

Users' Guide
BehavePlus Fire Modeling System
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Users' Guide, Online HELP Development

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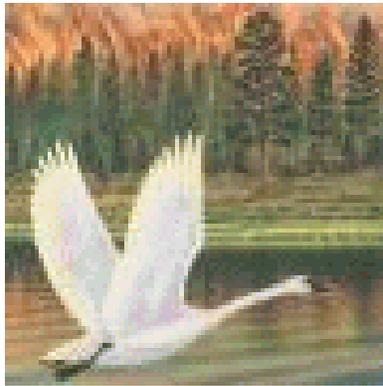


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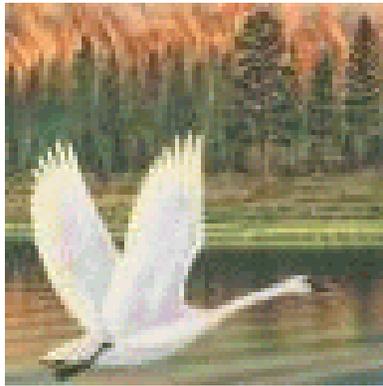
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Introduction

What is *BehavePlus*?

BehavePlus is a PC application to predict wildland fire behavior for fire management purposes. It is designed for use by wildland fire managers who are familiar with fuels, weather, topography, wildland fire situations, and associated terminology. *BehavePlus* uses site-specific input data to predict fire behavior for a point in time and space.

The *BehavePlus* Fire Modeling System replaces the 1984 BEHAVE Fire Behavior Prediction and Fuel Modeling System (Andrews 1986, Andrews and Chase 1989, Burgan and Rothermel 1984) with a new computation engine and graphical user interface. Currently, *BehavePlus* uses essentially the same mathematical models as the original BEHAVE. Future versions of *BehavePlus* will incorporate additional fire models.

Users are responsible for supplying valid input, correctly interpreting the fire behavior predictions, and understanding the assumptions and limitations of the models used in *BehavePlus*.

Who Developed *BehavePlus*?

BehavePlus is being developed by Pat Andrews (Fire Sciences Laboratory, USDA Forest Service) and Collin Bevins (Systems for Environmental Management). The *BehavePlus* feature list, functionality, and user interface is designed by Pat Andrews. Software design and development is handled by Collin D. Bevins.

Funding is provided by USDA Forest Service, Fire & Aviation Management, Washington, DC and by the Joint Fire Sciences Program. Additional support is provided by the Rocky Mountain Research Station and Systems for Environmental Management. The Users' Guide, and online Program Help were developed by Don Carlton, Fire Program Solutions, LLC.

Overview

BehavePlus replaces and improves upon the 1984 BEHAVE Fire Behavior Prediction and Fuel Modeling System. *BehavePlus* runs in the Windows 95/98 or NT/2000 environment and currently utilizes basically the same fire models as the old BEHAVE.

- o Surface fire spread, intensity, flame length
- o Area and perimeter of a point source fire
- o Spotting distance
- o Probability of ignition
- o Scorch height
- o Tree mortality
- o Relative humidity determination

Predictions of wildland fire behavior are made for a point in time and space given simple user-defined fuel, weather, and topography. This is unlike the FARSITE fire area simulator (Finney 1998), which predicts fire growth across the landscape for variable fuel, weather, and topography. *BehavePlus* inputs can be determined easily in the field while FARSITE inputs require extensive GIS support and theme development.

Features

BehavePlus is easy to customize, yet provides a standard mode for beginners and those familiar with the old *BEHAVE* to get up and running quickly. Customization of module inputs and outputs is done by clicking on the Options button (Figure 1).

BehavePlus improvements include:

- o Windows environment user interface
 - o One program (The old *BEHAVE* consisted of five programs)
 - o Online HELP system
- o An "equation tree" computational engine
 - o Designed to make program updates easier
 - o Input worksheets automatically request only required inputs
- o Tabular and graphical outputs
 - o User control of format

Figure 1

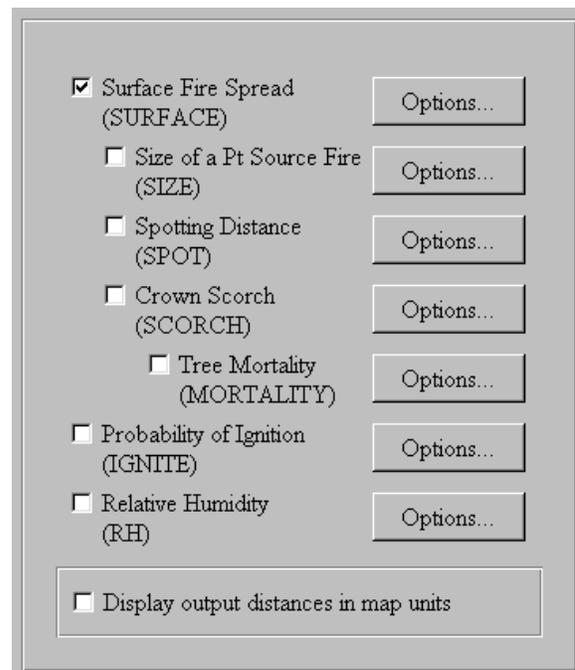
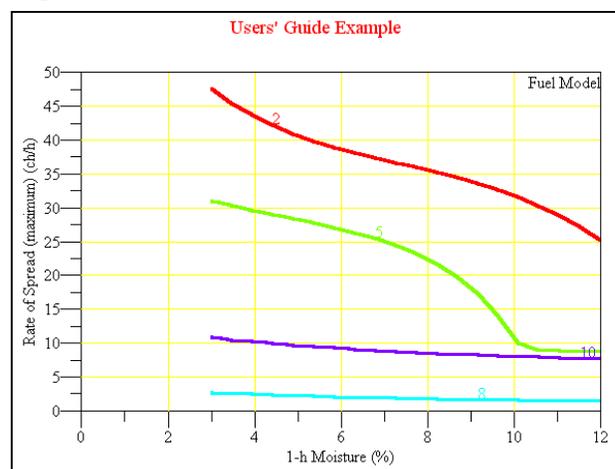


Figure 2

Users' Guide Example
Rate of Spread (maximum) (ch/h)

| Fuel Model | 1-h Moisture % | | | |
|------------|----------------|------|------|------|
| | 3 | 6 | 9 | 12 |
| 2 | 47.6 | 38.7 | 34.0 | 25.3 |
| 5 | 31.0 | 26.9 | 18.2 | 8.7 |
| 8 | 2.7 | 2.1 | 1.7 | 1.5 |
| 10 | 10.9 | 9.3 | 8.3 | 7.7 |

Figure 3



- o User selected input options and output variables
 - o For Example, the user can choose of input methods for wind direction
 - o Only selected output variables are displayed
- o Other features
 - o Variable descriptions
 - o Easy to modify and save fuel models
 - o Customized worksheet headers

Future Updates

Future versions of *BehavePlus* are already planned to include new wildland fire models.

- o Crown fire spread
- o Transition to crown fire
- o Burnout of fuel behind the fire front
- o Smoke production
- o Containment with additional suppression options
- o Soil heating
- o Safety zone size
- o Fire characteristics chart graphics

Program System Requirements

The following are the minimum system requirements to install and use *BehavePlus*:

- o Operating System: Windows 95/98 or NT/2000
- o RAM: minimum of 32Mb
- o Screen Resolution: minimum of 800 x 600 pixels
- o Free hard disk space: 10 Mb

Program Installation Instructions

To download latest version of BehavePlus:

1. Open your browser to www.fire.org.
2. Go to the BehavePlus page.
3. Go to the Download page.
4. Click on the version of BehavePlus you wish to download.
5. Save the download file to disk (probably at C:\WINDOWS\TEMP) when asked by the dialog.

BehavePlus uses the industry standard InstallShield software, so installation should be a familiar process. There are two ways to run the install file you downloaded.

Either

1. Press Start->Run.
2. Enter the name of the downloaded BehavePlus file and press "Ok".

Or

1. Press Start->Programs->Windows Explorer.
2. Locate the downloaded file and double click on it.

The InstallShield wizard will begin. It is recommend that you accept all the defaults by pressing "Ok" on all the wizard pages. When the wizard finishes, you will find BehavePlus in your Start->Programs menu.

Key Definitions and Concepts

Icon Summary

| | | | |
|---|----------------------|---|--------------------|
|  | Open a New Worksheet |  | Open a Saved Run |
|  | Save This Run |  | Print This Run |
|  | Module Selection |  | Calculate This Run |
|  | Program Help | | |
|  | Go to First Page |  | Go to Last Page |
|  | Go to Previous Page |  | Go to Next Page |

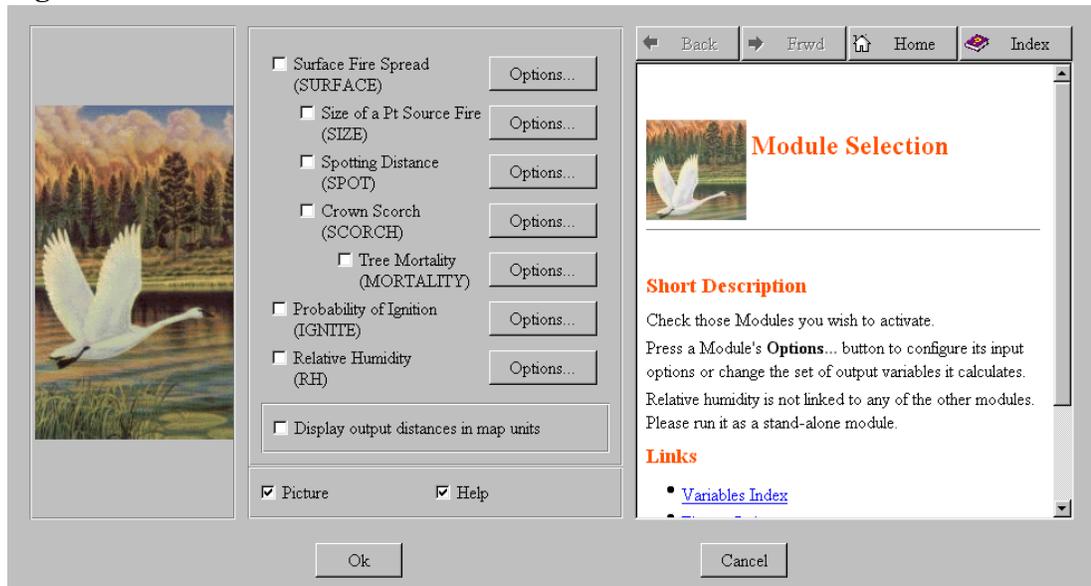
Abbreviations and Terms

The following abbreviations will be used in this document.

- **BEHAVE** refers to the old BEHAVE Fire Behavior Prediction and Fuel Modeling System
- **BehavePlus** refer to the new *BehavePlus* Fire Modeling System.
- A **Run** is a worksheet with inputs entered

- The **Module Selection Screen** is shown in Figure 4 and is the screen used to select which modules are to be included in a run. The configuration of module inputs and outputs is made using the Options button in this screen.

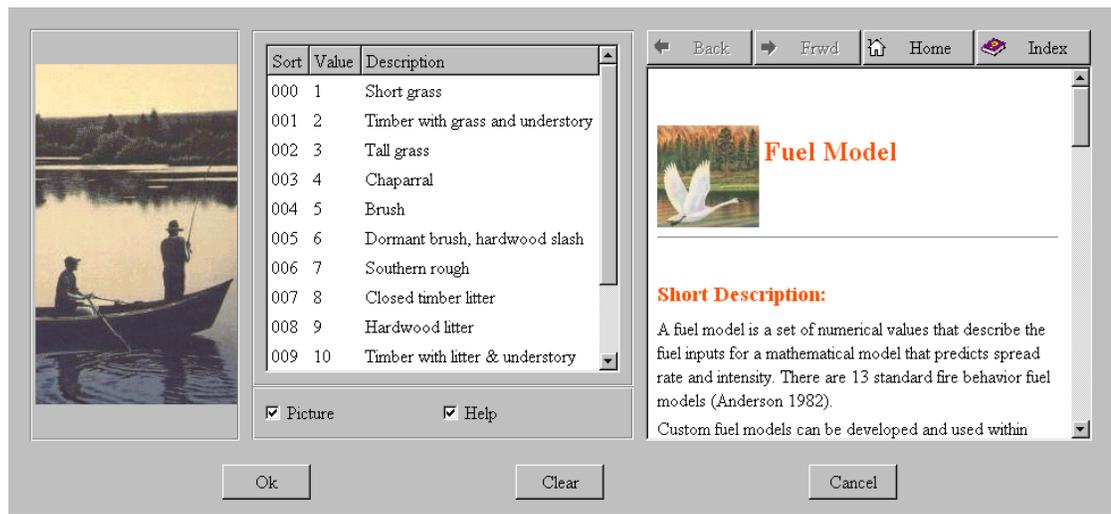
Figure 4



- The **Guide Button** is to the right of each input variable on the worksheet. 

Clicking on the Guide Button will allow for display of the **Input Guide Screen**. An example of this screen for the SURFACE module input Fuel Model is shown in Figure 5. Via this screen, the user can see a description of the variable and get assistance in the selection of values for the variable. The **Browser Pane** on the right side of the screen provides a description of what the variable is or what it represents.

Figure 5



What is a Worksheet?

A *Worksheet* within *BehavePlus* is created electronically to guide input of values for variables to the fire behavior prediction process. An example of a Worksheet is shown in Figure 6.

The worksheet is created and displayed based on the selected modules, input options, and output variables.

A user can create a save custom worksheets for later use.

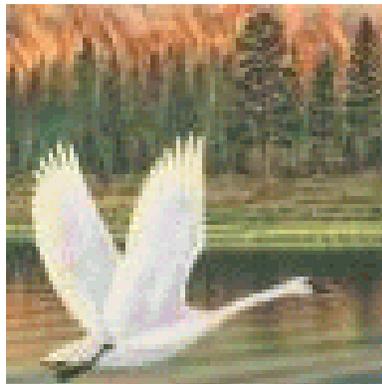
Figure 6

| | |
|--|---------------------------|
| MODULES: Surface | |
| Description | <input type="text"/> |
| FUEL/VEGETATION | |
| Fuel Model | <input type="text"/> |
| FUEL MOISTURE | |
| 1-h Moisture | % <input type="text"/> |
| 10-h Moisture | % <input type="text"/> |
| 100-h Moisture | % <input type="text"/> |
| Live Herbaceous Moisture | % <input type="text"/> |
| Live Woody Moisture | % <input type="text"/> |
| WEATHER | |
| Midflame Wind Speed | mi/h <input type="text"/> |
| Direction of Wind Vector (from upslope) | deg <input type="text"/> |
| TERRAIN | |
| Slope Steepness | % <input type="text"/> |
| OUTPUT VARIABLES | |
| Rate of Spread (maximum) (ch/h) | |
| Heat per Unit Area (Btu/ft ²) | |
| Fireline Intensity (Btu/ft/s) | |
| Flame Length (ft) | |
| Maximum Wind Exceeded? | |
| Direction of Maximum Spread (from upslope) (deg) | |

What is a Run?

A *Run* refers to the collection of inputs, a filled-in worksheet. As used in *BehavePlus*, “run” is a noun. The inputs are organized within *BehavePlus* on a worksheet.

Runs can be saved for later use. A saved Run includes input and output preferences for selected modules as well as the inputs values to these modules.



What are Modules?

The term *Module* is used in *BehavePlus* as it was in BEHAVE. The term Module refers to all the inputs, outputs and processes used to calculate a specific one or a series of fire behavior values. There are seven Modules currently within *BehavePlus*. Below is a listing of them and a short description of the primary module outputs.

- o Surface Fire Spread (SURFACE)
The SURFACE module is used to calculate surface fire behavior parameters including fire spread rate, flame length, and intensity.
- o Size of a Pt Source Fire (SIZE)
The SIZE module is used to calculate the area and perimeter of a fire that starts from a point source.
- o Spotting Distance (SPOT)
The SPOT module is used to calculate the maximum spotting distance for fires where the originating fire brand is produced from torching trees, a burning pile, or a wind-driven surface fire.
- o Crown Scorch (SCORCH)
The SCORCH module is used to calculate the height above the ground that the temperature in the convection column reaches the lethal temperature to kill live crown foliage.
- o Tree Mortality (MORTALITY)
The MORTALITY module is used to calculate probability that a tree will die from a surface fire.
- o Probability of Ignition (IGNITE)
The IGNITE module is used to calculate the probability that a firebrand will cause an ignition.
- o Relative Humidity (RH)
The RH module is used to calculate the relative humidity and/or dew point for a parcel of air.

What are Input Options?

For the SURFACE, SCORCH, MORTALITY and RH Modules, the inputs can be entered in more than one way. As an example, for the SURFACE module, fuel can be input either as a fuel model or by input of all of the parameters that define a fuel model. By selecting the input options, *BehavePlus* develops and displays a Worksheet with the required input.

The user can make this selection within *BehavePlus* from the Configure, Module Selection menu item.

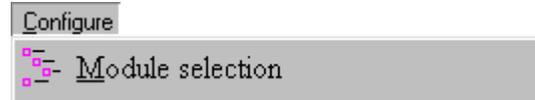


Figure 7

Follow this by clicking on the Options button (Figure 7) to select the format for inputs and desired outputs.

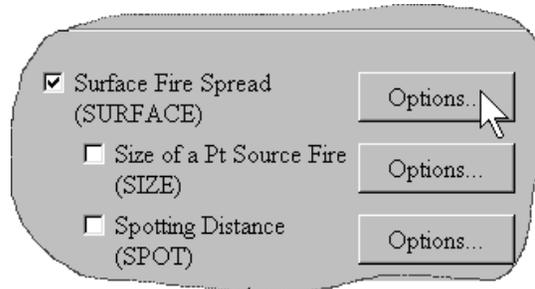


Figure 8

The *Input/Output Options Screen* for the SURFACE module is shown in Figure 8.

Fuel can be entered as one of the following:

- o fuel models
- o fuel parameters.

Fuel moisture can be entered as one of the following:

- o individual size classes
- o dead and live categories
- o moisture scenario.

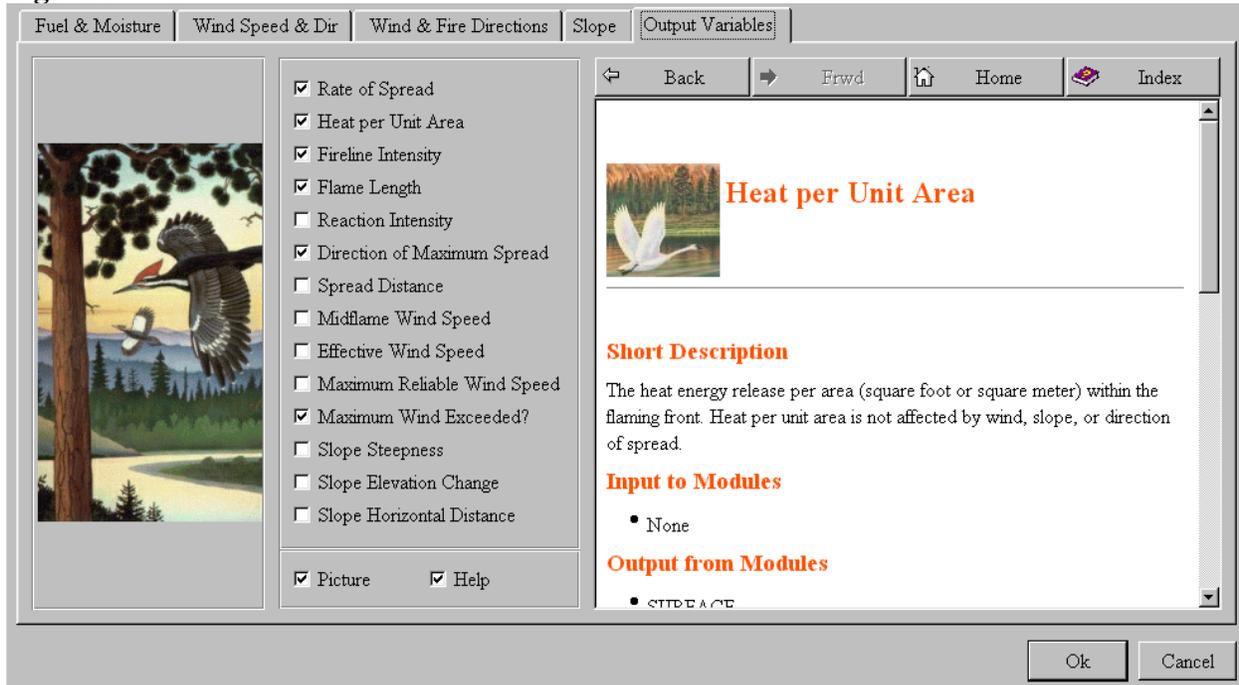


Selecting the other tabs allows for selection of other input and output options.

What are Output Options?

Except for the SCORCH and IGNITE modules, more than one output parameter is available from the Module's calculations. *BehavePlus* allows the user to specify which outputs will be displayed. The user can make this selection within *BehavePlus* from the Configure, Module Selection menu item, followed by a click on the Options button as with configuring inputs. Note the Output Variables Tab in Figure 8. Clicking on this tab will provide access to the selection of the desired output variables (Figure 9).

Figure 9



What is Browser Pane Help?

The Browser Pane appears on ALL dialog screens except file selection screens and error/warning, message screens. It provides a description of the variables. For Input variables, the description is displayed when the associated Guide Button is clicked. Scrolling within the Browser Pane will allow for viewing of all. For Output variables, placing the cursor over the output name will allow for viewing of descriptions (Figure 9).

In the Browser Pane, scrolling leads to links to description of related variables. The complete list of variables, figures, and tables is also available.

What is a Workspace?

A workspace is a folder that has additional folders for containing screen captures, custom fuel models, moisture scenarios, saved runs, custom unit sets and saved worksheets. Within *BehavePlus*, installation creates a DefaultDataFolder as the default workspace for these folders and files. The user may wish to create separate unique workspaces for individual users of a single computer system or for individual projects.

Map Applications

BehavePlus will display distance output parameters in map distances so that the user can easily draw output parameter distances on a map. This option is selected using the Configure, Module Selection menu item. A check box to specify Display output distances in map units is located on the Module Selection screen (Figure 10). The user will be prompted for map Representative Fraction as an input on the Worksheet.

Fuel Modeling

The FUEL subsystem of BEHAVE consists of the NEWMDL and TSTMDL programs (Burgan and Rothermel 1984). The NEWMDL program facilitates the development of input parameters for development of custom fuel models. *BehavePlus* does not include this capability, so a person may want to continue to use the NEWMDL program. *BehavePlus* does allow for the user to define a custom fuel model via direct input of the fuel characteristics. Once created, the user can save the custom fuel model with a unique number and name for use in future modeling. *BehavePlus* allows the user to display graphs of module input parameters with any of the output values as was possible via the TSTMDL program.

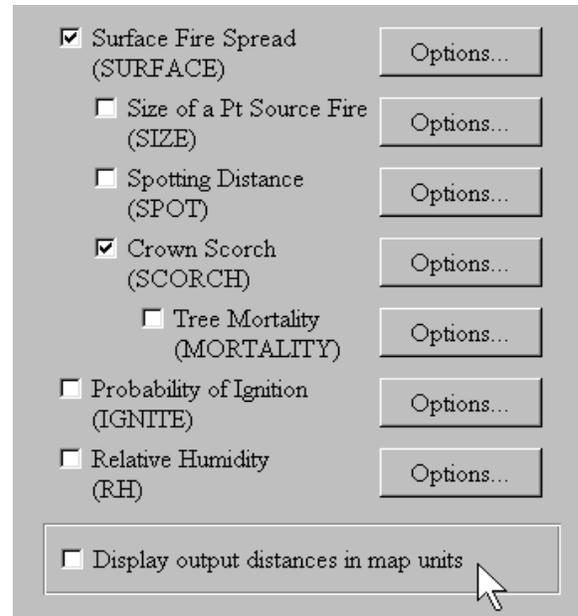
Moisture Scenarios Sets

BehavePlus allows the user to save a set of 1-hr, 10-hr, 100-hr, herbaceous and woody fuel moistures values as a Moisture Scenario Set. The user can Configure Inputs to the SURFACE module so that the fuel moisture values are input via a Moisture Scenario. For example, the user may wish to save the weather conditions that represent the 90th percentile conditions. The fuel moisture values termed low, moderate, and extreme in TSTMDL are provided with the *BehavePlus* program.

Using Custom Fuel Models and Moisture Scenarios Sets

The input options for fuel and fuel moisture entry to the SURFACE module is specified using the Configure, Module Selection menu item and the SURFACE - Options button. Using the Fuel & Moisture Tab, the fuel component can be entered as either a fuel model or as fuel parameters. By selecting the fuel parameters option, the user can create a custom fuel model. A previously saved custom fuel model can be retrieved under the fuel model input option. To create a new custom fuel model, the user can start with one of the standard fuel models (1-13) or a previously built custom fuel model. This is done by selecting the Initialize with A Fuel Model button on the worksheet. Care should be used to verify predicted fire behavior outputs using custom fuel models before these predications are used to support decision making. Fuel modeling is an “art” (Burgan 1987). Also using the Fuel & Moisture Tab, the fuel moisture values can be entered as either individual size classes, by dead and live category, or by Moisture Scenario.

Figure 10



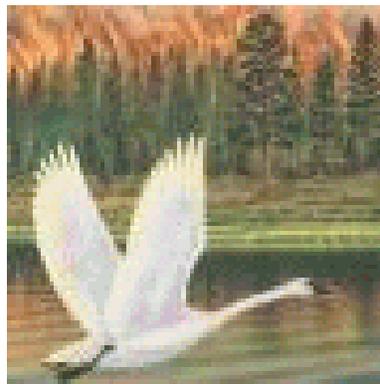
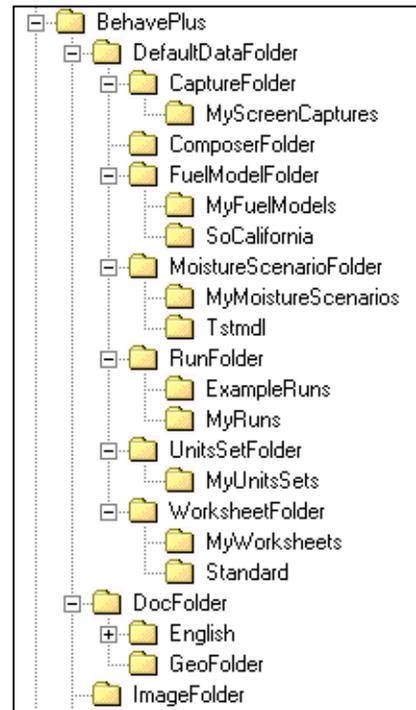
File Management

A standard folder hierarchy and naming convention is created when *BehavePlus* is installed. This allows for the storing of custom files created by the user which facilitates retrieval by the user and sharing by the user with others. The default file structure is in Figure 11. Note the existence of the folders: MyScreenCaptures, MyFuelModels, MyMoistureScenarios, MyRuns, MyUnitSets, and MyWorksheets. When saving a screen capture, a custom fuel model, a moisture scenario, a run, a unit set, or a worksheet, the respective default folder can be used. Alternatively new folders can be built to store related files.

Units

BehavePlus can accept input parameters and produce output values in either English or Metric units. The user can select the preferred choice of units by using the Configure, Units menu item. The user can also develop and use a custom units set.

Figure 11



Overview of Worksheets

Standard Worksheets

BehavePlus is installed with several Standard Worksheets to facilitate the use of common calculations provided by the program. These include:

- **The Blank Worksheet (Blank.bpw)**

When this worksheet is loaded, only the Description box and the Notes box are displayed. As a minimum, all worksheets contain the Description input block. Loading the Blank Worksheet resets all of the defaults. Once this worksheet is activated, the user should go to the menu Configure, Module Selection to select the modules to be included in the run. This is the way that simple module runs are done. The worksheets described below were developed because of changes to the default input options and output variables or because they are common linked runs.

- **The Surface Basic Fire Spread Worksheet (SurfaceBasic.bpw)**

This is the usual way of doing surface fire spread prediction. Calculations are made for the direction of maximum spread.

