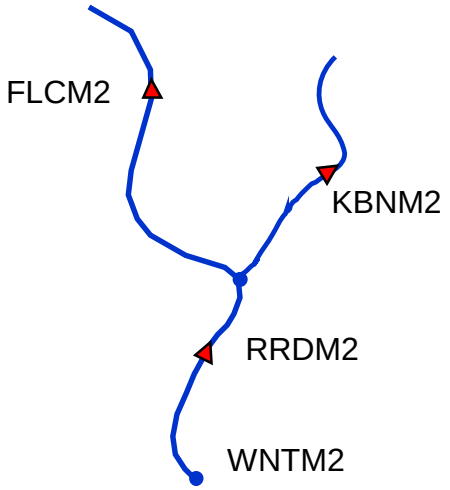
RES-J Joint Reservoir Model

- Designed as a network model to solve a system of reservoirs, reaches, and nodes.
- Fully integrated within NWSRFS as an operation in the calibration, forecast, and extended streamflow prediction systems
- Facilitates long-term simulations of individual reservoirs or systems of reservoirs
- Easily extended by adding new modeling methods
- Uses explicit simulation approach



Operations Table:	
LAG-K	KLGN1
SAC-SMA	LOCAL
UNIT-HG	LOCAL
ADD-SUB	INF_TOT
RES-J	WINSTON
PLOT-TUL	INFLOW
PLOT-TUL	RES_OP

The Reservoir Operations Problem

- NWSRFS/Hydrologic modeling relies on a sequential computation of natural hydrologic phenomenon
- Rain/Snow > runoff > hydrograph development > hydrograph transformation > hydrograph combination/superposition
- (LAG-K can effectively simulate a natural lake)
- Active reservoir operations intentionally alter the natural sequence
- Flood control/streamflow augmentation; avoiding summation of peak flows; hydropower operations
- New factors involve seasons, rules, forecasts, downstream conditions, other reservoirs, etc.
- Operations are based on states both internal and external to the forecast system, and upstream and downstream of the reservoir.
- Models evolve from storage routing to rules to systems

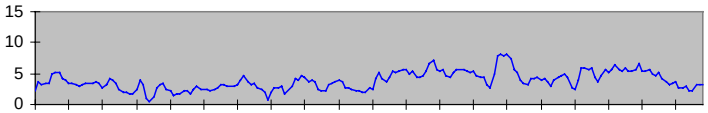
Explicit Solution Considerations

- Model states at the beginning of the time step are used to determine release at the end of the time step
- Model states at the end of the time step are computed based on inflows and outflows averaged over the time step
- Eliminates need to input mean inflows to the model; simplifies the solution technique
- May require smaller time steps; requires special handling to avoid numerical instabilities;
- Correct time step a function of rate of change of storage, inflow magnitude, rate of change of inflow, rate of change of outflow

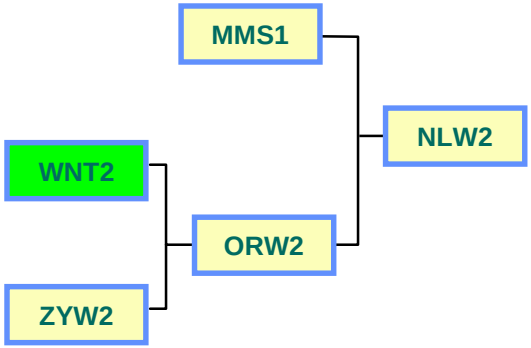
RES-J Input Sections

- Time series

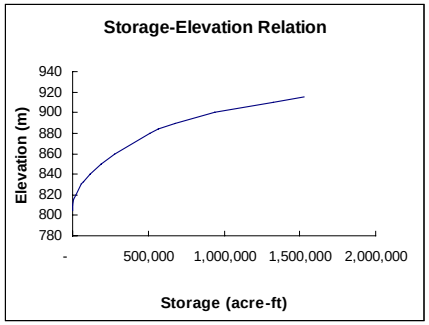
```
WINT2 QINE 6
WINT2 RQOT 6
.
.
```



- Topology



- Parameters



- Rules

```
[TRUE]
   RAINEVAP WINSTON SURFACE
[WINSTON POOL < 831.5]
   SETRELEASE WINSTON NORMAL
[WINSTON POOL > 831.5]
   SETRELEASE WINSTON FLOOD_OPS
```

RES-J Time Series Information

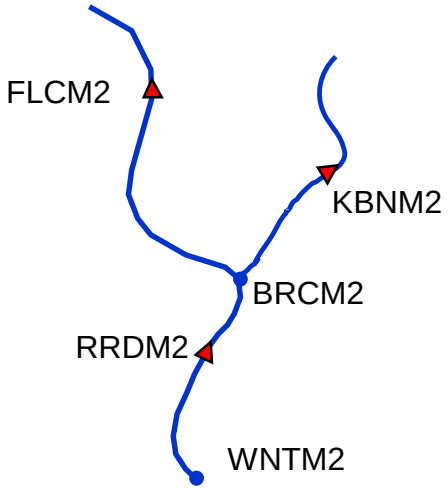
- All time series used in RES-J must be included in the segment definition containing the RES-J operation
- All time series used in RES-J must be identified separately within the RES-J model input section
- Time series can be assigned aliases for reference throughout the model

