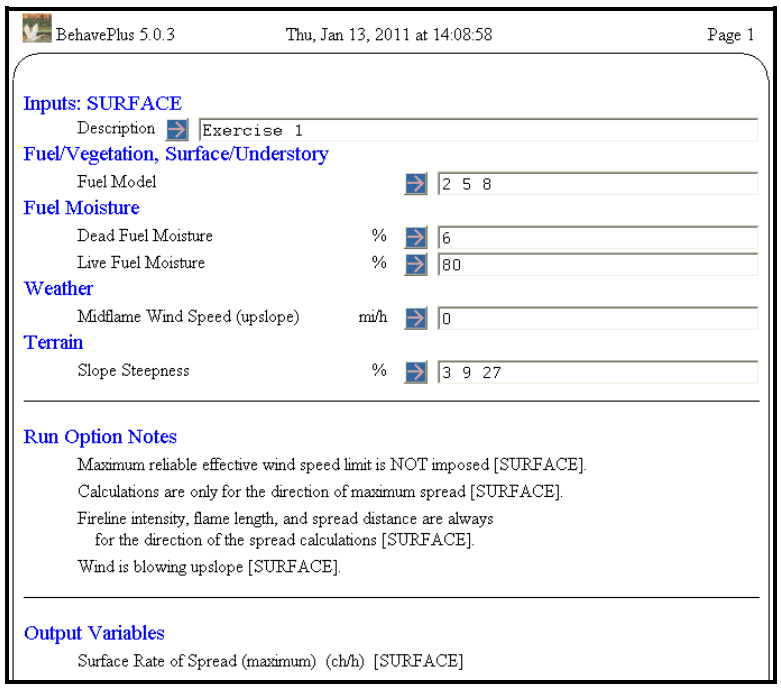
Exercise Answers

1. In the lesson, we used slopes of 8%, 24%, and 72% to test the following rule of thumb:

> **"The first tripling of slope roughly doubles the spread rate. The second tripling of slope increases spread rates by factors of 4 to 6. The effects of slope become greater as the slope increases, being only modest until slopes are moderate to steep."**

Compare those results to another example using slope values of 3%, 9%, and 27% and the following inputs: Fuel Model = 2, 5, 8; Dead Fuel Moisture = 6%; Live Fuel Moisture = 80%, and Midflame Wind Speed = 0 mi/h. Ensure the wind limit is NOT imposed.

The worksheet should look like the following. Remember to check the Run Option Notes!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Inputs: SURFACE
Description Exercise 1
Fuel/Vegetation, Surface/Understory
Fuel Model 2 5 8
Fuel Moisture
Dead Fuel Moisture % 6
Live Fuel Moisture % 80
Weather
Midflame Wind Speed (upslope) mi/h 0
Terrain
Slope Steepness % 3 9 27

Run Option Notes
Maximum reliable effective wind speed limit is NOT imposed [SURFACE].
Calculations are only for the direction of maximum spread [SURFACE].
Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].
Wind is blowing upslope [SURFACE].

Output Variables
Surface Rate of Spread (maximum) (ch/h) [SURFACE]

Fuel Model	ROS @ 9% Slope	ROS @ 3% Slope	Ratio (ROS@9% / ROS@3%)
2	2.9	2.5	2.9 / 2.5 = 1.2
5	1.7	1.4	1.7 / 1.4 = 1.2
8	0.3	0.2	0.3 / 0.2 = 1.5

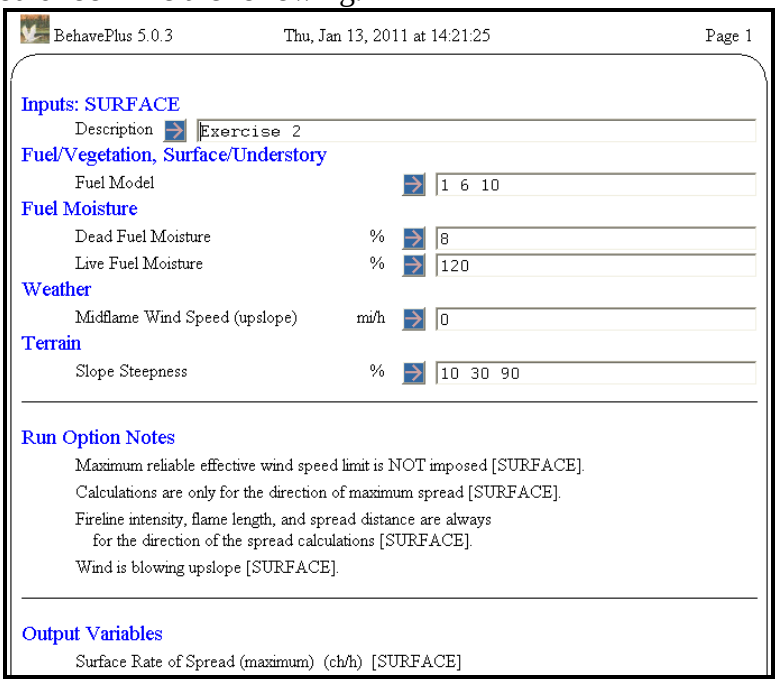
Fuel Model	ROS @ 27% Slope	ROS @ 9% Slope	Ratio (ROS@27% / ROS@9%)
2	6.8	2.9	6.8 / 2.9 = 2.3
5	4.6	1.7	4.6 / 1.7 = 2.7
8	0.5	0.3	0.5 / 0.3 = 1.7

Question – Does the rule seem to apply under these circumstances? Why or why not?
The first tripling of slope does not lead to a doubling of Surface Rate of Spread. The second tripling of slope in this example does not lead to a 4 to 6-fold increase in Surface Rate of Spread. However, the rule states that the effects of slope are only modest until slopes are moderately steep. In this case, a 3-9% slope is a gentle slope, and the rule would not be expected to apply. In fact, it seems the tripling of slope from 9% to 27% would be the "first tripling" to apply for this rule, leading to a doubling of Surface Rate of Spread. The answers would support this conclusion. It would be an interesting exercise to see what the impact of another tripling of slope–to 81% would have on Surface Rate of Spread.

