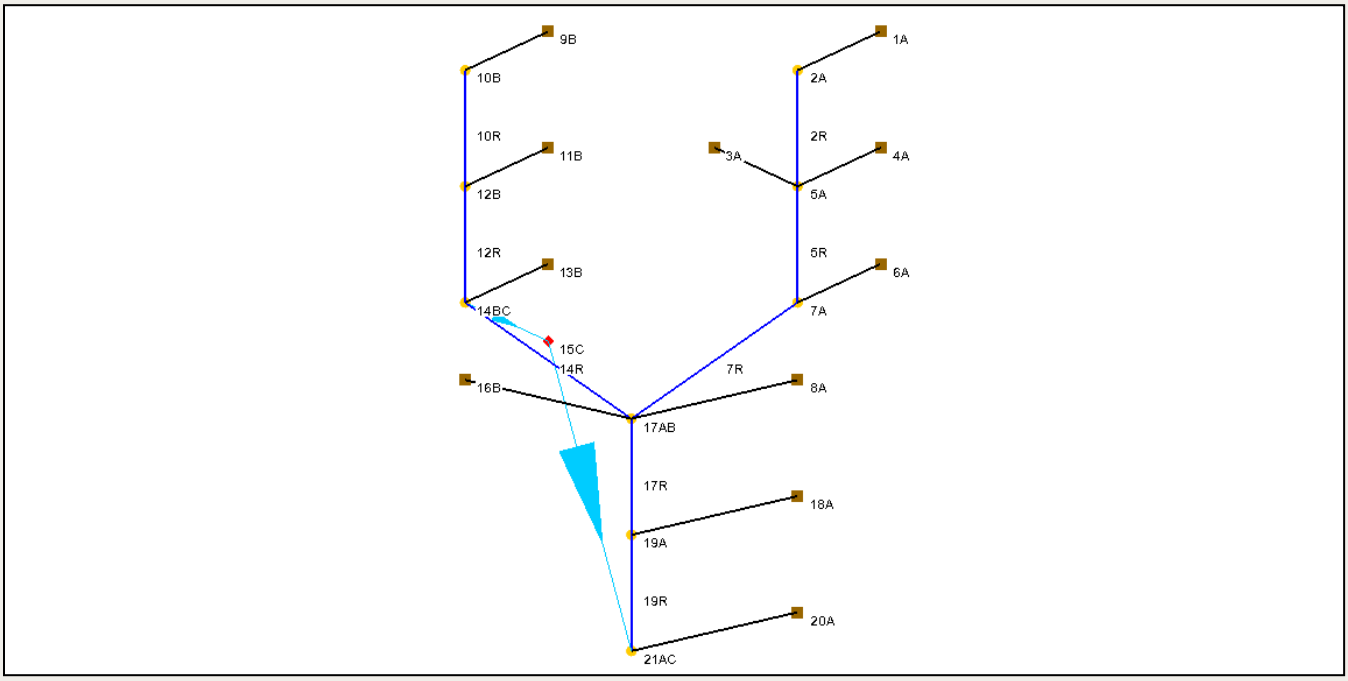
WMS 11.4 Tutorial

MODRAT Schematic

Build a MODRAT model by defining a hydrologic schematic



Objectives

Learn how to define a basic MODRAT model using the hydrologic schematic tree in WMS by building a tree and defining MODRAT hydrologic data for sub-basins and hydraulic structures.

Prerequisite Tutorials

- Introduction to WMS

Required Components

- WMS Core
- MODRAT Model

Time

- 20–40 minutes

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1 Introduction

The Modified Rational (MODRAT) model developed by the Los Angeles County Department of Public Works (LACDPW) can be set up and run using the Hydrologic Modeling Module in WMS. This module allows MODRAT simulation of a watershed without requiring GIS or digital terrain data.

The following steps demonstrate setting up a topologic tree—or schematic—representation of the watershed of Palmer Canyon (Figure 1), entering necessary parameters, and executing a MODRAT simulation.

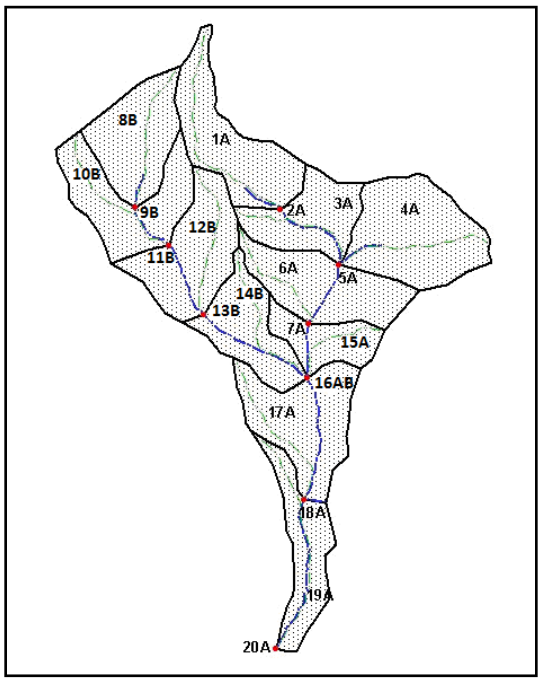

Figure 1 Palmer Canyon watershed

2 Getting Started

Starting WMS new at the beginning of each tutorial is recommended. This resets the data, display options, and other WMS settings to the defaults. To do this:

1. If necessary, launch WMS.
2. If WMS is already running, press *Ctrl-N* or select *File* | **New…** to ensure that the program settings are restored to the default state.
3. A dialog may appear asking to save changes. Click **No** to clear all data.

The graphics window of WMS should refresh to show an empty space.

3 Creating a Topologic Tree Schematic

A topologic tree is a simple schematic that shows the connectivity of drainage areas (basins) with outlets (confluence points) and reaches (stream segment). The schematic can be built in the Hydrologic Modeling Module.

1. Switch to the **Hydrologic Modeling Module** .
2. Select “MODRAT” in the *Model* drop-down list to make MODRAT the active model in WMS (Figure 2).

