
RiverWare Demonstration Tutorial



This RiverWare informational tutorial introduces you to the capabilities of RiverWare as an advanced water resource modeling tool and consists of three sections, **Simulation in RiverWare**, **Rulebased Simulation**, and **Multiple Run Management**. These tutorials are independent documents but later topics do build on skills you gain from earlier exercises, so if you have not gone through the earlier topics or have not used RiverWare recently it is recommended that you start with the tutorial on **Simulation in RiverWare**.

Before you start...

You must have RiverWare 9.3 or later installed on your computer and have a valid license file. For more information about downloading RiverWare, visit RiverWare.org. To acquire a demonstration license, please email Installation Support (installsupport@colorado.edu).

You must have downloaded the files associated with this tutorial and moved them to **C:\temp**. The following files are used in this tutorial:

- BighornBasin_MRM_InfoTutorial.mdl.gz - MODEL
- BighornDMI_inflows.xls - Inflow data
- Bighorn_Output.ctl

3 Analyzing Alternatives using MRM

This informational tutorial introduces you to Multiple Run Management (MRM) in RiverWare. You will be introduced to:

- Overview of Multiple Run Management (MRM)
- One format for inputs to MRM
- Setting up and Running an MRM
- Looking at Outputs from MRM runs

☐ First, make sure you've saved the above files in **C:\temp**.

This is critical to completing this tutorial due to this particular setup of MRM input and output files. **It will not work if you save it in any other location!**

To get started let's open the model in RiverWare:



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- ☐ Double-click the RiverWare icon on the desktop.
 - ☐ Close the Quick Start window as we'll open the model from the workspace.
 - ☐ Select **File** and then **Open Model...** from the main workspace menu bar or select the Open Model File toolbar button.
 - ☐ Open the file `BighornBasin_MRM_InfoTutorial.mdl.gz`



3.1 MRM Overview

Once you have a calibrated, working model, you may wish to run your model many times with different inputs or policies. One method is the Multiple Run Management (MRM) utility which is used to automatically run a model many times. The runs are set up through the user interface, then RiverWare carries out all runs, and results are sent to a text file, database or an Excel workbook.

A multiple run is defined as a set of one or more model runs, where for all runs:

- The model configuration (object network) remains constant.
- The run duration is the same.
- The timestep size is constant.
- The same set of slots are saved to the output file.

Runs are conducted automatically, i.e., RiverWare controls and invokes each run and exports results through the configuration of a Data Management Interface (DMI) without user interaction. MRMs can execute in three modes: Concurrent, Consecutive, and Iterative.

Consecutive mode performs multiple runs where the time horizons are laid out consecutively—the end time of one run is the initial time of the next run. Iterative mode executes multiple runs where MRM rules at the beginning and/or end of each run examine the state of the system and, if appropriate, set values for the subsequent simulation run. If no values are set or the maximum number of iterations occurs, then the simulation ends.


This tutorial will focus only on **Concurrent** mode, which executes multiple runs where the begin and end times are the same for all runs. Concurrent mode is useful for exploring how the system performs under a range of circumstances or management strategies by varying the inputs for each run. Inputs include rulesets (policy alternatives), input DMIs (i.e. series data like alternative hydrologies), and/or index sequential (data sampling technique).