Inputs

Fuel/Vegetation

Fuels - Entered as a standard fuel model or a previously saved custom fuel model

Fuel Moisture

Moisture Content - Entered individually by fuel size class

Weather

Wind speed-Entered as the midflame wind speed (degrees clockwise from upslope.)

Wind Direction - Entered as degrees measured clockwise from upslope (the method used in the old BEHAVE).

Terrain

Slope Steepness - Entered as percent slope

Outputs

Rate of Spread (maximum)

Heat per Unit Area

Fireline Intensity

Flame Length

Maximum Wind Exceeded?

Direction of maximum Spread (from upslope)

■ **The Surface Basic “From” Fire Spread Worksheet (SurfaceBasicFrom.bpw)**

Calculations are made for the direction of maximum spread. The difference from the SurfaceBasic Worksheet is the wind direction is specified in degrees clockwise “from North.”

Inputs

Fuel/Vegetation

Fuels - Entered as a standard fuel model or a previously saved custom fuel model

Fuel Moisture

Moisture Content - Entered individually by fuel size class

Weather

Wind speed- Entered as the midflame wind speed (degrees clockwise “from North.”)

Wind Direction - Entered as degrees measured clockwise from North.

Terrain

Slope Steepness - Entered as percent slope

Aspect - Entered as degrees measured clockwise from North.

Outputs

Rate of Spread (maximum)

Heat per Unit Area

Fireline Intensity

Flame Length

Maximum Wind Exceeded?

Direction of maximum Spread (from upslope)

■ **The Surface Simple Fire Spread Worksheet (SurfaceSimple.bpw)**

This worksheet provides simplified input to the SURFACE module. The same dead fuel moisture is used all dead fuel size classes, and the same live fuel moisture is used for all live fuel categories. The wind is assumed to be blowing up slope. Calculations are done for the direction of maximum spread (which is up slope with the wind).

Inputs

Fuel/Vegetation

Fuels - Entered as a standard fuel model or a previously saved custom fuel model

Fuel Moisture

Moisture Content - Entered as the Dead Fuel Moisture and as the Live Fuel Moisture.

Weather

Wind - Entered as the midflame wind speed

Wind Direction - Not entered, assumed to be blowing up slope

Terrain

Slope Steepness - Entered as percent slope

Outputs

Rate of Spread (maximum)
Heat per Unit Area
Fireline Intensity
Flame Length
Maximum Wind Exceeded?

■ **The Surface-Map Worksheet (SurfaceMap.bpw)**

This worksheet is set up the way that a Fire Behavior Analyst might want it for field application. The heading includes fire projection documentation and tabs are added to the worksheet. The option “Display outputs in map units” has been checked on the Module Selection Screen. Spread distance is selected as an output value. Slope steepness is calculated from map measurements. Wind direction is the direction from which the wind is blowing and is specified with respect to North. Calculations are done for the direction of maximum spread.

Inputs

Fuel/Vegetation

Fuels - Entered as a standard fuel model or a previously saved custom fuel model

Fuel Moisture

Moisture Content - Entered individually by fuel size class

Weather

Wind - Entered as the midflame wind speed
Wind Direction – Direction is from the North.

Terrain

Aspect from the North

Time

Elapsed Time

Map

Map Representative Fraction (1:x)
Contour Interval
Map Distance
Number of Contour Intervals

Outputs

Rate of Spread
Heat per Unit Area
Fireline Intensity
Flame Length
Maximum Wind Exceeded?
Direction of Maximum Spread (from north)
Spread Distance
Spread Map Distance
Slope Steepness

■ **The Surface-Scorch-Mortality Worksheet (SurfaceScorchMortality.bpw)**

This worksheet provides for the inputs for linking of the SURFACE-SCORCH-MORTALITY modules. Calculations are made for a specified spread direction.

Inputs

Fuel/Vegetation

Fuels - Entered as a standard fuel model or a previously saved custom fuel model
Tree Height
Crown Ratio
Mortality Trees Species
Bark Thickness

Fuel Moisture

Moisture Content - Entered as a value individually by fuel size class

Weather

Wind - Entered as the midflame wind speed
Wind Direction – Direction of the wind vector, the direction the wind is pushing the fire, entered as degrees clockwise from upslope.
Air Temperature – Entered in degrees

Terrain

Slope Steepness - Entered as percent slope

Fire

Spread direction – Direction from upslope

Outputs

Rate of Spread
Heat per Unit Area
Fireline Intensity
Flame Length
Maximum Wind Exceeded?
Scorch Height
Probability of Mortality

■ **The Surface-Spot-Ignite Worksheet (SurfaceSpotIgnite.bpw)**

This worksheet provides for the inputs for linking of the SURFACE-SPOT-IGNITE modules for spotting distance from a wind-driven surface fire. Wind direction is upslope. Calculations are made for the direction of maximum spread.

Inputs

Fuel/Vegetation

Fuels - Entered as a standard fuel model or a previously saved custom fuel model
Mean Cover Height

Fuel Moisture

Moisture Content - Entered as a value individually by fuel size class

Weather

Wind - Entered as the 20-ft wind speed
Wind Adjustment Factor
Air Temperature
Fuel Shading from the Sun

Terrain

Slope Steepness - Entered as percent slope
Ridge-to-Valley Elevation Difference
Ridge-to-Valley Horizontal Difference
Spotting Source Location

Outputs

Rate of Spread
Flame Length
Midflame Wind Speed
Maximum Wind Exceeded?
Probability of Ignition from a Firebrand
Spotting Distance from a Surface Fire

The Slope-Map Worksheet (SlopeMap.bpw)

This worksheet provides the inputs for calculation of slope steepness from map measurements.

Inputs

Map

Map Representative Fraction (1:x)
Contour Interval
Map Distance
Number of Contour Intervals

Outputs

Slope Elevation Change
Slope Distance
Slope Percent

■ **The Fuel Modeling Worksheet (FuelModeling.bpw)**

This worksheet provides for input of fuels into the SURFACE module as fuel parameters. Fuel modeling is the process of adjusting fuel parameters, testing under a range of environmental conditions, and comparing model results with known fire behavior. The final fuel parameters are saved as a custom fuel model for further use. This worksheet sets calculations to be done for the direction of maximum spread and the wind is assumed to be blowing upslope. Fuel moisture is entered by individual size classes. The user might want to change moisture input to moisture scenarios so that the TSTMDL fuel moisture levels can be used to test the new fuel model.

Inputs

Fuel/Vegetation

Fuels - Entered as a individual fuel parameters values (can be initialized using an existing fuel model)

Fuel Moisture

Moisture Content - Entered for individual size classes

Weather

Wind - Entered as the midflame wind speed
Wind Direction – Not entered, assumed to be blowing upslope

Terrain

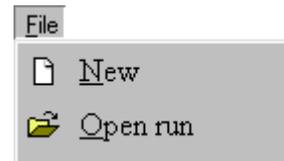
Slope Steepness - Entered as percent slope

Outputs

Rate of Spread (maximum)
Flame Length

Loading a Worksheet

The File New menu allows the user to select and load a new worksheet. File, Open run allows the user to select and load a run that has been previously saved. For specific information on either of these processes, refer to the Icon/Menu Overview section.



Worksheet Input

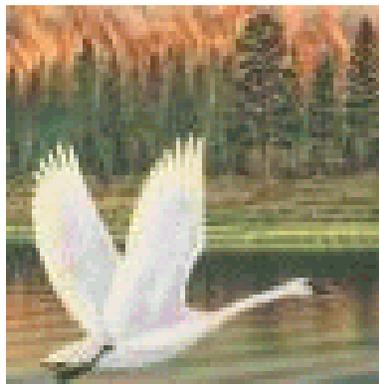
Several methods can be used to input values into a worksheet:

- Direct entry of a value into an input field or
- Assisted entry using an aid available by clicking on the Guide Button located to the right of each input variable on the worksheet.



Input values are one of the following three types:

- Text form, as in the project description cell and the fuel model name input boxes;
- Continuous variable for which any value within the specified range is valid, such as wind speed or fuel moisture;
- Discrete variable for which only specific values are allowed, such as fuel model or tree species.



Direct entry:

- One or several values can be typed directly into the input field. Multiple input values are separated by commas or spaces. A Tab or Enter moves the cursor to the next entry field.

Entry aids via the Guide Button:

- For continuous variables, a range of values is entered via start value, ending or stop value, and step value. It is valid to enter only start value, or start and stop values. The valid range of values for the input is displayed in this window. The example at the right shows a range for fuel moisture inputs of 3 to 12 at increments of 3. The Worksheet will show fuel moisture values of 3, 6, 9 and 12.

(1 - 60 %)

From

Thru

Step

- For discrete variables, selection is made from the list of valid inputs. The screen at the right shows a list of fuel models of which fuel model 10 has been selected. Multiple fuel models can be selected by performing a single click of each one desired.

| Num | Code | Description |
|-----|------|----------------------------------|
| 001 | 1 | Short grass |
| 002 | 2 | Timber with grass and understory |
| 003 | 3 | Tall grass |
| 004 | 4 | Chaparral |
| 005 | 5 | Brush |
| 006 | 6 | Dormant brush, hardwood slash |
| 007 | 7 | Southern rough |
| 008 | 8 | Closed timber litter |
| 009 | 9 | Hardwood litter |
| 010 | 10 | Timber with litter & understory |

- For selected variables, the Choices button offers additional entry aids. A selection can be made from a list of input values.

A validity check is done as soon as the value is entered to ensure that the entry is in an acceptable form and within the valid input range. A listing of the valid input ranges and codes is given in Appendix B. As soon as an input value is changed, the output pages are cleared. If a range of values is entered for more than two values, an error message is displayed when a Calculate is requested.

The Description Cell

The first cell on the worksheet is called Description. The user should enter a brief phrase documenting the run. The description is also used to identify the Run file when it is saved and opened. The run description appears at the top of all output pages and is stored with the Run file.

| | | |
|-------------|---|----------------------|
| Description | → | Users' Guide Example |
|-------------|---|----------------------|

Additional worksheet documentation may be entered by selecting Configure-> Appearance-> Worksheet Tab and checking the Fire project documentation and/or Training documentation check boxes. The Worksheet appearance for Fire project documentation (Figure 12) and/or Training documentation (Figure 13) are shown below.

Figure 12

| | | |
|-------------------------------|---|----------------------|
| Description | → | Users' Guide Example |
| Fire Name | → | |
| Fire Date & Projection Period | → | |
| Fire Analyst | → | |

Figure 13

| | | |
|-----------------------|---|----------------------|
| Description | → | Users' Guide Example |
| Training Course | → | |
| Training Exercise | → | |
| Trainee Name and Date | → | |

Input Of a Single Value via Direct Entry

To enter a single input value in a cell, click in the cell to place the cursor in the cell. The user can then enter the value desired. The user can move to the cell that follows by using the Tab key to move the cursor to that cell. If entries have been made by other methods, these entries can be changed using the direct entry method.

Entry of Multiple Input Values

Direct Entry

The user can enter multiple values for an input variable. The format is to enter each value followed by a comma or a space. For example, the entry of 1-h fuel moisture values of 3, 6, 9 and 12 could be in either of the formats that follows:

| | |
|-------------|----------|
| 3, 6, 9, 12 | 3 6 9 12 |
|-------------|----------|

Entries can be in any order. The output tables will display the outputs values in the order in which the multiple input values are entered.

Entry via a List of Valid Inputs for Discrete Variables

For discrete input variables, such as fuel model, a list of acceptable input values is displayed by clicking on the Guide Button. The user can select a single input by double clicking on the desired value or by highlighting the value with a single click and then clicking on the OK button. The user can also select multiple input values by selecting each with a single click followed by a clicking on the OK button. In the screen at the right, fuel models 2, 5, 8 and 10 have been selected.

| Num | Code | Description |
|-----|------|----------------------------------|
| 001 | 1 | Short grass |
| 002 | 2 | Timber with grass and understory |
| 003 | 3 | Tall grass |
| 004 | 4 | Chaparral |
| 005 | 5 | Brush |
| 006 | 6 | Dormant brush, hardwood slash |
| 007 | 7 | Southern rough |
| 008 | 8 | Closed timber litter |
| 009 | 9 | Hardwood litter |
| 010 | 10 | Timber with litter & understory |

Entry Using a Range of Values

For continuous input variables, clicking on the Guide Button reveals the Input Guide Screen where From, Thru and Step cells are displayed. Enter the smallest value desired in the From cell, enter the largest value desired in the Thru cell and enter the number of increments desired between the two values. For example, the input values of 3, 6, 9 and 12 would result from entering a 3 in the From cell, entering a 12 in the Thru cell and entering a 3 in the Step cell. If values are entered in the From cell and the Thru cell only with no entry in the Step cell, the program will enter these two values in the input cell on the worksheet. Similarly a single value will be entered in the worksheet if an entry is made only to the From cell.

(1 - 60 %)

From

Thru

Step

Entry via the Choices Option

For some input variables, clicking on the Guide Button reveals the Input Guide Screen where a Choices button is available. By clicking on the Choices button, a window is displayed with a list of input choices from which the user can select the desired input values.

For example, if the Choices button is clicked from the Input Guide window for live herbaceous fuel moisture, the following options are offered:

Figure 14

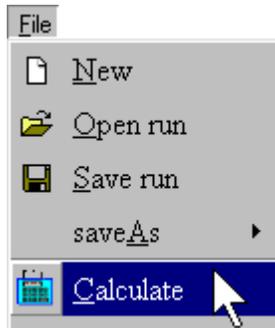
| % | Typical Season & Condition |
|-----|---|
| 50 | Entering dormancy, coloration started, some leaves may have dropped |
| 100 | Mature foliage, new growth complete and comparable to older perennial foliage |
| 200 | Maturing foliage, still developing, with full turgor |
| 300 | Fresh foliage, annuals developing, early in growing cycle |

The user can select the condition “100 Mature foliage, new growth complete and comparable to older perennial foliage” by clicking on this option and then by clicking on the OK button. The user can select multiple input values by selecting each choice with a single click followed by a clicking on the OK button.

Calculating Outputs

Once a worksheet for a run has all required entries defined, module output values can be calculated. This can be done using the File, Calculate menu or by clicking on the Calculate Icon on the *BehavePlus* Taskbar.

- By clicking on the Calculate Icon on the *BehavePlus* Taskbar or 
- By the File, Calculate menu.



BehavePlus can produce outputs in a list form, in a tabular form, or in a graphical form if multiple input values are used or one or two input variables.. Clicking in the box to the left of the Display table results will enable tabular output format. Clicking in the box to the left of the Display graph results will enable graphic output format.

- Display table results
- Display graph results

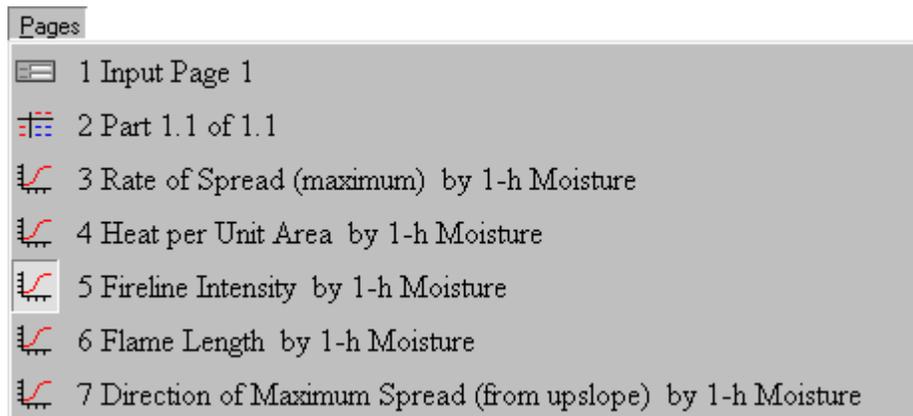
Viewing Output Pages

When the calculation is complete, the first page of output is displayed. To move to the next page, do one of the following:

- Click on the Down Arrow icon located on the *BehavePlus* Task Bar
- Hold the Ctrl key down while pressing the Up Arrow or Down Arrow

The Double Up Arrow icon displays the first page, the worksheet. The Double Down Arrow icon displays the last page of output.

Selecting the menu item Pages reveals a list of all of the currently active input and output pages. The user can select to view a specific page by selecting it from the pull down menu.



Output List

If each worksheet input variable is assigned only one value, then the output from *BehavePlus* will be in List form. For example, if singular inputs are made for all input variables to the SURFACE module, the list of output values similar to those shown in Figure 15 will be displayed.

Figure 15

| Users Guide Example | |
|--|--------------------------|
| Rate of Spread (maximum) | 9.7 ch/h |
| Heat per Unit Area | 1341 Btu/ft ² |
| Fireline Intensity | 239 Btu/ft/s |
| Flame Length | 5.6 ft |
| Maximum Wind Exceeded? | No |
| Direction of Maximum Spread (from upslope) | 79 deg |

Tabular and Graphical Outputs

If one or two input variables are assigned multiple values, then the output from *BehavePlus* can be displayed in Tabular or Graphic form. At most two input variables can have multiple input values.

Output If One Input Variable Has Multiple Input Values

If one input variable has multiple values, results can be displayed in tabular or graphical form. Graphs are continuous curves for continuous input variables and as bar charts for discrete input variables.

Output If One Continuous Input Variable Has Multiple Input Values

Note the inputs to SURFACE in Figure 16 where the continuous variable 1-h fuel moisture has been assigned multiple inputs of 3, 6, 9 and 12%.

Calculating outputs will result in the below.

Display table results

Display graph results

Select both table and graph results.

Figure 16

| MODULES: Surface | |
|---|----------------------|
| Description | Users' Guide Example |
| FUEL/VEGETATION | |
| Fuel Model | 10 |
| FUEL MOISTURE | |
| 1-h Moisture | % 3, 6, 9, 12 |
| 10-h Moisture | % 6 |
| 100-h Moisture | % 7 |
| Live Herbaceous Moisture | % |
| Live Woody Moisture | % 90 |
| WEATHER | |
| Midflame Wind Speed | mi/h 5 |
| Direction of Wind Vector (from upslope) | deg 90 |
| TERRAIN | |
| Slope Steepness | % 32 |

If both tabular and graphic output is selected for display, the tabular output will be displayed first (Figure 17).

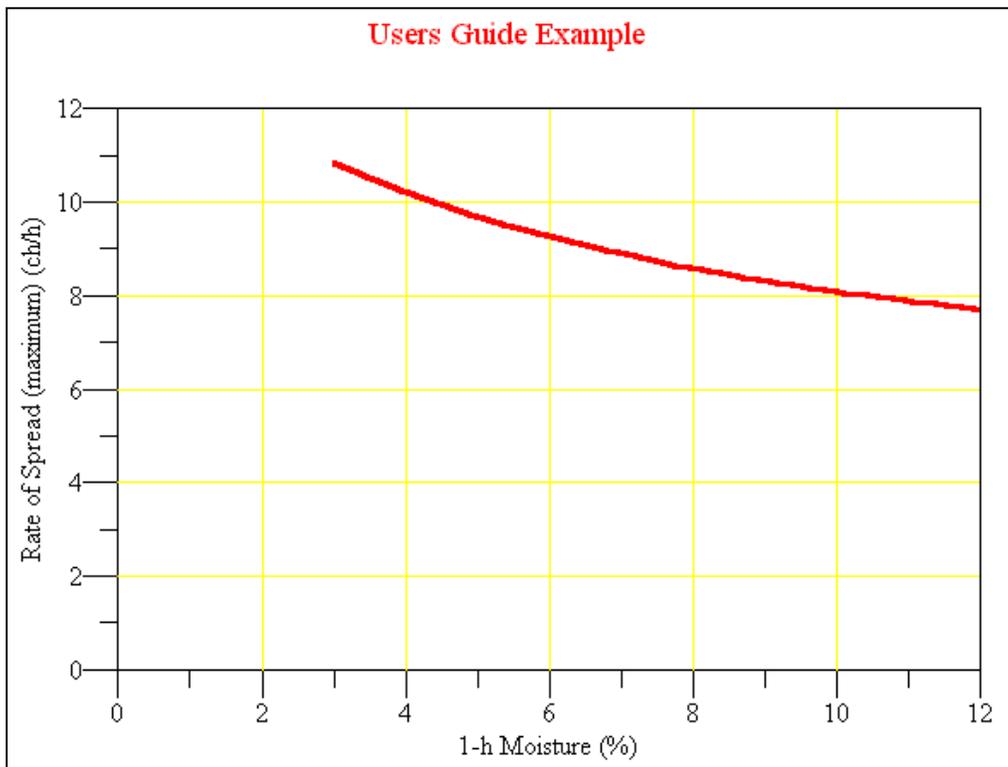
Figure 17

Users Guide Example

| 1-h Moisture % | ROS (max) ch/h | Heat per Unit Area Btu/ft ² | Fireline Intensity Btu/ft/s | Flame Length ft | Max Wind Exceeded | Direction Max ROS deg |
|----------------|----------------|--|-----------------------------|-----------------|-------------------|-----------------------|
| 3 | 10.9 | 1462 | 291 | 6.1 | No | 79 |
| 6 | 9.3 | 1296 | 220 | 5.4 | No | 79 |
| 9 | 8.3 | 1205 | 184 | 5.0 | No | 79 |
| 12 | 7.7 | 1155 | 163 | 4.7 | No | 79 |

Graphic output is produced for each selected output variable. Shown in Figure 18 is the graphic output for rate of spread.

Figure 18



Output If One Discrete Input Variable Has Multiple Input Values

Note the inputs to SURFACE as shown in Figure 19 where the discrete variable fuel model has been assigned multiple input values of 2, 5, 8 and 10.

Calculating outputs will result in the screen below.

Display table results

Display graph results

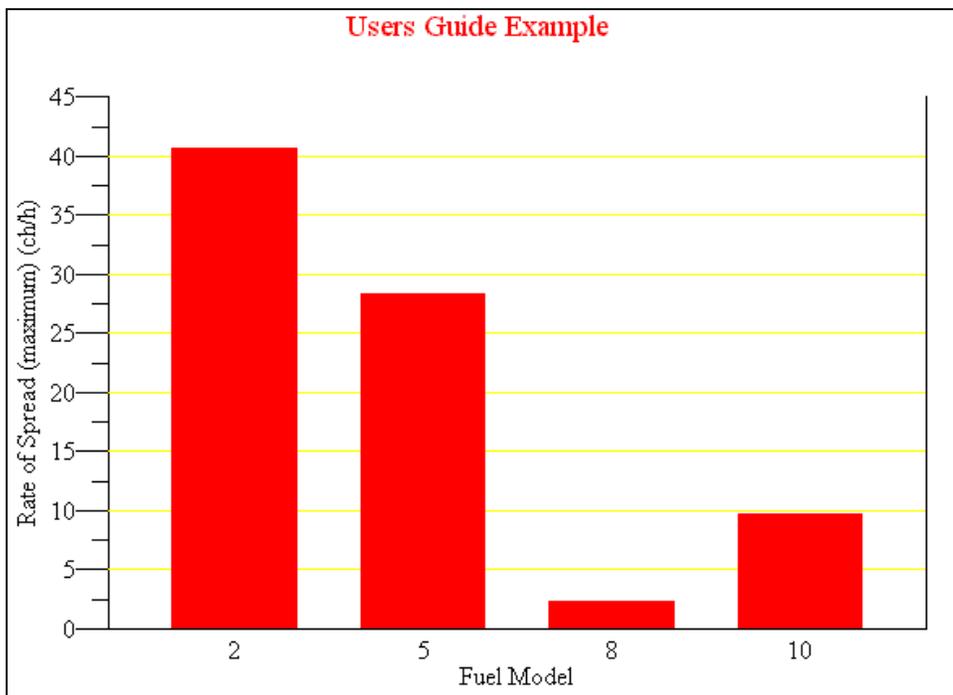
Figure 19

| MODULES: Surface | |
|---|----------------------|
| Description | Users' Guide Example |
| FUEL/VEGETATION | |
| Fuel Model | 2, 5, 8, 10 |
| FUEL MOISTURE | |
| 1-h Moisture | 5 |
| 10-h Moisture | 6 |
| 100-h Moisture | 7 |
| Live Herbaceous Moisture | 78 |
| Live Woody Moisture | 90 |
| WEATHER | |
| Midflame Wind Speed | 5 |
| Direction of Wind Vector (from upslope) | 90 |
| TERRAIN | |
| Slope Steepness | 32 |

Select graph results.

Note that the graphic output in Figure 20 is in the form of bar graphs.

Figure 20



Output If Two Input Variables Have Multiple Input Values

If two input variables have multiple values, results can be displayed in tabular or graphical form. Graphs are displayed with continuous curves for continuous input variables and as bar charts for discrete input variables.

Output With Two Continuous Input Variables Having Multiple Input Values

Note the inputs to SURFACE as shown in Figure 21 where the continuous input variable 1-h fuel moisture has been assigned multiple input values of 3, 6, 9 and 12%, and the continuous input variable midflame wind speed has multiple inputs of 2, 4, 6 and 8 mi/h. Calculating outputs results in the screen below.

Display table results
 Select the Table Row Variable

1-h Moisture
 Midflame Wind Speed

Display graph results
 Select the X-Axis Variable

1-h Moisture
 Midflame Wind Speed

Figure 21

MODULES: Surface
 Description → Users' Guide Example

FUEL/VEGETATION
 Fuel Model → 10

FUEL MOISTURE
 1-h Moisture % → 3, 6, 9, 12
 10-h Moisture % → 6
 100-h Moisture % → 7
 Live Herbaceous Moisture % →
 Live Woody Moisture % → 90

WEATHER
 Midflame Wind Speed mi/h → 2, 4, 6, 8
 Direction of Wind Vector (from upslope) deg → 90

TERRAIN
 Slope Steepness % → 32

Figure 22

Select both table and graph results. Since two input variables have been selected, the user can select which input variable should be the row variable for the tabular output and which input variable should be the x-axis variable for graphic output.

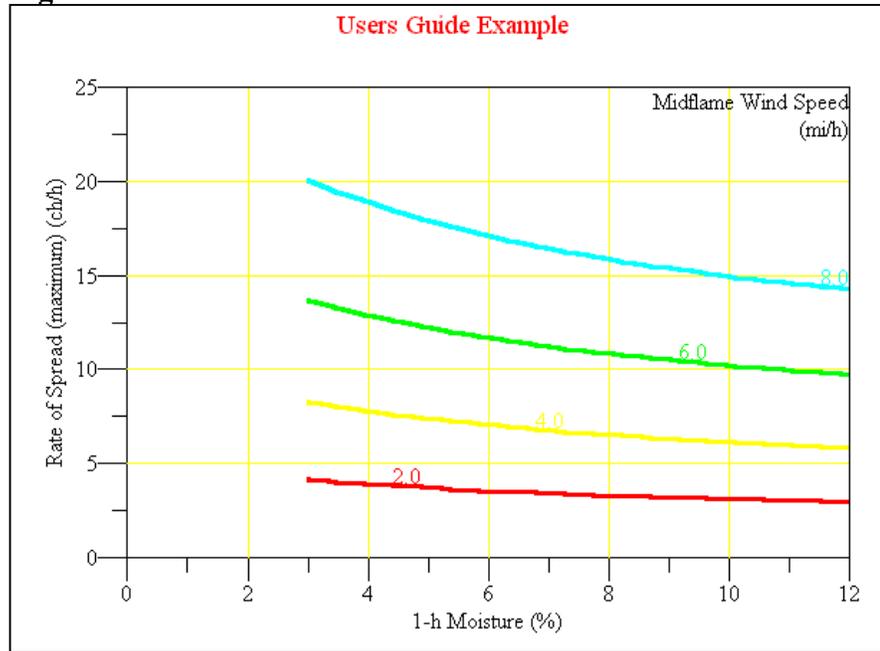
Figure 22 shows the tabular output for rate of spread. Note the rows are fuel moisture and the columns are midflame wind speed.