Figure 2 Model drop-down with MODRAT selected

For the following steps, basins can be created by selecting *Tree* **|** *Add* **| Basin** and outlets can be created by selecting *Tree* **|** *Add* **| Outlet**. The keyboard shortcuts for these are *B* and *O* (respectively), which greatly speeds up this process. The steps below will use the shortcuts, grouping several at a time to speed up the process even further.

3. Press *O*, *B*, *O*.

This creates the main watershed outlet, attaches a drainage area to the active outlet point, and adds a reach and outlet upstream from the active outlet point.

4. Press *B*, *O*, *B*, *B*.

This creates another basin, another outlet point, and two basins attached to that outlet point.

5. Press *O*, *B*, *O*, *B*.
6. Press *B*, *O*, *B*.

The main line in the Palmer Canyon watershed has been completed. Now create a tributary line.

7. Using the **Select outlet** tool, select “4C”.
8. Press *O*, *B*, *O*.
9. Press *B*, *O*, *B*.

This creates a second outlet and reach attached to the selected outlet point. The rest of the watershed is then created and the schematic is now complete (Figure 3). The connectivity of basins, reaches, and outlets is now established, so it is now possible to assign MODRAT input parameters to the watershed.

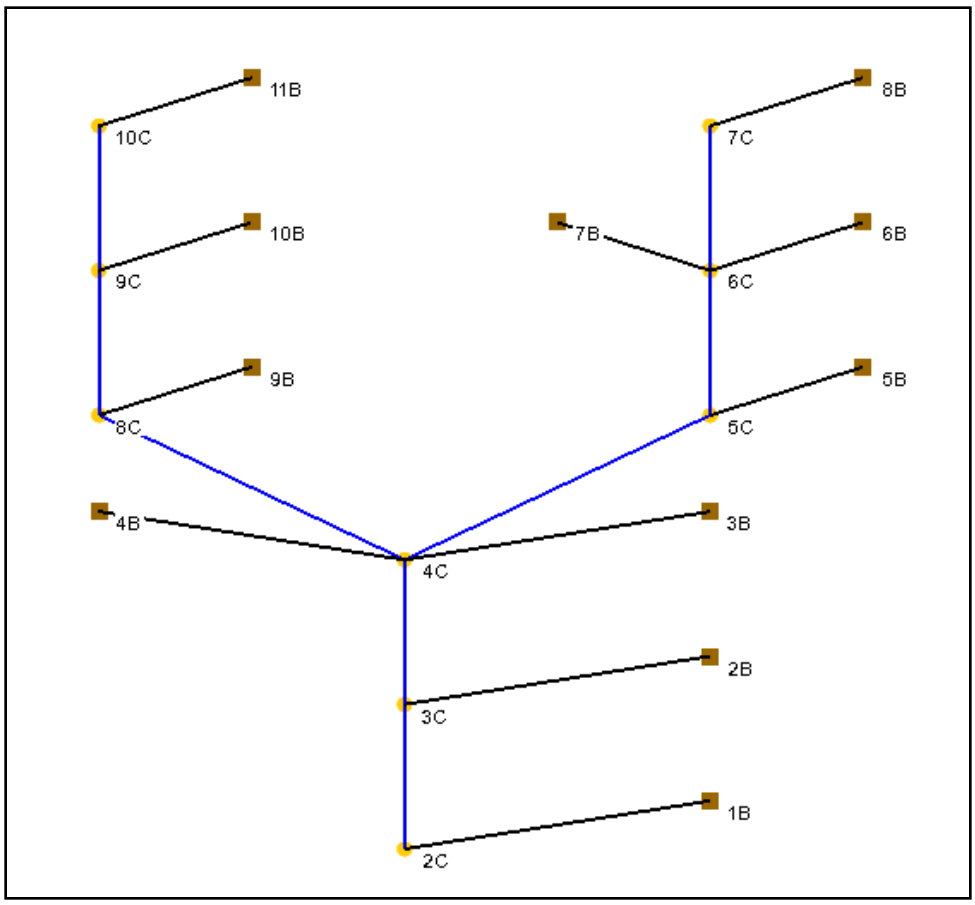

Figure 3 Schematic for Palmer Canyon watershed

4 MODRAT Job Control

The *MODRAT Job Control* dialog allows for specifying input and output filenames, simulation duration, and storm frequency.

1. Select *MODRAT* **| Job Control…** to bring up the *MODRAT Job Control* dialog.
2. In the left section, select *MODRAT 2.0*.
3. Select "2" from the *Run time* drop-down.
4. Select "25 year" from the *Frequency* drop-down.
5. In the *Filenames* section, enter "Palmer1" as the *Prefix* and click **Update**.

Note that the *Output files prefix* updated.

6. In the *Input* section, enter "palmer_rain.dat" in the *Rain* field.

WMS saves the rainfall input data to this filename.

7. Click **Browse** to the right of the *Soil* field to bring up the *Open* dialog.
8. Select "WMS Data Sets (*.dat)" from the *Files of type* drop-down.
9. Browse to the *MODRAT\MODRAT* directory and select "sgr_soilx_71.dat".
10. Click **Open** to exit the *Open* dialog.

The pathway to the selected DAT file should appear in the Soil field now. WMS imports the soil data from this file. This soil file contains data for the San Gabriel River watershed where Palmer Canyon is located.

11. Click **OK** to close the *MODRAT Job Control* dialog.

5 Schematic Tree Numbering

The MODRAT model requires that a watershed model be numbered sequentially in operational order from upstream to downstream. The order in which hydrologic units are processed depends on model numbering. WMS automatically numbers the tree.

1. Using the **Select basin** tool, select the top right basin.

This indicates to WMS in the next step that this is the upstream end of the main line of the watershed.

2. Select *MODRAT* **| Number Tree…** to bring up the *MODRAT Renumber* dialog.
3. Click **OK** to start numbering with location/lateral of “1A”, close the *MODRAT Renumber* dialog, and open the *Select a lateral* dialog.

