An Application of Water Conflict Resolution
in the Kum River Basin, Korea

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Abstract

The Kum River basin is one of most important river basins in Korea. This river provides benefits for some five million people in the form of water supply, irrigation, hydropower, and recreation. Two major dams are located on this river, Daechong Dam (constructed in the 1970's) and Yongdam Dam which is located upstream of Daechong Dam (and whose construction is just recently completed). Two major droughts have occurred in this basin, one in 1995 and one in 2001. These recent droughts have accentuated the need for careful planning in the basin and have highlighted potential trade-offs. The initial filling of Yongdam Dam was delayed due to concerns that its operation would negatively impact water availability at Daechong Dam.

Since this region's population is projected to grow very rapidly, larger demands will soon be made on Yongdam Dam's storage and downstream users are concerned that these demands may decrease the reliability of their water. In addition, there is considerable debate over what values should be established for environmental flows for both dams. The environmental releases from Daechong Dam have a significant impact on water quality downstream of the dam. Environmental releases from Yongdam Dam impact both the water quality between the two dams and the inflows to Daechong Dam.

These trade-offs between water supply reliability and environmental flows are explored in this paper. Analyses were made using a water resource model of the basin, developed using the STELLA® software environment.

Introduction

Kum River basin (Figure 1) is 9,810 square kilometers with a mainstem length of 396 kilometers. Two major dams are located on the Kum River. Daechong Dam (which creates a reservoir of approximately 1,500 million cubic meters) provides water to several major cities including Daejon, Chongju and Chonan. Yongdam Dam (which creates a reservoir of approximately 815 million cubic meters) is located in upstream of Daechong Dam and was completed in 2001. Water stored in the Daechong Dam serves approximately three million people, including the cities of Chongju and Chonan.

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Yongdam Dam will initially serve approximately one and half million people, including the city of Jonju. The construction of the Yongdam Dam created major disputes within the basin. Daechong Dam plays a key role in flood control, the production of hydroelectric power, and providing drinking and irrigation water in the regions, including the southwestern Chungnam Province. Yongdam Dam is also designed to provide water for several purposes. However, the Yongdam Dam remained unfilled after its construction because of concerns over how its operation would influence inflows into Daechong Dam. In many aspects these conflicts reflect classic upstream and downstream concerns: with Daechong Dam and the area it serves representing the previously established water needs and Yongdam Dam and the area it serves representing an area of growth. By the fall of 2001, Daechong Dam reached its lowest storage value since its initial filling.

In addition to water quantity concerns, there are water quality concerns. A minimum instream flow between dams has been suggested by downstream users of 12 m^3/sec, whereas upstream users have suggested 5.4 m^3/sec. Environmental flows of 21 m^3/sec have been suggested below Daechong Dam. In addition, there is considerable concern over the quantity and quality of instream flow released from Yongdam Dam. The rate of growth in the regions is an issue. Both regions claim the need for increase water allocations in the future. Much of this debate revolves around water demand forecasts for Jonju, which range from 2.5 to 3.5 million people in the year 2021. Table 1 summarizes some of the basin's major issues.

Table 1. Major Conflicts in Kum River Basin

	Daechong Dam serving Daejon (Downstream)	Yongdam Dam serving Jonju (Upstream)
Instream flow of between dams	12.4 m^3/s	5.4 m^3/s
Instream flow of downstream of Daechong Dam	21 m^3/s	Less than 21 m^3/s (Need to be reconsidered)
Population forecast for Jonju city	2.5 million	3.5 million
Yongdam Dam Operation	Disagree	Agree

Two significant droughts have impacted the region in recent years, one in 1995 and one in 2001. In the fall of 2001, Daechong Dam reached its lowest storage level since its initial filling. As droughts have been a reoccurring challenge, the frequency, intensity, and magnitude of drought damage in this region is of great concern. Drought, instream flow targets, regional water needs, and misunderstanding have resulted in a high level of conflict in the basin. This conflict was sufficiently great in 2001 that Yongdam Dam was not filled during the raining season, even though this storage would have been extremely valuable during the drought that followed.

This research describes the development of water resources, conflict resolution model to evaluate the impact of water management alternatives in Kum River basin under droughts. Such a model is necessary to support decision making in the basin, as well as for providing useful insights to potential conjunctive operation of the dams. In addition, the results of this study can contribute to promote long-term water sustainability in this region. The remainder of this paper is organized as follows. A brief review of models used in water resource conflict management is presented. Next, a short description of the model for this research is presented. A description of potential management alternatives that resolve water conflict in this basin is then presented. This is followed by evaluation of the each alternative associated with trade-offs. Finally, future work is described.

