RiverWare

CADSWES University of Colorado

Center for Advanced Decision Support for Water and Environmental Systems

Modeling Groundwater-Surface Water Interaction with RiverWare

RiverWare User Group Meeting

February 6 - 7, 2007

Presentation Outline

- Approach 1: Network of groundwater objects
- Approach 2:

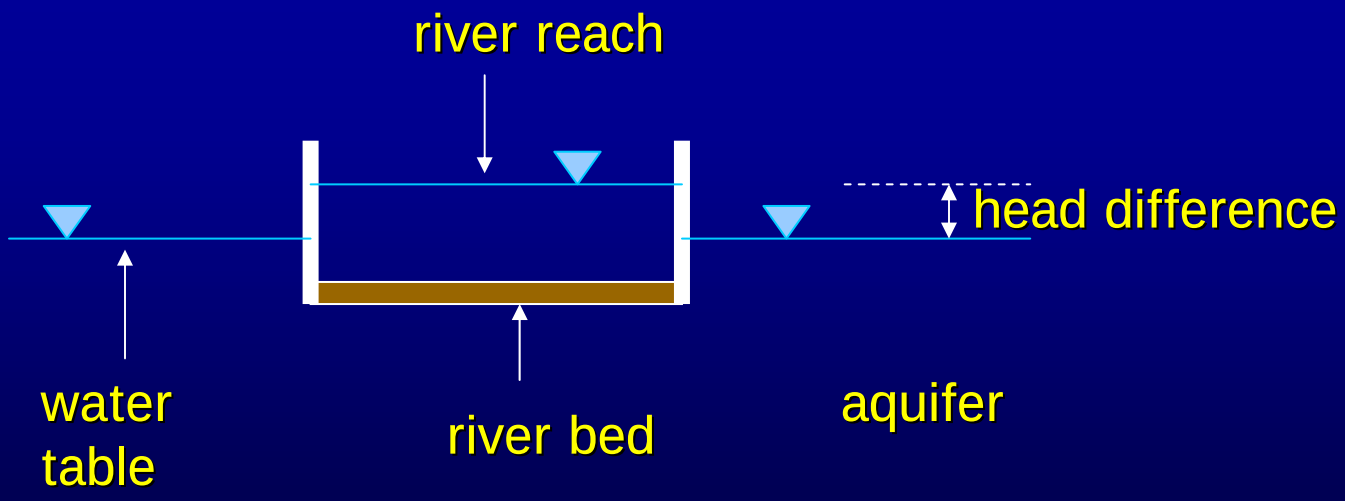
  Interactive RiverWare - MODFLOW link
  - Overview
  - Software Architecture

Network of Groundwater objects Outline

- Allow groundwater objects to interact with other reaches, canals, and other groundwater objects
  - Enhancements made to the:
    - Reach
    - Distribution canal
    - Groundwater objects
  - Solution Process

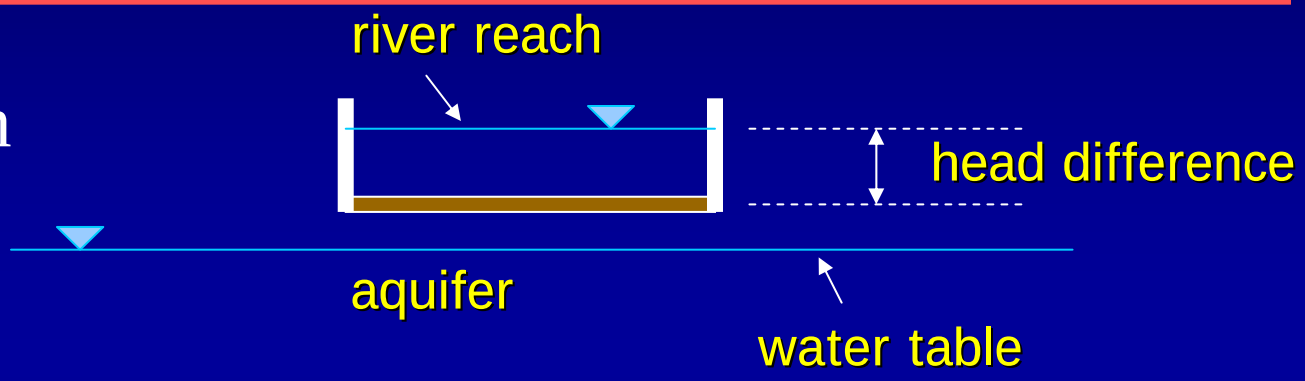
Enhancements to Reach Object

- Head based Seepage method solves for seepage given river elevation and water table elevation
- Losing Reach:

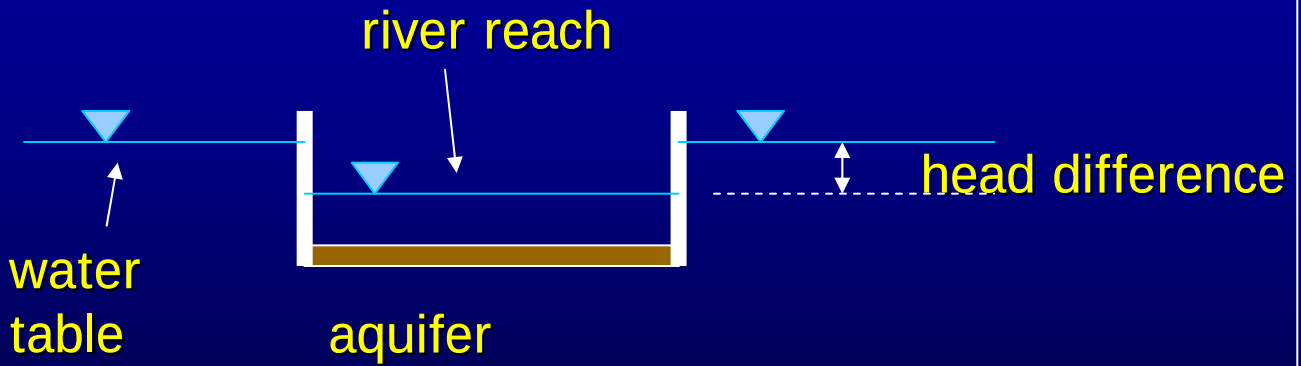


Enhancements to Reach Object

Perched Reach



Gaining Reach



Enhancements to Reach Object

- Reach elevation computed by stage method
- Previous Water Table Elevation linked to groundwater object's Previous Elevation
- Seepage = Head Difference * Conductance
  - Conductance = K * L * w / m
  - K = hydraulic conductivity of riverbed material
  - L = reach length
  - w = reach width
  - m = streambed thickness

Distribution Canal

- Head based Seepage method added to Distribution Canal object
- No stage method, instead input Canal Elevation

Groundwater Object Requirements

- Model Evapotranspiration and Deep Percolation as function of groundwater elevation
- Be able to connect to reach or canal based on aquifer and reach/canal elevation and conductance
- Be able to connect to adjacent groundwater objects to compute groundwater flows based on head differences and conductance between groundwater objects, i.e. each GW object acts like an aquifer cell or element

Enhancements to Groundwater Object

- New user selectable method: Connected GW Objects
- Evapotranspiration
  - Method to compute ET as a function of water table elevation (user input table)
- Deep Percolation
  - Method to compute flow to deep aquifer as a function of water table elevation and deep aquifer elevation/head (user input value)
  - Deep Aquifer Flow = Conductance * (Previous Elevation – Previous Deep Aquifer Elevation)