Fuel Model	ROS @ 81% Slope	ROS @ 27% Slope	Ratio (ROS@81% / ROS@27%)
2	6.8	6.8	41.8 / 6.8 = 6.1
5	4.6	4.6	30.4 / 4.6 = 6.6
8	0.5	0.5	2.5 / 0.5 = 5.0

2. Repeat the exercise using the following conditions: Fuel Model = 1, 6, 10; Dead Fuel Moisture = 8%; Live Fuel Moisture = 120%; Midflame Wind Speed = 0 mi/h; and Slope Steepness = 10%, 30%, 90%. Ensure the wind limit is NOT imposed.

The Worksheet should look like the following.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Inputs: SURFACE
Description Exercise 2
Fuel/Vegetation, Surface/Understory
Fuel Model 1 6 10
Fuel Moisture
Dead Fuel Moisture % 8
Live Fuel Moisture % 120
Weather
Midflame Wind Speed (upslope) mi/h 0
Terrain
Slope Steepness % 10 30 90

Run Option Notes
Maximum reliable effective wind speed limit is NOT imposed [SURFACE].
Calculations are only for the direction of maximum spread [SURFACE].
Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].
Wind is blowing upslope [SURFACE].

Output Variables
Surface Rate of Spread (maximum) (ch/h) [SURFACE]

- **Calculate** the Run and then compute the ratios.

Fuel Model	ROS @ 30% Slope	ROS @ 10% Slope	Ratio (ROS@30% / ROS@10%)
2	17.0	5.1	17.0 / 5.1 = 3.3
5	5.4	1.9	5.4 / 1.9 = 2.8
8	1.7	0.8	1.7 / 0.8 = 2.1

Fuel Model	ROS @ 90% Slope	ROS @ 30% Slope	Ratio (ROS@90% / ROS@30%)
2	124.1	17.0	124.1 / 17.0 = 7.3
5	36.8	5.4	36.8 / 5.4 = 6.8
8	10.0	1.7	10.0 / 1.7 = 5.9

Question – Does the rule seem to apply under these circumstances? Why or why not?
As a rough estimate, the rule of thumb provides some guidance, although it seems to underestimate the calculated Surface Rate of Spread, particularly in the flashier fuels. Even if underestimating the rate of spread, the rule of thumb does demonstrate there is dramatic increase in the rate of spread. You will want to look at the fuel models and conditions in your area of concern before using this rule of thumb for more than a rough guideline.

3. Using the following information, test this rule of thumb from Firefighter Math:

> **"For slopes above 20%, each additional 20% increase in slope translates to an additional 1 mph increase in the effective equivalent 'upslope' component of the wind."**

Inputs: the 40 Scott & Burgan Fuel Models; 1-h Fuel Moisture = 7%; 10-h Fuel Moisture = 8%; 100-h Fuel Moisture = 9%; Live Herbaceous Fuel Moisture = 75%; Live Woody Fuel Moisture = 90%; Midflame Wind Speed = 0 mi/h; Slope Steepness = 20 – 100% in steps of 20%.

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Inputs: SURFACE

Description: Exercise 3

Fuel/Vegetation, Surface/Understory

Fuel Model: gr1, gr2, gr3, gr4, gr5, gr6, gr7

Fuel Moisture

1-h Moisture	%	7
10-h Moisture	%	8
100-h Moisture	%	9
Live Herbaceous Moisture	%	75
Live Woody Moisture	%	90

Weather

Midflame Wind Speed (upslope) mi/h: 0

Terrain

Slope Steepness %: 20, 40, 60, 80, 100

Run Option Notes

Maximum reliable effective wind speed limit is NOT imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Output Variables

Effective Wind Speed (mi/h) [SURFACE]

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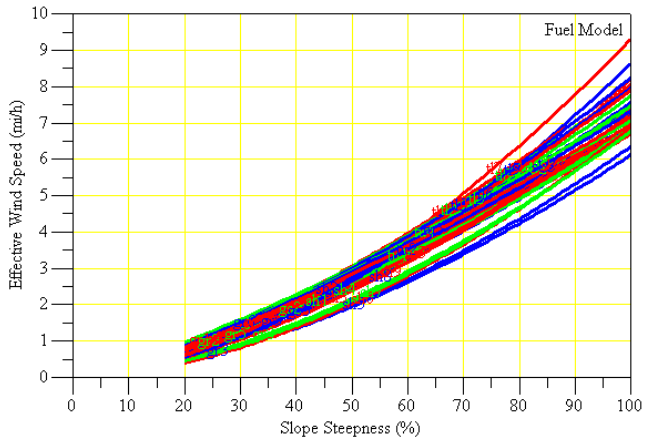
Exercise 3



