

ADVANCED RULE DEMO

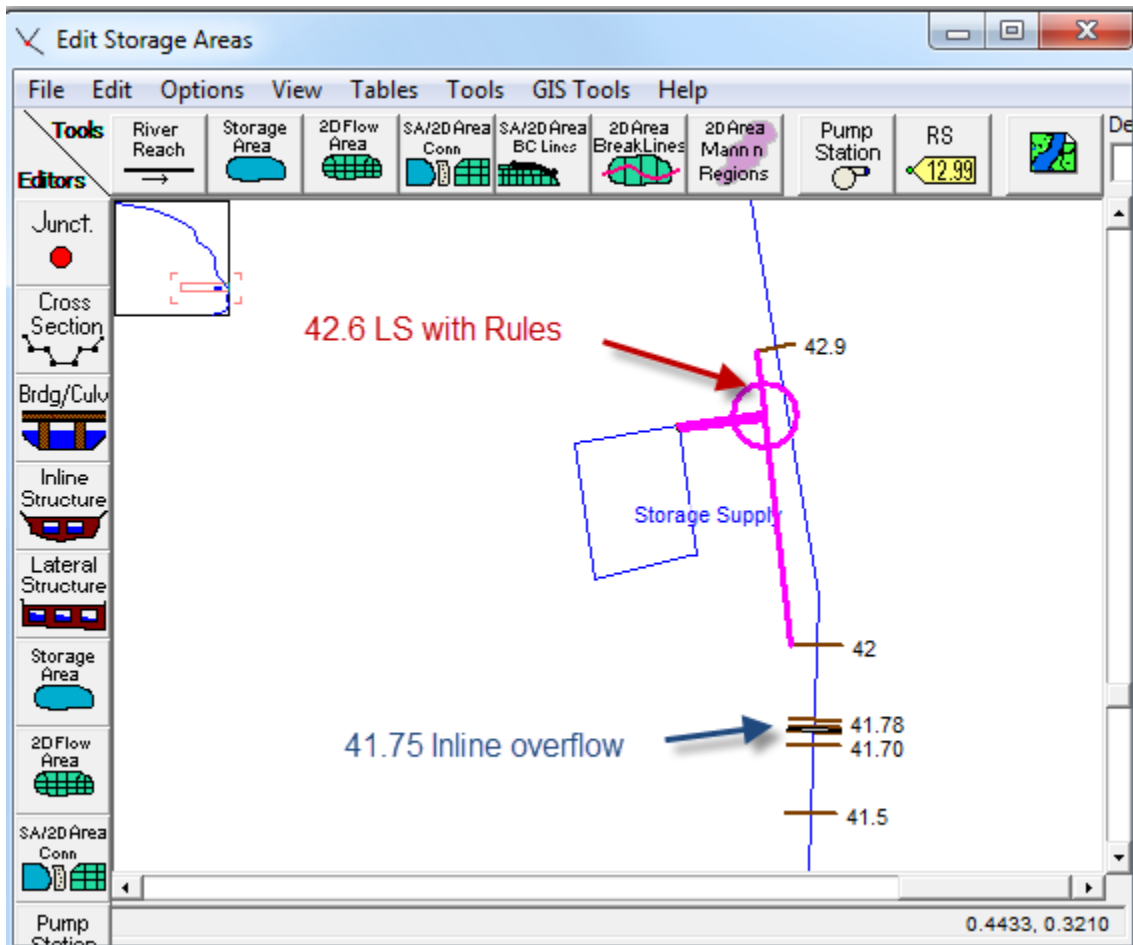
Introduction

This hands-on demonstration will help students learn how to use HEC-RAS to enter and edit advanced rules to control the gate operations at an inline structure.

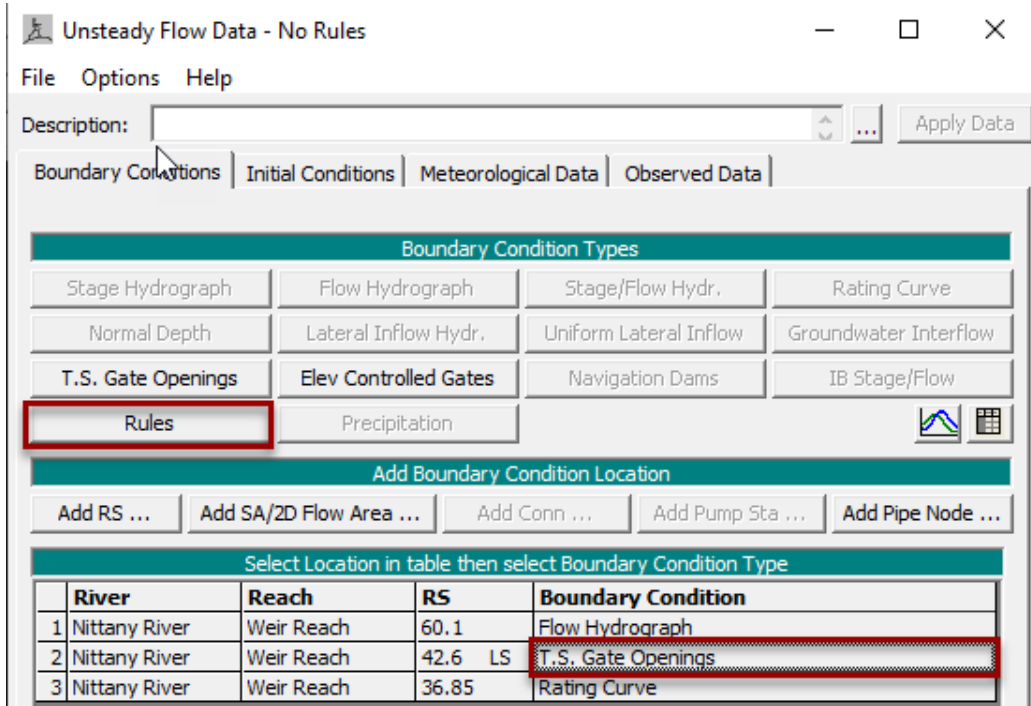
Problem

For this demonstration a project file (RuleDemo.prj) with the title “Advanced Rule Demonstration” has been loaded on your workshop computers. The initial gate information (opening rate, max opening, initial opening, etc.) has already been entered.

