CONTROL OF EXTREME FLOOD THAT EXCEEDED THE DESIGN OF NAMGANG DAM IN 2006

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Abstract : The Korean peninsula is located in a transitional zone with climate influenced by Northeastern Asia and the Western pacific ocean geographically. The Korean peninsula was seriously affected by heavy rainfall from typhoon and seasonal rain front in June, 2006. The rainy season period of 2006 was 46 days and was 2 weeks longer than usual. And accumulated rainfall was 321~1,244 mm according to area, and average rainfall was 717.3 mm which was 3 times more than usual (262 mm). This rainfall was one of the longest and heaviest on record. The amount of 1.4 billion tons flowed into the Namgang Dam due to the heavy rainfall at that time. And the discharge was implemented as the maximum 3,558 m^3/s, that main stream discharge is 392 m^3/s and Sacheon Bay is 3,166 m^3/s, 16:00 10, July considering the rainfall condition, dam inflow, restrictions of up-downstream and the safety of the dam. Thus, the flood control was accomplished at the maximum stage of EL. 44.48 m (24:00 10, July) which was 1.52 m lower than the designed flood water level 46 m. The maximum amount of 392 m^3/s and 3,200 m^3/s was discharged to the main downstream of Namgang Dam and Sacheon Bay for 5 hours, respectively. It was considered that flood discharge of 5,900 m^3/s and the stage of 2.62 m at the Jindong station were decreased as a result of flood control of the dam. Therefore, we are trying to make a general introduction on the flood control system of Korea Water Resources Corporation that is managing multi-purpose dams in the whole country and analyze the flood control effect of Namgang Dam that influenced on this flood control time in relation to the heavy rain in July of 2006.

Key words : Namgang Dam, Jindong station, Sacheon bay, Inflow

1. Introduction

Generally, the precipitation pattern is uneven distribution temporally and spatially and its variation is very large in Korean peninsula. Annual precipitation ranges from a low of 754 mm in 1,939 to a record maximum of 1,782 mm in 1998, and a mean annual of 1,283 mm in Korea Peninsula. About two thirds of the total precipitation is concentrated in the summer, while precipitation in the winter is less than 10% of the total precipitation. The summer is also the time for flooding caused by monsoonal moisture that advances towards the Korean Peninsula from the south in late June. As the inter-tropical convergence zone moves gradually to the north, the so-called Jangma season continues for about 30 days from late June until late July. During this period, Korea receives more than 60% of the annual precipitation at most meteorological stations. Annually, about 28 typhoons occur in the Western Pacific, but only two or three are land falling over the Korean Peninsula from July through September, and can bring heavy rainfall and flooding.

In Korea, there are 5 major river basins that are Han River, Nakdong River, Geum River, Seomjin River and Youngsan River. Among these rivers, the Nakdong River is the second largest catchment area, and the river is the longest in South Korea. The Korean peninsula was seriously affected by heavy rainfall from typhoon and seasonal rain front in June, 2006. The rainy season period of 2006 was 46 days and was 2 weeks longer than usual. And accumulated rainfall was 321~1,244 mm according to area, and average rainfall was 717.3 mm which was 3 times more than usual (262 mm). This rainfall was the longest and heaviest on record. As much larger volume than design frequency flood was flown into dam area due to the occurrence of a rainfall event with regionally considerable difference, it is thought that it was very difficult to accomplish reasonable decision support for dam up-downstream. Specially, No.3 typhoon EWINIAR had a direct effect on Gyeongnam area where Namgang Dam is located. As the sea level temperature at that time was 0.5~2.5℃ higher than before, in spite of typhoon of July, it became a cause of the northing with the strength-keeping of typhoon. Specially, there was a record-high case of 191mm in the Namgang basin on July 10.