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Exercise 3

Effective Wind Speed (mi/h)

Fuel Model	Slope Steepness %				
	20	40	60	80	100
gr1	0.9	2.1	3.5	5.1	6.8
gr2	0.7	1.9	3.3	4.9	6.7
gr3	0.4	1.3	2.6	4.2	6.1
gr4	0.7	1.9	3.3	4.9	6.7
gr5	0.7	1.8	3.3	5.0	6.9
gr6	0.9	2.1	3.6	5.2	6.9
gr7	0.8	2.0	3.4	5.1	6.9
gr8	0.5	1.5	2.9	4.7	6.8
gr9	0.7	1.8	3.3	5.0	6.9
gs1	0.8	1.9	3.4	5.0	6.8
gs2	0.8	2.0	3.4	5.0	6.9
gs3	0.6	1.8	3.2	4.9	6.8
gs4	0.7	2.0	3.5	5.4	7.4
sh1	0.7	1.8	3.3	5.0	6.9
sh2	0.7	2.0	3.6	5.5	7.6
sh3	0.6	1.7	3.2	5.1	7.3
sh4	0.7	1.8	3.3	4.9	6.8
sh5	0.4	1.4	2.7	4.4	6.4
sh6	0.4	1.4	2.8	4.6	6.9
sh7	0.4	1.4	2.9	4.6	6.8
sh8	0.6	1.7	3.2	5.0	7.2
sh9	0.5	1.7	3.2	5.0	7.2
tu1	0.7	1.9	3.5	5.4	7.5
tu2	0.8	2.0	3.5	5.3	7.2
tu3	0.7	1.8	3.3	5.0	7.0
tu4	1.0	2.3	3.8	5.4	7.1

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Exercise 3

Effective Wind Speed (mi/h)

Fuel Model	Slope Steepness %				
	20	40	60	80	100
tu5	0.6	1.8	3.6	5.9	8.6
tl1	0.8	2.2	4.0	6.0	8.2
tl2	0.9	2.2	3.9	5.8	7.9
tl3	0.7	2.1	3.8	5.9	8.2
tl4	0.7	2.1	3.8	5.8	8.1
tl5	0.8	2.1	3.7	5.6	7.7
tl6	0.9	2.2	3.8	5.6	7.5
tl7	0.6	2.0	3.9	6.4	9.3
tl8	0.8	2.2	3.9	5.8	8.0
tl9	0.8	2.2	3.9	5.8	8.0
sb1	0.8	2.1	3.8	5.7	7.9
sb2	0.9	2.2	3.8	5.5	7.5
sb3	0.9	2.2	3.7	5.4	7.3
sb4	0.8	2.1	3.6	5.3	7.2

Question – Does the rule seem to provide a reasonable estimate of the impact of slope on Effective Wind Speed?

As slope increases by 20%, the Effective Wind Speed increases by 1.0 – 1.5 mph in these Fuel Models under these conditions. Therefore, the rule of thumb does provide a reasonable estimate of the impact of wind. However, care should be taken at steeper slopes as this rule will underestimate the Effective Wind Speed.

4. Using the SURFACE module, calculate Slope Steepness for the following conditions.

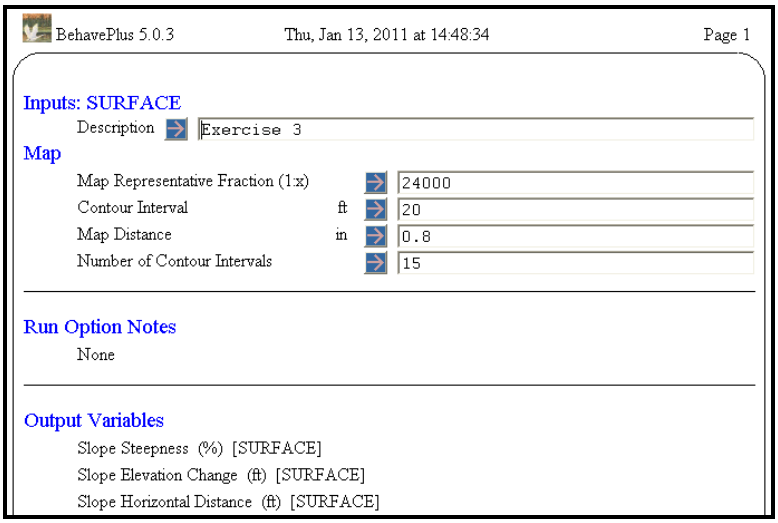
Map Representative Fraction	Contour Interval	Map Distance	Number of Contours	Slope, %	Slope, degrees
1:24000	**20 ft**	**.80 in**	**15**		
2 in/mi	**40 ft**	**0.6 in**	**24**		
1:10000	**10 m**	**2.8 cm**	**4**		

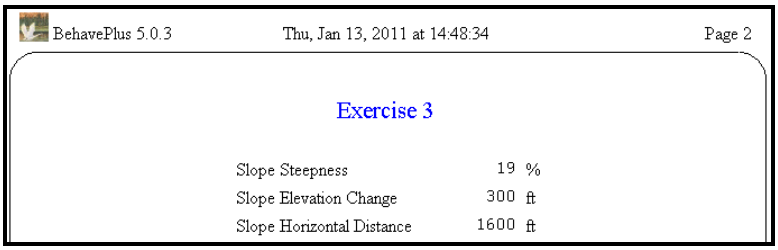
First, set up a Worksheet for calculating Slope Steepness.

