K-MODSIM DSS

DECISION SUPPORT SYSTEM FOR RIVER BASIN MANAGEMENT

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Need for Computer-Based Decision Support Tools

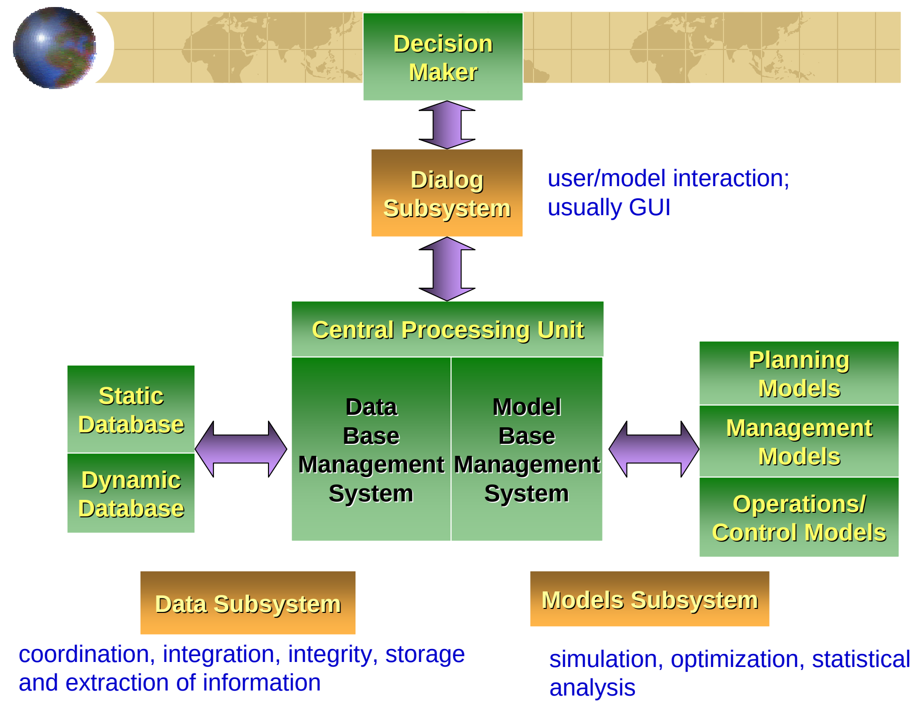
- **Size, complexity** of integrated river basin management
- **Administrative**, legal issues; water rights
- Interdependence of **surface and groundwater** resources
- **Environmental** and ecological impacts
- Resolving **conflicts** between urban, agricultural, environmental, energy interests

Concept of Decision Support System (DSS)

- **Optimization** available in a DSS as a **tool** under the direct control of reservoir system managers for decision-making purposes
- Provides "**support**" **for decision makers**, rather than overly empowering programmers/modelers
- Recognizes **river basin** as an **integrated "system"**