The amount of 1.4 billion tons flowed into the Namgang Dam due to the heavy rainfall at that time. And the discharge was implemented as the maximum 3,562 m^3/s (main stream 392 m^3/s, Sacheon Bay 3,166 m^3/s, 16:00 10, July) considering the rainfall condition, dam inflow, restrictions of up-downstream and the safety of the dam. Thus, the flood control was accomplished at the maximum stage of EL. 44.48 m (24:00 10, July) which was 1.52 m lower than the flood water level (46 m).
The maximum amount of 392 m^3/s and 3,200 m^3/s was discharged to the main downstream of Namgang Dam and Sacheon Bay for 5 hours, respectively. Therefore, it was considered that flood discharge of 5,900 m^3/s and the stage of 2.62 m at the Jindong station were decreased as a result of flood control of the dam.

In this paper, we are trying to make a general introduction on the flood control system of Korea that is managing multi-purpose dams and analyze the flood control effect of Namgang Dam that influenced on this flood control time in relation to the heavy rain in July of 2006.

2. Study area

The Namgang Dam is located in 8 km west of the city of Jinju and was constructed in 1969 on the Nam River, a tributary of the Nakdong River, which is the second largest river basin in Korea, to prevent flood damage and provide irrigation, living and industrial water in the cities of Jinju and Sacheon. Because of continuous flood damage and increasing need of water by urbanization since dam construction, the dam was reinforced by rising dam crest from 40.5m to 46m in 1999.

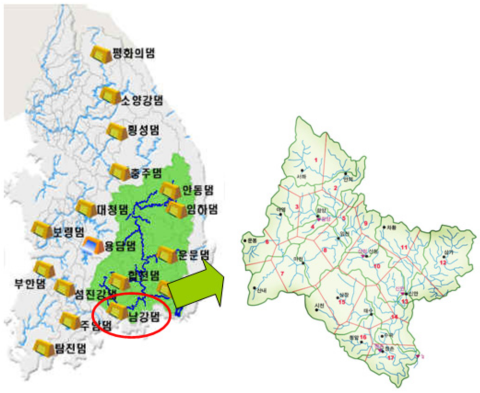


Fig. 1 Location of Namgang Dam (left) and Watershed and stream network (right)

This dam has a unique flood control method Such as main stream release and Sacheon Bay release. Usually, Namgang main stream is weak district by flood, and Sacheon Bay is a district related to environment issue and frequent fisher's complaint. Namgang Dam on operation now is controlling flood by using the way of flowing directly down to the main dam and Sacheon only flowing down to the main course of Namgang River. That is, in case 10,400 m^3/s as 200 years frequency's planned flood volume is flown into, by flowing 80% of dam release volume in 4,050 m^3/s as a planned release volume directly to the sea and releasing maximum 800 m^3/s as its 20% to the immediate downstream of Namgang Dam, it has made for the reduction of the flood volume in the mainstream of Nakdong River as well as in Jinju City. Fig 2 displays Namgamg dam's flood release system and Fig. 3~4 display the sacheon bay and Namgang dam's shape respectively.

This way has the flood control capacity of 270 million ton which can significantly reduce the flood damages in the downstream areas by regulating floods and diverting them to the Sacheon Bay through 12 spillway gates. It also generates hydropower energy of 41.3 GWh per year from the power plant with the installing capacity of 14,000 kW.