Enhancements to Groundwater Object

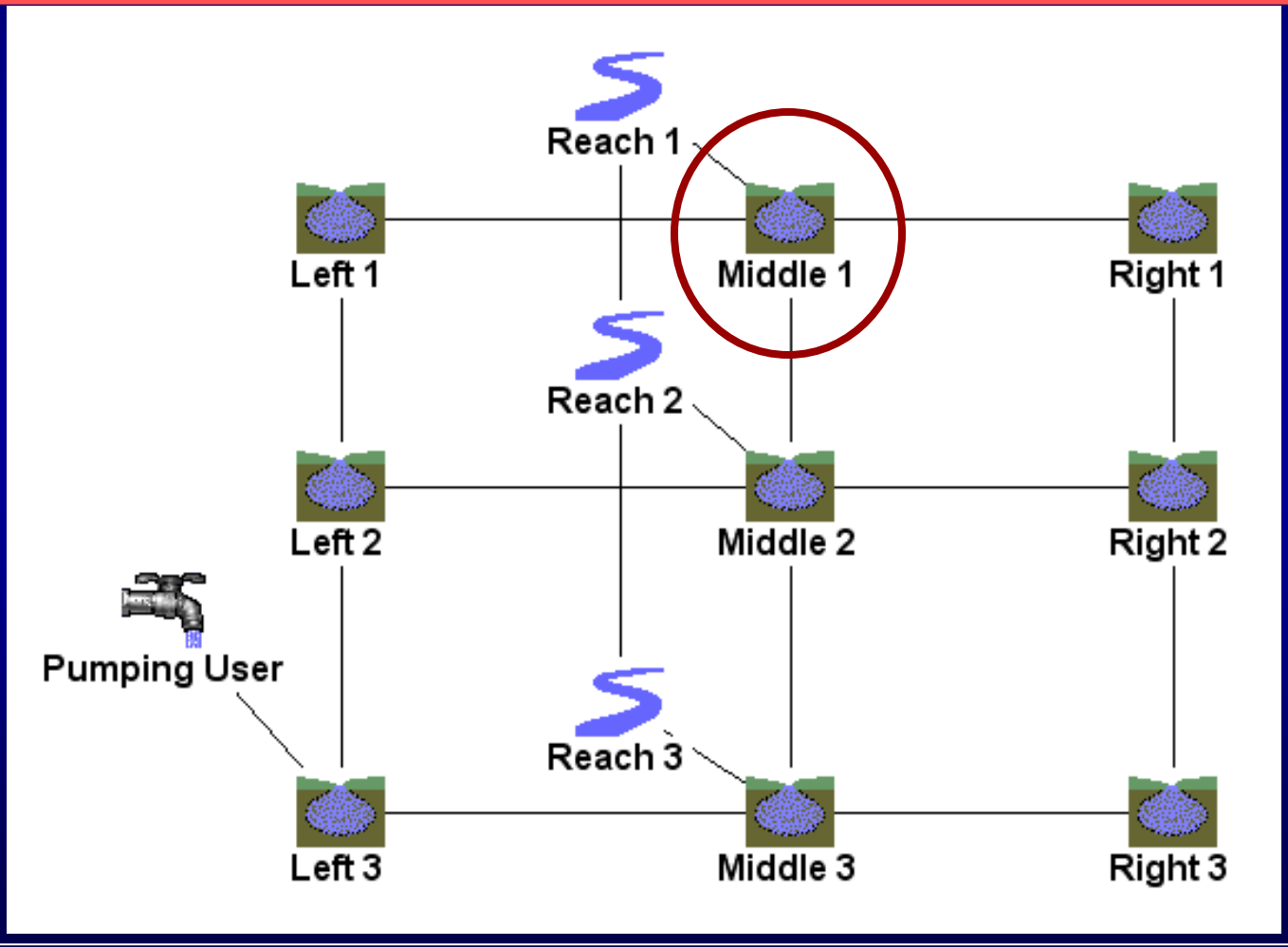
- Groundwater Flow:
  - New dispatch method: solveGWMB_givenPreviousElevations
  - Based on head difference between adjacent groundwater objects
  - GW Flow = Conductance * (Adjacent Previous Elevation – Previous Elevation)
    - Possible GW Flow value for each of the four sides of a GW object (user selectable)

Groundwater Solution

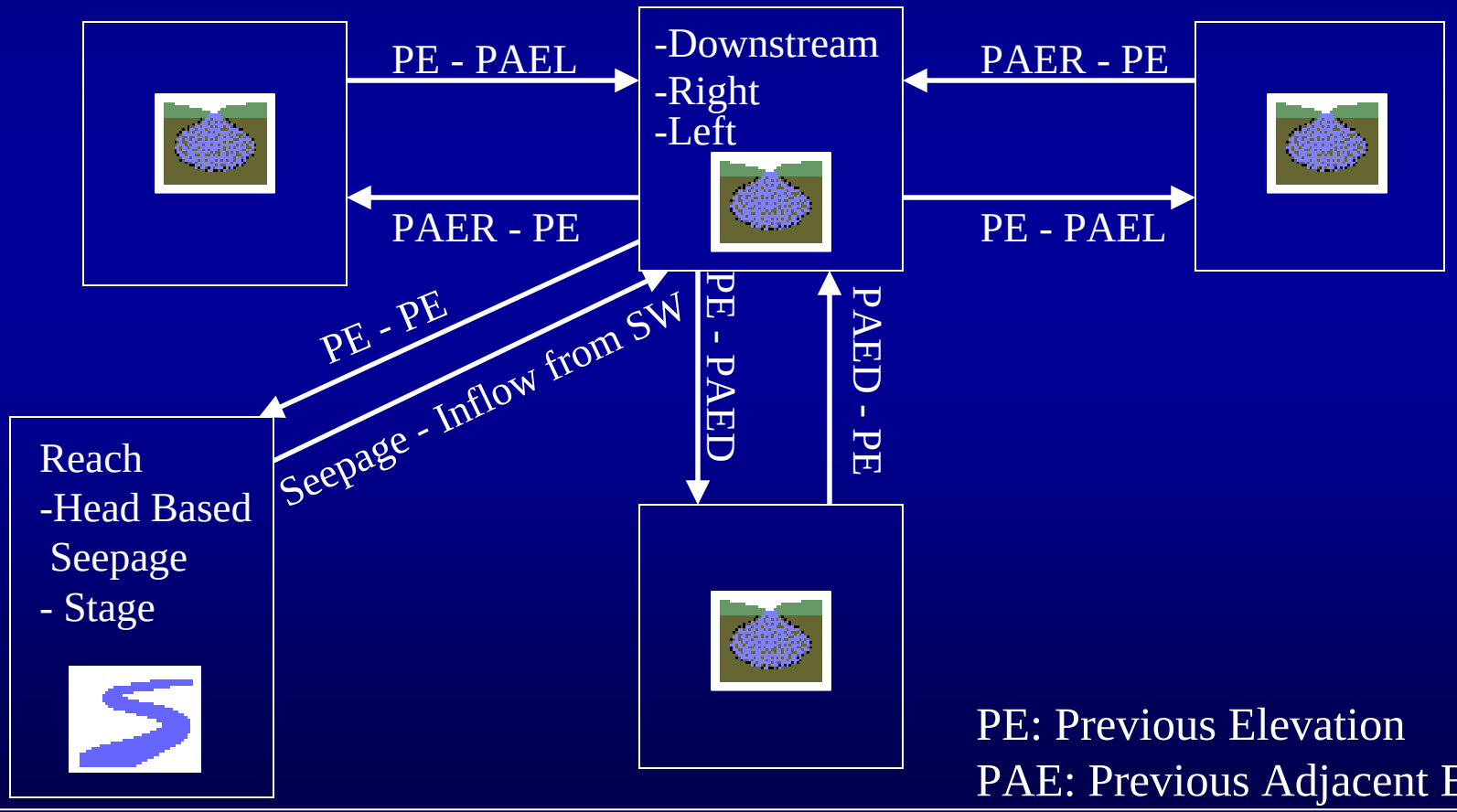
- Storage (t) = Storage (t-1) + Inflow from SW + Net Inflows from Adjacent GW Objects – Pumping – ET – Deep Aquifer Flow

- Elevation (t) = Elevation (t-1) + Change in Storage / (Specific Yield*Area)

Layout Example



Linking Structure



PE: Previous Elevation
PAE: Previous Adjacent Elevation

Solution Process

- Reach solves for seepage based on previous GW elevation
- GW object connected to the reach solves given seepage and previous adjacent elevations. Previous Elevation is set at the NEXT timestep
- Connected GW objects solve at the next timestep given the new previous adjacent elevations, if possible
- The next reach solves and all connected GW objects solve
- No iteration because only previous elevations are used

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  Interactive RiverWare - MODFLOW
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Why Improve Surface Water Groundwater Interaction Modeling?

- In areas with significant surface water groundwater interaction, prediction of flow and stage in the river channel is poor
- Riparian Evapotranspiration may significantly impact the water level in river corridors with highly interactive surface water and groundwater

MODFLOW

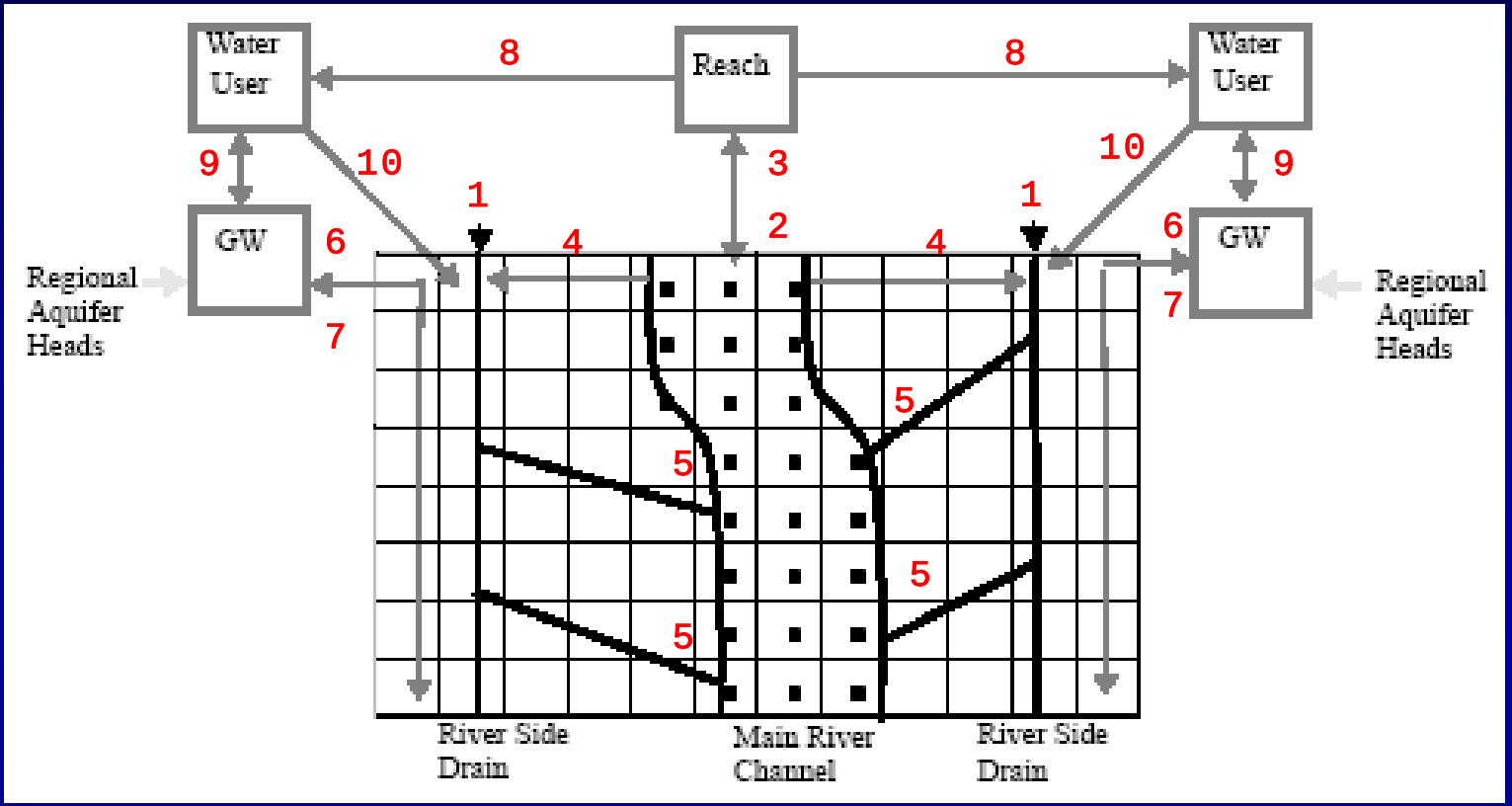
- Most widely used groundwater modeling program
- Stream/River modeling in MODFLOW: STR, SFR, and RIV Packages
- RIV: Flux between river and aquifer (no river routing)
- STR and SFR: Flux between river and aquifer, limited river routing capabilities (the SFR package is the updated version of STR and contains more options and improved routing calculations).
- A non-standard MODFLOW Package RIP-ET (Riparian and Evapotranspiration) is available for MODFLOW 2000. This package will be included in the MODFLOW executable that runs with RiverWare.