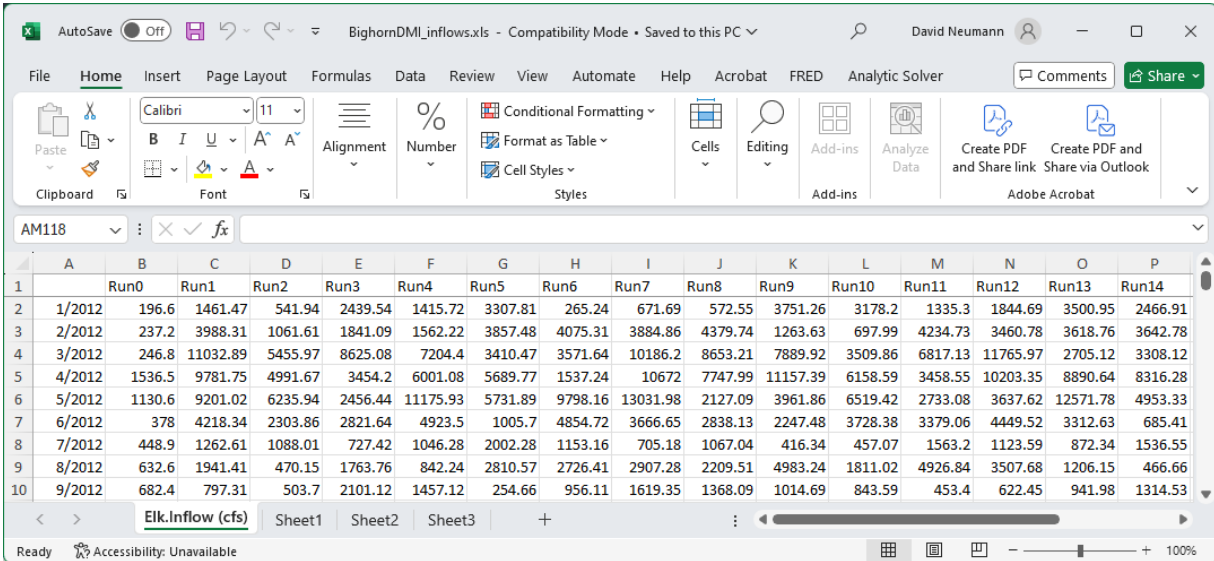
3.2 Inputs to MRM

As mentioned in the first section, concurrent MRM is an effective way to see how a system responds to varied inputs. Inputs to a concurrent MRM include:

- Input DMIs: Modify the hydrology, demands and other timeseries information to analyze their effect on the system.
- Rulesets: Alternative policies you wish to consider.
- Index sequential: Re-sample a set of data to generate stochastic inputs.

Here we will demonstrate the setup and results for the first item, using 20 different hydrologies as the inflow for the Elk reservoir.

 Open the "BighornDMI_inflows.xls" Excel file from the **C:/Temp** folder.



| | Run0 | Run1 | Run2 | Run3 | Run4 | Run5 | Run6 | Run7 | Run8 | Run9 | Run10 | Run11 | Run12 | Run13 | Run14 |
|--------|--------|----------|---------|---------|----------|---------|---------|----------|---------|----------|---------|---------|----------|----------|---------|
| 1/2012 | 196.6 | 1461.47 | 541.94 | 2439.54 | 1415.72 | 3307.81 | 265.24 | 671.69 | 572.55 | 3751.26 | 3178.2 | 1335.3 | 1844.69 | 3500.95 | 2466.91 |
| 2/2012 | 237.2 | 3988.31 | 1061.61 | 1841.09 | 1562.22 | 3857.48 | 4075.31 | 3884.86 | 4379.74 | 1263.63 | 697.99 | 4234.73 | 3460.78 | 3618.76 | 3642.78 |
| 3/2012 | 246.8 | 11032.89 | 5455.97 | 8625.08 | 7204.4 | 3410.47 | 3571.64 | 10186.2 | 8653.21 | 7889.92 | 3509.86 | 6817.13 | 11765.97 | 2705.12 | 3308.12 |
| 4/2012 | 1536.5 | 9781.75 | 4991.67 | 3454.2 | 6001.08 | 5689.77 | 1537.24 | 10672 | 7747.99 | 11157.39 | 6158.59 | 3458.55 | 10203.35 | 8890.64 | 8316.28 |
| 5/2012 | 1130.6 | 9201.02 | 6235.94 | 2456.44 | 11175.93 | 5731.89 | 9798.16 | 13031.98 | 2127.09 | 3961.86 | 6519.42 | 2733.08 | 3637.62 | 12571.78 | 4953.33 |
| 6/2012 | 378 | 4218.34 | 2303.86 | 2821.64 | 4923.5 | 1005.7 | 4854.72 | 3666.65 | 2838.13 | 2247.48 | 3728.38 | 3379.06 | 4449.52 | 3312.63 | 685.41 |
| 7/2012 | 448.9 | 1262.61 | 1088.01 | 727.42 | 1046.28 | 2002.28 | 1153.16 | 705.18 | 1067.04 | 416.34 | 457.07 | 1563.2 | 1123.59 | 872.34 | 1536.55 |
| 8/2012 | 632.6 | 1941.41 | 470.15 | 1763.76 | 842.24 | 2810.57 | 2726.41 | 2907.28 | 2209.51 | 4983.24 | 1811.02 | 4926.84 | 3507.68 | 1206.15 | 466.66 |
| 9/2012 | 682.4 | 797.31 | 503.7 | 2101.12 | 1457.12 | 254.66 | 956.11 | 1619.35 | 1368.09 | 1014.69 | 843.59 | 453.4 | 622.45 | 941.98 | 1314.53 |

This file is used by RiverWare as the **Input DMI**. The are 20 hydrologies represented by columns of monthly inflows (Run0 to Run19) and the sheet is named **Elk.Inflow (cfs)**. This structure is specified in the DMI settings and necessary for proper execution. RiverWare will run the entire simulation (from January 2012 through December 2021) 20 times, reporting the slot values requested by the user.