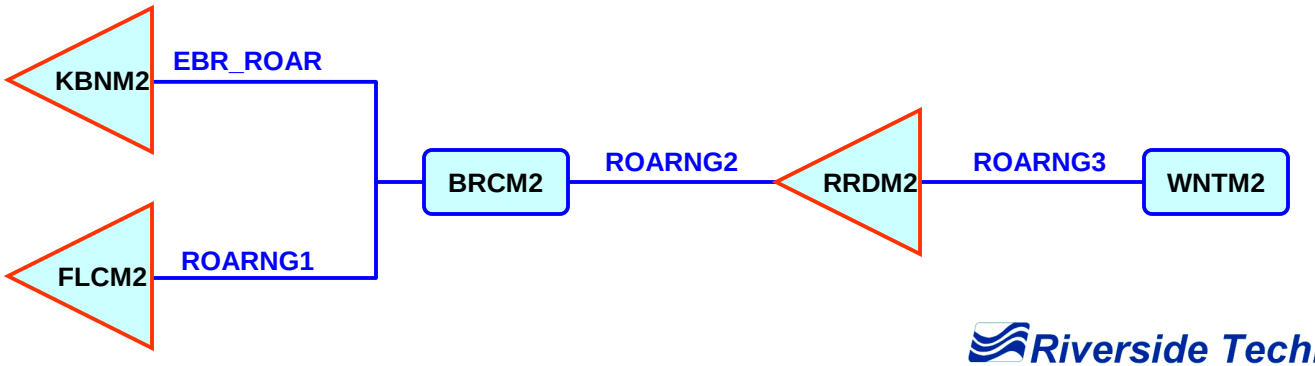
```
LOYALHANNA Reservoir
1 1970   12 1980  ENG
DEF-TS
SLTP1      RQIN    6            INPUT
agl/RQIN/sltp70_00.rqin06
SLTP1      PELV    6            INPUT
agl/PELV/sltp70_00.pelv06
SLTP1      RQOT    6            INPUT
agl/RQOT/sltp70_94.rqot06
SLSIMRL    SQIN    6            OUTPUT
agl/RQIN/loysimrel.sqin06
SLSIMEL    SPEL    6            OUTPUT
agl/PELV/loysimpel.sqin06
SLOBSRL    RQME   24
SLSIMRL    SQME   24            OUTPUT
agl/QME/SLSIMRL.SQME24
SLSIMEL    SPEL   24            OUTPUT
agl/PELV/SLSIMEL.SPEL24
END
RES-J       SLTP1
TIMESERIES
TIMESERIES
   TIMESTEP   6
   INPUT  SLTP1   RQIN  6  TOT_INFL
   INPUT  SLTP1   PELV  6  OBS_ELEV
   OUTPUT SLSIMRL SQIN  6  SIM_RELS
   OUTPUT SLSIMEL SPEL  6  SIM_POOL
ENDTIMESERIES
 TOPOLOGY
   RESERVOIR   LOYALHANNA
 ENDTOPOLOGY

 PARAMETERS
```

RES-J Topology Information

- Topology defines the connectivity of the network components: Reservoirs, Reaches, Nodes
- Components must be defined from upstream to downstream
- Each component may have many upstream components
- Each component may have at most one downstream component





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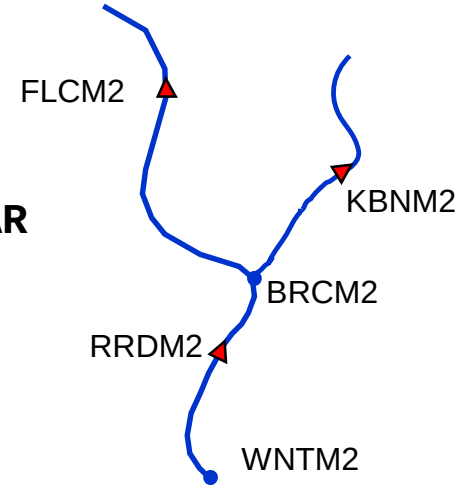
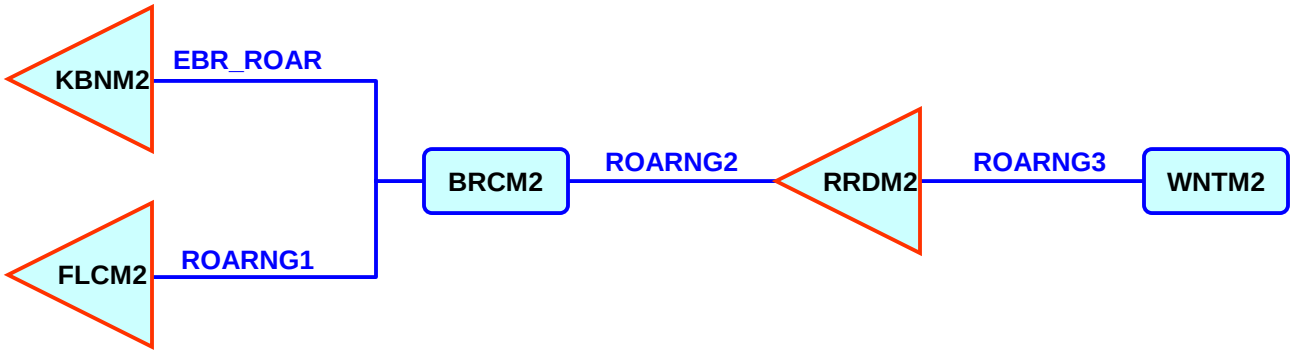
RES-J Topology Example