RiverWare

- Enhanced RiverWare Objects: data on these objects may be exchanged with MODFLOW
  - *Reach*
  - *Water User and AggDiversion Site*
  - *Groundwater Storage*
- Computational SubBasin: manages data exchange

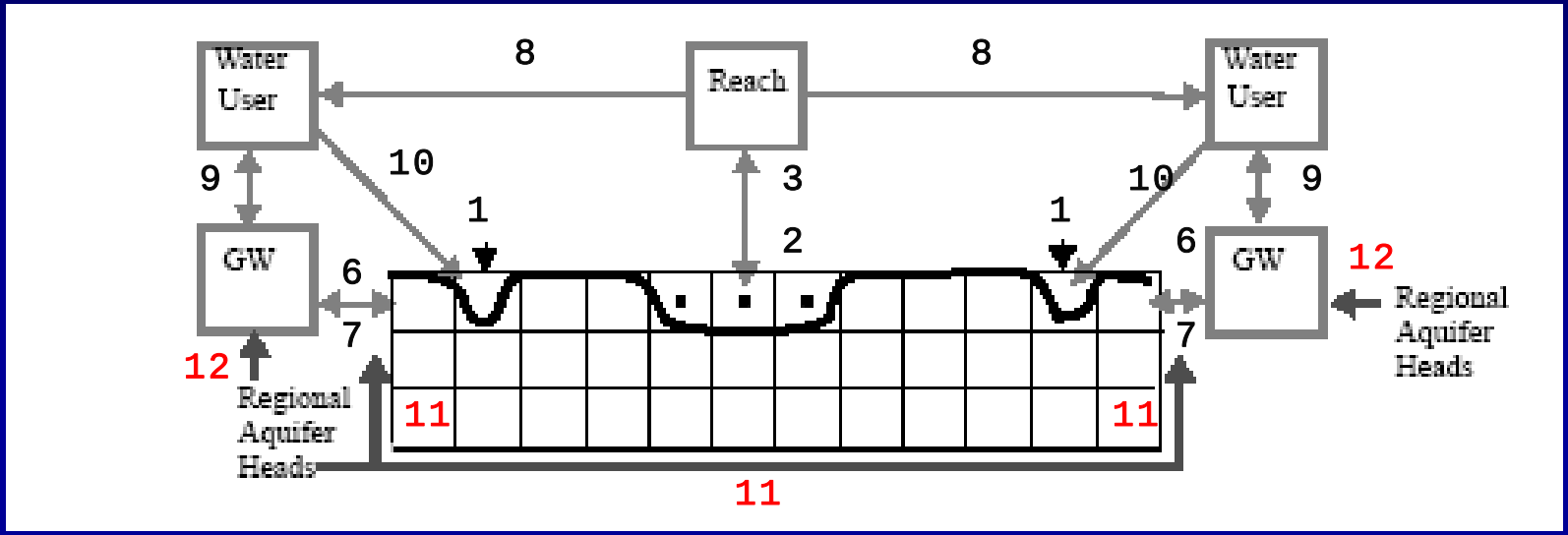
  Features:
  - User input "*Maps*": allow data from one or multiple MODFLOW cells/segments to be mapped to a RiverWare object
  - "*Exchanged* Data" is displayed as aggregated or disaggregated, as necessary, for all exchanged values

RiverWare and MODFLOW – Plan View



1) Inflow into riverside drain – *in MF*
2) River Stage – *to MF*
3) Gain/Loss between river and aquifer – *from MF*
4) Diversion from Reach to riverside drain – *to MF*
5) Local Inflow/Return Flow from riverside drain to Reach – *from MF*
6) Groundwater Head – *to MF*
7) Lateral Flux between MF Lateral Boundary cell and RW GW object head – *from MF*
8) Diversion from Reach to WaterUser – *in RW*
9) Groundwater Return Flow – *in RW*
10) Surface Water Return Flow – *to MF*

RiverWare and MODFLOW – Cross Section

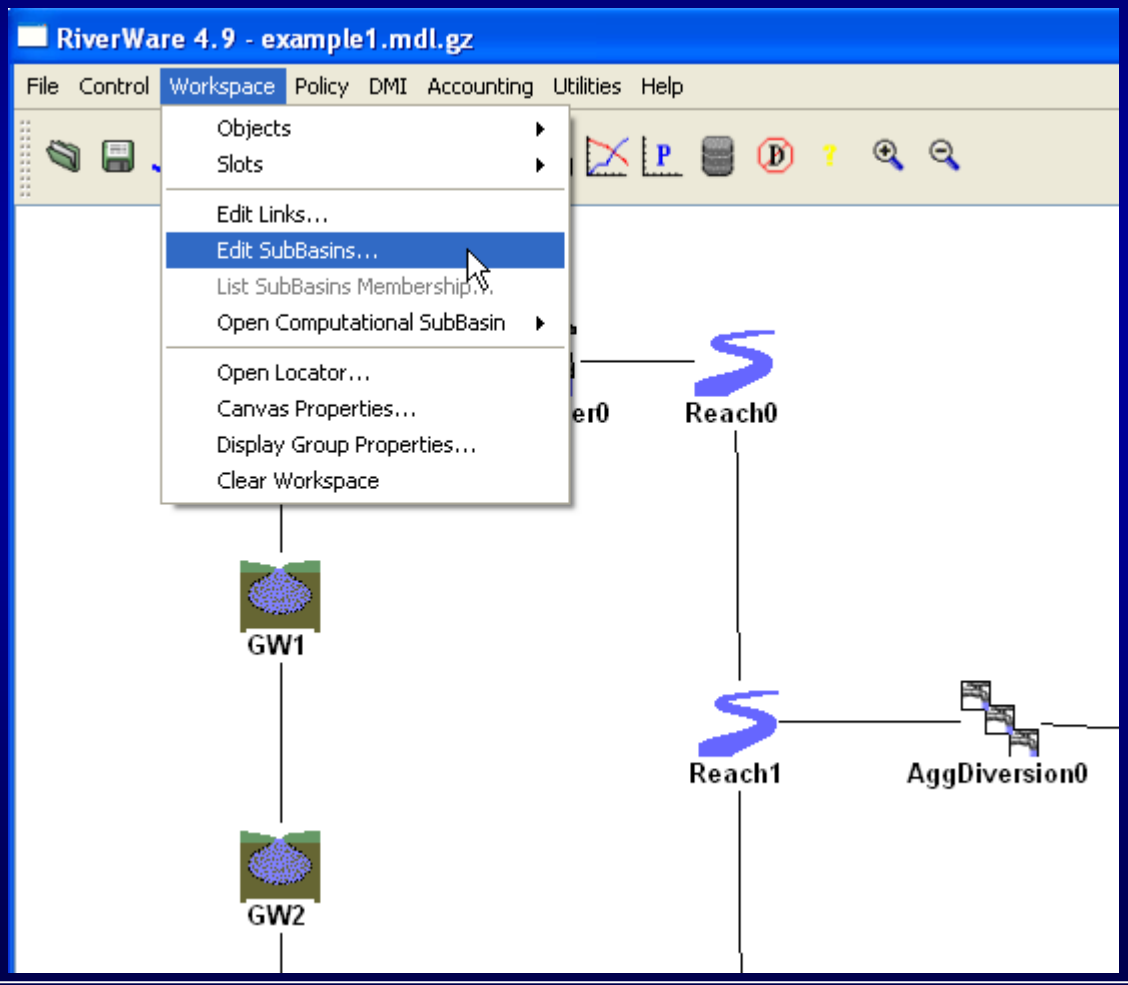


1) Inflow into riverside drain – in MF
2) River Stage – to MF
3) Gain/Loss between river and aquifer – from MF
4) Diversion from Reach to riverside drain – to MF
5) Local Inflow/Return Flow from riverside drain to Reach – from MF
6) Groundwater Head – to MF
7) Lateral Flux between MF Lateral Boundary cell and RW GW object head – from MF
8) Diversion from Reach to WaterUser – in RW
9) Groundwater Return Flow – in RW
10) Surface Water Return Flow – to MF
11) Regional Aquifer Heads – in MF (input by user)
12) Regional Aquifer Heads – in RW (input by user)

