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BehavePlus fire modeling system
Version 3.0
User's Guide

Patricia L. Andrews
Collin D. Bevins
Robert C. Seli

Abstract

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The BehavePlus fire modeling system is a program for personal computers that is a collection of mathematical models that describe fire and the fire environment. It is a flexible system that produces tables, graphs, and simple diagrams. It can be used for a multitude of fire management applications including projecting the behavior of an ongoing fire, planning prescribed fire, and training. BehavePlus is the successor to the BEHAVE fire behavior prediction and fuel modeling system. Primary modeling capabilities include surface fire spread and intensity, crown fire spread and intensity, safety zone size, size of point source fire, fire containment, spotting distance, crown scorch height, tree mortality, wind adjustment factors, and probability of ignition. The User's Guide describes operation of the program. Other papers describe the models and application of the system.

Keywords

Fire behavior, fire spread, fire intensity, computer program

The Authors

Patricia L. Andrews is a Research Physical Scientist at the Fire Sciences Laboratory in Missoula, MT. She received a B.A. degree in mathematics and chemistry from Montana State University, Billings in 1970 and an M.A. degree in mathematics and computer science in 1973 from the University of Montana, Missoula. She has been at the Fire Sciences Laboratory since 1973, serving as Project Leader of the Fire Behavior Research Work Unit from 1991 to 1996.

Collin D. Bevins is Director of Systems for Environmental Management, a Missoula, MT, nonprofit research and educational organization founded in 1977. Collin earned a B.A. degree from Carleton College, Northfield, MN in 1974, and an M.S. degree in forestry, University of Washington, Seattle, 1975.

Robert C. Seli is a Forester at the Fire Sciences Laboratory in Missoula, MT. He was previously a District Fire Management Officer on the Lolo National Forest, a Silviculturist on the Nezperce National Forest, and received a B.S. degree in forestry from North Carolina State University in 1974.

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The following SEM people contributed to the project: Collin Bevins (program design and development, version 2 User's Guide), Don Carlton (version 1 User's Guide and online help system), Deb Tirmenstein (program testing, document review and editing), Joe Scott (online help and supporting material for the fire models added in version 2), and Miguel Cruz (Portuguese translation for the 'language' option).

Other contributors include Dave Custer (tutorial editing and formatting), Rob Seli (tutorial development, editing, online help, and version 2 User's Guide), and Pat Andrews (project manager, system design, program testing, tutorial development, version 2 User's Guide).

Software technical support is provided by USDA Forest Service, Fire and Aviation Management, National Systems Support Group, Boise, ID.

Cover Art

"WILDFIRE" (C) 1992, an original acrylic painting by Monte Dolack. Trumpeter swans take refuge in the air as a threatening wildfire rages through the forest habitat. This image is from a 29" x 24" poster commissioned by the National Wildfire Foundation and used here by permission of the artist.

All images used in BehavePlus and its associated manuals and training materials are from original works by Monte Dolack and appear by permission of the artist.

Preface

This User's Guide explains how to use the BehavePlus fire modeling system software. Other papers will describe the models incorporated into the system and application of the predictions.

This is an RMRS online publication. It can be downloaded from the Rocky Mountain Research Station publications web page, http://www.fs.fed.us/rm/main/pubs/electronic.html

You can download this User's Guide and the BehavePlus program and provide comments through the BehavePlus web site, http://fire.org

This User's Guide is also an integral part of the BehavePlus system, serving as online help.

This publication will be updated as features and modeling capabilities are added to the program.

The BehavePlus system is supported by

USDA Forest Service
National Fire and Aviation Management Information Systems Team
3833 S. Development Avenue
Boise, ID 83705

(800) 253-5559

fire_help@dms.nwcg.gov

What's New

Version 3 is an upgrade to version 2 that was released in July, 2004. Several major new features have been added in version 3.

- Crown fire modeling
- Table shading for acceptable fire conditions (replaces RxWINDOW in BEHAVE)
- Calculating wind adjustment factors
- A expanded set of standard fuel models

A complete list of version 3 changes can be found in Appendix A

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

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1. Introduction

The BehavePlus fire modeling system is a PC-based program that is a collection of models that describe fire and the fire environment. It is a flexible system that produces tables and graphs and can be used for a multitude of fire management applications. BehavePlus is the successor to the BEHAVE fire behavior prediction and fuel modeling system (Andrews 1986, Andrews and Chase 1989, Burgan and Rothermel 1984, Andrews and Bradshaw 1990). It is called the BehavePlus fire modeling system to reflect its expanded scope (Andrews and Bevins 1999).

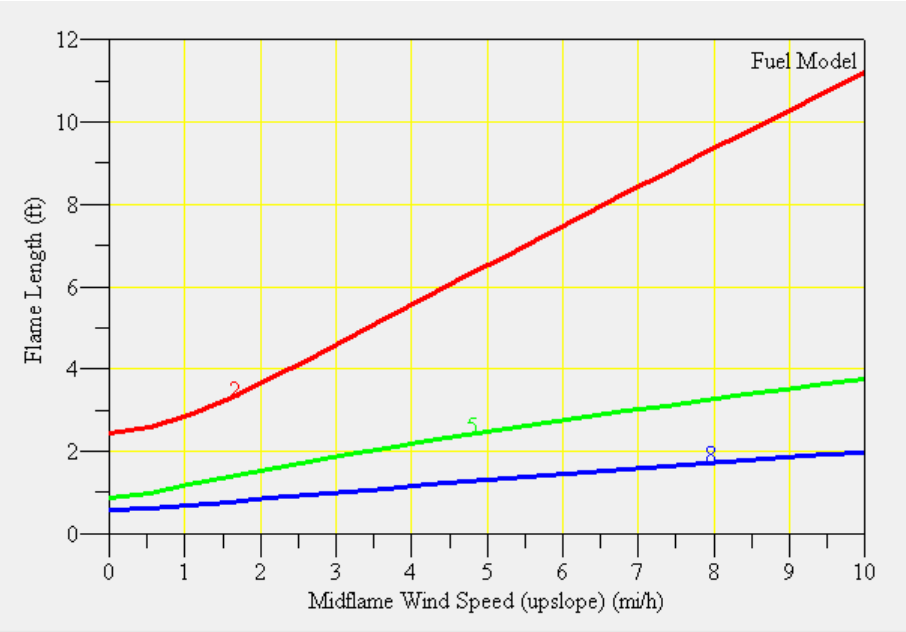
This document describes operation of the BehavePlus program. The fire models and their application are described elsewhere.

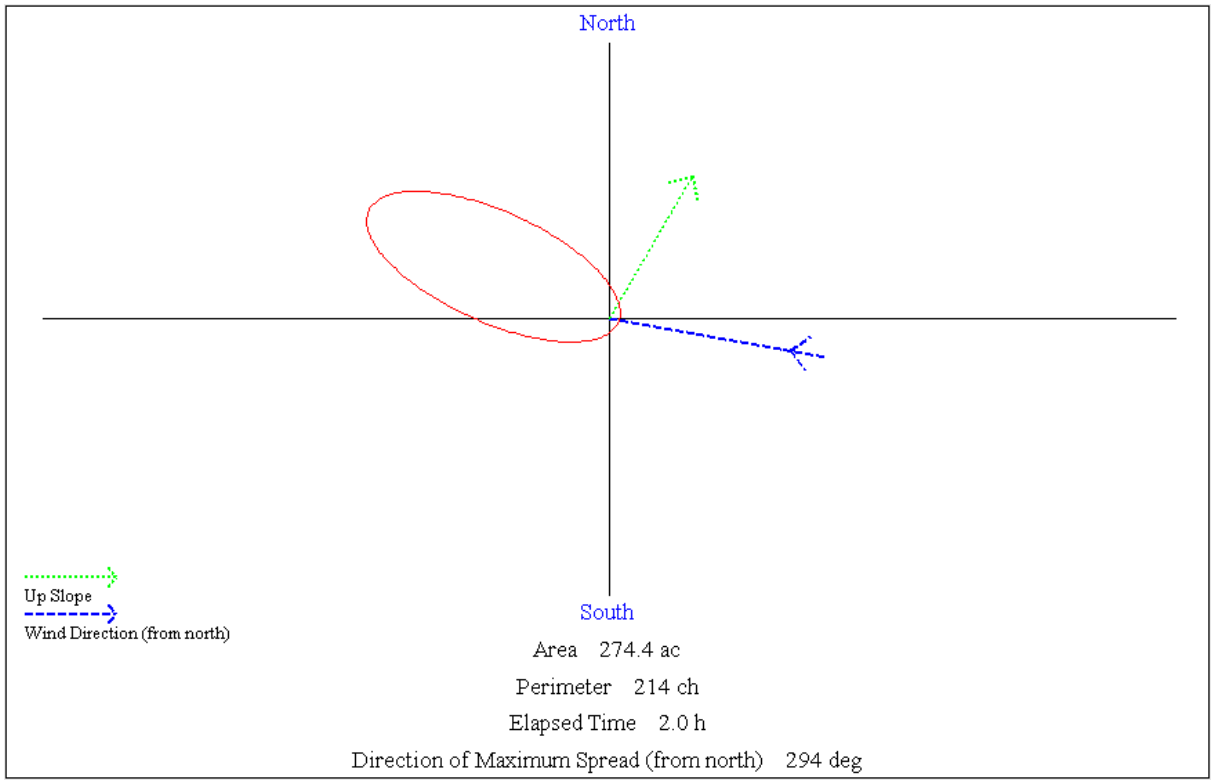
Many of the fire models in BehavePlus are the same as those in the *FARSITE* fire area simulator (Finney 1998), NEXUS fire hazard tool, and the FlamMap fire behavior mapping and analysis system. Each system meets a different need. The same surface fire spread model (Rothermel 1972) was used in each case. These three programs and supporting documentation are available through www.fire.org. Shown below are example outputs from each system.

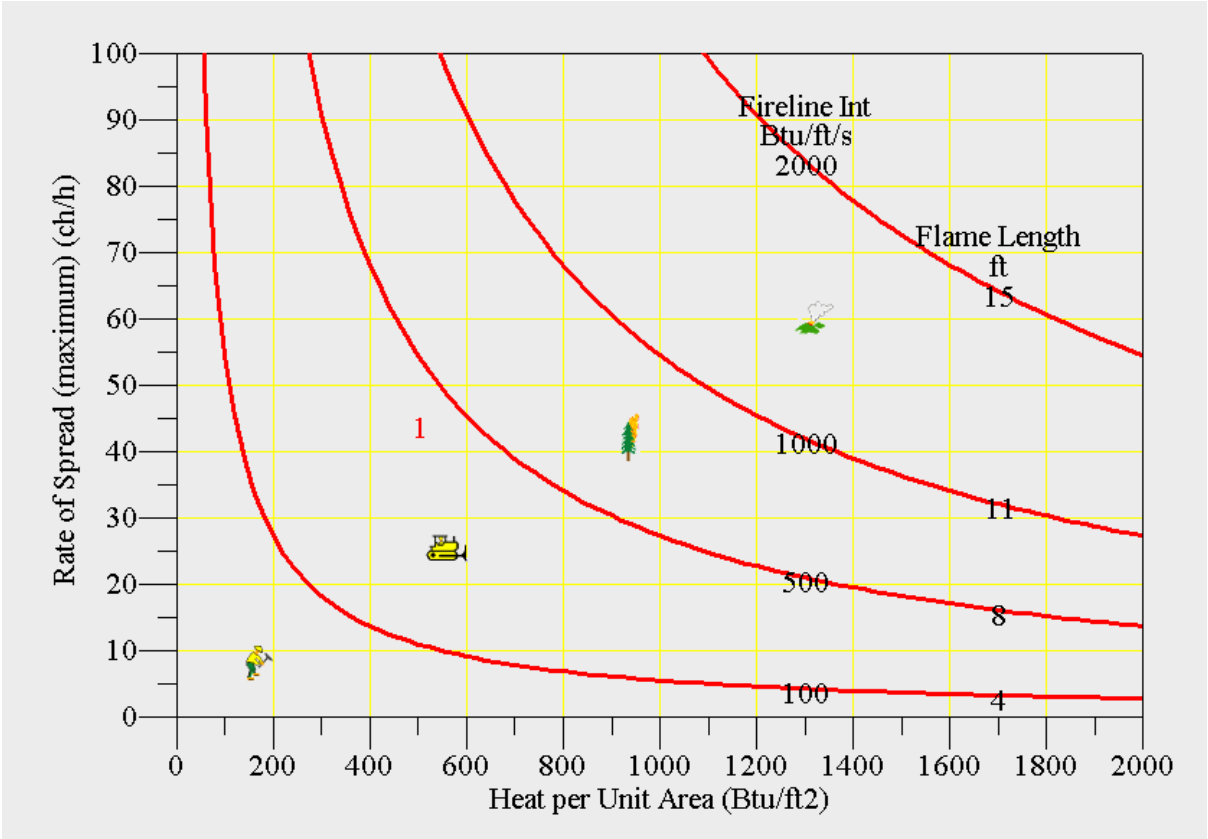
Sample table, graph, and diagram output from BehavePlus:

Flame Length (ft)

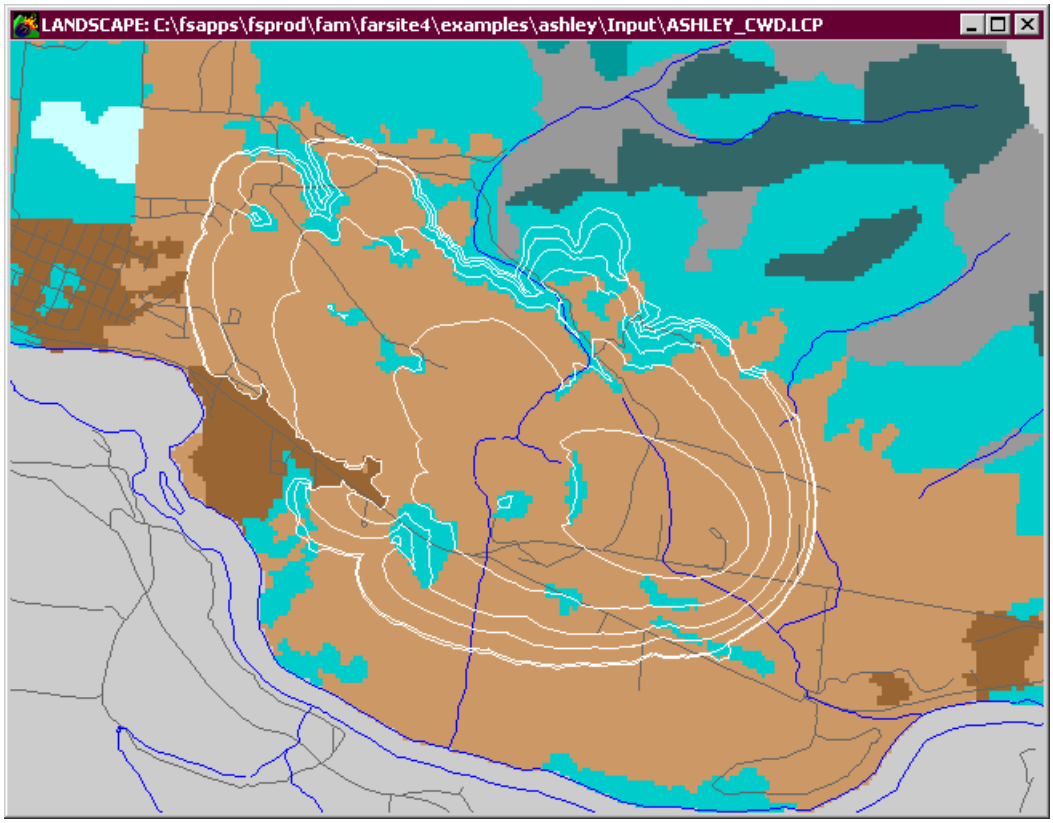
Fuel Model	Midflame Wind Speed (upslope) mi/h		
	0.0	5.0	10.0
2	2.5	6.5	11.2
5	0.9	2.5	3.8
8	0.6	1.3	2.0



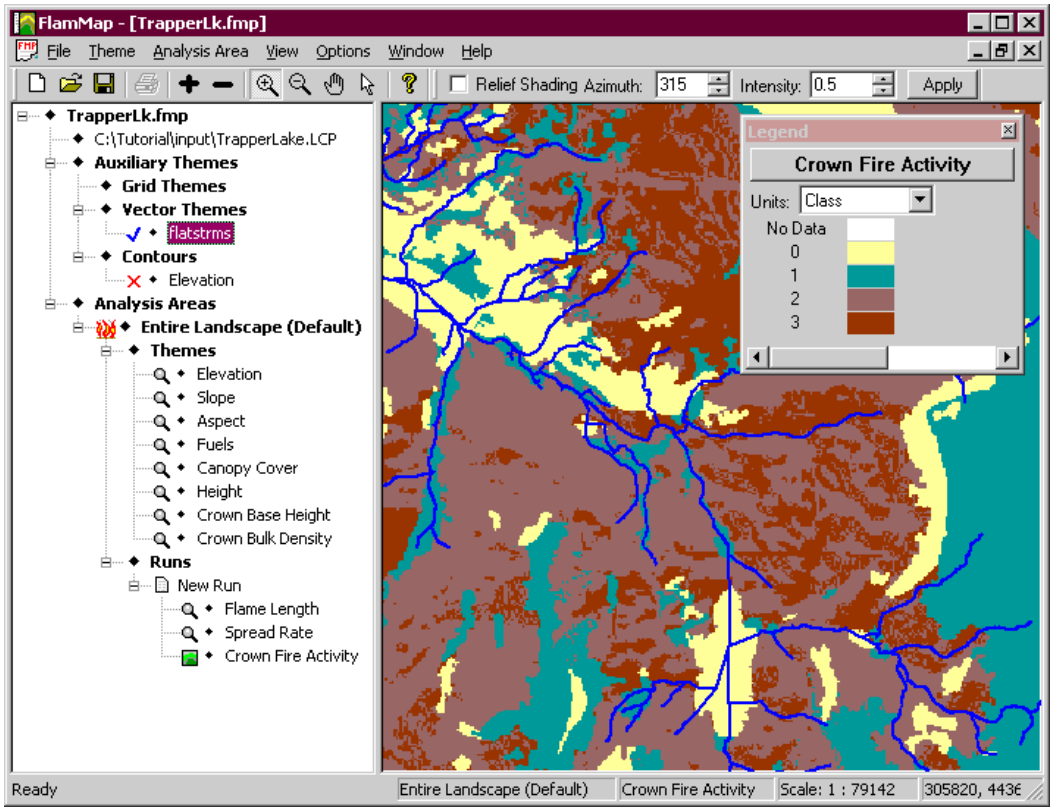

North
South
Up Slope
Wind Direction (from north)
Area 274.4 ac
Perimeter 214 ch
Elapsed Time 2.0 h
Direction of Maximum Spread (from north) 294 deg


Rate of Spread (maximum) (ch/h)
Heat per Unit Area (Btu/ft2)
Fireline Int
Btu/ft/s
2000
1000
500
100
1
Flame Length
ft
15
11
8
4

Sample fire perimeter output from *FASITE*:



Sample landscape fire potential output from FlamMap:



Version 1.0 of BehavePlus was based primarily on the same fire models that composed the old BEHAVE system. Development focus was initially on a new look and feel for the program. This paper describes version 3.0, which provides additional models and features. A summary of versions 3.0 changes is given in Appendix A.

The primary modeling capabilities of BehavePlus, version 3.0, include

- Surface fire spread and intensity
- Safety zone size
- Size of a point source fire
- Fire containment
- Spotting distance
- Crown scorch height
- Tree mortality
- Probability of ignition from fire brands or from lightning
- Transition from surface to crown fire
- Crown fire spread

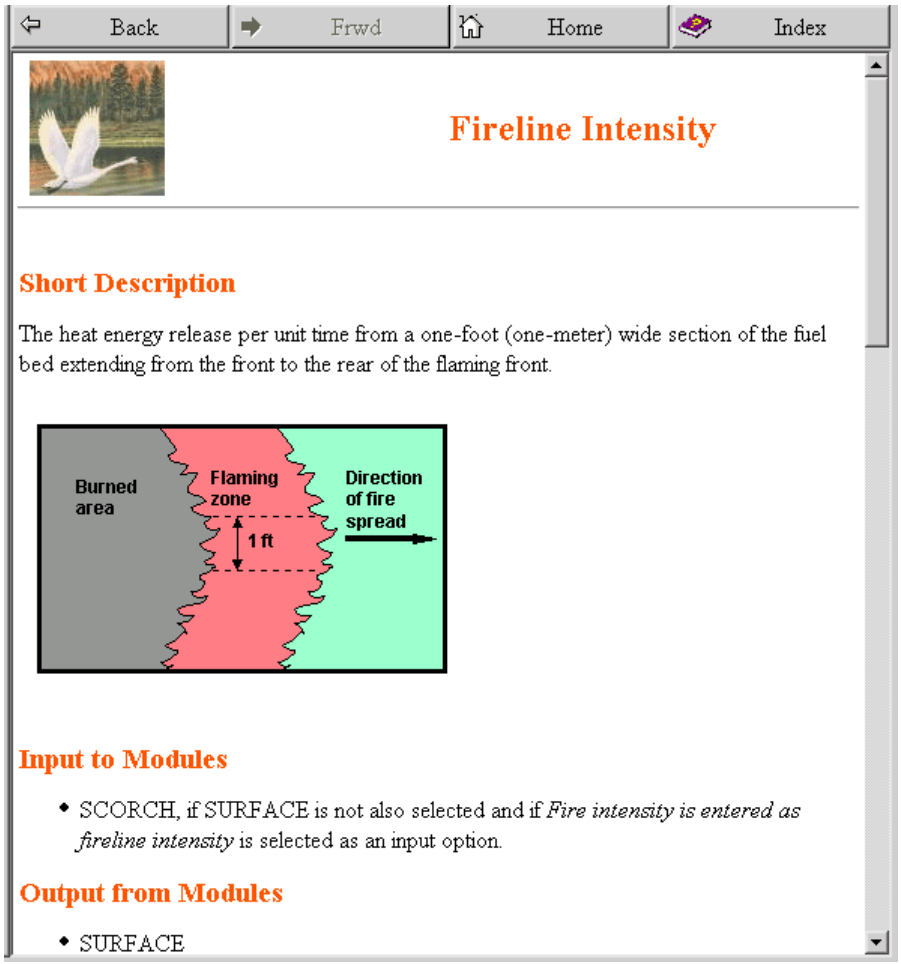
Other modeling capabilities include

- Tables for fine dead fuel moisture
- Tables for relative humidity or dew point
- Standard and custom fuel models
- Dynamic palmetto-gallberry fuel
- Three methods for weighting two fuel models: two-dimensional expected spread, harmonic mean, area weighted
- Sunrise, sunset, dawn, and dusk at any location or date

Key features include

- Diagrams for point source fire shape, shape of a contained fire, fire characteristics chart, wind / slope / fire directions
- Shading of table output for acceptable fire conditions
- Photographs and a key for the standard 13 fuel models
- Distances in map units
- User control of input options and output variables
- Description of each input and output variable
- User control of units and number decimal places displayed
- Multiple values can be entered for almost any input variable
- User interface language can be changed (currently English and Portuguese)

The help system is an important part of the BehavePlus system. This User's Guide is available with the program for help on operation of the program. In addition, a help browser is available in the dialog boxes providing immediate information on specific operations and definition of input and output variables as shown below.



2. Operation

This User's Guide addresses only operation of the program. The fire models, associated variables, and application are described elsewhere.

2.1. Organization

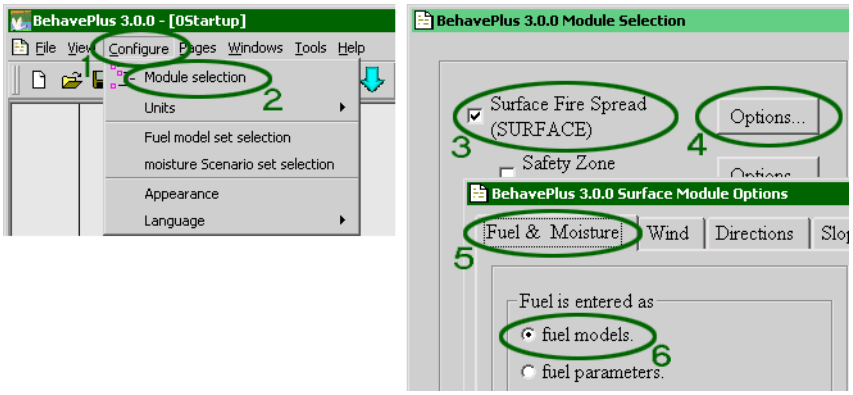
Organization of material on Operation of the BehavePlus program is different from the organization of the program itself. It is designed to help you find the answer to a question. Most users are comfortable with looking at menus and dialog boxes and associated information in the program without use of a User's Guide.

This is not a step-by-step operation manual, but a reference guide. The tutorials provide step-by-step instructions.

In describing operation of the program, we use the following font and/or conventions in describing menus, commands, buttons, tabs, and check boxes:

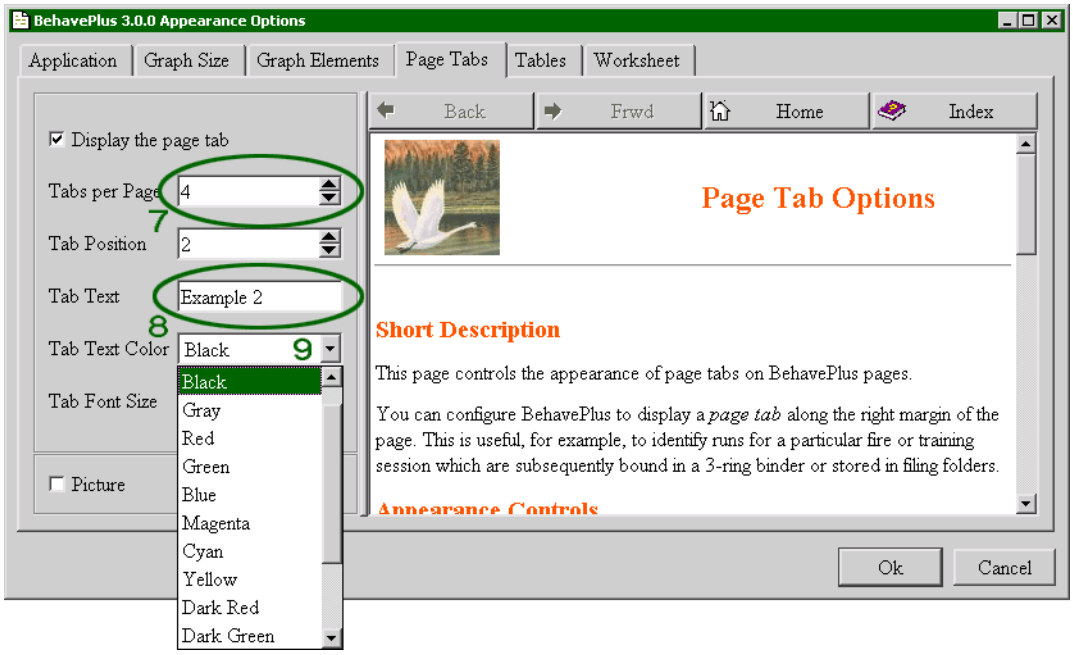
Configure > Module selection > SURFACE > Options... > Fuel & Moisture > fuel models radio button.

For example the sequence of menus, commands, check boxes, buttons, and tabs shown above refers to the following actions in BehavePlus:



Each of the above elements would be described in this User's Guide as

1. **Configure** menu
2. **Module selection** command
3. **SURFACE** check box
4. **Options...** button
5. **Fuel & Moisture** tab
6. **fuel models** radio button



Other elements used in BehavePlus include

7. Spin box - select the value using the buttons or enter a value from the keyboard,
8. Text box - click inside the box to enter values from the keyboard,
9. Drop-down list - Choose the value from the list displayed with the button.

In the interest of saving space and improving readability, we include screen captures of only the portion of concern. The Tutorials include more complete screen captures.

2.2. Design

2.2.1. Page Oriented

BehavePlus is meant to be more than just a fire modeling tool. It is meant to be a lesson book with a built-in training manual, and a planning tool whose results may be incorporated into management reports. It is meant to be a fire behavior assessment aid whose tables and graphs can be shared with others in briefings and in written documentation.

Because of these expectations, the BehavePlus user interface is designed around the concept of the standard 8.5 x 11 printed page.

Given input information BehavePlus can generate documentation, diagrams, tables, and graphs. Fortunately, BehavePlus has a variety of methods for saving and displaying your work. Six months later when you need to review the work, the What, How, and Why of each Run is considerably less obscure than it would have been otherwise.

The page on which you enter input information appears first (page 1) and is called the Worksheet. A complex Worksheet may span several pages. Once the Calculate button is pressed, BehavePlus generates additional pages containing output tables, graphs, and diagrams. These too are deigned to fit neatly on the printed page. Navigation buttons on the Tool Bar let you move to the first page, last page, next page, or previous page. The **Pages** menu lets you jump directly to any diagram, table, or graph. The "Print" dialog box lets you print selected pages.

2.2.2. Highly Configurable

BehavePlus is meant to be the repository of many current and future models related to fire behavior and effects. These models may have alternate input sets and can produce many output variables. Individual models may be linked together so that outputs from one module automatically become inputs for another module. Input and output variables may have user-specified units of measure. Outputs may be in the form of diagrams, tables, and/or graphs. The language displayed on Worksheets and output pages may be changed.

BehavePlus may be used for fire behavior training, for fire planning, or for real-time fire behavior assessment. It may be used to assess just fire behavior, or just fire effects, or the link between them. It may be used to build custom fuel models, to determine astronomical events, or as a units conversion utility.

2.2.3. Self Documenting

The brooding step-brother of configurability is complexity. Because BehavePlus is so highly configurable and may be used by people in various roles for various purposes, it strives to be self-documenting in an attempt to thwart entropy. The input Worksheet automatically documents all Modules in use, all input variables and units of measure, all output variables and units of measure, and pertinent notes on the current configuration. The Worksheet also allows you to enter a Run description (and possibly additional training or fire incident information) and contains a notes field for free-field entry of expository text.

2.2.4. User Manual and Help

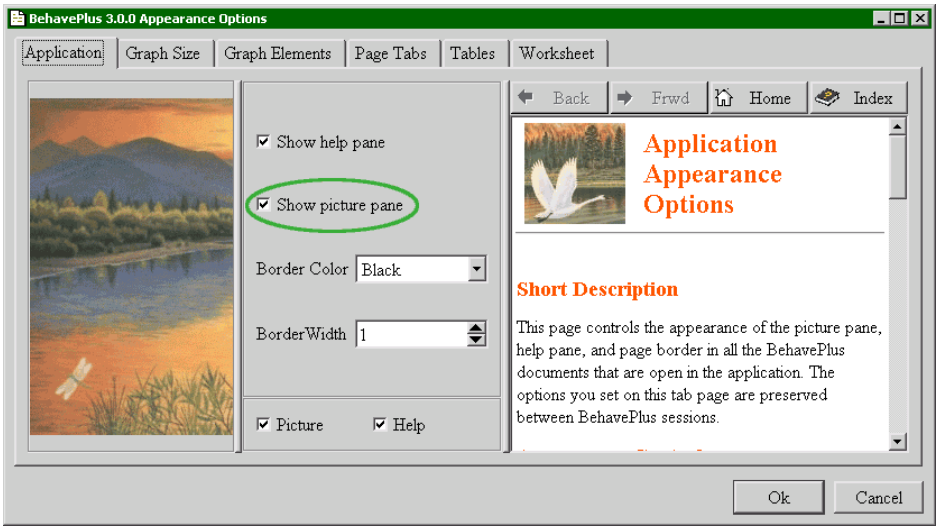
BehavePlus tries to provide pertinent information to you when you need it the most. The Guide Button next to each entry field opens a dialog box containing a help browser pane with suggested or valid inputs. The help browser pane describes input and output variables and program operation. The browser provides tables, photographs, and figures to help you select inputs.

In addition, this User's Guide is available as part of BehavePlus with the **Help > Program help** command.

2.2.5. Not Boring

Finally, every attempt has been made to keep BehavePlus from becoming yet another boring program with a gray personality. Just in case all the complexity, configurability, widgets, dialogs, models, diagrams, tables, graphs, browsers, and quirky behavior aren't enough to hold your attention, here and there we've inserted some paintings we rather enjoy to ease our weary eyes.

If you, however, prefer the gray approach, you can eliminate the pictures for the entire session by clearing the **Show picture pane** check box on the **Configure > Appearance > Application** tab.



You can also choose to show the art work or not in the dialog boxes with the **Picture** check box

2.3. Features

2.3.1. Fire Models

BehavePlus contains models to estimate

- surface fire spread rate, intensity, flame length, scorch height, and direction of maximum spread
- surface fire spread rate, intensity, flame length, and scorch height in any compass direction
- crown fire spread rate, critical thresholds, and fire type
- transition from surface to crown fire
- fire shape, area, and perimeter
- spotting distance from a burning pile, from torching trees, or from a wind-driven surface fire
- success or failure of suppression resources to build line around a fire
- recommended fire safety zone radius, separation distance, and zone size
- fire-induced tree mortality
- probability of fire ignition from firebrands
- probability of fire ignition from lightning strikes
- relative humidity or dew point temperature
- midflame wind speed and wind adjustment factor
- fine dead fuel moisture content
- sun-rise, sun-set, dawn, and dusk at any location or date
- palmetto-gallberry dynamic fuels
- create and save custom moisture scenarios
- weighted fire behavior within a two fuel model complex

2.3.2. Operation

BehavePlus has the following operational features:

- BehavePlus is cross-platform and works identically on all versions of Windows and Linux.
- Multiple Worksheets may be open at one time.
- Worksheets may be overlaid, tiled, cascaded, and resized.
- Modules (collections of related fire models) may be individually toggled on/off.
- Modules may have alternate input options available through the **Configure > Module selection > Options... > Input Options** tab.
- Module output variables can be toggled on/off via the **Configure > Module selection > Options... > Output Variables** tab.
- Modules may be linked so the outputs from one module are automatically input into another module.
- All distance outputs may be scaled to map units.
- All input and output units of measure may be modified by the user.
- Custom Worksheet configurations may be saved and re-used.
- Custom sets of units of measure may be saved and re-used.
- The Guide Button next to each Worksheet entry field displays a help browser pane with context-specific text and either a list of valid choices (for discrete variables) or fields for generating a range of input values.
- Zero, one, or two input variables may have multiple entry values, producing either a simple result list, a single one-way table, or a multi-page two-way table, respectively.
- If one input variable has multiple entry values, a separate graph can be generated for each output variable. If two input variables have multiple entry values each output variable graph contains a family of curves.
- The SURFACE, SIZE, and CONTAIN Modules can produce diagrams of their results.
- **Help > Program help** makes this manual and all associated documentation available in PDF format for reading, web browsing, and printing.
- The user interface language may be dynamically changed via **Configure > Language**. Portuguese (Portugal) was made available in version 2 as an example but was not updated to version 3. (Contact cbev-ins@montana.com if you'd like to volunteer to add support for another language).
- Completed Runs may be saved and re-used.

2.4. Installation

2.4.1. Download

BehavePlus is available for download from www.fire.org. Simply follow the BehavePlus links to the download page and select the Windows installation package.

You should check the downloaded file size against the original to ensure you received the entire package. To be absolutely certain the package arrived intact, use the md5sum program from a command line prompt:

- **md5sum bp_3_0_0.exe**

If the resulting 32-digit hexadecimal number is not identical to the one published on the BehavePlus download page, your download copy is corrupt.

2.4.2. System Requirements

BehavePlus has modest system requirements met by the most inexpensive computers available on the market:

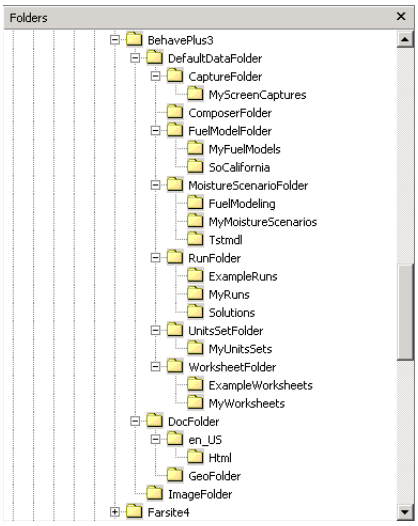
- Windows 95, 98, ME, NT, 2000, or XP
- Minimum 800 x 600 video resolution with 256 (8-bit) colors (recommend 1024 x 768 video resolution with 64K (16-bit) colors)
- 16 megabytes of available RAM
- 20 megabytes of disk storage

2.4.3. Windows Installation

BehavePlus for Windows is packaged using the Wise Installation System. Simply type the name of the package (e.g., bp_3_0_0.exe) at a command prompt (or click on its name in Windows Explorer) and the installation wizard will guide you through the process. This mostly consists of pressing the **OK** button.

2.4.4. File Structure

BehavePlus has a proscribed file system structure; all files must be located in specific subdirectories. The parent directory of this file structure and all its subdirectories and files are collectively known as a Workspace. When BehavePlus is first installed it has a single Workspace called "DefaultDataFolder" as shown below.



This is the default current Workspace every time BehavePlus is started.

We recommend that you use Workspaces to aid file management as you apply BehavePlus to several projects. See the section 20.1, Workspaces, for more information.

A list of three letter file extensions used by BehavePlus is shown in the following table. These extensions are automatically attached to the files you create in BehavePlus.

File extension	File Type	Folder
.bpf	Custom fuel models	FuelModelFolder
.bpm	Moisture scenarios	MoistureScenarioFolder
.bpr	Runs	RunFolder
.bpu	Custom Unit Sets	UnitsSetFolder
.bpw	Worksheets	WorksheetFolder

2.5. Definitions

A Worksheet is the first page or two containing the input Entry Fields. The content of a Worksheet depends upon the specific BehavePlus configuration including module selections, input options, output variables, units of measure, and diagram/table/graph options. Thus there are a large number of possible Worksheets. Some Example Worksheets are supplied with the BehavePlus distribution and are included in every Workspace. You may reconfigure BehavePlus as needed for any purpose, then save its Worksheet for later reuse. Functionally, a Worksheet is a BehavePlus configuration that does not have any input values associated with it.

A Run is a Worksheet that has a complete set of valid inputs, but no outputs are saved in a Run. You must calculate a saved Run to obtain outputs. Any given Worksheet may have an infinite number of Runs, each determined by its input values. Runs may be saved for later use and review. The BehavePlus installation includes Example Runs.

A Model is a set of equations that estimate one or more output variables from one or more input variables. While BehavePlus contains many models, you will more commonly see references to Modules, which are collections of models.

A Fuel Model is a set of numbers describing a fuel bed used by the surface fire spread model.

A Module is a collection of one or more Models that can be activated/deactivated by the user during Worksheet configuration. Selecting the IGNITE Module, for example, includes both the firebrand ignition model and the lightning strike ignition model.

A Continuous Variable is an input or output variable that has a continuous range of values. Continuous variables have a minimum and maximum valid value. Examples include fuel moisture content, and wind speed.

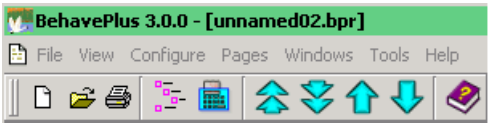
A Discrete Variable has a finite set of valid values. Examples include Fuel Model, Spotting Source Location, and Tree Species.