- If you saved a **SlopeCalc.bpw** Worksheet during the lesson, you can open the saved Worksheet by either going to **File > Open Worksheet** or clicking on the Worksheet button ( ). The Worksheet should be in the **MyWorksheets** folder.

Otherwise,

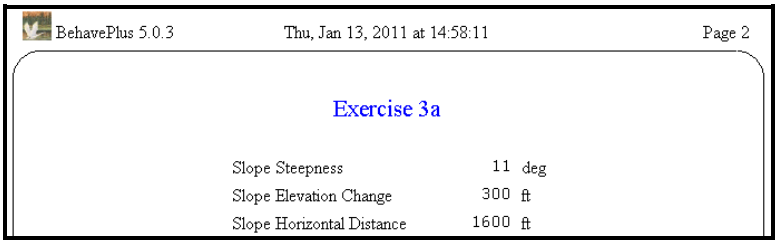
- Open **BasicStart.bpw**.
- Go to the **Module Selection > SURFACE Options… > Slope** tab and select **Slope steepness is calculated from map measurements**.
- On the **Basic Outputs** tab, uncheck the box next to Surface Rate of Spread and Flame Length.
- On the **Slope Outputs** tab, select Slope Steepness. It is generally good practice to select all of the slope outputs to verify that your results make sense, so also select Slope Elevation Change and Slope Horizontal Distance.
- Click **Ok** twice.





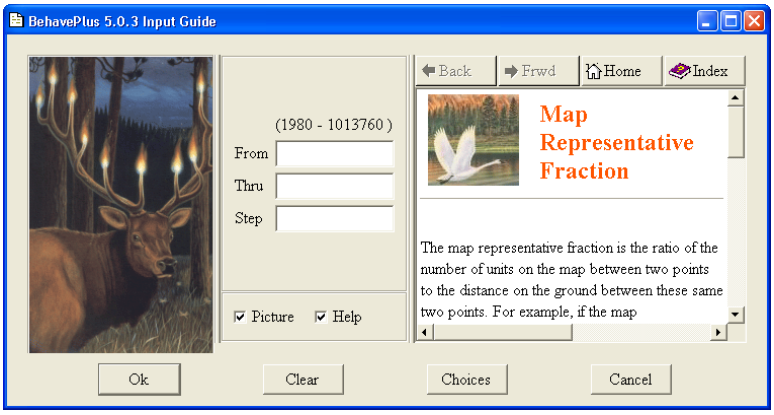
There are two ways to change the units of Slope Steepness – through the SURFACE module or by changing the Units Set. Remember, however, that changing the slope option in the **Module Selection > SURFACE Options… > Slope** tab will override any slope settings in the Units set.

- Therefore, go to the **Module Selection > SURFACE Options… > Slope** tab and select **Slope is specified as degrees.**
- **Calculate** the Run.



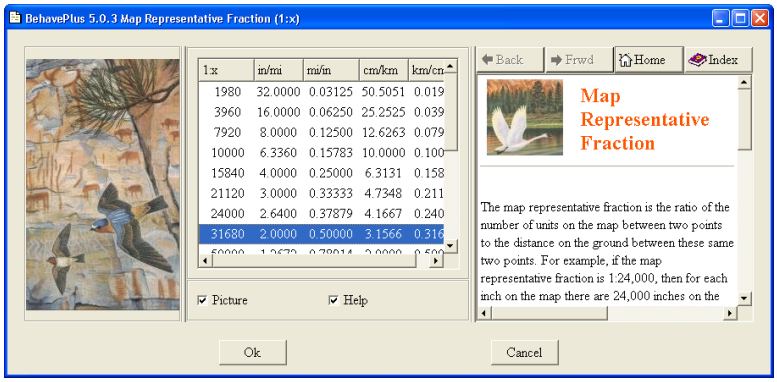
In the second example, you are not given the Map Representative Fraction, but rather a ratio indicating that 2 inches on the map represents 1 mile (2 in/mi). You have to convert this to a Map Representative Fraction.

- In the same Worksheet, click on the blue **Guide** button next to Map Representative Fraction.