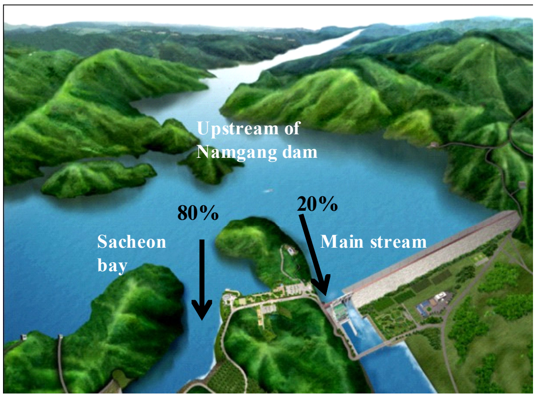


Fig. 2 Flood control method of Namgang Dam

Fig. 3 Sacheon bay Release System

Fig. 4 Namgang Dam Release System

3. Role of K-water in flood control

Water resources management is made difficult by the uneven distribution of rainfall seasonally. Conserving rainfall runoff in reservoirs is important during the summer to have sufficient water supply during the rest of the year, which is primarily dry. Most river reaches are short and small drainage areas when Korean rivers are compared with other major continental rivers. The channel slopes are relatively steep because of steep mountains and deep valleys in the uplands. Floods occur quickly with large peak discharges due to the combination of intense rainfall and mountainous terrain that serves to enhance precipitation and to accelerate runoff to low lying coastal areas with flatter gradients. Before and during heavy precipitation, water releases from reservoirs must often be made to make ready for expected runoff from incoming typhoons, which is the joint responsibility of the Korea Water Resources Corporation (K-water) and the Korea Flood Control Office. The large fluctuation of stream flow discharge poses serious difficulties in the management of water resources for both flood, maintenance of water quality, and water supply. Tremendous effort has been exerted to ameliorate these fluctuations through construction of many multipurpose reservoirs. Fig. 5 is the procedure that flood control is performed and display graphically by hydrological and hydraulic routing model. For the hydraulic routing modeling, the boundary conditions are needed as upstream and tributary flow. At first, by using the observed and forecasted rainfall, the lateral discharge is evaluated by rainfall-runoff analysis. And then, the hydraulic flood routing model is performed by using the newest surveying geometrical data. When these conditions are constructed, upstream and downstream of dam's flood control analysis is possible.

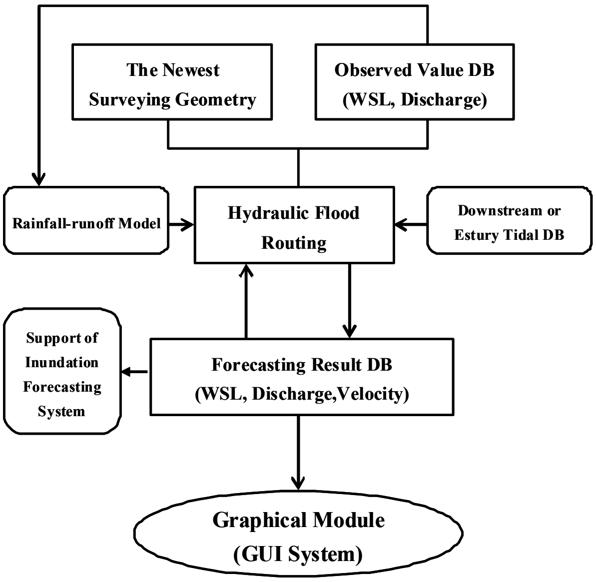


Fig. 5 Procedure of K-water flood control

4. K-water model

Flood runoff analysis model was the first to develop for basin and channel, by using storage function method which was developed by Japanese Kimura in 1985. In 1996, WROC standardized the models that had been operated independently for each reservoir. But multipurpose reservoir operation must be considered the hydrological situation in downstream area to determine spillway release schedule. So in 1997, our flood analysis model extended to develop the basin wide hydrological model (prototype of K-water model) coupled with hydraulic channel routing. Through 7 years efforts to develop and improve K-water model, it also developed the hydrological and a hydraulic channel routing model for downstream area, giving rise to the K-water flood forecasting system, which allows a comprehensive flood analysis of the upstream and downstream area of reservoirs.

The basin runoff model is developed to be able to select one of two methods with option in order to compute the effective rainfall on the basis of storage function model, the one is f1-Rsa and the other is SCS-CN method. Also the channel routing option is established to apply three different types of routing options (Storage function, Muskingum, Muskingum-Cunge), and reservoir operation model (SRC, Rigid, Technical ROM, and so on)

$$R_e(t) - Q_i(t) = \frac{dS_l(t)}{dt}$$

$$S_i(t) = kQ_i(t)^{pt}$$

$$S_l(t) = kQ_i(t)^p - T_l Q$$

By using these evaluated hydrological condition, the downstream channel routing is performed. This hydraulic channel routing model is made up of conservation of mass and momentum. The governing equations are as follow. To get the optimized solution, the trial and error numerical technique is applied by solving simultaneous equation. When the hydraulic channel routing is run, the stage and discharge's evaluation is possible in all river sections

$$\frac{\partial Q}{\partial x} + \frac{\partial S_c(A + A_0)}{\partial t} - q = 0$$

