An Optimization Model to Mitigate Conflicts in the Kum River Basin, Korea

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Overview

- Project Description
- Water Resource Conflict
- System Configuration for Linear Programming
- Model Application
- Analysis Output
- Conclusion
- Future Work

Kum River Project

- Length of Project
- Funded by Korea Government (KICT)
- Participants
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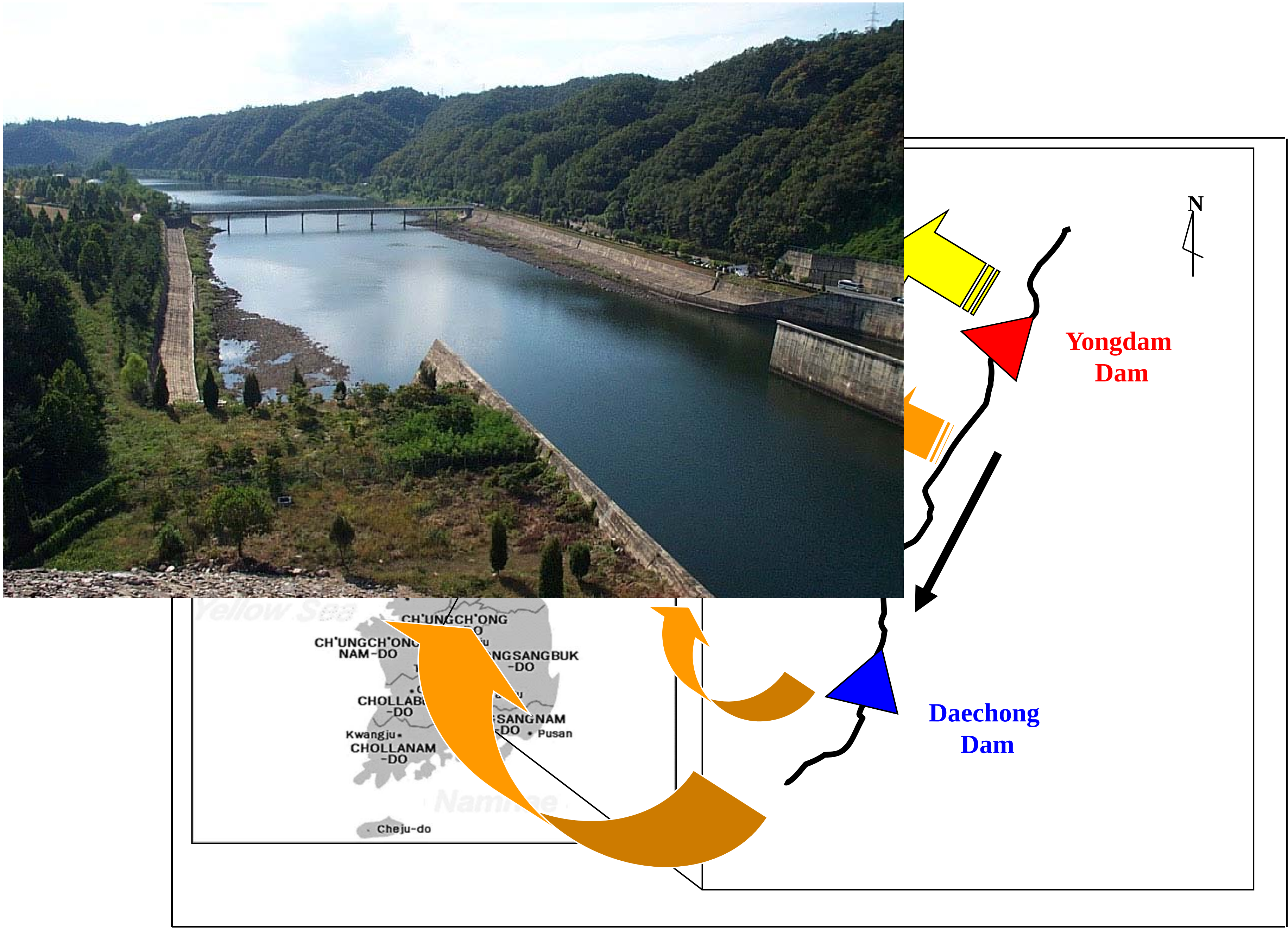
  - Jae Hyeon Ryu (UW, Seattle)
  - Dr. Sangman Jeong (KNU, Kongju, Korea)
  - Dr. Jooheon Lee (Joongbu, Korea)


NORTH KOREA
Demarcation Line
0 50 100 km
0 50 100 mi
Kangnŭng
SEOUL
Ullŭng-do
Inch'ŏn
Wŏnju
Pukp'yŏng-dong
Suwŏn
Sea of Japan
Taejŏn
P'ohang
Yellow Sea
Kunsan
Taegu
Chŏnju
Ulsan
Kwangju
Masan
Chinhae
Pusan
Mokp'o
Yŏsu
Korea Strait
Cheju-do
JAPAN


N
Yongdam
Dam
Daechong
Dam
Kwangju
CHOLLANAM
-DO
Pusan
Cheju-do

Background

- Kum River Basin
  - 9,800 km^2 (3,780 mi^2 : watershed area)
  - 400 km (250 mile : mainstem length)
- Daechong Dam
  - Constructed in 1971
  - Multi-objective dam
  - 1,500 million m^3 (53,000 mil. ft^3: reservoir size)
  - 3 million people
- Yongdam Dam
  - Constructed in 2001
  - Multi-objective dam (water supply)
  - 815 million m^3 (29,000 mil. ft^3 :reservoir size)
  - 1.5 million people