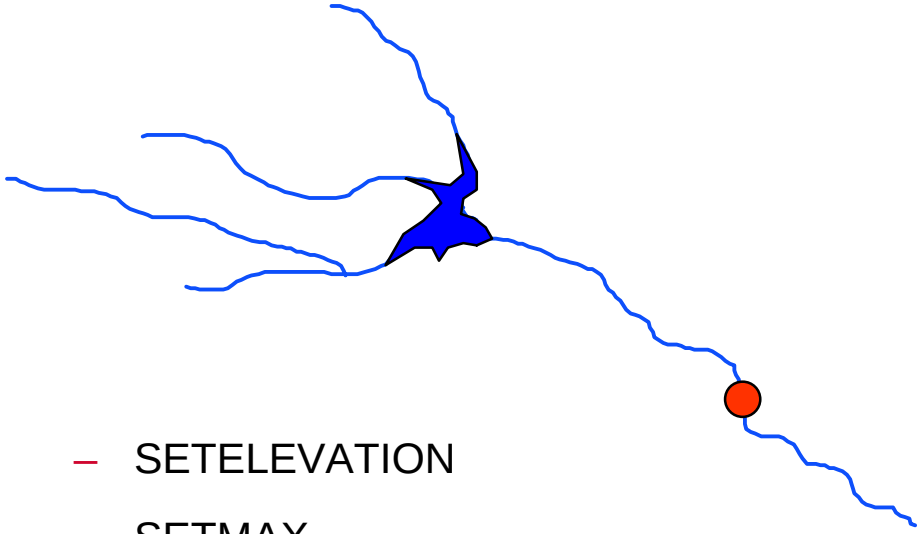
```
TOPOLOGY
  RESERVOIR    FLCM2
  RESERVOIR    KBNM2
  REACH        ROARNG1 BELOW FLCM2
  REACH        EBR_ROAR BELOW KBNM2
  NODE         BRCM2 BELOW ROARING BELOW EBR_ROAR
  REACH        ROARNG2 BELOW BRCM2
  RESERVOIR    RRDM2 BELOW ROARNG2
  REACH        ROARNG3 BELOW RRDM2
  NODE         WNTM2 BELOW ROARNG3
ENDTOPOLOGY
```





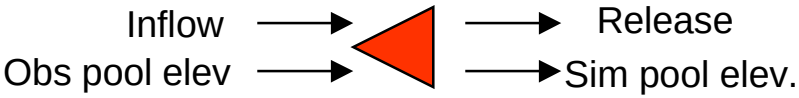
RES-J Parametric Information

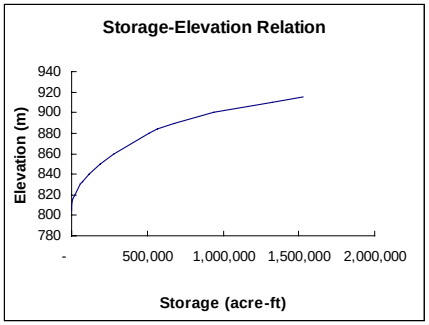
- Components
  - Reservoirs
  - Reaches
  - Nodes
- Methods
  - ADJUST
  - BALANCE
  - LAGK
  - MAXDECREASE
  - MAXINCREASE
  - MAXSTAGE
  - RAINEVAP
  - SETELEVATION
  - SETMAX
  - SETMIN
  - SETRELEASE
  - SETSUM
  - SETWITHDRAW

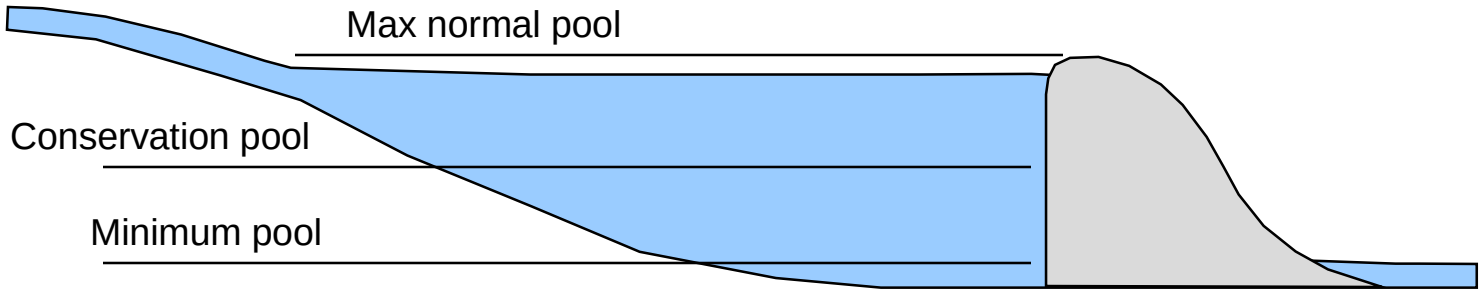


Reservoir Component Parameters

- Input and output time series
- Elevation versus storage table
- Initial pool and release values
- Minimum pool value
- Constants