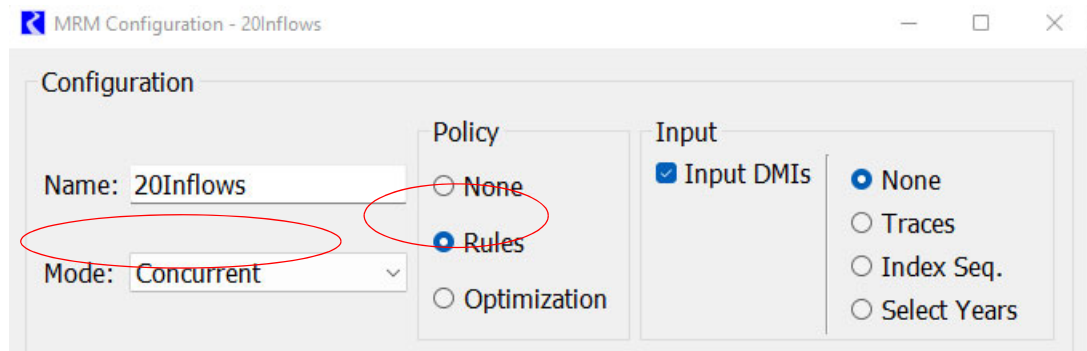
For simplicity this DMI is setup to use Excel as the input format, but other databases can also be used. HDB have automatic connections to RiverWare while you can connect to any database using a Control File-Executable DMI. For further information, see **Help** and then **RiverWare Help...** and then **Data Management Interface**.

3.3 Making Multiple Runs

Now let's examine the settings that govern this pre-configured MRM.

 Open the **Multiple Run Control** by clicking  in the main RiverWare workspace.

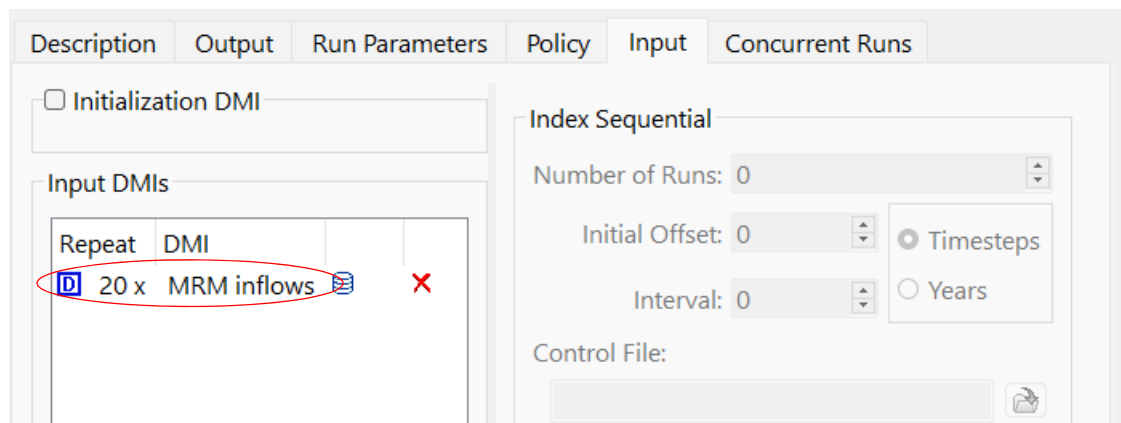
- ❑ Double-click the **20Inflows** configuration to see/edit details about it.



In the top panel are several basic configuration settings:

- The Mode is Concurrent
- The model is set up for Rulebased Simulation, so the Rules are activated. The rules are saved in the model file.
- The Input is an Input DMI

- ❑ Select the **Input** tab.



In this tab, we have specified the DMI (**MRM inflows**) to use for the Inputs and how many times to execute it (20x). This means we will run this same DMI before each individual run. Because of the way it is configured, it will know which run it is (run0, run1, ...) and import the correct data. You can further look at the **MRM inflows** DMI from the DMI Manager (**DMI** and then **DMI Manager**) and then double select **MRM inflows**.

- ❑ Select the **Output** tab.

