Riverware

CADSWES University of Colorado

Center for Advanced Decision Support for Water and Environmental Systems

Multi-objective modeling for the U.S. Army Corps of Engineers

RiverWare User Group Meeting
February 6 - 7, 2007

Presentation Outline

- Overview of multi-objective modeling in RiverWare using capabilities developed for the U.S. Army Corps of Engineers
- Calculation of Incremental Local Inflows
- Statistical slot enhancements

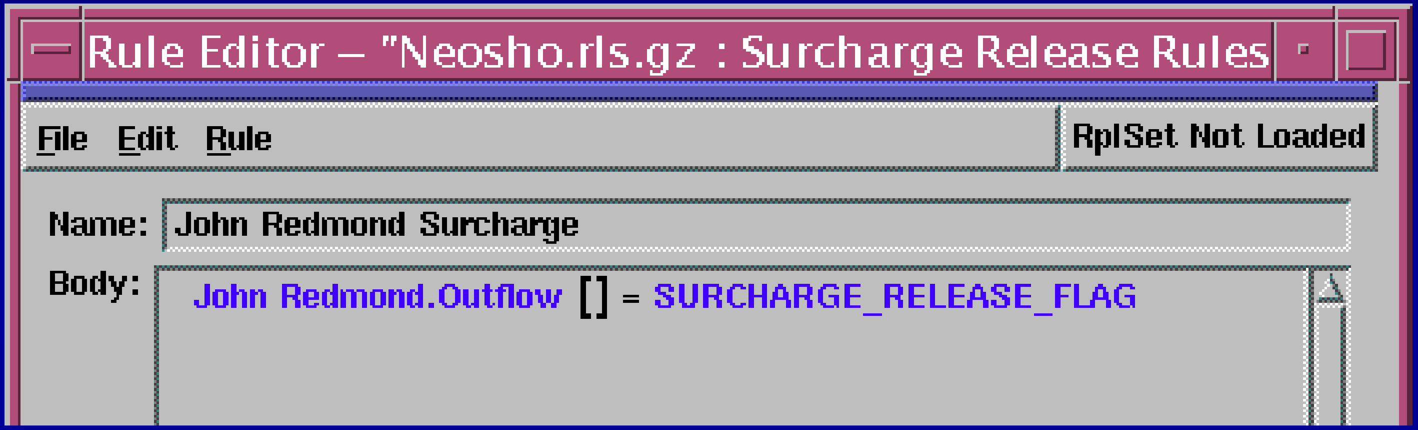
Overview

- Purpose: Develop methods and rule functions to duplicate the methodology used by USACE in the SUPER program
  - Flood Control
    - Surcharge Release
    - Regulation Discharge
    - Flood Control Releases
  - Conservation Operations
    - Low Flow / Demand Releases
    - Reservoir Diversions
    - Reach Diversions
  - Hydropower
- How does this all work together?

Surcharge

- Mandatory releases made regardless of downstream channel constraints
- Pool elevation exceeds top of the flood pool
- Ensures safety of the structure

At each timestep in Simulation:



Name: John Redmond Surcharge

Body: John Redmond.Outflow [] = SURCHARGE_RELEASE_FLAG

Rule: Set Surcharge Release Flag (S) on Res.Outflow slot of each Reservoir in Computational Subbasin

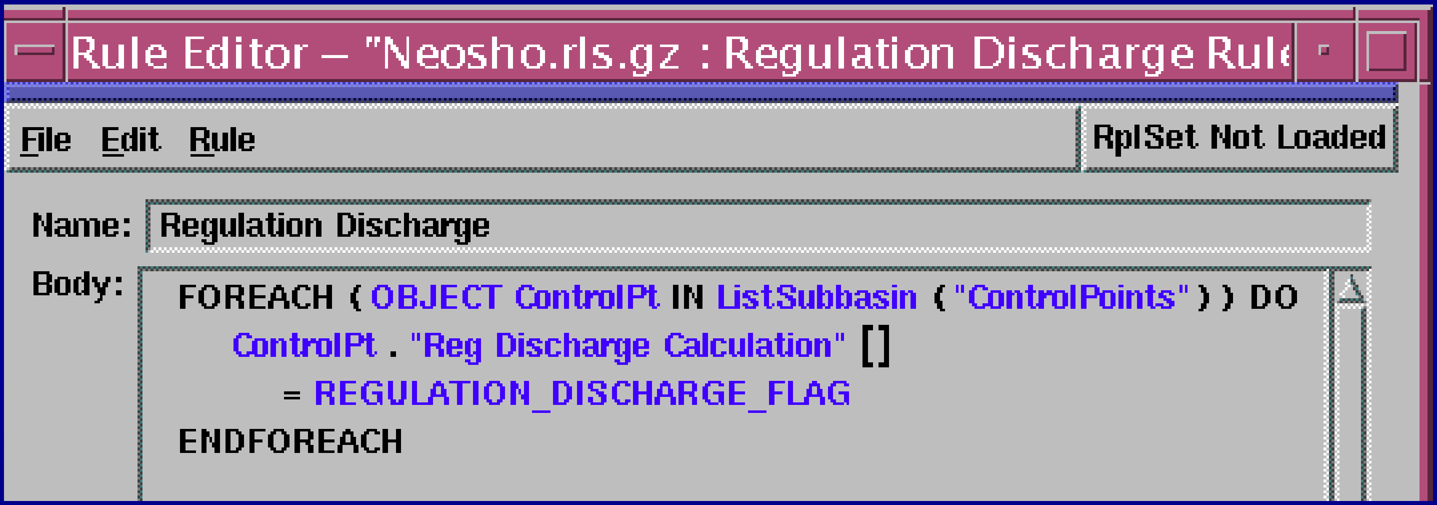
(separate rule for each reservoir starting at u.s. and working d.s.)