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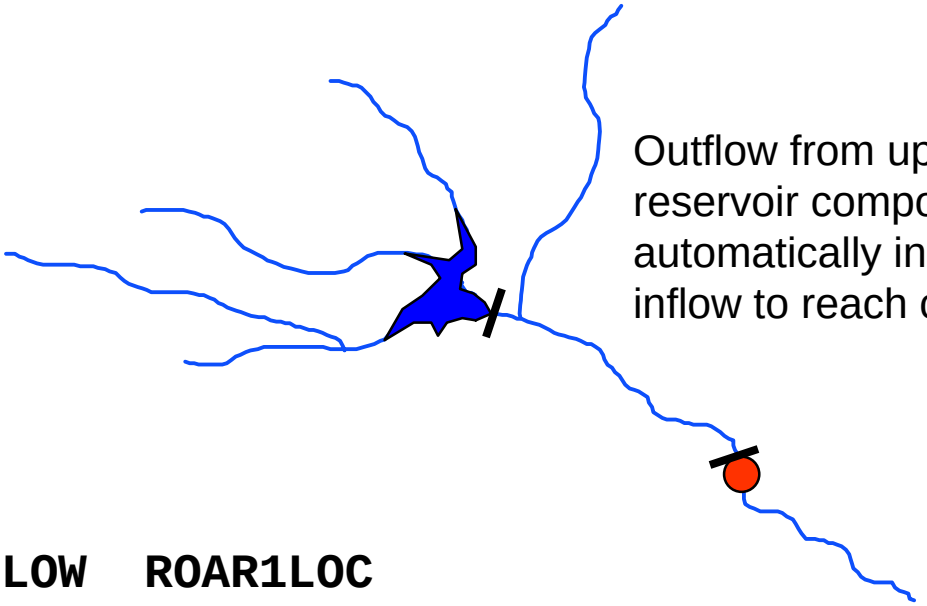
Reservoir Component Parameters

```
PARAMETERS
  UNITS ENGLISH
    RESERVOIR WINSTON
        CONSTANT WINSTON.CONS_POOL 205.0
        TSINPUT   INFLOW WIN_INFLOW
        TSINPUT   POOL WIN_OBS_POOL
        TSOUTPUT  RELEASE WIN_SIM_REL
        TSOUTPUT  POOL WIN_SIM_POOL
        TABLE  ELEV_STOR
               72.0   0.0
               205.0   50000.0
               210.0   55000.0
               212.0   60000.0
        ENDTABLE
        INITIALPOOL    206.0
        INITIALRELEASE         1200.0
        INITIALWITHDRAW        85.0
        MINPOOL        75.0
        MINRELEASE             15.0
    ENDRESERVOIR
ENDPARAMETERS
```

Reach Component Parameters

- Input time series
- Output time series

```
PARAMETERS
  UNITS ENGLISH
    RESERVOIR ...
    .
    .
    ENDRESERVOIR
    REACH ROARNG1
       TSINPUT  INFLOW  ROAR1LOC
       TSOUTPUT OUTFLOW ROAR1LAG
    ENDREACH
ENDPARAMETERS
```

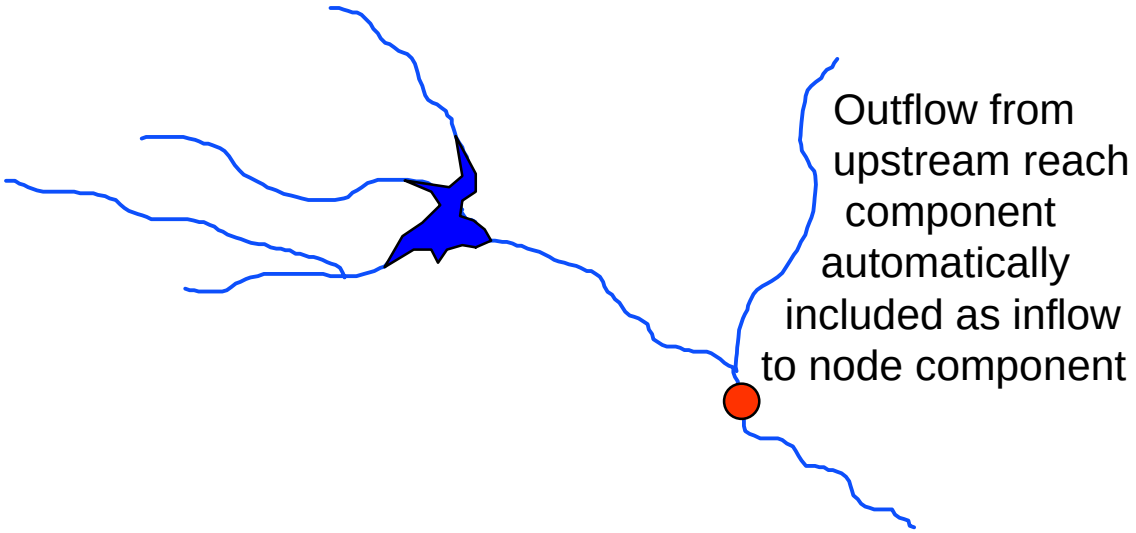


Outflow from upstream reservoir component automatically included as inflow to reach component

Node Component Parameters

- Input time series
- Output time series

```
PARAMETERS
  UNITS ENGLISH
    RESERVOIR ...
    .
    ENDRESERVOIR
    REACH ...
    .
    ENDREACH
    NODE WNTM2
       TSINPUT  INFLOW  WNTM2LOC
       TSOUTPUT OUTFLOW WNTM2TOT
    ENDNODE
ENDPARAMETERS
```



RES-J Adjust Method Parameters

The ADJUST method uses observed instantaneous discharges, mean discharges, and pool elevation values to adjust the simulated values to be consistent with the observations.