(Conservation of Mass)

$$\frac{\partial (S_m Q)}{\partial t} + \frac{\partial (\beta Q^2 / A)}{\partial x} + gA\left(\frac{\partial h}{\partial x} + S_f + S_{ec} + S_i\right) + L = 0$$

(Conservation of Momentum)

Thus, flood analysis system operating at WROC has been developed and complemented steadily from 1985 to now on the basis of the translation technique called storage function. Flood analysis model is utilized by naming as K-water flood analysis model and final flood volume is estimated by connecting outflow elements from small basin with channel network through discharge translation by small basin on the basis of storage function translation technique.

5. Analysis of flood control

Between July 8 and July 21 of 2006, in Namgang Dam basin, there was a rainfall of total 513mm with the effect of seasonal rain front, No. 3 typhoon EWINIAR and No. 4 typhoon Billis.

No. 3 typhoon EWINIAR occurred on the ocean floor near the south-western area of Guam on July 1, around 3:00 AM and passed the 180 km ocean floor in the west of Okinawa on Sept. 9, around 3:00 AM and, on July 10, around 11:00 AM, had a medium size shape between center air pressure 980hPa and maximum wind velocity 26 m/s strength level.

And, finally, it was removed in the nearby to the east 80 km of Seoul on Sept 11, around 22:00 PM. As the sea level temperature at that time was 0.5~2.5℃ higher than before, in spite of typhoon of July, it became a cause of the northing with the strength-keeping of typhoon. Specially, there was a record-high case of 191mm in the Namgang basin on July 10.

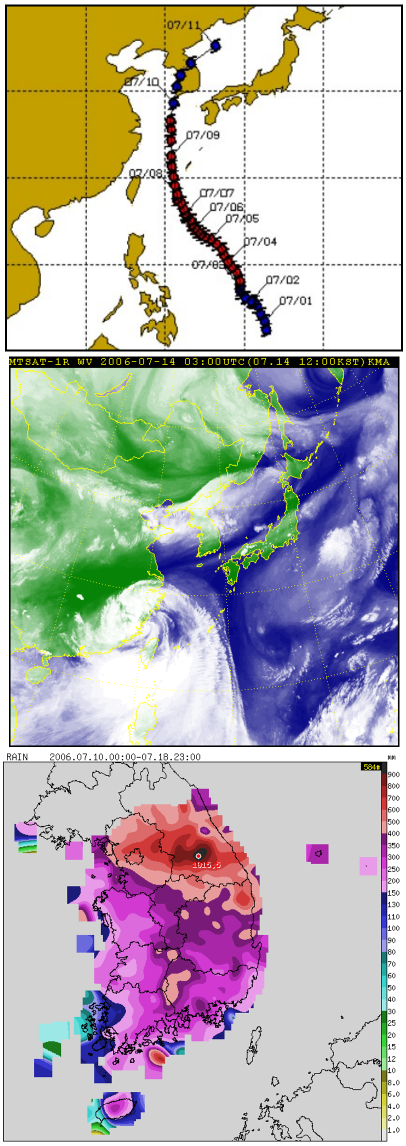


Fig. 6 Direction of movement of TY3.EWINIAR

Flood control effect of multi-purpose dam can be classified into the evaluation on the propriety regarding the flood control of dam and the evaluation on the downstream flood control. Flood control effect of dam can be indicated by the flood control rate (peak flood decrease rate) indicating how much inflow volume was reduced and released to downstream and the underflow rate indicating how much flood volume was under-flown to dam. Flood control effect of dam downstream rivers also can be indicated by how much water level and flood volume of dam downstream rivers was decreased by the controlled release of dam. Due to rainfall at that time, about 1.4 billion m^3/s water was flown into Namgang Dam. In spite of these much inflow, flood control was safely accomplished under EL. 44.48m (7/10 24:00) that is 1.52m lower than planned flood level EL. 46m by executing the release of maximum 3,562 m^3/s (7/10 16:00, mainstream 392 m^3/s, Sacheon bay 3,166 m^3/s) through the consideration of rainfall status, dam inflow volume, up-downstream limitations and dam's safety, etc.

