Calculations Lesson

Introduction

In the previous lessons you learned how to set up a Worksheet and to define input values. In this lesson you will perform calculations. produce and view tables and graphs, and change some of the units.

Tables and graphs can take several forms, depending on how many input variables are assigned ranges (none, 1, or 2) and whether those variables are continuous or discrete. You can personalize the output by changing the size of graphs, the orientation of tables, and other features.

Objectives

By the end of this lesson, you will be able to do the following.

1. Produce results for single and multiple values of input variables.
2. Explain differences in tables and graphs for continuous and discrete variables.
3. Modify table and graph appearances through selection of row, column, and X-Axis variables.
4. Change graph and table appearance.
5. Change units for input and output variables.

Where This Lesson Fits In

This is a lesson in the **Introduction Unit**, which teaches you basic program operation. These lessons should be completed in order.

This is the fourth and final of four lessons that introduce you to the BehavePlus fire modeling system.

1. Basic Start – simple entry of input to get answers in the form of tables and graphs
2. Worksheets – how the Worksheet is developed from user selections
3. Input Methods – various ways of entering input values
4. **Calculations – table and graph output options**

This lesson focuses on program operation, not fire behavior modeling. If you finish this lesson and have questions about the meaning of variables and modeling results, you are in good company. You will hopefully be inspired to continue to use BehavePlus to better understand concepts related to fire behavior modeling.

Lessons in other units cover the many features and fire modeling capabilities offered by BehavePlus. Those lessons can be done in any order unless otherwise specified in the lesson.

Note: There are questions (in blue) located throughout this lesson. The answers can be found at the end of the lesson starting on page 19.

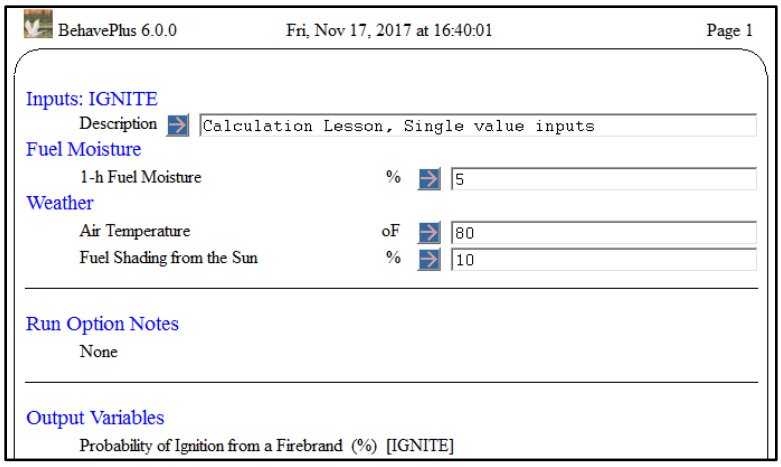
Methods for Entering Inputs

The type and number of variables you select will change the outputs created by BehavePlus. In this section, you will explore different input options to become more familiar with the calculations and outputs from BehavePlus. Interspersed with these input options are ways to change output appearance.

Single value for each input variable

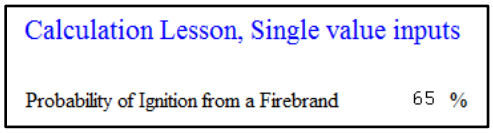
We will start with a simple example where a single value is input for each variable.

- Open a **BasicStart.bpw** Worksheet.
- Enter the **Description**: Calculation Lesson, Single value inputs.
- Click on the **Module Selection** button ( ) or go to **Configure > Module Selection**.
- Deselect the SURFACE module and select IGNITE.
- Click **Ok**.
- Enter values as shown on the Worksheet below.



- **Calculate** the Run ( ).

When there is one value for each input variable, the **Calculate Results** dialog box will not appear since there are no output options.



1. *Change **Fuel Shading from the Sun** to **65%**. What is the Probability of Ignition from a Firebrand?*

Multiple values for one continuous input variable

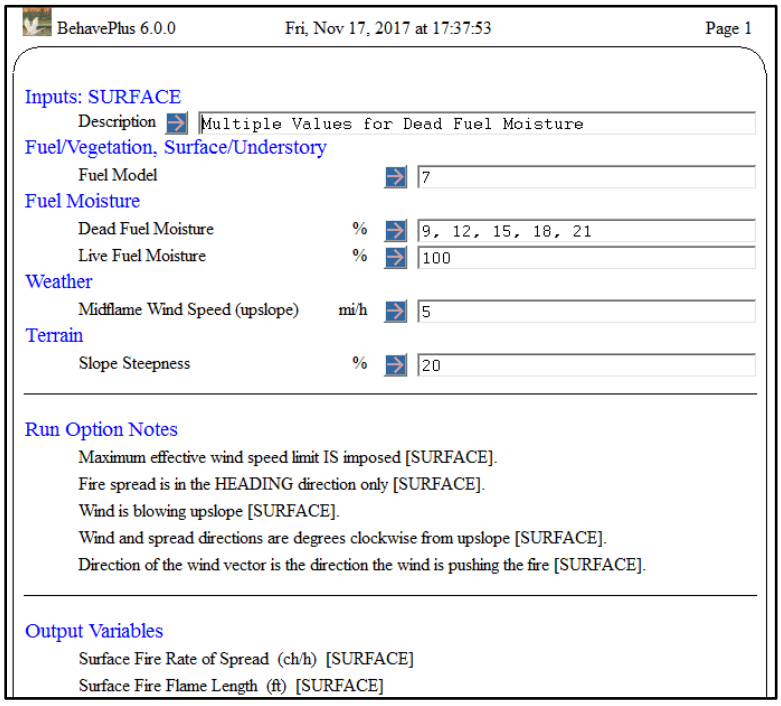
Let's enter multiple values for an input variable on a different Worksheet.

- Close the current Worksheet (**File > Close**).
- Open a new Worksheet (**File > Open worksheet** or).
- Look in the **ExampleWorksheets** folder.
- Select the **SurfaceSimple.bpw** Worksheet.

Enter values on the Worksheet using the various techniques from the *Input Methods Lesson*.

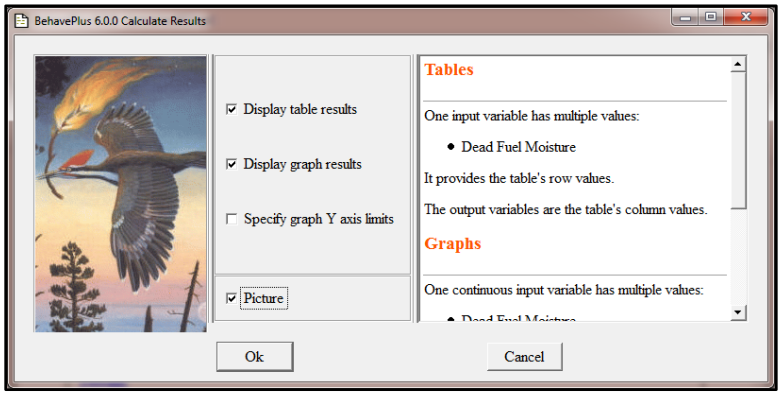
- Enter a **Description**: Multiple Values for Dead Fuel Moisture.
- Enter a **Fuel Model**. Click on the **Guide** button and select the fuel model for Southern rough.
- Enter a range of **Dead Fuel Moisture From** 9 **Thru** 21 **Step** 3 using the **Guide** button.
- Click on the **Live Fuel Moisture Guide** button. Use **Choices** to select the moisture value for Mature foliage, new growth complete and comparable to older perennial foliage.
- Enter **Midflame Wind Speed** of 5 mi/h.
- Enter **Slope Steepness** of 20%.

The Worksheet should look like the following.



- **Calculate** the Run.

The following **Calculate Results** window appears.



- Click **Ok** in the **Calculate Results** dialog box to accept the default selections. Both table and graph results are produced.

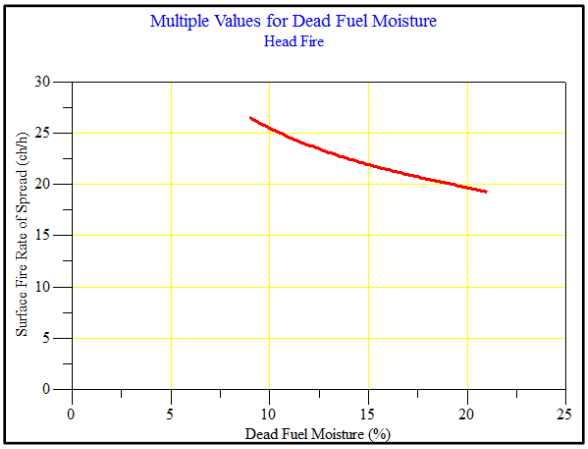
When the calculations are complete, the first output page is displayed. On the table, both output variables are calculated for each value of Dead Fuel Moisture.

Multiple Values for Dead Fuel Moisture

Head Fire

Dead Fuel Fuel Moisture %	Surface Fire Rate of Spread ch/h	Surface Flame Length ft
9	26.5	5.6
12	23.8	5.1
15	21.9	4.9
18	20.5	4.7
21	19.3	4.5

Click the **Next Page** () button to view the next page, which is, in this case, a graph of Surface Fire Rate of Spread.



Look at the **Next Page** to view the Surface Fire Flame Length graph. The final page shows the discrete variable codes related to this Worksheet and calculation.

The tables and graphs all include the header **Head Fire** to remind us that this Run is for a heading fire (burning in the direction of maximum spread) only.

2. *Change the following input variables. What is the predicted fire behavior?*
   - ***Dead Fuel Moisture: 12%***
   - ***Midflame Wind Speed: From 2 Thru 10 Step 2.***

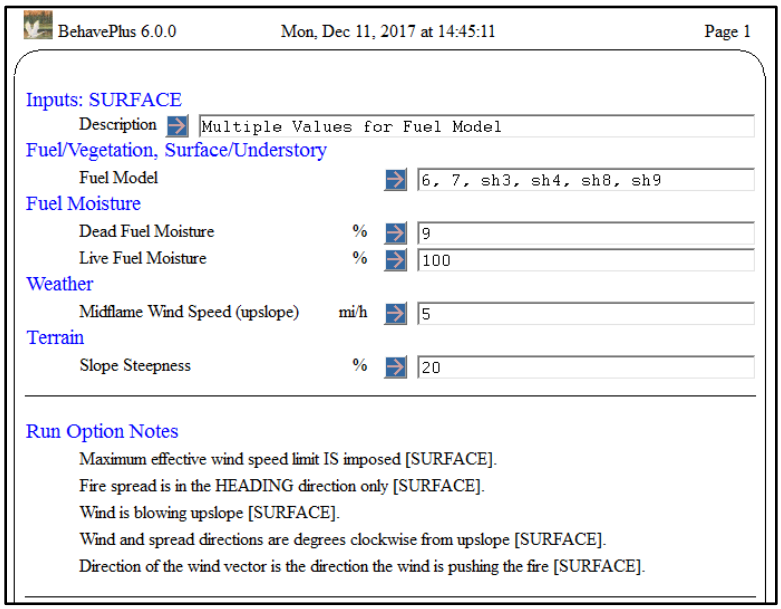
Multiple values for one continuous input variable

Next, let's see how multiple input values for a discrete variable, such as Fuel Model, affect the outputs.