- Input time series
- Number of time steps for blending from an observed value
- Simulated pool is adjusted at each time step
- Consider a feature to adjust only the carryover values

Adjust Method Example

```
ADJUST       WINSTON     WINSTON_ADJUST
             OBSERVEDPOOL WIN_OBS_POOL
             BLEND  5
ENDADJUST
```

Balance Method Parameters

The BALANCE method computes reservoir releases by balancing the available storage among multiple reservoirs.

- Option to balance by volume or percent of flood storage
- Minimum and maximum pool elevations for each reservoir
- Minimum release for each reservoir

Balance Method Example

```
BALANCE      Madden                  Mad_Gat_Bal
       VOLUME
       RESERVOIR   Gatun
             VALUES       LOWER POOL          135
                          UPPER POOL          140
                          MINRELEASE          12.4
             ENDVALUES
       ENDRESERVOIR
       RESERVOIR   Madden
             VALUES       LOWER STORAGE       1200000
                          UPPER STORAGE       1900000
                          MINRELEASE          11.8
             ENDVALUES
       ENDRESERVOIR
ENDBALANCE
```

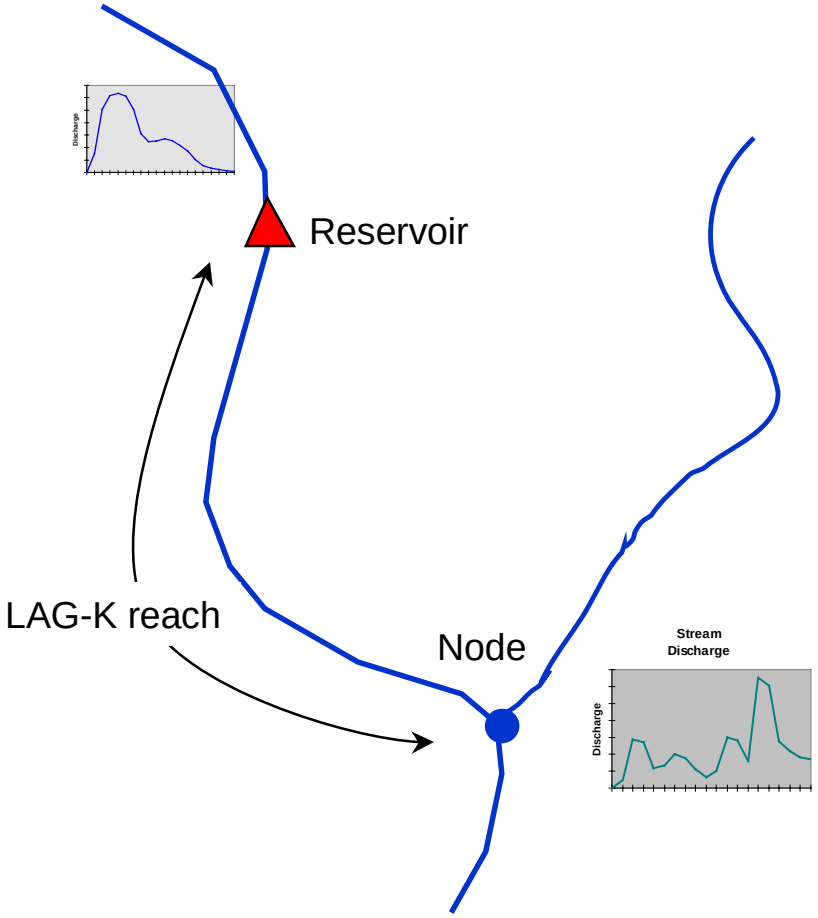
RES-J LAGK Method Parameters

The LAGK method performs reach routing using the Lag and K routing procedure.

- Lag time in hours
- K coefficient (constant or a table of outflow versus K)
- Inflow carryover information
- LAG-K is applicable only to reach components
- useful for constructing valid networks; permitting operations based on downstream outcomes.

LAGK Method Example

```
LAGK    WINSTON  ST_MDKR2
  LAG 12
  K    7
  COINFLOW
    VALUES
        1000
        1000
        1000
        1000
    ENDVALUES
  ENDCOINFLOW
ENDLAGK
```



MAXDECREASE/MAXINCREASE Method Parameters

- The MAXDECREASE / MAXINCREASE method limits the maximum decrease / increase in reservoir release from one time-step to the next
- MAXDECREASE - Maximum allowable decrease in flow (per time step)
- MAXINCREASE - Maximum allowable increase in flow (per time step)