Water Conflicts

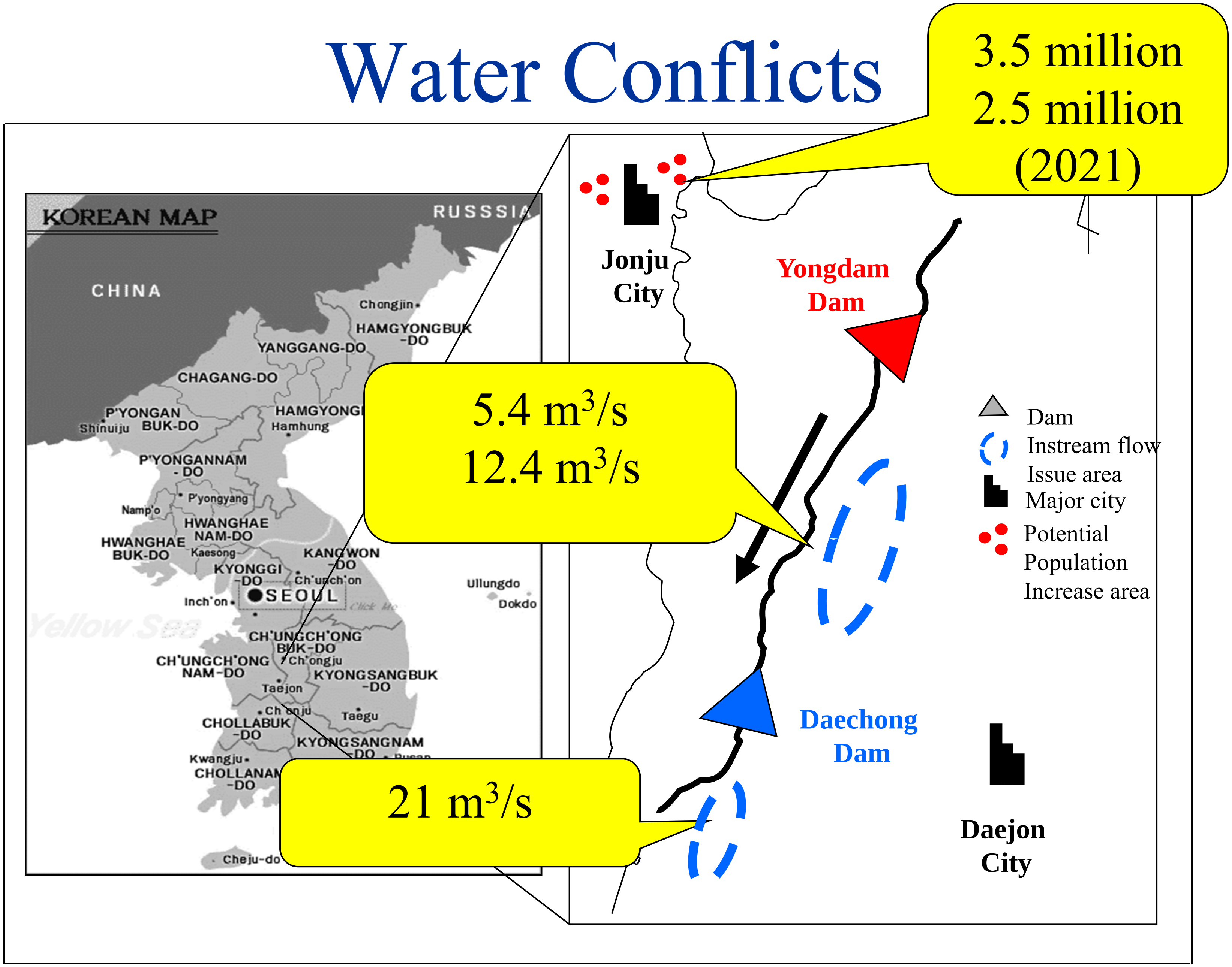
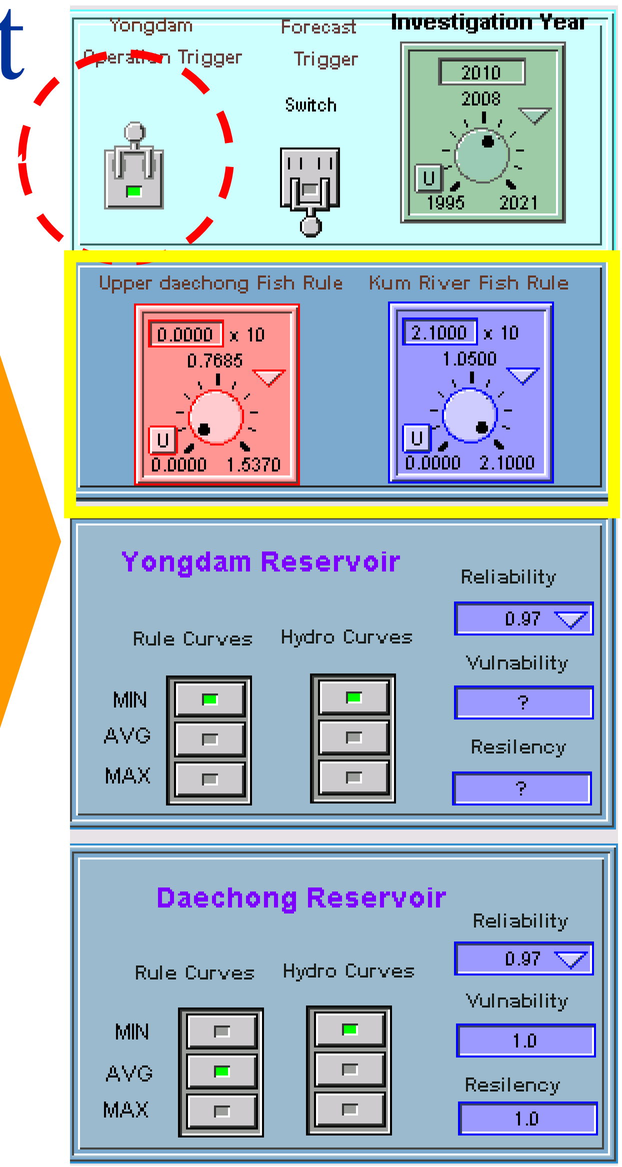


Figure 1. Map of Water System in Kum River Basin

STELLA® Modeling Environment

	Daechong Dam in downstream	Yongdam Dam in upstream
Fish flow of between dams	12.4 m^3/s	5.4 m^3/s
Yongdam dam operation	Disagree	Agree
Fish flow of downstream of Daechong Dam	21 m^3/s	Less than 21 m^3/s