- Return to the **First Page** ().
- Edit the **Description** to read **Multiple Values for Fuel Model**.

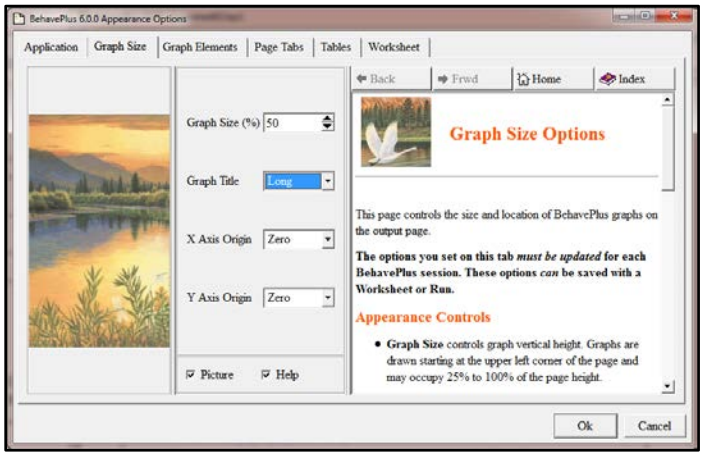
- Click on the **Fuel Model Guide** button and select **Fuel Models** 6, 7, sh3, sh4, sh8, sh9 (representing humid shrubs).
  Note: *You do not have to hold down the control key in BehavePlus to make multiple selections. Click on each one to select it; click on it again to deselect it.*
- Click **Ok**.
- Change **Dead Fuel Moisture** to 9%.
- **Midflame Wind Speed** is 5 mi/h.

The Worksheet has changed as follows.



Before calculating the Run, let's change the appearance of some of the outputs.

- Click on **Configure > Appearance Preferences**.
- Select the **Graph Size** tab.
- Change **Graph Title** to **Long**.



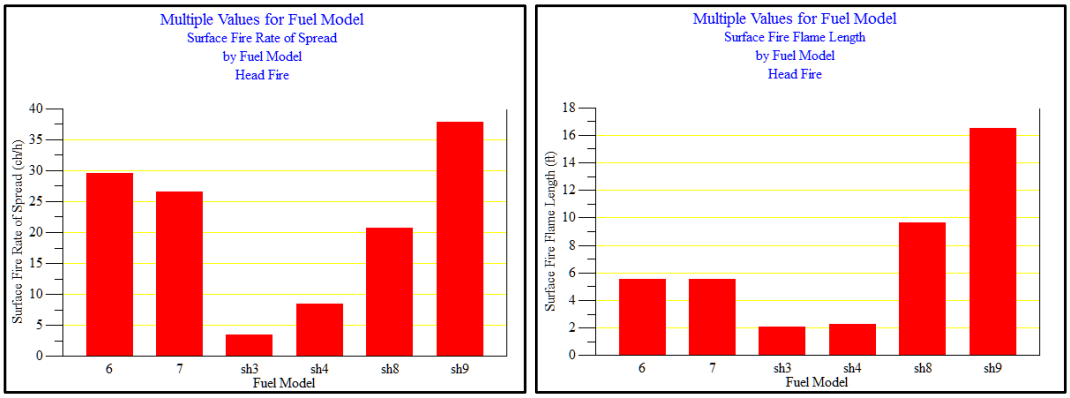
- Click **Ok**.
- **Calculate** the Run.

The table now shows Surface Fire Rate of Spread and Surface Fire Flame Length for the six different Fuel Models.

Multiple Values for Fuel Model
Head Fire

Fuel Model	Surface Fire Rate of Spread ch/h	Surface Flame Length ft
6	29.6	5.5
7	26.5	5.6
sh3	3.5	2.1
sh4	8.5	2.2
sh8	20.7	9.6
sh9	37.8	16.5

View the graphs for Surface Fire Rate of Spread and Surface Fire Flame Length.



Note the change in the graph headings. Additional information (e.g., **Surface Fire Flame Length by Fuel Model**) is displayed because the **Graph Title** option was changed from **Short** to **Long**.

The graphs help you compare fuel models given the same moisture, wind, and slope. The two graphs show that the fuel model you select may affect Surface Fire Rate of Spread (ROS) and Surface Fire Flame Length (FL) differently. The ROS is used to predict spread distance and fire size. The FL is important when you are examining fire effects, calculating required suppression resources, and investigating transition to crown fire.

Click on the **Last Page** button () to view the **Discrete Variable Codes**.

Discrete Variable Codes Used
Multiple Values for Fuel Model

Fuel Model		
6	6	Dormant brush, hardwood slash
7	7	Southern rough
143	sh3	Moderate load, humid climate shrub (S)
144	sh4	Low load, humid climate timber-shrub (S)
148	sh8	High load, humid climate shrub (S)
149	sh9	Very high load, humid climate shrub (D)

3. *Change the Fuel Model by selecting the hardwood litter models. What is the effect of these fuel models on Surface Fire Rate of Spread and Surface Fire Flame Length?*

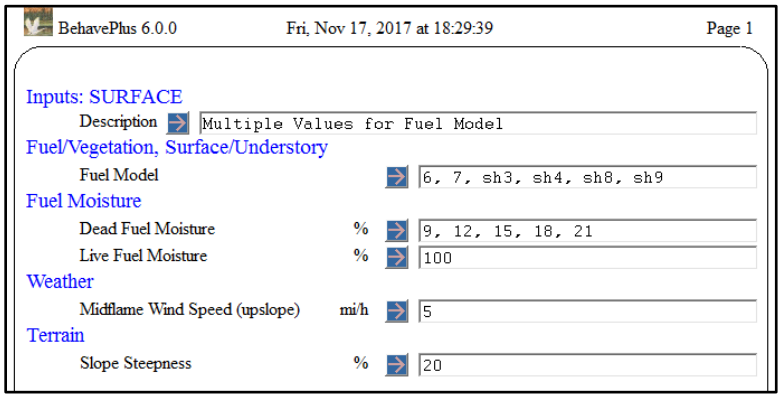
The graphs produced in the first example for a range of fuel moisture values are lines because it is a continuous variable. The graphs from the second example are bars, because fuel model is a discrete variable. BehavePlus will automatically select the correct graph to use.

Multiple values for two input variables: One continuous and one discrete

For this Run, you will include multiple input values for both a continuous variable (Dead Fuel Moisture) and a discrete variable (Fuel Model).

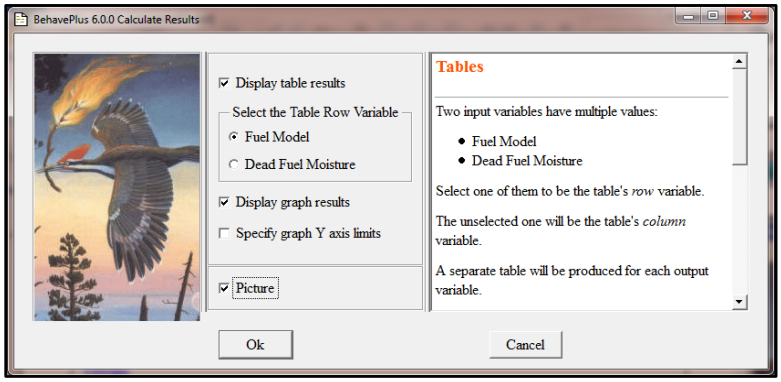
- Open a new **BasicStart.bpw** Worksheet.
- Using the skills you have gained so far, change the Worksheet and enter the following data.
  - **Description**: Multiple Values for Dead Fuel Moisture and Fuel Model
  - **Fuel Model**: 6, 7, sh3, sh4, sh8, sh9
  - **Dead Fuel Moisture (%)**: **From** 9 **Thru** 21 **Step** 3
  - **Live Fuel Moisture**: 100%
  - **Midflame Wind Speed (upslope)**: 5 mi/h
  - **Slope Steepness**: 20%

Your inputs should look like the following.



- **Calculate** the Run.

The following **Calculate Results** window appears. You can select which variable you would like to be the **Table Row Variable**. The Help file provides an explanation of the options available to you.



- Accept the defaults for now and click **Ok**.

A two-way table and a graph are produced for each of the selected output variables, **Surface Fire Rate of Spread** and **Surface Fire Flame Length**. Since we accepted the default values, a Fuel Model is listed on each row, and the Dead Fuel Moisture values are shown as columns.