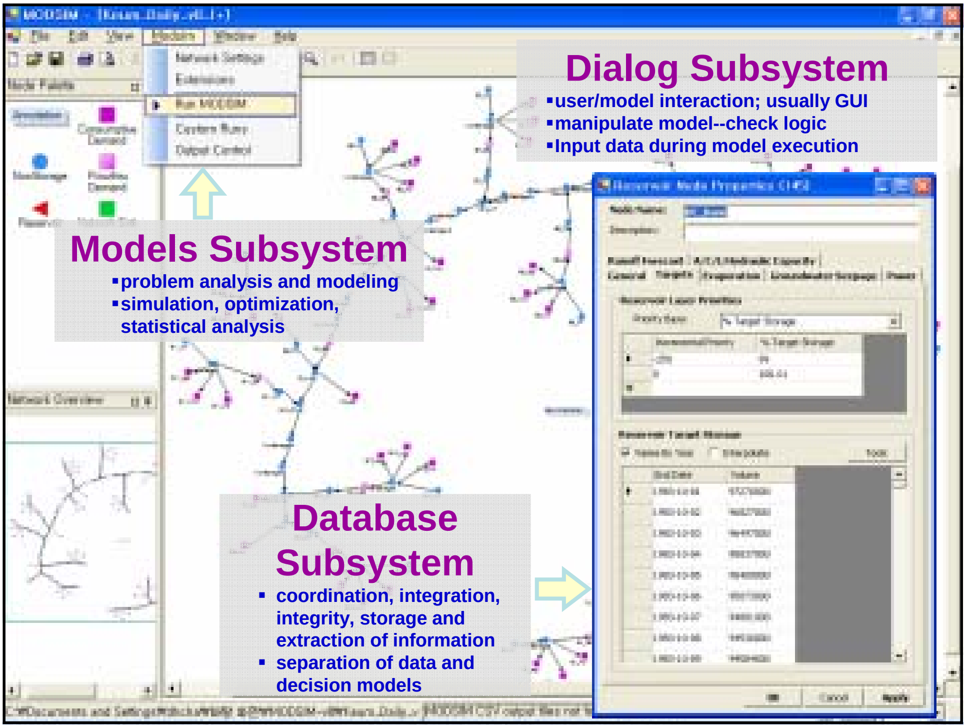
Components of a DSS

1. **Dialog Subsystem**
   - user/model interaction; usually GUI (graphical user interface)
   - manipulate model--check logic
   - Input data during model execution
2. **Data Base Management Subsystem**
   - coordination, integration, integrity, storage and extraction of information
   - separation of data and decision models
3. **Models Subsystem**
   - problem analysis and modeling
   - simulation, optimization, statistical analysis



K-MODSIM as a DSS

- Designed as **computer-aided tool** for developing improved basin-wide and regional strategies for
  - short-term water management
  - long-term operational planning
  - drought contingency planning
  - helping resolve conflicts between urban, agricultural, energy, environmental interests
- Powerful **GUI** connects K-MODSIM with data base management system and efficient network flow optimization model



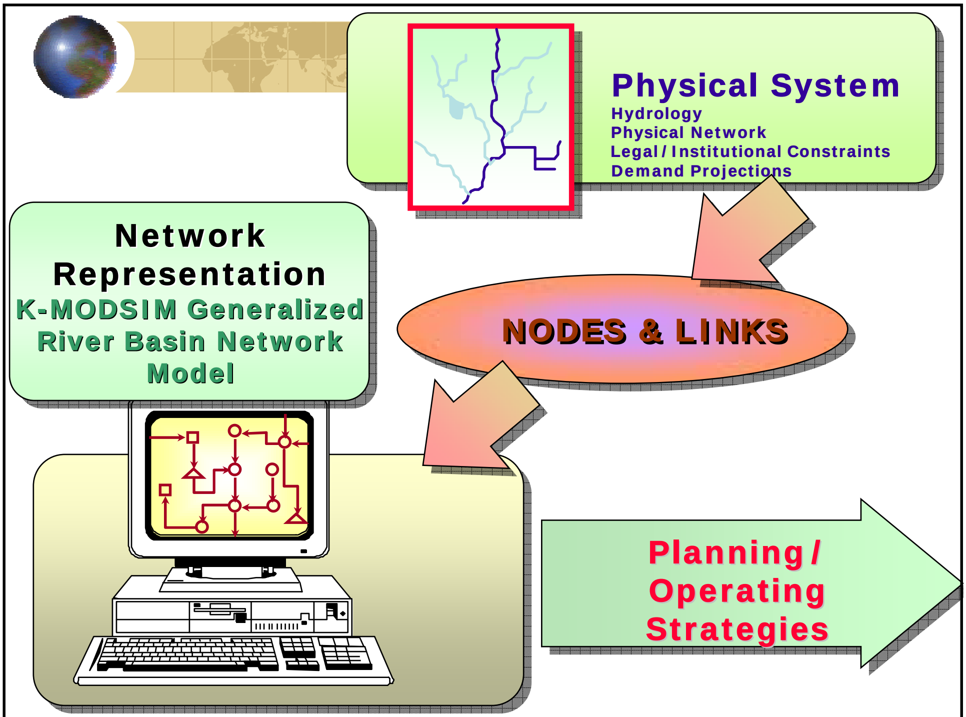
- **Objective function** and **constraints** of network flow optimization model **automatically constructed** through GUI
  - requires no background in optimization or computer programming
- **Optimization** used as efficient means of satisfying all system demands/guidecurves according to given priorities…
  - …while assuring water allocated according to physical, hydrological, and institutional/ administrative aspects of river basin management

