

Introduction to WaterGEMS



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History of WaterGEMS

1983: *KYPIPE* – 1st IBM-PC fully capable implementation of the mainframe solution for water distribution modeling

1991: *Cybernet* – 1st AutoCAD-based water distribution modeling solution

1996: *WaterCAD* – 1st commercial Windows stand-alone water distribution modeling solution

2002: *WaterGEMS* – 1st ArcGIS 8x water distribution modeling solution

2006: *WaterGEMS V8 XM Edition* – 1st MicroStation water distribution modeling solution

And: *WaterGEMS V8 XM Edition* – 1st fully unified cross-platform water distribution modeling solution

What is WaterGEMS?

- ✓ WaterGEMS is a comprehensive and easy to use water distribution modeling application.

OBJECTIVE

- To study the WaterGEMS software, to enhance our technical skills and to understand practical implementation of Pipe network analysis in broad area.

What is the software used for?

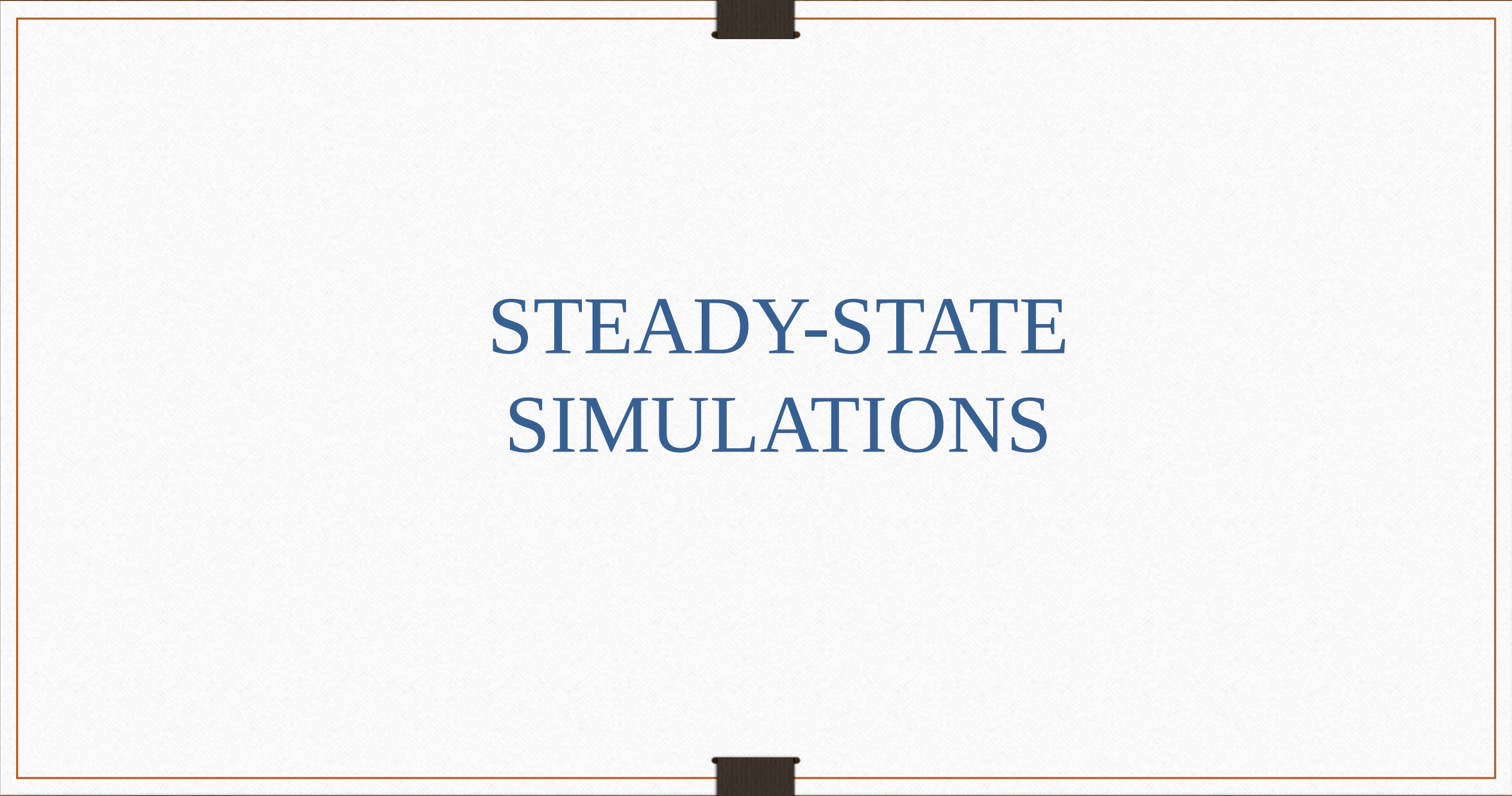
- ✓ Building a water-distribution network and performing steady state as well as extended period simulations
- ✓ Water Quality Analysis
- ✓ Network Design
- ✓ Model Calibration
- ✓ Network Design Optimization

THEORETICAL CONSIDERATIONS

- Hydraulic options control how the hydraulic computations are carried out. They consist of the following items:

Options	Descriptions
Flow Units	Units in which nodal demands and link flow rates are expressed. Choosing units in gallons, cubic feet, or acre-feet implies that the units for all other network quantities are Customary US. Selecting liters or cubic meters causes all other units to be SI metric. Use caution when changing flow units as it might affect all other data supplied to the project.

Options	Description
Headloss Formula	Formula used to compute headloss as a function of flow rate in a pipe. Choices are: • Hazen-Williams • Darcy-Weisbach • Chezy-Manning Because each formula measures pipe roughness differently, switching formulas might require that all pipe roughness coefficients be updated.
Methods	• Hardy Cross method • Linear optimization technique



STEADY-STATE SIMULATIONS

STEPS FOR SIMULATION EXERCISE

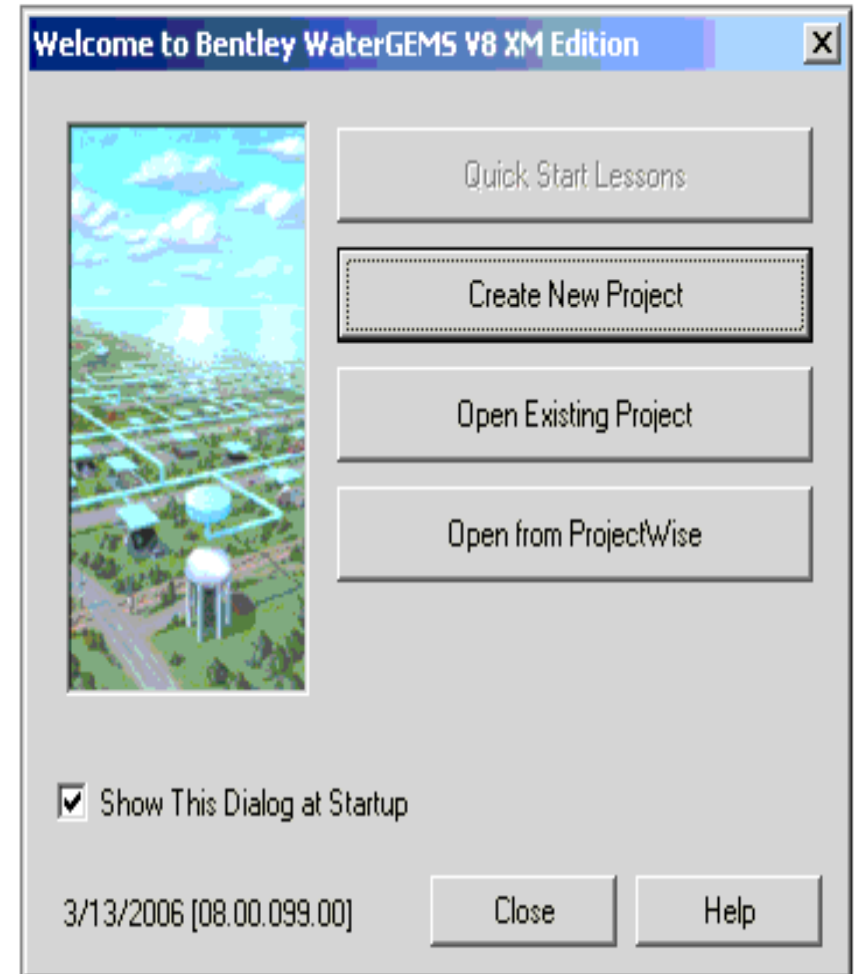
- 1) Selection of Drawing Mode and Units
- 2) Lay-out the network
- 3) Enter and modify data for different elements
- 4) Run a steady-state analysis