Users Guide Example
Rate of Spread (maximum) (ch/h)

| 1-h Moisture % | Midflame Wind Speed mi/h | | | |
|----------------|--------------------------|-----|------|------|
| | 2.0 | 4.0 | 6.0 | 8.0 |
| 3 | 4.2 | 8.3 | 13.7 | 20.1 |
| 6 | 3.6 | 7.1 | 11.7 | 17.1 |
| 9 | 3.2 | 6.3 | 10.5 | 15.4 |
| 12 | 3.0 | 5.9 | 9.7 | 14.3 |

Figure 23

The graph for rate of spread is in Figure 23. Note that the 1-h fuel moisture is on the x-axis, the rate of spread on the y-axis and the individual curves for each midflame wind speed value.



Output With One Continuous and One Discrete Input Variables Having Multiple Input Values

Note the inputs to SURFACE as shown in Figure 24 where the continuous variable 1-h fuel moisture has multiple values of 3, 6, 9 and 12% and that the discrete variable fuel model has multiple input values of 2, 5, 8 and 10.

Figure 24

Calculating outputs will result in the screen below.

Display table results

Select the Table Row Variable

Fuel Model

1-h Moisture

Display graph results

Select both table and graph results.

MODULES: Surface

Description Users' Guide Example

FUEL/VEGETATION

Fuel Model 2, 5, 8, 10

FUEL MOISTURE

1-h Moisture % 3, 6, 9, 12

10-h Moisture % 6

100-h Moisture % 7

Live Herbaceous Moisture % 78

Live Woody Moisture % 90

WEATHER

Midflame Wind Speed mi/h 5

Direction of Wind Vector (from upslope) deg 90

TERRAIN

Slope Steepness % 32

Since two input variables have been selected, the user can select which input variable should be the row variable for the tabular output and which input variable should be the x-axis variable for graphic output.

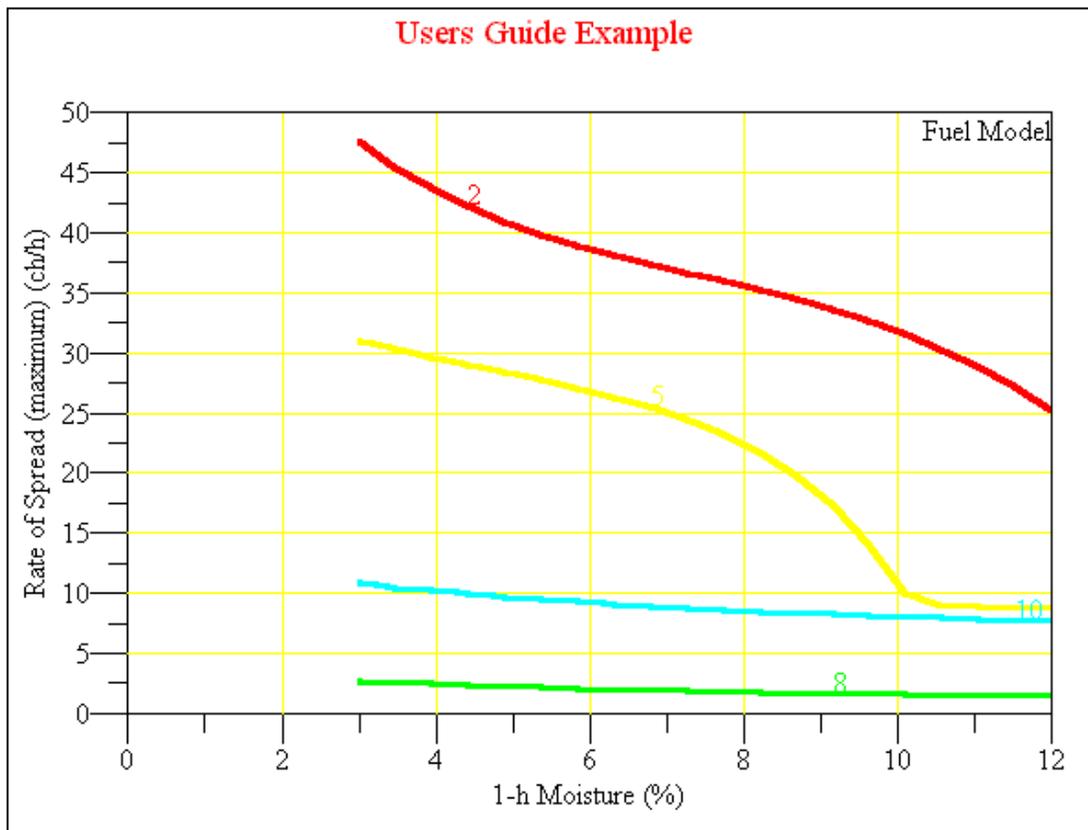
Figure 25 shows the tabular output for rate of spread. Note the rows are fuel model and the columns are 1-h fuel moisture.

Figure 25

| Users Guide Example | | | | |
|-----------------------------------|------|------|------|------|
| Rate of Spread (maximum) (ch/h) | | | | |
| Fuel Model | 3 | 6 | 9 | 12 |
| 2 | 47.6 | 38.7 | 34.0 | 25.3 |
| 5 | 31.0 | 26.9 | 18.2 | 8.7 |
| 8 | 2.7 | 2.1 | 1.7 | 1.5 |
| 10 | 10.9 | 9.3 | 8.3 | 7.7 |

The graph for rate of spread is in Figure 26. Note that the 1-h fuel moisture is on the x-axis, the rate of spread on the y-axis and the individual curves for each fuel model.

Figure 26



Output With Two Discrete Input Variables Having Multiple Input Values

Note the inputs to SPOT as shown in Figure 27 where the discrete variable tree species has multiple inputs of ABIGRA and PICENG, and that the discrete variable spotting source location has multiple inputs of RT and MW.

Calculating outputs will result in the screen below.

Display table results

Select the Table Row Variable

Tree Species

Spotting Source Location

Display graph results

Figure 27

Figure 27

MODULES: Spot

Description → Users' Guide Example

FUEL/VEGETATION

Mean Cover Height ft → 70

Tree Height ft → 70

Spot Tree Species → ABIGRA, PICENG

D.B.H. in → 20

WEATHER

20-ft Wind Speed mi/h → 20

TERRAIN

Ridge-to-Valley Elevation Difference ft → 3000

Ridge-to-Valley Horizontal Distance mi → 2

Spotting Source Location → RT, MW

FIRE

Number of Torching Trees → 12

Graphical output is not possible when two discrete variables have been assigned multiple values, which is why that option is grayed out (not available).

Since two input variables have been selected, the user can select which input variable should be the row variable for the tabular output and which input variable should be the x-axis variable for graphic output.

Figure 28

Users' Guide Example

Spotting Distance from Torching Trees (mi)

| Spot Tree Species | Spotting Source Location | |
|-------------------|--------------------------|-----|
| | RT | MW |
| ABIGRA | 0.8 | 0.7 |
| PICENG | 0.7 | 0.6 |

Figure 28 shows the tabular output for spotting distance. Note the rows are tree species and the columns are spotting source location.

Icon / Menu Overview

File Menu

New

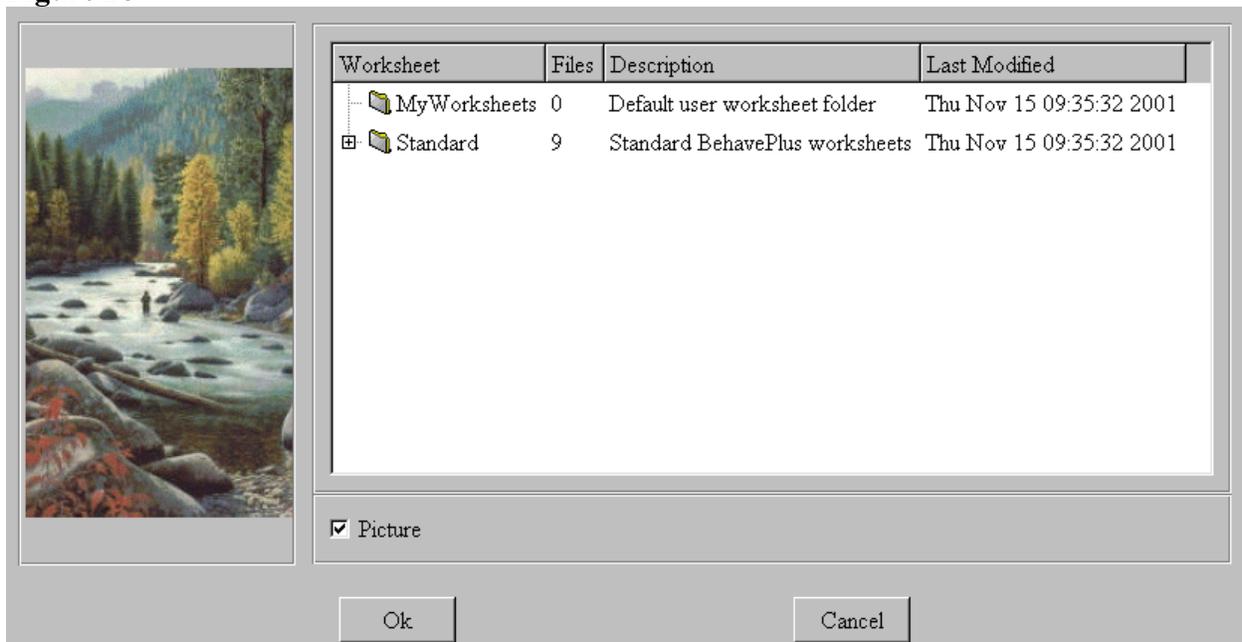
The File, New menu allows the user to load an existing worksheet. As a convenience to the user, *BehavePlus* has several Standard Worksheets included to facilitate the use of common calculations provided by the program. These include:

- A Blank Worksheet (Blank.bpw)
- A Surface Basic Worksheet (SurfaceBasic.bpw)
- A Surface Basic From Worksheet (SurfaceBasicFrom.bpw)
- A Simple Spread Worksheet (SurfaceSimple.bpw)
- A Surface-Map Worksheet (SurfaceMap.bpw)
- A Surface-Scorch-Mortality Worksheet (SurfaceScorchMortality.bpw)
- A Surface-Spot-Ignite Worksheet (SurfaceSpotIgnite.bpw)
- A Slope-MapWorksheet (SlopeMap.bpw)
- A Fuel Modeling Worksheet (FuelModeling.bpw)

The user can design and save custom worksheets as desired.

If the user selects the File, New menu, the window in Figure 28 will appear. As a minimum, two default folders will be displayed: MyWorksheets and Standard. To view the worksheets within these folders, click on the + to the left of either folder.

Figure 28

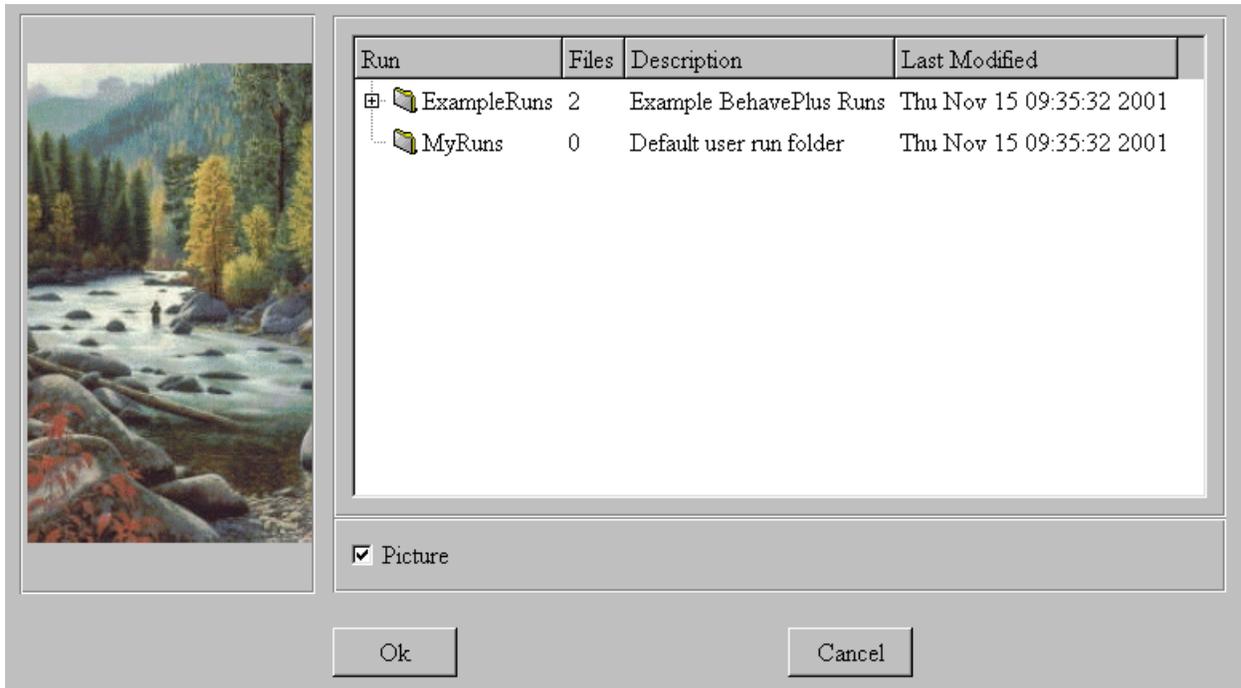


To select a worksheet, either double click on the desired worksheet or highlight the worksheet with a single click and then click on the OK button. Once a worksheet is loaded, the user may make changes using Configure Inputs and Outputs.

Open run

A *Run* is a worksheet with inputs entered. The File, Open menu allows the user to open a run that has been saved. The window in Figure 29 will appear. As a minimum, the default folder MyRuns will be displayed. To view the runs within folders, click on the + to the left of the folder.

Figure 29



To open a run, either double click on the desired run or highlight the run with a single click and then click on the OK button. Once a run is loaded, the user may make changes to the input values or to the configuration (Configure Inputs and Outputs).

Save run

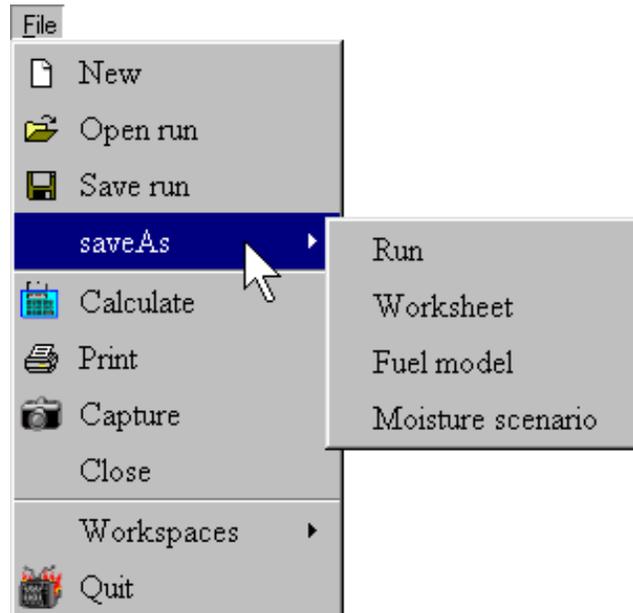
The File, Save run menu allows the user to save a run, which is a worksheet including entered inputs values. If the user selects the File, Save run menu, the program will automatically save the run with the same file name.

saveAs

The File, saveAs menu allows the user to save a Run, Worksheet, Fuel model, or Moisture scenario with a unique file name.

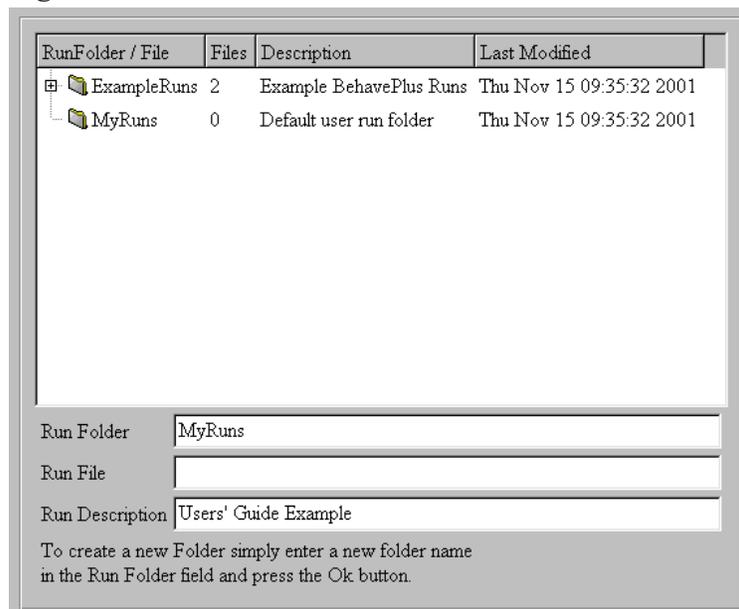
Run

If the user selects the File, saveAs, Run menu, the window in Figure 30 will appear. As a minimum, the default folder MyRuns will be displayed. To view the Run files within a folder, click on the + to the left of the folder.



At the bottom of this window, the user can enter a Run Folder name, a Run File name and a Run Description. If a new Run Folder name is entered, then a new folder will be created in the folder Drive:/ProgramFolder/DefaultDataFolder/RunFolder with the name you specified. The Run File will have the name specified with a bpr extension.

Figure 30



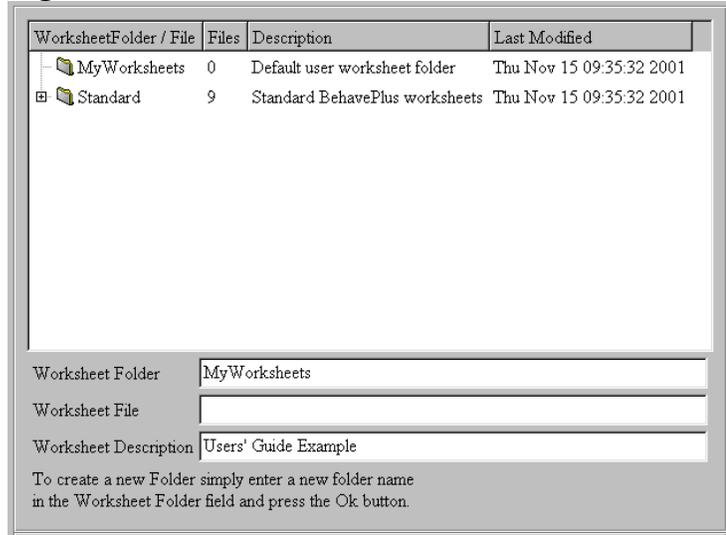
Worksheet

If the user selects the File, saveAs, Worksheet menu, the window in Figure 31 will appear. As a minimum, two default folders will be displayed: MyWorksheets and Standard. To view the Worksheets files within folders, click on the + to the left of the folder.

At the bottom of this window, the user can enter a Worksheet Folder name, a Worksheet File name and a Worksheet Description. If a new Worksheet folder name is entered, then a new folder will be created in the folder Drive:/ProgramFolder/DefaultDataFolder/WorksheetFolder with the name you specified.

The Worksheet File will have the name specified with a bpw extension.

Figure 31



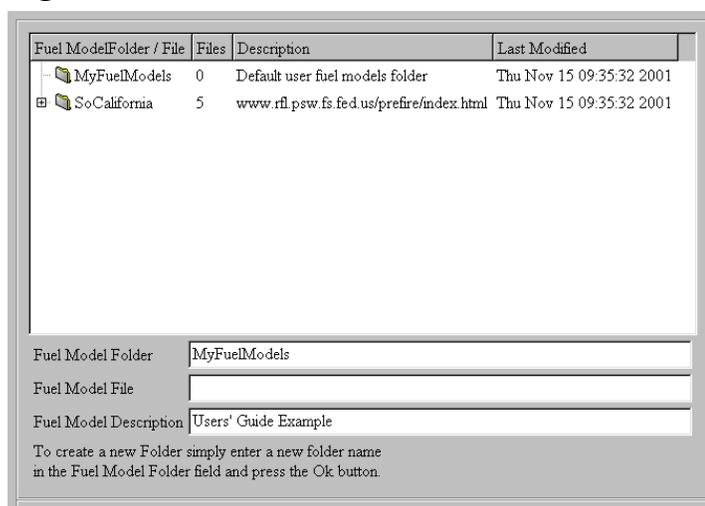
Fuel model

If the user selects the File, saveAs, Fuel model menu, the window in Figure 32 will appear. As a minimum, the default folder MyFuelModels will be displayed. To view the fuel model files within a folder, click on the + to the left of the folder.

At the bottom of this window, the user can enter a Fuel Model Folder name, a Fuel Model File name and a Fuel Model Description. If a new Fuel Model Folder name is entered, then a new folder will be created in the folder as follows Drive:/ProgramFolder/DefaultDataFolder/FuelModelFolder with the name you specified.

The Fuel Model File will have the name specified with a bpf extension. One fuel model is saved in each file.

Figure 32



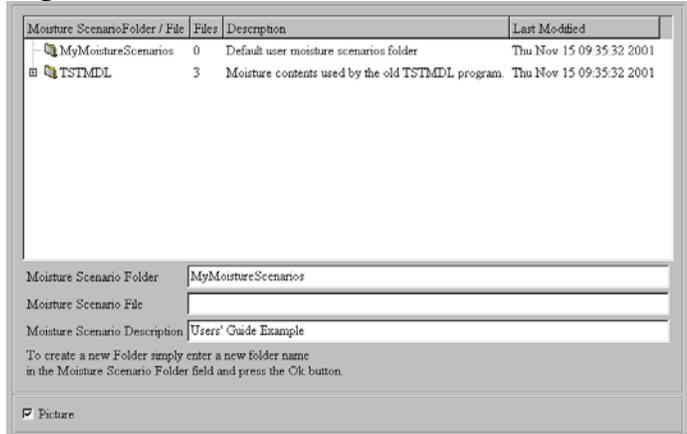
Moisture scenario

If the user selects the File, saveAs, Moisture scenario, the window in Figure 33 will appear. As a minimum, the default folder MyMoistureScenarios will be displayed. To view the Moisture Scenario files within a folder, click on the + to the left of the folder.

At the bottom of this window, the user can enter a Moisture Scenario Folder name, a Moisture Scenario File name and a Moisture Scenario Description. If a new

Moisture Scenario Folder name is entered, then a new folder will be created in the folder Drive:/ProgramFolder/DefaultDataFolder/MoistureScenariosFolder with the name you specified. The Moisture Scenarios File will have the name specified with a bpm extension.

Figure 33



Calculate

If the File, Calculate menu item is selected, program outputs are calculated and displayed. The Calculate function can also be initiated by clicking on the Calculate icon on the *BehavePlus* taskbar or by holding the Ctrl key down while depressing the C key.

Print

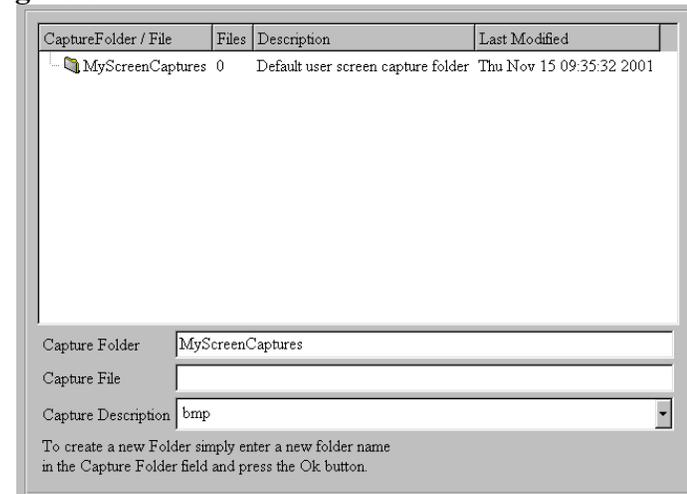
If the File, Print menu item is selected, the default Windows Print dialog box will appear. The user can select the printer desired and the print configuration desired from this dialog box.

Capture

If the File, Capture menu item is the selected, the window in Figure 34 will appear. As a minimum, the default folder MyScreenCaptures will be displayed. To view the Screen Capture files within a folder, click on the + to the left of the folder.

At the bottom of this window, the user can enter a Screen Capture Folder name and a Screen Capture File name. The user can also specify the file format desired such as bmp (bitmap), etc. If a new Screen Capture Folder name is entered, then a new folder will be created in the folder Drive:/ProgramFolder/DefaultDataFolder/CaptureFolder with the name you specified. The Screen Capture File will have the name specified. Captured files can be inserted into other documents.

Figure 34

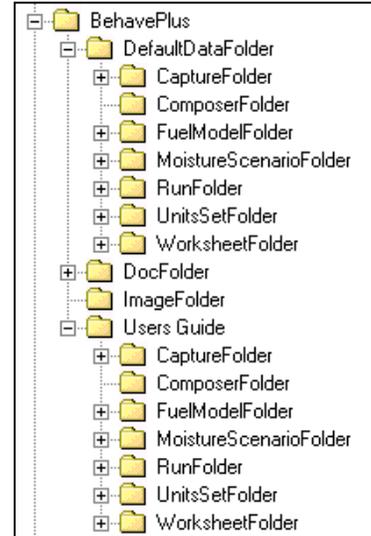


Close

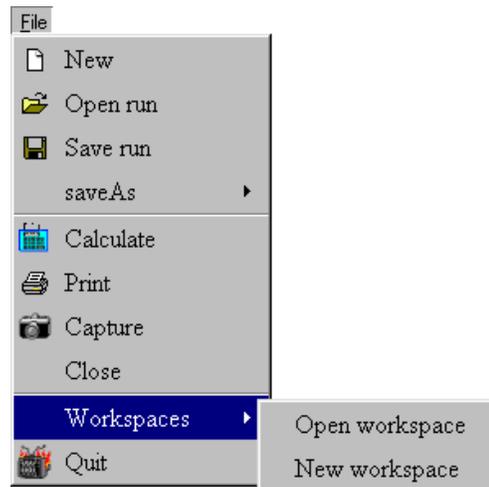
The File, Close menu item allows the user to close a worksheet.

Workspaces

A workspace is a folder that has additional folders for containing screen captures, custom fuel models, moisture scenarios, saved runs, custom unit sets and saved worksheets. Within BehavePlus, installation creates a DefaultDataFolder as the default workspace for these folders and files. The user may wish to create separate unique workspaces for individual users of a single computer system or for individual projects. Note the screen at the right showing the workspace called Users_Guide and note the presence of the same folders that are contained in the workspace default folder DefaultDataFolder.



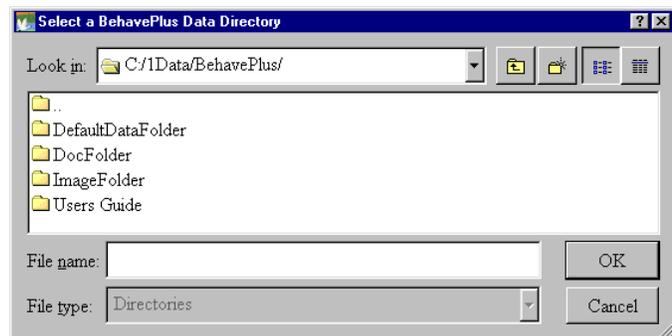
From the File menu, the user can Open a workspace or create a New Workspace.



Open Workspace

The screen at the right appears when the Open workspace menu item is selected. To select or open a workspace, click on the folder and then click on the OK button.

In this example, the Users Guide workspace data directory will become the open (active) workspace.



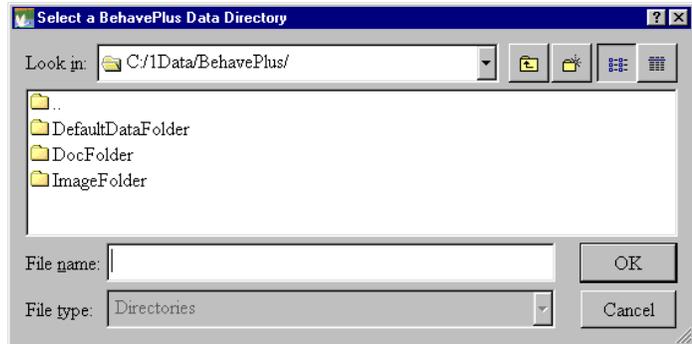
A screen will be displayed advising that the workspace data directory has been changed and advising which workspace data directory that is.