Simulation: Surcharge releases and Outflows are computed and set by the resulting dispatch method for entire forecast period;
S flag is removed from Outflow slot.

Regulation Discharge

- Methods determine the maximum flow permitted at the control point.
- Also determine the empty space available in the channel based on the regulation discharge and the current flow
- Dispatching controlled at each timestep by the setting of a regulation discharge flag by a rule.

At each timestep in Simulation:



Name: Regulation Discharge

Body:

```
FOREACH ( OBJECT ControlPt IN ListSubbasin ( "ControlPoints" ) ) DO
    ControlPt . "Reg Discharge Calculation" []
        = REGULATION_DISCHARGE_FLAG
ENDFOREACH
```

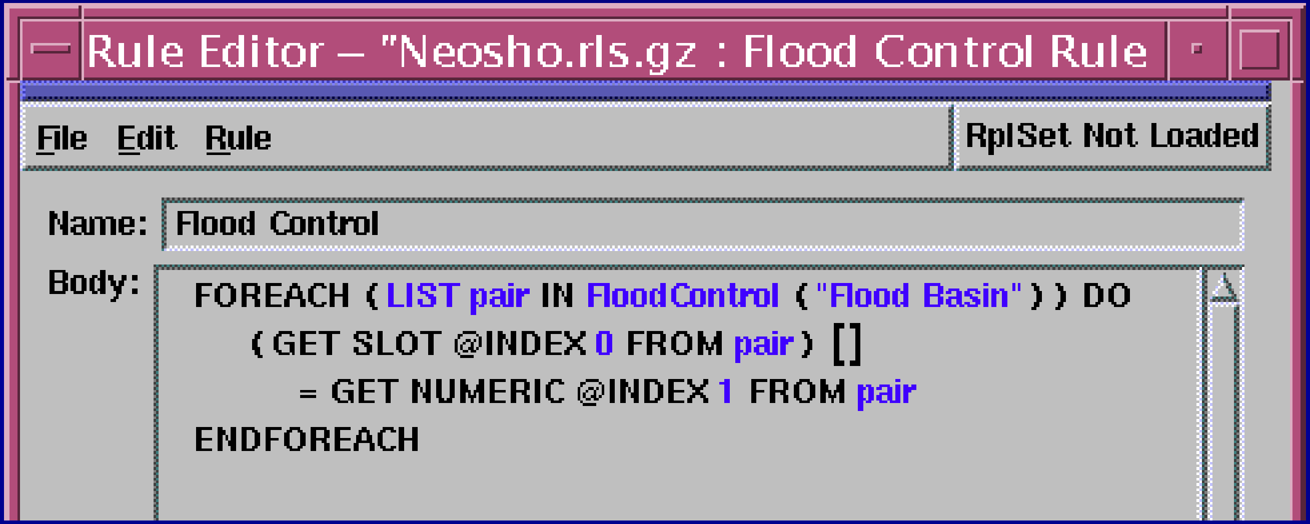
Rule: Set Regulation Discharge (G) Flag on all Control Point.RegDischargeCalc slots

Simulation: Calculate Regulation Discharge and dependent methods; remove G flag; do not reset Outflow

Flood Control

- Determine additional flood control releases for each reservoir in the subbasin
- Respect downstream channel constraints
- Balance reservoir storages to extent possible

Execution of Flood Control in Simulation
….. At Each Timestep:



Name: Flood Control

Body:

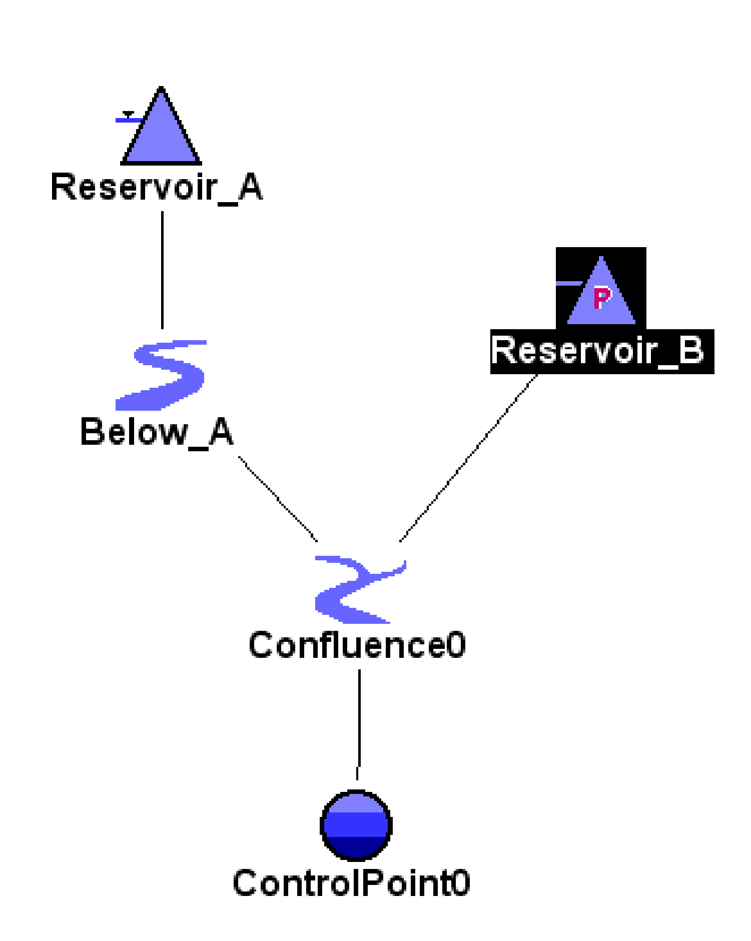
```
FOREACH ( LIST pair IN FloodControl ( "Flood Basin" ) ) DO
    ( GET SLOT @INDEX 0 FROM pair ) []
        = GET NUMERIC @INDEX 1 FROM pair
ENDFOREACH
```

Rule: Execute Flood Control Method on subbasin and set Reservoir.FloodRelease and Res.Outflow on subbasin (outflow = surcharge release + flood release)

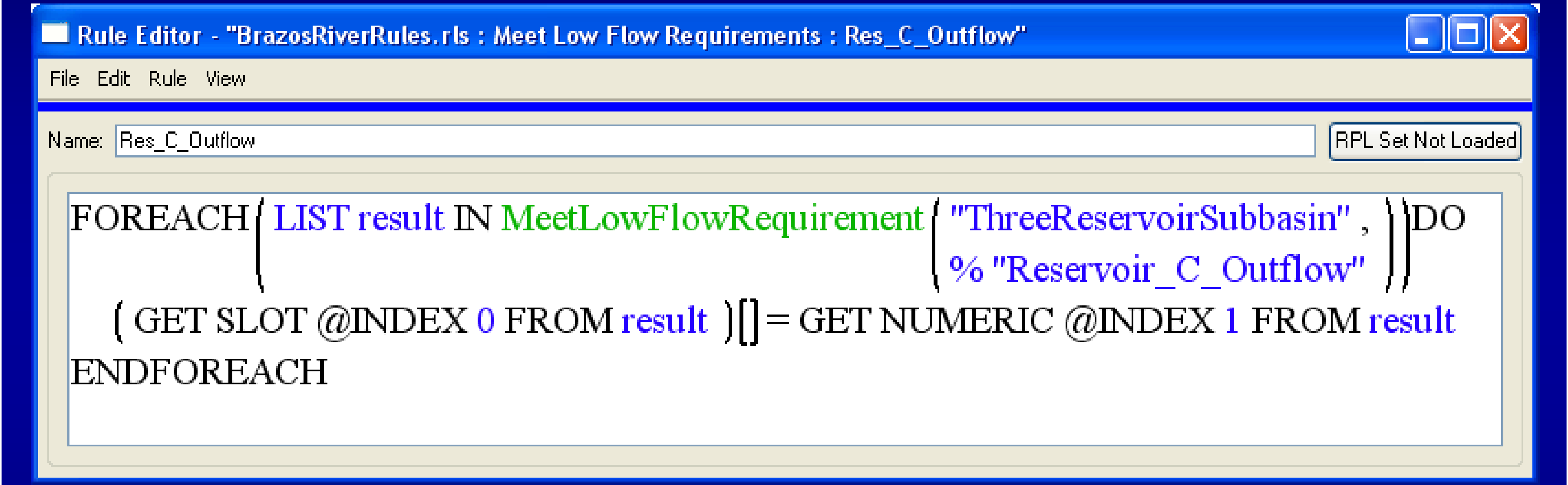
Simulation: solveMB_givenInflowOutflow, flood releases are set and results propagate downstream

Conservation Operations: Low Flow / Demand Releases

- Flow requirement on a Control Point represents environmental flows or demand
- Determine releases to meet a downstream flow requirement
- Reservoirs are considered in the order of highest operating level first
- Routing of release must be considered (adding this year)



MeetLowFlowRequirement()



Rule Editor - "BrazosRiverRules.rls : Meet Low Flow Requirements : Res_C_Outflow"

Name: Res_C_Outflow

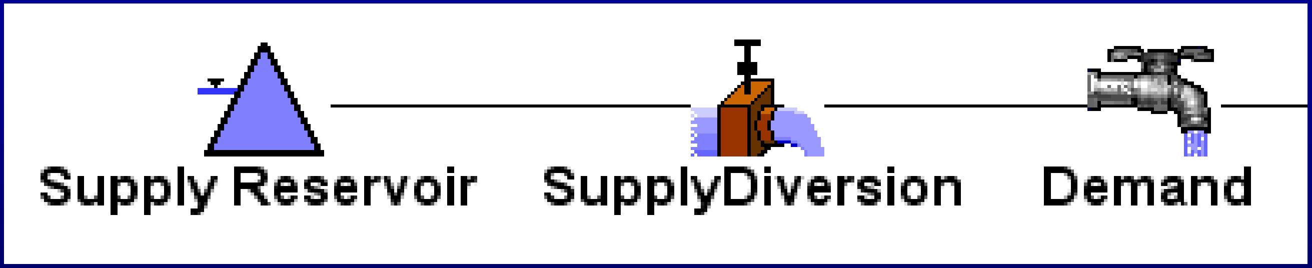
```
FOREACH ( LIST result IN MeetLowFlowRequirement ( "ThreeReservoirSubbasin" ,
                                                  % "Reservoir_C_Outflow" ) ) DO
    ( GET SLOT @INDEX 0 FROM result )[] = GET NUMERIC @INDEX 1 FROM result
ENDFOREACH
```

