

System Dynamics Modeling using Powersim Studio: Introductory Training Materials

Marissa D. Reno, Howard D. Passell, Jesse D. Roach, Leonard A. Malczynski, Vincent C. Tidwell

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



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Iraq National Water Modeling Workshop I

November 11-15, 2007
United Nations University
Amman, Jordan

A Brief Overview of System Dynamics



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System dynamics modeling methodology

System dynamics (SD) models represent a structure of reservoirs or levels interconnected by controlled flows. SD models include three basic features:

- 1) reservoirs, or levels, that accumulate (water, money, people . . .)
- 2) flows into and out of the reservoir
- 3) constants and other variables that influence flows

SD modeling has been metaphorically described as “bathtub dynamics.”

Levels are the bathtubs themselves, decision functions are the automated or human-controlled valves on the flows to and from the bathtubs, and information channels serve as pipes between levels.

Feedback is an important feature of these systems.

What is System Dynamics?

Jay Forrester, the founder of systems dynamics, suggested that a model should have the following characteristics:

- Able to describe any statement of cause-effect relationships that we may wish to include.
- Simple in mathematical nature.
- Closely synonymous in nomenclature to industrial, economic and social terminology.
- Extendable to large numbers of variables (thousands) without exceeding the practical limits of digital computers.
- Able to handle continuous interactions in the sense that any artificial discontinuities introduced by solution-time intervals will not affect the results. It should, however, be able to generate discontinuous changes in decisions when these are needed.

System dynamics modeling software

– Powersim Studio

www.powersim.com

– Vensim

www.vensim.com

– iThink and Stella

www.iseesystems.com

System dynamics modeling resources

System Dynamics methodology web sites (free)

System Dynamics Society

www.systemdynamics.org

System Dynamics tutorial done for USA Department of Energy

www.albany.edu/cpr/sds/DL-IntroSysDyn/inside.htm

Cornell University System Dynamics sources

www.csdnet.aem.cornell.edu/index.html

Papers on System Dynamics and software engineering

www2.umass.edu/systemdynamics/papers.html

System Dynamics resources for children and young adults

www.clexchange.org

MIT course in system dynamics

www.ocw.mit.edu/OCWWeb/Sloan-School-of-Management/15-874Fall2003/CourseHome

Dr. Craig Kirkwood textbook on system dynamics using Vensim PLE

www.public.asu.edu/~kirkwood/sysdyn/SDRes.htm

Australian Powersim Studio site

<http://www.argospress.com/books/system-dynamics/index.htm>

Powersim Studio independent user group on Yahoo (free)

<http://tech.groups.yahoo.com/group/powersimtools/>

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Powersim Studio* Training Slides

*Powersim Studio 7, Copyright © 1993-2007 Powersim Software AS



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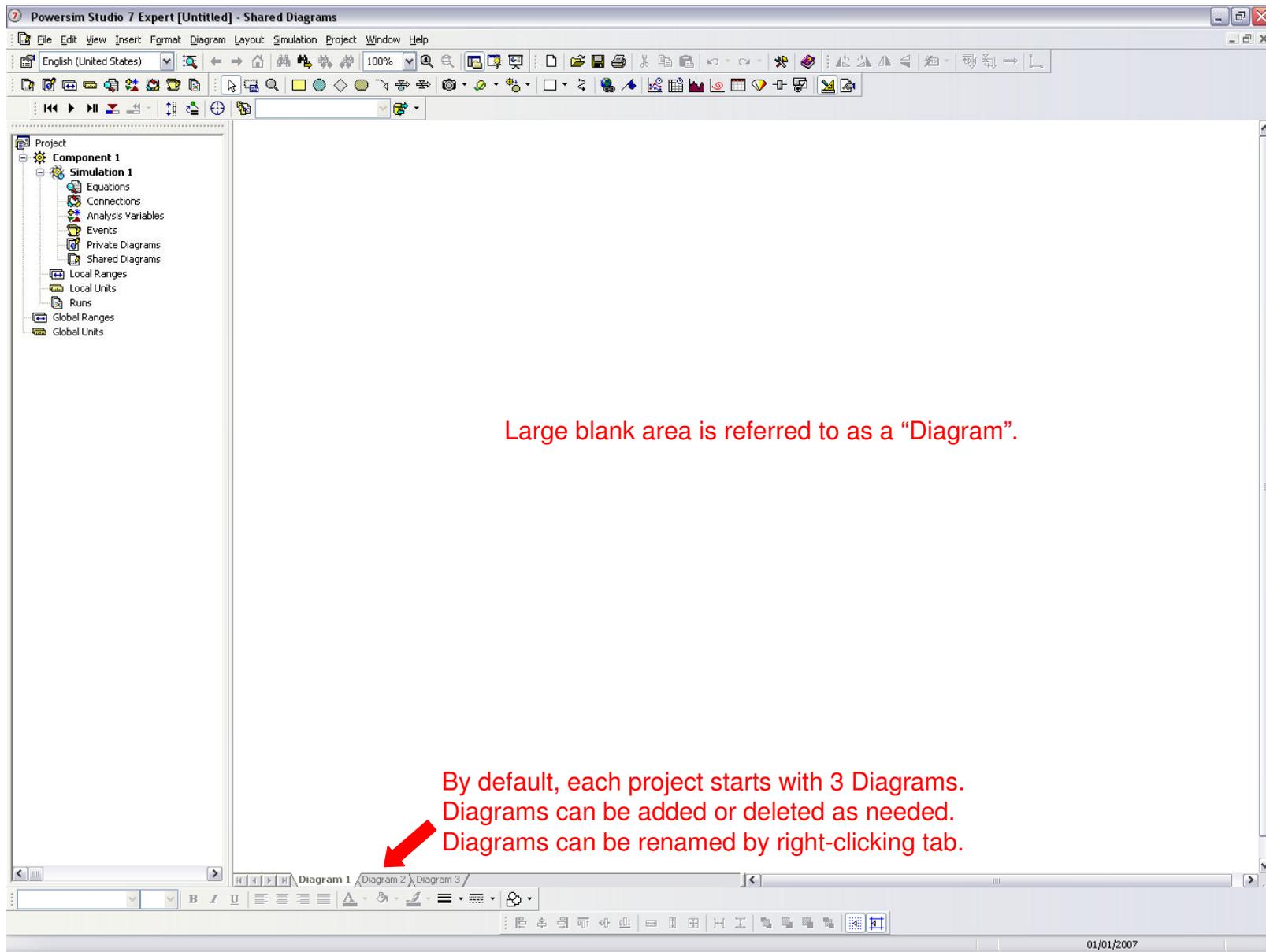
Starting a Model



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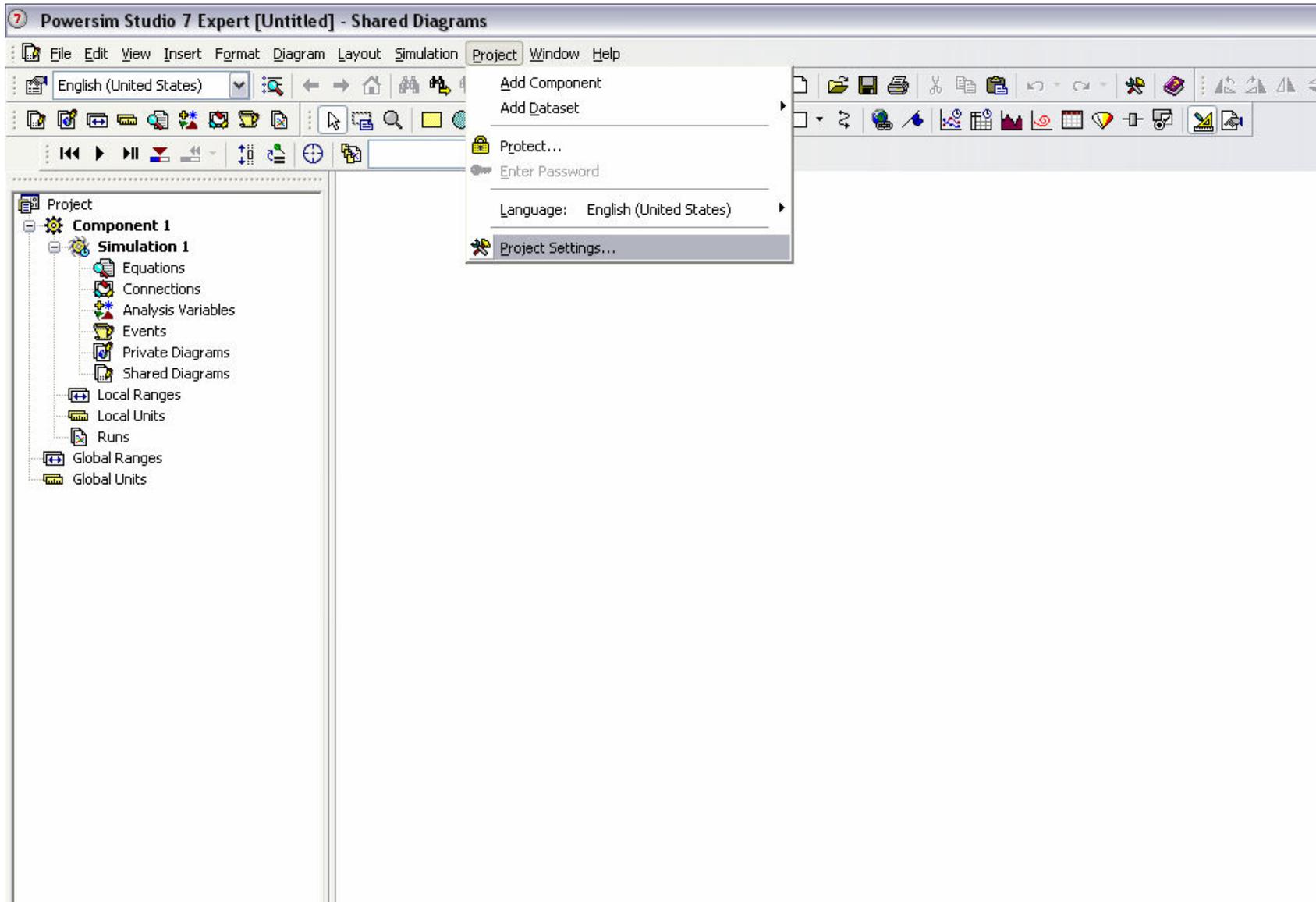
Blank Project



Large blank area is referred to as a "Diagram".

By default, each project starts with 3 Diagrams.
Diagrams can be added or deleted as needed.
Diagrams can be renamed by right-clicking tab.

Project Settings



Project Settings

The image shows the Powersim Studio 7 Expert interface with the Project Settings dialog box open. The dialog box has four tabs: Advanced, Compatibility, Spreadsheet Connections, and Time Measurement. A red arrow points to the Time Measurement tab. The Time Measurement tab contains the following settings:

- Start up in Presentation Mode
- Titlebar**
 - Icon:
 - Caption: Powersim Presentation
- Presentation Mode Home Page**
 - [Empty text box] [...]

At the bottom of the dialog box are buttons for OK, Cancel, Apply, and Help >>.

Project Settings

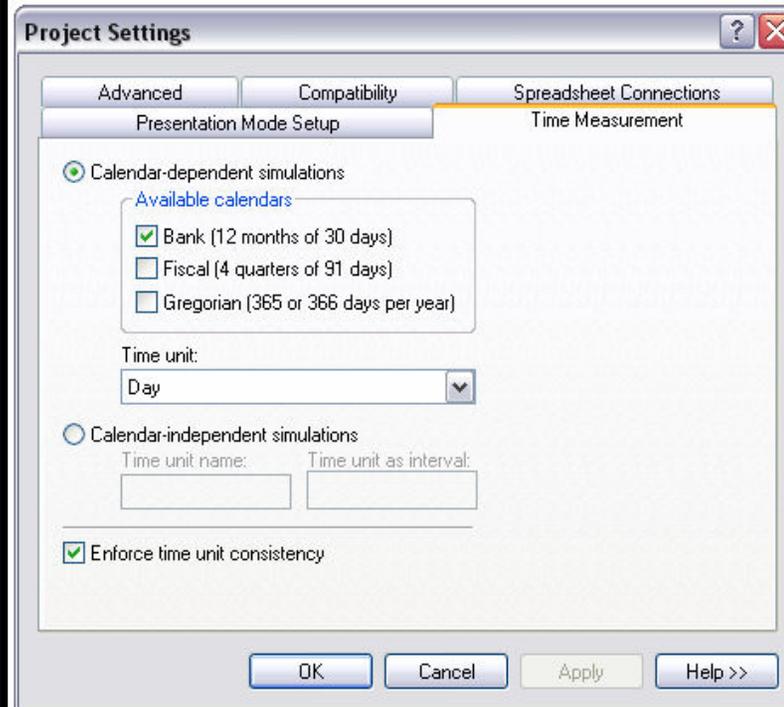


CALENDAR:

BANK – 12 months of 30 days each (second, minute, hour, day, week, month, quarter, and year are available units).

FISCAL – 4 quarters of 91 days each (month is no longer an available unit).

GREGORIAN – 365 or 366 days per year (month, quarter, and year are no longer available units).



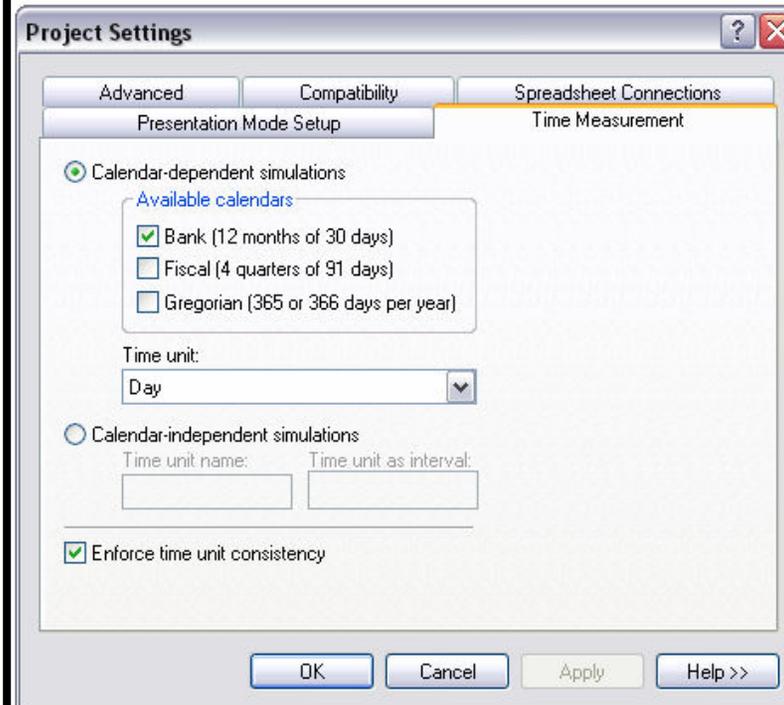
Project Settings



TIME UNIT:

-Select the time unit that you want Studio to use as a default when it displays any value involving time.

-Available time units will depend on the calendar that you select (see previous slide).



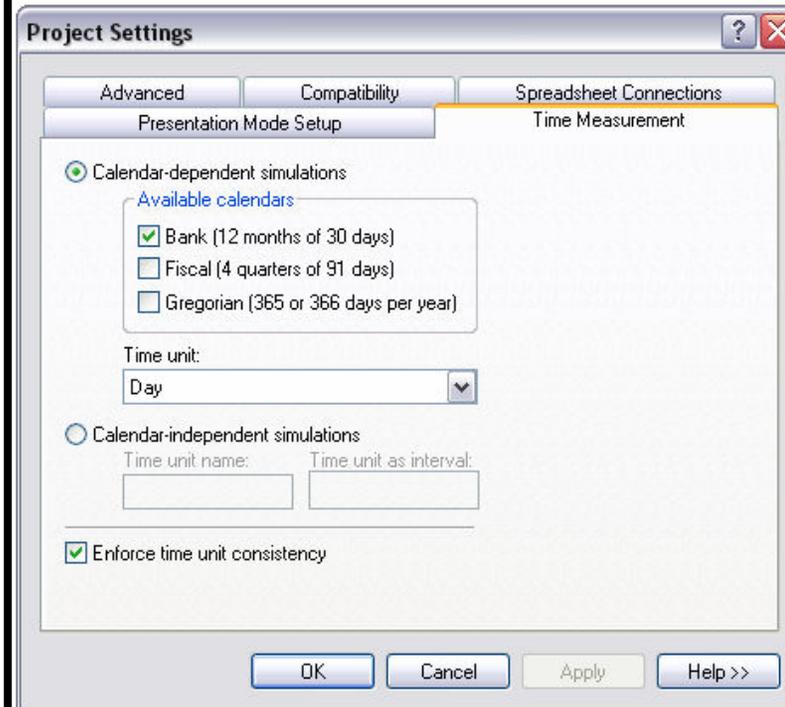
Project Settings



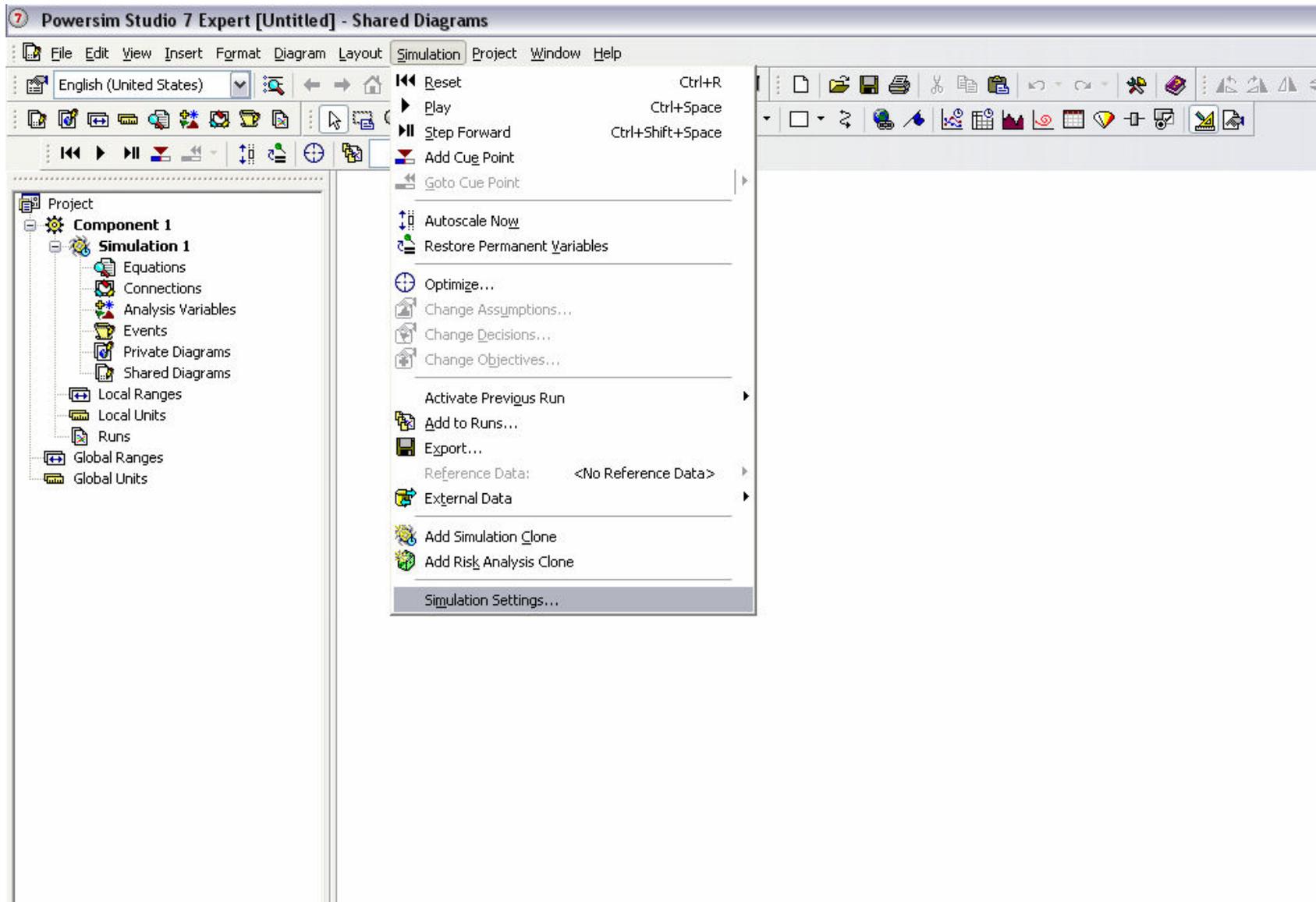
ENFORCE TIME UNIT CONSISTENCY:

-Leave checked if the measurement of time is important for the system that you are modeling. This is almost always true.

-If you choose to deselect this option, your simulation will no longer need time units in flow rates.



Simulation Settings



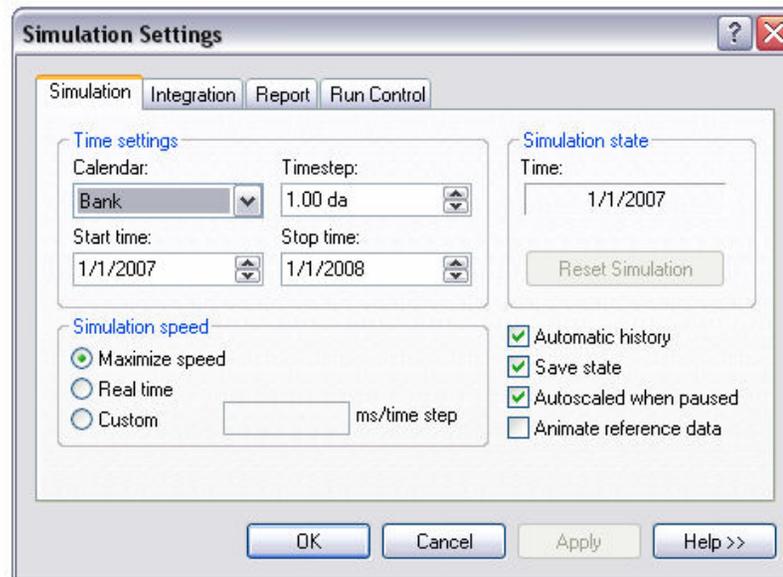
Simulation Settings



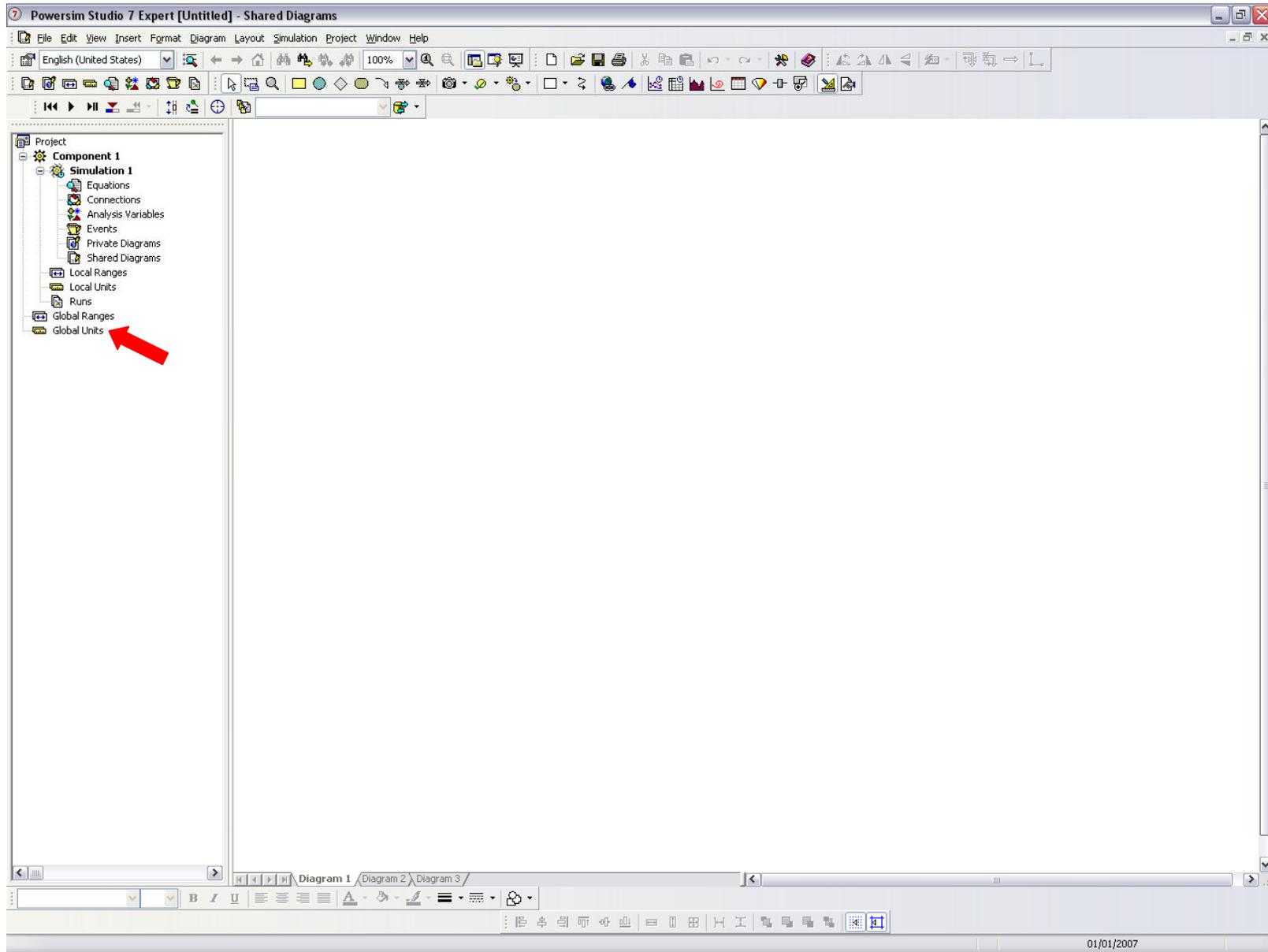
TIME SETTINGS:

CALENDAR – Displays choice made in Project Settings.

TIMESTEP – Choose a timestep that is appropriate for the data that you will be using and the simulation period of interest. In general, timestep will be equal to time unit.



Units



Units

The screenshot shows the 'Global Units' dialog box in Powersim Studio 7 Expert. The window title is 'Powersim Studio 7 Expert [Untitled] - Global Units'. The interface includes a menu bar (File, Edit, View, Insert, Simulation, Project, Window, Help), a toolbar, and a project tree on the left. The main area displays a table of units with columns for Name, Definition, Documentation, and Note. A red arrow points to the table with the text 'Built-in System Units'.

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da	@(24hr, 0@hr)	Day	System Time Unit
deg	@((3.14159265358979323846/180)rad, 0@rad)	Degrees - Plane angle	System Unit
grad	@((3.14159265358979323846/200)rad, 0@rad)	Gradians - Plane angle	System Unit
hr	@(60min, 0@min)	Hour	System Time Unit
min	@(60s, 0@s)	Minute	System Time Unit
mo	@(30da, 0@da)	Month	System Time Unit
period	@_TIME	Project Time Unit	System Time Unit
qtr	@(90da, 0@da)	Quarter	System Time Unit
rad	@_RADIAN	Radians - Plane angle	System Unit
s	@_SECOND	Second	System Time Unit
wk	@(7da, 0@da)	Week	System Time Unit
yr	@(360da, 0@da)	Year	System Time Unit

Unit types

ATOMIC – An atomic unit does not depend on other units (e.g., person, barrel of oil).

CURRENCY – Variables with currency units will be displayed with the corresponding currency symbol. Currency units can be defined relative to other currencies by an included exchange rate.

DERIVED – A derived unit is dependent upon another unit (it is derived from another unit).

CUSTOM – A custom unit is defined by a custom definition that you can enter freely.

STANDARD – A standard unit comes from Studio's list of built-in standard units.

Add new unit

The screenshot shows the 'Global Units' dialog box in Powersim Studio 7 Expert. The left sidebar shows a tree view with 'Global Units' selected. The main area displays a table of units with columns for Name, Definition, Documentation, and Note. A context menu is open over the 'Global Units' list, showing 'Add Unit...' and 'Add Empty Unit' options. A red box highlights the 'Add Unit...' option with the text 'Right-click to add new unit.'

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da	@(24hr, 0@hr)	Day	System Time Unit
deg	@((3.14159265358979323846/180)rad, 0@rad)	Degrees - Plane angle	System Unit
grad	@((3.14159265358979323846/200)rad, 0@rad)	Gradians - Plane angle	System Unit
hr	@(60min, 0@min)	Hour	System Time Unit
min	@(60s, 0@s)	Minute	System Time Unit
mo	@(30da, 0@da)	Month	System Time Unit
period	@_TIME	Project Time Unit	System Time Unit
qtr	@(90da, 0@da)	Quarter	System Time Unit
rad	@_RADIAN	Radians - Plane angle	System Unit
s	@_SECOND	Second	System Time Unit
wk	@(7da, 0@da)	Week	System Time Unit
yr	@(360da, 0@da)	Year	System Time Unit

Add new unit

Before creating a new unit, you must check for desired unit under “Select a built-in standard unit”!!

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da	@(24hr, 0@hr)	Day	System Time Unit
deg			
grad			
hr			
min			
mo			
period			
qtr			
rad			
s			
wk			
yr			

Add Unit

Name
Specify name of the new unit, or select a build-in unit.

Enter new name: Plural name:

Select a built-in standard unit:

- m - Meter - Length
- kg - Kilogram - Mass
- sr - Steradians - Solid angle
- mol - Mole - Amount of substance
- cd - Candela - Luminous intensity
- A - Ampere - Electric current
- K - Kelvin - Temperature
- km - Kilometer - Length
- cm - Centimeter - Length
- l - Liter - Volume
- N - Newton - Force
- J - Joule - Energy
- W - Watt - Power
- C - Celcius - Temperature
- F - Fahrenheit - Temperature

< Back Next > Finish Cancel Help >>

Create Unit “cubic meters per day”

The screenshot shows the Powersim Studio 7 Expert interface. The main window displays a table of units with columns for Name, Definition, Documentation, and Note. A context menu is open over the table, showing 'Add Unit...' and 'Add Empty Unit' options. The 'Add Unit' dialog box is open, showing the 'Name' field with the instruction 'Specify name of the new unit, or select a built-in unit.' The dialog has three radio buttons: 'Enter new name:', 'Select a built-in standard unit:', and 'Select a built-in currency unit:'. The 'Select a built-in standard unit:' option is selected, and a dropdown menu shows 'm - Meter - Length'. There is also a checked checkbox for 'Language independent name'. At the bottom of the dialog, there are buttons for '< Back', 'Next >', 'Finish', 'Cancel', and 'Help >>'. A red arrow points to the 'Finish' button.

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da			
deg			
grad			
hr			
min			
mo			
period			
qtr			
rad			
s			
wk			
yr			

Add Unit

Name
Specify name of the new unit, or select a built-in unit.

Enter new name: Plural name:

Select a built-in standard unit:
m - Meter - Length

Select a built-in currency unit:

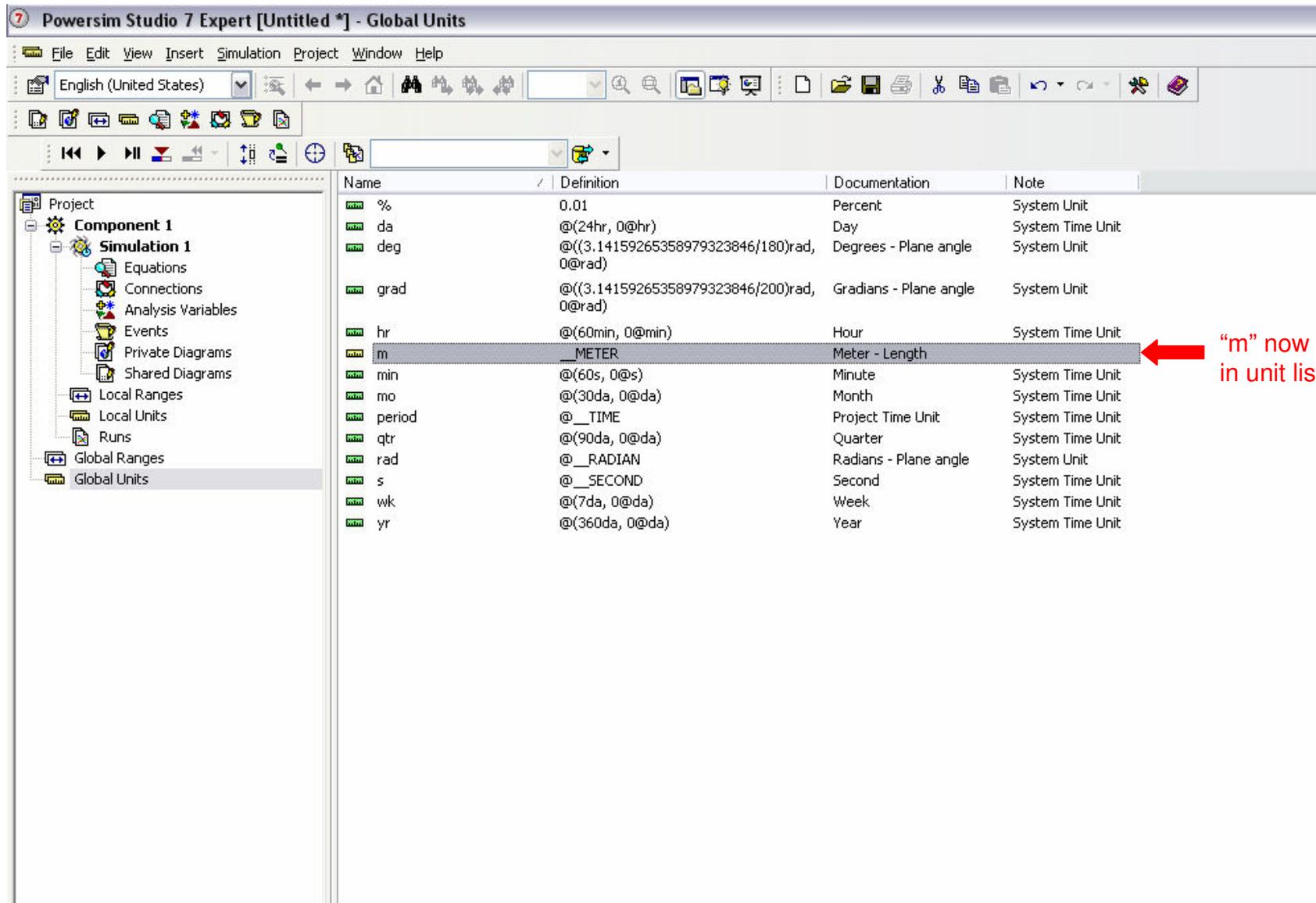
Language independent name

Enter a new name for your unit and click Next to define it, or click Finish to define it as a normal atomic unit. Note that local units cannot be atomic.

If you select a built-in unit, the definition will be provided automatically. Note that if the built-in unit depends on other units, these may be created automatically.

< Back Next > **Finish** Cancel Help >>

Create Unit “cubic meters per day”



The screenshot shows the Powersim Studio 7 Expert Global Units dialog box. The window title is "Powersim Studio 7 Expert [Untitled *] - Global Units". The menu bar includes File, Edit, View, Insert, Simulation, Project, Window, and Help. The toolbar contains various icons for file operations and simulation control. The left pane shows a project tree with "Component 1" expanded to "Simulation 1", which includes Equations, Connections, Analysis Variables, Events, Private Diagrams, Shared Diagrams, Local Ranges, Local Units, Runs, Global Ranges, and Global Units. The main pane displays a table of units:

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da	@(24hr, 0@hr)	Day	System Time Unit
deg	@((3.14159265358979323846/180)rad, 0@rad)	Degrees - Plane angle	System Unit
grad	@((3.14159265358979323846/200)rad, 0@rad)	Gradians - Plane angle	System Unit
hr	@(60min, 0@min)	Hour	System Time Unit
m	__METER	Meter - Length	
min	@(60s, 0@s)	Minute	System Time Unit
mo	@(30da, 0@da)	Month	System Time Unit
period	@__TIME	Project Time Unit	System Time Unit
qtr	@(90da, 0@da)	Quarter	System Time Unit
rad	@__RADIAN	Radians - Plane angle	System Unit
s	@__SECOND	Second	System Time Unit
wk	@(7da, 0@da)	Week	System Time Unit
yr	@(360da, 0@da)	Year	System Time Unit

A red arrow points to the highlighted row for "m", with the text "m" now appears in unit list.

Create Unit “cubic meters per day”

The screenshot shows the Powersim Studio 7 Expert interface with the 'Global Units' dialog box open. The dialog box has the following fields and options:

- Name:** Specify name of the new unit, or select a build-in unit.
- Enter new name:** A text box containing 'cubic meters per day'.
- Plural name:** A text box containing 'cubic meters per day'.
- Select a built-in standard unit:** A dropdown menu.
- Select a built-in currency unit:** A dropdown menu.
- Language independent name:** A checkbox that is unchecked.