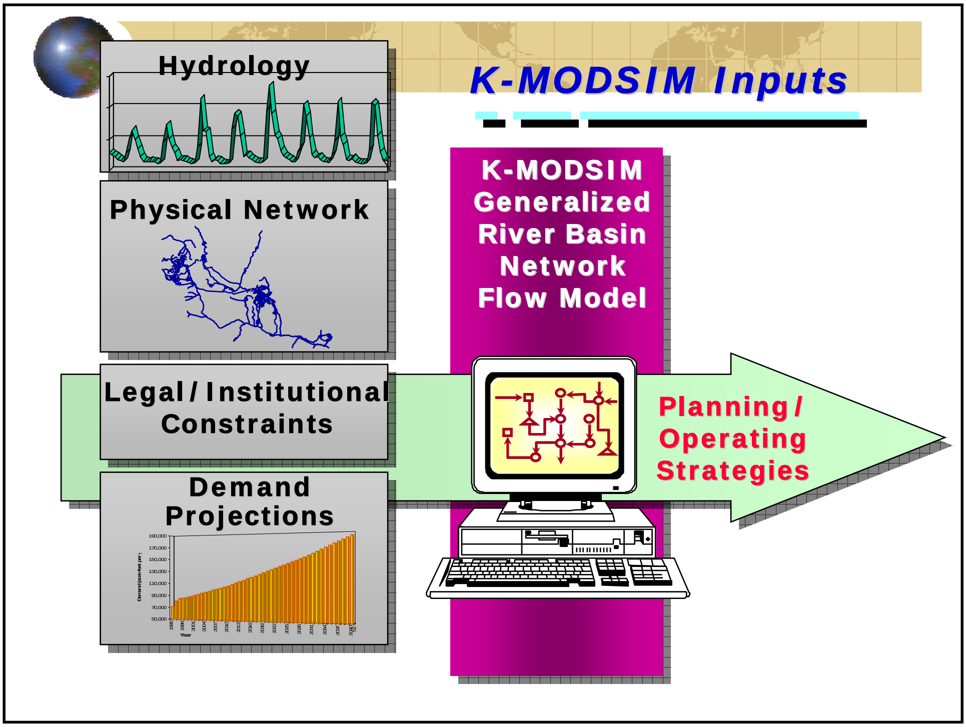
HOW DOES K-MODSIM WORK?

- **Underlying principle**-most complex river basin systems can be simulated as capacitated flow networks
- **Capacitated**—upper/lower (time variable) bounds on all flows

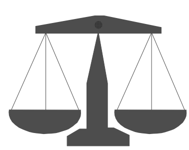
Model Objects:

- Reservoir (Storage) Nodes
- Non-Storage Nodes
- Demand Nodes (, ,)
- Links (or Arcs)