The numbering process prompts to “Select a lateral" for each of the basins at a confluence. Notice that WMS zooms into the outlet point labeled 14AB and its surrounding outlet points. The first one is the one on the left.

4. Select “B” from the wide drop-down to assign the basin on the left to the "B" lateral of the watershed.
5. Click **OK** to reload the *Select a lateral* dialog for the basin on the right.
6. Select “A” from the wide drop-down to assign the right basin to the "A" lateral of the watershed.
7. Click **OK** to close the *Select a lateral* dialog.
8. **Frame** the project.

The numbering is now complete. Note that the basin selected when the numbering was initiated is now “1A”. The main line is met by Line B at the “16AB” confluence (outlet) point (Figure 4). The numbers now indicate the order in which the units will be processed by MODRAT.

Before proceeding, save the WMS project.

1. Select *File* **| Save As…** to bring up the *Save As* dialog.
2. Select “WMS XMDF Project File (*.wms)” from the *Save as type* drop-down.
3. Enter “PalmerCyn25.wms” as the *File name*.
4. Click **Save** to save the project under the new name and close the *Save As* dialog.

WMS saves the project to a set of WMS project files. The WMS file is an index file and contains other information that instructs WMS to load all the files associated with the project when opening the project at a later time.

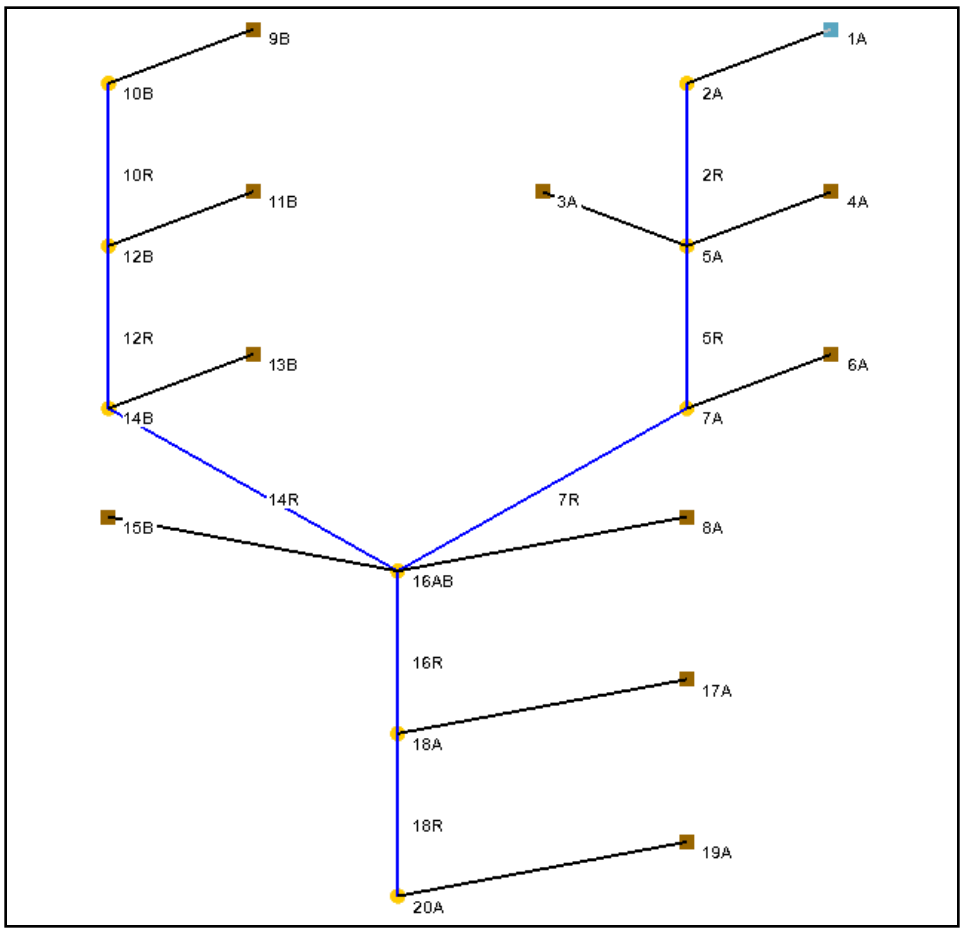

Figure 4 Schematic after renumbering

6 Editing MODRAT Input Parameters

Input parameters for each basin and reach must be defined for the watershed. The following sections demonstrate entering required data for basins and reaches and setting output preferences for each hydrologic unit.

6.1 Editing Basin Data

Each basin (drainage area) must have data associated with it to be successfully simulated by MODRAT.

1. Select *MODRAT* **| Edit Parameters…** to bring up the *MODRAT Parameters* dialog.
2. Select "All" from the *Show* drop-down.
3. In the *Temporal distribution* column in the *All* row, click **Define…** to open the *XY Series Editor* dialog.

This is where the rainfall temporal distribution (time vs. cumulative rainfall percentage) is specified.

4. Click **Import…** to bring up the *Open file* dialog.

5. Select “XY Series File (*.xys)” from the *Files of type* drop-down.
6. Select “LACDPWStorm-4thday.xys” and click **Open** to import the file and exit the *Open file* dialog.

The LACDPW curve will appear in the spreadsheet/plot window (Figure 5).