Building a Network and Performing a Steady-State Analysis

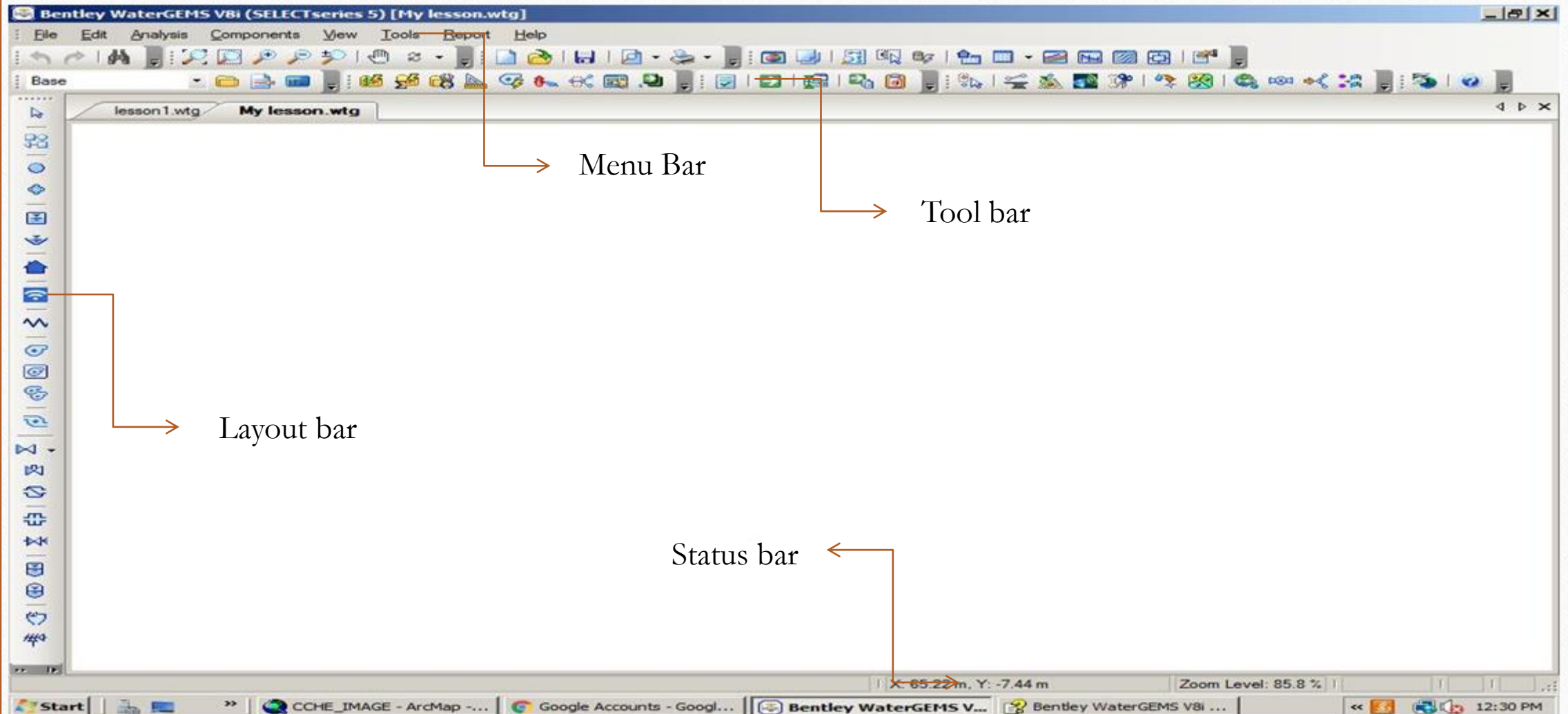
Step 1: Create a New Project File

Using the WaterCAD V8*i* interface:

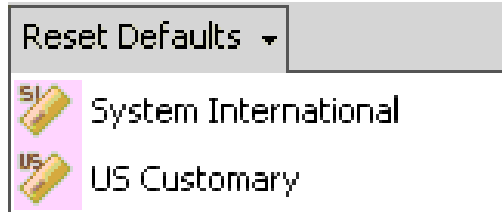
- ✓ Double-click the Bentley WaterCAD V8*i* icon.
The welcome dialog box opens.
- ✓ Click **Create New Project** and an untitled project opens.



Windows of WaterGEMS



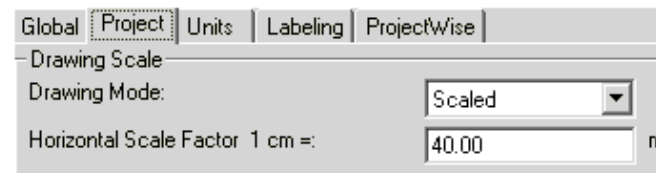
3. Choose **Tools > Options > Units**. Since you will be working in System International units, click **Reset Defaults to System International**.



4. Verify that the **Default Unit System for New Project** is set to **SI**. If not, select from



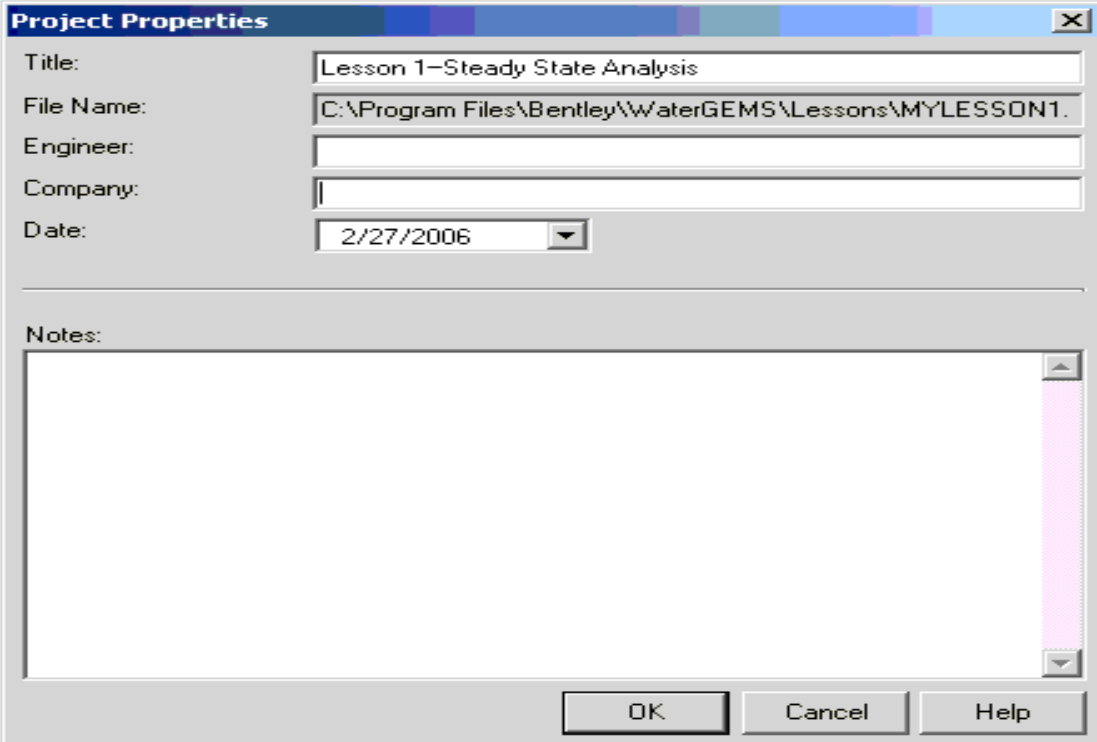
5. Select the **Project** tab to make sure **Drawing Mode** is set to **Scaled**.



6. Set the Horizontal Scale Factor 1 cm = 40 m.

7. Click OK.

8. Set up the project. Choose File > Project Properties and name the project Lesson 1—Steady State Analysis and click OK.

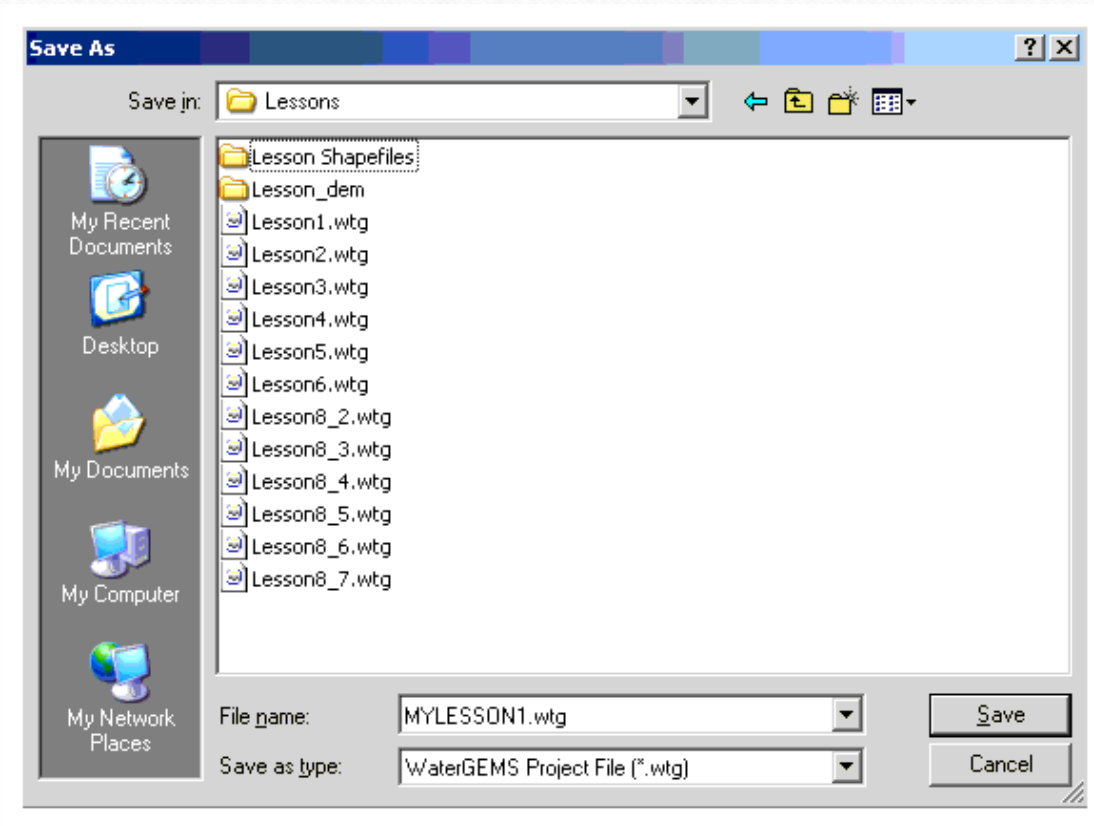


The screenshot shows the 'Project Properties' dialog box with the following fields and values:

Field	Value
Title:	Lesson 1—Steady State Analysis
File Name:	C:\Program Files\Bentley\WaterGEMS\Lessons\MYLESSON1.
Engineer:	
Company:	
Date:	2/27/2006

Below the fields is a 'Notes:' section with a large text area. At the bottom of the dialog are three buttons: 'OK', 'Cancel', and 'Help'.

