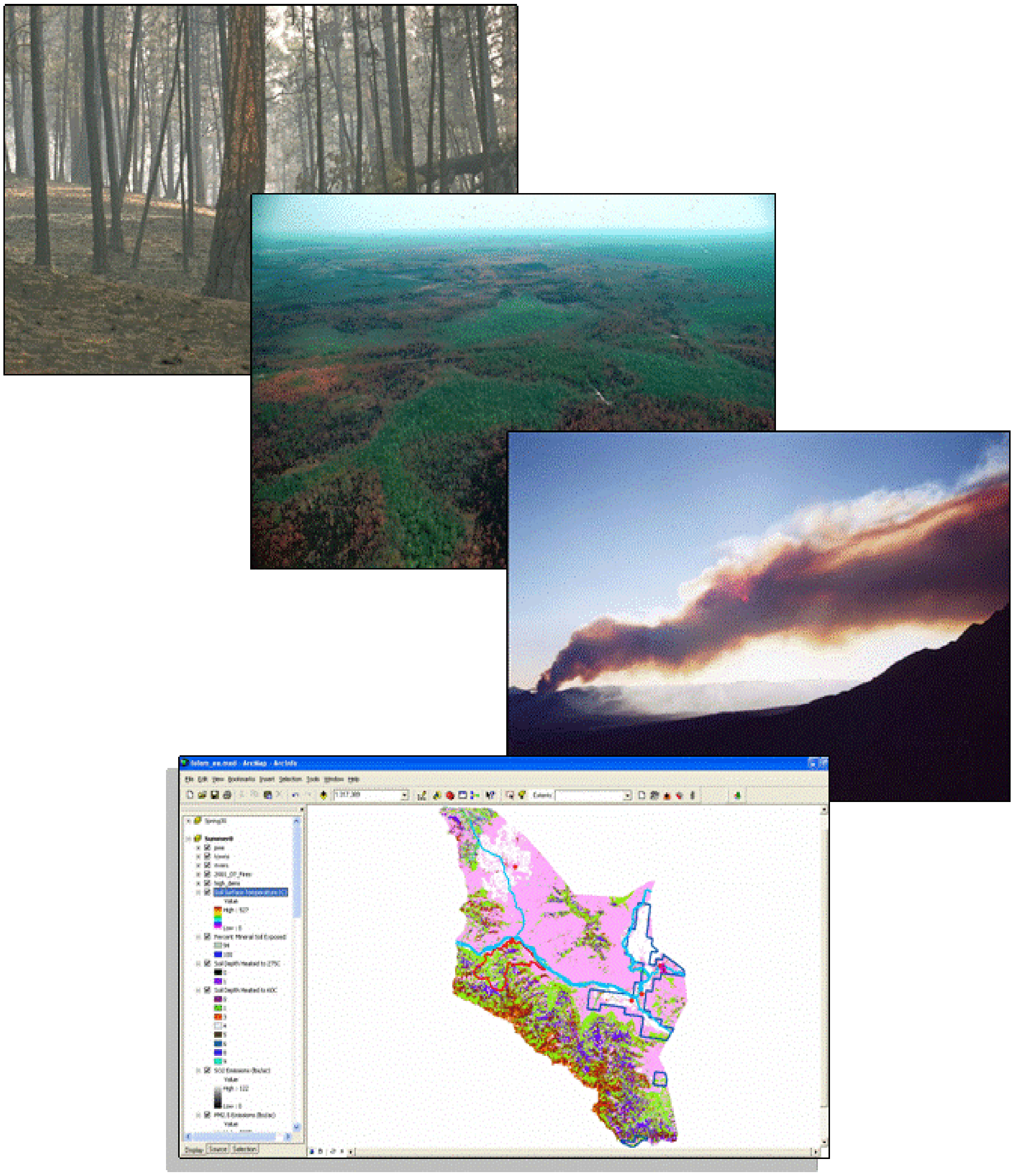

Wildland Fire Assessment Tool User's Guide

Version 2.0.0

April 4, 2011

National Interagency Fuels, Fire, and
Vegetation Technology Transfer Team

Preface

The Wildland Fire Assessment Tool (WFAT) is a custom ArcMap toolbar that provides an interface between ArcGIS desktop software, FlamMap3 algorithms (Finney 2006) and First Order Fire Effects Model (FOFEM) algorithms (Reinhardt 2003) to produce predicted fire behavior and fire effects map layers. WFAT is the successor to FBAT (Hamilton and others 2007) and FOFEMMT (Hamilton and others 2009) and incorporates the functionality of both tools into one convenient software application. It also provides a landscape file (.lcp) generator and an import tool to convert FARSITE and FlamMap ASCII Grids into ESRI Grid format for use on the ArcGIS platform. These outputs can be used to create additional predicted fire effects map layers.

The primary objectives behind the creation of WFAT were to develop a tool that would assist managers in prioritizing fuel treatments on the basis of predicted fire behavior and effects and in assessing the effectiveness of fuel treatment proposals *in a geospatial context*. Development of WFAT on the ArcGIS platform allows easy integration of other spatial data (such as land ownership, areas of special concern, and digital imagery) into wildland fire analysis. WFAT uses spatial data that are in the ESRI Grid format and saves all outputs to this format as well. Consequently, there is no need to convert files back and forth between ASCII Grid and ESRI Grid formats as with other fire modeling systems. WFAT can also be used to support the fire analysis and to calibrate fuel input layers for more complex applications, such as those available in FARSITE (Finney 2006).

In essence, WFAT is a planning tool that can be used to help:

- Define and identify the location of hazardous fuel
- Prioritize, design, and evaluate fuel treatment projects
- Develop burn plans for prescribed fire
- Predict fire behavior and effects for summary in planning and monitoring documents
- Calibrate fuel data layers based upon observed fire behavior

Future versions of WFAT may incorporate additional features, so be sure to check the NIFTT website (www.niftt.gov) for possible tool updates and enhancements as well as for associated updates to this user's guide. Any questions on WFAT can be directed to helpdesk@niftt.gov.

Prerequisites

WFAT serves as an interface between ArcMap, FOFEM, and FlamMap, and imports FARSITE and FlamMap output files, so users should be familiar with all relevant software. More importantly, users should have a good understanding of fire behavior and effects, including knowledge about fuel (specifically fire effects fuel models and fire behavior fuel models), weather, topography and wildland fire situations. Users should also understand the relationships between disturbance, vegetation attributes and fuel characteristics. This understanding should be accompanied by an ability to use non-spatial fire behavior and effects prediction systems such as BehavePlus, NEXUS, and FOFEM. WFAT users should be capable of using fire behavior and effects programs to directly analyze the effects of various input changes on outputs. In addition, because of its complexity, only those with the proper fire behavior and effects training and experience should use WFAT whenever the outputs are to be used in fire and land management decisions.

WFAT requires ArcGIS 9.2, 9.3, or 9.3.1 and the necessary computer hardware for operation. Specific computer requirements are described in detail in Chapter 1 of this guide.

Obtaining copies

To obtain additional copies of this WFAT User's Guide or to obtain the WFAT Tutorial, follow these steps:

1. Go to www.niftt.gov
2. Click on **Tools and User Documents** .
3. Select the material you wish to download (User's Guide or Tutorial).

Obtain the latest version of WFAT, as follows:

1. Go to www.niftt.gov
2. Click on **Tools and User Documents**.
3. Select the software you wish to download.

Credits

WFAT was developed for the National Interagency Fuels, Fire, and Vegetation Technology Transfer (NIFTT) by Jody Bramel, Marc Dousset, and Chris Finlayson of Axiom IT Solutions and Dale Hamilton (NIFTT) of Systems for Environmental Management (SEM), Missoula, Montana. Technical guidance was provided by Mark Finney, Wendel Hann, Don Helmbrecht, Jeff Jones, Bob Keane, Laurie Kurth, Duncan Lutes, and Elizabeth Reinhardt of the USDA Forest Service.

Support for the development of WFAT was provided by the National Interagency Fuel Coordination Group through NIFTT. Funding was provided by the USDA Forest Service and the U.S. Department of the Interior.

The Wildland Fire Assessment Tool User's Guide was written by Deb Tirmenstein and Jennifer Long of SEM, borrowing select material from the FBAT User's Guide (Jones and Tirmenstein 2008) and the FOFEMMT User's Guide (Helmbrecht and Tirmenstein 2009).

Your input

We value your input. Please forward any questions, comments, reports of bugs, or ideas to the National Interagency Fuels, Fire, and Vegetation Technology Transfer (NIFTT) at helpdesk@niftt.gov.

Table of Contents

Chapter 1: About the Wildland Fire Assessment Tool User's Guide

1.1 Before you begin

This user's guide describes the basic operation of the Wildland Fire Assessment Tool (WFAT). Because it is assumed that WFAT users have experience operating and understanding ArcMap, FOFEM, and FlamMap applications (as well as ArcGIS and Microsoft Windows in general), this user's guide will not repeat specific instructions for using any of this software. Instead, users are encouraged to refer to the help functions available with these programs should any questions arise.

1.2 How to use this guide

You need not read the entire guide to understand WFAT functionality and subject matter or to carry out a specific task. Once you are familiar with the basic concepts associated with WFAT, you can quickly locate commonly performed tasks by reviewing the headings in the Table of Contents located near the beginning of this guide and then refer to the specific section pertaining to your needs. Wherever appropriate, screen captures are used to illustrate the steps required to complete a task.

The WFAT User's Guide is not intended to provide step-by-step guidance on the tool's operation using specific examples; rather, it is intended to serve as a reference guide. The WFAT tutorial, available at www.niftt.gov, provides step-by-step instructions using specific examples.

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1.3 Computer requirements

Ensure the following programs are installed and functioning properly on your computer:

- ArcGIS 9.2, 9.3, or 9.3.1

- Spatial Analyst extension of ArcGIS
- Microsoft Access (2000 or higher)

Although system requirements to run ArcGIS 9.2, 9.3., or 9.3.1 will suffice to run WFAT, at least 10 GB of free hard drive space and 2 GB of RAM are recommended. Generally, faster processors, more memory, and increased free hard drive space will improve performance. In addition, NIFTT tools were developed for Windows Operating Systems.

We recommend that you uninstall any earlier versions of WFAT before running the most current version of the tool. It is not necessary to uninstall, FBAT and FOFEMMT before running WFAT, but since WFAT replaces these programs, both FBAT and FOFEMMT can be removed.

> ***Note****: Make sure that you have sufficient space and adequate permissions for storing WFAT outputs on your computer.*

> ***Note****: Make sure that the WFAT version you are using correctly matches the version of ArcGIS on your computer. Use WFAT version 2.0.0 only with ArcGIS 9.2, 9.3, and 9.3.1.*

Chapter 2: Wildland Fire Assessment Tool Function

2.1 What does the Wildland Fire Assessment Tool do?

WFAT produces predicted spatial fire effects and fire behavior data to support land management planning, including potential fire behavior map layers, such as flame length and rate of spread, and fire effects layers, such as fuel consumption, smoke emissions, soil heating and tree mortality. WFAT helps answer the question "Where on a landscape are fire behavior and effects likely to be most problematic in regards to specific land management objectives?"

Specifically, WFAT allows you to design, prioritize, and evaluate fuel treatment prescriptions and burn plans under given weather conditions and fuel moisture scenarios. It answers the question, "Under what fuel moisture and weather conditions will a burn result in desired fire effects or controllable fire behavior?" After a fuel treatment prescription is developed, WFAT can also be used to address the question "Will the fuel treatment prescriptions actually result in the desired fire effects and/or fire behavior characteristics?"

In addition, the tool's map layers serve as visual data for inclusion into planning and monitoring documents. Maps often present a clearer picture of fire effects across a landscape than do summary tables or text.

Lastly, one of the most powerful applications of WFAT is that the fire behavior outputs can be used to calibrate fuel input layers used in FARSITE, FlamMap, and WFAT. Fuel layers are commonly developed using vegetation characteristics as correlates; however, vegetation attributes alone can be poor predictors of the fuel complex. WFAT outputs may suggest that a certain fire behavior characteristic is difficult to simulate on a given landscape even though that characteristic has frequently been observed during actual fire events, indicating problems with one or more of the fuel input layers. For example, the lack of simulated passive crown fire may indicate a problem with the fire behavior fuel model, canopy base height, and/or canopy cover layers. Fuel layers can then be refined or calibrated until the expected fire behavior is simulated by WFAT.

2.2 How does the Wildland Fire Assessment Tool work?

WFAT incorporates three main processing steps where FOFEM and FlamMap are run as background models. First, WFAT builds the landscape (.lcp) file required to run FlamMap or utilizes an existing user-specified .lcp file. Next, WFAT runs FlamMap to condition fuel moistures – if the user has opted to do so – and to predict potential crown fire activity and scorch height. Lastly, WFAT runs FOFEM and FlamMap for each unique combination of inputs to predict potential fire behavior characteristics and potential first order fire effects. All WFAT outputs are in ESRI Grid format.

FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics (flame length, rate of spread, fire type or crown fire activity (CFA), and fireline intensity) at a pixel level (see Appendix B). We chose to link ArcMap with FlamMap because FlamMap predicts fire behavior characteristics across an entire assessment area, whereas FARSITE estimates fire behavior characteristics for only those areas within the simulated fire perimeter. WFAT uses an ArcGRID format and consequently there is no longer any need to convert files back and forth between ASCII and ArcGRID formats as required by FlamMap.

In addition, components of FlamMap were integrated into WFAT to more accurately estimate certain fire effects that are dependent on fire behavior calculations. While many fire effects are determined largely by the flaming and smoldering consumption of duff and coarse woody debris (CWD), other fire effects, such as canopy consumption and tree mortality, are better estimated using fire behavior characteristics such as crown fire activity and scorch height, which are calculated by FlamMap. FlamMap also calculates fuel moisture, which greatly influences both fire behavior and fire effects by affecting the amount of oxygen available for combustion and heat flux, and by determining the duration of flaming and smoldering combustion.

FOFEM is a non-spatial fire effects analysis program that computes potential first order fire effects (fuel consumption, smoke emissions, soil heating, and tree mortality). WFAT enhances non-spatial FOFEM by modeling and portraying fire effects outputs spatially and by simplifying the analysis of heterogeneous landscapes or multiple planning units through spatial analysis.

Chapter 3: Input Data

3.1 Input data overview

Prediction of potential fire behavior and effects requires input on site-specific fuel characteristics and topography, as well as information relating to the fuel moisture and fire weather scenario of interest. In WFAT, input data are split into three categories – spatial data, model inputs, and coarse woody debris (CWD) profile. Each category is represented as a tab on the user interface. Fuel and topographic information is provided by spatial data layers specified on the **Spatial Layers** tab. Environmental factors that describe fuel moisture and fire weather scenarios are required by the background models (FOFEM and FlamMap) and are specified on the **Model Inputs** tab. Information about the coarse woody debris profile (down woody fuel greater than or equal to 3 inches (7.6 cm) in diameter) is specified on the **CWD Profile** tab.

3.2 Spatial input layers

WFAT uses ten spatial input layers that characterize topography and fuel for a single spatial extent (table 3-1), (fig. 3-1). WFAT calculates most potential fire behavior and effects predictions using a landscape (.lcp) file. This .lcp file is built from some of the user-specified input layers plus additional fuel layers (duff and coarse woody grids) that are derived from the fire effects fuel model layer. WFAT can also be executed using an existing user-specified .lcp file. Fire effects relating to tree mortality are predicted using the .lcp file plus the tree list layer (see section 3.2.10 for additional information on this subject).

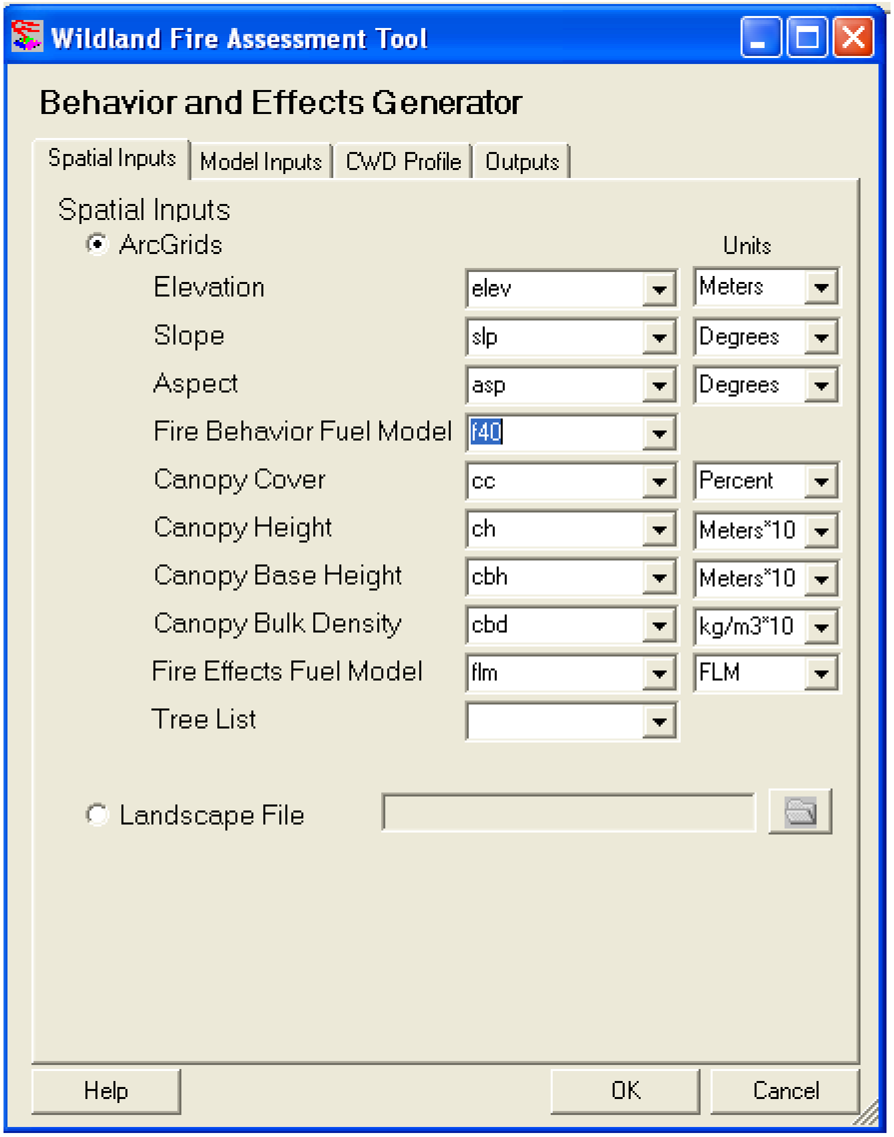


Figure 3-1. Spatial Inputs tab showing inputs for running WFAT.

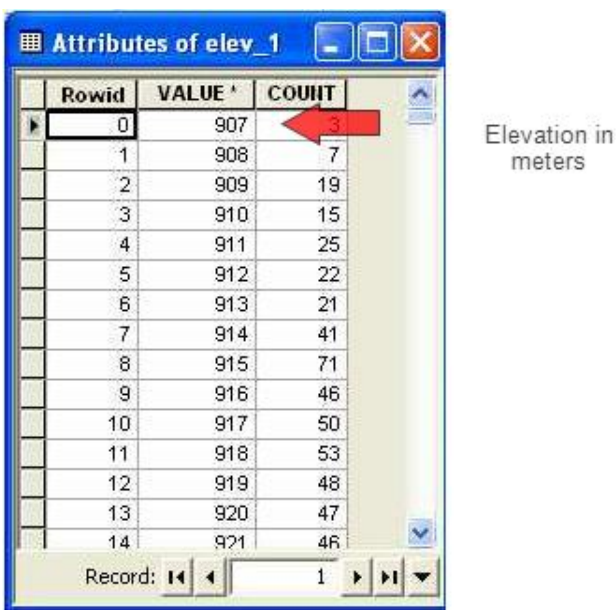
In order to successfully build an .lcp file, WFAT uses the same input theme requirements as FlamMap and FARSITE. Specifically, the input layers must have identical coordinate systems, spatial extents, cell resolutions, and cell alignments. In addition, the map layers must be in ESRI grid format and the units associated with each layer must correspond to those shown in table 3-1.

Table 3-1. Input grids.

Description	Default Units	Alternate Units
Elevation	Meters	Feet
Slope	Degrees	Percent
Aspect	Degrees	Class (1-25)
Fire Behavior Fuel Model	Anderson (1982), Scott and Burgan (2005)	none
Canopy Cover	Percent	Class (0-4)
Canopy Height	Meters*10	Meters, Feet, Feet*10
Canopy Base Height	Meters*10	Meters, Feet, Feet*10
Canopy Bulk Density	kg/m^3*100	Kg/m^3, lb/ft^3, lb/ft^3*1000
Fire Effects Fuel Model	Fuel Loading Model (FLM)	Fuel Characteristic Classification System (FCCS), Custom
Tree List	FOFEM format	

3.2.1 Elevation

The elevation layer represents meters or feet (table 3-1) above sea level, and zero values are used for those areas that are at or below sea level. Figure 3-2 shows the value attribute table of an elevation layer. WFAT uses the elevation layer to adjust fuel moistures using adiabatic lapse rates if the user opts to condition fuel moistures. The elevation layer is also used for conversion of fire spread between horizontal and slope distances.

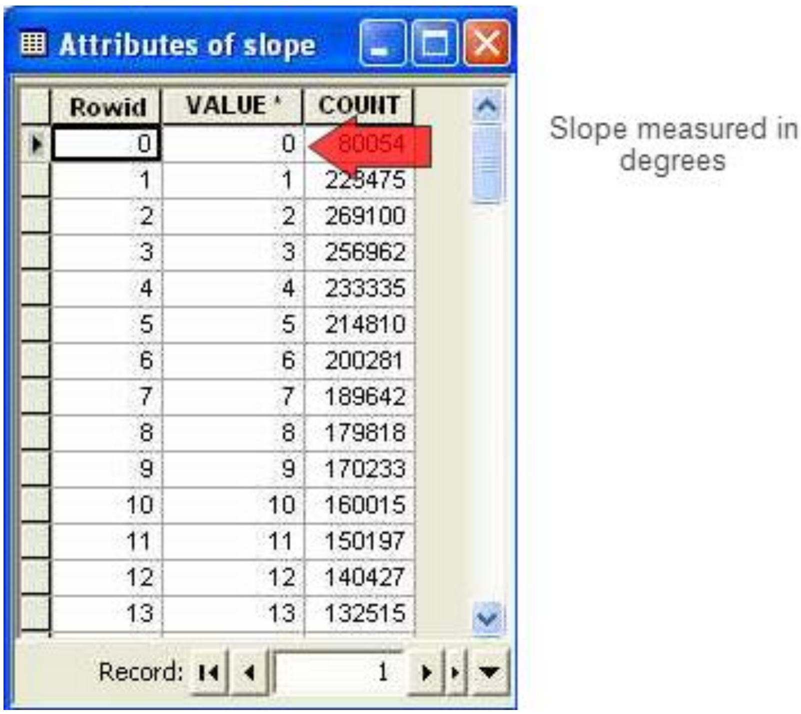


Rowid	VALUE	COUNT
0	907	3
1	908	7
2	909	19
3	910	15
4	911	25
5	912	22
6	913	21
7	914	41
8	915	71
9	916	46
10	917	50
11	918	53
12	919	48
13	920	47
14	921	46

Figure 3-2. Example value attribute table of an elevation layer. The **Value** field must depict elevation in meters or feet above sea level.

3.2.2 Slope

WFAT uses the slope layer for computing slope effects on flame length, fire spread – and if fuel moisture conditioning is used – solar radiance. The slope layer can have cell values represented by either floating point numbers (decimals) or integers, and the units may be expressed in either degrees or percent (table 3-1). Figure 3-3 displays the value attribute table of a slope layer.



Rowid	VALUE *	COUNT
0	0	80054
1	1	223475
2	2	269100
3	3	256962
4	4	233335
5	5	214810
6	6	200281
7	7	189642
8	8	179818
9	9	170233
10	10	160015
11	11	150197
12	12	140427
13	13	132515

Figure 3-3. Example value attribute table of a slope layer. The **Value** field must show slope in degrees or percent.

3.2.3 Aspect

The aspect layer determines the effect of slope orientation on fuel moisture with respect to solar radiance when fuel moisture conditioning is used. WFAT's aspect layer must denote slope azimuth in degrees clockwise from the north (table 3-1) or classes 1-25 if the input grid is derived from an older version GRASS ASCII file. Cell values can be represented by either floating point numbers (decimals) or integers. Flat areas which lack an aspect are identified by a value of -1 in degree units or 25 if in class units. Figure 3-4 displays the value attribute table of an aspect layer.

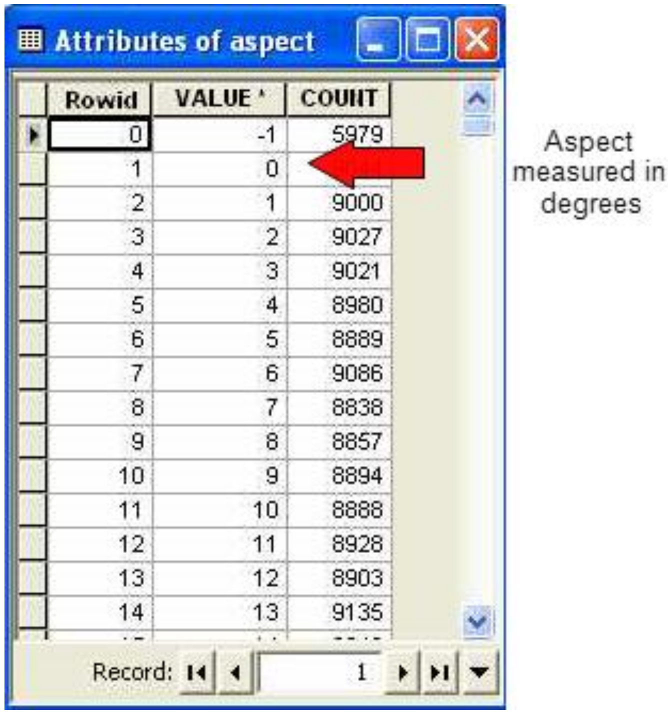
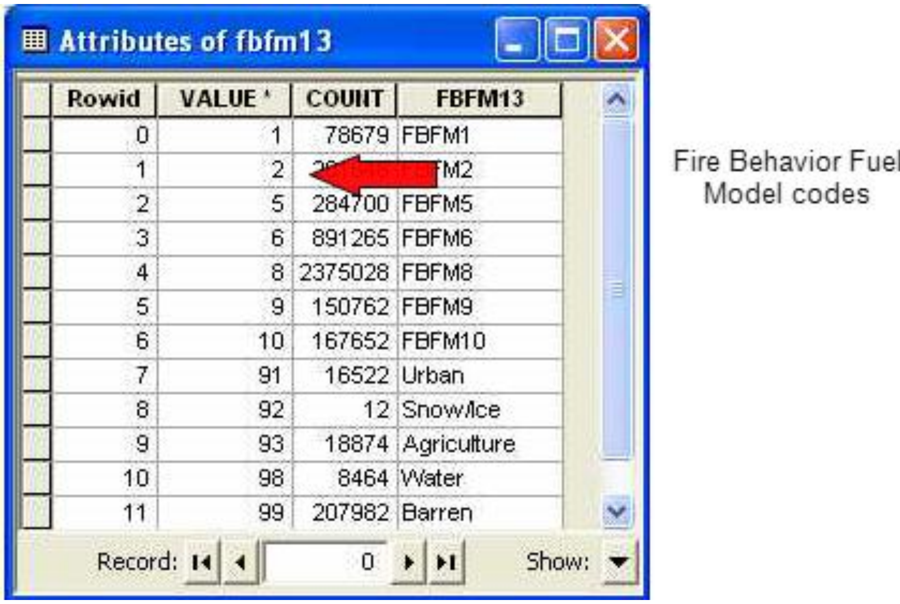


Figure 3-4. Example value attribute table of an aspect layer. The **Value** field must depict aspect in degrees or classes. (A value of -1 denotes flat areas that have no aspect if the units are degrees.)

3.2.4 Fire Behavior Fuel Model

Fire behavior fuel models represent distinct distributions of fuel loading found among surface fuel components (live and dead), size classes, and fuel types. The fuel models are described by the most common fire-carrying fuel type, loading and surface area-to-volume ratio by size class and component, fuelbed depth, and moisture of extinction. WFAT uses the fire behavior fuel model layer to predict potential fire behavior that influences fire effects (crown fire activity and scorch height) as well as to initialize the fuel moisture values of the fine woody debris (less than 3 inches (7.6 cm) in diameter) for fuel moisture conditioning.

WFAT can use either the 13 fire behavior fuel models characterized by Anderson (1982) or the 40 characterized by Scott and Burgan (2005) (table 3-1). However, WFAT cannot use a fuel layer containing custom fuel models. Cells must contain integers denoting the numeric codes of Anderson's (1982) models (values: 1 to 13) or the Scott and Burgan (2005) models (values: 91 to 204) (see fig. 3-5). Non-burnable fuel must be denoted by values 91, 92, 93, 98, and 99, which characterize urban/developed, snow/ice, agriculture, water, and bare ground, respectively. Additional attributes (such as a text descriptor of the model) are commonly included in the fuel model layer.



Attributes of fbfm13

Rowid	VALUE *	COUNT	FBFM13
0	1	78679	FBFM1
1	2	[illegible]	[illegible]M2
2	5	284700	FBFM5
3	6	891265	FBFM6
4	8	2375028	FBFM8
5	9	150762	FBFM9
6	10	167652	FBFM10
7	91	16522	Urban
8	92	12	Snow/Ice
9	93	18874	Agriculture
10	98	8464	Water
11	99	207982	Barren

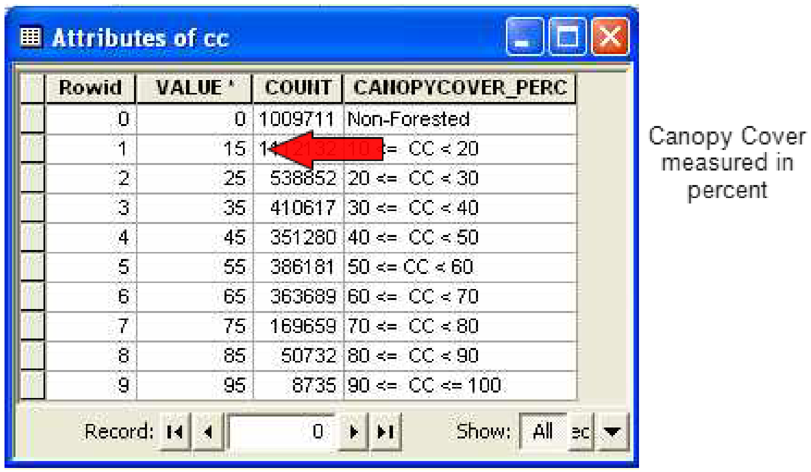
Figure 3-5. Example value attribute table for a fire behavior fuel model (FBFM) layer (Anderson 1982). The **Value** field must correspond to the numeric fire behavior fuel model codes of Anderson (1982) or Scott and Burgan (2005).

3.2.5 Canopy Cover

Canopy cover as used by LANDFIRE is a forested stand attribute that corresponds to the vertical projection of the forest canopy to the ground. The canopy cover layer is used to compute the wind reduction factor attributable to the canopy and the subsequent wind speed at the midflame height. The canopy cover layer is also used to modify solar radiance when fuel moisture conditioning is used. WFAT requires that the canopy cover layer be expressed in percent (0 – 100) (table 3-1) or in classes (0 – 4) (table 3-1). WFAT assumes the classes represent the following ranges:

0: 0%
1: 1-20%
2: 21-50%
3: 51-80%
4: 81-100%

A cell value of 0 in this layer indicates that the pixel is non-forested. The cell values can be denoted by either floating point numbers (decimals) or integers. Figure 3-6 shows the value attribute table of a canopy cover layer.