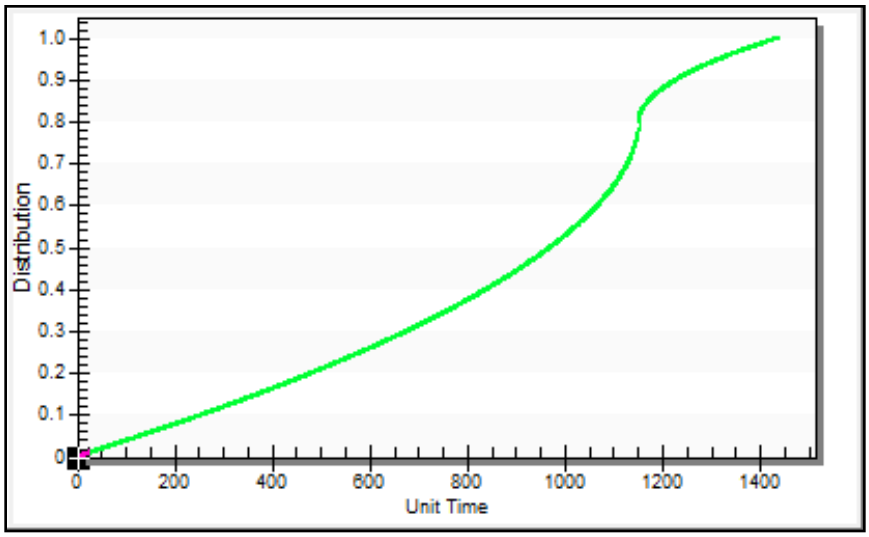

Figure 5 LACDPW curve

7. Click **OK** to assign this curve to all basins and close the *XY Series Editor* dialog.
8. In the *All* row, scroll to the right and select “Hydrograph (*.hyf) and WMS plot file (*.sol)” from the drop-down in the *Hydrograph Output* column.

The input for one of the basins in the Palmer Canyon watershed has been completed. Now define the rest of the data for all basins:

9. In an external spreadsheet program, open the “modrat-schematic.xls” file in the *MODRAT\MODRAT* directory.
10. Copy the values in the *Area (ac)* column of the *Basin Data* table.
11. In WMS, in the *MODRAT Parameters* dialog, paste the values into the *Area (ac)* column. Be sure to paste the values to the first white cell in the column.
12. Repeat steps 10–11 for the *Tc (min)*, *Soil type*, *Impervious %*, and *Rainfall depth (n)* columns.
13. When finished, click **OK** to close the *MODRAT Parameters* dialog.

The basin parameters for all drainage areas should now be entered for the simulation. Now is a good time to save the project.

14. **Save** the project.

6.2 Editing Reach Parameters

Each reach must have data associated with it to be successfully simulated by MODRAT. Reaches are selected in WMS by clicking on an outlet (confluence) point. The parameters for that point and the channel downstream from that point to the next can be edited.

1. Using the **Select outlet** tool, select outlet “2A”.

2. Select *MODRAT* **| Edit Parameters…** to bring up the *MODRAT Parameters* dialog.
3. Select "All" from the *Show* drop-down.
4. Scroll all the way to the right to the *Hydrograph Output* column, and select "Hydrograph (*.hyf) and WMS plot file (*.sol)" from the drop-down on the *All* row.
5. In an external spreadsheet program, open the "modrat-schematic.xls" file in the *MODRAT\MODRAT* directory.
6. Copy from "modrat-schematic.xls" the values in the *Length (ft)* column of the *Reach Parameters* table.
7. In WMS, paste the values into the *Length (ft)* column in the *MODRAT Parameters* dialog. Be sure to paste the values into the first white cell of the column.
8. Repeat steps 6-7 for the *Slope (ft/ft)*, *Routing type*, and *Manning's n* columns.
9. When finished, click **OK** to close the *MODRAT Parameters* dialog.

The input parameters for all reaches should now be entered for the simulation. Save this data to the working project file.

10. **Save** the project.

7 Running a MODRAT 2.0 Simulation

All the data required to run a simulation is now ready. To make sure there are no omissions in the data, WMS will perform a model check.

1. Select *MODRAT* **| Check Simulation…** to bring up the *MODRAT Model Check* dialog.

Notice that there are two possible errors in the MODRAT model for outlet "20A". Because this is the watershed outlet, there is no reach downstream to define.

2. Click **Done** to exit the *MODRAT Model Check* dialog.

The model checker is a simple way to verify that needed data has not been omitted. It does not verify that the model is correct, but that all the data needed to run the simulation is in place.

To execute the MODRAT simulation, do the following:

3. Select *MODRAT* **| Run Simulation…** to bring up the *MODRAT Run Options* dialog.
4. Click **Browse** to bring up the *Select MODRAT Input File Name* dialog.
5. Browse to the *MODRAT\MODRAT* directory for the tutorial.
6. Enter "Palmer1.lac" as the *File name* and click **Save** to close the *Select MODRAT Input File Name* dialog.
7. Turn on *Save file before run*.
8. Click **OK** to open the *Model Wrapper* dialog and start the simulation.
9. Once MODRAT finishes, turn on *Read solution on exit* and click **Close** to import the solution and close the *Model Wrapper* dialog.

The resulting hydrographs will be imported and a small hydrograph plot will appear next to each basin and outlet (Figure 6).