Optimization Tree

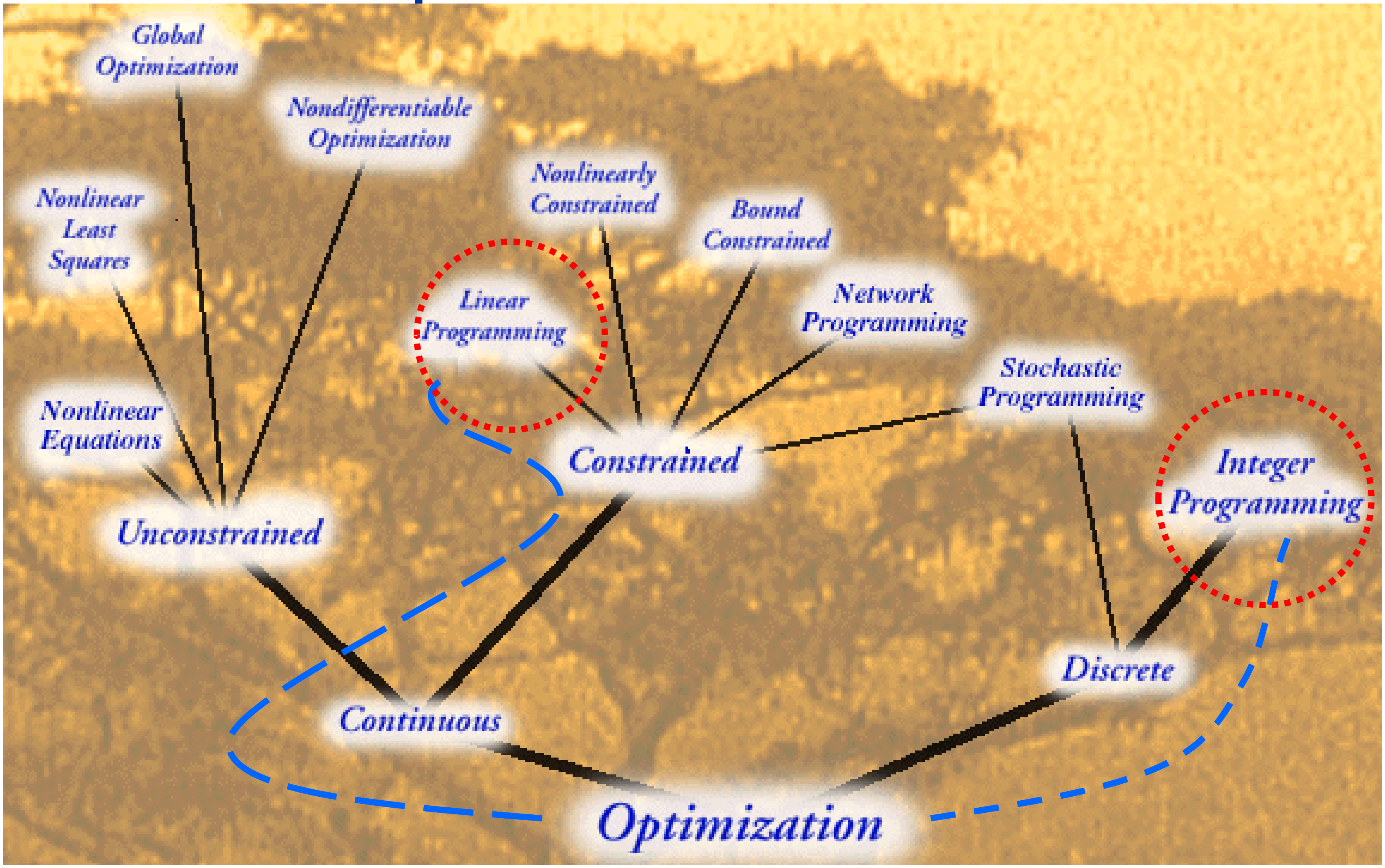


Figure 2. NEOS Guide Optimization Three

(http://www-fp.mcs.anl.gov/otc/Guide/OptWeb/index.html)

Objective and Constraints

Objective

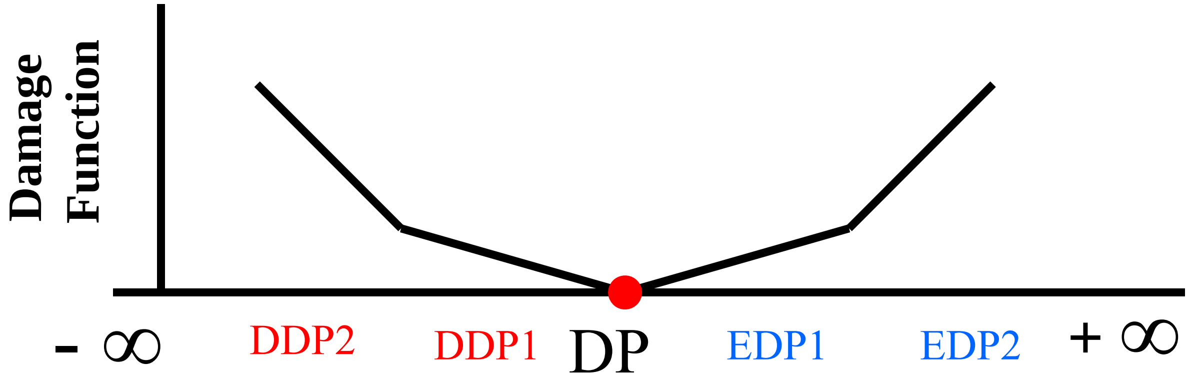
To minimize estimated damage function associated with water conflict (people, fish and hydropower target)

Constraints

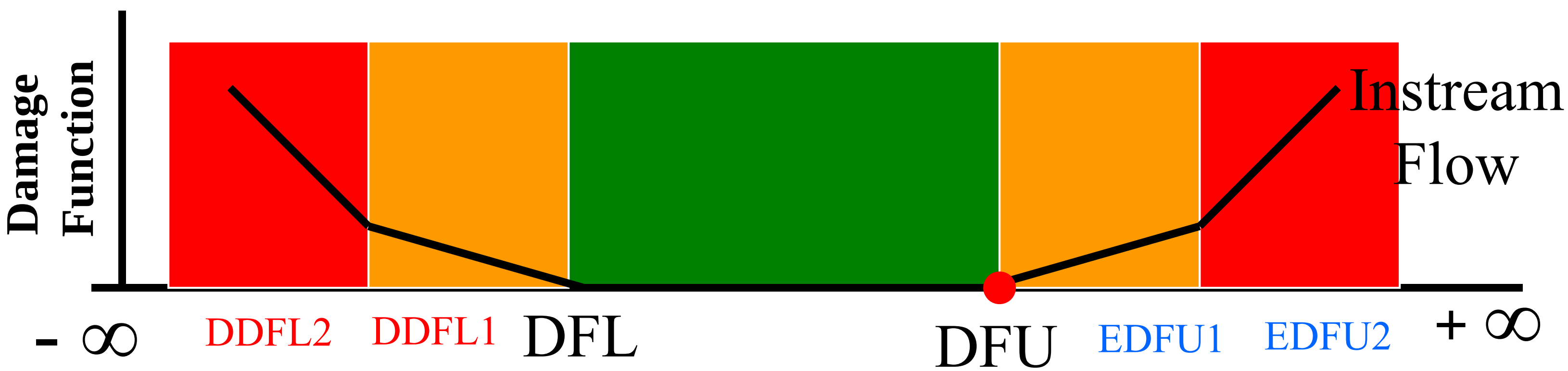
1. System Continuity
2. Reservoir storage limit (dead and full)
3. Diversion facility and Power turbine capacity limit (hydropower rule)
4. Instream flow requirement below each dam