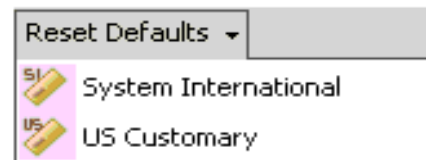
9. Choose File > Save as. In the Save File As dialog box, double-click the Lesson folder.



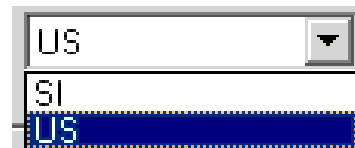
10. Enter the file name MYLESSON1.WTG for your project, and click Save.

Using the AutoCAD interface:

1. Double-click the Bentley WaterCAD V8i desktop icon to start Bentley WaterCAD V8i for AutoCAD.
2. Choose Tools > Options > Units. Since you will be working in System International units, click Reset Defaults to System International.



3. Verify that the Default Unit System for New Project is set to SI. If not, select from the menu.



4. Click OK.

5. Select File > Open

6. Select the existing AutoCAD file LESSON1.DWG from the Lesson folder.

7. With the drawing open, select File > Save As. In the Save Drawing As dialog box, double-click the Lesson folder, enter the filename as

MYLESSON1.DWG and click Save to save the file in your \Bentley WaterCAD V8i\Lesson directory. Now, select the Layout Elements tool in the Bentley WaterCAD V8i toolbar.

Then, move the cursor onto the drawing pane and right-click to select Reservoir from the shortcut menu. Click the approximate location of reservoir R-1 (see diagram above). You will be prompted to set up the project. Click Yes to open the Project Setup Wizard.

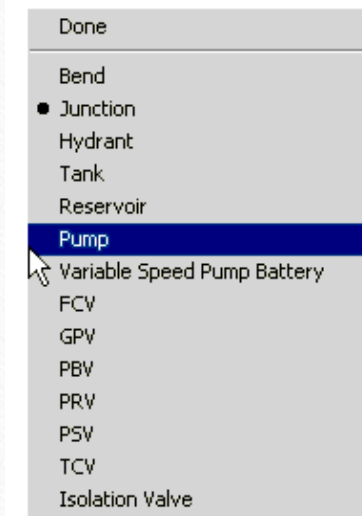
8. In the Project Setup Wizard, title the project Lesson 1—Steady State Analysis and click the Next button.
9. Choose your desired settings. For this lesson, use the program default values. Click the Next button.
10. Select the Scaled button located under the Drawing Scale option. Set the horizontal scale to $1 \text{ mm} = 4000 \text{ mm}$, and the vertical scale to $1 \text{ mm} = 400 \text{ mm}$.
11. Click the Next button to continue.
12. The element prototype buttons allow you to set default values for each element type. We will use the default prototype values in this lesson, so click the Finished button.

Step 2: Lay out the Network

1. Select Pipe  from the layout toolbar.
2. Move the cursor on the drawing pain and right click to select Reservoir from the  nu or click from the toolbar.
3. Click to place R-1.
4. Move the cursor to the location of pump P-1. Right-click and select Pump from the shortcut menu.

Click to place it.

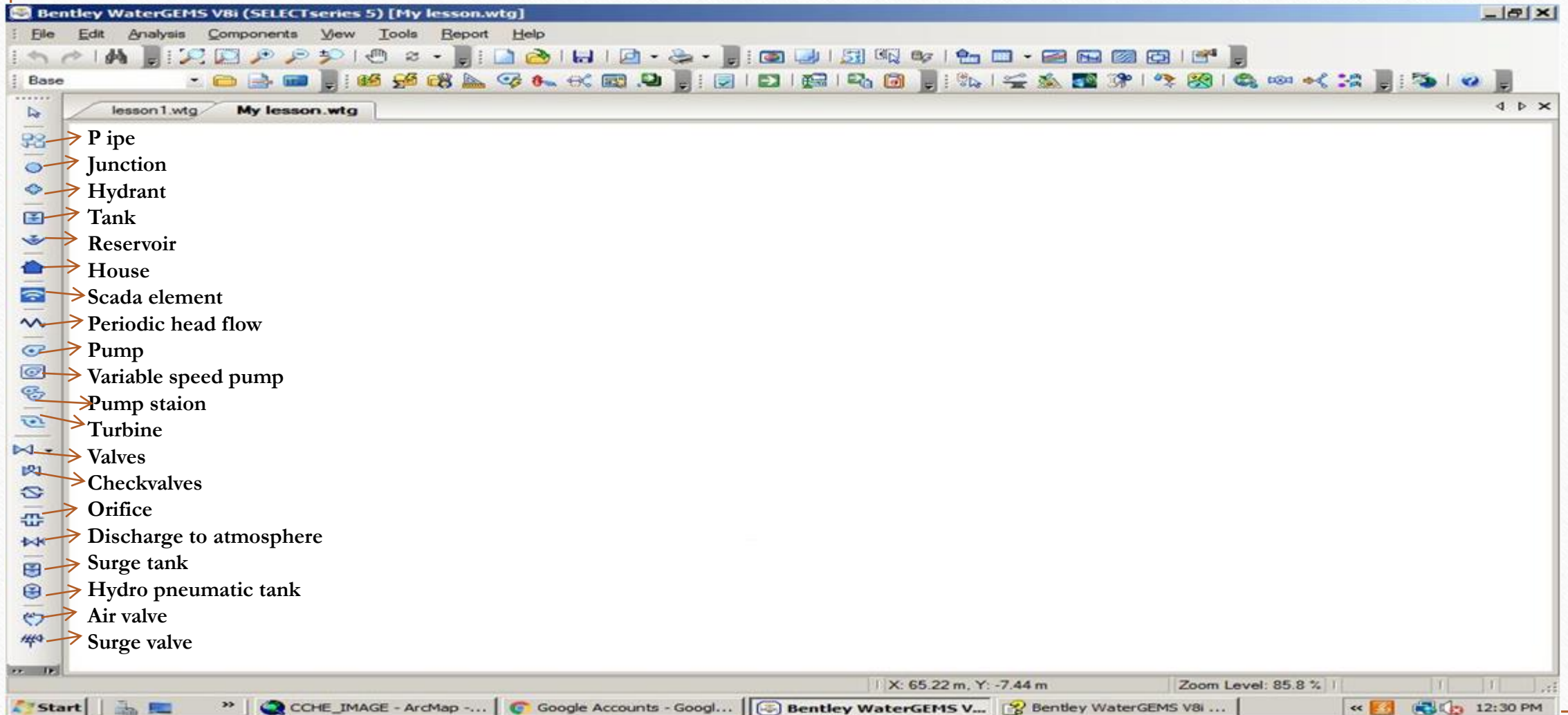
5. Right

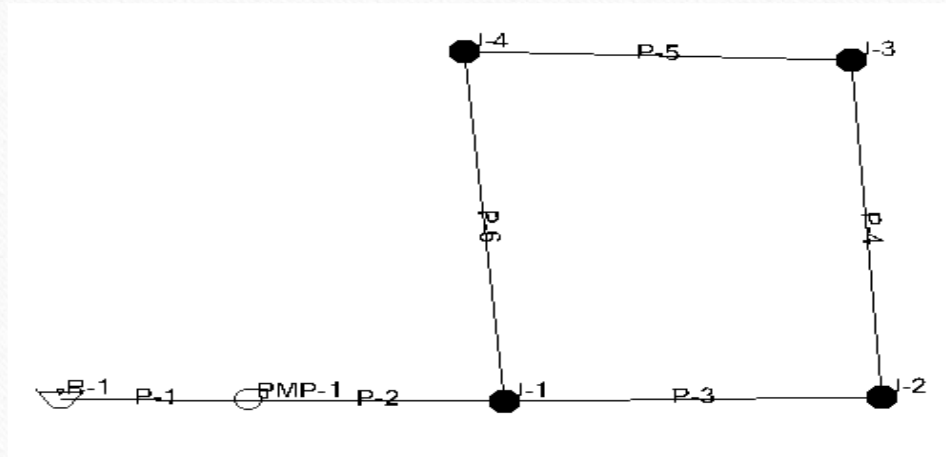


Click to place it.

5. Right click to select Junction from the menu and click to place J-1.
6. Click to place junctions J-2, J-3, and J-4.
7. Click on J-1 to finish.
8. Right-click and choose Done from the menu.

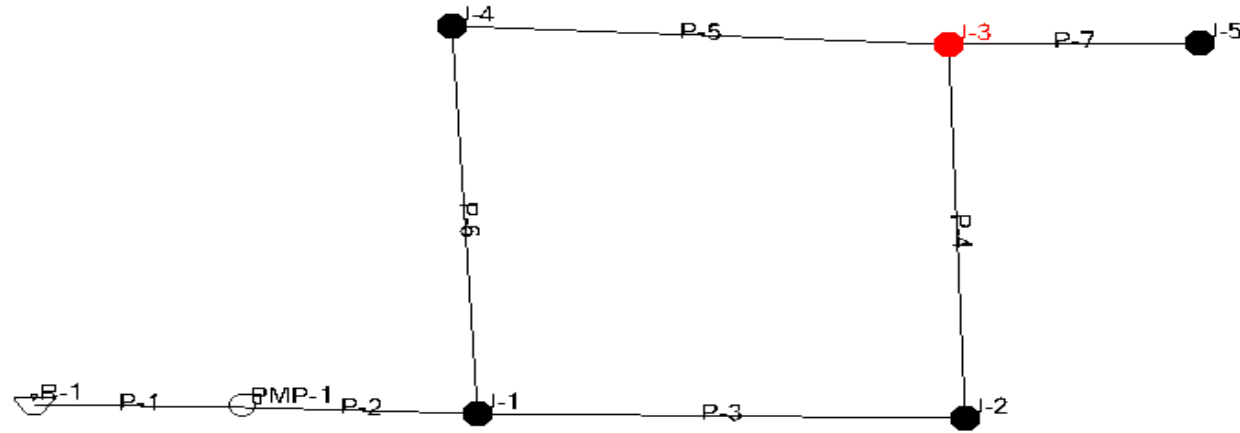
LAYOUT TOOLBAR





9. Create J-5.

- a. Select the Pipe layout tool again.
- b. Click junction J-3.
- c. Move the cursor to the location of J-5, and click to insert the element.
- d. Right-click and select Done.