The workspace data directory is now "C:/1Data/BehavePlus/Users Guide/".

(Create a) New Workspace

The screen at the right appears when the New workspace menu item is selected.

To create a New workspace data directory, follow the following steps.



Step 1

Navigate to the drive and folder where you want to create the new workspace data directory.

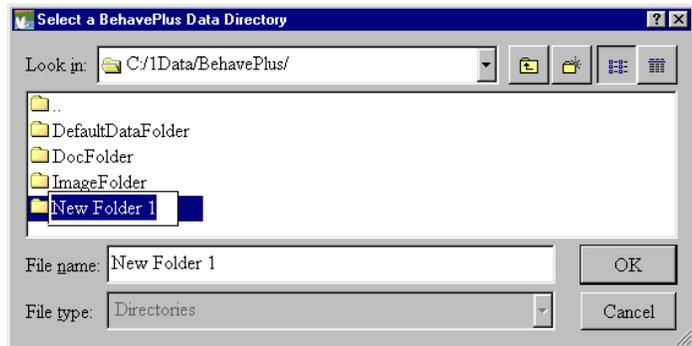
Step 2

Click on the New Folder icon.



Step 3

Clicking on the New Folder icon will result in the display of the screen at the right. Note there is now a New Folder created and the user can now rename this folder from New Folder X to any desired name based on standard Windows naming conventions.



Hot Tip



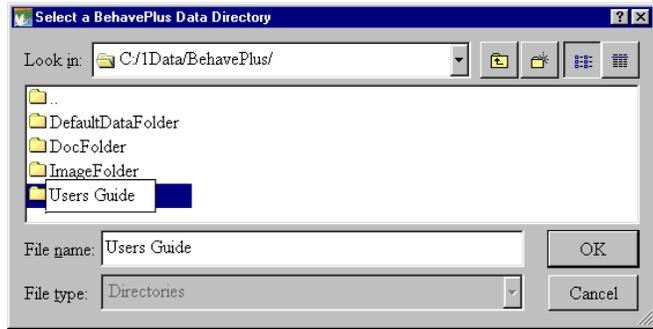
Ignore the "File name" box at the bottom. Do not enter information in this box.

Step 4

Type the name desired for the New workspace data directory.

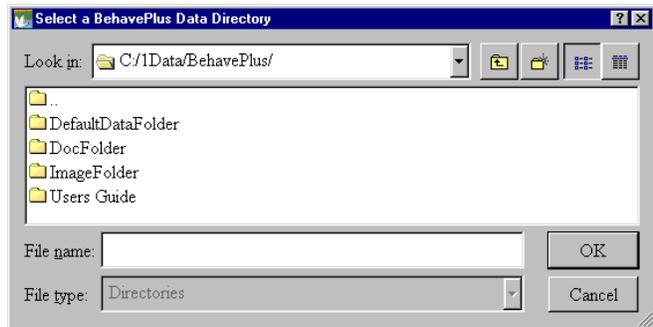
Depress the Enter key on the keyboard.

The program will not rename the New workspace data directory if you click on the OK button instead of depressing the Enter key.



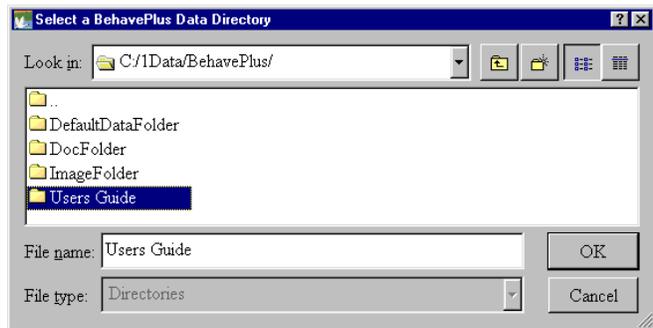
Step 5

After depressing the Enter key on the keyboard, the screen at the right will be displayed. Note the New workspace data directory is now shown.

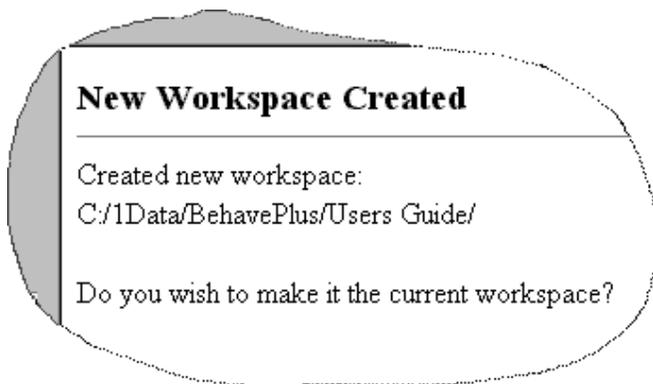


Click on the new folder so that it is highlighted.

Click on the OK button.



A screen similar to the one at the right will appear indicating that the new workspace data directory has been created.



Quit

The File, Quit menu item allows the user to exit the program.

View

The View menu item allows the user to set the size of the image within the program window. To select a specific image size, click on View and then on the percent designation from the scale at the right.

The size of the image on the monitor varies based on the screen resolution set on the computer. This capability can be valuable when there is a desire by the user to maximize the size of the image on the computer monitor.

Configure

The Configure menu item in many ways is the heart and sole of the program. Here is where the user selects the modules desired, the input options, and the output variables. In addition, the units (English or Metric) can be specified using this menu. The configuration of the appearance of the worksheet is the last menu item. Hence, the Configure menu allows the user to specify:

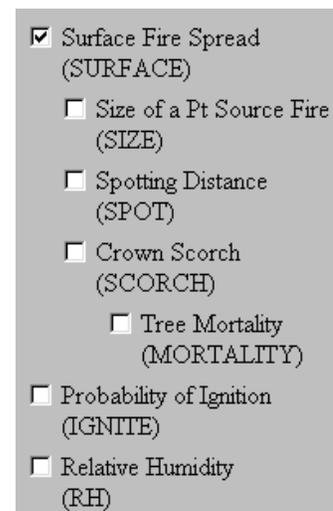
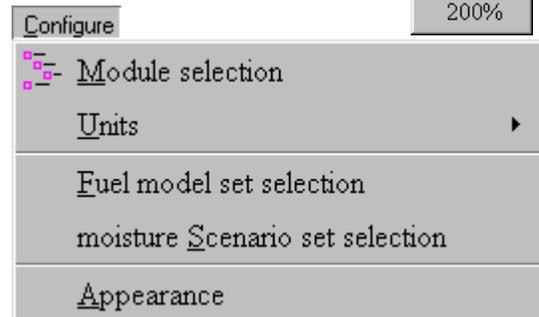
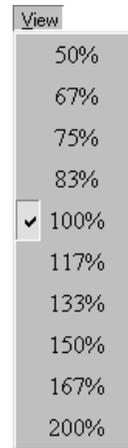
- Module Selection
 - Module Input Options
 - Module Output Variables
- Units Used (English or Metric)
- Fuel Model and Moisture Scenario Set Selection
- Appearance of worksheet, graphs, and tables

Module Selection

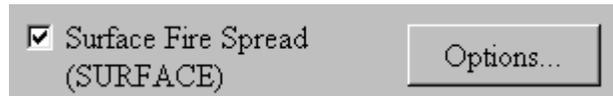
The Module Selection menu item allows the user to specify:

- Module Selection
 - Module Input Options
 - Module Output Variables

To select a Module, click in the box to the left of the module description. More than one module can be selected. Indentations indicate where linkages are possible. Linked modules cause outputs from one module to be used as inputs to another module. For example, forward rate of spread and effective wind speed calculated from SURFACE are used as inputs to SIZE.

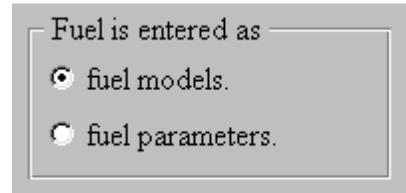


The Options button next to each module presents input options.



Click on the radio button by the desired input method.

Loading the Blank Worksheet sets default options as noted in the module descriptions below. Refer to the section of the User Guide titled Worksheet Inputs for guidance on input of values.



Surface Fire Spread (SURFACE Module)

The SURFACE module calculates 14 different fire behavior or input related values. The primary fire behavior related outputs are the rate of spread, heat per unit area, fireline intensity, flame length, and reaction intensity. Inputs to the SURFACE module include values that specify fuels, fuel moisture, wind speed, wind direction, and slope steepness. Input option selection determines how fuel type and fuel moisture are entered, how wind and spread directions are specified, and how slope is specified.

Fuel and Moisture Tab

Fuels

Fuel is entered as

- Fuel model (standard fuel models 1-13 or custom fuel models) (Default selection) or
- Fuel parameters (individual values that define a fuel model)

Fuel Moisture

Moisture is entered by

- Individual size class (fuel moisture percentage for each individual dead size class and each individual live size class) (Default Selection)
or
- Dead and live category (fuel moisture value for the dead fuels collectively and the live fuels collectively)
or
- Moisture scenario (Sets of fuel moisture values for each dead and live fuel size)

Wind Speed and Dir(ection) Tab

Wind Speed

Wind speed is entered as:

- midflame height, (Default Selection) or
- 20-ft. wind and wind adj(ustment) factor or
- 10-meter wind and wind adj(ustment) factor

Wind Direction

Wind direction is:

- Specified on the worksheet (Default Selection)
or
- Up slope.

Wind and Fire Directions Tab

Rate of Spread

The rate of spread is calculated:

- Only in the direction of maximum spread (Default Selection) or
- In directions specified on the worksheet.

Wind and Spread Directions

The wind and spread directions are:

- Degrees clockwise from up slope (the direction in which the wind is pushing the fire) (Default Selection)
or
- Degrees clockwise from North (the direction from which the wind is blowing)

Slope Tab

Slope Units

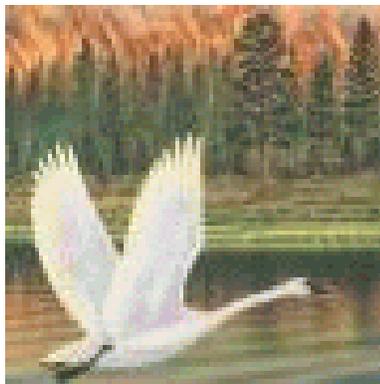
The slope is specified as:

- Percent (Default Selection)
or
- Degrees.

Slope Steepness Entry Method

Slope steepness is:

- Specified on the worksheet (Default Selection)
or
- Calculated from map measurements.



Output Variables Tab

The user can select the output of the following values. A pause of the cursor on an output item displays a description of that variable in the right-hand portion of the window.

- Rate of Spread (Default Selection)
- Heat per Unit Area (Default Selection)
- Fireline Intensity (Default Selection)
- Flame Length (Default Selection)
- Reaction Intensity
- Direction of Maximum Spread (Default Selection)
- Spread Distance
- Midflame Wind Speed
- Effective Wind Speed
- Maximum Reliable Wind Speed
- Maximum Wind Exceeded? (Default Selection)
- Slope Steepness
- Slope Elevation Change
- Slope Horizontal Distance

Click in the check box to the left of the desired output. Refer to the section of the User Guide titled Worksheet Inputs and Program Outputs for guidance on the use of these output values.

Size of a Point Source Fire (SIZE)

The SIZE module calculates seven fire size values. The SIZE module can be run independently where all input values are entered by the user. If both the SURFACE and SIZE modules are selected, SIZE is linked to the SURFACE module whereby the forward rate of spread and effective wind speed values from SURFACE are used in SIZE. Inputs to the SIZE module include effective wind speed, forward rate of spread, and elapsed time the fire has been spreading from its initiation. There are no input options for SIZE.

Output Variables

The user can select the outputs desired from the following 7 values.

- Area (Default Selection)
- Perimeter (Default Selection)
- Length-to-Width Ratio
- Forward Spread Distance
- Backing Spread Distance
- Fire Length
- Maximum Width of the Fire

Spotting Distance (SPOT)

The SPOT module can calculate three spotting distance values. The output selection includes spotting from torching trees, a burning pile, or a wind-driven surface fire. The SPOT module can be run independently with all input values entered by the user. Or if both SURFACE and SPOT are selected and if spotting distance is to be calculated from a wind-driven surface fire, then the two modules are linked. In the linked mode, the flame length from SURFACE is used in the SPOT calculations. Input and Output to the SPOT module include the following values based on the fire brand source, which is determined by the selected output values.

Fire Brand Source Is Torching Trees

Output

- Spotting Distance from Torching Trees (Default Selection)

Inputs

- Mean Cover Height
- Tree Height
- Spot Tree Species
- D.B.H. (Diameter Breast Height)
- 20-ft Wind Speed
- Ridge-to-Valley Elevation Difference
- Ridge-to-Valley Horizontal Distance
- Spotting Source Location
- Number of Torching Trees

Fire Brand Source Is A Burning Pile

Output

- Spotting Distance from a Burning Pile

Inputs

- Mean Cover Height
- 20-ft Wind Speed
- Ridge-to-Valley Elevation Difference
- Ridge-to-Valley Horizontal Distance
- Spotting Source Location
- Flame Height from a Burning Pile

Fire Brand Source Is A Spreading Surface Fire

Output

- Spotting Distance from a Wind Driven Surface Fire (in miles)

Inputs

- Mean Cover Height
- 20-ft Wind Speed
- Ridge-to-Valley Elevation Difference
- Ridge-to-Valley Horizontal Distance
- Spotting Source Location
- Flame Length

Crown Scorch (SCORCH)

The SCORCH module calculates the scorch height based on the input of either flame length or fireline intensity. The SCORCH module can be run independently with all input values entered by the user. If both SURFACE and SCORCH are selected, the modules are linked. Either the flame length or the fireline intensity (as specified) and wind speed from SURFACE are used in the SCORCH calculations for the scorch height.

Input Options

Fire intensity is entered as:

- Flame Length (Default Selection)
- Fireline Intensity

Output Variables

There is only one output variable:

- Scorch Height (Default Selection)

Tree Mortality (MORTALITY)

The MORTALITY module calculates the probability of tree mortality as well as three intermediate values. Probability of mortality is calculated from mortality tree species, tree height, crown ratio, and scorch height. The MORTALITY module can be run independently with all input values entered by the user. If both SCORCH and MORTALITY are selected, the modules are linked. Scorch height from SCORCH is used in MORTALITY.

Input Options

The bark thickness is:

- Specified on the worksheet (Default Selection)
- Estimated from species and d.b.h. (diameter breast height)

Output Variables

- Bark Thickness
- Tree Crown Length Scorched
- Tree Crown Volume Scorched
- Probability of Mortality (Default Selection)

Probability of Ignition (IGNITE)

The IGNITE module calculates the probability of ignition from a firebrand from 1-h fuel moisture, air temperature, and fuel shading from the sun. There are no input options.

Output Variables

There is only one output variable:

- Probability of Ignition from a Firebrand(Default Selection)

Relative Humidity (RH)

The RH module calculates the relative humidity and the dew point temperature. RH cannot be linked to any other module. To avoid confusion, it should be run separately.

Input Options

- Dew point and dry bulb temperatures (Default Selection)
- Dry and wet bulb temperatures and elevation

Output Variables

- Relative Humidity (Default Selection)
- Dew Point Temperature

Units

The Configure, Units menu item allows the user specify input and output in English, Metric, or Custom units. The default is English units.

- Units Used - English

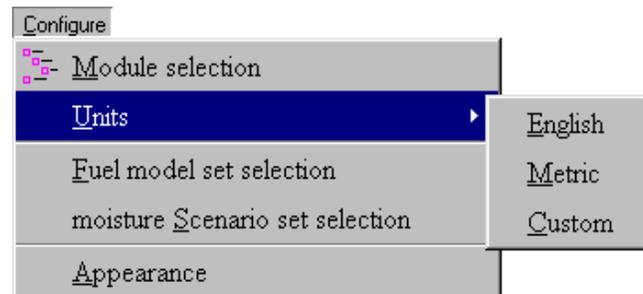
Selecting this menu item will require input values to be entered in the English System.

- Units Used - Metric

Selecting this menu item will require input values to be entered in the Metric System.

- Units Used - Custom

Selecting this menu item other will require the user to select a custom Units Set file. This set of custom units is created using the Tools, units Editor menu. Using the Tools, units Editor menu, the user creates a set of custom units for input and/or output variables. These are saved in a file in the MyUnitsSets folder.

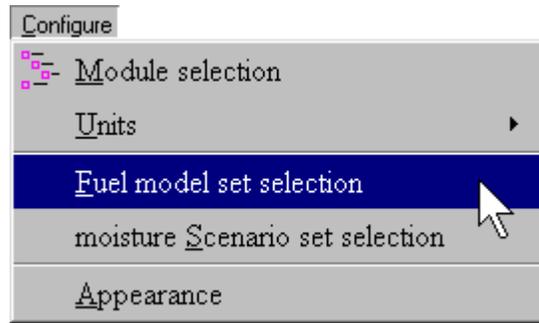


Fuel model set selection

This menu item allows the user to attach a custom fuel model folder which will make the custom fuel models available to be selected as an input to the SURFACE module.

A custom fuel model is created by following the steps below:

1. Load the Fuel Modeling Worksheet by selecting File, New Worksheet.
2. In the Worksheet that is displayed, enter the fuel model parameter values. Alternatively, the fuel model parameters can be initialized with an existing fuel model by clicking on the Initialize from a Fuel Model button.
3. Select the File, saveAs, Fuel model menu item.
4. Select the Fuel Model Folder, Fuel Model File Name and the Fuel Model Description. Click on the OK button.
5. Test the new fuel model for a range of environmental conditions. Do this by loading the SurfaceBasic or SurfaceSimple worksheet and compare the new fuel model to existing fuel models for a range of conditions.

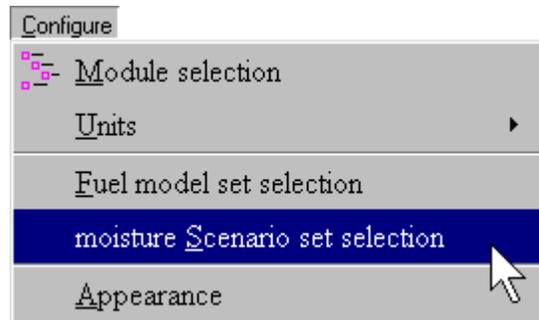


moisture Scenario set selection

This menu item allows the user to attach a moisture scenario set folder which will make these moisture scenarios available to be selected as an input to the SURFACE module.

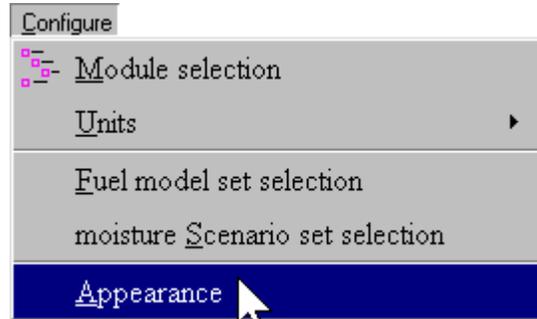
A moisture scenario is created by following the steps below:

1. Select the File, New worksheet menu.
2. Select the SurfaceBasic worksheet, which requires entry of fuel moisture by individual size classes.
3. In the Worksheet that is displayed, enter the fuel moisture values.
4. Select the File, saveAs, Moisture scenario menu item.
5. Select the Moisture Scenario Folder, Moisture Scenario File Name and the Moisture Scenario Description. Click on the OK button.



Appearance

This menu item allows the user to configure certain display attributes for the *BehavePlus* Application, Graphs, Page Tabs, Tables, and Worksheets.



Application

The application tab allows the user to choose whether the Browser Pane and/or the Picture Pane will be displayed or not. Note that at the bottom of each screen in *BehavePlus* where the Browser Pane and Picture Pane are shown, check boxes allow display of these panes to be turned on or off.

Graph Size

The user can adjust display attributes of graphs.

- **Graph Size (Default is 50%)**
This controls graph vertical height. Graphs are drawn starting at the upper left corner of the page and may occupy 25% to 100% of the page height.
- **Graph Title (Default is Short)**
This controls graph title content. *Short* will limit the title to the run description and *Long* will cause the run description as well as the X- and Y-axis variable names to be displayed in the title.
- **X-Axis Origin (Default is Zero)**
Controls the X-value displayed at the X-origin. *Zero* causes the graph's X-origin to begin at 0. *Min Value* sets the X-origin to the X-axis variable's minimum value as specified on the input worksheet.
- **Y-Axis Origin (Default is Zero)**
Controls the Y-value displayed at the Y-origin. *Zero* causes the graph's Y-origin to begin at 0. *Min Value* sets the Y-origin to the minimum value calculated for the Y-axis output variable.

Graph Elements

The user can adjust display attributes of graphs.

- **Background (Color) (Default is white)**
This controls the graph's background color. Select one of the predefined colors from the drop-down list. The current background color setting appears as the first item in the list.

- **Rainbow Colors (Default is 3)**
 This controls the number of colors used to display graph lines or bars when *Rainbow* coloring is selected. If 4 colors are requested, for example, four equally-spaced hues from the color spectrum are used to display each graph line or bar in turn. If there are more curves than the selected number of colors, the colors are reused.
- **Bar Color (Default is red)**
 This controls the color used to fill graph bars. Select one of the pre-defined colors from the drop-down list. The current bar color setting appears as the first item in the list. The special *Rainbow* color cycles through a series of colors so that each bar is filled with its own color. The number of rainbow colors is set by the *Rainbow Colors* control discussed above.
- **Curve Points (Default is 20)**
 This controls the number of points calculated for each curve in the graph. A straight line segment is drawn between each pair of points. Twenty points is visually adequate for most graphs. Requesting more points usually results in a marginal improvement in the visual appearance and requires more computation time.
- **Curve Color (Default is rainbow)**
 This controls the color used to draw graph lines. Select one of the pre-defined colors from the drop-down list. The current line color setting appears as the first item in the list. *Rainbow* cycles through a series of colors so that each line is drawn with its own color. The number of rainbow colors is set by the *Rainbow Colors* control discussed above.
- **Curve (Line) Width (Default is 3)**
 The controls the width of graph lines.
- **Axis Color (Default is black)**
 This controls the color used to draw graph axis lines, tic marks, and axis labels. Select one of the pre-defined colors from the drop-down list. The current axis color setting appears as the first item in the list.
- **Axis Width (Default is 1)**
 This controls the width of axis lines drawn on the graph.
- **Gridline Color (Default is yellow)**
 This controls the color used to draw graph grid lines. Select one of the pre-defined colors from the drop-down list. The current grid line color setting appears as the first item in the list.
- **Gridline Width (Default is 1)**
 This controls the width of grid lines drawn on the graph. Select *None* to prevent the display of any grid lines.

Page Tabs

You can configure *BehavePlus* to display a *page tab* along the right margin of the page. Page tabs can be displayed on the worksheet and appear with the worksheet when it is printed. This allows for a way to file and identify a worksheet in a notebook or file folder. The attributes that can be set include:

- **Display the Page Tab (Default is not checked)**
Check this box to have the program display page tabs on the worksheet and on printouts. If this attribute is not checked, the program will hide page tabs without affecting any of the other page tab properties.
- **Tabs per Page (Default is 4)**
The length of the tab is based on the specification of the number of tabs per page. There is only one tab displayed per page. The size of the tab depends upon this value. If it is 4, the displayed tab occupies one-fourth the page height. If it is 10, the displayed tab occupies one-tenth the page height. As this number increases, the displayed tab size decreases.
- **Tab Position (Default is 1)**
The vertical position of the tab is based on the number of tabs designated. This determines the position of the displayed tab. Tab position 1 is always at the upper edge of the right margin on the worksheet.
- **Tab Text (Default has no text in box)**
Enter in the box the text that is to appear on the tab. The text is centered within the tab, and will therefore be truncated at both ends if it is too long.
- **Tab Text Color (Default is black)**
The color of the text printed can be select from the list of colors displayed using the drop-down list.
- **Tab Font Size (Default is 12)**
The font of the printed text can be selected from the list of a font point sizes displayed using the spin control.

Tables

This tab allows for the control of the appearance of *BehavePlus* output tables. The user can choose to have alternate rows shaded in tables.

- Shade alternate table rows (Default is checked)
Checking this box causes all output tables to have alternating rows shaded with a background color. This may improve the readability of wide tables. If the box is not checked, tables are displayed without any row background color.
- Shade (Default is light gray)
Select a table row background shade from the drop-down list. The current shade appears as the first list item.

Worksheet

This tab allows for the control of the amount of additional input documentation that appears on the *BehavePlus* worksheet. The optional input documentation categories are Fire projection documentation and Training documentation. To enable a category, click in the box to the left of the category.

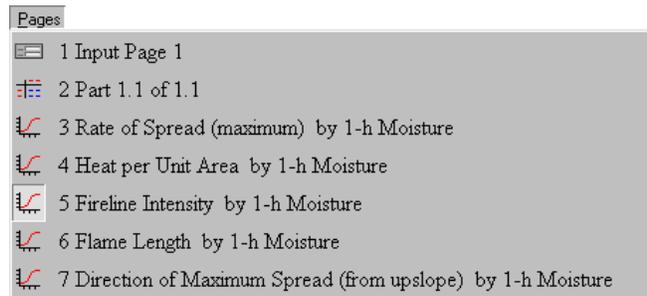
- Fire projection documentation (Default is not checked)
Checking this attribute causes the following input fields to appear below the description box on the worksheet:
 - Fire Name
 - Fire Date and Projection Period
 - Fire Analyst
- Training documentation (Default is not checked)
Checking this attribute causes the following input fields to appear below the description box on the worksheet:
 - Training Course
 - Training Exercise
 - Trainee Name and Date
- Show input codes for all discrete variables (Default is not checked)
Checking this attribute causes all valid input items for discrete input variables to be displayed on the worksheet. For example, if Fuel Model is an input item, then checking this option will cause the numbers and names of fuel models from the attached fuel model folders to be listed on the worksheet.
- Show output variables to be calculated (Default is checked)
Checking this attribute causes a list of all currently selected output variables to be listed at the end of the input worksheet.
- Show Notes Section (Default is checked)
Checking this attribute enables the display of the notes section on the worksheet.

- Notes Lines (Default is 4)

Use the spinner control to select the maximum number of lines of text allowed in the Notes section. The user can also click in the box and manually enter a number.

Pages

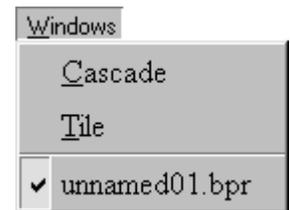
BehavePlus creates Input and Output Pages as the user creates Worksheets and generates outputs. This menu item allows the user to select Input or Output Page for use or display.



Windows

Cascade

Selecting Windows, Cascade allows multiple Runs to be displayed with one behind the other. If multiple Worksheets are open, each one's name will be displayed at the bottom of this menu.



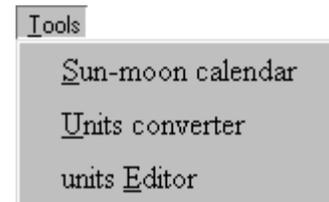
Tile

Selecting Windows, Tile allows multiple Runs to be displayed side by side.

Tools

Sun-moon calendar

The Sun-moon calendar menu item allows the user to determine for a location the difference in time from Greenwich Mean Time (GMT), the latitude and longitude, the sunrise time, the sunset time, the moon rise time and moon set time given a month and year specification.



The Location Tab allows the user to specify the point and time where predictions are desired.

Location Tab

- Location

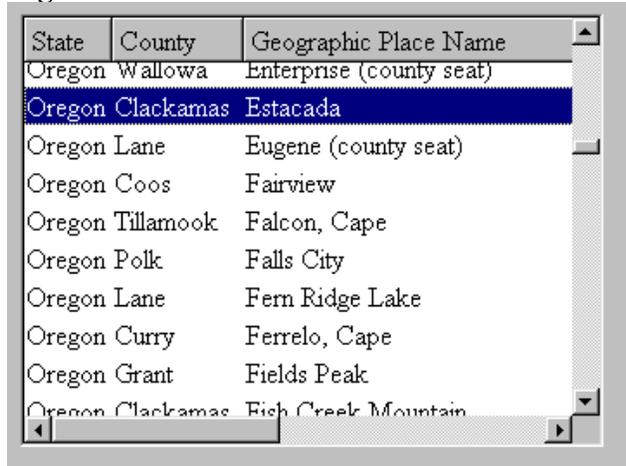
Enter the location name. The text entered here appears in the title of the sun/moon calendar.