Traditional Piecewise Linear Programming Approach

1. Target Water Demand



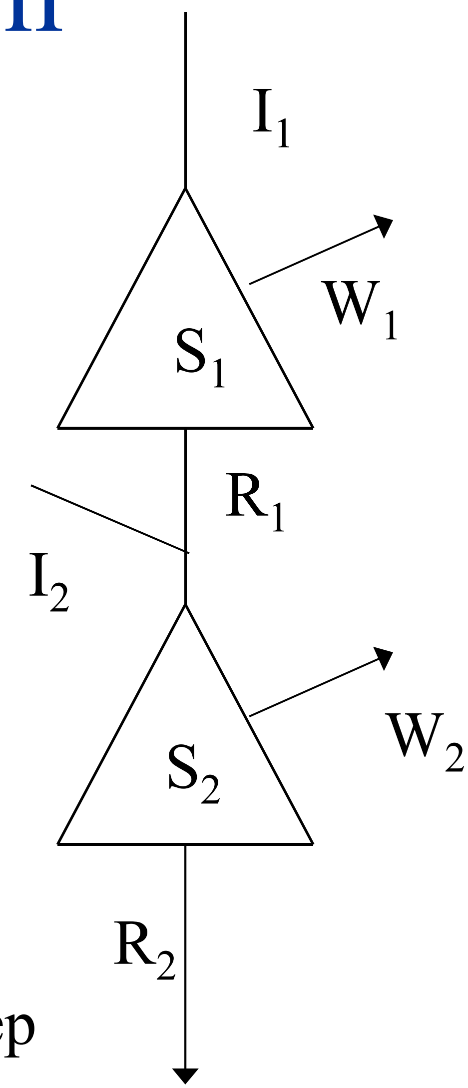
2. Acceptable Range of Instream Flow



System Configuration

Constraints:

1) $S_{j,t+1} = S_{j,t} + I_{j,t} - W_{j,t} + M*R_{j,t}$
2) $W_{j,t} - DP_{j,t} = EDP_{j,t} - DDP_{j,t}$
3) $EDP_{j,t} = EDP1_{j,t} - EDP2_{j,t}$
4) $DDP_{j,t} = DDP1_{j,t} - DDP2_{j,t}$
5) $R_{j,t} - DFL_{j,t} = EDFL_{j,t} - DDFL_{j,t}$
6) $DDFL_{j,t} = DDFL1_{j,t} - DDFL2_{j,t}$
7) $R_{j,t} - DFU_{j,t} = EDFU_{j,t} - DDFU_{j,t}$
8) $EDFU_{j,t} = EDFU1_{j,t} - EDFU2_{j,t}$

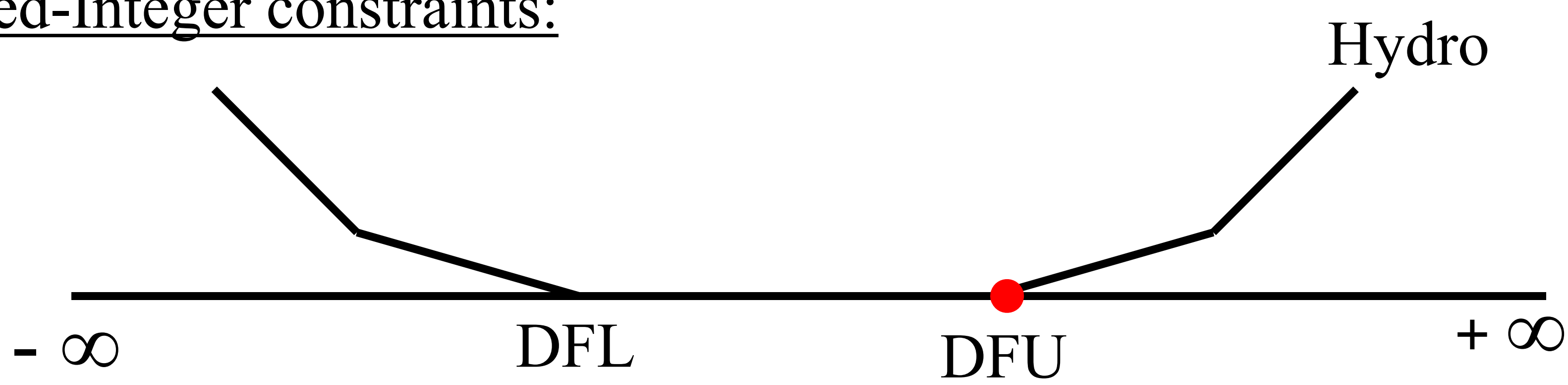


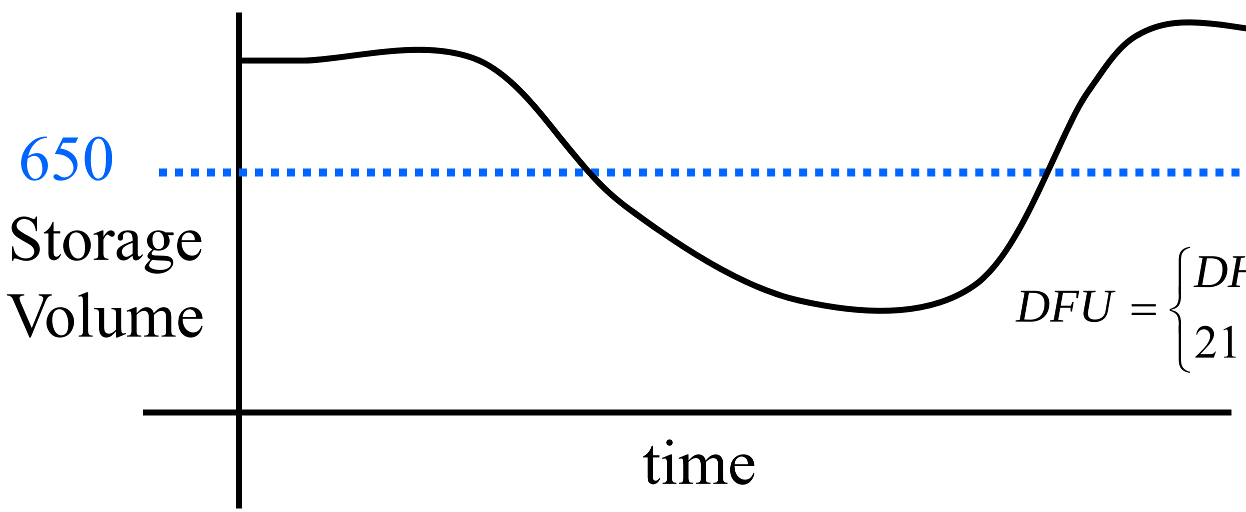
Where, j = reservoir index, t = weekly time step