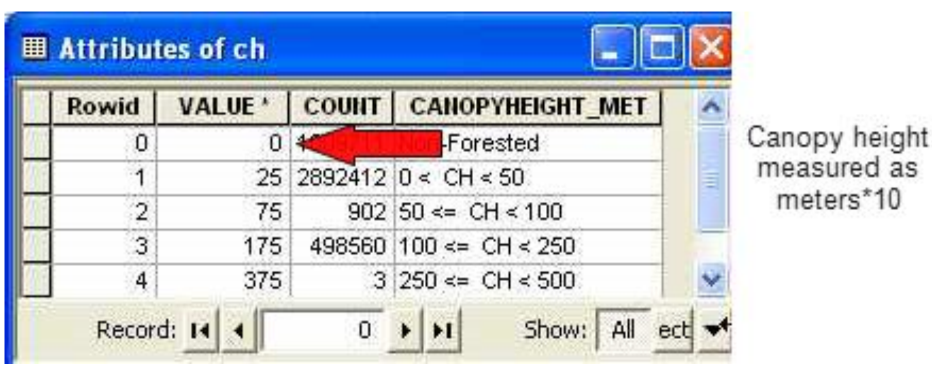
Attributes of cc

Rowid	VALUE *	COUNT	CANOPYCOVER_PERC
0	0	1009711	Non-Forested
1	15	1[illegible]	[illegible]= CC < 20
2	25	538852	20 <= CC < 30
3	35	410617	30 <= CC < 40
4	45	351280	40 <= CC < 50
5	55	386181	50 <= CC < 60
6	65	363689	60 <= CC < 70
7	75	169659	70 <= CC < 80
8	85	50732	80 <= CC < 90
9	95	8735	90 <= CC <= 100

Figure 3-6. Example value attribute table for a canopy cover layer. In this example, the **Value** field denotes canopy cover in percent and canopy cover has been grouped into ten classes in which the cell value corresponds to the class mid-point. Thus, a cell value of 15 represents a canopy cover class with values ranging from 10 to 20 percent. A value of 0 indicates a non-forested setting. This is the LANDFIRE standard.

3.2.6 Canopy Height

Canopy height is (in LANDFIRE data) a stand attribute that reflects the average height of the overstory dominant and co-dominant trees in a stand. The canopy height layer is used to compute the wind reduction factor attributable to the canopy and the subsequent wind speed at the midflame height. WFAT requires the canopy height layer units to be in meters*10 (fig. 3-7), meters, feet*10, or feet (table 3-1). A cell value of 0 in this layer indicates that the pixel is non-forested. The cell values can be denoted by either floating point numbers (decimals) or integers.



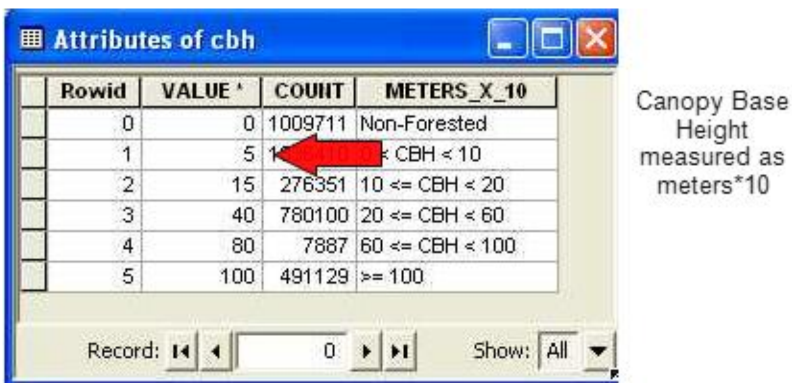
Attributes of ch

Rowid	VALUE *	COUNT	CANOPYHEIGHT_MET
0	0	4[illegible]	[illegible]-Forested
1	25	2892412	0 < CH < 50
2	75	902	50 <= CH < 100
3	175	498560	100 <= CH < 250
4	375	3	250 <= CH < 500

Figure 3-7. An example value attribute table for a canopy height layer. In this example, the units are in meters*10 and the canopy heights have been grouped into five classes in which the cell value corresponds to the mid-point of the class. This is the LANDFIRE standard.

3.2.7 Canopy Base Height

Canopy base height is a forested stand attribute that denotes the lowest height above the ground which has sufficient canopy or ladder fuel to propagate fire vertically. The canopy base height layer is necessary for determining the transition from a surface fire to a crown fire. Typically, lower canopy base heights increase the likelihood of torching or passive crown fire. WFAT requires the canopy base height layer units to be in meters*10 (fig. 3-8), meters, feet*10, or feet (table 3-1). A cell value of 0 in this layer characterizes a non-forested pixel. Cell values can be denoted by either floating point numbers (decimals) or integers.



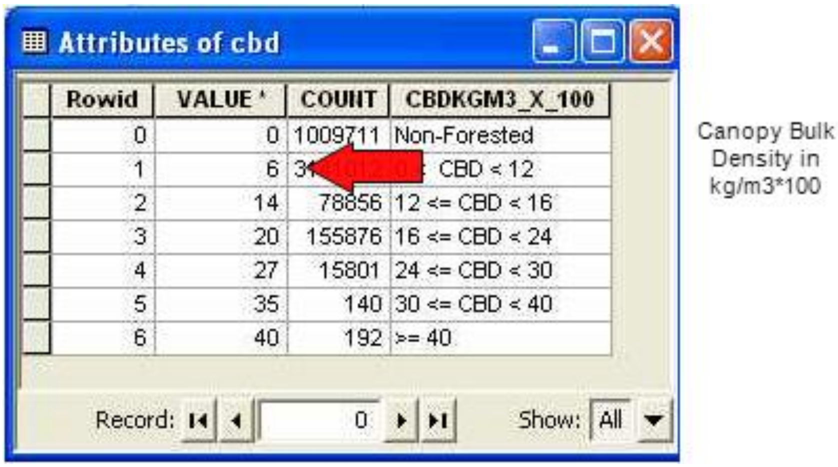
Attributes of cbh

Rowid	VALUE *	COUNT	METERS_X_10
0	0	1009711	Non-Forested
1	5	1[illegible]	[illegible] CBH < 10
2	15	276351	10 <= CBH < 20
3	40	780100	20 <= CBH < 60
4	80	7887	60 <= CBH < 100
5	100	491129	>= 100

Figure 3-8. Example value attribute table for a canopy base height layer. In this example, the **Value** field depicts heights expressed in meters*10. Thus, a cell value of 20 corresponds to a two-meter canopy base height. This is the LANDFIRE standard.

3.2.8 Canopy Bulk Density

Canopy bulk density is a stand attribute that refers to the weight (mass) of available canopy fuel, both dead and live, per unit volume of canopy. "Available" refers to fuel that is of a size and type that would be consumed in the flaming front.   WFAT uses canopy bulk density to determine the transition between passive and active crown fire. (See Scott and Reinhardt [2001] for a discussion on the derivation of crown fire activity). WFAT requires the units of the canopy bulk density layer to be expressed in kg/m^3 *100 (fig. 3-9), kg/m^3, lb/ft^3*1,000, or lb/ft^3 (table 3-1). A cell value of 0 in this layer indicates that the pixel is non-forested. Cell values can be represented by floating point numbers (decimals) or integers.



Rowid	VALUE *	COUNT	CBDKGM3_X_100
0	0	1009711	Non-Forested
1	6	3[illegible]	[illegible] CBD < 12
2	14	78856	12 <= CBD < 16
3	20	155876	16 <= CBD < 24
4	27	15801	24 <= CBD < 30
5	35	140	30 <= CBD < 40
6	40	192	>= 40

Figure 3-9. Example value attribute table for a canopy bulk density layer. In this example, the **Value** field depicts canopy bulk density in kg/m^3 *100. Thus a cell value of 20 corresponds to a 0.2 kgm^3 canopy bulk density. A value of 0 identifies a non-forested area.

3.2.9 Fire Effects Fuel Model

Fire effects fuel models (FEFM) represent categories of on-site fuel loading characteristics necessary to predict fire effects. Fire effects fuel models representing forested stands are described by eight surface fuel loading values: litter, duff, 1-hour, 10-hour, 100-hour, 1000-hr, shrub, and herbaceous. Non-forested model are described by total fuel loading.

WFAT accepts two standard FEFM characterizations mapped by the LANDFIRE Program: Fuel Loading Models (FLM) (Lutes and others 2008) and Fuel Characteristics Classification System (FCCS) (Ottmar and others 2007) fuelbeds – as well as a custom FEFM layer (table 3-1). See Section 3.5 for a discussion on the custom FEFM layer.

Figure 3-10 shows the value attribute table of an example FLM layer. These values correspond to a table of surface fuel loadings, which is determined by selecting the units for FEFM. By default, the units for this grid are FLM so remember to change them if selecting an FCCS or custom grid.

Fuel loading model code

Attributes of flm

Rowid	VALUE *	COUNT	FLM_DESC
0	11	52650	Light FWD, light to no duff
1	12	4446	Moderate FWD, light litter
2	13	39135	Moderate FWD, light to moderate litter, light duff
3	14	1648	Shrub_Sagebrush with low total load
4	15	32890	Shrub_Non-sagebrush with low total load
5	21	13504	Light logs, light duff
6	31	4859	Moderate litter, light duff, light logs
7	41	11569	Moderate FWD, light to moderate litter
8	63	194	Moderate duff, light to heavy logs, light litter
9	64	227067	Moderate to heavy duff, light to heavy logs
10	71	11113	Moderate to heavy logs, light duff
11	82	279	Moderate duff, light to heavy logs, moderate litter
12	83	8835	Heavy to very heavy logs, moderate duff
13	911	819	Open Water
14	920	98	Developed-General
15	931	386	Barren/Rock/Sand/Clay
16	980	17076	Agriculture-General

Record: 1 Show: All Selected Records

Figure 3-10. Example value attribute table of a fuel loading model (FLM) layer. The **Value** field corresponds to fuel loading model codes (Lutes and others 2008).

3.2.10 Tree List for Mortality

Tree List grids necessary for estimating tree mortality, are currently unavailable. Hopefully these data will become available in the near future. Please contact the helpdesk@niftt.gov for a status update on the availability of tree list grids for the continental United States.

Each cell in the tree list layer corresponds to a tree species list which represents a stand of trees (fig. 3-11). A tree species list includes a list of tree species that occur in a stand with related density (trees/acre), DBH (in), height (ft), canopy base height (ft), and crown class (codominant, dominant, emergent, open grown, intermediate, or suppressed). WFAT uses the tree species list to compute all tree mortality related fire effects.

Attributes of tre...

Rowid	VALUE *	COUNT
0	-9999	92616397
1	11	5900611
2	12	632
3	21	242838
4	22	1269400
5	23	93107
6	24	282667
7	31	174141
8	32	28541
9	81	6445361
10	82	2679104
11	83	978
12	84	350
13	2000001	17681
14	2000005	18267
15	2000036	37630
16	2000042	47885
17	2000100	218645
18	2000102	1054
19	2000104	89460
20	2000106	15333
21	2000168	16450

Record: 1

Figure 3-11. Example value attribute table of a tree list layer.

An example tree species list table is shown below.

Table 3-4. Example tree species list.

LFTL_Treelist CrownClass

Treelist_Tag	Tree_Numb	Species_ID	Density	DBH	HT	HBC	CC
1000323	16982	PSEMEN	4	5.6	39	3.9	D
1000323	16983	PSEMEN	4	3.7	25	2.5	D
1000323	16984	PSEMEN	4	6.2	43	4.3	D
1000323	16985	PSEMEN	4	3.6	24	2.4	C
1000323	16986	TSUHET	4	3.7	24	2.4	C
1000323	16987	TSUHET	4	4.7	27	2.7	D
1000323	16988	PSEMEN	4	5.8	35	3.5	D
1000323	16989	TSUHET	4	9	35	3.5	D
1000333	17958	ABIAMA	4	3.3	16	7.3	S
1000333	17959	ABIAMA	4	4.1	21	9.6	S
1000333	17960	ABIAMA	4	4.5	24	7.6	S
1000333	17961	TSUMER	4	4.1	15	6.6	S
1000333	17962	TSUMER	4	6.7	27	7.8	S

3.3 Model inputs

Input parameters that describe the fire environment, specify the crown fire calculation method, and determine consumption algorithms in WFAT background fire modeling systems – FlamMap and FOFEM – are specified on the **Model Inputs** tab (figure 3-12).

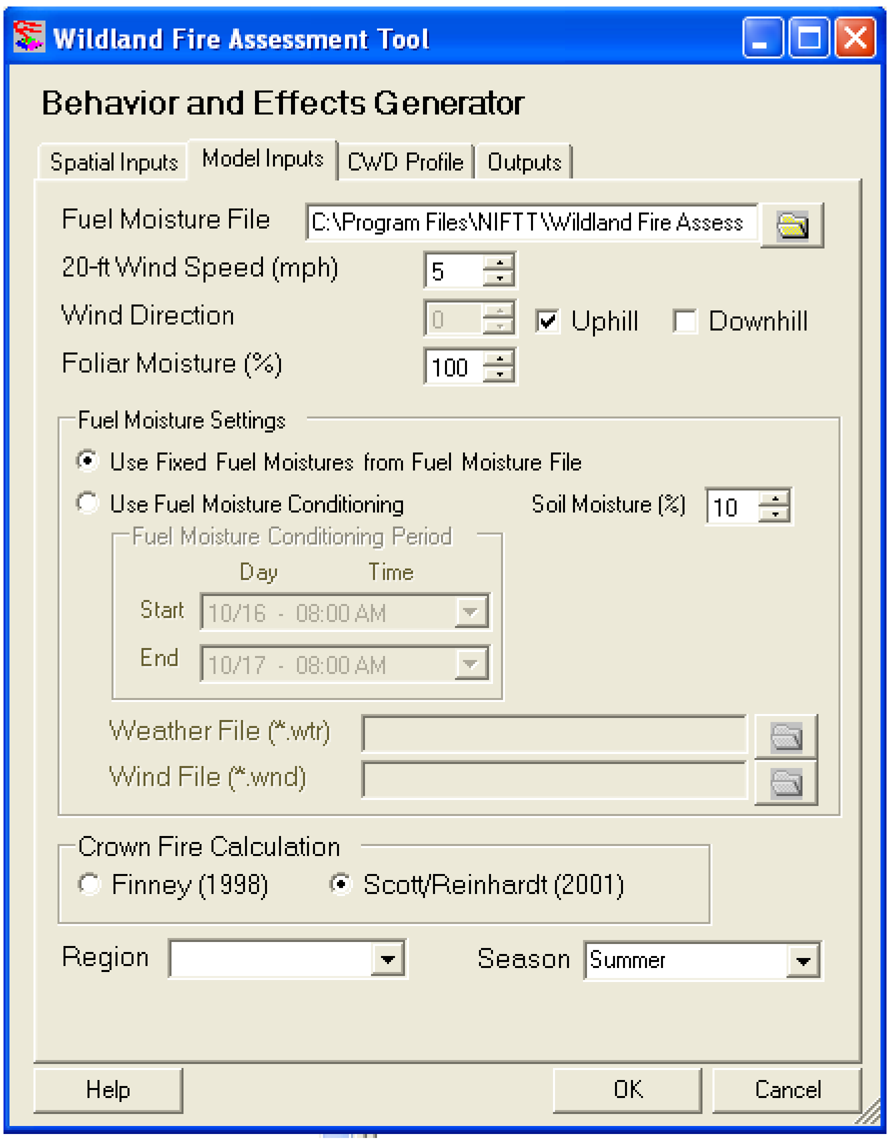


Figure 3-12. The **Behavior and Effects Generator** dialog box showing **Model Inputs** tab.

3.3.1 Fuel Moisture File

Like FlamMap, WFAT requires a text file (.fms) that specifies the initial fuel moisture values of the 1-hr, 10-hr, 100-hr, live herbaceous, and live woody fuel components for each of the fire behavior fuel models. The most important step in selecting appropriate fuel moisture values is to describe the type of fire weather and fuel moisture scenario to be simulated. For example, simulations designed for fire use or prescribed fire applications would likely have higher fuel moistures than those used for simulating rare event large wildfires in the extremes of the wildfire season. We recommend using data provided by the Weather Information Management System (WIMS) and FireFamily Plus to identify appropriate fuel moisture values for specific simulation scenarios.

The fuel moisture file used by WFAT is a space-delimited text file that has an .fms extension instead of a .txt extension. A column header is not included in the file; it is therefore very important that users understand the format. There are six columns in the .fms file that denote fire behavior fuel model, 1-hour dead fuel moisture (1-hr), 10-hour dead fuel moisture (10-hr), 100-hour dead fuel moisture (100-hr), live-herbaceous fuel moisture (LH), and live-woody fuel moisture (LW), respectively (see fig. 3-13). The values representing fire behavior fuel models (FBFM) correspond to the numeric codes used by Anderson (1982) or Scott and Burgan (2005). Fuel moisture values represent percent moisture and must be integers (in other words, no decimals). (See Appendix D for additional information on fuel moisture values).

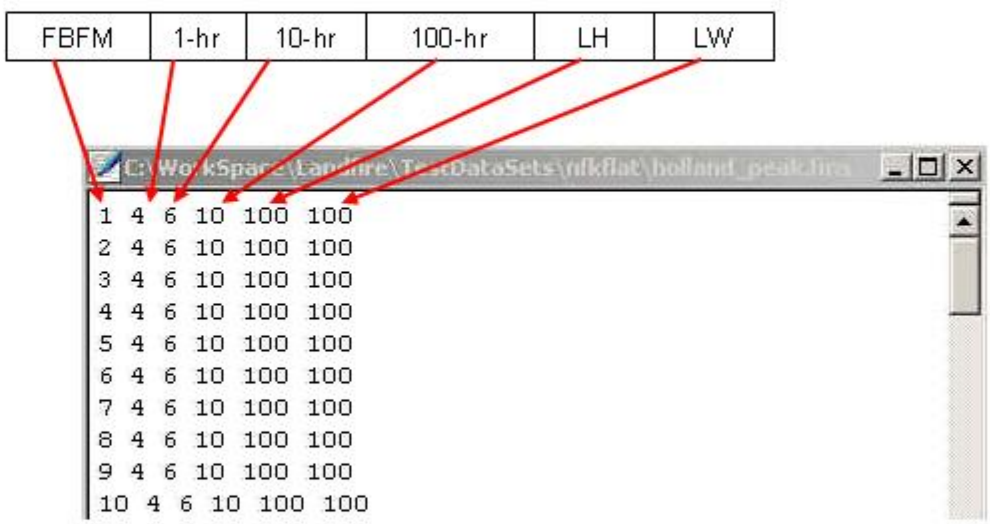


Figure 3-13. Example fuel moisture file that includes the first ten fuel models characterized by Anderson (1982). (FBFM = fire behavior fuel model; 1-hr = 1-hr fuel moisture; 10-hr = 10-hr fuel moisture; 100-hr = 100-hr fuel moisture; LH = live herbaceous fuel moisture; LW = live woody fuel moisture.)

3.3.2 20-ft Wind Speed (mph)

The 20-ft Wind Speed input refers to the speed of the wind that occurs 20 feet above the canopy of the dominant vegetation. Thus, in grasslands, the wind speed denotes winds at 20 ft (6.1m) above the grass, whereas in forests, the value represents winds 20 ft (6.1m) above the trees. Values must be integers that express wind speed in miles per hour. Using wind reduction factors, 20-ft wind speed is converted into midflame wind speed which helps predict scorch height.

3.3.3 Wind Direction

Three options are available for entering wind direction. WFAT users may specify that the wind is blowing uphill, downhill, or they may enter an azimuth in degrees indicating the direction that the wind is blowing from. Selecting the **Wind Direction Uphill** option will maximize potential fire behavior for any given pixel.

3.3.4 Foliar Moisture (%)

Foliar moisture represents the percent moisture contained by live leaves or needles of the overstory. Foliar moisture influences the transition between surface and crown fires. Typical foliar moisture values range from 80 to 130 percent. A value of 100 percent is frequently used for typical conditions and is used as the default value in WFAT. A value of 80 percent typically reflects the effects of cumulative drought in systems where average annual precipitation is less than 30 inches (76 cm), while 100 percent would reflect those same areas after recovery from drought. A value of 130 percent would reflect moist forest systems in a normal year, whereas 100 percent may reflect moist forest systems experiencing cumulative drought. Table 3-2 shows guidelines for estimating foliar moisture content based on vegetative development.

Table 3-2. Guidelines for estimating live fuel moisture content (from BehavePlus).

Moisture	**Stage of Vegetative Development**
300%	Fresh foliage, annuals developing, early in growing cycle
200%	Maturing foliage, still developing with full turgor
100%	Mature foliage, new growth complete and comparable to older perennial foliage
50%	Entering dormancy, coloration starting, some leaves may have dropped from the stem
30%	Completely cured, treat as dead fuel

> ***Tip**: In general, short needle species appear to have lower foliar moisture than long needle species and dry faster during dry seasons.*

3.3.5 Fuel Moisture Settings

In WFAT, dead fuel moisture values may either be fixed or conditioned.

3.3.5.1 Fixed Fuel Moistures from Fuel Moisture File

Under the fixed fuel moisture scenario, fuel moistures in the initial fuel moisture (.fms) file for 1-hour, 10-hour, and 100-hour dead fuel size classes and live herbaceous and live woody fuel components correspond directly to a fire behavior fuel model. The fuel moisture values vary spatially as the fire behavior fuel model value assigned to a cell varies across a landscape. Likewise, the 1000-hour+ (or 3"+) dead fuel moisture values specified in the Coarse Woody Debris (CWD) profile (see section 3.4) correspond to a fire effects fuel model and only vary spatially based on the model assigned to each cell. Fuel moistures remain the same for a specific fuel model regardless of topography or canopy cover (fig. 3-14).

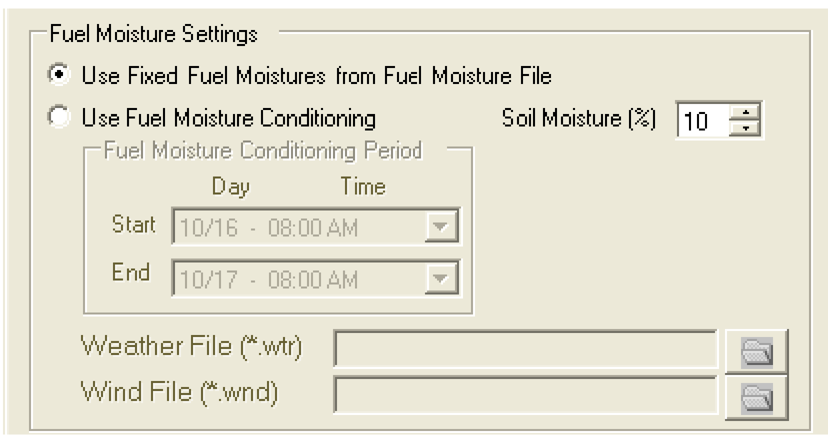


Figure 3-14. Using Fixed Fuel Moistures from Fuel Moisture File.

3.3.5.2 Fuel Moisture Conditioning

The fuel moisture conditioning function allows the program to vary fuel moisture content for dead fuel to better simulate expected variation in fuel condition. Dead fuel moisture content varies as weather and environmental conditions change. Capturing this variation can help more accurately predict fire behavior such as rate of spread and surface fire intensity.

Fuel moisture conditioning adjusts the moisture content of 1-hour, 10-hour, 100-hour, and 1000-hour+ dead fuel based on variable weather conditions, conditioning period length, and site characteristics (elevation, aspect, slope, and canopy cover). If fuel moisture conditioning is used, a separate fuel moisture value is calculated for each cell in the landscape. The user must specify a weather (.WTR) file, wind (.WND) file, and conditioning period (fig. 3-15). When calculating the output grids, the dead fuel moistures from the end of the conditioning period are used, so choose a conditioning period with weather appropriate to the analysis. Live fuel moistures are *not* adjusted with this option (from FlamMap Help utility).

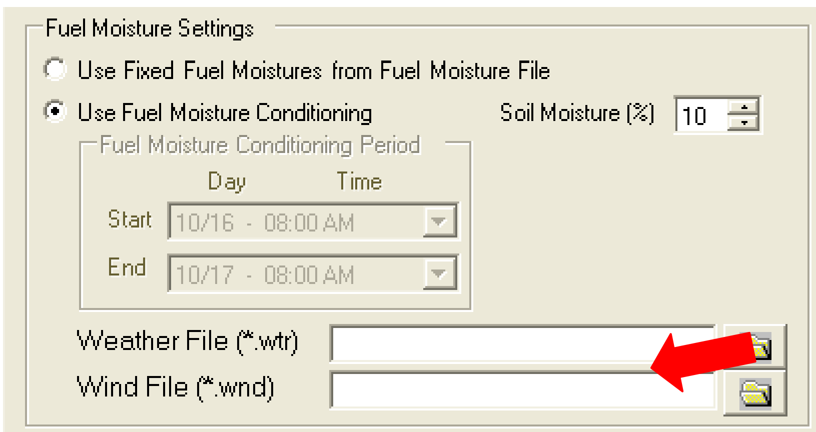


Figure 3-15. Weather and wind files are used as input for fuel moisture conditioning.

3.3.5.3 Weather File (*.wtr)

A .wtr file contains up to five *daily* summaries of temperature, relative humidity and precipitation. This temporal weather stream depicts a simplified version of weather changes over the days specified. The first row lists the units (for example, English units are used in the .wtr shown in figure 3-16). Columns of the .wtr file include**:** *month*, *day*, *total daily precipitation amount* (hundredths of an inch), *time* of minimum temperature (MST), *time* of maximum temperature (MST), *minimum daily temperature* (F), *maximum daily temperature* (F), *maximum daily relative humidity* (%), *minimum daily relative humidity* (%), *elevation* (feet), *beginning hour* (MST) of daily precipitation, *ending hour* (MST) of daily precipitation. The last two columns are only displayed if the cumulative daily precipitation is greater than zero.

```
broad.wtr - Notepad
File  Edit  Format  View  Help
ENGLISH
7 9 0 500 1500 43 79 59 15 7926
7 10 0 600 1700 47 83 41 15 7926
7 11 0 500 1600 45 85 45 14 7926
7 12 0 500 1600 45 85 42 14 7926
7 13 0 500 1600 45 85 42 14 7926
7 14 0 500 1600 44 82 47 16 7926
```

Figure 3-16. Example of a weather (.wtr) file.

3.3.5.4 Wind File (*.wnd)

A .wnd file contains *hourly* data of wind speed, wind direction, and cloud cover. This file is in text (ASCII) format. Columns of the .wnd file include: *month*, *day*, *hour* (MST), *wind speed* (mph), *wind direction* (deg from N), and *cloud cover* (%) (fig. 3-17).

```
broad.wnd - Notepad
File  Edit  Format  View  Help
ENGLISH
7 9 1600 4 360 0
7 10 1600 7 270 0
7 11 1400 5 45 0
7 11 1600 7 45 0
7 11 1700 4 20 0
7 12 1400 4 0 0
```

Figure 3-17. Example of a .Wind (.wnd) file.

3.3.5.5 Fuel Moisture Conditioning Period

The fuel moisture conditioning period is the length of time set to allow for dead fuel moistures to adjust based on weather and topography. Users must specify a start day and time as well as an end day and time. Initial fuel moistures are obtained from the fuel moisture file selected at the top of the **Model Inputs** tab.

3.3.5.6 Soil Moisture

Soil moisture is held constant in WFAT. Typical soil moisture values range from 5% (very dry) to 25% (wet). Wet soils tend to conduct heat more rapidly than drier soils due to the conductive properties of water. A soil with higher moisture has potential to heat up more rapidly and to a greater depth than a drier soil assuming the same amount and duration of heat.

***Note**: WFAT uses the empirical relationship developed by Harrington (1982) to predict duff moisture content from the 100-hr dead fuel moisture value. If fuel moisture conditioning is used, the duff moisture equation is applied after conditioning the 100-hr fuel*.

3.3.6 Crown Fire Calculation Method

WFAT allows the user to specify the crown fire calculation method to be used - Finney (1998) or Scott and Reinhardt (2001). The choice is largely dependent on the source of the canopy bulk density (CBD) data. If the source of the CBD data is based on a method that uses biomass equations (running mean methods), the Scott and Reinhardt method (2001) should produce the best results, whereas the Finney (1998) method would be expected to under-predict active crown fire potential. Examples of CBD data sources based on biomass equations include LANDFIRE National, FFE-FVS, FuelCalc, and FMAPlus. If the CBD data were created or modified (for example, multiplying biomass equation derived CBD by a factor of 1.5 – 2.0) to work well with the Finney method, then the Finney method should produce the best results and the Scott and Reinhardt method should over-predict active crown fire potential. Example data sources that have modified biomass equation-derived CBD include LANDFIRE Rapid Refresh (in some areas) and some other local data projects.

***Note**: If non-biomass equation estimates of CBD are used, canopy consumption estimates and the resultant contribution to emissions may be inaccurate (see section 4.2.2).*

3.3.7 Region

WFAT uses an algorithm decision key from FOFEM that selects the best available algorithm for predicting fire effects based on the conditions specified by the user. "Region" is one of the variables used within this key for selecting shrub and duff consumption algorithms. The available regions in WFAT are Interior West, Pacific West, Southeast, and Northeast (see Appendix C).

3.3.8 Season

WFAT uses the variable "Season" in the FOFEM algorithm decision key to select herbaceous and shrub consumption algorithms. The available seasons in WFAT are Spring, Summer, Fall, and Winter (see Appendix C).

3.4 Coarse Woody Debris (CWD) Profile

The **Coarse Woody Debris (CWD) Profile** tab (figure 3-18) allows the user to view the default coarse woody debris profile and, if required, specify a custom profile. Coarse woody debris refers to down dead woody material greater than or equal to 3 inches (7.6 cm) in diameter. This is also sometimes referred to as the 1000-hour and greater dead timelag fuel class. The information in the CWD profile is used to predict flaming and smoldering combustion of larger fuel.
The profile describes the total load, log distribution, percent rotten and percent moisture for CWD for each model in the fire effects fuel model layer.

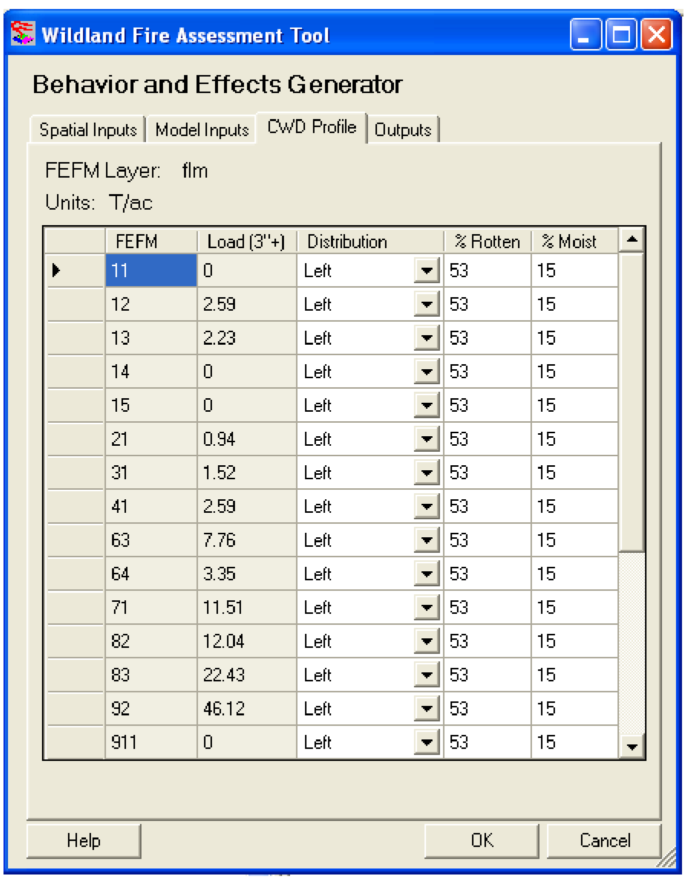


Figure 3-18. WFAT's CWD Profile tab.