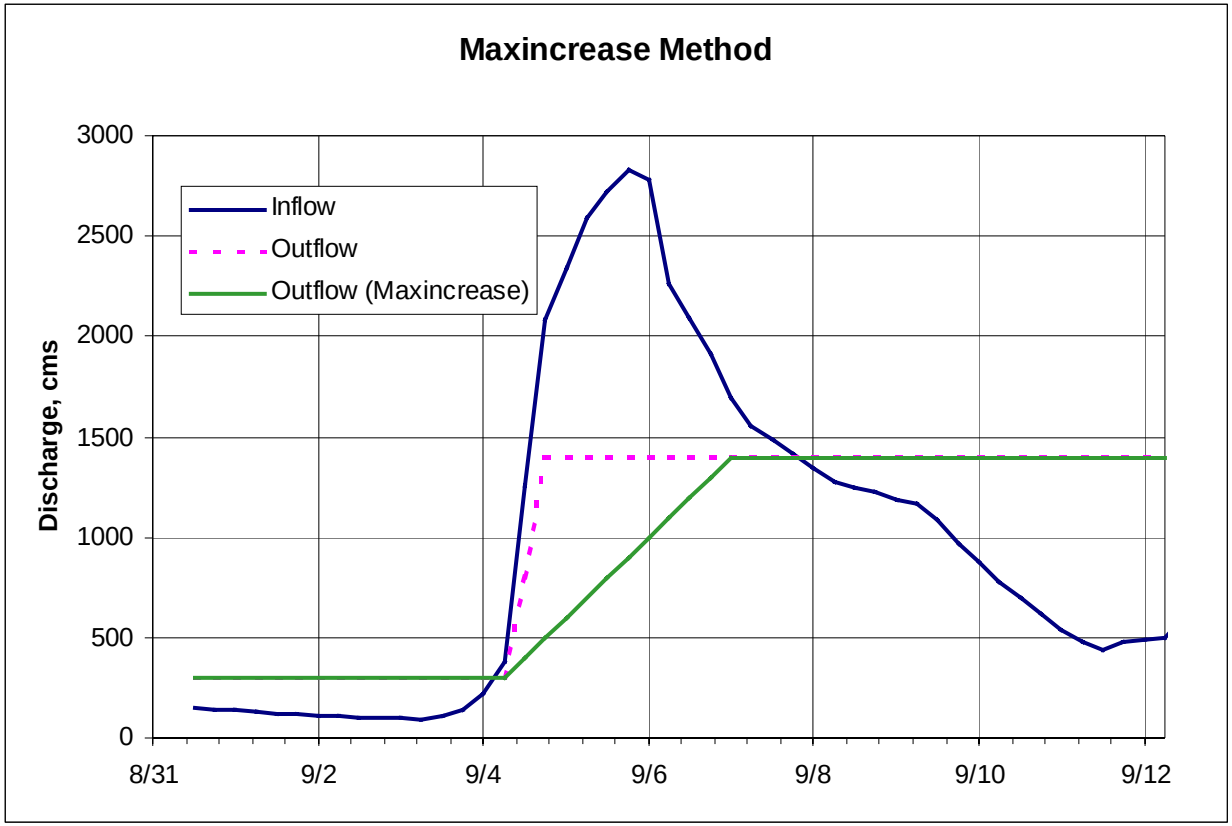
MAXDECREASE/MAXINCREASE Method Example

```
MAXDECREASE  WESTOVER WEST_DECR
  DECREASE    400.
ENDMAXDECREASE


MAXINCREASE   WESTOVER WEST_INC
  INCREASE    100.
ENDMAXINCREASE

RULES
.
.
.
[WESTOVER.POOL < 1241.7]
  :: MAXINCREASE WEST_INC
.
.
```

Maxincrease Method Example



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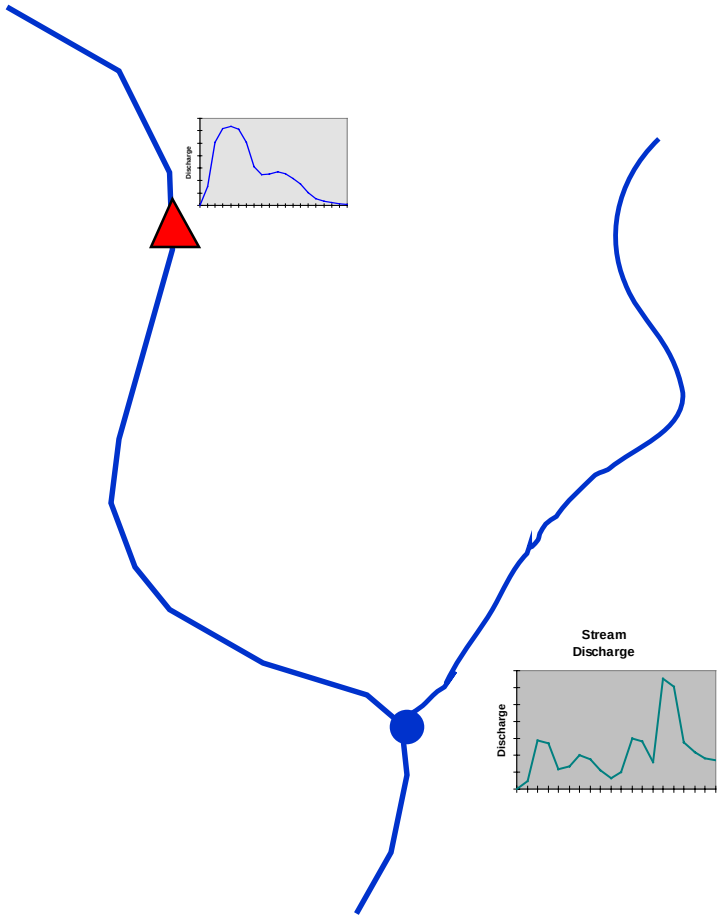
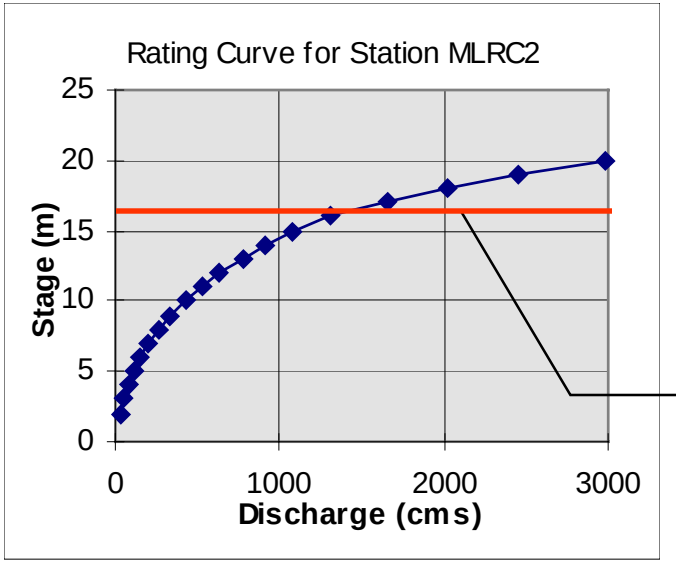
MAXSTAGE Method Parameters