Figure 35

Press the **Browse** button to select from over 400,000 named geographic places in the U.S.

Initially the user can select the state of on interest, which will provide a listing of the Geographic Place Name (Figure 35).

Note that by clicking on any of the column headings (State, County or Geographic Place Name), the information is sorted by the column clicked.



■ **GMT Diff**

Select the hours difference from Greenwich Mean Time (GMT). The table below shows the GMT difference for selected time zones. The GMT plus the hours from the table yields the local time.

GMT Time Difference by Time Zone

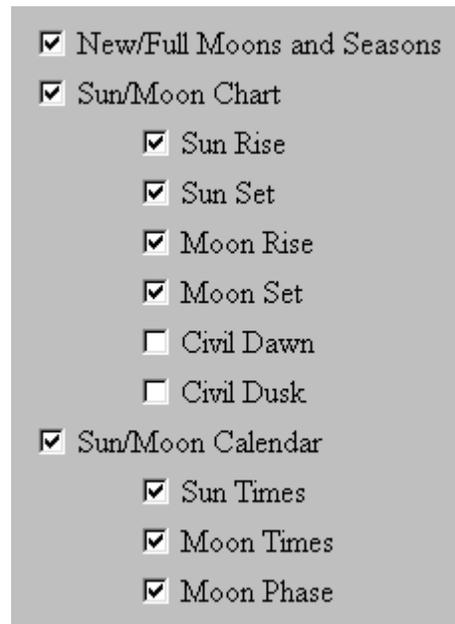
| Time Zone | GMT + h |
|-----------------------------|---------|
| GMT Greenwich Mean Time | +0 |
| US Eastern Standard | -5 |
| US Eastern Daylight | -4 |
| US Central Standard | -6 |
| US Central Daylight | -5 |
| US Mountain Standard | -7 |
| US Mountain Daylight | -6 |
| US Pacific Standard | -8 |
| US Pacific Daylight | -7 |
| US Alaska Standard | -9 |
| US Alaska Aleutian Standard | -10 |
| US Hawaiian Standard | -10 |
| Central Europe Summer | +2 |
| Central Europe Standard | +1 |

- Longitude and Latitude
If the user selects a Location, the longitude and latitude are displayed by the program. The user can also select a longitude and latitude by directly entering values in the boxes for the longitude *West* or *East* of the Greenwich meridian and the latitude *North* or *South* of the equator. Using the spinner controls is also an option. Enter the location's latitude or longitude in degrees (0-180), minutes (0-59), and seconds (0-59).
- Month
Select the month for which to have the sun/moon times calculated.
- Year
Enter the year for which to have the sun/moon times calculated.

Contents Tab

This Tab displays the contents of the Sun/Moon calendar and allows the user to select the outputs to be displayed. All outputs except civil dawn and civil dusk are selected as defaults.

- New/Full Moons and Seasons
Check this box to produce a table of new and full moon dates and times for the entire year. The table also contains the year's solstice and equinox dates and times.
- Sun/Moon Chart
Check this box to produce a table of daily sun and moon events for the month. Content options include:
 - Sun Rise
 - Sun Set
 - Moon Rise
 - Moon Set
 - Civil Dawn
 - Civil Dusk
- Sun/Moon Calendar
Check this box to produce a calendar for the specified month. Content options include:
 - Sun Times for sunrise and set times for each day
 - Moon Times for moon rise and set times for each day
 - Moon Phase for moon phase on appropriate days



Units converter

The Tools, Units converter menu item allows the user to convert units from one measure to a different measure. If the user selects the Tools, Units converter menu item, the window in Figure 36 will appear.

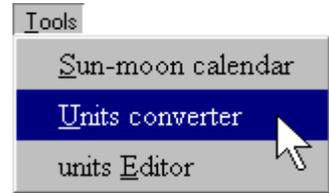
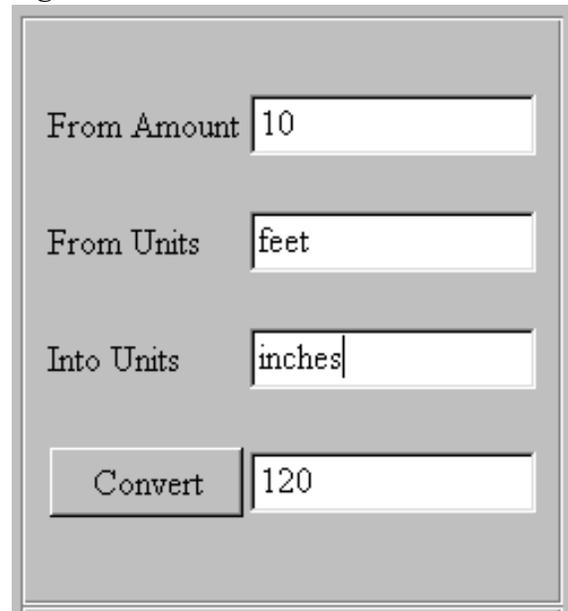


Figure 36

A screenshot of the "Units converter" dialog box. It has a light gray background and a thin border. The dialog contains four input fields and one button. The first field is labeled "From Amount" and contains the number "10". The second field is labeled "From Units" and contains the text "feet". The third field is labeled "Into Units" and contains the text "inches". The fourth field is labeled "Convert" and contains the number "120".

- **From Amount**
Enter a single quantity to be converted. The user may enter an integer or a real number value. The real number value may be in decimal or scientific notation.
- **From Units**
Enter the input variable's units of measure. The user may use common abbreviations, which must be in lower case. For example, the following are all equivalent and acceptable as input for pounds per square foot:
 - pounds per foot²
 - lb/ft²
 - lb / ft²
 - lb ft⁻²
 - lb per ft²

Note that a scrolling list of units contains all the units known to the converter. It is supplied for reference only. The user must manually enter the units names or abbreviations into the *Convert from Units* or the *Convert into Units* entry fields.

- **Into Units**
Enter the output variable's units of measure. The user may use common abbreviations, which must be in lower case. For example, the following are all equivalent and acceptable as output for kilograms per square meter:
 - kilograms per meter²
 - kg/m²
 - kg / m²
 - kg m⁻²
 - kg per m²
- **Convert Button**
Press this button to attempt the conversion. If successful, the answer appears in the field to the right. If unsuccessful, "Error" is displayed in the box to the right of Convert button. Errors can result from unknown units names or abbreviations, or from an attempt to convert between incompatible units (such as between feet and kilograms).

Units Editor

The units of measure to be used for input and/or output variables and the number of decimal places for display is controlled by the Units Editor. The Tabs control selection of units of measure and decimal places for the input, display, and output. To select units, select the desired variable from the Tab pages. The default units of measure in both the SI (metric) and English systems are marked with asterisks.



The variables where units can be set are grouped into five categories as follows.

Fuel and Vegetation Units

The fuel and vegetation variables where the units and number of decimal places can be set are as follows. The default units and number of decimal places are provided in the format (English units, Metric units, decimal places).

- Fuel Load (tons/ac, tonne/ha, 0)
 - C 1-h fuel load
 - C 10-h fuel load
 - C 100-h fuel load
 - C Live herbaceous fuel load
 - C Live woody fuel load
- Surface Area/Vol Ratio (ft²/ft³, m²/m³, 0)
 - C 1-h surface area/volume ratio
 - C Live herb surface area/volume ratio
 - C Live woody surface area/volume ratio
- Fuel Bed Depth (ft., m, 2)
- Fuel Moisture & Extinction (percent, percent, 0)
 - C Dead fuel moisture of extinction
 - C 1-h moisture
 - C 10-h moisture
 - C 100-h moisture
 - C Live herbaceous moisture
 - C Live woody moisture
 - C Dead fuel moisture
 - C Live fuel moisture
- Fuel Heat Content (BTU/ft², kJ/m², 0)
 - C Dead fuel heat content
 - C Live fuel heat content

A screenshot of the 'Units Editor' dialog box. It contains a list of variables with their corresponding units and decimal places. Each variable has a dropdown menu for units and a numeric input field with up/down arrows for decimal places. The variables and their settings are: Fuel Load (ton/ac, 2), Surface Area/Vol Ratio (ft²/ft³, 0), Fuel Depths (ft, 2), Fuel Moisture & Extinction Moisture (percent, 0), Fuel Heat Content (Btu/lb, 0), Tree Height & Mean Cover Height (ft, 0), and Tree D.b.h. & Bark Thickness (in, 0).

- Mean Cover & Tree Heights (ft., m, 1)
 - C Mean cover height
 - C Tree height
 - C Tree crown length scorched

- Tree D.B.H. (inches, cm., 0) and Bark Thickness (inches, cm, 1)

Weather Units

The weather variables where the units and number of decimal places can be set are as follows. The default units and number of decimal places are provided in the format (units, decimal places).

- Wind Speed (mi/h, m/min, 1)
 - C Midflame wind speed
 - C 20-ft wind speed
 - C 10-m wind speed
 - C Effective wind speed
 - C Wind speed limit

- Temperature (oF, oC, 0)
 - C Air (dry bulb) temperature
 - C Wet bulb temperature

- Relative Humidity (percent, percent, 0)

- Shading from the Sun (percent, percent, 0)

| Variable | Units | Decimals |
|-------------------|---------|----------|
| Wind Speed | mi/hr | 1 |
| Temperature | oF | 0 |
| Relative Humidity | percent | 0 |
| Shading from Sun | percent | 0 |

Terrain and Spotting Units

The terrain and spotting variables where the units and number of decimal places can be set are as follows. The default units and number of decimal places are provided in the format (units, decimal places).

- Slope Steepness (percent, percent, 0)

- Site Elevation & Ridge-to-Valley Elevation Difference (ft., m., 0)
 - C Site elevation
 - C Ridge-to-valley elevation difference
 - C Elevation change (slope rise)
 - C Horizontal distance (slope reach)

| | | |
|---|---------|---|
| Slope Steepness | percent | 0 |
| Site Elevation & Ridge-to-Valley Elevation Difference | ft | 0 |
| Spotting Distance & Ridge-to-Valley Horizontal Distance | mi | 1 |

- Spotting Distance & Ridge-to-Valley Horizontal Distance (mi., km., 1)
 - C Spotting distance from torching trees
 - C Spotting distance from a burning pile
 - C Spotting distance from a wind-driven surface fire
 - C Ridge-to-valley horizontal distance

Fire and Effects Units

The fire and effects variables where the units and number of decimal places can be set are as follows. The default units and number of decimal places are provided in the format (units, decimal places).

| | | |
|---|--------------------------|---|
| Rate of Spread | ft/min | 1 |
| Heat per Unit Area | Btu/ft ² | 0 |
| Fireline Intensity | Btu/ft/s | 0 |
| Flame Len & Scorch Ht | ft | 1 |
| Reaction Intensity | Btu/ft ² /min | 0 |
| Spread Distance | ch | 1 |
| Fire Area | ac | 1 |
| Fire Perimeter | ch | 0 |
| Probability of Mortality & Crown Vol Scorched | percent | 0 |
| Probability of Ignition | percent | 0 |

- Rate of Spread (ch/hr, m/min, 1)
- Heat per Unit Area (Btu/ft², kJ/m², 0)
- Fireline Intensity (Btu/ft/s, kJ/m/s, 0)
- Flame Length & Scorch Height (ft, m, 1)
 - C Flame length
 - C Scorch height
- Reaction Intensity (Btu/ft²/min, kJ/m²/min, 0)
- Spread Distance (ch, m, 1)
 - C Spread distance
 - C Forward spread distance
 - C Backing spread distance
 - C Fire length
 - C Maximum width of fire
- Fire Area (ac, ha, 1)
- Fire Perimeter (ch, m, 1)
- Probability of Mortality & Crown Volume Scorched (percent, percent, 0)
 - C Probability of mortality
 - C Tree crown volume scorched
- Probability of Ignition (percent, percent, 0)

Time and Map Units

The time and map variables where the units and number of decimal places can be set are as follows. The default units and number of decimal places are provided in the format (units, decimal places).

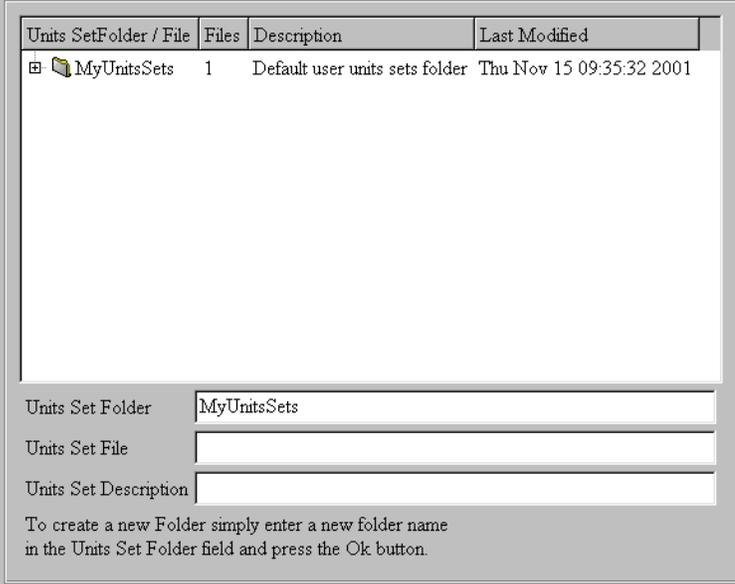
- Time (h, h, 0)
- Contour Interval (ft, m, 0)
- Map Distance (in, cm, 1)

| Variable | Units | Decimals |
|------------------|-------|----------|
| Time | h | 1 |
| Contour Interval | ft | 0 |
| Map Distance | in | 2 |

Figure 37

The selected units can be saved as a *custom Units Set*. To do this, click on the Ok button to save the selections to a *BehavePlus* custom Units Set file. A file dialog appears in Figure 37 will appear. Select the Units Set Folder, Units Set File Name and the Units Set Description. Click on the OK button.

To use a custom Units Set for a *BehavePlus* run, choose the menu option **Configure->Units->Custom** from the menu and select the desired file.



| Units Set Folder / File | Files | Description | Last Modified |
|-------------------------|-------|--------------------------------|--------------------------|
| MyUnitsSets | 1 | Default user units sets folder | Thu Nov 15 09:35:32 2001 |

Units Set Folder: MyUnitsSets
Units Set File:
Units Set Description:

To create a new Folder simply enter a new folder name in the Units Set Folder field and press the Ok button.

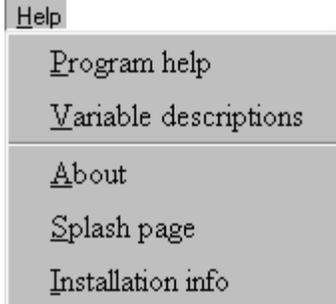
Help

Program Help

The user can view program help from the Help, Program Help menu or by clicking on the Help icon on the *BehavePlus* Toolbar. Program help provides guidance in program operation and functionality, essentially the contents of this user's manual.

Variable Descriptions

The Help, Variable descriptions menu item allows the user access the definitions and supporting information of input and output variables. To view information for a particular variable, click on the link for that variable. Variable descriptions appear in the browser window of the Assist Window, unless that feature has been turned off.



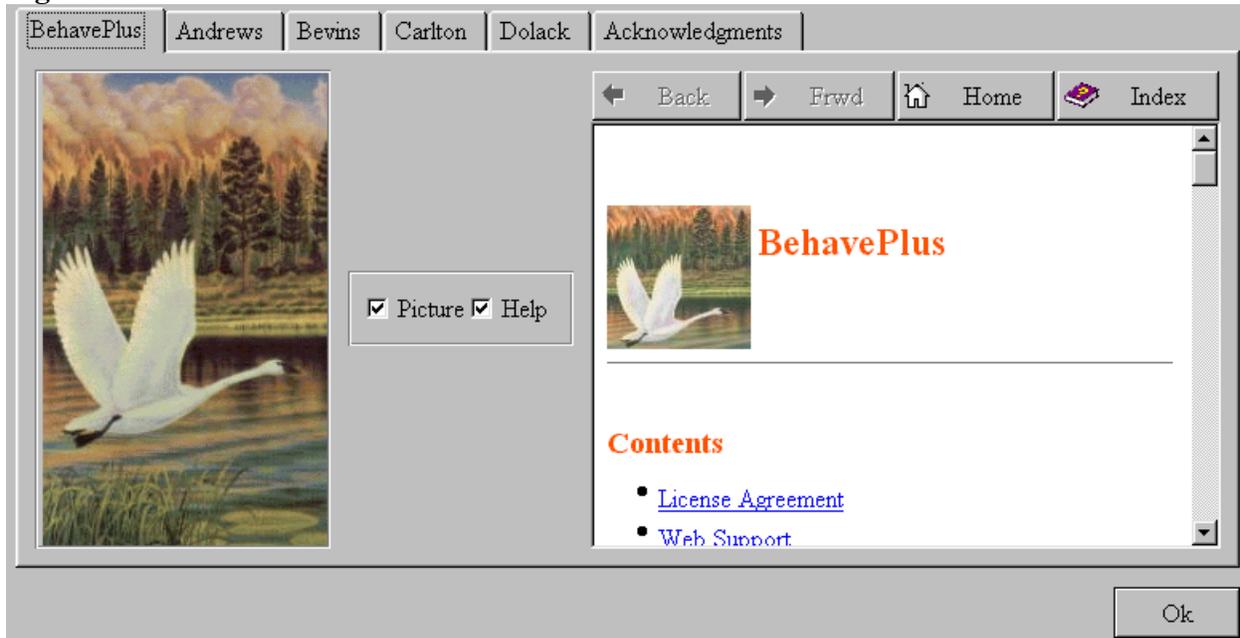
Help

- Program help
- Variable descriptions
- About
- Splash page
- Installation info

About

The Help, About menu item allows for the display of the About screen. This screen Tabs that display information on the program support staff and program sponsorship (Figure 38).

Figure 38



Splash Page

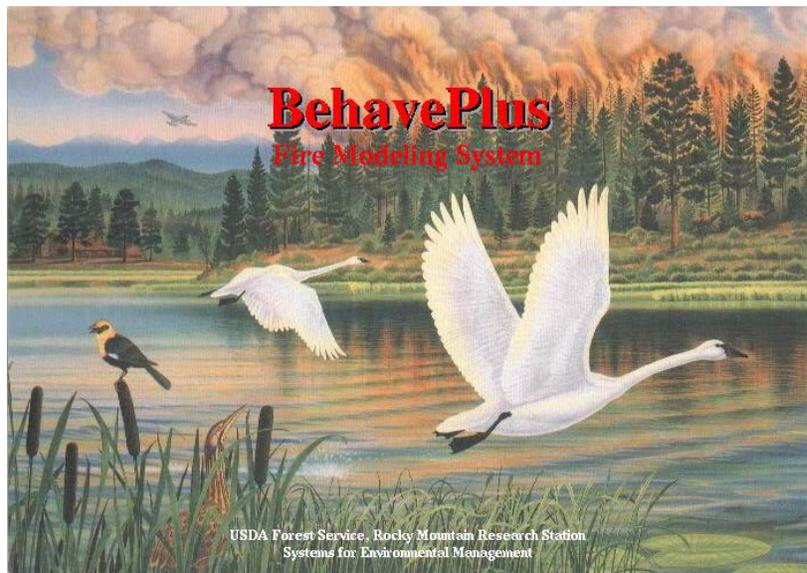
The Help, Splash Page menu item, when clicked, displays the graphic image that appears on the screen when the program starts.

Installation Info

The Help, Installation info menu item allows for display of the installed program version number.

Technical Support

Support for is available online from the Forest Service Help Desk at 800-253-5559 or via Email at fire_help@dms.nwcg.gov.



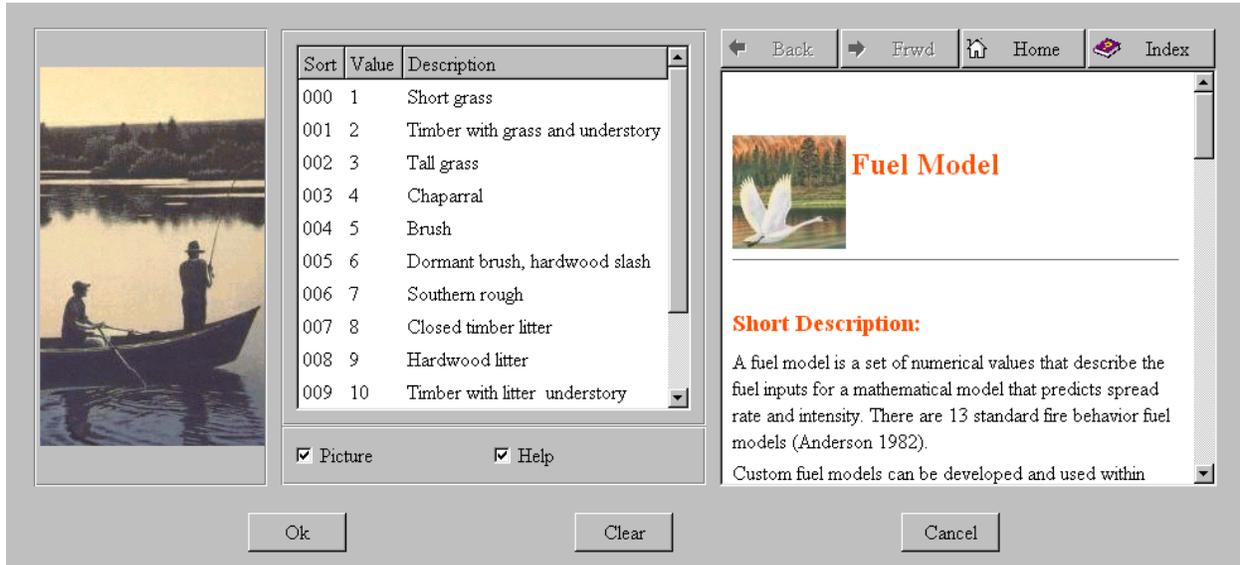
Information on can be found at <http://www.fire.org> .

Worksheet Inputs and Program Outputs

BehavePlus contains a description of each input variable needed or calculations by modules.

By clicking on the Guide Button  to the right of the input on the worksheet, an Assist and Input Guide Screen similar to the one in Figure 39 will be displayed.

Figure 39



The description of the input variable is shown in the browser pane on the right side of the screen. The user can toggle on/off the viewing of this pane by clicking in the box top the left of the Help title in the lower center of the Input Guide Screen.

Description

The first cell on the worksheet is called Description. As a minimum, all worksheets contain a Description input. The user should enter a brief phrase documenting the run. The description is also used to identify the file when it is saved and opened. The run description appears at the top of all output pages and is stored with the Run file. Other worksheet documentation may be entered by selecting Configure->Appearance->Worksheet Tab and checking the Fire projection documentation and/or Training documentation check boxes.

Fire projection documentation (Free text)

If fire projection documentation is selected, the following inputs are provided on the worksheet:

- **Description**
Enter a brief phrase documenting the run. The description is used to identify the file when it is saved and opened.
- **Fire Name**
Enter the name of the fire or project for which the projection is being done.

- **Fire Date & Projection Period**
Enter the date and time for which the fire projection is being done.
- **Fire Analyst**
Enter the name of the person making the run.

Training documentation (Free text)

If training documentation is selected, the following inputs are provided on the worksheet:

- **Description**
Enter a brief phrase documenting the run. The description is used to identify the file when it is saved and opened.
- **Training Course**
Enter the name of the training course.
- **Training Exercise**
Enter the unit, lesson, and exercise identification.
- **Trainee Name and Date**
Enter the name of the trainee and the date of the exercise.

SURFACE Module Inputs

The SURFACE module is used to calculate surface fire behavior parameters such as fire spread rate, flame length and surface fire intensity.

Fuel/Vegetation

Fuels can be entered using a standard fire behavior fuel model (1-13), using a previously saved custom fuel model or by entering the individual fuel parameter values. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- **Standard Fire Behavior Fuel Model (1 - 13)**
A fuel model is a set of numerical values that describe the fuel inputs for a mathematical model that predicts spread rate and intensity. There are 13 standard fire behavior fuel models (Anderson 1982). Fuel models are prepackaged sets of fuel parameters representing stylized fuel situations.

To enter fuels as a standard fire behavior fuel model (1-13), use the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Fuel & Moisture Tab. Select the option for “Fuel is entered as” fuel models. Checking this radio button allows the user to enter fuels via a fuel model rather than a dozen fuel model parameters.

- **Previously Saved Custom Fuel Model**

Before a previously developed custom fuel model can be used, a fuel model must be created and saved with a fuel model set. Refer to the section that follows titled Using Individual Fuel Parameter Values if the user wishes to learn how to create and save a fuel model sets and custom fuel model using *BehavePlus*.

To enter fuels using a previously saved custom fuel model, use the Configure, Fuel model set selection menu to view the Fuel Model Selection screen. Select the fuel model set that contains the custom fuel model desired by highlighting the fuel model set with a single click on the custom fuel model desired and then by clicking on the OK button. This action makes all of the custom fuel models within the fuel model set available for selection when the SURFACE configuration for “Fuel is entered as” fuel models.

- **Using Individual Fuel Parameter Values**

Fuel information can be entered for fuel bed depth, extinction moisture content, heat of combustion, and loading and surface area-to-volume ratio by fuel particle size class. Fire behavior fuel models consist of up to two live (woody and herbaceous) and three dead (1-h, 10-h, 100-h) timelag fuel classes. Fuels larger than the 100-h timelag fuel category, 3.0 inches (7.62 cm) and larger in diameter, are not included in surface fire spread and intensity calculations. Timelag is a term used to refer to the amount of time it takes a dead fuel particle to reach about 63% of the difference between its current moisture content and the equilibrium moisture content.

The individual fuel parameters are as follows.

- C 1-h fuel loading (0 - 30.49 tons/ac) (0.0 - 68.35 tonne/ac)

The one-hour (1-h) timelag dead fuel category includes fuels from 0 to 0.24 inches (0.64 cm) in diameter. This includes needles, leaves, cured herbaceous plants and fine dead stems of plants.

- C 10-h fuel loading (0 - 30.49 tons/ac) (0.0 - 68.35 tonne/ac)

The ten-hour (10-h) timelag dead fuel category includes fuels from 0.25 to 0.99 inch (0.64 to 2.54 cm) in diameter.

- C 100-h fuel loading (0 - 30.49 tons/ac) (0.0 - 68.35 tonne/ac)

The hundred-hour (100-h) timelag fuel category includes fuels from 1 to 2.99 inches (2.54 to 7.62 cm) in diameter.

- C Live herbaceous fuel loading (0 - 30.49 tons/ac) (0.0 - 68.35 tonne/ac)

Live herbaceous fuels are grasses and forbs that are living. Herbaceous fuels can be either annual or perennial.

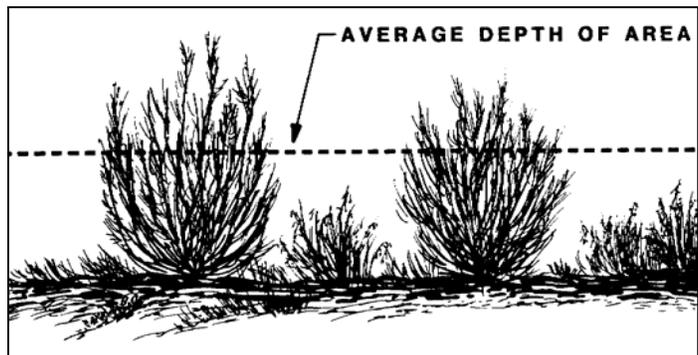
- C Live woody fuel loading (0 - 30.49 tons/ac) (0.0 - 68.35 tonne/ac)

Live woody fuels are shrubs that are living.