Summary of Data Exchange

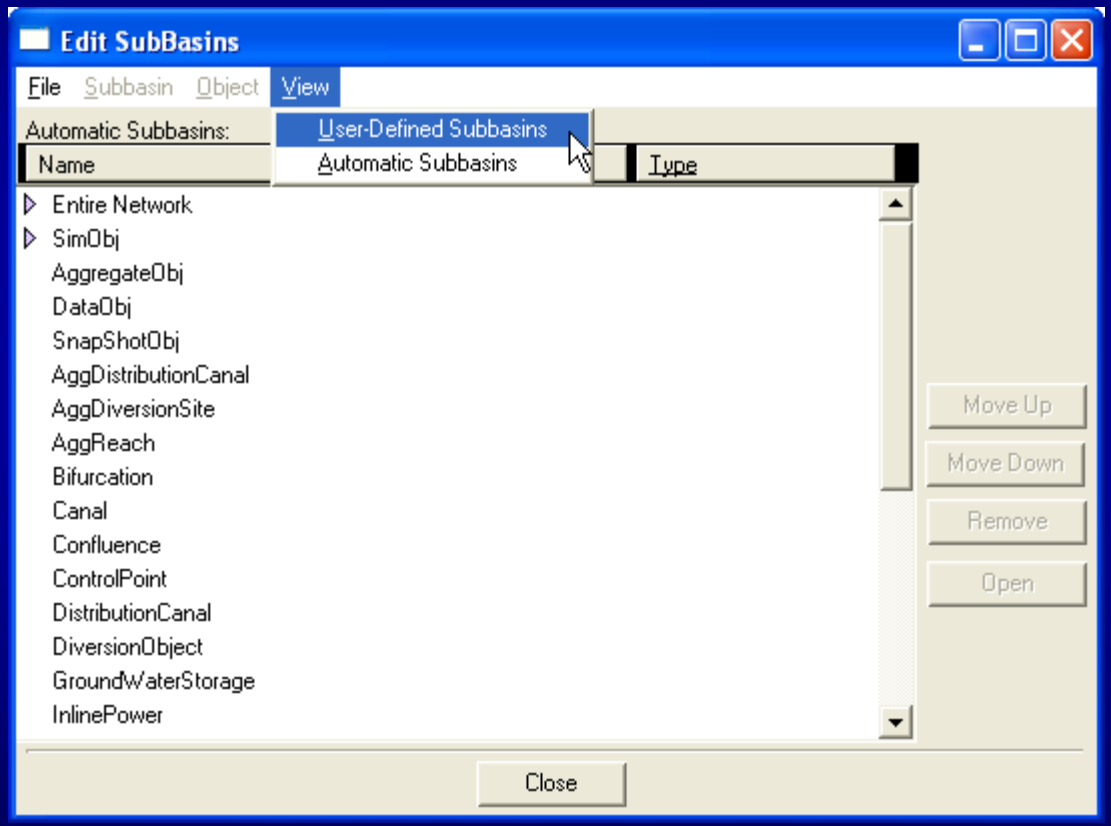
Simulation Object	Slot	Sum, Interpolation, or Single Value	MODFLOW Package and Identifier	From	To	Mandatory or Optional
Reach	Inflow Stage and Outflow Stage	Interpolation	RIV Cells (Layer, Row, Column)	RW	MF	Mandatory
	Total MODFLOW GainLoss	Sum	RIV Cells (Layer, Row, Column)	MF	RW	Mandatory
	Diversion	Single Value	STR or SFR Segment #	RW	MF	Optional
	Local Inflow MODFLOW Return	Single Value	STR or SFR Segment #	MF	RW	Optional
Groundwater Storage	Previous Elevation	Interpolation	GHB Cells (Layer, Row, Column)	RW	MF	Mandatory
	Lateral Flux from MODFLOW	Sum	GHB Cells (Layer, Row, Column)	MF	RW	Mandatory
Water User	Surface Return Flow	Single Value	STR or SFR Segment #	RW	MF	Optional
AggDiversion Site	Total Surface Return Flow	Single Value	STR or SFR Segment #	RW	MF	Optional