At the bottom of the dialog box, there are five buttons: '< Back', 'Next >', 'Finish', 'Cancel', and 'Help >>'. A red arrow points to the 'Next >' button, and a red callout box with the text 'Enter name for new unit.' is positioned over it.

Create Unit “cubic meters per day”

Powersim Studio 7 Expert [Untitled *] - Global Units

File Edit View Insert Simulation Project Window Help

English (United States)

Project

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da			
deg			
grad			
hr			
m			
min			
mo			
period			
qtr			
rad			
s			
wk			
yr			

Add Unit

Definition
Specify the definition of the new unit, or select a build-in unit.

Category: Atomic (dropdown menu)
The unit will be based on other units. An atomic unit is a unit that is not based on other units, cars, people, etc.

Normal unit Point unit

Definition: atomic

Status:

< Back Next > Finish Cancel Help >>

Create Unit “cubic meters per day”

Global Units

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da			
deg			
grad			
hr			
m			
min			
mo			
period			
qtr			
rad			
s			
wk			
yr			

Add Unit

Definition
Specify the definition of the new unit, or select a build-in unit.

Category: Custom (Normal unit, Point unit)

Definition: atomic

Insertable units:
%
da
deg
grad
hr
m
min
mo

Definition: ATOMIC

Status:

< Back Next > Finish Cancel Help >>

Double-click unit that you want to use.

Create Unit “cubic meters per day”

Powersim Studio 7 Expert [Untitled *] - Global Units

File Edit View Insert Simulation Project Window Help

English (United States)

Project

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
da			
deg			
grad			
hr			
m			
min			
mo			
period			
qtr			
rad			
s			
wk			
yr			

Add Unit

Definition
Specify the definition of the new unit, or select a build-in unit.

Category: Custom Normal unit Point unit

Definition: m*m*m/da

Insertable units:
%
da
deg
grad
hr
m
min
mo

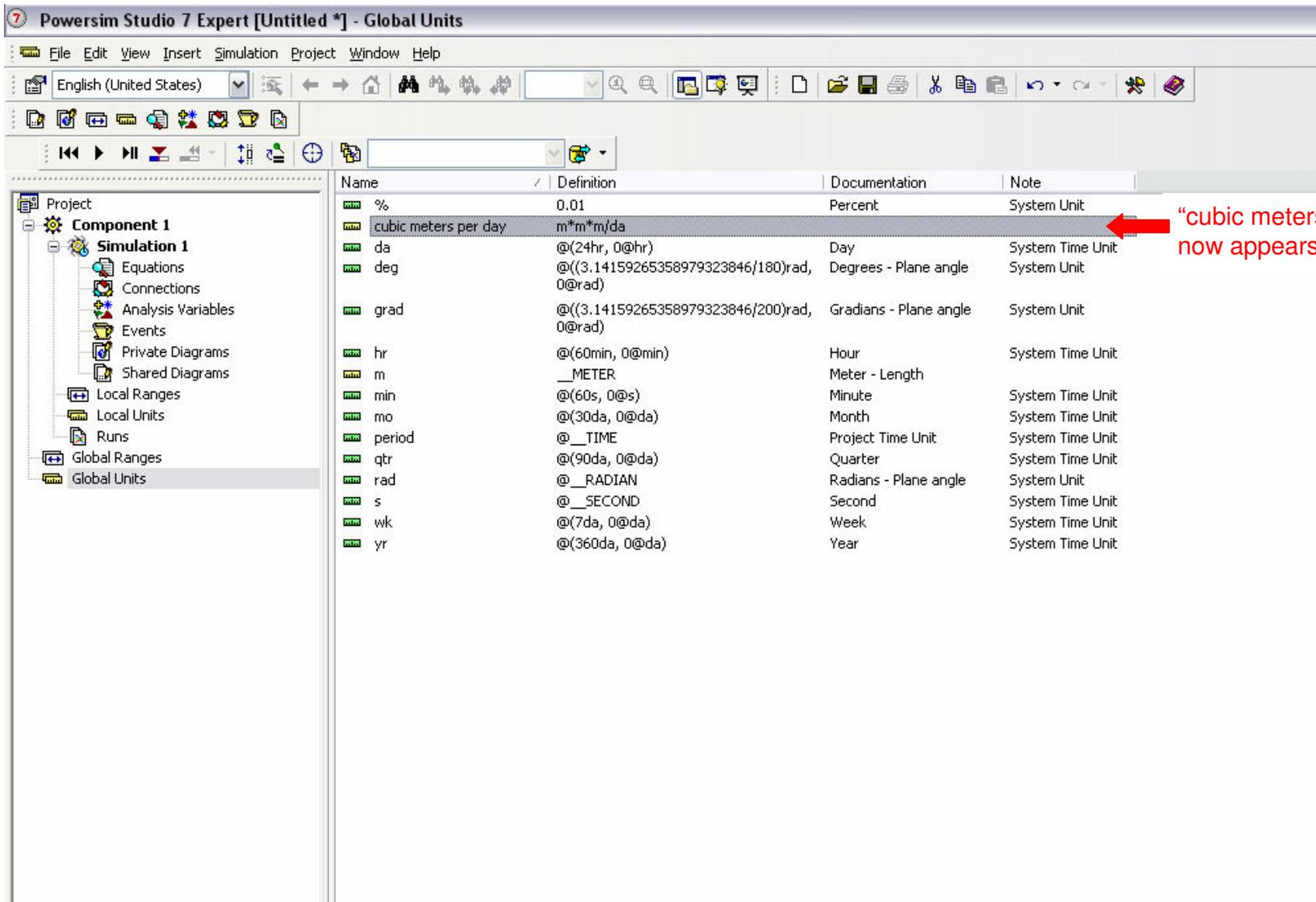
Enter definition using insertable units.

m*m*m/da

Status:

< Back Next > Finish Cancel Help >>

Create Unit “cubic meters per day”



The screenshot shows the Powersim Studio 7 Expert interface. The title bar reads "Powersim Studio 7 Expert [Untitled *] - Global Units". The menu bar includes File, Edit, View, Insert, Simulation, Project, Window, and Help. The toolbar contains various icons for file operations and simulation control. The left sidebar shows a project tree with "Component 1" expanded to "Simulation 1", which includes Equations, Connections, Analysis Variables, Events, Private Diagrams, Shared Diagrams, Local Ranges, Local Units, Runs, Global Ranges, and Global Units. The main window displays a table of global units:

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
cubic meters per day	m*m*m/da		
da	@(24hr, 0@hr)	Day	System Time Unit
deg	@((3.14159265358979323846/180)rad, 0@rad)	Degrees - Plane angle	System Unit
grad	@((3.14159265358979323846/200)rad, 0@rad)	Gradians - Plane angle	System Unit
hr	@(60min, 0@min)	Hour	System Time Unit
m	__METER	Meter - Length	
min	@(60s, 0@s)	Minute	System Time Unit
mo	@(30da, 0@da)	Month	System Time Unit
period	@__TIME	Project Time Unit	System Time Unit
qtr	@(90da, 0@da)	Quarter	System Time Unit
rad	@__RADIAN	Radians - Plane angle	System Unit
s	@__SECOND	Second	System Time Unit
wk	@(7da, 0@da)	Week	System Time Unit
yr	@(360da, 0@da)	Year	System Time Unit

A red arrow points to the "cubic meters per day" entry in the list, with the text "cubic meters per day" now appears in unit list." next to it.

Create Unit “Iraqi dinar”

Add Unit

Name
Specify name of the new unit, or select a build-in unit.

Enter new name:
Iraqi dinar

Plural name:
Iraqi dinar

Select a built-in standard unit:

Select a built-in currency unit:

Language independent name

Enter a new name for your unit and click Next to define it, or click Finish to define it as a normal atomic unit. Note that local units cannot be atomic.

If you select a built-in unit, the definition will be provided automatically. Note that if the built-in unit depends on other units, these may be created automatically.

< Back **Next >** Finish Cancel Help >>

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
cubic meters per day	m*m*m/da		
da	@(24hr, 0@hr)	Day	System Time Unit
deg			
grad			
hr			
km			
m			
min			
mo			
period			
qtr			
rad			
s			
wk			
yr			

Create Unit “Iraqi dinar”

Project 'starting a model_finis...'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
cubic meters per day	m*m*m/da		
da	@(24hr, 0@hr)	Day	System Time Unit
deg			
grad			
hr			
km			
m			
min			
mo			
period			
qtr			
rad			
s			
wk			
yr			

Add Unit

Definition
Specify the definition of the new unit, or select a build-in unit.

Category: Atomic (selected)
Normal unit (selected) | Point unit

The unit will be based on other units.
Currency (selected): An atomic unit is a unit that is not based on other units, cars, people, etc.

Definition: atomic

Status:

< Back | **Next >** | Finish | Cancel | Help >>

Create Unit "Iraqi dinar"

The screenshot shows the Powersim Studio 7 Expert interface. The main window displays a list of units with columns for Name, Definition, Documentation, and Note. The 'Add Unit' dialog box is open, showing the 'Definition' section. The 'Category' is set to 'Currency'. The 'Currency code' is 'IQD'. The checkbox 'Currency relates to another currency with a constant factor' is checked. The 'Base currency' is set to 'USD' and the 'Exchange rate' is '1000'. The 'Definition' field contains the text '___currency("IQD")'. The 'Finish' button is highlighted with a red arrow.

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
cubic meters per day	m*m*m/da		
da	@(24hr, 0@hr)	Day	System Time Unit
deg			
grad			
hr			
km			

If you want to relate your currency to another currency with a constant factor, check this box.

Then enter exchange rate.

Create Unit “Iraqi dinar”

The screenshot shows the Powersim Studio 7 Expert interface. The title bar indicates the project path: C:\Documents and Settings\mdreno\My Documents\SD\Projects\Iraq\ITAO\Training materials\My training materials\starting a mode. The menu bar includes File, Edit, View, Insert, Simulation, Project, Window, and Help. The toolbar contains various icons for file operations and simulation control. The left sidebar shows a project tree with 'Component 1' and 'Simulation 1' expanded, listing various simulation elements like Equations, Connections, Analysis Variables, Events, Private Diagrams, Shared Diagrams, Local Ranges, Local Units, Runs, Global Ranges, and Global Units. The main window displays a table of units with columns for Name, Definition, Documentation, and Note. The unit 'Iraqi dinar' is highlighted in the list, with a red arrow pointing to it from the text 'Iraqi dinar now appears in unit list.'.

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
cubic meters per day	m*m*m/da		
da	@(24hr, 0@hr)	Day	System Time Unit
deg	@((3.14159265358979323846/180)rad, 0@rad)	Degrees - Plane angle	System Unit
grad	@((3.14159265358979323846/200)rad, 0@rad)	Gradians - Plane angle	System Unit
hr	@(60min, 0@min)	Hour	System Time Unit
Iraqi dinar	__CURRENCY("IQD")		
km	1000*m	Kilometer - Length	
m	__METER	Meter - Length	
min	@(60s, 0@s)	Minute	System Time Unit
mo	@(30da, 0@da)	Month	System Time Unit
period	@_TIME	Project Time Unit	System Time Unit
qtr	@(90da, 0@da)	Quarter	System Time Unit
rad	@_RADIAN	Radians - Plane angle	System Unit
s	@_SECOND	Second	System Time Unit
wk	@(7da, 0@da)	Week	System Time Unit
yr	@(360da, 0@da)	Year	System Time Unit

Create Unit “person”

The screenshot shows the Powersim Studio 7 Expert interface. The main window displays a list of units with columns for Name, Definition, Documentation, and Note. The 'Add Unit' dialog box is open, and the 'Enter new name' field contains the text 'person'. A red arrow points to this field with a text box that says 'Enter name for new unit.' Another red arrow points to the 'Next >' button.

Name	Definition	Documentation	Note
%	0.01	Percent	System Unit
cubic meters per day	m*m*m/da		
da	@(24hr, 0@hr)	Day	System Time Unit
deg	@((3.14159265358979323846/180)rad,	Degrees - Plane angle	System Unit
grad			em Unit
hr			em Time Unit
Iraqi dinar			em Time Unit
km			em Time Unit
m			em Time Unit
min			em Time Unit
mo			em Time Unit
period			em Time Unit
qtr			em Time Unit
rad			em Time Unit
s			em Time Unit
wk			em Time Unit
yr			em Time Unit

Create Unit “person”

The screenshot shows the Powersim Studio 7 Expert interface. The main window displays a list of units with columns for Name, Definition, Documentation, and Note. The 'Add Unit' dialog box is open, showing the 'Definition' tab. The 'Category' is set to 'Atomic'. The 'Definition' field contains the text 'atomic'. The 'Status' field is empty. A red arrow points to the 'Finish' button.

Name	Definition	Documentation	Note
%	0,01	Percent	System Unit
cubic meters per day	m*m*m/da		
da	@(24hr, 0@hr)	Day	System Time Unit
deg	@((3.14159265358979323846/180)rad,	Degrees - Plane angle	System Unit
grad			em Unit
hr			em Time Unit
Iraqi dinar			em Time Unit
km			em Time Unit
m			em Time Unit
min			em Time Unit
mo			em Time Unit
period			em Time Unit
qtr			em Time Unit
rad			em Unit
s			em Time Unit
wk			em Time Unit
yr			em Time Unit

Create Unit “person”

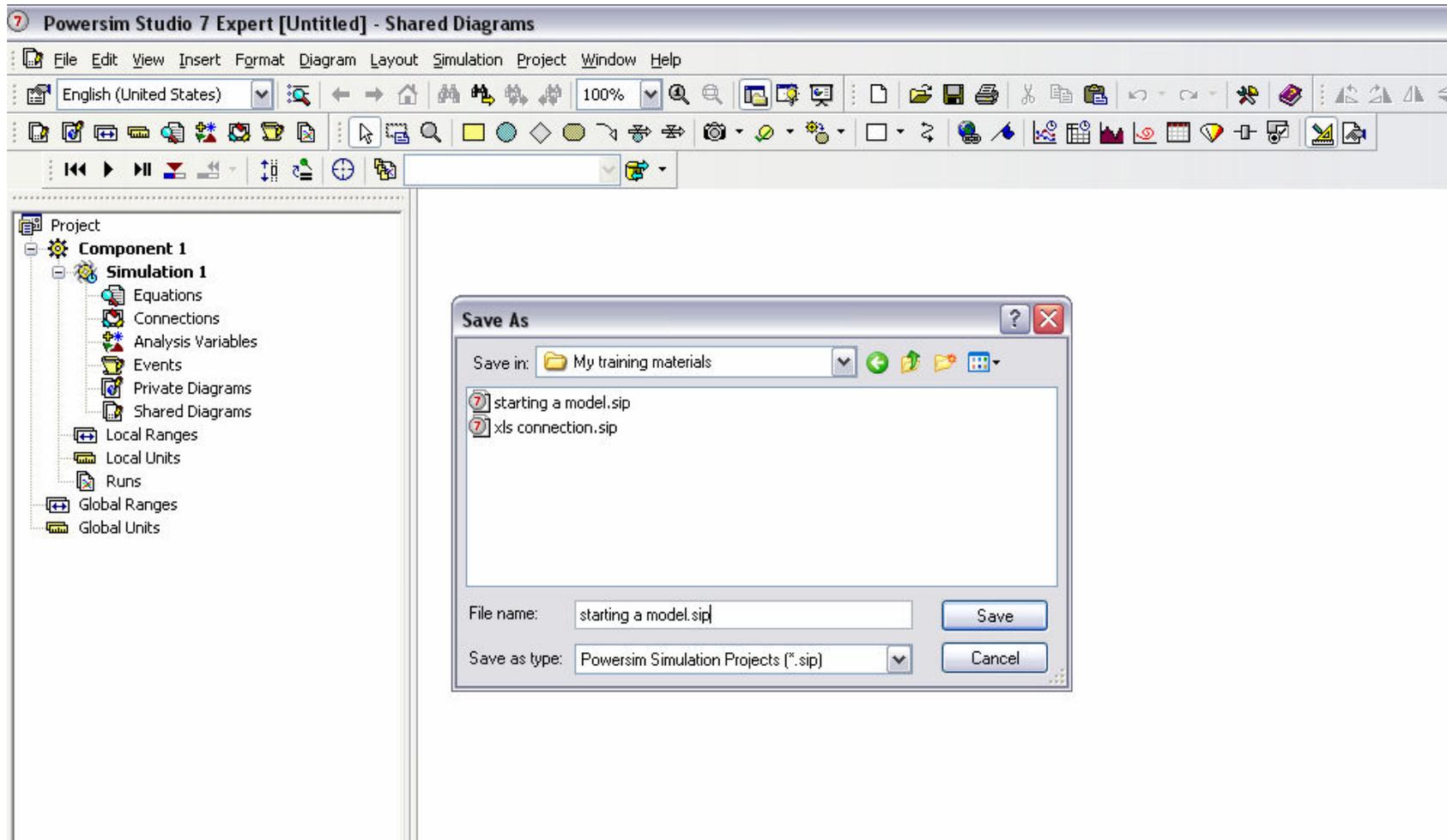
Double-click Shared Diagrams to get back to blank project window.

			Documentation	Note
			Percent	System Unit
		23846/180)rad,	Day	System Time Unit
			Degrees - Plane angle	System Unit
		23846/200)rad,	Gradians - Plane angle	System Unit
			Hour	System Time Unit
	hr	@(60min, 0@min)		
	Iraqi dinar	__CURRENCY("IQD")		
	km	1000*m	Kilometer - Length	
	m	__METER	Meter - Length	
	min	@(60s, 0@s)	Minute	System Time Unit
	mo	@(30da, 0@da)	Month	System Time Unit
	period	@_TIME	Project Time Unit	System Time Unit
	person	ATOMIC		
	qtr	@(90da, 0@da)	Quarter	System Time Unit
	rad	@_RADIANT	Radians - Plane angle	System Unit
	s	@_SECOND	Second	System Time Unit
	wk	@(7da, 0@da)	Week	System Time Unit
	yr	@(360da, 0@da)	Year	System Time Unit

“person” now appears in unit list.

Save model

File → Save → *Enter name of your choice.*



Basic model building blocks

Project 'starting a model'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Connectors show dependency between variables.

CONSTANTS

auxiliaries

flow rates

Levels

"CONSTANTS" are fixed values that are used in equations elsewhere in the model. Name constants using ALL CAPS.

"Auxiliaries" are equations that depend on time or input from constants or other auxiliaries. Name auxiliaries using all lowercase.

"flow rates" are auxiliaries that contribute to "Levels". "Levels" are scalars representing the accumulation of flows over time. Name 'Levels' using uppercase for first letter and lowercase for all subsequent.

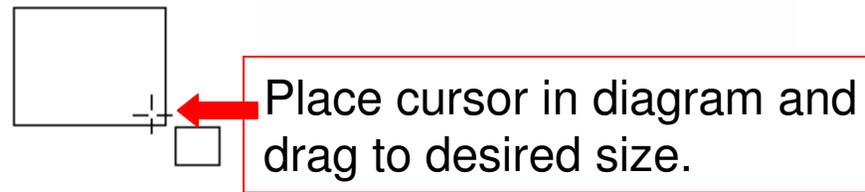
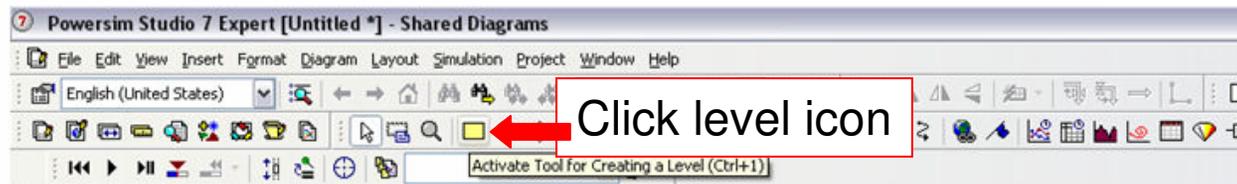
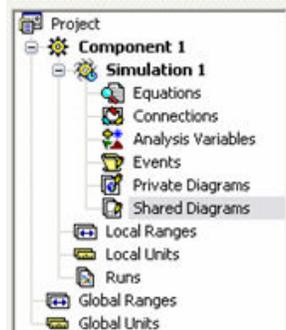
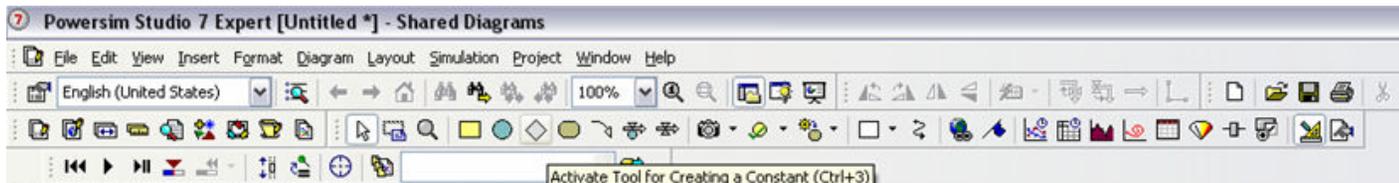
Naming convention is not mandatory; it is suggested for easy variable identification. Model functionality is not influenced by variable names.

flow rates are always a value per time (e.g., m^3/s , mm/da).

Levels are always a value without time because they are an accumulation (of **flow rates**) over time (e.g., m or mm).

Basic model building blocks

To add a constant, auxiliary, or level to your model, click the appropriate icon, place cursor in blank part of screen, hold down left mouse key, and drag to desired size.



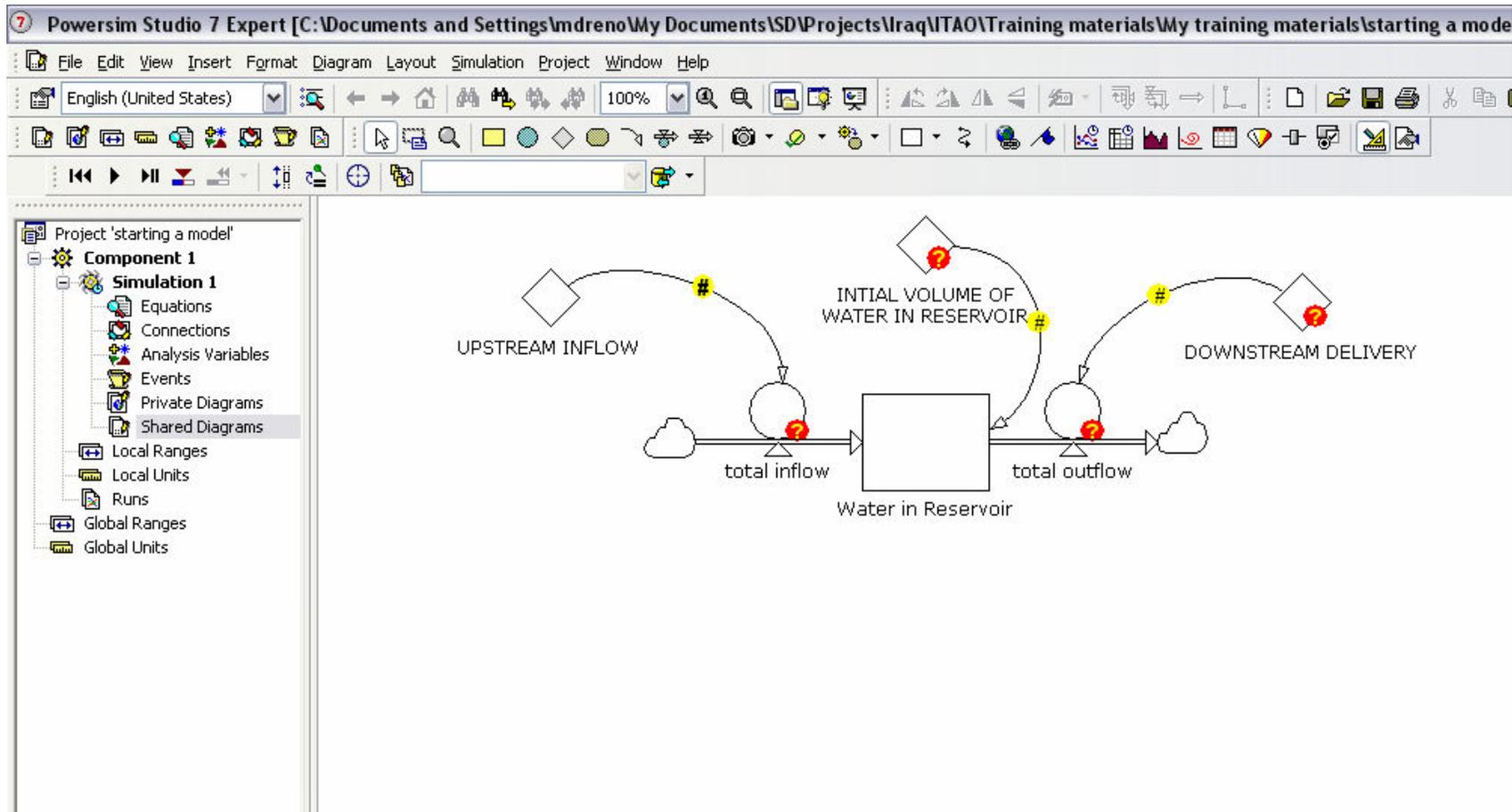
Note that cursor is no longer an arrow.

It is a cross with a small level next to it.

Basic model building blocks

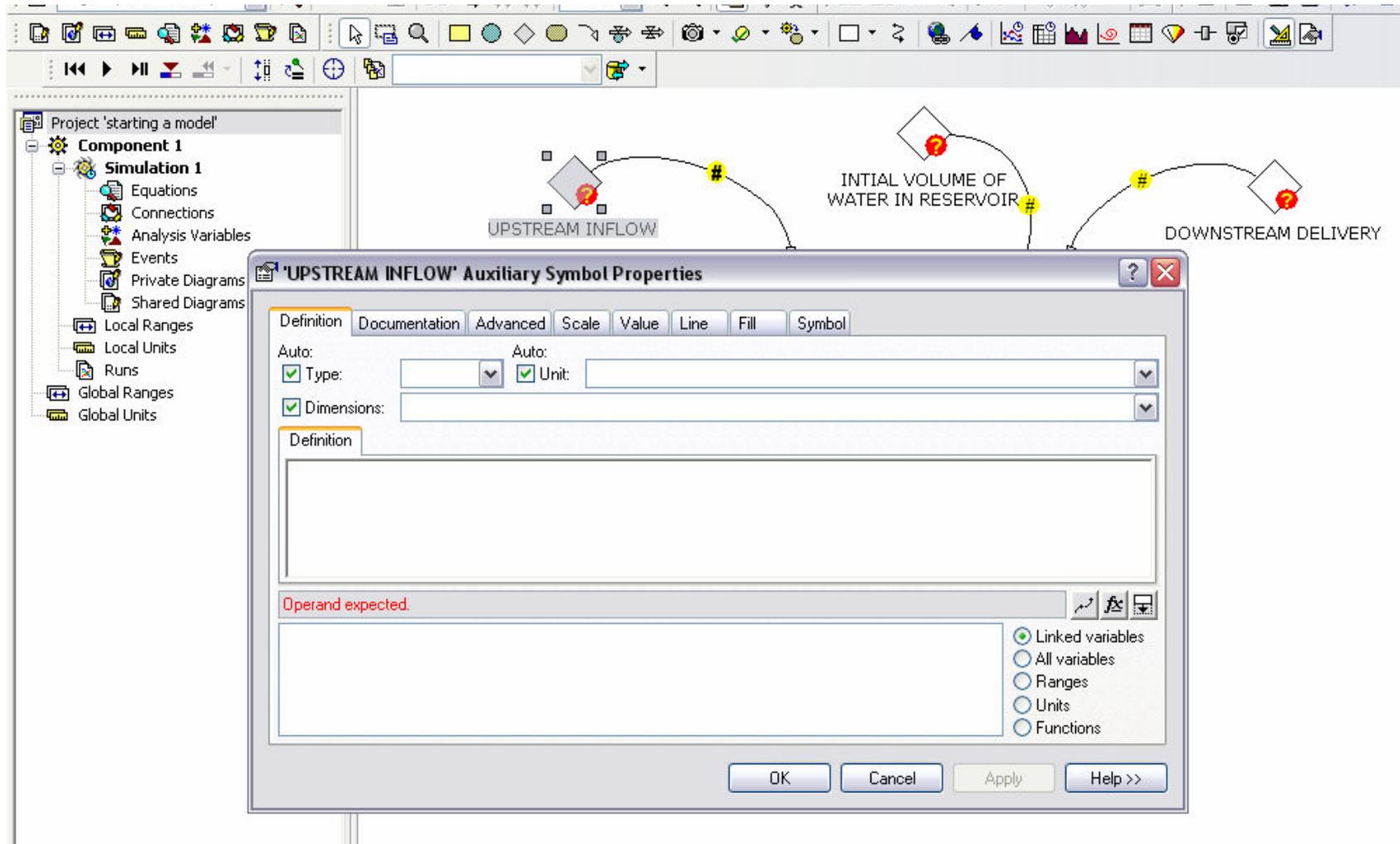
Suppose you want to model the volume of water in a reservoir. For now, we will consider greatly simplified inflow and outflow.

Step 1: Create model skeleton.



Basic model building blocks

Step 2: Define constants, auxiliaries, and level. Double-click variable to open it and add definition. Completing this step will make the warning (#) and error (?) symbols disappear.



Basic model building blocks

Enter definition for **UPSTREAM INFLOW** and click “Apply”. Then go to Documentation tab.

The screenshot shows a software interface with a project tree on the left and a main workspace. The project tree includes 'Component 1' and 'Simulation 1' with sub-items like 'Equations', 'Connections', 'Analysis Variables', 'Events', 'Private Diagrams', 'Shared Diagrams', 'Local Ranges', 'Local Units', 'Runs', 'Global Ranges', and 'Global Units'. The main workspace displays a diagram with three components: 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', and 'DOWNSTREAM DELIVERY'. A dialog box titled "'UPSTREAM INFLOW' Auxiliary Symbol Properties" is open, showing the 'Definition' tab. The dialog has tabs for 'Definition', 'Documentation', 'Advanced', 'Scale', 'Value', 'Line', 'Fill', and 'Symbol'. The 'Definition' tab contains the following fields:

- Auto: Type: Real, Unit: 'cubic meters per day'
- Dimensions: (empty)
- Definition: `1000000 <<'cubic meters per day'>>`
- Value: `= 1,000,000 cubic meters per day`

Red arrows point to the unit specification in the 'Auto' field, the unit specification in the 'Definition' field, and the '=' sign in the 'Value' field. Red text annotations provide instructions:

- Units must be enclosed by “<< >>”.
- Because unit name contains spaces, it must be enclosed by “ ’ ’ ”.
- Note that definition appears here, preceded by an “ = ” sign. This indicates that the definition is recognized by Studio.

The dialog also includes a list of options: Linked variables, All variables, Ranges, Units, Functions. Buttons for 'Apply' and 'Help >>' are at the bottom.

Basic model building blocks

Add documentation text.

The screenshot displays a software interface for model building. On the left, a project tree shows a hierarchy: Project 'starting a model' > Component 1 > Simulation 1 > Shared Diagrams. The main workspace shows a diagram with three diamond-shaped symbols: 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', and 'DOWNSTREAM DELIVERY'. A dialog box titled "'UPSTREAM INFLOW' Auxiliary Symbol Properties" is open, with the 'Documentation' tab selected. The 'Documentation' field contains the text: "1000000 <<'cubic meters per day'>> is the average flow measured at gage 12345678 during the year 2006." A red rectangular box highlights this text with the instruction: "Use the Documentation screen to provide the reference information for the data value entered on the Definition screen." The dialog box also has 'OK', 'Cancel', 'Apply', and 'Help >>' buttons.

Basic model building blocks

Enter definition for **DOWNSTREAM DELIVERY** and click “OK”.

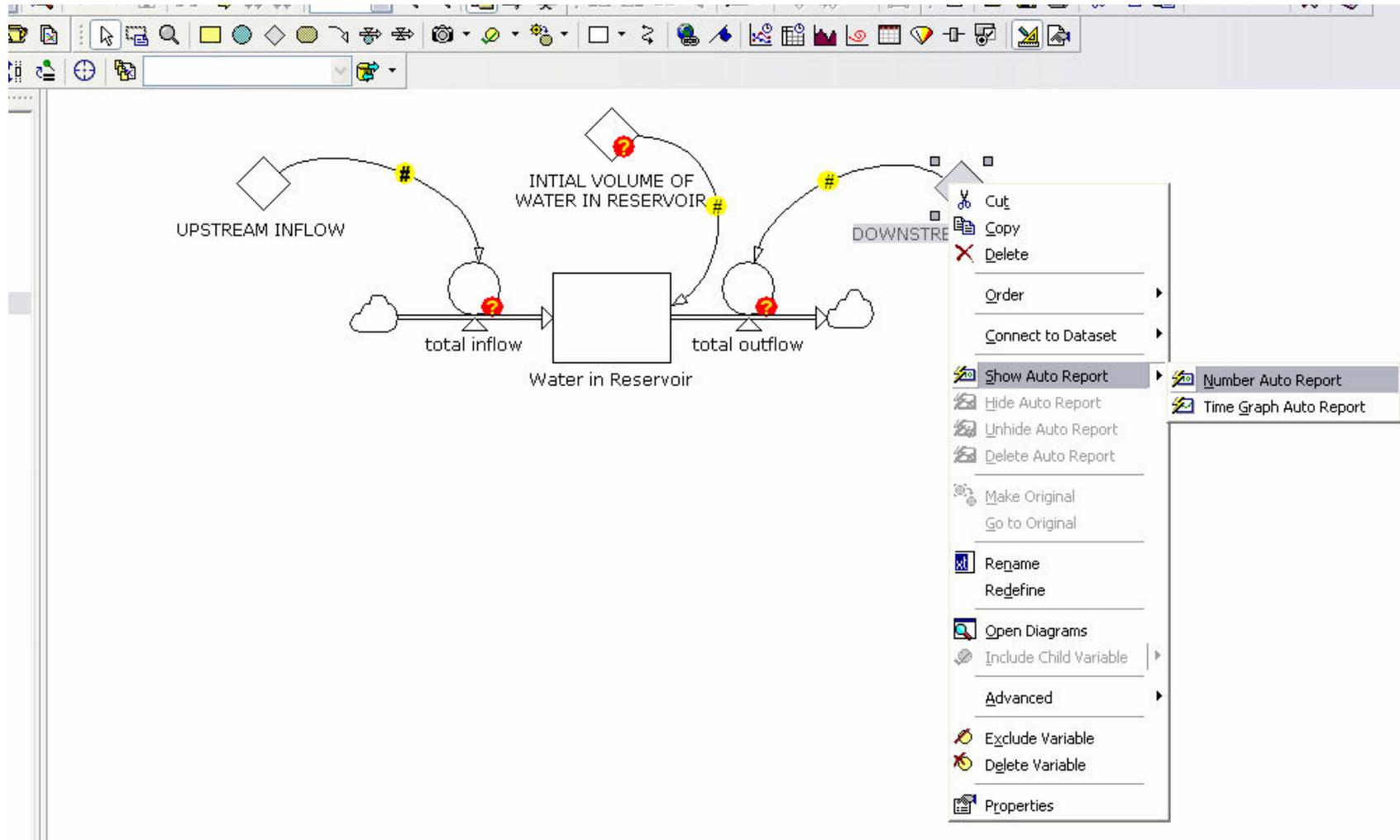
The screenshot displays the Powersim Studio 7 Expert interface. The main window shows a diagram with three components: 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', and 'DOWNSTREAM DELIVERY'. The 'DOWNSTREAM DELIVERY' component is highlighted, and its 'Auxiliary Symbol Properties' dialog box is open. The dialog box has several tabs: 'Definition', 'Documentation', 'Advanced', 'Scale', 'Value', 'Line', 'Fill', and 'Symbol'. The 'Definition' tab is active, showing the following settings:

- Auto: (empty)
- Type: Real
- Unit: 'cubic meters per day'
- Dimensions: (empty)
- Definition: `750000 <<'cubic meters per day'>>`
- Preview: = 750,000 cubic meters per day
- Linked variables: Linked variables, All variables, Ranges, Units, Functions

The dialog box has 'OK', 'Cancel', 'Apply', and 'Help >>' buttons at the bottom.