Rule: Execute Low Flow Release Method on computational subbasin and set reservoirs Low Flow Release slots and Outflow slots

Simulation: solveMB_givenInflowOutflow, releases are set and results propagate downstream

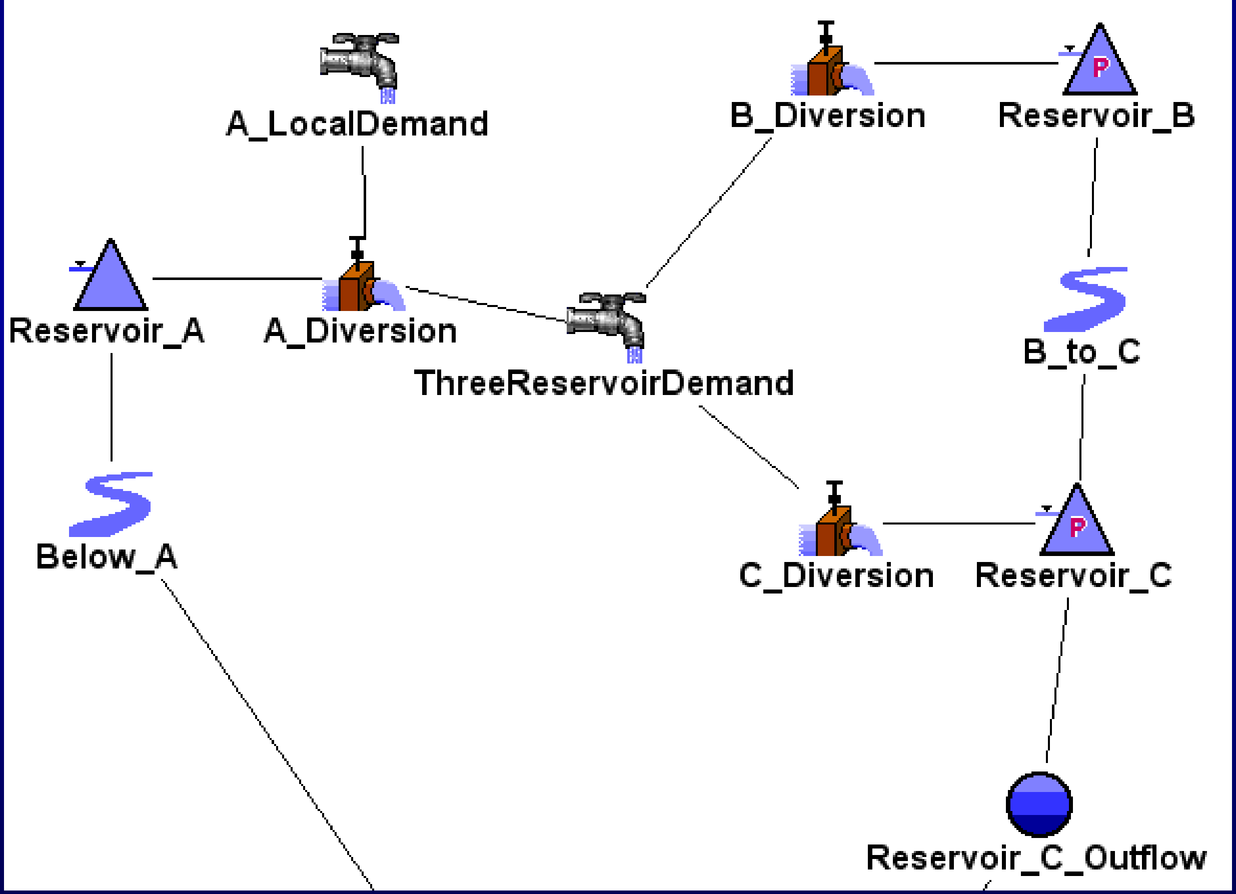
Conservation Operations: Reservoir Diversions

- Water is diverted directly out of a reservoir to meet demands
- Modeled using a Diversion and Water User



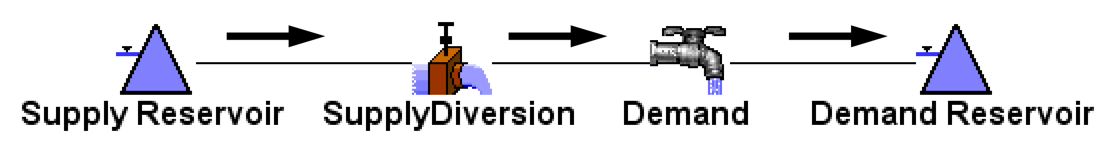
Conservation Operations: Reservoir Diversions