12. Save the network by clicking  Save or choose File > Save.

Step 3: Enter and modify data

Dialog Boxes—You can use the Select tool and double-click an element to bring up its Properties editor. In AutoCAD, click the element once with the Select tool to open the element's editor.

FlexTables—You can click FlexTables  bring up dynamic tables that allow you to edit and display the model data in a tabular format. You can edit the data as you would in a spreadsheet.

User Data Extensions—The User Data Extensions  feature allows you to import and export element data directly from XML files.

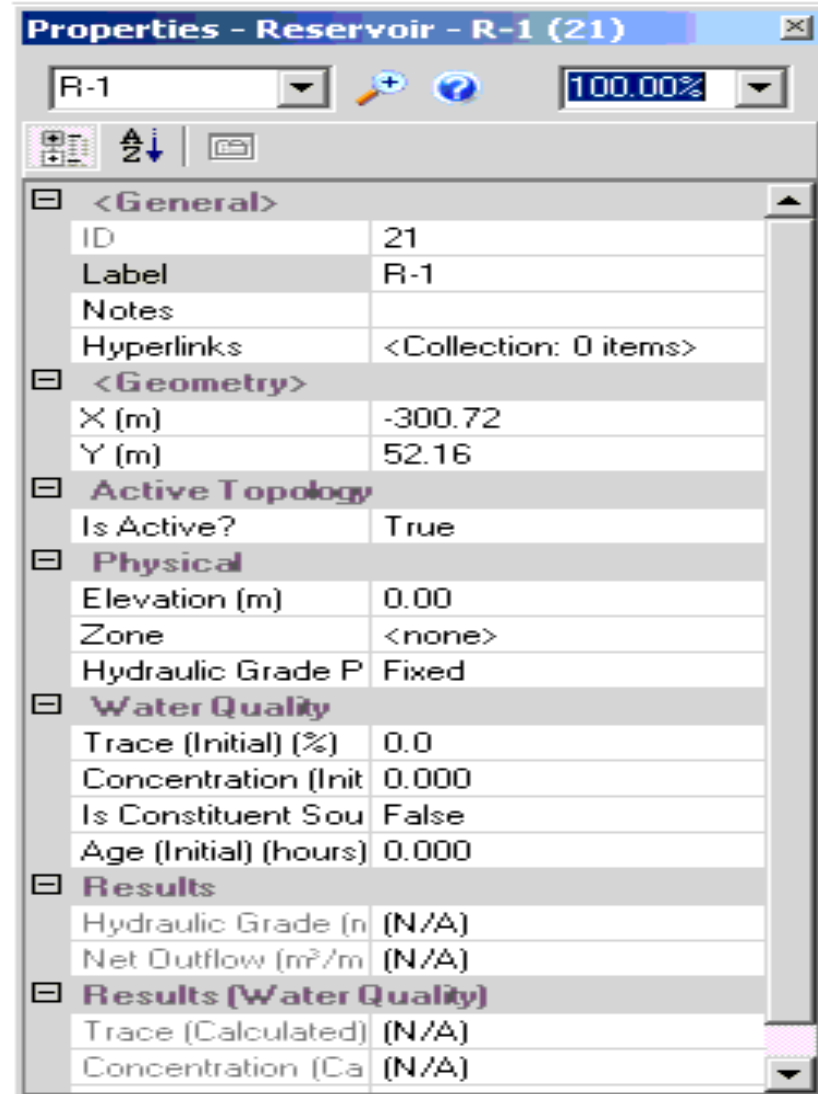
Alternative Editors—Alternatives are used to enter data for different "What If?" situations used in Scenario Management.

Entering Data through Dialog Boxes

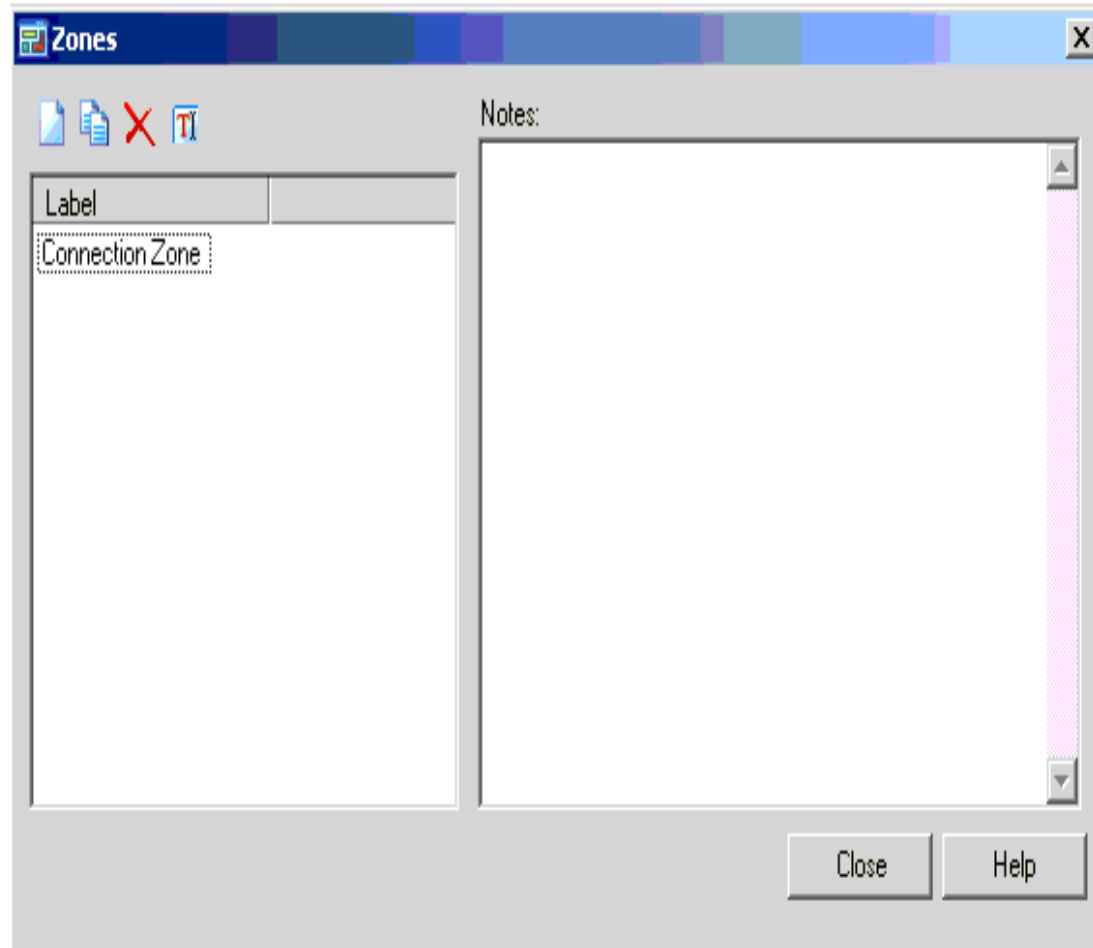
To access an element's dialog box in WaterCAD V8i mode, double-click the element. In AutoCAD, first click the Select tool on the toolbar, then click the element whose attributes you wish to modify.

STEPS:

1. Open the Reservoir Editor for reservoir R-1
2. Enter the Elevation as 198.
3. Set Zone to Connection Zone.
 - a. Click the menu to Edit Zones which will open the Zone Manager.
 - b. Click New  .
 - c. Enter a label for the new pressure zone called Connection Zone.
 - d. Click Close.



Properties - Reservoir - R-1 (21)	
R-1	
100.00%	
<General>	
ID	21
Label	R-1
Notes	
Hyperlinks	<Collection: 0 items>
<Geometry>	
X (m)	-300.72
Y (m)	52.16
Active Topology	
Is Active?	True
Physical	
Elevation (m)	0.00
Zone	<none>
Hydraulic Grade P	Fixed
Water Quality	
Trace (Initial) (%)	0.0
Concentration (Init)	0.000
Is Constituent Sou	False
Age (Initial) (hours)	0.000
Results	
Hydraulic Grade (n)	(N/A)
Net Outflow (m³/m)	(N/A)
Results (Water Quality)	
Trace (Calculated)	(N/A)
Concentration (Ca)	(N/A)



e. Select the zone you just created from the Zone menu.

f. Close the Reservoir Editor.