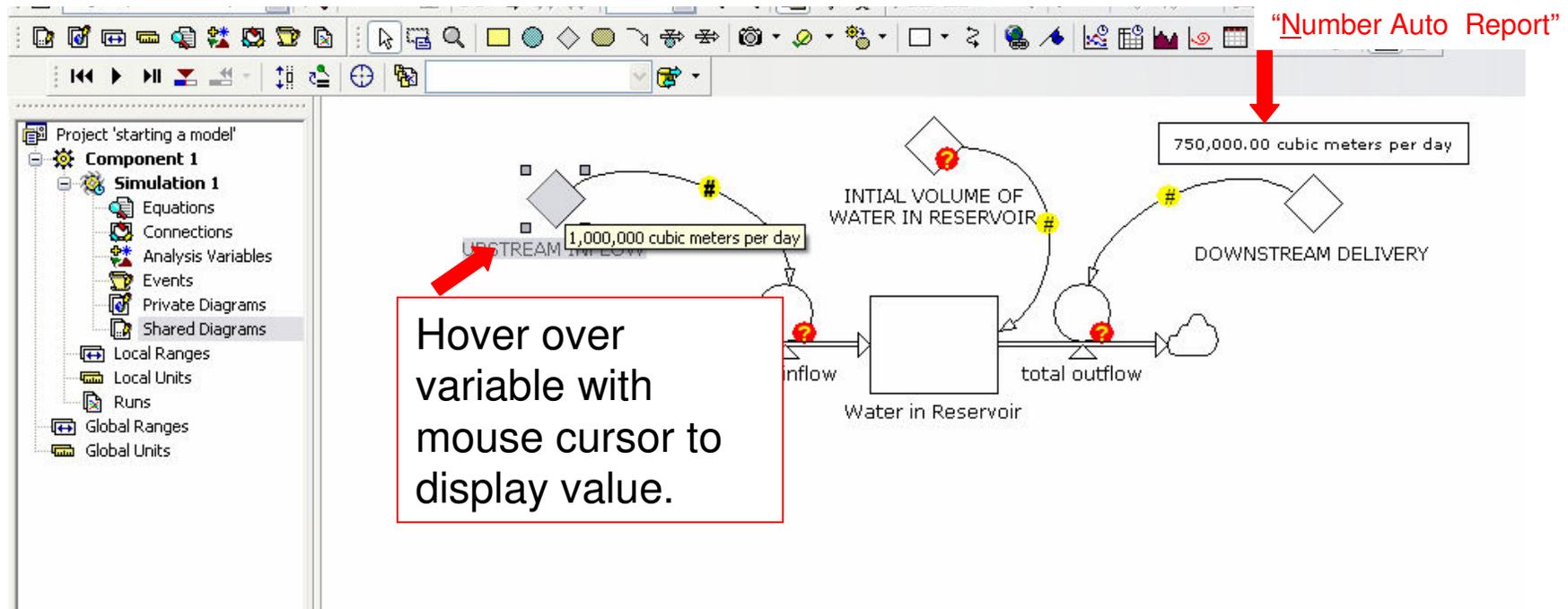
Basic model building blocks

To view value of any variable, right-click variable and select “Number Auto Report”.



Basic model building blocks

To view value of any variable, you can also hover over variable of interest with mouse cursor.



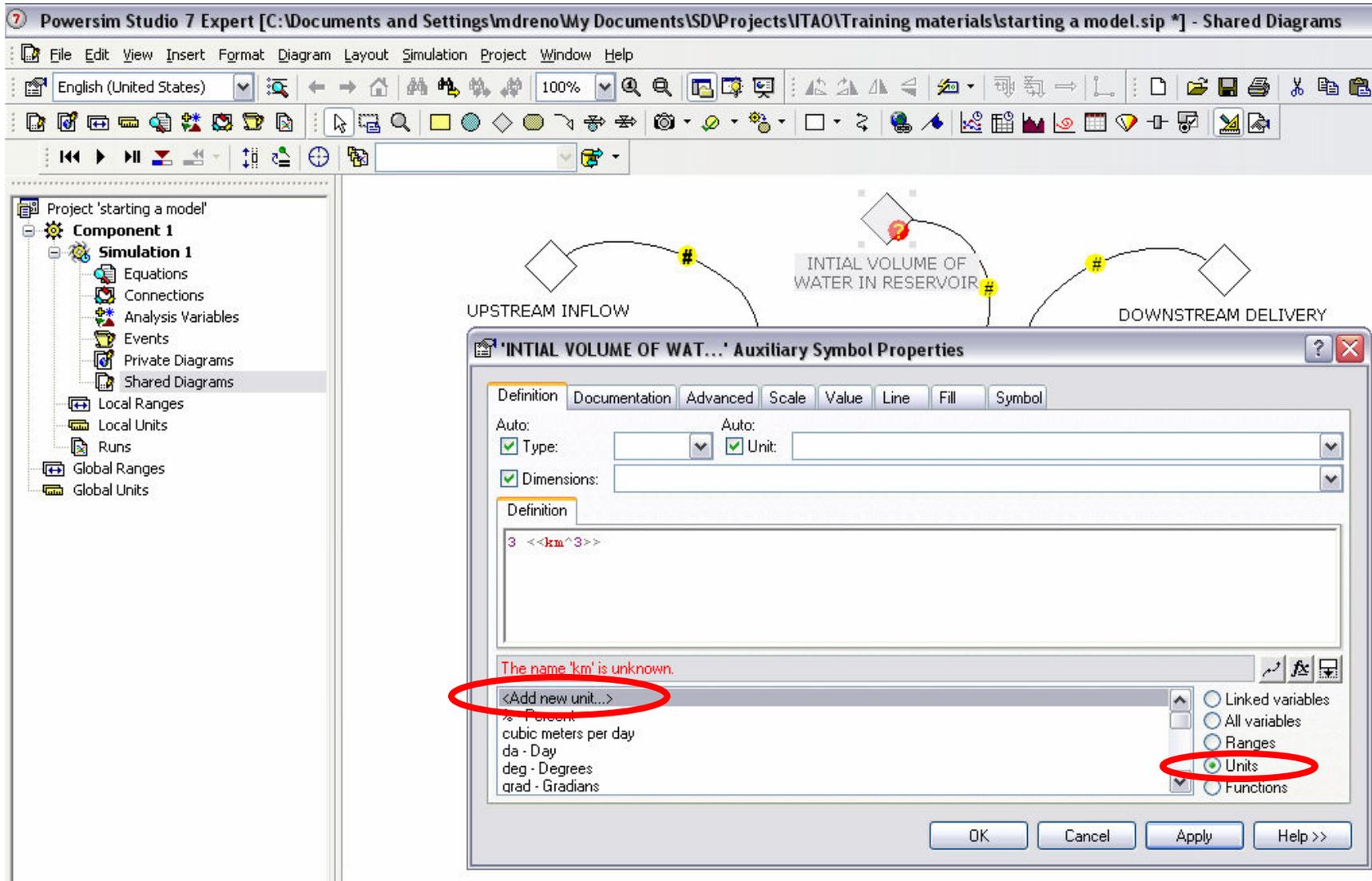
Basic model building blocks

Next, open **INITIAL VOLUME OF WATER IN RESERVOIR** and type “3 <<km^3>>”. Notice that Studio does not recognize “km”. This unit must be added before Studio will accept the definition.

The screenshot shows a software interface with a project tree on the left and a main workspace. The workspace contains a diagram with three components: 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', and 'DOWNSTREAM DELIVERY'. A dialog box titled "'INITIAL VOLUME OF WAT...' Auxiliary Symbol Properties' is open, showing the 'Definition' tab. The definition is '3 <<km^3>>'. Below the definition, there is an error message: 'The name 'km' is unknown.' A red arrow points to this message, and a red text box explains: 'Unlike **UPSTREAM INFLOW** and **DOWNSTREAM DELIVERY**, this variable has no time. This is because it will be the initial value for the level **Water in Reservoir** (recall that levels are always a value without time because they are an accumulation over time).' The dialog box also has buttons for 'OK', 'Cancel', 'Apply', and 'Help >>'.

Basic model building blocks

Add “km” to units by toggling “Units”, then double-clicking “<Add new unit...>”.



Basic model building blocks

“km” is a built-in standard unit. Add “km” using same method as for “m”.

The image shows a software interface for building a model. On the left is a project tree for 'starting a model' containing 'Component 1' and 'Simulation 1' with sub-items like Equations, Connections, Analysis Variables, Events, Private Diagrams, Shared Diagrams, Local Ranges, Local Units, Runs, Global Ranges, and Global Units.

The main area displays a diagram with three components: 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', and 'DOWNSTREAM DELIVERY'. Arrows with '#' symbols connect them.

Two dialog boxes are open:

- 'INITIAL VOLUME OF WAT...' Auxiliary Symbol Properties: Shows the 'Definition' tab with 'Auto: Type' checked and 'Unit' set to 'km'. The definition text is '3 <<km^3>>'. A red error message says 'The name 'km' is unknown.' Below is a list of existing units: '<Add new unit...>', '% - Percent', 'cubic meters per day', 'da - Day', 'deg - Degrees', and 'grad - Gradians'.
- 'Add Unit': Shows a list of built-in standard units. 'km - Kilometer - Length' is selected. A red arrow points to the 'Finish' button.

At the bottom right, the page number '49' is displayed.

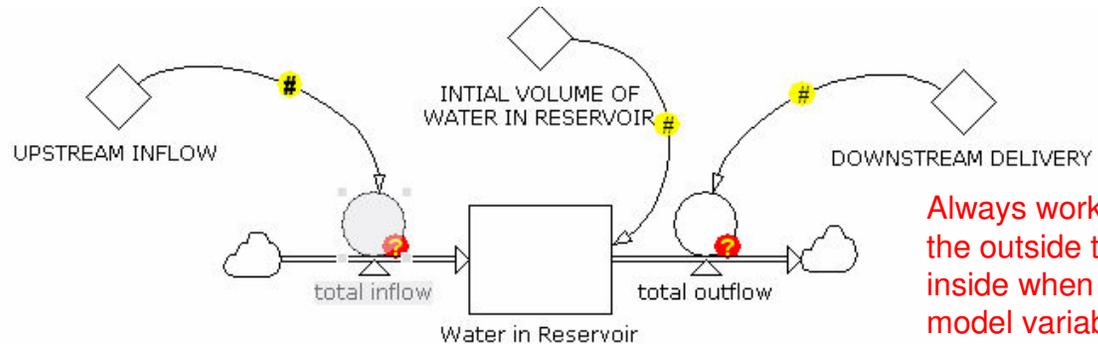
Basic model building blocks

Definition is now recognized.

The screenshot displays the Powersim Studio 7 Expert interface. The main window shows a simulation diagram with three diamond-shaped symbols: 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', and 'DOWNSTREAM DELIVERY'. The 'INITIAL VOLUME OF WATER IN RESERVOIR' symbol is highlighted with a yellow selection box. A dialog box titled "'INITIAL VOLUME OF WAT...' Auxiliary Symbol Properties' is open, showing the 'Definition' tab. The 'Definition' field contains the text `3 <<km^3>>`. Below this field, the value `= 3 km³` is displayed and circled in red. The dialog box also includes tabs for 'Documentation', 'Advanced', 'Scale', 'Value', 'Line', 'Fill', and 'Symbol'. The 'Value' tab is selected, showing 'Auto: Real' and 'Unit: km³'. The 'Definition' field is empty, and the 'Value' field contains the text `= 3 km³`. The 'Definition' field is circled in red. The dialog box also includes a 'Linked variables' section with radio buttons for 'Linked variables', 'All variables', 'Ranges', 'Units', and 'Functions'. The 'OK', 'Cancel', 'Apply', and 'Help >>' buttons are visible at the bottom of the dialog box.

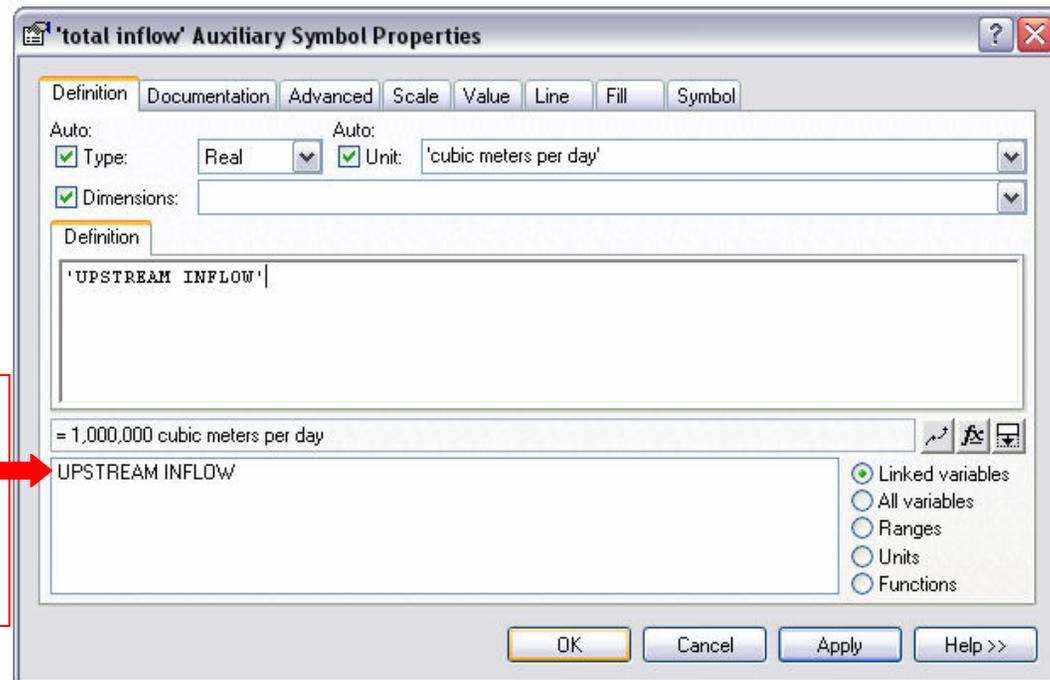
Basic model building blocks

Enter definition for **total inflow**. Notice that when you open this variable, **UPSTREAM INFLOW** appears in the box that lists available components for the variable definition. Any variable linked to **total inflow** with a connector will appear in this box. Double-click **UPSTREAM INFLOW** to use it in the definition of **total inflow**. Repeat these steps to enter definition for **total outflow** and **Water in Reservoir**.



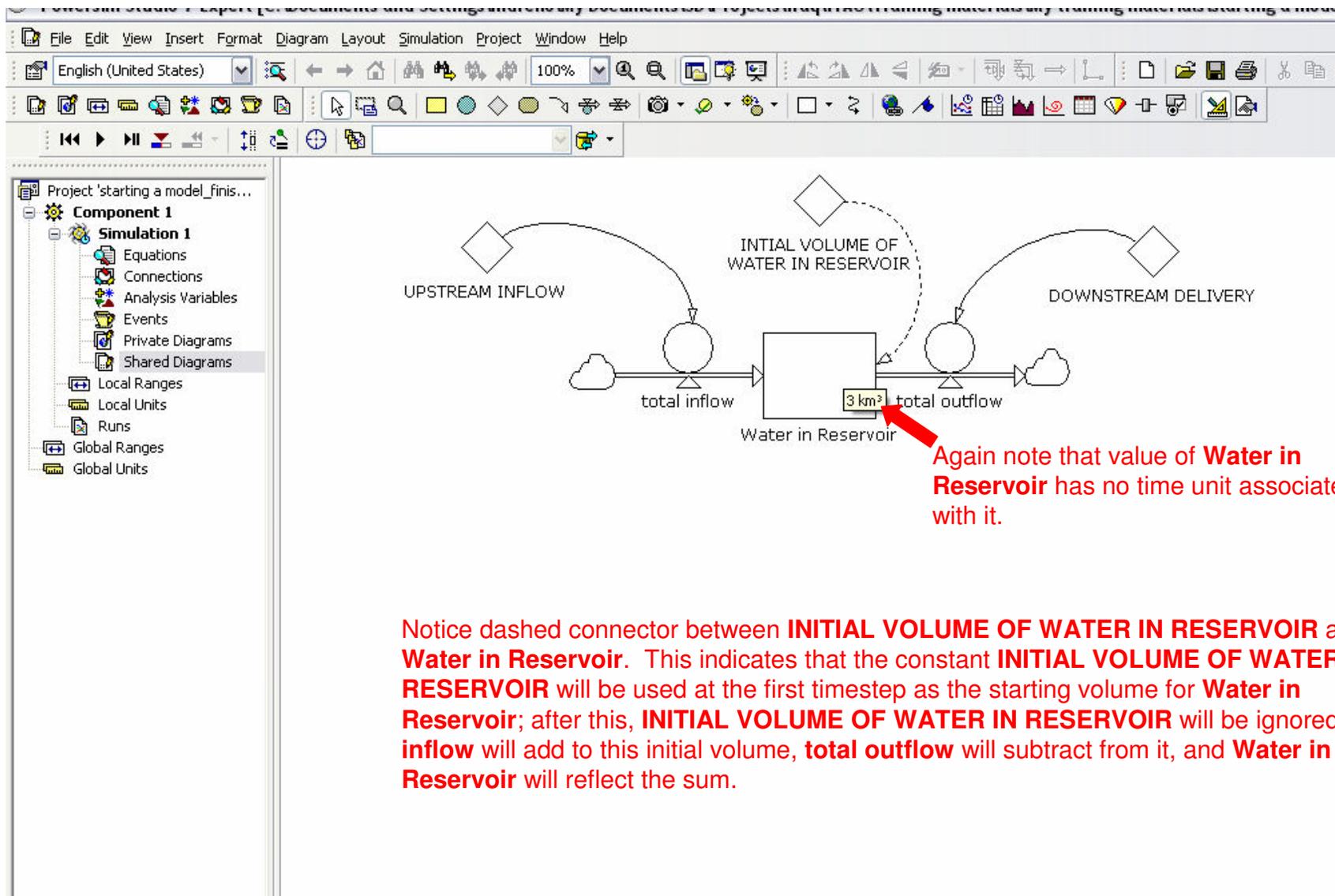
Always work from the outside to the inside when defining model variables.

Double-click **UPSTREAM INFLOW** to add it to the definition.



Basic model building blocks

Simple model complete.



Notice dashed connector between **INITIAL VOLUME OF WATER IN RESERVOIR** and **Water in Reservoir**. This indicates that the constant **INITIAL VOLUME OF WATER IN RESERVOIR** will be used at the first timestep as the starting volume for **Water in Reservoir**; after this, **INITIAL VOLUME OF WATER IN RESERVOIR** will be ignored. **total inflow** will add to this initial volume, **total outflow** will subtract from it, and **Water in Reservoir** will reflect the sum.

Iraq National Water Modeling Workshop

November 11-15, 2007
United Nations University
Amman, Jordan

Using Graph Functions



Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



Using Graph Functions

Suppose you want to add complexity to your initial reservoir model by adding precipitation and evaporation.

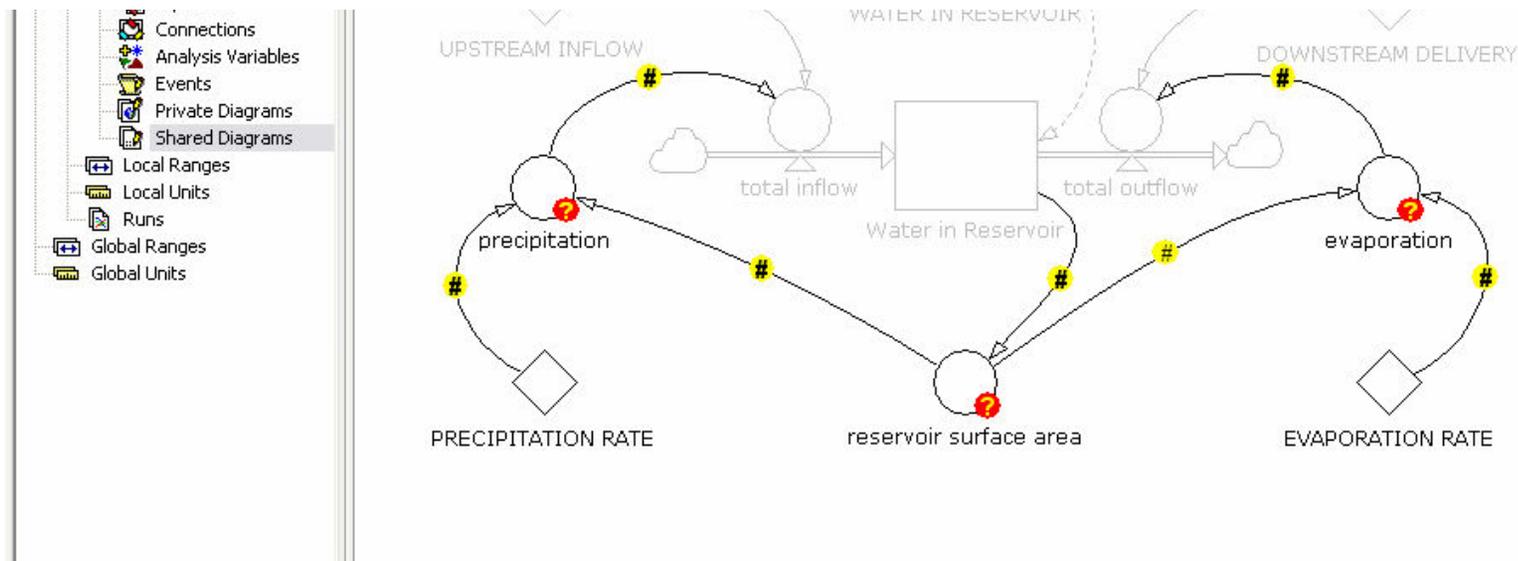


Precipitation will contribute to **total inflow**. We will calculate precipitation volume by multiplying a specified precipitation rate by the surface area of the reservoir.

Evaporation will contribute to **total outflow**. We will calculate evaporation volume by multiplying a specified evaporation rate by the surface area of the reservoir.

Using Graph Functions

Add additional variables. Define constants. If necessary, add new units (e.g., if you are entering precipitation in *mm/yr*, you will need to add the unit “mm”). **precipitation** and **evaporation** cannot be defined until **reservoir surface area** is defined. We will define **reservoir surface area** as a function of **Water in reservoir** using one of four Studio **GRAPH** functions.



For now, use realistic estimates of average annual precipitation and evaporation as the values for **PRECIPITATION RATE** and **EVAPORATION RATE**. We will add complexity to these values later.

Using Graph Functions

Studio offers four different graph functions: **GRAPH**, **GRAPHCURVE**, **GRAPHSTEP**, and **GRAPHLINAS**. We are going to demonstrate the use of **GRAPH**. The only difference between graph functions is the method of interpolation and extrapolation used. To define a variable using any graph function, the following syntax is used:

GRAPH FUNCTION NAME(X, X1, Dx, {Y(N)})

X: The input value for which a output value is to be found or computed.

X1: The first x-value of the graph.

Dx: The increment between fixed x-values.

Y(N): Vector of y-values.

For detailed information on each of the graph functions, search “graph” in Help (from Menu Bar, Help → Contents or press F1).

Using Graph Functions

To use the **GRAPH**, you should have several x,y data pairs and all x -values must be separated by the same increment. The table below gives hypothetical data that satisfy these criteria: there are several x,y pairs and x increases in increments of 1 km^3 .

Volume (km^3)	Surface area (km^2)
0	0
1	100
2	150
3	200
4	220
5	230
6	250
7	270
8	280

Using Graph Functions

In definition box of **reservoir surface area**, enter data from previous slide using syntax guidelines from slide 56. Syntax guidelines can also be found by searching for “GRAPH” in Help (from Menu Bar, Help → Contents or press F1).

The diagram shows a reservoir model with three auxiliary symbols: **PRECIPITATION RATE**, **reservoir surface area**, and **EVAPORATION RATE**. The reservoir is labeled **Water in Reservoir**. The **reservoir surface area** auxiliary symbol is highlighted, and its **'reservoir surface area' Auxiliary Symbol Properties** dialog box is open. The dialog shows the following definition:

```
GRAPH('Water in Reservoir', 0<<km^3>>, 1<<km^3>>, (0, 100, 150, 200, 220, 230, 250, 270, 280)<<km^2>>)
```

The dialog also shows the value **= 200 km²** and the variable **Water in Reservoir**. A red circle highlights the **Function Wizard** icon in the dialog, with a callout box saying **Click to open Function Wizard.**

Using Graph Functions

The **GRAPH** function can also be used through the Function Wizard.

The screenshot shows the 'Function Wizard' dialog box with the 'Graph' tab selected. A red arrow points to the 'Graph' tab. The 'Parameters' section contains the following fields:

Parameter	Value	Unit
X	'Water in Reservoir'	<R> = 3 km ²
X0	0<<km ³ >>	<R> = 0 km ²
DX	1<<km ³ >>	<R> = 1 km ²
Y(N)	{0, 100, 150, 200, 220, 230, 250, 270,	<A> = {0, 100, 150, :

The 'Result' section shows: **Result** GRAPH('Water in Reservoir', 0<<km³>>, 1<<km³>>, {0, 100, 150, 200, 220, 230, 250, 270, 280}<<km²>>) = 200 km²

The 'Description' section states: **Description** Returns values for a given value of X, based on linear interpolation or horizontal extrapolation from tabulated samples of a function F(X).

A red text box on the right says: "You can modify function by entering new values here, or go to Graph tab to modify curve by clicking and dragging points."

A red box on the right says: "Click  to open Function Wizard."

The bottom part of the image shows a preview window with the text "Water in Reservoir" and a list of options: Linked variables, All variables, Ranges, Units, Functions. A red circle highlights the 'Function Wizard' icon in the bottom right corner of the preview window.

Using Graph Functions

UPSTREAM INFLOW

INITIAL VOLUME OF WATER IN RESERVOIR

DOWNSTREAM DELIVERY

Function Wizard

Categories: Interpolation

Functions: GRAPH, GRAPHCURVE, GRAPHLINAS, GRAPHSTEP, POLICYGRID

X	Y
0	0
1	100
2	150
3	200
4	220
5	230
6	250
7	270
8	280

Unit Y: km²

Points Count: 9

X axis Min: 0<<km³> Step: 1<<km³>

Y axis Min: -1 Max: 300

Input X: 'Water in Reservoir'

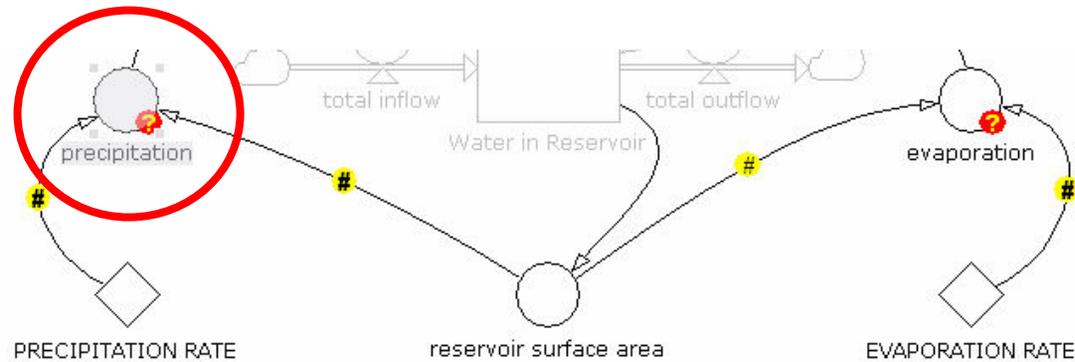
Modify function by left-clicking curve and dragging points to new locations.

Water in Reservoir

- Linked variables
- All variables
- Ranges
- Units
- Functions

Using Graph Functions

Define precipitation.



'precipitation' Auxiliary Symbol Properties

Definition Documentation Advanced Scale Value Line Fill Symbol

Auto: Type: Real Unit: 'cubic meters per day'

Dimensions:

Definition

'PRECIPITATION RATE' * 'reservoir surface area'

= 2,666,666.666667 cubic meters per day

PRECIPITATION RATE
reservoir surface area

Linked variables
 All variables
 Ranges
 Units
 Functions

OK Cancel Apply Help >>

Using Graph Functions

Define **evaporation**.

The image shows a simulation software interface with a reservoir model and a dialog box for defining the 'evaporation' auxiliary symbol.

Reservoir Model Diagram:

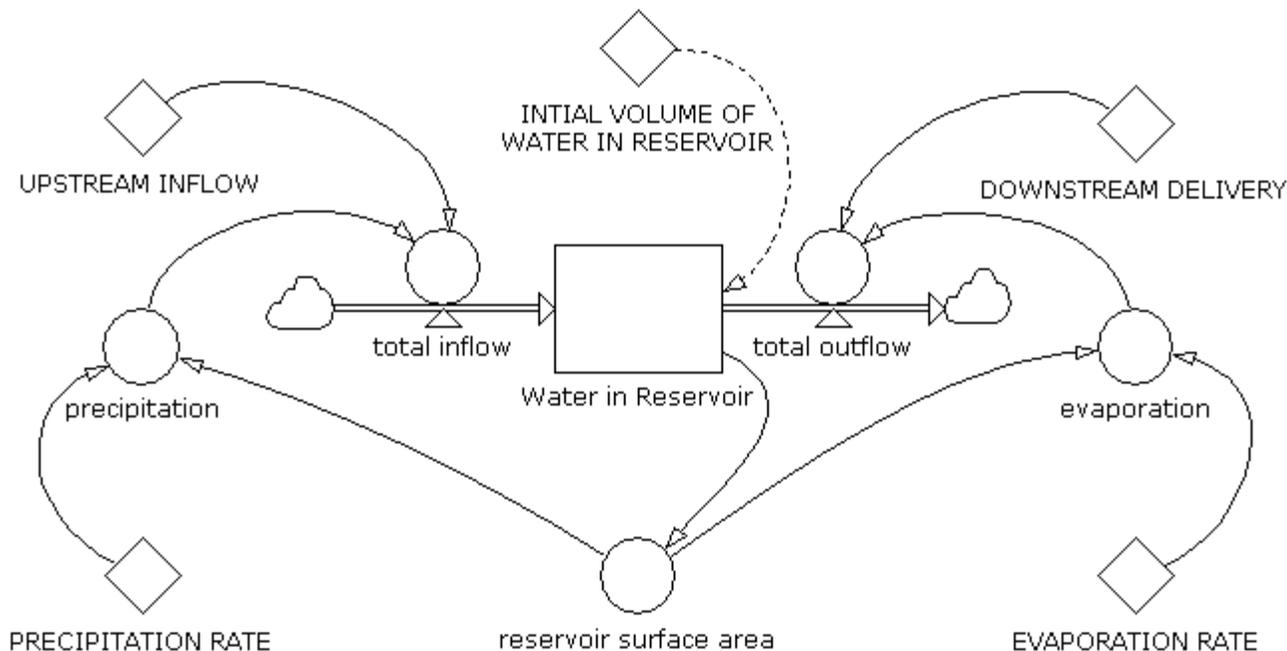
- A central reservoir labeled "Water in Reservoir".
- Inputs: "precipitation" (diamond symbol) and "total inflow" (valve symbol).
- Output: "total outflow" (valve symbol).
- Auxiliary Symbols: "evaporation" (circle symbol, circled in red) and "precipitation" (circle symbol).
- Variables: "PRECIPITATION RATE" (diamond symbol), "reservoir surface area" (circle symbol), and "EVAPORATION RATE" (diamond symbol).

'evaporation' Auxiliary Symbol Properties Dialog Box:

- Definition Tab:** Shows the definition of the auxiliary symbol.
- Auto:** Type: Real, Unit: 'cubic meters per day', Dimensions: (empty).
- Definition:** `'EVAPORATION RATE' * 'reservoir surface area'`
- Value:** = 1,333,333.333333 cubic meters per day
- Linked variables:** EVAPORATION RATE, reservoir surface area
- Options:** Linked variables, All variables, Ranges, Units, Functions
- Buttons:** OK, Cancel, Apply, Help >>

Using Graph Functions

As in the initial reservoir model, **Water in Reservoir** is still defined by **INITIAL VOLUME OF WATER IN RESERVOIR**, **total inflow**, and **total outflow**. **total inflow** and **total outflow** have been revised and now include **precipitation** and **evaporation**. **precipitation** and **evaporation** are both calculated using **reservoir surface area**, which is calculated using **GRAPH** with **Water in Reservoir** as the x-value.



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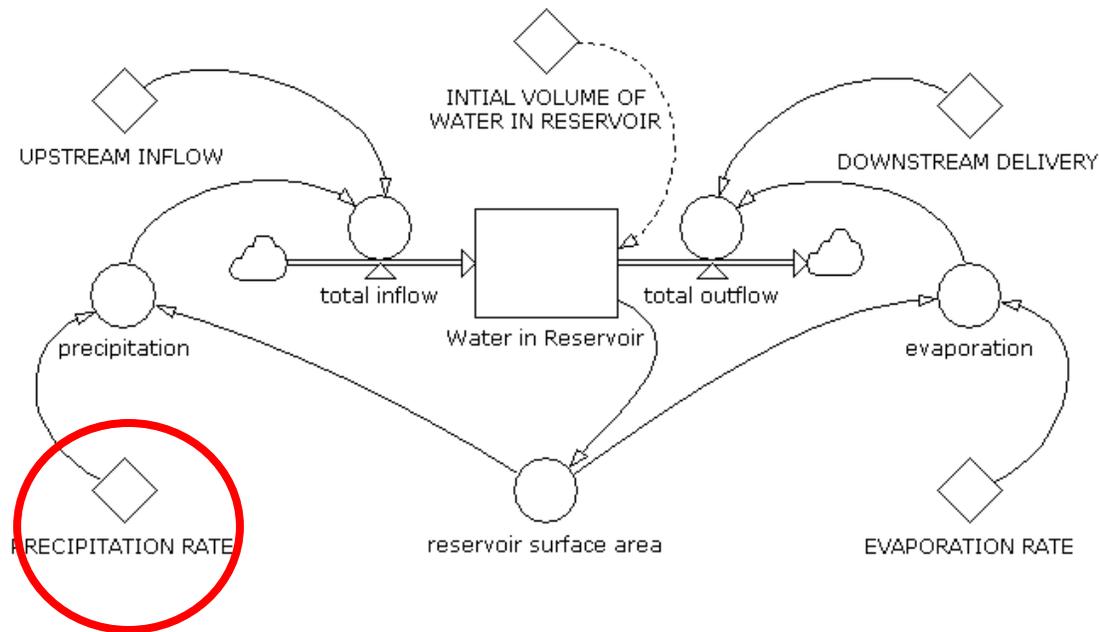
Arrays and Ranges



Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



Creating Arrayed Variables



Suppose you have unique precipitation data for each of the reservoirs in the system that you are modeling. We will replace the scalar variable **PRECIPITATION RATE** with an arrayed variable.

Scalar variable: a variable holding a single numerical value.

Arrayed variable: a variable holding several distinct values at the same time.

Creating Arrayed Variables

Double-click **PRECIPITATION RATE** and enter precipitation values corresponding to the average annual precipitation at each of the reservoirs in your model.

The screenshot shows a software interface with a model diagram on the left and a dialog box titled "'PRECIPITATION RATE' Auxiliary Symbol Properties" on the right. The model diagram includes components like 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', and 'DOWNSTREAM DELIVERY', with a 'precipitation' variable symbol circled in red. The dialog box has tabs for 'Definition', 'Documentation', 'Advanced', 'Scale', 'Value', 'Line', 'Fill', and 'Symbol'. The 'Definition' tab is active, showing 'Auto: Type: Real', 'Unit: mm/mo', and 'Dimensions: 1.9'. The 'Definition' text area contains the array: `{316, 316, 316, 400, 374, 350, 334, 400, 408} <<mm/mo>>`. Below this, a preview shows `= {316, 316, 316, 400, 374, 350, 334, 400, 408} mm/mo`. Red arrows point to the array elements and units with the following annotations: 'Appropriate units must follow entry.' and 'Each array element (i.e., precipitation data value) must be separated by a comma , .'. Another red arrow points to the curly brackets with the annotation 'Data must be enclosed in curly brackets { }.'

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UPSTREAM INFLOW

INITIAL VOLUME OF WATER IN RESERVOIR

DOWNSTREAM DELIVERY

precipitation

PRECIPITATION RATE

'PRECIPITATION RATE' Auxiliary Symbol Properties

Definition Documentation Advanced Scale Value Line Fill Symbol

Auto: Type: Real Unit: mm/mo Dimensions: 1.9

Definition

{316, 316, 316, 400, 374, 350, 334, 400, 408} <<mm/mo>>

Each array element (i.e., precipitation data value) must be separated by a comma , .

Appropriate units must follow entry.

Data must be enclosed in curly brackets { }.