- One reservoir can meet many demands
- A demand can be served by many reservoirs



Conservation Operations: Reservoir Diversions

- Diversion can be from one reservoir to another
- Diversions are limited if the receiving reservoir has a higher operating level
- Water user has demand but no consumptive use; all water diverted goes to demand reservoir

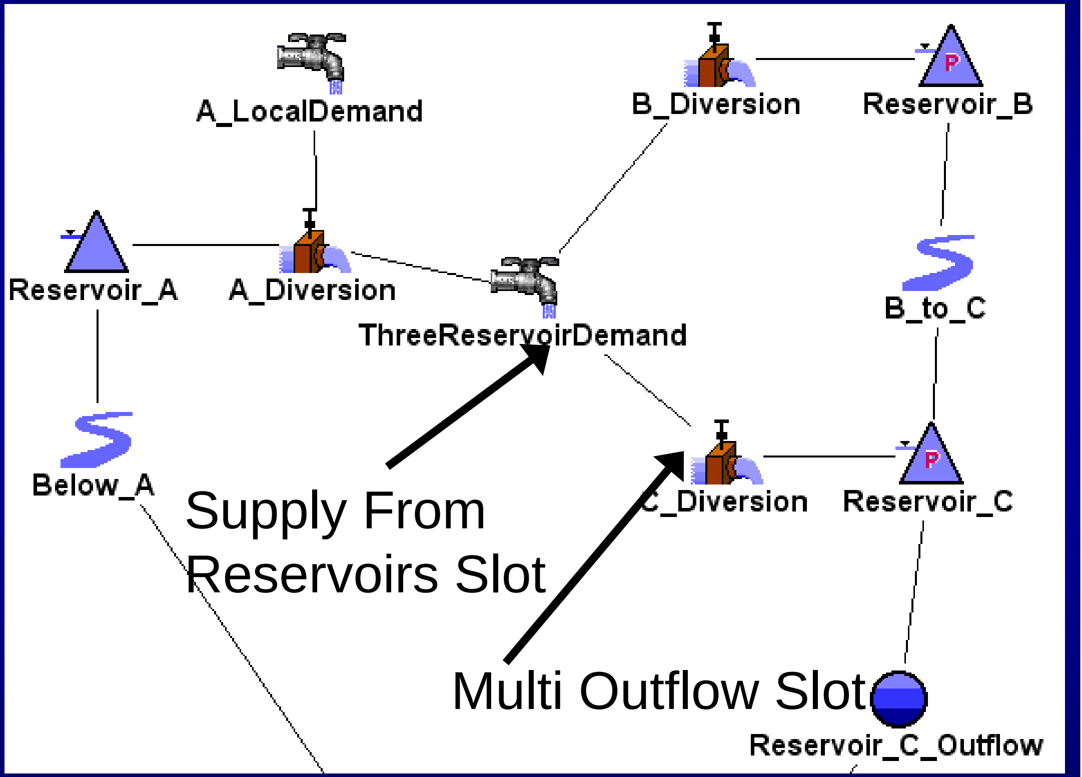


New Methods Developed

- Diversion Object
  - New method: Solve Given Outflows
    - Dispatch method: SolveMB_GivenOutflow
    - New Multi Outflow multislot – Split Outflows to multiple water users
- Water User Object
  - Multiple Supply Reservoirs method
    - Allows demand to be met from multiple reservoirs
  - Diversion Request Calc: Periodic and by Res Level
  - Limit by Reservoir Level method

Reservoir Diversions

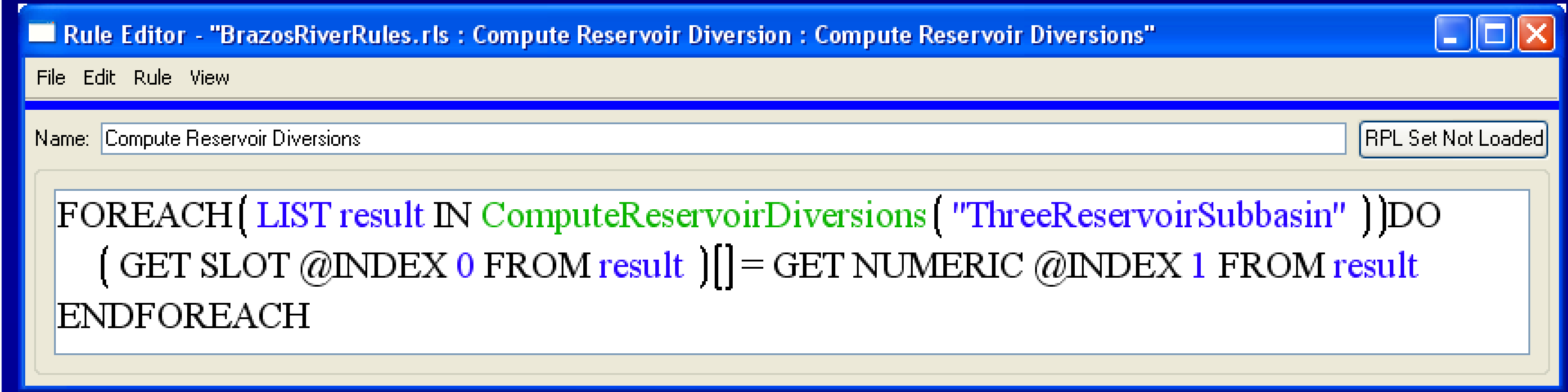
- Water User’s Diversion Requested is met by the highest reservoir first
- Diversions are limited by maximum rates and demand reservoir’s level where applicable