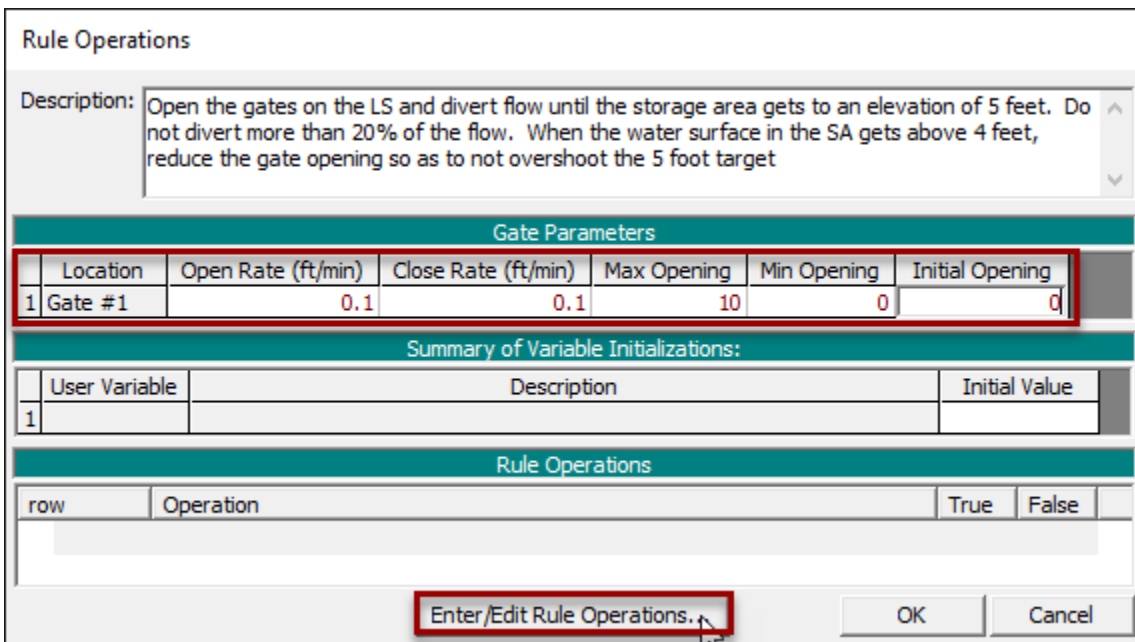
The rules will be used to open the gate on a lateral structure (RS 42.6) and fill a small storage area until the SA water surface reaches 5 feet. As class time permits, the flow being diverted will be limited to 20% of the flow going over the inline structure overflow weir (RS 41.75). Finally, additional logic will be added to keep the water surface in the SA from “overshooting” the 5 foot target.



The default plan (“No Rules”) models the lateral structure gates with 0-opening time series. To create rules, select this boundary condition and press the “Rules” button.



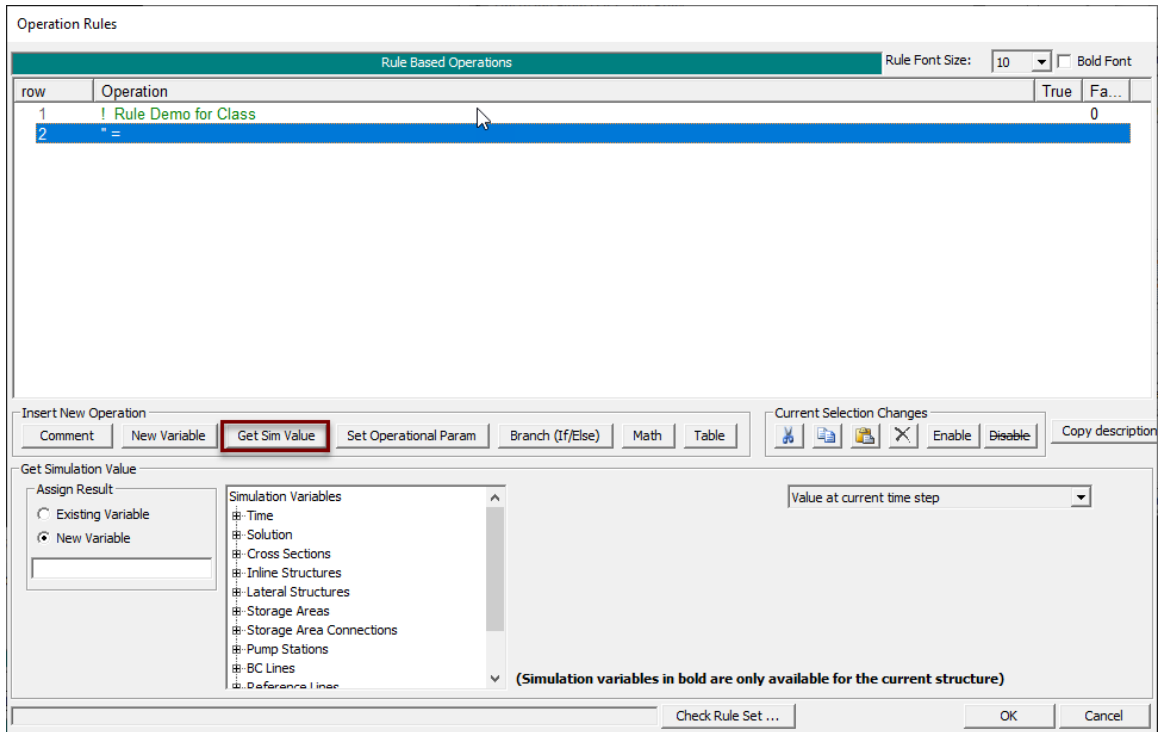
This will open the Rules Editor. The first step, before entering any rules, involves parameterizing the gate parameters. These five variables (open rate, close rate, max and min opening and initial opening) will provide critical gate information unless the rules override them. Then press **Enter/Edit Rule Operations...**



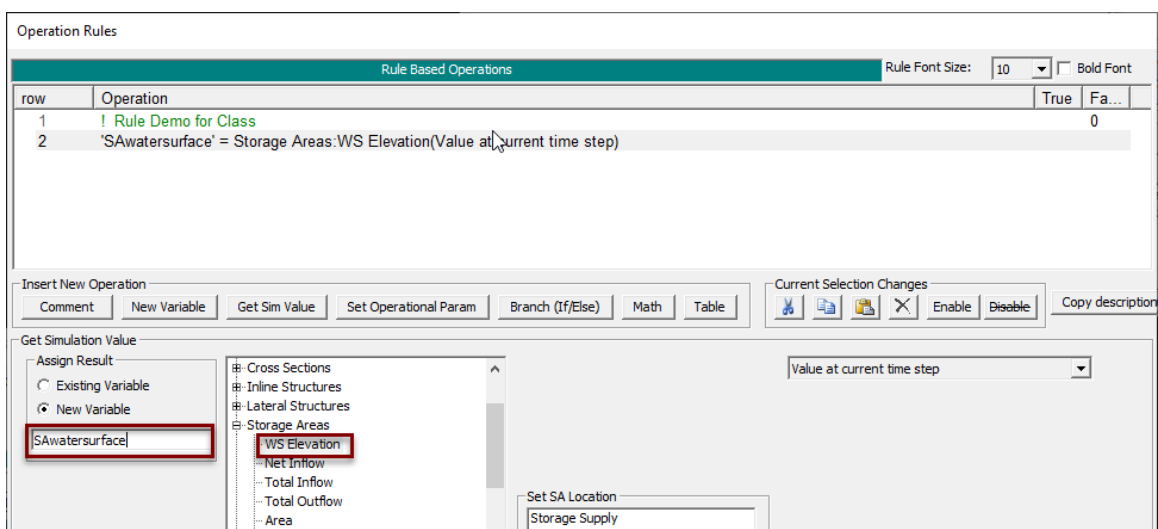
Press the **Comment** button to write a comment ! **Rules Demo for Class**

Click on line number two to start the code there.