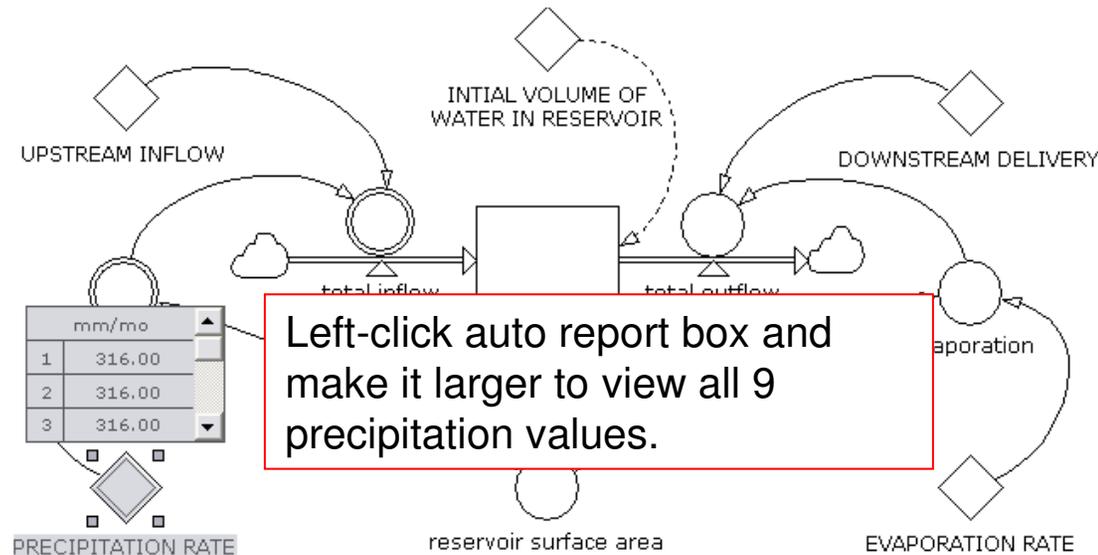
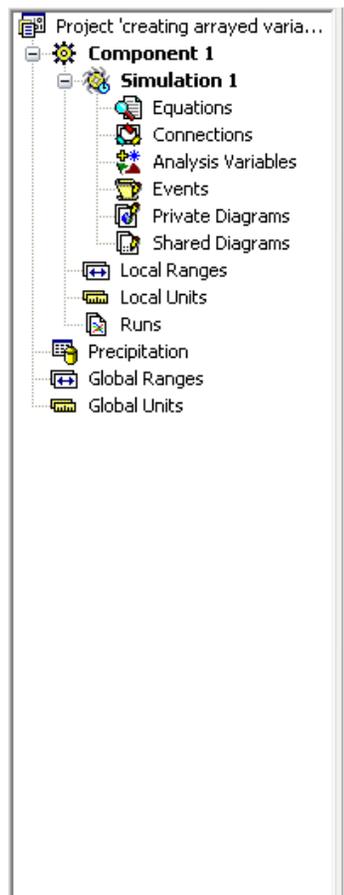
= {316, 316, 316, 400, 374, 350, 334, 400, 408} mm/mo

Linked variables
All variables
Ranges
Units
Functions

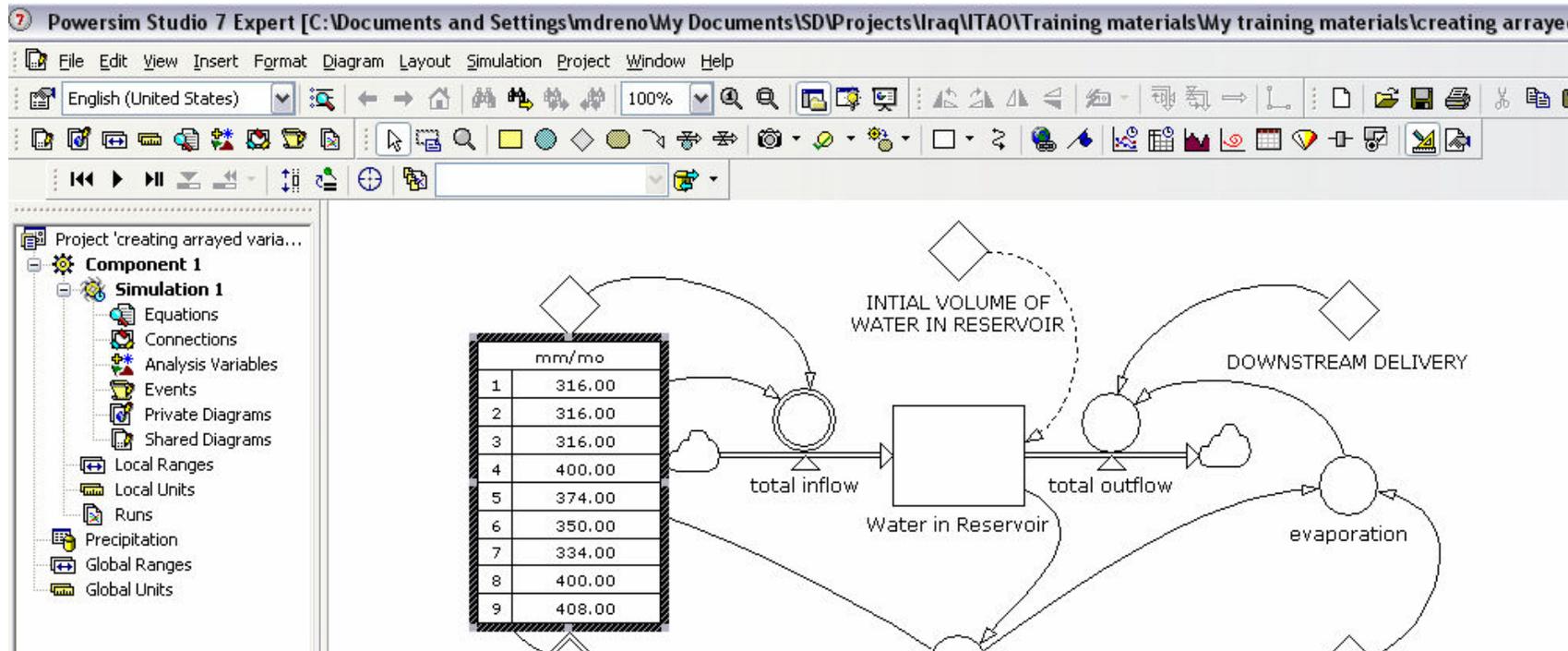
OK Cancel Apply Help >>

Creating Arrayed Variables

Right-click **PRECIPITATION RATE** and select “Number Auto Report” to view the definition that you just entered.



Creating Arrayed Variables



PRECIPITATION RATE is now a one-dimensional array with 9 elements corresponding to 9 different reservoirs.

The additional line around the variable indicates that the variable contains an array of values.



Creating Arrayed Variables

The screenshot shows the Powersim Studio 7 Expert interface. The main workspace displays a simulation diagram of a reservoir system. The diagram consists of several interconnected components:

- UPSTREAM INFLOW**: A diamond-shaped component at the top left.
- total inflow**: A circular component receiving input from 'UPSTREAM INFLOW' and 'PRECIPITATION RATE'.
- reservoir surface area**: A central rectangular component representing the reservoir.
- total outflow**: A circular component receiving input from the reservoir and outputting to 'DOWNSTREAM DELIVERY'.
- DOWNSTREAM DELIVERY**: A diamond-shaped component at the top right.
- PRECIPITATION RATE**: A diamond-shaped component at the bottom left.
- EVAPORATION RATE**: A diamond-shaped component at the bottom right.

 A tooltip is visible over the 'precipitation' component, displaying a 9-element array of values:

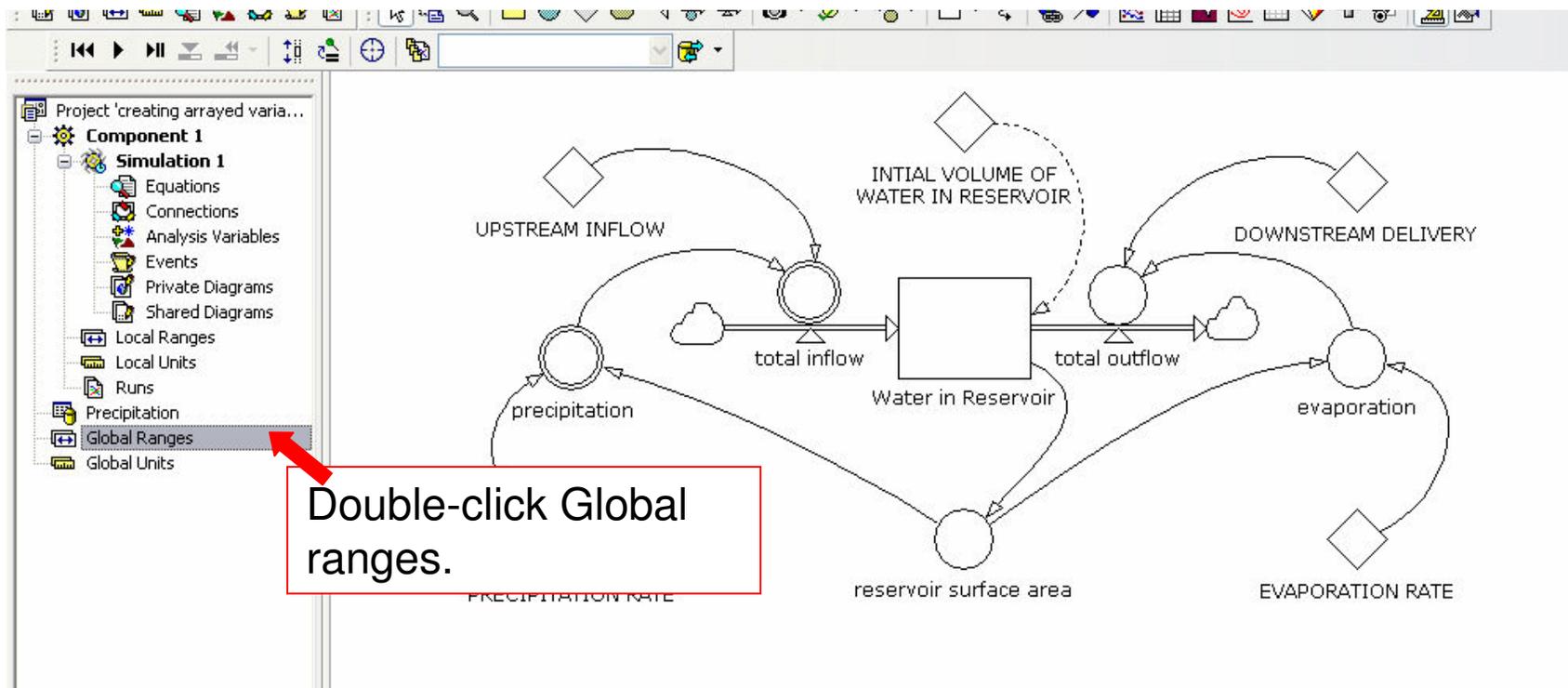

```
{2,106,666.666667, 2,106,666.666667, 2,106,666.666667, 2,666,666.666667, 2,493,333.333333, 2,333,333.333333, 2,226,666.666667, 2,666,666.666667, 2,720,000} cubic meters per day
```

All variables that are directly or indirectly defined by **PRECIPITATION RATE** are now one-dimensional arrays with 9 elements. Hover over **precipitation** and **total inflow** to see this. **Water in Reservoir** is now the sum of water in all 9 reservoirs.

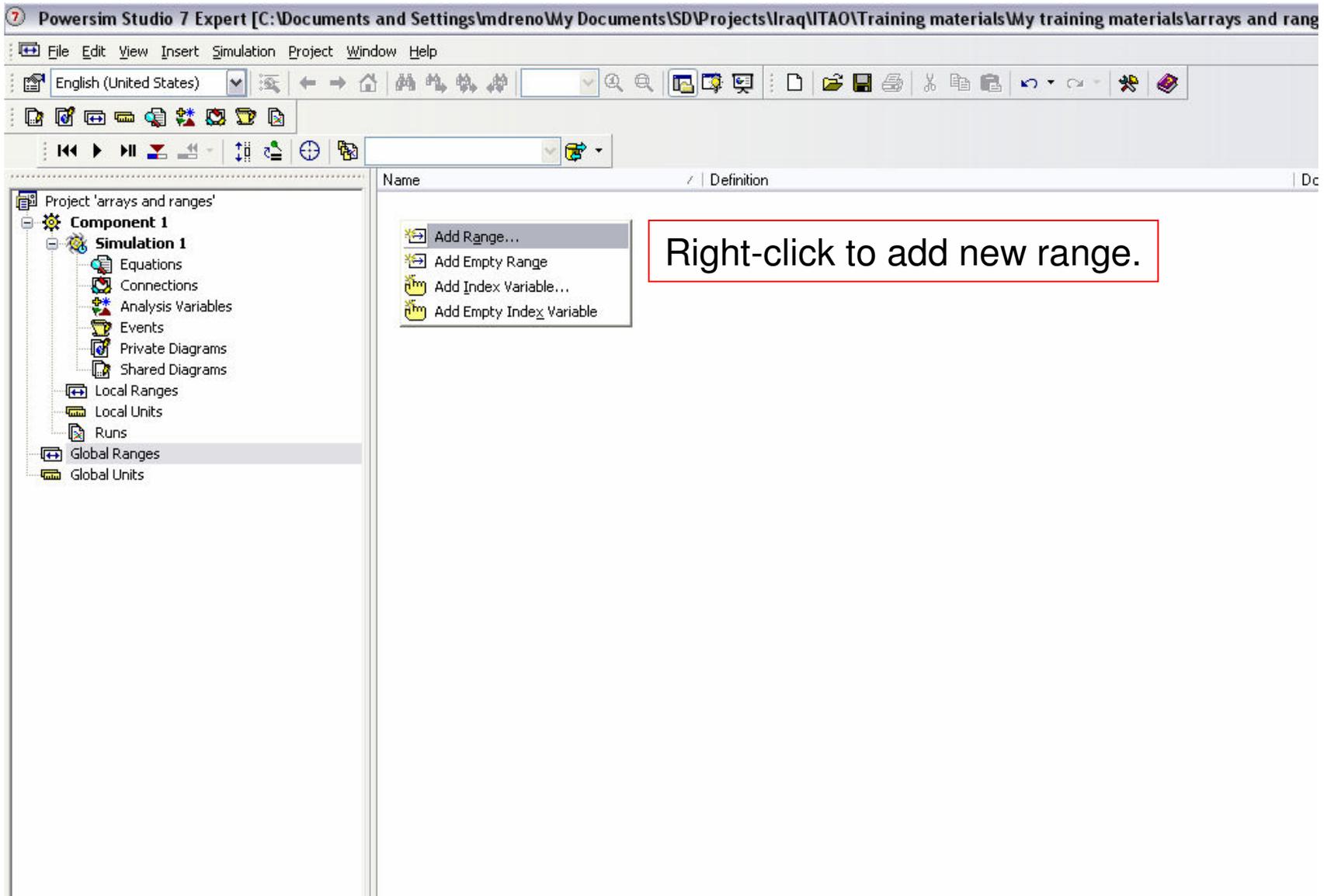
Note that because **UPSTREAM INFLOW** is defined as a single value, **total inflow** is using this same value 9 times to add to the 9 unique values from **precipitation**. This happens because total inflow has dimensions of 1..9.

Creating Ranges

Ranges are used to access variable elements in an intuitive way. The precipitation data that we have entered corresponds to an estimate of average monthly precipitation (12 months of data) at Adhaim Reservoir, Derbendi Khan Reservoir, Dokan Reservoir, Habbaniyah Lake, Haditha Reservoir, Hemrin Reservoir, Mosul Reservoir, Razzaza Lake, and Tharthar Lake. We will create the a range called “Reservoirs” that includes the names listed above.



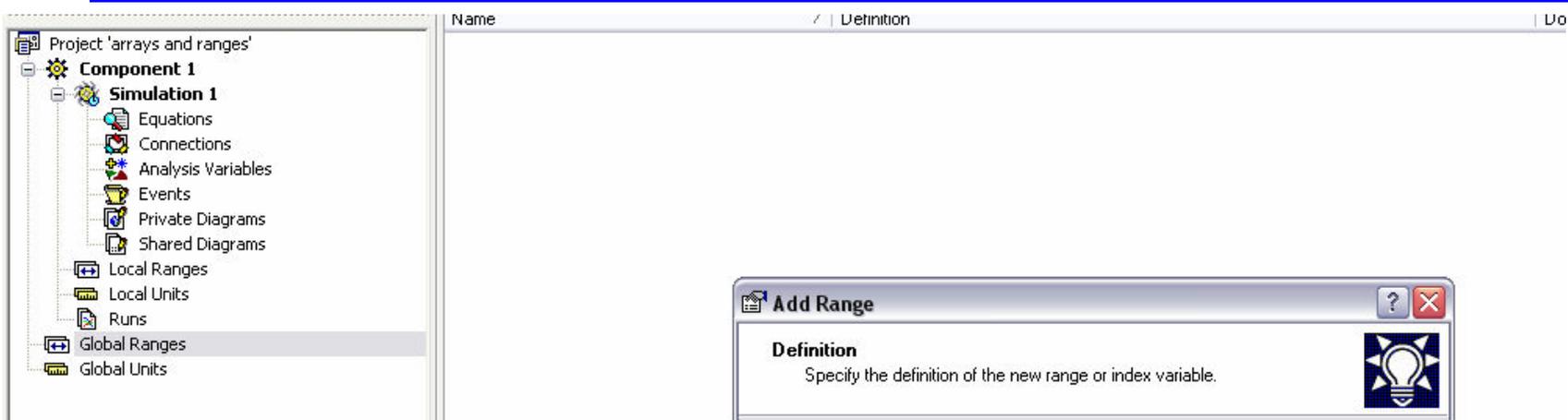
Creating Ranges



Creating Ranges

The screenshot shows a software interface with a project tree on the left and a main workspace on the right. The project tree is expanded to show 'Global Ranges'. A dialog box titled 'Add Range' is open in the foreground. The dialog box has a 'Name' section with a lightbulb icon and the text 'Specify name of the new range or index variable.' Below this is a text input field containing the word 'Reservoirs'. A red arrow points from the text 'Enter name of new range.' to the input field. At the bottom of the dialog box, there are five buttons: '< Back', 'Next >', 'Finish', 'Cancel', and 'Help >>'. A red arrow points to the 'Next >' button.

Creating Ranges



A list of the types of ranges and their descriptions can be found by searching titles only for “types of ranges” in Help (from Menu Bar, Help → Contents or press F1 *and* make sure “Search titles only” box is checked).

Select Enumeration range from category menu.

Creating Ranges

Project 'arrays and ranges'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Creating Ranges

Project 'arrays and ranges'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Creating Ranges

Project 'arrays and ranges'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Name | Definition

Add Range

Definition
Specify the definition of the new range or index variable.

Category: Enumeration range

Elements:
Adhaim

Definition:
Adhaim,

Status:

< Back Next > Finish Cancel Help >>

After you have entered the name of your first reservoir, click  to add the next reservoir name.

Creating Ranges

Project 'arrays and ranges'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Repeat until all reservoirs have been added. Then click "Finish".

Creating Ranges

Project 'arrays and ranges'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

Name	Definition
Reservoirs	Adhaim, 'Derbendi Khan', Dokan, Habbaniyah, Haditha, Hemrin, Mosul, Razzaza, Tharthar
Adhaim	
Derbendi Khan	
Dokan	
Habbaniyah	
Haditha	
Hemrin	
Mosul	
Razzaza	
Tharthar	

Note the single quotes around Derbendi Khan. Anytime a name containing spaces is used in a definition, it must be enclosed in single quotes.

Double-click Shared Diagrams to return to model.

New range now appears in Global Ranges window.

Creating Ranges

We will now modify the dimensions of **PRECIPITATION RATE** so that they relate to the newly created '**Reservoirs**' range.

The screenshot shows a software interface with a diagram and a dialog box. The diagram includes nodes for 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', 'DOWNSTREAM DELIVERY', 'precipitation', and 'PRECIPITATION RATE'. The dialog box, titled "'PRECIPITATION RATE' Auxiliary Symbol Properties", has tabs for Definition, Documentation, Advanced, Scale, Value, Line, Fill, and Symbol. The 'Definition' tab is active, showing 'Type: Real', 'Unit: mm/mo', and 'Dimensions: 1..9'. A dropdown menu for dimensions is open, showing 'Reservoirs' selected. The 'Definition' field contains the text '{316, 316, 316, 400, 374, 350, 334, 400, 408} <<mm/mo>>'. The 'Value' field contains '= {316, 316, 316, 400, 374, 350, 334, 400, 408} mm/mo'. A list of ranges is shown at the bottom, including 'Reservoirs', 'Adhaim', 'Derbendi Khan', 'Dokan', and 'Habbaniyah'. The 'Reservoirs' range is selected. A red circle highlights the dropdown menu, and a red arrow points to 'Reservoirs' in the list.

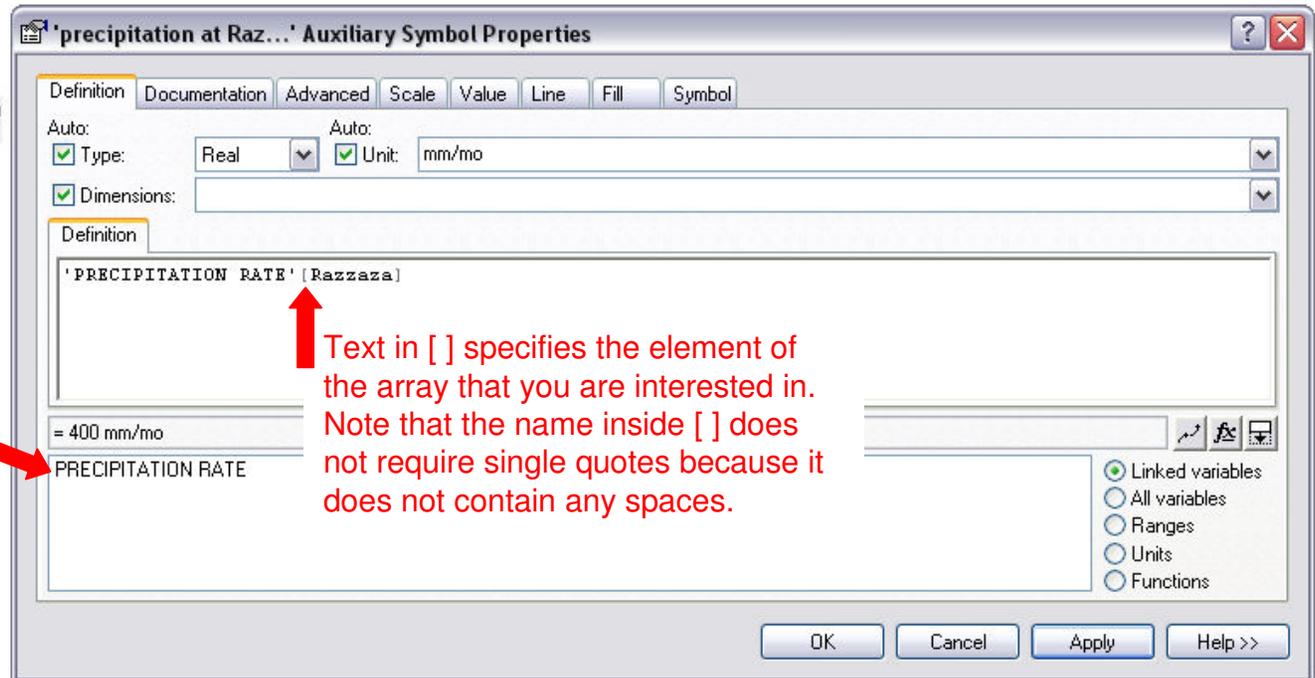
'Reservoirs' now appears in dimensions dropdown menu. Select it and click "OK".

Creating Ranges

The elements contained in **PRECIPITATION RATE** can now be accessed using the reservoir names. Suppose we want to use the precipitation at Razzaza Lake for another calculation in the model. To pull this single value from the **PRECIPITATION RATE** array, we create a new variable **precipitation at Razzaza Lake**, connect it to **PRECIPITATION RATE**, and define it as shown below.

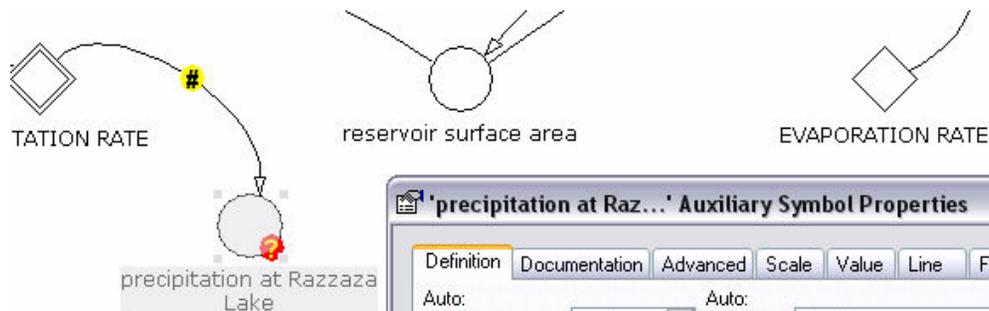


Add **PRECIPITATION RATE** to definition by double-clicking, then type “[Razzaza]”.

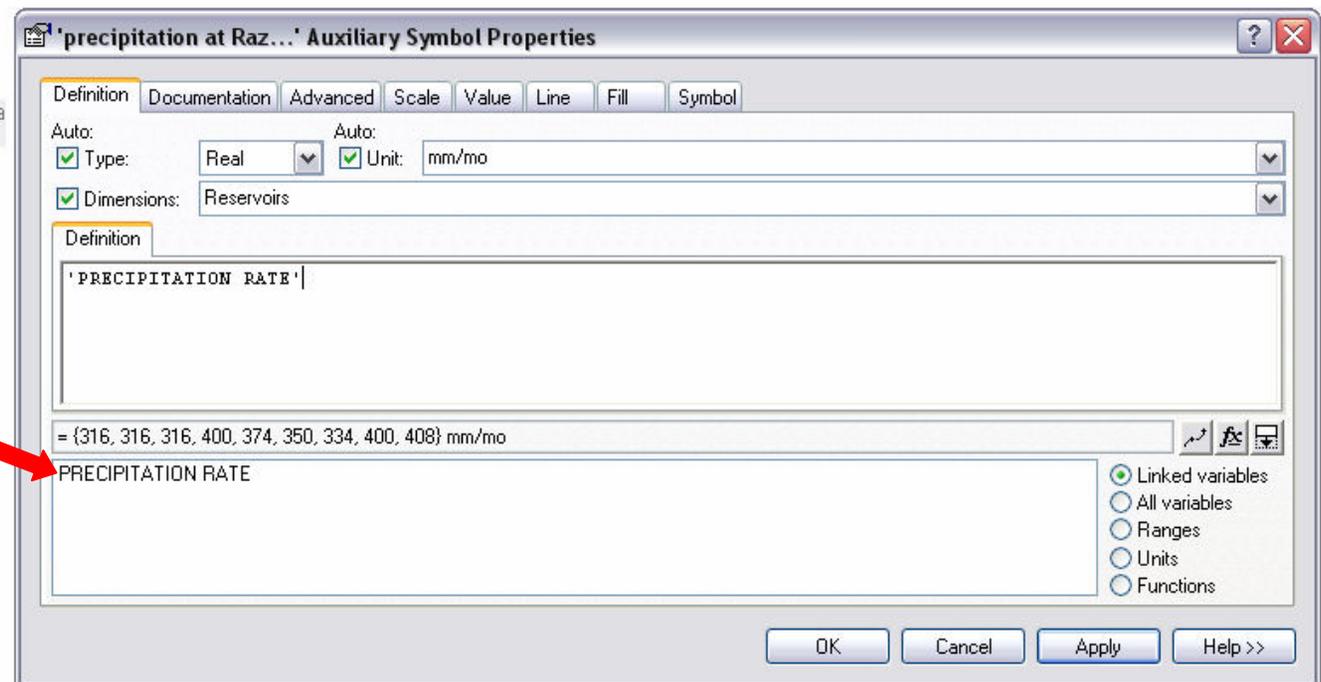


Creating Ranges

Another way to enter the definition from the previous slide is by double-clicking **PRECIPITATION RATE** as before...

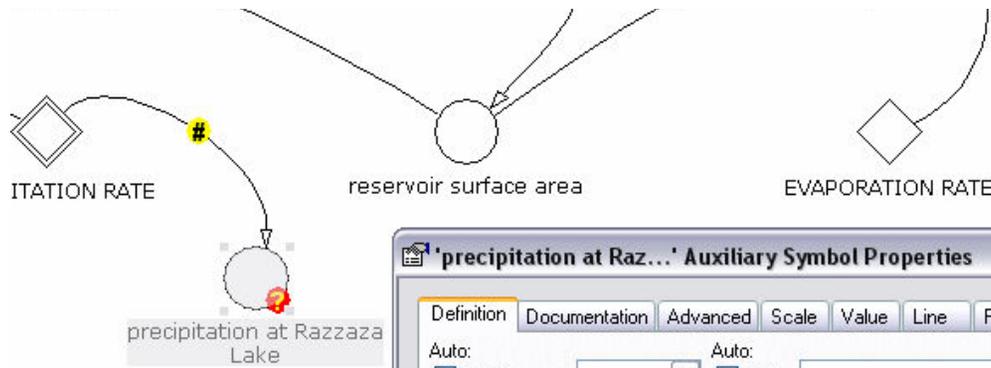


Add **PRECIPITATION RATE** to definition by double-clicking.



Creating Ranges

...then toggle Ranges button and double-click “Razzaza” from list of ranges that appears. Note that [] must be manually added to the definition.



Add “Razzaza” to definition by double-clicking/

The screenshot shows the 'Auxiliary Symbol Properties' dialog box for 'precipitation at Raz...'. The 'Definition' tab is active, showing the text: `'PRECIPITATION RATE' Razzaza`. Below this, a red error message states: `The name 'Razzaza' is unknown.` A list of variables is shown below the error message, including 'Habbaniyah', 'Haditha', 'Hemrin', 'Mosul', 'Razzaza', and 'Tharthar'. The 'Razzaza' variable is highlighted. On the right side of the dialog, there are several radio buttons: 'Linked variables', 'All variables', 'Ranges', 'Units', and 'Functions'. The 'Ranges' radio button is selected and circled in red. At the bottom of the dialog are buttons for 'OK', 'Cancel', 'Apply', and 'Help >>'. Two red arrows point from the text boxes to the 'Razzaza' variable in the list and the 'Ranges' radio button.

Add [] around “Razzaza” and this error message will disappear.

Array Functions

There are several functions available in Studio that enable you to perform various operations on array. These include [ARRAVERAGE](#), [ARRMAX](#), and [ARRMIN](#), which calculate the average, maximum, and minimum of array elements. A list of array functions and their descriptions can be found by searching titles only for “about array functions” in Help (from Menu Bar, Help → Contents or press F1 and make sure “Search titles only” box is checked).

Array Functions	
ARRAVERAGE - Average of Array Elements	LOOKUP - Lookup Value of Array Element
ARRMAX - Maximum of Array Elements	MINVERSE - Inverse Square Matrix
ARRMIN - Minimum	NUMERICAL - Convert Range Element to Number
ARRPOLY - Array Polynomial	PRIORITYALLOCDISCRETE - Discrete Prioritized Resource Allocation
ARRPRODUCT - Product of Array Elements	PRIORITYALLOC - Prioritized Resource Allocation
ARRSTDEV - Standard Deviation of Infinite Population of Array Elements	PRODUCT - Product
ARRSTDEVP - Standard Deviation of Finite Population of Array Elements	REDIM - Redimension Array
ARRSUM - Sum of Array Elements	SCANEQ - Scan Vector for Equal Element
CONCAT - Concatenate Arrays	SCANGT - Scan Vector for Greater Element
COUNTEQ - Count Number of Equal Elements in Array	SCANGTEQ - Scan Vector for Greater or Equal Element
COUNTNEQ - Count Number of Not Equal Elements in Array	SCANLT - Scan Vector for Smaller Element
COUNTGT - Count Number of Greater Elements in Array	SCANLTEQ - Scan Vector for Smaller or Equal Element
COUNTGTEQ - Count Number of Greater or Equal Elements in Array	SCANNEQ - Scan Vector for Unequal Element
COUNTLT - Count Number of Smaller Elements in Array	SCANNOTSAME - Scan Vector for Element with Different Representation
COUNTLTEQ - Count Number of Smaller or Equal Elements in Array	SCANSAME - Scan Vector for Element with Same Representation
COUNTNOTSAME - Count Number of Not Bit Equal Elements in Array	SORT - Sort Vector
COUNTSAME - Count Number of Bit Equal Elements in Array	SORTINDEX - Sort Vector Indices
CUMULATIVESUM - Cumulative Sum of Array Elements	SPARSESUM - Sparse Sum
DIM - Dimension of Variable	SPARSEVECTOR - Sparse Vectorize
DIMCOUNT - Dimension Count of Variable	SUM - Sum
ELEM COUNT - Number of Elements in an Array	TRANSPOSE - Transpose Matrix
INDEX - Convert a Variable to an Index Variable	VECTOR - Vectorize Elements
LENGTH - Length of Array	XPROD - Vector Cross Product

Array Functions

Calculate the average precipitation for all 9 reservoirs.

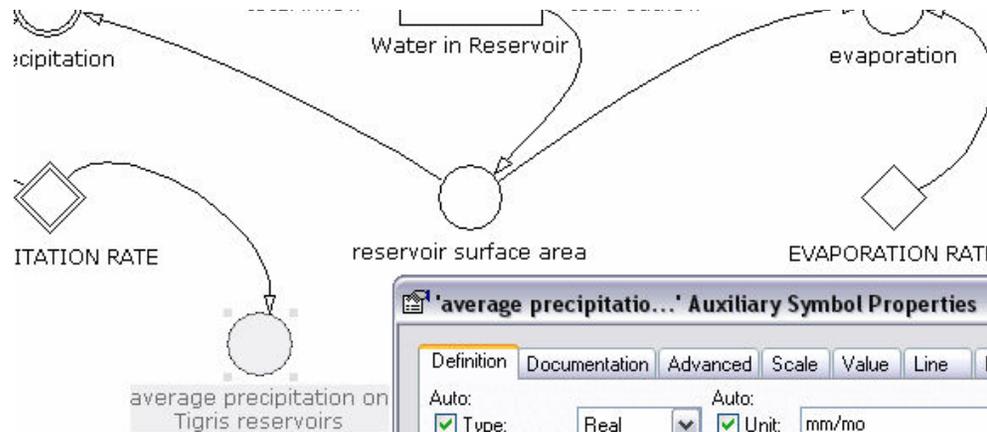
The image shows a software interface with a flow diagram on the left and a dialog box on the right. The flow diagram includes nodes for 'UPSTREAM INFLOW', 'INITIAL VOLUME OF WATER IN RESERVOIR', 'DOWNSTREAM DELIVERY', 'total inflow', 'precipitation', 'PRECIPITATION RATE', and 'average precipitation at all reservoirs'. The dialog box, titled 'average precipitation ... Auxiliary Symbol Properties', has tabs for 'Definition', 'Documentation', 'Advanced', 'Scale', 'Value', 'Line', 'Fill', and 'Symbol'. The 'Definition' tab is active, showing the following settings:

- Auto: Type: Real, Unit: mm/mo
- Dimensions:
- Definition: `ARRAVERAGE ('PRECIPITATION RATE')`
- Value: `= 357.111111111111 mm/mo`
- Symbol: `PRECIPITATION RATE`

At the bottom of the dialog box, there are radio buttons for 'Linked variables' (selected), 'All variables', 'Ranges', 'Units', and 'Functions'. Buttons for 'OK', 'Cancel', 'Apply', and 'Help >>' are located at the bottom of the dialog.

Array Functions

Calculate the average precipitation for reservoirs on the Tigris and its tributaries.



The screenshot shows the 'average precipitation...' Auxiliary Symbol Properties dialog box. The 'Definition' tab is active, showing the following configuration:

- Auto:** Type: Real, Unit: mm/mo
- Dimensions:**
- Definition:**

```
ARRAVERAGE({'PRECIPITATION RATE' [Adhaim], 'PRECIPITATION RATE' ['Derbendi Khan'],  
'PRECIPITATION RATE' [Dokan], 'PRECIPITATION RATE' [Hemrin], 'PRECIPITATION RATE' [Mosul]})
```
- Value:** = 326.4 mm/mo
- PRECIPITATION RATE**: A list of variables with 'Linked variables' selected.

Annotations in the image:

- A red arrow points to the opening curly brace of the array definition: **Entry enclosed by { }.**
- A red arrow points to the closing curly brace of the array definition: **[] around Derbendi Khan.**
- A red arrow points to the closing curly brace of the array definition: **Ctrl + Enter to continue definition on next line.**

Note that we are creating a new array using 5 of the 9 elements from the **'Reservoirs'** range.