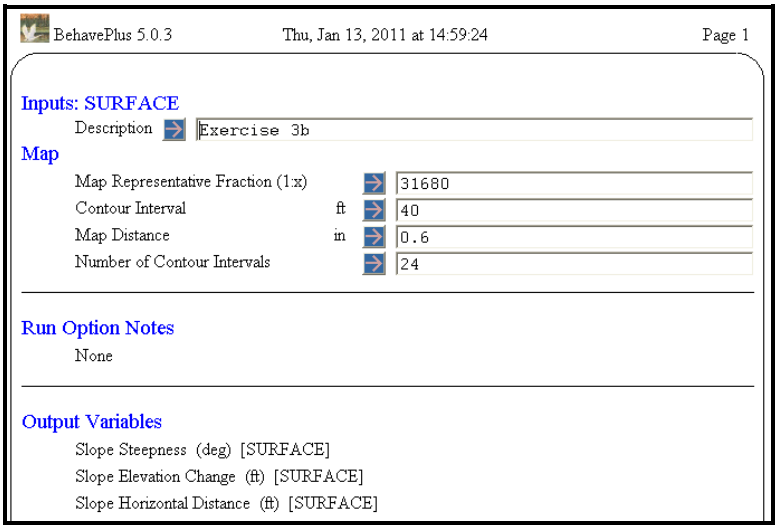


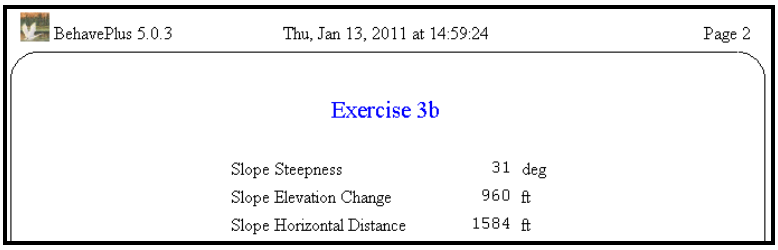
- Click on the **Choices** button. This will show many of the map representative fractions currently in use in the U.S.

- In the second column (in/mi), look for the 2.0000. You can either double-click on it or click on it and then click **Ok**. The equivalent Map Representative Fraction of 31680 is inserted in the Worksheet.



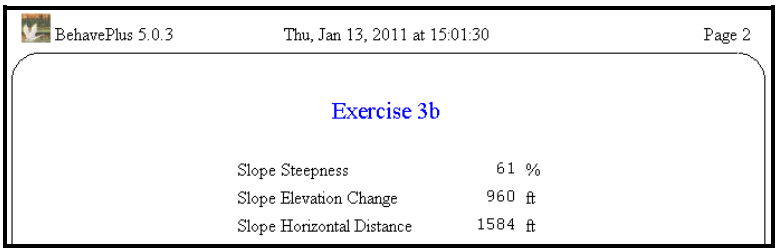
- Fill in the rest of the Worksheet and **Calculate** the Run.





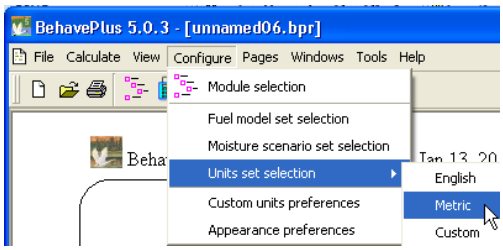
In this case, the Slope Steepness is given in degrees. To find the equivalent percent, you will need to do the following.

- Go to the **Module Selection > SURFACE Options… > Slope** tab and select **Slope is specified as percent.**
- **Calculate** the Run again.

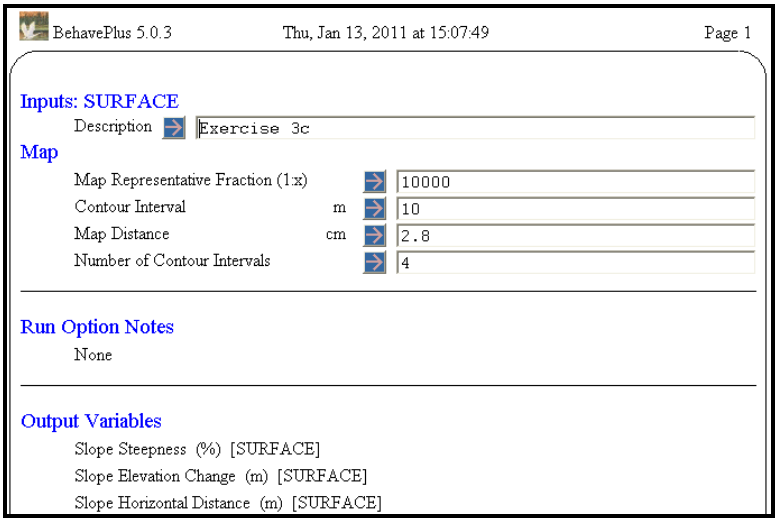


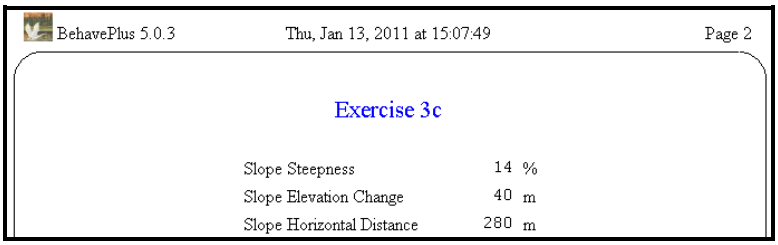
And, finally, the third example in this exercise uses metric units, which are becoming more common on maps in some parts of the U.S. You will need to change the units of the Worksheet before you can begin.

- Go to the **Configure > Units set selection > Metric** tab and select **Slope is specified as percent.**

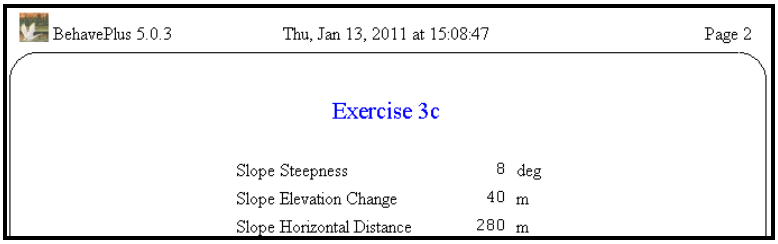


- Fill in the Worksheet and **Calculate** the Run.