M = reservoir connection matrix $\begin{bmatrix} -1 & 0 \\ 1 & -1 \end{bmatrix}$

Integer Component

<u>Mixed-Integer constraints:</u>





$$DFU = \begin{Bmatrix} DH_{2,t} & if\ S_{2,t} > 650 \\ 21\ m^3/s & otherwise \end{Bmatrix}$$

Integer Component –cont'd

Additional integer constraints:

1) $DFU_{j,t} - A_{j,t}*DH_{j,t} - B_{j,t}*DF_{j,t} \leq 0$

2) $A_{j,t} + B_{j,t} = 1$

3) $S_{j,t} - G*A_{j,t} \leq 650.01$

4) $S_{j,t} - 650.01*A_{j,t} \geq 0$

Where, G = big value, $A_{j,t}$ and $B_{j,t}$ = binary integer variable
$DF_{j,t}$ = Fish target below each dam at given time

Objective Function

Objective Function

$2*EDP1_{j,t} + 5000*EDP2_{j,t}$: Excess for people target
$+ 3*DDP1_{j,t} + 5000*DDP2_{j,t}$: Deficit for people target
$+ 3*DDFL1_{j,t} + 5000*DDFL2_{j,t}$: Deficit for Fish target
$+2*EDFU1_{j,t} + 2.5*EDFU2_{j,t}$: Excess for Fish target

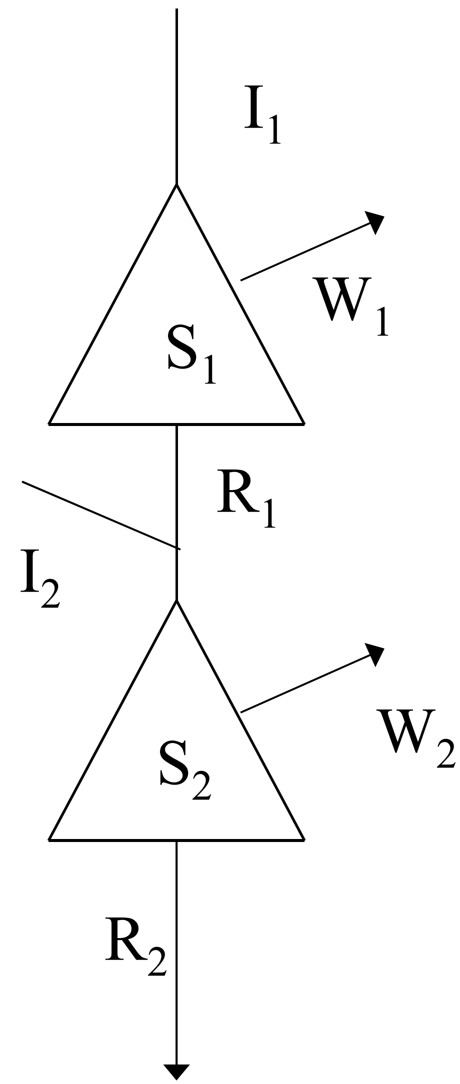
Relative weight in Objective Function

Weight	Variables
5000	Meeting demand
3	Equality for fish and people
2	Allowable excess range for fish and people
2.5	Allowable spill during flood

System Dimensionality

<u>6 year (1992~1997) modeling period</u>

- Daechong Dam only
  - Total constraints: 4,056
  - Total variables: 6,241
- Daechong and Yongdam Dam
  - Total constraints: 6,552
  - Total variables: 11,546



Xpress-MP (http://www.dashoptimization.com)

+

Tomlab (http://www.tomlab.biz)

Constraint Scenarios

- Hydropower options (Hydro, No hydro)
- Instream below Daechong dam
  - 21 m^3/s
  - No consideration
- Instream between two dams
  - 5.4 m^3/s
  - 12.4 m^3/s
- Jonju city population in 2021
  - 2.5 million
  - 3.5 million
  - No consideration