Iraq National Water Modeling Workshop I

November 11-15, 2007
United Nations University
Amman, Jordan

Creating Datasets



Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



Dataset Types

Excel Spreadsheet Dataset

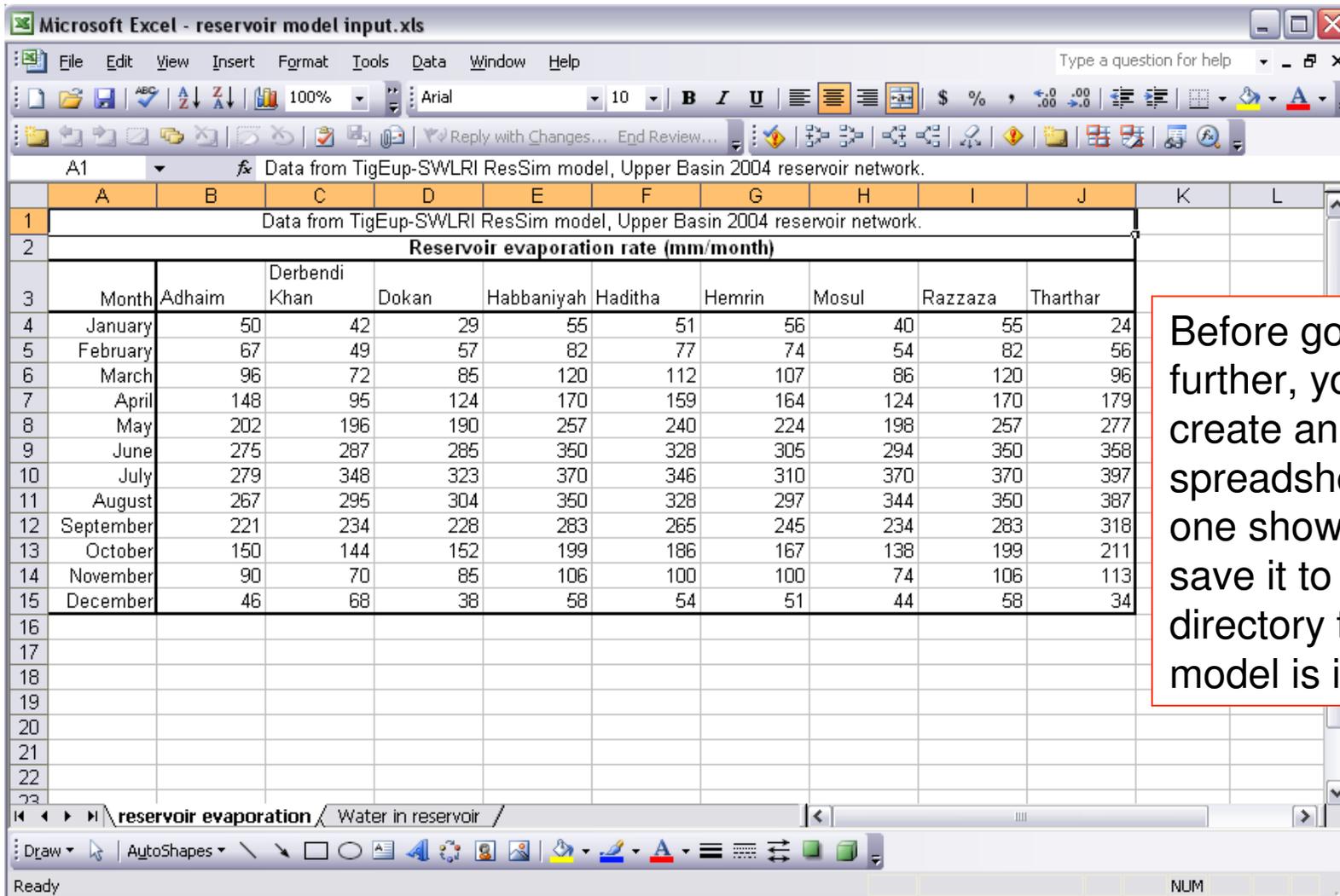
- Requires link to an external Excel file (i.e., in order to work with this kind of dataset, Excel will have to be running in parallel with Studio).
- Allows you to quickly import and work with large datasets.

Manually-entered Dataset Array

- If you have a small amount of data, it might be easier to manually enter it directly into the variable of interest rather than import it from Excel. We did this for **PRECIPITATION RATE** on slide 66.
- Does not require link to external file.

Create Excel Dataset Connection

Suppose you want to use monthly evaporation data for each of the 9 reservoirs in place of the fixed annual average evaporation rate.



Microsoft Excel - reservoir model input.xls

Data from TigEup-SWLRI ResSim model, Upper Basin 2004 reservoir network.

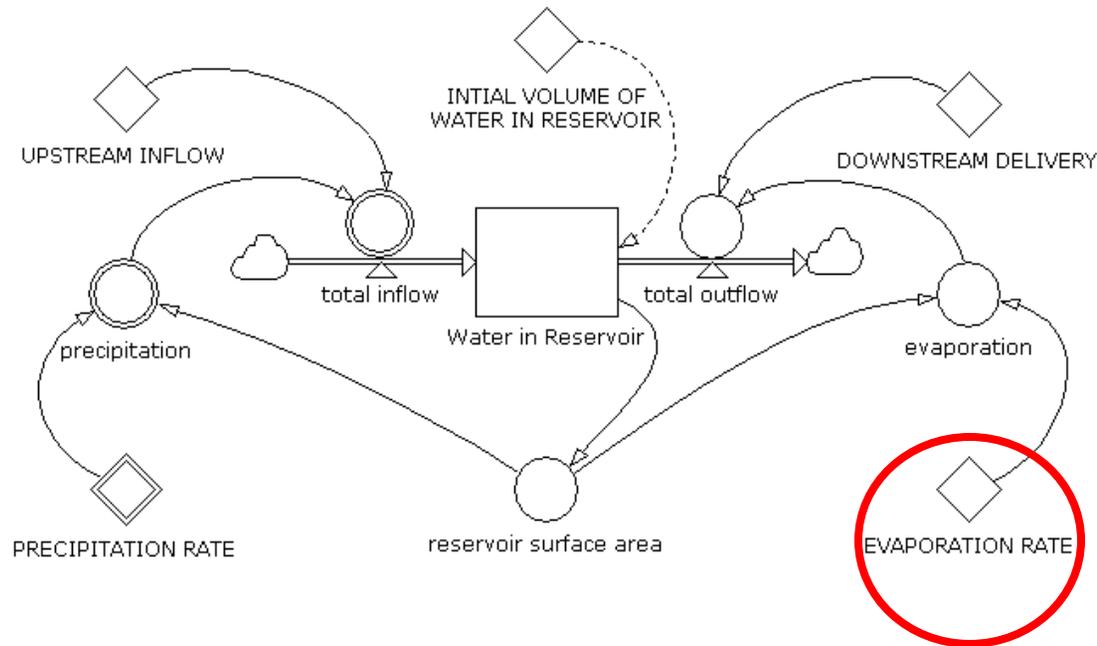
	A	B	C	D	E	F	G	H	I	J	K	L
1	Data from TigEup-SWLRI ResSim model, Upper Basin 2004 reservoir network.											
2	Reservoir evaporation rate (mm/month)											
3	Month	Adhaim	Derbendi Khan	Dokan	Habbaniyah	Haditha	Hemrin	Mosul	Razzaza	Tharthar		
4	January	50	42	29	55	51	56	40	55	24		
5	February	67	49	57	82	77	74	54	82	56		
6	March	96	72	85	120	112	107	86	120	96		
7	April	148	95	124	170	159	164	124	170	179		
8	May	202	196	190	257	240	224	198	257	277		
9	June	275	287	285	350	328	305	294	350	358		
10	July	279	348	323	370	346	310	370	370	397		
11	August	267	295	304	350	328	297	344	350	387		
12	September	221	234	228	283	265	245	234	283	318		
13	October	150	144	152	199	186	167	138	199	211		
14	November	90	70	85	106	100	100	74	106	113		
15	December	46	68	38	58	54	51	44	58	34		
16												
17												
18												
19												
20												
21												
22												
23												

reservoir evaporation / Water in reservoir

Ready NUM

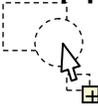
Before going any further, you need to create an Excel spreadsheet like the one shown here and save it to the same directory that your model is in.

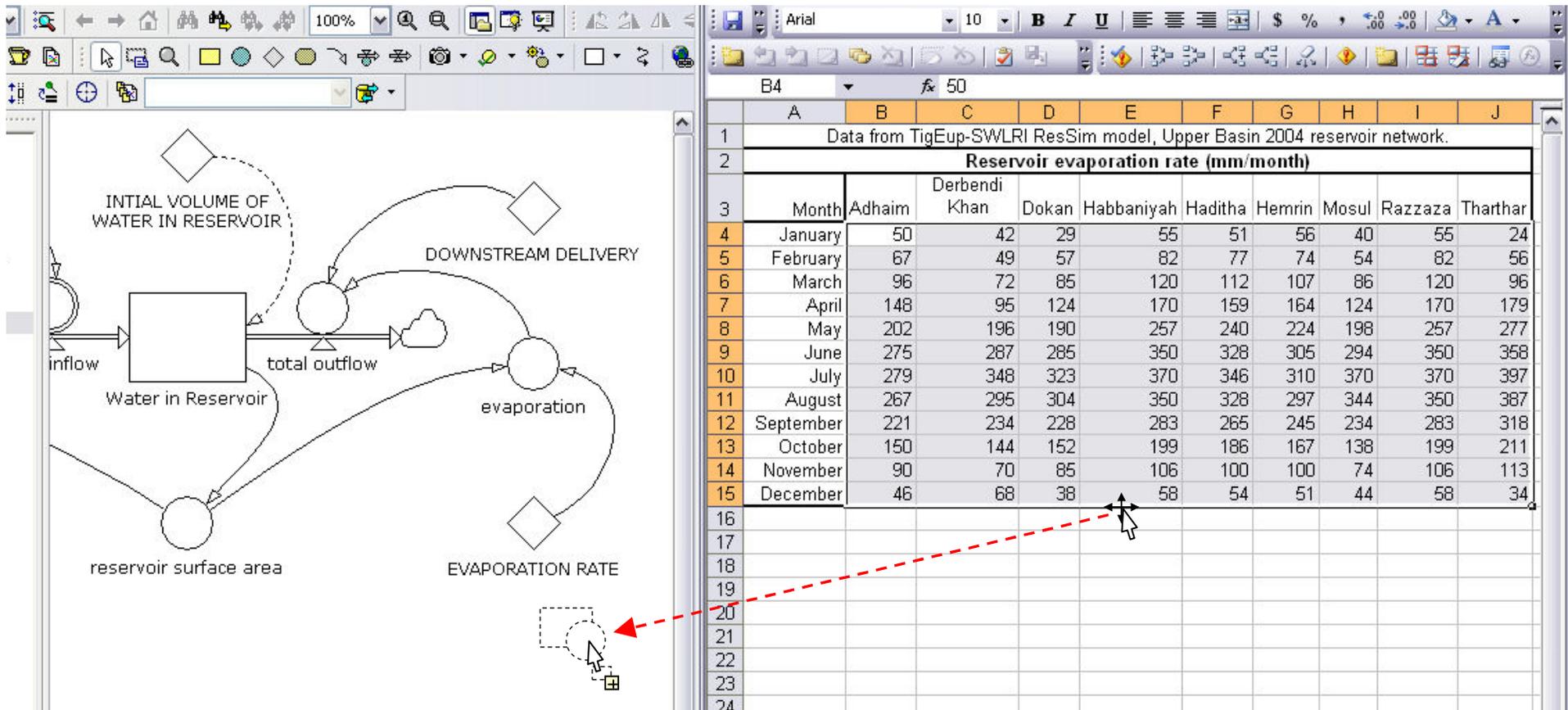
Create Excel Dataset Connection



We will replace the fixed value that currently defines **EVAPORATION RATE** with a series of monthly values (shown on the previous slide). These monthly values will be imported into Studio from an Excel spreadsheet using the function **XLDATA**. For additional information on this function, search for “XLDATA” in Help (from Menu Bar, Help → Contents or press F1).

Create Excel Dataset Connection

With Studio and Excel running side by side, highlight the data that you want to import. Move cursor to one of edges until  symbol appears. Left-click, hold mouse button down, and drag into Studio screen. When  symbol appears, let go of mouse button.

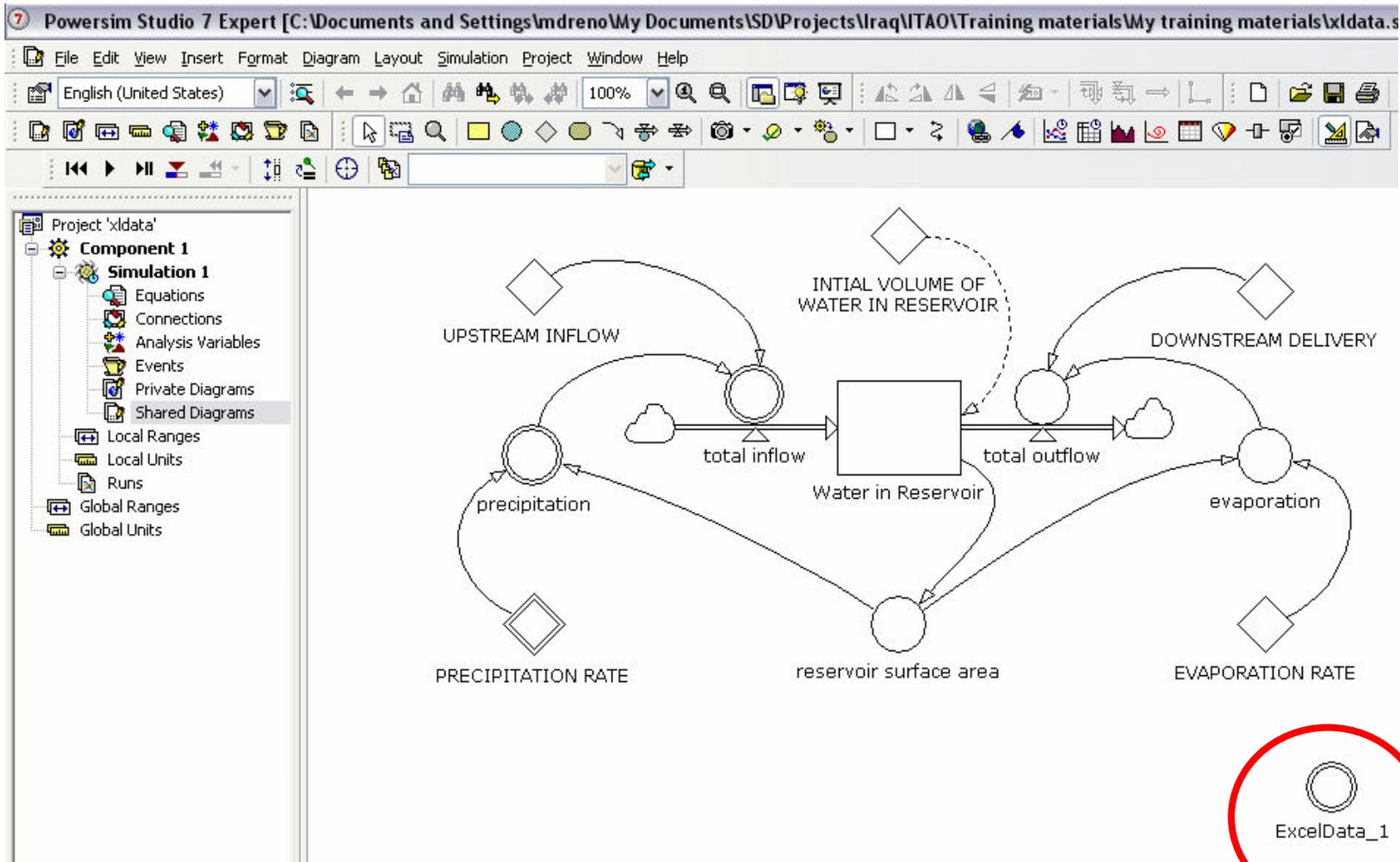


The screenshot shows a software interface with two main windows. The left window displays a reservoir model diagram with components like 'Water in Reservoir', 'inflow', 'total outflow', 'evaporation', and 'reservoir surface area'. The right window shows an Excel spreadsheet with the following data:

Month	Adhaim	Derbendi Khan	Dokan	Habbaniyah	Haditha	Hemrin	Mosul	Razzaza	Tharthar
January	50	42	29	55	51	56	40	55	24
February	67	49	57	82	77	74	54	82	56
March	96	72	85	120	112	107	86	120	96
April	148	95	124	170	159	164	124	170	179
May	202	196	190	257	240	224	198	257	277
June	275	287	285	350	328	305	294	350	358
July	279	348	323	370	346	310	370	370	397
August	267	295	304	350	328	297	344	350	387
September	221	234	228	283	265	245	234	283	318
October	150	144	152	199	186	167	138	199	211
November	90	70	85	106	100	100	74	106	113
December	46	68	38	58	54	51	44	58	34

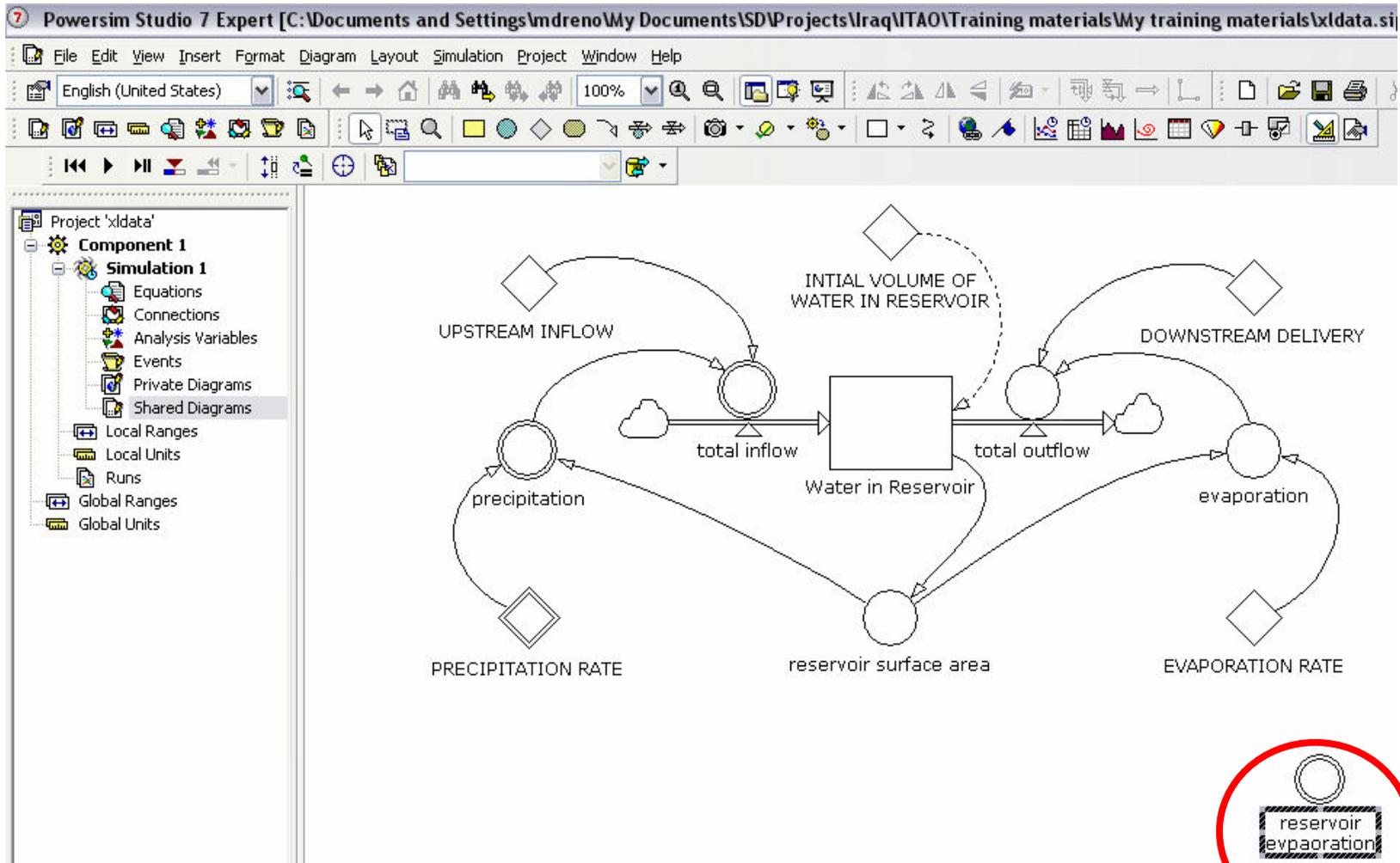
Create Excel Dataset Connection

New variable appears in diagram window.



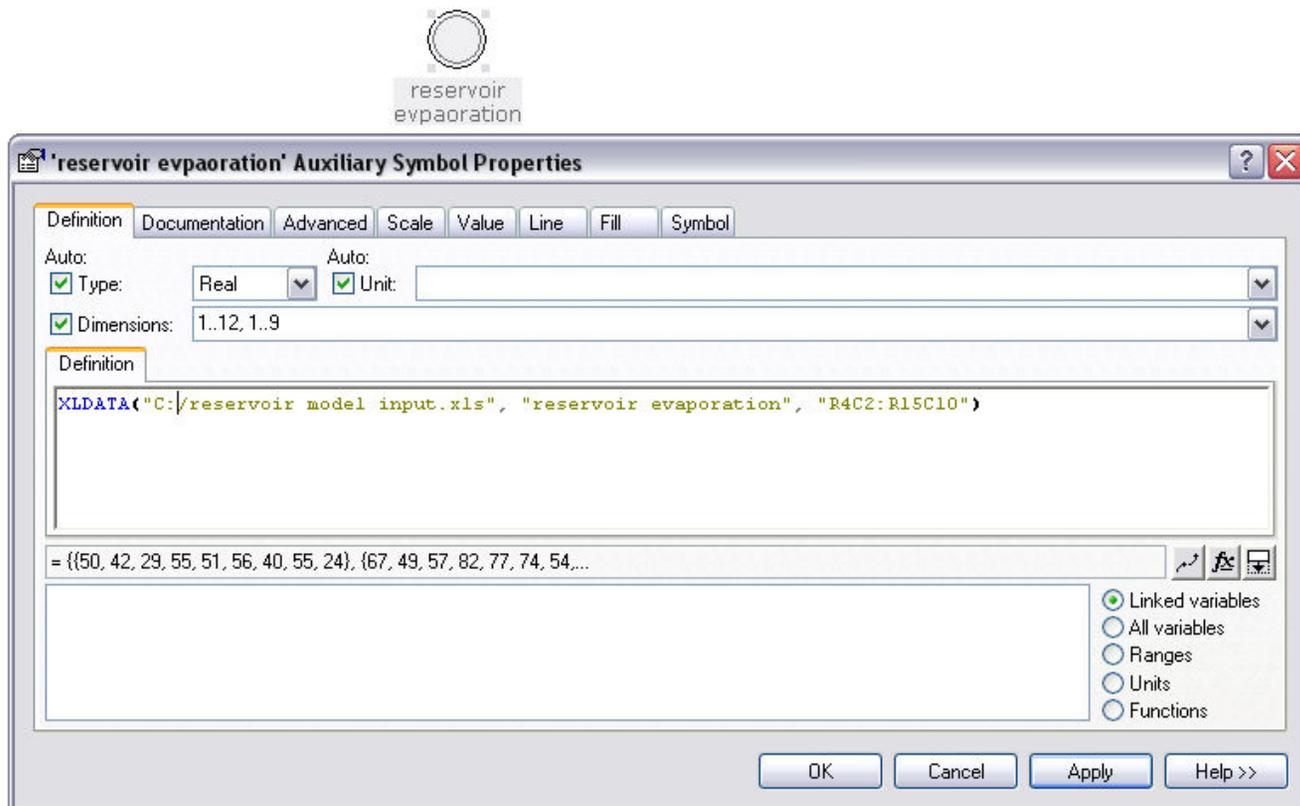
Use XLDATA Variable

Rename variable.



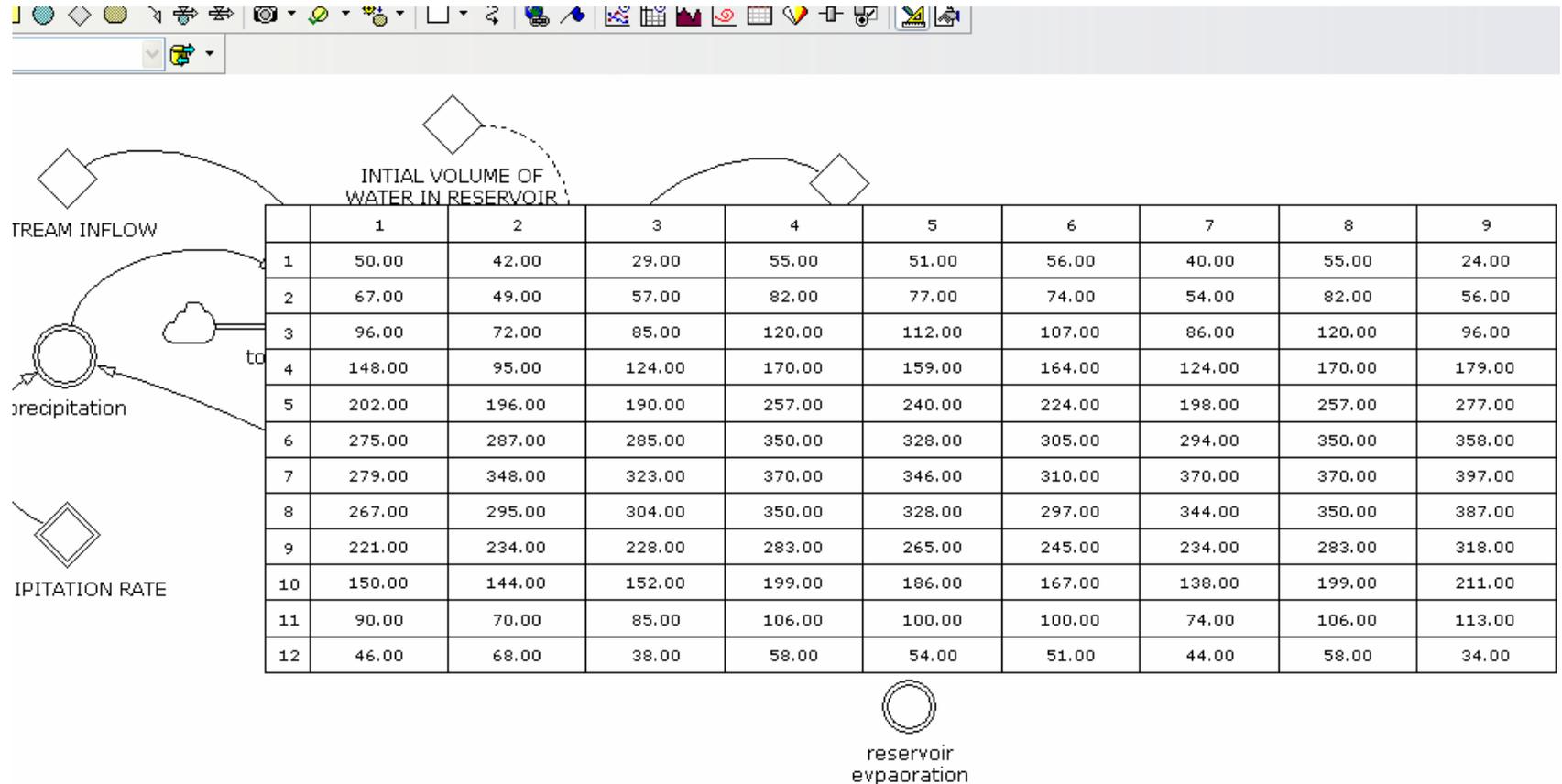
Use XLDATA Variable

Open **reservoir evaporation** and change path to “C:/name of spreadsheet.xls” (delete all text between “C:/” and “name of spreadsheet.xls”). Once you do this, you must keep your Studio model (.sip file) and spreadsheet in the same directory! This allows you to transfer the model and spreadsheet between computers or copy to other directories without breaking the data connection.



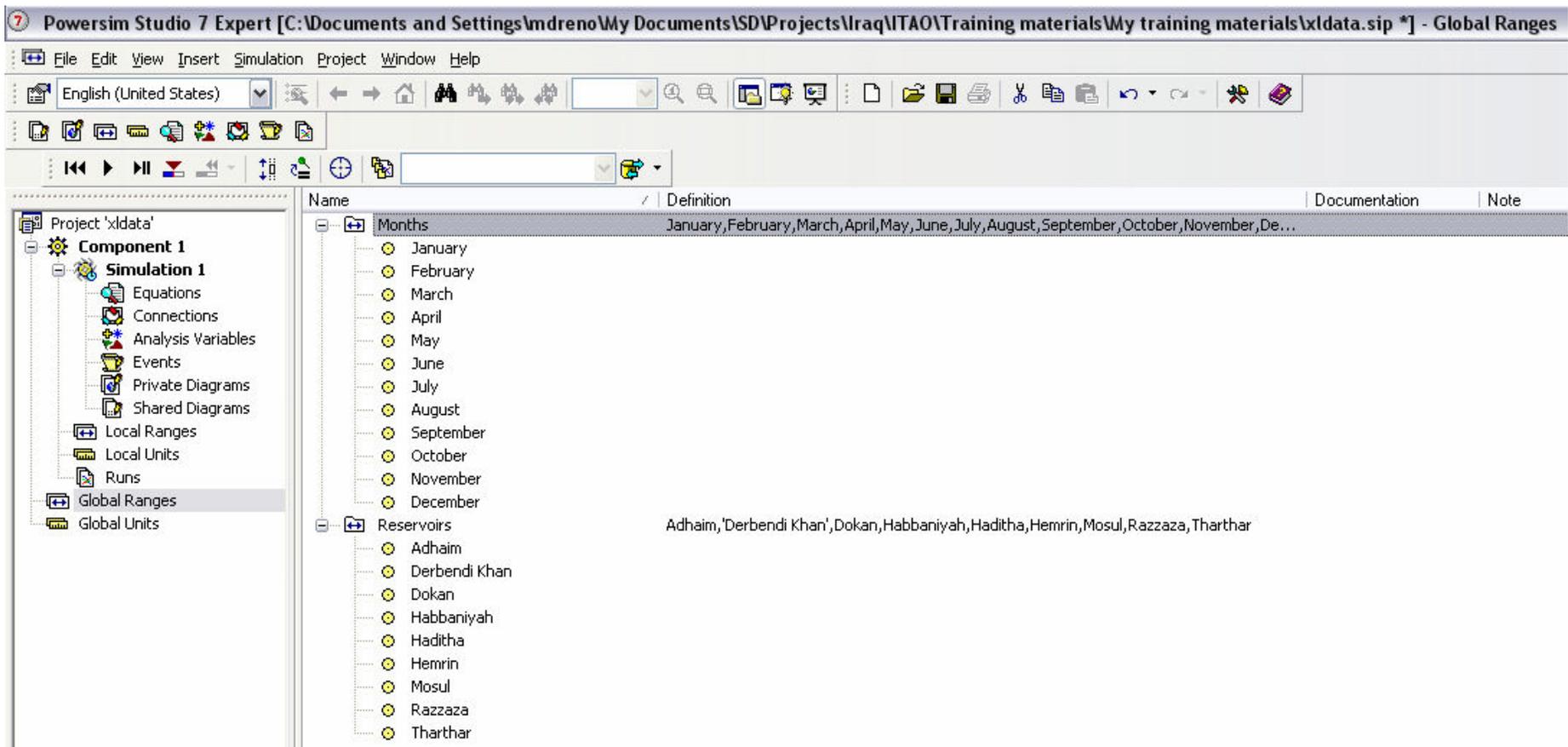
Use XLDATA Variable

Show number auto report and observe that you have created a 12 x 9 array. The 12 rows correspond to the 12 months of a year. The 9 columns correspond to the 9 reservoirs.



Use XLDATA Variable

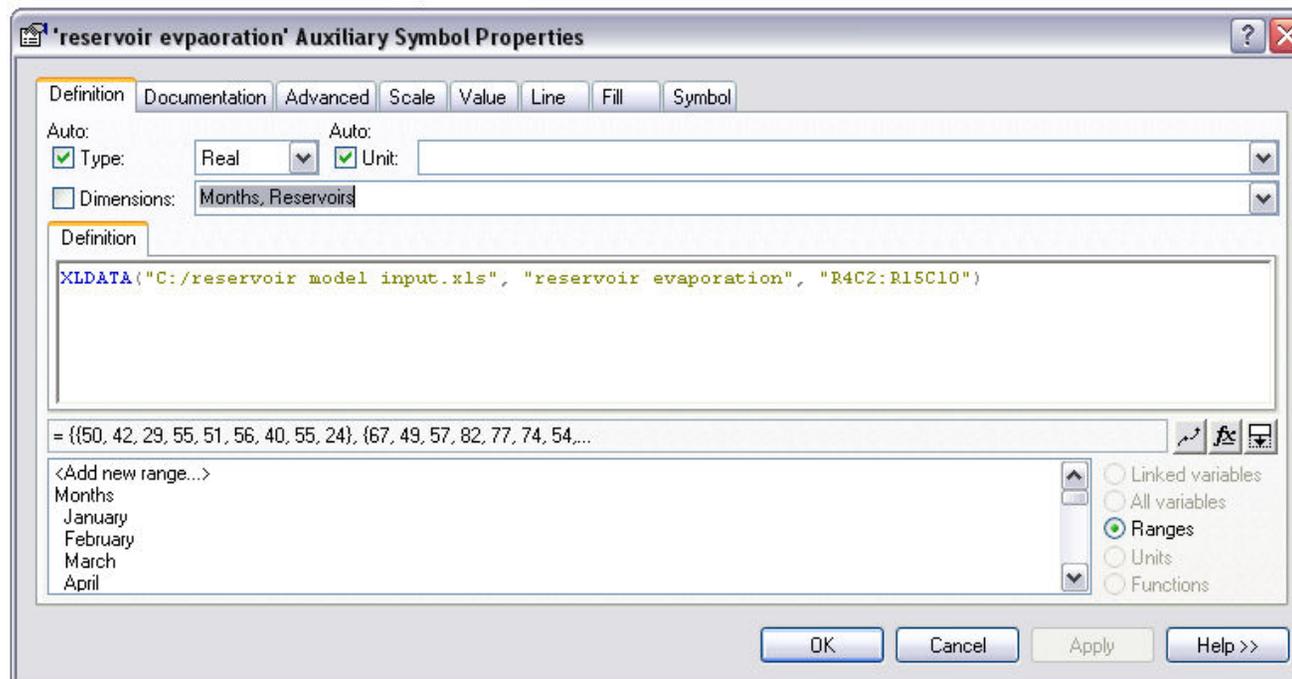
We want to give this array dimensions of **'Months'** x **'Reservoirs'**. The **'Reservoirs'** range has already been created. Create a range called "Months". The Global Ranges screen should now look like this:



Use XLDATA Variable

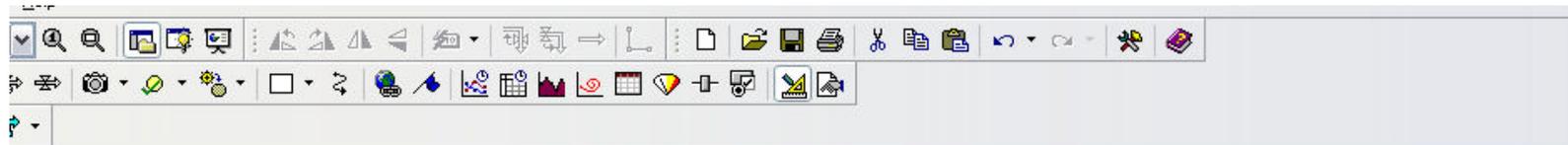
Open **reservoir evaporation** and change the dimensions from “1..12, 1..9” to “Months, Reservoirs”. Click “Apply”.

90.00	70.00	85.00	106.00	100.00	100.00	74.00	106.00	113.00
46.00	68.00	38.00	58.00	54.00	51.00	44.00	58.00	34.00



Use XLDATA Variable

Notice that the row and column labels now reflect the appropriate months and reservoirs. Note also that no units appear (i.e., all of these values have units of *mm/mo*, but these do not appear anywhere). We will add these later.



INITIAL VOLUME OF WATER IN RESERVOIR

	Adhaim	Derbendi Khar	Dokan	Habbaniyah	Haditha	Hemrin	Mosul	Razzaza	Tharthar
January	50.00	42.00	29.00	55.00	51.00	56.00	40.00	55.00	24.00
February	67.00	49.00	57.00	82.00	77.00	74.00	54.00	82.00	56.00
March	96.00	72.00	85.00	120.00	112.00	107.00	86.00	120.00	96.00
April	148.00	95.00	124.00	170.00	159.00	164.00	124.00	170.00	179.00
May	202.00	196.00	190.00	257.00	240.00	224.00	198.00	257.00	277.00
June	275.00	287.00	285.00	350.00	328.00	305.00	294.00	350.00	358.00
July	279.00	348.00	323.00	370.00	346.00	310.00	370.00	370.00	397.00
August	267.00	295.00	304.00	350.00	328.00	297.00	344.00	350.00	387.00
September	221.00	234.00	228.00	283.00	265.00	245.00	234.00	283.00	318.00
October	150.00	144.00	152.00	199.00	186.00	167.00	138.00	199.00	211.00
November	90.00	70.00	85.00	106.00	100.00	100.00	74.00	106.00	113.00
December	46.00	68.00	38.00	58.00	54.00	51.00	44.00	58.00	34.00



Use XLDATA Variable

We will now link these data to the simulation time calculated by Studio when you run your model. We will do this by creating additional variables that use **INDEX** and **TIME** functions.