- Change the Slope Steepness and find the other output value. The output units (percent or degrees) may vary depending on the Worksheet used.



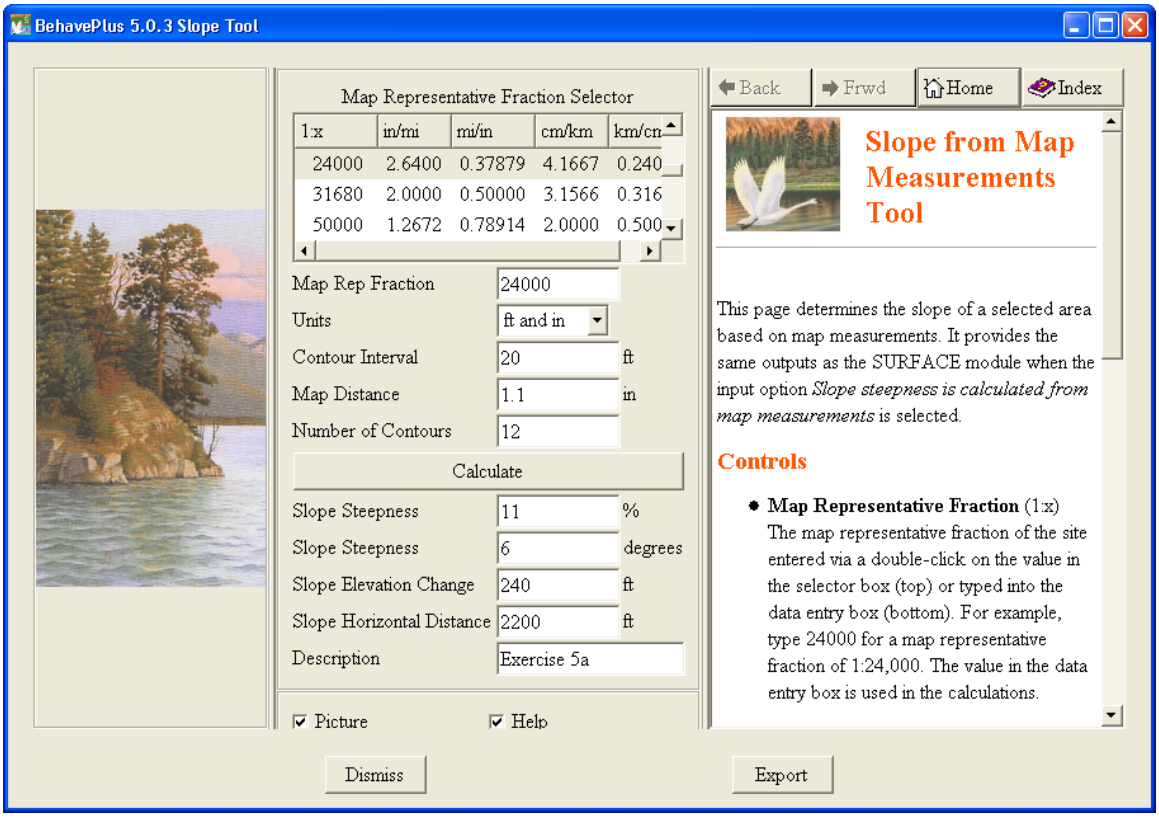
In this exercise, you calculated the Slope Steepness in both percent and in degrees. This is for practice only, as you will typically be required to report slope in only one set of units.