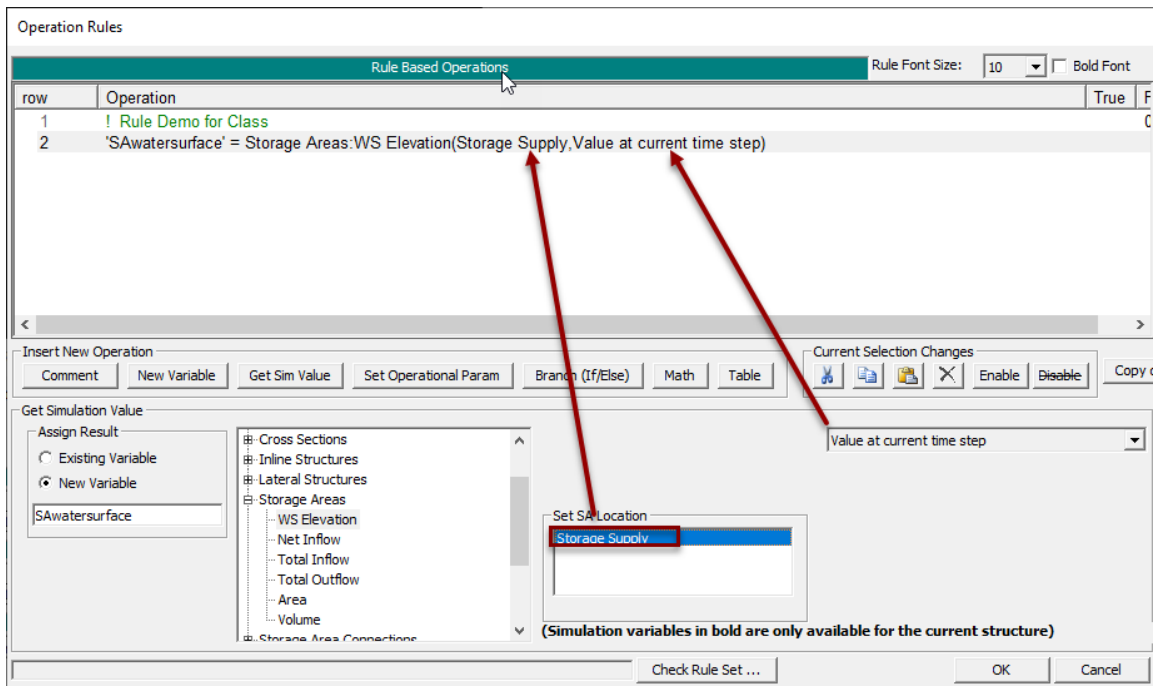
Click on the **Get Sim Value** button to select a RAS result and name it as a Variable.



Select the storage area WS Elevation and assign the result to a new variable called SAwatersurface as shown in the green circle below.

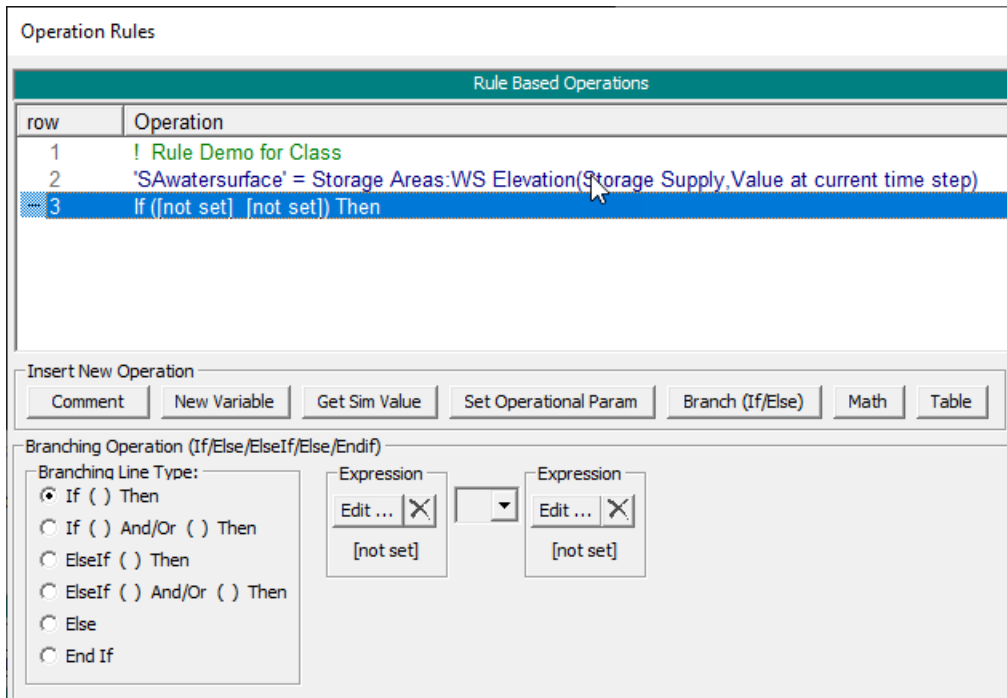


Even though there is only one storage area, the storage area must still be selected by clicking on it as shown below. The name of the SA should then show up in the rule (green circle).

