Exercise 5.1: Load Duration Curve Instructions

Open the Load Duration Curve Excel workbook (*Exercise 5.1 Load Duration Curve.xlsx*) and review the *Introduction* sheet. This will introduce you to the contents of the Excel file. Then complete the following tasks.

Task 1: Create Flow Duration Curve

a. The Flow Duration Curve uses streamflow data from the USGS gaging station on the Opal River (site number 1000000). Mean daily streamflow records for May to October over the period 2015 to 2020 are stored in the *Streamflow Data* worksheet.

☐ To make the *Streamflow Data* worksheet easier to interpret, first change the header name of column D from "00060_00003" (the default USGS name) to "Mean Daily Streamflow (cfs)".

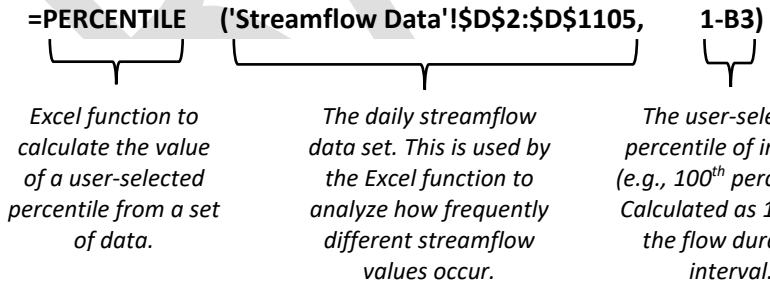
b. Go to the *Data Analysis* worksheet. Columns in the "Flow Duration Curve & Load Duration Curve" section will be used to create the Flow Duration Curve and the Load Duration Curve.

☐ Review the Flow Duration Interval column (column B), which is pre-populated with flow duration intervals that range from 0% to 100%.

c. To create the Flow Duration Curve, you must calculate the streamflow magnitude that corresponds to each percentage listed in the Flow Duration Interval column (column B) of the *Data Analysis* worksheet.

The calculated streamflows will be stored in the Mean Daily Streamflow column (column C).

☐ Use the Excel "PERCENTILE" function to calculate streamflow magnitudes by pasting the following formula into cell C3: **PERCENTILE('Streamflow Data'!$D$2:$D$1105,1-B3)** The formula is explained below.



Remember that Excel formulas must start with an equal (=) sign. When pasting formulas into Excel, be sure to delete any blank spaces before the equal sign.

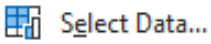
The above formula uses the streamflow records stored in the *Streamflow_Data* worksheet to determine the 100th percentile streamflow value (the maximum value in the dataset).

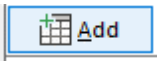
The calculated value of cell C3 should be 5,320 cfs.

d. ☐ Copy and paste the cell C3 formula into the remaining cells in the Mean Daily Streamflow column (cells C4 through C35).

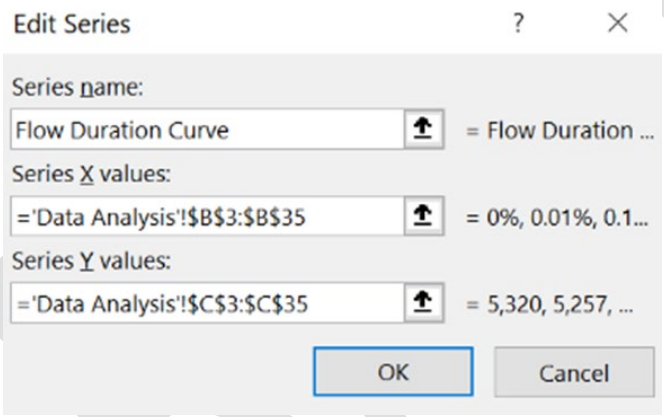
Streamflow values for each additional flow duration interval should now be calculated.

e. Go to the *FDC Chart* worksheet and add a new data series to plot the Flow Duration Curve:

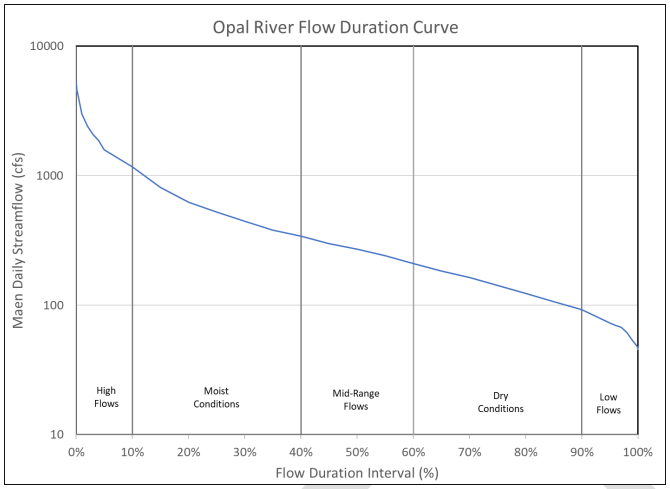
- ☐ Right-click on the chart and choose "Select Data…". 

- ☐ In the "Select Data Source" box, click "Add". 

- ☐ Type "Flow Duration Curve" as the Series name.
- ☐ Add the flow duration intervals to the x-axis. Click the up arrow in the "Series X values" section. Go to the *Data Analysis* worksheet, highlight cells in the Flow Duration Interval column (cells B3 through B35) and press enter.
- ☐ Add the streamflow values to the y-axis. Click the up arrow in the "Series Y values" section. Go to the *Data Analysis* worksheet, highlight cells in the Mean Daily Streamflow column (cells C3 through C35) and press enter.
- ☐ Verify that your "Edit Series" box matches the screenshot below and click OK. Click OK once more in the "Select Data Source" box.



f. ☐ Review the Flow Duration Curve for the Opal River on the *FDC Chart* tab and verify that it matches the image below (the color of the curve may differ in your chart).



- Note that the flow zones (High Flows, Moist Conditions, etc.) on the chart have been preset to typical ranges used for Load Duration Curve analysis.

  The zones are defined in the "Flow Zones" section of the *Data Analysis* worksheet.

  Flow zones are used to understand the magnitude of streamflow and pollutant loading under different hydrologic conditions and will be discussed further in later tasks during this exercise.

Task 2: Create Load Duration Curve

a. Go to the *Data Analysis* worksheet. The Load Duration Curve for the Opal River will use the same flow duration intervals as the Flow Duration Curve (column B). You must calculate the *E. coli* load associated with each interval.

☐ Start by identifying the target *E. coli* concentration for the Load Duration Curve. For this exercise, you will use the single sample maximum *E. coli* concentration for the Opal River defined in Westport Water Quality Standards (not the monthly geometric mean).

Refer to Exercise 2.1 - Westport WQS V2.pdf to identify the appropriate *E. coli* target concentration.

b. ☐ Enter the target *E. coli* concentration identified in the previous step into cell D3 of the *Data Analysis* worksheet. This target is constant and will be used across all flow conditions.

☐ Copy and paste the concentration into the remaining cells in the Target *E. coli* Concentration column (cells D4 through D35).

c. You will now calculate the daily *E. coli* loads that correspond to attainment of the water quality target at each flow duration interval.

The values represent the number of *E. coli* bacteria cells present in Opal River flow per day. The daily *E. coli* load is calculated by multiplying mean daily streamflow (column C) by the target concentration (column D) and applying unit conversion factors.

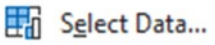
☐ Paste the following formula into cell E3: **=C3*D3*283.17*86400**. The formula is explained below.

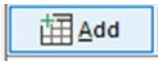
=	**C3**	*	**D3**	*	**283.17**	*	**86400**
	Mean daily streamflow in cubic feet per second.		*Target E. coli concentration in organism count per 100 mL.*		*Unit conversion factor to convert streamflow from cubic feet to 100 mL.*		*Unit conversion factor to convert seconds to days.*

The calculated value of cell E3 should be 3.9 x 10^{13} *E. coli* per day. This is the *E. coli* load that attains the target concentration when Opal River mean daily streamflow is 5,320 cfs.