Supply From Reservoirs Slot

Multi Outflow Slot

ComputeReservoirDiversions()


Rule Editor - "BrazosRiverRules.rls : Compute Reservoir Diversion : Compute Reservoir Diversions"
File
Edit
Rule
View
RPL Set Not Loaded

Name: Compute Reservoir Diversions

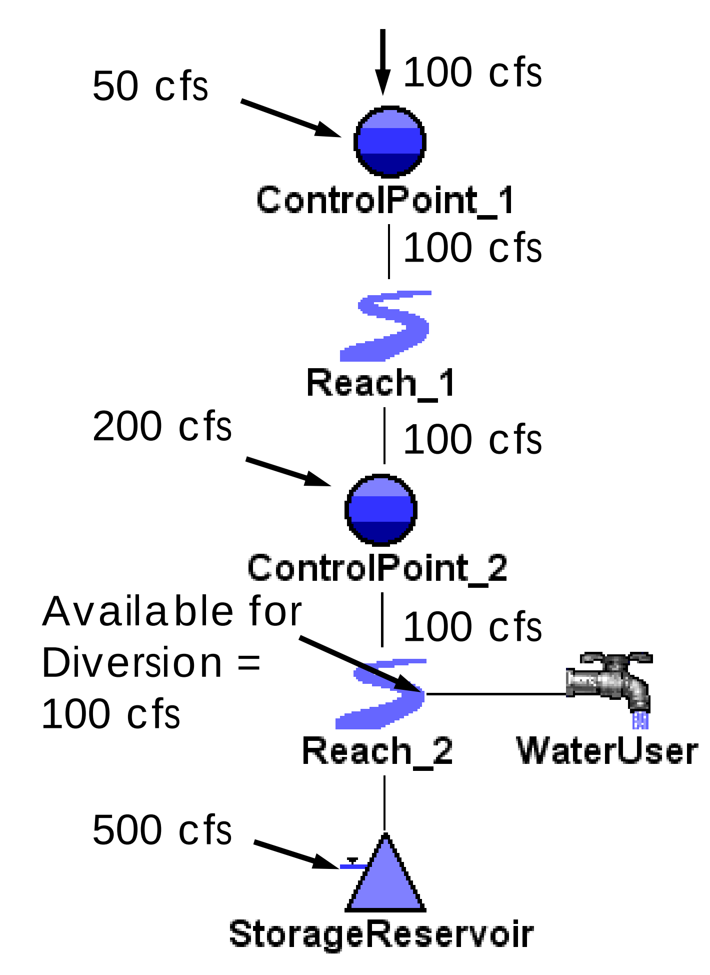
```
FOREACH ( LIST result IN ComputeReservoirDiversions ( "ThreeReservoirSubbasin" ) ) DO
    ( GET SLOT @INDEX 0 FROM result ) [] = GET NUMERIC @INDEX 1 FROM result
ENDFOREACH
```

Rule: Execute method on subbasin and set
Water Users' Incoming Available Water subslots
and Diversion objects' Multi Outflow slots

Simulation: Reservoirs and Water Users dispatch as before,
Diversion objects dispatch with a new method
SolveMB_givenOutflow