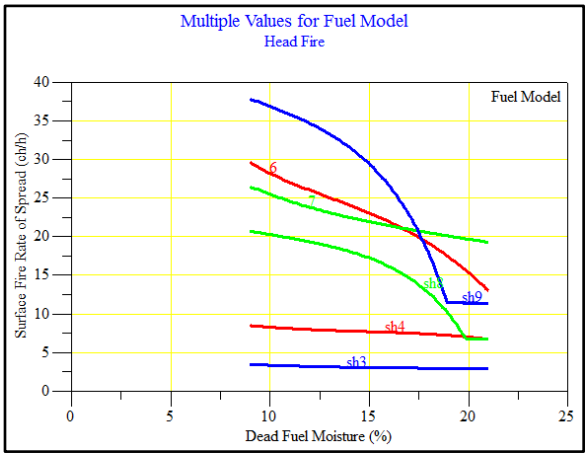
Multiple Values for Fuel Model
Head Fire
Surface Fire Rate of Spread (ch/h)

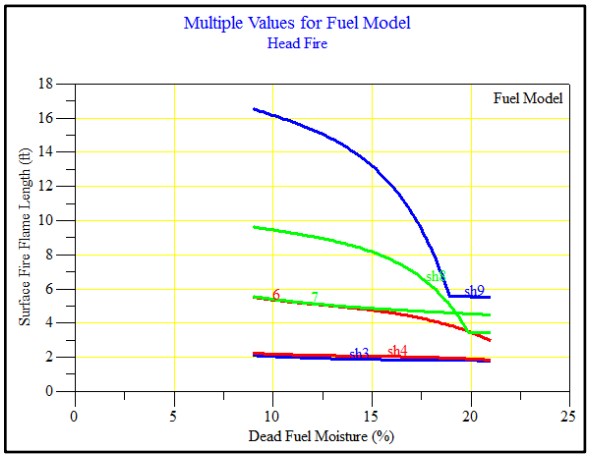
Fuel Model	Dead Fuel Moisture %				
	9	12	15	18	21
6	29.6	26.0	23.1	19.1	13.0
7	26.5	23.8	21.9	20.5	19.3
sh3	3.5	3.2	3.1	3.0	2.9
sh4	8.5	8.0	7.7	7.4	6.7
sh8	20.7	19.3	17.2	12.7	6.7
sh9	37.8	34.7	29.4	17.8	11.3

Multiple Values for Fuel Model
Head Fire
Surface Fire Flame Length (ft)

Fuel Model	Dead Fuel Moisture %				
	9	12	15	18	21
6	5.5	5.1	4.8	4.1	3.0
7	5.6	5.1	4.9	4.7	4.5
sh3	2.1	2.0	1.9	1.8	1.8
sh4	2.2	2.1	2.1	2.0	1.8
sh8	9.6	9.1	8.2	6.2	3.4
sh9	16.5	15.3	13.2	8.3	5.5

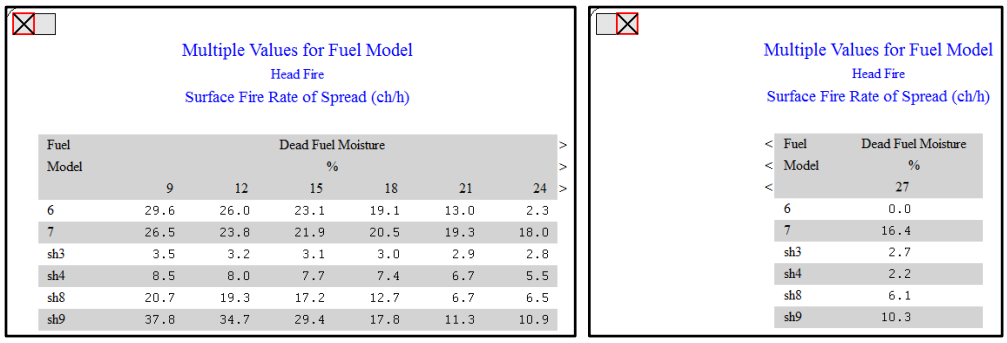
Since Fuel Model is a discrete variable, it cannot be the **X-Axis Variable** if there is a continuous variable that has multiple values. Therefore, Dead Fuel Moisture is the **X-Axis Variable**, and each Fuel Model is plotted separately on the graph. The text in the upper right-hand corner of the graph lets you know there is a curve for, in this case, every Fuel Model.





4. *Examine the graphs for Surface Fire Rate of Spread and Surface Fire Flame Length. What can you say about the fire behavior for SH3 and SH4 under these conditions?*

- Return to the Worksheet and change the **Dead Fuel Moisture (%)** to **From** 9 **Thru** 27 **Step** 3.
- **Calculate** the Run, accepting the defaults in the **Calculate Results** window.



Multiple Values for Fuel Model
Head Fire
Surface Fire Rate of Spread (ch/h)

Fuel Model	Dead Fuel Moisture %					
	9	12	15	18	21	24
6	29.6	26.0	23.1	19.1	13.0	2.3
7	26.5	23.8	21.9	20.5	19.3	18.0
sh3	3.5	3.2	3.1	3.0	2.9	2.8
sh4	8.5	8.0	7.7	7.4	6.7	5.5
sh8	20.7	19.3	17.2	12.7	6.7	6.5
sh9	37.8	34.7	29.4	17.8	11.3	10.9

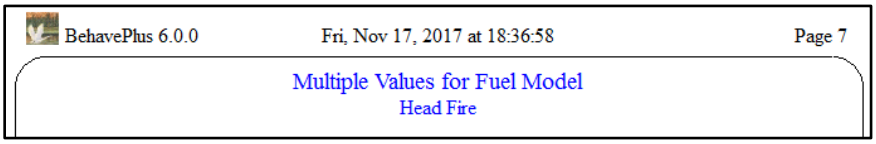
Multiple Values for Fuel Model
Head Fire
Surface Fire Rate of Spread (ch/h)

Fuel Model	Dead Fuel Moisture %
	27
6	0.0
7	16.4
sh3	2.7
sh4	2.2
sh8	6.1
sh9	10.3

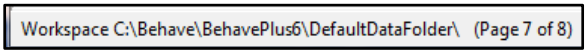
In this case, the table is too wide to fit on one page. The box in the upper right-hand corner of the page shows how many pages there are in the table (number of boxes) and which page you are currently viewing (highlighted in red and marked with a black "X"). The arrows to the right side of the first table indicate that the graph continues on the next page. The arrows to the left of the 2nd table indicate that there are pages before it. There are no arrows to the right of this page, indicating that it is the last page for the table.

- Click on the **Next Page** button until you reach the **Surface Fire Flame Length** output graph.

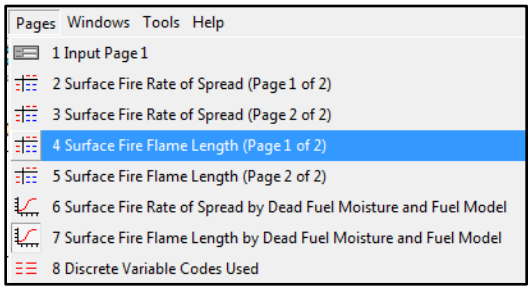
This graph is on page 7 of the Run as shown in the upper right-hand corner.



There are eight pages in the Run as shown at the bottom of the window.

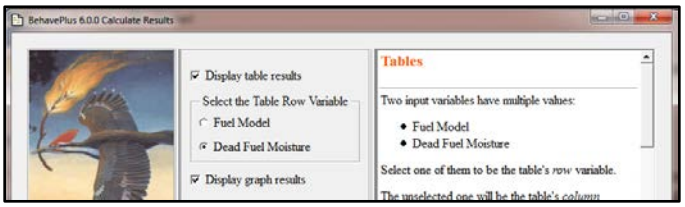


You can quickly navigate through the Run using the **Pages** tab on the main menu. When you click on it, a list of pages appears. It lets you know if the page is a Worksheet (), a table (), a graph (), or a list of discrete codes (). Click on any page to view it.



Let's change one more thing before we move on.

- **Calculate** the Run again (don't change any inputs).
  Hint: *You do not need to be on the first page (Worksheet) to calculate a Run.*
- In the **Calculate Results** window, change the **Table Row Variable** to **Dead Fuel Moisture** and click **Ok**.



All of the tables fit on a single page now as shown for Surface Fire Rate of Spread below. You can use this option to format your tables for printing or saving.

Multiple Values for Fuel Model
Head Fire
Surface Fire Rate of Spread (ch/h)

Dead Fuel Fuel Moisture	Fuel Model					
%	6	7	sh3	sh4	sh8	sh9
9	29.6	26.5	3.5	8.5	20.7	37.8
12	26.0	23.8	3.2	8.0	19.3	34.7
15	23.1	21.9	3.1	7.7	17.2	29.4
18	19.1	20.5	3.0	7.4	12.7	17.8
21	13.0	19.3	2.9	6.7	6.7	11.3
24	2.3	18.0	2.8	5.5	6.5	10.9
27	0.0	16.4	2.7	2.2	6.1	10.3

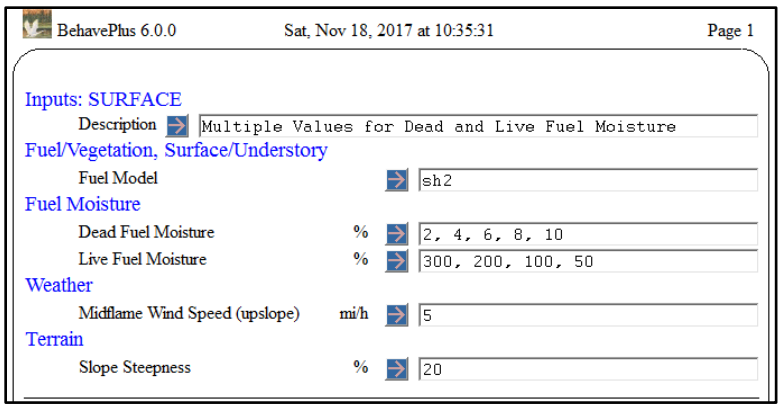
Hint: *Remember from the Input Methods Lesson that you can reverse the order of the Dead Fuel Moisture input values so that the table reads from minimum (upper left) to maximum (lower right) Surface Fire Rate of Spread and Surface Fire Flame Length.*

5. *What is the maximum Surface Fire Rate of Spread for these fuel models when the Dead Fuel Moisture is 15%? What is the range of Surface Fire Flame Length values for a Fuel Model SH3?*

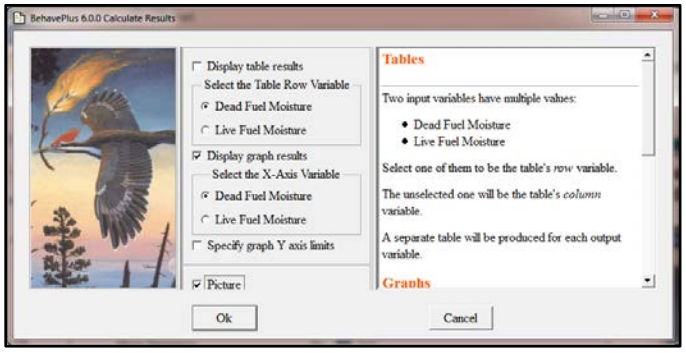
Multiple values for two input variables: both continuous

In this example, you will examine the effect of changes in both live and dead fuel moisture on the outputs.