Computational SubBasin



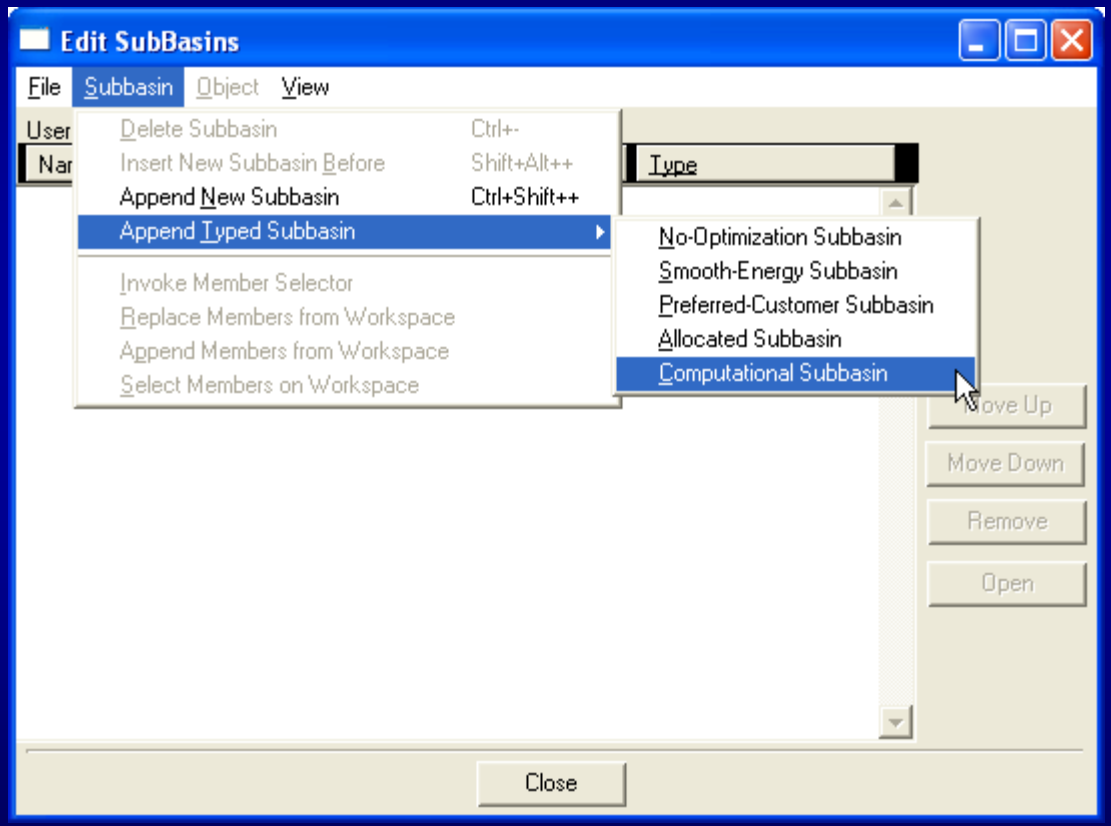
Open a SubBasin

Computational SubBasin



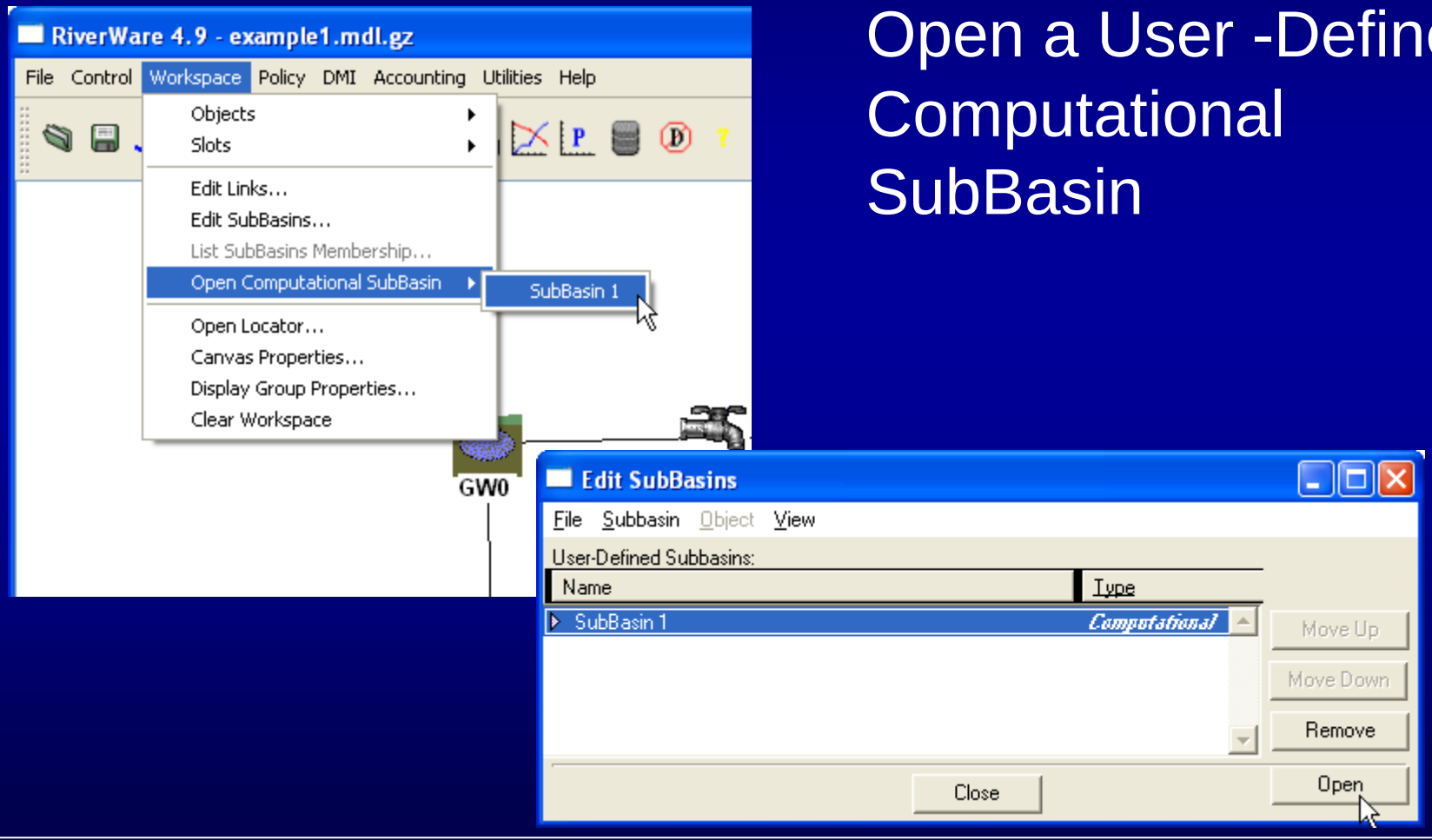
User - Defined Subbasin

Computational SubBasin



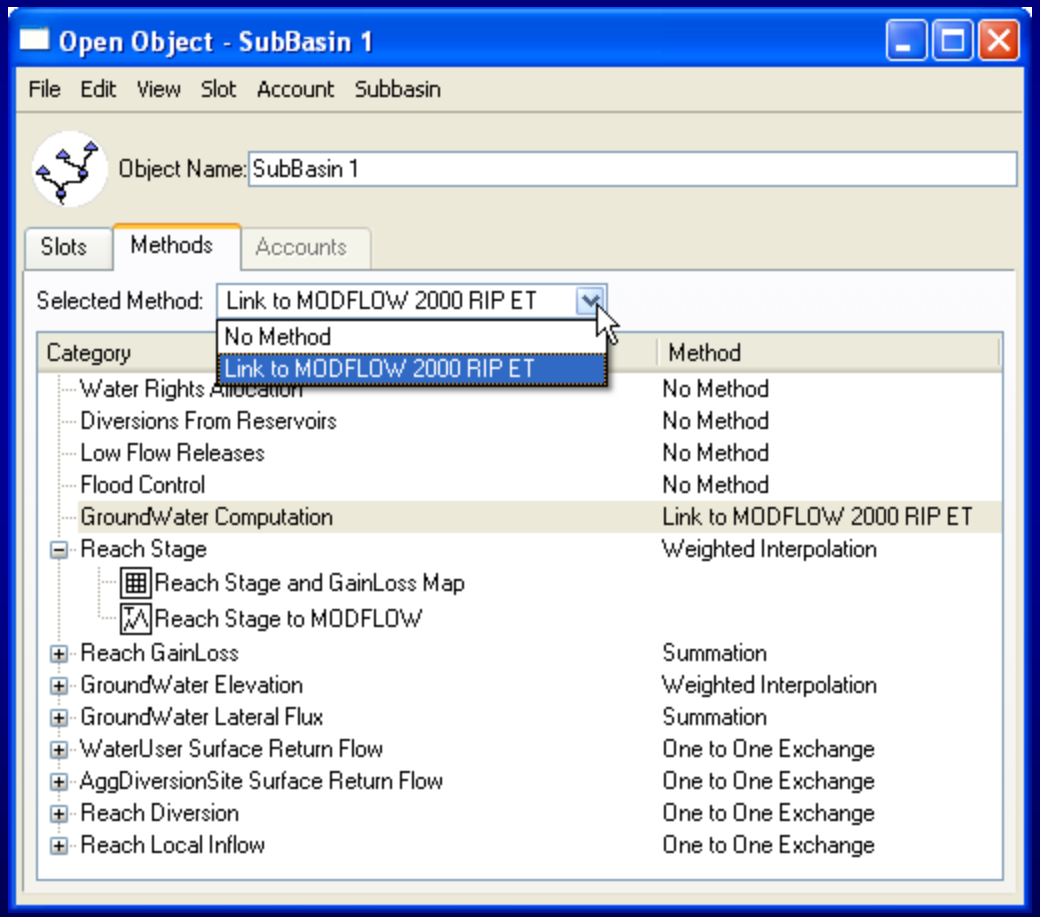
Create a new Computational SubBasin

Computational SubBasin



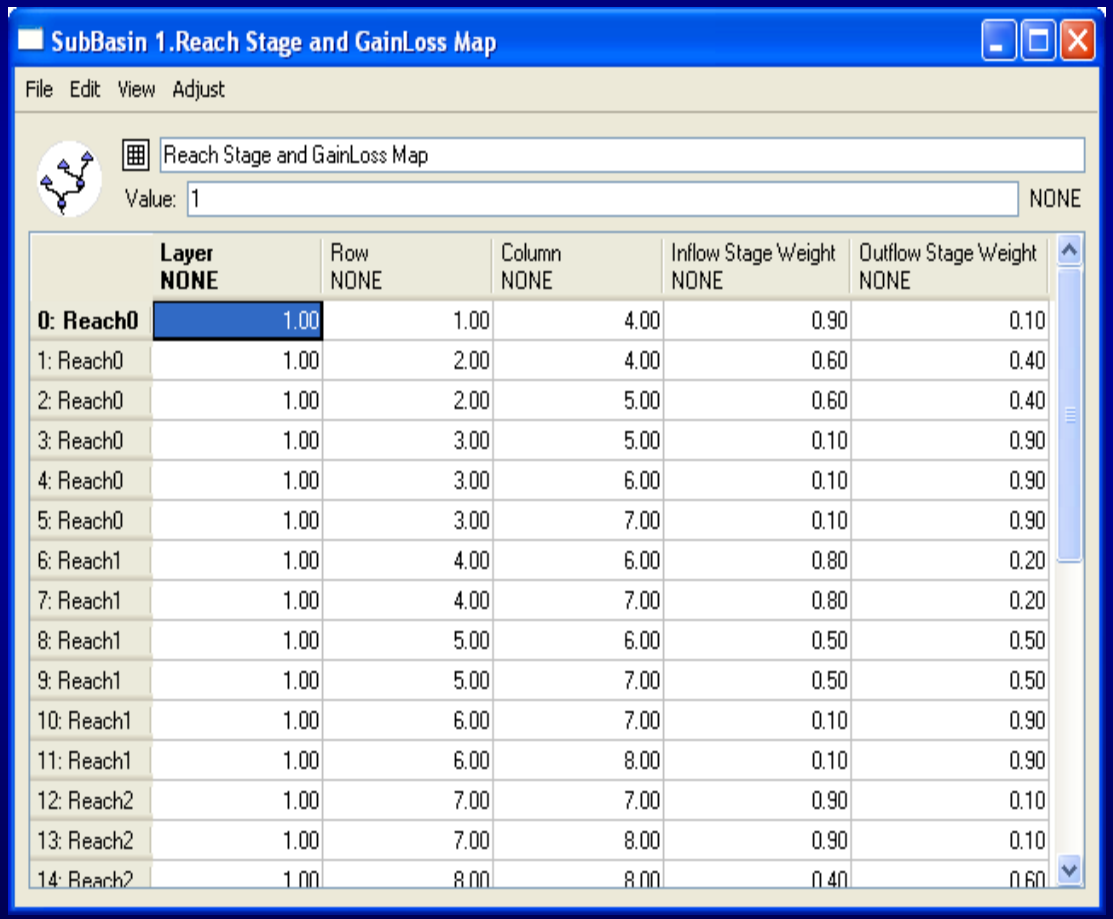
Open a User -Defined Computational SubBasin

Computational SubBasin



- Categories and Methods on the Computational SubBasin Associated with a MODFLOW Link
- Note the Map and Data Exchange Slots in the Reach Stage Category