A Guide Button is the button with the arrow icon next to each Worksheet entry field. Pressing the Guide Button activates an "Input Guide" dialog box containing a help browser pane and input assistance. For continuous variables, the dialog facilitates entry of a large number of inputs by specifying the minimum input value, maximum input value, and increment value. For discrete variables the "Input Guide" dialog box contains a list of all valid inputs from which the user may select zero or more values.

A Workspace is a complete subdirectory tree containing all required BehavePlus files plus any additional Worksheet, Run, Fuel Model, Moisture Scenario, Units Set, or capture files saved by the user. A Workspace corresponds to a single BehavePlus project, and each BehavePlus project should have its own Workspace. Workspaces are created by the **File > Workspaces > New workspace** and the **Files > Workspaces > Clone current workspace** commands.

2.6. Menus and Toolbar

All BehavePlus operations are available from the menu bar.



The more common operations, such as Module Selection or Calculate, may also be invoked from Toolbar buttons. Toolbar buttons and their equivalent Menu commands are shown below:

Toolbar Buttons	Definitions	Equivalent menu operation
	Open a new Worksheet	**File > New**
	Open a saved Run	**File > Open Run**
	Print this Run	**File > Print**
	Module selection	**Configure > Module selection**
	Calculate this Run	**File > Calculate**
	Display first page	**Page >** then select page #
	Display last page	**Page >** then select page #
	Display previous page	**Page >** then select page #
	Display next page	**Page >** then select page #
	Access User's Guide	**Help > Program help**

3. Worksheets

A Worksheet is a form on which you enter input. Worksheets vary in appearance and content in response to the current module configuration: a SURFACE module configuration requires different inputs than a SPOT module configuration.

Module selection, input options, and output variable selections determine BehavePlus configuration, which in turn defines the Worksheet appearance and content.

BehavePlus starts with the BasicStart.bpw example Worksheet. This gives the option of doing a quick basic fire behavior Run without having to load or configure a Worksheet.

3.1. Worksheet layout

A BehavePlus Worksheet is more than just an input form; it is the primary source of documentation about the Run. Worksheets include the following sections:

Header - The Worksheet header shows the BehavePlus version number, useful for reporting bugs and determining if you have the most recent update. The header also includes the date and time of the last calculation and the page number, which lets you collate the correct pages after printing and spreading them out for further study.

Border - The line surrounding the Worksheet body may be modified with the **Configure > Appearance > Worksheet** tab.

Tabs - Zero, one, or more page tabs with labels along the right-hand margin of the Worksheet may be activated with the **Configure > Appearance > Page Tabs** tab.

Documentation - This section lists all the currently selected modules and contains an entry field for the Run description. Additional documentation entry fields for training or fire projection applications are optionally activated on the **Configure > Appearance > Worksheet** tab.

Input - This section contains the required input data entry fields identified by a short phrase and their units of measure. Each entry text box also has a Guide button that may be pressed for input assistance. Entry text boxes are grouped under headings such as "Fuel/Vegetation, Surface/Understory", "Fuel/Vegetation, Overstory", "Fuel Moisture", "Weather", "Terrain", and “Fire”.

Acceptable Fire Conditions - Used to enter ranges of acceptable fire behavior when using the table shading option. Table shading is enabled by selecting the **Configure > Table shading for acceptable fire conditions** check box.

Run Option Notes - This section documents some of the configuration settings that are selected for the Worksheet.

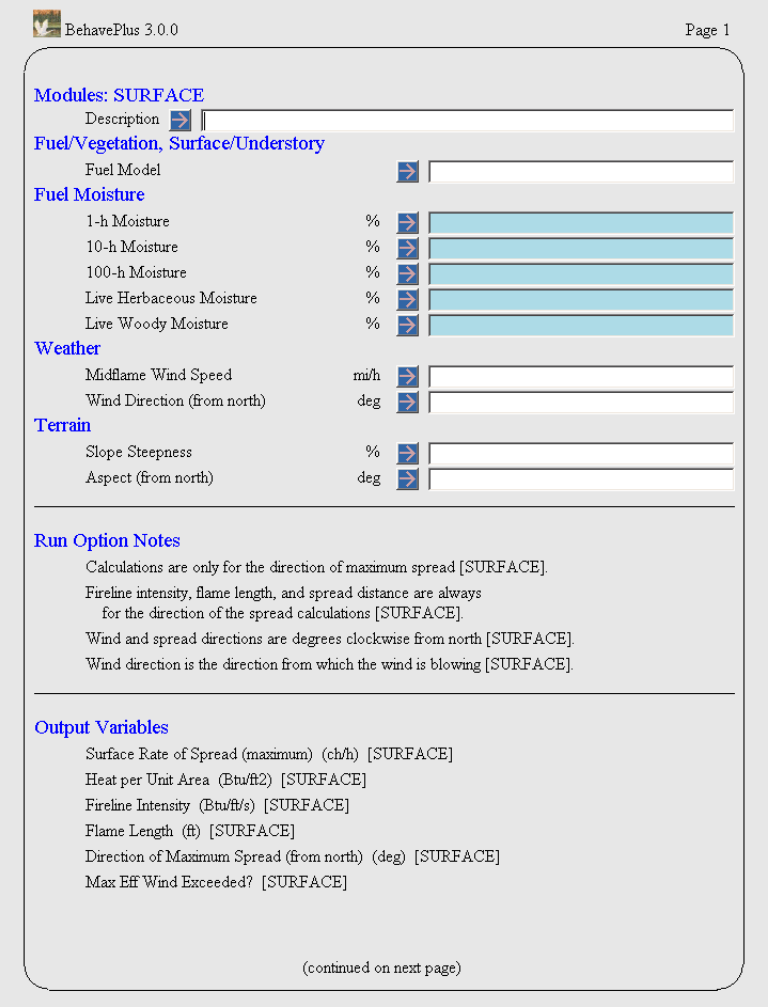
Output Variables - This section lists all the selected output variables and their units of measure. This section may be toggled on/off in the **Configure > Appearance > Worksheet** tab.

Notes - This section permits the user to enter free-field expository text. The user has control of the size of this section or whether it is displayed using the **Configure > Appearance > Worksheet** tab.

3.2. Example Worksheets

A number of predefined example Worksheets are included with the BehavePlus installation in the **Example-Worksheets** folder. The example Worksheets are described in Appendix E. You may use these Worksheets as provided, or use them as starting points for your own configuration. Use the **File > New** command to open an example Worksheet and proceed to change your module selection, input options, and/or output variables as needed. Once BehavePlus is configured the way you want, you may name and save it as a new Worksheet. During subsequent BehavePlus sessions you may load your custom Worksheet and BehavePlus is configured as expected.

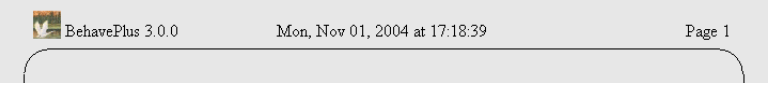
Shown below is the SurfaceBasicFrom.bpw example Worksheet:



3.3. Worksheet Sections

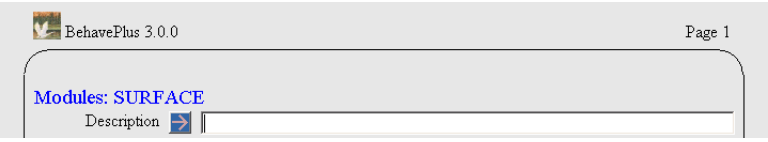
3.3.1. Page Header

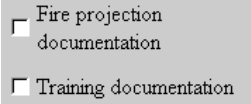
The header of each page includes the version number of the BehavePlus program and the page number. Once a Run is calculated the date and time of the calculation is added. The date and time and page number can be used to correctly collate printed documents.



3.3.2. Documentation

Documentation is the header information on the Worksheet. The calculation modules that have been selected are listed. Documentation always includes a Description field.

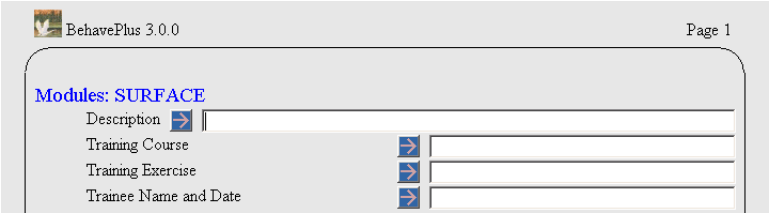




Additional documentation lines can be added by selecting the **Fire projection documentation** and/or **Training documentation** check boxes from the **Configure > Appearance > Worksheet** tab.

Selecting the **Fire projection documentation** check box adds the following input fields to the Worksheet:

Selecting the **Training documentation** check box adds the following input fields to the Worksheet:

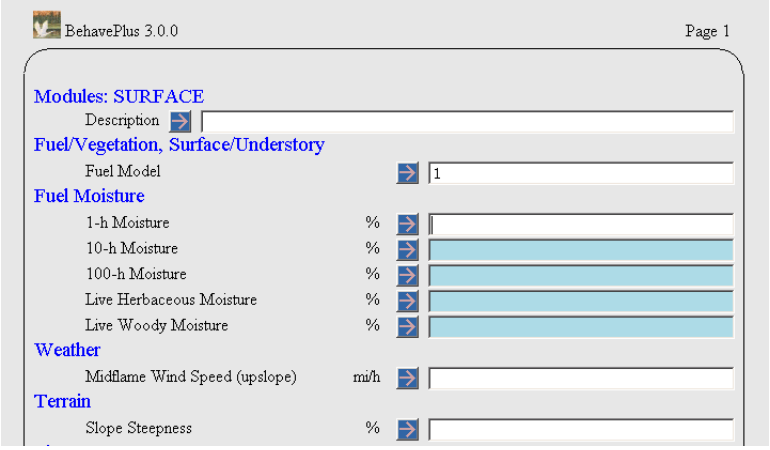


Both options can be selected at the same time.

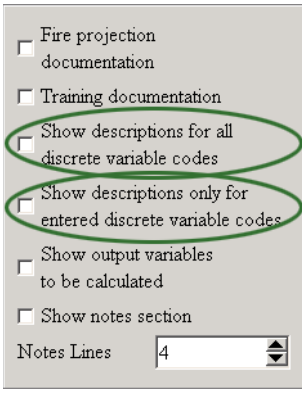
3.3.3. Input section

The required input variables and their units are displayed next to their text boxes. Fuel moisture variables that are not required have the text box shaded. In the example below, only 1-h fuel moisture is required for fuel model 1, because the other fuel categories are not included in the fuel model.

The Guide button for each input variable provides access to definitions and input assistance. Input variables are organized by logical association (rather than by calculation module). A table of all possible input variables by category is given in Appendix B.

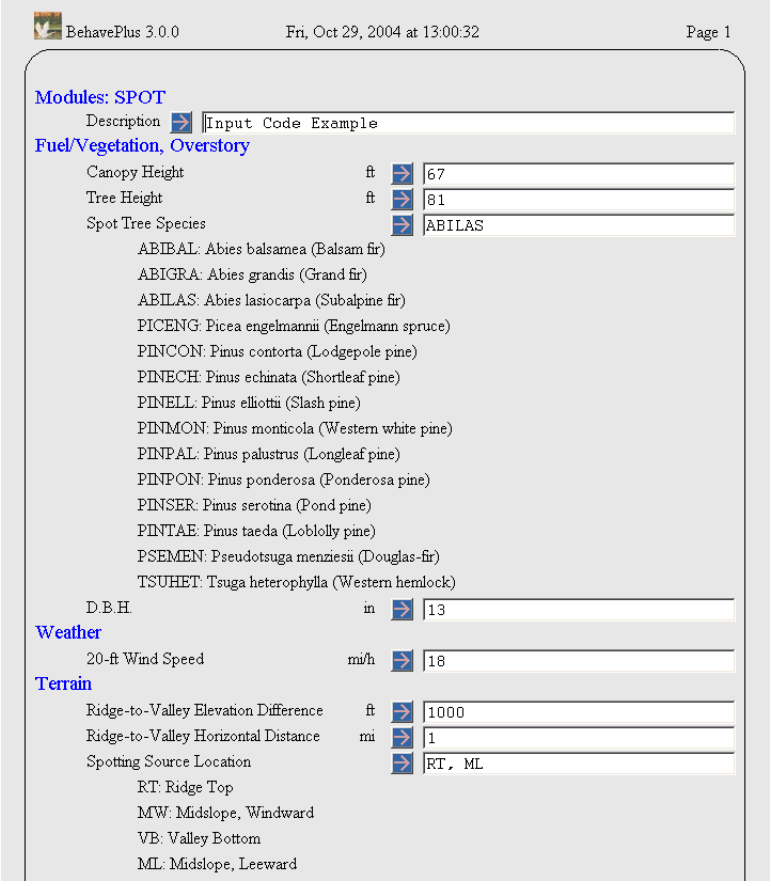


3.3.4. Input codes

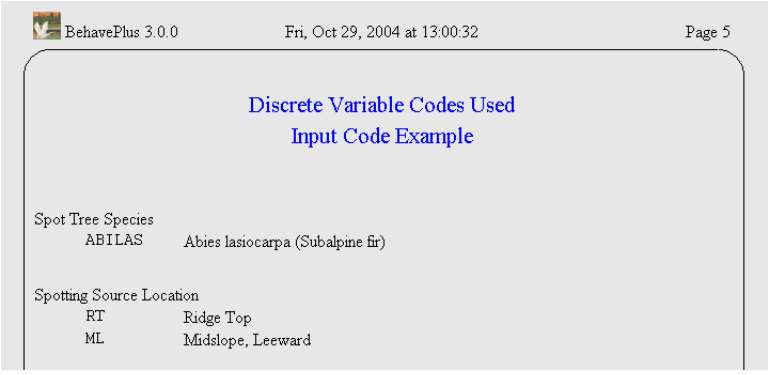


The definition of descrete variable input codes can be displayed by selecting two options on the **Configure > Appearance > Worksheet** tab. Selecting the **Show description for all discrete variable codes** check box displays the codes on the Worksheet beneath the variable. The **Show descriptions only for entered discrete variable codes** check box displays the codes used in the Run on a seperate output page when selected.

For example, on the SPOT module with the **Show descriptions for all discrete variable codes** check box selected, all tree species and spotting source location codes are shown.



With the **Show descriptions only for entered discrete variable codes** check box selected a page is generated at the end of outputs listing the codes and descriptions used in the Run.


BehavePlus 3.0.0 Fri, Oct 29, 2004 at 13:00:32 Page 5

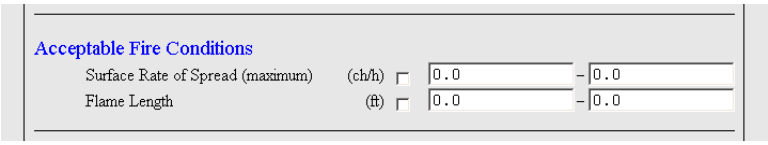
Discrete Variable Codes Used
Input Code Example

Spot Tree Species
ABILAS Abies lasiocarpa (Subalpine fir)

Spotting Source Location
RT Ridge Top
ML Midslope, Leeward

3.3.5. Acceptable Fire Conditions

This section is displayed on the Worksheet when the the **Table shading for acceptable fire conditions** check box in the "Module Selection" dialog box is selected.

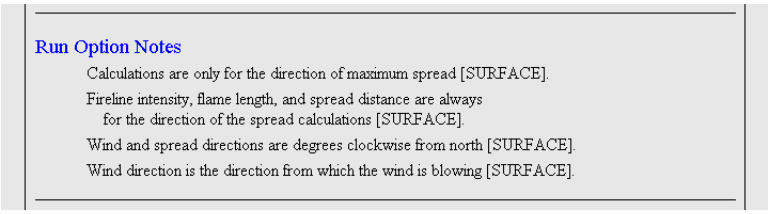

Acceptable Fire Conditions

Surface Rate of Spread (maximum)	(ch/h)	☐	0.0	-	0.0
Flame Length	(ft)	☐	0.0	-	0.0

Acceptable Fire Conditions are fully explained in Chaper 7, Table Shading.

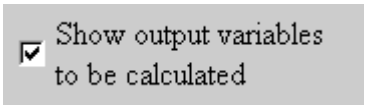
3.3.6. Run Option Notes

For clarification, Run options are given after the input variables. The user does not have the option of suppressing this information. The module using the option is also listed in brackets.


Run Option Notes

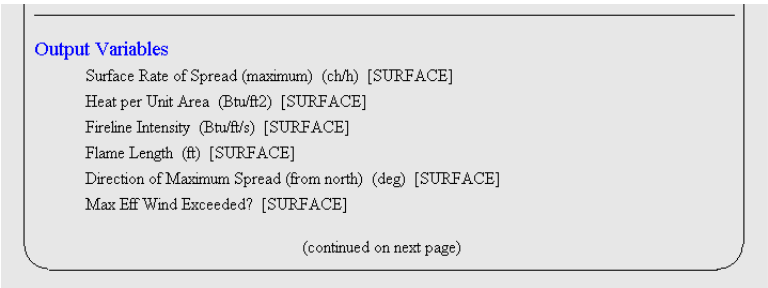
Calculations are only for the direction of maximum spread [SURFACE].
Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].
Wind and spread directions are degrees clockwise from north [SURFACE].
Wind direction is the direction from which the wind is blowing [SURFACE].

3.3.7. Output variables



Selected output variables and their units can be displayed at the end of the input Worksheet using the **Configure > Appearance > Worksheet** tab. The module calculating the output variable is also listed in brackets.

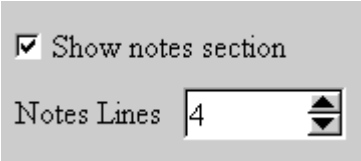
For example:


Output Variables

Surface Rate of Spread (maximum) (ch/h) [SURFACE]
Heat per Unit Area (Btu/ft2) [SURFACE]
Fireline Intensity (Btu/ft/s) [SURFACE]
Flame Length (ft) [SURFACE]
Direction of Maximum Spread (from north) (deg) [SURFACE]
Max Eff Wind Exceeded? [SURFACE]

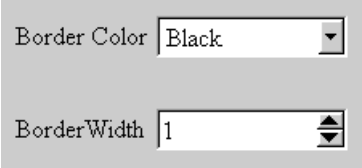
(continued on next page)

3.3.8. Notes



The Notes section of the Worksheet allows the user to enter a large amount of text associated with a Run. The user has the option of changing the number of lines provided for notes or even eliminating the notes section on the **Configure > Appearance > Worksheet** tab with the **Show notes section** check box and the **Notes Lines** spin box.

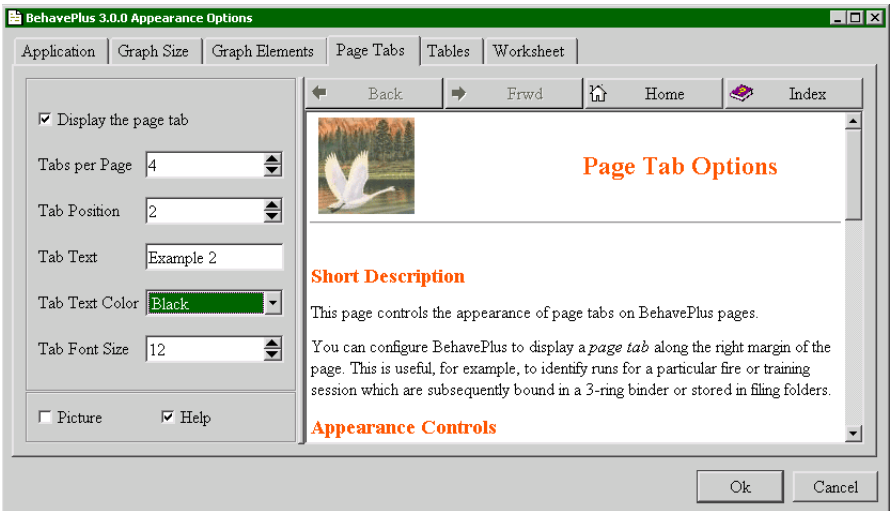
3.3.9. Borders



The border color and thickness on the Worksheet and output pages can be changed on the **Configure > Appearance > Application** tab using the **Border Color** drop-down list and the **Border Width** spin box. The border can be eliminated by entering a **Border Width** of 0.

3.3.10. Page Tabs

Page tabs can be displayed along the right margin of the page. This is useful, for example, to identify Runs for a particular fire or training session that are subsequently bound in a three-ring binder or stored in filing folders. Page tabs can be added and defined with the **Configure > Appearance > Page Tabs** tab.



Tabs per page - The size of the tab depends upon the value selected in this spin box. Only one tab is actually displayed per page. If tabs per page 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.

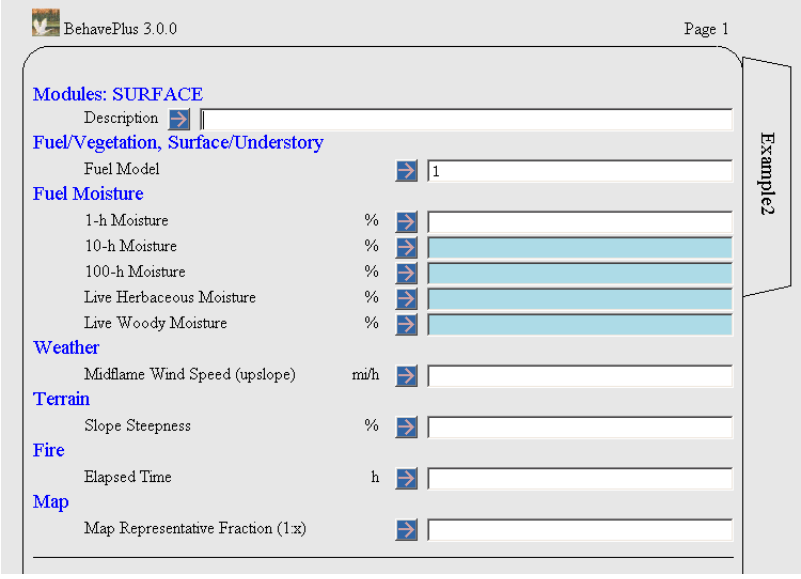
Tab position - Determines the position of the displayed tab. Tab position 1 is always at the upper edge of the right margin.

Tab text - The text 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 - A color is selected from the drop-down list.

Tab font size - Font point size is selected using this spin box.

The above settings create the tab on the Worksheet below:



3.4. Loading a previously saved Worksheet

A previously saved Worksheet can be loaded using

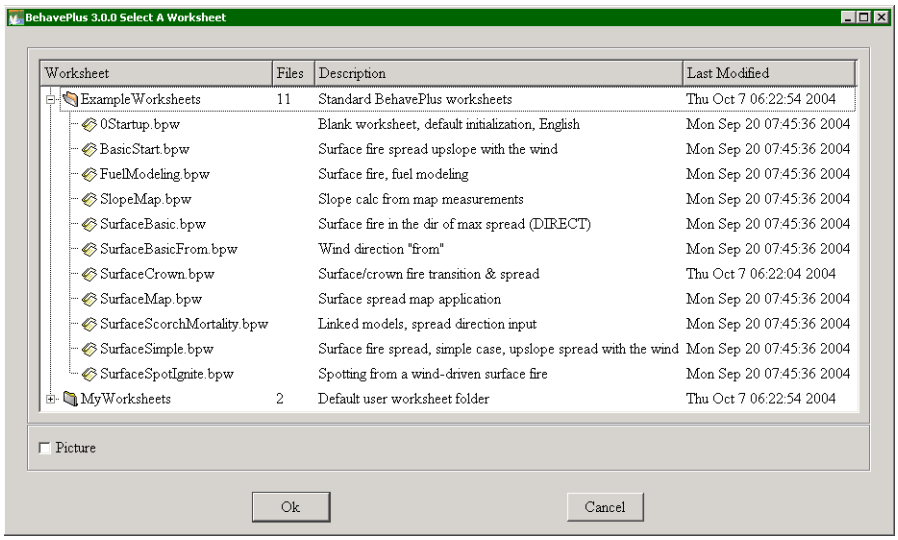
- the **File > New** command,
- or the toolbar button.

To see the Worksheets in the folder click on the button to the left of the folder.

To select a Worksheet either

- double click on it,
- or select and click the **OK** button.

A set of Worksheets is supplied with the program in the "ExampleWorksheets" folder. A short description is given for each. See Appendix E for further description of the "ExampleWorksheets".



3.5. The 0Startup Worksheet

The 0Startup.bpw Worksheet is a special case. It is used as the starting place for selecting calculation modules. It shows no input or output variables, but it sets defaults for all Run settings as described in Appendix D. The 0Startup.bpw Worksheet was used to initialize all of the example Worksheets.

A Worksheet can be designed to meet specific needs by starting with the 0Startup.bpw Example Worksheet, selecting the desired modules, and changing options as needed. The startup Worksheet is named 0Startup.bpw to assure that it is the first selection of the Example Worksheets folder.

3.6. Changing a Worksheet

A Worksheet can be changed at any time by changing the selected modules and associated options. The changes are in effect only for the current session unless the revised Worksheet is saved. If a Worksheet that came with the program in the ExampleWorksheets folder is changed, the revised version must be saved in another Worksheet folder.

3.7. Saving a Worksheet or a Run

A Worksheet can be saved for later use with the **File > save As > Worksheet** command. The values entered onto the Worksheet are not saved.

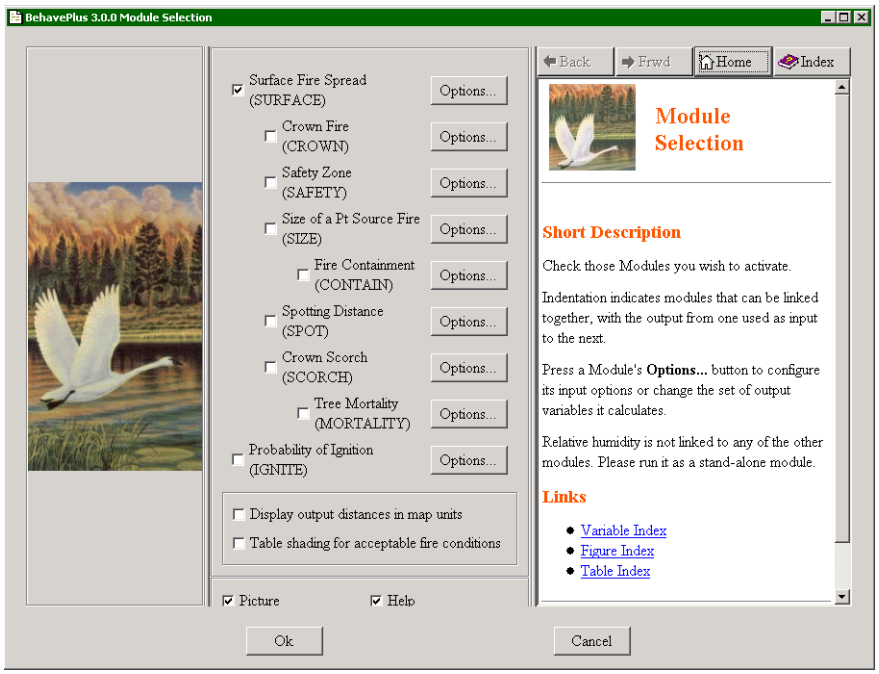
Save the Run, which is just a Worksheet with the defined input values, with the **File > save As > Run** command.

See the Section 20.4, Save As, for more specific information.

4. Modules

Modules define a set of fire models for a Worksheet. Selection can be made with the **Configure > Module** command.

The output variables that can be calculated by each module are given in the output variable table in Appendix B.

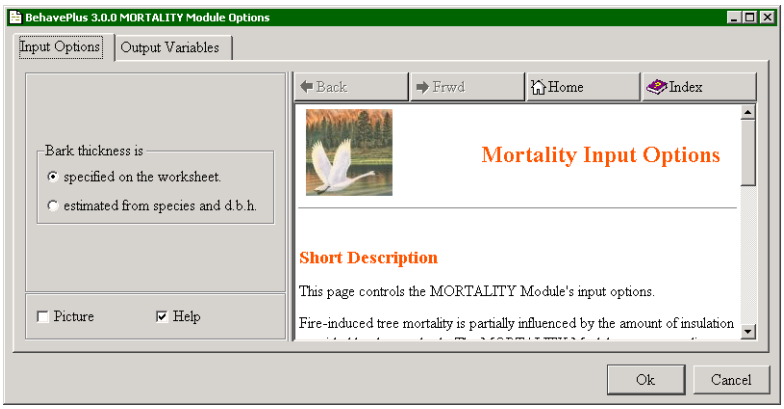


Indentation indicates that the modules can be linked, which means that output from one module is used as input to the other. For example, if both SURFACE and SAFETY are selected, the modules are linked. Output from SURFACE is used as input to SAFETY. If only SAFETY is selected, all required input is entered by the user. A table of input variables and associated modules is given in Appendix B.

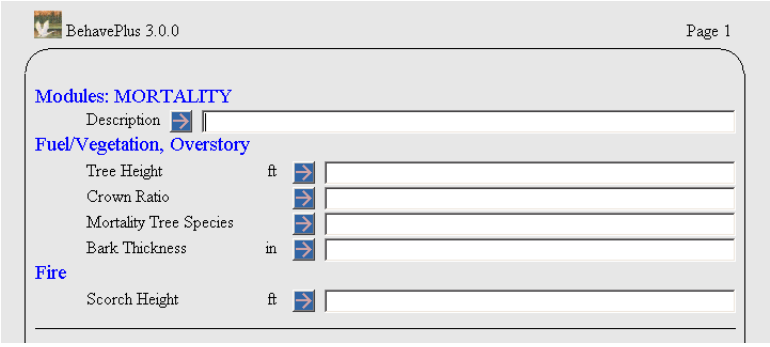
Selection of modules, options, and output variables determines the required input variables on the Worksheet. The **Options...** button is used to configure a module's input options or change the output variables calculated.

4.1. Input options

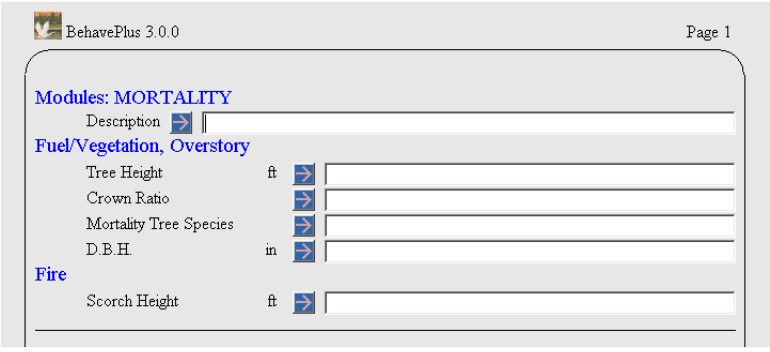
Some modules offer options on alternate ways of specifying input. Others do not. For example, clicking the MORTALITY **Options...** button displays the "Mortality Module Options" dialog box with the **Bark thickness is** input option:



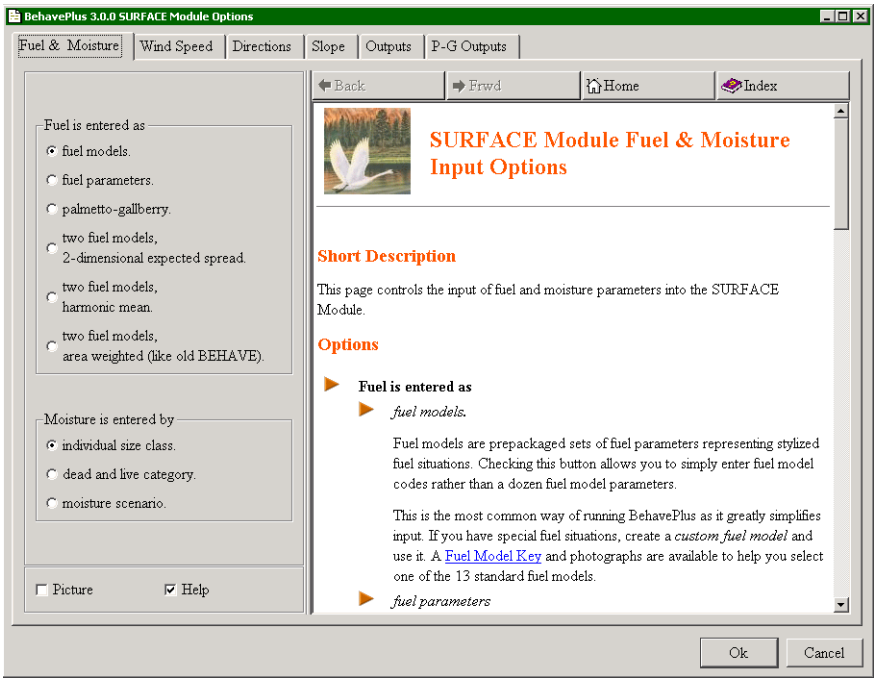
The bark thickness option affects the input variables included on the Worksheet. If **Bark thickness is specified on the worksheet** is selected, the resulting Worksheet is as follows:



If **Bark thickness is estimated from species and d.b.h.** is selected, the Worksheet is as follows:

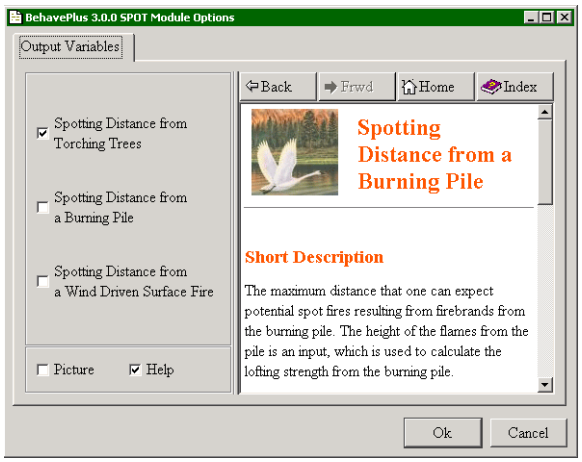


The SURFACE module has many input options. For readability, they are available on several tabs:



4.2. Output Options

The desired output variables are selected through the **Options...** button associated with each module.The selected output determines the input requirements. For example, input variables for the SPOT Module are different for each spotting source.



Pause the mouse over the name of an output variable to see its description in the browser pane. For example, a pause over **Spotting Distance from a Wind Driven Surface Fire** in the SPOT **Output Variables** tab results in this browser pane.

5. Entering input

There are several ways to input to the BehavePlus program. Values can be typed directly into the input field, choices can be made from a list of valid input values, a range of values can be specified, and for some variables, selecting from a list of common choices.

5.1. Shaded text boxes

In some cases, input variables depend on values entered elsewhere on the Worksheet. When an input variable is not required, its text box is shaded. If a value is entered for a shaded text box, it is not used.

5.2. Direct entry

Values can be typed directly into the variable text boxes and the 'Enter' or 'Tab' keys moves the cursor to the next field. The cursor can also be moved to any text box with a mouse click. More than one value can be entered for an input variable. Multiple values are separated by a space or comma delimiter. You do not need to always specify equal steps. You can enter several independent values separated by delimiters.

For table output a separate row and/or column will be created for each value from the input variable text box. For graphs of continuous input variables the curve is drawn between the smallest and largest value entered. Graphs of discrete variables will display a separate bar for each input value. See chapter 6, Table output, for more on how multiple values affect outputs.

5.3. Input Guide

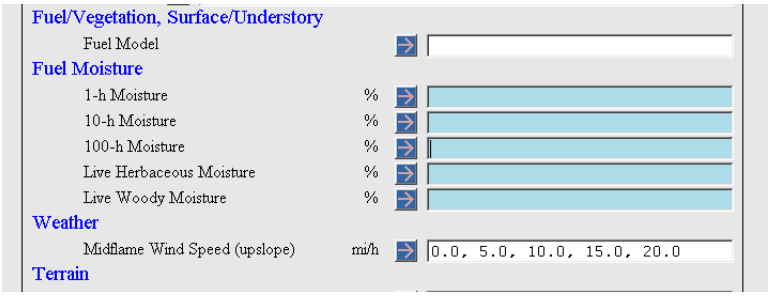
The "Input Guide" dialog box is opened by clicking the Guide button to the left of each input variable text box.

5.3.1. Continuous variables

Valid input ranges can be viewed in the "Input Guide" dialog box.

Single values are entered in just the **From** text box and a second value can be entered in the **Thru** text box.

For continuous variables the "Input Guide" dialog box allows definition of a range of values by a constant increment. For example, midflame wind speed from 0 to 20 mi/h in steps of 5 enters 0, 5, 10, 15, 20 on the Worksheet as shown below.

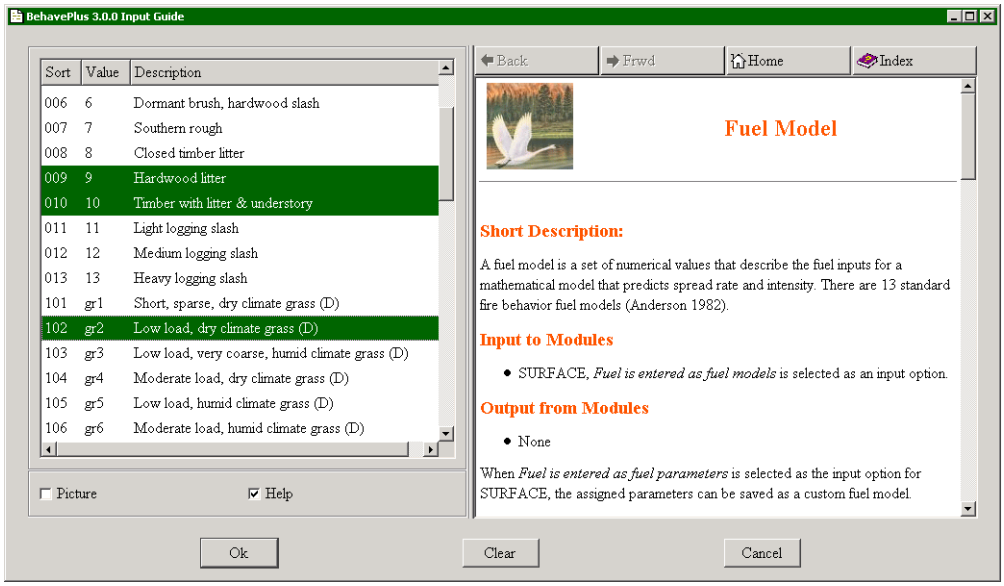


You can also enter a decreasing range with a negative step. This is useful when you have two input variables, such as wind and fuel moisture, that have opposite effect on fire behavior

5.3.2. Discrete variables

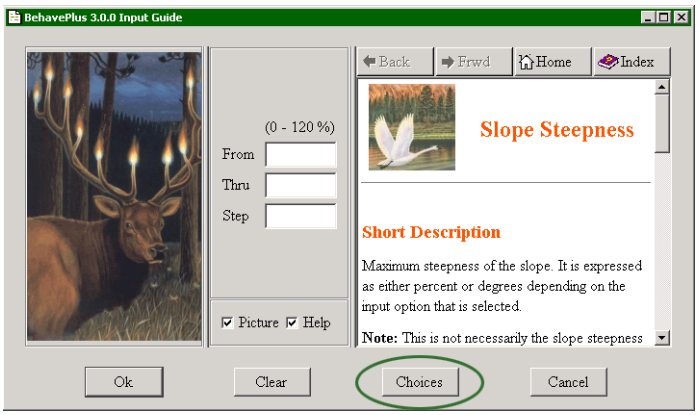
When the Guide button is clicked for a discrete variable, the allowed selections are given in the center pane of the "Input Guide" dialog box.