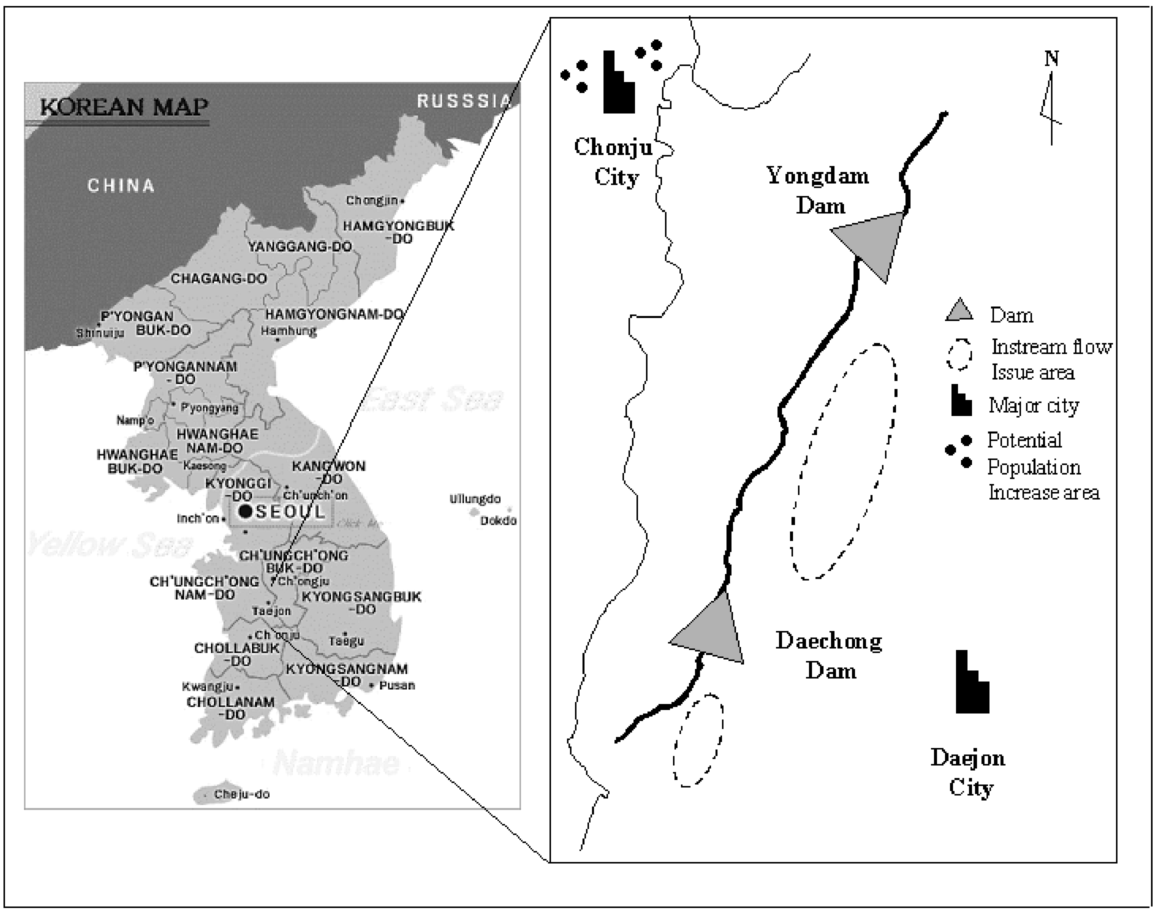

Figure 1. Map of Water System in Kum River Basin

Review Of Water Conflict Resolution Model

Conflicts occur in water resources planning and management for a variety of reasons. In general, water conflicts occur when people disagree about how much water of a given quality is available at a specific region for a specific purpose at a particular time (Palmer et. al, 1999). Conflicts can be resolved in many ways, through litigation, through formal agreements, through legislative order, through mediation, and through informed discussions. Lord et al. (1979) notes that water conflicts tend to arise because of disputes associated with perceived ownership, because of differences in how resources are valued, and because of differing interests. Computer models can be used to address both the reasons for conflicts and our perception of conflicts.

Many computer simulation models have been widely applied to water resource planning and management. By the 1980's, Corps of Engineers Hydrologic Engineering Center (HEC) developed the HEC-3 and HEC-5, applied for conservation storage and flood control systems (Yeh, 1985). Optimization models have also been widely used in reservoir system studies as well as water allocation studies. During the 1990's, Palmer et. al. (1993) introduced "Shared Vision Model" as a procedure that allows interested participants to achieve consensus by forming a shared vision of a system or process. The goals of shared vision modeling are to:

1. provide insight into questions and concerns generating conflicts,
2. include information that represent the interests and perspectives of all participants,
3. obtain equitable benefits for all participants, and
4. provide the opportunity for a high level of involvement by all stakeholders.