3.4.1 Log Distribution

Log distribution refers to the distribution of the coarse woody debris fuel load across four diameter classes (3-5.9, 6-8.9, 9-19.9, and 20 inch and greater). Distributing the total coarse woody debris load among diameter classes improves model precision when simulating burning rate and total consumption (Lutes 2005). WFAT uses five generic representations of CWD load distribution as follows:

1. Even – the load in all diameter classes is within 10% of each other.

2. Right - most of the load is in pieces 9 inches (22.9 cm) and larger in diameter

3. Left – most of the load is in pieces 3-8.9 inches (7.6-15.0 cm) in diameter

4. Center – load is concentrated in the 6-19.9 inch (15.2 -22.9 cm) diameter range

5. End – load is in pieces 3-5.9 inches (7.6-15.0 cm) and 20 inches (50.8 cm) or greater in diameter

Log distribution is expressed graphically as follows (fig. 3-19):

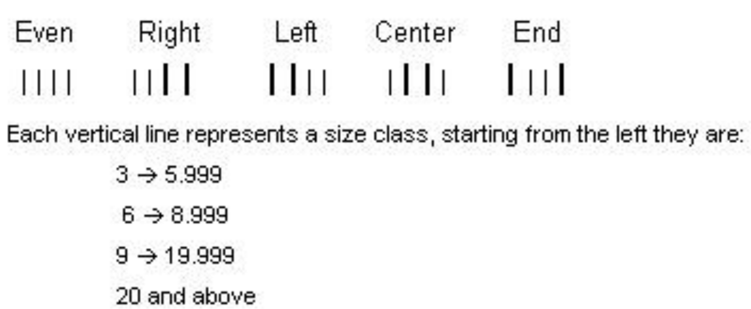


Figure 3-19. Graphical representation of a log distribution.

The CWD load in FCCS fuelbeds is distributed into three diameter classes (3-8.9, 9-19.9, and 20 inch and greater). To accommodate the four FOFEM distribution classes, the 3-8.9 inch class is first split equally into the 3-5.9 and 6-8.9 inch classes.

3.4.2 Log Percent Rotten

Percent rot of CWD is specified for each fire effects fuel model on the **CWD Profile** tab. Rotten wood has both a lower density and lower ignition temperature than sound wood. The proportion of rot within the fuel complex significantly influences consumption (Lutes 2005).

3.4.3 Log Percent Moisture

Fuel moisture greatly influences fire effects by affecting the amount of oxygen available for combustion and heat flux, and by determining the duration of flaming and smoldering combustion. Initial CWD fuel moisture values for each fire effects fuel model are specified on the **CWD Profile** tab. If fuel moisture conditioning is used, these values will be modified (section 3.3.5).

3.5 Custom FEFM

In addition to the Fuel Loading Models (FLM) (Lutes and others 2008) and Fuel Characteristics Classification System (FCCS) fuelbeds (Ottmar and others 2007), a custom FEFM layer can be used in the WFAT analysis as long as the coordinate system, spatial extent, cell resolution, and cell alignment are identical to the other input grids. The **Custom FEFM** tab enabling this option will appear when "**Custom**" units are selected for the Fire Effects Fuel Model Layer (figure 3-20).

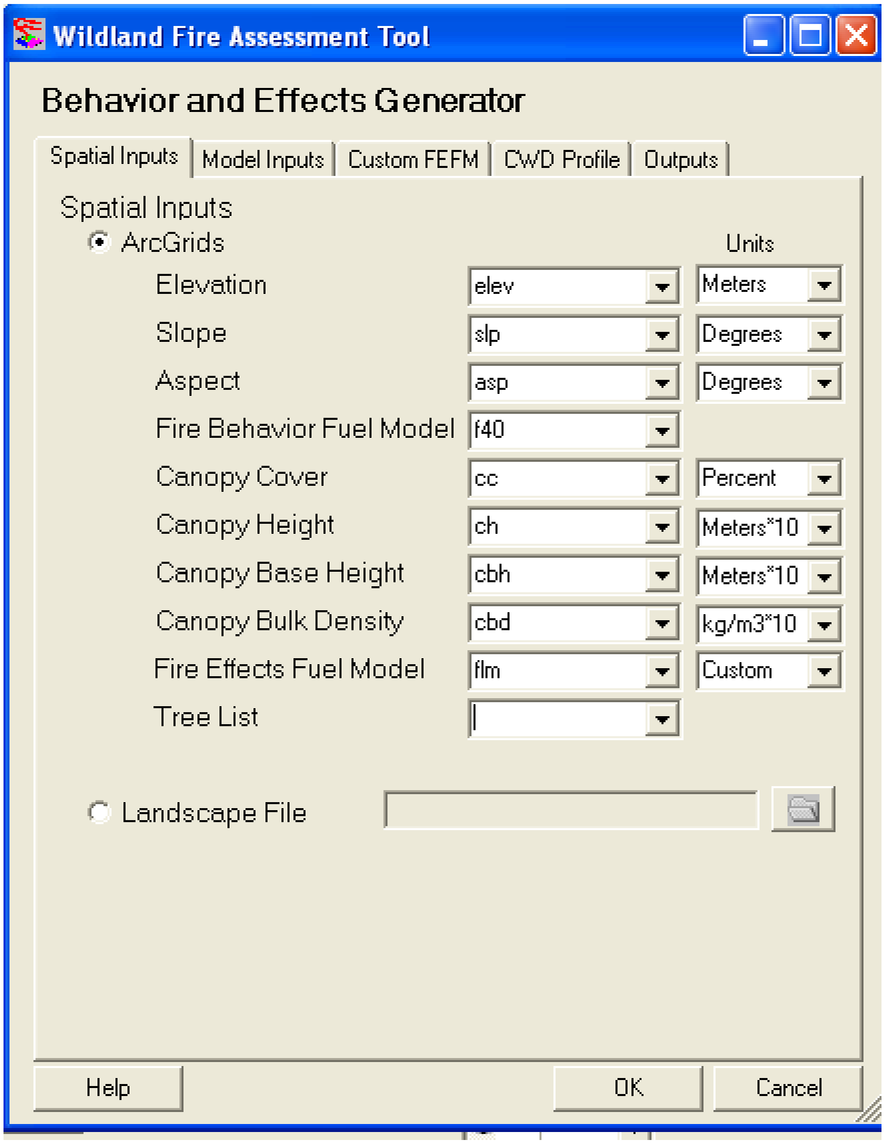


Figure 3-20. **Custom FEFM** tab appears on **Behavior and Effects Generator** dialog box if "Custom" is selected as Fire Effects Fuel Model "Units" using the drop-down menu.

The fuel loading units must be the same for all of the loading attributes and can be specified on the **Custom FEFM** tab. The correct format of the custom FEFM grid is critical to the successful execution of WFAT. The map layer must be in ESRI grid format and have a value attribute table with cell values represented by either floating point numbers (decimals) or integers that correspond to the following fuel component values:

Fire Effects Fuel Model Identification Number
Litter Load
Duff Load
1-Hour Load
10-Hour Load
100-Hour Load

1000+ Hour Load
Shrub Load
Herbaceous Load

An example value attribute table is shown in the following figure (fig 3-21).

Attributes of fefm_custom

Rowid	VALUE *	COUNT	CODE	DESC_	LITTER	DUFF	HR	HR_1	HR_12	HR_12_13	HERB	SHRUB
0	11	101536	11	Light FWD, Light to no duff	0.18	0	0.07	0.08	0.04	0	0.23	0.35
1	12	10427	12	Moderate FWD, light litter	0.27	0	0.27	1.56	2.68	2.59	0.23	0.35
2	13	72066	13	Moderate FWD, light to moderate litter, light duff	2.5	1.2	0.23	1.52	2.05	2.23	0.23	0.35
3	14	4349	14	Shrub - Sagebrush with low total load	0	0	0	0	0	0	0	6
4	15	113898	15	Shrub - Non-sagebrush with low total load	0	0	0	0	0	0	0	9.5
5	21	29928	21	Light logs, Light duff	1.16	3.3	0.2	0.64	0.67	0.94	0.23	0.35
6	31	9654	31	Moderate litter, light duff, light logs	1.87	7.31	0.27	0.89	1.07	1.52	0.23	0.35
7	41	15762	41	Moderate FWD, light to moderate litter	2.41	0	0.27	1.67	2.57	2.59	0.23	0.35
8	63	673	63	Moderate duff, light to heavy logs, light litter	1.52	17.04	0.2	1.39	2.38	7.76	0.23	0.35
9	64	476011	64	Moderate to heavy duff, light to heavy logs	2.9	25.87	0.31	1.11	1.66	3.35	0.23	0.35
10	71	24329	71	Moderate to heavy logs, light duff	2.19	9.37	0.45	1.42	2.19	11.51	0.23	0.35
11	82	645	82	Moderate duff, light to heavy logs, moderate litter	3.79	17.71	0.53	1.58	3.16	12.04	0.23	0.35
12	83	17438	83	Heavy to very heavy logs, moderate duff	2.5	11.91	0.5	1.58	2.87	22.43	0.23	0.35
13	911	1483	911	Open Water	0	0	0	0	0	0	0	0
14	920	211	920	Developed-General	0	0	0	0	0	0	0	0
15	931	940	931	Barren/Rock/Sand/Clay	0	0	0	0	0	0	0	0
16	980	29075	980	Agriculture-General	0	0	0	0	0	0	0	0

Record: 1 Show: All Selected Records (0 out of 17 Selected) Options

Figure 3-21. Example value attribute table for a custom FEFM layer.

The field names in the custom grid and/or the order in which they are organized may vary from those associated with the FLM and FCCS map layers so it is *very* important to match the custom grid field to the appropriate fuel component attribute in the **Custom FEFM** tab before running WFAT.

Chapter 4: Output Data

4.1 Output data overview

WFAT outputs can be used to spatially identify areas with the potential for problematic fire behavior and effects based on fire behavior outputs such as fireline intensity, flame length and/or rate of spread, and fire effects outputs related to fuel consumption, emissions, soil heating, and tree mortality.

4.2 Description of outputs

Fire behavior output layers are generated by WFAT as are four categories of spatial fire effects layers: fuel consumption, emissions, soil heating, and tree mortality. The following sections discuss individual outputs further.

4.2.1 Fire behavior and associated outputs

Table 4-1 lists both the layer and ESRI Grid names, as well as the pixel type of the individual spatial outputs.

Table 4-1. Summary table of spatial outputs generated by WFAT characterizing potential fire behavior.

Grid Name	Layer Name and Description	Grid Format	Units
Flame	Flame length	Floating point	Meters
ros	Rate of spread	Floating point	Meters/minute
Cfa	Fire type	Integer	Class 0 = non-burnable 1 = surface fire 2 = passive crown fire 3 = active crown fire
Lineintn	Fireline intensity	Floating point	Kilowatts/meter
firintn	Wildland fire intensity (common log of fireline intensity)	Floating point	Log10(kW/meter)
sh	Scorch height	Integer	mph
MWS	Midflame wind speed	Floating point	mph
FMI	1-hour fuel moisture	Integer	percent
FMX	10-hour fuel moisture	Integer	percent
FMC	100-hour fuel moisture	Integer	percent
FMM	1000-hour fuel moisture	Integer	percent
DM	Duff fuel moisture	Integer	percent
CFL	Preburn canopy fuel load	Integer	tons/acre

Fire behavior output selections are shown in the following figure (fig. 4-1).

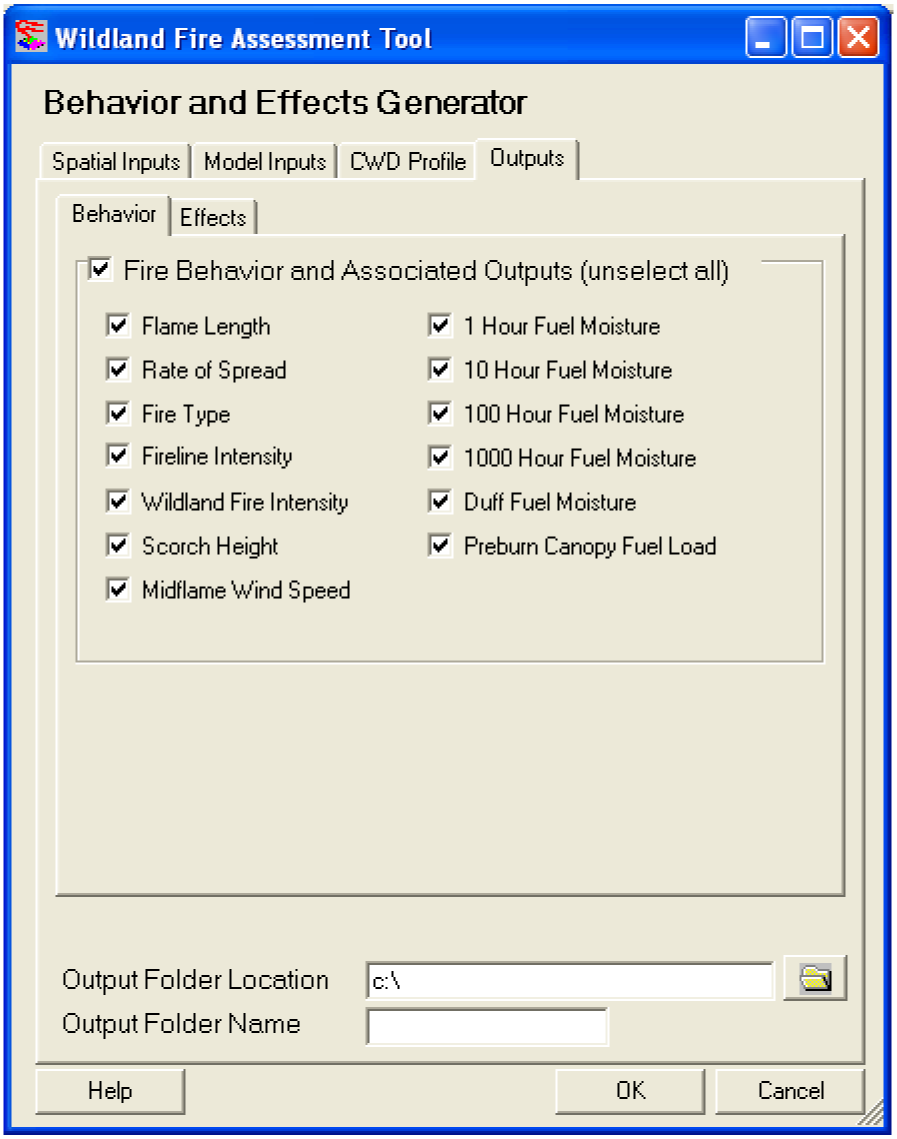


Figure 4-1. Fire Behavior **Outputs** tab on **Behavior and Effects Generator** dialog box.

Note: *The default symbology for all output grids can be saved if the ArcMap project containing the outputs is saved. The default symbology is lost when the output grids are added to a new ArcMap project*

4.2.1.1 Flame Length

The flame length output layer represents the average flame length in each map pixel. Units are expressed in meters. Flame length is the distance between the flame tip and the midpoint of the flame depth at the base of the flame (generally the ground surface). It is an indicator of fire intensity and helps predict scorch height and canopy mortality.

Selecting the flame length output generates both a floating point rate of spread layer and an integer flame length layer. WFAT's Flame Length classes are derived from the Hauling Chart (Rothermel 1983, Roussopoulo 1974).

4.2.1.2 Rate of Spread

The rate of spread layer represents the average rate of spread (ROS) in each map pixel. ROS is the speed with which a fire moves in a horizontal direction across the landscape. Units are expressed in meters per minute.

Selecting the rate of spread output generates both a floating point rate of spread layer and an integer rate of spread layer. Rate of Spread classes used by WFAT are based on Scott and Burgan (2005).

4.2.1.3 Fire Type (Crown Fire Activity)

Fire Type (CFA) describes the type of fire that will potentially occur for each cell based on fire line intensity, canopy cover, canopy base height, canopy bulk density, and foliar moisture content. If a cell is typed to an active or passive crown fire, surface fire is also potentially occurring. Fire types are classified into four values:

0	No fire	
1	Surface fire	
2	Passive or torching fire	Low wind speed, low canopy bulk density and cover; high canopy base height
3	Active crown fire	Higher wind speed, high canopy bulk density and cover; low canopy base height

4.2.1.4 Fireline Intensity

The fireline intensity layer represents the average fireline intensity in each map pixel. Fireline intensity is the rate of heat released per unit width of fire front, regardless of its depth (Byram 1959). Units are expressed in kilowatts/meter.

4.2.1.5 Wildland Fire Intensity

The Wildland Fire Intensity metric was proposed by Scott (in press) to facilitate communication about and interpretation of fireline intensity. In essence, it is analogous to the logarithmic Richter scale used to measure the magnitude of earthquakes. The Wildland Fire Intensity metric is derived from the common logarithm of fireline intensity. Values typically range between zero and six, where each whole number represents an incremental increase of one order of magnitude. That is, a value of 2.0 is 10 times more intense than a value of 1.0; a value of 3.0 is 100 times more intense than a value of 1.0 and 10 times more intense than a value of 2.0. Units are expressed as Log10 (kW/meter).

4.2.1.6 Scorch Height

WFAT produces an output layer that represents the average scorch height or the average height of foliage browning or bole blackening caused by fire.

4.2.1.7 Midflame Wind Speed

The mid-flame wind speed is the speed of the wind at the mid-height of the flames. It is considered to be the most representative wind speed that affects fire behavior, including rate of spread. In WFAT, wind speed is calculated using the 20-ft wind speed and wind reduction factors.

4.2.1.8 1-Hour Fuel Moisture

The 1-hour fuel moisture output grid theme is created by using the fuel moisture for each cell at the end of the optional fuel moisture conditioning period if a fuel moisture conditioning period is specified on the **Model Inputs** tab of the **Wildland Fire Behavior and Effects Evaluator** dialog box. Otherwise WFAT uses the fuel moistures values from the initial fuel moisture file, which specifies the initial fuel moistures of the surface and ground fuel based on the fire behavior fuel model assigned to the cell.

Moisture content of dead fuel and its change over time affects fire behavior characteristics – drier fuel, in general, tends to increase rate of spread, fireline intensity and fuel consumption.

4.2.1.9 10-Hour Fuel Moisture

The 10-hour fuel moisture output grid theme is created using the fuel moisture for each cell at the end of the optional fuel moisture conditioning period if a fuel moisture conditioning period is specified on the **Model Inputs** tab of the **Wildland Fire Behavior and Effects Evaluator** dialog box. Otherwise WFAT uses the fuel moistures values from the initial fuel moisture file, which specifies the initial fuel moistures of the surface and ground fuel based on the fire behavior fuel model assigned to the cell.

Moisture content of dead fuel and its change over time affects fire behavior characteristics – drier fuel, in general, tends to increase rate of spread, fireline intensity and fuel consumption.

4.2.1.10 100-Hour Fuel Moisture

The 100-hour fuel moisture output grid theme is created using the fuel moisture for each cell at the end of the optional fuel moisture conditioning period if a fuel moisture conditioning period is specified on the **Model Inputs** tab of the **Wildland Fire Behavior and Effects Evaluator** dialog box. Otherwise WFAT uses the fuel moistures values from the initial fuel moisture file, which specifies the initial fuel moistures of the surface and ground fuel based on the fire behavior fuel model assigned to the cell.

Moisture content of dead fuel and its change over time affects fire behavior characteristics – drier fuel, in general, tends to increase rate of spread, fireline intensity and fuel consumption.

4.2.1.11 1000-Hour Fuel Moisture

The 1000-hour fuel moisture output grid theme is created using the fuel moisture for each cell at the end of the optional fuel moisture conditioning period if a fuel moisture conditioning period is specified on the **Model Inputs** tab of the **Wildland Fire Behavior and Effects**

Evaluator dialog box. Otherwise WFAT uses the fuel moistures values from the initial fuel moisture file, which specifies the initial fuel moistures of the surface and ground fuel based on the fire behavior fuel model assigned to the cell.

Moisture content of dead fuel and its change over time affects fire behavior characteristics – drier fuel, in general, tends to increase rate of spread, fireline intensity and fuel consumption.

4.2.1.12 Duff Fuel Moisture

WFAT uses the empirical relationship developed by Harrington (1982) to predict duff moisture content from the 100-hr dead fuel moisture value. If fuel moisture conditioning is used, the duff moisture equation is applied after conditioning the 100-hr fuel

4.2.1.13 Preburn Canopy Fuel Load

Preburn canopy load is calculated for each cell from canopy bulk density, canopy height and canopy base height input grid values. It is used as a baseline to calculate canopy consumption and predict tree mortality.

4.2.2 Fire effects outputs

WFAT produces four general categories of spatial fire effects layers: fuel loading, emissions, soil heating, and tree mortality. Fire effects outputs are summarized in the following table.

Table 4-2. Spatial outputs generated by WFAT characterizing potential fire effects.

	Layer Name (units)	Grid Name	Grid Format
Fuel Loading	**Postburn Litter Load (T/ac)**	litter_pos	Floating point
	Postburn 1-Hour Load (T/ac)	one_hr_pos	Floating point
	Postburn 10-Hour Load (T/ac)	ten_hr_pos	Floating point
	Postburn 100-Hour Load (T/ac)	hun_hr_pos	Floating point
	Postburn CWD Sound Load (T/ac)	cwd_snd_pos	Floating point
	Postburn CWD Rotten Load (T/ac)	cwd_rot_pos	Floating point
	Postburn Duff Load (T/ac)	duff_pos	Floating point
	Postburn Herbaceous Load (T/ac)	herb_pos	Floating point
	Postburn Shrub Load (T/ac)	shrub_pos	Floating point
	Postburn Canopy Load (T/ac)	can_pos	Floating point
	Total Postburn Load (T/ac)	total_pos	Floating point
	Postburn Fuel Loading Model (FLM)	flm_pos	Integer
	Consumed Litter Load (T/ac)	litter_cns	Floating point
	Consumed 1-Hour Load (T/ac)	one_hr_cns	Floating point
	Consumed 10-Hour Load (T/ac)	ten_hr_cns	Floating point
	Consumed 100-Hour Load (T/ac)	hun_hr_cns	Floating point
	Consumed CWD Sound Load (T/ac)	cwd_snd_cns	Floating point
	Consumed CWD Rotten Load (T/ac)	cwd_rot_cns	Floating point
	Consumed Duff Load (T/ac)	duff_cns	Floating point
	Consumed Herbaceous Load (T/ac)	herb_cns	Floating point
	Consumed Shrub Load (T/ac)	shrub_cns	Floating point
	Consumed Canopy Load (T/ac)	can_cns	Floating point
	Total Consumed Load (T/ac)	total_cns	Floating point
	Fuel Loading Model – Post FLM	Class	Integer
Emissions	**PM10 Emissions (lbs/ac)**	pm10	Integer
	PM2.5 Emissions (lbs/ac)	pm2_5	Integer
	CH_4 Emissions (lbs/ac)	ch4	Integer
	CO Emissions (lbs/ac)	co	Integer
	CO_2 Emissions (lbs/ac)	co2	Integer
	NOX Emissions (lbs/ac)	nox	Integer
	SO_2 Emissions (lbs/ac)	so2	Integer
Soil Heating	**Soil Depth Heated to 60C (cm)**	dep_60c	Integer
	Soil Depth Heated to 275C (cm)	dep_275c	Integer
	Percent Mineral Soil Exposed (percent)	min_exp	Integer
	Soil Surface Temperature (C)	surf_temp	Integer
Tree Mort ality	**Percent Mortality**	avg_mort	Integer
	Percent Basal Area Mortality	perc_ba_mort	Integer
	Average diameter of fire-killed	avg_dbh_k	Integer

	trees		
	Fire Severity (Keane)	fire_sev	Integer

Separate tabs labeled "**Fuel**," "**Emissions**," "**Soil**," and "**Mortality**" under the "**Effects**" tab, allow the user to select outputs within each of the general categories (figure 4-2).

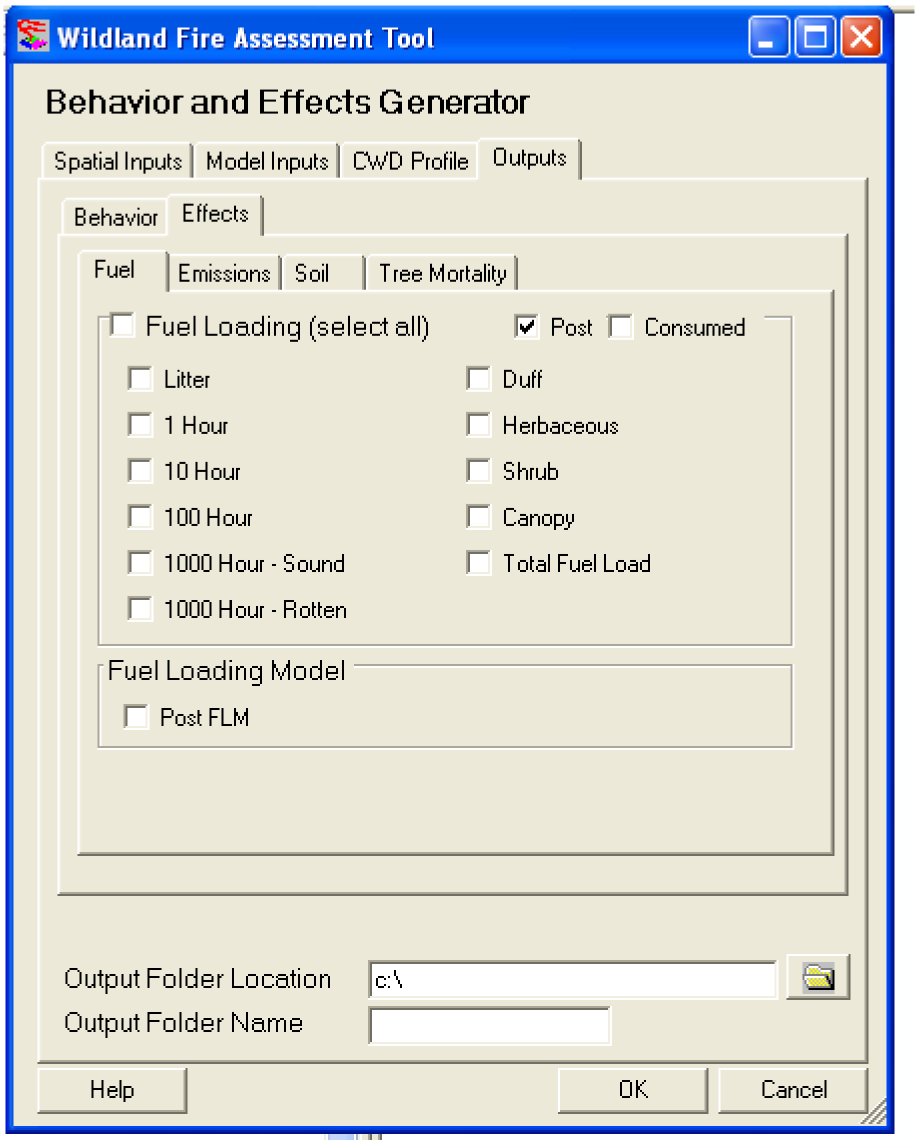


Figure 4-2. Categories of Fire Effects with the "**Fuel**" tab selected.

4.2.2.1 Fuel Loading (Post and Consumed)

WFAT allows the user to specify which fuel component layers are generated and whether to generate these layers for post-burn fuel load, consumed fuel load, or both. Post burn load plus consumed load equals pre-burn fuel load for all fuel components. Fuel components include duff, litter, 1-hr, 10-hr, 100-hr, sound and rotten CWD (1000-hr, or 3 inches (7.6 cm) and greater), herbaceous, shrub, and canopy fuel affected by crown fire.

WFAT assumes that the entire area of concern experienced fire when predicting fuel consumption. In other words, WFAT does not predict fire effects for patchy or discontinuous burns. For these situations, results should be weighted by the percent of the area burned.

WFAT via FOFEM uses the Burnup model to predict consumption of woody fuel (Albini and Reinhardt 1995; Albini and others 1995; Albini and Reinhardt 1997). Consumption of herbaceous fuel, shrub, and duff is predicted using the best available algorithm as determined by an algorithm decision key that takes into account the region, season, and cover type of the project area (see Appendix C).

4.2.2.1.1 Litter

The consumption of litter is calculated by the Burnup model. Generally 100% of the litter is consumed.

4.2.2.1.2 1-Hour

Consumption of the 1-hour down dead woody fuel is calculated by the Burnup model. The amount of consumption is highly dependent on the amount, distribution, and moisture of this fuel component. Although FOFEM allows the user to specify the fuel category (natural, activity, or piles), WFAT assumes that the fuel category is natural.

4.2.2.1.3 10-Hour

The consumption of the 10-hour down dead woody fuel is calculated by the Burnup model. The amount of consumption is highly dependent on the amount, distribution, and moisture of this fuel component. Although FOFEM allows the user to specify the fuel category (natural, activity, or piles), WFAT assumes that the fuel category is natural.

4.2.2.1.4 100-Hour

Consumption of 100-hour down dead woody fuel is calculated by the Burnup model. The amount of consumption is highly dependent on the amount, distribution, and moisture of this fuel. Although FOFEM allows the user to specify the fuel category (natural, activity, or piles), WFAT assumes that the fuel category is natural.

4.2.2.1.5 1000-Hour Sound

The consumption of sound CWD is calculated by the Burnup model. The amount of consumption is highly dependent on the amount, distribution, and moisture of the wood as specified in the CWD profile (section 3.4).

4.2.2.1.6 1000-Hour Rotten

Consumption of rotten CWD is also calculated by the Burnup model. The amount of consumption is highly dependent on the amount, distribution and moisture of the wood, as specified in the CWD profile (section 3.4).

4.2.2.1.7 Duff

A number of duff consumption algorithms are incorporated in WFAT. Separate predictions are made for percent duff consumption, duff depth consumed, and mineral soil exposure. The most appropriate algorithm is determined by the algorithm decision key (see Appendix C). Variables in WFAT that affect the selection of the duff consumption algorithm include region and cover type. Region is a user-selected variable and cover type is pre-set for fire effects fuel models in both the FLM and FCCS characterizations.

Two other variables used to determine the duff consumption algorithms in FOFEM, fuel category (natural, activity, or piles) and duff moisture method (for example, lower, upper, entire) have been set to natural and entire (average) by default in WFAT.

4.2.2.1.8 Herbaceous

Herbaceous fuel generally represents a small component of the total fuel load. However, for completeness, especially in the modeling of emissions, consumption is computed in WFAT. Generally, 100% of the herbaceous fuel is assumed to burn. If the cover type is "grass" and the season "spring," however, only 90% of the herbaceous fuel is consumed.

4.2.2.1.9 Shrub

Shrub consumption is modeled according to general rules summarized as follows:

- If the cover type is sagebrush and the season is fall, shrub consumption is 90%; for all other seasons consumption is 50%.
- For other cover types dominated by shrubs (except in the southeast), shrub consumption is assumed to be 80%.
- For cover types not dominated by shrubs, shrub consumption is set to 60%.
- For the southeastern region and the pocosin cover type, in spring or winter shrub consumption is 90%; in summer or fall it is 80%.
- For non-pocosin types in the southeast, Hough's (1968, 1978) research was used to predict shrub consumption: percent consumption = ((3.2484 + 0.4322 * preburn litter and duff loading + .6765 * preburn shrub and regeneration loading - .0276* duff moisture – (5.0796 / preburn litter and duff loading) – litter and duff consumption) / preburn shrub and regeneration loading) * 100%.