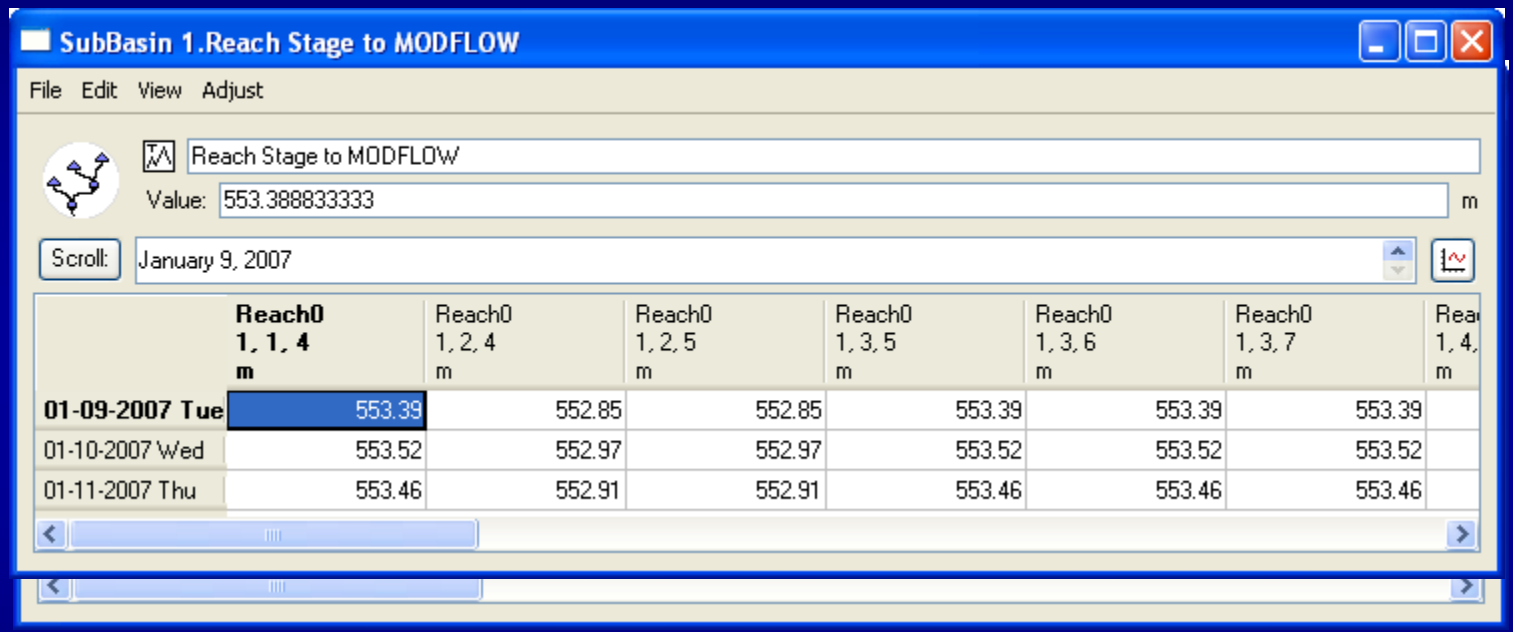
Computational SubBasin



	Layer NONE	Row NONE	Column NONE	Inflow Stage Weight NONE	Outflow Stage Weight NONE
0: Reach0	1.00	1.00	4.00	0.90	0.10
1: Reach0	1.00	2.00	4.00	0.60	0.40
2: Reach0	1.00	2.00	5.00	0.60	0.40
3: Reach0	1.00	3.00	5.00	0.10	0.90
4: Reach0	1.00	3.00	6.00	0.10	0.90
5: Reach0	1.00	3.00	7.00	0.10	0.90
6: Reach1	1.00	4.00	6.00	0.80	0.20
7: Reach1	1.00	4.00	7.00	0.80	0.20
8: Reach1	1.00	5.00	6.00	0.50	0.50
9: Reach1	1.00	5.00	7.00	0.50	0.50
10: Reach1	1.00	6.00	7.00	0.10	0.90
11: Reach1	1.00	6.00	8.00	0.10	0.90
12: Reach2	1.00	7.00	7.00	0.90	0.10
13: Reach2	1.00	7.00	8.00	0.90	0.10
14: Reach2	1.00	8.00	8.00	0.40	0.60

- Map slot: Input by the User. Data in the table may be imported.
- Rows must be labeled with the corresponding object name.

Computational SubBasin



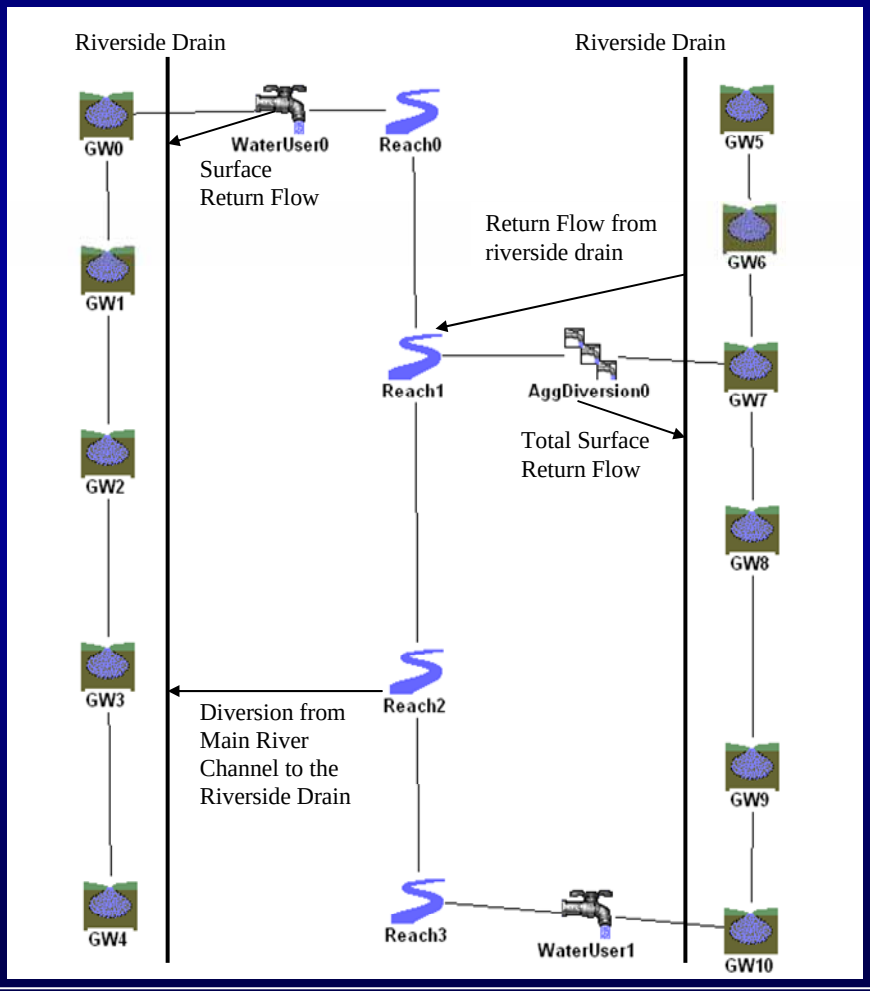
	Reach0 1, 1, 4 m	Reach0 1, 2, 4 m	Reach0 1, 2, 5 m	Reach0 1, 3, 5 m	Reach0 1, 3, 6 m	Reach0 1, 3, 7 m	Rea 1, 4, m
01-09-2007 Tue	553.39	552.85	552.85	553.39	553.39	553.39	
01-10-2007 Wed	553.52	552.97	552.97	553.52	553.52	553.52	
01-11-2007 Thu	553.46	552.91	552.91	553.46	553.46	553.46	

Data Exchange slot: Column Headings show the MODFLOW cell identifier and the corresponding RiverWare Object. In this table the values shown are interpolated between the inflow stage and outflow stage of the corresponding Reach.

Data Transfer Sequence

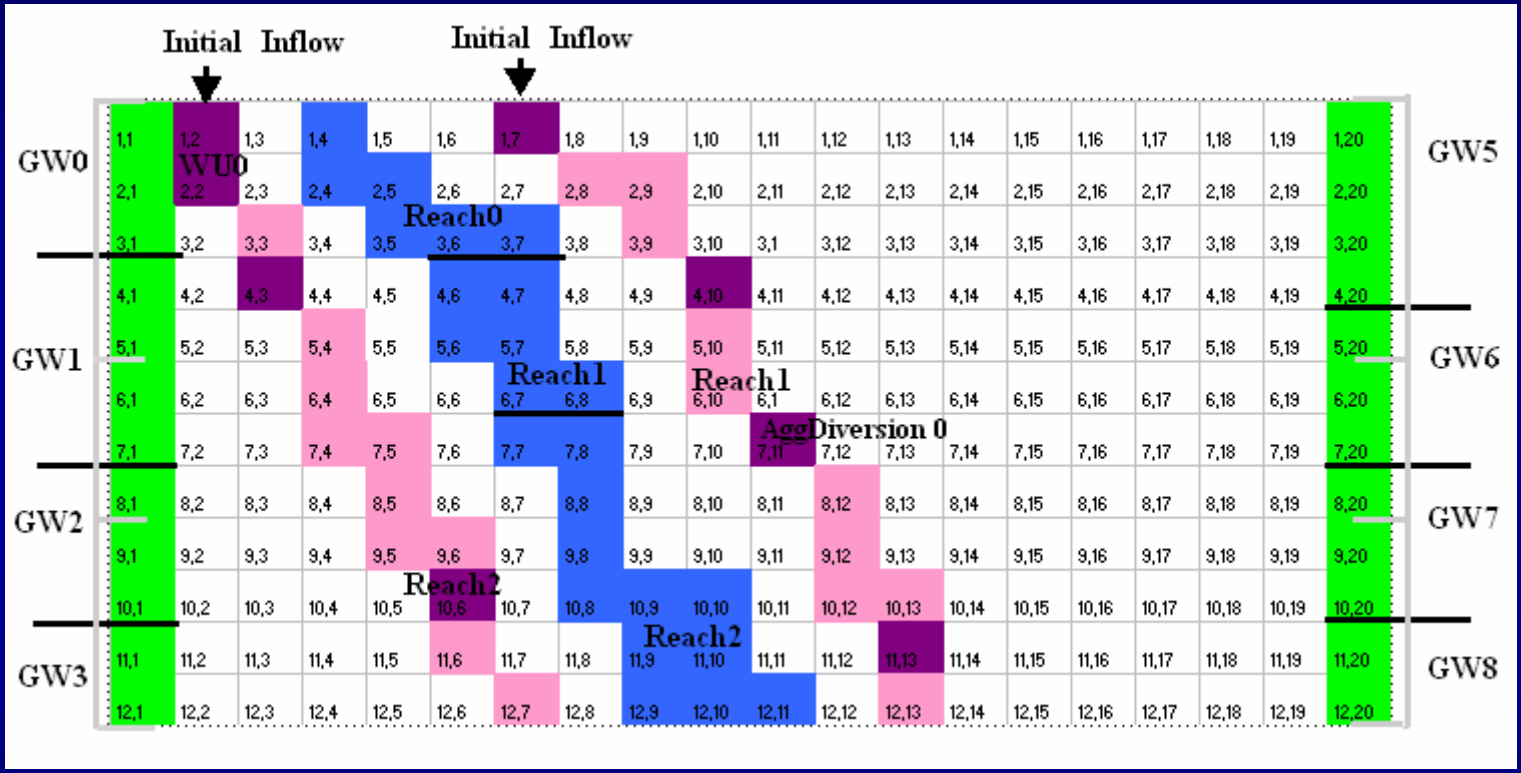
- Begin current timestep
- RiverWare sends data to MODFLOW (slot values from previous timestep)
- MODFLOW executes at current timestep
- RiverWare retrieves data from MODFLOW
- RiverWare executes at current timestep