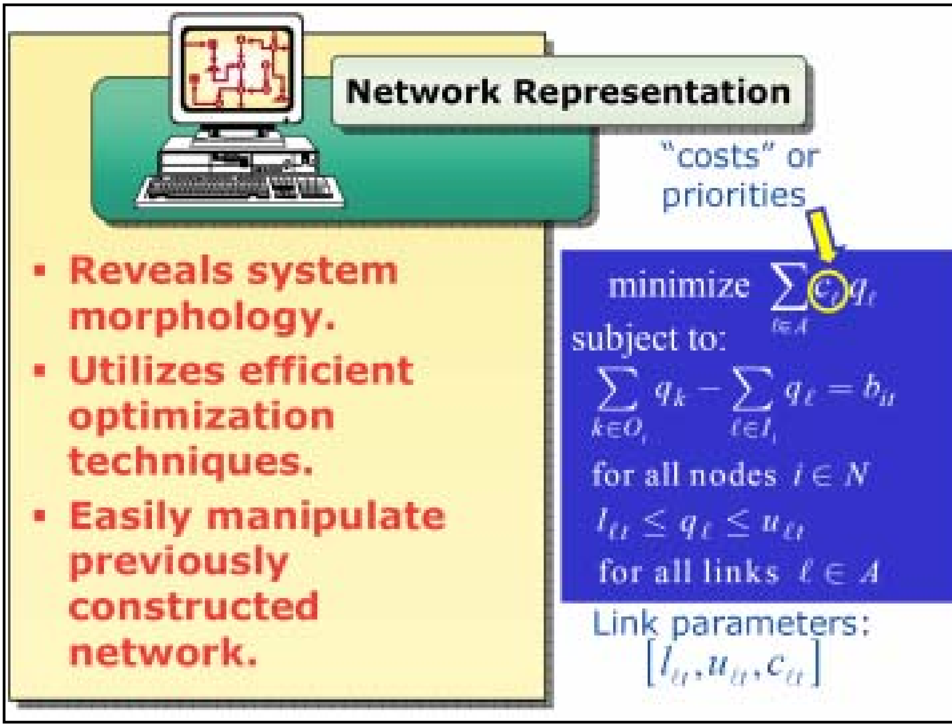




Water Allocated according to:



- Water Rights
- Economic Criteria
- Exchange Mechanisms
- Storage Accounts and Contracts
- Complex IF-THEN Operational Rules
- Instream Flow Requirements



Network Flow Approach

- Network flow models **do not need** precise **economic-based** objective functions
- Objectives in network flow models can be formulated from **rankings** and **water right priorities**
  - if available, economic data can be used
- Simulation structures based on network flow optimization **more efficient**
  - extremely large networks can be efficiently solved—1000's of nodes and links

Network Flow Optimization

- Technically speaking, **K-MODSIM is an optimization model**
  - **BUT**, K-MODSIM primarily uses **optimization** as an efficient mechanism **for simulation**
- **Minimum cost network flow problem** solved iteratively in **sequential** fashion **over time**; **not** fully dynamic (i.e., no presumed foreknowledge of future events)
- **State-of-the-art** network flow optimization
  - Up to 2 orders of magnitude faster than best linear programming solvers

Network Flow Optimization

- State-of-the-art network flow optimization algorithm **simultaneously** assures allocation of water according to:
  - physical
  - hydrological
  - institutional

  …aspects of river basin management
- Network flow optimization **enhances** the ability to simulate complex river basin systems

Network Flow Optimization

$$\underset{\mathbf{q}}{\text{minimize}} \sum_{\ell \in A} c_\ell \cdot q_\ell$$

subject to:

$$\sum_{j \in O_i} q_j - \sum_{k \in I_i} q_k = b_i$$

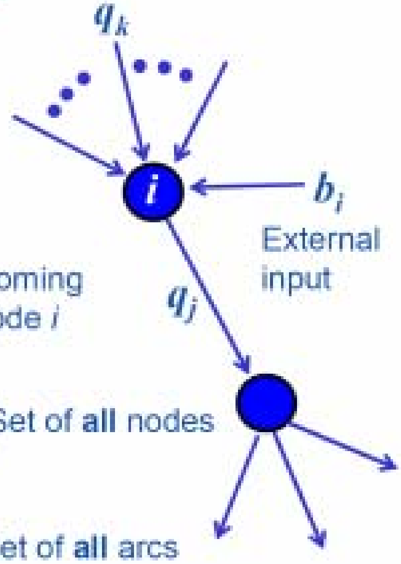
O_i: Set of outgoing arcs from node *i*

I_i: Set of incoming arcs to node *i*

for all nodes $i \in N$ — N: Set of all nodes

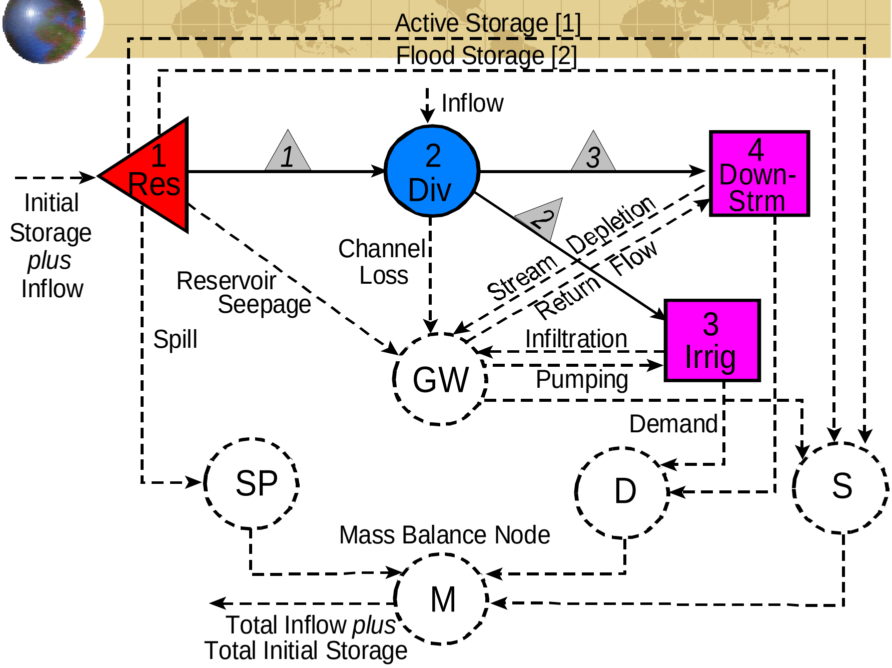
$$l_\ell \le q_\ell \le u_\ell$$

for all arcs $\ell \in A$ — A: Set of all arcs



Accounting Nodes and Links

- When user constructs K-MODSIM network, certain artificial or accounting nodes and links are automatically created (not seen by user):
  - these insure maintenance of mass balance throughout network
  - useful for modeling complex administrative and legal mechanisms governing water allocation



- **MOD**ified **SIM**yld (Shafer, 1979)
  - Originally an extension of the SYMYLD network simulation model developed by Texas Water Development Board (1972)
- MODSIM extensively updated and extended far beyond original structure of SIMYLD (surface water model only)
- MODSIM now employs much more efficient algorithm based on **Lagrangian relaxation**
  - SIMYLD and early versions of MODSIM employed out-of-kilter method (OKM) for network flow optimization

Adaptive K-MODSIM DSS for Real-Time Operation of the Geum River Basin, Korea

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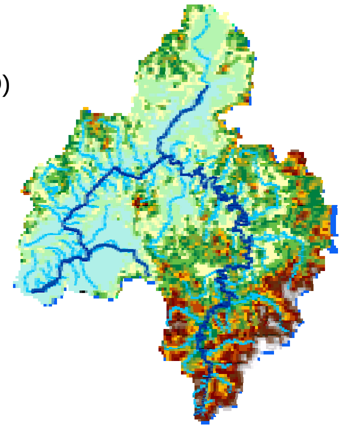


한국수자원공사 KOREA WATER RESOURCES CORPORATION

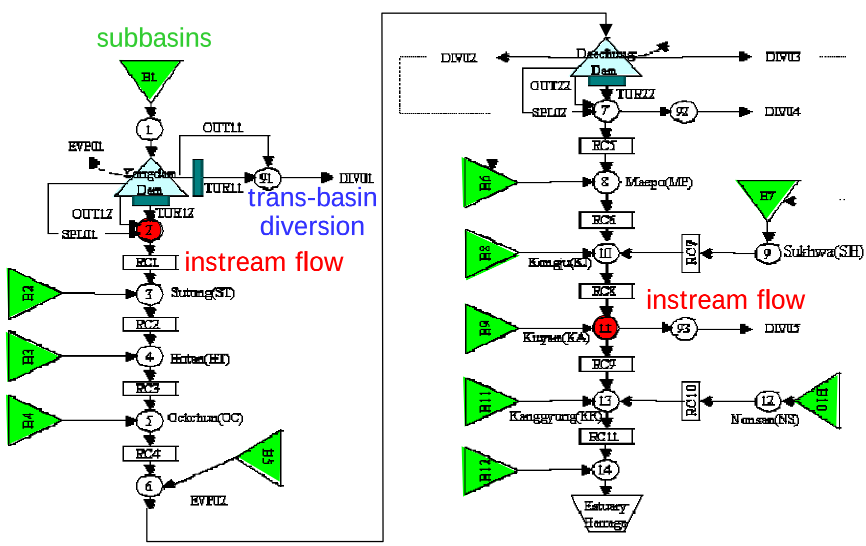
Colorado State University Knowledge to Go Places