4.2.2.1.10 Canopy

The canopy layer represents the consumed or post-fire load of canopy fuel. Units are expressed as tons per acre.

Canopy fuel load (CFL) is the oven-dry mass of available canopy fuel per unit ground area. Available canopy fuel refers to the foliage and fine branchwood (0 – 0.25 inch (0 – 6 cm)) biomass available for consumption in a crown fire.

The pre-fire canopy fuel load is calculated in WFAT using the canopy layers (cc, ch, cbd, and cbh) utilizing the following general rule of thumb equation: CFL = (CBD * (CH – CBH))/2

Where,

CFL is canopy fuel load (kg/m^2)
CBD is canopy bulk density (kg/m^3)
CH is canopy height (m)
CBH is canopy base height (m)

> ***Note**: This equation assumes that the canopy bulk density data is based on a method that uses biomass equations (for example, running mean methods), such as those used in LANDFIRE National, FFE-FVS, FuelCalc, and FMAPlus. If non-biomass equation estimates of CBD are used, canopy consumption estimates and the resultant contribution to emissions may be inaccurate (see section 3.3.6).*

WFAT uses the crown fire activity output layer values to estimate the proportion of canopy affected by crown fire. Under passive crown fire (CFA = 2) we assume that 50% of the canopy is affected. Under active crown fire (CFA = 3) we assume that 100% of the canopy is affected.

It is also assumed that the canopy fuel load consists of 10% branch biomass and 90% foliage biomass (Reinhardt personal communication). WFAT then applies the proportion of canopy affected, as based on CFA, to 100% of the foliage biomass and 50% of the branch biomass so that consumption of these fuel is represented for purposes of estimating smoke production.

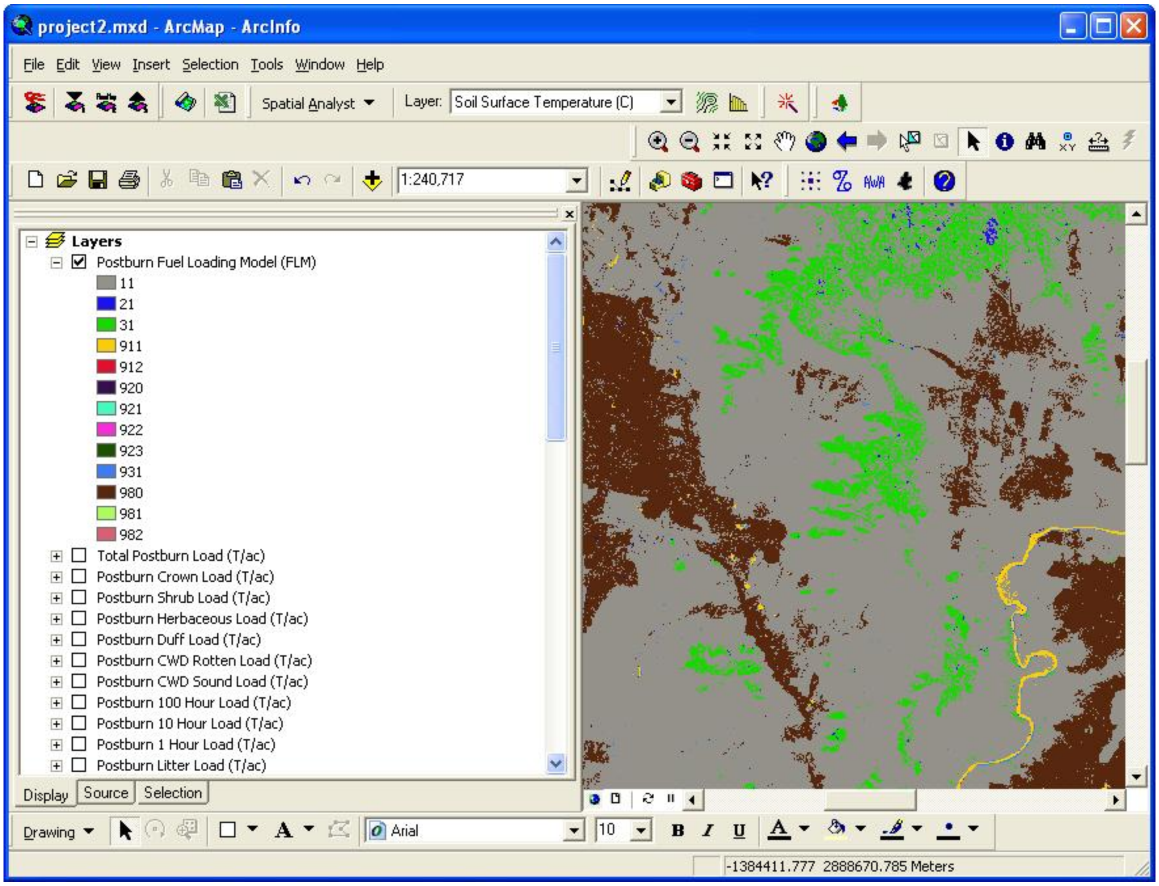


Figure 4-3. Fuel consumption output layers.

4.2.2.1.11 Total Fuel Load

This output represents the total post-burn fuel load or the total post-burn fuel consumption.

4.2.2.2 Fuel Loading Model - Post FLM

WFAT uses a key to assign a new Fuel Loading Model (FLM) to each pixel after the simulation based on the post-fire fuel loading values of the surface fuel components.

4.2.2.3 Emissions

The Clean Air Act requires the Environmental Protection Agency to set standards for common air pollutants that may impact the health of people, especially the young, elderly and those with respiratory illness

(EPA). WFAT includes output layers for five of these pollutants: $PM_{2.5}$, PM_{10}, CO, NO_X and SO_2. It also produces outputs for CH_4 and CO_2.

Calculating emissions: Flaming and smoldering combustion can be simulated simultaneously in WFAT. For example, flaming combustion in woody fuel may be occurring at the same time that smoldering combustion is occurring in the duff or CWD. By distinguishing fuel weight consumed in the flaming and smoldering phases of combustion, the Burnup model allows emission factors to be applied separately to the fuel consumed in each phase. The emission factor for a particular pollutant is defined as the mass of pollutant produced per mass of fuel consumed (Hardy and others 2001). Emission factors vary by pollutant and type and arrangement of fuel. WFAT applies emission factors for particulate and chemical emissions to the fuel consumed in flaming and smoldering combustion, assuming combustion efficiencies of 0.97 for flaming and 0.67 for smoldering. For example:

Total emission = mass x combustion efficiency x emission factor.

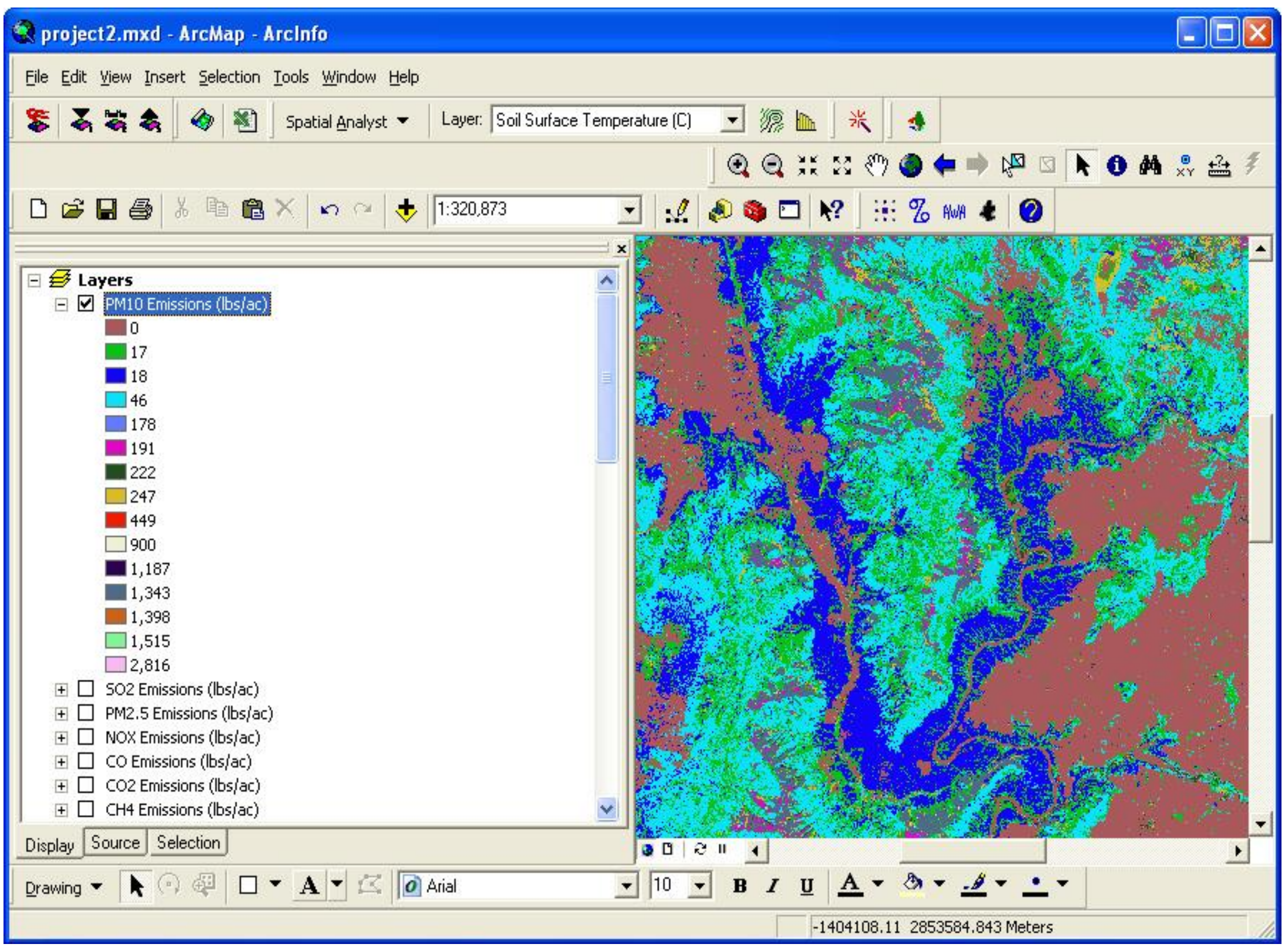


Figure 4-4. Emissions output layers in Table of Contents.

Figure 4-5 shows available outputs for Emissions.

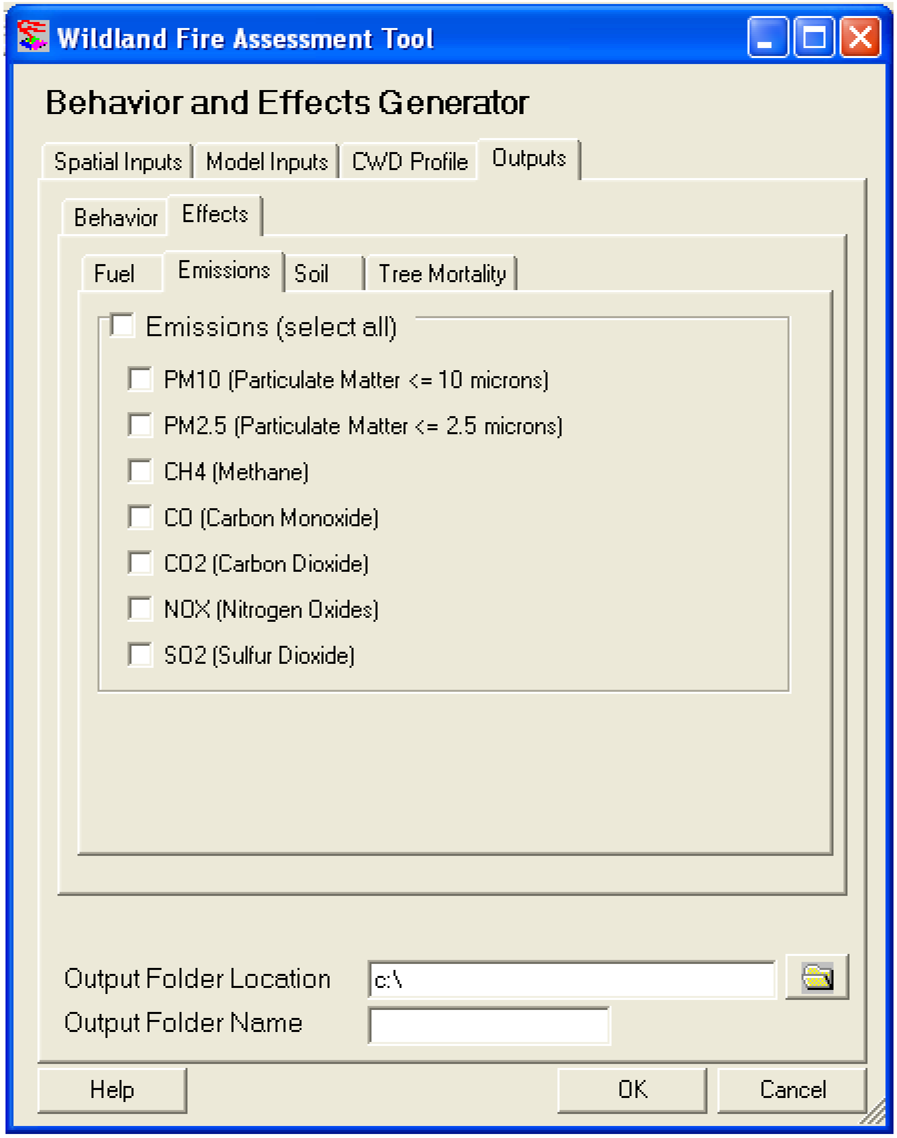


Figure 4-5. Available emissions output layers.

4.2.2.3.1 PM10 (Particulate Matter ≤10 microns)

The PM10 output layer represents particulate matter consisting of particles less than 10 microns in diameter (a micron is one millionth of a meter) produced by wildfire. PM10 is considered an inhalable particle and as such can cause respiratory problems for people. It can also be transported by the wind and can change the nutrient balance and acidity of water and soil where it settles. Units are expressed in lbs/acre.

4.2.2.3.2 PM2.5 (Particulate Matter ≤2.5 microns)

PM2.5 is a small diameter pollutant (particles less than 2.5 microns in diameter) found in wild and prescribed fire smoke emissions. It can cause serious health problems, particularly in the very young and old as well as in those with heart and lung conditions. It is therefore regulated by the EPA. It also causes reduced visibility or haze in many wildland areas (EPA).

The amount of pollutant produced by a fire is determined by the length of the flaming and smoldering combustion phases, by fuel moisture, and by fuel size and arrangement. The PM2.5 layer is expressed as lbs/acre.

> ***Note:*** *Over 90 percent of the mass of particulate matter produced by wildland fire is less than 10 microns in diameter and over 80-90 percent of that is less than 2.5 microns in diameter (Forest Encyclopedia).*

4.2.2.3.3 CH_4 (Methane)

Methane is released during forest fires due to incomplete combustion of organic material. Fires can lead to the release of large amounts of methane from soil, especially in high latitude regions. Here, fires melt permafrost which traps methane in the soil. In addition, warmer soil temperatures after fire events lead to greater microbial activity. Greater microbial activity increases the diffusion of methane from soils to the atmosphere. (EPA). In this layer, methane is expressed as lbs/acre.

4.2.2.3.4 CO (Carbon Monoxide)

Carbon monoxide (CO) is produced by the incomplete combustion of fuel such as wood and represents the most abundant emission product from wildland fires. Its negative effect on human health depends on the duration of exposure, CO concentration, and level of physical activity during the exposure. Generally, dilution occurs rapidly enough from the source of the fire that carbon monoxide will not be a problem for local citizens unless a large fire occurs and inversion conditions trap the carbon monoxide near rural communities. Carbon monoxide is always a concern for wildland firefighters however, both on the fire line at prescribed fires and wildfires, and at fire camps (Reinhart and others 2000, Forest Encyclopedia).

4.2.2.3.5 CO_2 (Carbon Dioxide)

Two products of complete **combustion** during fires, carbon dioxide (CO_2) and water (H_2O), generally make up over 90 percent of the total emissions from wildland fire. Under ideal conditions, complete combustion of one ton of forest fuel requires 3.5 tons of air and yields 1.84 tons of CO_2 and 0.54 tons of water (NWCG 1985). Under wildland conditions, however, inefficient combustion produces different yields. Neither carbon dioxide nor water vapor are considered air pollutants in the usual sense, even though carbon dioxide is considered a greenhouse gas and the water vapor will sometimes condense into liquid droplets and form a visible white smoke near the fire. This fog/smoke mixture can dramatically reduce visibility and create hazardous driving conditions. As combustion efficiency decreases, less carbon is converted to CO_2 and more carbon is available to form other combustion products such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), and sulfur oxides (SO_x), all of which are considered pollutants (Forest Encyclopedia).

4.2.2.3.6 NO_x (Nitrogen Oxides)

Small amounts of nitrogen oxides are produced in wildland fires, primarily from the oxidation of nitrogen compounds present in the fuel. The highest emissions of NO_x occur from burning fuel that has a high nitrogen content but most fuels contain less than 1 percent nitrogen and of that amount, only about 20 percent is converted to NO_x when burned. Nitrogen oxides from large wildfires may contribute to increased ozone formation under some circumstances (EPA, Forest Encyclopedia).

4.2.2.3.7 SO_2 (Sulfur Dioxide)

Sulfur dioxide emissions produced by wildland fire are usually in low concentrations because most fuel is low in sulfur compounds, with exceptions being highly organic mucky or peat soils (GTR-SE-010). Sulfur dioxide emissions (along with NO_X) contribute to the production of acid rain and sulfur dioxide exposure is associated with respiratory illnesses, particularly in at-risk populations including children, the elderly, and asthmatics. Units in this map layer are expressed as lbs/acre.

4.2.2.4 Soil

Two variations of the soil heating model were developed in FOFEM in order to simulate soil heating under conditions with burnable duff material and where there is an absence of any burnable duff. In the later case, soil heating is attributed to the surface fire rather than the slower moving, lower intensity smoldering duff fire.

WFAT assumes the duff depth (inches) to be 1/10th of the duff load (tons/acre). By knowing the depth and density of duff, WFAT computes the total amount of heat that is released when it burns. This heat is released over a period of time, which is determined by the rate of spread of the fire, which in turn is correlated to the moisture of the duff material. The dryer the duff, the faster it will burn. Duff moisture is based on 100-hr fuel moisture in WFAT (see section 4.2.1.12).

Part of the heat produced by the fire is radiated and convected away at the duff surface, and part flows into the soil. Attempting to separate these values is difficult and highly variable depending on the fire behavior; therefore, WFAT assumes a worse-case scenario with the model and applies all of the heat generated from the burning duff into the soil. It is often observed that not all of the duff material is consumed in the fire and the remaining unburned duff acts as a soil insulator. In such cases, the model accounts for the amount of heat absorbed by the unburned duff and predicts soil heating based not only on the amount of heat generated from the burning duff, but also from the amount of heat absorbed by the unburned duff layer.

High temperatures deep into the soil profile break down organic material and can change soil chemical and physical composition. Predicting first order fire effects can aid managers in determining possible second order fire effects such as erosion and nutrient release due to loss of the vegetation layer and changes in soil characteristics.

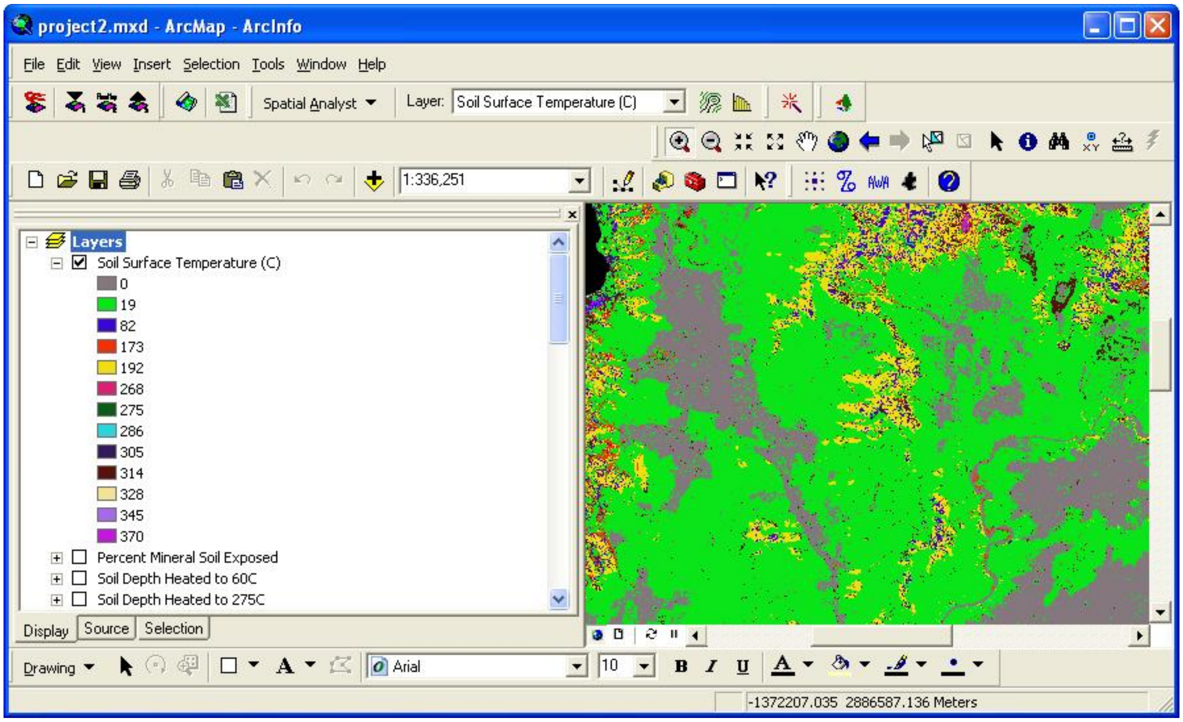


Figure 4-6. Soil output layers.

The following figure (fig. 4-7) shows available outputs for Effects – Soil. All available soil output layers can be selected by checking the first box "**Soil (select all)**."

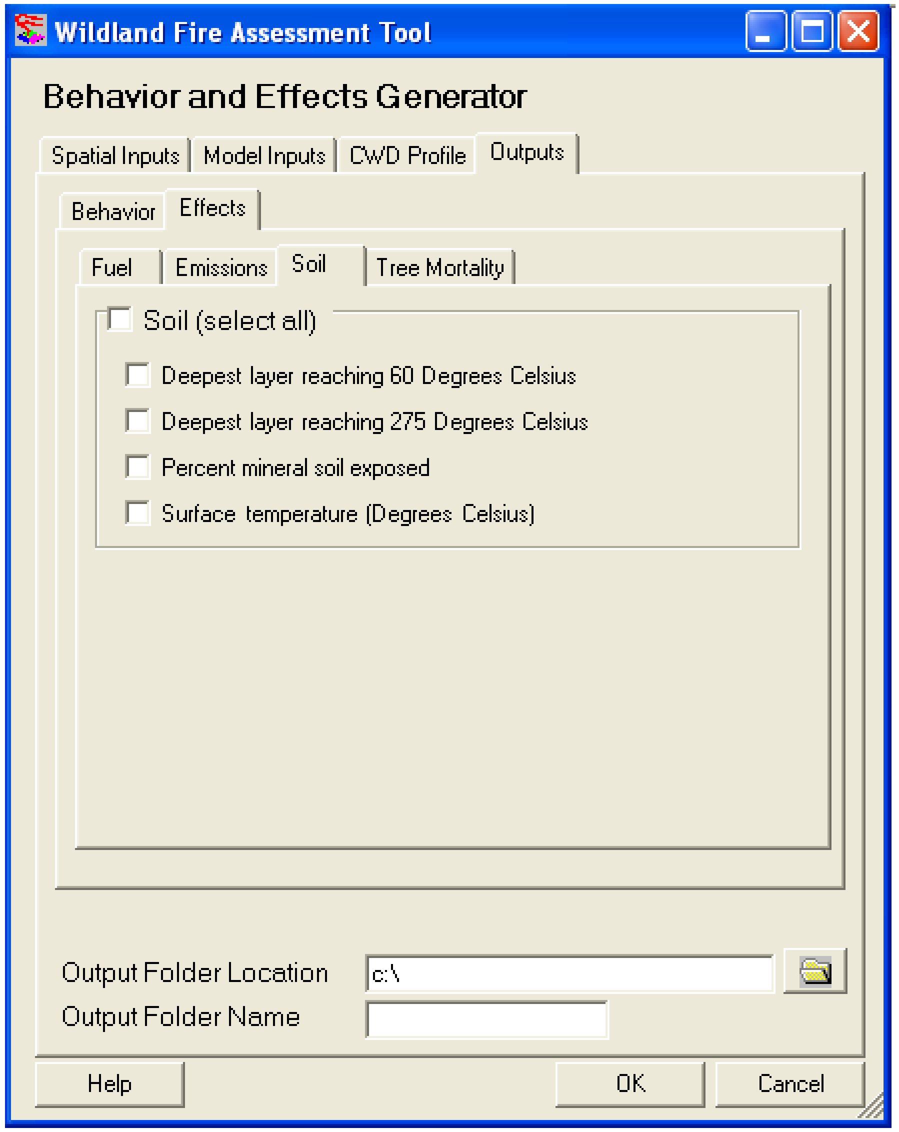


Figure 4-7. Soil output.

4.2.2.4.1 Deepest layer reaching 60° C

This layer represents the depth at which soil temperature reaches 60 degrees Celsius – the temperature at which unprotected plant tissue death begins to occur.

4.2.2.4.2 Deepest layer reaching 275° C

This layer represents the depth at which soil temperature reaches 275 degrees Celsius – the temperature at which hydrophobic soil characteristics begin to break down.

4.2.2.4.3 Percent mineral soil exposed

This layer depicts percent mineral soil exposed by fire as a result of duff and litter consumption.

4.2.2.4.4 Surface temperature (^{o} C)

Soil surface temperature during a fire can affect vegetation in several ways. High surface temperatures can enhance seed germination and stimulate plant growth in some species, but it can also reduce surface vegetation, which can increase water flow and erosion across the soil surface. Surface temperature alone is not necessarily a good indicator of fire's effects on soil and vegetation. Duration and temperature depth also play a significant role in the effects of soil heating.

4.2.2.5 Tree Mortality

Each cell in the tree mortality layer corresponds to a tree species list which represents a stand of trees. A tree species list includes a list of tree species that occur in a stand with related density (trees/acre), DBH (in), height (ft), canopy base height (ft), and crown class (codominant, dominant, emergent, open grown, intermediate, or suppressed). The tree species list is used in WFAT to compute all tree mortality related fire effects.

The following figure (fig. 4-8) shows available outputs for Tree Mortality. All available mortality outputs can be selected by checking the first box, "**Tree Mortality (select all)**."

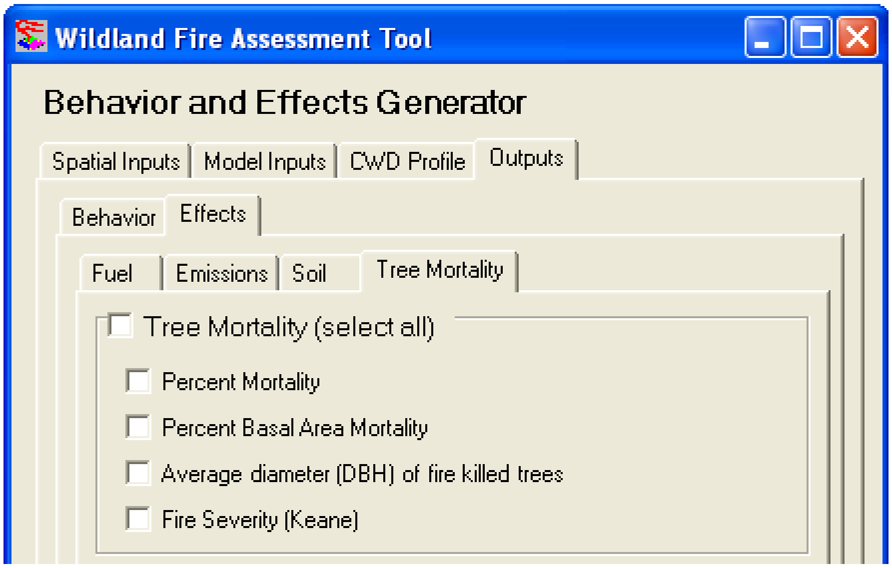


Figure 4-8. Tree List Mortality outputs.

4.2.2.5.1 Percent Mortality

Tree mortality is the number of dead trees post-fire divided by total number of pre-fire trees in the original stand, expressed as a percent. In WFAT, tree mortality is determined using predicted fireline intensity and midflame wind speed along with species-specific mortality models listed in the tree species list assigned to the pixel.

4.2.2.5.2 Percent Basal Area Mortality

Percent basal area mortality is the percentage of basal area of the original pre-fire stand that was killed as a result of the fire. For example, if the original stand had 33.29 ft^2 basal area and 28.92 ft^2 was killed, then percent basal area mortality would be 28.92/33.29*100 or 87%.

4.2.2.5.3 Average diameter (DBH) of fire-killed trees

The average diameter of fire-killed trees is calculated for each pixel in the map layer by averaging the diameter (found in the tree species list) of post-fire dead trees. This output can be especially useful when simulating a prescribed fire that has specific size allowances for fire-killed trees. An example might be when your objective is to remove small understory trees while retaining larger overstory trees.

4.2.2.5.4 Fire Severity (Keane)

The Fire Severity (Keane) index rates fire severity based on percent basal area mortality, percent non-canopy (surface and ground) fuel consumption, and depth of soil heated to 60^{o} C. It scores each variable and then averages the total to produce the index. The thresholds for each score are listed below:

Percent Basal Area Mortality	0	1-20	20-70	>70
Percent Non-canopy Fuel Consumption	0	1-20	20-50	>50
Depth Soil Heating to 60^{o} C (cm)	0	1-2	2-6	>6
Score:	**0**	**1**	**2**	**3**

Chapter 5: Installing the Wildland Fire Assessment Tool

5.1 General installation instructions

All NIFTT tools, including the Wildland Fire Assessment Tool (WFAT), are now downloaded and installed as single tools. A complete or package install is no longer available for versions of NIFTT tools compatible with ArcMap 9.2 and 9.3.

> ***Note**: For WFAT 2.0.0 to operate properly, you will need to verify that you are using ArcGIS 9.2, 9.3, or 9.3.1.*

If you have an earlier version of WFAT, installed on your computer, you will first need to uninstall it before proceeding with installation of the current version of WFAT. Since WFAT replaces FBAT and FOFEM Mapping Tool, we recommend that you uninstall those tools as well.

To determine which version is currently installed on your computer, go to **Start > Control Panel > Add or Remove Programs** as shown (fig. 5-1).

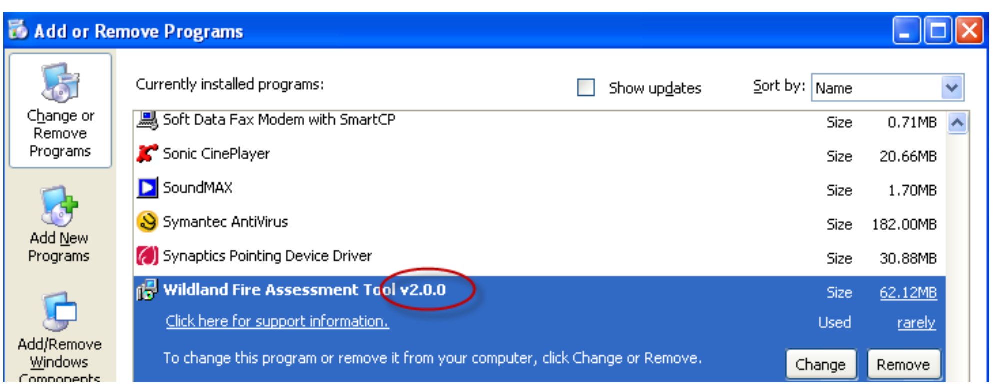


Figure 5 -1. Wildland Fire Assessment Tool version 2.0.0.