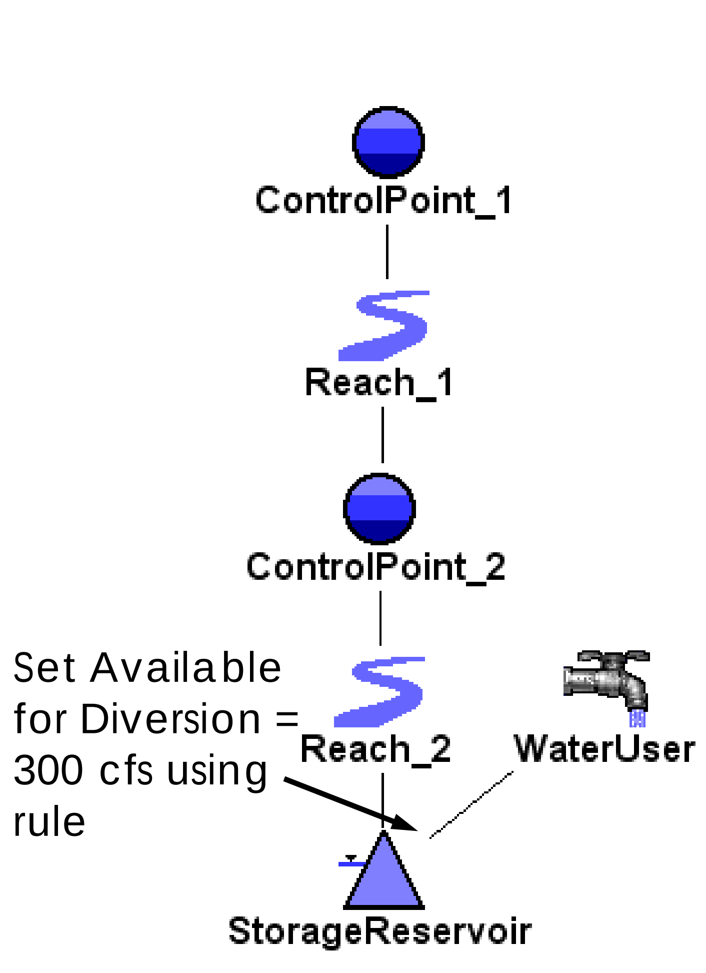
Reach Diversions

- Diversions from reaches
- Release are not specifically made for this purpose
- We modeled these as Reach and Water User objects
- Problem:
    - Local Inflows are accumulated
    - Locals are not included in control point outflows
    - Not enough water is available for Diversion



Reach Diversions

- Solution for now: Move diversions to reservoir below reach, Set Available for Diversion using a rule
- Long term solution: Disaggregate Locals, See Next presentation

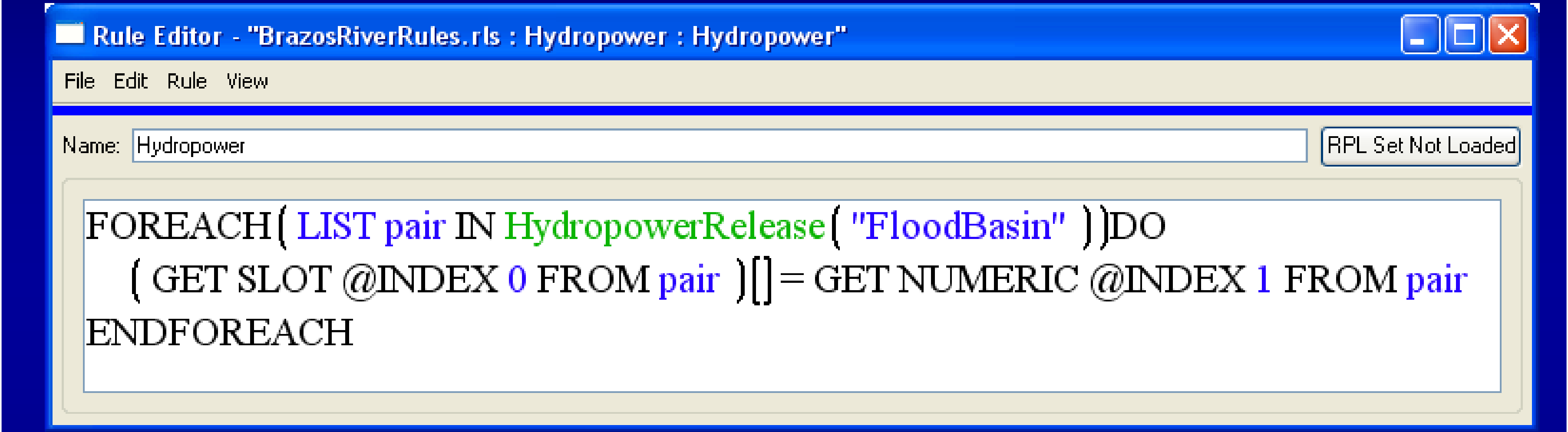


Set Available for Diversion = 300 cfs using rule

Hydropower

- Make releases to meet energy demand, given all other releases
- Cannot draw below min power pool or exceed max drawdown
- Cannot cause additional downstream flooding

HydropowerRelease Function


Rule Editor - "BrazosRiverRules.rls : Hydropower : Hydropower"
File Edit Rule View
RPL Set Not Loaded

Name: Hydropower

```
FOREACH ( LIST pair IN HydropowerRelease( "FloodBasin" ))DO
    ( GET SLOT @INDEX 0 FROM pair )[] = GET NUMERIC @INDEX 1 FROM pair
ENDFOREACH
```

- Prioritizes the reservoirs by relative energy shortage
- Loops through each reservoir in the basin and calculates the proposed release to meet the demand.
- Calculates portion of the proposed release that will not cause additional downstream flooding
- Returns the Outflow and Additional Hydropower Release

How does this all work together:

- Rules execute in following order:
  - Surcharge Release } Mandatory Releases
  - Regulation Discharge } Find Empty Space
  - Flood Control Releases } Additional Flood Releases
  - Low Flow / Demand releases } Increase Outflow
  - Reservoir Diversions } Divert water from Res.
  - Hydropower } Increase Outflow