INDEX function

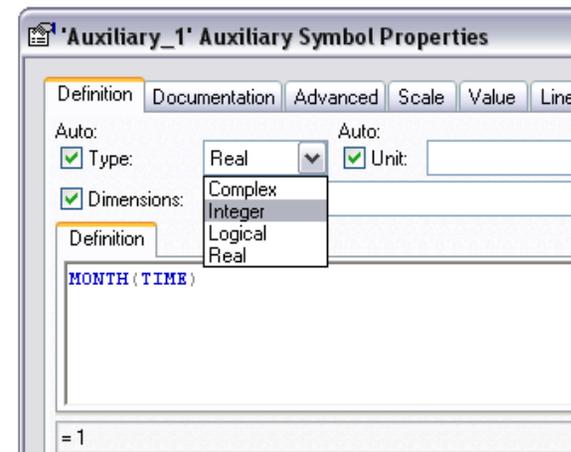
Used to access elements of an array. It allows you to use the integer value of any variable as an index when accessing an array element. For more information on this function, search “INDEX function” in Help (from Menu Bar, Help → Contents or press F1).

TIME function

Returns the current time of the simulation.

DAY(**TIME**) returns the current day of the simulation. **MONTH**(**TIME**) returns the current month of the simulation.

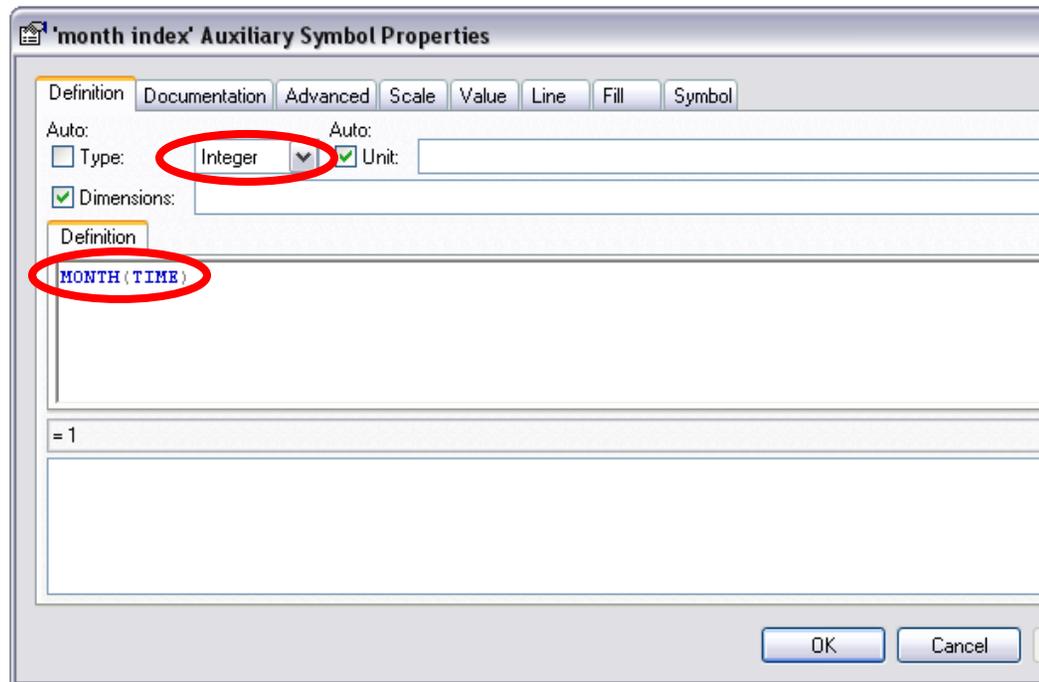
YEAR(**TIME**) returns the current year of the simulation. In order to use any of these values in an **INDEX** function, you must specify “Integer” as variable type.



Use XLDATA Variable

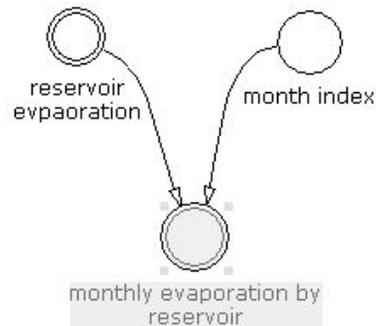
The data that we have imported are monthly and there is only 1 year of data. If we run our model for more than 1 year, we will need to reuse these data over and over again for the appropriate month. We will create a variable called “month index” to keep track of what the current month of the simulation is. Then we will use this variable to call the correct evaporation value.

Create a new variable **month index** and define it as shown here.



Use XLDATA Variable

Create a new variable **monthly evaporation by reservoir** and define it as shown here. Note that you must add the units “mm/mo”.



The screenshot shows the 'Auxiliary Symbol Properties' dialog box for the variable 'monthly evaporation ...'. The 'Definition' tab is active. The 'Auto:' section shows 'Type' set to 'Real' and 'Unit' set to 'mm/mo'. The 'Dimensions' are set to 'Reservoirs'. The 'Definition' text area contains the formula: `'reservoir evaporation'[INDEX('month index')] * 1<<mm/mo>>`. A red annotation next to the formula states: ** 1<<mm/mo>> gives **monthly evaporation by reservoir** units of mm/mo.* Below the definition, the value is shown as `= {50, 42, 29, 55, 51, 56, 40, 55, 24} mm/mo`. The 'Linked variables' section is checked, and the 'month index' and 'reservoir evaporation' variables are listed. The 'Apply' button is highlighted.

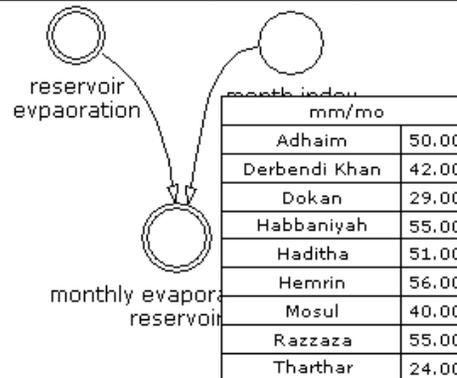
Use XLDATA Variable

Show auto report for **monthly evaporation by reservoir** and compare it to the auto report for **reservoir evaporation**.

	Adhaim	Derbendi Khar	Dokan	Habbaniyah	Haditha	Hemrin	Mosul	Razzaza	Tharthar
January	50.00	42.00	29.00	55.00	51.00	56.00	40.00	55.00	24.00
February	67.00	49.00	57.00	82.00	77.00	74.00	54.00	82.00	56.00
March	96.00	72.00	85.00	120.00	112.00	107.00	86.00	120.00	96.00
April	148.00	95.00	124.00	170.00	159.00	164.00	124.00	170.00	179.00
May	202.00	196.00	190.00	257.00	240.00	224.00	198.00	257.00	277.00
June	275.00	287.00	285.00	350.00	328.00	305.00	294.00	350.00	358.00
July	279.00	348.00	323.00	370.00	346.00	310.00	370.00	370.00	397.00
August	267.00	295.00	304.00	350.00	328.00	297.00	344.00	350.00	387.00
September	221.00	234.00	228.00	283.00	265.00	245.00	234.00	283.00	318.00
October	150.00	144.00	152.00	199.00	186.00	167.00	138.00	199.00	211.00
November	90.00	70.00	85.00	106.00	100.00	100.00	74.00	106.00	113.00
December	46.00	68.00	38.00	58.00	54.00	51.00	44.00	58.00	34.00

These values do not have any units.

For every month of the simulation, **monthly evaporation by reservoir** calculates the evaporation at each reservoir for the current month of the simulation.



These values have units of *mm/mo*.

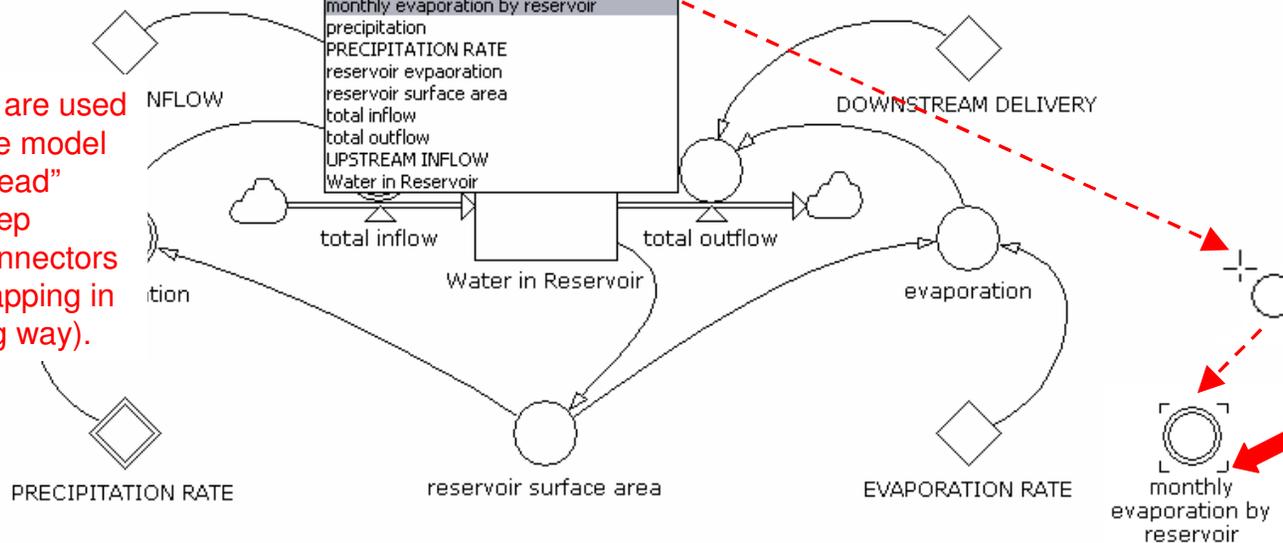
Use XLDATA Variable

Now we are going to replace **EVAPORATION RATE** with **monthly evaporation by reservoir**.

First, create a snapshot of **monthly evaporation by reservoir** by clicking the  icon, selecting “monthly evaporation by reservoir”, placing the  cursor in the part of the diagram window where you want the snapshot to appear, and clicking again.



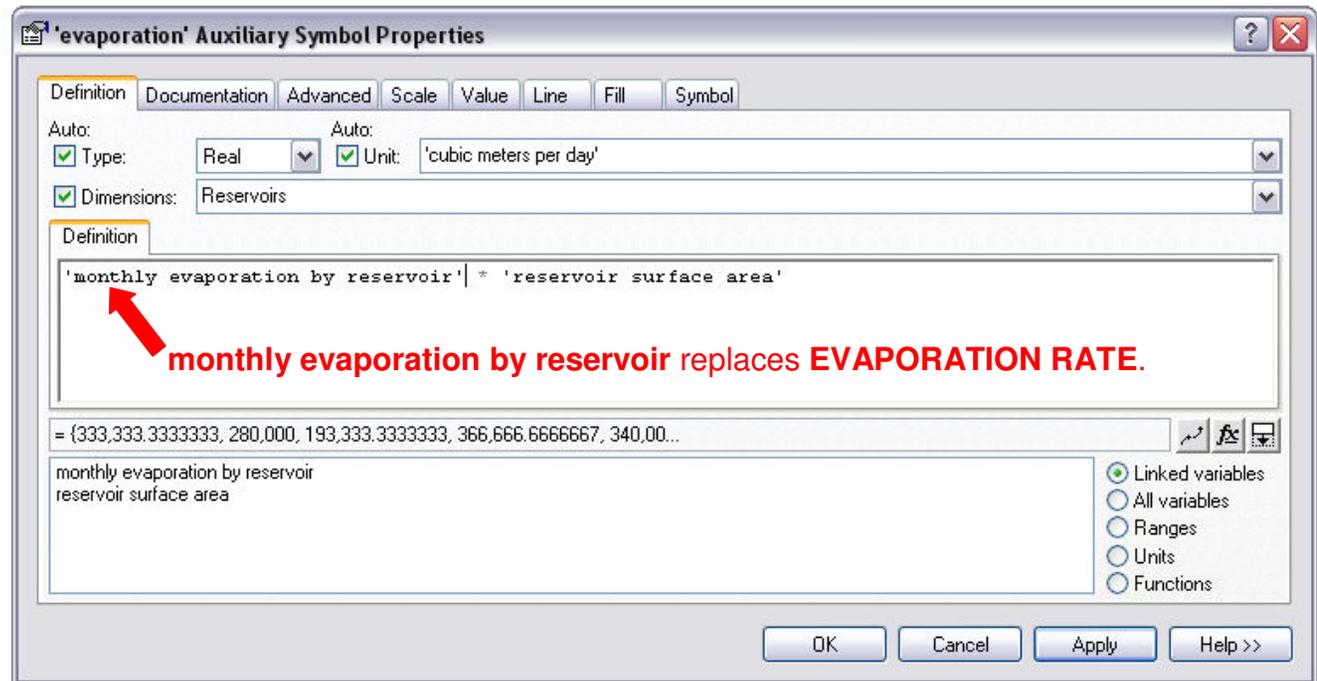
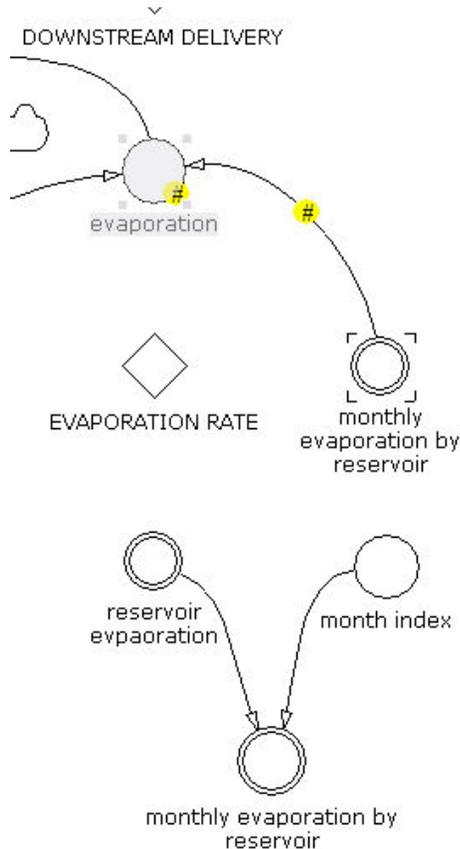
Snapshots are used to make the model easier to “read” (e.g., to keep multiple connectors from overlapping in a confusing way).



Notice brackets, indicating that this variable is a snapshot of another variable in the model.

Use XLDATA Variable

Delete connection between **EVAPORATION RATE** and **evaporation**. Create new connection between **monthly evaporation by reservoir** and **evaporation**. Redefine **evaporation**.



Use XLDATA Variable

A screen will appear asking if you want to turn off the 'Automatic history' option; click "Yes". You can turn this option back on at any time through Simulation Settings. From Menu Bar, Simulation → Simulation Settings, then check the 'Automatic history' box.

The image displays a simulation diagram on the left, a dialog box titled "'evaporation' Auxiliary Symbol Properties" in the center, and a warning dialog box titled "Powersim Studio" at the bottom.

The simulation diagram shows a reservoir with various flows and variables. Labels include: "total outflow", "DOWNSTREAM DELIVERY", "evaporation", "monthly evaporation by reservoir", "reservoir surface area", "EVAPORATION RATE", and "total volume of water in reservoir".

The "'evaporation' Auxiliary Symbol Properties" dialog box has tabs for "Definition", "Documentation", "Advanced", "Scale", "Value", "Line", "Fill", and "Symbol". The "Definition" tab is active, showing the following settings:

- Auto: Type: Real, Unit: km²
- Auto: Dimensions: Reservoirs
- Definition: `'monthly evaporation by reservoir' * 'reservoir surface area'`
- Value: = {10,000, 8,400, 5,800, 11,000, 10,200, 11,200, 8,000, 11,000, 4,800...}
- Text: monthly evaporation by reservoir, reservoir surface area

The "Powersim Studio" warning dialog box contains the following text:

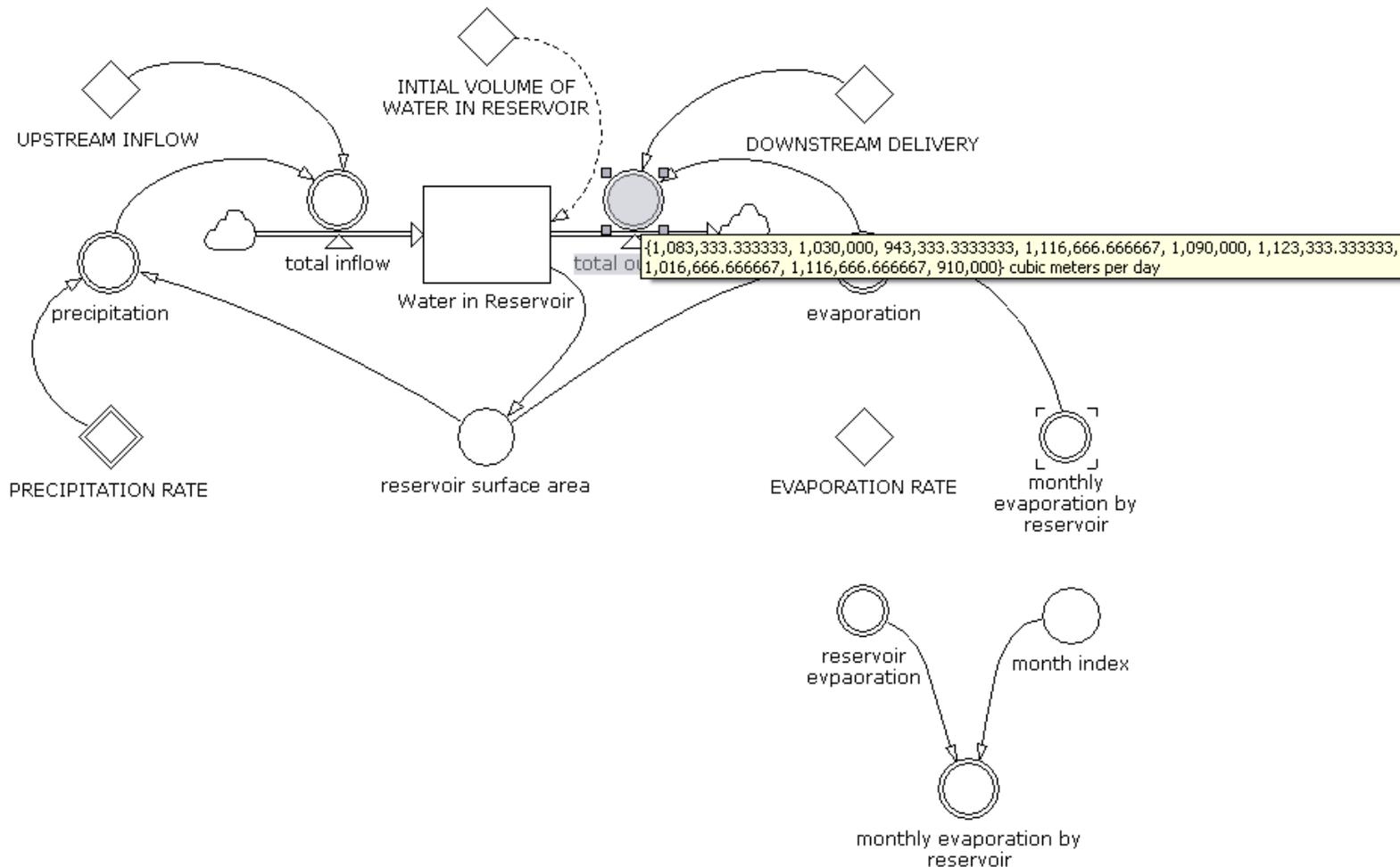
! The current simulation has the 'Automatic history' option turned on (Simulation settings). This option allows you to create time graphs after performing a simulation and see the results instantly (without having to simulate over again). Now the number of automatically recorded variable elements has exceeded 50 and therefore adds considerable overhead to the simulation, both in terms of memory consumption and performance.

Do you want to turn off the 'Automatic history' option now (strongly recommended)?

Buttons: Yes, No

Use XLDATA Variable

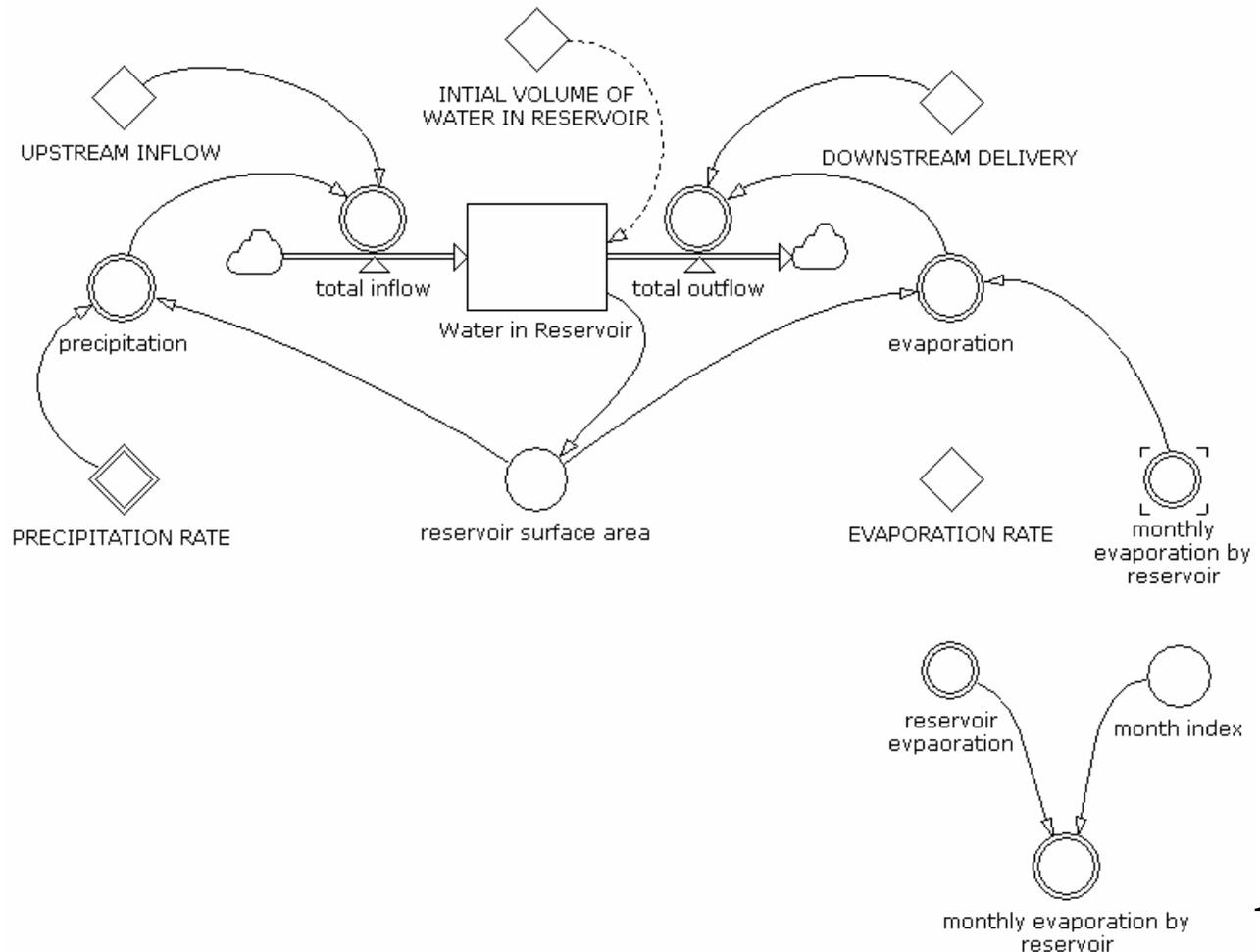
total outflow now has dimensions of 'Reservoirs' and **DOWNSTREAM DELIVERY** is used in the same way that **UPSTREAM INFLOW** is (see slide 69 for relevant details) .



Use XLDATA Variable

The reservoir model now includes reservoir-specific precipitation and evaporation data for the 9 reservoirs defined in the range 'Reservoirs'. **precipitation** is a single average monthly value for each of the reservoirs, while **evaporation** uses a different value for every month of the year for each of the reservoirs.

Because **evaporation** varies by month, we have to index it appropriately so that the model uses the correct value every month.



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Amman, Jordan

Other Useful Functions and Operators



Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



IF

Description

The **IF** function is used to conduct conditional tests on values and formulas.

Syntax

IF(*Condition*, *A*, *B*, *C*)

Explanation

Condition is the statement that you are evaluating.

The IF statement returns *A* when *Condition* is true.

The IF statement returns *B* when *Condition* is false.

The IF statement returns *C* when *Condition* is indefinite.

Operator AND

Description

The **AND** operator is used to evaluate two arguments within the **IF** function.

Syntax

IF(*Condition1* **AND** *Condition2*, *A*, *B*, *C*)

Values

<i>Condition1</i>	<i>Condition2</i>	<i>Condition1</i> AND <i>Condition2</i>
FALSE	FALSE	FALSE
FALSE	TRUE	FALSE
TRUE	FALSE	FALSE
FALSE	INDEFINITE	FALSE
INDEFINITE	FALSE	FALSE
TRUE	TRUE	TRUE
TRUE	INDEFINITE	INDEFINITE
INDEFINITE	TRUE	INDEFINITE
INDEFINITE	INDEFINITE	INDEFINITE

Operator OR

Description

The **OR** operator is used to evaluate two arguments within the **IF** function.

Syntax

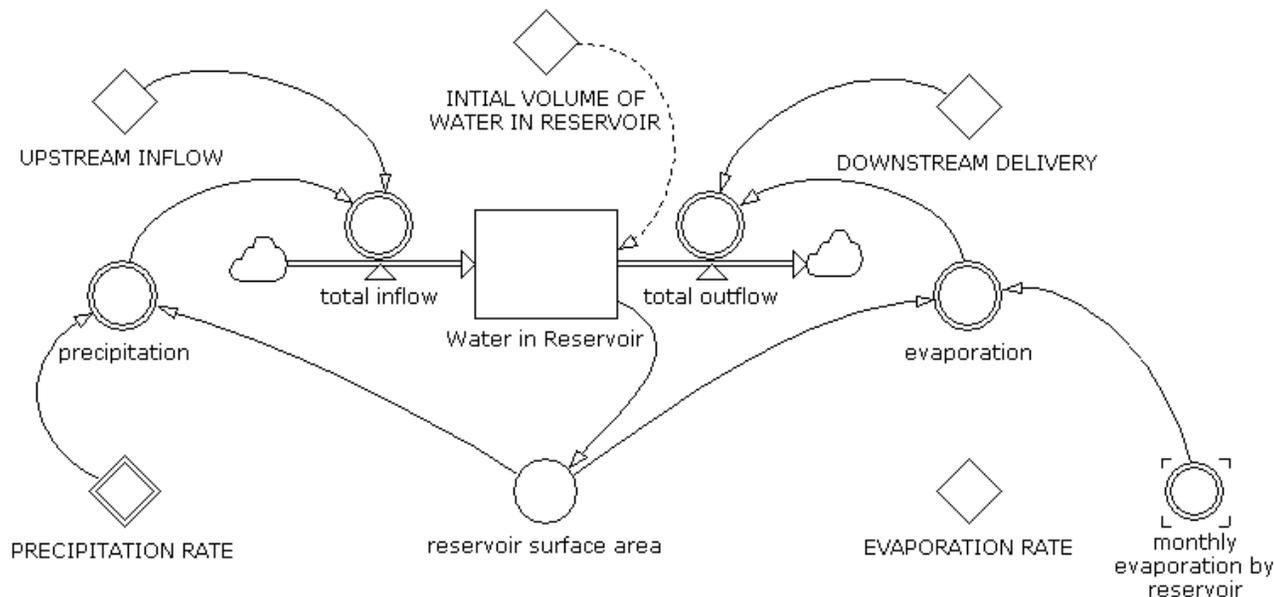
IF(*Condition1* **OR** *Condition2*, *A*, *B*, *C*)

Values

<i>Condition1</i>	<i>Condition2</i>	<i>Condition1</i> OR <i>Condition2</i>
FALSE	FALSE	FALSE
TRUE	FALSE	TRUE
FALSE	TRUE	TRUE
TRUE	TRUE	TRUE
INDEFINITE	FALSE	FALSE
INDEFINITE	TRUE	TRUE
TRUE	INDEFINITE	TRUE
FALSE	INDEFINITE	FALSE
INDEFINITE	INDEFINITE	INDEFINITE

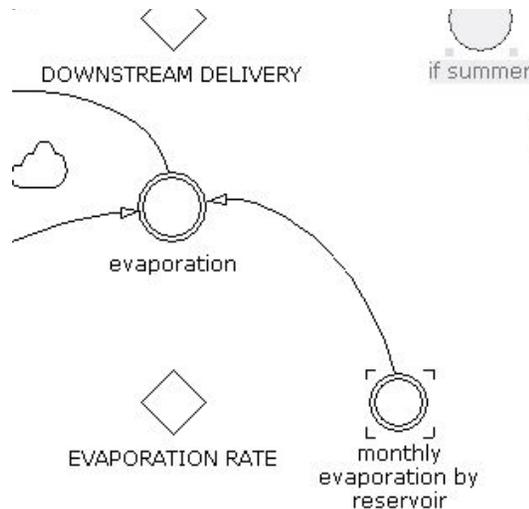
Apply IF to Reservoir Model

Suppose you want to change your downstream deliveries based on what time of year it is. Using the **IF** function, we will create a variable that calculates whether or not the current simulation date is during the summer season. If it is summer, downstream deliveries will increase. If it is not summer, downstream deliveries will decrease.

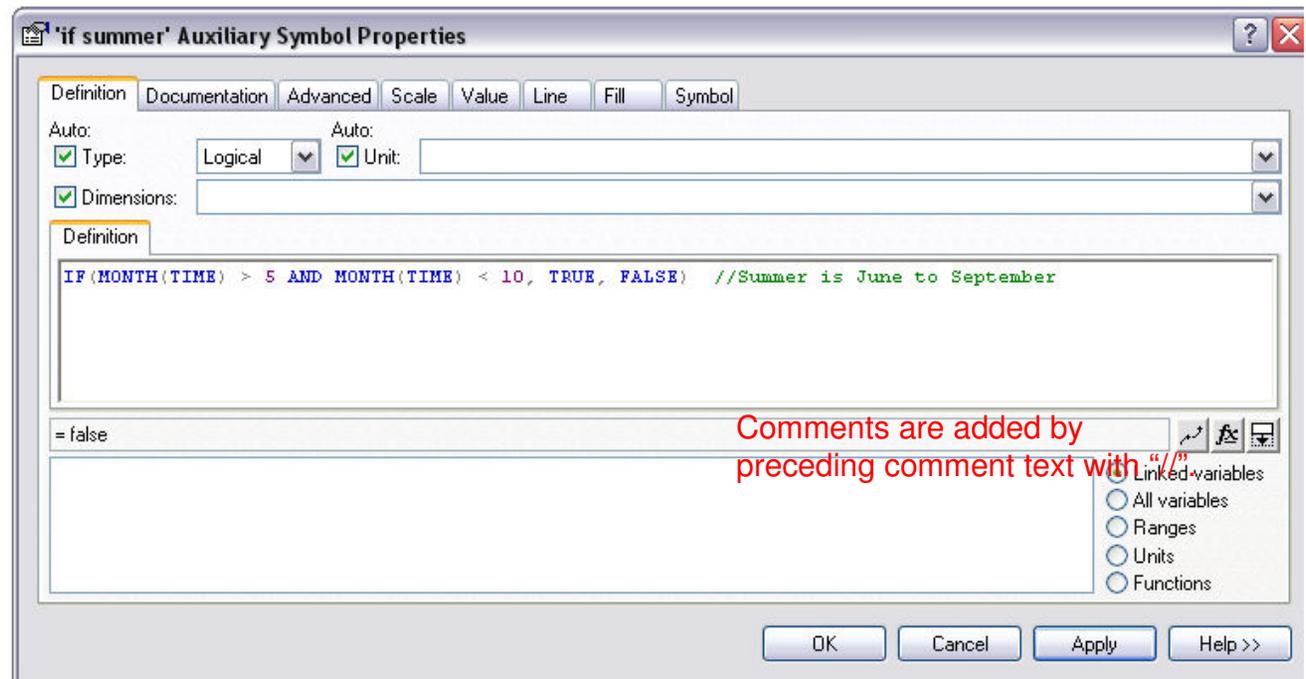


Apply IF to Reservoir Model

Create variable **if summer** and define it as shown below. This statement says that if the current simulation time is between June (greater than May) and September (less than October), then return the value **TRUE**, otherwise return the value **FALSE**.

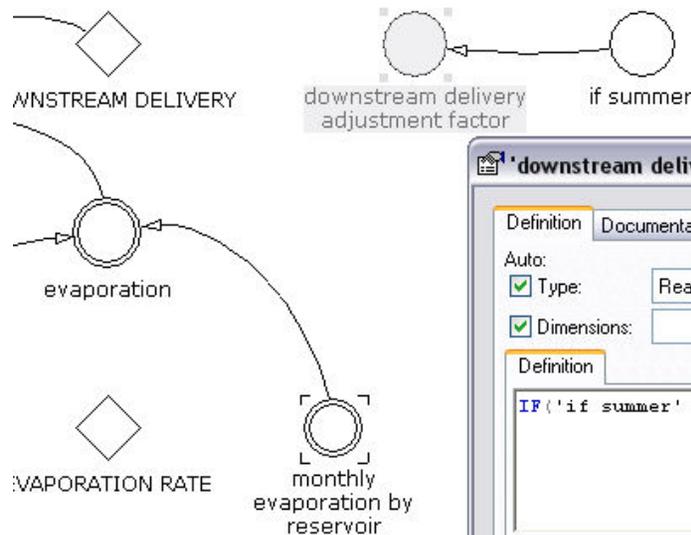


This definition could be embedded in the variable that uses it and still function properly. However, this is poor modeling practice because then **if summer** might be effectively “lost”.



Apply IF to Reservoir Model

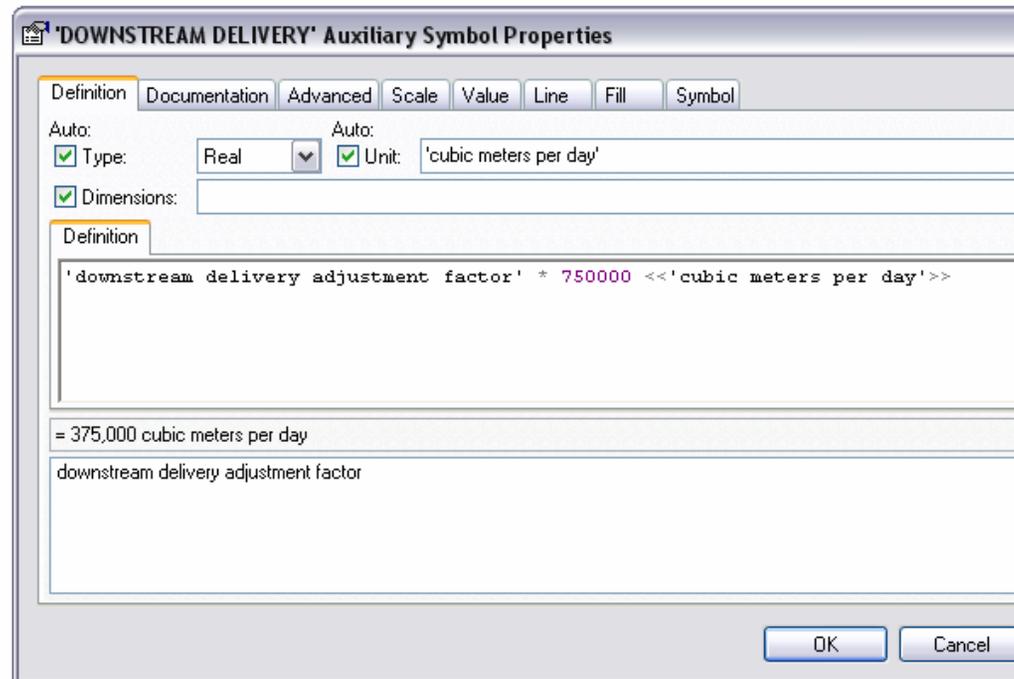
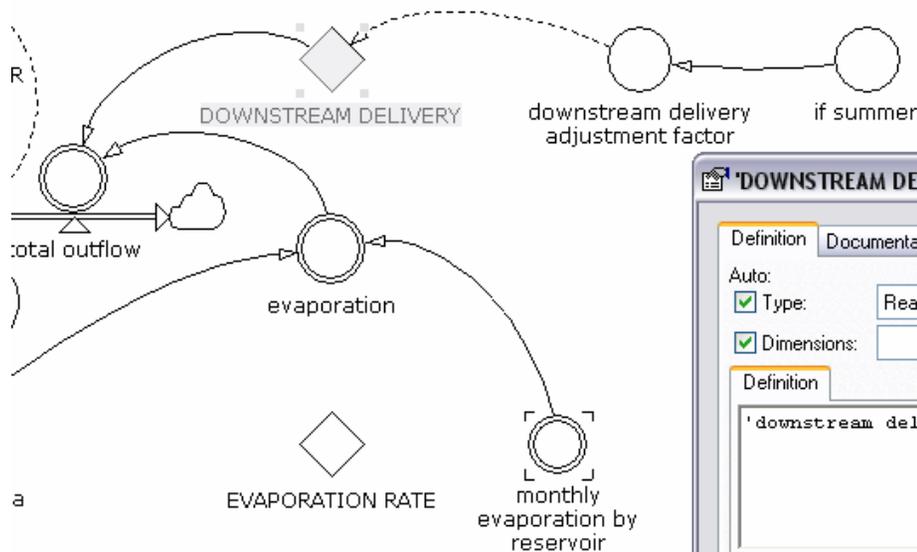
Create variable **downstream delivery adjustment factor** and define it as shown below. This statement says that if is summer (**if summer** is **TRUE**), return the value 1.5, otherwise return the value 0.5.