- C 1-h surface area to volume ratio (109 - 4000 ft²/ft³) (358-13,123 m²/m³)
The 1-h surface-area-to-volume ratio (1-h SA/V) is the amount of area on the outside of the fuel (surface area) divided by the volume of the fuel. A way to visualize the surface-area-to-volume ratio is the square feet of wrapping paper in would need wrap a box divided by the volume of the box in cubic feet. The 10-h and 100-h SA/V are set at 109 ft²/ft³ (358 m²/m³) and 30 (98 m²/m³) for all fire behavior fuel models.
- C Live herbaceous surface area to volume ratio (109 - 4000 ft²/ft³) (358-13,123 m²/m³)
This is the total surface area of a herbaceous plant leaf divided by the volume occupied by the plant leaf. Live herbaceous fuels frequently have surface-area-to-volume ratios from 1500 to 3500 (ft²/ft³) (4921 to 11,483 m²/m³). Some course grass and some conifer needles have a 1-h SA/V of 500 to 1,500 square feet per cubic foot (1640 to 4921 m²/m³). Average grasses, broadleaf tree leaves can most conifer needles have a 1-h SA/V of 1,500 to 2,500 square feet per cubic foot (4921 to 8202 m²/m³). Fine grasses, most broadleaf tree leaves and some conifer needles have 1-h SA/V of 2,500+ square feet per cubic foot (8202 m²/m³).
- C Live woody surface area to volume ratio (109 - 4000 ft²/ft³) (358-13,123 m²/m³)
This is the total surface area of a woody plant leaf divided by the volume occupied by the plant leaf. Woody fuels frequently have surface-area-to-volume ratios from 1000 to 2000 ft²/ft³ (3281 to 6562 m²/m³).

- C Fuel bed depth
(0.5 - 6.00 ft) (0.2-1.83 m)
This is the average depth of the surface fuel. Fuel bed depth is sometimes called fuel bed bulk depth and should not be confused with the average high particle depth which is an output of the planar intercept dead down woody fuel sampling process (Brown 1974).

Figure 40



- C Dead fuel moisture of extinction (5 - 100%)
This is the maximum moisture content of the dead fuels at a predictable steady state rate of fire spread is attainable. If the dead fuel moisture is greater than this value, a predictable steady state rate of fire spread cannot be predicted even though the fire may continue to smolder and spread.
- C Dead fuel heat content (6,000 - 12,000 Btu/lb) (13,967-27,934kJ/kg)
This is the amount of heat energy contained in a unit of fuels. The heat content for the 13 standard fire behavior fuel models is 8000 BTUs per pound of fuel (18,622 kJoules/kg).

C Live fuel heat content (6,000 - 12,000 Btu/lb) (13,967-27,934kJ/kg)

This is the amount of heat energy contained in a unit of fuels. The heat content for the live fuels in the 13 standard fire behavior fuel models is 8000 BTUs / pound of fuel (18,622 kJoules/kg). Note that this live heat content value applies to both live herbaceous and live woody fuels.

To save a custom fuel model, select the menu File, saveAs, Fuel model.

Fuel Moisture

Fuel moisture can be entered using individual size classes, using the dead and live fuel categories or using a moisture scenario. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- Individual size classes (1-60% for 1-h, 10-h, and 100-h dead fuels) (30-300% for live fuels)
To enter fuel moisture using individual size classes, use the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Fuel & Moisture Tab. Select the option for “Moisture is entered by” individual size classes. Selecting this option enables entry of the moisture content for each fuel size class which has fuel present (1-h, 10-h, and 100-h dead fuels and herbaceous and woody live fuels).
- Dead and live category (1-60% dead fuels) (30-300% for live fuels)
To enter fuel moisture using dead and live categories, use the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Fuel & Moisture Tab. Select the option for “Moisture is entered by” dead and live categories. Selecting this option enables entry of one moisture content value for all dead fuel categories (1-h, 10-h, and 100-h dead) and one moisture content value for the live fuel categories (herbaceous and woody). In summary, selecting this option enables the entry of just two moisture contents; one is applied to all the dead fuels, and the second is applied to all the live fuels.

Hot Tip



For the dead fuel moisture, a value should be entered that approximates the 1-h fuel moisture. For the live fuel moisture, not that type of live fuel loading in the fuel model (herbaceous, woody or both) as the moisture content of live herbaceous and live woody fuel may differ significantly. If significant differences exist, the user should use the “Moisture is entered by” individual size classes or by a moisture scenario configurations.

- Moisture scenario (1-60% for 1-h, 10-h, and 100-h dead fuels) (30-300% for live fuels)
A moisture scenario is a predefined set of fuel moistures for 1-h, 10-h, and 100-h dead fuel and herbaceous and woody live fuel. Fuel moisture scenarios may be developed, for example, to represent local 50th, 90th or 97-percentile weather situations. A moisture scenario MUST contain fuel moistures for all of the fuel categories: 1-h, 10-h, and 100-h dead fuel, live herbaceous and live woody fuel.

To enter fuel moistures using a previously saved moisture scenario, two actions are needed. First, the user needs to “attach” the moisture scenario set. To do this, use the Configure, moisture Scenario set selection menu to view the Moisture Scenario Selection screen. Select the moisture scenario set(s) desired by highlighting the moisture scenario set with a single click on the moisture scenario set and then by clicking on the OK button. This makes the moisture sets identified available to be selected for use in a run. To actually select the moisture scenario to be used, click on the Guide Button to the right of Moisture Scenario on the worksheet. The fuel moisture input guide screen will be displayed. To select a moisture scenario set, click on the desired moisture scenario set and then click on the OK button.

To save a moisture scenario, select the menu File, saveAs, Moisture scenario.

Weather

The weather inputs include a measure of the wind speed as well as a specification of the direction the wind is blowing (either blowing from or blowing toward). For information on how to enter input values, refer to the section titled Overview of Worksheets.

Wind Speed

The wind speed is frequently taken at a National Fire Danger Rating System weather station. The National Fire Weathers Observers Handbook provides the standards for the gathering of weather at stations designated to provide data for the National Fire Danger Rating System. The wind speed measurement is taken at 20 feet above the ground and is measured based on a 10 minute average. Wind speed values used in the SURFACE module should be average expected values that can be expected to occur during the period of time the projection is for.

- Midflame wind speed (0 - 60 mi/h) (0.0 - 96.6 km/h)
This is the wind speed that exists at midflame height above the fuel bed. Midflame is often called eye-level. Technically midflame wind speed is the average wind speed measured from the top of the fuel bed to the height of the flame above the fuel (Albini and Baughman, 1979). Calculation of the height as a function of the flames is not feasible as the variability in the fuel bed depth, the flames, and the wind overwhelm other considerations.
- 20-ft wind and wind adjustment factor (0 - 99 mi/h and 0 - 1) (0.0 - 159 km/h and 0.1-1)
This is the 10 minute average wind speed measured 20 feet above the vegetation.

For fire spread and intensity calculations in SURFACE, the 20-foot wind speed is reduced to the midflame wind speed (sometimes called eye-level wind speed) within *BehavePlus* by multiplying it by the wind adjustment factor.

Wind adjustment factor (WAF), a number between 0 and 1, depends on sheltering of fuels from the wind. If fuels are sheltered from the wind, WAF does not depend on the surface fuel model. If fuels are not sheltered from the wind, WAF is a function of fuel bed depth. The following table documents the wind adjustment factors based on fuel (Albini and Baughman, 1979).

| Fuel Exposure | Fuel Model | Wind. Adj. Factor | |
|--|----------------------|-------------------|-----|
| Unsheltered Fuel Fuel exposed directly to the wind, no overstory or sparse overstory; fuel beneath timber that has lost its foliage; fuel beneath timber near clearings; fuel high on ridges where trees offer little shelter from the wind. | 4 | 0.6 | |
| | 13 | 0.5 | |
| | 1,2,3,5,6,7,10,11,12 | 0.4 | |
| | 8, 9 | 0.3 | |
| Partially Sheltered Fuel Fuel beneath patchy timber where it is not well sheltered; fuel beneath standing timber at midslope or higher on a mountain with wind blowing directly at the slope. | All Fuel Models | 0.3 | |
| Fully Sheltered Fuel Fuel sheltered beneath standing timber on flat or gentle slope or near the base of a mountain with steep slopes. | All Fuel Models | Open Stands | 0.2 |
| | | Dense Stands | 0.1 |

- 10-m wind and wind adjustment factor (0 - 99 mi/h and 0 - 1) (0.0 - 159 km/h and 0.1-1)
This is the 1 minute average wind speed measured 10 meters above the vegetation. There can be significant differences between the 10-meter/1 minute average wind speed and the 20-foot/10 minute average wind speed values. For fire spread and intensity calculations in SURFACE, the 10-m wind speed is reduced to the midflame wind speed (sometimes called eye-level wind speed) within *BehavePlus*. The 10-m wind speed is divided by 1.15 to get the 20-ft wind speed and the wind adjustment factor is then applied to the 20-ft wind speed.

Wind Directions - Specified upslope

If the wind direction is specified as upslope, then the wind is assumed to be blowing directly up the slope hence no wind direction input is required.

If the wind direction is not upslope, then the wind direction must be specified on the worksheet. There are two options available which are:

- the wind direction is specified as degrees clockwise from upslope
- or
- the wind direction is specified as degrees clockwise from north.

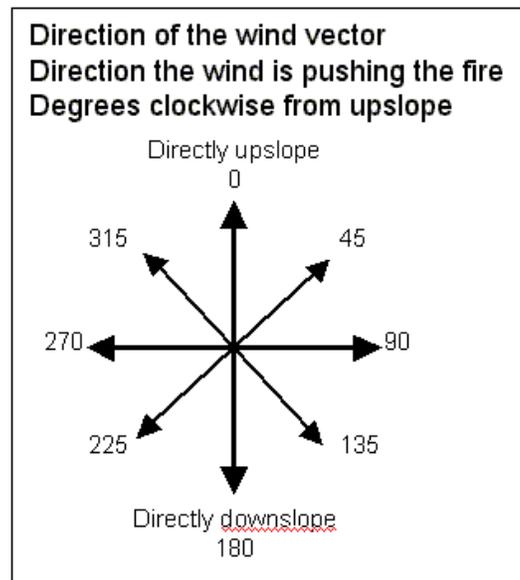
Wind Directions - Specified as degrees clockwise from upslope (0 - 360 deg)

Definition of wind direction depends on the input option that is selected. Selection of *Wind and spread directions are degrees clockwise from upslope* results in the wind direction being the direction that the wind is pushing the fire. This is the method used in the old BEHAVE system, and was meant to be used in vectoring wind and slope influences.

- Direction of the wind vector (from upslope)
To enter the direction of the wind vector as degrees clockwise from upslope, use the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Wind & Fire Directions Tab. Select the option for “Wind & spread directions are” degrees clockwise from upslope.

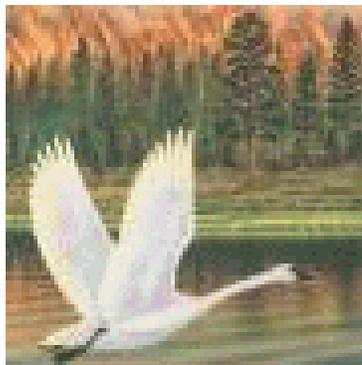
When this option is selected, *BehavePlus* treats the wind direction as the direction the wind is pushing the fire relative to the upslope direction (NOT the direction from which the wind is blowing). Enter 0 degrees for an upslope wind, 180 degrees for a downslope wind, 90 degrees for a "right-to-left" blowing cross slope wind, and 270 degree for a "left-to-right" blowing cross slope wind.

Figure 41



Hot Tip

The user should be careful to know the direction the wind is blowing from and hence the direction the wind is blowing towards. Accidentally interchanging these two will lead to seriously flawed fire spread projections.



Wind Directions - Specified as degrees clockwise from north (0 - 360 deg)

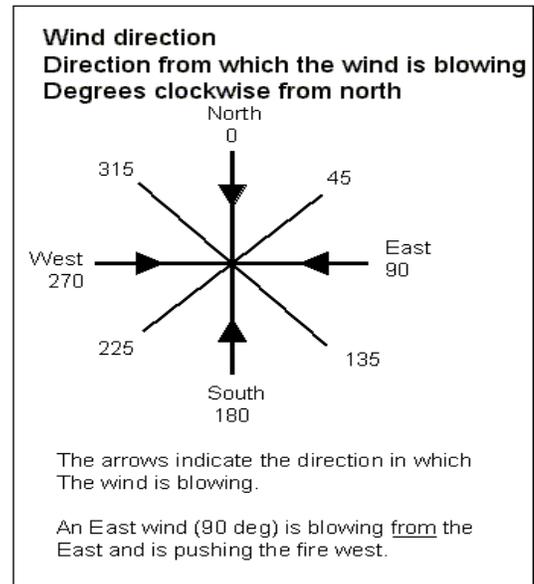
Selection of *Wind and spread directions are degrees clockwise from north* results in the wind direction being the direction from which the wind is blowing. A North wind is blowing toward the south. The user should be careful to know the direction the wind is blowing from and hence the direction the wind is blowing towards. Accidentally interchanging these two will lead to seriously flawed fire spread projections.

- Wind Direction (from north)

To enter the direction of the wind vector as degrees clockwise from north, use the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Wind & Fire Directions Tab. Select the option for “Wind & spread directions are” degrees clockwise from north.

When this option is selected, *BehavePlus* treats the wind direction as the direction from which the wind is blowing; e.g. an east wind is blowing from the east and is pushing the fire to the west. In this case, enter 90 degrees to specify an east wind.

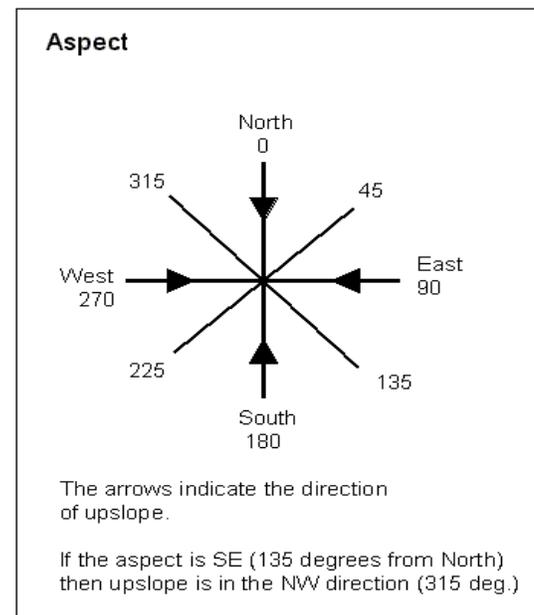
Figure 42



- Aspect (0 - 360 deg)

For *BehavePlus* to correctly perform its calculations using this method of specifying the wind direction, the aspect of the projection site must be specified. The Aspect is the direction a slope faces; i.e. a south aspect faces south. The Aspect in *BehavePlus* is specified in degrees; i.e. north aspect = 0, east aspect = 90, south aspect = 180 and west aspect = 270.

Figure 43



Terrain

The terrain section of the worksheet is where slope steepness is entered and the aspect is specified. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- Slope Steepness (0 - 100% or 0-45 degrees)
To enter the slope steepness directly on the worksheet, set the configuration by using the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Slope Tab. Select the option for “Slope steepness is” specified on the worksheet.
- Aspect (0 - 360 deg)
See description on *Wind Directions - Specified as degrees clockwise from north.*

Map

The Map section on the worksheet is used to input values needed by *BehavePlus* to calculate map distances and slope steepness. For information on how to enter input values, refer to the section titled Overview of Worksheets.

To have *BehavePlus* calculate the slope steepness, set the configuration by using the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Slope Tab. Select the option for “Slope steepness is” calculated from map measurements. To calculate map distances for selected distance output variables, select “Display output distances in map units” on the module selection screen. Input variables are:

- Map representative fraction (1,980 - 1,013,760)
The map representative fraction is the ratio of the number of units on the map between two points to the distance on the ground between these same two points. For example, if the map representative fraction is 1:24,000, then for each inch on the map there are 24,000 inches on the ground. Entry on the worksheet is us use if the map value in the ratio; ie. 1:24,000 would be entered in the box to the right of Map representative fraction as 24000.
- Contour interval (1 - 1000 ft) (0.3 – 304.8 m)
The contour interval is the difference in elevation between adjacent topographic contours on a topographic map.
- Map Distance (0.10 - 100.00 in.) (0.3 - 254 cm)
The map distance is the distance between two points on a map generally expressed in inches or centimeters.
- Number of Contour Intervals (1 - 100)
The contour interval is the difference in elevation between adjacent topographic contours on a topographic map.

Fire

The Fire section on the worksheet is used to input Spread Direction that the user wishes for *BehavePlus* to calculate the fire behavior outputs; ie. rate of spread, spread distance, etc This section appears on the worksheet when SURFACE is configured to display the rate of spread in directions specified on the worksheet. To configure *BehavePlus* to display the rate of spread in directions specified on the worksheet, use the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Wind & Fire Directions Tab. Select the option for “Rate of spread is calculated” in directions specified on the worksheet. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- Spread Direction (from upslope) (Figure 44)
Enter the direction of the wind vector as degrees clockwise from upslope.
- Spread Direction (from north) (Figure 45)
Enter the direction of the wind vector as degrees clockwise from north.

Figure 44

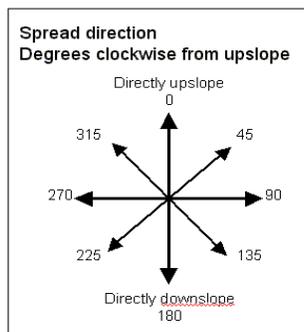
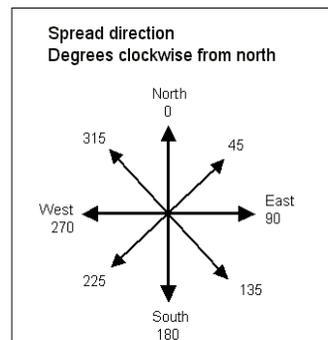


Figure 45



The Fire section on the worksheet is also used to input the length of time for the projection. It is needed if the Spread Distance is specified as a desired output from SURFACE or is needed for calculated related to another module; i.e. SIZE. For SURFACE, this section appears on the worksheet when SURFACE is configured to display the spread distance. To configure *BehavePlus* to display the spread distance, use the Configure, Module selection menu to view the Module Selection screen. Click on the SURFACE Option button and select the Output Variables Tab. Select Spread Distance as an output. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- Elapsed Time (0.5 - 8.0 h)
The time from when a fire begins spreading until a time that the user wants to know the fire's spread distance or size. The fire is assumed to be spreading at a constant rate during this time period. Elapsed time can also be referred to as projection time. The fuel model, fuel moisture, wind speed and direction, and slope steepness (and thus the rate of spread) are assumed to be constant for the entire elapsed time. Because wildland fires almost always burn under non-uniform conditions, the elapsed time and choice of input values must be considered carefully to achieve useful projections.

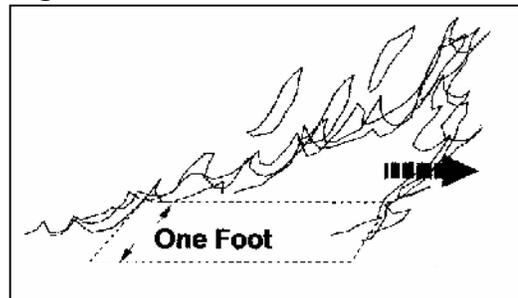
SURFACE Module Outputs

The user can select the output of the following values.

- **Rate of Spread (Default Selection)**
Rate of spread is the “speed” the fire travels through the surface fuels. A SURFACE input option determines whether rate of spread calculations are done for the direction of maximum spread or for any other direction as specified on the worksheet. The maximum rate of spread is the spread rate of the head fire. This value is used along with elapsed time to determine the size of an elliptically shaped fire in SIZE. The rate of spread prediction uses the Rothermel (1972) surface fire spread model, which assumes the weather, topography and fuels remain uniform for the elapsed time. The Y-axis value on the Fire Characteristics Chart is rate of spread (Figure 49).
- **Heat per Unit Area (Default Selection)**
The heat energy release per area (square foot or square meter) within the flaming front. Heat per unit area is not affected by wind, slope, or direction of spread. Additional energy is released in the burnout phase of combustion, so care should be exercised when using heat per unit area to predict second order fire effects. The X-axis value on the Fire Characteristics Chart is heat per unit area (Figure 49).

- **Fireline Intensity (Default Selection)**
The heat energy release per unit time from a one-foot (one-meter) wide section of the fuel bed extending from the front to the rear of the flaming front. Fireline intensity is a function of rate of spread and heat per unit area, and is directly related to flame length. Fireline intensity and the flame length are related to the heat felt by a person standing next to the flames.

Figure 46



- **Flame Length (Default Selection)**
The length of the flame in a spreading surface fire within the flaming front. Flame length is measured from midway in the combustion zone to the average tip of the flames. "Flame length is an elusive parameter that exists in the eye of the beholder. It is a poor quantity to use in a scientific or engineering sense, but it is so readily apparent to fireline personnel and so readily conveys a sense of fire intensity that it is worth featuring as a primary fire variable" (Rothermel 1991). Flame length is shown on the Fire Characteristics Chart as the curved lines in the chart (Figure 49). Interpretations based on flame length are shown in Figure 48.

Figure 47

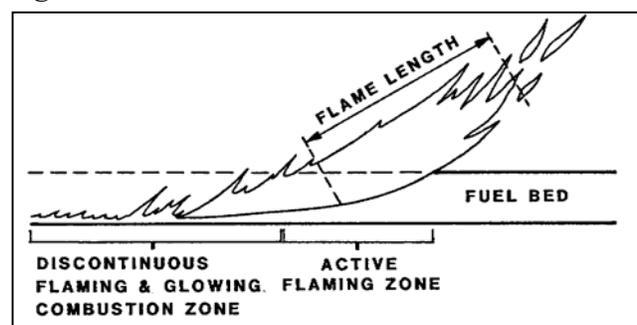
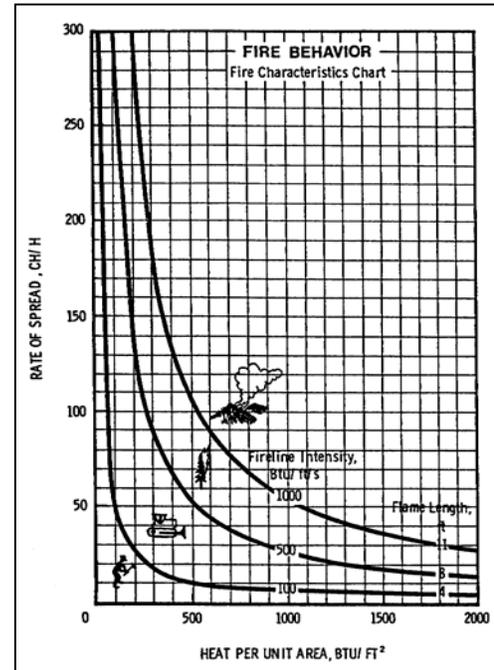


Figure 48

| Flame Length (ft) | Fireline Intensity (Btu/ft/s) | Interpretations |
|-------------------|-------------------------------|--|
| Under 4 | Under 100 | Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire. |
| 4-8 | 100-150 | Fires are too intense for direct attack on the head by persons using hand tools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, pumpers, and retardant aircraft can be effective. |
| 8-11 | 500-1000 | Fires may present serious control problems -- torching out, crowning, and spotting. Control efforts at the fire head will probably be ineffective. |
| Over 11 | Over 1000 | Crowning, spotting, and major fire runs are probable. Control efforts at head of fire are ineffective. |

Figure 49

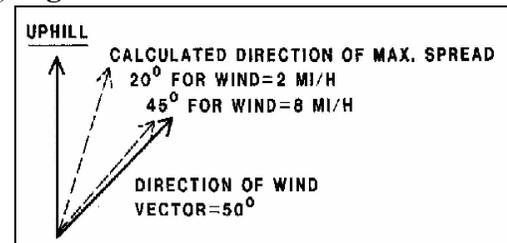


■ **Reaction Intensity**

Rate of the energy release per area (square foot or square meter) within the flaming front. It is equal to the heat per unit area times the residence time. Residence time is the time that a given spot on the ground is in the flaming front. Reaction intensity is not affected by wind, slope, or direction of spread.

■ **Direction of Maximum Spread (Default Selection) Figure 50**

When the wind is not blowing directly uphill, the direction of maximum spread will be between the uphill direction and the direction in which the wind is blowing. This direction will be expressed as either “degrees clockwise from upslope” or “degrees clockwise from north” depending on the configuration of SURFACE.



■ **Spread Distance**

The distance a fire travels during a specified elapsed time. It is the product of the rate of spread and elapsed time.

■ **Midflame Wind Speed**

If the 20-ft or 10-m wind speed and the adjustment factor are input to SURFACE, the midflame wind speed is an output. See Midflame wind speed in inputs section above for a description of the midflame wind speed.

- **Effective Wind Speed**

The combined effect of midflame wind speed and slope steepness in the direction of the spread calculation. The effective wind speed in the direction of maximum spread is used to determine the shape (length-to-width ratio) of a point source fire.

- **Maximum Reliable Wind Speed**

The maximum midflame wind speed used in the surface fire spread model calculations. It is a function of reaction intensity. Mathematically, the following is calculated with in *BehavePlus*:

$$\text{Maximum Reliable Wind Speed (mi/h)} = 0.01 * \text{Reaction Intensity (Btu/ft}^2\text{/min)}$$

At high wind speeds, fire spread rate can become difficult to predict. In fact, studies have shown that at high wind speeds, the spread rate can actually decrease when the wind speed increases. The wind speed at which predictions of rate of spread by the Rothermel spread model become unreliable is called the windspeed limit. If the user enters a windspeed that is higher than this wind speed limit, the model uses the maximum reliable wind speed limit value in the fire spread calculation.

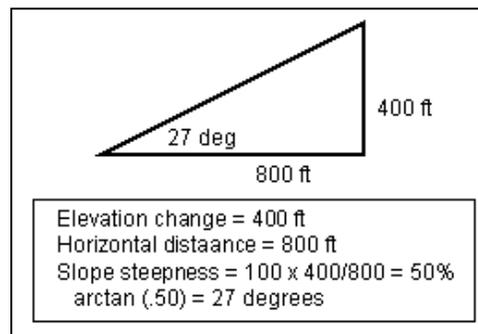
- **Maximum Wind Exceeded? (Default Selection)**

This is an indication of whether the maximum reliable wind speed, as calculated in the surface fire spread model, has been exceeded. If so, the maximum reliable wind speed is used in the calculations.

- **Slope Steepness**

If the slope steepness is calculated by *BehavePlus* from map measurements (inputs), then the slope steepness is a SURFACE output. This is the maximum steepness of the slope. It is expressed as either percent or degrees depending on the input option that is selected. Note that this is not the slope steepness in the direction of spread.

Figure 51



- **Slope Elevation Change**

This is the difference in elevation between the two selected locations on the ground between which the slope steepness is being calculated. It is an intermediate value in the calculation of slope steepness from map measurements.

- **Slope Horizontal Distance**

This is the difference in horizontal distance as measured on a map between the two selected locations on the ground between which the slope steepness is being calculated. It is an intermediate value in the calculation of slope steepness from map measurements.

SIZE Module Inputs

The SIZE module is used to calculate the area and perimeter of a fire that starts from a point source. For information on how to enter input values, refer to the section titled Overview of Worksheets.

Weather

- Effective Wind Speed (0.0 - 60.0 mi/h) (0.0 - 96.6 km/h)
The combined effect of midflame wind speed and slope steepness in the direction of the spread calculation. The effective wind speed in the direction of maximum spread is used to determine the shape (length-to-width ratio) of a point source fire.

Fire

The Fire section on the worksheet is used to input the rate of spread for the projection. It is also used to input the length of time for the projection.