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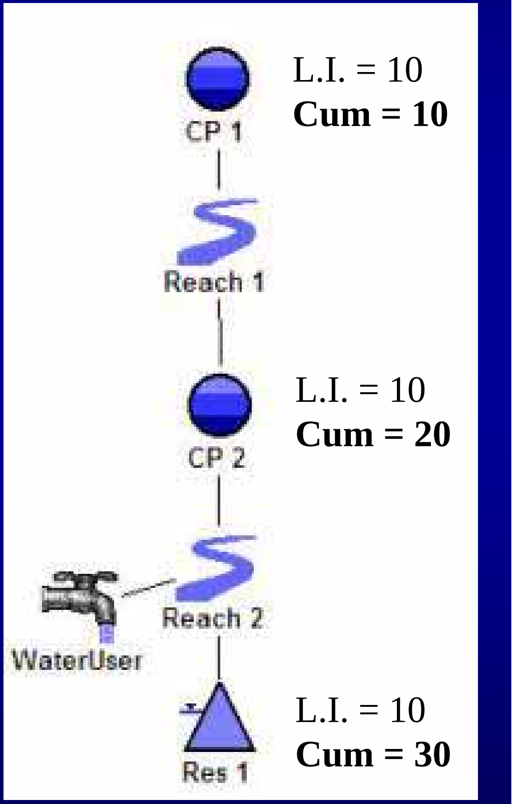
Calculation of Incremental Local Inflows - Overview

- COE local inflow data to control points and reservoirs is cumulative
  - Problem: local inflow potentially added to the system more than once
    - Locals Not Included in Outflow method to avoid this
  - Problem: when diversions are introduced, the cumulative local inflow data does not reflect any loss to the diversion
- There is a need to calculate the incremental local inflows given cumulative data

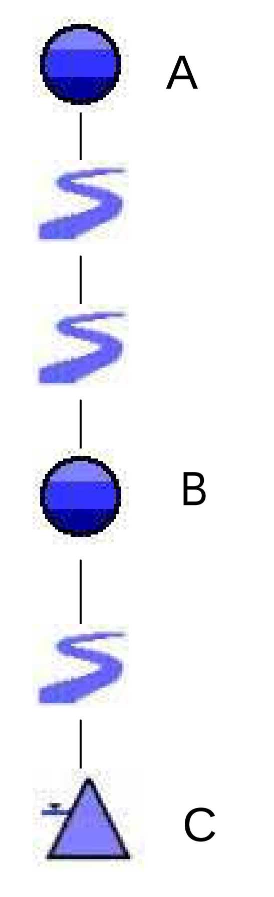


Calculation

- Calculate incremental inflows:

$$B_{(t)\ incremental} = B_{(t)\ cum} - A_{(t)\ cum\ routed}$$

  - Use routing method(s) on intervening reach(es) to calculate routed flow



Approach

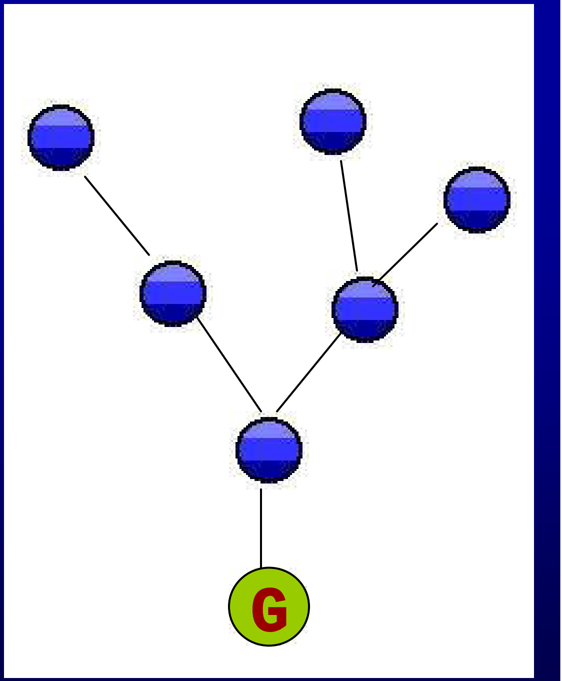
- Calculation done only once or as needed (i.e., not at the beginning of every run)

- Method on Computational Subbasin to do calculation
  - Users set up subbasin and turn on method
- Methods on control points and reservoirs to hold slots

- Comp Subbasin method executed at beginning of run for all subbasin(s) with method selected AND subbasin(s) enabled
  - Users should save model with calculated incrementals and then disable the subbasin(s)

Spatial Disaggregation of Local Inflows

- Lower Neches Valley Authority (LNVA)
- Flow known at one control point in a subbasin, need to spatially distribute that flow to other control points (currently done in WAM)
  - NRCS Curve Number
  - Mean Precipitation
  - Drainage Area
- Four-step algorithm that relates basin attributes of known-flow control point to get flow at other control points



Spatial Disaggregation of Local Inflows

- Method on Computational Subbasin
  - User sets up subbasin and selects method
  - Method executes at beginning of run
  - User saves model and disables subbasin
- Method on Control Point
  - Holds slots
- LNVA spatially disaggregates monthly data, later computes daily data then incrementals…
  - Spatial disagg method flexible to support different timestep sizes

Temporal Disaggregation of Local Inflows

- LNVA method to calculate daily flow values given monthly data and daily demand data
- Similar approach as spatial disaggregation
  - method on comp subbasin, flexible timestep sizes

Local Inflow Calculation Methods

1. Spatial Disaggregation
2. Temporal Disaggregation
3. Calculation of Incrementals

} new methods on comp subbasin

4. Forecast Local Inflows — existing methods on cp and res

- Any combination of these methods can be selected
- Executed in order and data is made available on cp or res for next stage of calculation

- End result: "True" local inflow data in the Local Inflow slot

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Questions?

- Comments / Suggestions?