The Shared Vision Modeling environment include STELLA® (High Performance Systems 1992), Extend™ (Imagine That 1992), PowerSim® (MicroWorlds, 1995), SIMULAB™ (The Math Works, Inc. 1991), and DS Lab Pro (DS Group 1993). The Shared Vision Model built in STELLA® framework has been widely applied for National Drought Study (NDS) in national wide including Washington, Virginia, West Virginia, Kansas, Missouri, and Massachusetts. A benefit of the shared vision modeling approach is interactive use in a group setting to support joint fact finding, policy dialogue and alternative evaluation. This approach was viewed as an appropriate one to be applied to the Kum River basin to resolve water conflict.

Model Application

The remainder of this paper focuses on an application of the water conflict resolution model based on the Shared Vision modeling approach. Researchers at the University of Washington (UW) have had the opportunity to begin to apply the Shared Vision modeling approach to Kum River basin in Korea. The purpose of this research is to assess an existing plan, to develop alternatives for the management of all water resources in the region, and to resolve the water conflict based on an appropriate mechanism for implementing the plan.

There are a number of operational issues associated with the current water resources conflict in the Kum River basin. Instream flows downstream of Daechong Dam and instream flows between reservoirs are under debate and widely different values are being suggested. The construction of Yongdam Dam and the continued growth in this basin has created the need to address a number of fundamental water resource questions. The models developed in this research address specific planning issues that must be resolved in the basin. These issues include: 1) An appropriate fishflow target between dams; 2) Safe yield of both dams as a function of established fish flow; 3) Benefits of conjunctive operation; and 4) Relative water distribution in the two dams. These general concerns can be framed into a series of questions that explore system operation and management, including:

1. What was the safe yield of the Daechong Dam before Yongdam Dam was constructed?
2. What is the safe yield of both dams, if they are operated for a single, downstream user and there is no required environmental flow?
3. How much of this yield is lost if there are required environmental flows between the two dams?
4. How much yield is lost when there are required environmental flows downstream on Daechong Dam?

The analysis begins with the selection of model parameters and year of interest to analyze. The model incorporates the regional hydrology, conjunctive reservoir management and operating rules, and multi-objective programming to illustrate the trade-offs between system reliability, operating strategy, environmental flows, and drought triggers. Operational parameters under consideration were incorporated into the Shared Vision model. The safe yield of the system was defined as the maximum amount of water that could be taken from the reservoir system over the twenty-year historic record that resulted in a failure in one year. Appropriate operating policies that improved the performance of the conjunctive system with respect to safe yield were developed in the course of this research. The model is designed specifically as a conflict resolution tool to allow its incorporation into the ongoing debate concerning the regional goals and objectives of water management in this basin. This design required that the model be user friendly and technically detailed to allow its results will be accepted by those that will eventually arrive at a compromise between the various conflicting operational objectives.

Analysis Output

Each of the four management questions is answered in turn and is described below.

Safe Yield of Daechong Dam

The safe yield of Daechong Dam prior to the construction of Yongdam Dam was calculated to be 40.1 cubic meters per second (m^3/s). This value assumes that all water entering the dam could be diverted for use. The safe yield of the system was also calculated with different environmental flows downstream. The results of this analysis are presented in Table 1. The table indicates the expected trade-off between providing more water downstream and the ability to provide water to divert from the system. This yield (40.1 m^3/s) represents that maximum yield that could have been provided from the Daechong Dam. It can be considered the "status quo" value for the uses of Daechong Dam, prior to the construction of Youngdam Dam.

Safe Yield of Daechong Dam and Yongdam Dam
It is instructive to determine the yield of both Daechong Dam and Yongdam Dam as the starting point of negotiations between the two. This value represents the total yield of the system after Yongdam Dam's construction, and could be view by the downstream users of the water that rightfully belongs to them. The difference between this value and the yield of the Daechong Dam without Yongdam Dam could, from a different perspective, be considered the amount of yield that should be provided to the users of the Yongdam Dam.