Clicking the values selects them; you can select several values. This example shows the fuel model "Input Guide" dialog box. The **Ok** button enters the selected fuel models on the Worksheet.



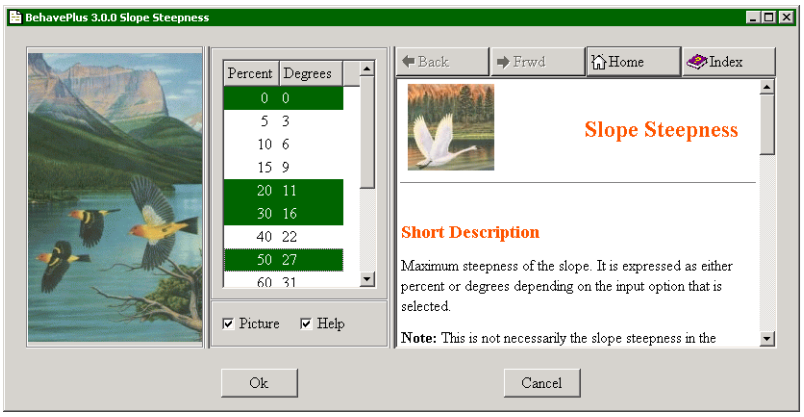
5.3.3. Choices button

Although any value in the valid range can be entered for a continuous variable, in some cases common values can be entered with the **Choices** button.



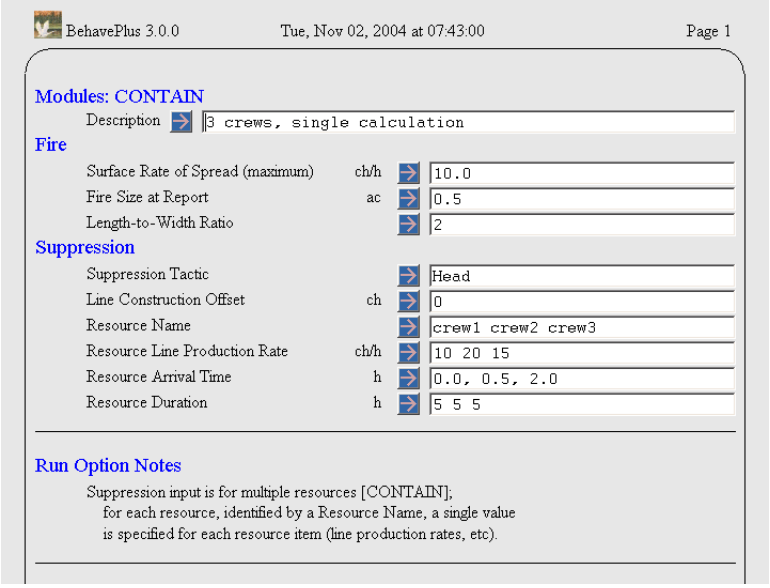
When available on the "Input Guide" dialog box, clicking the **Choices** button displays commonly used values.

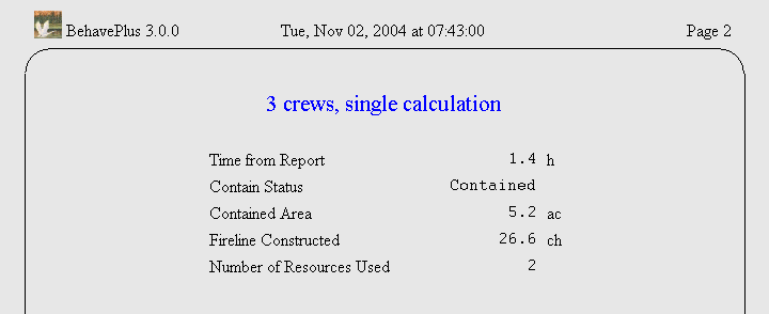
After selecting values in the "Slope Steepness" dialog box, clicking **Ok** enters them on the Worksheet.



5.4. Linked input variables

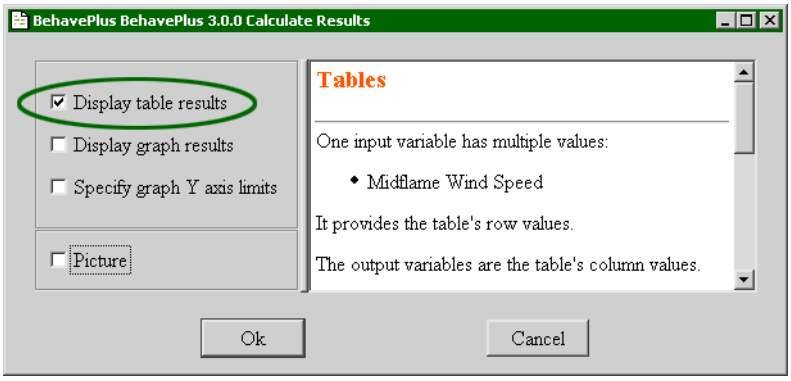
When using the CONTAIN module, with the **multiple resources** input option selected some, input variables are directly associated with each other (an exception to the general BehavePlus rule). For example, a line production rate, arrival time, and duration are assigned to each resource. Linked input variables also allow you to enter multiple values for more than two input variables. In the following example, although multiple values are assigned to several input variables, those variables are linked together, so only a single calculation is done.





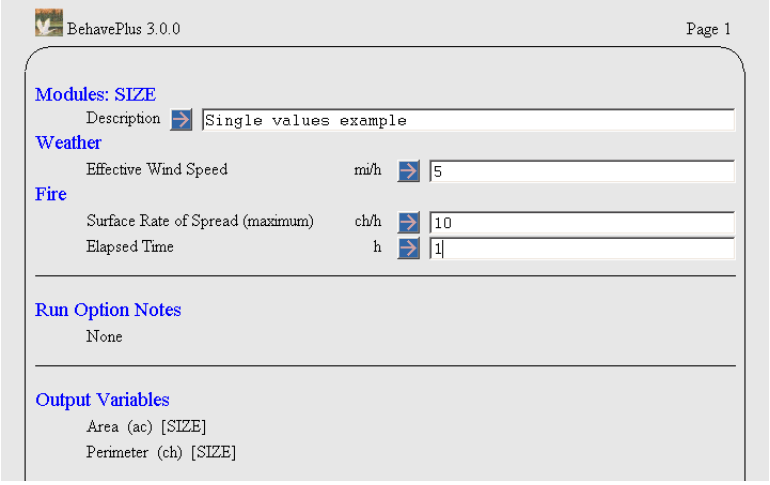
6. Table output

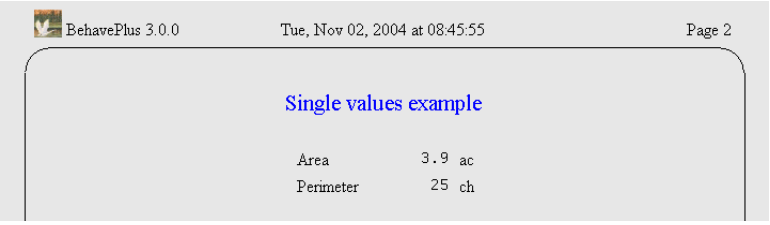
When more than one value is assigned to one or two input variables, table output is produced. Tables are produced by selecting the **Display table results** check box in the "Calculate Results" dialog box that displays after selecting a **File > Calculate** command.



6.1. Single value calculation

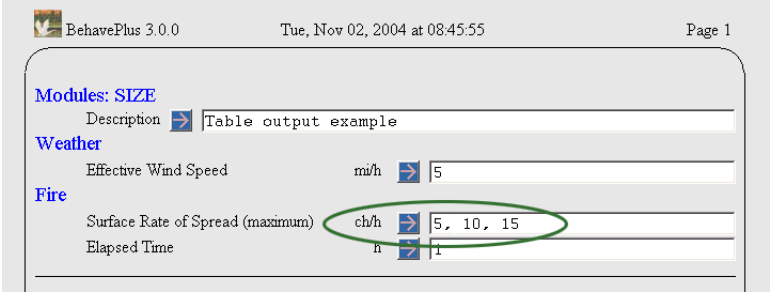
When each variable is assigned only one value, a simple list of output is given. No table or graph is possible. For example:

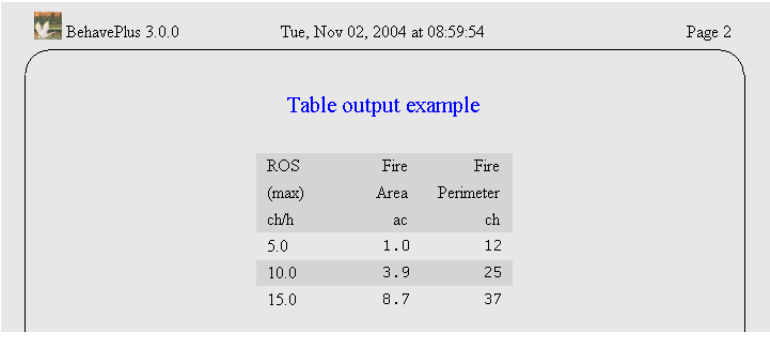




6.2. Table output

When more than one value is assigned to a variable, table output is produced. Each output variable is a specified column. For example, these multiple **Rate of Spread** inputs produce the page 2 table below:

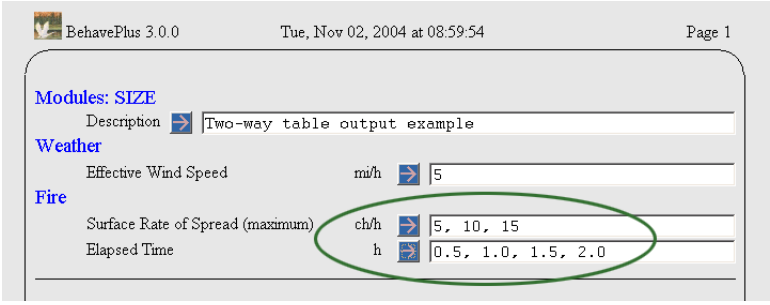


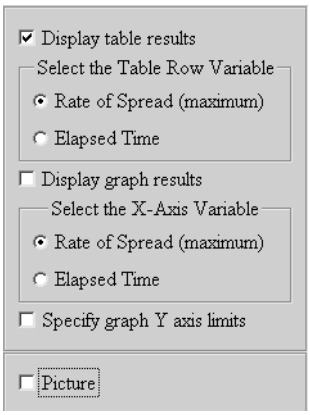


ROS (max) ch/h	Fire Area ac	Fire Perimeter ch
5.0	1.0	12
10.0	3.9	25
15.0	8.7	37

6.3. Two way tables

When more than one value is assigned to two variables, a two way table is produced. A table is produced for each selected output variable. Either variable can be specified as the row variable in the "Calculate Results" dialog box.





For example, with the above inputs this dialog box appears when you Calculate the Run.

After selecting the Rate of Spread (maximum) option button and clicking the Ok button, the following tables are produced:

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Two-way table output example

Area (ac)

ROS (max) ch/h	Elapsed Time h 0.5	1.0	1.5	2.0
5.0	0.2	1.0	2.2	3.9
10.0	1.0	3.9	8.7	15.5
15.0	2.2	8.7	19.7	35.0

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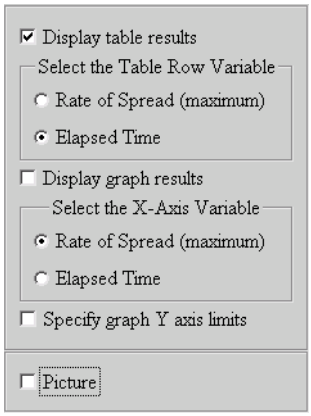
Two-way table output example

Perimeter (ch)

ROS (max) ch/h	Elapsed Time h 0.5	1.0	1.5	2.0
5.0	6	12	19	25
10.0	12	25	37	50
15.0	19	37	56	74



Changing the Table Row Variable to the **Elapsed Time** option button swaps the table columns and rows produces the following tables:

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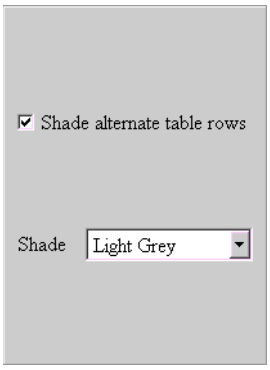
Two-way table output example

Area (ac)

Elapsed Time h	Surface Rate of Spread (maximum) ch/h 5.0	10.0	15.0
0.5	0.2	1.0	2.2
1.0	1.0	3.9	8.7
1.5	2.2	8.7	19.7
2.0	3.9	15.5	35.0

6.4. Table appearance

Table row shading can be enabled with the **Configure > Appearance > Tables** tab.



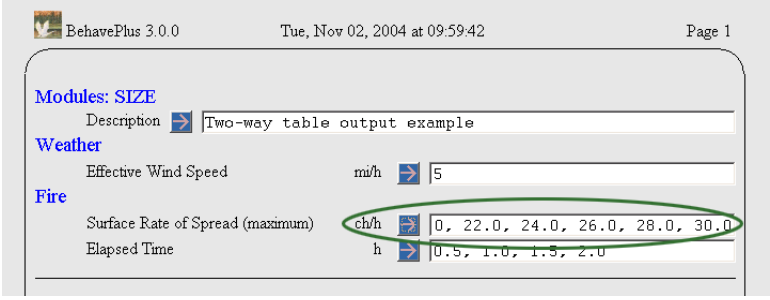
Selecting the **Shade alternate table rows** check box causes all output tables to have alternating rows shaded with a background color. This may improve the readability of wide tables. If the check box is cleared, tables are displayed without any row background color.

The table row background color is selected from the **Shade** drop-down list.

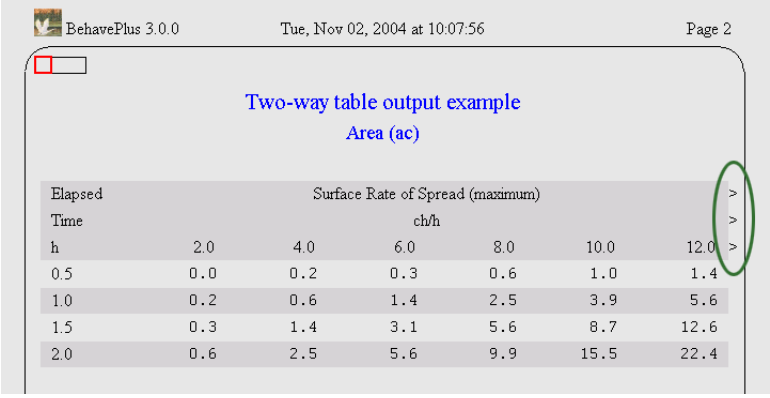
This table appearance option is used to improve table readability, don't confuse it with the **Table shading for acceptable fire conditions** output option. See chapter 7, Table shading, for more information.

6.5. Multiple pages

There is essentially no limit on the number of values that can be assigned to an input variable. But the resulting table might not fit on a single page. For example, if rate of spread is calculated for values from 2 to 30 in steps of 2, and elapsed time is specified as the row variable, the table overlaps onto 3 pages.



The > or < symbols lined to the right and/or left of the table heading indicates that there are additional results for those variables in the indicated direction.



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Two-way table output example

Area (ac)

< Elapsed	Surface Rate of Spread (maximum)					>
< Time	ch/h					>
< h	14.0	16.0	18.0	20.0	22.0	24.0 >
0.5	1.9	2.5	3.1	3.9	4.7	5.6
1.0	7.6	9.9	12.6	15.5	18.8	22.4
1.5	17.1	22.4	28.3	35.0	42.3	50.3
2.0	30.5	39.8	50.3	62.2	75.2	89.5

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Two-way table output example

Area (ac)

< Elapsed	Surface Rate of Spread (maximum)		
< Time	ch/h		
< h	26.0	28.0	30.0
0.5	6.6	7.6	8.7
1.0	26.3	30.5	35.0
1.5	59.1	68.5	78.7
2.0	105.0	121.8	139.9

The box diagram at the upper left of the pages shows the relative position of the currently viewed page in the multi-page table.

In this example, however, it would make more sense to specify rate of spread as the row variable since it produces a table that fits on a single page as shown below:

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Two-way table output example

Area (ac)

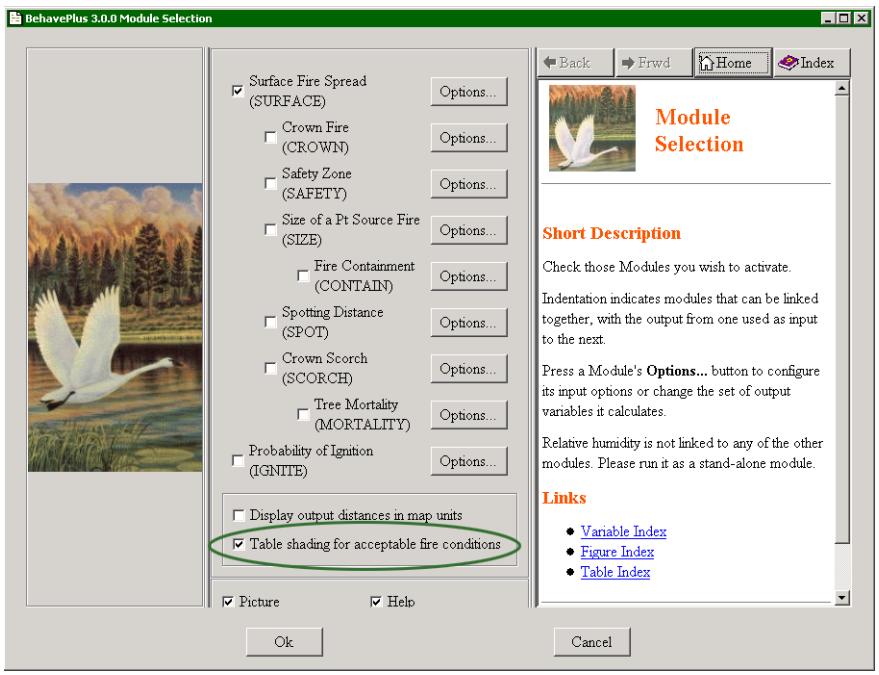
ROS	Elapsed Time			
(max)	h			
ch/h	0.5	1.0	1.5	2.0
2.0	0.0	0.2	0.3	0.6
4.0	0.2	0.6	1.4	2.5
6.0	0.3	1.4	3.1	5.6
8.0	0.6	2.5	5.6	9.9
10.0	1.0	3.9	8.7	15.5
12.0	1.4	5.6	12.6	22.4
14.0	1.9	7.6	17.1	30.5
16.0	2.5	9.9	22.4	39.8
18.0	3.1	12.6	28.3	50.3
20.0	3.9	15.5	35.0	62.2
22.0	4.7	18.8	42.3	75.2
24.0	5.6	22.4	50.3	89.5
26.0	6.6	26.3	59.1	105.0
28.0	7.6	30.5	68.5	121.8
30.0	8.7	35.0	78.7	139.9

7. Table Shading

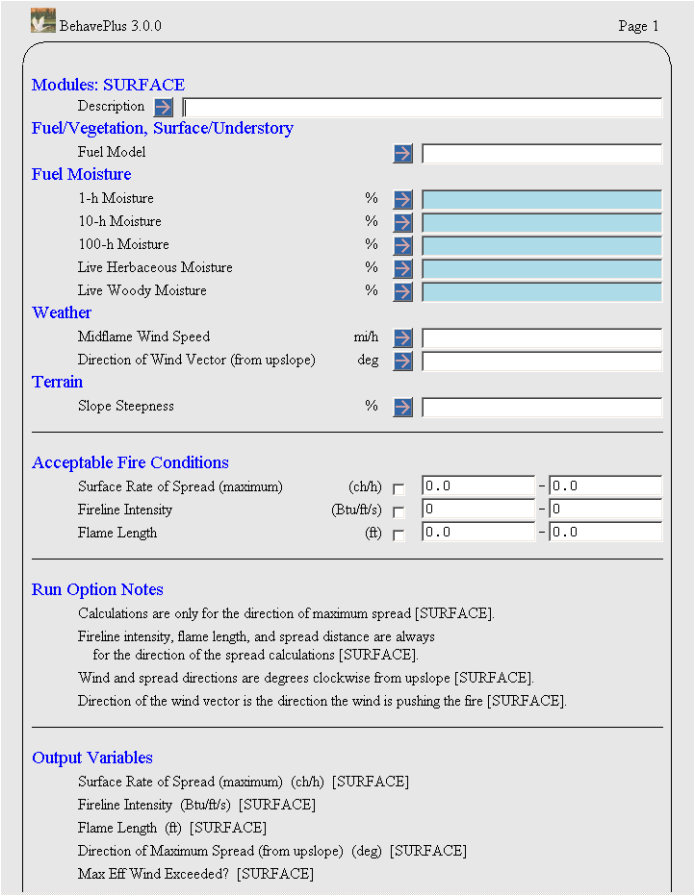
Table shading for acceptable fire conditions is designed to display the conditions that contribute to acceptable fire behavior, such as in developing a prescribed fire prescription. It replaces the RXWINDOW program of the old BEHAVE system. RXWINDOW attempted to reverse the calculations to determine conditions that corresponded to specified fire conditions. As additional fire models have become available, this approach is unfeasible. The approach taken in BehavePlus is different from that in RXWINDOW.

7.1. Activating the Table Shading Option

To implement the table shading option select the **Table shading for acceptable fire conditions** check box in the "Module Selection" dialog box.



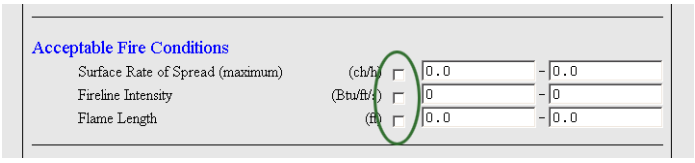
Once the **Table shading for acceptable fire conditions** check box is selected a new section, **Acceptable Fire Conditions**, appears on the Worksheet.



Notice that some of the output variables are listed in the **Acceptable Fire Conditions** section. Not all the output variables are available to be constrained. The output variables that can be used to identify acceptable fire conditions are listed in Table 2 of Appendix B.

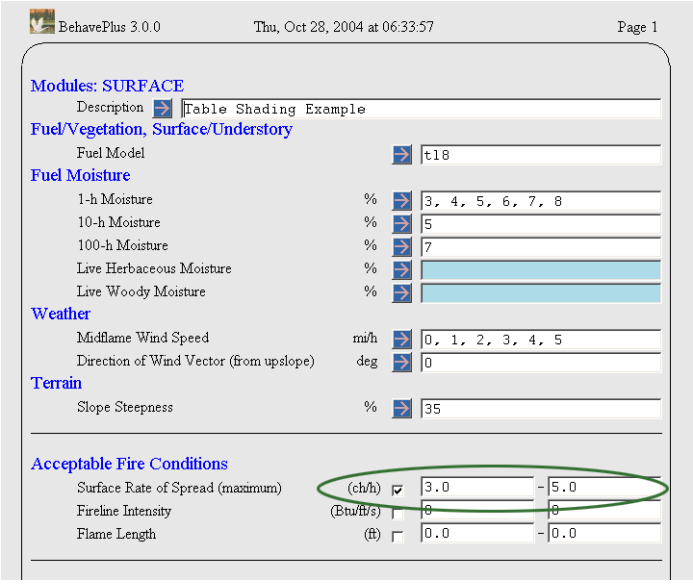
7.2. Entering Acceptable Fire Conditions

In the **Acceptable Fire Conditions** section each output variable listed has a check box and two text boxes for entering the range of acceptable fire conditions. By default the check boxes are cleared. The ranges specified in the text boxes are only considered if the output variable check box is selected.



This allows you to view all the output variables you want while only using a subset to define your acceptable fire conditions. Of course if an output variable is of no interest then clear it from the **Outputs** tab for the appropriate module and it appears in neither the **Acceptable Fire Conditions** or **Output Variables** section.

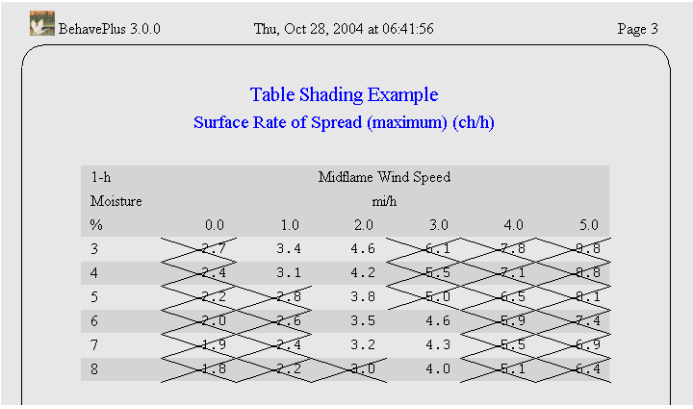
After selecting the output variables to define acceptable fire conditions enter the acceptable ranges in the corresponding text boxes.



If you decide to clear a check box in the **Acceptable Fire Conditions** section there is no need to zero out the range text boxes, any ranges are ignored if the check box is cleared.

7.3. Viewing Results

After calculating the Run the table output will look like this.



1-h Moisture %	Midflame Wind Speed mi/h 0.0	1.0	2.0	3.0	4.0	5.0
3	2.7	3.4	4.6	6.1	7.8	9.8
4	2.4	3.1	4.2	5.5	7.1	8.8
5	2.2	2.8	3.8	5.0	6.5	8.1
6	2.0	2.6	3.5	4.6	5.9	7.4
7	1.9	2.4	3.2	4.3	5.5	6.9
8	1.8	2.2	3.0	4.0	5.1	6.4

The output values are crossed out (shaded) except for those specified as acceptable on the Worksheet. The table outputs for all output variables are shaded, but only for the ranges selected on the Worksheet in the **Acceptable Fire Conditions** section. For example,

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Table Shading Example
Fireline Intensity (Btu/ft/s)

1-h Moisture %	Midflame Wind Speed mi/h 0.0	1.0	2.0	3.0	4.0	5.0
3	41	52	70	93	119	149
4	35	44	60	79	102	127
5	30	38	52	69	88	110
6	26	33	45	60	77	96
7	23	29	40	53	68	85
8	21	26	36	47	61	76

on the Fireline Intensity table, the shaded values are the ones that are outside of the 3-5 ch/h surface rate of spread range.

If Fireline Intensity is also selected to define acceptable fire conditions all output tables will change.

Acceptable Fire Conditions

Surface Rate of Spread (maximum)	(ch/h)	☑	3.0	-	5.0
Fireline Intensity	(Btu/ft/s)	☑	0	-	50
Flame Length	(ft)	☐	0.0	-	0.0

For the above ranges using the same fuel, weather, and topography inputs the table outputs looks like this;

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Table Shading Example
Surface Rate of Spread (maximum) (ch/h)

1-h Moisture %	Midflame Wind Speed mi/h 0.0	1.0	2.0	3.0	4.0	5.0
3	2.7	3.4	4.6	6.1	7.8	9.8
4	2.4	3.1	4.2	5.5	7.1	8.8
5	2.2	2.8	3.8	5.0	6.5	8.1
6	2.0	2.6	3.5	4.6	5.9	7.4
7	1.9	2.4	3.2	4.3	5.5	6.9
8	1.8	2.2	3.0	4.0	5.1	6.4

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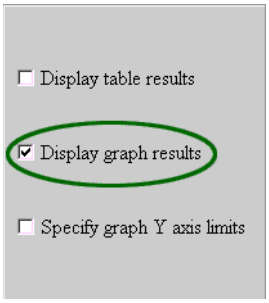
Table Shading Example
Fireline Intensity (Btu/ft/s)

1-h Moisture %	Midflame Wind Speed mi/h 0.0	1.0	2.0	3.0	4.0	5.0
3	41	52	70	93	119	149
4	35	44	60	79	102	127
5	30	38	52	69	88	110
6	26	33	45	60	77	96
7	23	29	40	53	68	85
8	21	26	36	47	61	76

Now acceptable output must meet both ranges of acceptable conditions which further constrains the fuel moisture and wind conditions that give desired results. Selecting two or more variables in the **Acceptable Fire Conditions** section can give very complex results that should be interpreted carefully.

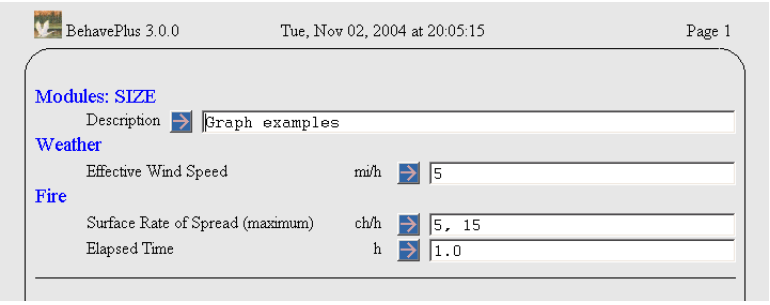
8. Graph output

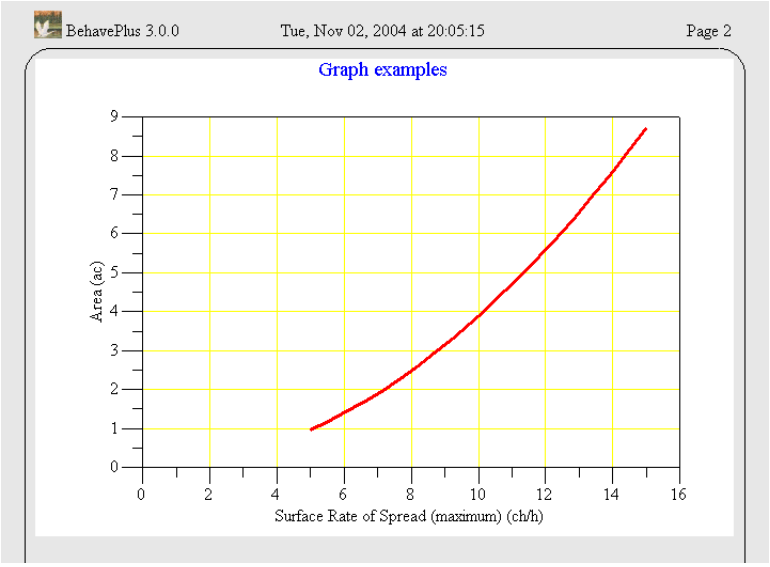
When more than one value is entered for one or two input variables, graphs can be produced. Graphs are viewed by selecting the **Display Graph Results** check box in the "Calculate Results" dialog box that displays after Calculate is requested. The form of the graph depends on whether the variables are continuous or discrete. The program automatically takes care of the differences for the user..



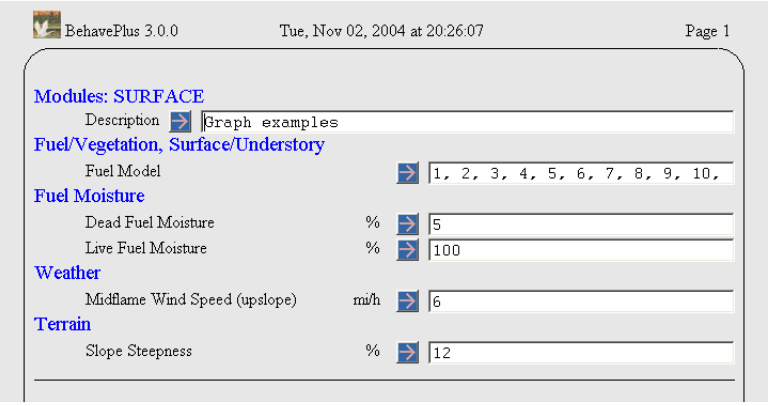
8.1. Single variable graph

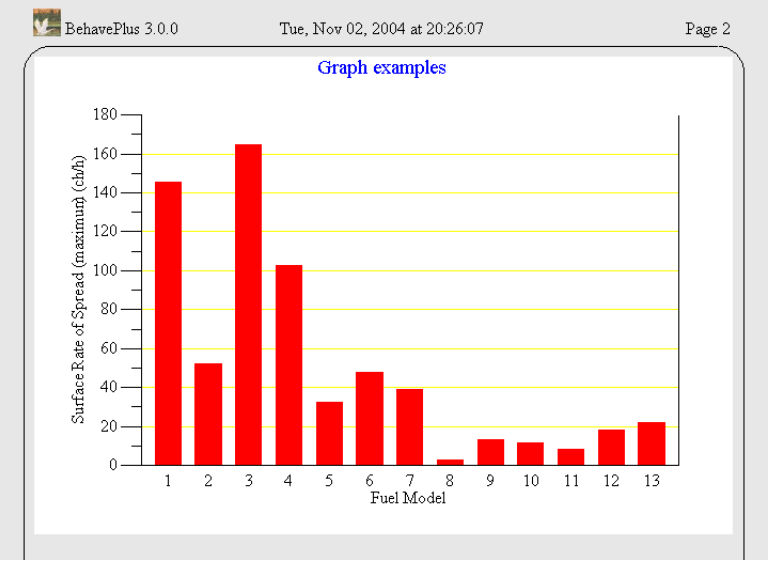
When a range of values is entered for a single continuous variable, a graph is produced by calculating a fixed number of points (which can be changed in the **Configure > Appearance > Graph Elements** tab) over the entered range. Intermediate values entered on the Worksheet are ignored. For example, rate of spread entry of 5, 7, 9, 11, 13, 15 produces the same graph as rate of spread entry of 5, 15:





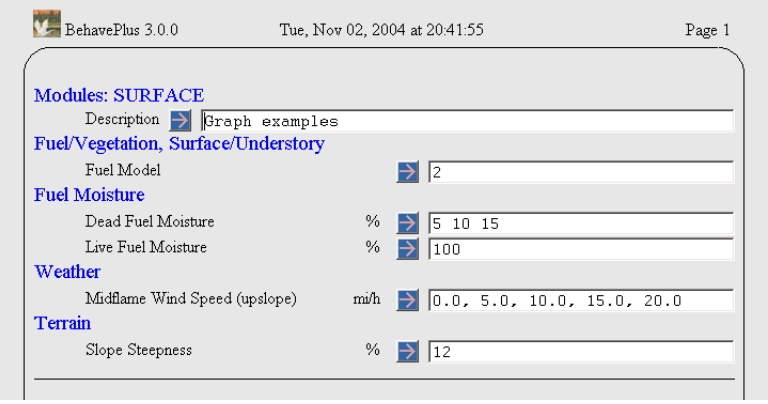
When a range of values is assigned to a discrete variable, a single calculation is performed for each value and a bar graph is produced. For example, the following is a comparison of surface fire spread rates for the standard 13 fire behavior fuel models:



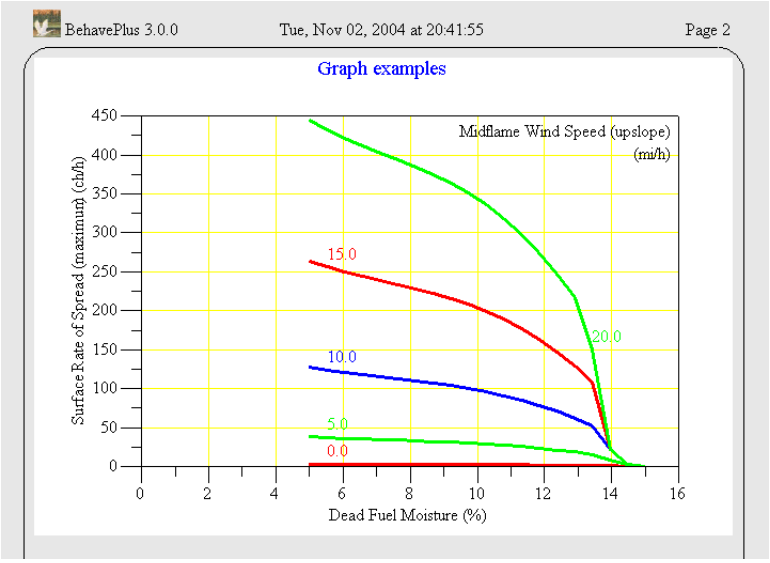


8.2. Two variable graph

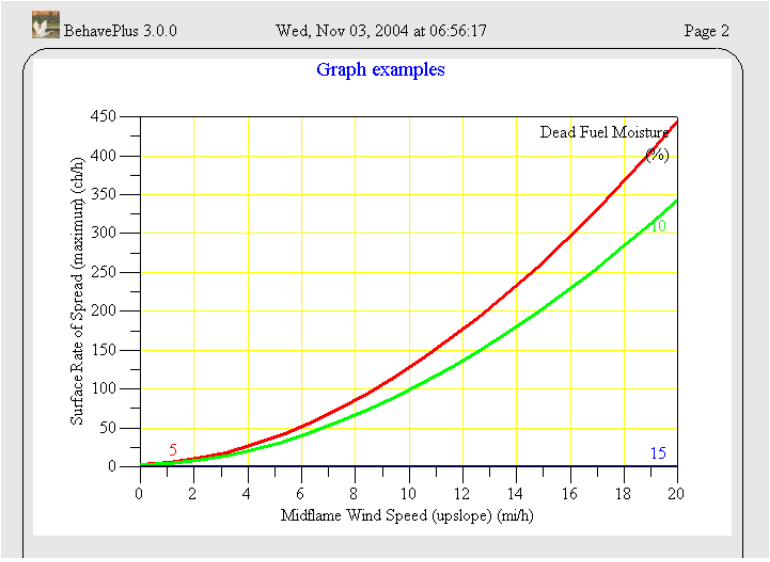
When a range of values is assigned to two variables, a graph is produced. If both variables are continuous, the variable used for the X-axis can be selected from the "Calculate Results" dialog box. For example:



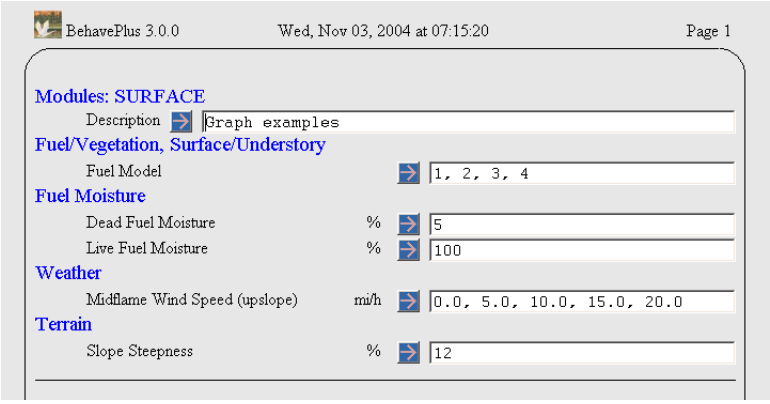
In the "Calculate Results" dialog box clear the **Display table results** check box and accept the defaults in the **Display graph results** section:

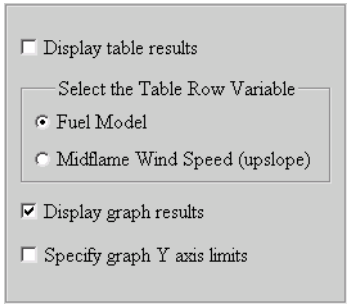


Changing the **X-Axis Variable** to the **Midflame Wind Speed (upslope)** in the "Calculate Results" dialog box produces a very different graph:

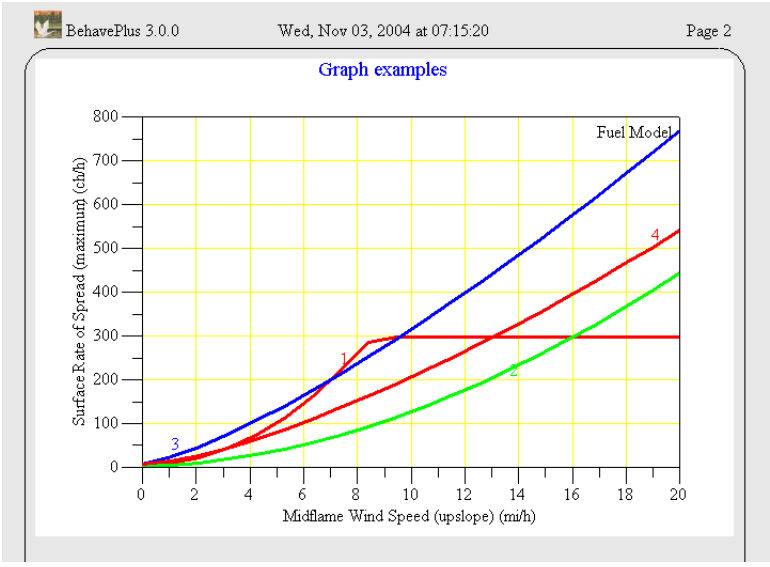


If a range is assigned to two variables, one continuous and one discrete, the continuous variable is always on the X-axis. For example:





With two variables, one continuous and one discrete, you no longer have the option of changing the **X-Axis Variable** in the "Calculate Results" dialog box.