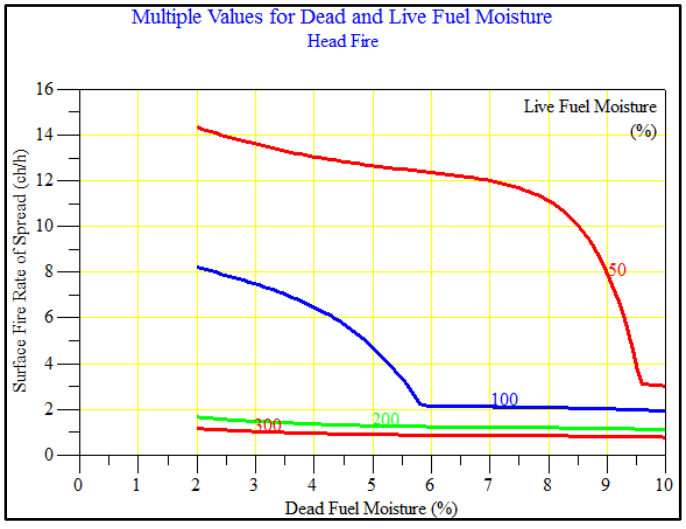
- Open a new **SurfaceSimple.bpw** Worksheet.
- Change your Worksheet to look like the following.



- **Calculate** the Run.
- In the **Calculate Results** window, make sure the **Display table results** box is unchecked. The **Display graph results** box should be checked, so that only graphs will be displayed.



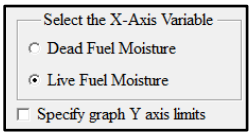
- Click **Ok**.

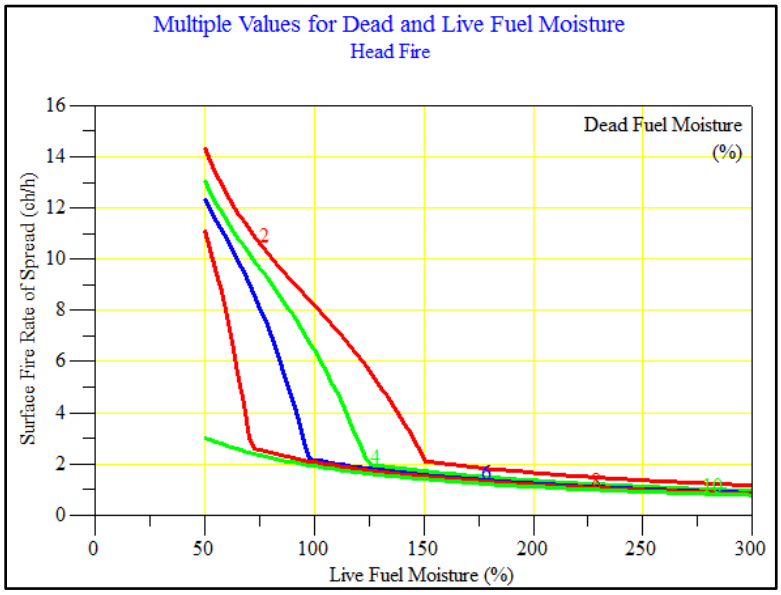


Running a range of values allows you to explore the sensitivity of the fire behavior models to inputs. This example shows the effect of Live Fuel Moisture on Surface Fire Rate of Spread. Notice the distinct difference between the lower values for Live Fuel Moisture (50-100%) and the higher ones (200-300%). When the Live Fuel Moisture is low, it contributes to the rate of fire spread. When the Live Fuel Moisture

reaches the critical value of Live Fuel Moisture of Extinction, it acts as a heat sink, lowering the Surface Fire Rate of Spread. There is no input for Live Fuel Moisture of Extinction. It is a function of the Dead Fuel Moisture of Extinction, which is a Fuel Model parameter.

- **Calculate** the Run again, putting Live Fuel Moisture on the X-Axis.





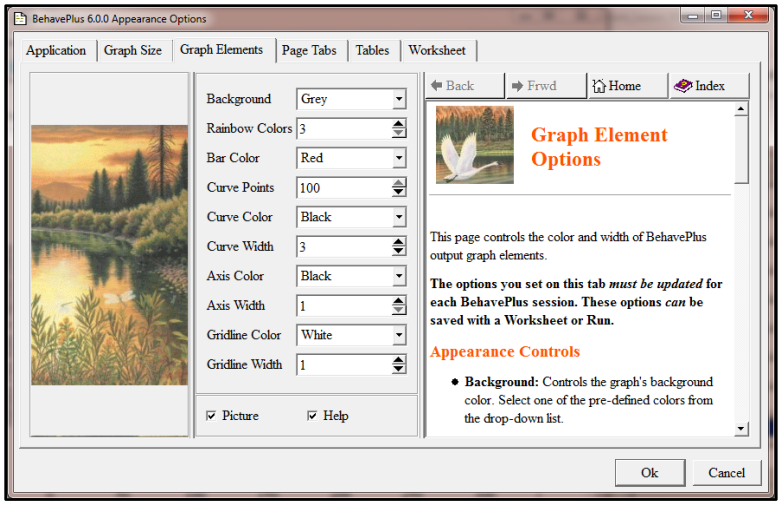
Now, the lines represent the Dead Fuel Moisture. Changing the X-Axis variable may help you better interpret the predicted fire behavior and examine model sensitivity.

Graph Appearance

BehavePlus allows you to change the appearance of graphs to meet your needs. In this section, you will explore some of those options. We will continue using the Run from the previous section.

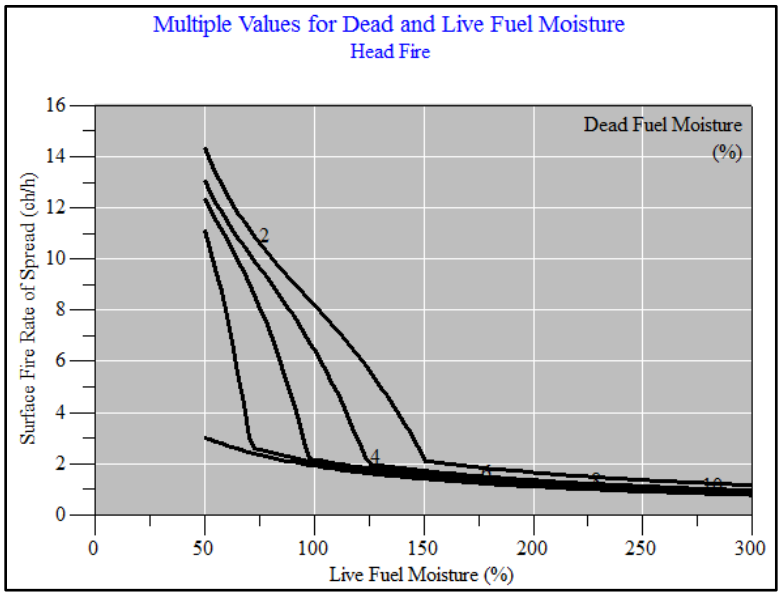
Changing the graph appearance

- Select the **Configure > Appearance preferences** command from the menu bar.
- Select the **Graph Elements** tab.
- Choose **Gray** from the drop-down list for **Background**.
- Choose **Black** from the drop-down list for **Curve Color**.
- Choose **White** from the drop-down list for **Gridline Color**.



- Click the **Ok** button to close the **Appearance Options** dialog box.
- **Calculate** the Run.

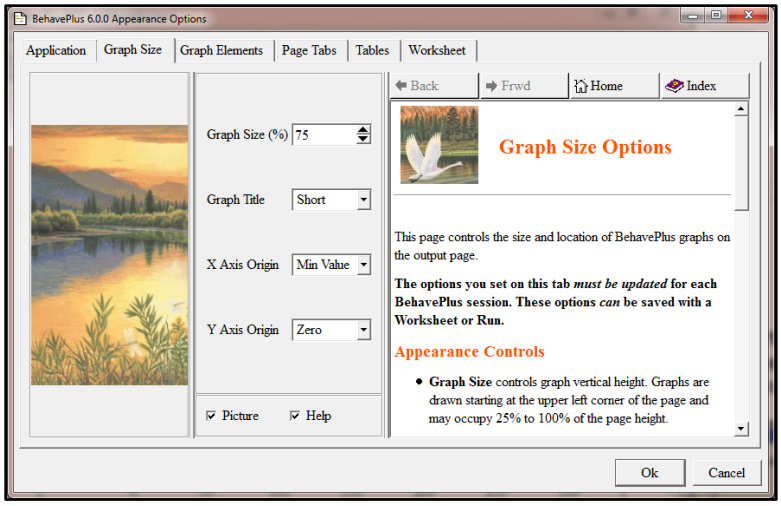
The graph now looks like the following.



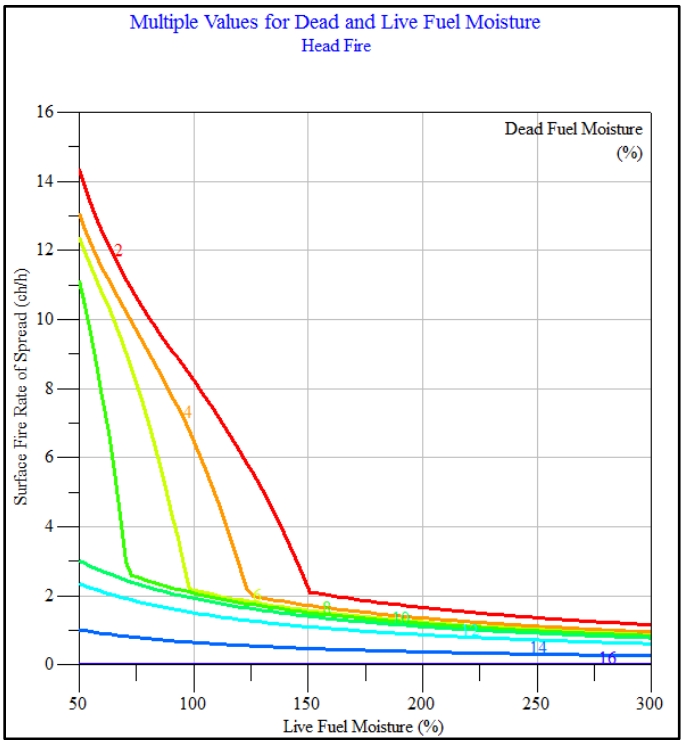
Changing the X-Axis minimum value

- Using the previous instructions, change the following **Graph Elements**.
  - **Background** to **White**
  - **Rainbow Colors** to **10**
  - **Curve Color** to **Rainbow Colors**
  - **Gridline Color** to **Gray**

- Click on the **Graph Size** tab and change the following elements.
  - **Graph Size** to **75**%
  - **X Axis Origin** to **Min Value**



- Click **Ok**
- Change the **Dead Fuel Moisture** to **From 2 Thru 16 Step 2**.
- **Calculate** the Run.