Flood control effect evaluation of dam downstream rivers calculates the decrease effect of peak flood volume and the water level reduction effect of major place, measure out the damage reduction amount before and after flood control from water level flood damage amount according to water level reduction and also considers submersion reduction time generating submersion damage at downstream place(Table 1). As an analysis tool, K-water flood analysis model developed by Korea Water Resources Corporation was used. Fig 8 display Namgang dam’s real release status. By these condition, the hydraulic channel routing’s results is display in case hydropower release and main stream real release(Fig 9~10).

Table 1. Assessment method of flood control effect in Dam

Items	Method
Flood control rate	= (peak inflow-peak release)/peak inflow
Use rate of flood control volume	= Storage over restricted stage at peak stage/flood control volume
Release rate	= total release / total inflow (amount)
Storage rate	= 100 - Release rate

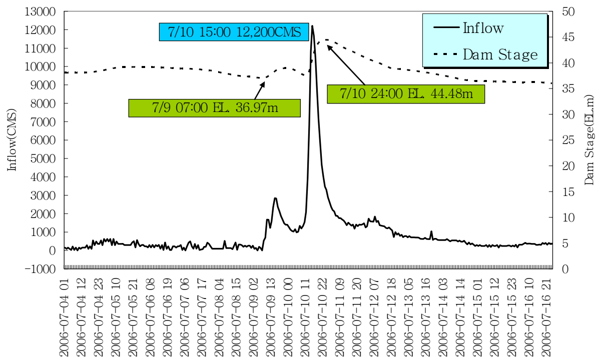


Fig. 7 Inflow and Dam Stage

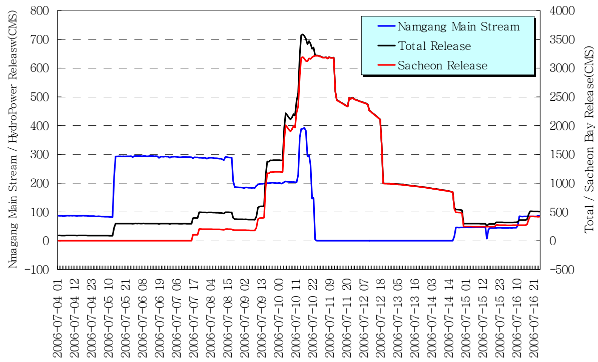
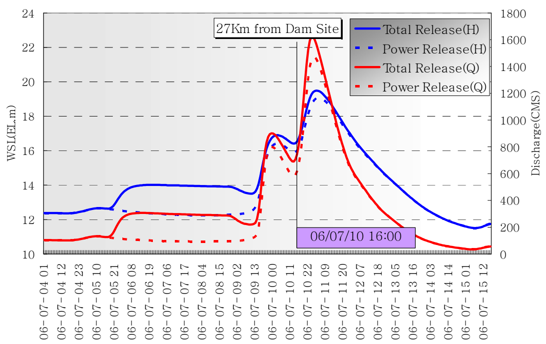
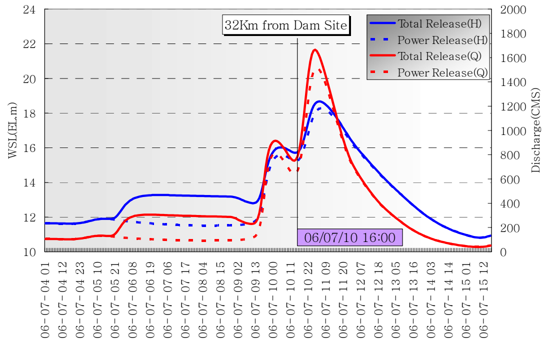