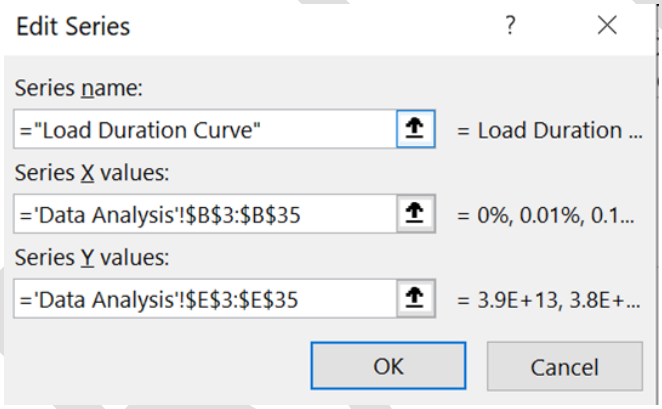
d. ☐ Copy and paste the cell E3 formula into the remaining cells in the *E. coli* Load column (cells E4 through E35). Loads for each additional flow duration interval should now be calculated.

e. Go to the *LDC Chart* worksheet and add a new data series to plot the Load Duration Curve:

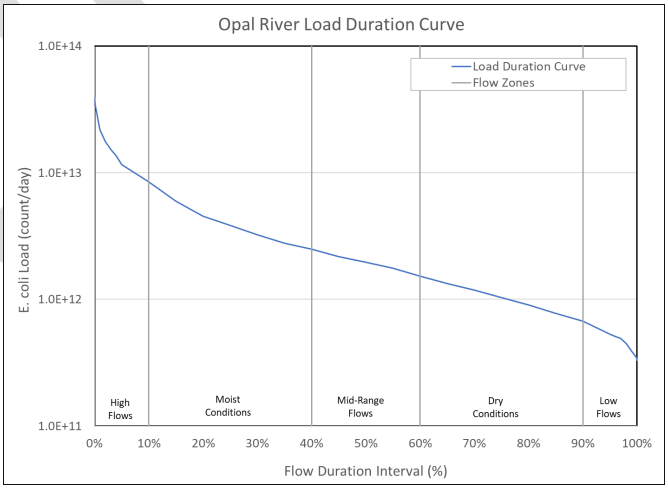
- ☐ Right-click on the chart and choose "Select Data…". 

- ☐ In the "Select Data Source" box, click "Add". 

- ☐ Type "Load Duration Curve" as the Series name.
- ☐ Add the flow duration intervals to the x-axis. Click the up arrow in the "Series X values" section. Go to the *Data Analysis* worksheet, highlight cells in the Flow Duration Interval column (cells B3 through B35) and press enter.
- ☐ Add the *E. coli* loads to the y-axis. Click the up arrow in the "Series Y values" section. Go to the *Data Analysis* worksheet, highlight cells in the *E. coli* Load column (cells E3 through E35) and press enter.
- ☐ Verify that your "Edit Series" box matches the screenshot below and click OK. Click OK once more in the "Select Data Source" box.



f. ☐ Review the Load Duration Curve for the Opal River on the *LDC Chart* tab and verify that it matches the image below (the color of the curve may differ in your chart).



Task 3: Prepare Water Quality Sample Results

a. You will now prepare water quality monitoring data to add to the Load Duration Curve. Sample data are stored on the *E. coli Data* worksheet.

   Begin by copying sample dates into the "Sample Results" section of the *Data Analysis* worksheet.

   ☐ On the *E. coli Data* worksheet, highlight cells in the ActivityStartDate column (cells D2 through D173). Copy and paste the values into cells the Date column (cells G3 through G174) of the *Data Analysis* sheet.

b. Copy the sampled *E. coli* concentrations into the "Sample Results" section of the *Data Analysis* worksheet.

   ☐ On the *E. coli Data* worksheet, highlight cells N2 through N173. Copy and paste the values into the *E. coli Concentration* column (cells H3 through H174) of the *Data Analysis* sheet.

c. In order to plot the sample results on the Load Duration Curve, you must convert the sampled concentration into a load.

   Loads are calculated using the measured streamflow from the day each sample was collected. Add the measured streamflow to each sample row using the Excel VLOOKUP function.