A graph is not possible when ranges are selected for two discrete variables.

8.3. Axis scales

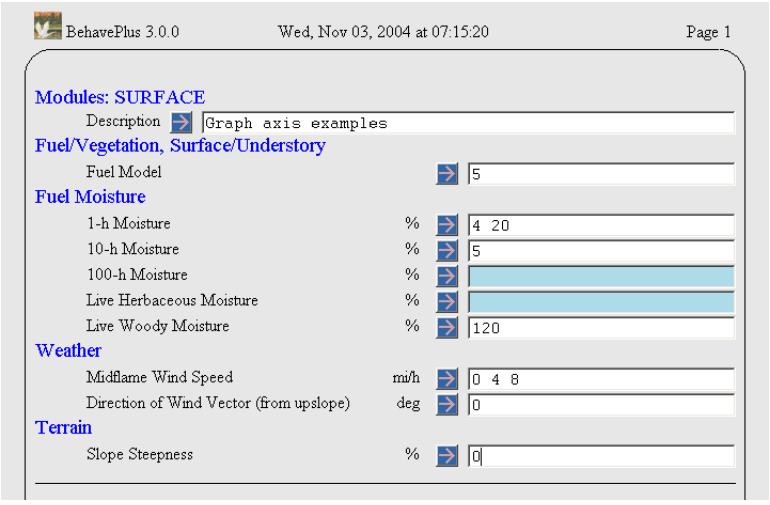
Setting axis scales is important for getting the best information from your Runs, and especially for comparing graph output from different Runs.

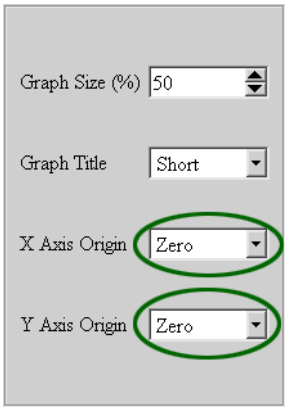
8.3.1. X-axis

The X-axis variable and scale are the same for all graphs produced by a Run. The maximum for the x-axis is set to be the maximum value specified for the variable on the Worksheet.

X Axis Origin and **Y Axis Origin** (minimum values) can be set for each as either zero or as the variable's minimum value as specified on the input Worksheet. The graph origin is set to (0,0) as the default.

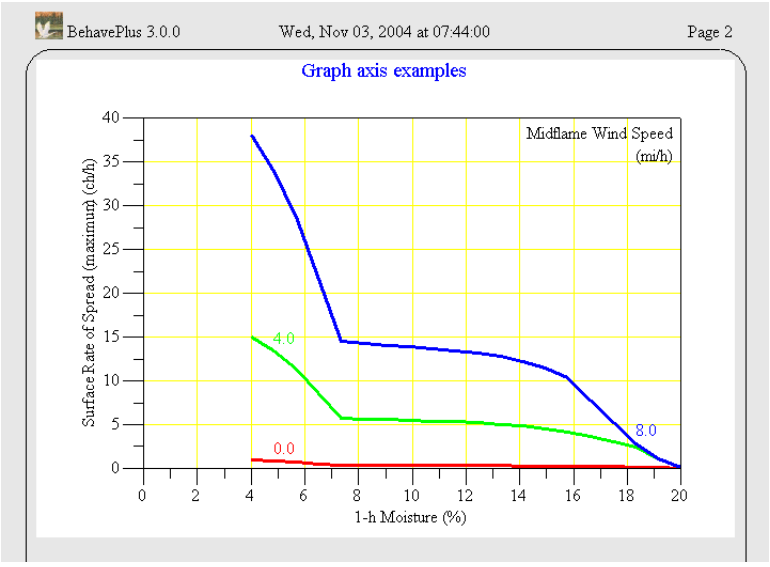
For example, consider the following Run:

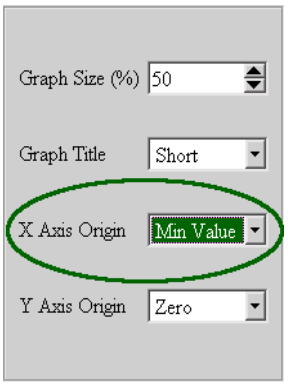




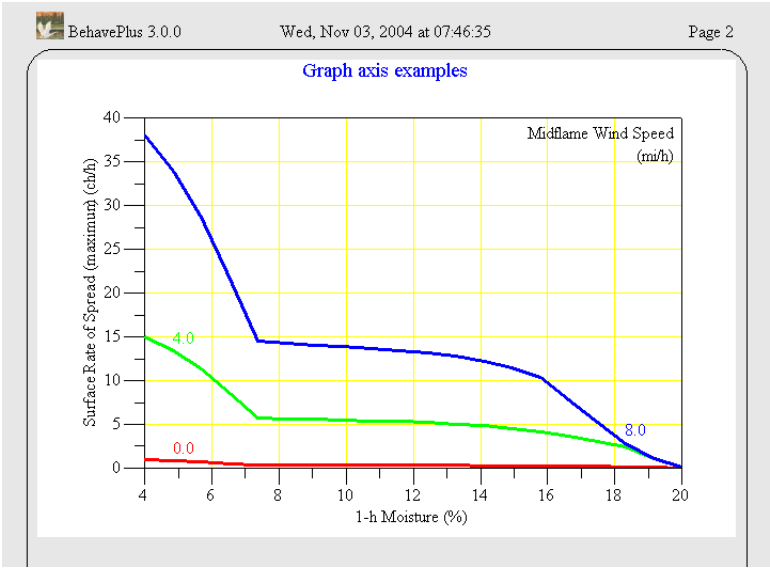
Options to define the origin of the graph are set through the **Configure > Appearance > Graph Size** tab.

Setting both the **X Axis Origin** and **Y Axis Origin** to zero produces the following graph:





In the **Configure > Appearance > Graph Size** tab select **Min Value** from the **X-Axis Origin** drop-down list to alter the graph appearance.

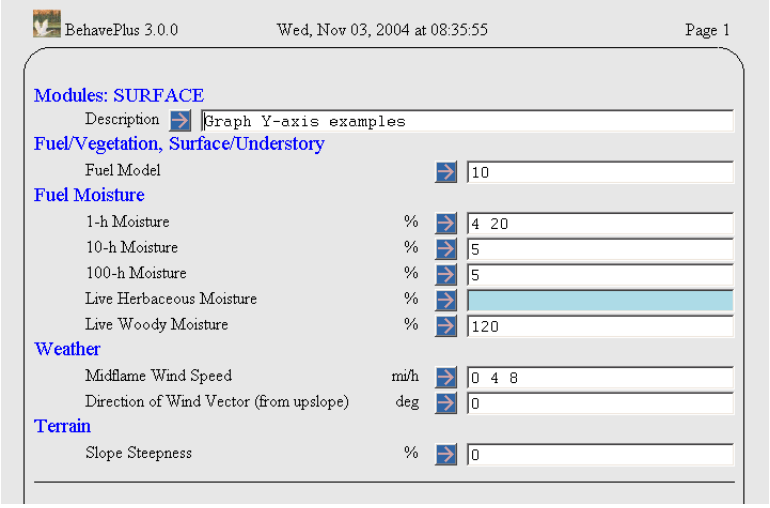


8.3.2. Y-axis

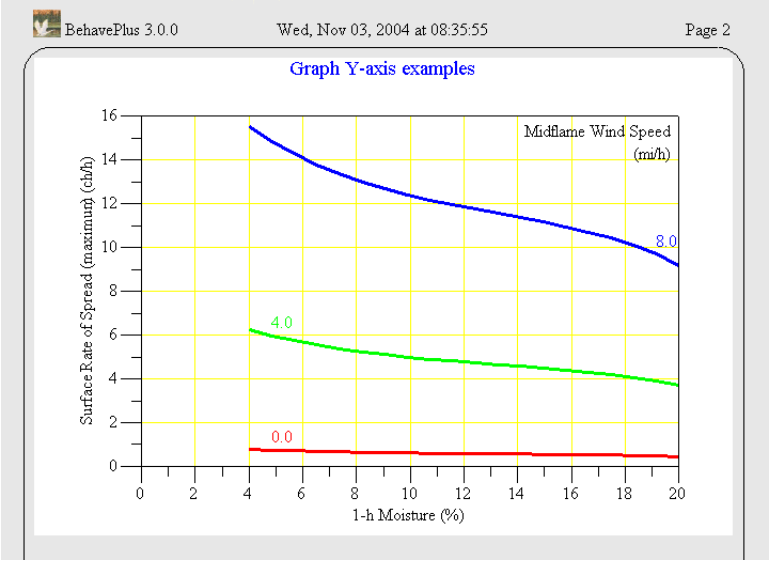
The Y-axis scale normally differs between graphs produced by a Run since each graph is for a different output variable. For example, fireline intensity and flame length have different ranges of output and require a different Y-axis scale. By default the Y-axis is scaled to the maximum calculated output value for the variable to make best use of the graph area.

When you want to compare graphs between Runs, different Y-axis scales can obfuscate the comparison. A rate of spread graph for fuel model 10, for example, usually has a narrower output range than for fuel model 5 under the same conditions. To better compare calculated rate of spread graphs for the two fuel models, you can set both graphs to have the same Y-axis scale.

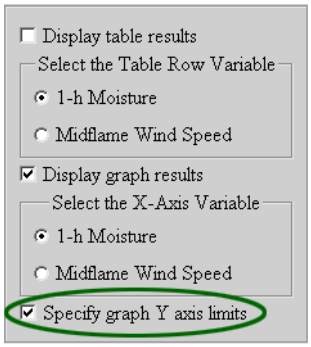
The following Run is for fuel model 10, which has relatively low rates of spread.



With the **X Axis Origin** and **Y Axis Origin** set to zero, the rate of spread graph below is produced:

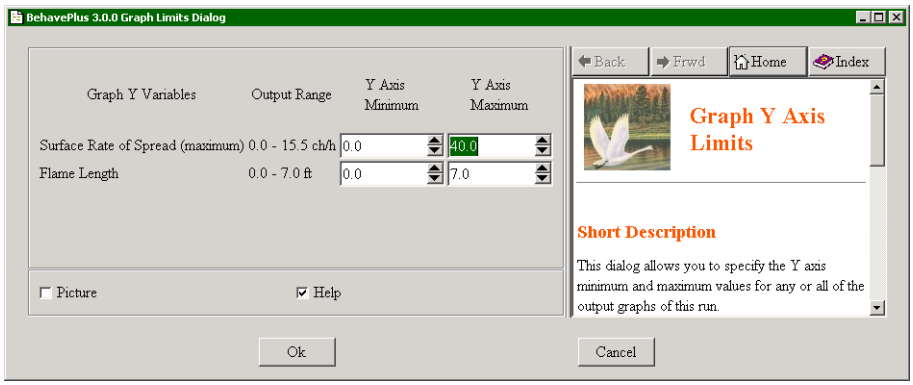


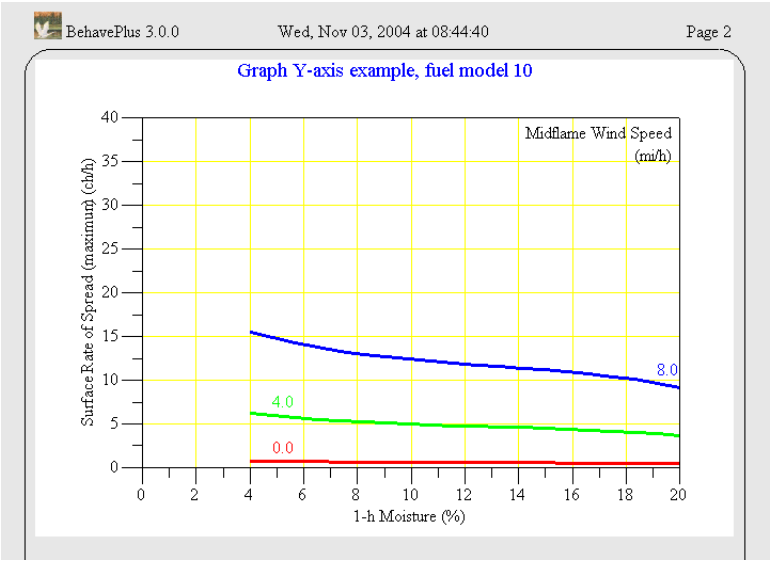
To compare the results for fuel model 10 with the faster spreading fuel model 5, the scale for the fuel model 10 Run is changed to match that produced by model 5. The calculated maximums are given for each of the selected output variables as a reference.



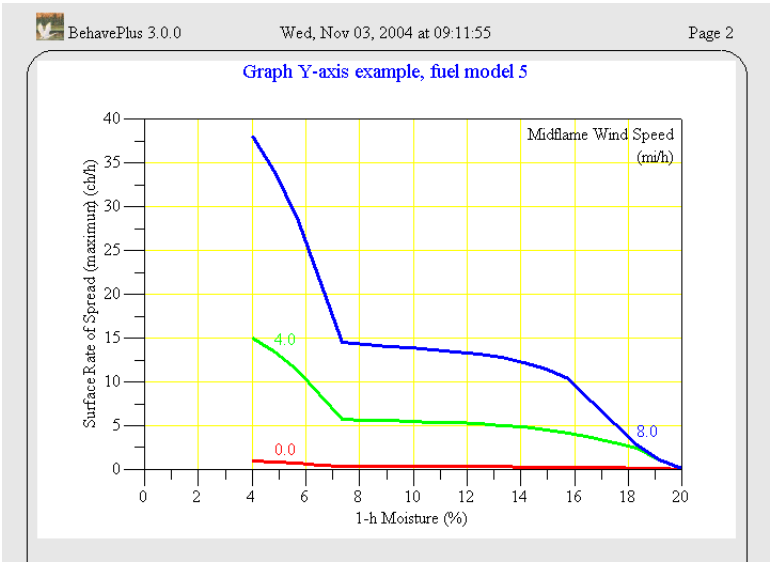
In the "Calculate Results" dialog box select the **Specify graph Y axis limits** check box if you wish to modify the Y-axis ranges of the output graphs before they are displayed.

This displays the "Graph Limits" dialog box, where you can change the Y-axis maximum for the variable **Rate of Spread (maximum)** to 40:



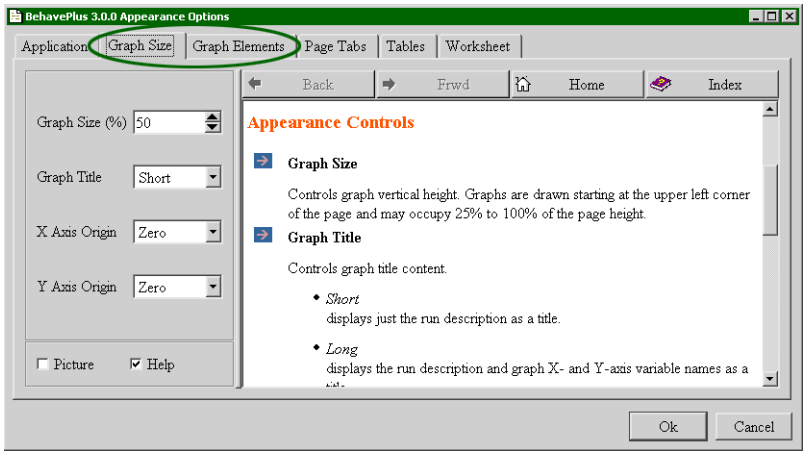


The comparison with the corresponding graph for fuel model 5 is now more straightforward now that the axis are the same.

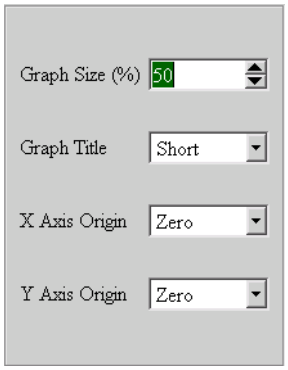


8.4. Graph appearance

The appearance of the graph can be changed through the **Configure > Appearance > Graph Size** and **Configure > Appearance > Graph Elements** tabs.

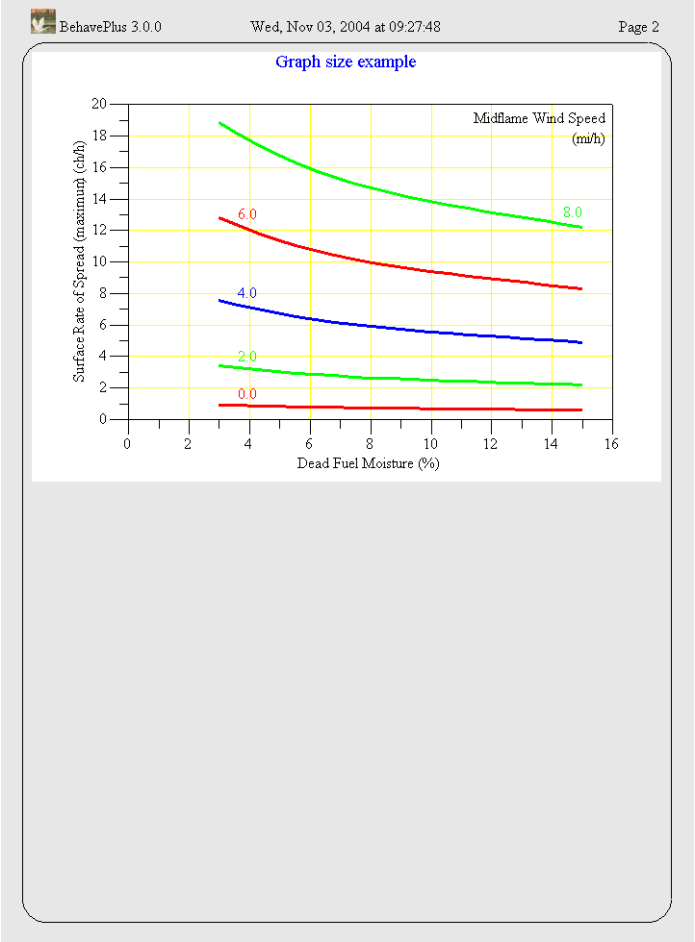


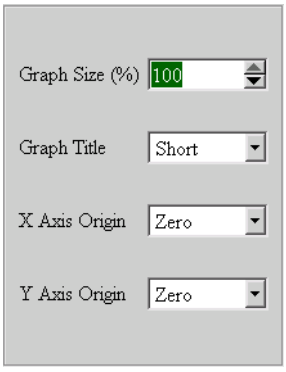
8.4.1. Graph Size



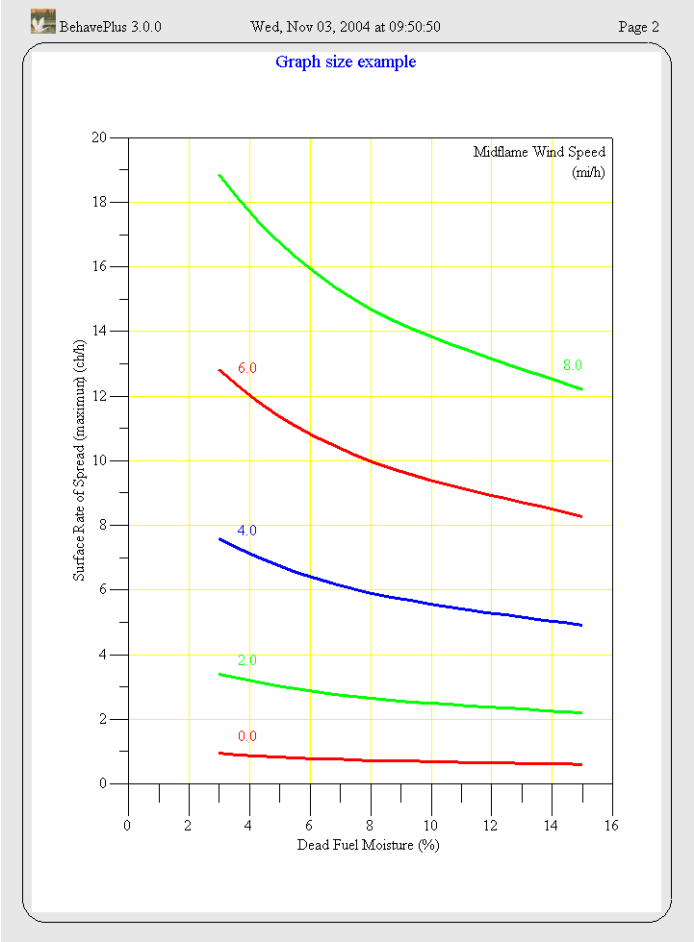
The vertical graph height on the page is set with the **Graph Size(%)** spin box on the **Configure > Appearance > Graph Size** tab.

Graphs are drawn starting at the upper left corner of the page and may occupy 25% to 100% of the page height. The default is 50%, as shown in the following graph.

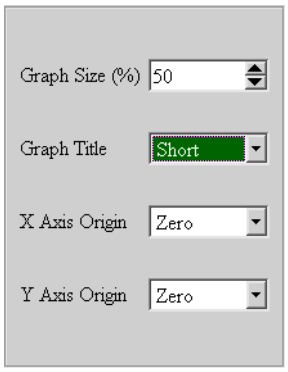




Changing the Graph Size to 100% changes the above to the following graph:

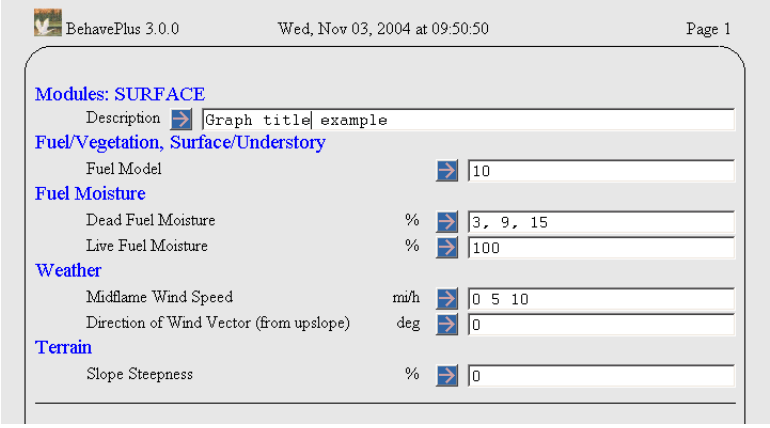


8.4.2. Graph Title

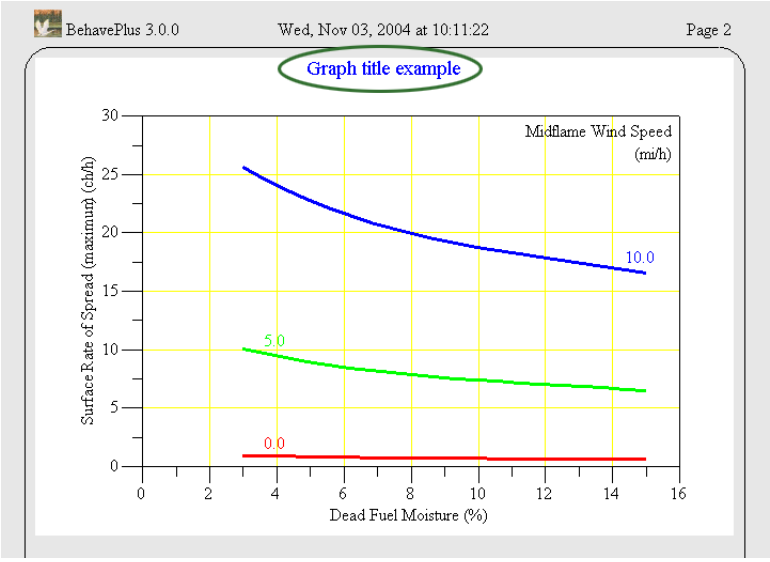


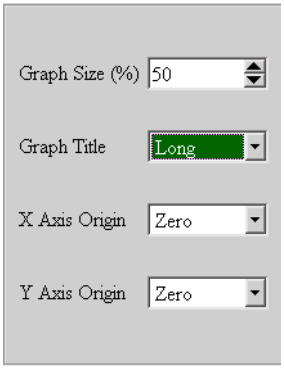
The graph title content is controlled using the **Graph Title** drop-down list on the **Configure > Appearance > Graph Size** tab.

Selecting **Short** from the **Graph Title** drop-down list displays just the contents of the Worksheet **Description** text box as the title. Selecting **Long** displays the **Description** text box and the graph variables.

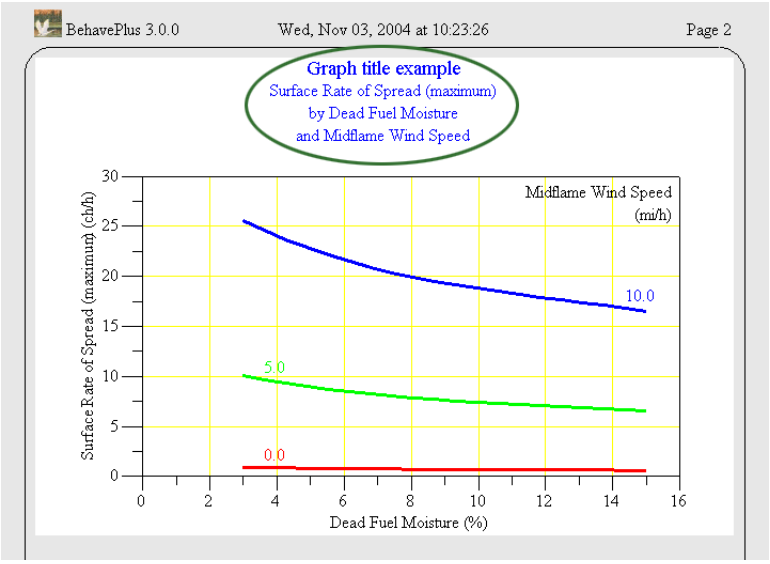


Using the above Run a graph with a short title (the default) looks like the following.



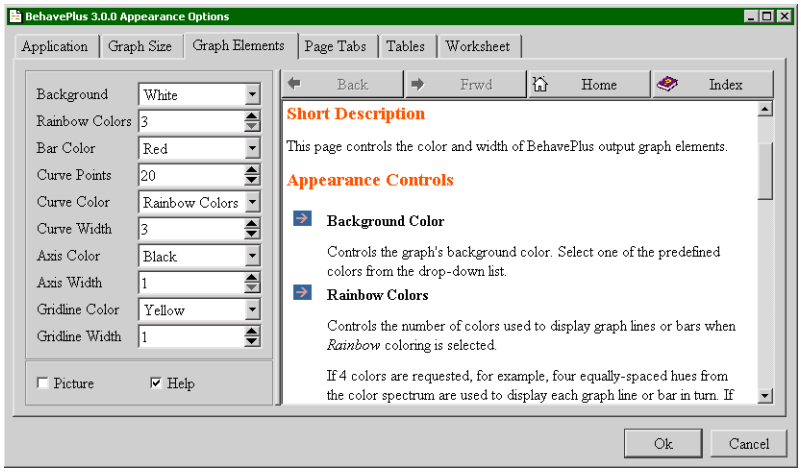


Selecting **Long** from the **Graph Title** drop-down list on the **Configure > Appearance > Graph Size** tab adds more information to the title.



8.4.3. Graph colors

Graph colors can be changed with the **Configure > Appearance > Graph Elements** tab.



Colors are selected from the predefined drop-down lists.

Background is the background color of the graph.

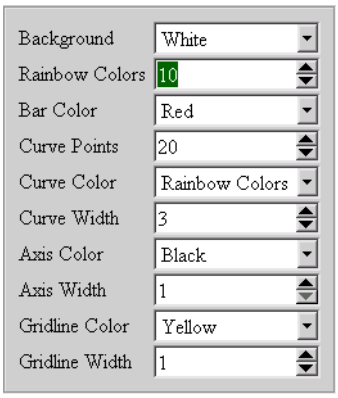
Rainbow Colors sets the number of colors used to display graph lines or bars when **Rainbow Colors** is selected as the curve color. With three rainbow colors, the colors are red, green, and blue. If 4 colors are requested, four equally spaced hues from the color spectrum are used to display each graph line or bar in turn.

Bar Color is used to fill graph bars. Selecting **Rainbow Colors** fills each bar with its own color. The number of rainbow colors is set by the **Rainbow Colors** spin box discussed above.

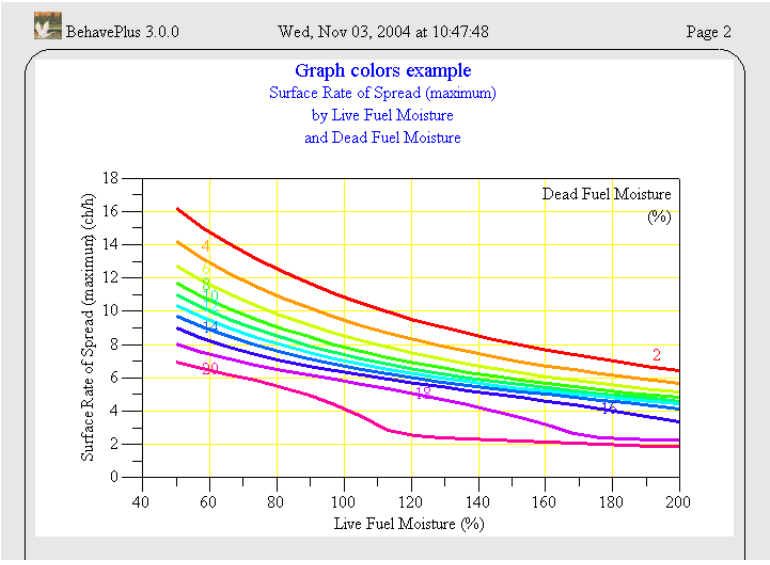
Curve Color is used to draw graph lines. Selecting **Rainbow Colors** draws each line with its own color. The number of rainbow colors is set by the **Rainbow Colors** spin box discussed above.

Axis Color is used to draw graph axis lines, tic marks, and axis labels.

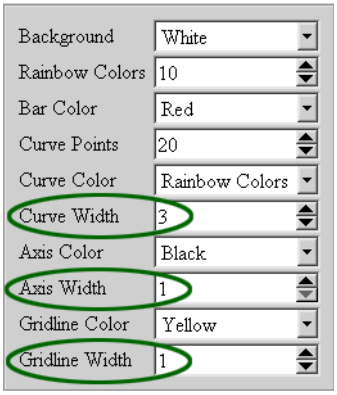
Gridline Color is for the graph grid lines. The default is yellow.



Changing **Rainbow Colors** to 10 results in the following graph coloring:



8.4.4. Line widths



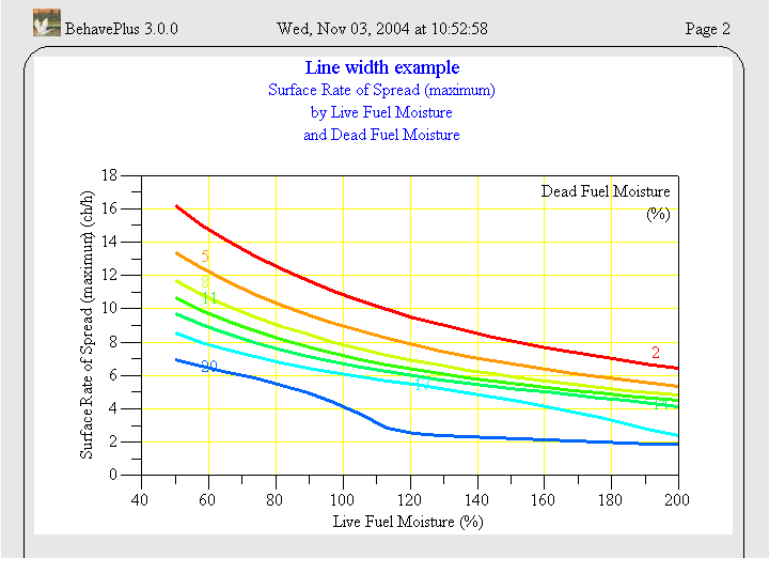
Line widths can be changed using the **Curve Width**, **Axis Width**, and **Gridline Width** spin boxes on the **Configure > Appearance > Graph Elements** tab

Curve Width sets the width of graph lines. 0 is the thinnest and 9 thickest.

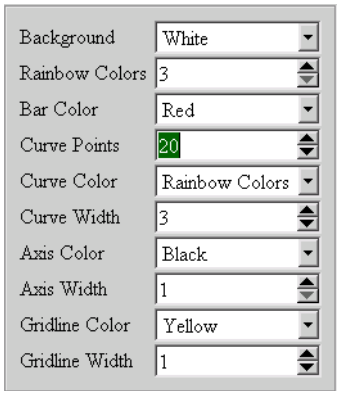
Axis Width sets the width of axis lines drawn on the graph. 1 is thinnest and 9 thickest.

Gridline Width sets the width of grid lines drawn on the graph. 1 is thinnest and 9 thickest. To prevent the display of any grid lines set **Gridline Width** to 0.

The following graph uses the default line settings.

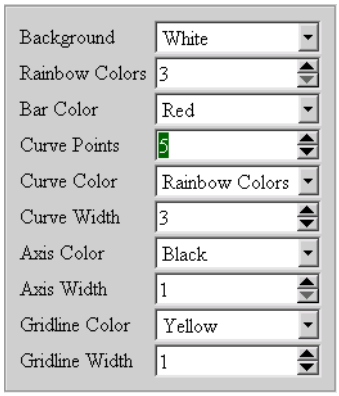


8.5. Number of curve points



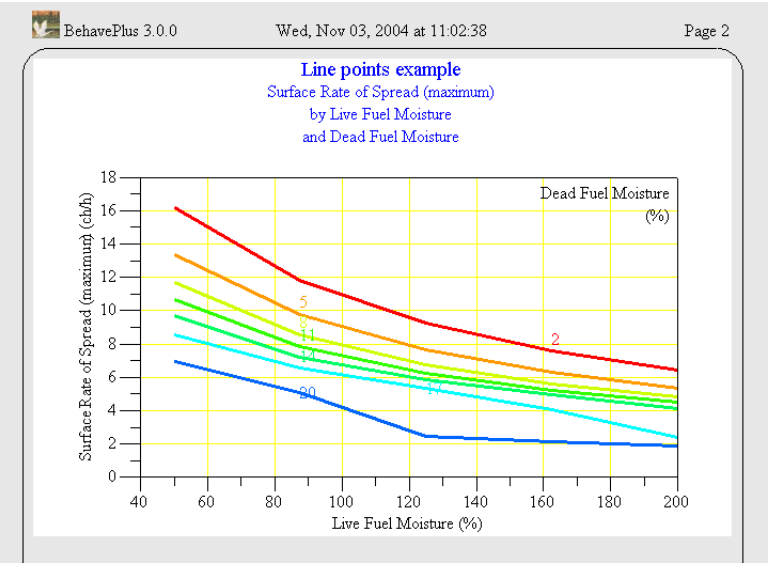
The resolution of the curves can be changed with the **Curve Points** spin box on the **Configure > Appearance > Graph Elements** tab.

The **Curve Points** spin box determines the number of points calculated for each curve in the graph. A straight-line segment is drawn between each pair of points. The default of 20 is visually adequate for most graphs. Requesting more points usually results in a marginal improvement in the visual appearance and requires more computation time. In cases where many curves are plotted and the calculation time is slow, reducing the number of curve points will speed things up.



Changing **Curve Points** from the default of 20 to 5 results in the following graph:

Compare with the graph in the previous Line widths section. The fewer line points give the curves a more jagged appearance.



9. Diagram output

In addition to the usual table and graph output, BehavePlus produces diagrams for the following output variables.

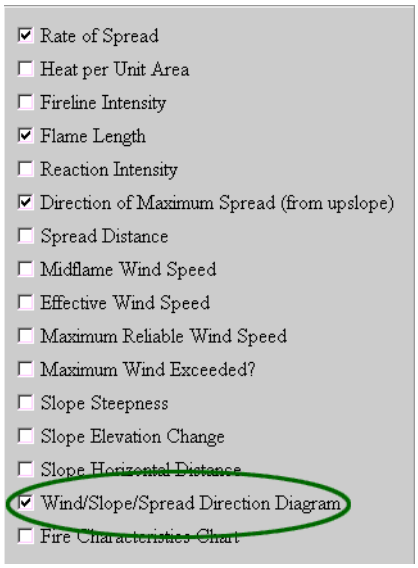
- Wind/slope/fire spread direction diagrams from the SURFACE module
- Fire characteristics chart from the SURFACE module
- Shape of a point source fire from the SIZE module
- Shape of a fire after suppression action from the CONTAIN module

Diagram output is selected from the lists on the **Configure > Module selection > (module name) > Options... > Outputs** tab for the corresponding module.

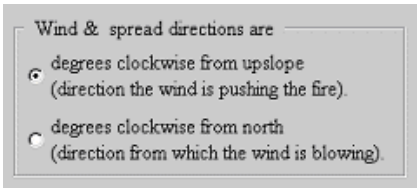
9.1. Wind/slope/spread direction

Direction diagrams can help the user avoid confusion on directions for wind, slope, and spread directions. Direction input options are selected on the **Configure > Module selection > SURFACE > Options... > Directions** tab.

Direction diagrams are produced with the **Configure > Module selection > SURFACE > Options... > Outputs** tab and selecting the **Wind/Slope/Spread Direction Diagram** check box.



The diagrams differ according to the direction Input Options selected from the **Configure > Module selection > SURFACE > Options... > Directions** tab. The following shows the Input Option selection, the resulting Worksheet, the outputs table and diagrams.