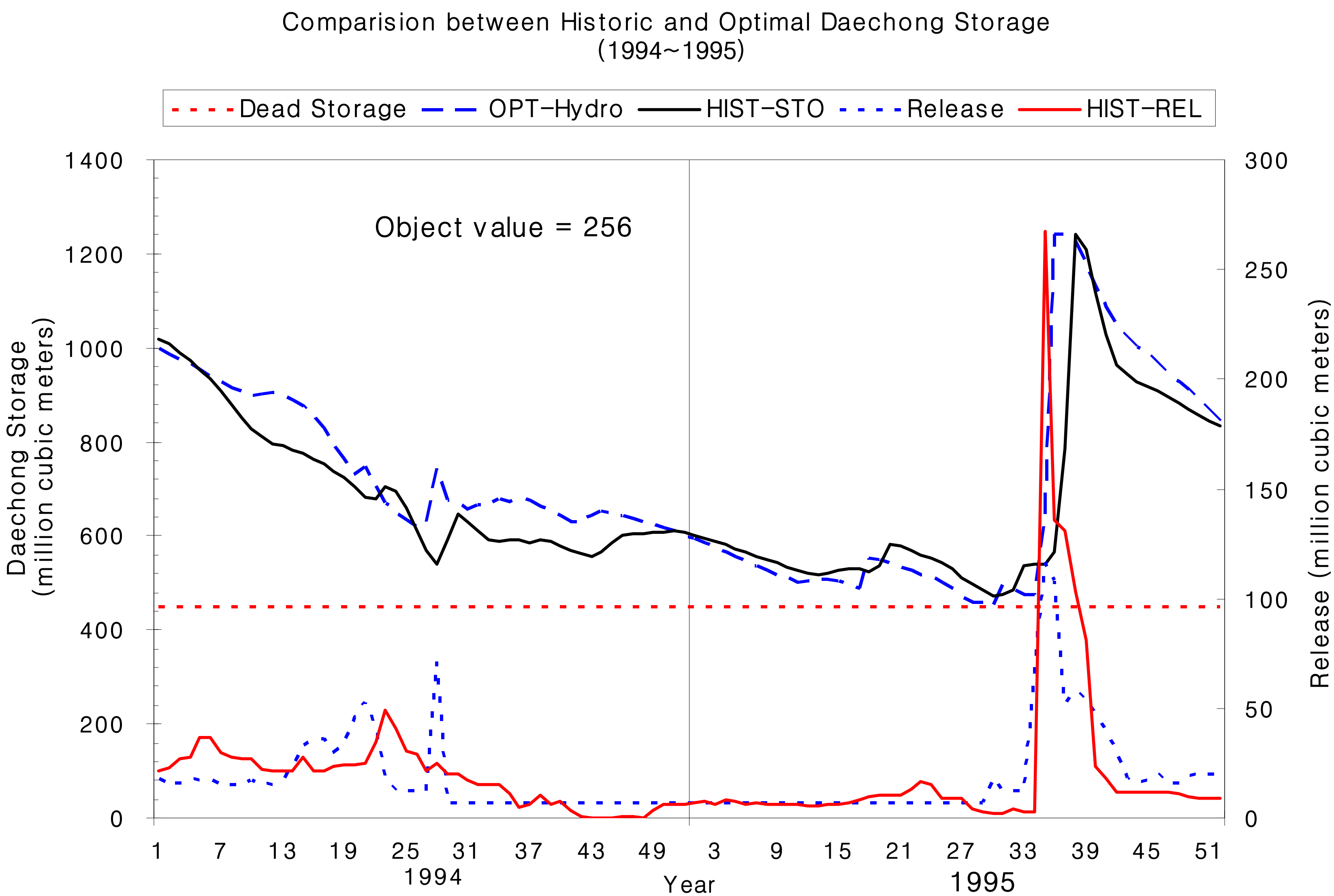
Total constraint scenarios: 24

Constraint Scenarios –cont'd (Status Quo)

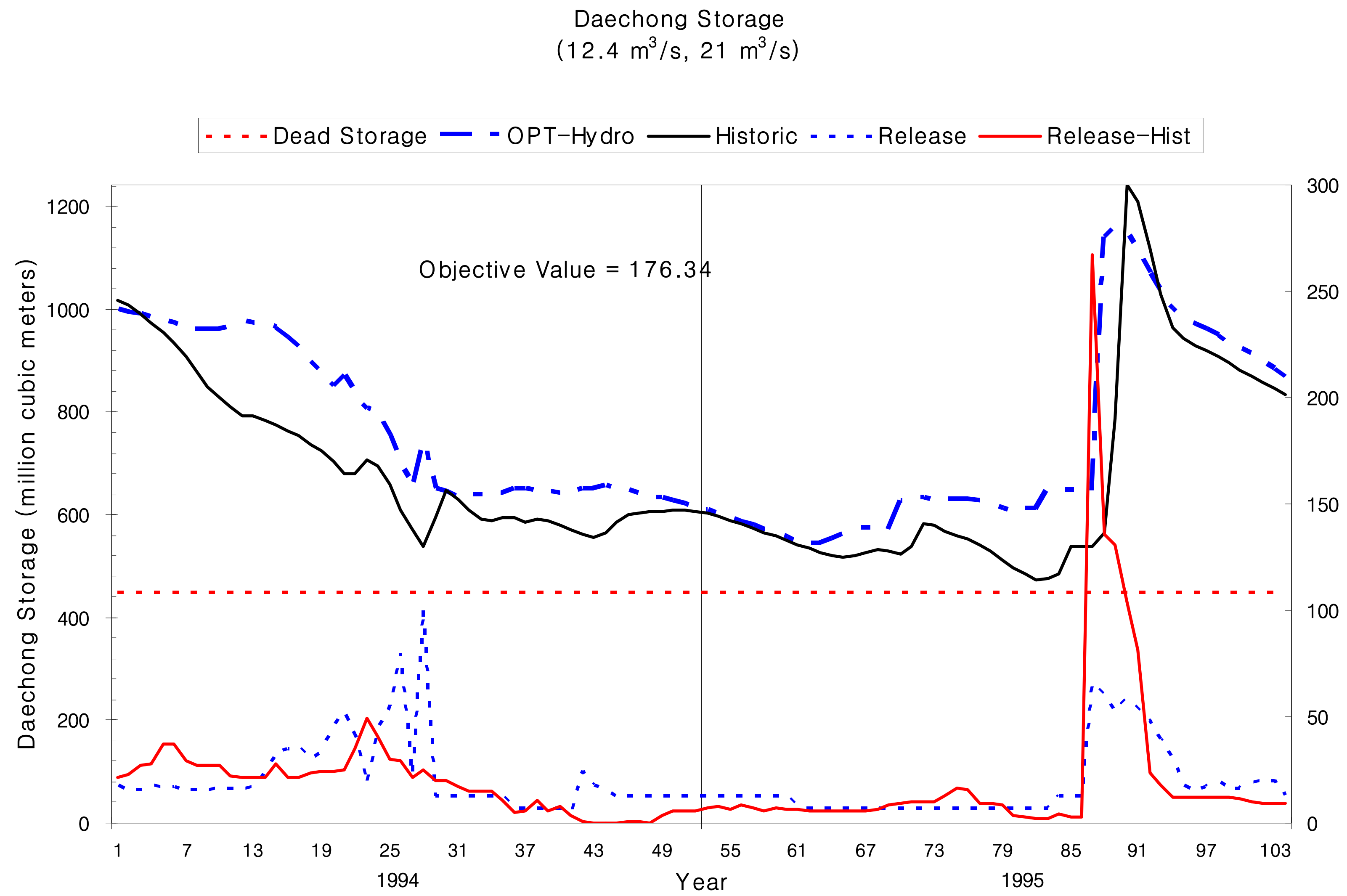
Year / Cases	Reliability	2000	2005	2010	2015	2020	2025
1	Yongdam	1.00	1.00	1.00	1.00	1.00	1.00
	Daechong	0.98	0.96	0.94	0.92	0.90	0.87
2	Yongdam	1.00	1.00	1.00	1.00	1.00	NA
	Daechong	0.98	0.96	0.94	0.92	0.89	NA
3	Yongdam	1.00	1.00	1.00	1.00	0.98	NA
	Daechong	0.98	0.96	0.94	0.92	0.88	NA
4	Yongdam	0.99	0.98	0.97	0.96	0.94	0.93
	Daechong	0.99	0.98	0.97	0.95	0.93	0.91
5	Yongdam	0.99	0.98	0.97	0.96	0.93	NA
	Daechong	0.99	0.98	0.97	0.95	0.93	NA
6	Yongdam	0.99	0.98	0.97	0.96	0.86	NA
	Daechong	0.99	0.98	0.97	0.95	0.90	NA
7	Yongdam	1.00	1.00	1.00	1.00	1.00	1.00
	Daechong	1.00	1.00	0.99	0.98	0.96	0.94
8	Yongdam	1.00	1.00	1.00	1.00	1.00	NA
	Daechong	1.00	1.00	0.99	0.98	0.96	NA
9	Yongdam	1.00	1.00	1.00	1.00	0.98	NA
	Daechong	1.00	1.00	0.99	0.98	0.94	NA
10	Yongdam	0.99	0.98	0.97	0.96	0.94	0.93
	Daechong	1.00	1.00	0.99	0.98	0.97	0.96
11	Yongdam	0.99	0.98	0.97	0.96	0.93	NA
	Daechong	1.00	1.00	0.99	[illegible]	0.97	NA