   ☐ Paste the following formula into cell I3: **=VLOOKUP(G3,'Streamflow Data'!$C$2:$D$1105,2)**. The formula is explained below.

=VLOOKUP	**(G3,**	**'Streamflow Data'!$C$2:$D$1105,**	**2)**
Excel function to lookup a value in a data table.	*The date to lookup.*	*The daily streamflow data table. Includes the date of measurements in the first column and measured streamflow in the second column.*	*The column number in the daily streamflow data table containing measured streamflow values to lookup.*

   The above formula finds the measured streamflow value for the first sample date (5/2/2015) within the records stored on the *Streamflow Data* worksheet. The calculated value of cell I3 should be 684 cfs.

d. ☐ Copy and paste cell I3 into the remaining cells in the Mean Daily Streamflow column (cells I4 through I174). Flows should now be stored for each additional sample date.

e. ☐ Calculate the flow duration interval associated with each sample date. Use the PERCENTRANK function of Excel. Paste the following formula into cell J3**: =1-(PERCENTRANK('Streamflow Data'!$D$2:$D$1105,I3))**. The formula is explained below.

=1-	**(PERCENTRANK(**	**'Streamflow Data'!$D$2:$D$1105,**	**I3))**
Converts the percentile rank to a flow duration interval.	*Excel function to calculate the rank of a user-supplied value in a data set. The rank is expressed as a percentile (e.g., 10th percentile).*	*The range of daily streamflow measurements.*	*The user-supplied streamflow value. The percentile rank of this value is calculated by the Excel function.*

The above formula determines the percentile rank of the streamflow value on the first sample date (5/2/2015). Because a flow duration interval is the inverse of a percentile rank, the flow duration interval is calculated as 1 minus the percentile rank.

The calculated value of cell J3 should be 17.4%. In other words, in the Opal River there is a 17.4% probability of the exceeding a mean daily flow magnitude of 684 cfs.

f. ☐ Copy and paste cell J3 into the remaining cells in the Flow Duration Interval column (cells J4 through J174).

g. Calculate the *E. coli* load on each sample date. The *E. coli* load is calculated by multiplying the sampled concentration (column H) by mean daily streamflow (column I) and applying unit conversion factors.

☐ Paste the following formula into cell K3: **=H3*I3*283.17*86400**. The formula is explained below.

=	**H3**	*****	**I3**	*****	**283.17**	*****	**86400**
	Sampled E. coli concentration in organism count per 100 mL.		*Mean daily streamflow on the sample date in cubic feet per second.*		*Unit conversion factor to convert streamflow from cubic feet to 100 mL.*		*Unit conversion factor to convert seconds to days.*

The calculated value of cell K3 should be 3.2 x 10^{11} *E. coli* per day. This is the measured *E. coli* load for the first sample date (5/2/2015).

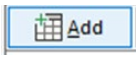
g. ☐ Copy and paste cell K3 into the remaining cells in the *E. coli* Load column (cells K4 through K174). Loads for each additional sample date should now be calculated.

Task 4. Plot Water Quality Sample Results

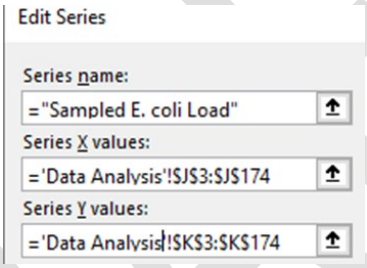
h. Go to the *LDC Chart* worksheet and add a new data series to plot the sample results:

- ☐ Right-click on the chart and choose “Select Data…”.

- ☐ In the “Select Data Source” box, click “Add”.

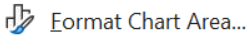


- ☐ Type “Sampled E. coli Load” as the Series name.
- ☐ Add the flow duration intervals to the x-axis. Click the up arrow in the “Series X values” section. Go to the *Data Analysis* worksheet, highlight cells in the Flow Duration Interval column (cells J3 through J174) and press enter.
- ☐ Add the sampled *E. coli* loads to the y-axis. Click the up arrow in the “Series Y values” section. Go to the *Data Analysis* worksheet, highlight cells in the *E. Coli* Load column (cells K3 through K174) and press enter.
- ☐ Verify that your “Edit Series” box matches the screenshot below and click OK. Click OK once more in the “Select Data Source” box.