BehavePlus 3.0.0 Wed, Nov 03, 2004 at 11:19:03 Page 1

Modules: SURFACE

Description: Wind/Slope/Spread direction example

Fuel/Vegetation, Surface/Understory

Fuel Model: 2

Fuel Moisture

Dead Fuel Moisture %: 6

Live Fuel Moisture %: 120

Weather

Midflame Wind Speed mi/h: 5

Direction of Wind Vector (from upslope) deg: 100

Terrain

Slope Steepness %: 10 40

Run Option Notes

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

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

Wind and spread directions are degrees clockwise from upslope [SURFACE].

Direction of the wind vector is the direction the wind is pushing the fire [SURFACE].

Output Variables

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

Flame Length (ft) [SURFACE]

Direction of Maximum Spread (from upslope) (deg) [SURFACE]

Wind/Slope/Spread Direction Diagram [SURFACE]

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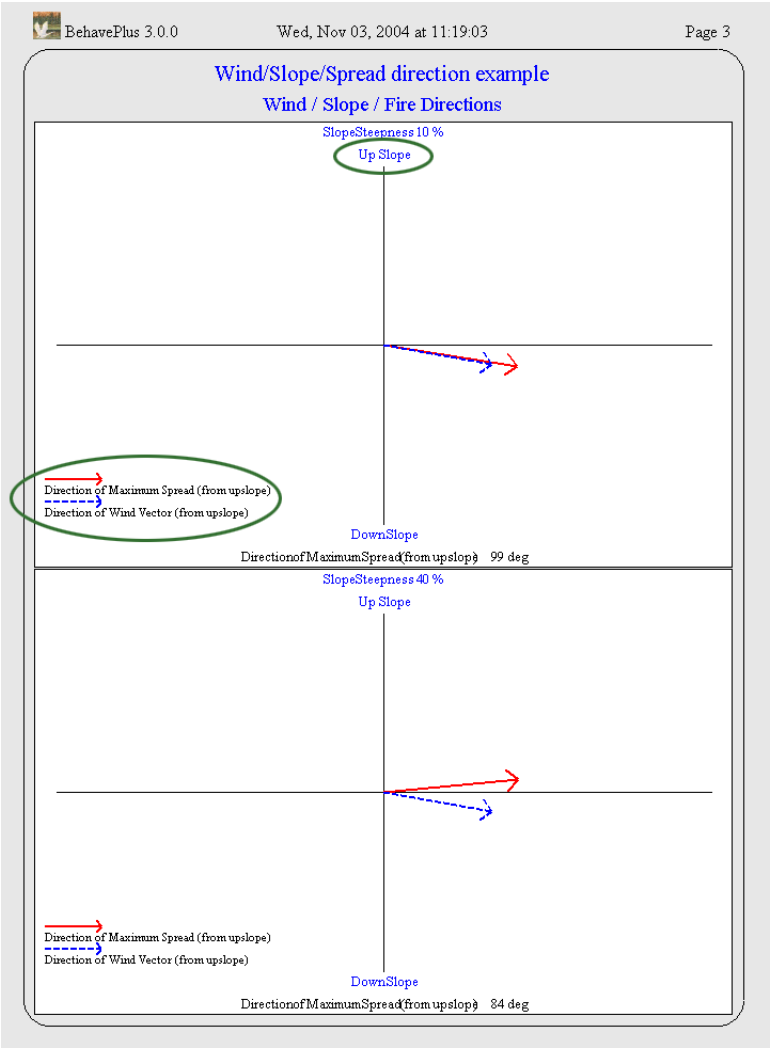
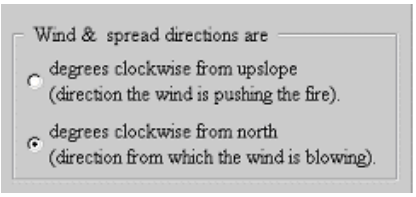
Wind/Slope/Spread direction example

Slope %	ROS (max) ch/h	Flame Length ft	Direction Max ROS deg
10	33.1	6.1	99
40	32.9	6.1	84



The following illustrates the effect of selecting the **Wind & spread directions are** radio button on the variables that are requested on the Worksheet.



BehavePlus 3.0.0 Mon, Nov 08, 2004 at 06:03:54 Page 1

Modules: SURFACE

Description: Wind/Slope/Spread direction example

Fuel/Vegetation, Surface/Understory

Fuel Model: 2

Fuel Moisture

Dead Fuel Moisture % 6

Live Fuel Moisture % 120

Weather

Midflame Wind Speed mi/h 5

Wind Direction (from north) deg 190

Terrain

Slope Steepness % 10, 40

Aspect (from north) deg 90

Run Option Notes

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

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

Wind and spread directions are degrees clockwise from north [SURFACE].

Wind direction is the direction from which the wind is blowing [SURFACE].

Output Variables

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

Flame Length (ft) [SURFACE]

Direction of Maximum Spread (from north) (deg) [SURFACE]

Wind/Slope/Spread Direction Diagram [SURFACE]

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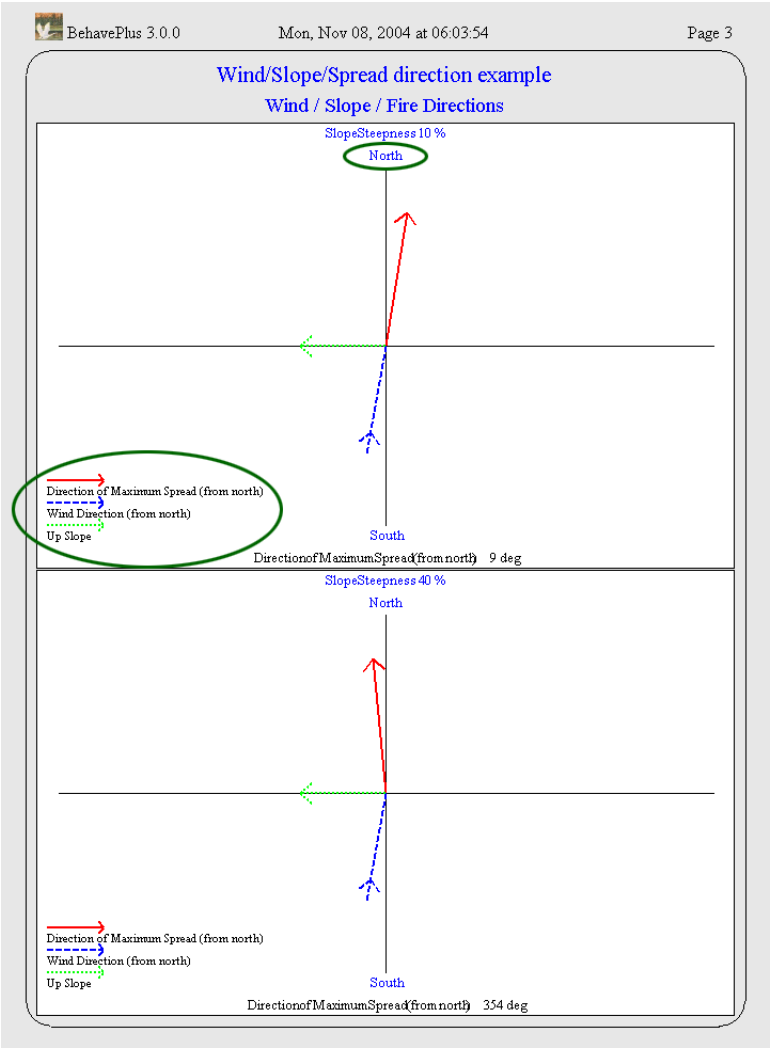
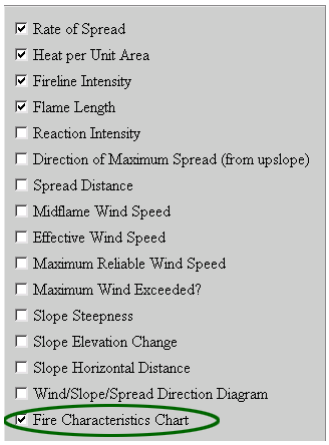
Wind/Slope/Spread direction example

Slope %	ROS (max) ch/h	Flame Length ft	Direction Max ROS deg
10	33.1	6.1	9
40	32.9	6.1	354



9.2. Fire characteristics chart

A fire characteristics chart diagram plots the relationship of rate of spread, heat per unit area, flame length, and fireline intensity. This option is a simplified plot and does not offer the user any display options. Axis scales are set automatically and points are labeled with simple numbers. In the future, BehavePlus will provide a Fire Characteristics Tool so that the user can customize it for a specific need.



Fire characteristics charts are produced with the **Configure > Module selection > SURFACE > Options... > Outputs** tab and selecting the **Fire Characteristics Chart** check box.

It is not necessary to select the four output variables that are plotted on the chart.

The following shows the Worksheet and resulting output table and Fire Characteristics Chart.

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Modules: SURFACE

Description: Fire Characteristics Chart example

Fuel/Vegetation, Surface/Understory

Fuel Model: 2 5 10

Fuel Moisture

Dead Fuel Moisture %: 5

Live Fuel Moisture %: 100

Weather

Midflame Wind Speed (upslope) mi/h: 7

Terrain

Slope Steepness %: 10

Run Option Notes

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

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

Wind is blowing upslope [SURFACE].

Output Variables

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

Fireline Intensity (Btu/ft/s) [SURFACE]

Flame Length (ft) [SURFACE]

Fire Characteristics Chart [SURFACE]

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Fire Characteristics Chart example

Fuel Model	ROS (max) ch/h	Fireline Intensity Btu/ft/s	Flame Length ft
2	67.6	608	8.6
5	39.5	477	7.7
10	14.1	344	6.6

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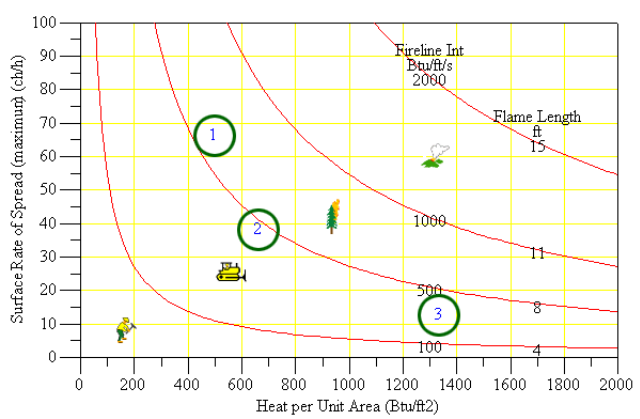
Fire Characteristics Chart example

Fire Characteristics Chart



The points labeled 1, 2, and 3 correspond to the three lines of the output table. Point 1 is for fuel model 2, point 2 for fuel model 5, and point 3 for fuel model 10.

In the case of two variables with multiple entry values a two-way table is produced:

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Modules: SURFACE

Description: Fire Characteristics Chart example

Fuel/Vegetation, Surface/Understory

Fuel Model: 5

Fuel Moisture

Dead Fuel Moisture %: 3 6 9

Live Fuel Moisture %: 100

Weather

Midflame Wind Speed (upslope) mi/h: 7 10

Terrain

Slope Steepness %: 10

Run Option Notes

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

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

Wind is blowing upslope [SURFACE].

Output Variables

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

Fire Characteristics Chart [SURFACE]

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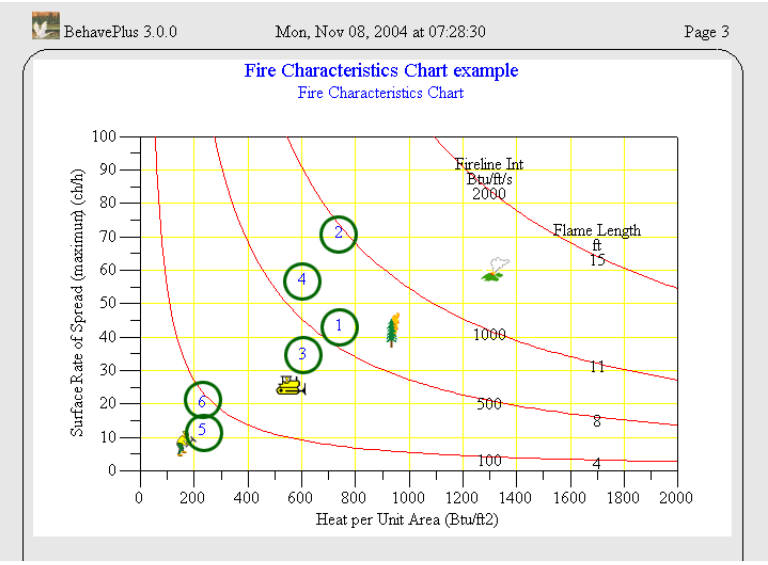
Fire Characteristics Chart example

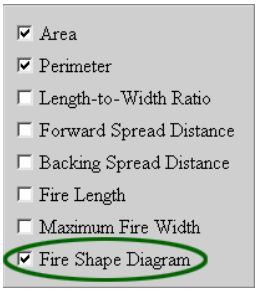
Surface Rate of Spread (maximum) (ch/h)

Dead Fuel Moisture %	Midflame Wind Speed (upslope) mi/h 7.0	10.0
3	44.7	72.4
6	36.1	58.5
9	13.5	21.8



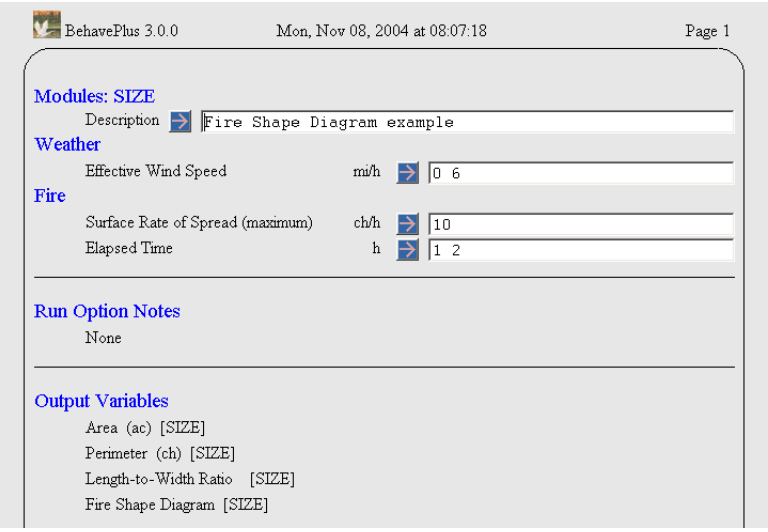
The numbers on the chart correspond to the table cells in left-to-right and top-to-bottom order. In this example, Points 1 and 2 are for the first row of the result table (3% moisture) at the two wind speeds (7 and 10 mi/h). Points 3 and 4 are for the second row of the result table (6% moisture) at the two wind speeds. Points 5 and 6 are for the third row of the result table (9% moisture) at the two wind speeds.

9.3. Shape of a point source fire



The elliptical shape of a point source fire can be plotted on the **Configure > Module selection > SIZE > Options ... > Output Variables** tab by selecting the **Fire Shape Diagram** check box.

For example, the following shows the Worksheet, output table, and Fire Shape Diagram.



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Fire Shape Diagram example

Area (ac)

Effective Wind mi/h	Elapsed Time h 1.0	2.0
0.0	31.4	125.7
6.0	3.4	13.7

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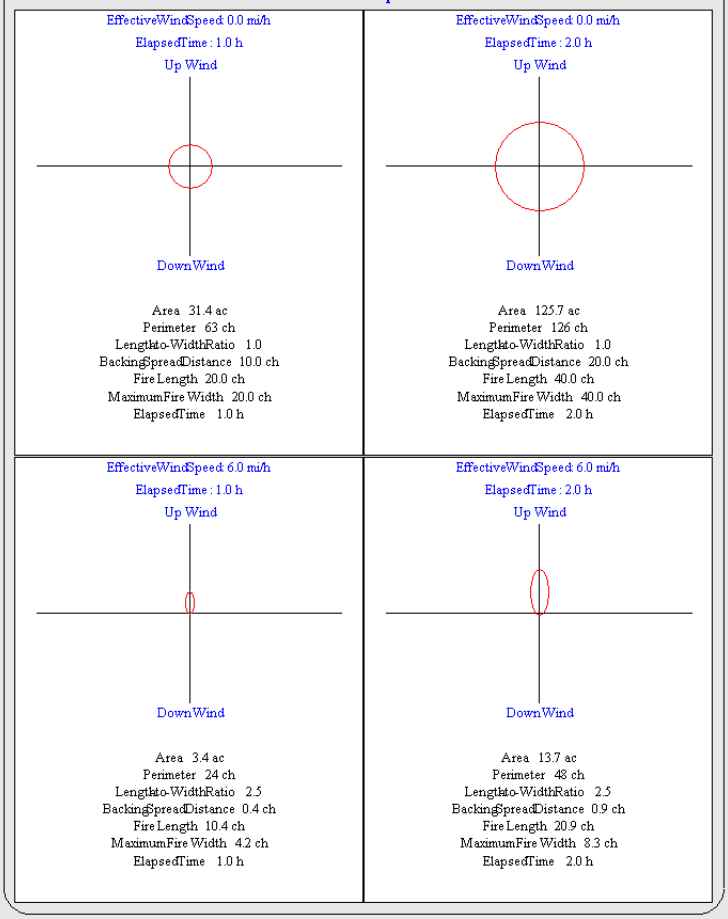
Fire Shape Diagram example

Fire Shape



In addition to the shape diagrams, values for all of the selected output variables are given on each diagram.

A word of caution when using the SIZE module by itself as shown by the above example. The above diagram could be wrongly interpreted to show that higher wind speeds result in a smaller fire. But remember the surface rate of spread (10 ch/h) was the same for o and 6 m.p.h. winds, which is not realistic if all other fire environment conditions were the same. In this example the wind speed only determines the shape of a fire for a given forward spread distance.

When the SIZE Module is linked to the SURFACE Module, the wind vector is also shown on the diagram.

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Modules: SURFACE, SIZE

Description: Fire Shape Diagram example

Fuel/Vegetation, Surface/Understory

Fuel Model: 2

Fuel Moisture

Dead Fuel Moisture % 5

Live Fuel Moisture % 100

Weather

Midflame Wind Speed mi/h 7

Direction of Wind Vector (from upslope) deg 120

Terrain

Slope Steepness % 50

Fire

Elapsed Time h 1

Run Option Notes

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

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

Wind and spread directions are degrees clockwise from upslope [SURFACE].

Direction of the wind vector is the direction the wind is pushing the fire [SURFACE].

Output Variables

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

Direction of Maximum Spread (from upslope) (deg) [SURFACE]

Area (ac) [SIZE]

Perimeter (ch) [SIZE]

Length-to-Width Ratio [SIZE]

Fire Shape Diagram [SIZE]

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Fire Shape Diagram example

Surface Rate of Spread (maximum)	61.0	ch/h
Direction of Maximum Spread (from upslope)	107	deg
Area	118.6	ac
Perimeter	144	ch
Length-to-Width Ratio	2.7	

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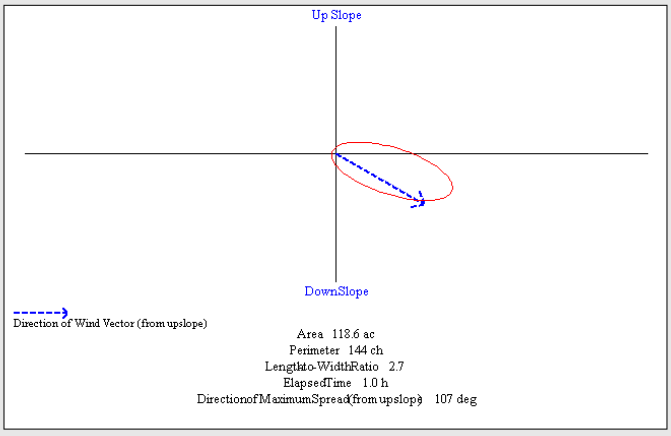
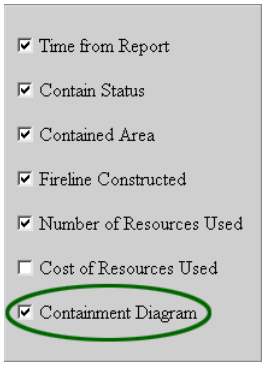
Fire Shape Diagram example

Fire Shape

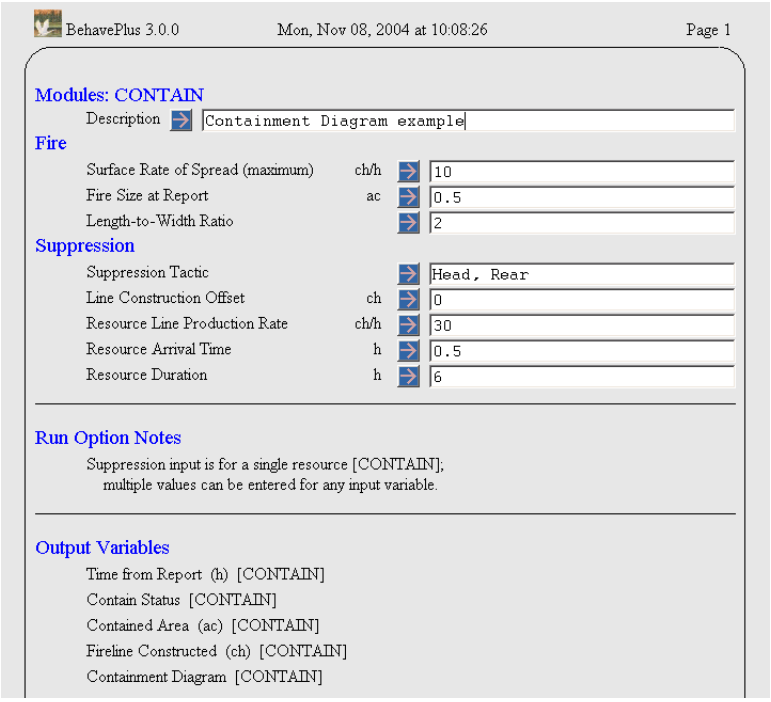


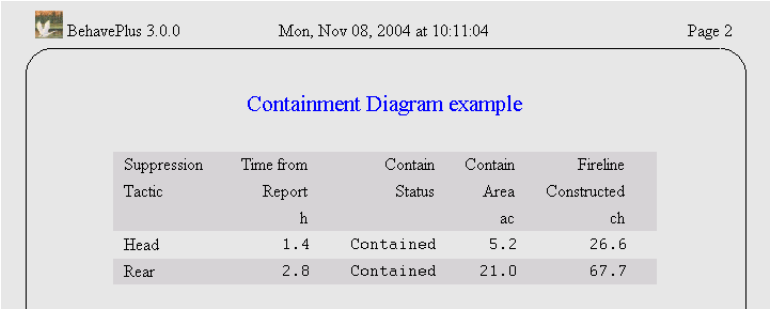
9.4. Containment shape

The Containment Diagram shows fire perimeter at time of report, at initial attack, and constructed fireline at the time the fire was successfully contained or when it escaped initial attack (all resources exhausted before containment).

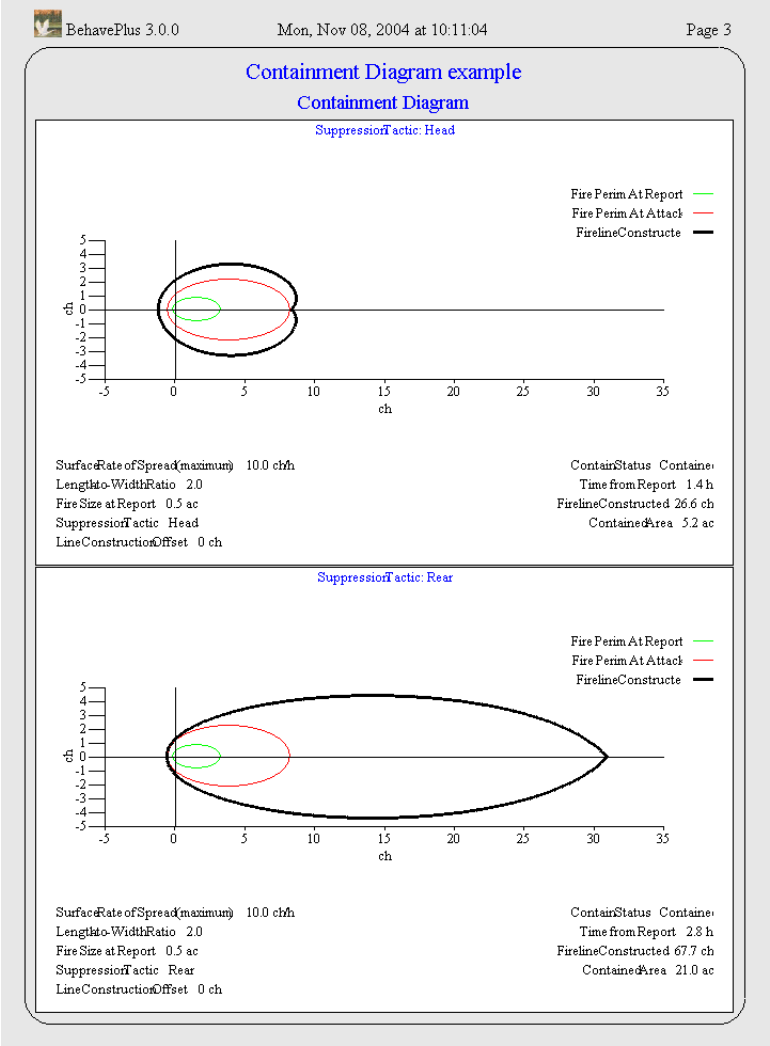


The Containment Diagram is displayed by selecting the **Containment Diagram** check box from the **Configure > Module selection > CONTAIN > Options ... > Output Variables** tab. Also select the **Contain Status** check box to output whether the fire was Contained or Escaped on the Containment Diagram.



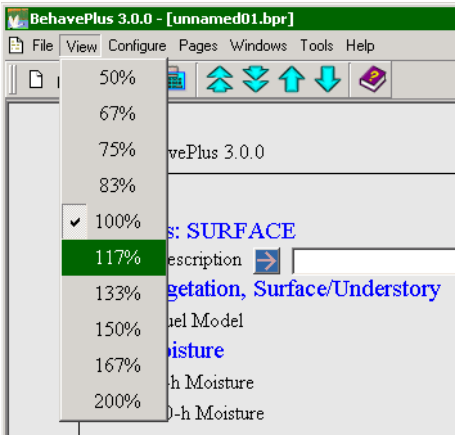


Suppression Tactic	Time from Report h	Contain Status	Contain Area ac	Fireline Constructed ch
Head	1.4	Contained	5.2	26.6
Rear	2.8	Contained	21.0	67.7


BehavePlus 3.0.0
Mon, Nov 08, 2004 at 10:11:04
Page 3
Containment Diagram example
Containment Diagram
SuppressionTactic: Head
Fire Perim At Report
Fire Perim At Attack
FirelineConstructe
ch
ch
SurfaceRateofSpread(maximum) 10.0 ch/h
Lengthto-WidthRatio 2.0
Fire Size at Report 0.5 ac
SuppressionTactic Head
LineConstructionOffset 0 ch
ContainStatus Containe
Time from Report 1.4 h
FirelineConstructed 26.6 ch
ContainedArea 5.2 ac
SuppressionTactic: Rear
Fire Perim At Report
Fire Perim At Attack
FirelineConstructe
ch
ch
SurfaceRateofSpread(maximum) 10.0 ch/h
Lengthto-WidthRatio 2.0
Fire Size at Report 0.5 ac
SuppressionTactic Rear
LineConstructionOffset 0 ch
ContainStatus Containe
Time from Report 2.8 h
FirelineConstructed 67.7 ch
ContainedArea 21.0 ac

10. View, print, & capture results

10.1. View size



The **View > xx%** command changes the size of your Worksheet and Run when viewed on screen. It does not affect the size of printed output.

10.2. Pages

While each Run has its own window, the window has one or more Pages. The first page(s) contain the Worksheet, and subsequent pages contain results tables, graphs, and diagrams.

You can navigate between pages using the following toolbar buttons:

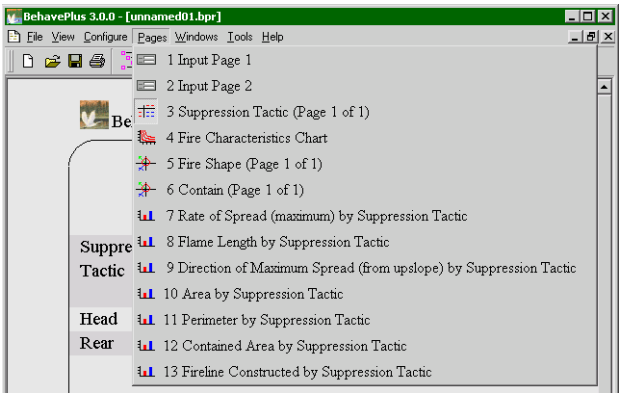
Go to the first page

Go to the last page

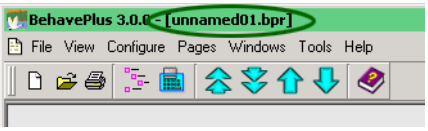
Go to the previous page

Go to the next page

The keyboard navigation arrows will also move you from one page to the next. The **Pages >** command allows you to jump directly to a specific page.

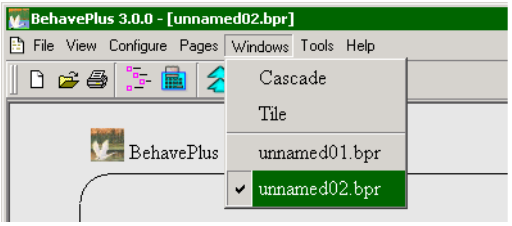


10.3. Windows



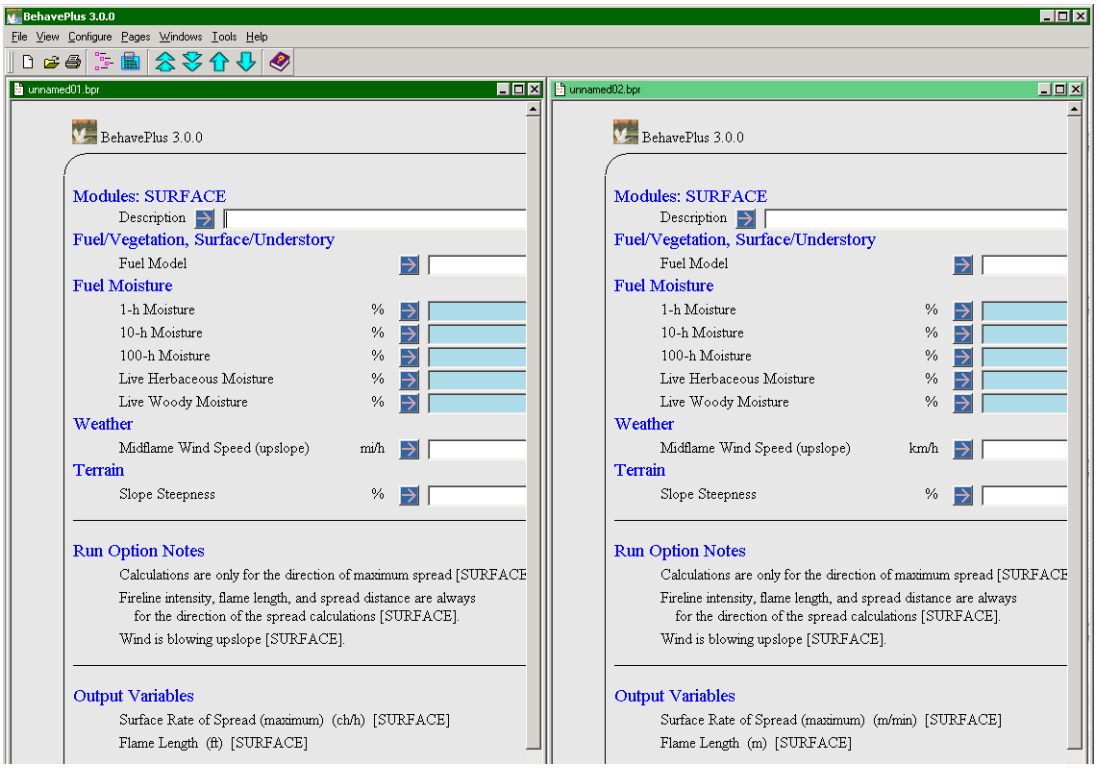
When a Worksheet is first opened, the Run it represents is assigned a default name such as "unnamed01.bpr", "unnamed02.bpr", etc. This name is displayed on the title bar at the top of the BehavePlus application window.

When you save a Run with the **File > saveAs > Run** command you should rename the Run. The name of the Run is then displayed in the title bar of the BehavePlus window. The complete path name for the Run is shown at the bottom of the BehavePlus application window.



BehavePlus allows you to have any number of Runs open at once. Each Run has its own display window containing a Worksheet and possibly containing calculation results. Only one Run window is active at a time. The Windows menu item allows you to switch between Runs. It also allows you to cascade or tile the Runs within the BehavePlus window area with the **Windows > Cascade** or **Windows > Tile** commands. By default the Run windows are stacked on top of each other, so you only see the active Run. If your Run windows are already cascaded or tiled, you can make a Run active by clicking it.

The following is a "tiled" display of the two Runs, one English, one metric. The English Run (unnamed01.bpr) is the active Run.



Selection can be made from the list of pages with text descriptions and an icon indicating whether it is a table, graph, diagram, etc.

10.4. Print

You can print all pages or selected pages with the **File > Print** command. Alternatively, select **Print** from the shortcut menu when you right click inside a page.

Whenever an output page is printed, it is good practice to print the associated Worksheet pages to avoid confusion on conditions for the Run. Printed pages are numbered and the date and time of the Run are included on the page header.

10.5. Saving Output

You can save your BehavePlus table output several ways. Tables, graphs, and diagrams can all be saved as an image of the screen display. The image file can then be edited with an image processor or inserted into word processor or layout documents. Table output can also be saved to a tab delimited text file or HTML file. The text file can then be imported into another application, such as word processor, spreadsheet, or database. The HTML file can be used in a Web page or is a handy, compact way to E-mail your BehavePlus results.

10.5.1. Saving a screen image

The currently displayed page can be captured and saved as a file in bmp, jpg, or png format with the **File > saveAs > Image** command. In the "Save As" dialog box enter a file name in the **Capture File** text box and select a file type from the **Capture Type** drop-down list. The file extension will be automatically added to the file name

In addition to the **File > saveAs > Image** command, you can use the ALT-Print Screen key or a screen capture utility (e.g. FullShot) to insert results from BehavePlus in other documents. The following steps are an example and do not constitute endorsement of specific software.

- Startup BehavePlus, WORD word processor, and FullShot software.
- On BehavePlus display, select the 'R' (for Region) in upper right hand of the window (put there by FullShot).
- Use the cursor to select the desired area
- Upon release of the mouse, FullShot opens with the selected image
- CTRL-C to save it in a clip board
- Go to the WORD document
- CTRL-V to insert the image

This is a quick and efficient method. There is no need to save the image in a file of its own. The image can be resized, cropped, or moved within WORD if desired.

10.5.2. Saving a Text File

Once you have calculated a Run you can save the table output as a tab delimited text file. Select the **File > saveAs > Results > Spreadsheet** command to open a standard Windows "Save As" dialog box. You can save this file anywhere, it does not have to be in a BehavePlus Workspace. The .123 file extension will be automatically added to your file name.

To use this file in Microsoft Excel, select the **File > Open** command and select your saved text file from the "Open" dialog box. Make sure that **All Files (*.*)** is selected from the **Files of Type:** drop down list at the

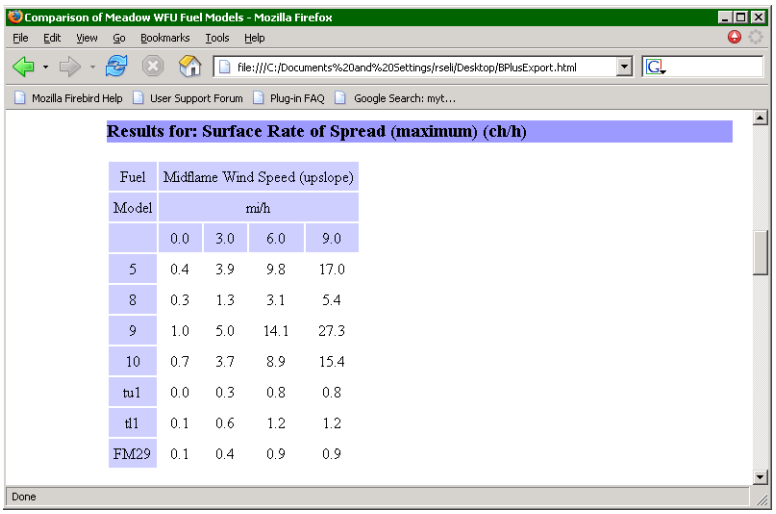
bottom of the dialog box. Then follow the instruction in the "Text Import Wizard", accepting the defaults and a simple Run should look something like this in Excel.

	A	B	C	D	E	F	G
1	BehavePlu	3.0.0	Build 253				
2							
3	Compariso	Thu, Oct 2	11:36:10				
4							
5	Fuel	ROS	Heat per	Fireline	Flame	Max Wind	
6	Model	(max)	Unit Area	Intensity	Length	Exceeded	
7		ch/h	Btu/ft2	Btu/ft/s	ft		
8	5	3.9	274	20	1.8	No	
9	8	1.3	211	5	0.9	No	
10	9	5	416	38	2.4	No	
11	10	3.7	1323	90	3.6	No	
12	tu1	0.3	143	1	0.4	No	
13	tl1	0.6	117	1	0.5	No	
14	FM29	0.4	146	1	0.5	No	
15							

10.5.3. Saving a HTML File

Once you have calculated a Run you can save the Run as a HTML file. In addition to the table outputs the HTML file also contains the **Input Variables** and **Run Option Notes** sections of the Worksheet. Select the **File > saveAs > Results > HTML** command to open a standard Windows "Save As" dialog box. You can save this file anywhere, it does not have to be in a BehavePlus Workspace. The .html file extension will be automatically added to your file name.

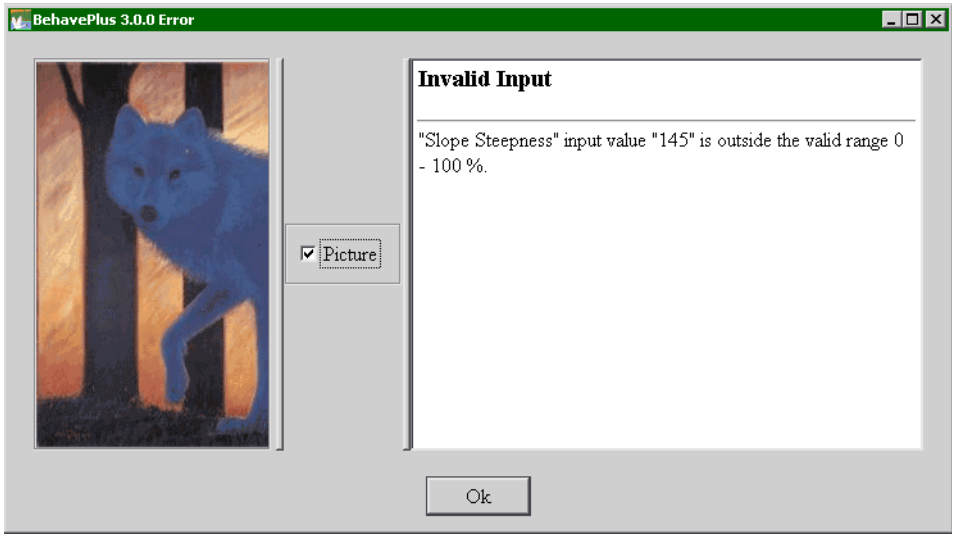
Simply double-clicking your saved file will display your Run in your Web browser.