4. Open the Tank Editor for tank T-1 and enter the following:

Elevation (Base) = 200

Elevation (Minimum) = 220

Elevation (Initial) = 225

Elevation (Maximum) = 226

Diameter (m) = 8

Section = Circular

Set the Zone to Zone 1

Properties - Tank - T-1 (39)

T-1 100.00%

Active Topology

Is Active? True

Demand

Demand Collection <Collection: 0 items>

Unit Demand Collection <Collection: 0 items>

Operating Range

Operating Range Type Elevation

Elevation (Base) (m) 200.00

Elevation (Minimum) (m) 220.00

Elevation (Initial) (m) 225.00

Elevation (Maximum) (m) 226.00

Physical

Elevation (m) 0.00

Zone 43: Zone - 1

Volume (Inactive) (ML) 0.00

Installation Year 0

Section Circular

Diameter (m) 8.00

Volume (Calculated Active) (N/A)

Water Quality

Trace (Initial) (%) 0.0

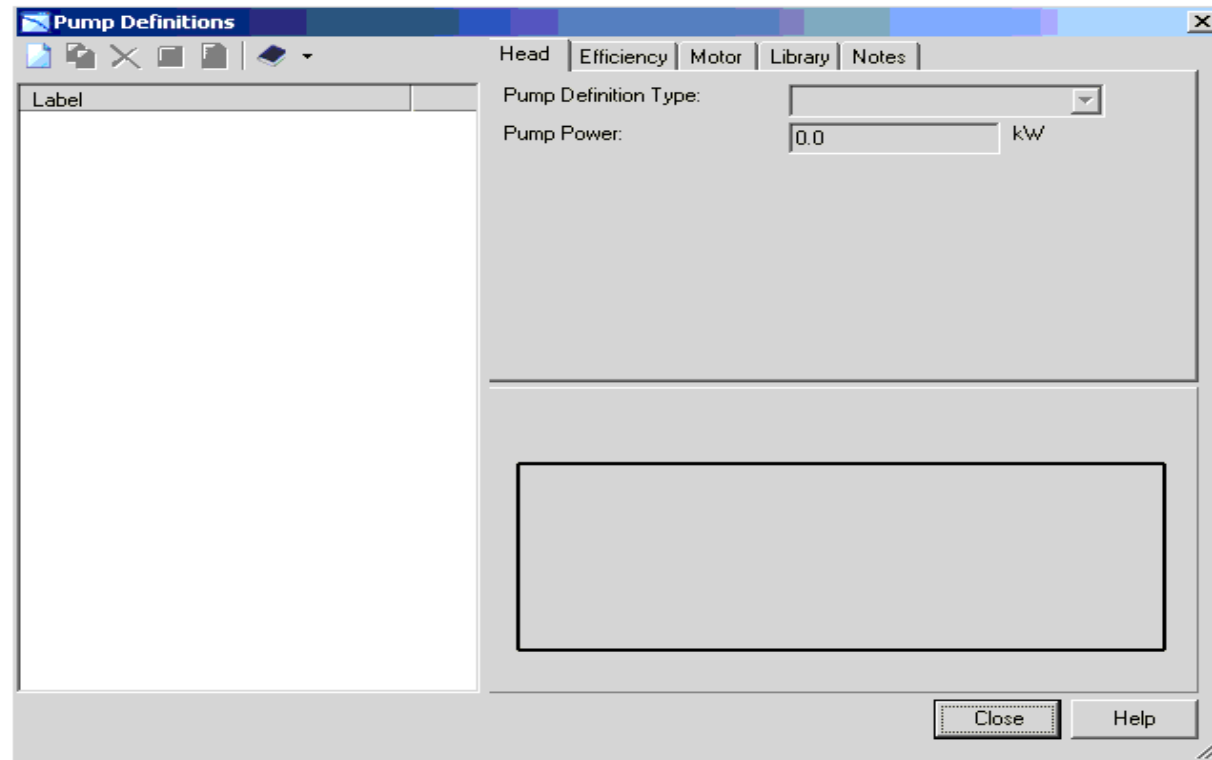
Concentration (Initial) (mg/L) 0.000

Is Constituent Source? False

5. Open the Pump Editor for pump PMP-1.

- Enter 193 for the Elevation.
- Click in the Pump Definition field and click on Edit Pump Definitions from the drop-down list to open the Pump Definitions manager

Close the Tank editor.



- c. Click New to create a new pump definition. Name it **PMP-1**.
- d. Select Standard (3 Point) from the Pump Type menu.
- e. Right click on Flow to open the Units and Formatting menu.
- f. Click on it and then in the Set Field Options box set the Units to L/min.

Set Field Options - Flow

Preview
Value: L/min

Unit:

Display Precision:

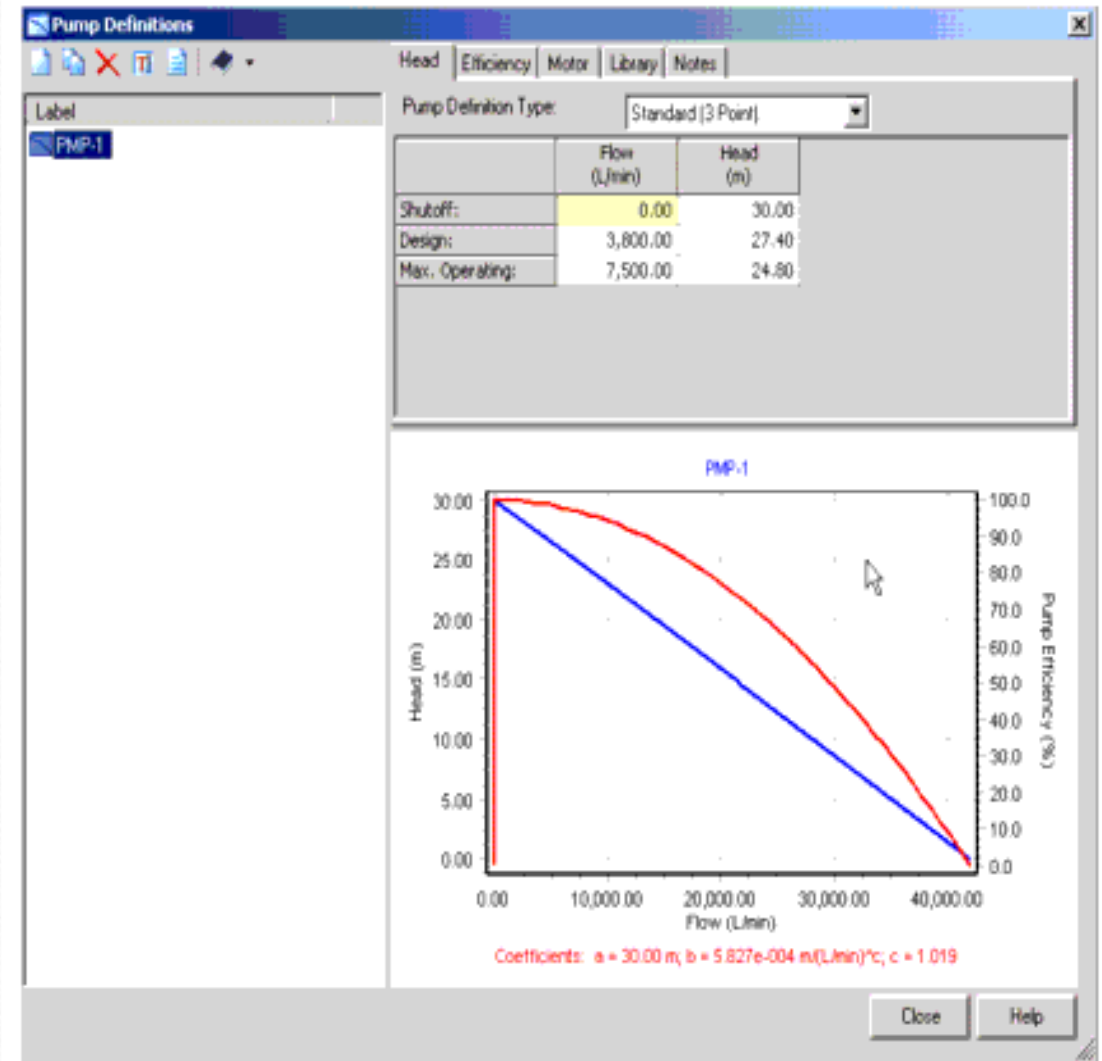
Format:

OK
Cancel
Help

g. Click OK.

h. Enter the following

	Flow (L/min)	Head (m)
Shutoff:	0.00	30.00
Design:	3,800.00	27.40
Max. Operating:	7,500.00	24.80



- i. Click Close.
- j. Select PMP-1 from the Pump Definition menu.
- k. Click to exit the dialog box.

6. Click to open the PRV Editor for valve PRV-1.

Enter in the following:

Elevation = 165

Diameter = 150

Pressure = 390

Status = Active

Settings = Pressure

Create Zone-

Properties - PRV - PRV-1 (36)

P-9 100.00%

<General>

ID	36
Label	PRV-1
Notes	
Hyperlinks	<Collection: 0 items>
Downstream Pipe	38: P-9

<Geometry>

X (m)	-139.25
Y (m)	244.47

Active Topology

Is Active?	True
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Initial Settings

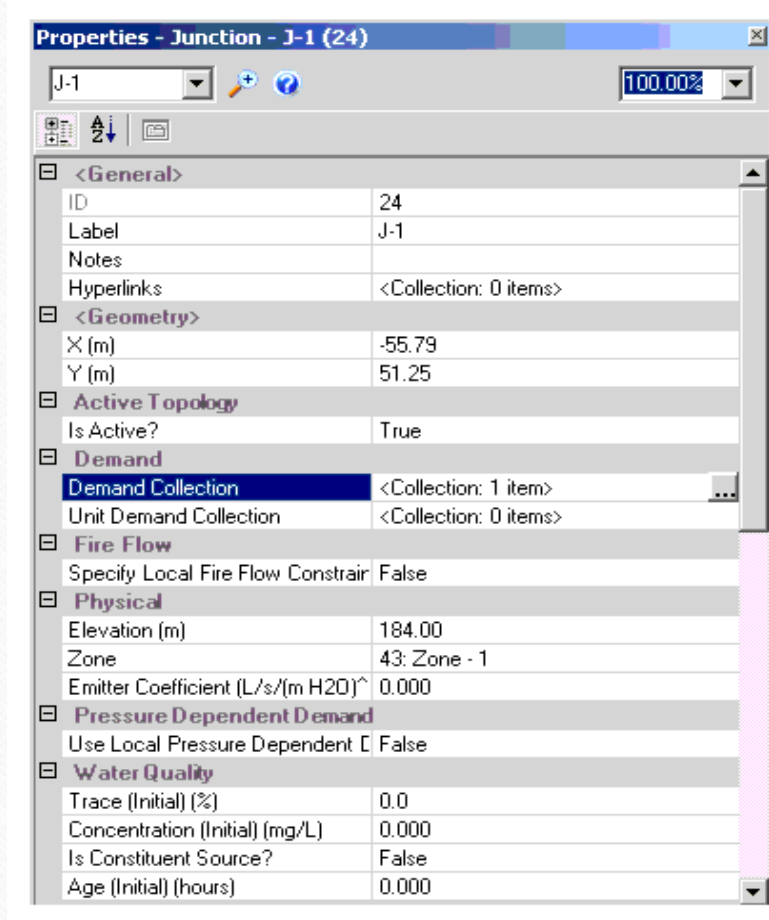
Status (Initial)	Active
Setting Type	Pressure
Pressure Setting (Setting) (kPa)	390

Physical

Elevation (m)	165.00
Installation Year	0
Zone	<none>
Diameter (Valve) (mm)	150.0
Minor Loss Coefficient	0.000
Minor Losses	<Collection: 0 items>

Create Zone-2 and set it.
Click to exit.