The MAXSTAGE method computes a restricted reservoir release to control the stage at a downstream control point

- Table of rating curve values
- Maximum allowable stage at the downstream control point
- Minimum allowable reservoir release
- Convergence criterion
- Downstream node identifier
- Maximum number of iterations for solving

MAXSTAGE Method Example

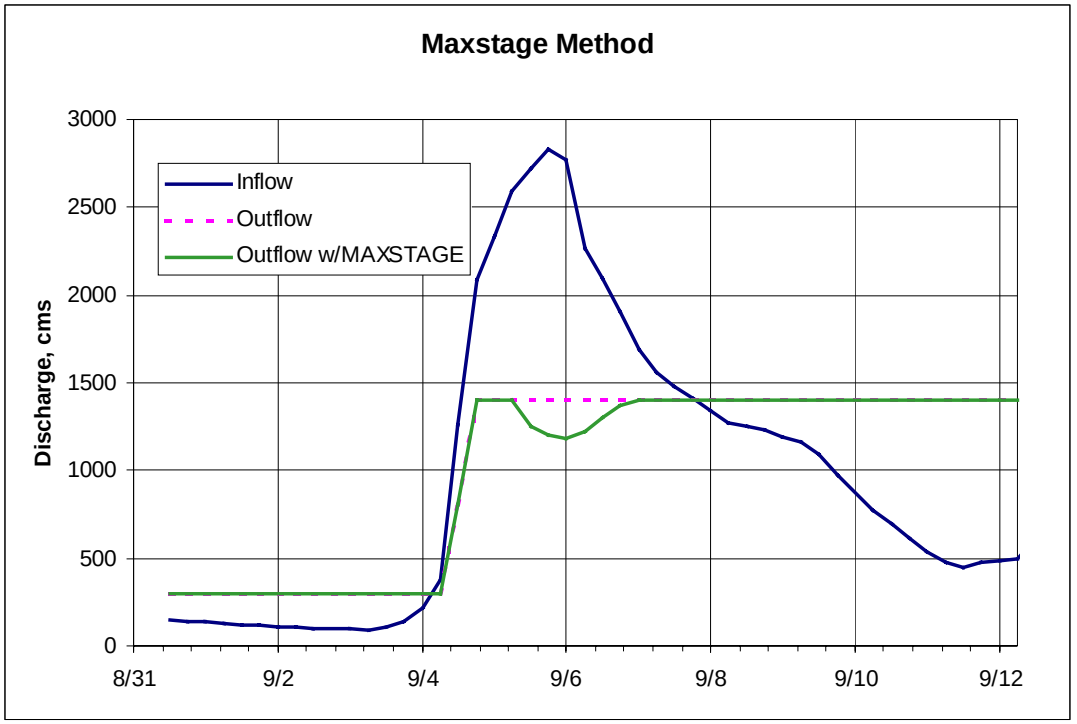




Critical stage at MLRC2

MAXSTAGE Method Example

```
MAXSTAGE  WINSTON  ST_MLRC2
  TABLE   MLRC2_RATING
   1   50
   5   200
   10  450
   15  1100
   20  3000
  ENDTABLE
  MAXIMUMSTAGE 16.1
  MINRELEASE   250
  DSCONTROL MLRC2_GAGE
  MAXITERATIONS     15
ENDMAXSTAGE
```



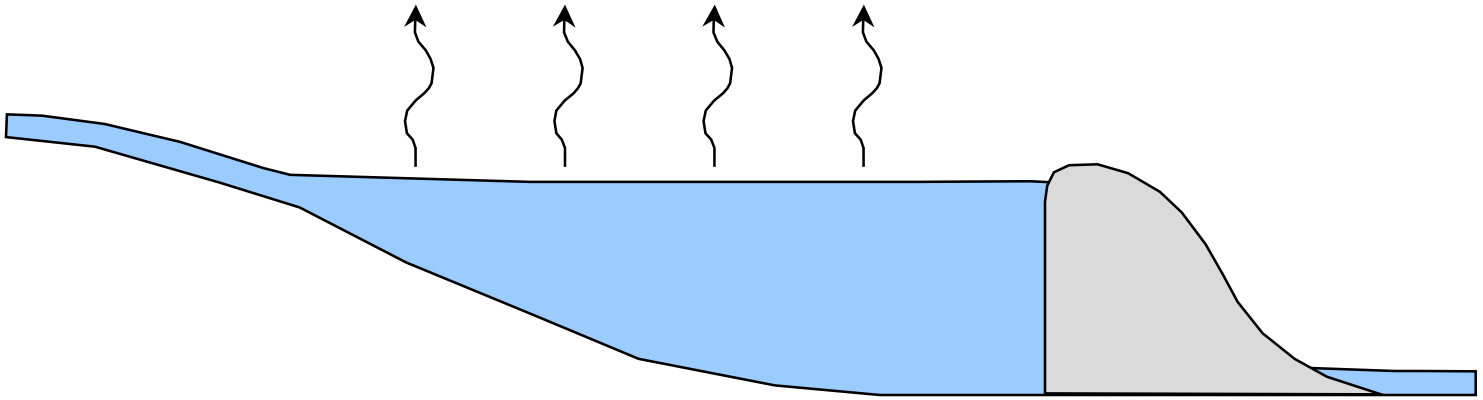
RAINEVAP Method Parameters

The RAINEVAP method computes the change in reservoir storage resulting from rain and evaporation occurring over the lake surface.

