annual average inflow of Chungju Reservoir based on climatic change scenario B2 was 222.0 m³/s in 2011 to 2040 and 227.0 m³/s in 2051 to 2080, increasing by 35.5 % and 38.5 %, respectively, compared to the historical inflow. Most of the monthly average inflows in climatic change scenarios A2 and B2 increased compared to the historical inflow.

4 Result

4.1 Water Supply

Reservoir simulation was performed using the HEC-5 model and long-term inflow data based on the five scenarios. The annual water supply capacity was estimated with a reliability of 95 %. Table 3 shows the results of the evaluation of the annual water supply capability of each operation.

Table 1 95 % Water Supply Capacity

(MCM/Year)

		Soyang Reservoir	Chungju Reservoir
1986-2000 (Actual value)		2,150.80	3,065.90
Scenario A2	2011-2040	1,591.90	Scenario A2
	2051-2080	1,772.30	4,418.20
Scenario B2	2011-2040	1,825.90	Scenario B2
	2051-2080	1,542.10	4,973.20

Using the inflow from scenario A2, the annual water supply for Soyang Reservoir, computed with 95 % reliability, was 1,591.9 MCM in 2011 to 2040 and 1,772.3 MCM in 2051 to 2080. These amounts were smaller, by as much as 558.8 MCM and 378.4 MCM, respectively, than the 2,150.8 MCM from the operation by the historical inflow in 1986 to 2000. Although the inflow in 2011 to 2040 was larger than the inflow in 2051 to 2080, the smaller water supply was caused by the fact that the annual inflows in 2051 to 2080 were more uniformly

distributed than the annual inflows in 2011 to 2040. A change in the water supply capability of Soyang Reservoir for scenario A2 is shown in Fig. 2.

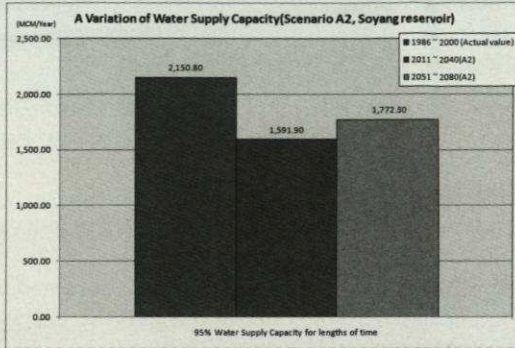


Fig. 2 Water Supply Capability at Soyang Reservoir (A2)

Using the inflow from scenario B2, the annual water supply for Soyang Reservoir, computed with 95 % reliability, was 1,825.9 MCM in 2011 to 2040 and 1,542.1 MCM in 2051 to 2080. These amounts were smaller, by as much as 324.8 MCM and 608.6 MCM, respectively, than the 2,150.8 MCM that resulted from the operation by the historical inflow in 1986 to 2000. Although the inflow in 2011 to 2040 was smaller than the inflow in 2051 to 2080, the larger water supply was caused by the fact that the annual inflows in 2011 to 2040 were larger, especially in May and September, than the annual inflows in 2051 to 2080. A change in the water supply capability of Soyang Reservoir for scenario B2 is shown in Fig. 3.

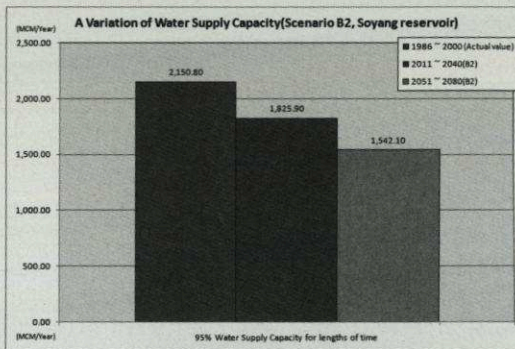


Fig. 3 Water Supply Capability at Soyang Reservoir (B2)

Using the inflow from scenario A2, the annual water supply for Chungju Reservoir, computed with 95 % reliability, was 4,768.2 MCM in 2011 to 2040 and 4,418.2 MCM in 2051 to 2080. These amounts were larger, by as much as

1,702.3 MCM and 1,352.3 MCM, respectively, than the 3,065.9 MCM that resulted from operation by the historical inflow in 1986 to 2000. The great change in the 95 % water supply capability of Chungju Reservoir, depending on the period, appears to be caused by the increased inflow. The water supply capability of Chungju Reservoir for scenario A2 is shown in Fig. 4.

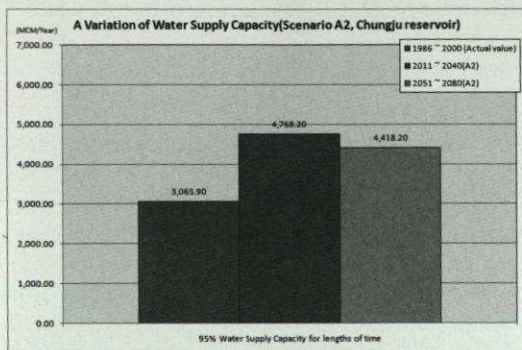


Fig. 4 Water Supply Capability at Chungju Reservoir (A2)

Using the inflow from scenario B2, the annual water supply for Chungju Reservoir, computed with 95 % reliability, was 4,733.6 MCM in 2011 to 2040 and 4,973.2 MCM in 2051 to 2080. These amounts were larger, by as much as 1,667.6 MCM and 1,907.3 MCM, respectively, than the 3,065.9 MCM that resulted from operation by the historical inflow in 1986 to 2000. The increase in the 95 % water supply capability for scenario B2, depending on the period, is judged to be due to the increased inflow. The change in the water supply capability of Chungju Reservoir for scenario B2 is shown in Fig. 5.