The graph takes up more of the page, which means it may be easier to see. Graphing the X-Axis by starting with the minimum value expands graph output, reduces white space and enables you to better see results.

Each of the elements in the **Appearance Options** window are described in the associated Help files.

6. How can you eliminate the black border around the output?

Any changes made in the **Appearance Options > Application** tab are program-wide. They *will* carry over from one session to the next. You can turn off the **Picture** shown with all of the **Guide** windows using this option. While you can also turn off the **Help**, we strongly suggest you retain it.

All other **Appearance Options** changes will be retained with the current Worksheet or Run once you save it. They *will not* carry over to new Worksheets. Remember, if there is a Worksheet that you use often, save it and consider making it your startup Worksheet. You can specify many options including:

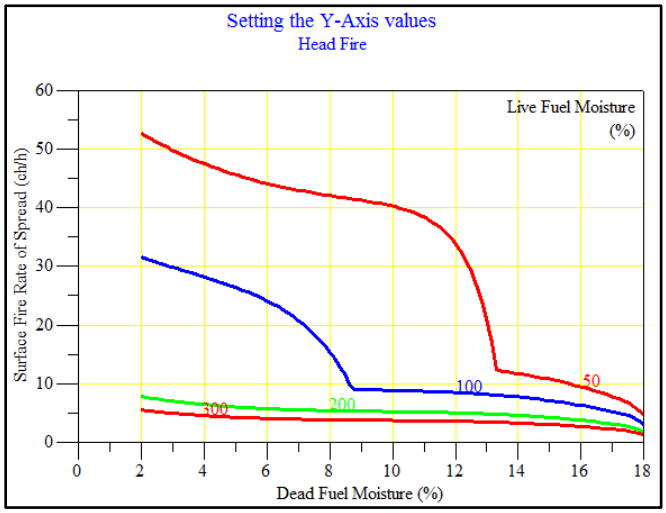
- **Module Selection**,
- Input options,
- Output variables,
- **Appearance preferences**, and
- Default units and precision (number of decimal places).

Changing the Y-Axis maximum value

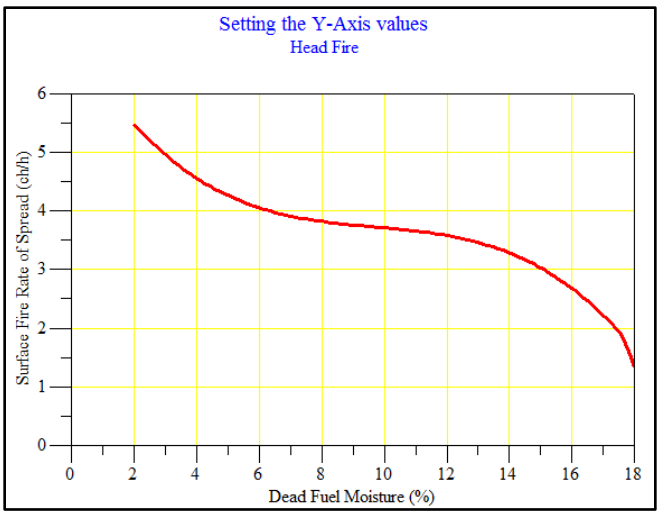
Let's look at one final graph option. Sometimes you want to compare results from two different graphs. In this case, it is helpful to use the same range on the Y-Axis to facilitate comparison.

- Open a **BasicStart.bpw** Worksheet.
- Outputs are Surface Fire Rate of Spread and Surface Fire Flame Length.
- Modify a Worksheet to use the following inputs.
  - **Description:** Setting the Y-Axis values
  - **Fuel Model:** 5
  - **Dead Fuel Moisture:** 2-18%, Step 1.
  - **Live Fuel Moisture:** 300, 200, 100, 50%
  - **Midflame Wind Speed:** 5 mi/h
  - **Slope Steepness:** 20%
- **Calculate** the Run.
- In the **Calculate Results** dialog box, deselect **Display table results** and click **Ok**.

7. What is the maximum value on the Y-Axis?



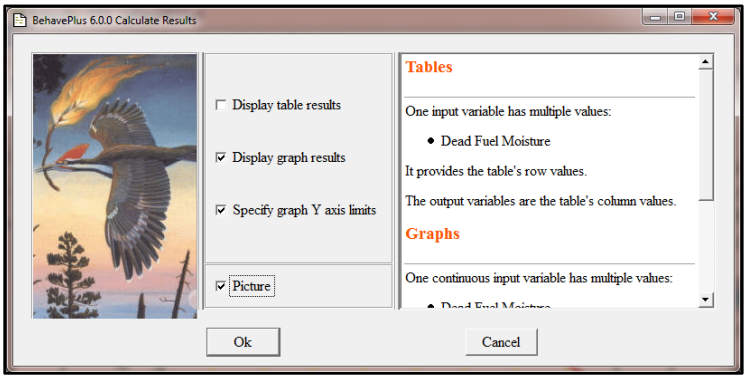
- Return to the Worksheet (**First Page**).
- Change the **Live Fuel Moisture** to 300%.
- **Calculate** the Run.



8. What is the maximum value on the Y-Axis in this Run?

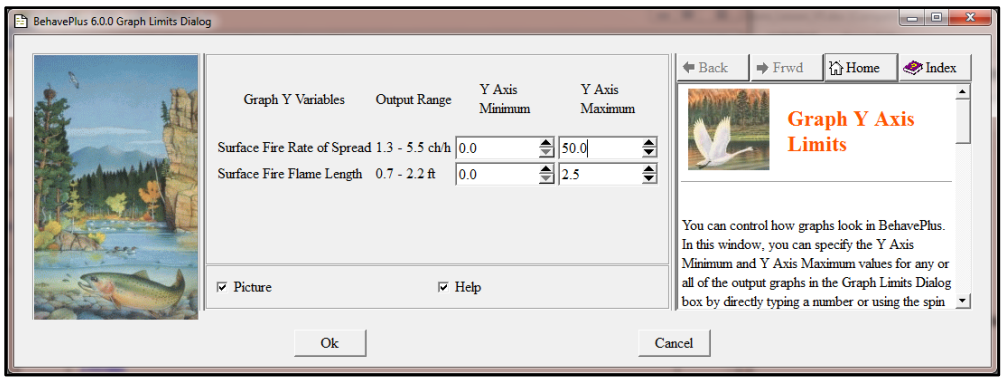
The scale of the graph changes automatically to reflect the maximum Y-Axis value for the current calculation. If we want to compare this graph to the previous one, we need to change the Y-Axis values.

- **Calculate** the Run again.
- Check the box next to **Specify graph Y axis limits** and click **Ok**.

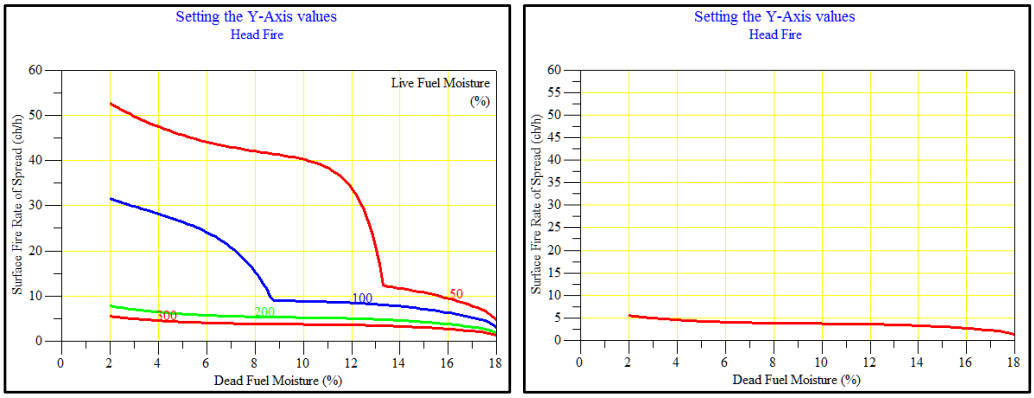


A new window pops up allowing you to change the Y-Axis variables for all of the output variables, in this case Surface Fire Rate of Spread and Surface Fire Flame Length. The current range of variables for each variable is also displayed.

- Change the **Y Axis Maximum** to **60** and click **Ok**.



Now you can more easily compare the two graphs as shown below with the original Run on the left and the revised Run for Live Fuel Moisture of 300% on the right.



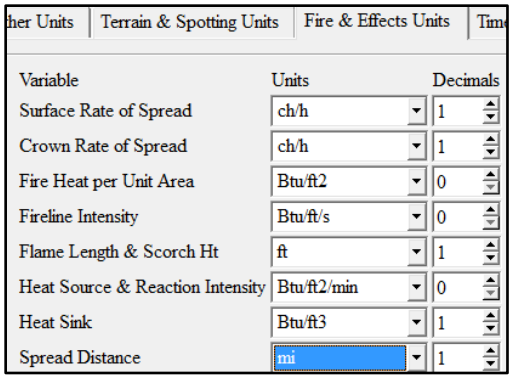
Changing Units

The default units on the Worksheet are simply those that are used often. Sometimes, however, you may need to report outputs differently. Let's examine a fast-moving crown fire and see how the units might be changed.

- Open a new **BasicStart.bpw** Worksheet.
- Select both the SURFACE and CROWN modules.
- Include the following outputs.
  - **SURFACE module:** no outputs
  - **CROWN module:** Active Crown Fire Rate of Spread, Active Crown Fire Flame Length, Crown Fire Type, and Active Crown Fire Spread Distance

You must select the SURFACE module if you want to calculate crown fire from calculated surface fire parameters. You do not have to show any outputs from the SURFACE module if you only want to use the calculations in the CROWN module. First, let's look at the outputs. Active Crown Fire Rate of Spread is output in ch/h, and Flame Length values are in ft. Active Crown Fire Spread Distance is in chains. Since this is a fast-moving crown fire, it may be more useful to output the Active Crown Fire Spread Distance in miles.

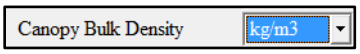
- Click on **Configure > Custom units preferences**.
- Go to the **Fire & Effects Units** tab.
- Change the **Spread Distance** from **ch** to **mi**.