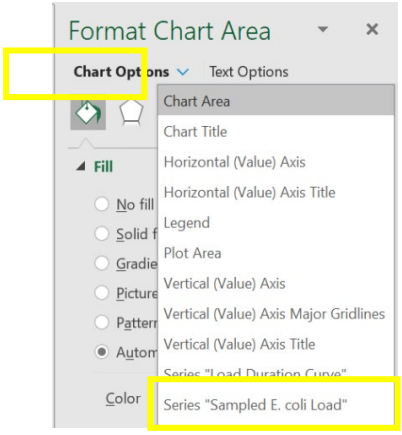


- By default, Excel displays the new series as a collection of connected lines. Because lines are not useful for viewing sample data, you must change the formatting to display the *E. coli* samples as points on the Load Duration Curve.

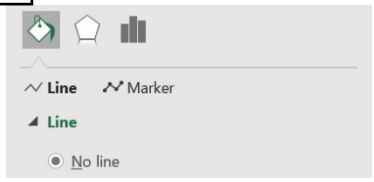
☐ Right click on the bottom-left corner of the chart and select “Format Chart Area” to prompt the formatting menu to appear on the right side of the screen.



- ☐ On the formatting menu, click the down arrow next to Chart Options and choose Series “Sampled *E. coli* Load”. This activates the *E. coli* sample dataset for formatting.

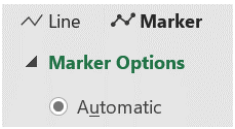


- ☐ Click the “No line” option button to remove the lines from the chart.

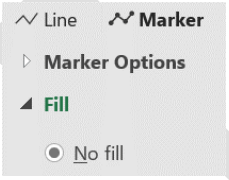


- ☐ Click “Marker” to adjust display settings for data points.

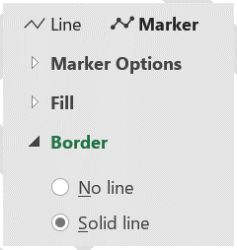
- ☐ Under the “Marker Options” section, select “Automatic”.



- ☐ Under the “Fill” section, select “No Fill”.



- ☐ Under the “Border” section, select “Solid line”.



Task 5: Evaluate Load Duration Curve

Use the *LDC Chart*, the *Data Analysis* worksheet, and information from previous exercises to answer the following questions. Submit your answers using this Microsoft Form: https://forms.office.com/r/7xFhTfiMRy

1. Why are May through October streamflow data used in the Flow Duration Curve and Load Duration Curve (instead of data from all months of the year)?
    a. Applicable water quality criteria and the numeric target for the TMDL apply during May through October.
    b. *E. coli* loading occurs during May through October only.
    c. Stakeholders have expressed concern over elevated *E. coli* levels during the recreation season.
2. Which flow zone contains the highest number of *E. coli* target exceedances?
    a. Low
    b. Dry
    c. Mid-Range
    d. Moist
    e. High
3. Based on your answer to the previous questions, which pollutant sources in the Opal River Watershed are likely to be the most significant contributors to the pathogen impairment? (check all that apply)
    a. Stormwater discharge
    b. Livestock access to the river/direct deposition
    c. Agricultural runoff
    d. Wastewater discharge from point sources
4. Previous pathogen TMDLs for State of Westport waterbodies have used a single loading capacity when exceedances cluster in one flow zone of a Load Duration Curve. In those cases, the loading capacity is set to the *E. coli* load at the midpoint of the flow zone containing the exceedances. The approach was initially used in pilot *E. coli* TMDLs in the Westport and has remained in place since the pilot waterbodies have attained recreational water quality criteria following TMDL implementation.
   Following this approach, what is the loading capacity for the Opal River TMDL?
   (Hint: flow zone midpoints are 5% for high flows, 25% for moist conditions; 50% for mid-range flows; 75% for dry conditions; 95% for low flows)
    a. 3.8×10^{12} cfu per day
    b. 1.2×10^{13} cfu per day
    c. 1.0×10^{12} cfu per day
    d. 2.0×10^{12} cfu per day