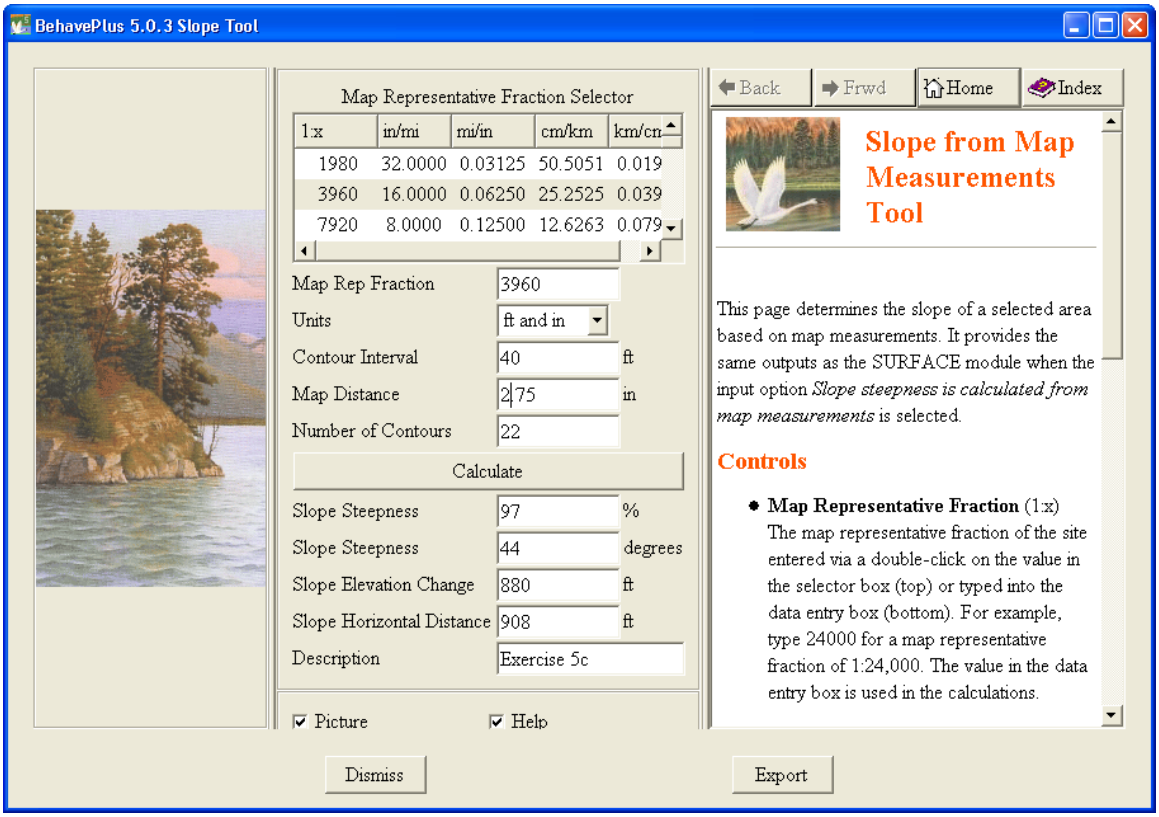
In summary,

Map Representative Fraction	Contour Interval	Map Distance	Number of Contours	Slope, %	Slope, degrees
1:24000	**20 ft**	**.80 in**	**15**	19	11
2 in/mi	**40 ft**	**0.6 in**	**24**	61	31
1:10000	**10 m**	**2.8 cm**	**4**	14	8

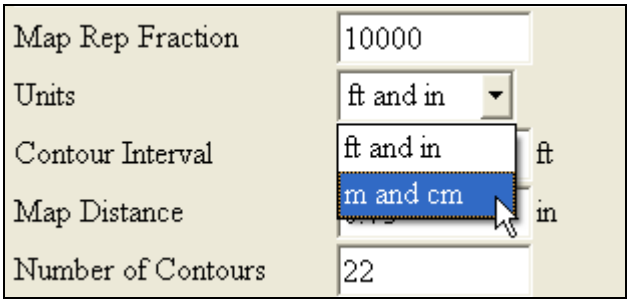
5. Using the Slope from Map Measurements Tool, calculate slopes for the following conditions.

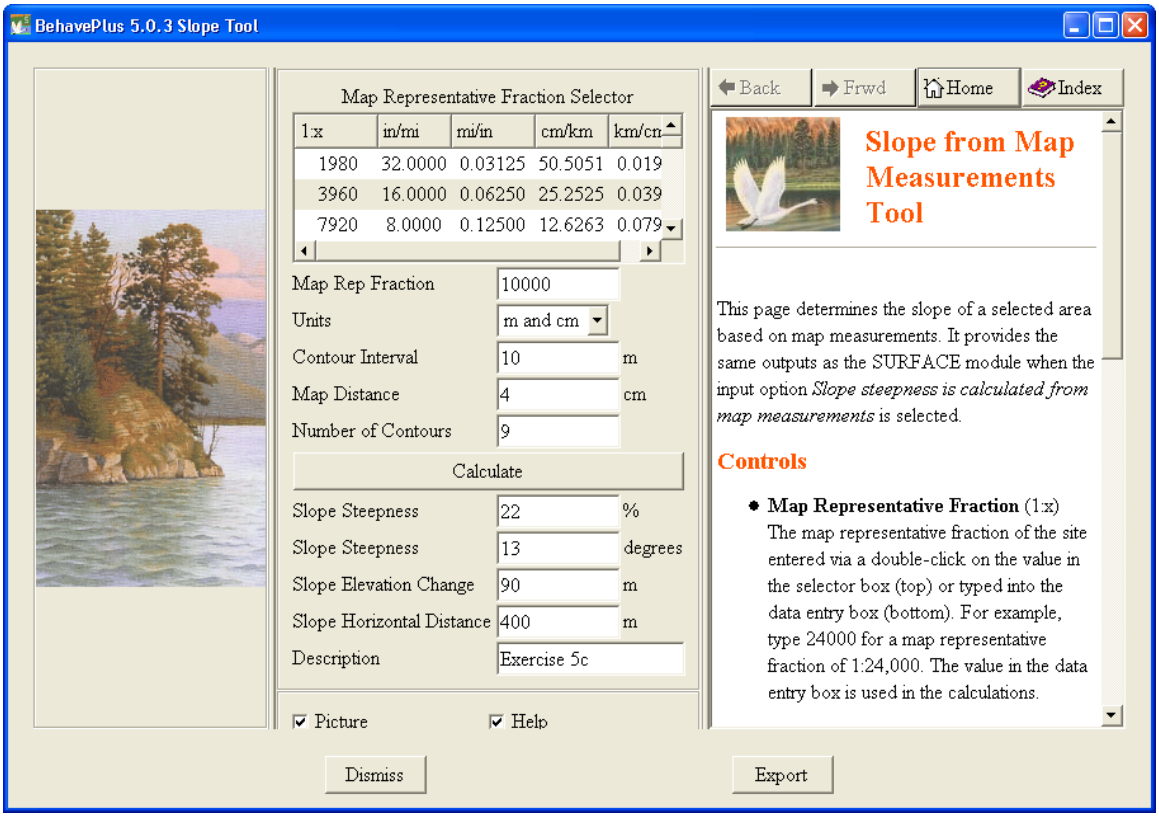
Map Representative Fraction	Contour Interval	Map Distance	Number of Contours	Slope, %	Slope, degrees
1:24000	**20 ft**	**1.1 in**	**12**		
16 in/mi	**40 ft**	**0.75 in**	**22**		
1:10000	**10 m**	**4 cm**	**9**		





For the last exercise, don't forget to change the units!