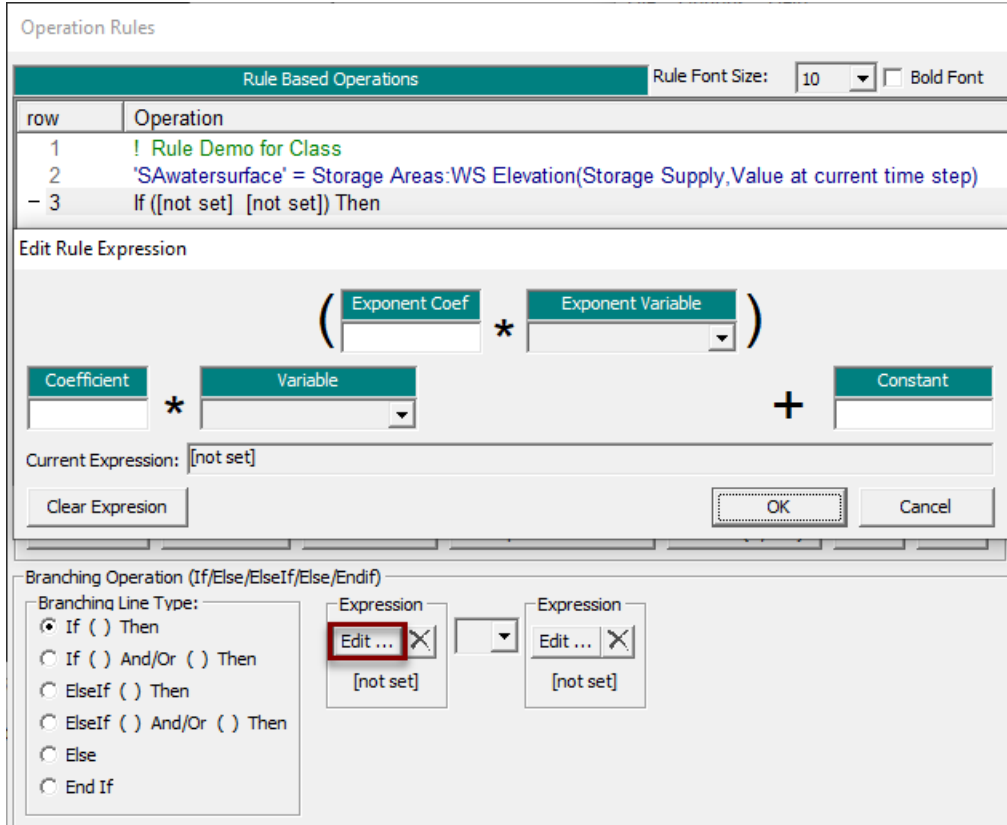


Click on line 3

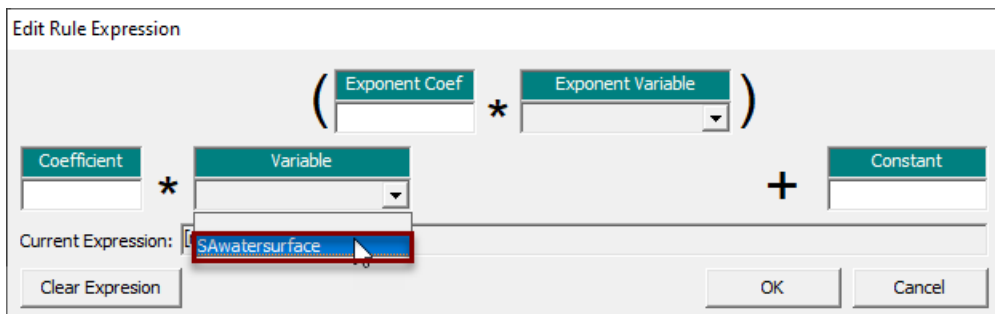
Create an If/Then rule by clicking on the **Branch** button Branch (If/Else).



And then click on the left most **Edit** button to bring up the Expression editor.



Click on the pull down menu under the **Variable** field and select the SAwatersurface variable and then click ok.



From the operator pull down, select “<” (less than).
Select the second Expression and enter “5” in the constant field.

The screenshot displays the 'Operation Rules' dialog box. At the top, there is a 'Rule Based Operations' section with a 'Rule Font Size' dropdown set to 10 and a 'Bold Font' checkbox. Below this is a table with the following content:

row	Operation
1	! Rule Demo for Class
2	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply,Value at current time step)
- 3	If ('SAwatersurface' [not set]) Then

An 'Edit Rule Expression' dialog box is overlaid on top. It features a mathematical expression builder with fields for 'Exponent Coef', 'Exponent Variable', 'Coefficient', 'Variable', and 'Constant'. The 'Constant' field contains the value '5'. Below the builder, the 'Current Expression' is shown as '5'. There are 'Clear Expression', 'OK', and 'Cancel' buttons.

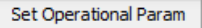
Below the 'Edit Rule Expression' dialog is the 'Branching Operation (If/Else/ElseIf/Else/Endif)' section. It includes a 'Branching Line Type' list with 'If () Then' selected. Two 'Expression' fields are visible: the first contains 'Awatersurfac' and the second contains '[not set]'. A dropdown menu is open between these fields, showing comparison operators: '<<', '<', '>', '>=', '=', and '<>'. The '<' operator is highlighted with a blue selection bar. There are 'Edit ...' buttons for each expression field and 'OK' and 'Cancel' buttons at the bottom.

The next step is to add a rule to open the gate.

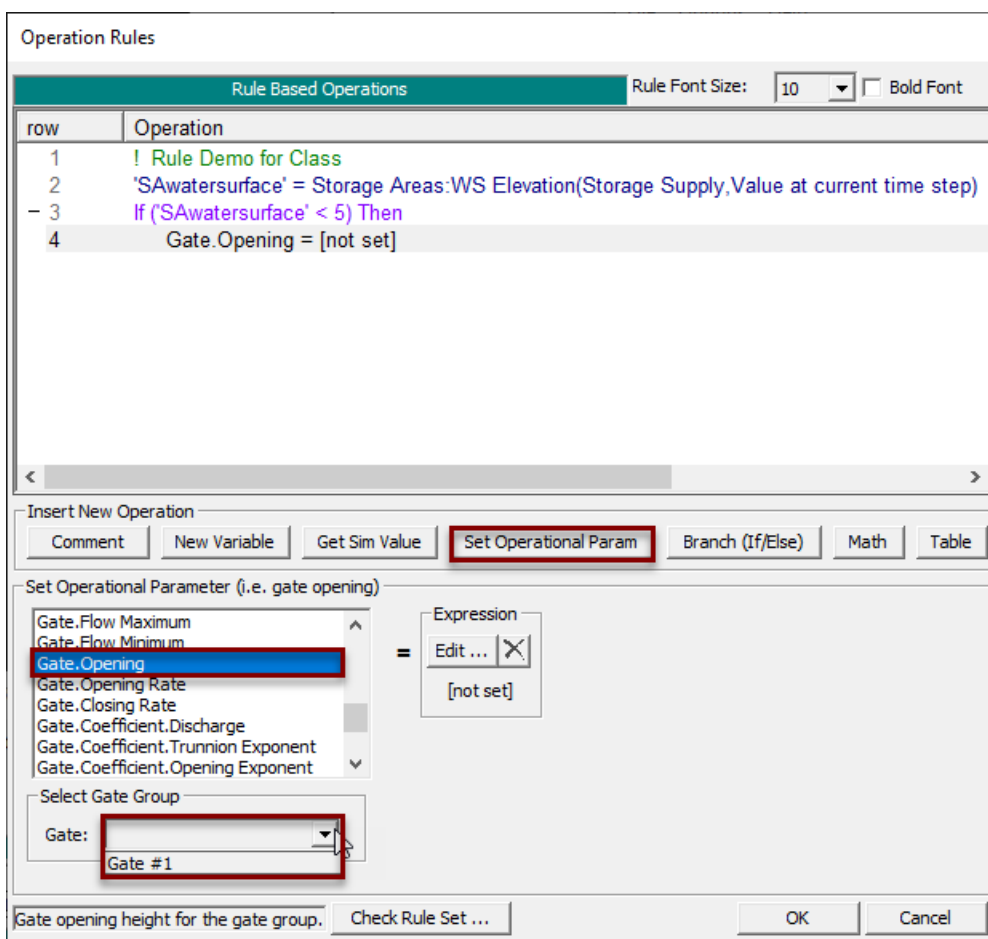
Click on Line 4

The gate opening will be set to the maximum gate opening of 10 feet.

However, because the gate opening rate is limited to 0.1 feet/minute (as entered on the main Rule Operations Editor) and the time step is one minute duration, the gate opening will only increase by 0.1 feet per time step.

Because opening the gate is an “Operation” set it with the **Set Operational Param** button .

Then Scroll down and select “Gate.Opening”. Even though there is only one gate group, it still needs to be selected (green circle).



Select the gate group and Edit the Expression and set it to a constant of ten.