- Daechong Hydro (AVG)
- Instream flow below Daechong (21 m^3/s)
- Instream between dams (12.4m $^3/s$)
- Jonju population in 2021 (inconclusive)

Comparison Status Quo to Optimization

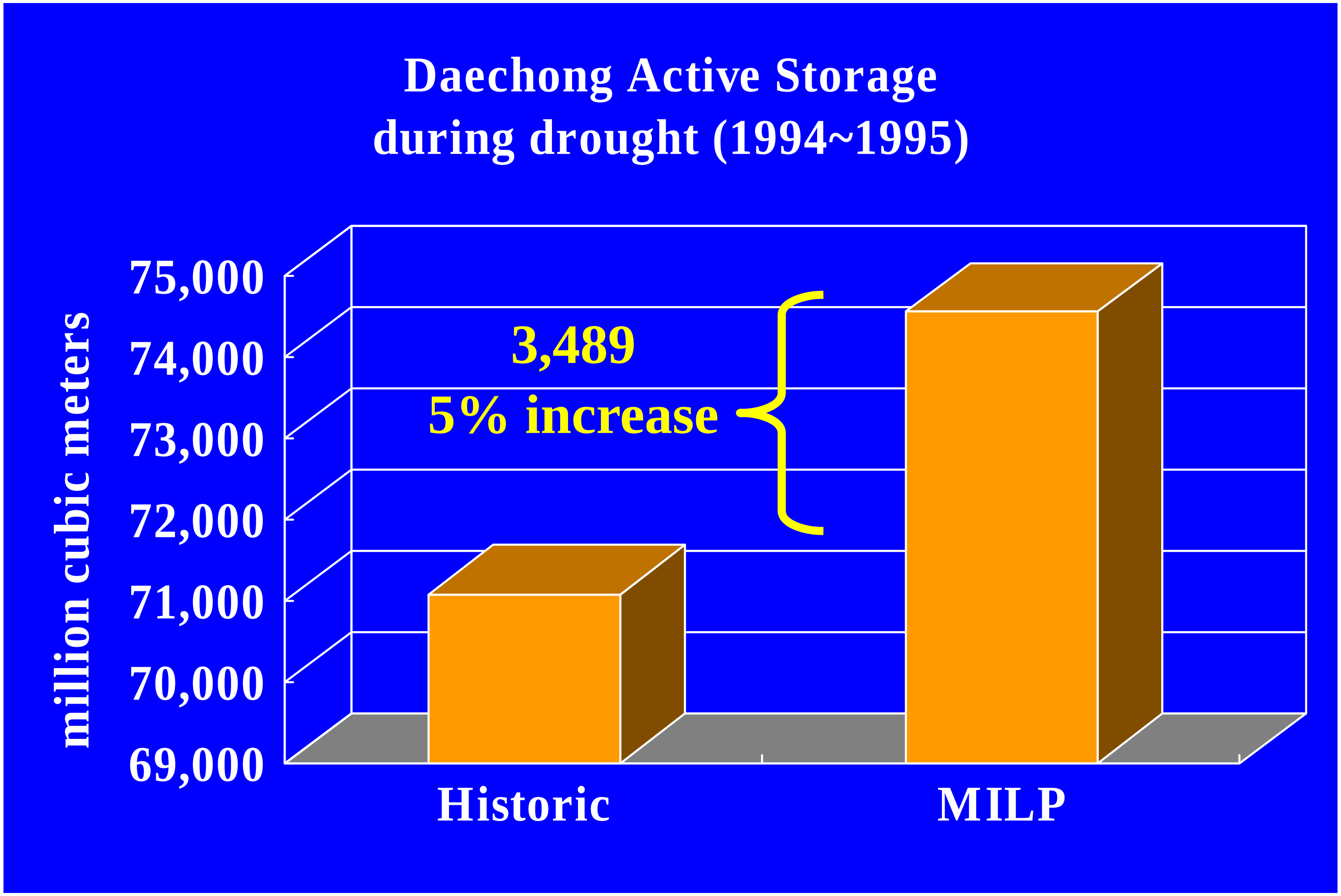


Comparison Status Quo to Optimization –cont'd



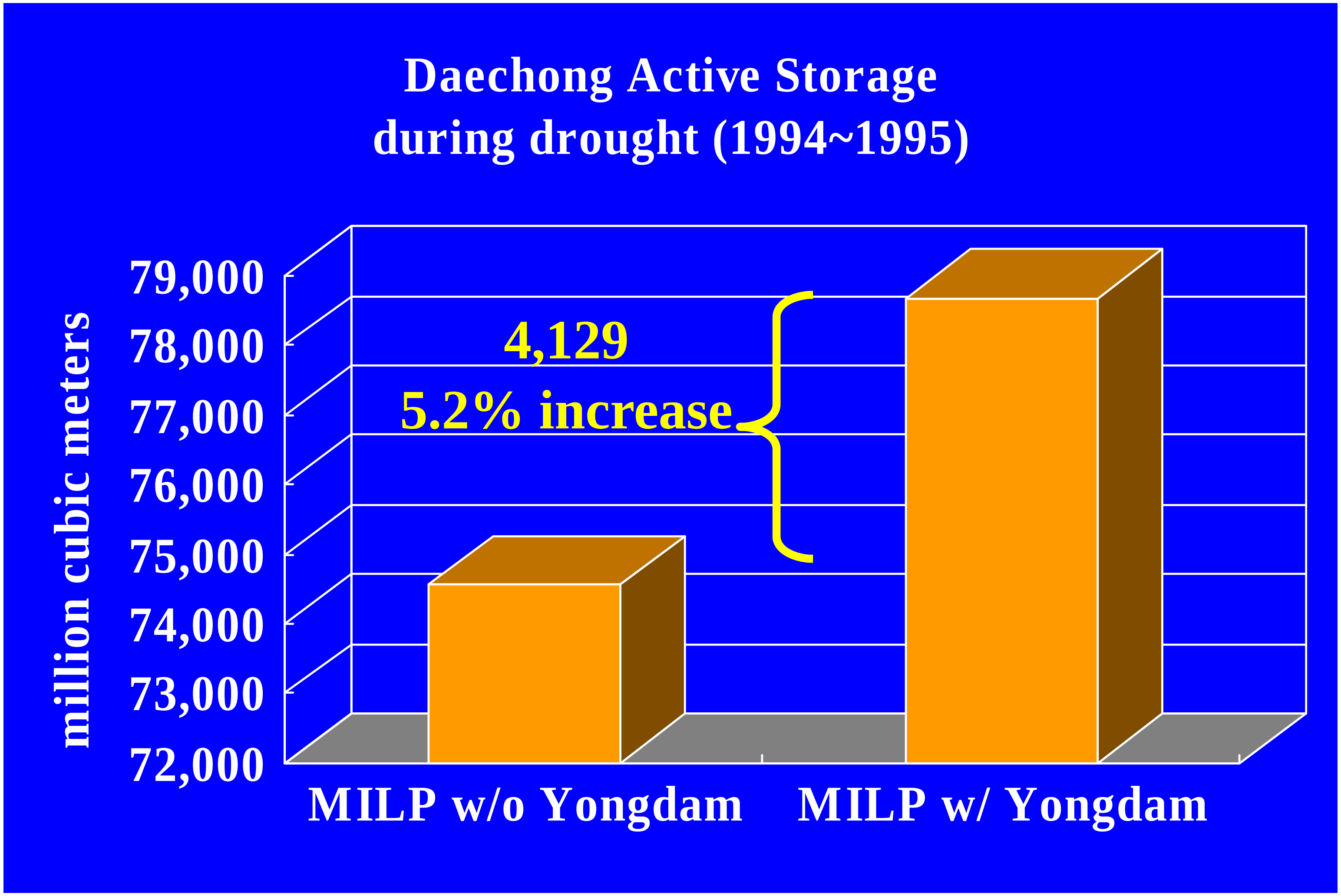
Analysis Output

Figure 3. Active Storage difference between historic and optimized Daechong Storage without Yongdam Dam



Analysis Output –cont'd

Figure 4. Active Storage difference between historic and optimized Daechong Storage with Yongdam Dam

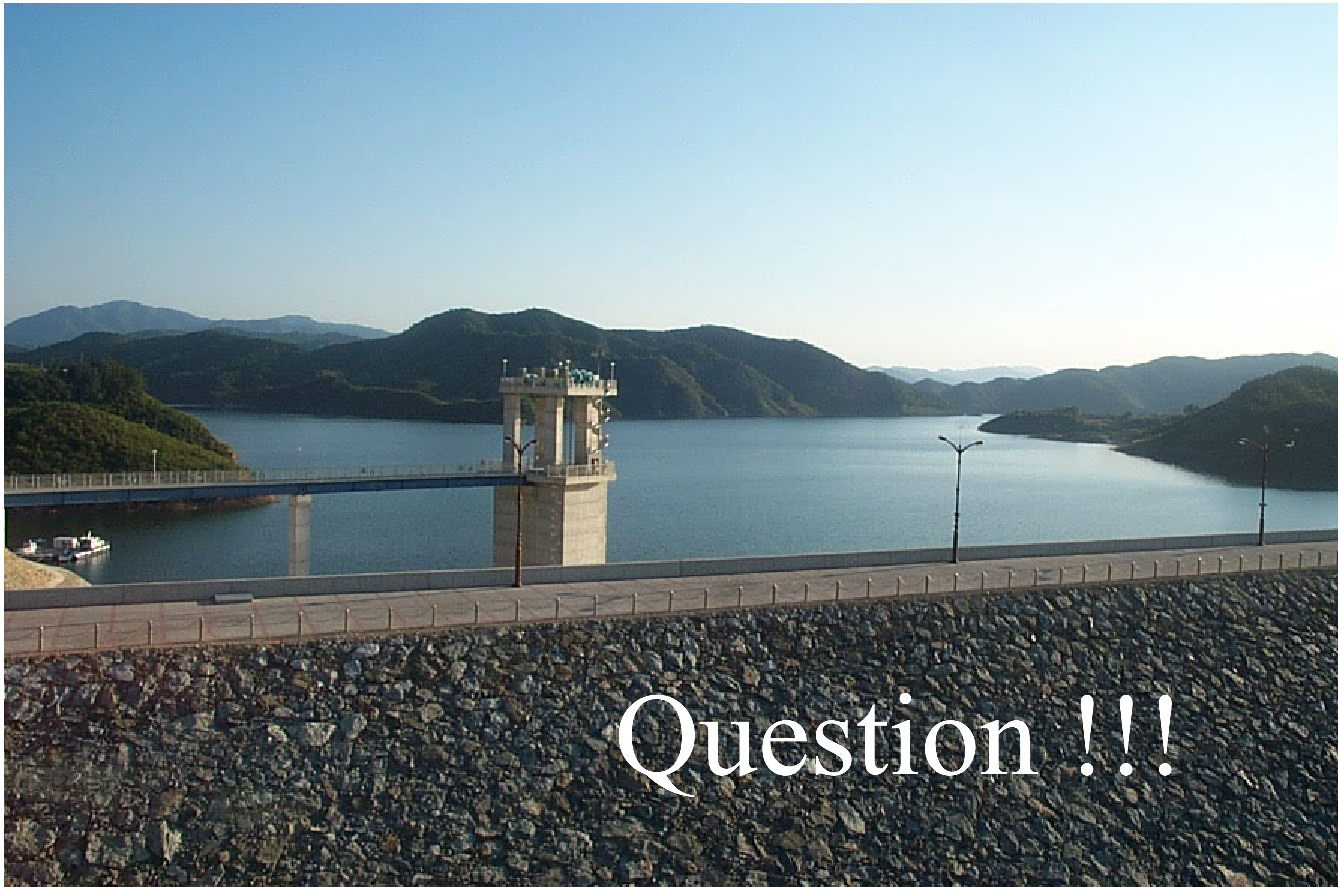


Conclusion

- MILP well represented storage behavior associated with water conflicts
- MILP increases active storage volume during severe drought
- A lead-time streamflow forecast can improve system operational analysis
- Conjunctive dam operation is necessary to optimize regional water resources
- Jonju population concern in 2021require alternative water resource

Future Work

- Development of a lead-time streamflow forecast method
- To reduce computation time associated with high dimensionality
- More accurate damage parameter required
- Verification of model in real situation



Question !!!