11. Error checking

If you do something that causes the program to crash, it is a program bug. Please report it through www.fire.org.

When you do something in error, the program will tell you what the problem is and give you a chance to fix it.

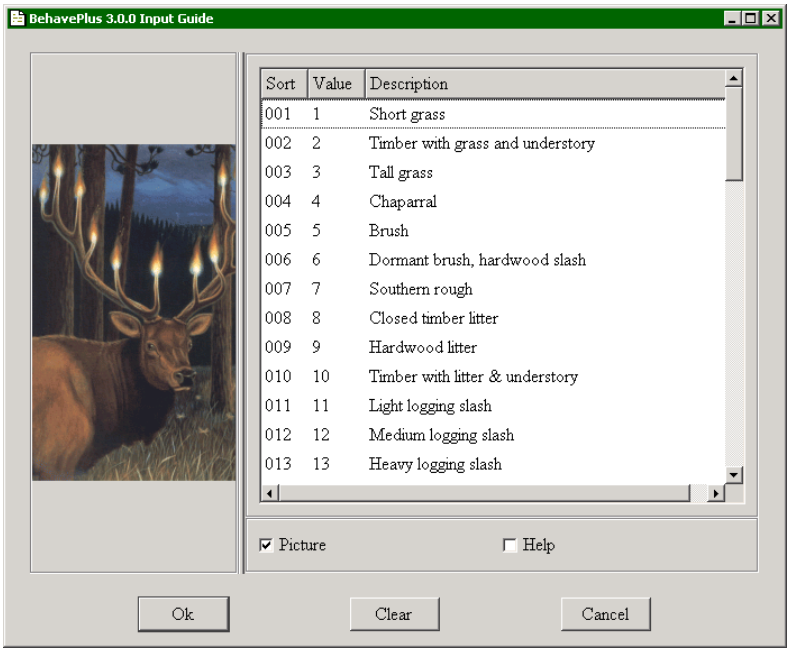


12. Fuel models

A fuel model is a set of values that describe a fuel type for the surface fire spread model. The original standard fuel models are numbered 1 through 13. An expanded set of 40 fuel models is also available. Additionally Custom Fuel Models, can be developed, tested, saved, used in BehavePlus, and exported for use in other applications.

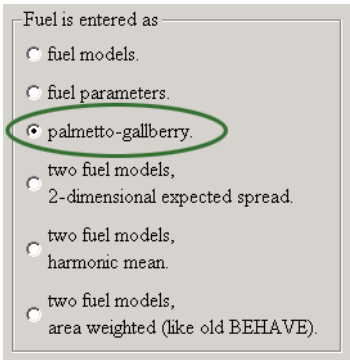
12.1. 13 Standard fuel models

The original 13 standard fuel models are always available by using the **Fuel Model** input Guide Button or entering the fuel model code directly into the text box from the keyboard. A complete description of the 13 standard fuel models is found in the publication Aids to Determining Fuel Models For Estimating Fire Behavior. Gen. Tech. Rep. INT-122. Anderson, 1982. These fuel models are found at the top of the list in the **Fuel Model** Input Guide.



12.2. Palmetto-Gallberry fuel option

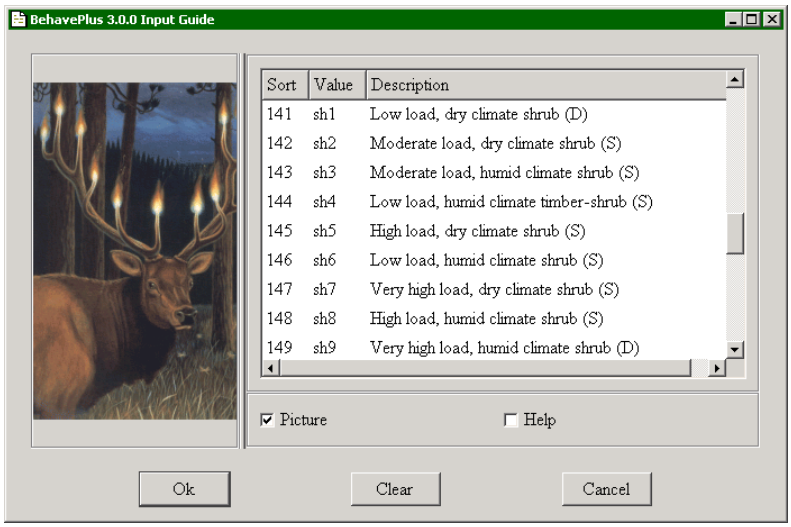
The palmetto-gallberry fuel option estimates fuel parameters from vegetation characteristics. (Hough and Albini 1978) The Palmetto-Gallbery fuel option is not selected from the "Input Guide" dialog box like fuel models, but is selected with the **Configure > Module selection > SURFACE > Options... > Fuel & Moisture > fuel models** radio button.



The Palmetto-Gallberry option cannot be used with other fuel models in a Run, it can only be used by itself. Notice that "P-G" has been added to each of the input variables on the Worksheet used specifically for the palmetto-Gallberry fuel model.

12.3. Expanded set of 40 fuel models

The expanded set of 40 fuel models is also always available in BehavePlus. These fuel models are also selected from the **Fuel Model** Input Guide or entered directly in the **Fuel Model** text box on the Worksheet. They are listed after the original 13 in the "Input Guide" dialog box, but they use an alpha-numeric code rather than a number for the value on the Worksheet.



Notice that the expanded models are identified as dynamic or static with a (D) or (S) in the description. See Section 11.4 below for more on dynamic fuel models. An example Run, FuelCompare.bpr, can be found in the **ExampleRuns** folder to explore the expanded fuel model set and see the effect of dynamic fuel models. A full description of the expanded fuel model set is found in Scott and Burgan, 2004.

12.4. Dynamic fuel models

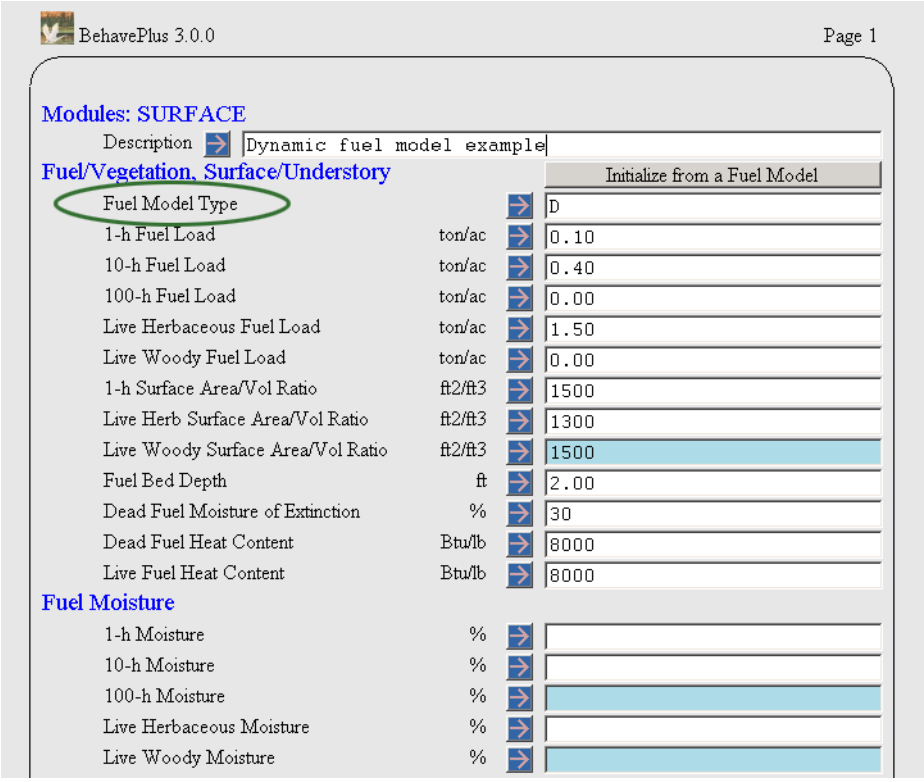
Dynamic load transfer of herbaceous fuel is available in BehavePlus. If the **Fuel Model Type** is identified as dynamic and contains live herbaceous fuel, then fuel load is transferred from live to dead as a function of the **Live Herbaceous Moisture** entered on the Worksheet. Dynamic fuel models must have a live herbaceous fuel load while with static fuel models a live herbaceous fuel load is optional.

Dynamic Fuel Model Combinations		Live Herbaceous Fuel Load	
		Yes	No
Fuel Model Type	Dynamic	Ok	n/a
	Static	Ok	Ok

The origional 13 standard fuel models are static. In the expanded set models that contains a live herbacous fuel load are dynamic. The dynamic fuel models are identified by a (D) at the end of their description and a Fuel Model Type parameter of **D**.

Two output variables are available to help users understand dynamic fuel modeling. **Live Herb Load Transfer** and **Dead Herbaceous Fuel Load** can be selected on the **Configure > Module selection > SUR-**

FACE > Options... > Outputs tab. A full explanation of dynamic fuel modeling is found in Scott and Burgan, 2004.

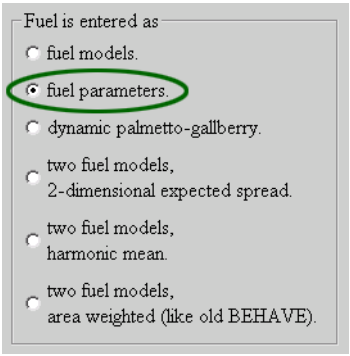


12.5. Custom fuel models

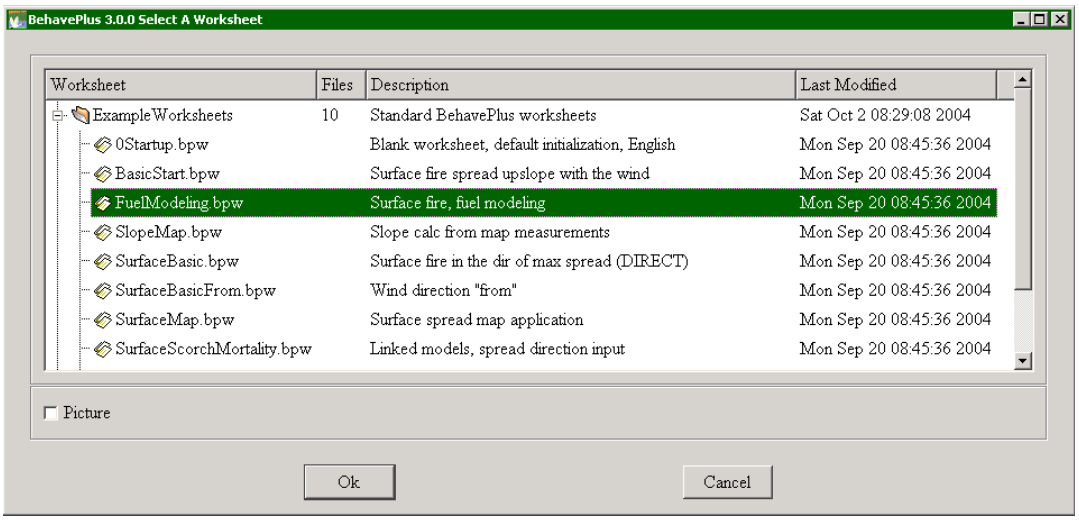
In addition to the standard fuel models you can create, save, and reuse custom fuel models in BehavePlus. These custom fuel models can be exported in a file format used by *FARSITE*, NEXUS, and FlamMap.

12.5.1. Defining and saving custom fuel models

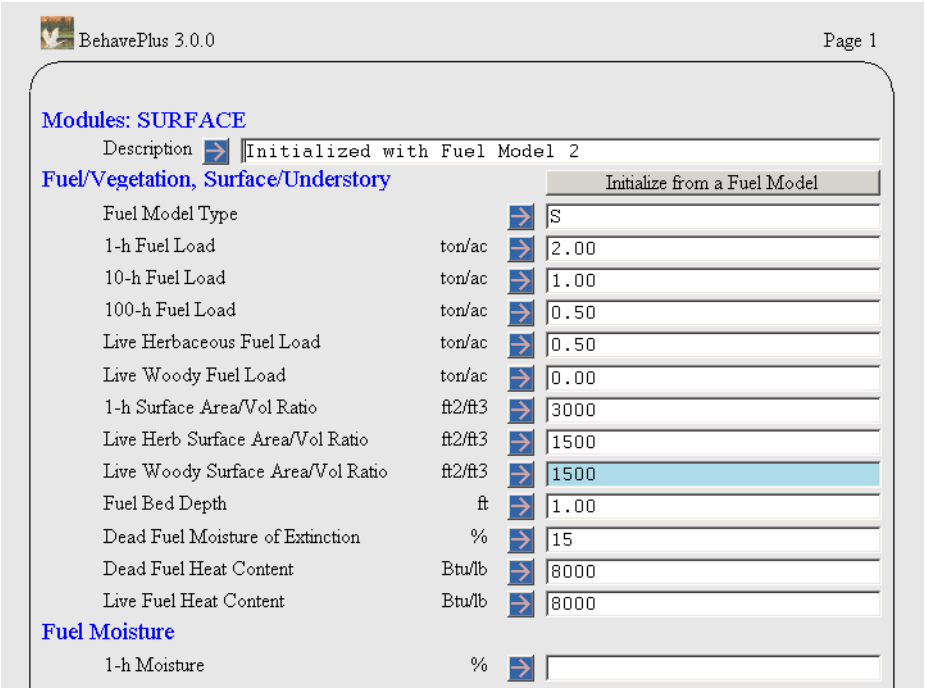
The first step in creating a custom fuel model is to change the Worksheet so that individual fuel parameters are entered in place of the fuel model code. Use the **Configure > Module selection > SURFACE > Options... > Fuel and moisture** tab and select the **fuel parameters.** radio button.



Or you can load the Example Worksheet FuelModeling.bpw, which as been set up to use fuel parameters, using the **File > New** command or toolbar button.



Fuel model parameters can be typed directly into the parameter text boxes. Or they can be initiated with an existing fuel model by clicking the **Initialize from a Fuel Model** button on the Worksheet.



The process of developing a custom fuel model is more complex that just filling in these blanks. It involves a process of evaluation and revision which is not covered in this User's Guide.

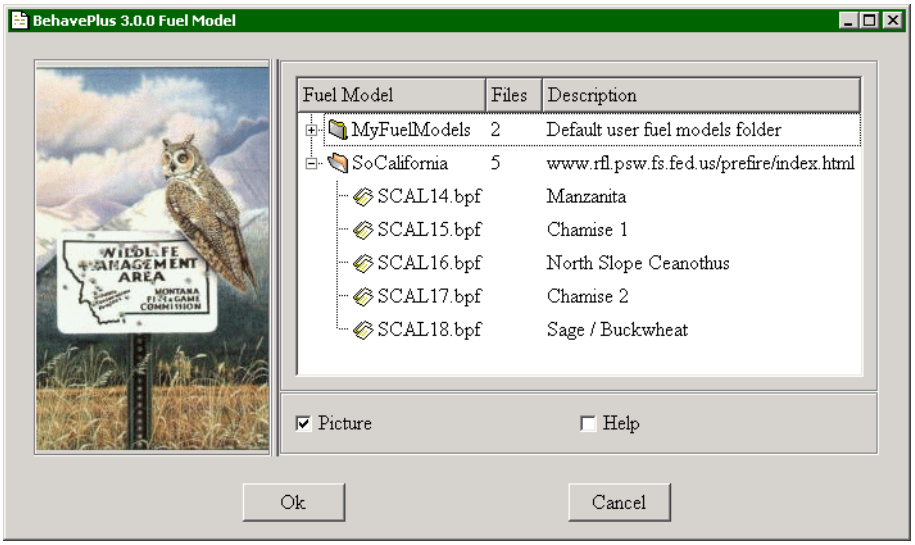
Once the fuel model parameters are defined, a custom fuel model can be saved for later use with the **File > saveAs > Fuel model > BehavePlus format** command. In the "Save As" dialog box enter a file name in the **Fuel Model File** text box and a short description in the **Fuel Model Description** text box. If more than one value is assigned to a fuel model parameter for testing purposes, the first value in the list is the one that is saved.

Fuel models should be grouped in folders named by some logical association of meaning to the user. See Section 20.4, Save As, for more information.

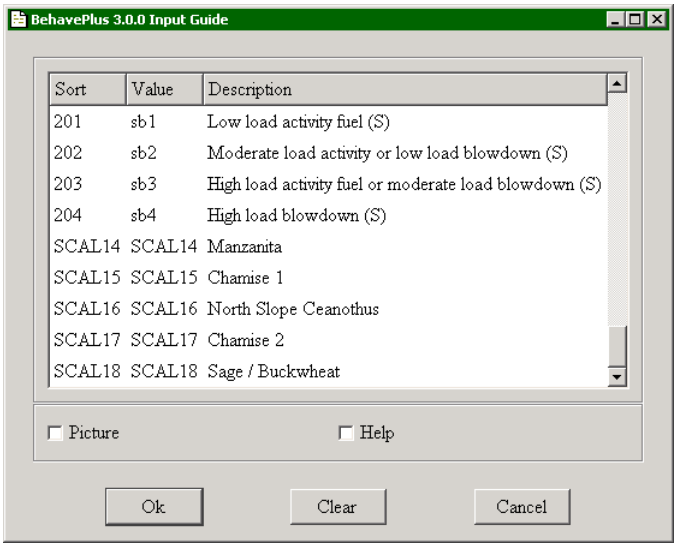
12.5.2. Using previously saved custom fuel models

In order to use previously saved custom fuel models, the folder in which they are stored must be attached using the **Configure > Fuel model set selection** command.

Click on a folder's button to view its fuel model files. Each fuel model is stored in a separate file.



Fuel model files are attached by attaching the folder in which they reside. This makes the fuel models in that folder accessible for use. It is not possible to select and attach individual fuel models; the entire folder must be attached. For example, all the southern California fuel models are attached by selecting the **SoCalifornia** folder in the "Fuel Model" dialog box and clicking the **Ok** button. Once a fuel model folder is attached, the fuel models appear in the **Fuel Model** input guide and may be entered as the **Fuel Model** input variable.



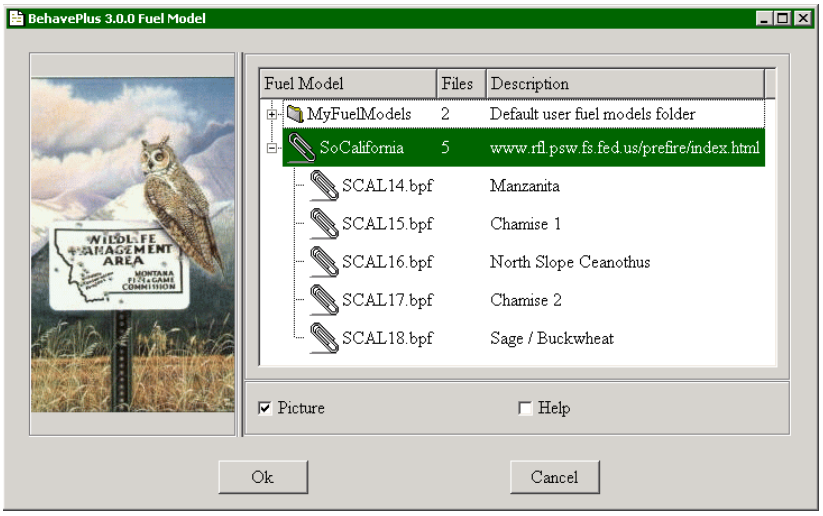
After the SoCalifornia fuel model folder is attached, the **Fuel Model** input Guide Button gives the following valid selections for the **Fuel Model** text box.

To view the parameters of a particular fuel model, right-click on it's name and select the **View parameters** command from the shortcut menu.

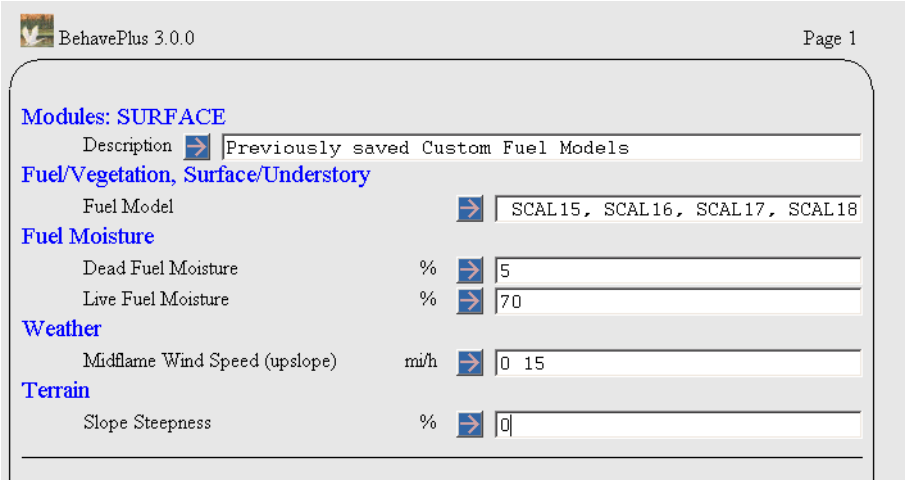
Fuel Model SCAL14

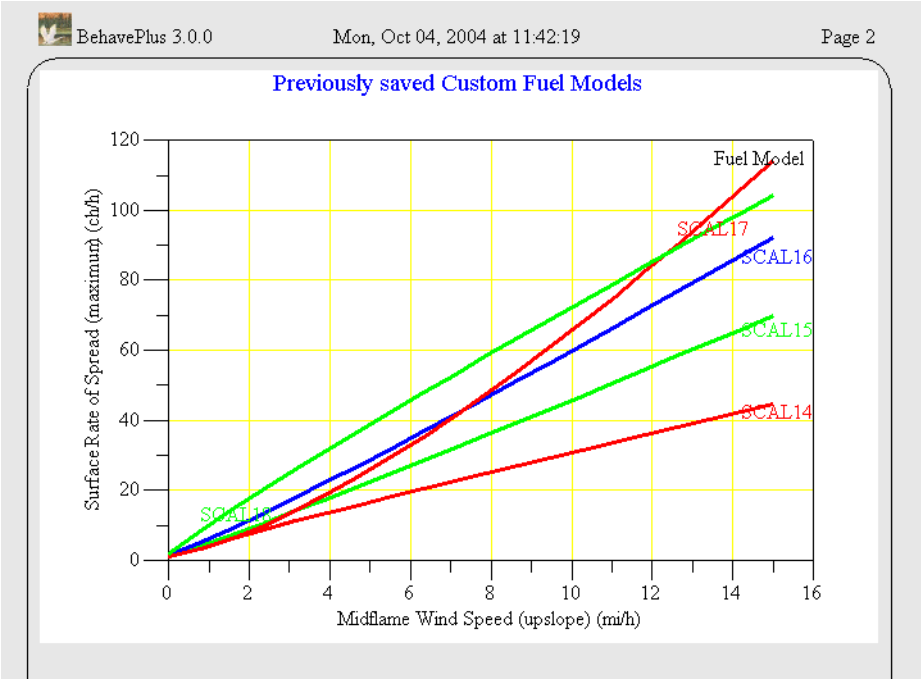
Fuel Model Name	SCAL14
Description	Manzanita
1-h Fuel Load	3 tons/ac
10-h Fuel Load	4.5 tons/ac
100-h Fuel Load	1.05 tons/ac
Live Herbaceous Fuel Load	1.45 tons/ac
Live Woody Fuel Load	5 tons/ac
1-h Surface Area/Vol Ratio	350 ft2/ft3
Live Herbaceous Surface Area/Vol Ratio	1500 ft2/ft3
Live Woody Surface Area/Vol Ratio	250 ft2/ft3
Fuel Bed Depth	3 feet
Dead Fuel Moisture of Extinction	15 percent
Dead Fuel Heat Content	9211 Btu/lb
Live Fuel Heat Content	9211 Btu/lb

When viewed in the "Fuel Model" dialog box (opened with the **Configure > Fuel model set selection** command), folders and files with a paper clip icon are currently attached to (i.e., accessible for use by) BehavePlus in the current session. Once the **Ok** button is pressed, only the currently selected folders will have their files attached. Unselected folders will NOT have their files attached, even if they are currently marked as attached by the paper clip icons.



Custom fuel models are selected just like the standard models. They can be selected with the Fuel Model input guide or entering the fuel model code directly into the text box from the keyboard.



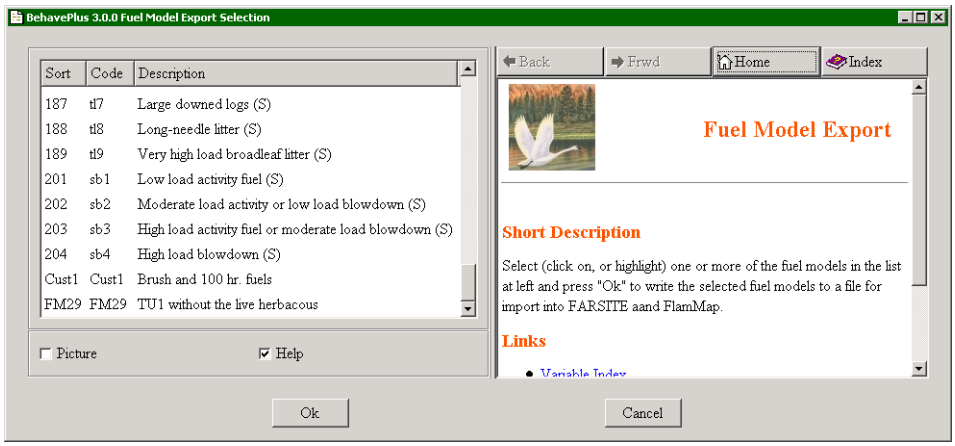


12.5.3. Exporting custom fuel models

Custom fuel models you create and save in BehavePlus can be exported in the Custom Fuel Model (.fmd) file format used by *FARSITE*, NEXUS, and FlamMap. To avoid confusion, remember the distinction between saving and exporting custom fuel models; saving a fuel model lets you reuse it only in another BehavePlus session, while exported fuel models can only be used in an application that uses the Custom Fuel Model (.fmd) file format. Files with a .fmd extension cannot be used in BehavePlus and .bpf files cannot be used in *FARSITE*, NEXUS, or FlamMap.

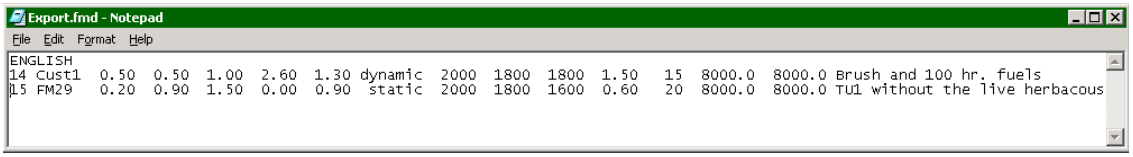
Before you can export a BehavePlus custom fuel model it must be saved and attached. See Sections 11.5.2 and 11.5.1 above for information on saving and attaching custom fuel models.

To export a custom fuel model use the **File > saveAs > Fuel model > FARSITE format** command. In the "Fuel Model Export Selection" dialog box the attached custom fuel models are found at the end of the standard fuel models list.



For custom fuel models both the **Sort** and **Code** columns in the list display the file name truncated to five characters. You select one or more fuel models to export and then click the **Ok** button. Type the filename in the "Save As" dialog box and BehavePlus will automatically attach a .fmd extension.

The exported .fmd file will look similar to this when viewed in a text editor.



The first field for each fuel model is the fuel model number. Exported fuel models begin with number 14 and continue to 90 if you elect to export that many fuel models. If these fuel model numbers do not match the landscape file in *FARSITE* or FlamMap you should change these to match by editing the exported .fmd file. You may also want to edit the second field, the fuel model code. The default that is exported is the first five characters of the BehavePlus .bpf filename.

13. Moisture scenarios

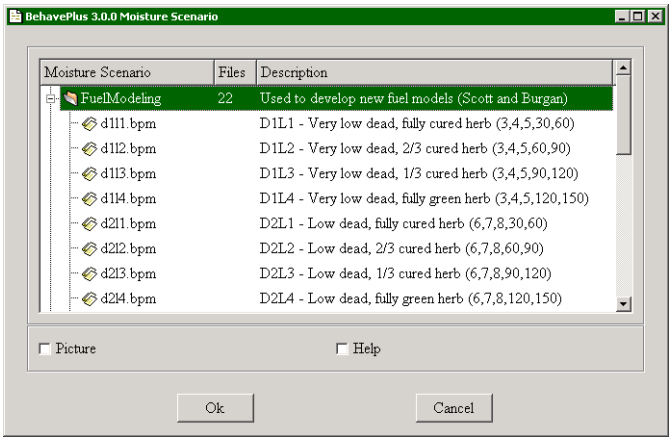
A moisture scenario is a set of fuel moistures for 1-h, 10-h, and 100-h dead fuel and herbaceous and woody live fuel. It is analogous to the fuel model concept in that a single code represents a set of live and dead fuel moisture values. Fuel moisture scenarios may be developed, for example, to represent local 90-, 95-, and 97-percentile weather situations. The set of moisture scenarios used in the old BEHAVE TSTMDL fuel modeling program and the set used to test the expanded standard fuel models are provided with the BehavePlus program.

Fuel model scenarios are for developing and comparing fuel models. They are not designed for fire behavior prediction, in which case actual fuel moisture values should be assigned directly.

13.1. Using previously saved moisture scenarios

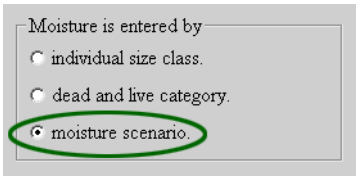
In order to use previously saved moisture scenarios, the folder in which they are stored must be attached. A folder of moisture scenarios is attached using the **Configure > moisture Scenario set selection** command to open the "Moisture Scenarios" dialog box.

Click on a folder's ⊞ to view its moisture scenario files. Each moisture scenario is stored in a separate file. The details of a moisture scenario can be viewed or printed by right-clicking and selecting the appropriate command from the shortcut menu.

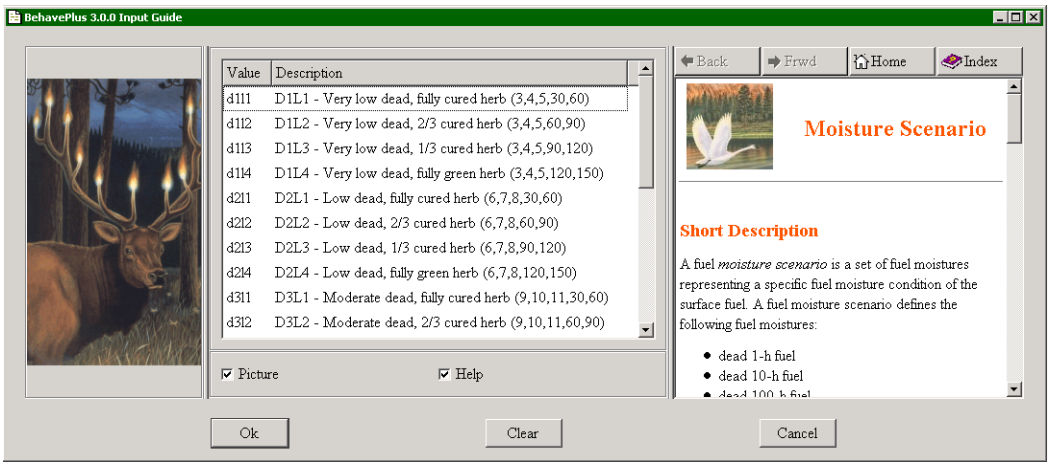


Moisture scenario files are attached by selecting the folder in which they reside and clicking the **Ok** button in the "Moisture Scenario" dialog box. This makes all the moisture scenarios in that folder accessible for use. It is not possible to select and attach individual moisture scenarios; the entire folder must be attached. For example, one set of the moisture scenarios that come with the BehavePlus program are attached by selecting the **FuelModeling** folder. Once a moisture scenario folder is attached, its moisture scenarios appear in the Moisture Scenario input guide.

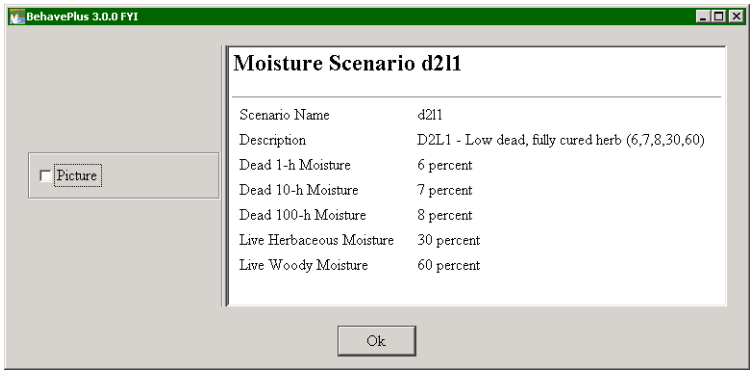
Worksheet options also need to be set to use moisture scenarios. Set up the Worksheet to enter fuel moistures with moisture scenarios using the **Configure > Module selection > SURFACE > Options... > Fuel & Moisture** tab and select the **Moisture is entered by moisture scenario.** option button.



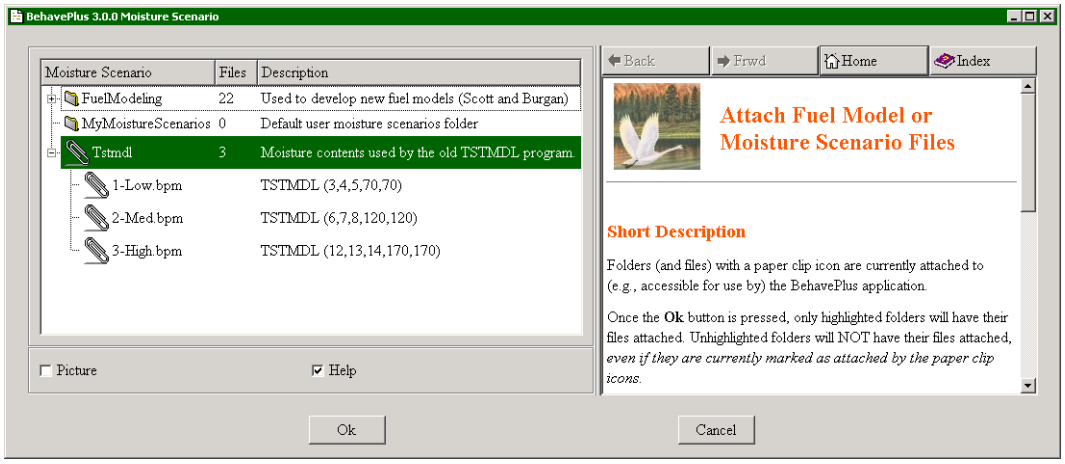
After the **FuelModeling** moisture scenario folder is attached, the **Moisture Scenario** Guide button on the Worksheet shows the following valid selections for moisture scenarios in the "Input Guide" dialog box.

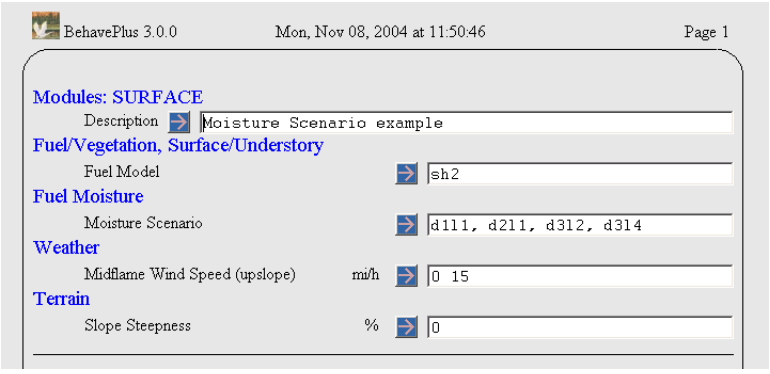


To view the parameters of a particular moisture scenario, right-click on the description and select **View parameters** from the shortcut men.

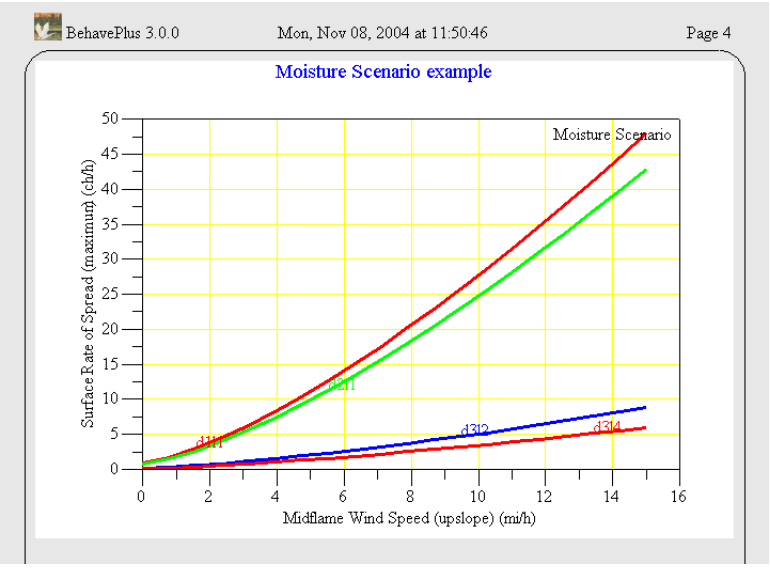


When viewing folders (and files) in the "Moisture Scenario" dialog box, those scenarios with a paper clip icon are currently attached to (e.g., accessible for use by) the BehavePlus application. Once the **Ok** button is pressed, only the selected folders will have their files attached. Currently attached folders will NOT have their files attached if not selected when the **Ok** button is clicked. Use the Cancel button to maintain the current attached sets.



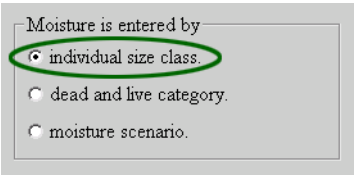


This Worksheet creates the following graph. The fuel model used is a dynamic type, and the output graph indicates the dramatic effect the live fuel moisture can have when using a dynamic fuel model.

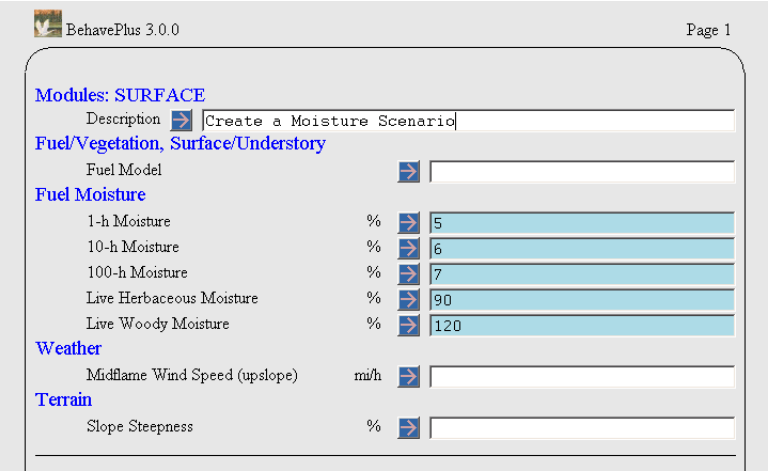


13.2. Defining and saving moisture scenarios

To define a Moisture Scenario first set the Worksheet to require individual fuel moisture values by selecting **individual size class** in the **Configure > Module selection > SURFACE > Options... > Fuel & Moisture** tab.