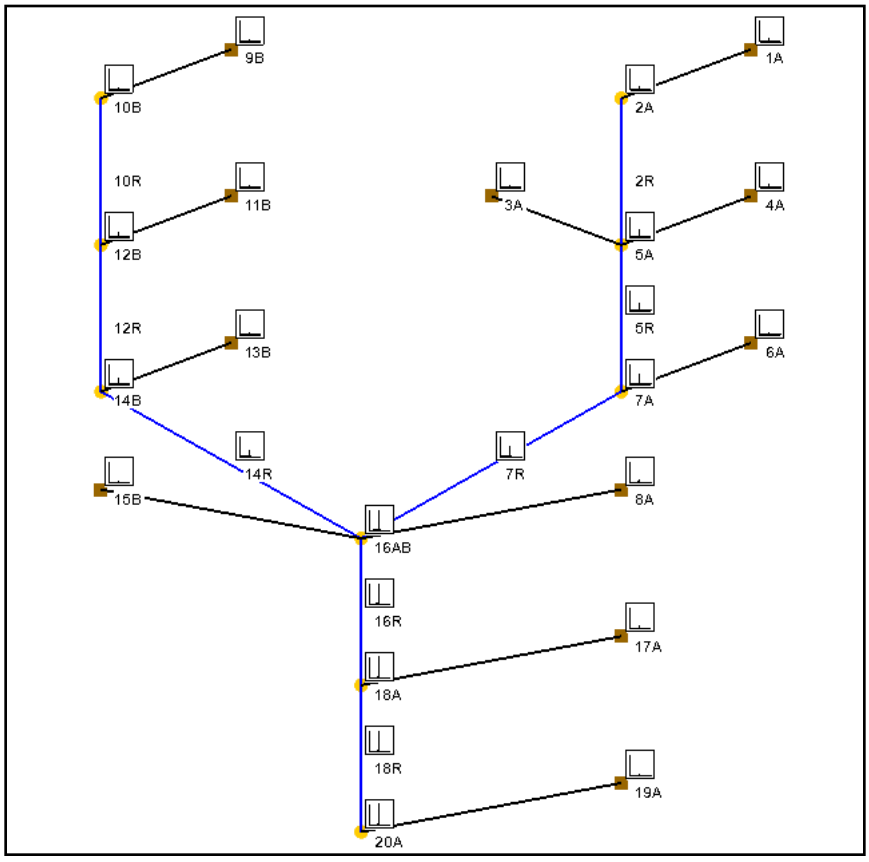

Figure 6 Hydrographs generated for each basin and outlet

10. Using the **Select hydrograph** tool, double-click on the hydrograph icon next to outlet "20A" to bring up the *Hydrograph* dialog.
11. Review the hydrograph plot. Notice that peak flow, time to peak, and volume are reported both below the title and in legend of the plot.
12. Hold the *Shift* key and double-click on the hydrograph icon next to outlet "16AB" to bring up a new *Hydrograph* dialog.
13. Notice that both hydrographs are plotted on the same axes.
14. Close both plot windows by clicking on the in the upper right corner of each window.
15. Select *File* | **Edit File…** to bring up the *Open* dialog.
16. Select "Palmer1.out" and click **Open** to exit the *Open* dialog and open the *View Data File* dialog. If the *Never ask this again* option has previously been checked, this dialog will not appear. If this is the case, skip to step 18.
17. Select the desired text editor from the *Open with* drop-down and click **OK** to close the *View Data File* dialog and open the file in the selected text editor.
18. When done reviewing the output data, close the text editor by clicking the in the top right corner and return to WMS.
19. Clear the results by selecting *Hydrographs* | **Delete All**.

This successfully completes this simple simulation with MODRAT. There are many other options in MODRAT not included in this simple model. The following sections will present two of those options: detention basins and diversions.

8 Adding a Diversion (Flow Split)

The flow in a line of a MODRAT model can be split using a diversion in WMS. The diverted flow can be routed and returned to a downstream location in the model, if desired. To split flow at one location in the model, do the following:

1. Using the **Select outlet** tool, select outlet “14B”.
2. Select *Tree* **|** *Add* **| Diversion.**

WMS will insert the diversion.

3. Click on the outlet named 20A.
4. Select *Tree* **| Retrieve Diversion**.

Note that the diversion arrow returns to the outlet named 20A (Figure 7).

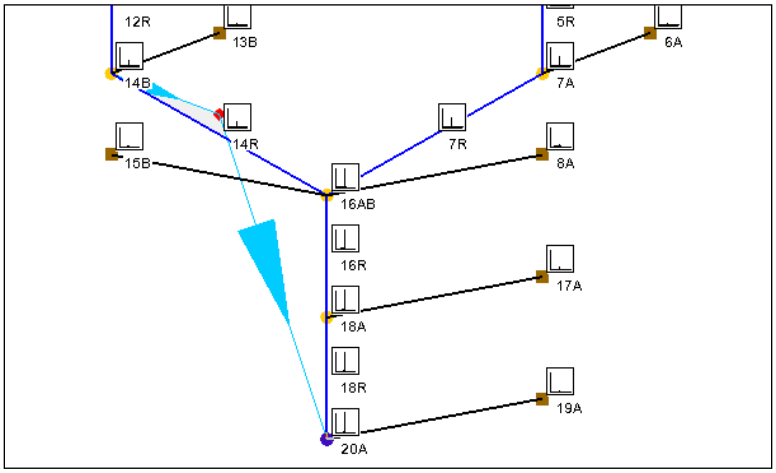

Figure 7 Diversion from 14B to 20A

8.1 Renumbering to Include Diversion

Since a diversion has been added to the model, renumber the model to include this new diversion in the numbering scheme.

1. Using the **Select basin** tool, select sub-basin 1A (most upstream on the right branch).
2. Select *MODRAT* **| Number Tree…** to bring up the *MODRAT Renumber* dialog.
3. Click **OK** to start numbering with location/lateral of “1A”, close the *MODRAT Renumber* dialog, and open the *Select a lateral* dialog.
4. Select “B” from the wide drop-down to assign basin “15B” to the "B" lateral of the watershed.
5. Click **OK** to reload the *Select a lateral* dialog for the basin on the right.
6. Select “A” from the wide drop-down to assign basin “8A” to the "A" lateral of the watershed.

7. Click **OK** to close the *Select a lateral* dialog.
8. **Frame** the project.

Notice that the diversion basin has been numbered “15C” (it may be difficult to see due to the hydrograph icon), and the stream from “14BC” to “21AC” has been renumbered (Figure 8).