Background of Project

- **Decision Support System** developed for daily operations in Geum River Basin, Korea
- Geum River Basin facing severe **conflicts** from:
  - instream flow needs vs. traditional water uses
  - drought contingency planning—increasing pressures
  - integrated operation of existing Daechung Dam with new upstream Yongdam project (2001)
  - uncertainties in hydrology and demands
  - priority-based water allocation, with deficit-sharing
  - long time lags—importance of routing for daily operations

Geum River Basin, Korea

Schematic of Basin Features



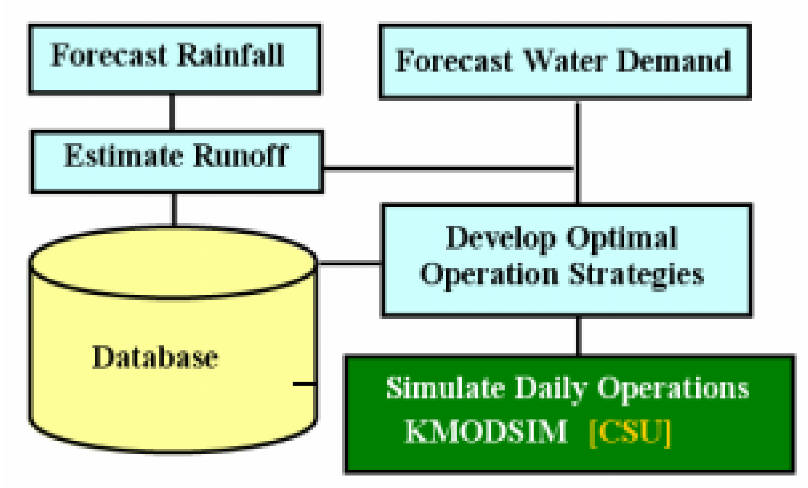
Basin Characteristics

- High seasonal **hydrologic variability**
  - monsoon created floods in summer
  - dry periods in fall, winter and spring
- Basin drainage area: 9,810 km^2
- **Daechung** Multipurpose Reservoir
  - storage capacity: 1490 million m^3
  - hydropower generation 196-240 GWh/yr
  - water supply: 1,650 million m^3/yr (2001)
  - flood control: draw down reservoir by June 20 of each year

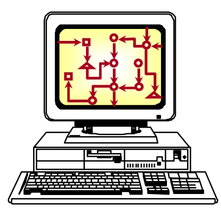
Basin Characteristics (cont.)

- **Yongdam** Multipurpose Reservoir
  - storage capacity: 815 million m^3/yr
  - hydropower generation: 198 GWh/yr
  - water supply: 650 million m^3/year (2001)
  - provides transbasin diversion to the Jeonju, Iksan cities for water supply augmentation (2 turbine units: Geum release and Jeonju diversion)
  - increases hydropower generation, but reduces inflow to Daechung
  - enhances instream flow between Yongdam and Daechung for environmental and water quality purposes

K-MODSIM DSS for the Geum River Basin



K-MODSIM Customization



- Microsoft **.NET Framework**
  - implemented on desktop computers operating under MS Windows NT, 2000, XP
- **Freeware**--all components developed from native Visual C++.NET and Visual Basic.NET code—no proprietary licensing requirements
- **Customization** through embedded **vb.NET custom code**
  - custom code compiled through free MS .NET Framework
  - users provided access to all key variables and object classes in K-MODSIM

K-MODSIM Customization

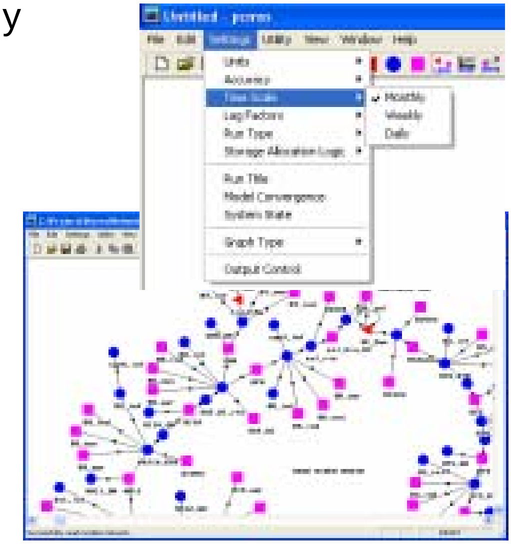
- Custom .NET code can be developed for:
  - defining **complex operating rules** and policies
  - executing external modules such as **water quality models**
  - allows **linkage** of K-MODSIM **with database management systems** providing access to timely data and forecast information for **adaptive** real-time river basin management