7. Enter the following data for each of the junctions.



Properties - Junction - J-1 (24)

J-1 100.00%

<General>

ID: 24
Label: J-1
Notes:
Hyperlinks: <Collection: 0 items>

<Geometry>

X (m): -55.79
Y (m): 51.25

Active Topology

Is Active?: True

Demand

Demand Collection: <Collection: 1 item> ...
Unit Demand Collection: <Collection: 0 items>

Fire Flow

Specify Local Fire Flow Constrai: False

Physical

Elevation (m): 184.00
Zone: 43: Zone - 1
Emitter Coefficient (L/s/(m H2O)^: 0.000

Pressure Dependent Demand

Use Local Pressure Dependent: False

Water Quality

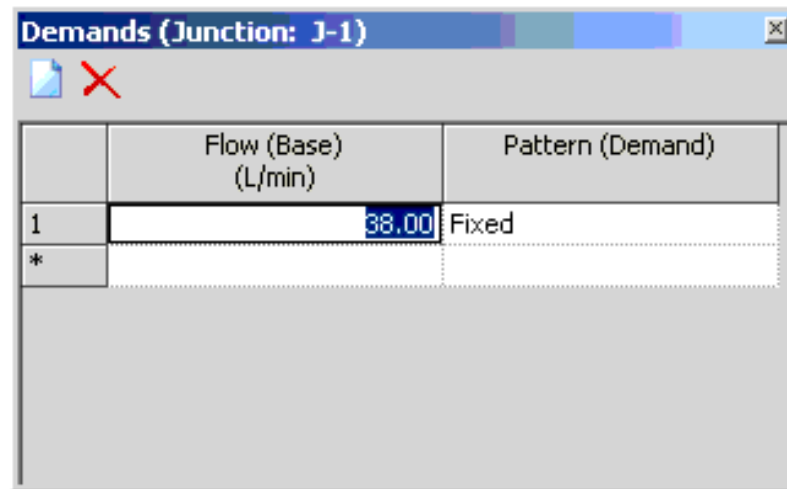
Trace (Initial) (%): 0.0
Concentration (Initial) (mg/L): 0.000
Is Constituent Source?: False
Age (Initial) (hours): 0.000

Junction	Ground Elevation (m)	Zone	Demand (l/min)
J-1	184	Zone-1	38
J-2	185	Zone-1	31
J-3	184	Zone-1	34
J-4	183	Zone-1	38
J-5	185.5	Zone-1	350
J-6	165	Zone-2	356

In order to add the demand, click the ellipsis  in the Demand Collection field to open the Demand box, click New, and type in the numbers for Flow (L/min).

Leave all other fields set to their default values.

Click to exit.



	Flow (Base) (L/min)	Pattern (Demand)
1	38.00	Fixed
*		

8. Specify user-defined lengths for pipes P-1, P-7, P-8, P-9 and P-10.

- Double-click pipe P-1 to open the Pipe Editor.
- Set Has User Defined Length? to True. Then, enter a value of 0.01 m in the Length field. Since you are using the reservoir and pump to simulate the connection to the main distribution system, you want headloss through this pipe to be negligible. Therefore, the length is very small and the diameter will be large.
- Enter 1000 mm as the diameter of P1.

d. Repeat for pipes P-7 through P-10 using the following user-defined lengths and diameters.

P7 = 400

P8 = 500

P9 = 31

P-10 = 100

e. Click to close.

Physical	
Zone	<None>
Diameter (mm)	1,000.0
Material	Ductile Iron
Hazen-Williams C	130.0
Has User Defined Length?	True
Length (User Defined) (m)	0.01
Length (m)	0.01
Has Check Valve?	False
Minor Loss Coefficient	0.000
Minor Losses	<Collection: 0 items>
Installation Year	0

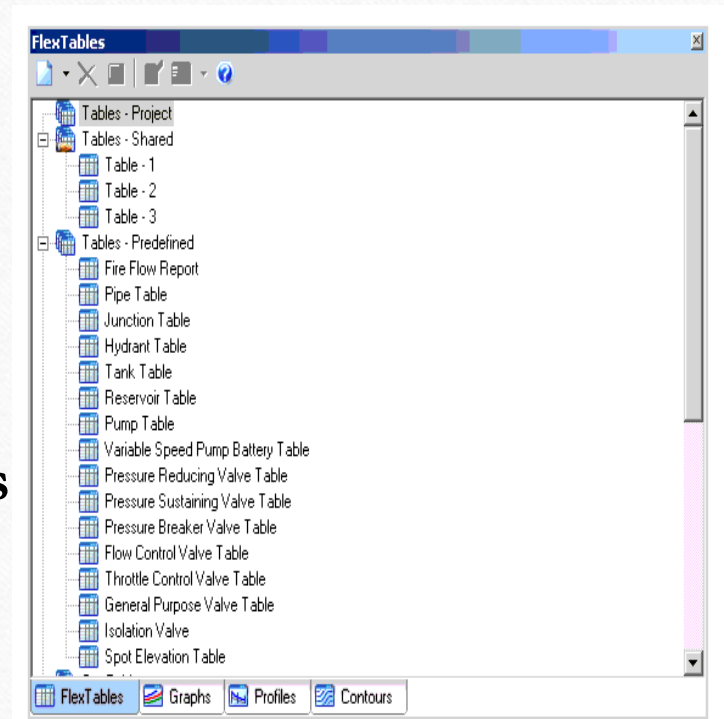
Step 4: Entering Data through Flex Tables

It is often more convenient to **enter data for similar elements in tabular form**, rather than to individually open a dialog box for an element, enter the data into the dialog box, and then select the next element.

Using Flex Tables, you can enter the data as you would enter data into a spreadsheet.

To use FlexTables

1. Click FlexTables  or choose View > Flex Tables



2. Double-click Pipe Table and click OK. Fields that are white can be edited, but yellow fields can not.

	ID	Label	Scaled Length (m)	Start-node ID	Stop-node ID	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss	Flow (L/min)	Velocity (m/s)	Headloss (m)	Has User Defined Length?	Length (User Defined) (m)
23: P-1	23	P-1	113.40	21: P-1	22: PMP-1	1,000.0	Ductile	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☒	0.01
25: P-2	25	P-2	131.54	22: PMP-1	24: J-1	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☐	131.54
27: P-3	27	P-3	195.95	24: J-1	26: J-2	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☐	195.95
29: P-4	29	P-4	188.76	26: J-2	28: J-3	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☐	188.76
31: P-5	31	P-5	201.46	28: J-3	30: J-4	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☐	201.46
32: P-6	32	P-6	192.62	30: J-4	24: J-1	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☐	192.62
34: P-7	34	P-7	118.96	30: J-5	28: J-3	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☒	400.00
37: P-8	37	P-8	68.06	35: J-6	36: PRR-1	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☒	500.00
38: P-9	38	P-9	72.58	38: J-4	36: PRR-1	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☒	31.00
40: P-10	40	P-10	56.27	28: J-3	39: T-1	152.4	None	120.0	☐	0.000	(N/A)	(N/A)	(N/A)	☒	100.00

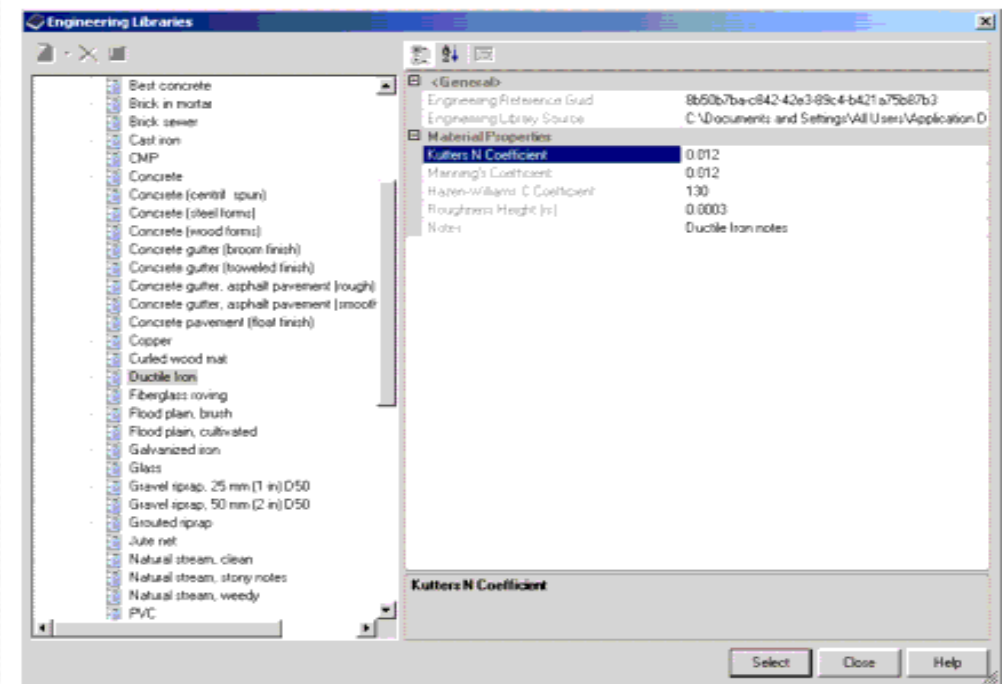
10 of 10 elements displayed

3. For each of the pipes, enter the diameter and the pipe material as follows:

Pipe	Material	Diameter (mm)
P-1	Ductile Iron	1000
P-2	Ductile Iron	150
P-3	Ductile Iron	150
P-4	PVC	150
P-5	Ductile Iron	150
P-6	Ductile Iron	150
P-7	PVC	150
P-8	Ductile Iron	150
P-9	Ductile Iron	150
P-10	Ductile Iron	150