RiverWare Example Model



- Optional Data Transfers are shown.
- Mandatory Data transfers are on every Reach object (Stage and GainLoss) and Groundwater Storage object (GW Elevation and Lateral Flux).

MODFLOW Example Model

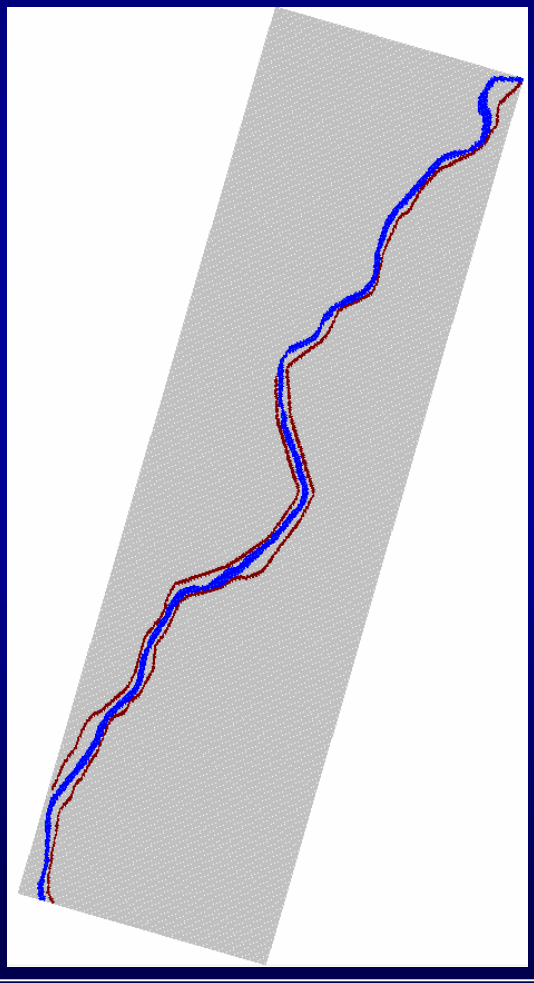


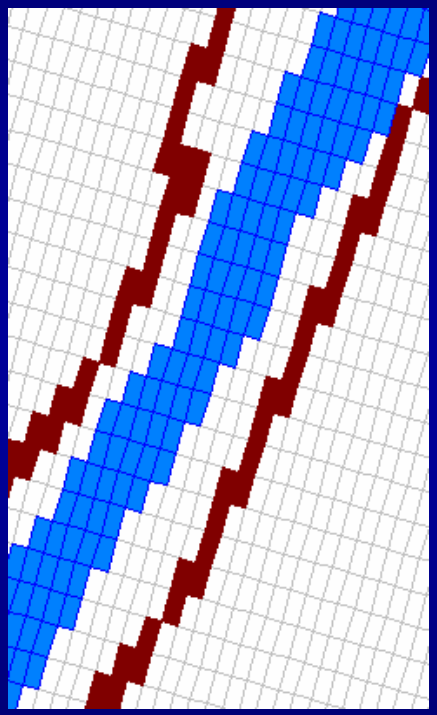
- *Green – GHB Boundary Cells*. Matching RiverWare Groundwater Storage Objects shown (summation between black dividers, interpolation between gray dividers).
- *Blue – RIV Boundary Cells.* Matching RiverWare Reachs Objects shown
- *Pink/Purple – STR or SFR Segments* (purple indicates start of a segment). Matching RiverWare Water User and AggDiversion Site Objects shown.

Middle Rio Grande

- Surface Water and Groundwater are highly interactive along the main river corridor, this interaction affects flow in the channel
- A system of drains and canals spread laterally away from the main channel
- The parallel riverside drains capture seepage from the main channel
- Seepage from the canals recharges the shallow aquifer
- Riparian Evapotranspiration is significant in the area between the main channel and the riverside drains
- Agricultural irrigation returns provide additional flow to the riverside drains

Current Upper Albuquerque MODFLOW Model

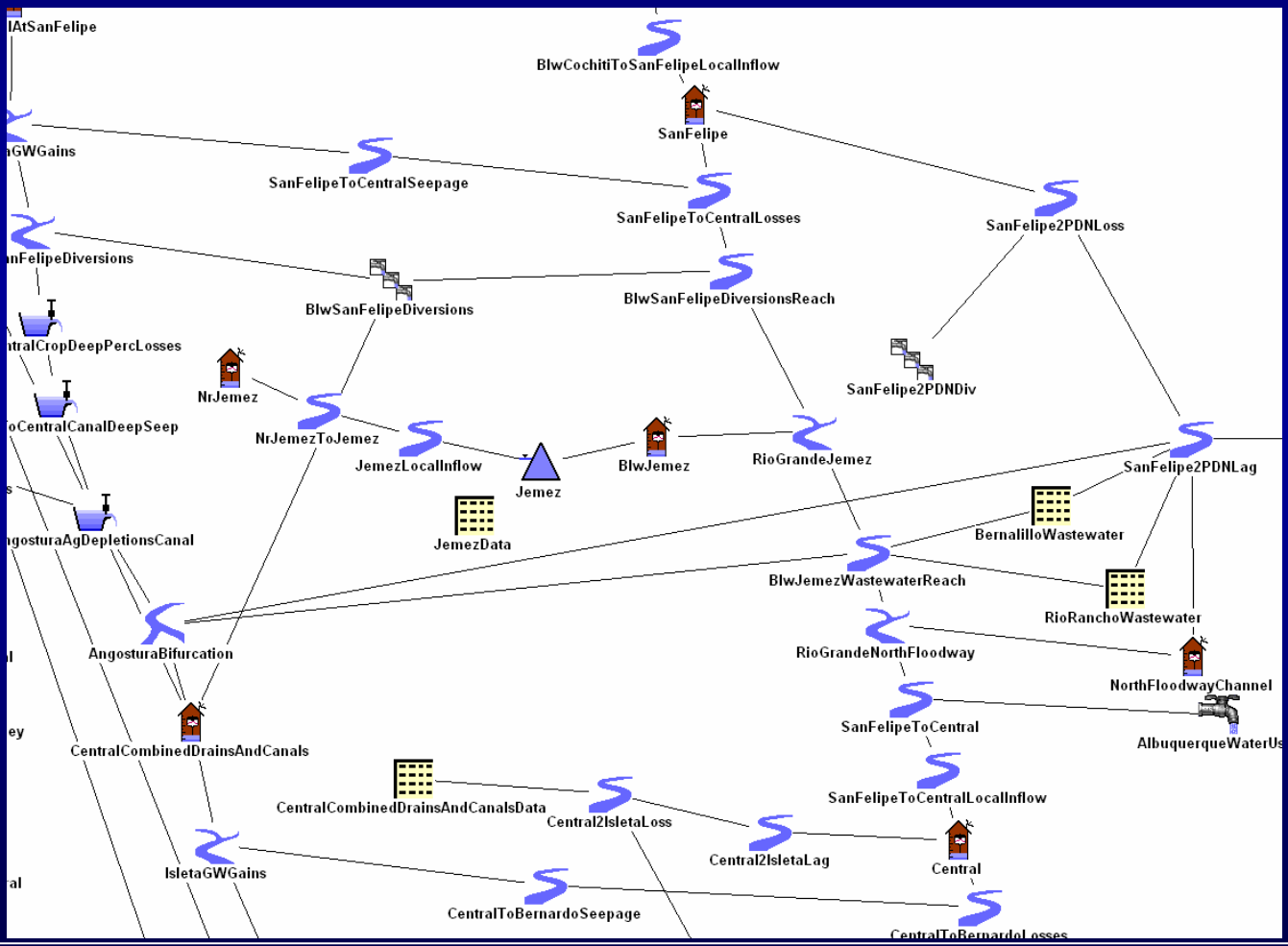




Model Cells are 125’ by 250’
Blue – RIV
Red – STR

Note: model cells from just outside the riverside drain to the model boundary are no-flow