Fig. 8 Namgang Dam Release Condition



(a) 27km from Dam Site



(b) 32km from Dam Site

Fig. 9 Hydraulic Channel Routing Result

At the time of the invasion of this typhoon No.3, 12,214 m^3/s (7/10 15:00) that is 1,814 m^3/s more than planned flood volume was flown into Namgang Dam basin. Due to this, flood control was accomplished by releasing maximum 392 m^3/s was released to main dam downstream direction for 5 hours and releasing 3,200 m^3/s to Sacheon bay direction. That is, it is thought that it was possible to reduce about 5,900 m^3/s of flood volume and about 2.62m of water level at Nakdong River area by controlling and releasing to 97% to mainstream direction.

At the time of this flood, it is also thought that flow volume of 392 m^3/s released to mainstream river from Namgang Dam is optimal release volume for dam's smooth flood control at the inflow situation exceeding flood volume planned by dam. It is thought that this volume has the least effect on downstream river and has contributed to reducing flood volume of mainstream and downstream rivers.

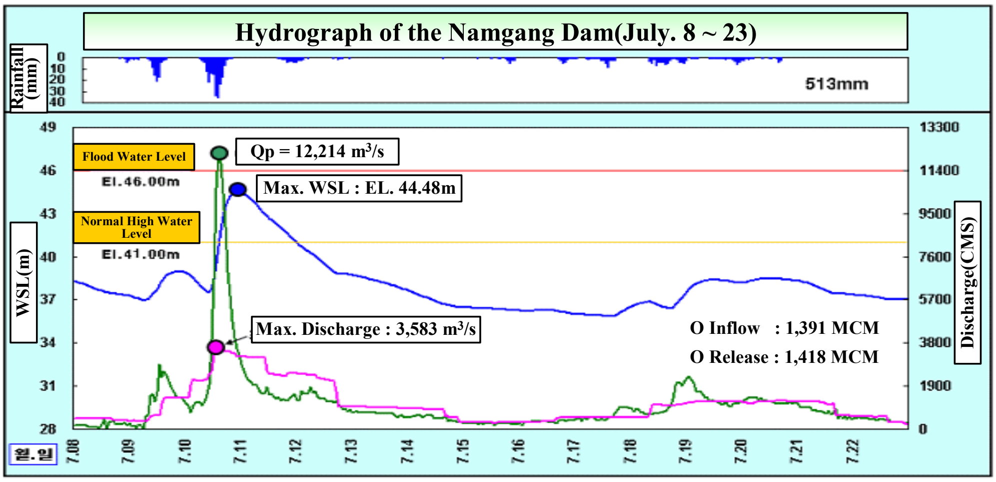


Fig. 10 Hydrograph of the Namgang Dam during July.8~23

6. Conclusions

During this flood period, 12,213 m^3/s that is the maximum flood volume of July 10, was flown into Namgang Dam. It is the volume concerning to 117% of 200 years frequency 10,400 m^3/s that was original planned volume. However, flood control was reasonably accomplished under EL. 44.48m (7/10 24:00) that is 1.52m lower than planned flood level EL. 46m by executing the release of maximum 3,562 m^3/s (7/10 16:00, mainstream 392 m^3/s, Sacheon bay 3,166 m^3/s) through the consideration of rainfall status, dam inflow volume, up-downstream limitations, etc.. Therefore, it was considered that flood discharge of 5,900 m^3/s and the stage of 2.62 m at the Jindong station were decreased as a result of flood control of the dam.

The rainfall from rainy season and typhoon can be utilized as valuable resources through scientific water resources management. Structural and non-structural plans are needed to reliably store and supply the water and to prevent disasters through scientific water resources management. There was a occasional excess of designed inflow in Namgang watershed due to the regional rainfall concentration, to overcome this problem, the continuous improvement of dam operation techniques should more be considered along with the organizational countermeasure considering the existing dams. It is also thought that it is necessary to improve dam management technique steadily and review constructional countermeasure with consideration of the existing dam at this situation that submersion and bank destruction are occurred by gentle slope and regional rainfall overemphasis phenomenon.

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