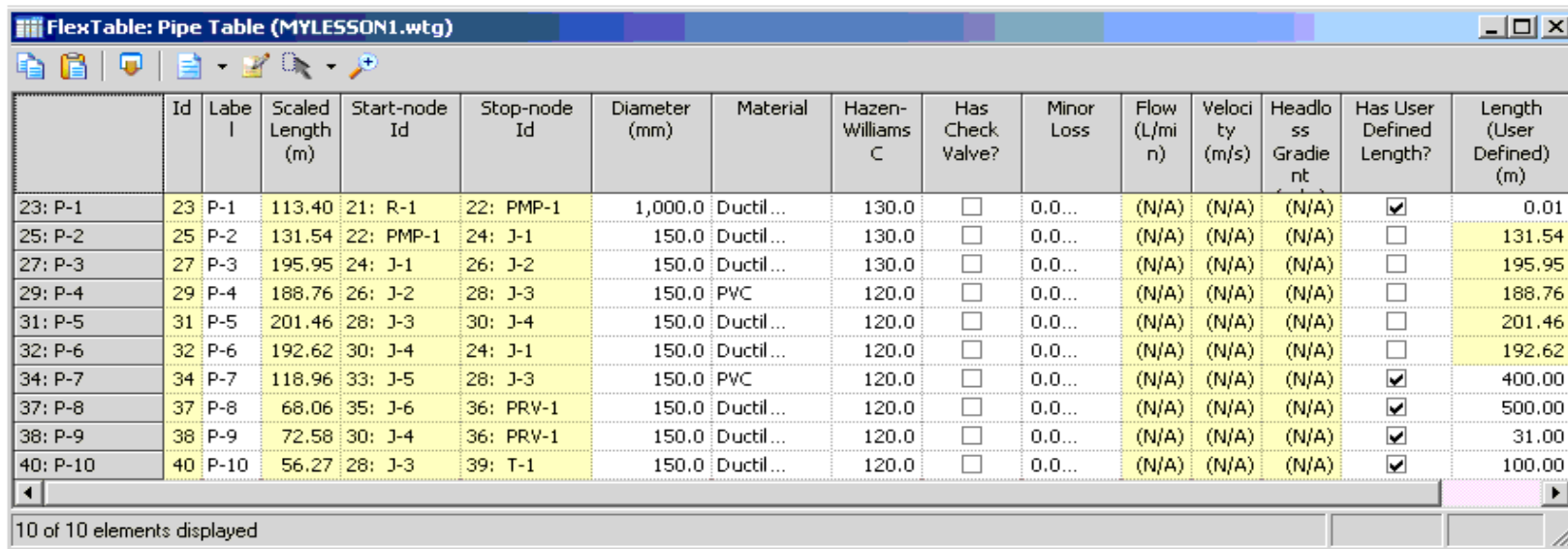
4. In order to enter the material type, click the ellipsis  to open the Engineering Libraries box.

Click on Material Libraries > Material Libraries.xml and then click the appropriate material type and then click Select.
Or, enter the material type in the field



5. Notice that the C values for the pipes will be automatically assigned to preset values based on the material; however, these values could be modified if a different coefficient were required.

6. Leave other data set to their default values. Click to exit the table when you are finished.



	Id	Label	Scaled Length (m)	Start-node Id	Stop-node Id	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Minor Loss	Flow (L/min)	Velocity (m/s)	Headloss Gradient	Has User Defined Length?	Length (User Defined) (m)
23: P-1	23	P-1	113.40	21: R-1	22: PMP-1	1,000.0	Ductil...	130.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☒	0.01
25: P-2	25	P-2	131.54	22: PMP-1	24: J-1	150.0	Ductil...	130.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☐	131.54
27: P-3	27	P-3	195.95	24: J-1	26: J-2	150.0	Ductil...	130.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☐	195.95
29: P-4	29	P-4	188.76	26: J-2	28: J-3	150.0	PVC	120.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☐	188.76
31: P-5	31	P-5	201.46	28: J-3	30: J-4	150.0	Ductil...	120.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☐	201.46
32: P-6	32	P-6	192.62	30: J-4	24: J-1	150.0	Ductil...	120.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☐	192.62
34: P-7	34	P-7	118.96	33: J-5	28: J-3	150.0	PVC	120.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☒	400.00
37: P-8	37	P-8	68.06	35: J-6	36: PRV-1	150.0	Ductil...	120.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☒	500.00
38: P-9	38	P-9	72.58	30: J-4	36: PRV-1	150.0	Ductil...	120.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☒	31.00
40: P-10	40	P-10	56.27	28: J-3	39: T-1	150.0	Ductil...	120.0	☐	0.0...	(N/A)	(N/A)	(N/A)	☒	100.00

10 of 10 elements displayed

Step 5: Run a Steady-State Analysis

1. Click  to open the Base Calculation Options box.
2. Double-click or right click to open the Properties manager and make sure that the Time Analysis Type is set to Steady State.

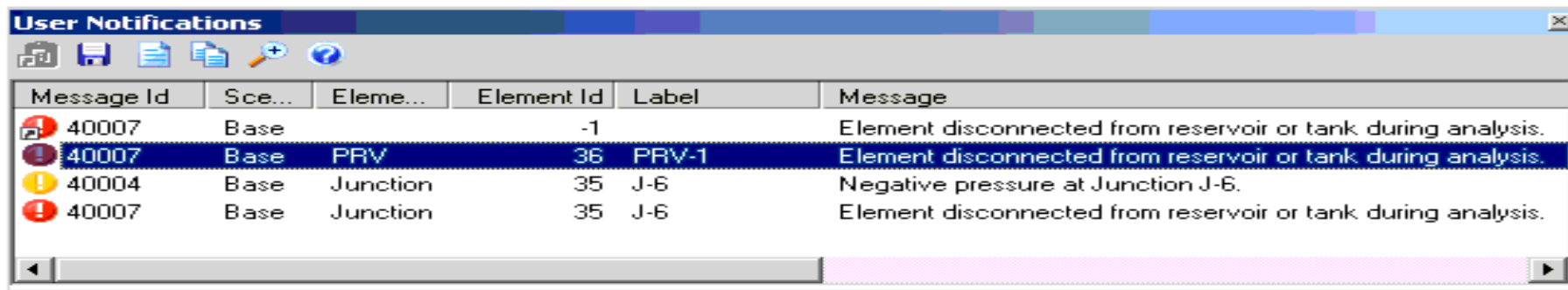
Calculation Times	
Base Date	1/1/2000
Time Analysis Type	Steady State
Use Simple Controls?	True
Is EPS Snapshot?	False
Start Time	12:00:00 AM

Click to close

3. Click Validate  then click Ok if no problems are found.

4. Click Compute  to analyze the model.

5. When calculations are completed, User Notifications open

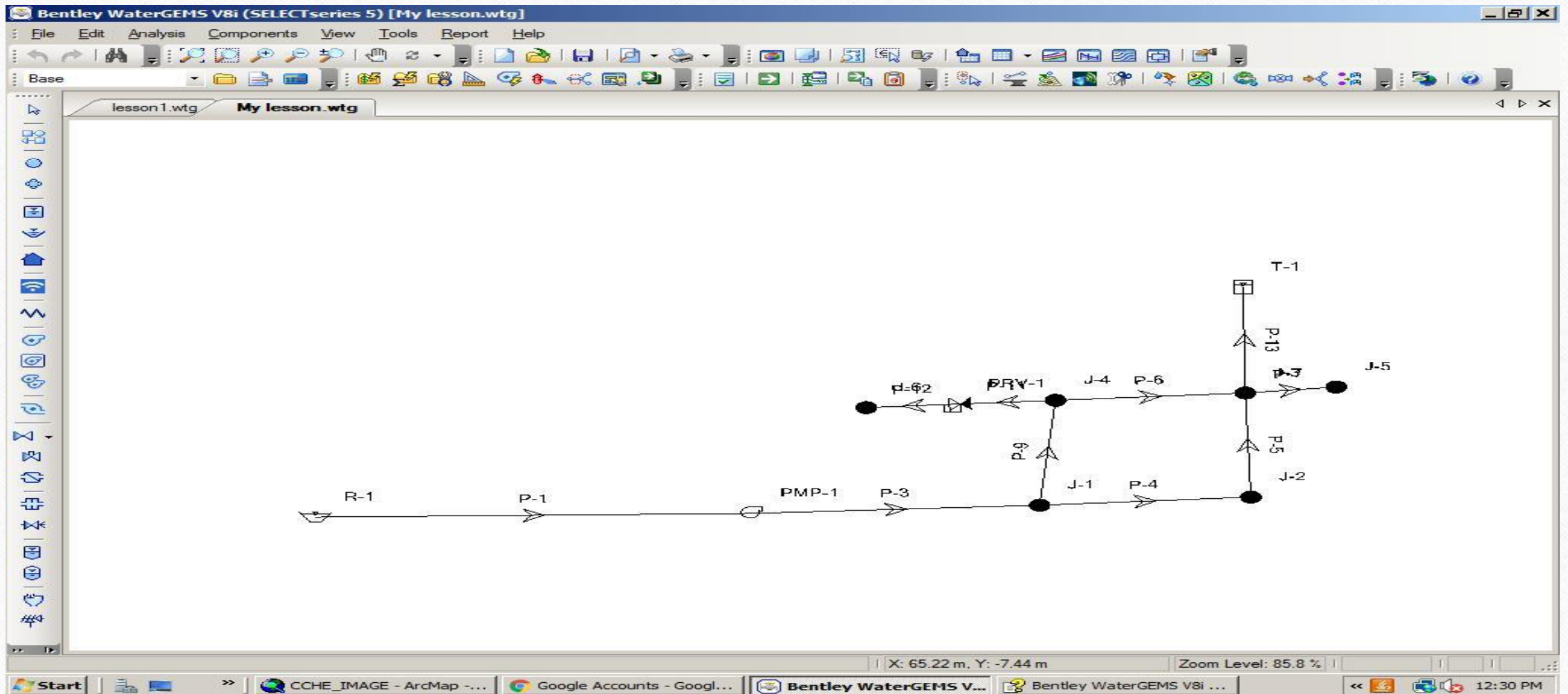


The image shows a 'User Notifications' dialog box with a table of messages. The table has columns for Message Id, Scenario, Element, Element Id, Label, and Message. There are four rows of data. The first row has a red icon, the second a red icon, the third a yellow icon, and the fourth a red icon. The second row is highlighted in blue.