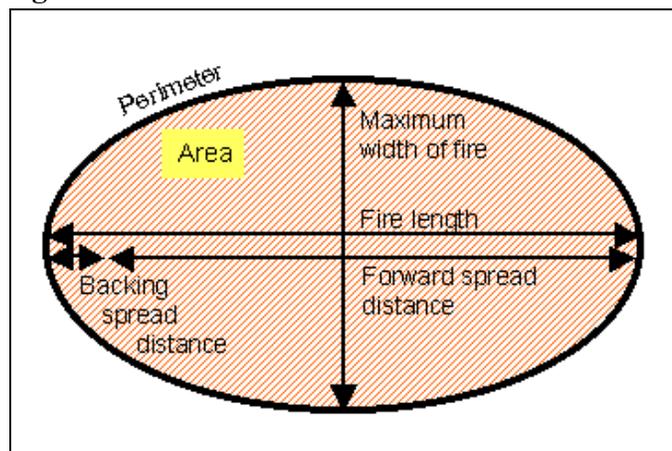
- Rate of Spread (maximum) (0 - 500 ch./h) (0.0 - 167.6 m/min)
Rate of spread is the "speed" the fire travels through the surface fuels. The maximum rate of spread is the spread rate of the head fire. This value is used along with elapsed time to determine the size of an elliptically shaped fire in SIZE.
- Elapsed Time (0.5 - 8.0 h)
The time from when a fire begins spreading until a time that the user wants to know the fire's spread distance or size. The fire is assumed to be spreading at a constant rate during this time period. Elapsed time can also be referred to as projection time. The fuel model, fuel moisture, wind speed and direction, and slope steepness (and thus the rate of spread) are assumed to be constant for the entire elapsed time. Because wildland fires almost always burn under non-uniform conditions, the elapsed time and choice of input values must be considered carefully to achieve useful projections.

SIZE Module Outputs

The user can select the outputs desired from the following seven values.

- Area (Default Selection)
This is the area of an elliptically shaped fire which started from a point source. Calculations are based on maximum rate of spread, effective wind speed, and elapsed time. Anderson (1983) expanded on the work of Fons (1942) to develop the double ellipse-based equations to describe fire shape. *BehavePlus* (as well as the old BEHAVE and Farsite) uses a simple ellipse model to characterize fire size and shape.

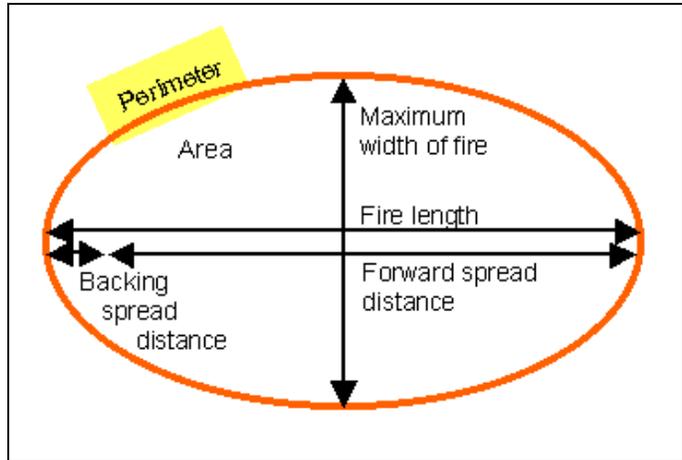
Figure 52



- **Perimeter (Default Selection)**

The perimeter of a fire is based on the elliptical fire shape model. Perimeter is the distance around the outside of the ellipse. As with the area, the perimeter is dependent on the maximum rate of spread, effective wind speed, and elapsed time.

Figure 53



- **Length-to-Width Ratio**

This is the length-to-width ratio of an elliptically shaped fire, also called length-to-breath ratio. The length-to-width ratio is a function of the effective wind speed. Fire burning under a high wind speed will be long and narrow with a large length-to-width ratio. (Figure 54).

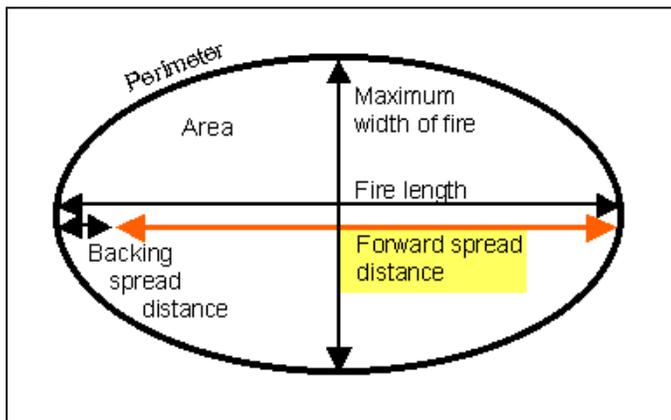
Figure 54

| Effective wind speed mi/h | Length-to-width ratio |
|---------------------------|-----------------------|
| 1 | 1.3 |
| 3 | 1.8 |
| 5 | 2.3 |
| 7 | 2.8 |
| 11 | 3.8 |
| 15 | 4.8 |

- **Forward Spread Distance**

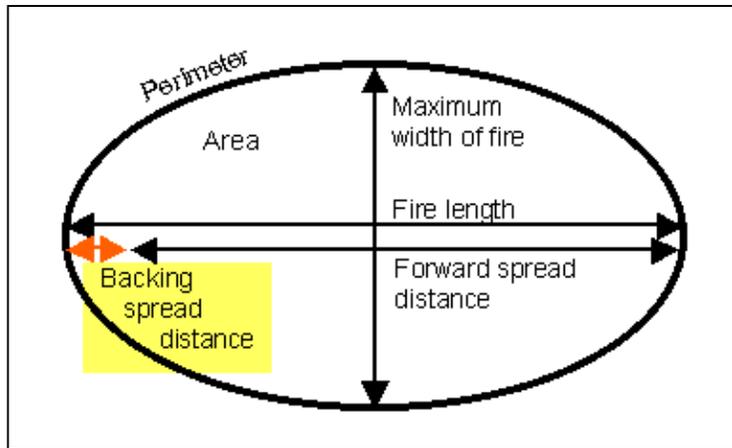
This is the distance the fire travels in the direction of maximum spread in a specified period of time. (Figure 55)

Figure 55



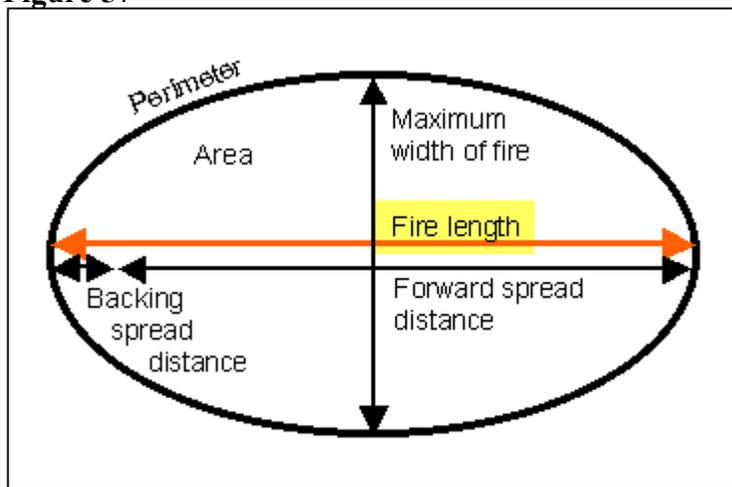
- Backing Spread Distance**
 The backing spread distance is based on the elliptical fire shape model and is the distance the fire travels in a specified period of time in the direction of 180 degrees from the direction of maximum spread. (Figure 56)

Figure 56



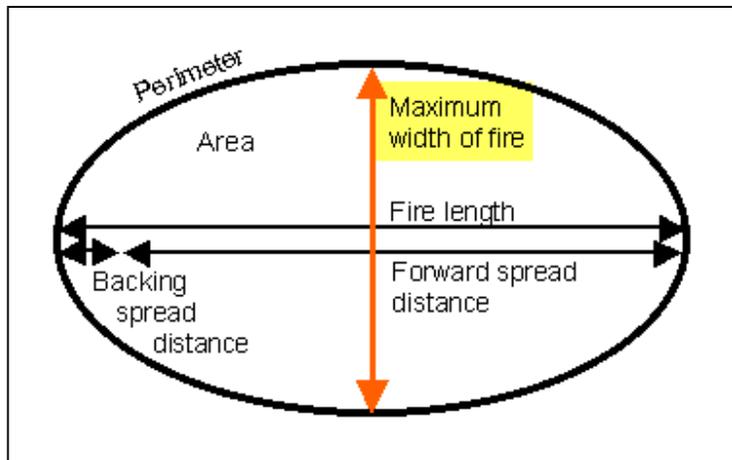
- Fire Length**
 The distance from the head of a fire to the back end of the fire calculated for an elliptically shaped fire. Fire length is the sum of the forward spread distance and the backing spread distance. (Figure 57)

Figure 57



- Maximum Width of the Fire**
 The maximum width of a fire is based on the elliptical fire shape model and is maximum width of the ellipse. (Figure 58)

Figure 58



SPOT Module Inputs

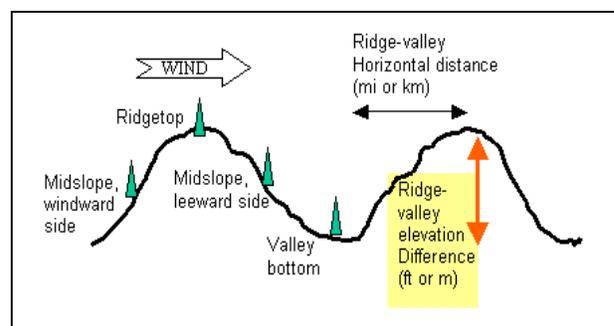
The SPOT module is used to calculate the maximum spotting distance for fires where the originating fire brand is produced from torching trees, a burning pile or a wind driven surface fire. For information on how to enter input values, refer to the section titled Overview of Worksheets.

These input values for calculating the spotting distance from torching trees have no configuration options but are as follows:

- **Mean Cover Height (0 - 300 ft) (0 - 91 m)**
The mean cover height is the average height of the vegetation in the downwind direction from the spotting source location. If the area downwind is open, enter the average height of the vegetation divided by two.
- **Tree Height (0 - 300 ft) (0 - 91 m)**
The tree height is the distance from the ground to the top of a tree. Tree height is used to calculate percent crown volume scorched, which is used to calculate tree mortality.
- **Spot Tree Species (ABIBAL, ABIGRA, ABILAS, PICENG, PINCON, PINECH, PINELL, PINMON, PINPAL, PINPON, PINSER, PINTAE, PSEMEN, TSUHET)**
This is the tree species and care should be used to use correct tree codes. Top view and list of tree codes for species, click on the Guide Button. Tree species available are: Balsam fir, Douglas-fir, Engelmann Spruce, Grand Fir, Longleaf Pine, Loblolly Pine, Lodgepole Pine, Pond Pine, Ponderosa Pine, Subalpine Fir, Shortleaf Pine, Slash Pine, Western Hemlock, Western Larch, Western Red Cedar and Western White Pine. If the tree species of interest is not listed, the user with caution should select a surrogate.
- **D.B.H. (Diameter Breast Height) (5 - 40 in) (13 -102 cm)**
DBH is the abbreviation for diameter breast high. It is the measurement of the diameter of a tree measured at about 4.5 feet (1.4 meters) from the ground level.
- **20-ft Wind Speed (0 - 99 mph) (0.0 - 159 km/h)**
This is the wind speed 20 feet above the vegetation. In SPOT, this is the wind that carries the embers.

- **Ridge-to-Valley Elevation Difference (0 - 4000 ft) (0 - 1,219 m)**
The ridge-to-valley elevation difference is the vertical distance between the ridge top and the valley bottom in the direction of the wind flow. A stylized terrain shape is used by the model to support calculation of the maximum spotting distance. (Figure 59) If winds are blowing directly up a valley or down a valley, the ridge-to-valley elevation difference most likely is zero. Note that ridge-to-valley elevation difference is in feet (or meters).

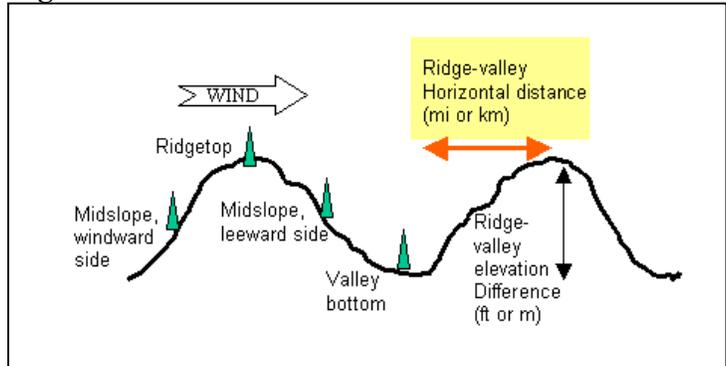
Figure 59



- Ridge-to-Valley Horizontal Distance (0.0 - 4.0 mi) (0 - 6.4 km)

The ridge-to-valley horizontal distance is the horizontal distance between the ridge top and the valley bottom in the direction of the wind flow. A stylized terrain shape is used by the model to support calculation of the maximum spotting distance. (Figure 60) If winds are blowing directly up a valley or down a valley, the ridge-to-valley horizontal distance most likely is zero. Note that the ridge-to-valley horizontal distance is in miles (or kilometers).

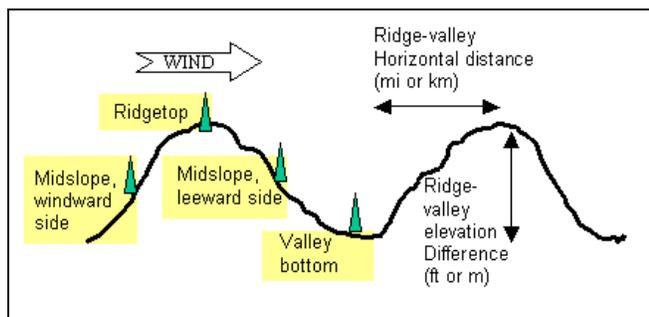
Figure 60



- Spotting Source Location (RT, MW, VB, ML)

The spotting source location refers to the origin of the firebrands that can result in spotting. The possible locations are ridge top (RT); mid-slope, leeward side (MW); valley bottom (VB); and mid-slope, windward side (ML). The model uses a stylized terrain shape.

Figure 61



- Number of Torching Trees (0 - 30)

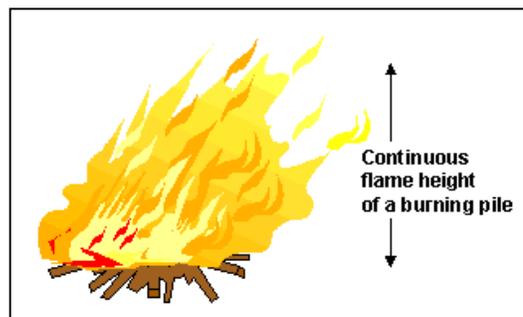
This is the number of trees that torch simultaneously. It is used to calculate the height at which firebrands are lofted.

Calculation of the spotting distance from a burning pile requires input of the Mean (Tree) Cover Height, the 20-ft Wind Speed, the Ridge-to-Valley Elevation Difference, the Ridge-to-Valley Horizontal Distance and the Spotting Source Location. These are described above. In addition, the following input is required:

- Flame Height from a Burning Pile (0.0 - 100.0 ft) (0 - 30.5 m)

The average height of the flames measured from the base of a burning pile. Note that flame length and flame height are different measures.

Figure 62



Calculation of the spotting distance from a wind driven surface fire requires input of the Mean Cover Height, the 20-ft Wind Speed, the Ridge-to-Valley Elevation Difference, the Ridge-to-Valley Horizontal Distance and the Spotting Source Location. These are described above. In addition, the following input is required:

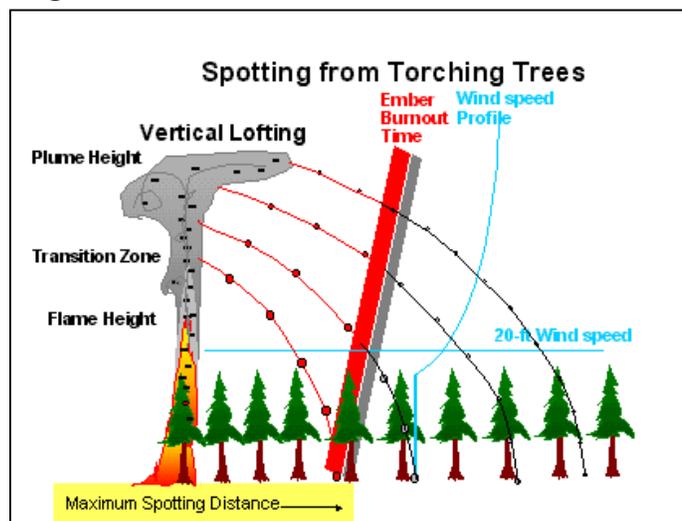
- **Flame Length (0.0 - 100.0 ft) (0 - 30.5 m)**
The length of the flame in a spreading surface fire within the flaming front. Flame length is measured from midway in the combustion zone to the average tip of the flames. "Flame length is an elusive parameter that exists in the eye of the beholder. It is a poor quantity to use in a scientific or engineering sense, but it is so readily apparent to fireline personnel and so readily conveys a sense of fire intensity that it is worth featuring as a primary fire variable." (Rothermel 1991)

SPOT Module Outputs

The user can select the outputs desired as follows:

- **Spotting Distance from Torching Trees (in miles) (Default Selection)**
This is the maximum distance that one can expect potential spot fires resulting from firebrands from torching trees. The spotting model is applicable under conditions of intermediate fire severity in which spotting distance up to a mile or two might be expected. This model does not apply to those extreme where spotting may occur up to tens of miles from the fire front. The model is for spotting from torching trees, not from a spreading crown fire.

Figure 63



- **Spotting Distance from a Burning Pile (in miles)**
The maximum distance that one can expect potential spot fires resulting from firebrands from the burning pile. The height of the flames from the pile is an input, which is used to calculate the lofting strength from the burning pile.
- **Spotting Distance from a Wind Driven Surface Fire (in miles)**
The maximum distance that one can expect potential spot fires based on firebrands from the spreading surface fire. The model is applicable only if the fire is truly wind-driven through surface fuels that are not sheltered from the wind by overstory.

SCORCH Module Inputs

The SCORCH module is used to calculate the height above the ground that the temperature in the convection column reaches the lethal temperature to kill live crown foliage. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- **Flame Length (Default Selection) (0.0 - 100.0 ft) (0 - 30.5 m)**

The length of the flame in a spreading surface fire within the flaming front. Flame length is measured from midway in the combustion zone to the average tip of the flames. If both SURFACE and SCORCH modules are selected, midflame wind speed and the flame length in the direction of the spread calculation are used input to SCORCH. "Flame length is an elusive parameter that exists in the eye of the beholder. It is a poor quantity to use in a scientific or engineering sense, but it is so readily apparent to fireline personnel and so readily conveys a sense of fire intensity that it is worth featuring as a primary fire variable." (Rothermel 1991)

or

- **Fireline Intensity (0 - 10000 BTU/ft/s) (0 -34,641 kW/m)**

The heat energy release per unit time from a one-foot (one-meter) wide section of the fuel bed extending from the front to the rear of the flaming front. Fireline intensity is a function of rate of spread and heat per unit area, and is directly related to flame length. Fireline intensity and the flame length are related to the heat felt by a person standing next to the flames.

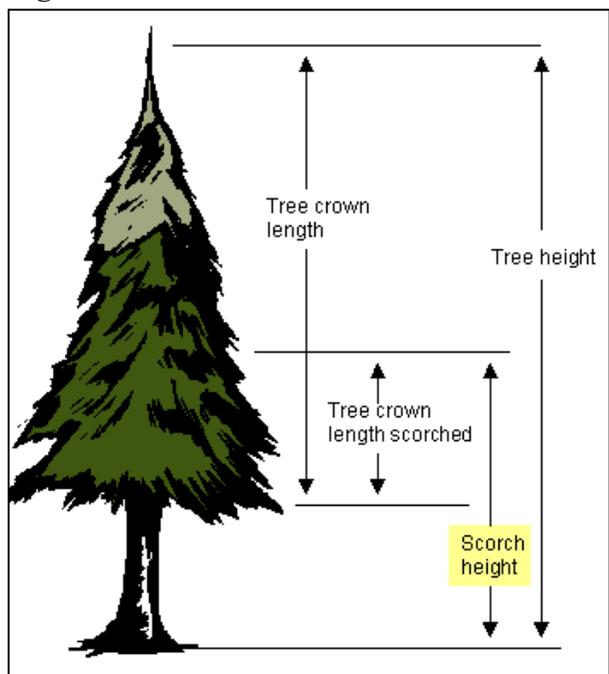
SCORCH Module Outputs

The SCORCH module has only one output:

- **Scorch Height (Default Selection)**

The height above the ground that the temperature in the convection column reaches the lethal temperature to kill live crown foliage. This temperature is assumed to be 140 degrees Fahrenheit (60 Celsius).

Figure 64



MORTALITY Module Inputs

The MORTALITY module is used to calculate probability that a specific tree will die from a surface fire. For information on how to enter input values, refer to the section titled Overview of Worksheets.

Input Variables

Input variables that have no configuration options are:

- **Tree Height (10 - 300 ft) (0 - 91 m)**
The tree height is the distance from the ground to the top of a tree. Tree height is used to calculate percent crown volume scorched, which is used to calculate tree mortality.
- **Mortality Tree Species (206 species)**
These are the tree species available for estimating bark thickness and fire-induced tree mortality.

- **Crown Ratio (0.1 - 1.0)**
The proportion of the total vertical tree height that is occupied by the vertical length of the tree crown.

$$\text{Crown Ratio} = \frac{\text{Live Crown Length}}{\text{Tree Height}}$$

Figure 65

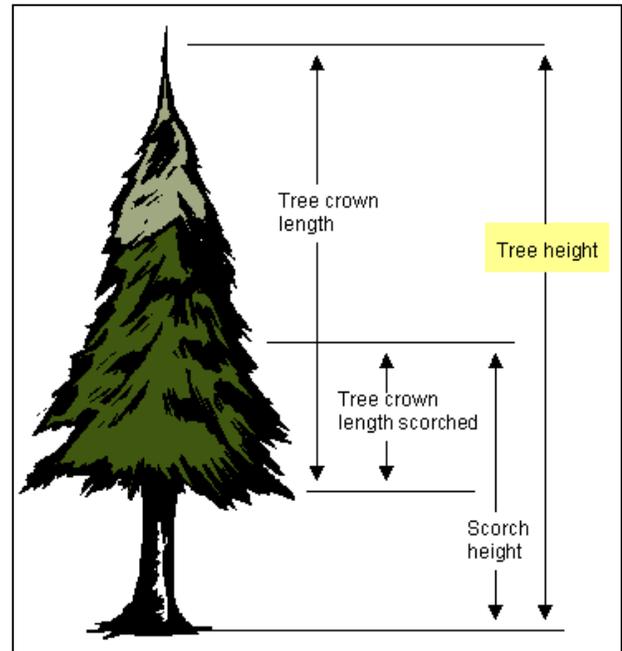
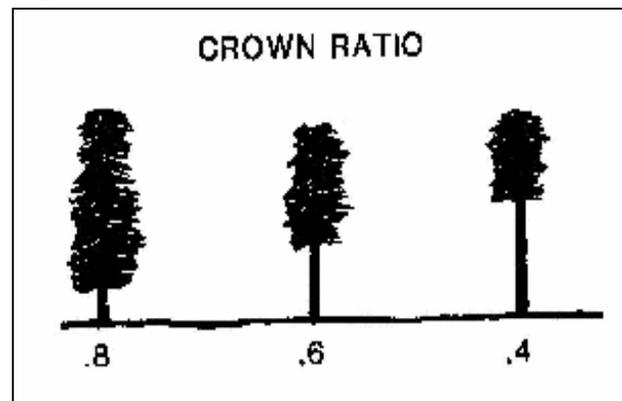


Figure 66



The input variable where configuration is possible is:

- **Bark Thickness (0.1 - 2.0 in) (0.3 - 5.1 cm)**
This is the thickness of the tree bark, which affects mortality due to cambium damage. The equations to calculate bark thickness have been changed from those used in the old BEHAVE (Andrews and Chase 1989) to match those that will be implemented First Order Fire Effects Model (FOFEM) (Reinhardt, et. al. 1997).

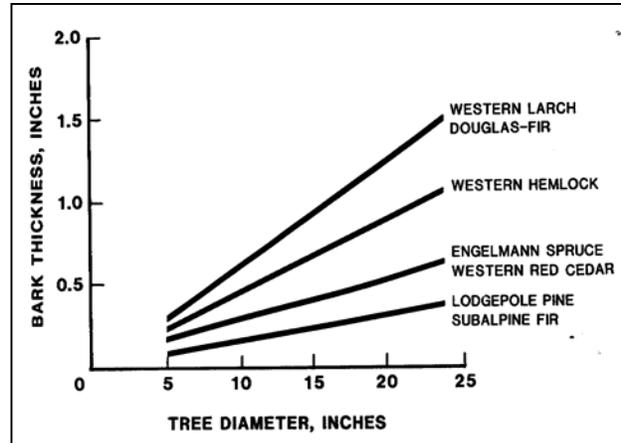
The bark thickness can be:

- Specified on the worksheet (Default Selection)

or

- Estimated from Mortality Tree Species and d.b.h. (diameter breast height). The bark thickness can be estimated from the tree species and d.b.h.

Figure 67



- Scorch Height

The height above the ground that the temperature in the convection column reaches the lethal temperature to kill live crown foliage. This temperature is assumed to be 140 degrees Fahrenheit (60 Celsius).

MORTALITY Module Outputs

The user can select the outputs desired as follows:

- Bark Thickness

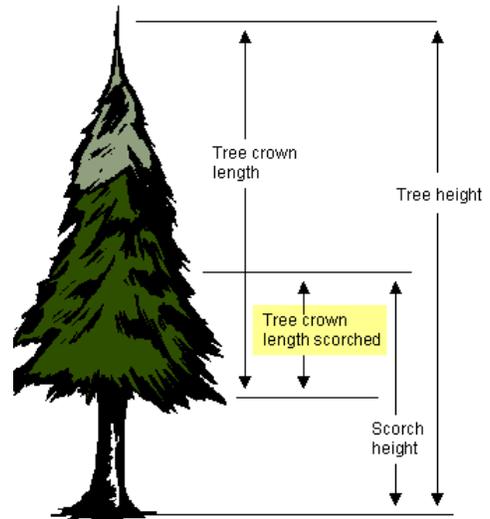
This is a program output if the bark thickness is calculated by *BehavePlus*.

- Tree Crown Length Scorched

This is the length of the tree crown that is scorched. It is calculated as Scorch Height - (Tree Height - Live Crown Length). If scorch height is greater than the tree height, then the Length of the Tree Crown Scorched equals the Live Crown Length. Tree crown length scorched is used to calculate percent crown volume scorched, which is used to calculate tree mortality (see Figure 62).

- Tree Crown Volume Scorched

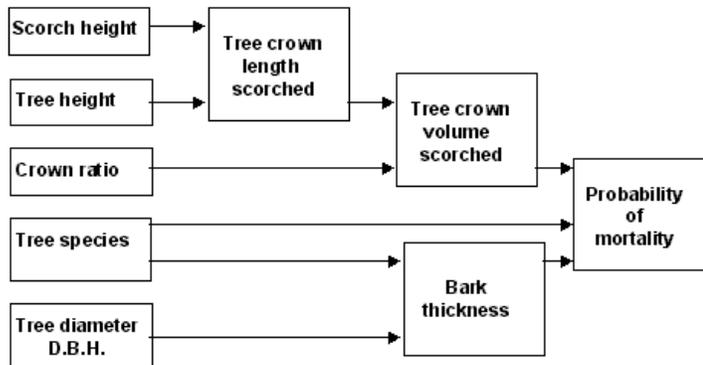
This is the percentage of the tree crown volume that is scorched is calculated from the length of tree crown scorched and the total crown length. It is used to calculate tree mortality.



- **Probability of Mortality (Default Selection)**

This is the probability of mortality and is the likelihood that a tree will be killed by a fire. Probability of mortality is based on bark thickness and percent crown volume scorched, which are derived from scorch height, tree height, crown ratio, species, and tree diameter.