***Note**: NIFTT naming conventions are as follows: WFAT_Setup_110_081008 indicates that this "install" is version 1.1.0 and was completed on 8/10/2008.*

You may need administrative privileges to install WFAT. Contact your system administrator if you experience problems with the installation.

5.2 Wildland Fire Assessment Tool installation

5.2.1 Downloading the Wildland Fire Assessment Tool

Install or reinstall the Wildland Fire Assessment Tool (WFAT) as follows:

***Note**: If you have an earlier version of WFAT installed on your computer, you will first need to uninstall it before proceeding with installation of the current version. You should also uninstall any version of FBAT or the FOFEM Mapping Tool. Refer to section 5.1 for more information on this subject.*

Download WFAT from www.niftt.gov. Click on **Tools and User Documents** page.

***Note**: To continue with the download, you will need to have WinZip or a similar program installed on your computer.*

Click **OK** or **Save** to download the self-extracting WinZip WFAT installation file and then save it to a convenient location on your computer.

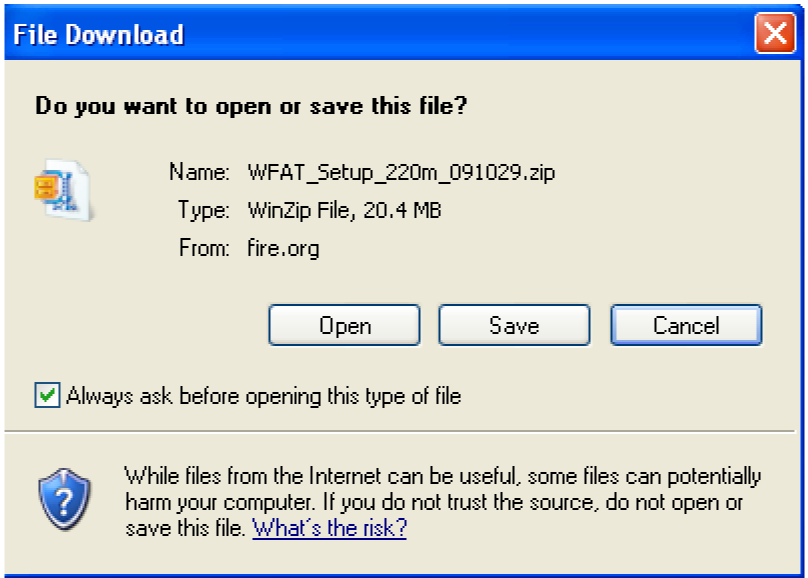


Figure 5-2. Download and save installation file.

5.2.2 Beginning the installation process

Go to the file in which you stored the WFAT zip file and double-click on the file as shown in figure 5-3.

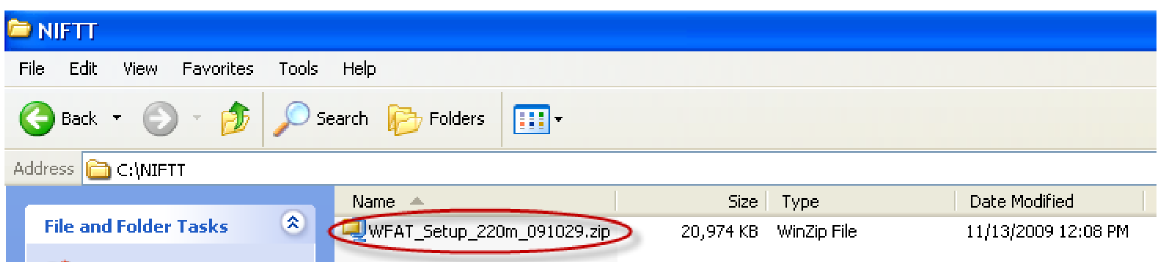


Figure 5-3. Self-extracting WFAT installation file has been downloaded and saved.

The box shown in figure 5-4 will open. Unzip the files to either the default location (C:\\NIFTT as shown in figure 5-3) or to another location of your choice by using the browse button. Next, navigate to the directory in which you have saved your extracted WFAT files.

> ***Note:*** *Do not install the Wildland Fire Assessment Tool or any other NIFTT tool to a pathway that may contain a space in the folder name such as "My Documents" or "Program Files."*

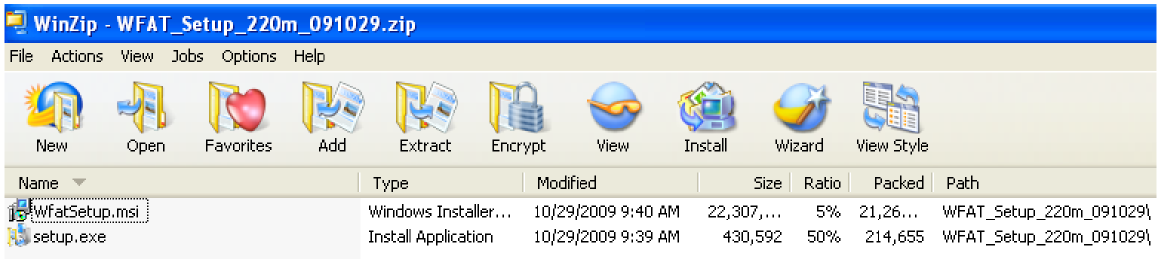


Figure 5-4. WFAT installation files.

Click on **setup.exe**.

> ***Note**: If the setup determines that an earlier version of WFAT is already installed on your computer, go to **Start > Control Panel** and select **Add/Remove Programs.** Uninstall the previous version of WFAT and then rerun **setup.exe**.*

If the setup.exe determines that you already have the proper .NET Framework (2.0) installed on your computer, the WFAT zip file contains everything that you will need to install the tool. A series of dialog boxes will now open. Skip to section 5.2.4 to continue installation.

5.2.3 Obtaining the latest .NET Framework

If the installer determines that the setup requires a .NET Framework that has not been previously installed on your computer, you will see a dialog box similar to the one displayed in figure 5-5 instead of the first WFAT Setup Wizard screen shown in figure 5-12.

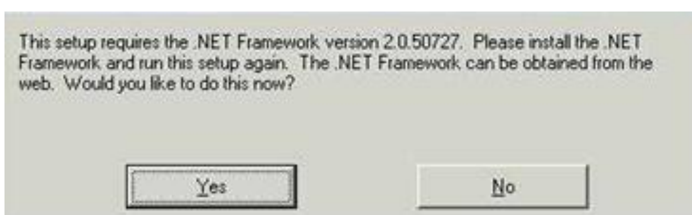


Figure 5-5. Dialog box indicating the need to first install .NET Framework for installation to proceed.

Click on **Yes** and follow all prompts as directed. If the .NET Framework 2.0 has not been previously installed on your computer, the setup will at this point direct you to a website where you will be able to download the appropriate file (fig. 5-6).

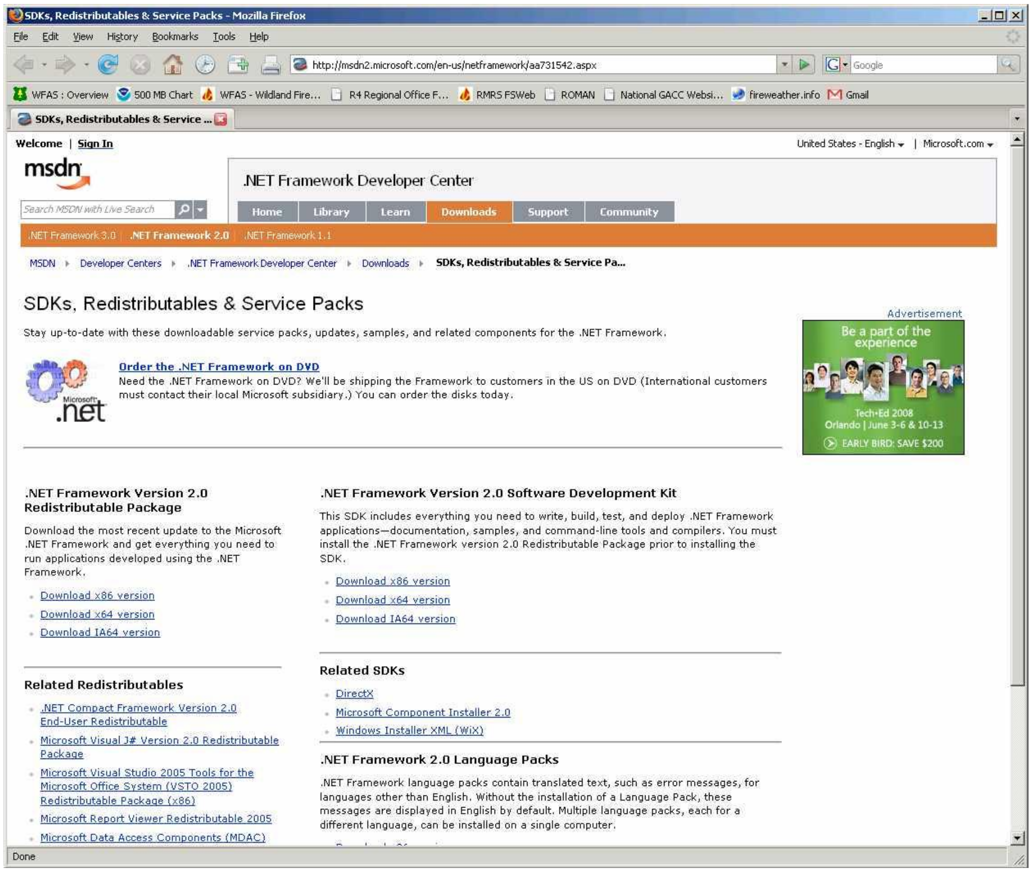


Figure 5-6. Website for downloading .NET Framework 2.0.

As shown in figure 5-7, you will now need to specify which version of the .NET Framework you would like to install on your computer. Select the x86 version if you have a Pentium (or other 32-bit) computer. Click on **Download x86 version**.

> ***Tip:*** *Most users will need to specify the x86 version of NET Framework 2.0. If you are unsure, contact your system administrator.*

Figure 5-7. Select an appropriate version of .NET Framework.

A screen similar to the following (fig. 5-8) will appear after your selection has been made. Click on the **Download** button to continue.

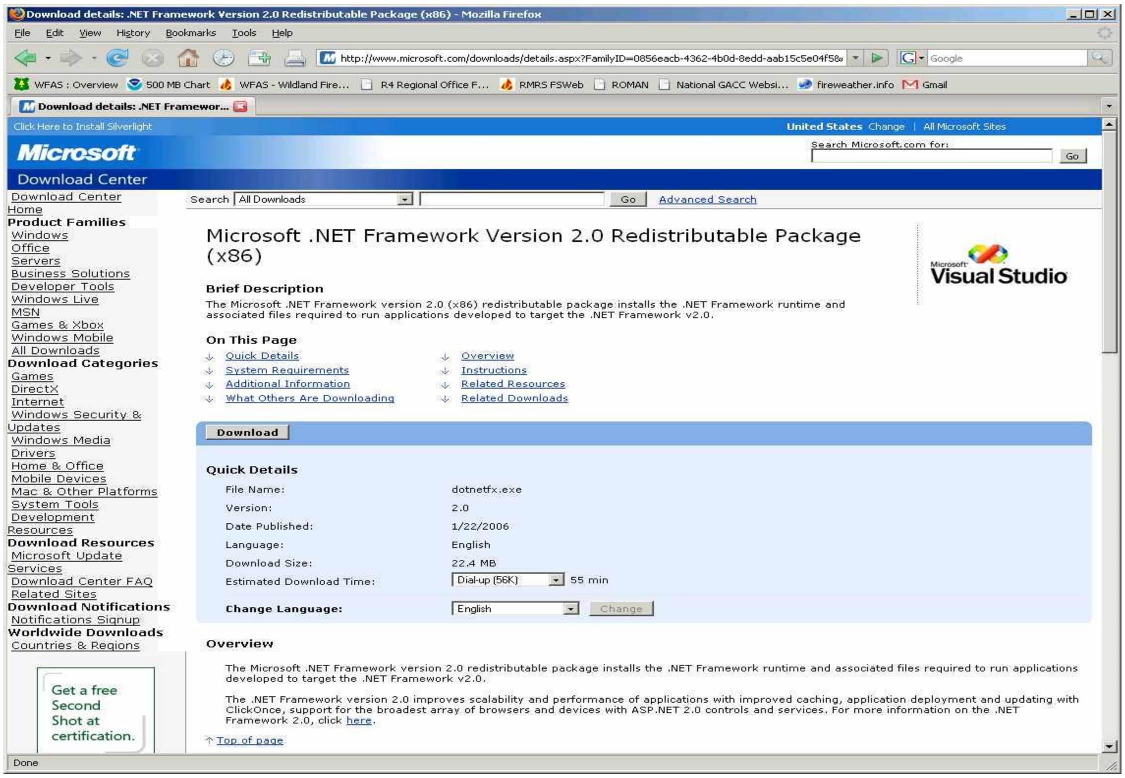


Figure 5-8. Microsoft .NET Framework Version 2.0 (x86) download page.

Browse to a location of your choice. Download and save the dotnetx.exe file as shown below (fig. 5-9).

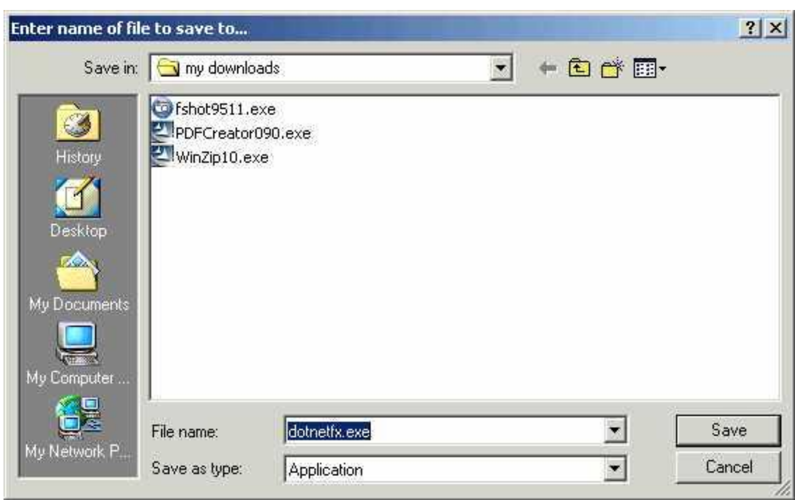


Figure 5-9. Save the file to a location of your choice.

Figure 5-10. Progress bar for download of dotnetfx.exe.

The Microsoft .NET framework 2.0 will automatically download, extract and install as shown in figures 5-10 and 5-11.

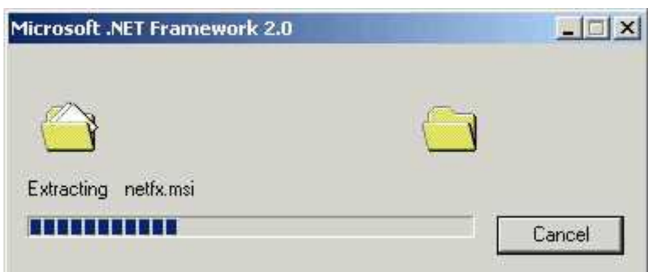


Figure 5-11. .NET Framework installation.

Click on the setup.exe file as shown in figure 5-4 to initiate the setup wizard and to continue installation of WFAT.

At this point, you may need administrative privileges to continue. Contact your system administrator if you experience problems

5.2.4 Finishing the installation

After clicking on the setup.exe file, the first in a series of WFAT Setup Wizard dialog boxes will open. Follow all instructions as directed by the dialog boxes in the WFAT Setup Wizard. During the installation process you may see a radio button asking you to specify whether the tool is to be installed for "Everyone" or "Just Me." Select the "Everyone" option.

***Note**: With WFAT version 2.0.0, it is no longer necessary to reboot your computer during the installation process.*

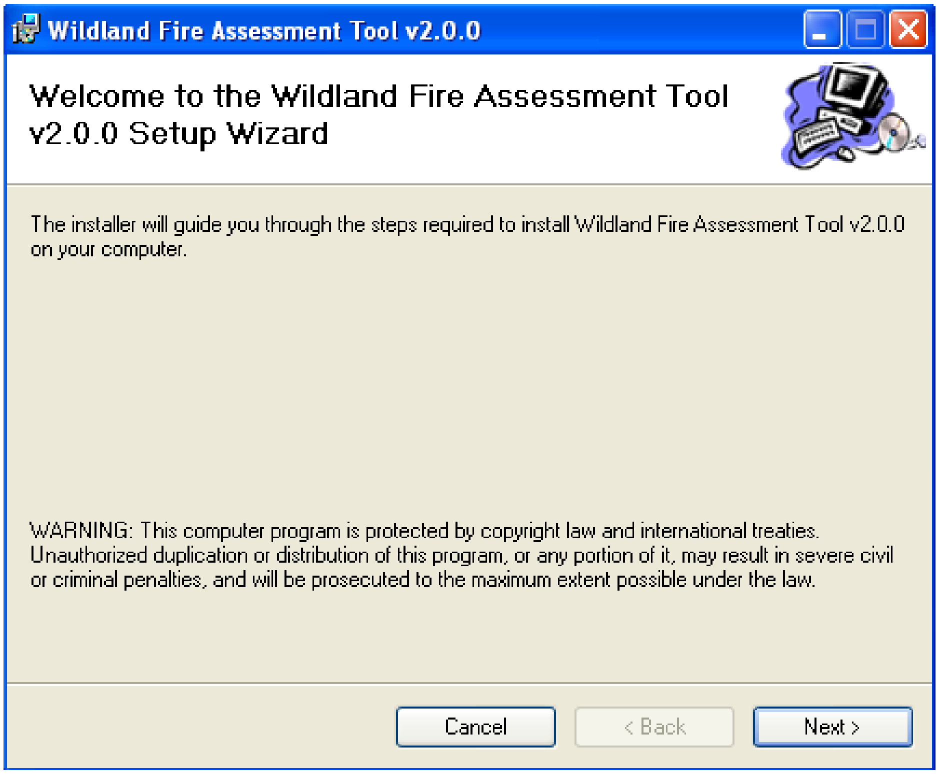


Figure 5-12. WFAT setup wizard.

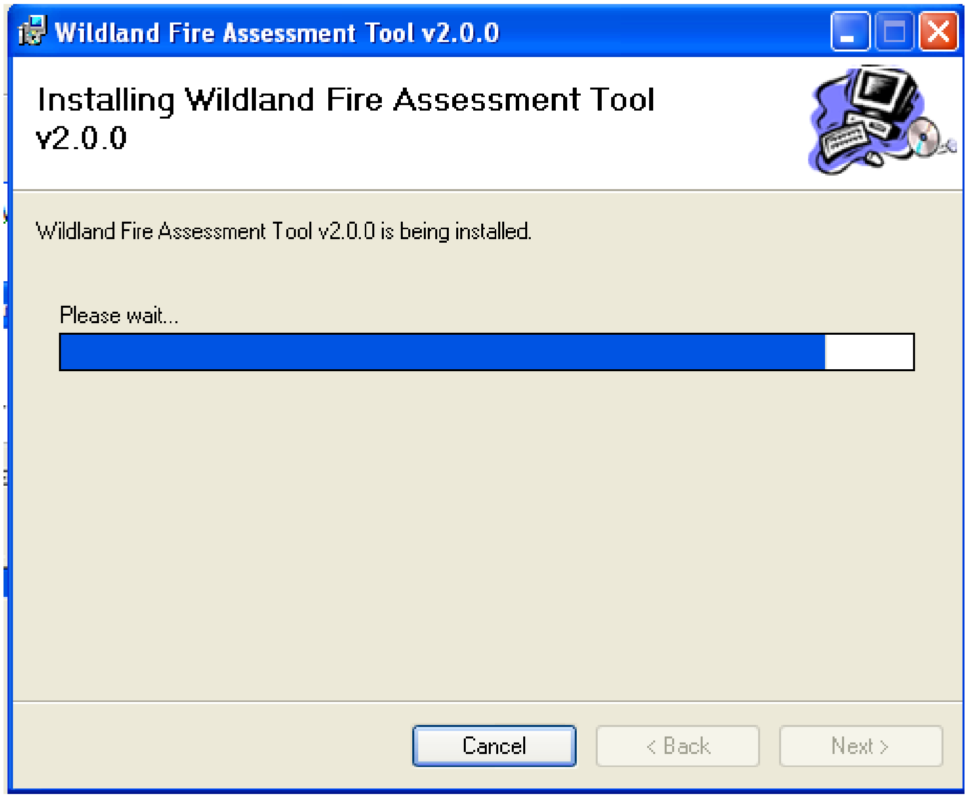


Figure 5-13. Setup Wizard continues installation process.

Click on **Finish** when WFAT installation is complete.

Open ArcMap and make sure that the WFAT toolbar  is visible.

Note: *The WFAT toolbar may be "floating." If so, you will need to anchor it in a convenient location.*

Tip*: For best results, make sure that you have installed the most recent ArcGIS service packs and patches. Go to www.esri.com to verify that you have the most recent versions (for 9.2 or 9.3) already installed on your computer. If you do not, download the newer service packs and patches as directed on the website.*

5.3 Troubleshooting the Wildland Fire Assessment Tool installation

If the WFAT toolbar as shown at right  does not install automatically, select **View > Toolbars** and check the box to the left of **WFAT** as shown in figure 5-14.

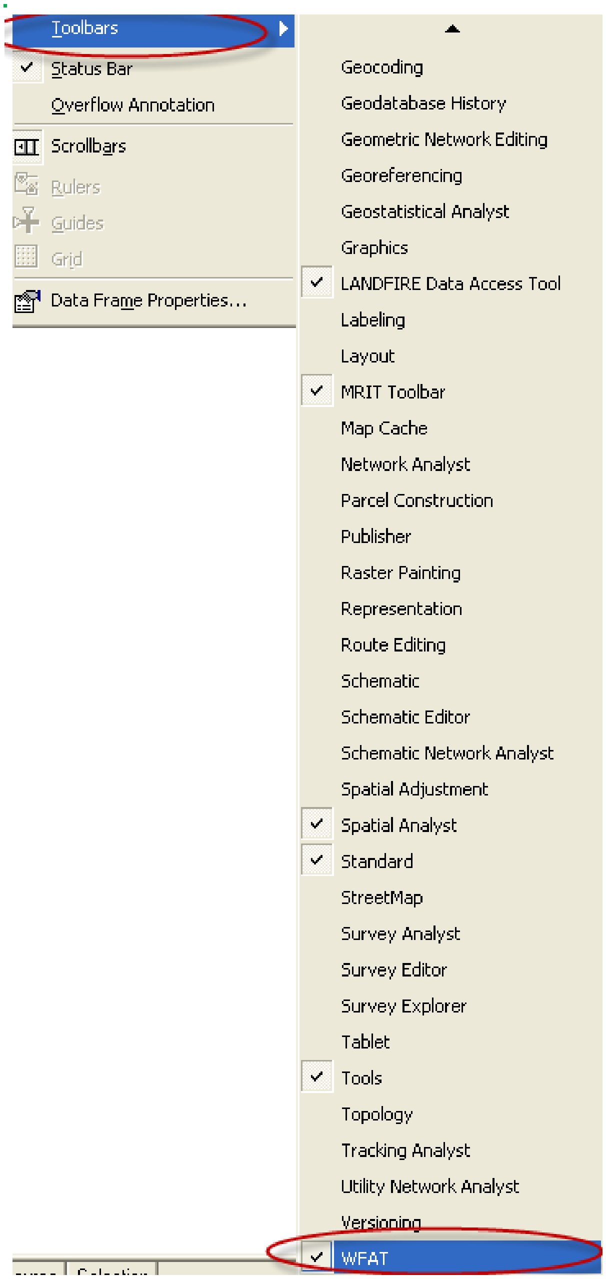


Figure 5-14. Verify that the box to the left of WFAT is checked.

In ArcMap, select the **Tools** menu and click on **Customize**. Again, make sure that the box to the left of WFAT is checked (fig. 5-15).

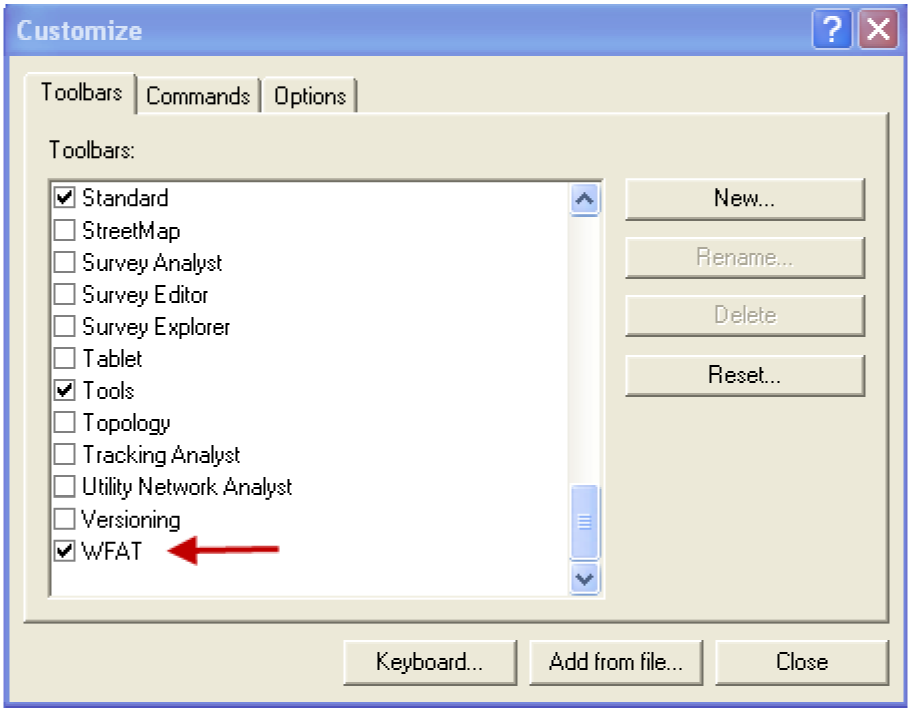


Figure 5-15. Check the box to the left of **WFAT.**

If the WFAT box is still unavailable in the **Toolbars** list, click on **Add from file** (fig. 5-16).

> ***Note***: *To continue this process, you must first log on as an "Administrator." Contact your systems administrator if you experience problems.*

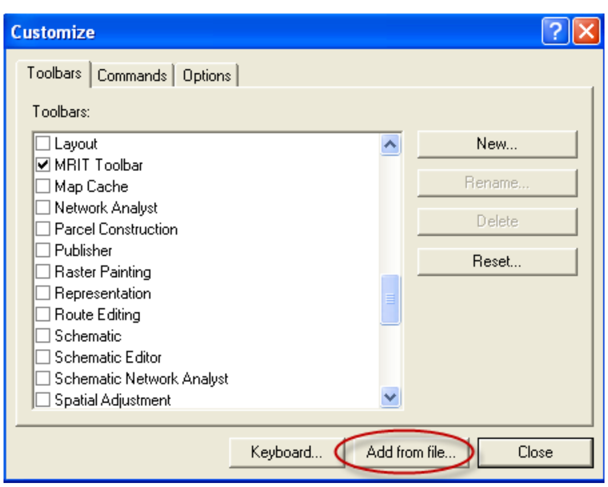


Figure 5-16. Select **Add from file...**

Navigate to the directory in which you have saved your extracted WFAT files (the default location is (C:\\NIFTT)) and select **WFAT.dll** from the **Wildland Fire Assessment Tool v2.0.0 bin** folder as shown in figure 5-17.

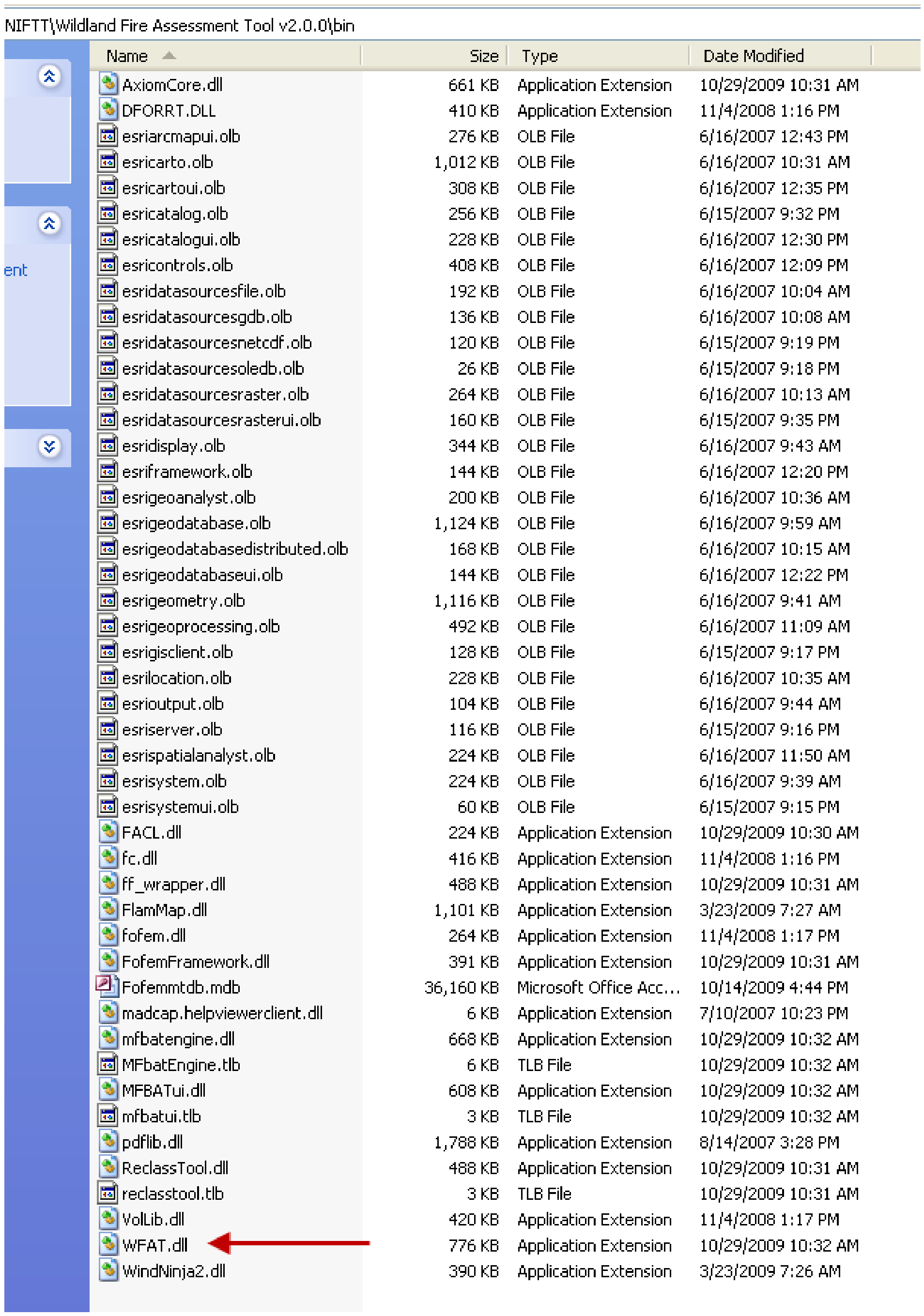


Figure 5-17. Select **WFAT.dll** from bin folder.