- Click **Ok**.
- When it asks if you would like to **Save as Units Set File?** Click **No**.
  Note: *If you select* ***Yes****, you will be prompted to save the file in your BehavePlus Workspace. You can use it later by going to* ***Configure > Units set selection > Custom*** *and navigating to the saved* ***Units Set File****.*

Next, look at the inputs. The Canopy Bulk Density is often obtained from the academic literature and reported in metric units (kg/m3). Let's change these units as well.

- Return to **Custom units preferences**.
- Go to the **Fuel & Vegetation Units** tab.
- Change the **Canopy Bulk Density** to kg/m3.



- Click **Ok** and do not save the Units Set File.

You are now ready to enter the data.
Hint: *Determine your outputs, and then set up the input options before entering any data.*

- Fill out the Worksheet as follows.
  - **Description:** Changing Units, Crown Fire
  - **Fuel Model:** tu5
  - **Canopy Height:** 45

- Click on the **Guide** button next to **Canopy Base Height**.
- Scroll down in the **Help** file. We have included published descriptions for fire in Interior West conifer stands with varying treatment levels.
- Click on **Douglas-fir / Lodgepole pine**.
  - **Canopy Base Height:** Select the value for 75% of Initial Basal Area (in feet)
    Hint: *You can enter the appropriate value in the* ***From*** *box and click* ***Ok****.*
  - **Canopy Bulk Density:** Select the value for 75% of Initial Basal Area (in kg/m3)
  - **Dead Fuel Moisture:** 5-10%, Step 1
  - **Live Fuel Moisture:** 100%
  - **Foliar Moisture:** 100%
  - **20-ft Wind Speed:** 5-25 mi/h, Step 5
  - **Wind Adjustment Factor:** In the **Help** file, select the appropriate value for a partially sheltered TU5.
  - **Slope Steepness:** 23%
  - **Elapsed Time:** 2 hours

- **Calculate** the Run.

9. *Which 20-ft Wind Speed predicts crowning across all Dead Fuel Moisture values? What is the range of Active Crown Fire Spread Distance when the model predicts crowning?*

This is only a brief introduction to changing variable units. Please see the **Operation Unit** *Units and Decimals Lesson* for more information.

Summary

In this lesson, you have produced results for single and multiple values of input variables while modifying the appearance of tables and graphs. You also learned the basics of changing variable units

This is the last of four lessons in the **Introduction Unit** which provide the basics of program operation. The remaining BehavePlus lessons may be done in any order you wish. Subsequent lessons cover the many features and fire modeling capabilities offered by BehavePlus.

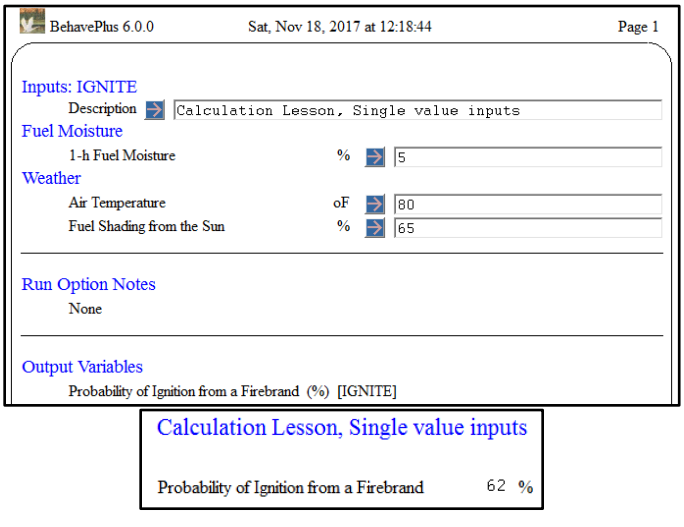
There are exercises associated with this lesson. They start on page 24, after the answers to the questions in the lesson.

You have completed the final lesson in the Introduction Unit.

1. Basic Start – simple entry of input to get answers in the form of tables and graphs
2. Worksheets – how the Worksheet is developed from user selections
3. Input Methods – various ways of entering input values
4. **Calculations – table and graph output options**

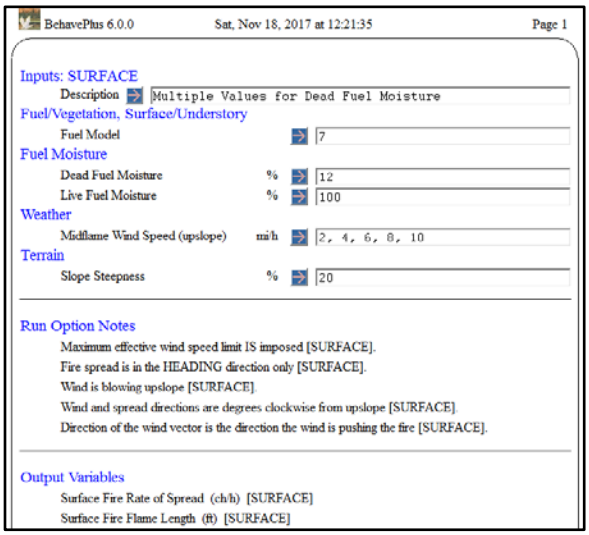
Answers to questions in the lesson

1. *Change **Fuel Shading from the Sun** to **65%**. What is the Probability of Ignition from a Firebrand?*
   The Probability of Ignition from a Firebrand is now 62%.



2. *Change the following input variables. What is the predicted fire behavior?*
   - ***Dead Fuel Moisture: 12%***
   - ***Midflame Wind Speed: From 2 Thru 10 Step 2.***

The Surface Fire Rate of Spread varies from 8.7 ch/h to 56.5 ch/h, while the Surface Fire Flame Length varies from 3.2 to 7.6 ft.



Multiple Values for Dead Fuel Moisture

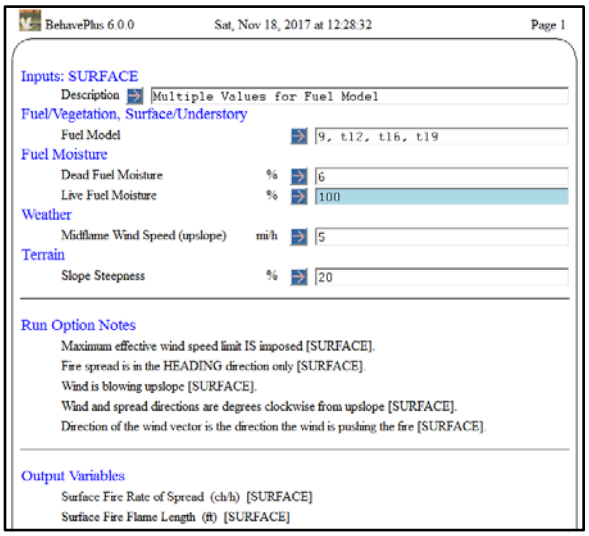
Head Fire

Midflame Wind Speed mi/h	Surface Fire Rate of Spread ch/h	Surface Flame Length ft
2	8.7	3.2
4	18.3	4.6
6	29.7	5.7
8	42.5	6.7
10	56.5	7.6

3. *Change the Fuel Model by selecting the hardwood litter models. What is the effect of these fuel models on Surface Fire Rate of Spread and Surface Fire Flame Length?*

The Fuel Models that may represent hardwood litter are 9, tl2, tl6, and tl9. Note, however, that you should always choose the Fuel Model that best represents the *fire behavior* for the area. Don't simply rely on a name, description, or picture of the fuel. Look at fuel model parameters and outputs as well.

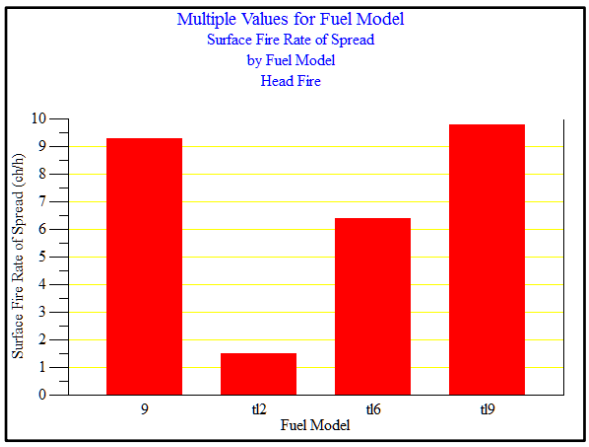
Fire behavior for these Fuel Models is low, with Surface Fire Rate of Spread ranging from 1.5 to almost 10 ch/h and Surface Fire Flame Lengths that are 5 ft or less. Fuel Model TL2 (182) has the least fire behavior with both low ROS and FL. Fuel Models 9 and TL9 have similar rates of spread, but slightly different flame lengths.

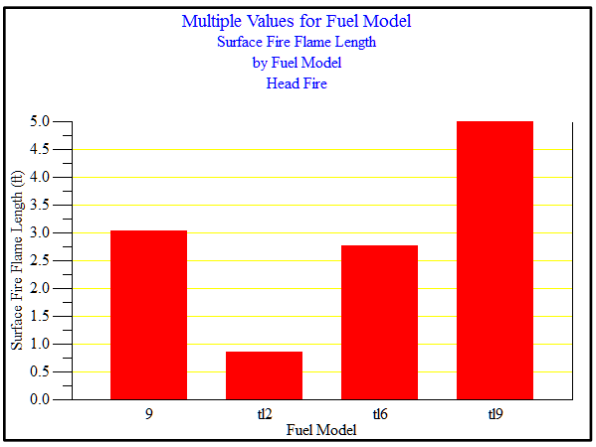


Multiple Values for Fuel Model

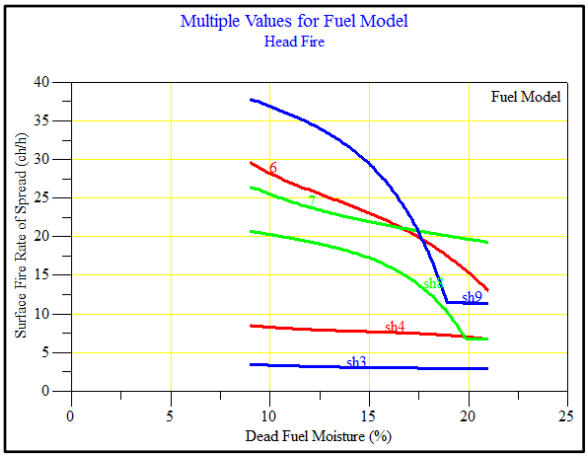
Head Fire

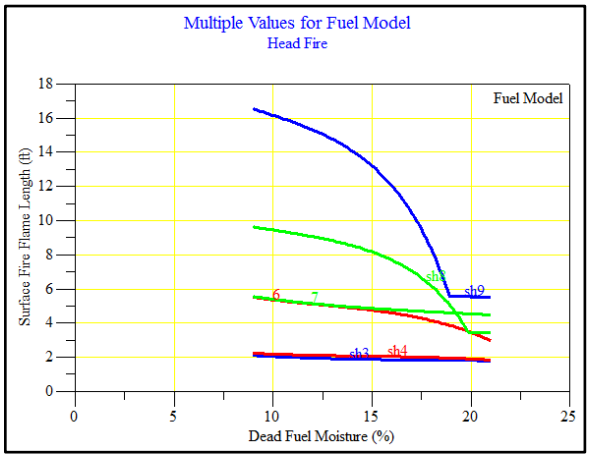
Fuel Model	Surface Fire Rate of Spread ch/h	Surface Flame Length ft
9	9.3	3.0
tl2	1.5	0.9
tl6	6.4	2.8
tl9	9.8	5.0





4. *Examine the graphs for Surface Fire Rate of Spread and Surface Fire Flame Length. What can you say about the fire behavior for SH3 and SH4 under these conditions?*
SH3 and SH4 predict the lowest fire behavior. Their fire behavior does not change much across the range of Dead Fuel Moisture values (10-20%). SH4 has a higher ROS than SH3 but very similar FL.