The screenshot shows the 'Output' tab of the MRM configuration window. It includes fields for 'Per Trace Output DMI', 'RDF Options' (Control File, Data File), 'Timesteps' (Must Match), and 'Excel Options' (Generate Excel Workbooks From RDF, Slot Names, Delete RDF Files, Configuration). There are also checkboxes for 'Generate Comma-Separated Values Files' and 'Generate NetCDF Files'.

This tab is where the Output is from each run is specified. First, the **RDF Options** (Riverware Data Format) files must be designated. The RDF file is a text file, external to RiverWare, to which all output values are written.

- The **Control File** is a specially formatted text file that tells RiverWare which slots to output to the RDF file.

- ❑ Navigate to the location of the control file and open it using Wordpad, Notepad, or some other text editor.

```
Elk.Outflow:
Elk.Pool Elevation:
```

As you can see, two Elk slots are included: Outflow and Pool Elevation.

- The **Data File** specifies the location of the RDF file that is generated when the MRM simulation is run.

You will see in the next section that the data file is long and unwieldy, making it useful to convert the data in the RDF into an Excel file. In the **Excel Options** section of the Output tab you can appoint the orientation of the output values by changing the **Configuration** pulldown menu and choose the naming convention for the data written to Excel.

Finally, you can choose to write data directly to a DMI after each run by specifying an output DMI in the DMI field. We do not need to do this for our example.

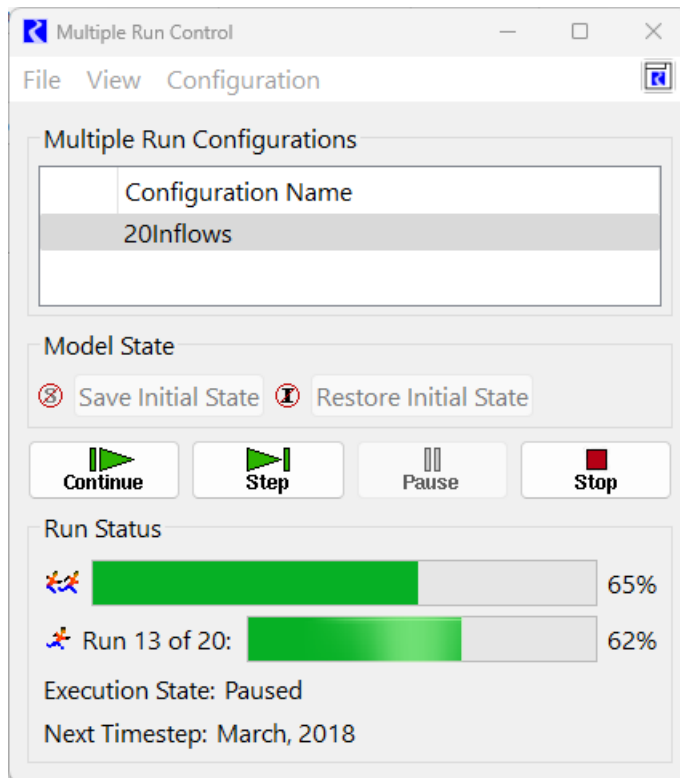
Three other tabs of the MRM configuration are:

- The **Run Parameters** tab allows you to designate a shorter time period to run the simulations (or keep the entire time horizon as we have in this instance).
- The **Policy** tab is where you choose what ruleset you want to use to operate the system. In this model, we have just one ruleset that is saved in the model file.
- The **Concurrent Runs** tab gives details about each run that will result from running the MRM. In our case, there are 20 runs.

Now that you've seen the different settings that govern the MRM, let's run it.

- ☐ Close the **MRM Configuration** window by selecting Cancel and return to the **Multiple Run Control**.