K-MODSIM Features

- Data-driven model
  - complete reliance on **user input data** and specifications on system features, operational requirements, priorities
  - **Examples of Input data**
    - **Hydrologic or physical characteristics**
      - Natural runoff flow
      - amount of demand (mun., ind., agr., etc.)
      - capacity of facilities related to water
    - **Management Characteristics**
      - Operation strategies
      - Priorities

K-MODSIM Capabilities

- Monthly, weekly, daily time steps
- Complex river basin configurations
  - IF-THEN rules not required for priorities
  - looped, bifurcating network topologies
  - georeferenced networks loaded into K-MODSIM from GIS



Details of K-MODSIM Development

- Design and calibrate ***most appropriate*** model networks for Geum River basin
- Both monthly and daily networks required
- Streamflow routing included in daily network simulation
  - new **backrouting** procedure implemented for routing time lags exceeding 1 day

Calibration Procedure

HYDROLOGIC OR PHYSICAL CALIBRATION

- Attempt to infer missing hydrologic inflow data and system losses
- Dummy source and sink terms provide inflows or losses where needed to match gaged flows and historical reservoir storage levels (highest priority)

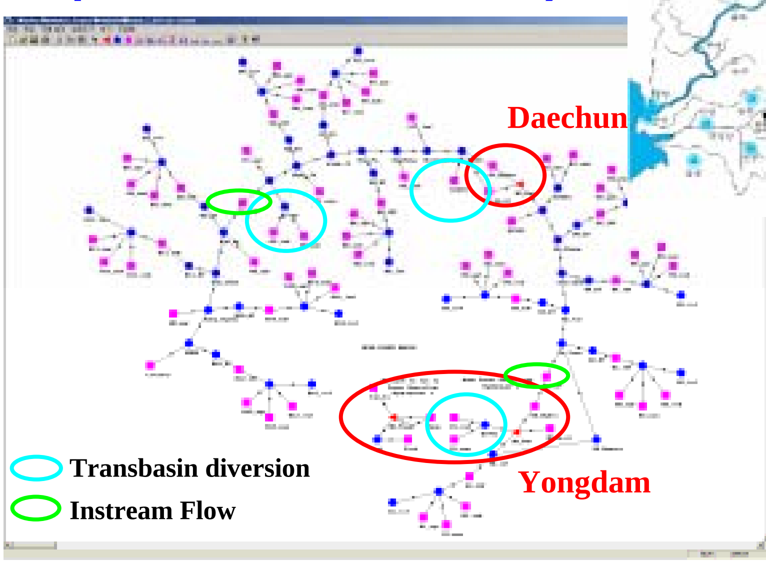
Estimated hydrologic gains and losses

MANAGEMENT CALIBRATION

- Historical storage levels no longer used as targets
- Adjust hydrologic state operating rules and priorities until simulated storage levels match historical levels

K-MODSIM

(Final Geum Network)



How Does K-MODSIM Help Basin Water Managers?

- **Generalized, flexible river basin simulation model** that performs operational analysis over various time steps
- Provides accurate description of physical and operational characteristics of basin, including **priority-based allocation** and deficit-sharing policies
- Provides innovative backrouting procedure for daily simulation of water allocation

How Does K-MODSIM Help Basin Water Managers?

- .NET custom code allows simulation of a variety of adaptive operational policies, as well as real-time linkage to data base management system
- Convenient connection to GIS for map-based simulation

Value of K-MODSIM in IWRM

- **Basin Water Management Toolkit** for Integrated Reservoirs System Operation
- Tool for Long-term National/Basin Water Plan
- **Common Tool for Conflict Resolution** on Basin/Regional Water Allocation considering Efficiency, Equity, and Environmentally Sustainability
- Management of Complex Water Right System

Thank You