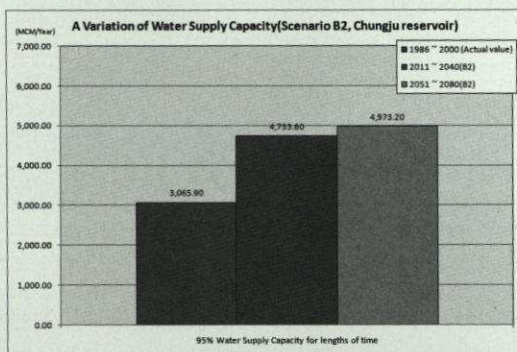


Fig. 5 Water Supply Capability at Chungju Reservoir (B2)

4.2 Hydroelectric Power Generation

Generally, power generation is in proportion to water discharge. However, the water discharge during electric power generation is limited by the penstock capacities. Furthermore, because the maximum power generation capacity is based on the limits of the generator, a sudden increase of water discharge during a flooding period cannot be used entirely for power generation. Therefore, even though the total water discharge is the same, the power generation is affected by how much of the unavailable water discharge is used to generate power.

The 15 year annual average power generation using the historical inflow of Soyang Reservoir in 1986 to 2000 was 537.0 GWhr, and the 30 year annual average power generation for climatic change scenario A2 was 481.9 GWhr in 2011 to 2040 and 456.9 GWhr in 2051 to 2080. The 30 year annual average power generation for climatic change scenario B2 was 450.0 GWhr in 2011 to 2040 and 487.1 GWhr in 2051 to 2080. Because Soyang Reservoir showed an overall decrease in the amount of inflow based on the climatic change scenarios, the water discharge also decreased; as a result, the power generation decreased by 10 to 15 %. The results are presented in Fig. 6.

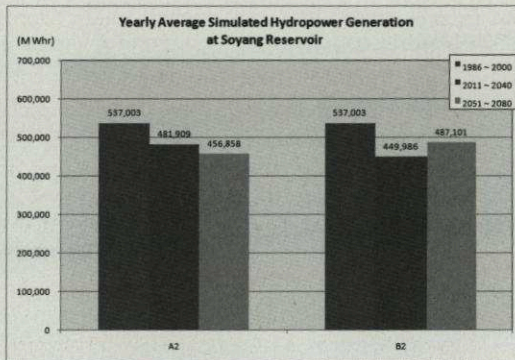


Fig. 6 Yearly Average Simulated Hydropower Generation at Soyang Reservoir

The 15 year annual average power generation using the historical inflow of Chungju Reservoir in 1986 to 2000 was 762.2 GWhr, and the 30 year annual average power generation for climatic change scenario A2 was 928.4 GWhr in 2011 to 2040 and 899.7 GWhr in 2051 to 2080. The 30 year annual average amounts of power generation for climatic change scenario B2 was 813.1 GWhr in 2011 to 2040 and 826.0 GWhr in 2051 to 2080. Because Chungju Reservoir showed an overall increase in the inflow based on the climatic change scenarios, the water discharge also increased; as a result, the power generation increased by 5 to 22%. However, although the inflow of Chungju Reservoir increased by 35

to 50% and the water discharge also increased, the power generation could not increase in proportion to the increased water discharge because the water discharge for electric power generation was limited. Thus a large amount of unusable water discharge was produced. The results are shown in Fig. 7.

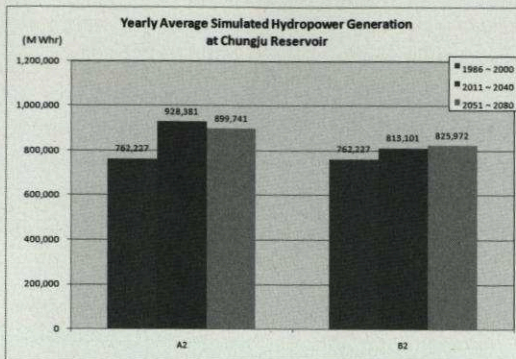


Fig. 7 Yearly Average Simulated Hydropower Generation at Chungju Reservoir

5 Conclusion

In this study, the changes in water supply capability and hydroelectric power generation for different climatic change scenarios are evaluated for multi-purpose reservoirs in the Han River basin. The water supply capability and hydroelectric power generation of Soyang Reservoir decreased overall, and the water supply capability and hydroelectric power generation of Chungju Reservoir drastically increased. These results are caused by the drastically decreased inflow into Soyang Reservoir and the drastically increased inflow into Chungju Reservoir. Therefore, it is suggested that Soyang Reservoir be operated to decrease any waste of water resources and hydroelectric power generation and that Chungju Reservoir be operated to properly distribute water resources and hydroelectric power generation and efficiently manage the reservoir during a rainy period.

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References

Cieto, J., Simons, S., Fortes, P., and Seixas, J. (2008) Renewable Energy Sources Availability under Climate Change Scenarios-Impacts on the Portuguese Energy System. European Electric Market, 2008 5th International Conference on the European Electricity Market, 28-30 May 2008 Pages: 1-6.

IPCC (2002). Climate Change 2001; Impacts, Adaptations, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University, UK.

Kosnik, L., (2008) The Potential of Water Power in the Fight against Global Warming in the US. Energy Power, Volume 36 Issue 9, September 2008, Pp. 3252-3265.

Lehner, B., Czisch, G., Vassolo, A. (2005) The Impact of Global Change on the Hydropower Potential of Europe: a Model-Based Analysis. Energy Policy, Volume 33, Issue 7, May 2005, pp.839-855.

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