Current URGWOM Model



URGWOM

RiverWare Model Changes:

- Remove riverside drains represented using RiverWare Reach objects and represent them in MODFLOW using STR or SFR packages
- Add Groundwater Storage objects to represent shallow groundwater system outside MODFLOW model

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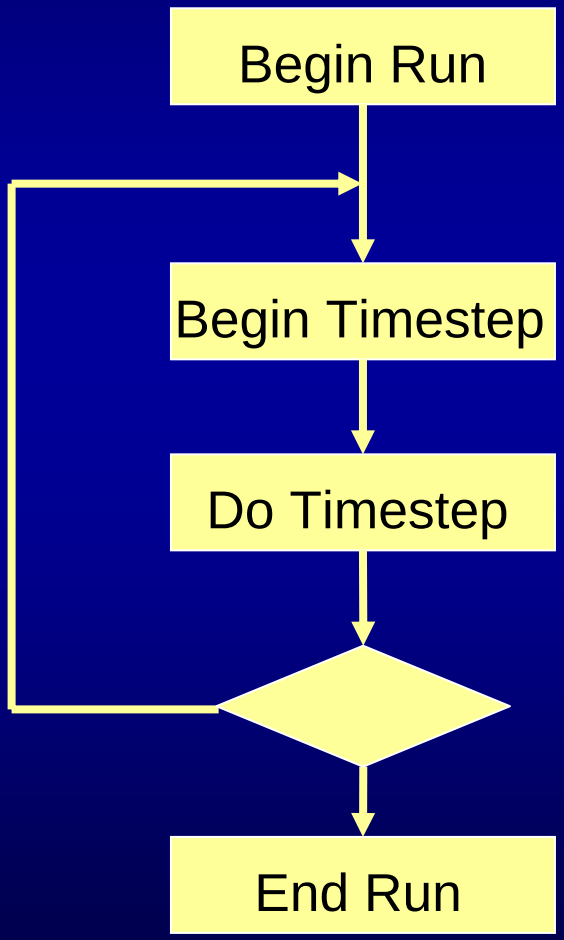
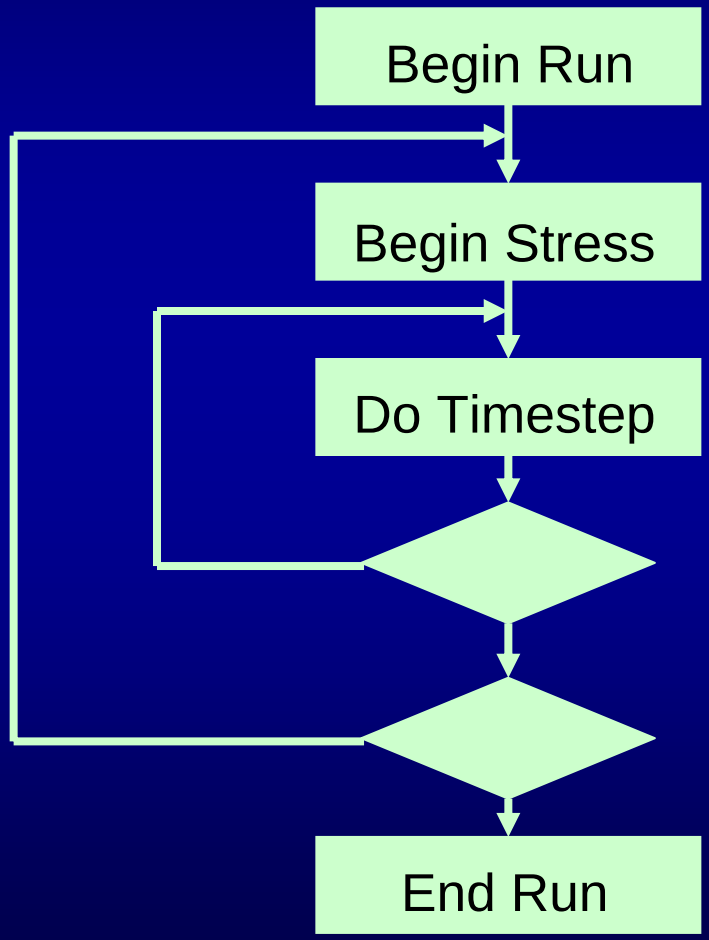
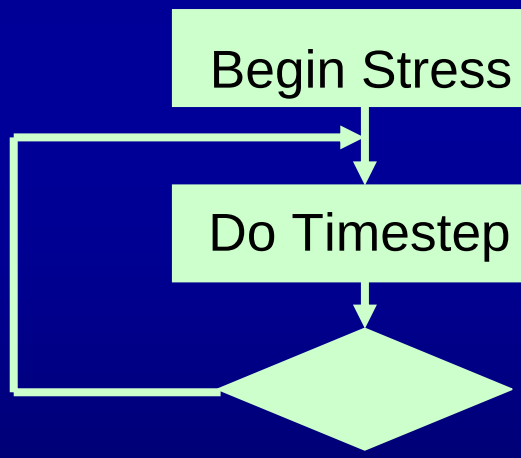
A RiverWare Run



A MODFLOW Run



Decomposing MODFLOW into Subroutines

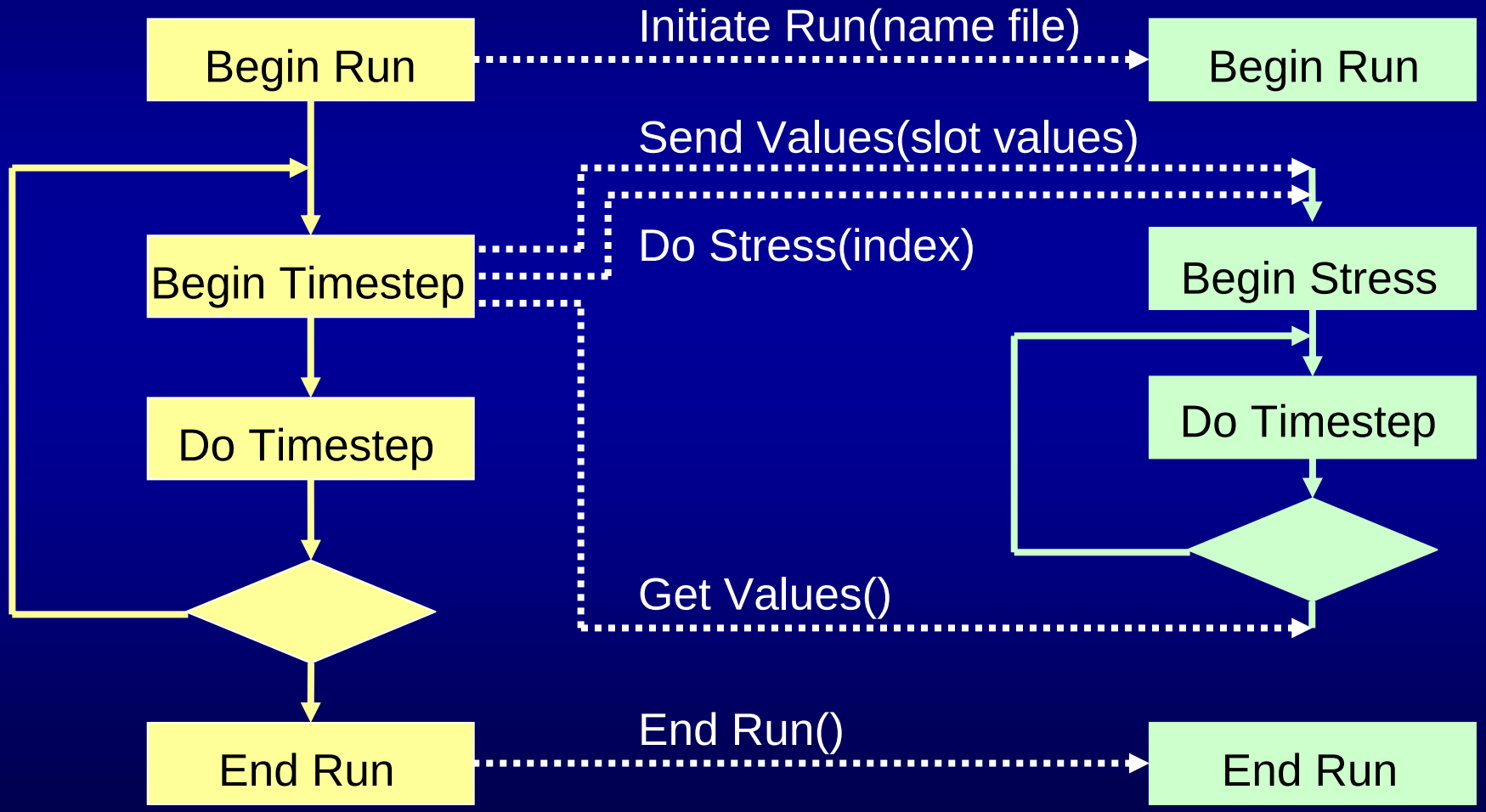


Begin Run } Initiate Run(name file)

Do Stress(index)

End Run } End Run()

A Combined RiverWare MODFLOW Run



Feedback

- Questions/Suggestions?