Table 1. Safe yield of Daechong Dam with varying fish flows, without Yongdam Dam

Fish below Daechong	Safe Yield
0 m^3/s	40.1 m^3/s
5 m^3/s	36.3 m^3/s
10 m^3/s	29.6 m^3/s
15 m^3/s	23.9 m^3/s
21 m^3/s	18.1 m^3/s

Table 2 presents the results of an analysis that calculates the yield of the two-reservoir system. In general, the yield of the system increases by approximately 11 m^3/s. On could argue that the users of the Yongdam Dam should not expect more than 11 m^3/s of yield from the system, because taking more than this would decrease the yield of the more senior user of the river. If less than 11 m^3/s is taken from Yongdam Dam, however, the construction of the new dam could be viewed as a regional benefit.

Table 2. Safe Yield of Daechong Dam with varying fish target below, with new dam operation that support Daechong Dam

Fish below Daechong	Safe Yield
0 m^3/s	52.0 m^3/s
5 m^3/s	46.3 m^3/s
10 m^3/s	41.3 m^3/s
15 m^3/s	36.3 m^3/s
21 m^3/s	29.7 m^3/s

Safe Yield of Yongdam Dam
Another perspective is to ignore any previous beneficial uses of the water and to assume that when Yongdam Dam is constructed, its users will consume the entire yield that they

can derive from the project. This value was also calculated, based upon an appropriate assumption for the appropriate portion of the streamflows that would flow into Yongdam Dam. The yield of this system proved to be 13.8 m^3/s. It should be noted that this value is very similar to the increased yield of the two-reservoir system.

Impact of Environmental Flows on Yongdam Dam and on Daechong Dam

Because of water quality concerns, the flow between the two dams is very important. The ability to operate the two reservoirs conjunctively to maximize yield can be negatively impacted if environmental flows between the two dams cause system storage to be inequitable between the reservoirs. Setting the environmental flow at a high value between Yongdam Dam and Daechong Dam can also significantly decrease the yield of Yongdam Dam while increasing Daechong Dam.

Table 3 presents the safe yield of Daechong Dam and Yongdam Dam for two assumptions relating to the environmental flows between the dams. The yield of Yongdam Dam is very sensitive to fish flows between dams. As noted previously, the yield of Yongdam Dam, without environmental flows between the two dams is 13.8 m^3/s. If an environmental flow of 5.4 m^3/s is maintained, the yield drops to 8.1 m^3/s. If an environmental flow of 12.4 m^3/s is maintained, the yield drops essentially to zero. The yield of the Daechong Dam benefits from increasing fish flows between the two dams, increasing from 23.9 m^3/s to 31.4 m^3/s as the fish flow requirement increases.

Table 3. Safe Yield of Daechong Dam with fish targets between the Dams

Year	Fish below Daechong	Fish below Yongdam	Safe Yield of Daechong Dam	Safe Yield of Yongdam Dam
2010	21 m^3/s	5.4 m^3/s	23.9 m^3/s	8.1 m^3/s
2010	21 m^3/s	12.4m^3/s	31.4 m^3/s	0.79 m^3/s

Implications of the Results on Conflict Resolution

This analysis illustrates the range of benefits that can be obtained during drought years similar to 1988 and 1995 by the construction of the Yongdam Dam. It appears that the construction of Yongdam Dam can provide benefits to both upstream and down stream users of the Kim River. The additional storage provided by this dam could be used for many purposes including providing water to upstream users and ensuring that environmental flows can be maintained between the two reservoirs. Yongdam Dam could also, perhaps, provide additional water during drought periods to downstream users, water that would not have been available unless the dam was constructed.

However, there are clear conflicts between the environmental flows established downstream of Daechong and the amount of water that can be diverted for municipal, industrial and agricultural water supply from that dam. There are also clear conflicts between the environmental flows established between the two dams and the ability to supply water from Yongdam Dam.

The advantages of a model such as the one developed in this research is that these trade-offs can be clearly illustrated to stakeholder groups and that decisions can be made based upon a foundation fact, rather than conjecture. As the water supply needs and demands in the region change, and as the value of the water for various uses is more clearly defined, informed decisions can be made to allow for the best management possible.

Future Work

With the completion of the simulation model of the Kum River basin, the authors anticipate continued efforts to evaluate potential water management trade-offs in the basin and the opportunity to work with stakeholders to better incorporate regional considerations, constraints, and objectives. Because the establishment of environmental flows will have a significant impact on system yield and because the region continues to grow, the conflicts will worsen unless cooperative solutions can be reached.

A number of improvements, enhancements, and new directions can be taken to provide increased decision support in the Kum River basin. These new directions may include:

- Development of a detailed Drought Management Plan to support system operation and management during periods of low flow,
- Development of evaluation criteria (reliability, resiliency, and vulnerability) for system operation during drought,
- Advanced analysis of the influence that instream flow requirements have on system safe yield, and
- Economic evaluation of the trade-offs between instream flow values and water used in the basin for other purposes.

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