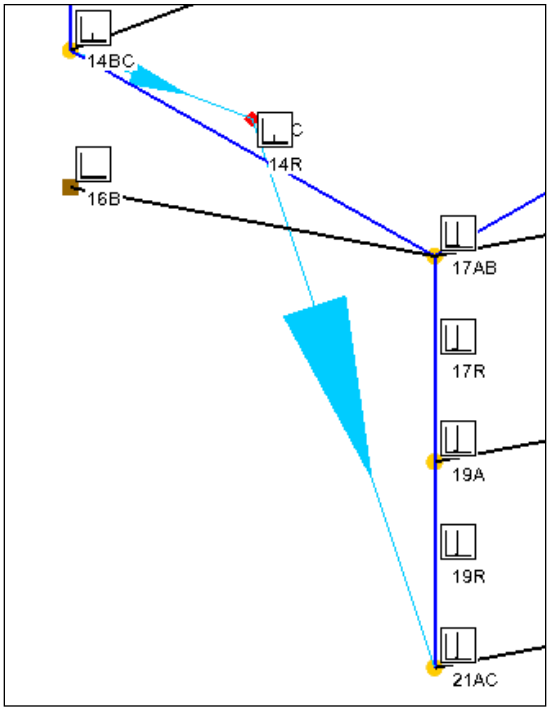

Figure 8 Renumbered section

8.2 Defining the Diversion

Now that the location and return have been defined, instruct MODRAT how to split the flow and route it in the diversion channel.

1. Using the **Select outlet** tool, double-click outlet “14BC” to bring up the *MODRAT Parameters* dialog.
2. To the right of *Display*, turn on *Relief Drains*.
3. Scroll to the right to the *Relief drain type* column and select “Drain Capacity” from the drop-down menu.
4. Enter “250.0” in the *Flow rate* column.

This is the maximum flow allowed in the main channel. Flow above this rate will be diverted.

5. Click **OK** to exit the *MODRAT Parameters* dialog.
6. Using the **Select diversion** tool, double-click diversion “15C” to bring up the *MODRAT Parameters* dialog.
7. In the spreadsheet on the *15C* row, enter “5000.0” in the *Length* column.
8. Enter “0.05” in the *Slope* column.

9. Select “Circular pipe” from the *Routing type* drop-down.
10. Enter “0.014” in the *Manning’s n* column.
11. Enter “3.0” in the *Size* column.

This is the diameter of the pipe.

12. Scroll to the right and select “Hydrograph (*.hyf) and WMS plot file (*.hyf)” in the *Hydrograph output* column.
13. Click **OK** to exit the *MODRAT Parameters* dialog.
14. **Save** the project.

8.3 Running MODRAT with Diversion

The diversion is now complete. Now re-run the simulation to see the effects of the diversion.

1. Select *MODRAT* | **Job Control…** to bring up the *MODRAT Job Control* dialog.
2. In the *Filenames* section, enter “Palmer2” as the *Prefix* and click **Update**.
3. Click **OK** to close the *MODRAT Job Control* dialog.
4. Select *MODRAT* **| Run Simulation…** to bring up the *MODRAT Run Options* dialog.
5. Click **Browse** to bring up the *Select MODRAT Input File Name* dialog.
6. Enter “Palmer2.lac” as the *File name* and click **Save** to close the *Select MODRAT Input File Name* dialog.
7. Turn on *Save file before run* and click **OK** to close the *MODRAT Run Options* dialog and bring up the *Model Wrapper* dialog.
8. Once MODRAT is finished, turn on *Read solution on exit* and click **Close** to exit the *Model Wrapper* dialog.

The resulting hydrographs will be imported and a small hydrograph plot will appear next to each basin and outlet.

9. Using the **Select hydrograph** tool, double-click on the hydrograph icon next to outlet “14BC” to bring up the *Hydrograph* dialog.
10. Note that the hydrograph peak is cut off at 250.0 cfs.
11. Double-click on the hydrograph icon next to diversion “15C”.
12. Compare the two hydrographs, and notice that the one for “15C” appears to be a continuation of the one for “14BC” (Figure 9).
13. Close all *Hydrograph* dialogs by clicking the in the upper right corner of each window.
14. Clear the hydrograph results by selecting *Hydrographs* **| Delete All**.

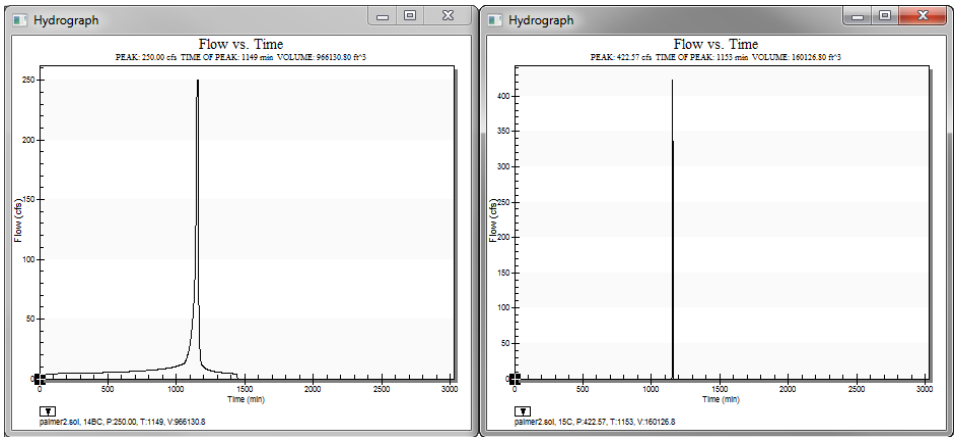

Figure 9 Hydrographs for 14BC (left) and 15C (right)

9 Adding a Detention Basin

A detention basin can be placed at any outlet point, routing incoming flow through that structure with MODRAT. In this model, define a detention basin at the watershed outlet (the mouth of Palmer Canyon).

1. Using the **Select outlet** tool, double-click outlet “21AC” to bring up the *MODRAT Parameters* dialog.
2. To the right of *Display*, turn on *Reservoir Routing*.
3. Scroll to the right and check the box on the *21AC* row in the *Reservoir routing* column.
4. Click the **Define…** button in the *Reservoir* column to bring up the *Detention Basin Hydrograph Routing* dialog.
5. Click **Define…** to bring up the *Storage Capacity Input* dialog.

9.1 Defining a Detention Basin

Now define a hypothetical detention basin from approximate geometric parameters. WMS can compute a storage capacity curve for a rectangular basin. A pre-computed storage capacity curve should also be entered.