Operation Rules

Rule Based Operations Rule Font Size: 10 Bold Font

row	Operation
1	! Rule Demo for Class
2	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply,Value at current time step)
- 3	If ('SAwatersurface' < 5) Then
4	Gate.Opening(Gate #1) = [not set]

Edit Rule Expression

(Exponent Coef * Exponent Variable)

Coefficient * Variable + Constant

Current Expression: 10

Clear Expression OK Cancel

Set Operational Parameter (i.e. gate opening)

- Gate.Flow Maximum
- Gate.Flow Minimum
- Gate.Opening
- Gate.Opening Rate
- Gate.Closing Rate
- Gate.Coefficient.Discharge
- Gate.Coefficient.Trunnion Exponent
- Gate.Coefficient.Opening Exponent

Expression = Edit ... [not set]

Select Gate Group

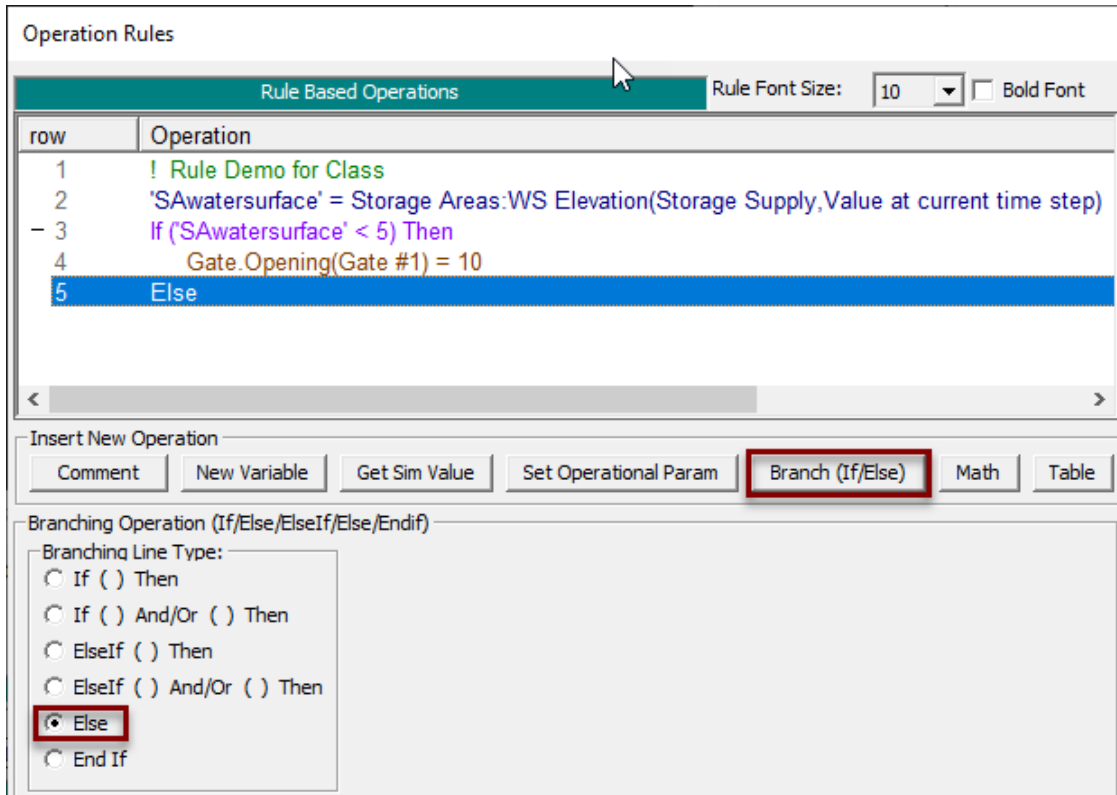
Gate: Gate #1

Gate opening height for the gate group. Check Rule Set ... OK Cancel

When the SA water surface gets to 5 feet, the gate needs to be closed. A new If/Then test could be created for this. However, it is simpler to just add an “Else” statement to the existing test.

Click on line 5.

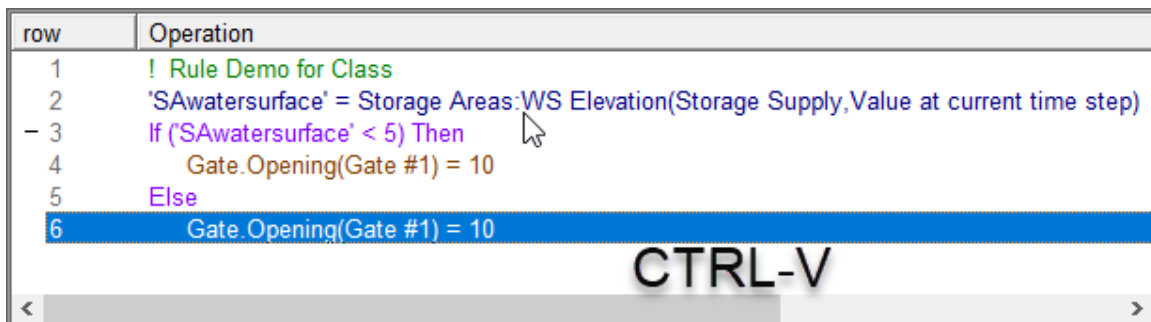
The “Else” is created by first clicking on the **Branch** button and then selecting the Else radial button.



The next rule needs to close the gate by setting the opening to “0”. A rule could be created from scratch just like the rule shown in row 4. However, it is much quicker to copy and paste rule 4 and then change the value of the expression.

Highlight row 4 by clicking on it and then click the **Copy** button (or use **Ctrl+C** on the keyboard).

Move the control below row 5, as would normally be done for a new rule, and click on the **Paste** button (or **Ctrl+V**).



fter pasting the new rule, the row may look highlighted by the blue line but the bottom half of the Rule Editor is blank (as shown below). This can be fixed by moving the blue line up a row and then back down. (The highlighted blue line can be moved by using the up and down arrows on the keyboard.)

The screenshot shows the 'Operation Rules' dialog box. At the top, there is a 'Rule Based Operations' section with a 'Rule Font Size' dropdown set to 10 and a 'Bold Font' checkbox. Below this is a table with the following content:

row	Operation
1	! Rule Demo for Class
2	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply, Value at current time step)
3	If ('SAwatersurface' < 5) Then
4	Gate.Opening(Gate #1) = 10
5	Else
6	Gate.Opening(Gate #1) = 10

Below the table is the 'Edit Rule Expression' section, which contains a mathematical expression editor with fields for 'Exponent Coef', 'Exponent Variable', 'Coefficient', 'Variable', and 'Constant'. The 'Current Expression' field shows '0'. There are 'Clear Expression', 'OK', and 'Cancel' buttons.

The bottom section is 'Set Operational Parameter (i.e. gate opening)'. It features a list of parameters with 'Gate.Opening' selected. An 'Expression' dialog box is open, showing '10' and an 'Edit ...' button. Below the list is a 'Select Gate Group' dropdown set to 'Gate: Gate #1'. At the bottom, there are 'Gate opening height for the gate group.', 'Check Rule Set ...', 'OK', and 'Cancel' buttons.

Click on the **Edit** button and change the constant from “10” to “0” to close the gate.

Every If/Then rule must have a corresponding End If.
Create a new Branch rule **Branch (If/Else)** and set it to End If.

At this point, the editor could be closed, the data saved, and the model run. However, it is useful to check the rules for bugs while the editor is still open. Click on the **Check Rule Set** button and RAS will pop up a window that will list the bugs, if any.