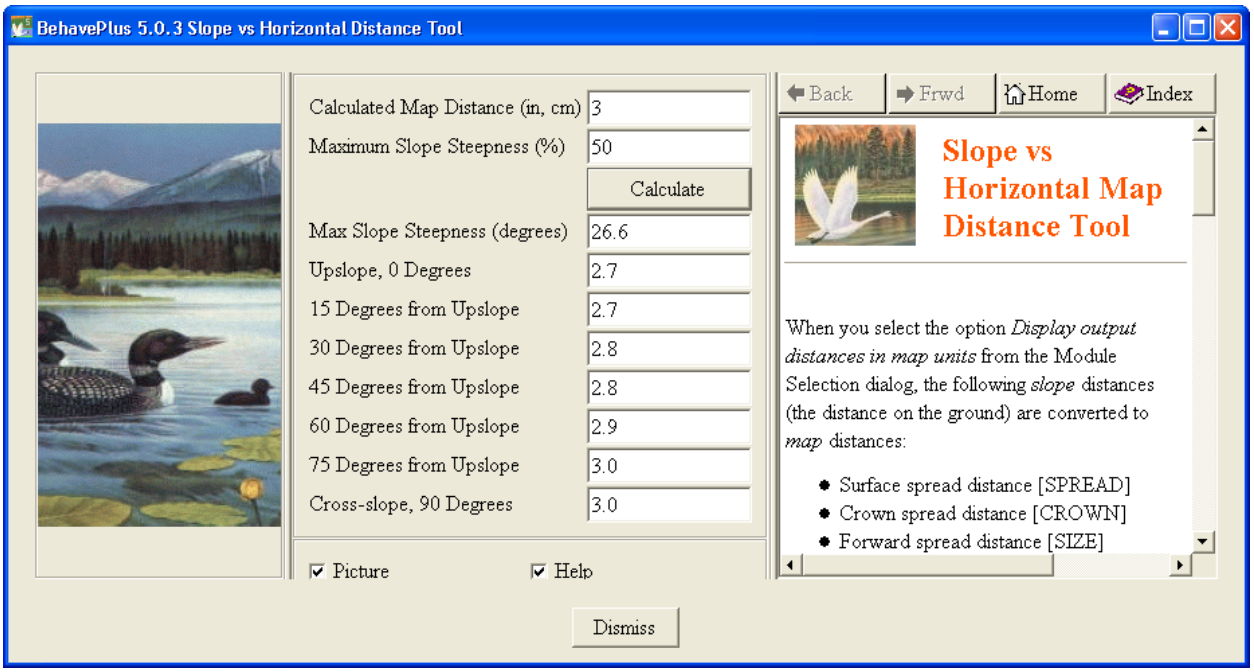
In summary,

Map Representative Fraction	Contour Interval	Map Distance	Number of Contours	Slope, %	Slope, degrees
1:24000	**20 ft**	**1.1 in**	**12**	11	6
16 in/mi	**40 ft**	**2.75 in**	**22**	97	44
1:10000	**10 m**	**4 cm**	**9**	22	13

Remember, the Slope from Map Measurements Tool is designed to calculate one slope at a time, and your results can be exported for documentation purposes. The results will need to be typed into a BehavePlus Worksheet if they are needed. Therefore, if you need slope to, for example, determine the fine dead fuel moisture, the Slope from Map Measurements Tool is the way to go. However, you may want to calculate it on your BehavePlus Worksheet using the SURFACE module if, for example, (1) you need to calculate a number of slopes or (2) you want to calculate slope as part of a larger BehavePlus run and you already have a value for fine dead (1-h) fuel moisture,. Both methods will provide the same answer.

6. Using the Slope vs Horizontal Map Distance Tool. Use a Calculated Map Distance of 3 in or cm and Maximum Slope Steepness of 50%, 100%, 125%, 150% to examine the difference between Calculated Map Distance and Horizontal Map Distance.

Unfortunately, the Slope vs Horizontal Map Distance Tool allows only one calculation at a time.



Using the tool, you can develop the following table:

	Horizontal Map Distance (based on Calculated Map Distance of 3 cm or in and the slope below)			
	50% Slope	**100% Slope**	**125% Slope**	**150% Slope**
Upslope, 0°	2.7	2.1	**1.9**	**1.7**
15° from Upslope	2.7	2.2	2.0	**1.8**
30° from Upslope	2.8	2.4	2.2	2.1
45° from Upslope	2.8	2.6	2.5	2.4
60° from Upslope	2.9	2.8	2.8	2.7
75° from Upslope	3.0	2.9	2.9	2.9
Cross-slope, 90°	3.0	3.0	3.0	3.0

Question: Which combination of Slope Steepness and Direction from Upslope has the greatest difference?

The greatest difference between Calculated Map Distance and Horizontal Map Distance is directly upslope at 150% slope. In general, upslope and near upslope (0° and 15°) have the greatest differences, with differences increasing as slope increases.