The WFAT toolbar should now be enabled and ready for use. Check it now if it is not already selected.

***Note**: For all NIFTT tools, including WFAT, to function properly, the Spatial Analyst extension must be installed and activated. To make sure, open ArcMap, go to the **Tools** menu and select **Extensions**. Make sure that the box to the left of **Spatial Analyst** is checked and click **Close**.*

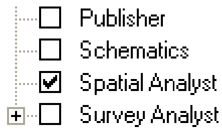


Figure 5-18. Check the box to the left of Spatial Analyst.

Direct any questions on WFAT installation to helpdesk@niftt.gov.

Chapter 6: Running the Wildland Fire Assessment Tool

6.1 The Wildland Fire Assessment Tool toolbar

The WFAT toolbar consists of the icons shown in figure 6-1.

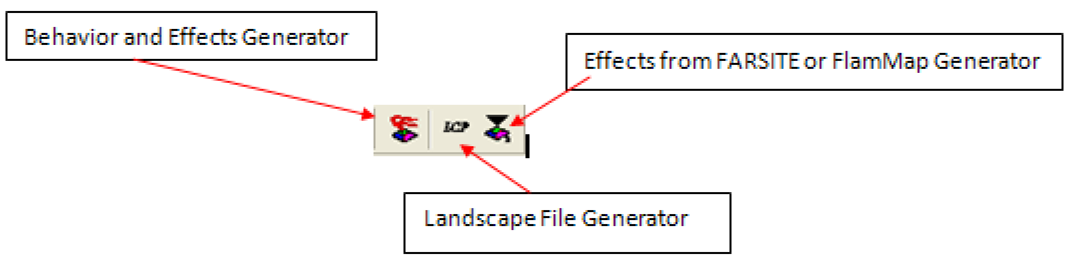


Figure 6-1. Wildland Fire Assessment Tool toolbar.

Clicking the first icon on the WFAT toolbar opens the **Wildland Fire Assessment Tool, Behavior and Effects Generator** dialog box (fig. 6-2). This dialog box is used to specify spatial and model inputs, a CWD profile, as well as desired outputs.

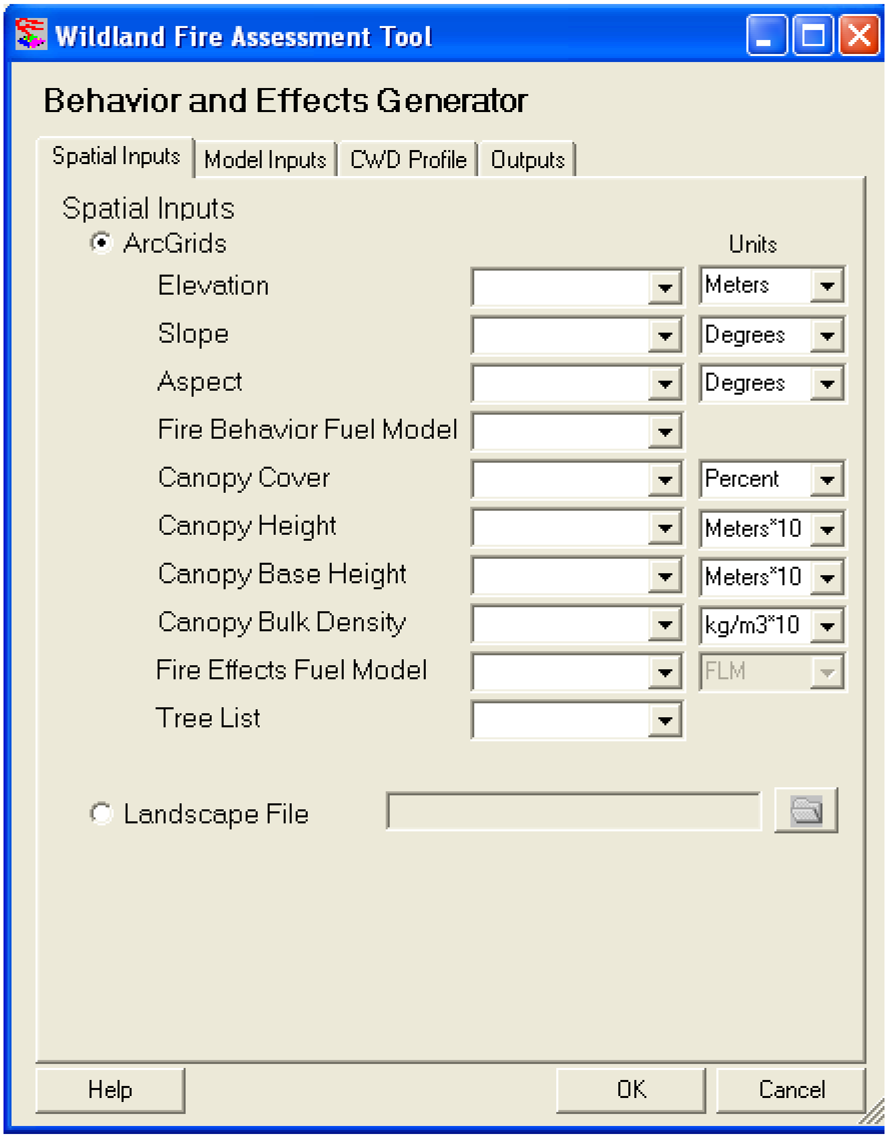


Figure 6-2. **Wildland Fire Assessment** dialog box showing the **Behavior and Effects Generator**.

> ***Note**: The Wildland Fire Assessment Tool dialog box consists of several tabs but initially opens to the **Spatial Inputs** tab. Default units are shown in figure 6-2.*

6.2 How to run the Wildland Fire Assessment Tool – an overview

To run the Wildland Fire Assessment Tool:

1. Start ArcMap and load spatial input layers into your ArcMap project by clicking the **Add Data** icon (fig. 6-3):

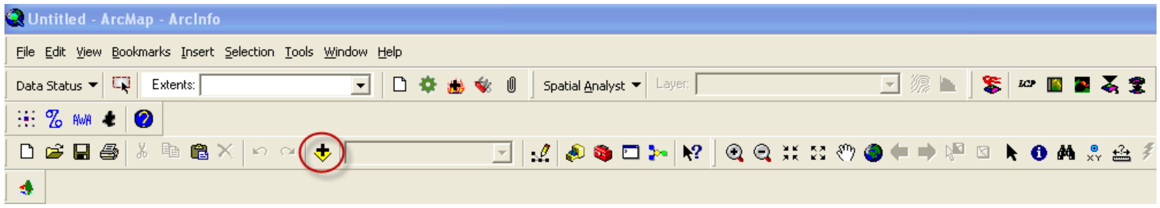


Figure 6-3. Loading spatial input layers.

2. Navigate to the directory where your data layers are stored and add the following spatial input layers: Elevation, Aspect, Slope, Fire Behavior Fuel Model (FBFM), Canopy Cover (CC), Canopy Height (CH), Canopy Base Height (CBH), Canopy Bulk Density (CBD), Fire Effects Fuel Model (FEFM), and Tree List.

   ***Note**: All spatial layers must be in ESRI Grid format for use as WFAT inputs.*

   ***Tip**: At this point, you may see several "Create pyramids" dialog boxes similar to the box shown in figure 6-4. Click **No** to speed up processing. If you do not want to see this box again, put a check in the lower left-hand corner to disable it.*

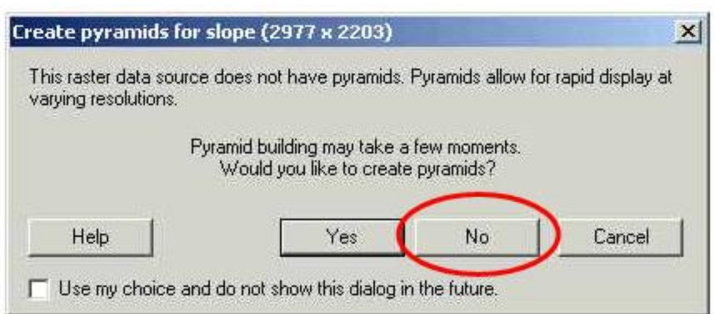


Figure 6-4. Create pyramids dialog box.

3. Ancillary layers can be added at this time. Layers such as cities, roads, streams, wildland-urban interface, ownership, and other files can often be useful for interpretation and description, as well as for consideration of management implications.

4. Select **Model Inputs**, a **CWD Profile**, and then specify outputs by clicking on the appropriate tabs on the **Wildland Fire Assessment Tool** dialog box. Fill in all required fields (fig. 6-2). (Sections 6.2.1 through section 6.2.5 discuss these steps in detail).

5. Click **OK**.

6. Save your project with the file name of your choice.

   ***Note**: You do not need to include the extension .mxd when naming your project.*

6.2.1 Selecting spatial inputs for the Wildland Fire Assessment Tool

Click on the **Wildland Fire Assessment Tool** icon in ArcMap as shown in figure 6-5:

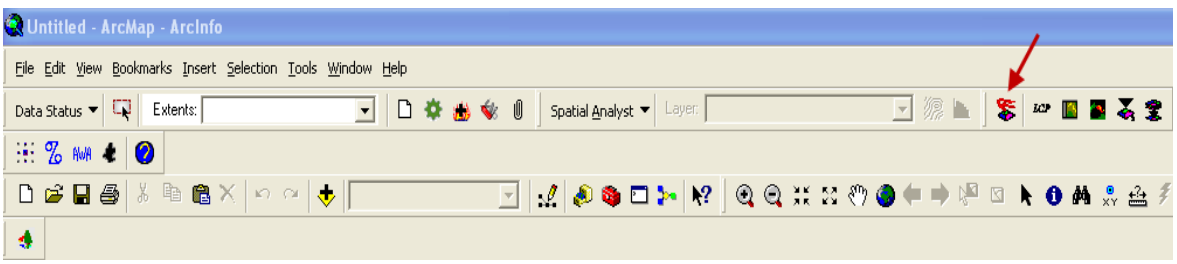


Figure 6-5. Wildland Fire Assessment Tool toolbar.

The following **Behavior and Effects Generator** dialog box will open:

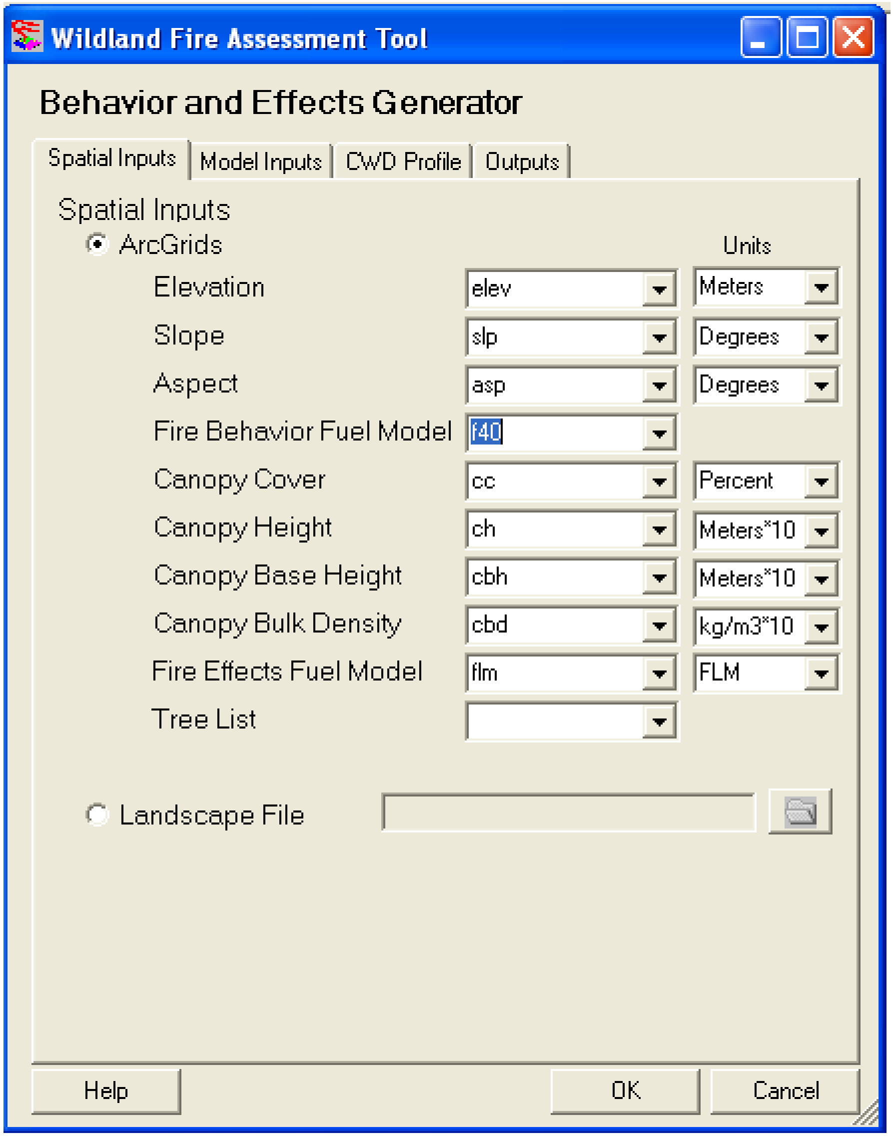


Figure 6-6. The **Behavior and Effects Generator** dialog box with **Spatial Inputs** tab selected.

> ***Note**: First click on the "**Spatial Inputs**" tab if this screen is not already active (fig. 6-6).*

Spatial Input layers

> ***Note**: WFAT will automatically enter layers named according to the LANDFIRE Data Access Tool conventions. If layers are not immediately inserted into the correct field, you can use the drop-down menu to select the appropriate layer from the ArcMap Table of Contents.*

Select **Elevation**, **Slope**, and **Aspect** from the drop-down options.

For the Fire Behavior Fuel Model input, WFAT can use either the original 13 fire behavior fuel models described by Anderson (1982) or the 40 fire behavior fuel models as characterized by Scott and Burgan (2005). Custom fire behavior fuel models cannot be used.

Enter **Canopy Cover**, **Canopy Height**, **Canopy Base Height**, and **Canopy Bulk Density** from the drop-down menu options.

Select a fire effects fuel model characterization to describe fuelbed inputs from the drop-down box to the right of the FEFM layer. Three choices are currently available: FLM (LANDFIRE Fuel Loading Model), FCCS (LANDFIRE Fuel Characteristic Classification), and Custom (fig. 6-7). Custom layers must be created in the ESRI Grid format with a value attribute table. (See section 3.2.9 for more information). Relative advantages of fuel bed characterization models are discussed in Lutes and others (2008).

Select the **Tree List** layer if desired.

Tree List grids necessary for estimating tree mortality, are currently unavailable. Hopefully these data will become available in the near future. Please contact the helpdesk@niftt.gov for a status update on the availability of tree list grids for the continental United States.

***Note**: All spatial input layers must be in ESRI Grid format.*

Where applicable, you can select English or metric units from drop-down menus associated with each spatial input layer (fig. 6-6). A summary of available units for each spatial layer is provided in table 3-1. Default units are displayed in figure 6-6.

***Note:** Default unit selections correspond to LANDFIRE units.*

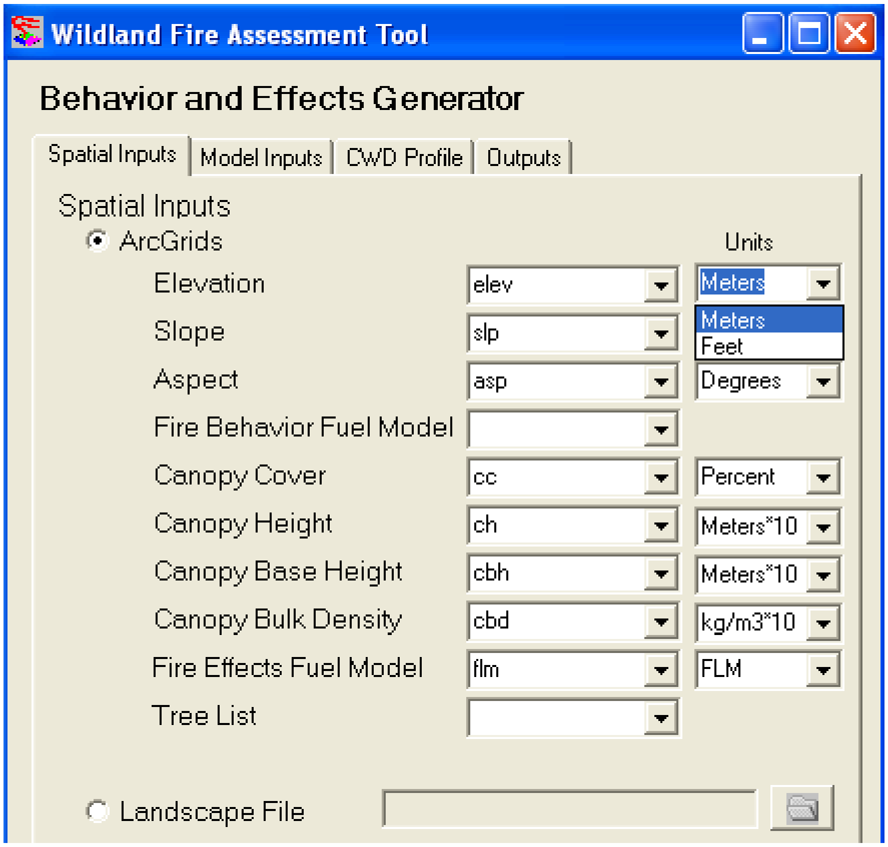


Figure 6-7. Drop-down menu showing "**Units**" options for elevation.

If a "Custom" FEFM layer is selected, an additional tab (**Custom FEFM**) will be added to the **Behavior and Effects Generator** dialog box as shown in figure 6-8. If using a custom fuelbed characterization, you will need to select field names for each corresponding attribute by using the drop-down menu to the right of each attribute box (fig. 6-8).

> ***Note**: If you have selected a FLM or FCCS fuelbed characterization for your run, the Custom FEFM tab will not appear at the top of the dialog box. Only four tabs will be visible (fig. 6-7).*

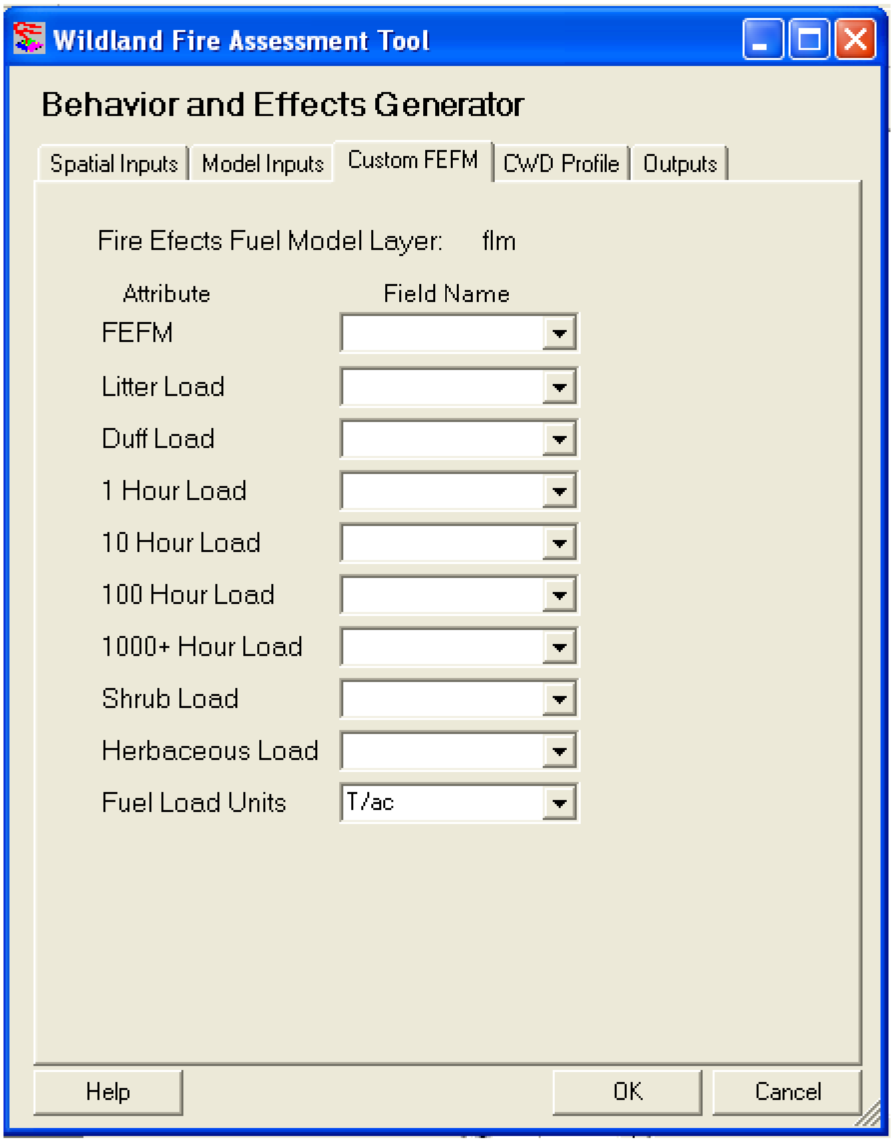


Figure 6-8. **Custom FEFM** tab in **Behavior and Effects Generator** dialog box.

Do not click **OK** until you have completed the **Model Inputs**, **CWD Profile**, and **Outputs** tabs. You will also need to specify an output folder location before running WFAT.

Landscape Files

As an alternative to specifying each spatial input layer, you can use an already existing landscape file or (.lcp) that was derived using FlamMap, FARSITE, FBAT, FOFEMMT, or WFAT. Check the radio button to the left of **Landscape File** and use the browse button to navigate to the .lcp you would like to use for your analysis (fig. 6-9). You will also need to specify a fire effects fuel model.

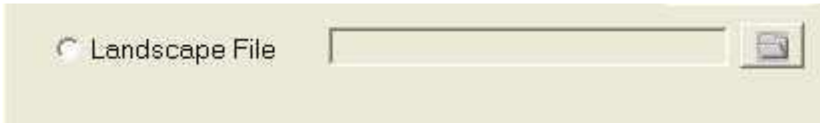


Figure 6-9. Use the browse button to select a preexisting Landscape File (.lcp).

Do not click **OK** until you have completed the **Model Inputs, CWD Profile**, and **Outputs** tabs.

6.2.2 Selecting model inputs

After you have completed the **Spatial Inputs** tab, click on the **Model Inputs** tab as shown below (fig. 6-10):

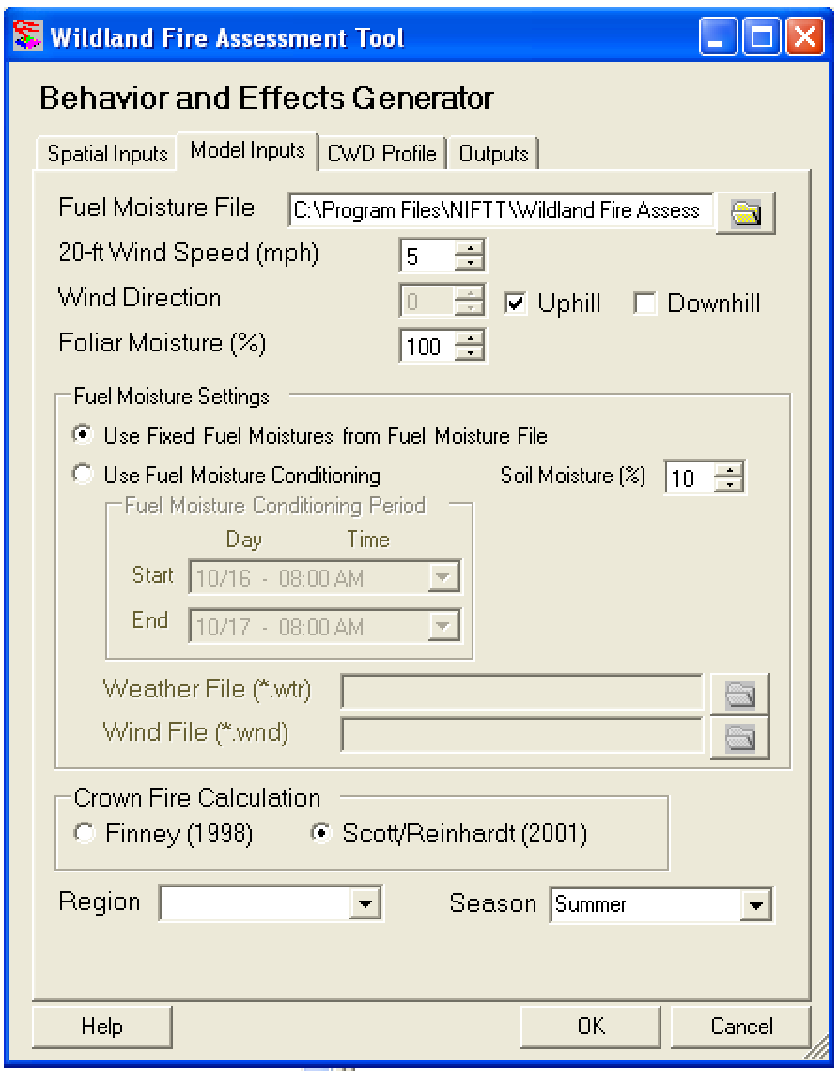


Figure 6-10. **Model Inputs** tab of the **Behavior and Effects Generator** dialog box showing default values.

This dialog box is used to specify model inputs to WFAT including fuel moisture values, wind speed and direction, crown fire calculation method, region, and season (see section 3.3 for more information).

1. First use the browse button to the right of the **Fuel Moisture File** box (fig. 6-11) to navigate to the file you would like to use to specify initial fuel moisture values for each of the fire behavior fuel models. The Fuel Moisture File includes values for 1-hr, 10-hr, 100-hr, live herbaceous and live woody fuel. WFAT is installed with a folder of default fuel moisture files for High, Moderate, Low, and Very Low fuel moisture conditions, as well as default files for Fire Behavior Fuel Model 13 and FBFM 40 data. To use any of these files, navigate to the "Fuel Moisture" folder inside the WFAT installation folder (default is C:\Program Files\NIFTT\Wildland Fire Assessment Tool v2.0.0). (See section 3.3.1 for specific information on the derivation and use of this file).

Note: *1000-hr initial fuel moistures are specified in the CWD Profile.*

Figure 6-11. Use the browse button to select a Fuel Moisture File.

Tip: *You can use data obtained from WIMS and FireFamily Plus to create a fuel moisture file appropriate for specific simulation scenarios by developing a space-delimited text file as described in section 3.3.1.*

2. Next enter a 20-ft (6.1 m) wind speed in the box to the right of **Wind Speed** (20-ft). You can type in the value directly, or you can use the spinner box to raise or lower the value. This parameter represents the wind speed occurring 20 feet (6.1 m) above the canopy as expressed in *miles per hour*. The default wind speed is 5 miles per hour (8.1 km/hr).

3. Enter **Wind Direction** by using either the drop-down menu (make sure that both **Uphill** and **Downhill** are unchecked to enable this selection), or by checking one of the boxes to the left of **Uphill** or **Downhill**. Wind Direction is expressed in azimuth in degrees in the direction the wind is blowing *from* (fig. 6-12). Check the **Uphill** box if you want to maximize potential fire behavior on any particular site.

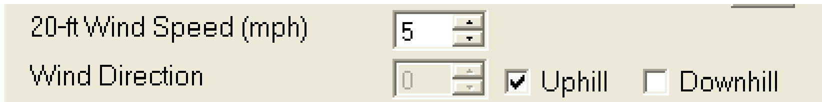


Figure 6-12. Select Wind Speed and Direction.

4. Next enter the **Foliar Moisture Content** (in percent) of live leaves or needles in the overstory by typing in the value directly, or by using the spinner box to raise or lower the value. Foliar moisture content usually ranges between 80 and 130 percent. Typical conditions are often represented by a value of 100 percent foliar moisture content (see section 3.3.4 for additional information).

5. Specify **Fuel Moisture Settings** by using the radio button to the left of the options shown in figure 6-13. Two options are included in the dialog box: **Use Fixed Fuel Moistures from Fuel Moisture File**, the default selection, and **Use Fuel Moisture Conditioning**. Fixed fuel moisture values correspond to the fuel moistures in the initial fuel moisture (.fms) file and vary spatially only with the fire behavior fuel model (see section 3.3.5). Fuel moisture conditioning corresponds to adjusting fuel moisture values spatially based on topography, shading, weather, and conditioning period length.

6. Next enter a **Soil Moisture** value. You can type in the value directly or you can use the spinner box to raise or lower the value. Typical soil moisture values range from approximately 5% (very dry) to 25% (wet) (see section 3.3.5.6 for additional information).

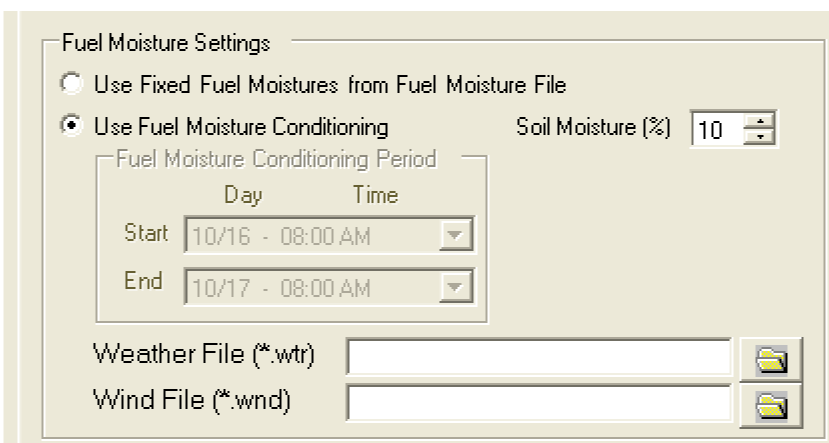


Figure 6-13. Fuel Moisture Settings.

7. If you selected the Fuel Moisture Conditioning option, you will need to select a Weather File (.wtr) and Wind File (.wtr) using the browse buttons to the right of the "Weather File (*.wtr)" and "Wind File (*.wnd)" windows. (See section 3.3.5.3 for additional information on these files).

Note: *Weather (.wtr) and Wind (.wnd) files are ASCII text files that are required to run the optional dead fuel moisture model in FlamMap. This is the same format used in FARSITE and FlamMap, so files are interchangeable between the applications.*

8. To use the Fuel Moisture Conditioning option, you will need to identify a "Start" and "End" period including both Day and Time *after* selecting your wind and weather files. (These options are available only after selecting the radio button next to "Use Fuel Moisture Conditioning"). Use the spinner box to the right of the "Start" and "End" windows to specify a time period for fuel moisture conditioning. The start and end times must fall within the range provided by your wind and weather files; for help on reading the files, see sections 3.3.5.3 and 3.3.5.4.

9. Select one of two available **Crown Fire Calculation** methods: Finney (1998) or Scott/Reinhardt (2001) to model the transition between passive and active crown fire. Select the radio button to the left of the algorithm that you prefer to use (see section 3.3.6).

10. Select a **Region** from the options available by using the drop-down menu to the right of the box as shown (fig. 6-14) (see section 3.3.7 for additional information).

Figure 6-14. Drop-down menu showing options for **Region**.

11. Finally, choose **Season** from the drop-down list at the bottom right of the dialog box (fig. 6-15). (See section 3.3.8 for more information).

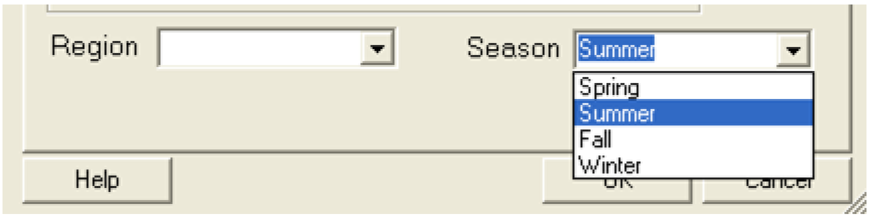


Figure 6-15. **Drop-d**own menu showing **Season** options.