Operation Rules

Rule Based Operations Rule Font Size: 10 Bold Font

row	Operation	True	Fa...
1	! Rule Demo for Class	2	2
2	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply, Value a...	3	3
- 3	If ('SAwatersurface' < 5) Then	4	5
4	Gate.Opening(Gate #1) = 10	7	7
5	Else	6	6
6	Gate.Opening(Gate #1) = 0	7	7
7	End If	0	0

Insert New Operation

Comment New Variable Get Sim Value Set Operational Param Branch (If/Else) Math Table

Branching Operation (If/Else/ElseIf/Else/Endif)

Branching Line Type:

- If () Then
- If () And/Or () Then
- ElseIf () Then
- ElseIf () And/Or () Then
- Else
- End If

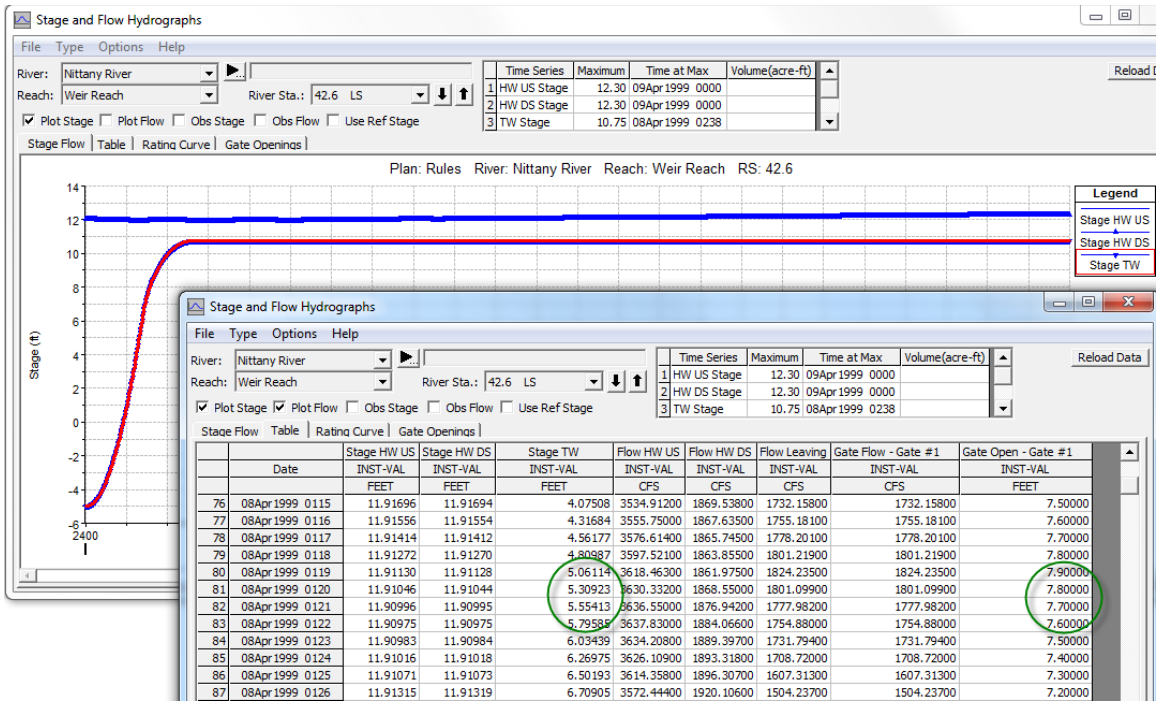
RAS

No inconsistencies were found in the current rule set

OK

Check Rule Set ... OK Cancel

Fix any bugs, run the data set, and look at the lateral structure hydrographs.



Since the lateral structure is connected to the storage area, the Stage TW of the lateral structure is the same as the water surface in the SA. The lateral structure is diverting flow into the SA and when the target water surface reaches 5 feet, the gate starts closing (although the target is dramatically exceeded by the time the gate gets fully closed).

The next step is to limit the diversion to no more than 20% of flow that is going over the dam.

Add two more Get Sim Value rules [Get Sim Value](#). One that gets the total flow in the inline structure (there is only a single inline structure at 41.75) and a second that gets the total flow for the lateral structure. New variable names will have to be entered (green circle). Note also that these rules must come before the If/Then test rule.

Click on Line 3 to add.

row	Operation	True	Fa...
1	! Rule Demo for Class	2	2
2	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply, Value a...	3	3
3	LSFlow' = Lateral Structures:Structure.Total Flow(Nittany River, Weir Re...	4	4
- 4	If ('SAwatersurface' < 5) Then	5	6
5	Gate.Opening(Gate #1) = 10	8	8
6	Else	7	7
7	Gate.Opening(Gate #1) = 0	8	8
8	End If		0

Insert New Operation

Get Simulation Value

Assign Result

Existing Variable
 New Variable

LSFlow

Lateral Structures

- Structure.Total Flow
- Structure.Stage (Fixed)
- Weir.Flow
- Weir.Flow Maximum
- Weir.Flow Minimum

Set Node Location

River: Nittany River

Reach: Weir Reach

RS: 42.6 LS

row	Operation	True	Fa...
1	! Rule Demo for Class	2	2
2	'FlowInline' = Inline Structures:Structure.Total Flow(Nittany River, Weir Re...	3	3
3	'LSFlow' = Lateral Structures:Structure.Total Flow(Nittany River, Weir Re...	4	4
4	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply, Value a...	5	5
- 5	If ('SAwatersurface' < 5) Then	6	7
6	Gate.Opening(Gate #1) = 10	9	9
7	Else	8	8
8	Gate.Opening(Gate #1) = 0		0
9	End If		0

Insert New Operation

Get Simulation Value

Assign Result

Existing Variable
 New Variable

FlowInline

Structure.Total Flow

- Structure.Stage (Fixed)
- Weir.Flow
- Weir.Flow Maximum
- Weir.Flow Minimum
- Weir.Weir Coefficient

Set Node Location

River: Nittany River

Reach: Weir Reach

RS: 41.75 IS

There are multiple options for how the 20% limit could be added. In this example, the If/Then test is going to be changed to a compound test that has the 20% built into the same row.

Highlight the If/Then test in row 5 and change the Branching Operation to a compound test. The rule for opening the gate is going to be changed so that it only opens if the SA water surface is less than 5 *and* the diverted flow is less than 20%. The “And” operator comes up by default (green circle). Since the check requires that both parts of the test

must be True in order to open the gate, the And is correct. (The other choice is an Or operator which would be used to check if either test is true.)

row	Operation	True	Fa...
1	! Rule Demo for Class	2	2
2	'FlowInLine' = Inline Structures:Structure.Total Flow(Nittany River,Weir Re...	3	3
3	'LSFlow' = Lateral Structures:Structure.Total Flow(Nittany River,Weir Re...	4	4
4	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply,Value a...	5	5
5	If ('SAwatersurface' < 5) And ((not set) [not set]) Then	6	7
6	Gate.Opening(Gate #1) = 10	9	9
7	Else	8	8
8	Gate.Opening(Gate #1) = 0		0
9	End If		0