Figure 68



IGNITE Module Inputs

The IGNITION module is used to calculate the probability that a firebrand will cause an ignition. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- **1-h Moisture (1 - 60%)**

The 1-h fuel moisture content is the percent of the 1-h timelag dead fuel that is water, calculated on a dry weight basis. Timelag is a term used to refer to the amount of time it takes a dead fuel particle to reach about 63% of the difference between its current moisture content and the equilibrium moisture content.

- **Air Temperature (-40 to 120 degrees F) (-40 - 40 deg C)**

This is the ambient dry bulb temperature measured in the shade.

- **Fuel Shading from the Sun (0 - 100%)**

Percent of the fuel that is not receiving direct sunlight due to cloud cover and overstory. Frequently, a fuel surface with 0% to 49% shading is referred to as being in an unshaded condition. A fuel surface with 50% to 100% shading is referred to as being in a shaded condition.

IGNITE Module Outputs

The IGNITE module has only one output:

- **Probability of Ignition from a Firebrand**

The probability of ignition is an indication of the chance that a firebrand will cause an ignition. The number of firebrands, their size, and the fuel on which they land is unknown. Probability of Ignition should not be confused with Ignition Component from the National Fire Danger Rating System (Deeming et al. 1977).

RH Module Inputs

The RH module is used to calculate the relative humidity and/or dew point for a parcel of air. For information on how to enter input values, refer to the section titled Overview of Worksheets.

- Dew Point and Dry Bulb Temperatures (Default Selection)
 - Dew Point (-40 to 120 degrees F) (-40 - 40 deg C)
The temperature at which a given parcel of air will have 100 percent relative humidity assuming no additional moisture is added or removed. If a given parcel of air has an air temperature higher than the dew point temperature and that parcel of air is cooled to the dew point without any moisture being added or removed, then the relative humidity of the parcel of air will be 100 percent and further cooling will cause rain, fog, etc. to occur.
 - Dry Bulb Temperature (-40 to 120 degrees F) (-40 - 40 deg C)
The ambient dry bulb temperature measured in the shade.
- Dry Bulb and Wet Bulb Temperatures and Elevation (above MSL)
 - Dry Bulb Temperature (-40 to 120 degrees F) (-40 - 40 deg C)
The ambient dry bulb temperature measured in the shade.
 - Wet Bulb Temperature (-40 to 120 degrees F) (-40 - 40 deg C)
Wet bulb temperature is the steady value reached during a period of brisk ventilation of a thermometer with a water soaked muslin wick surrounding the thermometer bulb. If the air is saturated, the wet bulb and dry bulb temperatures are the same.
 - Site Elevation (-1,000 to 30,000 ft)
This is the elevation above sea level where the observations are being taken.

RH Module Outputs

The RH outputs are as following depending on inputs:

- Relative Humidity (Default Selection)
Relative humidity is the percent moisture in a parcel of air based on the maximum amount of moisture that the parcel of air can hold.
- Dew Point Temperature
See explanation of Dew Point Temperature in the Inputs section above.

Application

Within the limits imposed by the mathematical models within *BehavePlus*, application of *BehavePlus* is essentially up to the user. Running the program is easy. But understanding the basis of the predictions and applying them properly requires skill.

Computer systems have played an important role in fire management activities (Rothermel 1980). A computer does not tire of routine calculations. Given a set of data, it will be consistent in coming up with the same answer. (The same cannot be said for humans.) Systems offer an organized way of looking at things. An individual's experience can be applied to wildfire predictions, but it is hard to apply this type of knowledge to planning or analysis situations.

BehavePlus can be viewed as an expert assistant, but the fire manager always makes the final decision. Predictions from the computer must be tempered with real-world fire experience. *BehavePlus* will willingly process numbers that are supplied and then produce impressive-looking tables. But what do the predictions mean? What is a flame length of 4.2 ft? It is vital that the fire manager make interpretations in terms of the application at hand.

Decisions based on predictions must consider the resolution of the input that is used. Consider wind speed. In predicting spread rate, the value for midflame wind speed might be obtained by direct measurement near the fire. It might be estimated from a spot weather forecast or even from a general weather forecast. For planning purposes a range of wind speeds might be used: "What is the predicted rate of spread for a range of wind speeds from 2 to 10 mi/h?"

BehavePlus differs somewhat from other fire management systems because of the flexibility of design. Many others were designed for a single specific purpose. The following discussion of possible applications of *BehavePlus* illustrates its flexibility.

Dispatch

Initial attack dispatch is an appropriate application of fire behavior prediction models. At first report of a smoke, a dispatcher may have no information about the fire other than location. Nevertheless, fire behavior can be predicted from information available from maps, weather reports, and so on.

Although it takes less than a minute to enter data into SURFACE and SIZE and get predictions, deciding what input values to use will take additional time that in some cases cannot be afforded. Whether calculations are done at the time of a fire call will depend on response time standards.

Wildfire

Wildfire prediction was the initial application of the Fire Behavior Prediction System. The system was developed through the Fire Behavior Officer (FBO) S-590 (1976) course utilizing tables and nomograms. Refinement of the system was based on field application. Methods are published in "How to Predict.. ." (Rothermel 1983). These methods are automated in *BehavePlus*. *BehavePlus* can be a great aid to the Fire Behavior Analyst in predicting wildfire behavior.

The well-established methods for predicting wildfire growth and intensity require extensive fire experience. The FBA course emphasizes the final products of the written fire behavior forecast, oral briefings to the fire team, and a map of predicted fire growth. An important aspect of using predictions for real-time wildfire prediction is translating calculated values into a form that can be used by other,

Some aspects of wildfire can be predicted using models, others cannot. *BehavePlus* provides predictions of spread rate, flame length, and intensity of surface fires. Fireline intensity can be used to indicate the likelihood of severe fire behavior; and spotting distance can be predicted. However, none of the models in *BehavePlus* can be used to predict the behavior of crown fires. Other aspects of fire behavior do not readily lend themselves to mathematical models. They are best handled by personal experience and "rules-of-thumb." For example, a person can learn to recognize conditions that can lead to the formation of fire whirls.

Prescribed Fire

A Prescribed Fire is any fire ignited by management actions to meet specific objectives. A written, approved prescribed fire plan must exist, and NEPA requirements must be met, prior to ignition. An approved plan must be in effect before the prescribed fire can take place. Fire behavior predictions can be an important element in the plan.

Wildland Fire

This category of fire includes fires that are started at random, generally by lightning. If ignition occurs in an area where wildland fire use is permitted, then the fire may be managed within the guidelines defined. *BehavePlus* can be used to set the prescription and to predict the behavior of an on-going wildland fire (Andrews and Burgan 1985).

Planning

Wildland fire use fires may have the potential to burn for weeks or even months. Setting up the prescription can involve looking at historical fire occurrence and weather to determine how large fires would have gotten if suppression action had not been taken. This involves using *BehavePlus* and FBA techniques to project fire growth.

Real-Time Prediction

Wildland fire use fires offer a unique opportunity to apply fire behavior prediction technology developed for wildfires or free-burning fires. Monitoring of the wildland fire will of course involve observing what the fire is doing. But monitoring could also include projecting what the fire is expected to do the next day. This would be especially important if the fire is nearing a boundary of the area included in the management plan. Contingency plans can be based on fire behavior predictions. These techniques were used on the Independence Fire of 1979 as documented by Andrews (1980) and Keown (1985).

Pattern of Ignition

The option in SURFACE of being able to calculate the behavior of a fire in a direction other than that of maximum spread can, in some limited cases, be used to determine the preferred pattern of ignition. If scorch height (which is related to flame length) (Van Wagner 1973) is an important factor in a prescription, then the predicted flame length for various spread directions can be used to determine the preferred pattern of ignition.

The behavior of the fire is often controlled by the pattern of ignition. One of the basic assumptions of the fire spread model is thereby violated because these fires are not free-burning, steady-state fires spreading independent of the source of ignition. Nevertheless, with care and experience, steady-state fire behavior predictions can be used as a baseline for prescribed fire planning. These predictions can be viewed as what the fire would be expected to do on its own. The pattern and method of ignition can then be used to increase or decrease the fire behavior. For example, strips could be ignited so that the fire is never able to reach its full steady-state potential. On the other hand, one line of fire could be used to create in-drafts that effectively increase the wind speed on another portion of the fire, thereby causing the fire to exceed its steady state potential.

In some cases, steady-state predictions might indicate that a prescribed fire would be unsuccessful. With an ignition method such as helitorch, however, it is possible to get enough fire into an area fast enough to have a successful burn. If the same ignition is used under conditions when the steady-state predictions are higher, the conditions may actually be too severe for aerial ignition.

At present there are no prediction models or even formalized "rules-of-thumb" to guide the translation of steady-state predictions to actual fire behavior under various firing patterns. Interpretation must be based on personal experience.

Prescription Window

A prescription sets the conditions under which a prescribed fire can be conducted. This often includes acceptable ranges for temperature, relative humidity, wind speed, and so on. When prescription limits occur simultaneously on the high flammability side, a fire may be hotter than desirable. The converse is true on the low flammability side. It is possible to increase the number of potential burning days by looking at tradeoffs between variables. An approach in setting up a prescription window is to work backwards, deciding what the desired steady-state fire behavior is, then determining what conditions would cause it. The use of Tables and Graphs in *BehavePlus* can aid the user in developing a prescription window.

These tables are primarily used for fire control aspects of prescribed fire. *BehavePlus* will help with fire behavior aspects, the constraints, of a prescription. Other considerations depend on the land management objectives of the burn, such as to regenerate trees, increase capacity of wildlife habitat, or protect resources from wildfire. It is possible that conflicts will arise in setting the prescription. An example is the conflict between the objective to minimize fuel consumption by burning at high fuel moistures and the constraint to control smoke production. Resolution of these conflicts must be based on priorities of the objectives and constraints.

Contingency Planning

The contingency plan is a critical element of a prescribed fire plan. If a prescribed fire escapes, it is important to be able to estimate what it will do and what resources must be available to control it. Predicting the behavior of a spot fire outside of the designated burn area is an appropriate application for *BehavePlus*. All of the predictions currently in the *BehavePlus* program can be used: SPOT for potential spotting distance, SURFACE for spread and intensity of the escaped fire and SIZE for the potential fire size in a given time. The CONTAIN module in BEHAVE which can be used to estimate the attack forces that should be on hand in the event of an escape will be added to *BehavePlus* in the future.

Predictions from SPOT can be used to estimate the maximum distance from the burn that a spot fire might be expected to occur. At present the model can be used if the spotting is from torching trees, from burning piles or from a wind driven surface fire. The burning piles might be logging slash or natural accumulations of dead and down material encountered in an understory burn. It might also be a log deck on the edge of a clearcut. A torching tree might be the source of the firebrand when an occasional tree torches in an understory burn or on the edge of a clearcut. Remember that spotting under the conditions covered by the spot model is only one way that a prescribed fire can escape. The fire might just jump the line or spots might be carried outside of the area by a fire whirl.

Sources of firebrands can be indicated on a map with a sketch of potential spotting distance. This map can be used to place patrols for spot fires during the burn. The location can also be used in setting the conditions (fuel model, fuel moisture, wind and slope) to be used in the SURFACE calculations for spread and intensity of a spot fire.

If SURFACE is used to set up tables to define a prescription window, then similar tables could be used to predict the behavior of an escaped fire under a range of conditions. Even if the fire inside of the block is controlled by the ignition method, the behavior of an escaped fire should more closely match the SURFACE predictions. If the burn is in a grass or shrub fuel type, it is possible that the same table could be used because the spot will likely be into the same fuel type. On the other hand, if the prescribed fire is in logging slash, the spot fire may be in adjacent timber. Then not only would the fuel model and possibly the slope change, but the canopy cover would cause differences in fuel moisture and midflame wind speed.

The predictions from SURFACE give potential spread rate and intensity. Flame length and fireline intensity can be used for fire suppression interpretations, giving an indication of whether SURFACE attack would be successful. And if the escaped fire is in timber, this will indicate whether torching and other severe fire behavior is probable.

The SIZE calculations indicate how large a spot fire would be expected to get in a given period of time. The time would be based on how long, you think it would take your forces to get to the fire and begin suppressing it.

Custom Fuel Models

Custom fuel models are not needed for each area to be burned. A single fuel model can be used for many situations. Development of a new fuel model is more involved than sampling the fuel in an area, "plugging" it into the computer, and getting a fuel model. A vital step is incorporating the fire experience of the user in this general fuel type in the test and refinement of the fuel model. The 13 standard fuel models are adequate for many decisions. In some cases, however, none of the 13 models fit the situation. For example, logging slash with a significant component of live shrubs and herbaceous fuels may require a custom fuel model.

Fire Effects

A change in emphasis from strictly fire control to fire management brings about an increased need for predicting fire behavior as it relates to fire effects. Fire effects includes such things as seed survival and vegetation response after a fire. *BehavePlus* as it now stands has very limited application to fire effects.

Because the fire spread model was designed to predict the growth of a wildland fire for fire suppression applications, it characterizes the behavior in the flaming front. Therefore, it is of limited use for predicting fire effects. Nevertheless, a few such predictions are possible. For example, scorch height has been correlated to fireline intensity (Van Wagner 1973), which relates well to flame length. In general, flame length and fireline intensity are best related to the effect of fire on items in the flame and in the hot convective gases above the flame. In light fuels, heat per unit area could be used to measure heat directed to the surface and related to fire effects in the duff and soil (Rothermel and Deeming 1980).

Many aspects of fire effects are dependent upon the fire behavior after the flaming front has passed, in the burnout of large fuels and smoldering combustion of the duff. Research is in progress in these areas.

More fire effects studies are being related to quantitative measures of fire behavior, rather than just a record of fire or no-fire, hot or cool, spring or fall burn. This, in addition to work on mathematical fire behavior models that are designed to be related to fire effects, should strengthen the link between fire behavior and fire effects in the future.

Training

BehavePlus has a place in both classroom training and on-the-job training. *BehavePlus* is now being included in college curricula to train new fire professionals. Besides giving newcomers a head start at becoming fire behavior experts, *BehavePlus* can also give old-timers a new perspective on fire. They begin to translate their "feel for fire" into quantitative terms that can be better communicated to others.

BehavePlus can be used as part of training in relation to any of the specific applications discussed above. It is especially useful for "what if" games. For example, it might be used to train a seasonal dispatcher who has minimal fire experience. *BehavePlus* offers a focal point for discussion and helps illustrate the factors that are important in affecting fire behavior.

Before an individual uses *BehavePlus* as an operational fire management tool, he or she should spend some time on personal training. This does not referring to operation of the programs, but rather to using *BehavePlus* enough to know how the models can be applied. This involves looking at the effect of a change in an input value on the predictions and getting a feel for what the prediction models in *BehavePlus* can do.



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Appendix A
Variables and Modules

Appendix A – Variables and Modules

| Input variable | SURFACE | SIZE | SPOT | SCORCH | MORTALITY | IGNITE | RH | Notes |
|-------------------------------------|---------|------|------|--------|-----------|--------|----|------------------------------------|
| FUEL / VEGETATION | | | | | | | | |
| Fuel model | I | | | | | | | |
| 1-h fuel load | I | | | | | | | Fuel model parameter |
| 10-h fuel load | I | | | | | | | “ |
| 100-h fuel load | I | | | | | | | “ |
| Live herbaceous fuel load | I | | | | | | | “ |
| Live woody fuel load | I | | | | | | | “ |
| 1-h surface area / vol ratio | I | | | | | | | “ |
| Live herb surface area / vol ratio | I | | | | | | | “ |
| Live woody surface area / vol ratio | I | | | | | | | “ |
| Fuel bed depth | I | | | | | | | “ |
| Dead fuel moisture of extinction | I | | | | | | | “ |
| Dead fuel heat content | I | | | | | | | “ |
| Live fuel heat content | I | | | | | | | “ |
| Mean cover height | | | I | | | | | |
| Tree height | | | I | | I | | | |
| Crown ratio | | | | | I | | | |
| Mortality tree species | | | | | I | | | |
| Spot tree species | | | I | | | | | |
| D.B.H. | | | I | | I | | | |
| Bark thickness | | | | | IO | | | |
| FUEL MOISTURE | | | | | | | | |
| 1-h moisture | I | | | | | I | | Fuel moisture scenario parameter |
| 10-h moisture | I | | | | | | | “ |
| 100-h moisture | I | | | | | | | “ |
| Live herbaceous moisture | I | | | | | | | “ |
| Live woody moisture | I | | | | | | | “ |
| Dead fuel moisture | I | | | | | I | | Used for 1-h, 10-h, 100-h |
| Live fuel moisture | I | | | | | | | Used for live herbaceous and woody |

| Input variable | SURFACE | SIZE | SPOT | SCORCH | MORTALITY | IGNITE | RH | Notes |
|--------------------------------------|----------------|-------------|-------------|---------------|------------------|---------------|-----------|--------------|
| WEATHER | | | | | | | | |
| Midflame wind speed | IO | | | I | | | | |
| 20-ft (or 10-m) wind speed | I | | I | | | | | |
| Wind adjustment factor | I | | | | | | | |
| Effective wind speed | O | I | | | | | | |
| Wind direction | I | | | | | | | |
| Air temperature | | | | I | | I | I | |
| Wet bulb temperature | | | | | | | I | |
| Dew point temperature | | | | | | | IO | |
| Fuel shading from the sun | | | | | | I | | |
| TERRAIN | | | | | | | | |
| Slope steepness | I | | | | | | | |
| Aspect | I | | | | | | | |
| Site elevation | | | | | | | I | |
| Ridge-to-valley elevation difference | | | I | | | | | |
| Ridge-to-valley horizontal distance | | | I | | | | | |
| Spotting source location | | | I | | | | | |
| FIRE | | | | | | | | |
| Rate of spread (maximum) | O | I | | | | | | |
| Flame length | O | | I | I | | | | |
| Fireline intensity | O | | | I | | | | |
| Flame height from a burning pile | | | I | | | | | |
| Spread direction | IO | | | | | | | |
| Number of torching trees | | | I | | | | | |
| Scorch height | | | | O | I | | | |
| Elapsed time | I | I | | | | | | |
| MAP | | | | | | | | |
| Map representative fraction | I | I | I | | | | | |
| Contour interval | I | | | | | | | |
| Map distance | I | | | | | | | |
| Number of contour intervals | I | | | | | | | |

| Output variable | Default output variable | Can be output as map dist. | Notes |
|---|--------------------------------|-----------------------------------|---------------|
| SURFACE | | | |
| Rate of spread | X | | |
| Heat per unit area | X | | |
| Fireline intensity | X | | |
| Flame length | X | | |
| Reaction intensity | | | |
| Direction of maximum spread | X | | |
| Spread distance | | X | |
| Midflame wind speed | | | |
| Effective wind speed | | | |
| Maximum reliable wind speed | | | |
| Maximum wind exceeded? | X | | “yes” or “no” |
| Slope steepness | | | |
| Slope elevation change | | | |
| Slope horizontal distance | | | |
| SIZE | | | |
| Area | X | | |
| Perimeter | X | | |
| Length-to-width ratio | | | |
| Forward spread distance | | X | |
| Backing spread distance | | X | |
| Fire length | | X | |
| Maximum fire width | | X | |
| SPOT | | | |
| Spotting distance from torching trees | X | X | |
| Spotting distance from a burning pile | | X | |
| Spotting distance from a wind-driven surface fire | | X | |
| SCORCH | | | |
| Scorch height | X | | |
| MORTALITY | | | |
| Bark thickness | | | |
| Tree crown length scorched | | | |
| Tree crown volume scorched | | | |
| Probability of mortality | X | | |
| IGNITE | | | |
| Probability of ignition from a firebrand | X | | |

Appendix B

Valid Input Variable Ranges and Default Output Units

Input Variables--Units and Valid Ranges

| Input Variable | Type | English | Metric |
|--|-----------|--|---|
| | | Range / Units | Range / Units |
| Description | Free Text | N/A | N/A |
| Fuel / Vegetation | | | |
| Fuel model | Discrete | N/A | N/A |
| 1-h fuel loading | Cont. | 0.0 - 30.49 tons/ac | 0.0 - 68.35 tonne/ac |
| 10-h fuel loading | Cont. | 0.0 - 30.49 tons/ac | 0.0 - 68.35 tonne/ac |
| 100-h fuel loading | Cont. | 0.0 - 30.49 tons/ac | 0.0 - 68.35 tonne/ac |
| Live herbaceous fuel loading | Cont. | 0.0 - 30.49 tons/ac | 0.0 - 68.35 tonne/ac |
| Live woody fuel loading | Cont. | 0.0 - 30.49 tons/ac | 0.0 - 68.35 tonne/ac |
| 1-h surface area/vol ratio | Cont. | 109 - 4,000 ft ² /ft ³ | 358-13,123 m ² /m ³ |
| Live herbaceous surface area/vol ratio | Cont. | 109 - 4,000 ft ² /ft ³ | 358-13,123 m ² /m ³ |
| Live woody surface area/vol ratio | Cont. | 109 - 4,000 ft ² /ft ³ | 358-13,123 m ² /m ³ |
| Fuel bed depth | Cont. | 0.5 to 6.0 feet | 0.2-1.83 m |
| Dead fuel moisture of extinction | Cont. | 5 - 100% | 5 - 100% |
| Dead fuel heat content | Cont. | 6,000-12,000 BTU/lb | 13,967-27,934kJ/kg |
| Live fuel heat content | Cont. | 6,000-12,000 BTU/lb | 13,967-27,934kJ/kg |
| Mean cover height | Cont. | 0 - 300 ft | 0 - 91 m |
| Tree height | Cont. | 10 - 300 ft | 3 - 91 m |
| Crown ratio | Cont. | 0.1 - 1.0 | 0.1 - 1.0 |
| Mortality tree species | Discrete | (206 species) | (206 species) |
| Spot tree species | Discrete | (14 species) | (14 species) |
| Diameter breast height (dbh) | Cont. | 5 - 40 in | 13 -102 cm |
| Bark thickness | Cont. | 0.1 - 2.0 in | 0.3 - 5.1 cm |

Input Variables--Units and Valid Ranges

| Input Variable | Type | English | Metric |
|----------------------------|----------|-----------------|-----------------|
| | | Range / Units | Range / Units |
| Fuel Moisture | | | |
| Moisture scenario | Discrete | N/A | N/A |
| 1-h fuel moisture | Cont. | 1 - 60% | 1 - 60% |
| 10-h fuel moisture | Cont. | 1 - 60% | 1 - 60% |
| 100-h fuel moisture | Cont. | 1 - 60% | 1 - 60% |
| Live herbaceous moisture | Cont. | 30 - 300% | 30 - 300% |
| Live woody moisture | Cont. | 30 - 300% | 30 - 300% |
| Dead fuel moisture | Cont. | 1 - 60% | 1 - 60% |
| Live fuel moisture | Cont. | 30 - 300% | 30 - 300% |
| Weather | | | |
| Midflame wind speed | Cont. | 0 - 60 mi/h | 0.0 - 96.6 km/h |
| 20-ft (or 10-m) wind speed | Cont. | 0 - 99 mi/h | 0.0 - 159 km/h |
| Wind adjustment factor | Cont. | 0.1 - 1.0 | 0.1 - 1.0 |
| Effective wind speed | Cont. | 0 - 60 mi/h | 0.0 - 96.6 km/h |
| Wind direction | Cont. | 0 - 360 deg | 0 - 360 deg |
| Air temperature | Cont. | -40 - 120 deg F | -40 – 49 deg C |
| Wet bulb temperature | Cont. | -40 - 120 deg F | -40 – 49 deg C |
| Dew point temperature | Cont. | -40 - 120 deg F | -40 - 49 deg C |
| Fuel shading from the sun | Cont. | 0 - 100% | 0 - 100% |

Input Variables--Units and Valid Ranges

| Input Variable | Type | English | Metric |
|--------------------------------------|----------|---------------------|--------------------|
| | | Range / Units | Range / Units |
| Terrain | | | |
| Slope Steepness | Cont. | 0-45 deg 0-100% | 0-45 deg 0-100% |
| Aspect | Cont. | 0-360 deg | 0-360 deg |
| Site elevation | Cont. | -1,000 - 30,000 ft | -305 - 9,144 m |
| Ridge-to-valley elevation difference | Cont. | 0 - 4,000 ft | 0 - 1,219 m |
| Ridge-to-valley horizontal distance | Cont. | 0 - 4.0 mi | 0 - 6.4 km |
| Spotting source location | Discrete | RT, MW, VB, ML | RT, MW, VB, ML |
| Fire | | | |
| Rate of spread | Cont. | 0 - 500 ch/h | 0.0 - 167.6 m/min |
| Flame length | Cont. | 0 - 100 ft | 0 - 30.5 m |
| Fireline intensity | Cont. | 0 - 10,000 BTU/ft/s | 0 - 34,641 kW/m |
| Flame height from a burning pile | Cont. | 0 - 100 ft | 0 - 30.5 m |
| Spread direction | Cont. | 0-360 deg | 0-360 deg |
| Number of torching trees | Cont. | 0 - 30 | 0 - 30 |
| Scorch height | Cont. | 0 - 200 ft | 0 - 61 m |
| Elapsed Time | Cont. | 0.5 - 8.0 h | 0.5 - 8.0 h |
| Map | | | |
| Map representative fraction | Cont. | 1,980 - 1,013,760 | 1,980 - 1,013,760 |
| Contour interval | Cont. | 1 - 1000 ft | 0.3 - 304.8 m |
| Map distance | Cont. | 0.1 - 100 in | 0.3 - 254 cm |
| Number of contour intervals | Cont. | 1 - 100 | 1 - 100 |

Output Variables--Default Units

| Output Variable | Type | English | Metric |
|-----------------------------|----------|--------------------------|-------------------|
| | | Units | Units |
| SURFACE | | | |
| Rate of spread | Cont. | ch/h | m/min |
| Heat per unit area | Cont. | BTU/ft ² | kJ/m ² |
| Fireline intensity | Cont. | BTU/ft/s | kW/m |
| Flame length | Cont. | ft | m |
| Reaction intensity | Cont. | BTU/ft ² /min | kW/m ² |
| Direction of maximum spread | Cont. | degrees | degrees |
| Spread distance | Cont. | ch | m |
| Spread map distance | Cont. | in | cm |
| Midflame wind speed | Cont. | mi/h | km/h |
| Effective wind speed | Cont. | mi/h | km/h |
| Maximum reliable wind speed | Cont. | mi/h | km/h |
| Maximum wind exceeded | Discrete | yes/no | yes/no |
| Slope steepness | Cont. | percent | percent |
| Slope elevation change | Cont. | ft | m |
| Slope horizontal distance | Cont. | ft | m |
| SIZE | | | |
| Area | Cont. | ac | ha |
| Perimeter | Cont. | ch | m |
| Length to width ratio | Cont. | real number | real number |
| Forward spread distance | Cont. | ch | m |
| Forward spread map distance | Cont. | in | cm |
| Backing spread distance | Cont. | ch | m |
| Backing spread map distance | Cont. | in | cm |

Output Variables--Default Units

| Output Variable | Type | English | Metric |
|---|-------|---------|---------|
| | | Units | Units |
| Fire length | Cont | ch | m |
| Fire length map distance | Cont | in | cm |
| Maximum width of fire | Cont. | ch | m |
| Maximum width of fire map dist. | Cont. | in | cm |
| SPOT | | | |
| Spotting distance from torching trees | Cont. | mi | km |
| Spotting distance from a burning pile | Cont. | mi | km |
| Spotting distance from a wind-driven surface fire | Cont. | mi | km |
| Map Spotting distance from torching trees | Cont. | in | cm |
| Map Spotting distance from a burning pile | Cont. | in | cm |
| Map Spotting distance from a wind-driven surface fire | Cont. | in | cm |
| SCORCH | | | |
| Scorch height | Cont. | ft | m |
| MORTALITY | | | |
| Bark thickness | Cont. | in | cm |
| Tree crown length scorched | Cont. | ft | m |
| Tree crown volume scorched | Cont. | percent | percent |
| Probability of mortality | Cont. | percent | percent |
| IGNITE | | | |
| Probability of ignition | Cont. | percent | percent |