- Time series identifier for observed evaporation and observed rainfall
- Table of average evaporation values by date
- Optional diurnal distribution of daily evaporation
- Loss is computed based on reservoir surface area at beginning of time-step

RAINEVAP Method Example

```
RAINEVAP  WINSTON WN_RAINEV
  PRECIP
    TSINPUT   ObservedPrecip WIN_MAP
  ENDPRECIP
  EVAP
    VALUES    01/01  0.13
              04/01  0.20
              07/01  0.25 0.3 0.3 0.25 0.15
              10/01  0.18
    ENDVALUES
  ENDEVAP
ENDRAINEVAP
```



SETELEVATION Method Parameters

The SETELEVATION method computes a reservoir release in order to achieve a prescribed reservoir pool elevation. The elevation can be specified in a table as a function of date or can be given as a time series.

- Observed pool elevation time series
- Reservoir rule curve information in date/elevation pairs
- Period for blending between rule curve values and time series values
- Period for blending between rule curve dates
- Interpolation option
- (interpolation and date blending are mutually exclusive)

SETELEVATION Method Example

```
SETELEVATION  WINSTON  WIN.FLOOD
        TSINPUT  OBSERVEDPOOL  WIN_POOL
        VALUES
                01/01  205.0
                04/01  208.0
                07/01  210.0
                10/01  215.0
        ENDVALUES
        BLEND          30
        BLENDTS        8
ENDSETELEVATION
```

SETMAX / SETMIN Method Parameters

The SETMAX / SETMIN methods selects the maximum / minimum release (or withdrawal) from a list of previously computed methods.

- Other method identifiers from which to compute maximum / minimum output variable

SETMAX / SETMIN Method Example

```
SETMIN WINSTON                WIN_MIN
       SETRELEASE    WINSTON       WIN.FLOOD
       SETELEVATION  WINSTON       WIN_RULE
       MAXSTAGE      WINSTON       ST_MLRC2
ENDSETMIN


SETMAX WINSTON                WIN_MAX
       SETRELEASE    WINSTON       WIN_SPILL
       SETMIN        WINSTON       WIN_MIN
ENDSETMAX
```

SETRELEASE Method Parameters

The SETRELEASE method computes reservoir release based on a table that specifies release as a function of date and pool elevation, or as a prescribed release entered as a time series.

- Observed release time series
- Table of elevation/release values by date
- Period for blending between table values and time series values
- Period for blending between elevation/release table dates
- Interpolation between elevations and/or dates

SETRELEASE Method Example

```
SETRELEASE    Madden          Power_Rel
        TSINPUT         Observed_Rel          MAD_OBS_POWER
        VALUES
        ELEV   215     220     230     240     250     ENDELEV
        01/01  300     300     350     400     500
        04/01  310     310     375     450     550
        07/01  350     400     450     500     750
        10/01  310     310     375     450     550
        ENDVALUES
        BLEND  0
        BLENDTS         0
        NORMAL
ENDSETRELEASE
```

SETSUM Method Parameters

The SETSUM method computes reservoir release (or withdrawal) as the sum of previously computed reservoir release (or withdrawal) methods.

- Method identifiers from which to compute sum of output variables
- Valid methods are:
  - SETMAX
  - SETMIN
  - SETRELEASE
  - SETWITHDRAW

SETSUM Method Example

```
SETSUM Madden Power&Spills
       SETRELEASE    Madden Power
       SETRELEASE    Madden Spill
ENDSETSUM
```

SETWITHDRAW Method Parameters

The SETWITHDRAW method computes reservoir withdrawal based on a table that specifies withdrawal as a function of date and pool elevations, or as a prescribed withdrawal entered as a time series.

- Observed withdrawal time series
- Table of elevation/withdrawal values by date
- Period for blending between elevation/withdrawal table dates
- Period for blending between elevation/withdrawal table values and time series values

SETWITHDRAW Method Example

```
SETWITHDRAW   Madden          Muni
       TSINPUT         Observed_Muni Mad_Muni
       VALUES
              ELEV    80.0    ENDELEV
              01/01   125
              04/01   130
              07/01   120
              10/01   310
       ENDVALUES
       BLEND  0
       BLENDTS         0
       NORMAL
ENDSETWITHDRAW
```

RES-J Rules Information

Rules are specified using [*expression*] - [*method*] syntax

If *expression* evaluates to TRUE, the listed *methods* are executed

Use of compound expressions is supported

Expressions are written in terms of component states, dates, constants, and Boolean operators

RES-J Rules Examples

```
RULES

#Executed every time step
[TRUE]
      ::SETWITHDRAW     Madden      Mad_Muni
      ::SETSUM          Madden      Power&Spills
      ::LAGK            Chagres     ChagresLAGK

#Conditional Execution
[Madden.Pool < Madden.Drought]
      ::SETELEVATION    Madden      Mad_pool_205

ENDRULES
```