Insert New Operation

Current Selection C

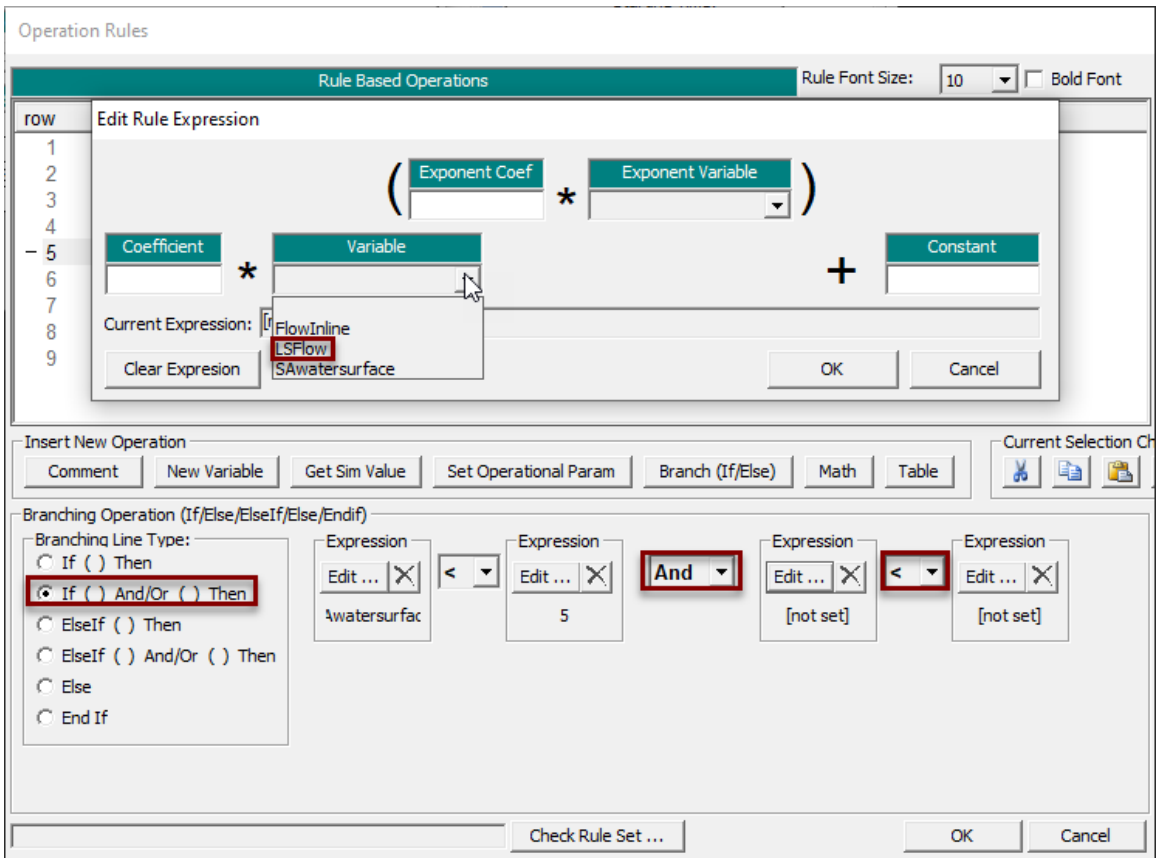
Branching Operation (If/Else/ElseIf/Else/Endif)

Branching Line Type:

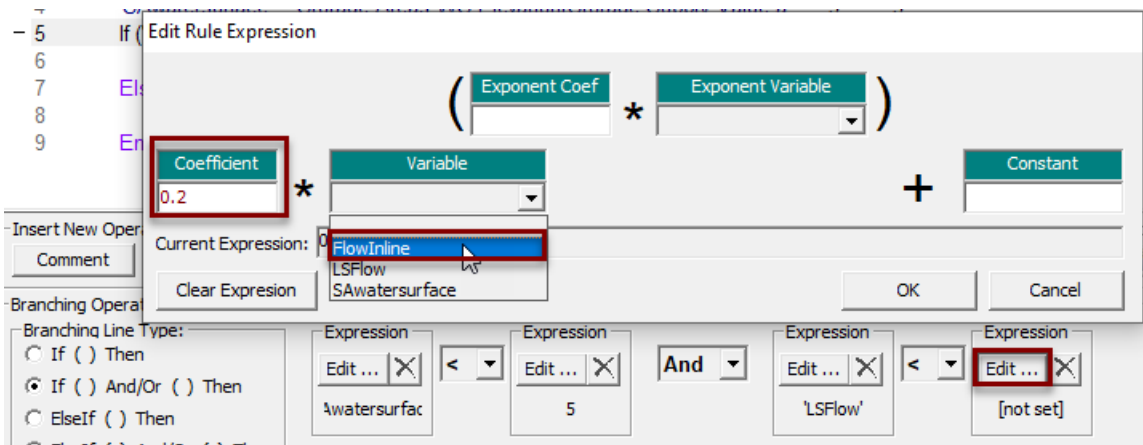
If () Then
 If () And/Or () Then
 ElseIf () Then
 ElseIf () And/Or () Then
 Else
 End If

Expression: Awatersurfac < Expression: 5 And Expression: [not set] Expression: [not set]

For the third expression select the lateral structure flow and set the second test to “<” (less than).



For the final Expression, select the variable for the flow over the inline structure. Since the test for the lateral structure flow is limited to 20% of the inline flow, a coefficient of 0.2 should be added.



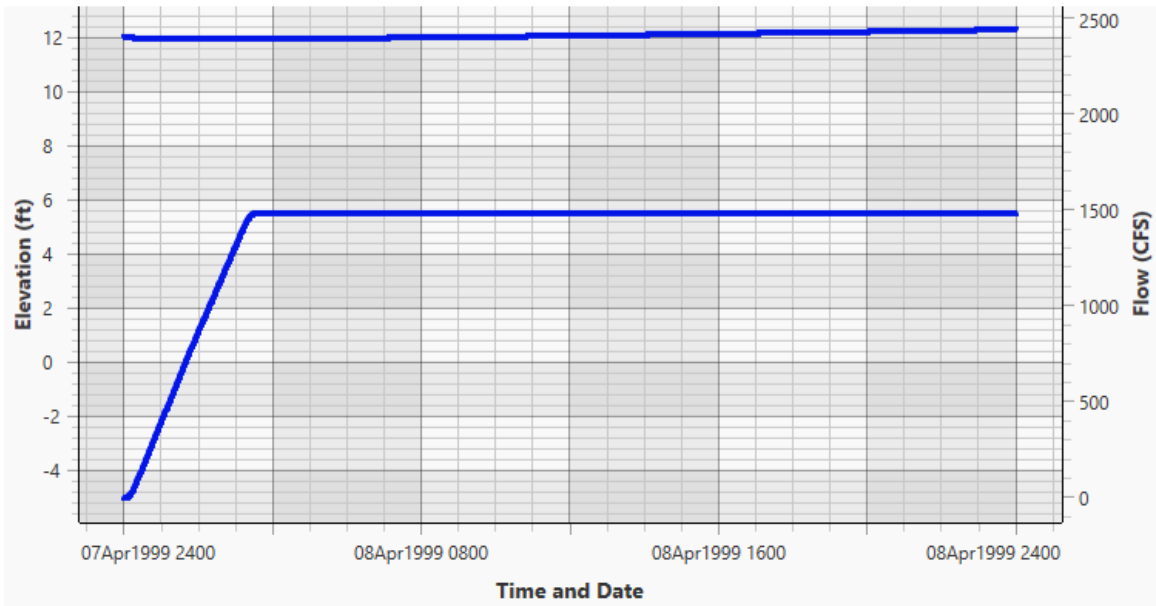
The final If/Then test is shown below.

```

1 ! Rule Demo for Class
2 'Flowline' = Inline Structures:Structure.Total Flow(Nittany River,Weir Reach,41.75,Value at current time step)
3 'LSFlow' = Lateral Structures:Structure.Total Flow(Nittany River,Weir Reach,42.6,Value at current time step)
4 'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply,Value at current time step)
5 If ('SAwatersurface' < 5) And ('LSFlow' < 0.2 * 'Flowline') Then
6     Gate.Opening(Gate #1) = 10
7 Else
8     Gate.Opening(Gate #1) = 0
9 End If

```

With the additional test, the SA fills more slowly and the overshoot of the target is considerably reduced. Once the flow gets up to the 20% limit, the structure is oscillating between opening and closing the gate every other time step. Although this is not shown in this demo, more rules could be added to limit how frequently the gate is adjusted.