Enter values for each size class on the Worksheet, even if that item is shaded. Other input text boxes don't matter.



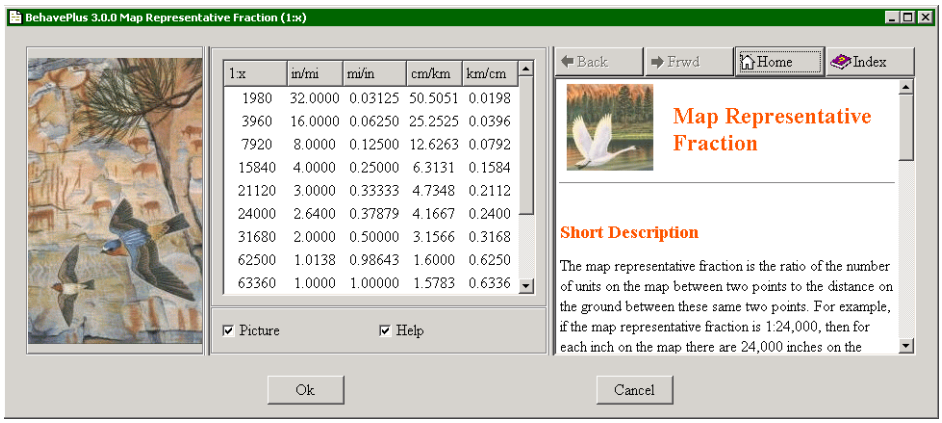
Save the moisture scenario with the **File > saveAs > Moisture scenario** command. In the "Save As" dialog box enter a file name in the **Moisture Scenario File** text box and a short description in the **Moisture Scenario Description** text box. See Section 20.4, Save As, for more information on saving moisture scenarios.

14. Map applications

BehavePlus allows the calculation of slope steepness from map measurements and conversion of distances to map measurements.

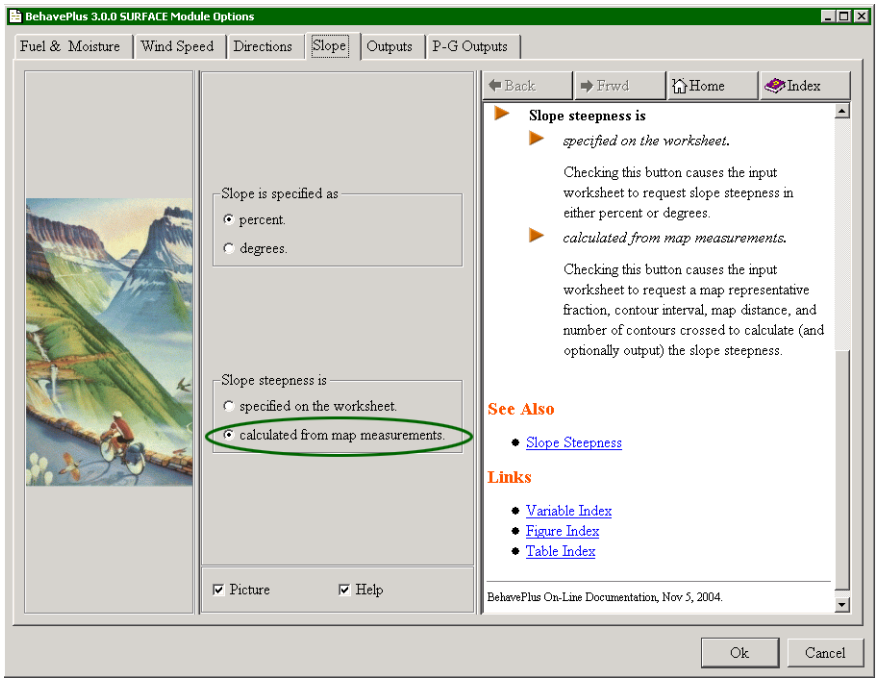
Map scale is given as map representative fraction, which is the ratio of the number of units on the map between two points to the distance on the ground between the same two points. For example, if the map representative fraction is 1:24,000, then for each inch on the map there are 24,000 inches on the ground.

Although any value can be entered, the "Input Guide" dialog box provides common map scales, available by clicking the **Choices** button.

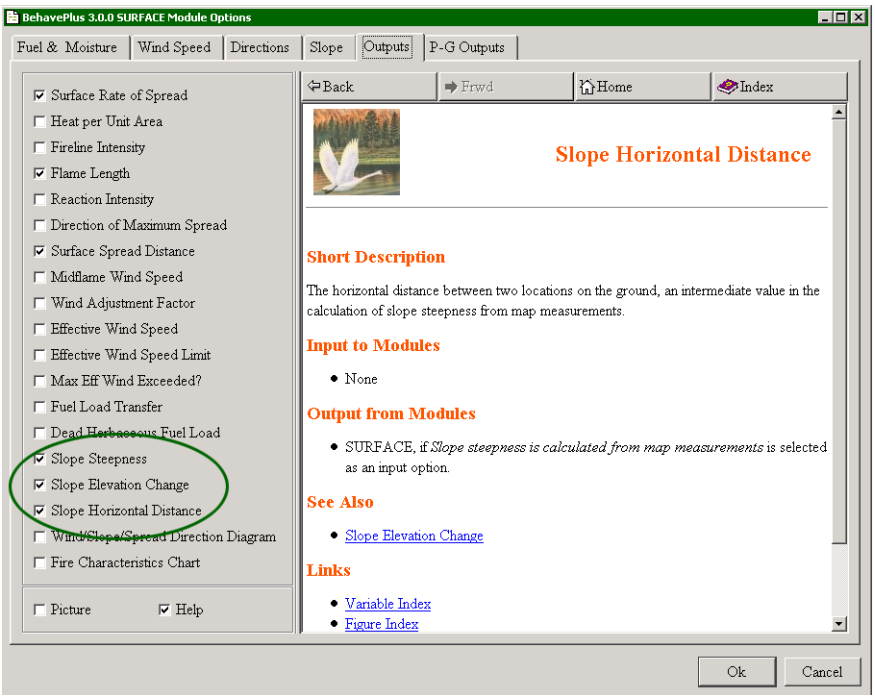


14.1. Slope from map measurements

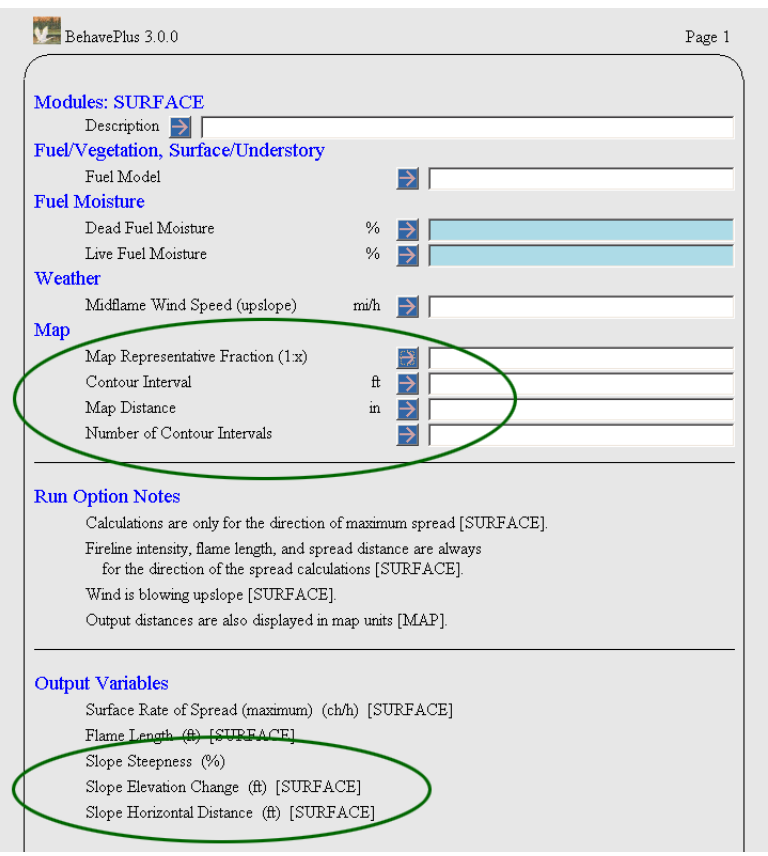
To set up a Worksheet to calculate slope steepness from measurements on a topographic map use the **Configure > Module selection > SURFACE > Options... > Slope** tab and select **Slope steepness is calculated from map measurements.**



You can add the calculated slope steepness and intermediate values to the output list with the **Configure > Module selection > SURFACE > Options... > Outputs** tab. Select any or all of the **Slope Steepness**, **Slope Elevation Change**, or **Slope Horizontal Distance** check boxes.



The Worksheet then includes a **Map** section with text boxes for data.

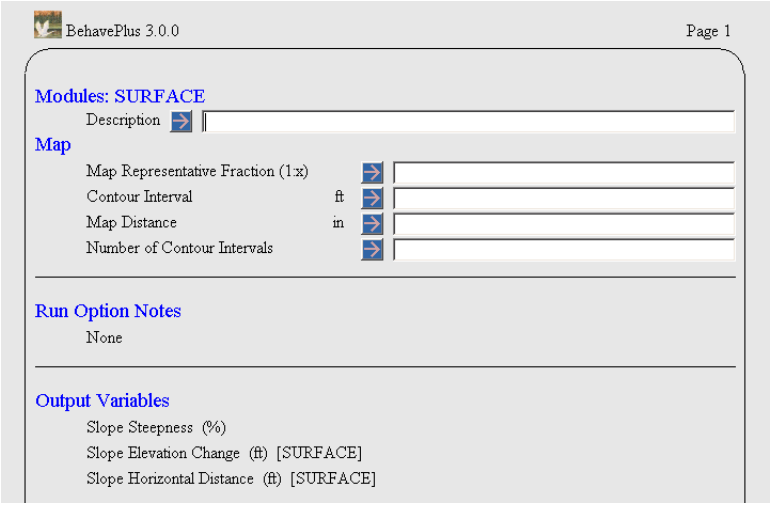


The contour interval is the difference in elevation between adjacent topographic contours on a topographic map.

The map distance is the distance between two points on a map generally expressed in inches or centimeters.

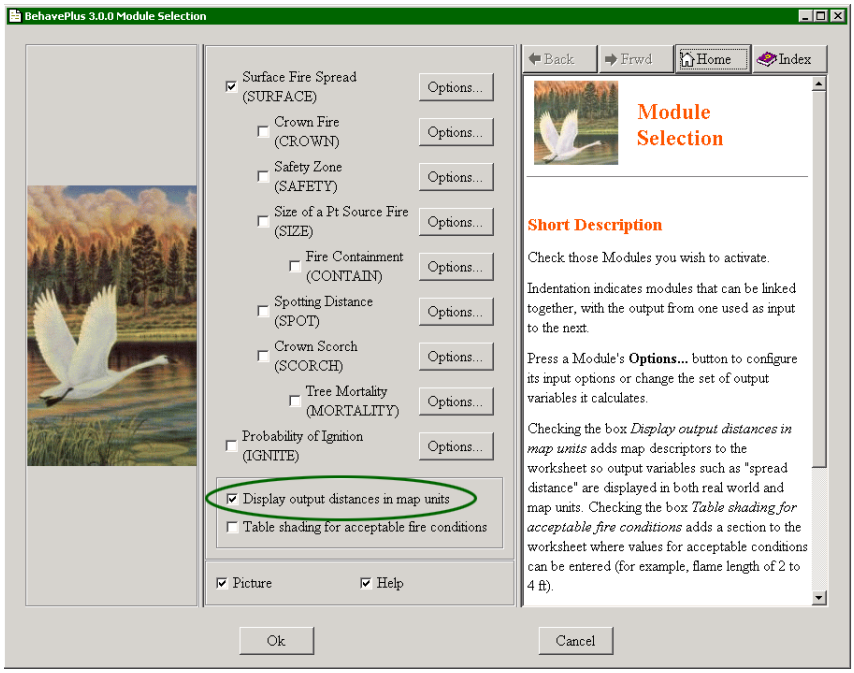
Number of contour intervals is a count between two points on a map.

If only slope values are requested as output, then only Map input variables are requested. An existing Worksheet, SlopeMap.bpw, showing this configuration is found in the ExampleWorksheets folder.



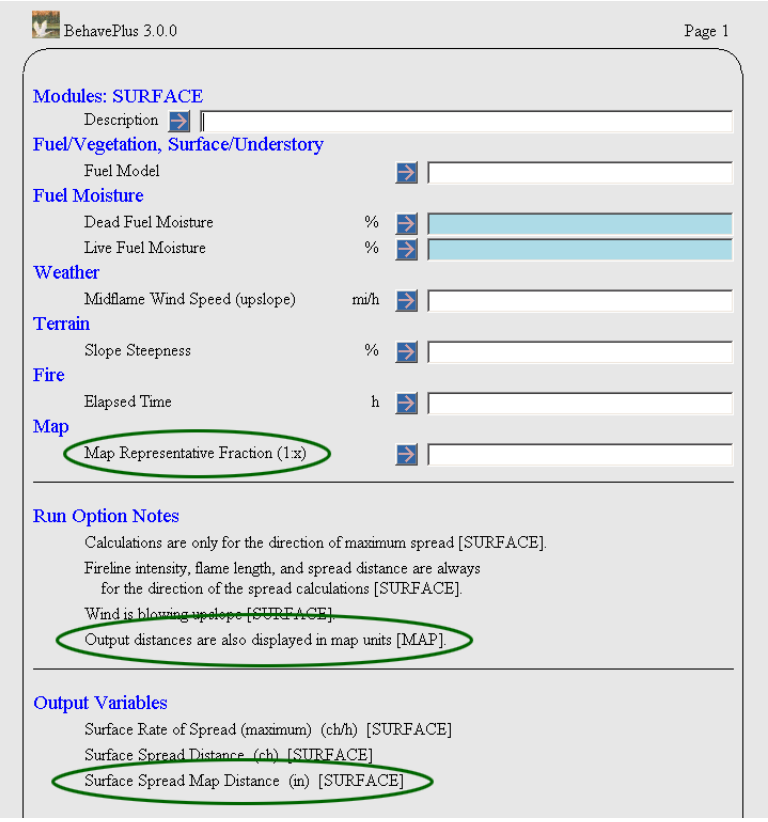
14.2. Map distances

To specify that output calculated distances should also be given in map units use the **Configure > Module selection** command and select the **Display output distances in map units** check box below the list of modules.



When a distance is calculated in SURFACE, SIZE, or SPOT and the **Display output distances in map units** check box is selected, a **Map Representative Fraction (1:x)** text box is added to the Worksheet and map distances are added to the list of output variables.

For example, when the **Spread Distance** check box is selected in the **Configure > Module selection > SURFACE > Options... > Outputs** tab the following Worksheet results:



15. Units

Default units for BehavePlus are English for use in the United States It is easy to change all units to metric using the **Configure > Units > metric** command.

If a user wishes to use something other than the units we have selected for English or metric, a custom set of units can be defined and saved for later use.

The Units set also defines the number of decimal places displayed for each variable.

Note that whenever a Worksheet or Run is saved, its current units of measure and display decimals are saved with it. The next time you open the Worksheet or Run, the units and decimal settings are restored.

BehavePlus also provides a quick units conversion tool accessed with the **Tools > Units converter** command.

15.1. English or metric

The units set can be changed using the **Configure > Units > English** or **metric** or **custom** commands.

Immediately upon change, the units on the active Worksheet and all values that have been entered are changed.

Because units are stored with a Worksheet or Run, if units are changed to metric and then another Worksheet is loaded from the ExamplesWorksheets folder, with the **File > New** command, the new Worksheet will be English units.

15.2. Custom units set

Develop and save a custom units set using the "Units Editor" dialog box opened with the **Tools > units Editor** command.

The Units editor controls the selection of units of measure and decimal places for the input, display, and output of variables. The selected units are then applied to the current Worksheet and saved as a custom units set.

The units of measure initially displayed by the dialog are those in use for the current Worksheet.

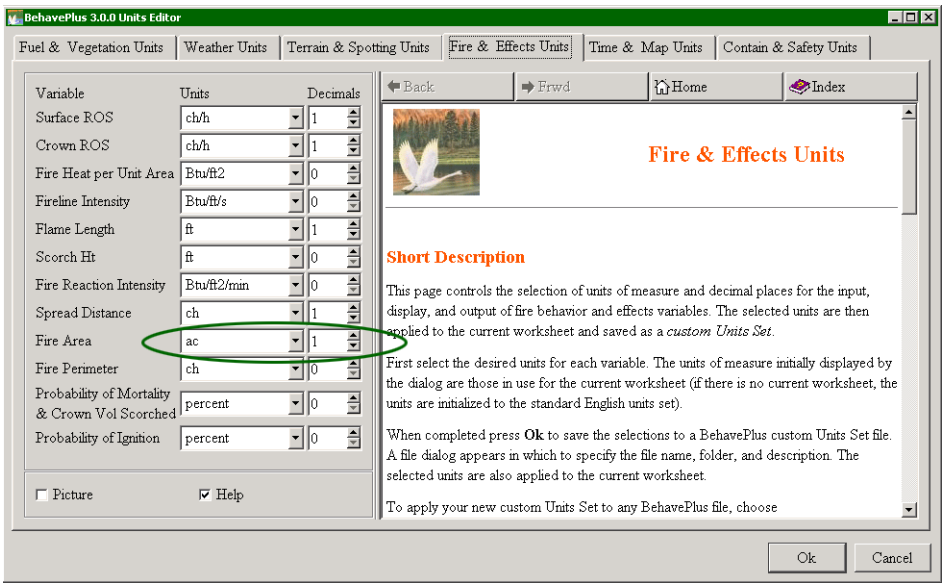
Select the desired units for each variable set. Rather than repetitiously having to enter units for every variable, they are grouped by type of unit of measure. Appendix C gives these groupings and their default English and metric units.

Once you have defined and saved a custom units set, you can apply it to a Worksheet or Run with the **Configure > Units > Custom** command that opens the "Select A Units Set" dialog box.

15.3. Number of decimal places

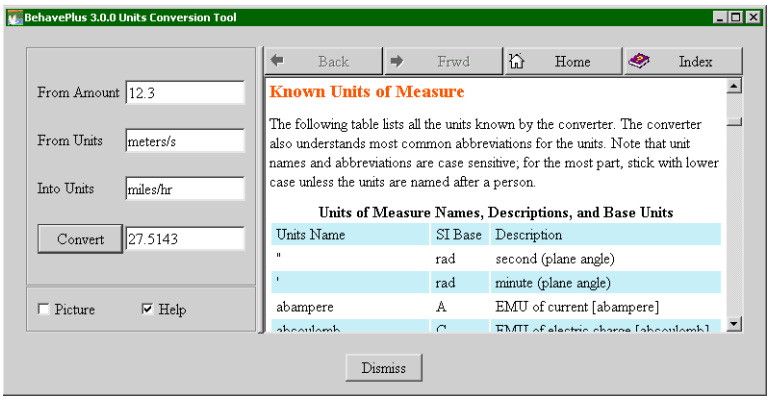
In addition to setting units of measure, the "Units Editor" dialog box also allows you to change the number of digits displayed after the decimal place of all input and output variables.

For example, fire area has 1 decimal place as the default. You may want to round area to the nearest acre by changing the number of decimals to 0.



15.4. Units conversion tool

For all those times when somebody gives you an observed spread rate in furlongs/fortnight or you just need to know what the temperature is at that Canadian RAWS station just across the border, BehavePlus has a utility you can reach with the **Tools > Units conversion tool** command.



In the "Units Conversion Tool" dialog box enter your known observation into the **From Amount** and **From Units** text boxes (12.3 meters per second in the above example). Then enter the desired units in the **Into Units** text box and click the **Convert** button to get your results (27.5143 miles per hour in the above example).

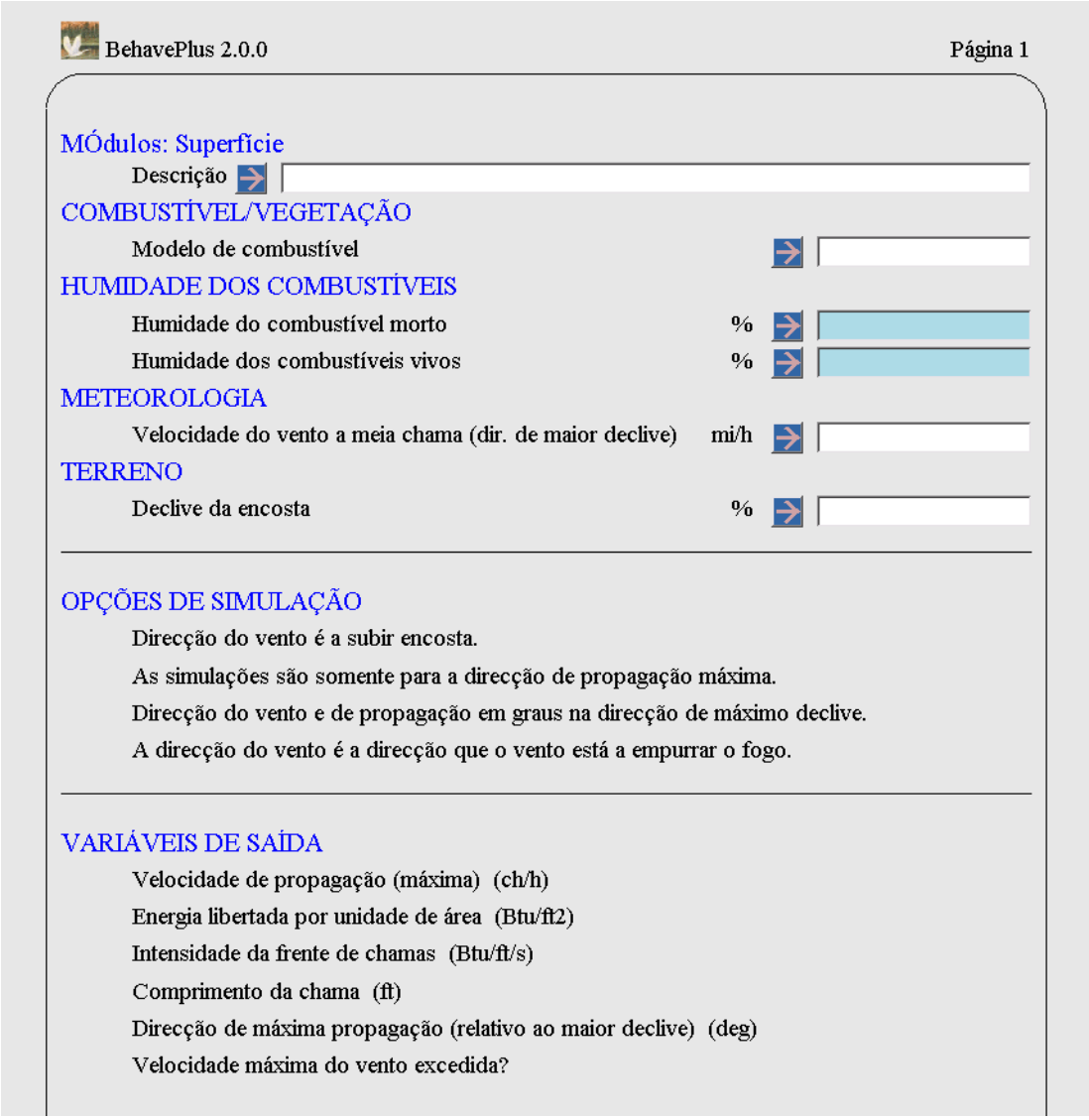
In the "Help" pane of the "Units Conversion Tool" dialog box there is a list of all the available units.

16. Language

The FIRE1 program of the old BEHAVE system was translated into several languages including Spanish and Chinese. We have designed BehavePlus to make the translation process easier. A Portuguese translation is included as an example. Instructions are available for translation to other languages. This translation process applies to the program interface itself, not to the help files.

16.1. English or Portuguese

To change the language from the default English to Portuguese use the **Configure > Language > Portuguese (Portugal)** command.

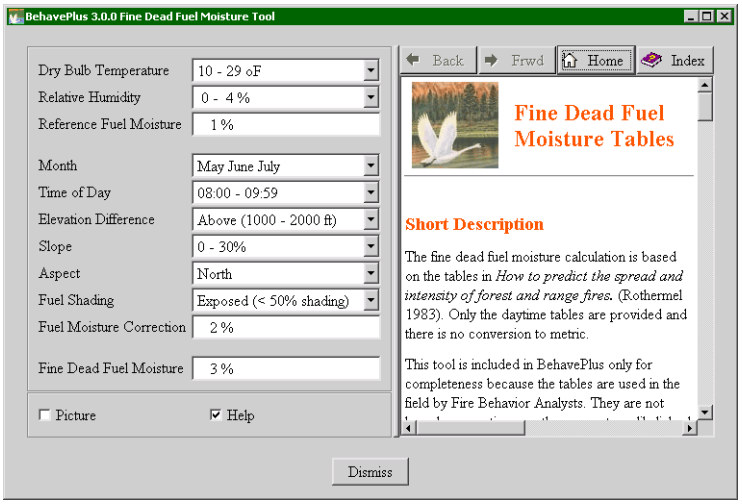


16.2. Custom language set

To develop a custom language set contact Collin Bevins at cbevins@montana.com

17. Fine Dead Fuel Moisture Tool

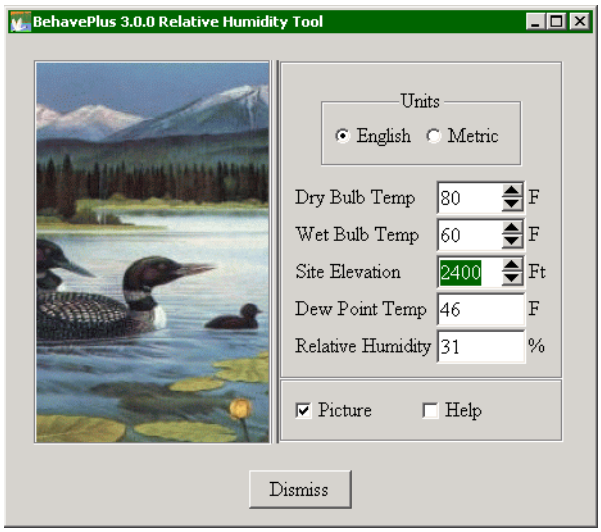
The "Fine Dead Fuel Moisture Tool" dialog box can be accessed with the **Tools > Fine dead fuel moisture** command.



This tool is an automation of only the *daytime* tables from Rothermel (1983). Selections are made through drop down lists. As soon as a change is made, the results are displayed. Since these tables are not based on equations, they can't effectively be linked to any other tools or modules in BehavePlus.

18. RH Tool

The “Relative Humidity” dialog box is opened with the **Tools > Relative humidity** command.

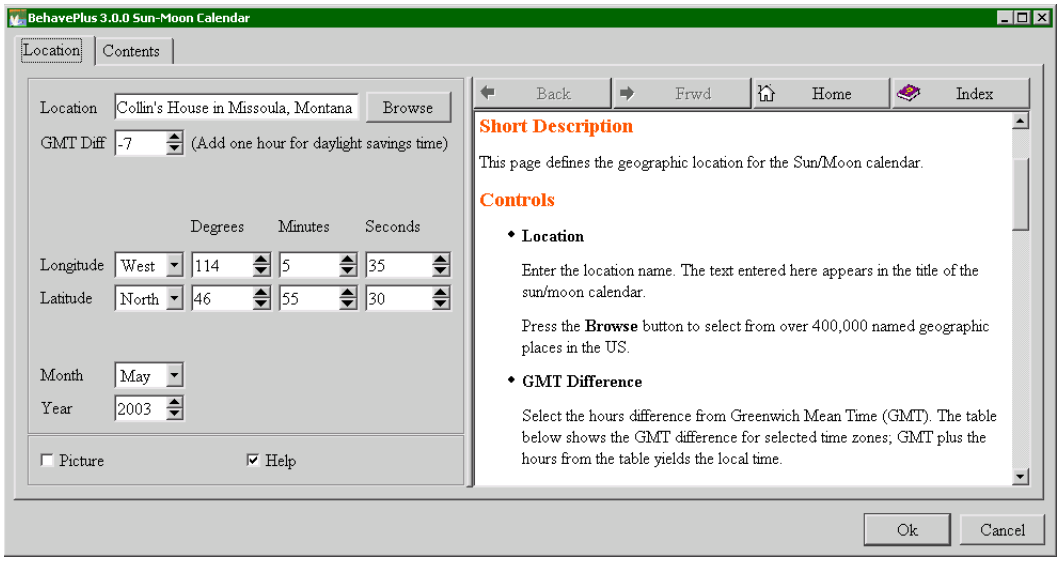


Simply type or use the spin box to enter the wet and dry bulb temperatures and elevation. The dew point temperature and relative humidity immediately change with input changes.

Remember the RH Tool is a stand alone utility, it does not link to any other tools or modules.

19. Sun-Moon Calendar Tool

The "Sun-Moon Calendar" dialog box is opened with the **Tools > Sun-moon calendar** command.



This tool allows you to specify any month of any year at a location on the globe and generate a calendar of sun-rise, sun-set, civil dawn, civil dusk, moon-rise, and moon-set times in table or calendar format. It can also display a table of equinox, solstice, and moon phases for the year.

The calendar tool also includes a large database of named places within the United States so you can select a location by name rather than by coordinates.

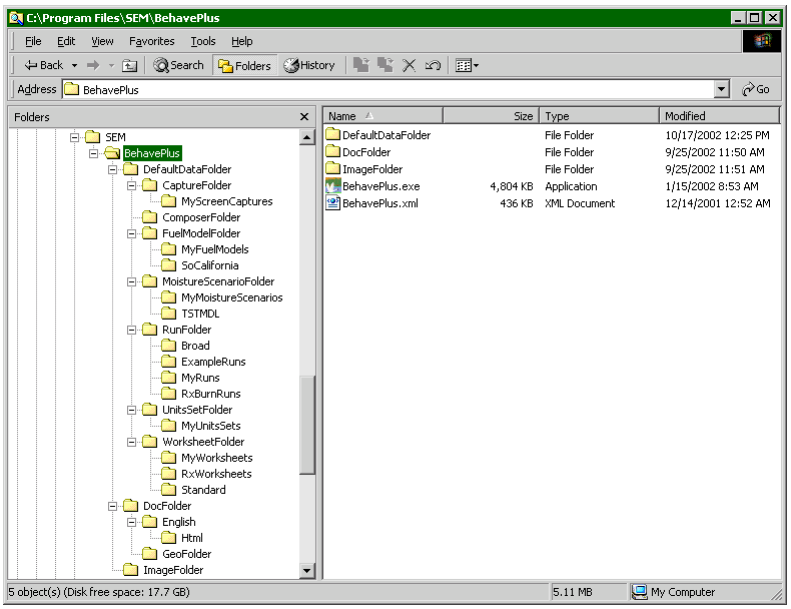
20. File management

20.1. Workspaces

BehavePlus has a proscribed file system structure; all files must be located in specific subdirectories. The parent directory of this file structure and all its subdirectories and files are collectively known as a Workspace.

A Workspace is a complete subdirectory tree containing all required BehavePlus files plus any additional Worksheet, Run, Fuel Model, Moisture Scenario, Units Set, or screen capture files saved by the user. A Workspace corresponds to a single BehavePlus project, and each BehavePlus project should have its own Workspace. Workspaces are created with either the **File > Workspaces > New Workspace** or **Clone current workspace** commands.

When BehavePlus is first installed it has a single Workspace called the "DefaultDataFolder". This is the default current Workspace every time BehavePlus is started.



We recommend you create a new Workspace using the **File > Workspaces > New Workspace** command for every BehavePlus project you're working on. A project can be a collection of fire behavior projections for a wildfire or a fuels analysis for an environmental impact statement. The new, “pristine” Workspace is automatically populated with all example Worksheets, example Runs, and standard and predefined custom fuel models just like the **DefaultDataFolder** Workspace.

Alternatively, you may clone an existing Workspace with the **File > Workspaces >Clone current workspace** command to copy all of the current Workspace into a new Workspace, including all Run, Units Sets, custom Fuel Models, and custom Moisture Scenarios.

The Workspace concept provides the following benefits:

- All files pertaining to a specific training class, fire situation, or other project are segregated into their own file structure.
- Workspaces are easily backed up or copied onto removable media using either the **File > Workspaces > Clone current workspace** command or Windows Explorer.
- BehavePlus has self-validation tests and informs you whenever it is missing required files.
- BehavePlus knows where to find all custom Fuel Models and Moisture Scenarios and include them in Guide Button dialog boxes.

We recommend using a compression utility such as WinZip, PKZip, or gzip when E-mailing or moving a Workspace over the Internet as compression significantly reduces BehavePlus file sizes.

A list of three letter file extensions used by BehavePlus is shown in the following table. These extensions are automatically attached to the files you create in BehavePlus.

File extension	File type	Folder
.bpf	Custom fuel models	FuelModelFolder
.bpm	Moisture scenarios	MoistureScenarioFolder
.bpw	Worksheets	WorksheetFolder
.bpr	Runs	RunFolder
.bpu	Custom Units Sets	UnitsSetFolder
.exe	Executable program file	BehavePlus
.png	Portable network graphic image format	MyScreenCaptures
.bmp	Bitmap graphic image format	MyScreenCaptures
.jpg	JPEG graphic image format	MyScreenCaptures
.xml	Extensible Markup Language	Various places

20.2. Load a Worksheet

A previously saved Worksheet is loaded with the **File > New** command, which opens the "Select a Worksheet" dialog box.

The Worksheet is 'blank' in that none of the input variables have been assigned values. But all of the associated options are still part of the Worksheet (e.g., graph appearance).

20.3. Load a Run

A previously saved Run is loaded through **File > Open Run** command, which opens the "Select a Run" dialog box.

A Run is a Worksheet with valid values assigned to all input variables. Calculated values, tables, graphs, and diagrams are not saved. These are generated with the **File > Calculate** command.

20.4. Save as...

A sub-menu of the **File > saveAs** command offers many choices of what to save from the active Worksheet or Run:

- Run
- Worksheet
- Fuel models
- Moisture scenario
- Results
- Image

A Run can be saved only if all valid values have been assigned to all variables on the Worksheet. The Run can be opened at a later time using the **File > Open Run** command or the toolbar button.

When a Worksheet is saved, it is saved without any values assigned to input variables. The Worksheet can be opened at a later time using the **File > New** command or the toolbar button.

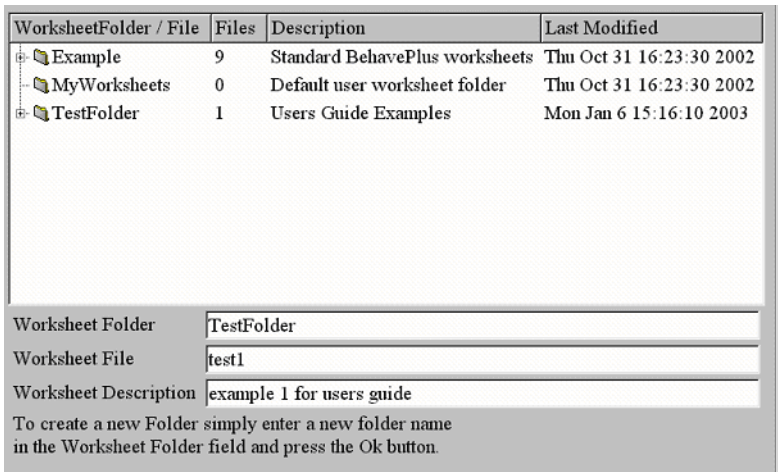
Fuel models can be saved in either BehavePlus or the FARSITE Custom Fuel Model (.fmd) format. Before saving a fuel model make sure the SURFACE module check box is selected and the **fuel parameters** check box is selected in the **Fuel is entered as** section of the **SURFACE > Options... > Fuel & Moisture** tab. Valid values must be assigned to each fuel model parameter. Also make sure the **Fuel Model Type** parameter is correct, dynamic (D) fuel models must have a live herbaceous fuel load. (see Section 12.4) To use custom fuel models at a later time they must be attached with the **Configure > Fuel model set selection** command. (see Section 12.5.2)

Before saving a moisture scenario make sure the SURFACE module is selected and the **individual size class** check box is selected in the **Moisture is entered by** section of the **SURFACE > Options... > Fuel & Moisture** tab. Valid values must be assigned to each size class, even those that are shaded. To make a moisture scenario available use the **Configure > moisture Scenario set selection** command. (See Section 13.2)

Table results can be saved to a tab delimited text file or HTML file. The text file can then be imported into another application, such as word processor, spreadsheet, or database. The HTML file can be used in a Web page or is a handy, compact way to E-mail your BehavePlus results. (See Sections 10.5.2 and 10.5.3)

Images of table, graph, and diagram screens can all be saved as an image file. The image file can then be edited with an image processor or inserted into word processor or layout documents. (See Section 10.5.1)

The following example saves a Worksheet. The process is similiar for other file types. The **File > saveAs** command requests input of folder name, file name, file description, or file type in the "Save As" dialog box.



In this case, the **Worksheet Folder** text box is initially set to MyWorksheets. To create a new folder, simply type a new name into the **Worksheet Folder** text box: TestFolder in the above example. You are asked to enter a Worksheet folder description. The folder description subsequently appears in the file selection dialog box as a reminder of its contents. The Worksheet description is initially set to whatever is in the **Description** text box on the Worksheet. When saving a Worksheet, you should assure that it describes the blank Worksheet, not the specific Run.

To export your table output as a spreadsheet or HTML document use the **Export > Results** command.

20.5. Deleting Files & Folders

Files and folders in a BehavePlus Workspace are deleted using Windows Explorer. However you should only delete files and folders you create, not any of the files and folders BehavePlus creates for the Workspace.

21. Help

Help features are a primary feature of BehavePlus. The Users Guide is available from the menu bar, and all dialogs and wizards include a help browser pane. Input fields include a Guide button for help in entering range inputs or selecting one or more discrete choices.

21.1. Browser pane help

The right-hand pane of many BehavePlus dialog boxes is a help browser. These can be printed by right-clicking in the help window to display a shortcut menu and selecting the appropriate command.

It includes a description of input variables when the guide button associated with the variable on the Worksheet is clicked. It includes a description of output variables when the cursor is held over a variable name on the list of possible output variables for a MODULE, reached through **Configure > Module selection > MODULE > Options... > Outputs** tab.