The screenshot shows the 'downstream delivery ...' Auxiliary Symbol Properties dialog box. The 'Definition' tab is active, displaying the definition: `IF('if summer' = TRUE, 1.5, 0.5)`. A red note states: **Note that these values are arbitrary.** The dialog also shows options for Type (Real), Unit, and Dimensions, and a list of variable types (Linked variables, All variables, Ranges, Units, Functions).

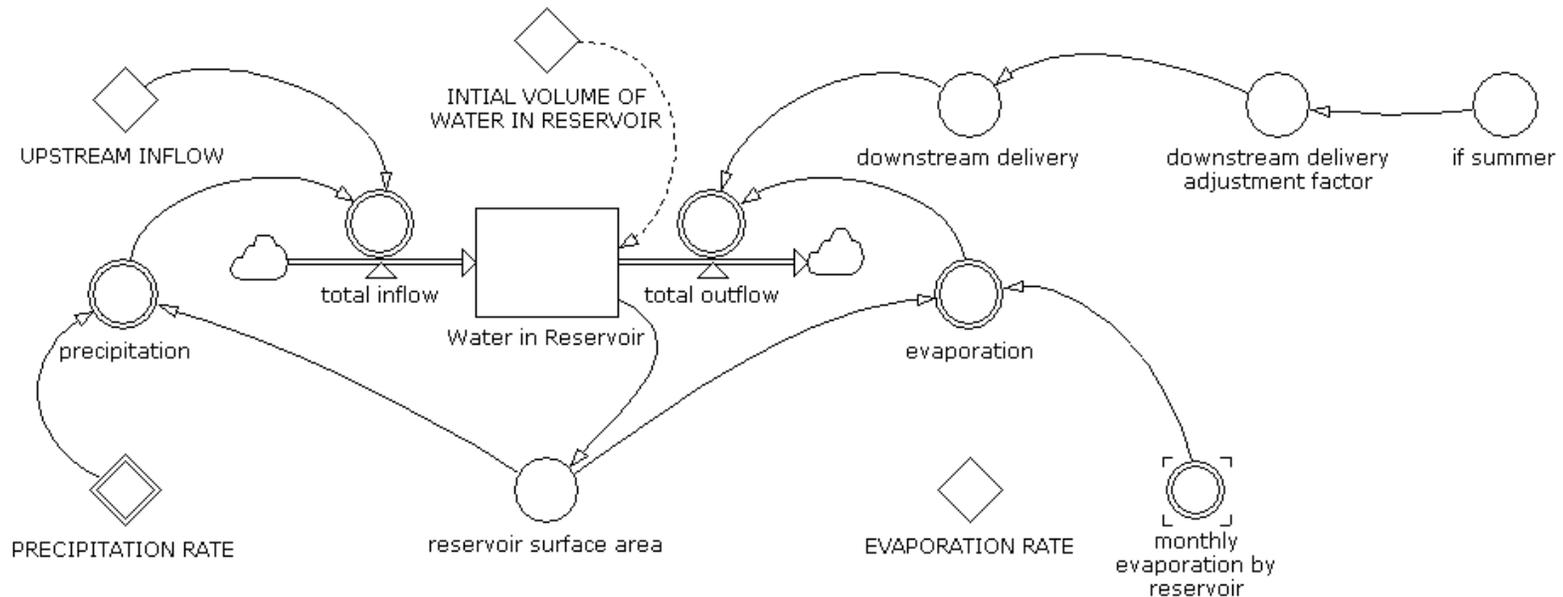
Apply IF to Reservoir Model

Attach **downstream delivery adjustment factor** to **DOWNSTREAM DELIVERY** and redefine **DOWNSTREAM DELIVERY** as shown below. You must change **DOWNSTREAM DELIVERY** to an auxiliary for this calculation to work properly. Go to the Advanced tab and make this change.



Apply IF to Reservoir Model

downstream delivery is now an auxiliary (circle icon and name in all lowercase). If the current simulation time is during the summer (between June and September), the original fixed value that defined **DOWNSTREAM DELIVERY** will be increased by 50%. Otherwise, the original fixed value will be decreased by 50%.



FOR

Description

The **FOR** function is used to perform operations on elements of an array.

Generic Examples

FOR(i =1..3 | i * 1<<m>>) = {1, 2, 3}m

FOR(i =1..2, j =1..2 | i+j) = {{1+1, 1+2},{2+1, 2+2}} = {{2,3},{3,4}}

Important note

i, *j*, and *k* are internal index variables. Otherwise, you must use a variable that you have created.

Apply FOR to Reservoir Model

Suppose you want to perform calculations specific to the reservoirs on the Tigris and its tributaries. We did this on slide 85 by calling individual elements from the ‘**Reservoirs**’ array. Now we want to create a range with the Tigris reservoirs only. This range can be used with the **FOR** function to calculate the same average that we did on slide 85.

Adhaim,'Derbendi Khan',Dokan,Hemrin,Mosul,Habbaniyah,Haditha,Razzaza,Tharthar

In the Global Ranges window, reorder the elements in the range ‘**Reservoirs**’ so that all of the Tigris reservoirs appear first. Do this by right-clicking any element and selecting “Move Up” or “Move Down”.

Apply FOR to Reservoir Model

Now, create an enumeration subrange called “Tigris Reservoirs” using Adhaim through Mosul from the ‘**Reservoirs**’ enumeration range.

Adhaim, 'Derbendi Khan',Dokan,Hemrin,Mosul,Habbaniyah,Haditha,Razzaza,Tharthar

Add Range

Definition
Specify the definition of the new range or index variable.

Category: Enumeration subrange

Enumeration: Reservoirs

First: Adhaim

Last: Mosul

Definition:
Adhaim..Mosul

Status:

< Back Next > Finish Cancel Help >>

Apply FOR to Reservoir Model

Create the variable **precipitation on Tigris reservoirs** and use the **FOR** function and the newly created 'Tigris Reservoirs' subrange to define it.

The image shows a reservoir model diagram and a dialog box for defining a variable. The diagram includes a central box labeled 'Water in Reservoir' with arrows for 'total inflow' and 'total outflow'. It also shows 'precipitation' and 'evaporation' processes. A separate diagram shows a 'PRECIPITATION RATE' variable being applied to 'precipitation on Tigris reservoirs'.

The dialog box, titled 'precipitation on Tig...' Auxiliary Symbol Properties, has the following settings:

- Auto: Type: Real, Unit: mm/mo
- Dimensions: 'Tigris Reservoirs'
- Definition: `FOR(i = 'Tigris Reservoirs' | 'PRECIPITATION RATE'[i])`
- Value: = {316, 316, 316, 400, 374} mm/mo
- Linked variables: Linked variables, All variables, Ranges, Units, Functions

A red arrow points to the definition field with the text: **Precipitation is shown for the reservoirs on the Tigris only.**

MIN

Description

The **MIN** function returns the smallest of the elements in Input1, Input2, The function needs at least two input parameters. The minimum value is found element by element and the function returns an array of the same dimension as its input parameters.

Syntax

MIN(Input1, Input2, Input3, ...)

Examples

MIN(1,2,3,4) = 1

MIN({4,5,2,3},{3,2,1,6}) = {3,2,1,3}

MAX

Description

The **MAX** function returns the largest of the elements in Input1, Input2, The function needs at least two input parameters. The maximum value is found element by element and the function returns an array of the same dimension as its input parameters.

Syntax

MAX(Input1, Input2, Input3, ...)

Examples

MAX(1,2,3,4) = 4

MAX({4,5,2,3},{3,2,1,6}) = {4,5,2,6}

NUMERICAL

Description

For a range element in an enumeration range, the **NUMERICAL** function returns the numerical value of a corresponding element in a numerical subrange starting at 1.

Generic Example

Enumeration range = {'RangeElement1', 'RangeElement2', 'RangeElement3'}

Numerical subrange corresponding to above enumeration range = {1, 2, 3}

NUMERICAL('RangeElement2') = 2

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Building an Interface

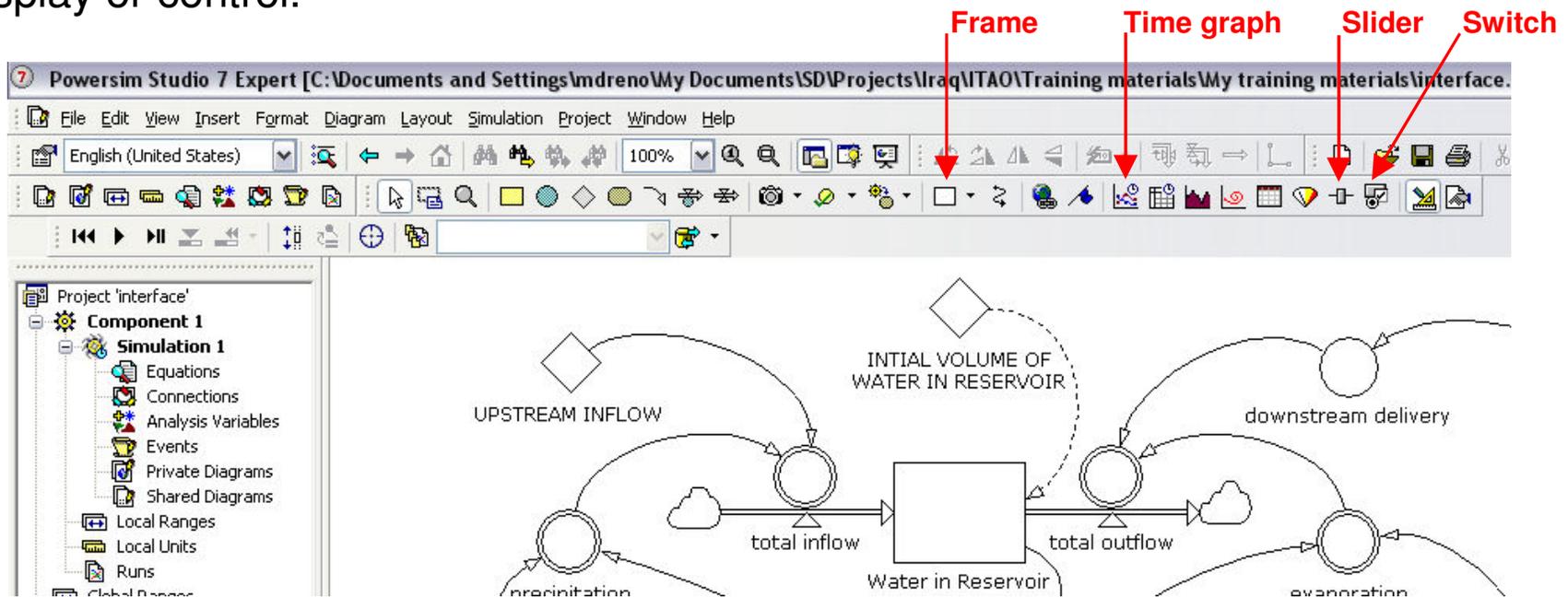


Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



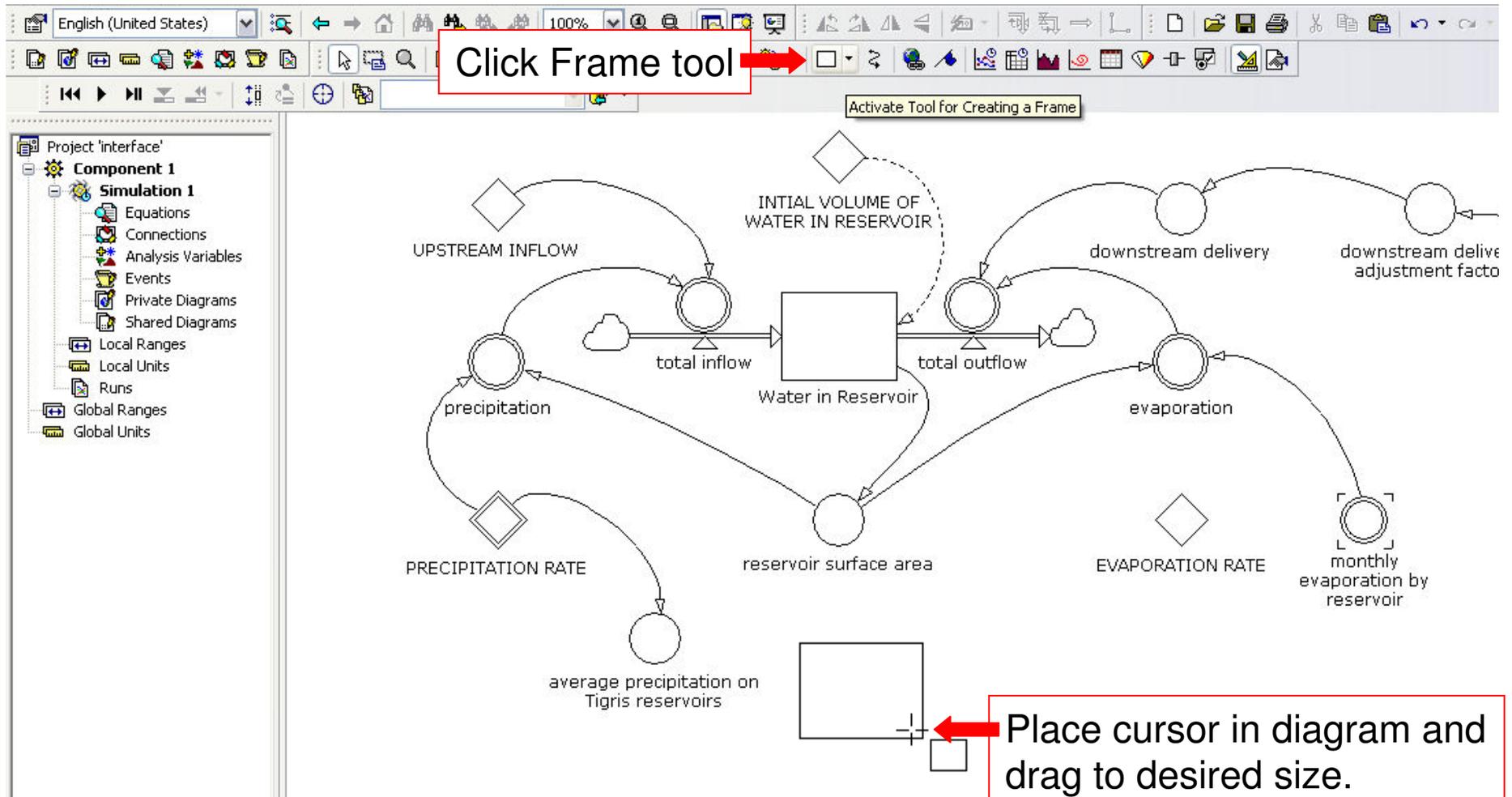
Basic Interface Components

Studio provides several interface components that are easily accessed by clicking the appropriate icon on the menu bar and adding the selected component to the diagram window in the same way that a Level is added (slide 39). The components that we will demonstrate are frames  (commonly referred to as “text boxes”), time graphs , sliders , and switches . The easiest way to use any of these components is to add a blank copy to the diagram window and then drag and drop the variable that you want it to display or control.



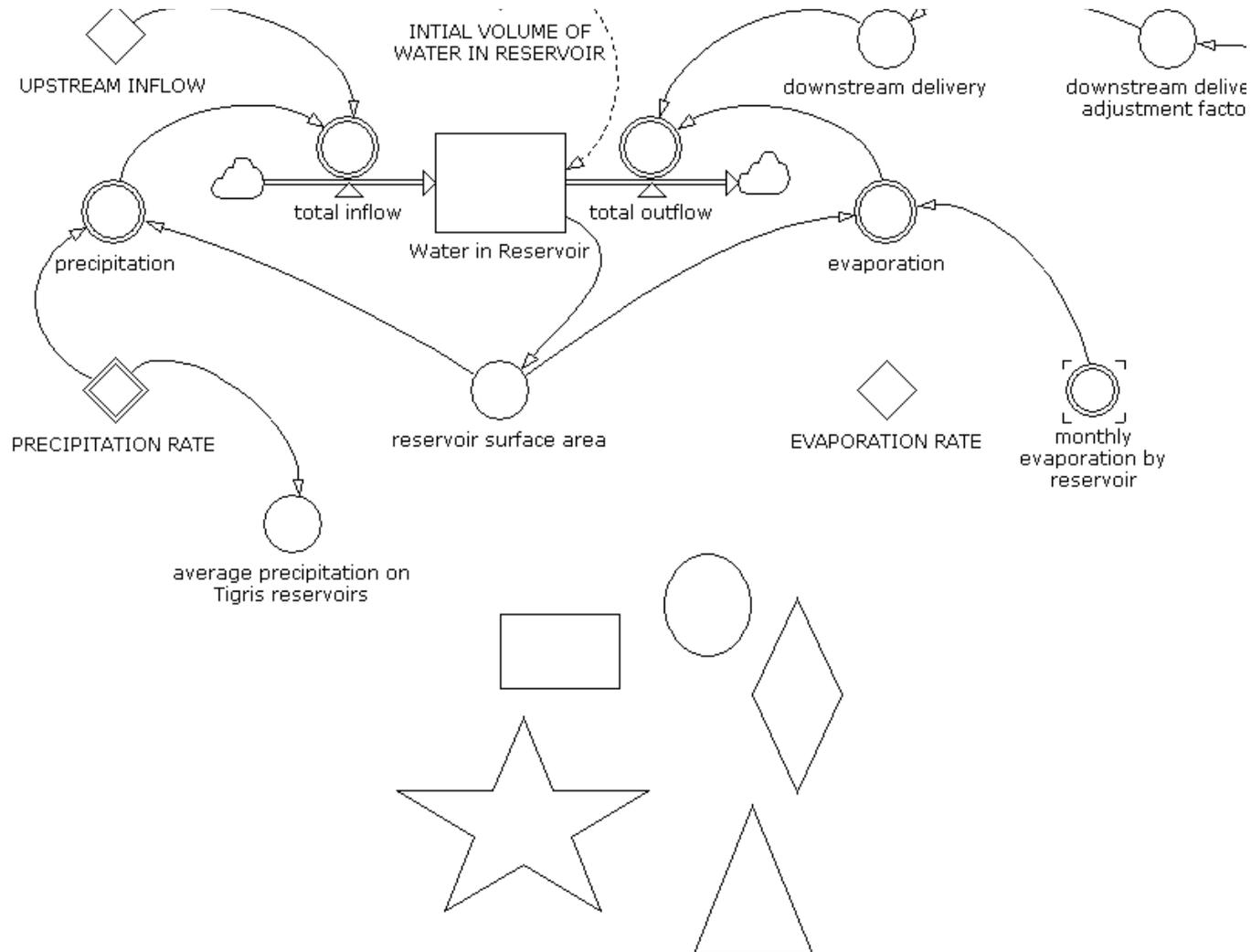
Basic Interface Components

Create a frame.



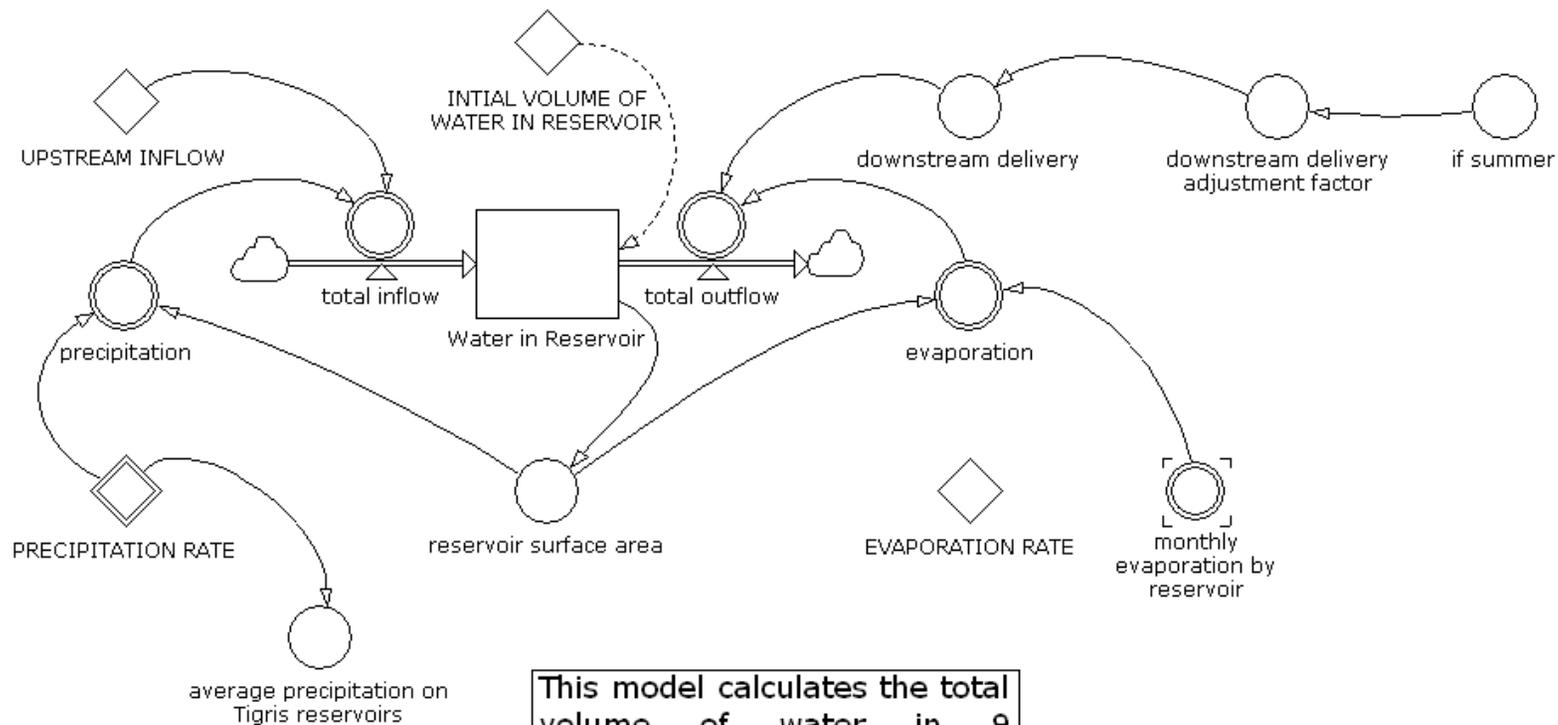
Basic Interface Components

Create several small empty frames of various shapes to familiarize yourself with frame shape options.



Basic Interface Components

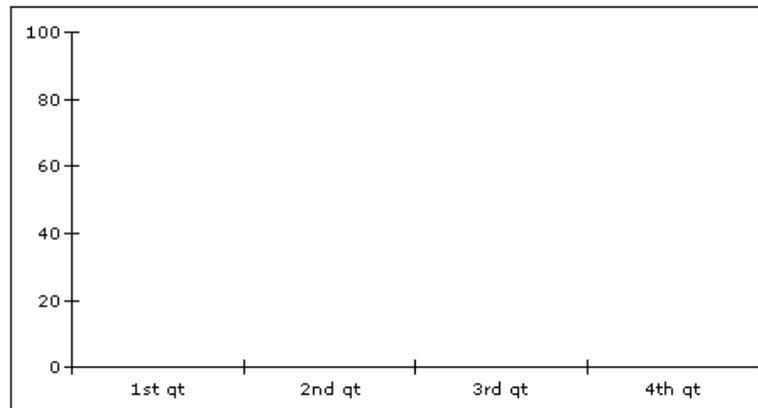
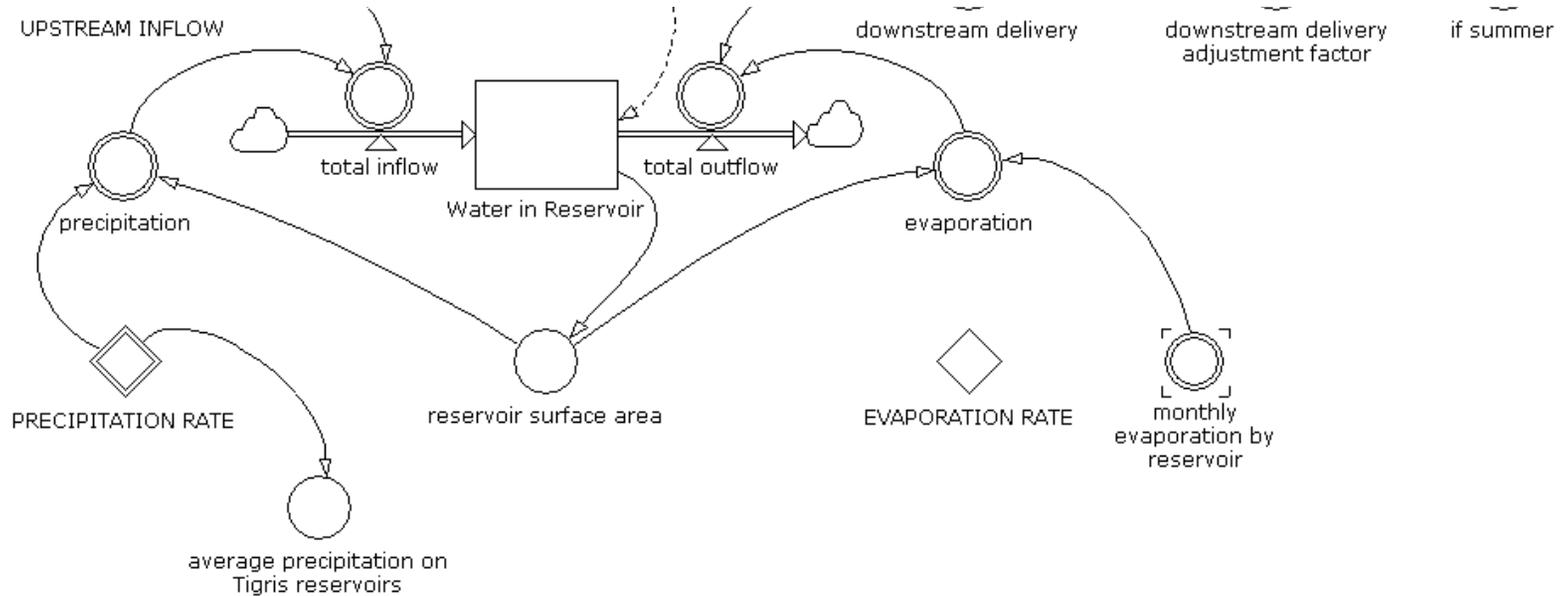
Use frame to display text, outline select variables, or enhance the appearance of other interface components. Frames can also be used to note important points as you are building a model.



This model calculates the total volume of water in 9 reservoirs as a function of inflows and outflows. Inflow includes precipitation and flow from upstream. Outflow includes evaporation and downstream deliveries.

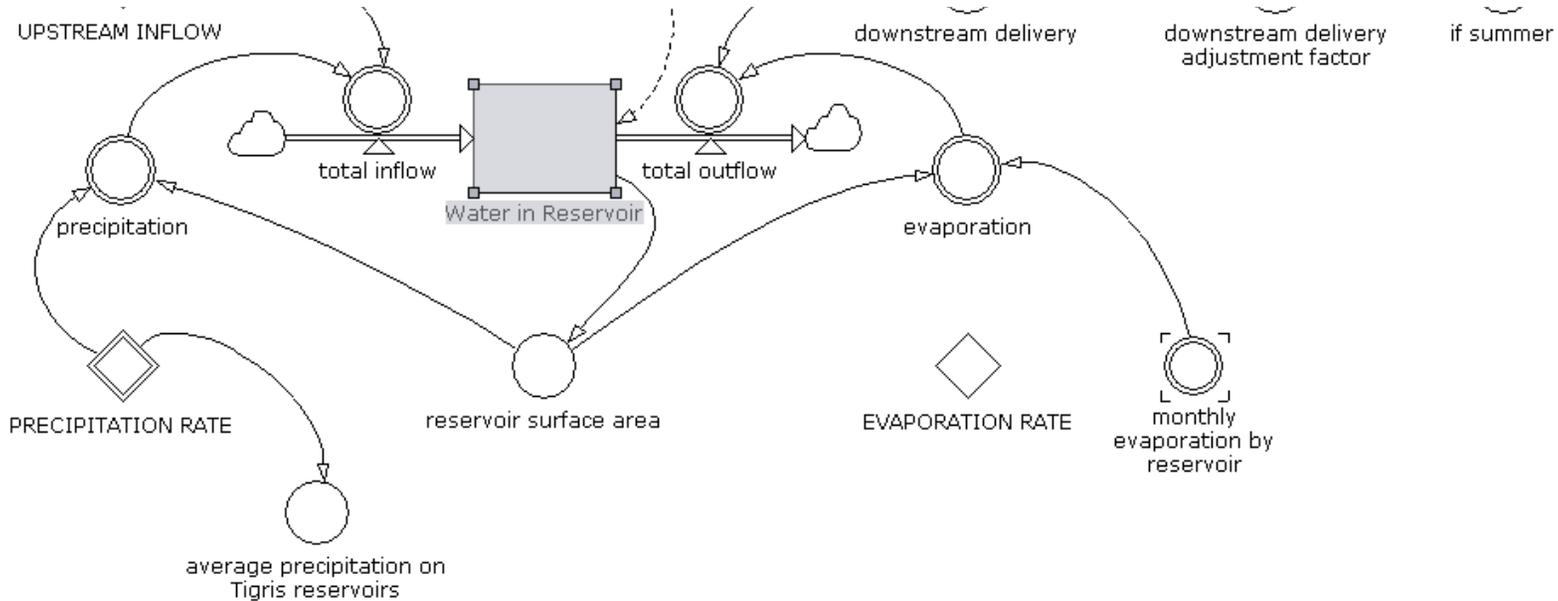
Basic Interface Components

Create empty time graph in the same way that you created a frame. See slide 124 for time graph icon. See slide 125 for drag-and-drop method.

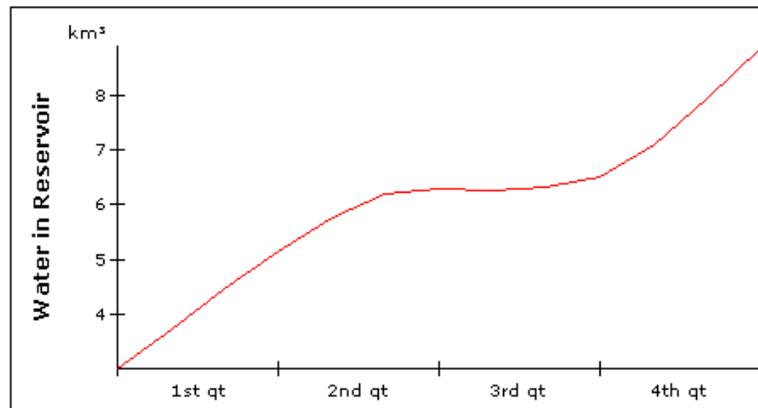


Basic Interface Components

Create time graph of **Water in Reservoir**.

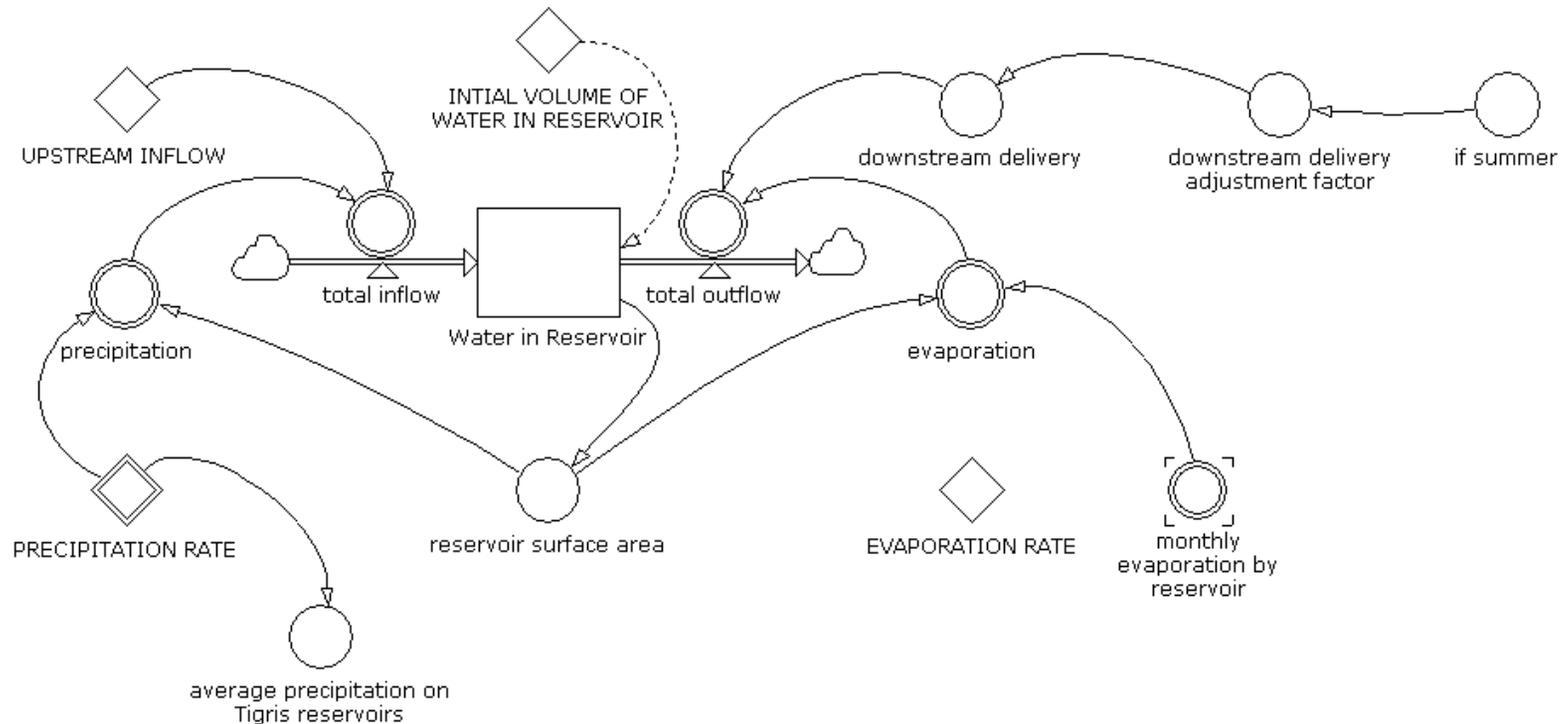


Draw empty
Time Graph
and then drag
**Water in
Reservoir**
into it.