Do not click **OK** until you have completed the **CWD Profile**, and **Outputs** tabs in addition to the tabs (**Spatial Inputs** and **Model Inputs**) you have already completed.

6.2.3 Selecting a Coarse Woody Debris (CWD) profile

Coarse Wood Debris (CWD) refers to down woody material greater than or equal to 3 inches (7.6 cm). Click on the **CWD Profile** tab at the top of the **Behavior and Effects Generator** dialog box and the following screen will open (fig. 6-16):

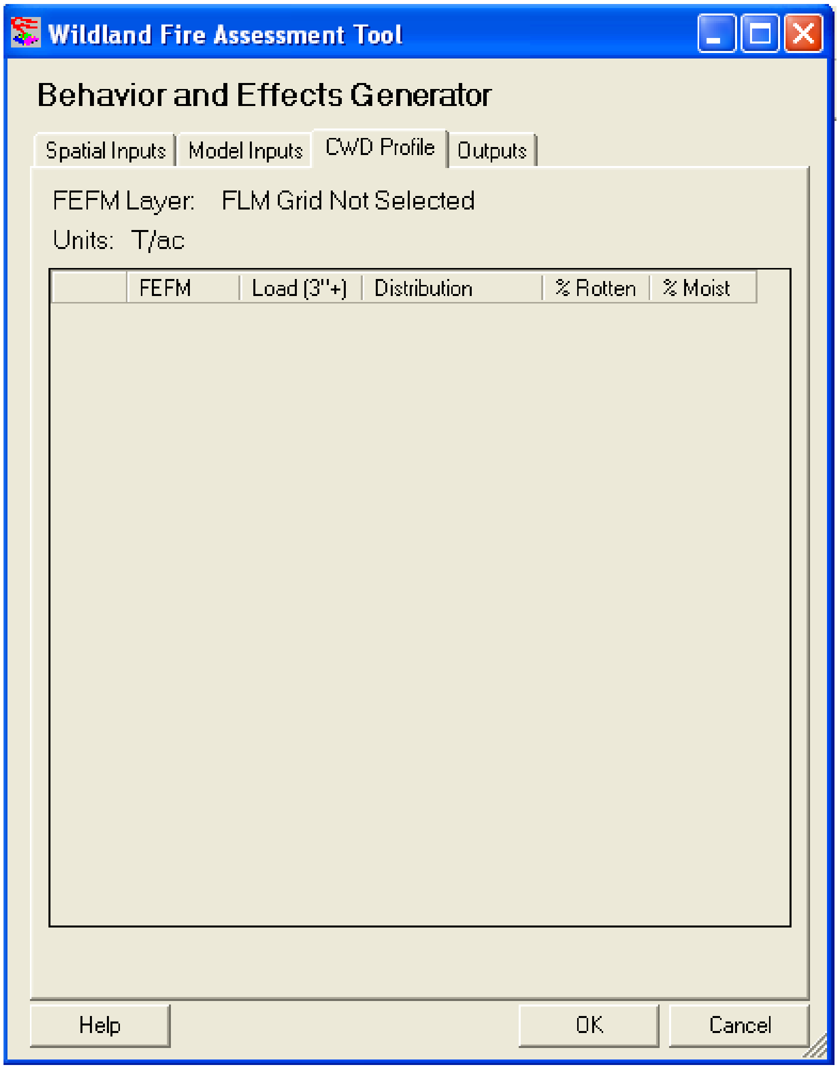


Figure 6-16. **CWD Profile** tab on the **Behavior and Effects Generator** dialog box.

Once you have completed the **Spatial Inputs** tab, including the Fire Effects Fuel Model drop-down selection, the **CWD Profile** tab is populated using the FEFM layer you specified.

An example CWD Profile for a FEFM layer (FLM) is shown below (fig. 6-17):

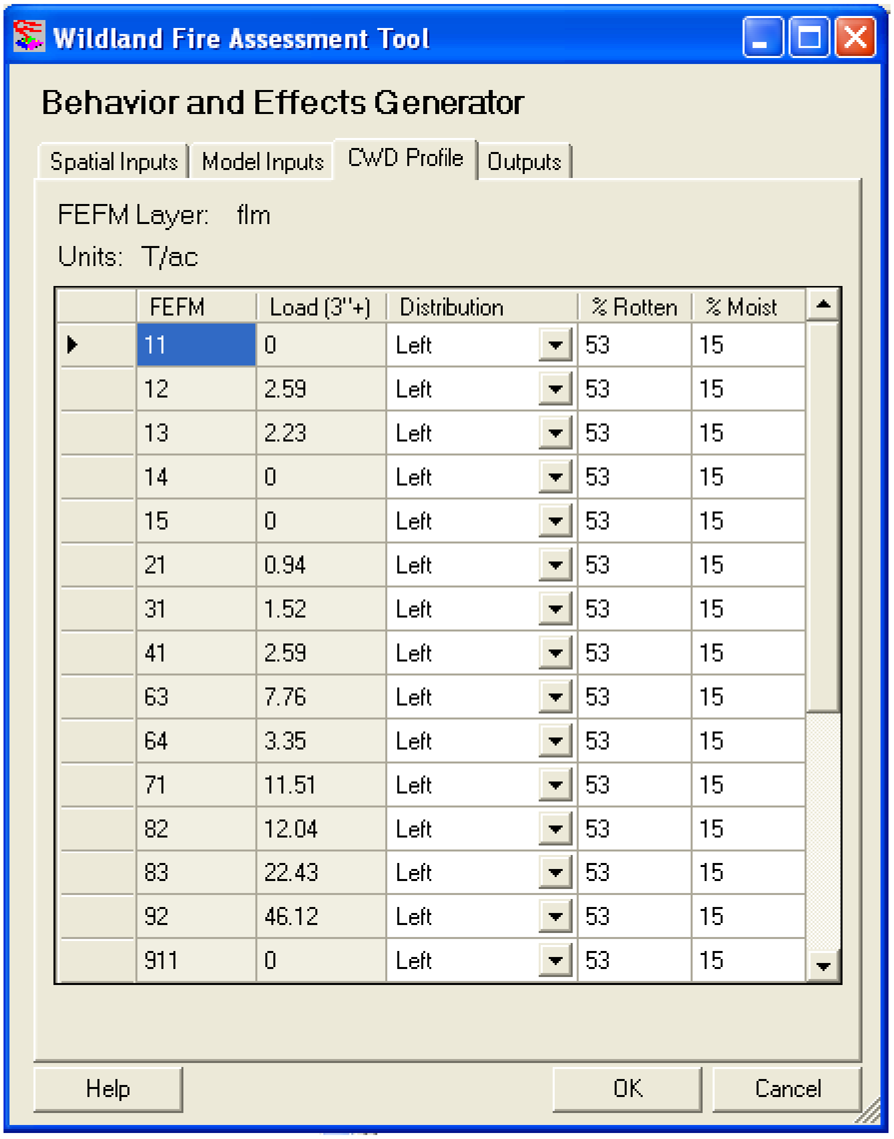


Figure 6-17. Example FEFM layer on **CWD Profile** tab.

***Note**: The "Load (3"+)" column displays the total fuel load of the CWD. If an FLM or Custom FEFM is selected, a default "Left" distribution and 53% rot is applied to the load for each FEFM. FCCS fuelbeds include information on the distribution and percent rot of the CWD load and are shown in the dialog box. Any modifications made here will redistribute the load from its original values. (See section 3.4 for more information on this subject.)*

Use the **CWD Profile** tab to specify a CWD profile for each value in the FEFM layer. Values include fuel load 3 inch (7.6 cm) or greater in tons per acre, load distribution, percent rotten, and percent moisture (see section 3.4).

1. To edit values, click in the cell within the FEFM that you would like to change.

2. Highlight the cell and type in a new value if desired.

3. The third column, "Distribution" contains a drop-down menu for convenience. Use the drop-down menu to select a new log distribution (Left, Center, Right, Even, or End) for each value you would like to edit (fig.6-18).

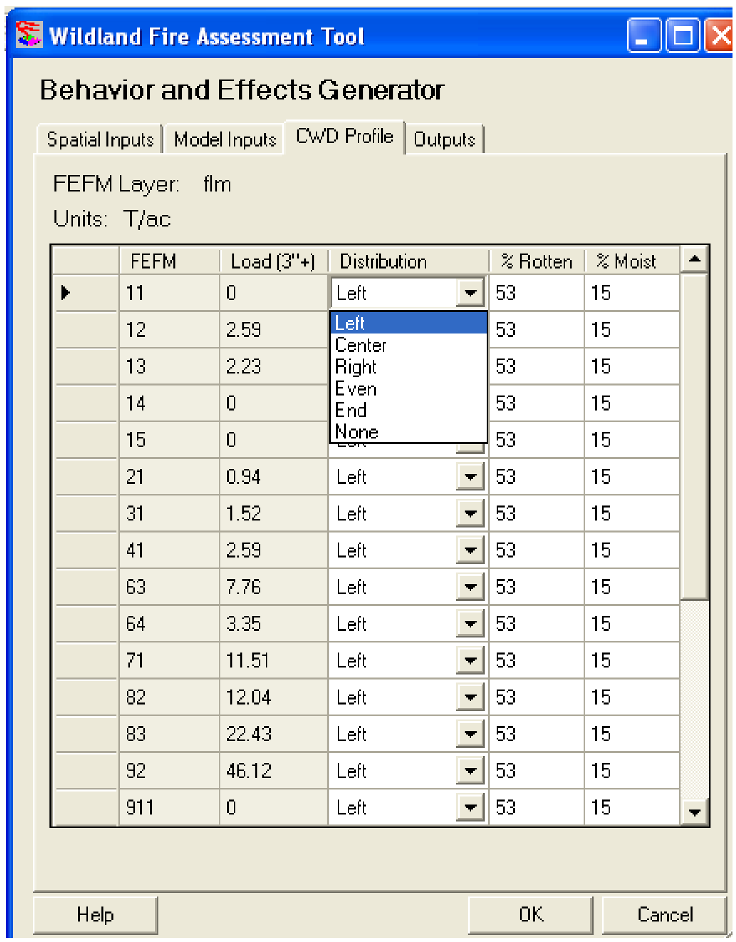


Figure 6-18. Distribution drop-down menu on **CWD Profile** tab.

4. Finish all edits on the **CWD Profile** tab, but do not click **OK** until you have completed required information on all tabs and have specified an output folder name and location.

6.2.4 Selecting output layers

1. Click on the **Outputs** tab located at the top right of the **Behavior and Effects Generator** dialog box and the following screen will open (fig. 6-19).

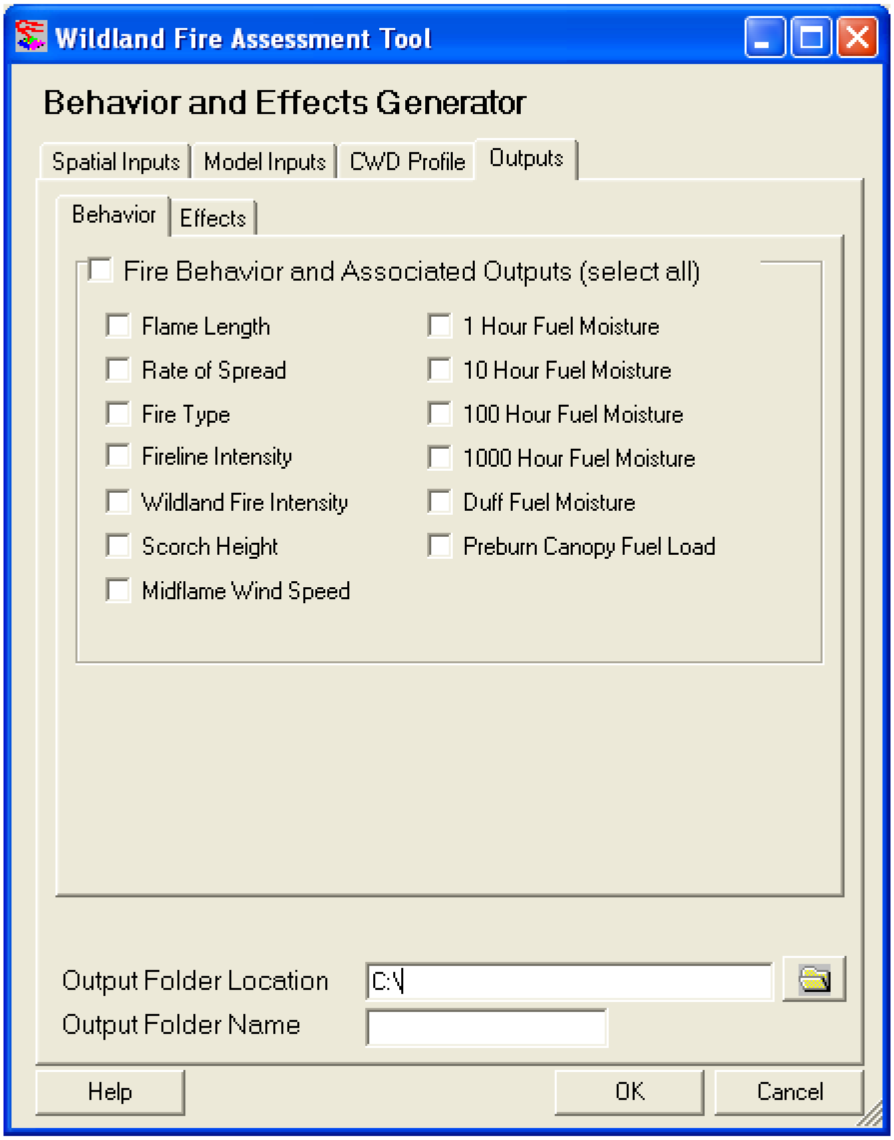


Figure 6-19. **Outputs** tab of the **Wildland Fire Assessment Tool** dialog box.

WFAT generates fire behavior outputs as well as four categories of spatial fire effects outputs: Fuel, Emissions, Soil, and Tree Mortality (fig. 6-20).

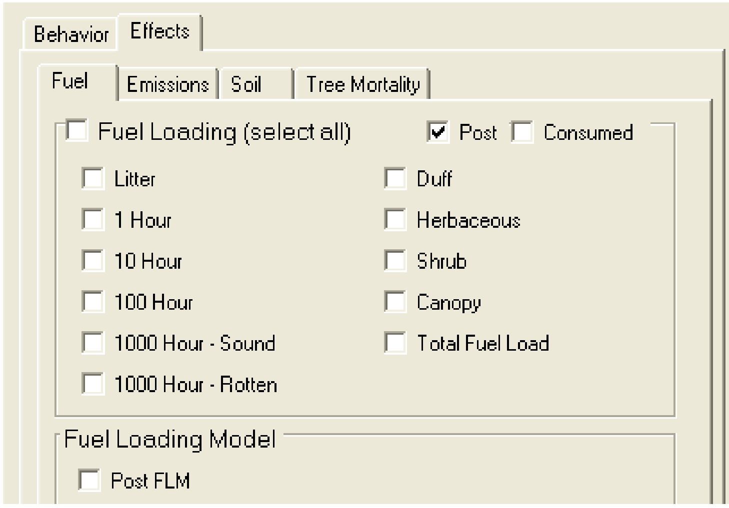


Figure 6-20. **Effects** tab showing "**Fuel**" selected.

2. View the **Outputs** tab and select all layers to be generated in each category. (Chapter 4 provides a detailed discussion of available output layers.) Click on the "**Behavior**" tab and begin with the desired Fire Behavior Outputs. Click on the top box "**Fire Behavior and Associated Outputs**" to select all of the available fire behavior outputs (fig. 6-21).

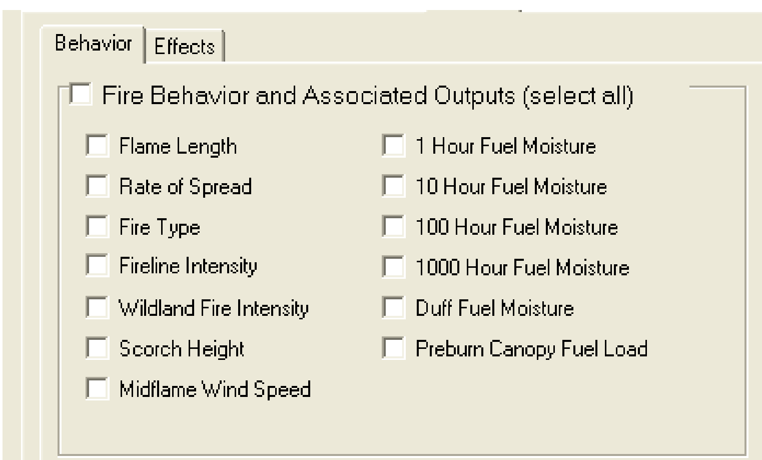


Figure 6-21. **Behavior** tab showing possible output selections.

3. Next click on the **Effects** tab and select the **Fuel** tab at the top left to view selections for fuel consumption outputs (fig. 6-22).

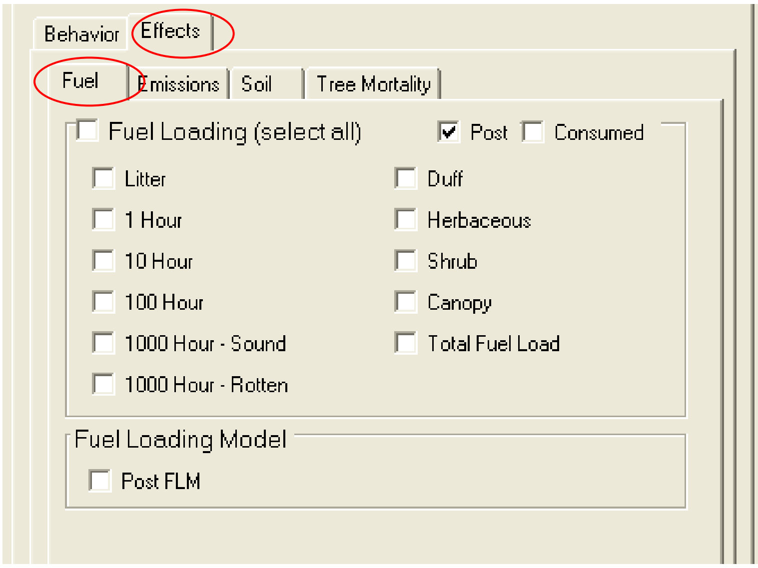


Figure 6-22. **Effects** tab showing **Fuel** selection options.

The upper portion of the **Outputs** tab of the dialog box shown above (fig. 6-22) provides options for fuel consumption. You can select postburn fuel load (Post), the amount of fuel load that is consumed (Consumed) or both options by checking the appropriate boxes. (The default selection is "Post"). See section 4.2.1 for further information. All Fuel Loading output options will be selected if you check the top **Fuel Loading (select all)** box.

4. If you would like to select individual fuel loading layers, check the appropriate boxes of all of the layers you would like to generate.

5. Select the **Emissions** tab to view all available emissions options (see section 4.2.2). Check the boxes to the left of the emission layers you would like to generate (fig. 6-23). Select the box to the left of **Emissions (select all)** to select all of the emission layers.

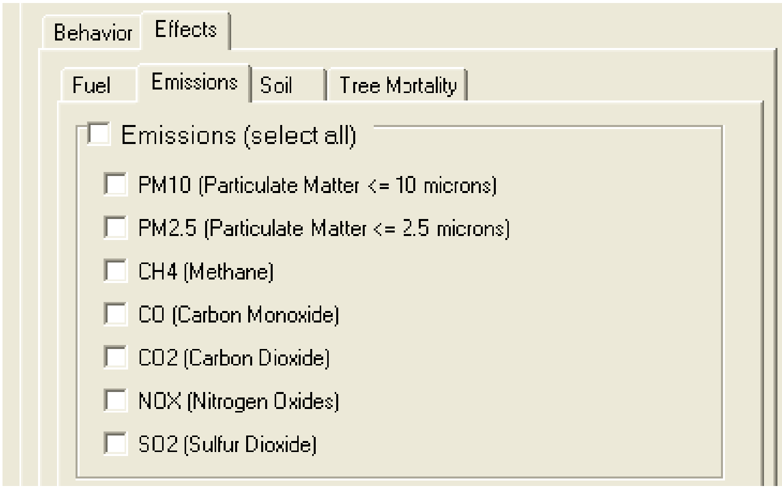


Figure 6-23. **Emissions** output layers showing default selections.

6. Click on the **Soil** tab under the **Effects** tab. The following output layers address soil heating and the percent of mineral soil exposed (fig. 6-24). Select the soil heating layers you would like to generate by checking the boxes to the left of each. Click the box to the left of **Soil** (**select all**) to select all soil layers shown. (For additional information refer to section 4.2.2.4.)

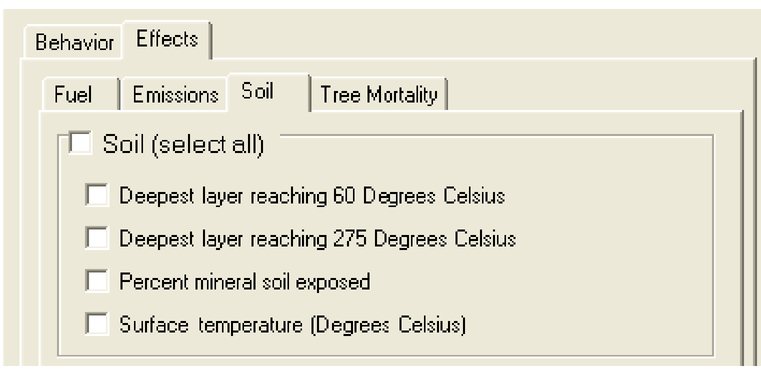


Figure 6-24. **Soil** output layers showing default selections.

7. Select the **Tree Mortality** tab (fig. 6-25). Check the **Tree Mortality (select all)** box at the top to generate all tree mortality output options. Click on the individual boxes to choose layers you would like to generate.

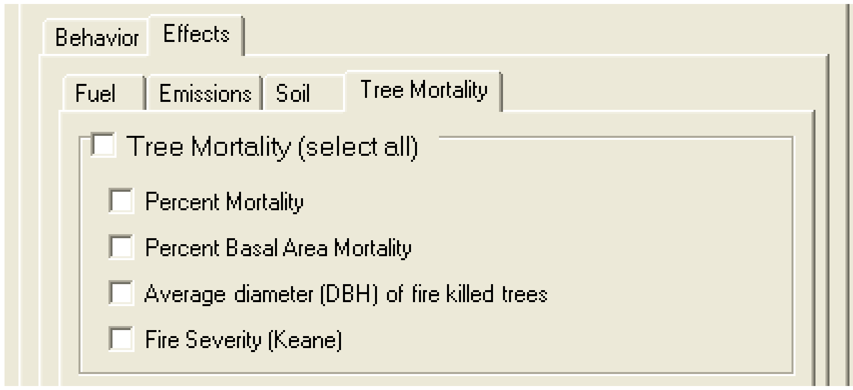


Figure 6-25. **Tree Mortality** output options.

> ***Note****: Important – do not click* ***OK*** *until you have completed the* ***Outputs*** *tab and entered an output location and output folder name.*

6.2.5 Selecting output location and name of output folder

Once your output layer selections have been made, you will need to specify an output folder name and path for your run. All WFAT outputs are stored in an output folder with the name you specified (fig. 6-26).

1. Click on the browse button to the right of the **Output Folder Location** box and navigate to a folder of your choice.

2. Next, enter an **Output Folder Name** for your WFAT run. The folder will be located in the pathway identified (fig. 6-26).

Figure 6-26. Select output location and name for output folder.

3. After completing the **Spatial Inputs**, **Model Inputs**, **CWD Profile**, and **Outputs** dialog boxes click **OK**. WFAT will now begin processing.

   Tip*: Be patient. Processing may take a few minutes.*

The output layers will appear in your ArcMap Table of Contents and the WFAT user interface will disappear automatically when the run is complete (fig. 6-27).

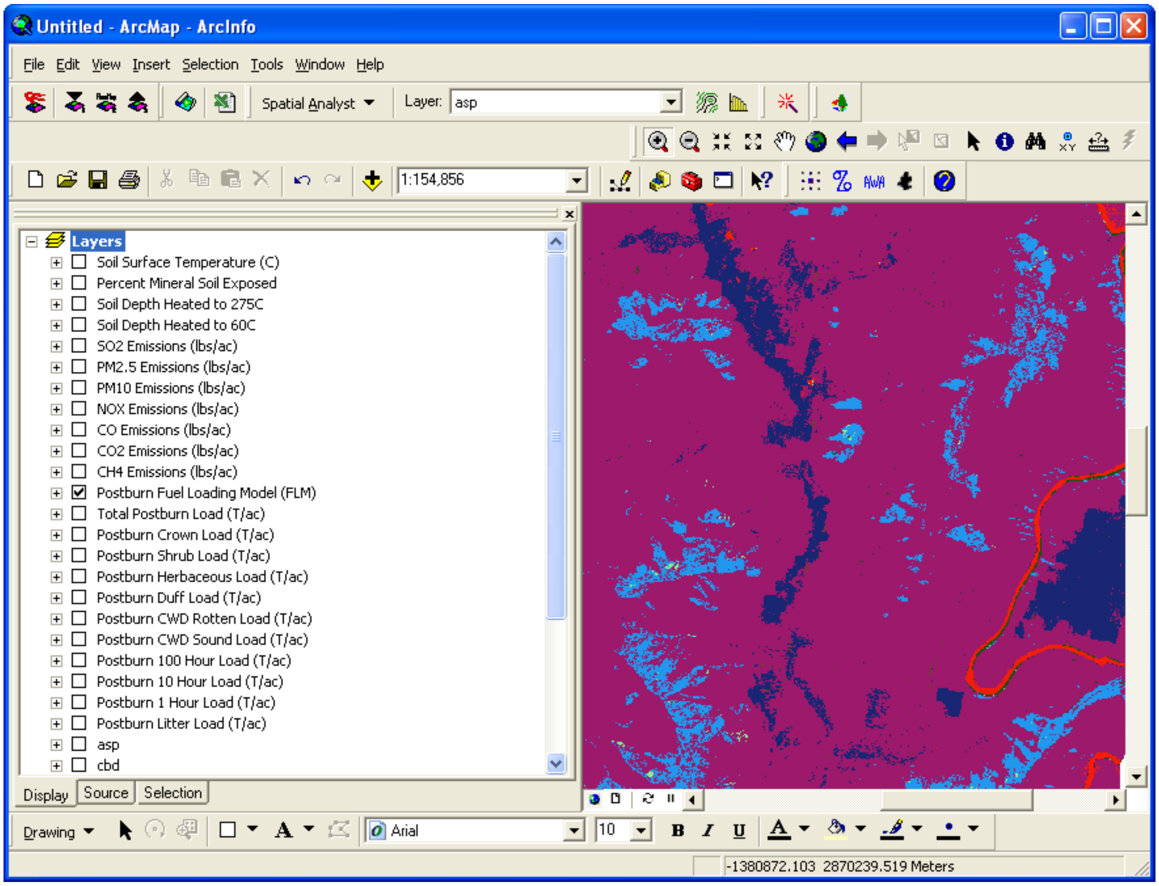


Figure 6-27. WFAT output layers in ArcMap's Table of Contents.

We recommend that users save their ArcMap project as soon as the WFAT run has finished. Saving the ArcMap project will preserve the label and color schemes for each output layer.

> ***Note**: The names of the output layers that appear within ArcMap's Table of Contents are descriptive labels; they are not the ESRI Grid names that will appear in the output folder you specified on The Outputs tab. (See table 4-2 for the layer names as they will appear in ArcCatalog).*

Chapter 7: Generating a Landscape File (.lcp)

The second icon on the WFAT toolbar, the Landscape File Generator, generates a landscape (LCP) file, but does not run FlamMap to simulate fire behavior (fig. 7-1). This utility was added to WFAT for those who would like to create a landscape file for later use with FlamMap or FARSITE.

Figure 7-1. Icon for generating a landscape file.

7.1 What is a landscape file?

A landscape file is a binary file comprised of a header and a body of short integers for each of the themes it contains. The header contains information on the bounds of the area, the resolution of the cells, and the units of the themes. The Landscape (LCP) File contains the five basic rasterized data themes needed to run FlamMap or FARSITE: elevation, slope, aspect, fuel model, and canopy cover. The landscape file may include optional files for stand height, crown base height, canopy bulk density, coarse woody fuel, and duff loading. Optional parameters not provided in a raster file will be constant across the entire landscape as set in FlamMap's Inputs tab of the Run dialog box. Because this is the same landscape file format used in FARSITE version 4 and beyond, landscape files generated in either application are interchangeable. To use a WFAT-generated landscape file in FlamMap or FARSITE, the user must ensure that the unit settings in the data layers are the same as those required for WFAT.

7.2 Selecting input layers

The following spatial layers are required to generate a landscape file.

- Elevation
- Slope
- Aspect
- Fire Behavior Fuel Model
- Canopy Cover
- Canopy Height
- Canopy Base Height
- Canopy Bulk Density
- Fire Effects Fuel Model

***Note**: All nine input layers must have the same spatial extents and coordinate system to successfully generate a landscape file. Also, remember that the input layers must be expressed in the appropriate units (see table 3-1).*

1. Start ArcMap and create a new project by selecting **A new empty map**.

2. Next, click on the **Add Data** icon to load input layers into your ArcMap project (fig. 7-2).

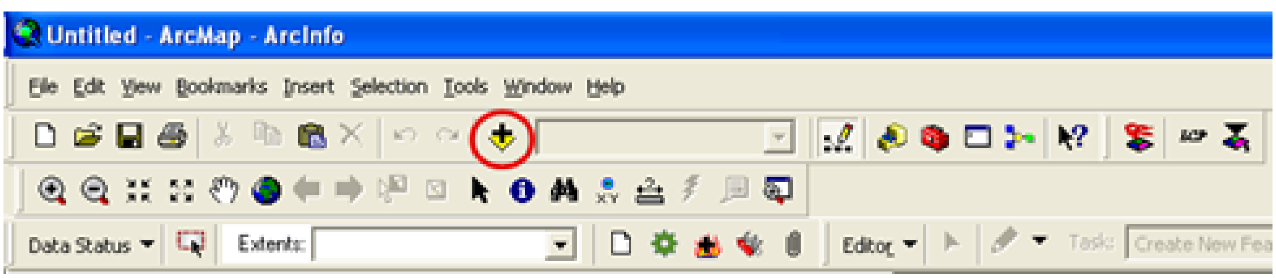


Figure 7-2. **Add Data** icon.

3. Navigate to the directory where your data layers are stored and add the following input layers: elevation, slope, aspect, fire behavior fuel model, canopy cover, canopy height, canopy base height, canopy bulk density, and fire effects fuel model. These layers provide the direct input for WFAT.

***Tip**: At this point, you may see several "**Create pyramids**" dialog boxes similar to the box shown in figure 7-3. Click No to speed up processing. If you do not want to see this box again, put a check in the lower left-hand corner to disable it.*

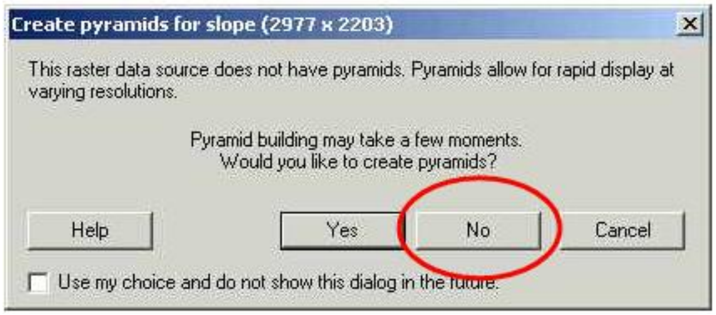


Figure 7-3. Create pyramids dialog box.