1. In the *Storage capacity* section, select *Known Geometry*.
2. Enter “500.0” as the *Length*.
3. Enter “500.0” as the *Width*.
4. Enter “20.0” as the *Depth*.
5. Enter “1.0” as the *Side slope*.

The *Base Elevation* is assumed to be on-grade at the outlet location for this tutorial, so it does not need to be set.

6. Click **OK** to close the *Storage Capacity Input* dialog and bring up the *Detention Basin Analysis* dialog.

9.2 Defining the Outlet Pipe and Spillway

Now define a low-level outlet pipe and spillway (weir) for outlet structures and WMS will compute the elevation-discharge relationship automatically. In addition to standpipes and weirs, low-level outlets can be defined, or a pre-computed elevation-discharge relationship can be entered.

1. Click **Define Outflow Discharges…** to bring up the *Elevation Discharge Input* dialog.
2. Click **Add Riser** to add a riser ("Riser 1") to the *Discharges* section.
3. In the *Parameter* section, select "Circular" from the *Opening Shape Type* drop-down.
4. Enter "4.90" as the *Opening Diameter*.
5. Enter "1.0" as the *Height above Base Elev to Bottom of Opening*.
6. Click **Add Weir** to add a weir ("Weir 2") to the *Discharges* section.
7. Enter "50.0" as the *Weir length*.
8. Enter "17.0" as the *Height above Base Elev*.
9. Click **OK** to close the *Elevation Discharge Input* dialog.
10. Click **OK** to close the *Detention Basin Analysis* dialog.

The curves should be plotted in the *Detention Basin Hydrograph Routing* dialog (Figure 10).

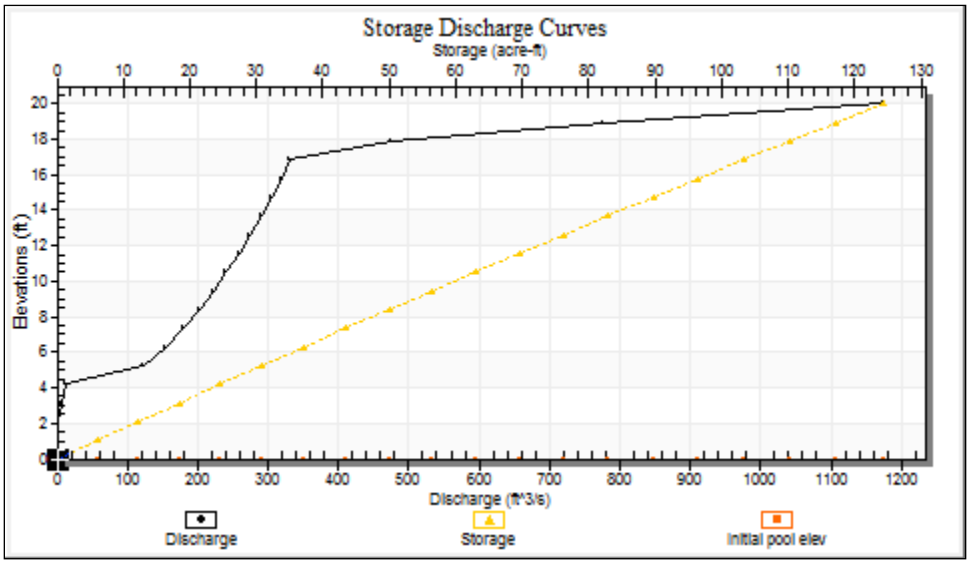

Figure 10 Reservoir Storage-Elevation-Discharge

11. Click **OK** to close the *Detention Basin Hydrograph Routing* dialog.
12. Click **OK** to exit the *MODRAT Parameters* window.

A detention facility has now been defined that has an outlet pipe and a spillway for control structures. The incoming hydrograph to this outlet point will be routed through the detention facility before being routed downstream and combined with the hydrographs of other basins.

9.3 Running MODRAT with Diversion Control Structures

To re-run the simulation and see the effects, do the following:

1. Select *MODRAT* **| Job Control…** to bring up the *MODRAT Job Control* dialog.
2. In the *Filenames* section, enter “Palmer3” as the *Prefix* and click **Update**.
3. Click **OK** to close the *MODRAT Job Control* dialog.
4. Select *MODRAT* **| Run Simulation…** to bring up the *MODRAT Run Options* dialog.
5. Click **Browse** to bring up the *Select MODRAT Input File Name* dialog.
6. Enter “Palmer3.lac” as the *File name* and click **Save** to close the *Select MODRAT Input File Name* dialog.
7. Turn on *Save file before run*.
8. Click **OK** to close the *MODRAT Run Options* dialog, open the *Model Wrapper* dialog, and start the simulation.
9. Once MODRAT finishes, turn on *Read solution on exit* and click **Close** to import the solution and close the *Model Wrapper* dialog.

The resulting hydrographs will be imported and a small hydrograph plot will appear next to each basin and outlet. Note that there are two hydrograph icons near “21AC”.

10. Using the **Select hydrograph** tool, select one of them, then hold Shift wile double-clicking the other to open the *Hydrograph* dialog. Notice that both are plotted together on the same plot.

Both hydrographs will be plotted in a new window (Figure 11). Note the effects of the detention basin on the incoming hydrograph. When selecting multiple hydrographs, view all the selected hydrographs in a single plot by selecting *Display* **| Open Hydrograph Plot**.

11. When done reviewing the *Hydrograph* dialog, close it by clicking the in the top right corner.
12. Clear all the hydrograph results by selecting *Hydrographs* **| Delete All**.
13. **Save** the project.