- ☐ Click Start 

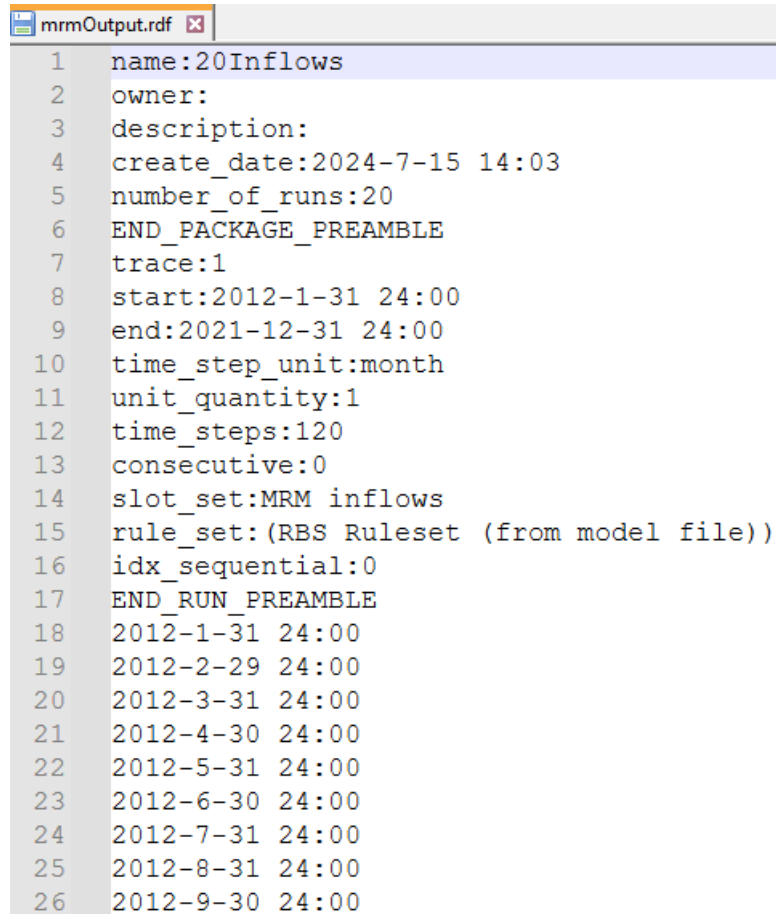


The Run Status window shows RiverWare's progress on each single run and on the 20 runs that make up the MRM.

- ☐ When the MRM is complete, close the **Run Status** window.

3.4 Viewing and Analyzing Outputs

- Use a text editor program to open the RDF file generated by RiverWare "mrmOutput.rdf" located in the **C:/Temp** folder.



```
mrmOutput.rdf
1 name:20Inflows
2 owner:
3 description:
4 create_date:2024-7-15 14:03
5 number_of_runs:20
6 END_PACKAGE_PREAMBLE
7 trace:1
8 start:2012-1-31 24:00
9 end:2021-12-31 24:00
10 time_step_unit:month
11 unit_quantity:1
12 time_steps:120
13 consecutive:0
14 slot_set:MRM inflows
15 rule_set:(RBS Ruleset (from model file))
16 idx_sequential:0
17 END_RUN_PREAMBLE
18 2012-1-31 24:00
19 2012-2-29 24:00
20 2012-3-31 24:00
21 2012-4-30 24:00
22 2012-5-31 24:00
23 2012-6-30 24:00
24 2012-7-31 24:00
25 2012-8-31 24:00
26 2012-9-30 24:00
```

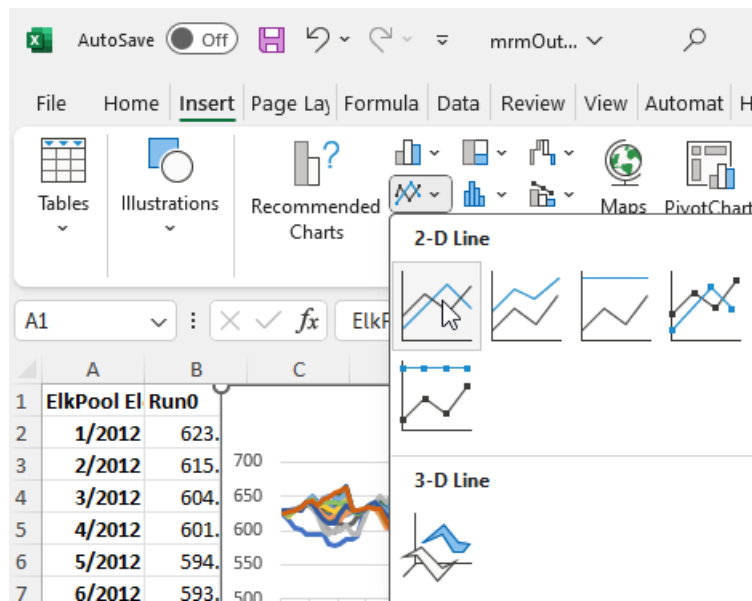
The RDF starts by recording the settings you investigated in the previous section and then indexes the exact times that the slot values are reported (midnight on the last day of each month from January 2012 through December 2021). As you scroll through the RDF you will see that it reports every value for Elk.Outflow and Elk.Pool Elevation for the entire time horizon and for each of the 20 runs of the MRM. This format is somewhat difficult to use, hence the Excel file.