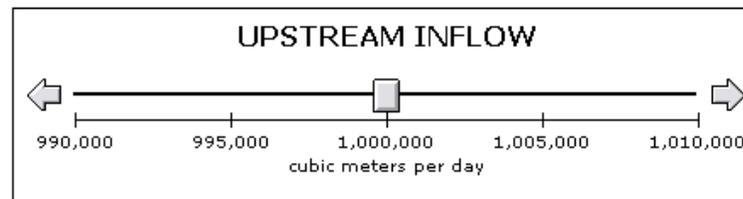
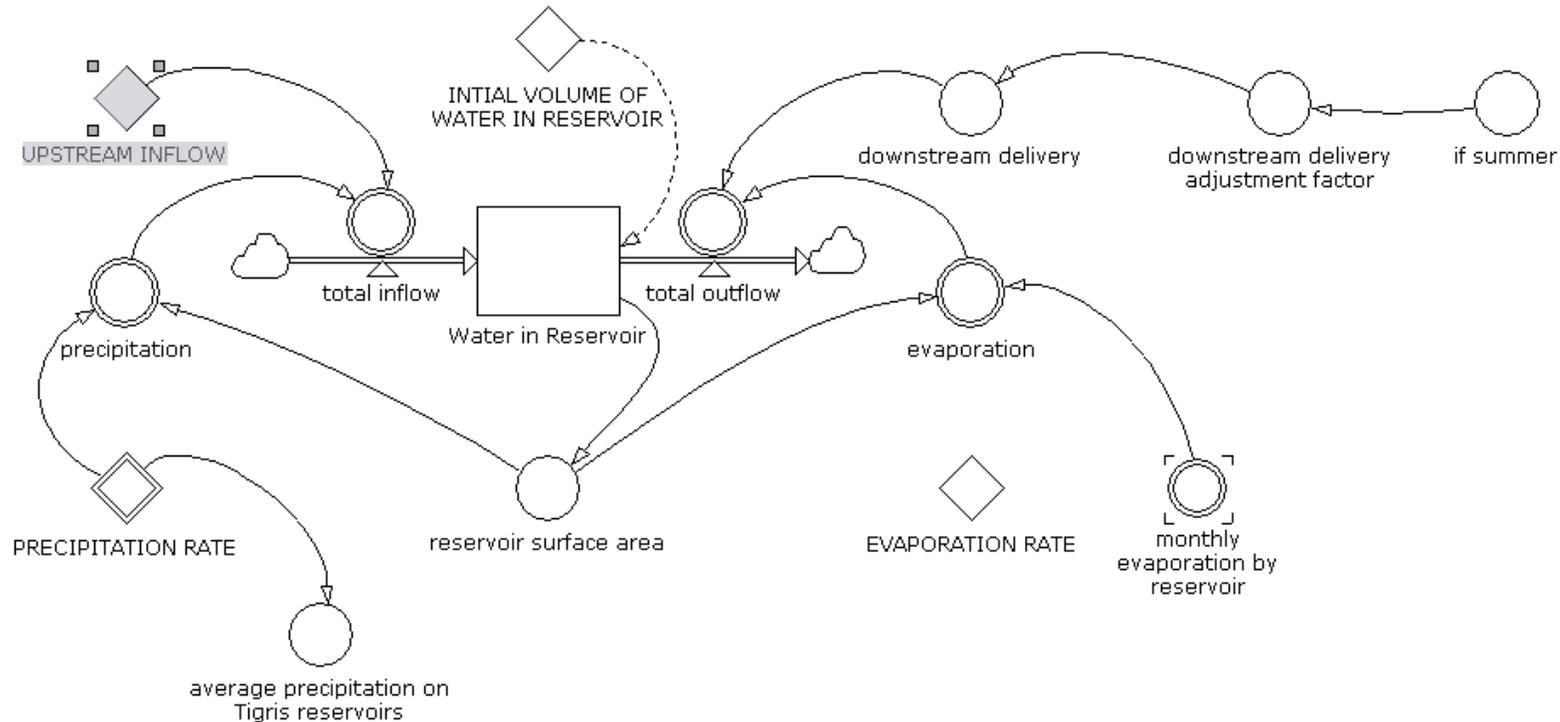
Basic Interface Components

Create an empty slider. See slide 124 for slider icon. See slide 125 for drag-and-drop method.



Basic Interface Components

Drag and drop **UPSTREAM INFLOW** into slider.



Basic Interface Components

To demonstrate the utility of the switch tool, we are going to create a new variable: **DROUGHT SWITCH**. This switch will have two values: 0 and 1. If 0 is selected, the simulation will assume precipitation conditions that are drier than normal. If 1 is selected, wetter than normal conditions will be assumed.

The diagram illustrates the configuration of a 'DROUGHT SWITCH' variable in a simulation. The flowchart shows the relationship between 'precipitation', 'Water in Reservoir', and 'evaporation'. The 'DROUGHT SWITCH' variable is represented by a diamond symbol. The dialog box 'DROUGHT SWITCH' Auxiliary Symbol Properties is open, showing the variable's definition and configuration options.

'DROUGHT SWITCH' Auxiliary Symbol Properties

Definition | Documentation | Advanced | Scale | Value | Line | Fill | Symbol

Auto: Type: Real Unit:

Dimensions:

Definition

```
0
//0: conditions that are drier than average
//1: conditions that are wetter than average
```

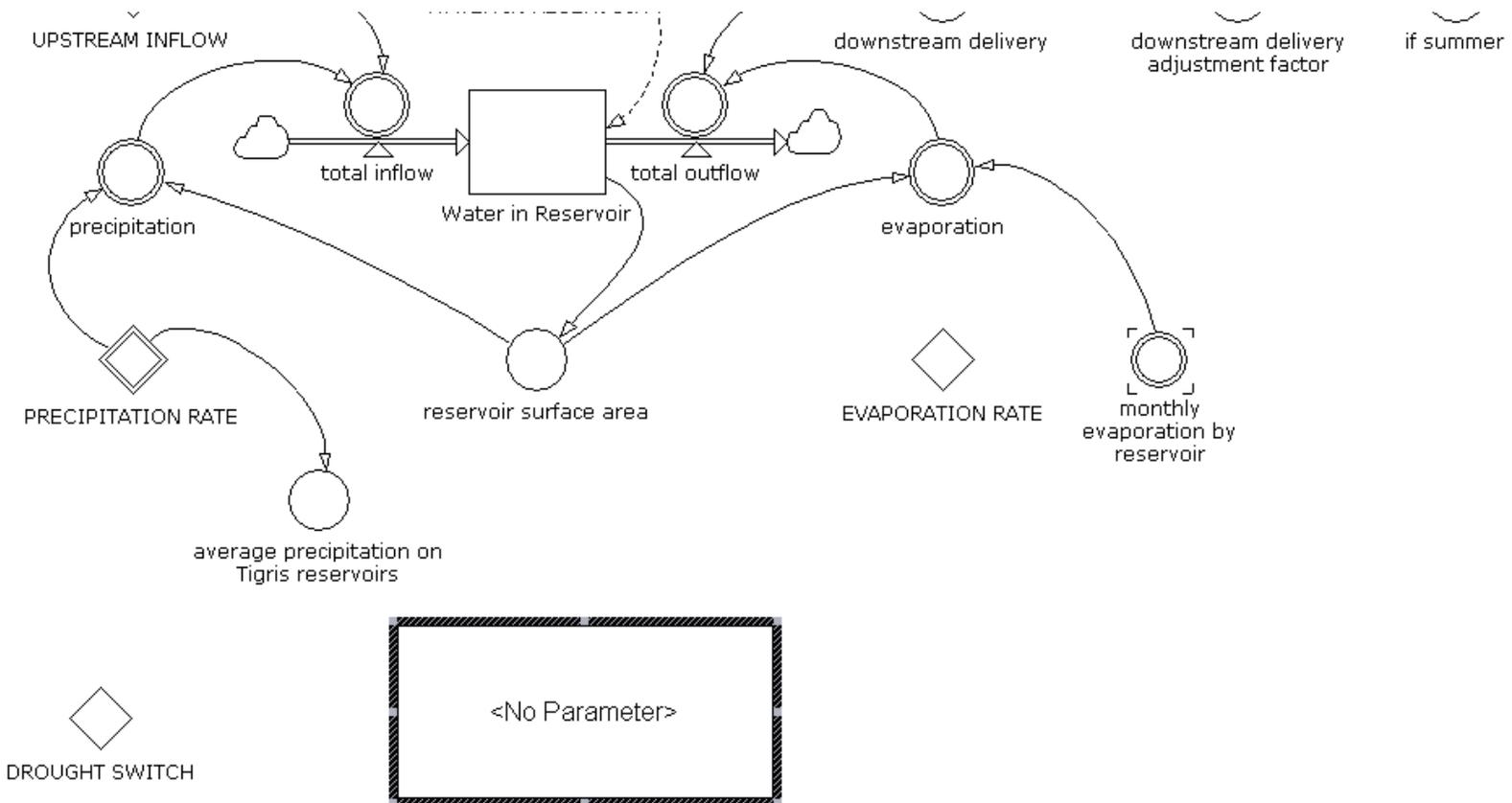
= 0

Linked variables
 All variables
 Ranges
 Units
 Functions

OK Cancel Apply Help >>

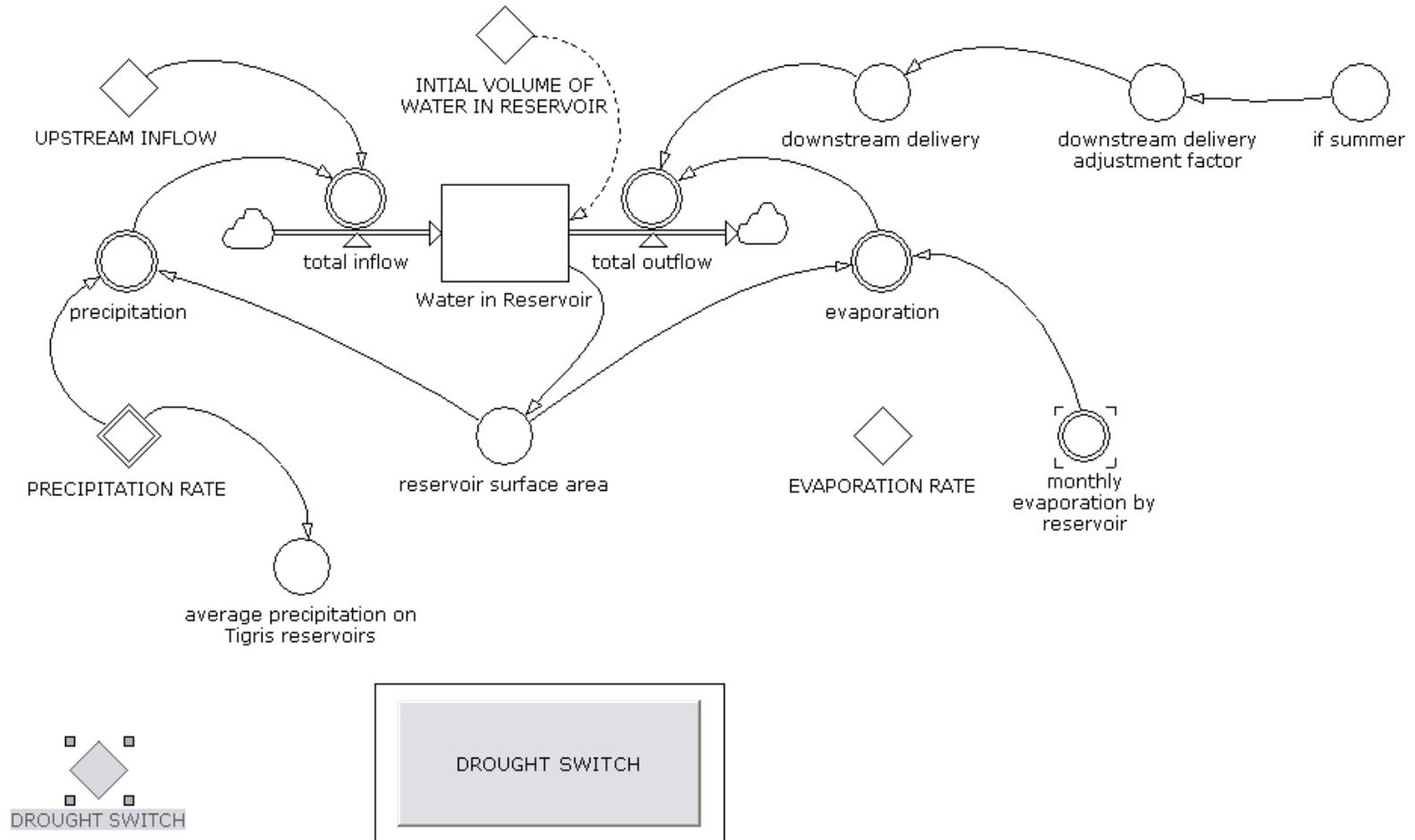
Basic Interface Components

Create empty switch control. See slide 124 for switch icon. See slide 125 for drag-and-drop method.



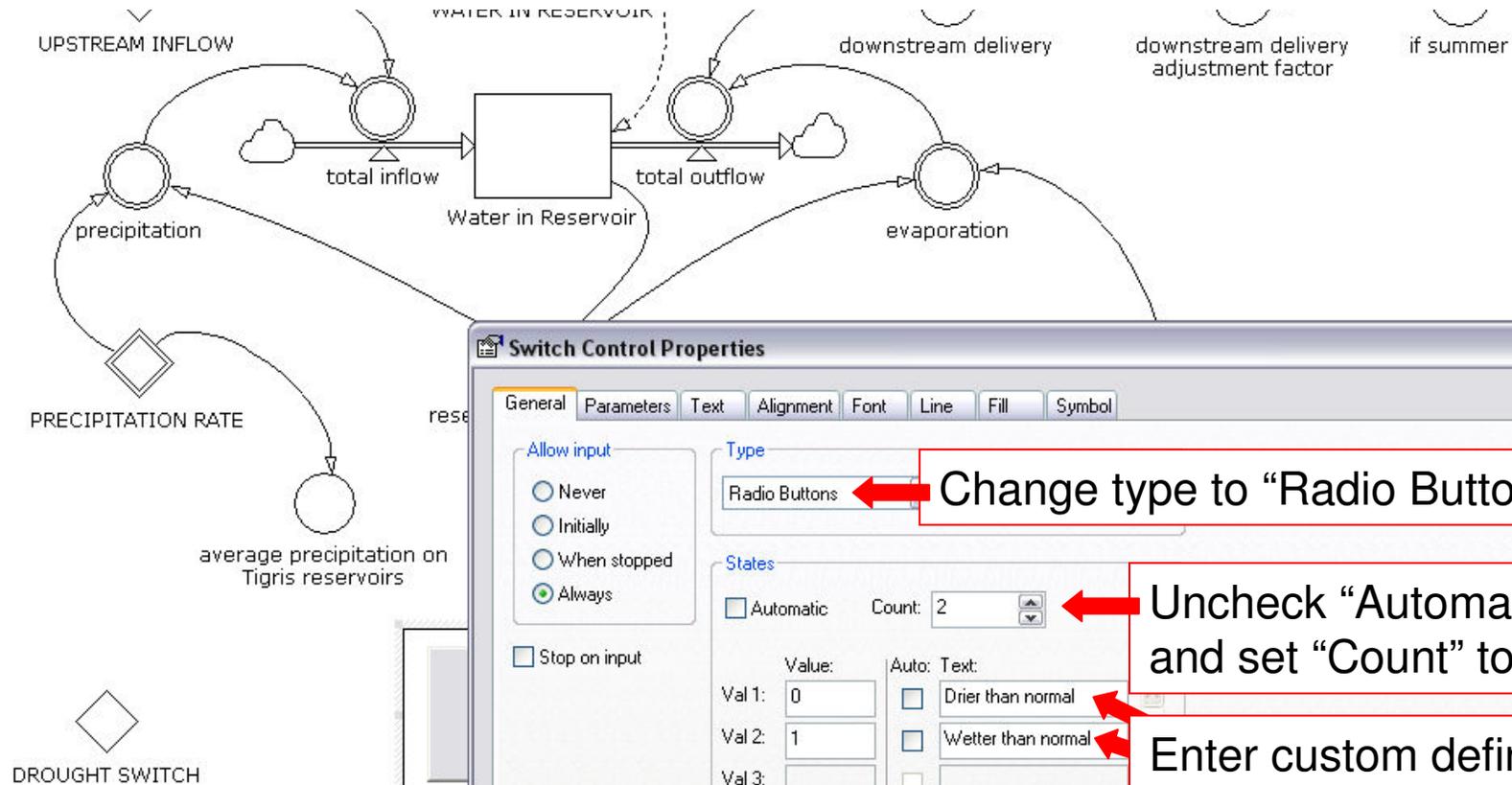
Basic Interface Components

Drag and drop **DROUGHT SWITCH** into switch control.



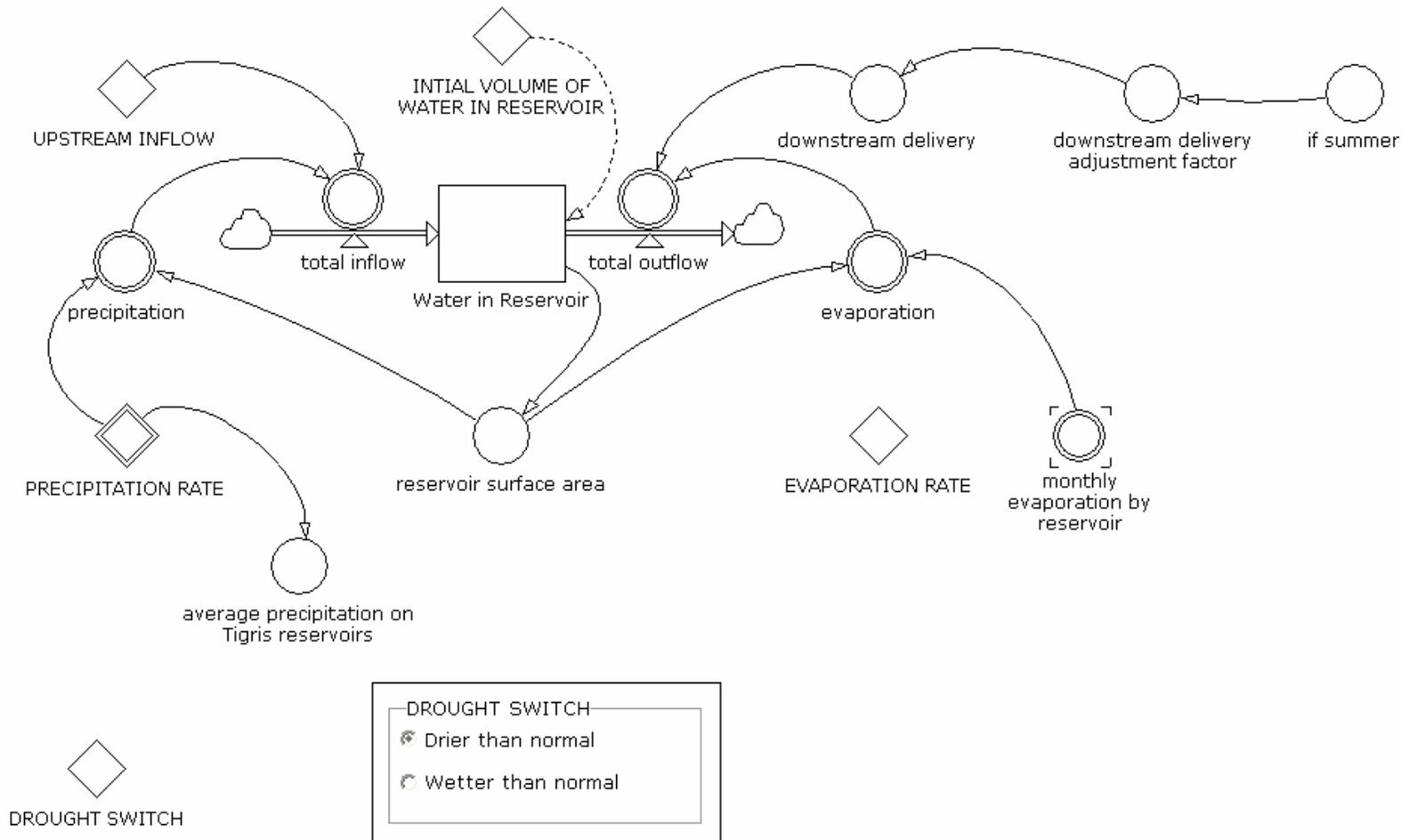
Basic Interface Components

Customize switch.



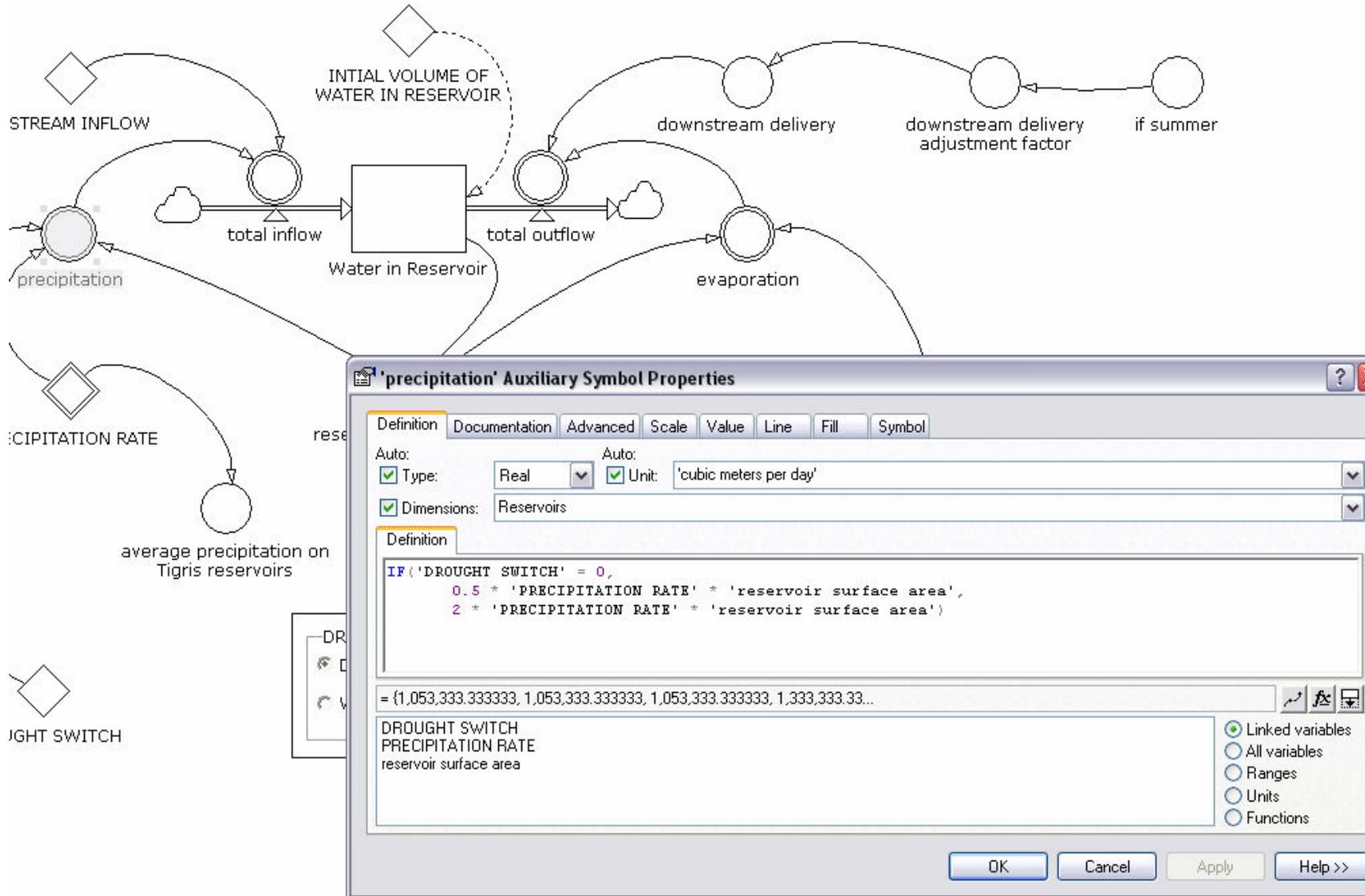
Basic Interface Components

You can now select “Drier than normal” or “Wetter than normal” precipitation conditions by toggling your choice on the switch control.



Basic Interface Components

Connect **DROUGHT SWITCH** to **precipitation** and redefine **precipitation** as shown.



Reservoir Model Interface

Rename blank diagram "Interface" and cut and paste all interface components here.

This model calculates the total volume of water in 9 reservoirs as a function of inflows and outflows. Inflow includes precipitation and flow from upstream. Outflow includes evaporation and downstream deliveries.

DROUGHT SWITCH

- Drier than normal
- Wetter than normal

UPSTREAM INFLOW

← 990,000 995,000 1,000,000 1,005,000 1,010,000 →
cubic meters per day

Water in Reservoir

km³

4.0
3.5
3.0
2.5

1st qt 2nd qt 3rd qt 4th qt

Diagram 1 Diagram 2 Interface

01/01/2007

Reservoir Model Interface

Run model.

Project 'interface'

- Component 1
 - Simulation 1
 - Equations
 - Connections
 - Analysis Variables
 - Events
 - Private Diagrams
 - Shared Diagrams
 - Local Ranges
 - Local Units
 - Runs
 - Global Ranges
 - Global Units

This model calculates the total volume of water in 9 reservoirs as a function of inflows and outflows. Inflow includes precipitation and flow from upstream. Outflow includes evaporation and downstream deliveries.

DROUGHT SWITCH

- Drier than normal
- Wetter than normal

UPSTREAM INFLOW

990,000 995,000 1,000,000 1,005,000 1,010,000
cubic meters per day

water in Reservoir

km³

4.5
4.0
3.5

1st qt 2nd qt 3rd qt 4th qt

Double-click to reformat axis.

Double-click the outer line of any interface component (frame, time graph, slider, or switch) to, customize fonts (size and color), lines (thickness and color), and axes (line thickness and color).

Create Reference Run

Add model run to reference runs.

The screenshot shows the Powersim Studio 7 Expert interface. The 'Simulation' menu is open, and the 'Add to Runs...' option is highlighted. A tooltip for 'Add to Runs...' is visible, containing the text: 'calculates the total of water in 9 as a function of l outflows. Inflow ecipitation and flow cream. Outflow evaporation and n deliveries.'

The interface also shows a project tree on the left with 'Simulation 1' selected, and a graph on the right titled 'Water in Reservoir' showing water volume in km³ over four quarters. The graph shows a peak in the 2nd quarter and a trough in the 3rd quarter.

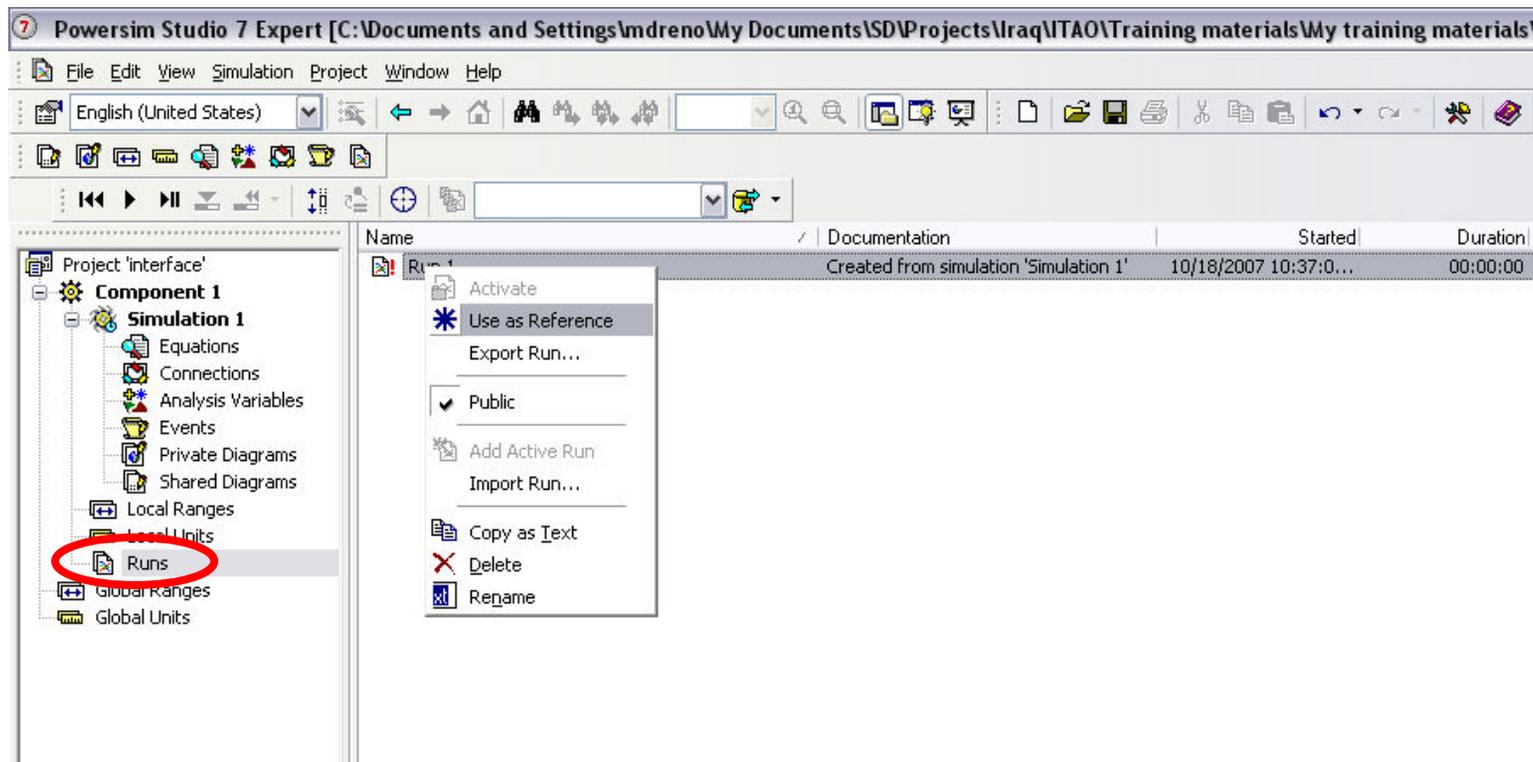
Below the menu, a slider control is visible for 'DROUGHT' with a value of 1,000,000 cubic meters per day. The x-axis ranges from 990,000 to 1,010,000.

Create Reference Run

The screenshot displays the SimStudio 7 Expert interface. The title bar reads "SimStudio 7 Expert [C:\Documents and Settings\mdreno\My Documents\SD\Projects\Iraq\ITA0\Training materials\My training materials\interface.sip *] - Shared Dia". The menu bar includes View, Insert, Format, Diagram, Layout, Simulation, Project, Window, and Help. The toolbar contains various icons for navigation and simulation control. On the left, a tree view shows the simulation structure: Component 1, Simulation 1, Equations, Connections, Analysis Variables, Events, Private Diagrams, Shared Diagrams, Local Ranges, Local Units, Units, and Global Ranges. The main workspace contains a "DROUGHT SWITCH" control with radio buttons for "Drier than normal" (selected) and "Wetter than normal". Below it is a slider for "UPSTREAM INFLOW" ranging from 990,000 to 1,000,000 cubic meters per day. A text box explains: "This model calculates the total volume of water in 9 reservoirs as a function of inflows and outflows. Inflow includes precipitation and flow from upstream. Outflow includes evaporation and downstream deliveries." An "Add to Runs..." dialog box is open, showing "Name: Run 1" and "Documentation: Created from simulation 'Simulation 1'". A graph on the right shows a red curve over time, with a label "4th qt" on the x-axis.

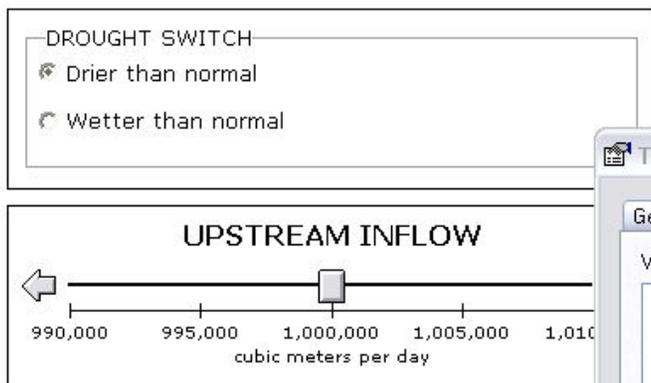
Create Reference Run

Saved run must now be set as “Reference”. Make this change by going to Runs window, right-clicking “Run 1”, and selecting “Use as Reference”. Then return to interface page (double-click Shared Diagrams).

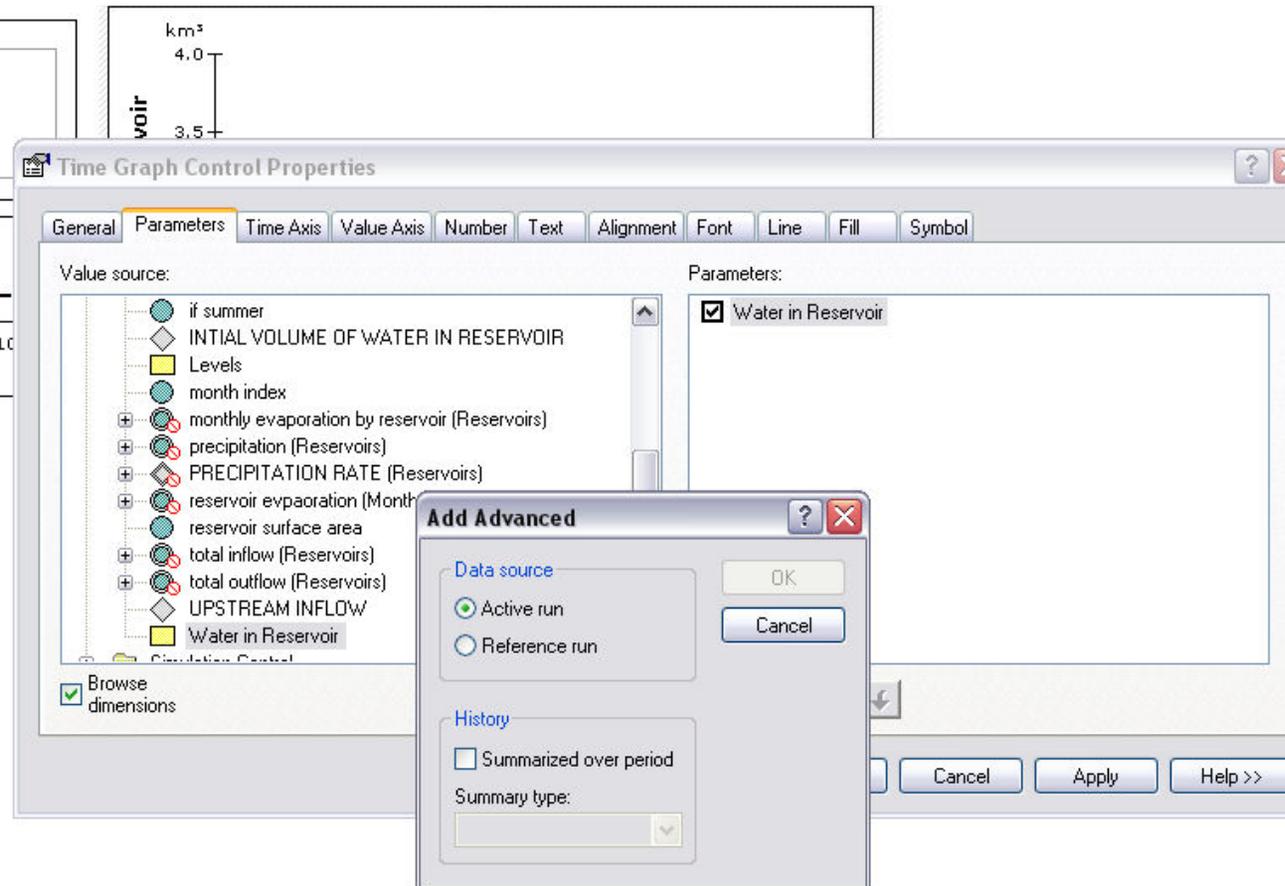


Create Reference Run

Reset model. Double-click time graph to view its properties. Click Parameters tab. **Water in Reservoir** will appear in the parameter list (this list shows the variables that the time graph will display).



From the value source list, select **Water in Reservoir**. When you try and add it to the parameter list, the Add Advanced box appears and you must toggle "Reference run" and click "OK". Click "OK" again to exit properties box.



Create Reference Run

Notice new legend on time graph.

The screenshot displays a software interface with a menu bar (File, View, Insert, Format, Diagram, Layout, Simulation, Project, Window, Help) and a toolbar. A left sidebar lists components like 'Component 1' and 'Simulation 1'. A central text box explains the model's function. Below it, a 'DROUGHT SWITCH' panel has radio buttons for 'Drier than normal' and 'Wetter than normal'. An 'UPSTREAM INFLOW' slider is set to 1,000,000 cubic meters per day. On the right, a line graph titled 'Water in Reservoir' shows two data series: 'Current' (red) and 'Reference' (blue). The 'Reference' series is circled in red. The graph's y-axis is labeled 'Water in Reservoir' with units 'km³' and values 3.5, 4.0, 4.5. The x-axis is labeled '1st qt', '2nd qt', '3rd qt', '4th qt'.

This model calculates the total volume of water in 9 reservoirs as a function of inflows and outflows. Inflow includes precipitation and flow from upstream. Outflow includes evaporation and downstream deliveries.

DROUGHT SWITCH

Drier than normal

Wetter than normal

UPSTREAM INFLOW

990,000 995,000 1,000,000 1,005,000 1,010,000

cubic meters per day

Water in Reservoir

km³

4.5

4.0

3.5

1st qt 2nd qt 3rd qt 4th qt

Current

Reference

Create Reference Run

Toggle “Wetter than normal” in **DROUGHT SWITCH**. Run model and note change in **Water in Reservoir**.