Stage and Flow Hydrographs

River: Nittany River
Reach: Weir Reach
River Sta.: 42.6 LS

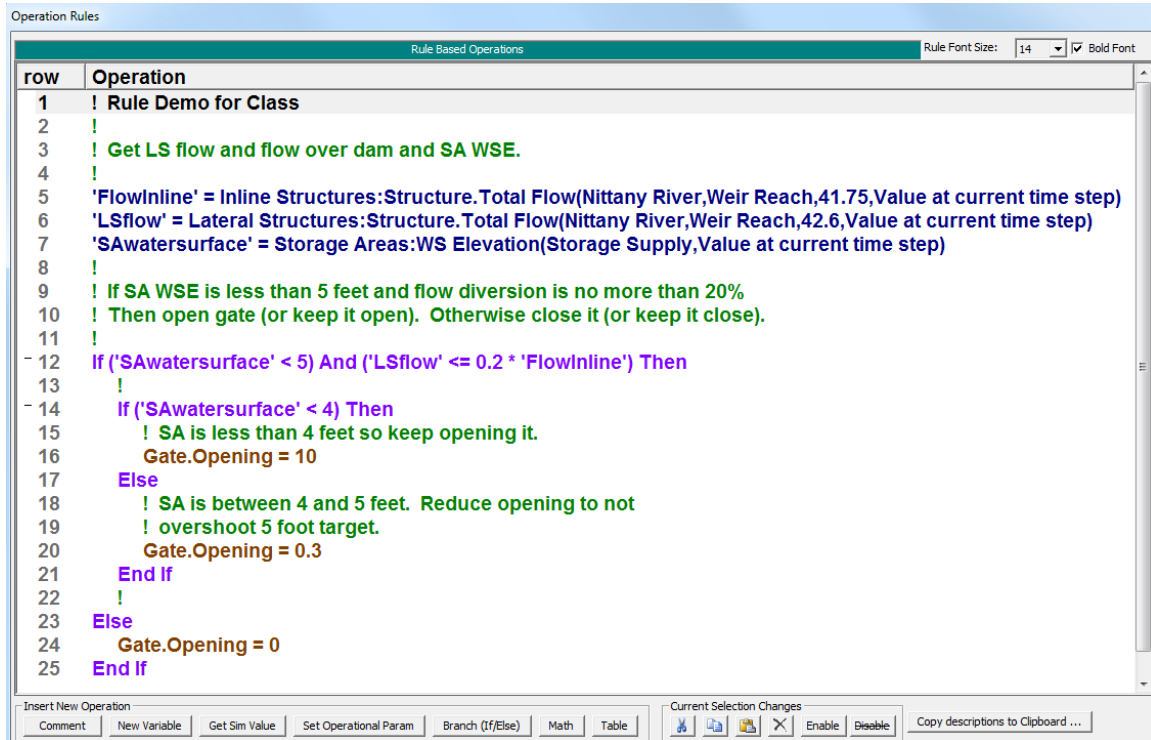
Plot Stage Plot Flow Obs Stage Obs Flow Use Ref Stage

Time Series	Maximum	Time at Max	Volume(acre-ft)
1 HW US Stage	12.30	09Apr1999 0000	
2 HW DS Stage	12.30	09Apr1999 0000	
3 TW Stage	5.39	08Apr1999 0328	

Date	Stage HW US INST-VAL FEET	Stage HW DS INST-VAL FEET	Stage TW INST-VAL FEET	Flow HW US INST-VAL CFS	Flow HW DS INST-VAL CFS	Flow Leaving INST-VAL CFS	Gate Flow - Gate #1 INST-VAL CFS	Gate Open - Gate #1 INST-VAL FEET
13 08Apr1999 0012	11.99976	11.99973	-4.78950	2173.94900	1979.01800	277.82290	277.82290	1.20000
14 08Apr1999 0013	11.99850	11.99846	-4.75124	2194.31500	1977.07900	300.96370	300.96370	1.30000
15 08Apr1999 0014	11.99722	11.99719	-4.70979	2214.94600	1975.17500	324.10250	324.10250	1.40000
16 08Apr1999 0015	11.99594	11.99590	-4.66514	2235.82500	1973.33000	347.23960	347.23960	1.50000
17 08Apr1999 0016	11.99465	11.99461	-4.61732	2256.93100	1971.54700	370.37490	370.37490	1.60000
18 08Apr1999 0017	11.99335	11.99332	-4.56630	2278.22300	1969.81400	393.50830	393.50830	1.70000
19 08Apr1999 0018	11.99206	11.99202	-4.51210	2299.65300	1968.12800	416.64000	416.64000	1.80000
20 08Apr1999 0019	11.99076	11.99073	-4.45472	2321.17800	1966.46600	393.47830	393.47830	1.70000
21 08Apr1999 0020	11.99005	11.99001	-4.40052	2333.58400	1973.30200	416.61530	416.61530	1.80000
22 08Apr1999 0021	11.98910	11.98907	-4.34314	2349.44800	1973.46400	393.45910	393.45910	1.70000

A final option is to start closing the gate before the SA reaches the 5 foot target. This is done by closing the gate to 0.3 feet once the water surface gets above 4 feet.

Additionally, comments can be used to document and explain the rule data set.



row	Operation
1	! Rule Demo for Class
2	!
3	! Get LS flow and flow over dam and SA WSE.
4	!
5	'FlowInline' = Inline Structures:Structure.Total Flow(Nittany River,Weir Reach,41.75,Value at current time step)
6	'LSflow' = Lateral Structures:Structure.Total Flow(Nittany River,Weir Reach,42.6,Value at current time step)
7	'SAwatersurface' = Storage Areas:WS Elevation(Storage Supply,Value at current time step)
8	!
9	! If SA WSE is less than 5 feet and flow diversion is no more than 20%
10	! Then open gate (or keep it open). Otherwise close it (or keep it close).
11	!
12	If ('SAwatersurface' < 5) And ('LSflow' <= 0.2 * 'FlowInline') Then
13	!
14	If ('SAwatersurface' < 4) Then
15	! SA is less than 4 feet so keep opening it.
16	Gate.Opening = 10
17	Else
18	! SA is between 4 and 5 feet. Reduce opening to not
19	! overshoot 5 foot target.
20	Gate.Opening = 0.3
21	End If
22	!
23	Else
24	Gate.Opening = 0
25	End If