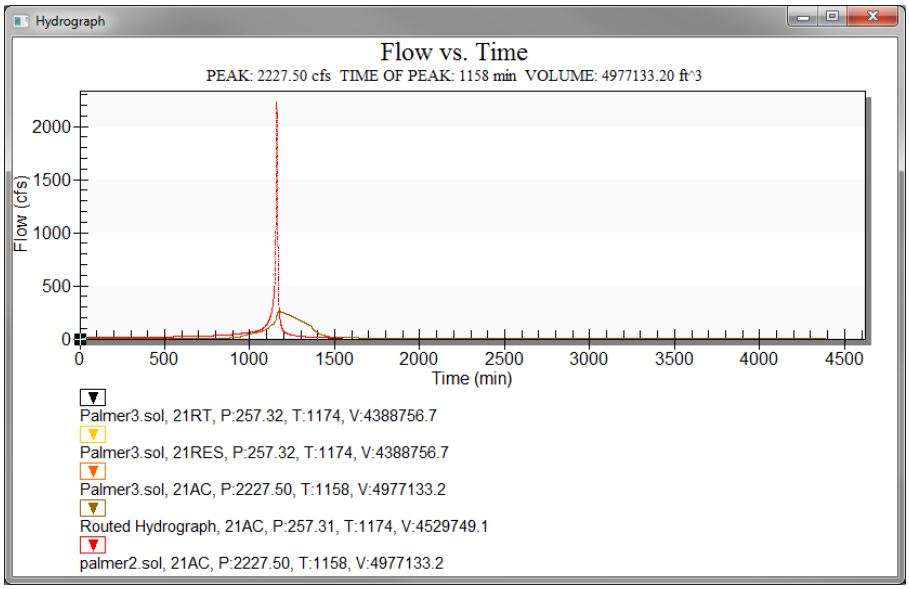

Figure 11 Both hydrographs at outlet 21AC

10 Running MODRAT 1.0

This section is optional as it discusses how to run a simulation using the older MODRAT 1.0 version of MODRAT that uses the 4-day storm approach instead of a continuous simulation approach

To run MODRAT 1.0, some Job Control items and precipitation input for the basins in the model must be entered and edited.

1. Select *MODRAT* | **Job Control…** to bring up the *MODRAT Job Control* dialog.
2. In the left section, select *MODRAT*.
3. Select “Days: 4” from the *Time period* drop-down.
4. In the *Filenames* section, enter “Palmer4” as the *Prefix* and click **Update**.
5. Click **OK** to close the *MODRAT Job Control* dialog.
6. Select *MODRAT* | **Edit Parameters…** to bring up the *MODRAT Parameters* dialog.
7. Select “Basins” from the *Type* drop-down.
8. Select “All” from the *Show* drop-down.
9. In the *All* row of the *Temporal distribution* column, click **Define…** to bring up the *XY Series Editor* dialog.
10. Click **Import…** to bring up the *Open File* dialog.
11. Select “LACDPWStorm1500min.xys” and click **Open** to exit the *Open File* dialog.

The “LACDPWStormSeries1500min” curve will appear in the spreadsheet/plot window (Figure 12).

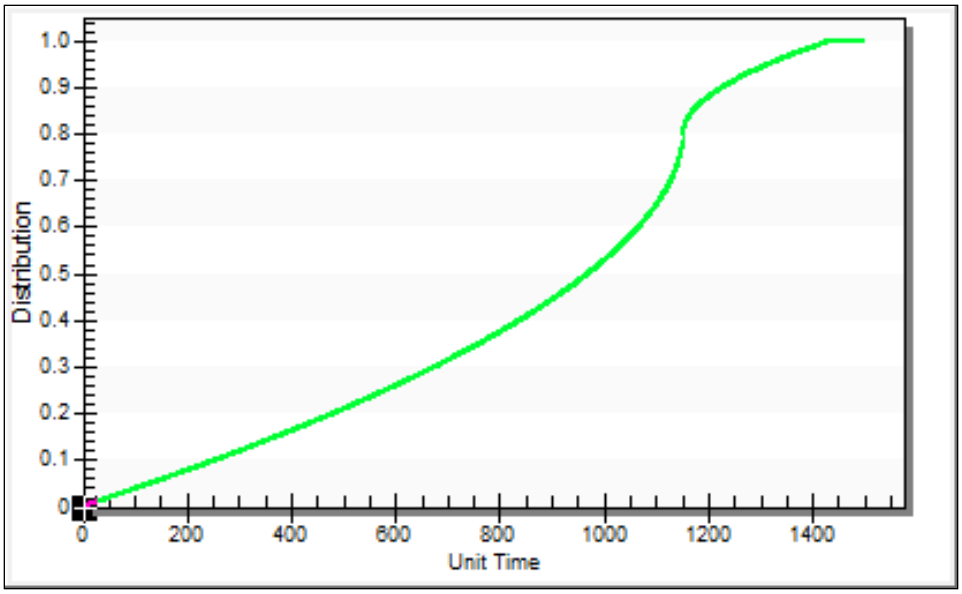

Figure 12 LACDPWStormSeries1500min curve plot

12. Click **OK** to close the *XY Series Editor* dialog and assign this curve to all basins.

Note that the rainfall depths entered do not need to be changed due to running a 4th day simulation with MODRAT 2.0. These depths correspond to a 24 hour design storm and are appropriate with the 1500 min. curve used with MODRAT 1.0.

13. Click **OK** to close the *MODRAT Parameters* dialog.
14. Select *MODRAT* | **Run Simulation…** to bring up the *MODRAT Run Options* dialog.
15. Click **Browse** to bring up the *Select MODRAT Input File Name* dialog.
16. Enter "Palmer4.lac" as the *File name* and click **Save** to close the *Select MODRAT Input File Name* dialog.
17. Turn on *Save file before run* and click **OK** to close the *MODRAT Run Options* dialog and bring up the *Model Wrapper* dialog.
18. Once MODRAT 1.0 finishes, turn on *Read solution on exit* and click **Close** to exit the *Model Wrapper* dialog and import the solutions.

The resulting hydrographs will be imported and a small hydrograph plot will appear next to each basin and outlet. Feel free to review the hydrographs as desired.

11 Conclusion

This concludes the "MODRAT Schematic" tutorial. Key concepts discussed and demonstrated include some of the options available for using the MODRAT model in WMS. Feel free to continue experimenting with the different options to become familiar with all the capabilities in WMS for doing MODRAT simulations.