- ☐ Close the RDF and open the Excel file: "mrmOutput.xlsx".

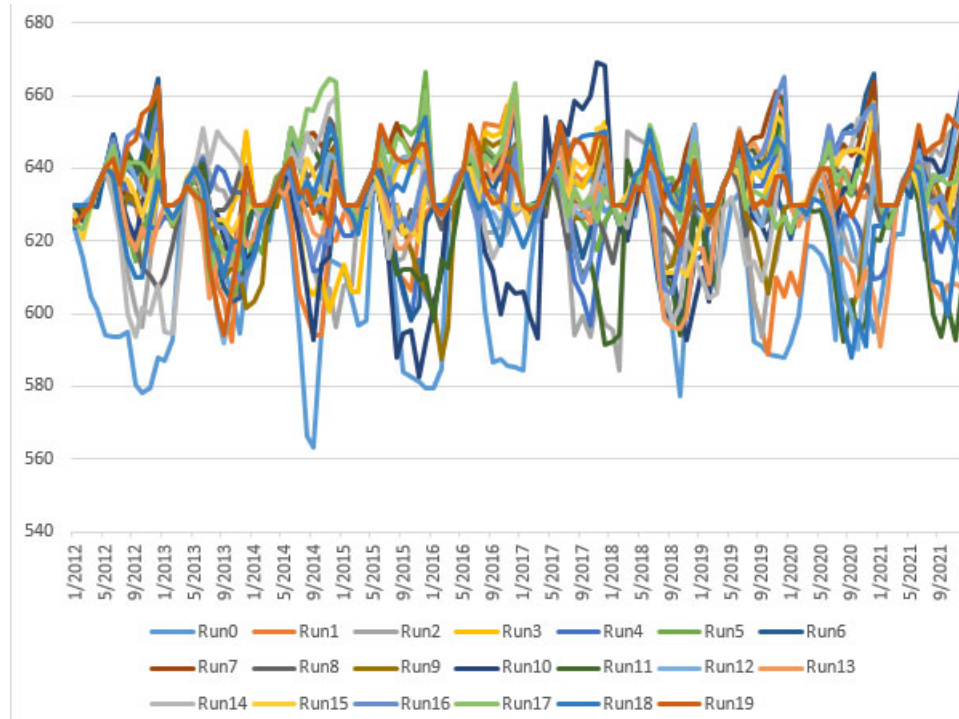
| | A | B | C | D | E | F | G | H | I | J |
|----|--------------|--------------|-------------------|----------------------|------------------|------------------|------------------|------------------|------------------------|-----------------|
| 1 | Name | Owner | Descriptio | Creation Date | Number C | Number C | Number Of | Timesteps | | |
| 2 | 20Inflows | | | 7/15/2024 14:03 | 20 | 2 | 120 | | | |
| 3 | Run # | Start | End | Timestep Unit | Unit Quan | Timesteps | Consecuti | Index Seq | Rule Set | Slot Set |
| 4 | Run0 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 5 | Run1 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 6 | Run2 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 7 | Run3 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 8 | Run4 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 9 | Run5 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 10 | Run6 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 11 | Run7 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 12 | Run8 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 13 | Run9 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |
| 14 | Run10 | 1/2012 | 12/2021 | month | 1 | 120 | 0 | 0 | (RBS Rule: MRM inflows | |

As you saw in the Excel settings from section 3.3, each slot has its own sheet (with a header sheet to report the settings) with each column representing a run.

- ☐ Select the **Elk Pool Elevation** worksheet
- ☐ From the **Insert** tab, select a **2-D Line** plot



You may need to resize the graph to see the results clearly.



The graph shows the resulting 10 years of pool elevation for each of the 20 hydrologies. This simulation is based on synthesized inputs but it demonstrates the ease of visualizing MRM outputs in Excel. Alternatively, we could have done this and other analysis in RiverWare using the Ensemble Data Tool, but that is beyond the scope of the tutorial.

The results of the MRM you just ran are largely external from RiverWare, so it's important when setting up a configuration that you choose slots that are useful indicators of your system. Also beyond the scope of this tutorial, the Graphical Policy Analysis Tool is a useful tool to analyze the results of a concurrent run. It takes the excel sheet you created and performs statistics and generates plots of the data. More information and the download can be found on www.riverware.org in the download supporting applications section.