Message Id	Sce...	Eleme...	Element Id	Label	Message
40007	Base		-1		Element disconnected from reservoir or tank during analysis.
40007	Base	PRV	36	PRV-1	Element disconnected from reservoir or tank during analysis.
40004	Base	Junction	35	J-6	Negative pressure at Junction J-6.
40007	Base	Junction	35	J-6	Element disconnected from reservoir or tank during analysis.

A green light indicates no warnings or issues, a yellow light indicates warnings, and a red light indicates issues.

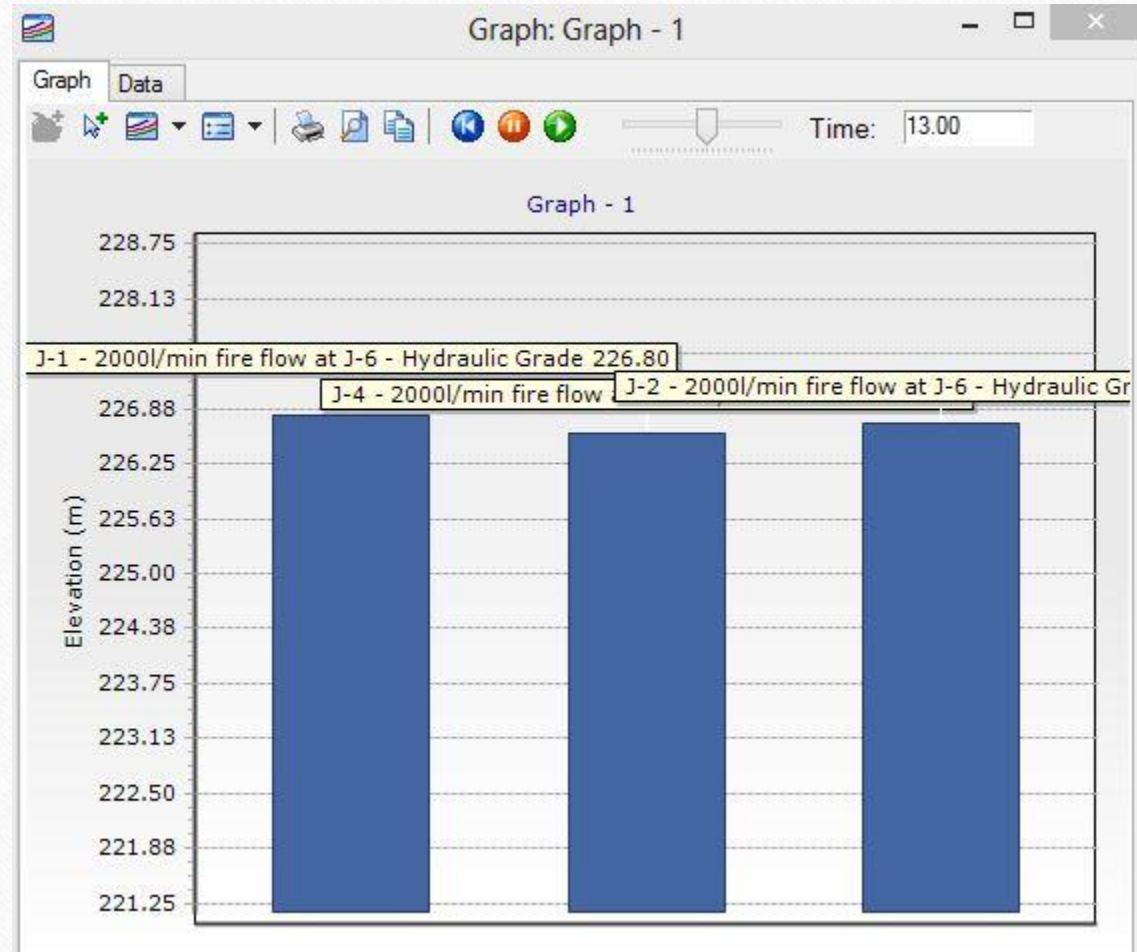
Final Network



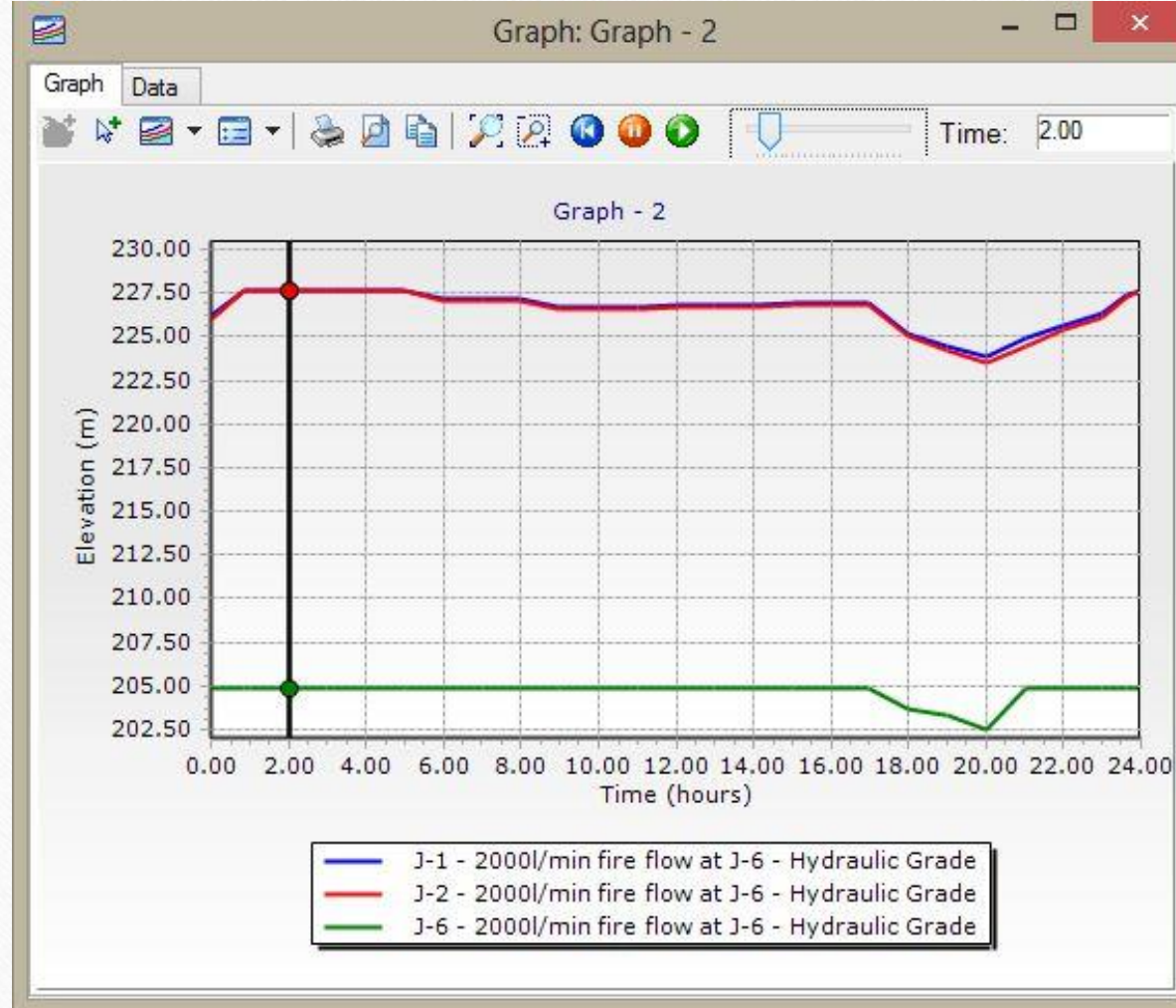
6. Click to close User Notification.

7. Click to Save  project.

RESULTS



Bar-chart graph



Line-series graph



SCENARIO MANAGEMENT

Scenario Management is used for computation of “WHAT-IF” type of conditions

There are 14 alternative types



Results could be in any of the following forms

- ✓ **Reports** - which display and print information on any or all elements in the system.
- ✓ **Element Tables (Flex Tables)** -for viewing, editing, and presentation of selected data and elements in a tabular format.
- ✓ **Profiles** - to graphically show, in a profile view, how a selected attribute, such as hydraulic grade, varies along an interconnected series of pipes.
- ✓ **Contouring** -to show how a selected attribute, such as pressure, varies throughout the distribution system.
- ✓ **Element Annotation** - for dynamic presentation of the values of user-selected variables in the plan view.
- ✓ **Color Coding** -which assigns colors based on ranges of values to elements in the plan view. Color coding is useful in performing quick diagnostics on the network.