For each variable, information includes

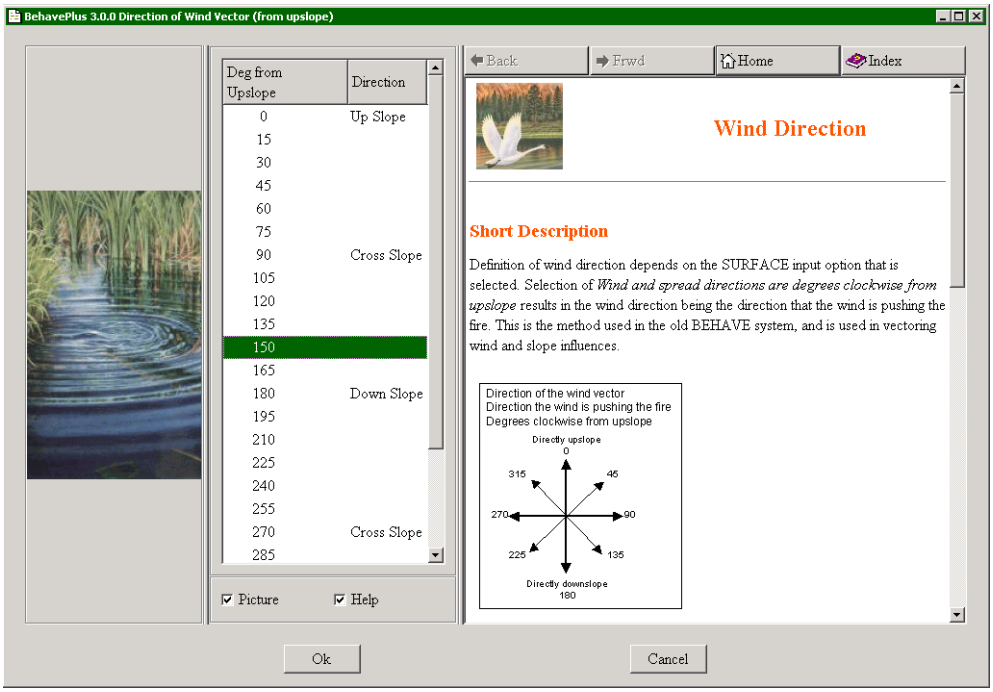
- Short description
- Input to modules
- Output from modules
- More Information
- See also
- Links

21.2. Guide button

Help on entering a specific Worksheet variable is available by pressing the Guide button next to each Worksheet entry field to activate an "Input Guide" dialog box containing a help browser pane and input assistance.

For continuous variables, the dialog facilitates entry of a large number of inputs by specifying the minimum input value, maximum input value, and increment value.

Additional values are sometimes displayed by clicking the **Choices** button where available in the "Input Guide" dialog box.



For discrete variables the dialog contains a list of all valid inputs from which the user may select values.

21.3. User's Guide

This User's Guide can either be printed or accessed interactively using a PDF viewer such as Adobe Acrobat Reader. It serves as the online help for BehavePlus and can be opened with the **Help > Program help** command. When viewed with the Adobe Acrobat Reader, the contents at the left provide access to the section in question.

References

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Appendix A: Version Comparison

This appendix contains a summary of changes between BEHAVE and the versions of BehavePlus. The different versions were introduced on the following dates.

Version	Date
BEHAVE	1984
BehavePlus v1.0.0	January, 2002
BehavePlus v2.0.0	July, 2003
BehavePlus v3.0.0	December, 2004

Older versions of the software are available in the ARCHIVES section at www.fire.org.

Version 2 and Version 3

- Van Wagner's (1977) transition to crown fire and Rothermel's (1991) crown fire spread models have been added with the new CROWN module.
- Calculating wind adjustment factors is now a SURFACE module option.
- The expanded set of fuel models (Scott and Burgan, in prep) have been added.
- Support for dynamic fuel models has been added.
- Two new output variables have been added to the SURFACE module to help understand dynamic fuel modeling, **Live herb load transfer** and **Dead herb fuel load**.
- New Moisture Scenarios for dynamic fuel models have been added.
- Identifing acceptable ranges of fire behavior with table shading is included to replace RxWINDOW from the old BEHAVE system.
- Output tables can be exported into Microsoft Excel and HTML format files.
- The new example Worksheet, BasicStart.bpw, is loaded at startup so the user can quickly do a simple run without having to load a Worksheet or configure one.
- Module names are listed with the the output variables and run options shown on the Worksheet.
- Several new options for listing descriptions of discrete variable codes on the Worksheet are added.
- The **Fuel/Vegetation** input category has been split into two new categories; **Fuel/Vegetation, Surface/Understory** and **Fuel/Vegetation, Overstory**.
- A new input catagory named **Acceptable Fire Conditions** is displayed on a Worksheet when the **Table shading for acceptable fire conditions** option is selected.
- Several new example Runs are available, FuelCompare.bpr, FuelMoisWInd.bpr, and FuelWind.bpr,
- **P-G** has been added to the input variables used specifically for the palmetto-gallberry fuel model.
- The **RH Tool** has been removed as a module and is now included in the Tool menu. This was done since the RH module did not link to any of the other modules.
- The Probability of Ignition module now draws a smooth curve on the output graphs instead of the steps in previous versions.

Version 1 and Version 2

- Following are significant differences between BehavePlus version 1.0 and version 2.0. Minor changes are not listed here.
- Safety zone size model added as a new SAFETY module
- Containment model added as a new CONTAIN module. This is a new model that allows multiple resources to make direct or parallel attack.
- Probability of ignition by lightning model added to the IGNITE module
- Two fuel weighting, three methods added to the SURFACE module
- Dynamic palmetto-gallberry fuel model added to the SURFACE module
- Size diagram output added to SIZE
- Contain diagram output in CONTAIN
- Direction diagram added to SURFACE
- Fire characteristics chart diagram output added to SURFACE
- Fine dead fuel moisture added as a new tool
- A Run Option section is added to the worksheets for clarification
- The contents of the Notes section on example worksheets is blank. The description of the worksheet that was there for version 1 is not necessary, especially with the addition of the Run Options section.
- The 'Standard' worksheet folder that was supplied with version 1 of the program is called the Example-Worksheets folder in version 2 to better reflect what it is. The worksheets in that folder are just some that the developers put together. The term 'standard' gave them significance that they didn't deserve.
- The Blank.bpw Worksheet that was in version 1 is called the 0Startup.bpw Worksheet in version 2 to better reflect what it is-the worksheet to use as a startup in selecting calculation modules. The '0' (zero) as a first character of the file name puts it as the first item on the list for easy selection.
- The program now automatically loads the 0Startup.bpw worksheet upon initiation. This saves some steps if the worksheet is set up by module selection. If a previously saved worksheet is desired, it is selected and loaded as before with the **File > New** command.
- The Fuel model guide button gives you access to the photographs and descriptions in Anderson (1982) "Aids to selecting fuel models" and to the selection key in Rothermel (1983) "How to predict the spread and intensity of forest and range fires"
- The Program Help and the Users Guide for version 1 have been replaced by a single, new document-a users guide in PDF format that can be both printed and accessed online for specific help.
- A Language option has been added. Portuguese is provided as an example.
- Additional Workspace options aid in file management.
- Graph Y-axis are now user-scalable.

BEHAVE and BehavePlus

The old BEHAVE fire behavior prediction and fuel modeling system is a set of five DOS programs, three of which were first available in 1984. The whole look and feel of the BehavePlus fire modeling system is different, using modern user interface technology

Following are some specific differences that will be of interest to users of the old BEHAVE system.

- BehavePlus is one program. The old BEHAVE was five programs (FIRE1, FIRE2, RXWINDOW, NEWMDL, TSTMDL). The separation was due to computer limitations at the time and an extended development period.
- BehavePlus gives the user control of input options that were fixed on the old BEHAVE. For example, in the old BEHAVE, the DIRECT module required direct input of fuel moisture by size class, midflame wind speed, and direction of wind and spread with respect to upslope. The SITE module calculated fine fuel moisture and requested input of 20-ft wind speed, exposure to the wind, and direction of wind and spread.

The DISPATCH module requested dead and live fuel moisture, 20-ft wind speed and wind adjustment factor. Calculations were for upslope spread with the wind. In the TSTMDL program, fuel moisture was specified by category. In contrast, the BehavePlus SURFACE module allows users to specify the method of entry for fuel moisture, wind speed, and directions.

- In BEHAVE only continuous variables could be assigned more than one value for a maximum of seven values. For example, wind speed could be assigned a range of values, but fuel model could not. BehavePlus allows multiple input values for every variable and there is essentially no limit to the number of values. Table output is carried over to multiple pages if necessary.
- BehavePlus produces graphs and diagrams as well as tables. The primary output of the old BEHAVE was tables. Crude graphs were produced using characters.
- The fuel modeling portion of the old BEHAVE consisted of the NEWMDL and TSTMDL programs. The features in NEWMDL are not in BehavePlus. The TSTMDL fuel model testing methods are in BehavePlus.
- BehavePlus does not include the fine dead fuel moisture model in MOISTURE and SITE modules in the FIRE2 program of BEHAVE. A better moisture model based on hourly weather data has been developed and is being incorporated into the National Fire Danger Rating System (NFDRS) and the FireFamily Plus program. Eventually it will be available for fire behavior calculations in BehavePlus. BehavePlus offers the fuel moisture tables as a tool.
- The CONTAIN module of BehavePlus is different from that used in BEHAVE. The old model had a mathematical problem that occasionally surfaced. BehavePlus uses a model by Fried and Fried (1996) that offers the application of multiple resources with various productivity rates and arrival times, and direct or parallel attack at either the fire head or rear. BehavePlus does not offer the option of reverse calculation that was in the old BEHAVE (i.e. given a final fire size, what is the required line production rate).
- The RxWindow program is not and will not be part of BehavePlus. Reverse calculation becomes more difficult (essentially impossible) as models are added. The plan is to provide a new method of table shading to aid in prescribed fire planning.
- The equations in the MORTALITY module in BehavePlus have been updated to match those of FOFEM. Many new tree species have been added.
- BehavePlus lists input values by category (Fuel/Vegetation, Weather, …) rather than by module (DIRECT, SIZE, …) as was done in the old BEHAVE.
- In BehavePlus users select the output variables to be displayed. In BEHAVE the output list was fixed.
- Map distance calculation was a stand-alone feature in BEHAVE. It is integrated into BehavePlus.
- BEHAVE asked users whether they were using a computer with a screen. The program could be run in either WORDY or TERSE mode. BehavePlus assumes it is being run on a 21st century personal computer.

Appendix B: Input and Output Variable Tables

Each input variable in BehavePlus, version 2, is listed in the table according to category. 'I' (for Input) in a Module column indicates that it is a possible input for that module. In some cases an input variable may also be an output variable, indicated by 'O' (for Output). It depends on the selected modules, input options, and output variables.

For example, note that

- Midflame wind speed is an input to SURFACE under the input option **Wind speed is entered as midflame height**. However, it is an output variable if **Wind speed is entered as 20-ft wind and wind adjustment factor** is selected.
- Rate is spread is an output from SURFACE and an input to SIZE. If both SURFACE and SIZE are selected, the rate of spread from SURFACE is automatically used in SIZE. If only SIZE is selected, then the user must input values for rate of spread.
- Temperature is used only in SCORCH and RH, it is not used for the spread rate and intensity calculations in SURFACE.
- These tables also give the English and metric units and number of decimal places and the output variables selected for display initiated by the 0Startup.bpw worksheet. (See Appendix D.)

Table 1: Input Variables and Modules

Input variable	SURFACE	SAFETY	SIZE	CONTAIN	SPOT	SCORCH	MORTALITY	IGNITE	RH	Variable Type	English Range/ Units	Metric Range/ Units	Notes
Fuel / Vegetation													
Fuel model	I									D	N/A	N/A	
First fuel model	I									D	N/A	N/A	For two fuel models
Second fuel model	I									D	N/A	N/A	"
First fuel model cover-age	I									C	0-100%	0-100%	"
1-h fuel load	I									C	0.0-30.49 ton/ac	0.0-68.35 tonne/ha	Fuel model parameter
10-h fuel load	I									C	0.0-30.49 ton/ac	0.0-68.35 tonne/ha	"
100-h fuel load	I									C	0.0-30.49 ton/ac	0.0-68.35 tonne/ha	"
Live herbaceous fuel load	I									C	0.0-30.49 ton/ac	0.0-68.35 tonne/ha	"
Live woody fuel load	I									C	0.0-30.49 ton/ac	0.0-68.35 tonne/ha	"
1-h surface area / vol ratio	I									C	109-4,000 ft2/ft3	358-13,123 m2/m3	"
Live herb surface area / vol ratio	I									C	109-4,000 ft2/ft3	358-13,123 m2/m3	"
Live woody surface area / vol ratio	I									C	109-4,000 ft2/ft3	358-13,123 m2/m3	"
Fuel bed depth	I/O									C	0.05 to 10.0 ft	0.02-3.05 m	" output for P-G
Dead fuel moisture of extinction	I									C	5 - 100%	5 - 100%	Fuel model parameter
Dead fuel heat content	I									C	6,000-12,000 BTU/lb	13,967-27,934kJ/kg	"
Live fuel heat content	I									C	6,000-12,000 BTU/lb	13,967-27,934kJ/kg	"
Palmetto-gallberry age of rough	I									C	1-25 years	1-25 years	For dynamic palmetto-gallberry
Height of understory	I									C	1-6 ft	0 -2 m	"

Table 1: Input Variables and Modules

Input variable	SURFACE	SAFETY	SIZE	CONTAIN	SPOT	SCORCH	MORTALITY	IGNITE	RH	Variable Type	English Range/ Units	Metric Range/ Units	Notes
Palmetto coverage	I									C	15-85 %	15-85 %	"
Overstory basal area	I									C	30-110 ft2/ac	6.8-25.3 m2/ha	"
Mean cover height					I					C	0 -300 ft	0 -91 m	
Tree height					I		I			C	10 - 300 ft.	3 - 91 m	
Crown ratio							I			C	0.1 - 1.0	0.1 - 1.0	
Mortality tree species					I		I			D	(206 species)	(206 species)	
Spot tree species					I					D	(14 species)	(14 species)	
D.B.H.					I		I			C	5 - 40 in	13 - 102 cm	
Bark thickness							I/O			C	0.1 - 2.0 in	0.3 - 5.1 cm	
Lightning ignition fuel type								I		D	PPL, PWC, PWD, PWS, LPD, DFD, ESH, PMC	PPL, PWC, PWD, PWS, LPD, DFD, ESH, PMC	
Lightning duff and litter depth								I		C	0-12 in	0-30 cm	
Fuel Moisture													
Moisture scenario										D	N/A	N/A	
1-h moisture	I							I		C	1 - 60%	1 - 60%	Fuel moisture scenario parameter
10-h moisture	I									C	1 - 60%	1 - 60%	"
100-h moisture	I							I		C	1 - 60%	1 - 60%	"
Live herbaceous moisture	I									C	30 - 300%	30 - 300%	"
Live foliage for P-G													
Live woody moisture	I									C	30 - 300%	30 - 300%	"
Live stemwood for P-G													
Dead fuel moisture	I							I		C	1 - 60%	1 - 60%	Used for 1-h, 10-h, 100-h
Live fuel moisture	I									C	30 - 300%	30 - 300%	Used for live herbaceous and woody

Table 1: Input Variables and Modules

Input variable	SURFACE	SAFETY	SIZE	CONTAIN	SPOT	SCORCH	MORTALITY	IGNITE	RH	Variable Type	English Range/ Units	Metric Range/ Units	Notes
Weather													
Midflame wind speed	I/O				I					C	0 - 60 mi/h	0.0 - 96.6 km/h	
20-ft (or 10-m) wind speed	I			I						C	0 - 99 mi/h	0.0 - 159 km/h	
Wind adjustment factor	I									C	0.1 - 1.0	0.1 - 1.0	
Effective wind speed	O		I							C	0 - 60 mi/h	0.0 - 96.6 km/h	
Wind direction (from North) or (from ups-lope)	I									C	0 - 360 deg	0 - 360 deg	Reference depends on input option selections
Air temperature					I		I	I		C	-40 - 120 deg F	-40 - 49 deg C	
Wet bulb temperature								I		C	-40 - 120 deg F	-40 - 49 deg C	
Dew point temperature								I/O		C	-40 - 120 deg F	-40 - 49 deg C	
Fuel shading from the sun							I			C	0 - 100%	0 - 100%	by cloud or canopy
Lightning strike type							I			D	+, -, or unknown	+, -, or unknown	
Terrain													
Slope steepness	I									C	0 - 45 deg 0 - 100%	0 - 45 deg 0 - 100%	
Aspect	I									C	0 - 360 deg	0 - 360 deg	
Site elevation								I		C	-1,000-30,000 ft	-305 - 9,144 m	
Ridge-to-valley eleva-tion difference				I						C	0 - 4,000 ft	0 - 1,219 m	
Ridge-to-valley horizon-tal distance				I						C	0 - 4.0 mi	0 - 6.4 km	
Spotting source location				I						D	RT, MW, VB, ML	RT, MW, VB, ML	
Fire													
Rate of spread (maxi-mum)	O		I	I						C	0 - 500 ch/h	0.0-167.6 m/min	Head fire
Flame length	O	I			I	I				C	0 - 200 ft	0 - 61 m	Worst-case estimate of flame height for SAFETY

Table 1: Input Variables and Modules

Input variable	SURFACE	SAFETY	SIZE	CONTAIN	SPOT	SCORCH	MORTALITY	IGNITE	RH	Variable Type	English Range/ Units	Metric Range/ Units	Notes
Fireline intensity	O					I				C	0 - 10,000 BTU/ft/s	0 - 34,641 kW/m	
Flame height from a burning pile					I					C	0 - 100 ft	0 - 30.5 m	
Spread direction (from North) or (from ups-lope)	I/O									C	0 - 360 deg	0 - 360 deg	Reference depends on input option selections
Number of torching trees					I					C	0 - 30	0 - 30	
Scorch height						O	I			C	0 - 200 ft	0 - 61 m	
Elapsed time	I		I							C	0.5 - 8.0 h	0.5 - 8.0 h	From ignition/start
Fire size at report			O	I						C	0.1-100 ac	0.0-40.5 ha	'area' from SIZE
Length-to-width ratio			O	I						C	1-7	1-7	
Map													
Map representative frac-tion (1:x)	I		I		I					C	1,980 - 1,013,760	1,980 - 1,013,760	
Contour interval	I									C	1 - 1000 ft	0.3 - 304.8 m	
Map distance	I									C	0.1 - 100 in	0.3 - 254 cm	
Number of contour intervals	I									C	1 - 100	1 - 100	
Suppression													
Suppression tactic				I						D	Head or Rear	Head or Rear	
Line construction offset				I						C	0-100 ch	0-2012 m	0 = direct attack, else parallel attack
Resource name				I						D	N/A	N/A	Entry for each resource
Resource line produc-tion rate				I						C	1-200 ch/h	20.1-4023.4 m/h	"
Resource arrival time				I						C	0-8 h	0-8 h	"
Resource duration				I						C	0.0-10 h	0.0-10 h	"
Resource base cost				I						C	0-500,000	0-500,000	"
Resource hourly cost				I						C	0-500,000	0-500,000	"

Table 1: Input Variables and Modules

Input variable	SURFACE	SAFETY	SIZE	CONTAIN	SPOT	SCORCH	MORTALITY	IGNITE	RH	Variable Type	English Range/ Units	Metric Range/ Units	Notes
Number of personnel		I								C	1-200	1-200	Integer
Area per person		I								C	10-100 ft2	.93-9.3 m2	
Number of heavy equipment		I								C	0-10	0-10	Integer
Area per heavy equipment		I								C	100-500 ft2	9.3-46.5 m2	

I = Input

O = Output

I/O = Input or Output depending on the selected modules and options

C = Continuous variable

D = Discrete variable

Table 2: Output Variables and Modules

Output variable	Default output variable	English Units	Metric Units	Notes
SURFACE				
Rate of spread	X	ch/h	m/min	
Heat per unit area	X	BTU/ft2	KJ/m2	
Fireline intensity	X	BTU/ft/s	KW/m	
Flame length	X	ft	m	
Reaction intensity		BTU/ft2/min	KW/m2	
Direction of maximum spread	X	degrees	degrees	
Spread distance		ch	m	Can be map distance
Midflame wind speed		mi/h	km/h	
Effective wind speed		mi/h	km/h	
Maximum reliable wind speed		mi/h	km/h	
Maximum wind exceeded?	X	Yes or No	Yes or No	

Table 2: Output Variables and Modules

Output variable	Default output variable	English Units	Metric Units	Notes
Slope steepness		percent	percent	
Slope elevation change		ft	m	
Slope horizontal distance		ft	m	
Wind/slope/fire direction diagram		N/A	N/A	
Fire characteristics chart		N/A	N/A	
P-G dead fine fuel load		ton/ac	tonne/ha	
P-G dead medium fuel load		ton/ac	tonne/ha	
P-G dead foliage fuel load		ton/ac	tonne/ha	
P-G live fine fuel load		ton/ac	tonne/ha	
P-G live medium fuel load		ton/ac	tonne/ha	
P-G live foliage fuel load		ton/ac	tonne/ha	
P-G litter fuel load		ton/ac	tonne/ha	
Fuel bed depth		ft	m	
SAFETY				
Safety zone separation distance	X	ft	m	
Safety zone size	X	ac	ha	
Safety zone radius		ft	m	
SIZE				
Area	X	ac	ha	
Perimeter	X	ch	m	
Length-to-width ratio		N/A	N/A	Real number
Forward spread distance		ch	m	Can be map distance
Backing spread distance		ch	m	Can be map distance
Fire length		ch	m	Can be map distance
Maximum fire width		ch	m	Can be map distance
Fire shape diagram		N/A	N/A	
CONTAIN				
Time from report	X	h	h	To containment or escape

Table 2: Output Variables and Modules

Output variable	Default output variable	English Units	Metric Units	Notes
Contain status	X	Contained, Withdrawn, or Exhausted	Contained, Withdrawn, or Exhausted	Either withdrawn or exhausted is escaped
Contained area	X	ac	ha	At containment. If escape, area = 0
Fireline constructed	X	ch	m	
Number of resources used	X	N/A	N/A	Integer
Cost of resources used		N/A	N/A	
Containment diagram		N/A	N/A	
SPOT				
Spotting distance from torching trees	X	mi	km	
Spotting distance from a burning pile		mi	km	
Spotting distance from a wind-driven surface fire		mi	km	
SCORCH				
Scorch height	X	ft	m	
MORTALITY				
Bark thickness		in	cm	
Tree crown length scorched		ft	m	
Tree crown volume scorched		percent	percent	
Probability of mortality	X	percent	percent	
IGNITE				
Probability of ignition from a firebrand	X	percent	percent	
Probability of ignition from lightning		percent	percent	
RH				
Relative humidity	X	Percent	Percent	
Dew point temperature		deg F	deg C	

Appendix C: Units Editor

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Variable	English units	No. Dec.	Metric units	No. Dec.
Fuel and Vegetation Units				
Fuel Load • 1-h fuel load • 10-h fuel load • 100-h fuel load • Live herbaceous fuel load • Live woody fuel load • Palmetto-gallberry dead fine fuel load • Palmetto-gallberry dead medium fuel load • Palmetto-gallberry dead foliage fuel load • Palmetto-gallberry live fine fuel load • Palmetto-gallberry live medium fuel load • Palmetto-gallberry live foliage fuel load • Palmetto-gallberry litter fuel load	ton/ac	2	tonne/ha	2
Surface Area/Vol Ratio • 1-h surface area/volume ratio • Live herb surface area/volume ratio • Live woody surface area/volume ratio	ft2/ft3	0	m2/m3	0
Understory Fuel Depths • Fuel bed depth • Palmetto-gallberry height of understory	ft	2	m	2
Ground Fuel Depth • Lightning duff and litter depth	in	1	cm	0
Fuel Moisture & Extinction Moisture • Dead fuel moisture of extinction • 1-h moisture • 10-h moisture • 100-h moisture • Live herbaceous moisture • Live woody moisture • Dead fuel moisture • Live fuel moisture	percent	0	percent	0
Fuel Heat Content • Dead fuel heat content • Live fuel heat content	Btu/lb	0	kJ/kg	0

Variable	English units	No. Dec.	Metric units	No. Dec.
Tree Height & Mean Cover Height • Mean cover height • Tree height • Tree crown length scorched	ft	0	m	0
Tree D.b.h. and Bark Thickness • D.b.h. • Bark thickness	in	0	cm	0
Coverage • First fuel model coverage • Palmetto coverage	percent	0	percent	0
Basal Area • Palmetto-gallberry overstory basal area	ft2/ac	0	m2/ha	0
Weather Units				
Wind Speed • Midflame wind speed • 20-ft wind speed • 10-m wind speed • Effective wind speed • Maximum reliable wind speed	mi/h	1	km/h	1
Temperature • Air (dry bulb) temperature • Wet bulb temperature • Dew point temperature	oF	0	oC	0
Relative Humidity • Relative humidity	percent	0	percent	0
Shading from sun	percent	0	percent	0
Terrain & Spotting Units				
Slope steepness • Slope steepness (Note: these units only apply when the SURFACE Module option Slope is specified as percent is selected. When Slope is specified as degrees is selected, all slope units are degrees.)	percent	0	percent	0
Site Elevation & Ridge-to-Valley Elevation Difference • Site elevation • Ridge-to-valley elevation difference • Elevation change (slope rise) • Horizontal distance (slope reach)	ft	0	m	0

Variable	English units	No. Dec.	Metric units	No. Dec.
Spotting Distance & Ridge-to-Valley Horizontal Distance • Spotting distance from torching trees • Spotting distance from a burning pile • Spotting distance from a wind-driven surface fire • Ridge-to-valley horizontal distance	mi	1	km	1
Fire & Effects units				
Rate of Spread	ch/h	1	m/min	1
Fire Heat Per Unit Area	Btu/ft2	0	kW/s/m2	0
Fireline Intensity	Btu/ft/s	0	kW/m	0
Flame Length & Scorch Height • Flame length • Flame height of a burning pile • Scorch height	ft	1	m	1
Fire Reaction Intensity	Btu/ft2/min	0	kW/m2	0
Spread Distance • Spread distance • Forward spread distance • Backing spread distance • Fire length • Maximum width of fire	ch	1	m	1
Fire Area • Area • Contained area • Fire size at report	ac	1	ha	1
Fire Perimeter	ch	0	m	0
Probability of Mortality & Crown Volume Scorched • Tree crown volume scorched • Probability of mortality	percent	0	percent	0
Probability of Ignition • Probability of ignition from a firebrand • Probability of ignition from a lightning strike	percent	0	percent	0

Variable	English units	No. Dec.	Metric units	No. Dec.
Time & Map Units				
Time • Elapsed time • Resource Arrival Time • Resource Duration • Time from Report	h	1	h	1
Contour Interval • Map contour interval	ft	0	m	1
Map Distance • Map distance (for slope calculation) • Fire spread map distances • Fire length and width map distances • Spotting map distance from torching trees • Spotting map distance from a burning pile • Spotting map distance from a wind-driven surface fire	in	2	cm	1
Contain & Safety Units				
Rate • Resource Line Production Rate	ch/h	1	m/h	1
Distance, Containment • Fireline Constructed • Line Construction Offset	ch	1	m	0
Distance, Safety Zone • Safety Zone Radius • Safety Zone Separation Distance	ft	0	m	0
Area, Safety Zone • Safety Zone Size	ac	2	ha	0
Area, Personnel and Equipment • Area per person • Area per heavy equipment	ft2	0	m2	0

Appendix D: The 0Startup.bpw worksheet, defaults

The 0Startup.bpw worksheet is generally the starting place for selection of calculation modules. Therefore, upon initiation, the BehavePlus program automatically loads that worksheet. You have the option of ignoring or closing it and loading a previously saved worksheet loaded through the **File > New** command.

The 0Startup.bpw worksheet doesn't look like much on the screen, but it carries with it all of the 'default' selections for calculation modules and displays. Any of those selections can be changed, of course. The 0Startup.bpw worksheet can be reloaded at any time to reset the defaults. The 0 (zero) is the first character in the file name to assure that it is listed first in the list of Example Worksheets for easy selection.

If you want to use a different set of 'defaults', simply develop and save a similar startup worksheet in your own folder. For example, if you generally use metric units or if you prefer to display graphs as full screen rather than 50%, then you can define an alternate appropriate startup worksheet. The program will, however, continue to load our 0Startup.bpw worksheet when the program is initiated. You will need to load your own using the **File > New** command.

Following are the 'default' selections that come with the 0Startup.bpw worksheet.

Module	Input option	0startup.bpw selection	Other options
SURFACE	Fuel is entered as	Fuel models	• Fuel parameters • Dynamic palmetto-gallberry • Two fuel models, two-dimensional expected spread • Two fuel models, harmonic mean • Two fuel models, area weighted
	Moisture is entered by	Individual size class	• Dead and live category • Moisture scenario
	Wind speed is entered as	Midflame height	• 20-ft wind and wind adjustment factor • 10-m wind and wind adjustment factor
	Wind direction is	Specified on the worksheet	Upslope
	Rate of spread is calculated	Only in the direction of maximum spread	In directions specified on the worksheet
	Wind & spread directions are	Degrees clockwise from upslope (direction the wind is pushing the fire)	Degrees clockwise from north (direction from which the wind is blowing)
	Slope is specified as	Percent	degrees
	Slope steepness is	Specified on the worksheet	Calculated from map measurements
SCORCH	Fire intensity is entered as	Flame length	Fireline intensity
MORTALITY	Bark thickness is	Specified on the worksheet	Estimated from species and d.b.h
RH	Relative humidity is derived from	Dew point and dry bulb temperature	Dry and wet bulb temperature and elevation

Module	0Startup.bpw output variable selection	Other output variables
SURFACE	• Rate of spread • Heat per unit area • Fireline intensity • Flame length • Direction of maximum spread • Maximum wind exceeded?	• Reaction intensity • Spread distance • Midflame wind speed • Effective wind speed • Maximum reliable wind speed • Slope steepness • Slope elevation change • Slope horizontal distance • Wind/slope/spread direction diagram • Fire characteristics chart • For Palmetto-gallberry dynamic fuel: • P-G dead fine fuel load • P-G dead medium fuel load • P-G dead foliage fuel load • P-G live fine fuel load • P-G live medium fuel load • P-G live foliage fuel load • P-G litter fuel load • Fuel bed depth
SAFETY	• Safety zone separation distance • Safety zone size	• Safety zone radius
SIZE	• Area • Perimeter	• Length-to-width ratio • Forward spread distance • Backing spread distance • Fire length • Maximum fire width • Fire shape diagram
CONTAIN	• Time from report • Contain status • Contained area • Fireline constructed • Number of resources used	• Cost of resources used • Containmen diagram
SPOT	• Spotting distance from torching trees	• Spotting distance from a burning pile • Spotting distance from a wind-driven surface fire
SCORCH	• Scorch height	
MORTALITY	• Probability of mortality	• Bark thickness • Tree crown length scorched • Tree crown volume scorched

Module	0Startup.bpw output variable selection	Other output variables
IGNITE	• Probability of ignition from a fire-brand	• Probability of ignition from light-ning
RH	• Relative humidity	• Dew point temperature

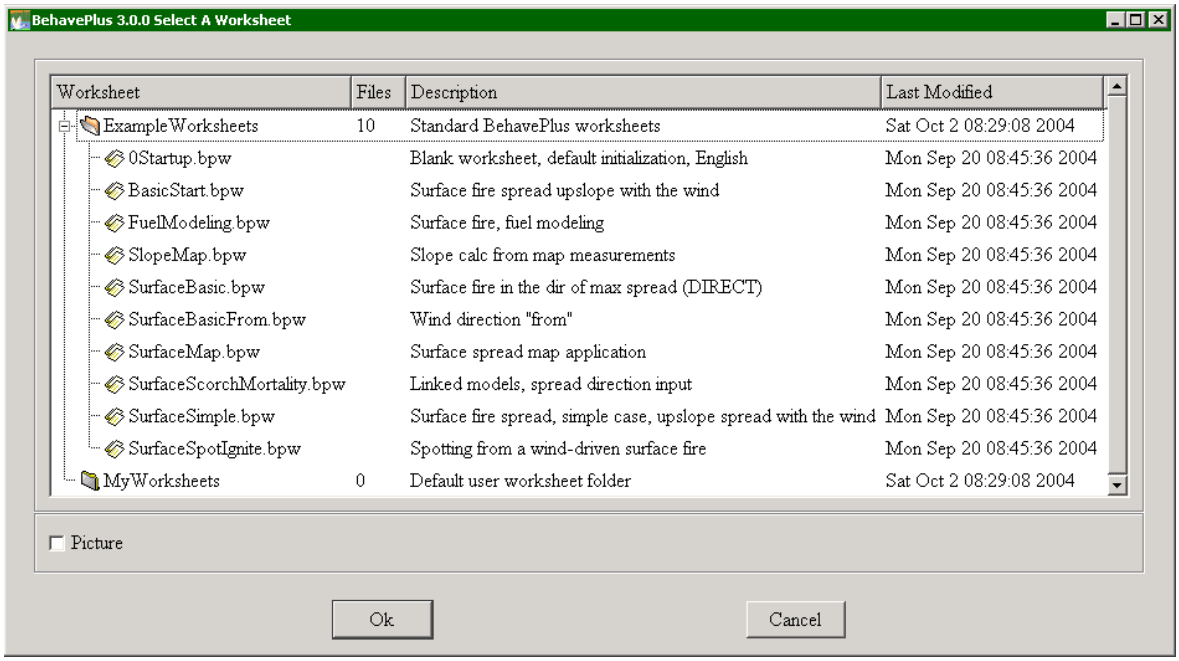
Menu item	0Startup.bpw selection	Other options
View	100%	50, 67, 75, 83, 117, 133, 150, 167, 200%
Configure > Module selection	None	SURFACE, SAFETY, SIZE,CON-TAIN, SPOT, SCORCH, MORTAL-ITY, IGNITE, RH
	Display output distances in map units. Off	On
Configure > Units	English	Metric Custom
Configure > Language	English (US)	Portuguese (Portugal)
Configure > Fuel model set selec-tion	None	No other options. Fuel model set selection must be done every time a Worksheet or Run is loaded
Configure > Moisture scenario set selection	None	No other options. Moisture scenario set selection must be done every time a Work-sheet or Run is loaded

Configure > Appearance Tab	Option	0Startup.bpw selection	Other options
Application	Show help pane	On	Off
	Show picture pane	On	Off
	Border color	Black	Other colors
	Border width	1	0 = no border 2-9= thicker border
Graph size	Graph size	50%	25-100%
	Graph title	Short	Long
	X axis origin	Zero	Min value
	Y axis origin	Zero	Min value
Graph elements	Background	White	Other colors
	Rainbow colors	3	4-18
	Bar color	Red	Other colors
	Curve points	20	4-100
	Curve color	Rainbow colors	Single color
	Curve width	3	0-9
	Axis color	Black	Other colors
	Axis width	1	2-9
	Gridline color	Yellow	Other colors
	Gridline width	1	0=no gridlines 2-9=thicker gridlines
Page tabs	Display page tab	Off	On
	Tabs per page	4	0 = no tabs 1-10
	Tab position	1	0=no tabs 1- #tabs per page
	Tab text	Blank	User defined
	Tab text color	Black	Other color
	Tab font size	12	8-24
Tables	Shade alternate table rows	On	Off
	Shade	Light grey	Other colors

Configure > Appearance Tab	Option	0Startup.bpw selection	Other options
Worksheet	Fire projection documentation	Off	On
	Training documentation	Off	On
	Show input codes for all discrete variables	Off	On
	Show output variables to be calculated	On	Off
	Show notes section	On	Off
	Notes lines	4	1-10

Appendix E: Example Worksheets

BehavePlus allows the user to define and save a worksheet for later use. A set of Example Worksheets is provided with the program. Those worksheets are described in this appendix. A worksheet is selected through **File > New**. Clicking on the ⊞ by the Example Worksheets folder displays the following list. A double click on the selection or a single click and **Ok** loads the worksheet.



It is important to recognize that these are only examples. We expect that users will set up their own folder of commonly used worksheets.

0Startup.bpw

This worksheet is a special case. It is used as the starting place for selecting calculation modules. It shows no input or output variables, but it sets defaults for all run settings as described in Appendix D. The 0Startup.bpw worksheet was used to initialize all of the following example worksheets.

BasicStart.bpw

This is the Worksheet that appears when you start BehavePlus. It is designed so the user can quickly do a simple run without having to load a Worksheet or configure one.

- Calculations are for maximum spread rate, upslope spread with the wind.
- Fuel moisture is entered by individual size class.

SurfaceSimple.bpw

This worksheet is the ultimate simplification of the setup for a surface fire spread and intensity calculation. It can be used to examine relationships among the basic variables (fuel, moisture, wind, and slope) on surface fire spread. For specific fire behavior prediction, more information would be used.

- Fuel moisture is entered as dead and live category. A single value is used for 1-h, 10-h, and 100-h moisture content and another for live herbaceous and live woody fuel moisture.
- Calculations are for maximum spread rate, upslope spread with the wind.

SurfaceBasic.bpw

This worksheet is similar to the DIRECT module in the old BEHAVE. This method of specifying directions is used to show the relative effects of wind and slope by vectoring. Reference is to upslope, so there is no need to define aspect or reference directions with respect to north.

- A fuel moisture value is required for each size class.
- Calculations are only for the direction of maximum spread
- Wind and spread directions are specified as degrees clockwise from upslope
- Wind direction is specified as the direction the wind is pushing the fire

SurfaceBasicFrom.bpw

This worksheet is like SurfaceBasic.bpw except the other option for specifying directions is selected. This method of specifying directions is suited for onsite calculations for a specific location on the landscape. The wind direction is that used in weather forecasts.

- A fuel moisture value is required for each size class.
- Calculations are only for the direction of maximum spread.
- Wind and spread directions are specified as degrees clockwise from north.
- Wind direction is the direction from which the wind is blowing.

FuelModeling.bpw

This is the SURFACE module set up to examine the effect of changing fuel parameters, part of the process of developing a custom fuel model.

- Fuel is entered as fuel parameter.
- Fuel moisture is entered as moisture scenario.
- Wind is blowing upslope.
- Calculations are only for the direction of maximum spread.
- Only rate of spread (maximum) and flame length are selected as output.

SurfaceMap.bpw

This worksheet might be used when using maps in projecting fire growth.

- The header includes those for 'fire projection documentation'.
- Output distances are displayed as map units.
- Calculations are only for the direction of maximum spread.
- Wind and spread directions are degrees clockwise from north.
- Wind direction is the direction from which the wind is blowing.
- Direction of maximum spread and spread distance are selected as additional output variables.
- Slope steepness is calculated from map measurements.

SlopeMap.bpw

This simple worksheet is used to calculate slope steepness from map measurements. It is available from the SURFACE module.

- Slope steepness is specified to be calculated from map measurements.
- Only the slope output variables are selected.

SurfaceScorchMortality.bpw

This worksheet enables the three modules SURFACE, SCORCH, and MORTALITY.

- Calculations are for specified spread directions (rather than for the direction of maximum spread).
- Wind and spread directions are degrees clockwise from upslope.
- Wind direction is the direction the wind is pushing the fire.

SurfaceSpotIgnite.bpw

This worksheet enables the three modules; SURFACE, SPOT, and IGNITE

- Spotting distance is calculated from a wind-driven surface fire, which is the only spotting distance output option that makes sense for a link to SURFACE.
- Wind is entered as 20-ft wind speed and wind adjustment factor (rather than as midflame wind speed).
- Wind direction is upslope.
- Calculations are only for the direction of maximum spread (the only option that is valid for this spotting option).

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RMRS
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