5. *What is the maximum Surface Fire Rate of Spread for these fuel models when the Dead Fuel Moisture is 15%? What is the range of Surface Fire Flame Length values for a Fuel Model SH3?*
When the Dead Fuel Moisture is 15%, the maximum Surface Fire Rate of Spread is 29.6 ch/h for fuel model SH9. The Surface Fire Flame Length ranges from 2.7 to 3.5 ft for an SH3.

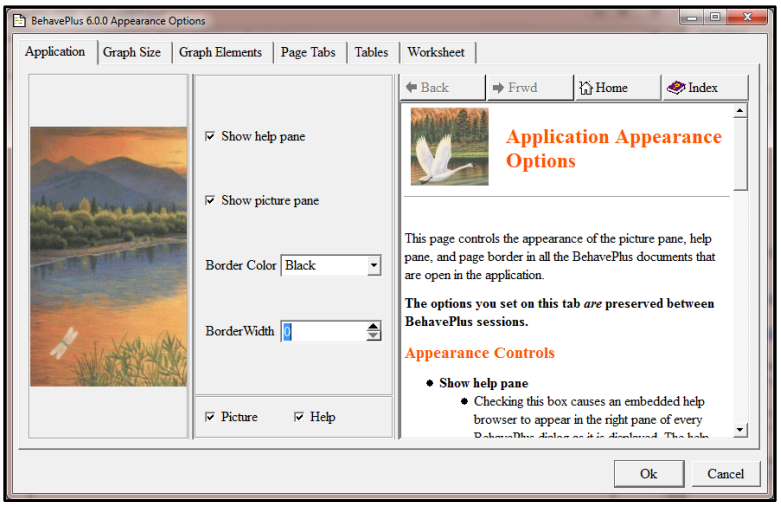
Multiple Values for Dead Fuel Moisture and Fuel Model
Head Fire
Surface Fire Rate of Spread (ch/h)

Dead Fuel Moisture	Fuel Model					
%	6	7	sh3	sh4	sh8	sh9
9	29.6	26.5	3.5	8.5	20.7	37.8
12	26.0	23.8	3.2	8.0	19.3	34.7
15	23.1	21.9	3.1	7.7	17.2	29.4
18	19.1	20.5	3.0	7.4	12.7	17.8
21	13.0	19.3	2.9	6.7	6.7	11.3
24	2.3	18.0	2.8	5.5	6.5	10.9
27	0.0	16.4	2.7	2.2	6.1	10.3

Multiple Values for Dead Fuel Moisture and Fuel Model
Head Fire
Surface Fire Flame Length (ft)

Dead Fuel Moisture	Fuel Model					
%	6	7	sh3	sh4	sh8	sh9
9	5.5	5.6	2.1	2.2	9.6	16.5
12	5.1	5.1	2.0	2.1	9.1	15.3
15	4.8	4.9	1.9	2.1	8.2	13.2
18	4.1	4.7	1.8	2.0	6.2	8.3
21	3.0	4.5	1.8	1.8	3.4	5.5
24	0.8	4.3	1.8	1.5	3.4	5.4
27	0.0	4.0	1.7	0.8	3.2	5.1

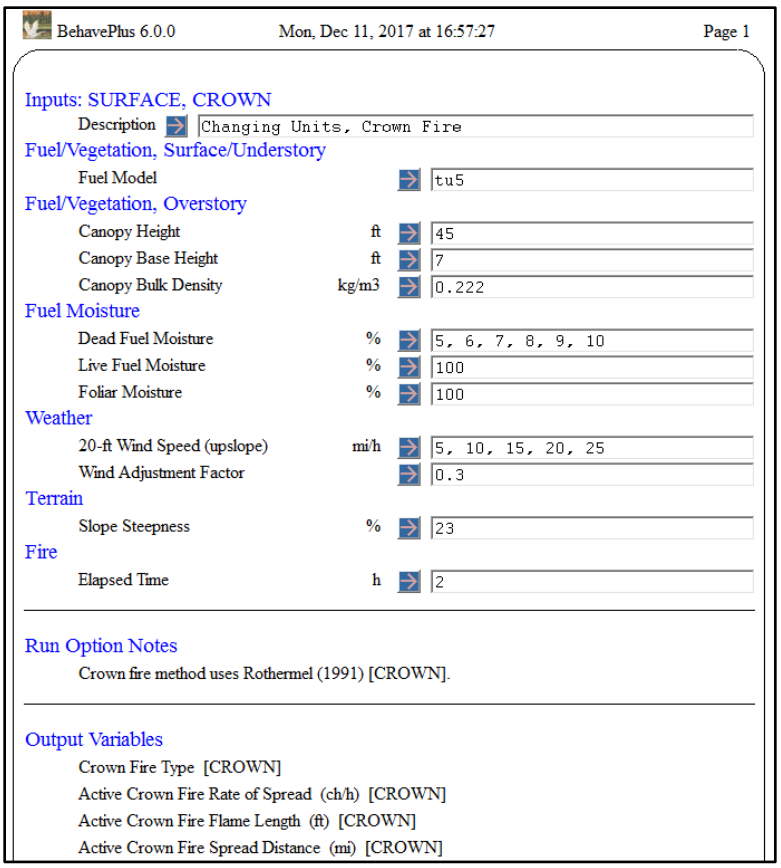
6. *How can you eliminate the black border around the output?*
   In the **Configure > Appearance preferences > Appearance Options** window, open the **Application** tab and change **Border Width** to 0 (see the **Help** file). This eliminates the border for all current and future BehavePlus Worksheets and Runs. This change is saved with the application, not the Worksheet or Run.



7. *What is the maximum value on the Y-Axis?*
   The maximum Y-Axis value is 60 ch/h.

8. *What is the maximum value on the Y-Axis in this Run?*
   The maximum Y-Axis value is 6 ch/h.

9. *Which 20-ft Wind Speed predicts crowning across all Dead Fuel Moisture values? What is the range of Active Crown Fire Spread Distance when the model predicts crowning?*
   A 20-ft Wind Speed of 20 mi/h generates crown fire for all Dead Fuel Moisture values. Active Crown Fire Spread Distance for the 2-hour period ranges from 1.2 to 1.9 miles.



BehavePlus 6.0.0 Mon, Dec 11, 2017 at 16:57:27 Page 1

Inputs: SURFACE, CROWN

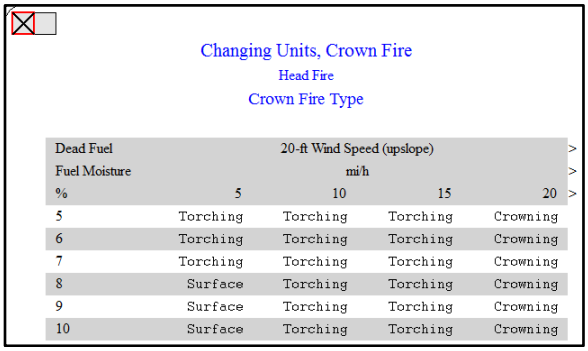
Description		Changing Units, Crown Fire
Fuel/Vegetation, Surface/Understory		
Fuel Model		tu5
Fuel/Vegetation, Overstory		
Canopy Height	ft	45
Canopy Base Height	ft	7
Canopy Bulk Density	kg/m3	0.222
Fuel Moisture		
Dead Fuel Moisture	%	5, 6, 7, 8, 9, 10
Live Fuel Moisture	%	100
Foliar Moisture	%	100
Weather		
20-ft Wind Speed (upslope)	mi/h	5, 10, 15, 20, 25
Wind Adjustment Factor		0.3
Terrain		
Slope Steepness	%	23
Fire		
Elapsed Time	h	2

Run Option Notes

Crown fire method uses Rothermel (1991) [CROWN].

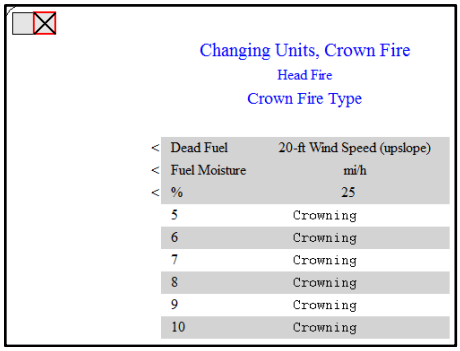
Output Variables

Crown Fire Type [CROWN]
Active Crown Fire Rate of Spread (ch/h) [CROWN]
Active Crown Fire Flame Length (ft) [CROWN]
Active Crown Fire Spread Distance (mi) [CROWN]



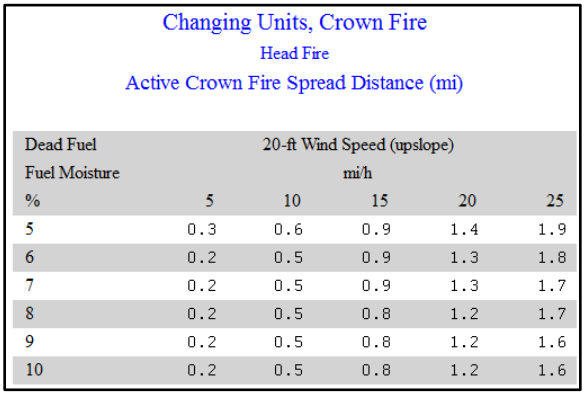
Changing Units, Crown Fire
Head Fire
Crown Fire Type

Dead Fuel Fuel Moisture %	20-ft Wind Speed (upslope) mi/h 5	10	15	20
5	Torching	Torching	Torching	Crowning
6	Torching	Torching	Torching	Crowning
7	Torching	Torching	Torching	Crowning
8	Surface	Torching	Torching	Crowning
9	Surface	Torching	Torching	Crowning
10	Surface	Torching	Torching	Crowning



Changing Units, Crown Fire
Head Fire
Crown Fire Type

Dead Fuel Fuel Moisture %	20-ft Wind Speed (upslope) mi/h 25
5	Crowning
6	Crowning
7	Crowning
8	Crowning
9	Crowning
10	Crowning

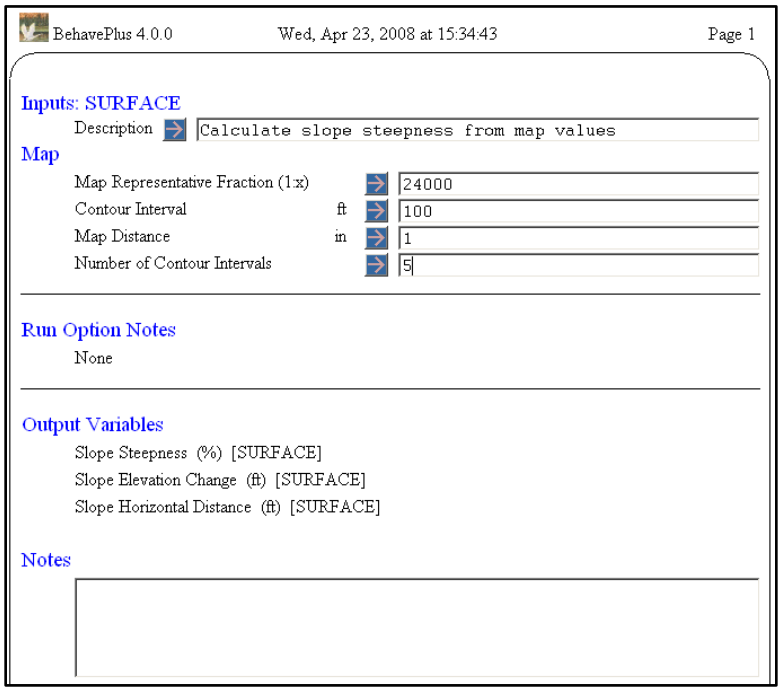


Changing Units, Crown Fire
Head Fire
Active Crown Fire Spread Distance (mi)

Dead Fuel Fuel Moisture %	20-ft Wind Speed (upslope) mi/h 5	10	15	20	25
5	0.3	0.6	0.9	1.4	1.9
6	0.2	0.5	0.9	1.3	1.8
7	0.2	0.5	0.9	1.3	1.7
8	0.2	0.5	0.8	1.2	1.7
9	0.2	0.5	0.8	1.2	1.6
10	0.2	0.5	0.8	1.2	1.6

Exercises

1. Develop a new Worksheet that looks like the following and answer the questions.
   Hint: *Go to* ***SURFACE Module Options… > Input Options > Slope*** *and select* ***Slope Steepness is calculated from map measurements***.



   a. If the Map Representative Fraction is 24000, how many inches on the map represent a mile on the ground?
   b. What is Slope Steepness in percent?
   c. What is Slope Steepness in degrees? ***Hint:*** *Look in the SURFACE Module Input Options.*

2. Calculate maximum spotting distance from a single 40-ft tall torching subalpine fir with a D.B.H. of 12 in. Trees downwind are 50 ft high, and Downwind Canopy Cover is open. The terrain is flat. Consider 20-ft wind speeds of 5, 10, 15, 20, and 25 mi/h.

3. Using the following information, create a table for Surface Fire Rate of Spread and Surface Fire Flame Length that ranges from lowest value in the upper left-hand corner to highest value in the lower right-hand corner. Create tables and graphs that looks like the following.

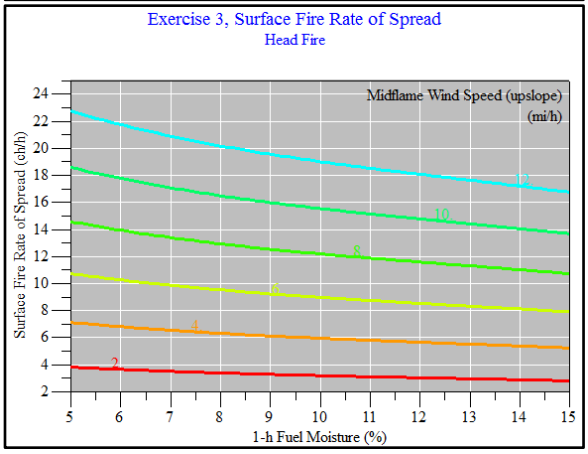
   - **Description:** Exercise 3, Surface Fire Rate of Spread
   - **Fuel Model:** TU5
     Hint: *You can also enter 165, the Fuel Model Number associated with Fuel Model Code TU5.*
   - **1-h Fuel Moisture:** 5-15%, Step 2
   - **10-h Fuel Moisture:** 7%
   - **100-h Fuel Moisture:** 9%
   - **Live Herbaceous Fuel Moisture:** 90%
   - **Live Woody Fuel Moisture:** 110%
   - **Midflame Wind Speed:** 2-12 mi/h, Step 2
   - **Slope Steepness:** 15%

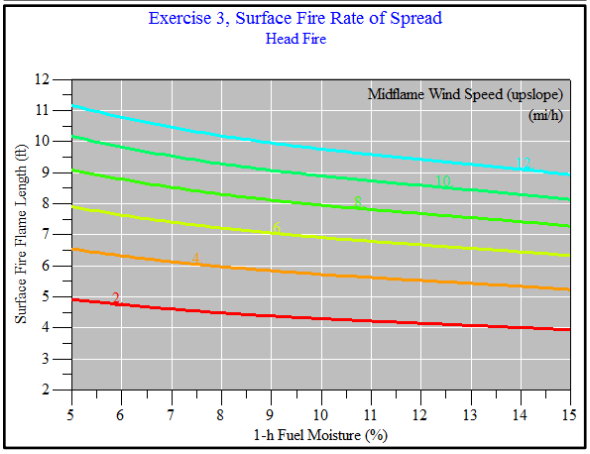
Exercise 3, Surface Fire Rate of Spread
Head Fire
Surface Fire Rate of Spread (ch/h)

Midflame Wind Speed mi/h	1-h Fuel Moisture % 15	13	11	9	7	5
2	2.8	3.0	3.1	3.3	3.5	3.8
4	5.2	5.5	5.8	6.1	6.5	7.1
6	7.9	8.3	8.8	9.2	9.9	10.7
8	10.7	11.3	11.9	12.5	13.4	14.6
10	13.7	14.4	15.1	16.0	17.1	18.6
12	16.7	17.6	18.5	19.6	20.9	22.8

Exercise 3, Surface Fire Rate of Spread
Head Fire
Surface Fire Flame Length (ft)

Midflame Wind Speed mi/h	1-h Fuel Moisture % 15	13	11	9	7	5
2	3.9	4.1	4.2	4.4	4.6	4.9
4	5.2	5.4	5.6	5.8	6.1	6.5
6	6.3	6.6	6.8	7.1	7.4	7.9
8	7.3	7.6	7.8	8.1	8.5	9.1
10	8.1	8.4	8.7	9.1	9.5	10.2
12	8.9	9.3	9.6	10.0	10.5	11.2

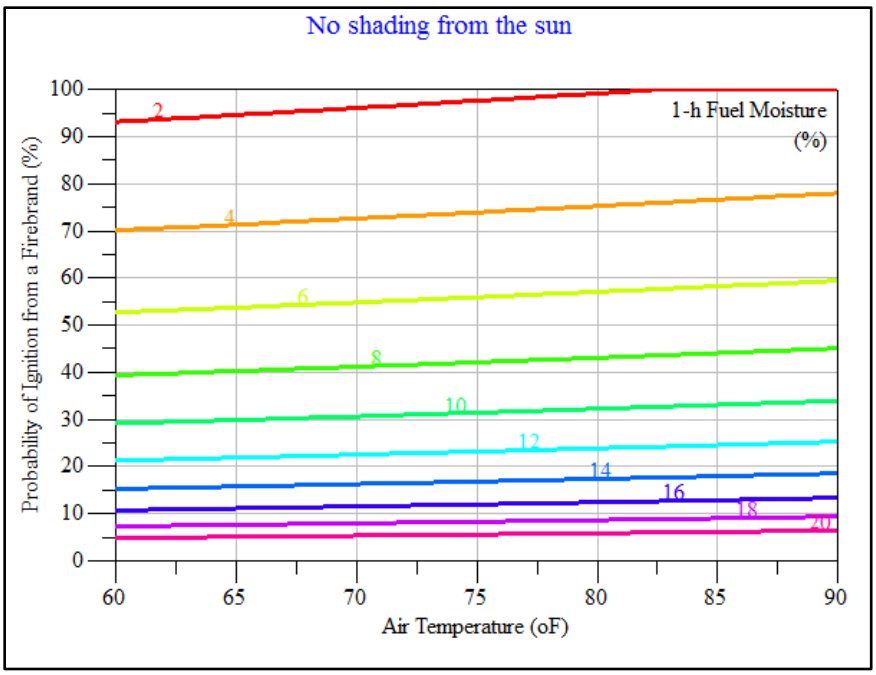




4. Produce a table and graph as shown below. All of the information you need can be obtained by reading the **Description** and looking at the variables in the table.

No shading from the sun
Probability of Ignition from a Firebrand (%)

1-h Fuel Moisture %	Air Temperature oF 60	65	70	75	80	85	90
2	93	95	96	98	99	100	100
4	70	71	73	74	75	77	78
6	53	54	55	56	57	58	59
8	39	40	41	42	43	44	45
10	29	30	31	31	32	33	34
12	21	22	23	23	24	25	25
14	15	16	16	17	17	18	19
16	11	11	12	12	12	13	13
18	7	8	8	8	9	9	9
20	5	5	5	6	6	6	6



Answers to these exercises can be found in the accompanying PDF file.