4. If desired, rename the data frame as shown in figure 7-4 with a slow double-click on the default name **Layers** and save your project.

***Note**: You do not need to include the extension ".mxd" when naming your project.*

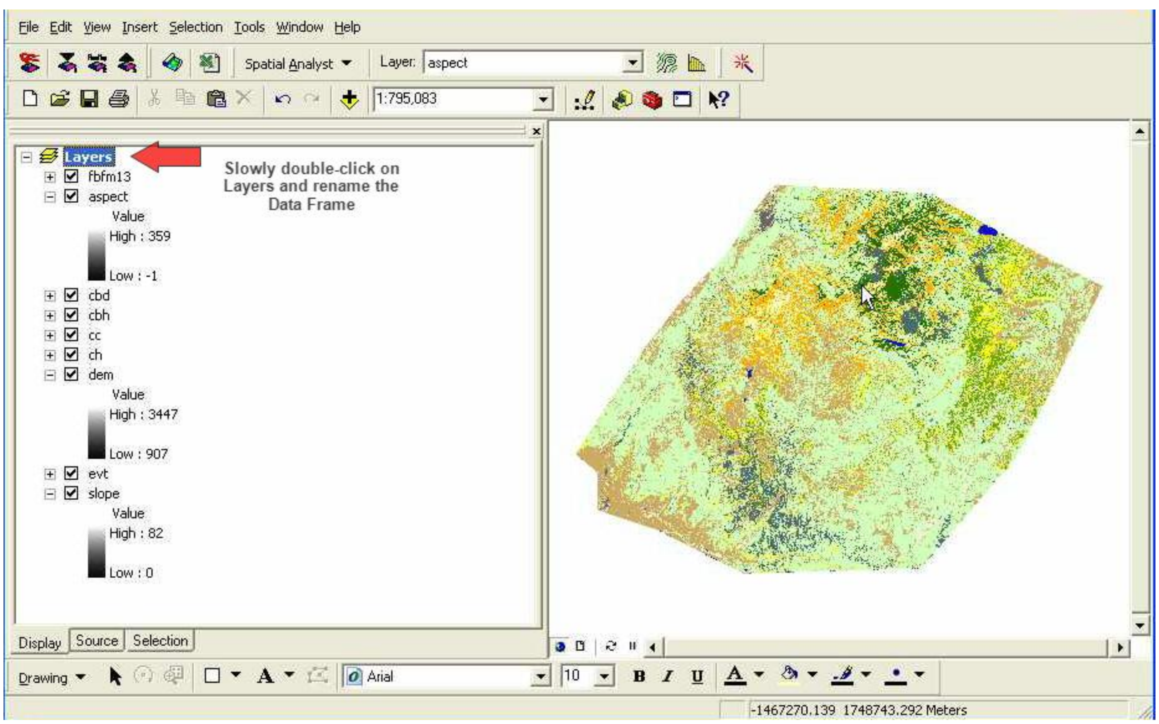


Figure 7-4. Renaming the data frame (if desired).

7.3 Steps for generating a landscape file

1. After you have finished loading the input layers into ArcMap, click on the **Landscape File Generator** icon located second from the left on the WFAT toolbar (fig. 7-5).

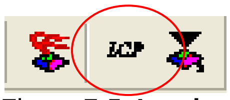


Figure 7-5. **Landscape File Generator** icon, second from the left.

Selecting this command will open the **Landscape File Generator** dialog box as shown in figure 7- 6.

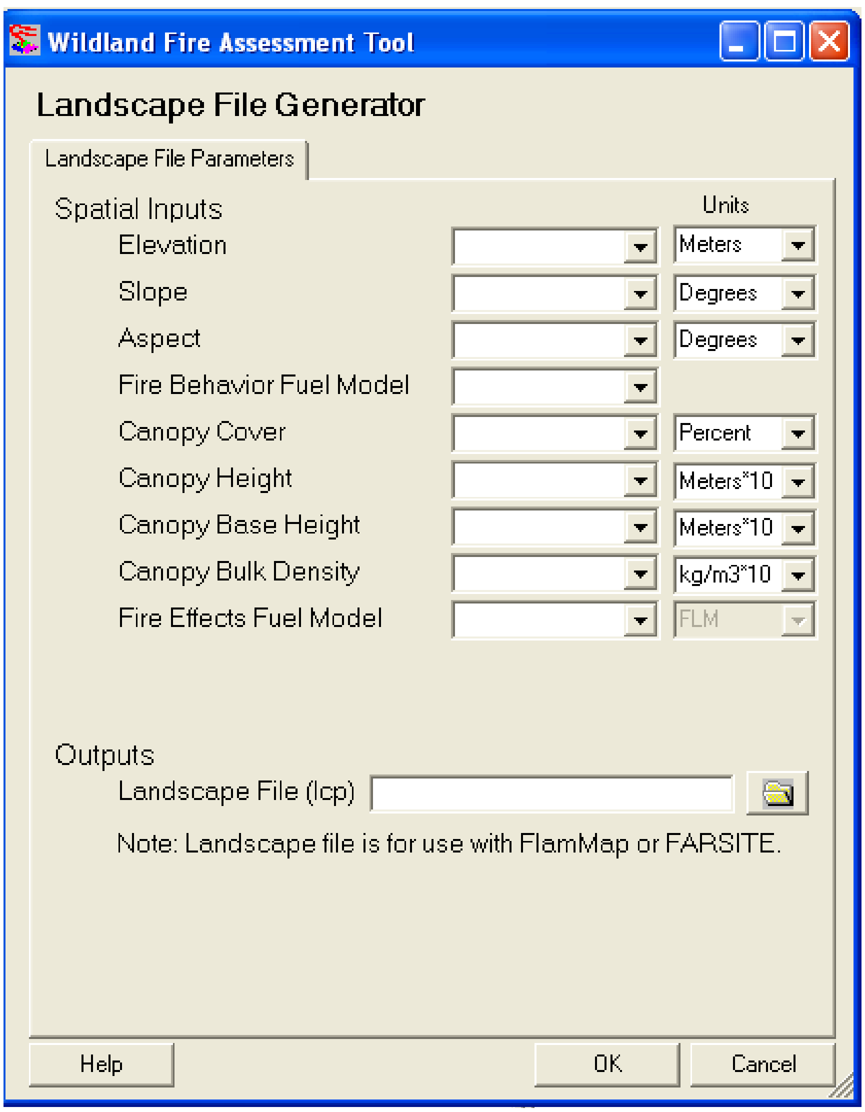


Figure 7-6. **Landscape File Generator** dialog box.

2. Select the appropriate input layers from the drop-down menu located to the right of each layer (fig. 7-7). Clicking on the drop-down menu will display all raster layers that are currently loaded in your ArcMap project.

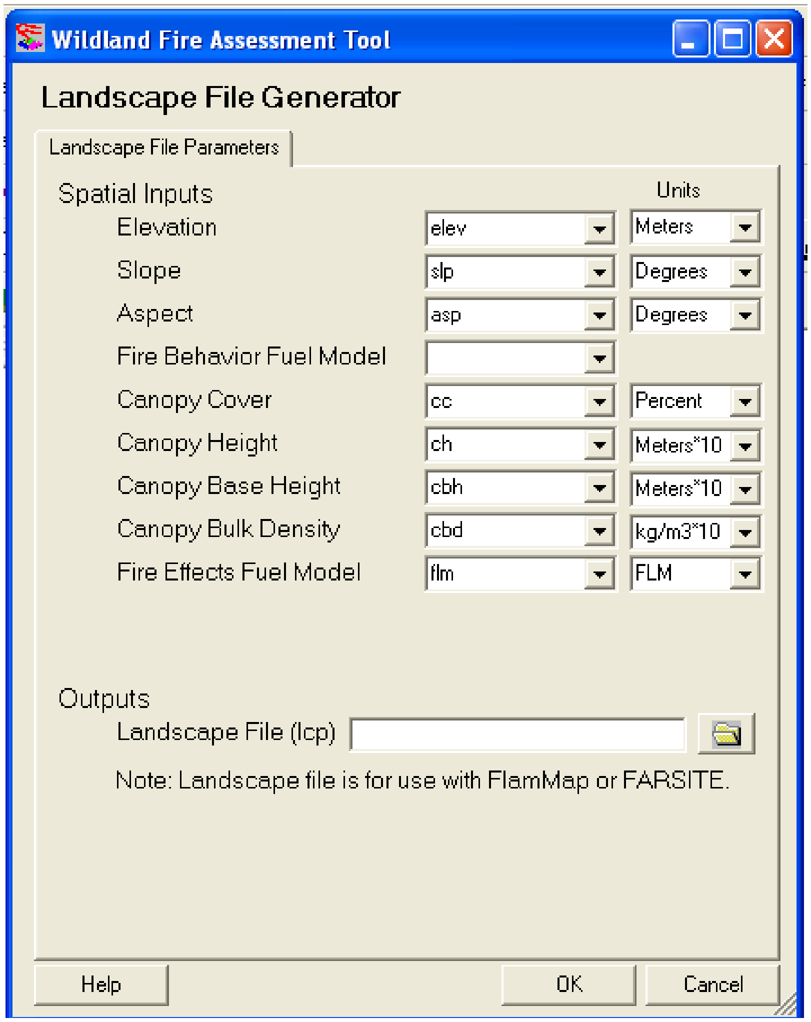


Figure 7-7. **Landscape File Generator** dialog box.

***Note**: "Slope" and "Aspect" layers are optional inputs. If these layers are not selected by the user, WFAT will automatically derive slope and aspect layers from the elevation layer. However, slope may be calculated incorrectly if your data contains pixels with a value of "-9999," which denotes that those pixels lack data. In addition, the elevation layer will not always be named "elev." In some data sources it will be named "dem," an abbreviation for Digital Elevation Model.*

3. Next, select a Landscape File name and location by using the browse button located to the right of the **Landscape File (lcp)** field (fig. 7-8).

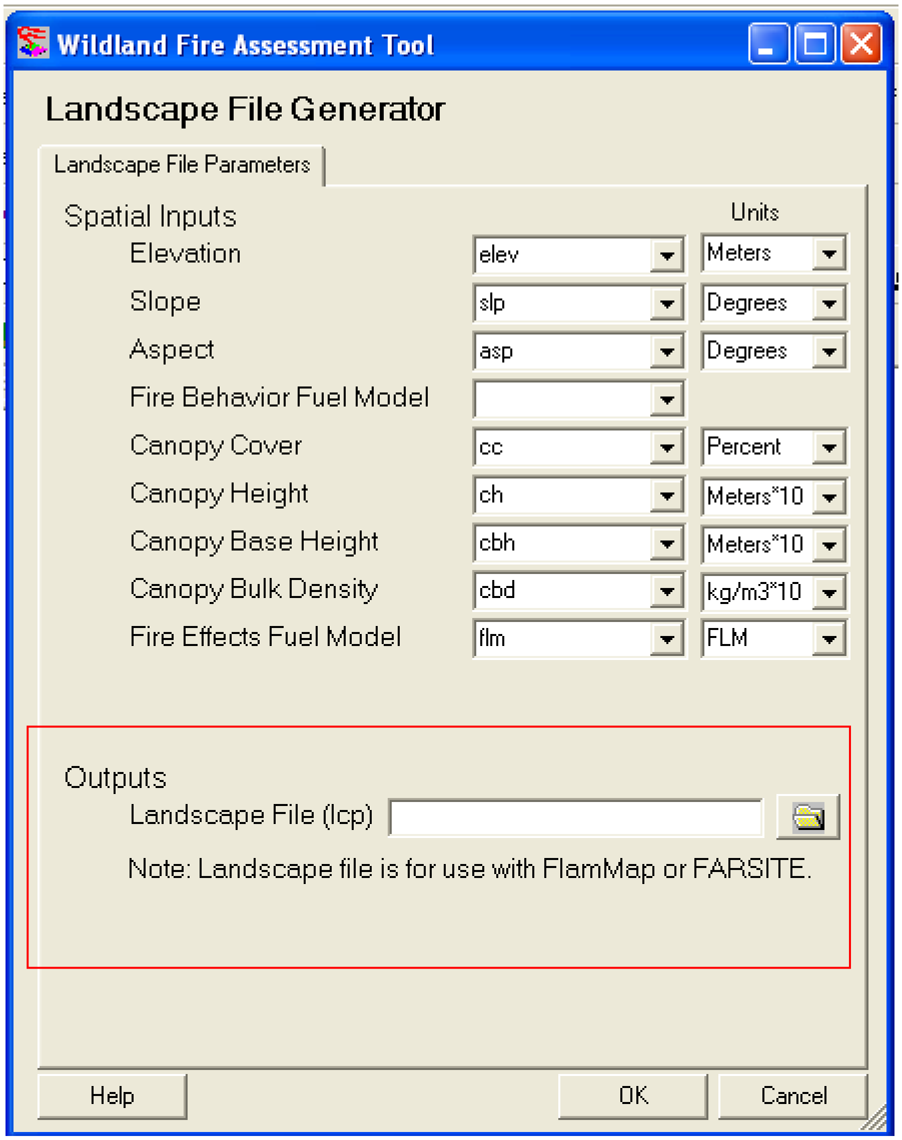


Figure 7-8. Specify a **Landscape File** using the browse button.

4. When you have completed the dialog box, click on **OK** to generate the landscape file.

5. A dialog box will notify you after the landscape (LCP) file and a related param.txt file have been created. Click **OK**.

6. Verify that the LCP file has been generated by checking for the file in the project folder you specified in the field depicted in figure 7- 8. Your lcp file is now ready for use in FlamMap or FARSITE.

   ***Tip**: The only indication that the LCP file has been created is that the "LCP File Creation" dialog box disappears automatically. This is not an error.*

Chapter 8: Generating outputs from the Effects from FARSITE or FlamMap Generator

8.1 Selecting inputs
8.2 Selecting a Coarse Woody Debris profile
8.3 Selecting a project folder location and name

Effects from the FARSITE or FlamMap Generator is typically used to convert ASCII layers generated in FARSITE or FlamMap into ArcGrids for use in WFAT. The tool can also use outputs from FARSITE or FlamMap to generate WFAT fire behavior and effects output layers.

To begin, click on the third icon (Effects from FARSITE or FlamMap Generator) from the left on the WFAT toolbar as shown in figure 8-1:

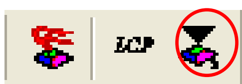


Figure 8-1. **Effects from FARSITE or FlamMap Generator** icon.

Selecting this icon will open the dialog box displayed in figure 8-2. This dialog box consists of three tabs: **Inputs**, **CWD Profile**, and **Outputs.**

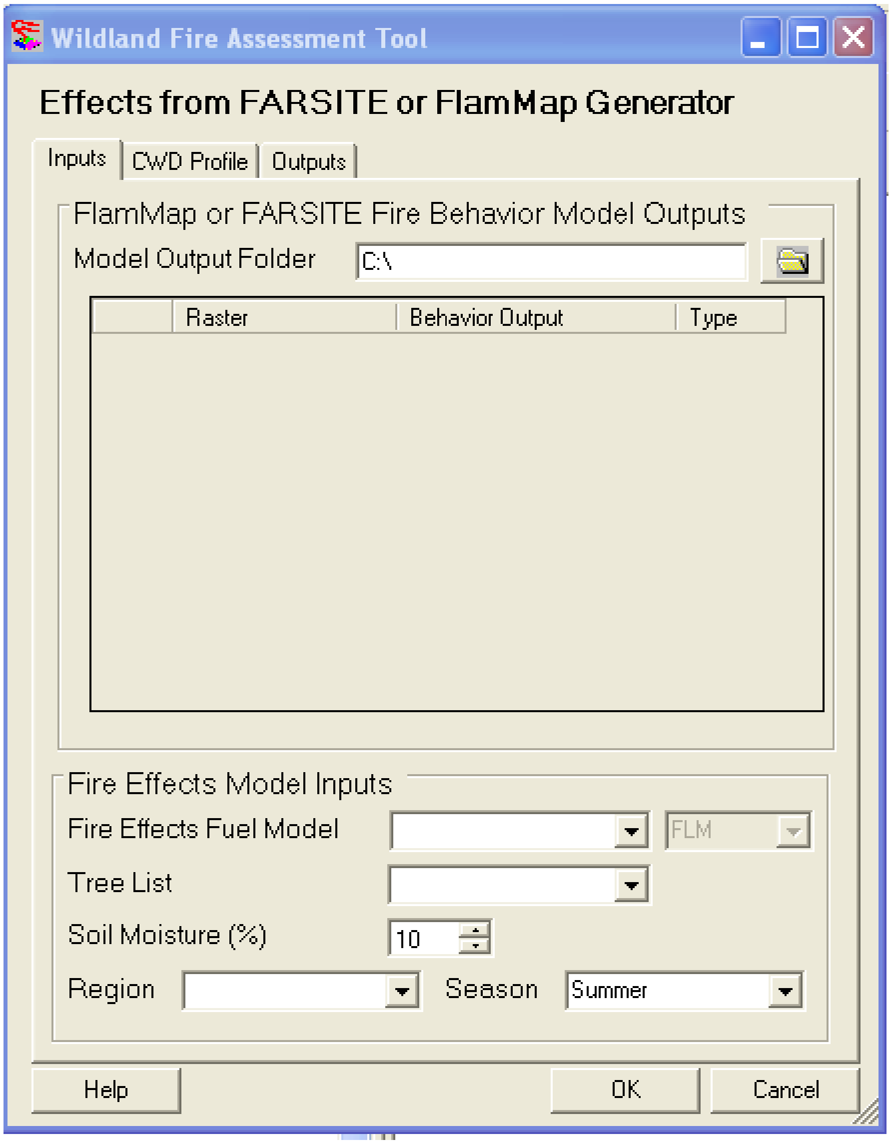


Figure 8-2. **Effects from FARSITE or FlamMap Generation** dialog box.

8.1 Selecting inputs

1. First, add the Tree List and Fire Effects Fuel Model layers for your project into ArcMap.

2. Next, open the **Effects from FARSITE or FlamMap Generator** by clicking the third icon on the toolbar. The tool will open to the **Inputs** tab (fig. 8-3).

WFAT requires that input layers be in ASCII format. The ASCII-formatted layers can be found in the Results folder of previous WFAT FARSITE or FlamMap runs and are denoted as **FlamMap.CFR**, **FlamMap.FML**, **FlamMap.ROS**, and **FlamMap.FLI** for crown fire activity (CFA), flame length, rate of spread, and fireline intensity, respectively. To generate any Effects outputs, these required files must be present in the input folder: a Landscape (LCP) File for the project area, FlamMap.CFR, FlamMap.FMX, and FlamMap.FMM, (for crown fire activity [CFA], 10-Hour Moisture, and 1000-Hour Moisture). A FEFM layer must be entered in the **Fire Effects Model Inputs** box.

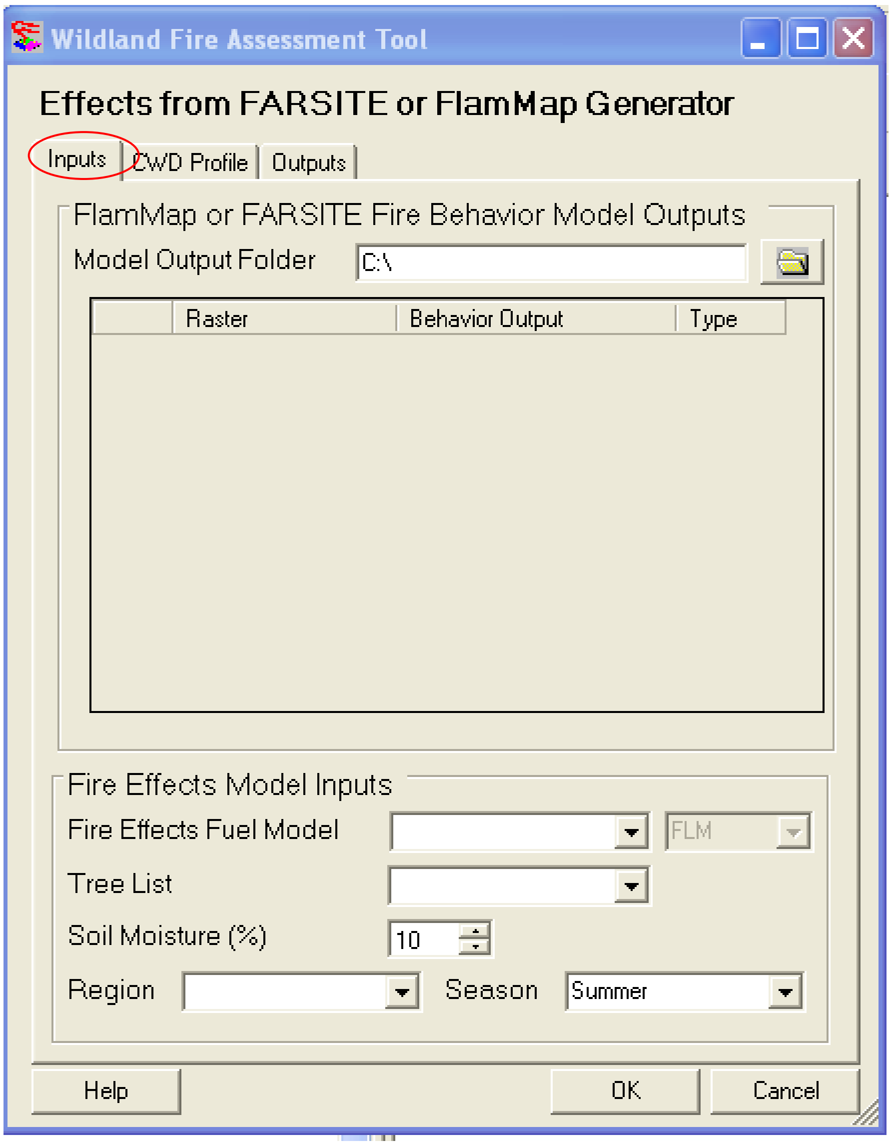


Figure 8-3. **Inputs** tab.

3. Click on the browse button to the right of the required input folder as shown in figure 8-4 and navigate to the output folder of a previous WFAT, FARSITE, or FlamMap run.

You will see a dialog box similar to the following (figure 8-4).

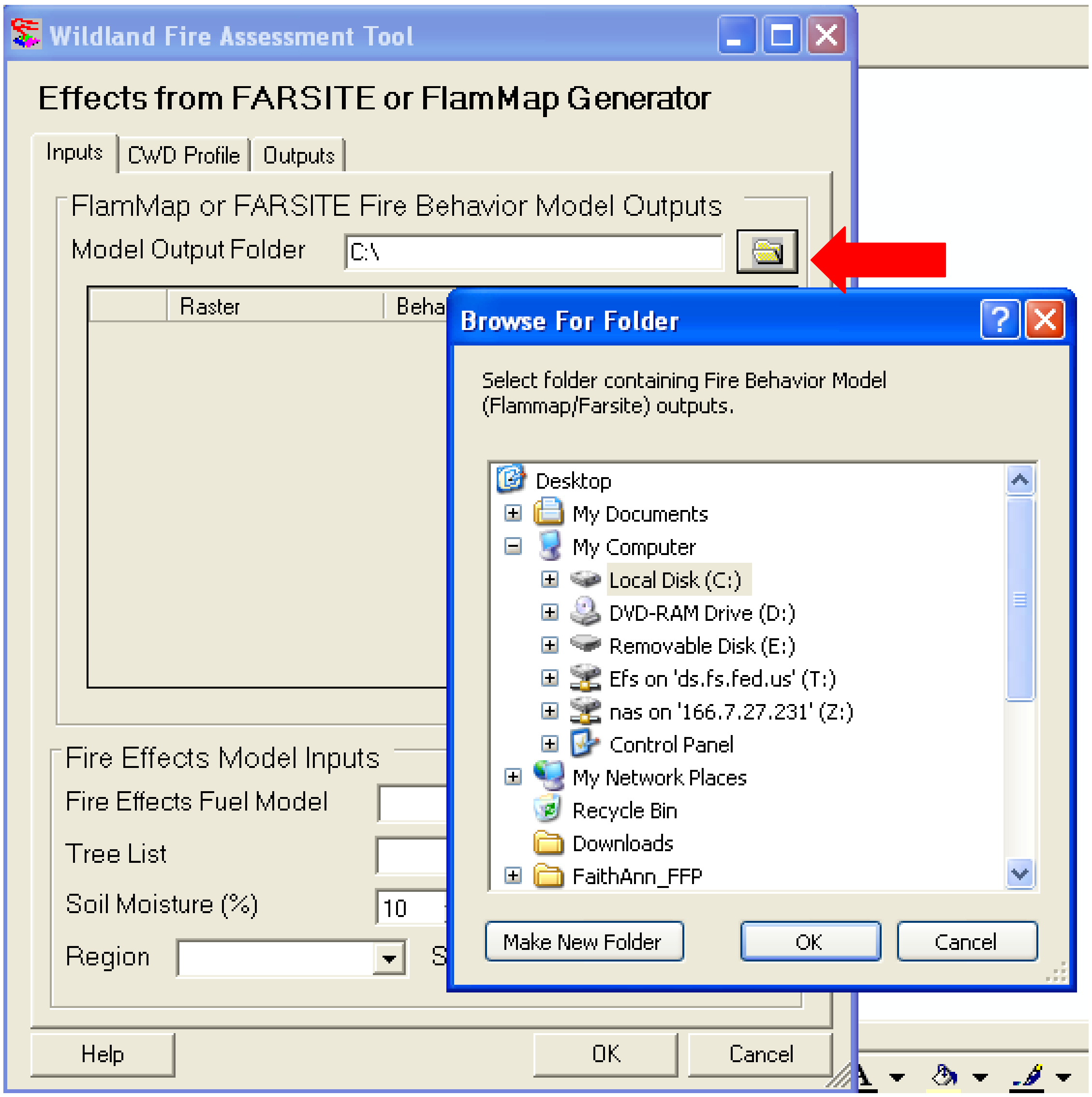


Figure 8-4. Navigate to **Outputs** folder.

Once you have identified and selected an existing output folder containing all required output layers, the box is populated automatically as shown (fig. 8-5).

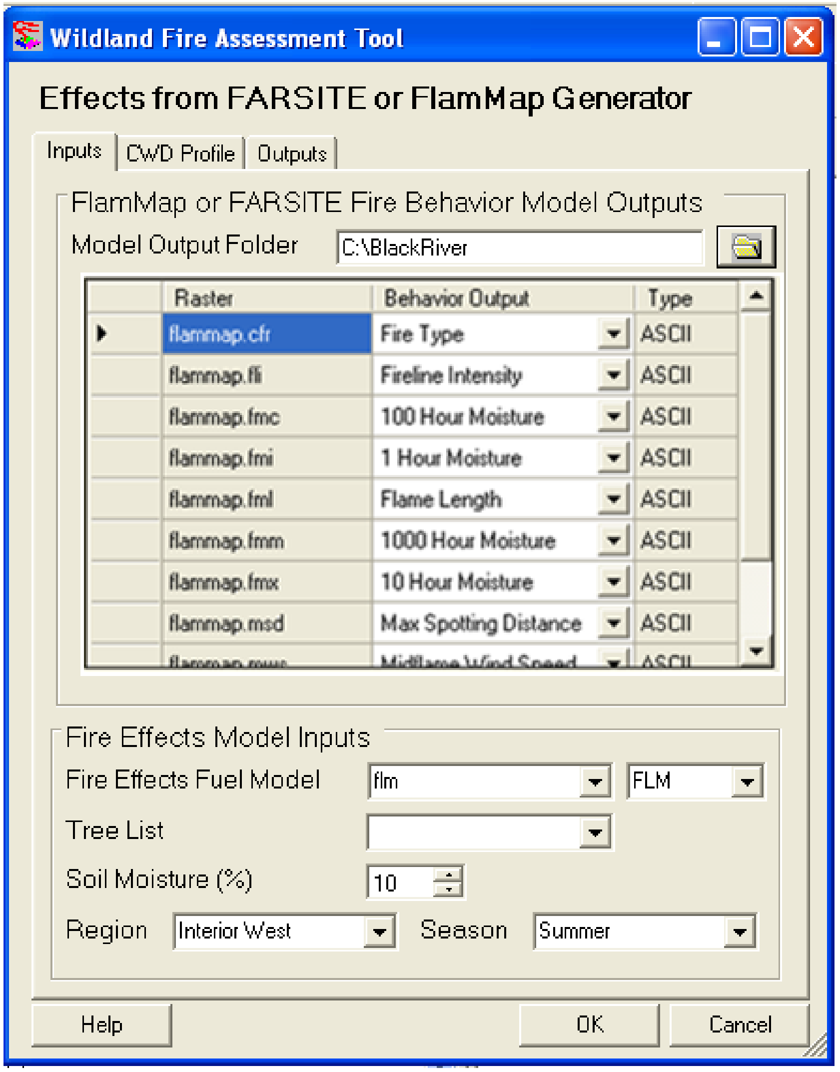


Figure 8-5. Effects from FARSITE or FlamMap Generator dialog box showing Inputs tab.

4. Complete the fields in the **Fire Effects Model Inputs** box at the bottom of the **Effects from FARSITE or FlamMap Generator** dialog box (fig. 8-6).

5. Select an appropriate **Fire Effects Fuel Model (FLM, FCCS, or Custom)** layer in the top drop-down box, which lists all layers currently available in the ArcMap Table of Contents.

6. Select the type of FEFM used in the second drop-down box (FLM, FCCS, or Custom). If using a Custom FEFM, you will also need to fill out the Custom tab which will appear in the dialog box.

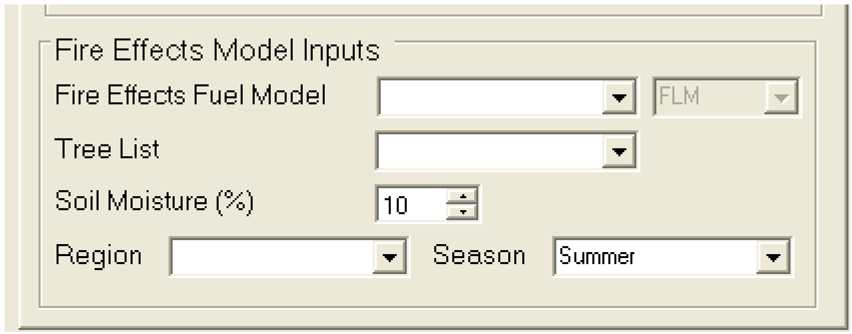


Figure 8-6. **Fire Effects Model Inputs** box portion of dialog box.

7. Select your "**Tree List**" input layer from the drop-down box (only if you plan to generate Tree Mortality Effects outputs). The drop-down box will show all of the layers currently in the ArcMap Table of Contents.

8. Next enter a **Soil Moisture** value. You can type in the value directly or you can use the spinner box to raise or lower the value. Typical soil moisture values range from approximately 5% (very dry) to 25% (wet) (for more information on this subject see section 3.3.5).

9. Select a **Region** from the options available by using the drop-down menu (see section 3.3.7 for additional information).

10. Finally choose **Season** from the drop-down list at the bottom right of the dialog box. (See section 3.3.8 for more information).

> ***Note:*** *Do not click* ***OK*** *until you have completed the* ***CWD Profile****, and* ***Outputs*** *tabs in addition to the* ***Spatial Inputs*** *tab you have just completed.*

8.2 Selecting a Coarse Woody Debris (CWD) Profile

Coarse Wood Debris (CWD) refers to down woody material greater than or equal to 3 inches (7.6 cm) in diameter.

1. Click on the **CWD Profile** tab at the top of the dialog box and the following screen will open (fig. 8-7):

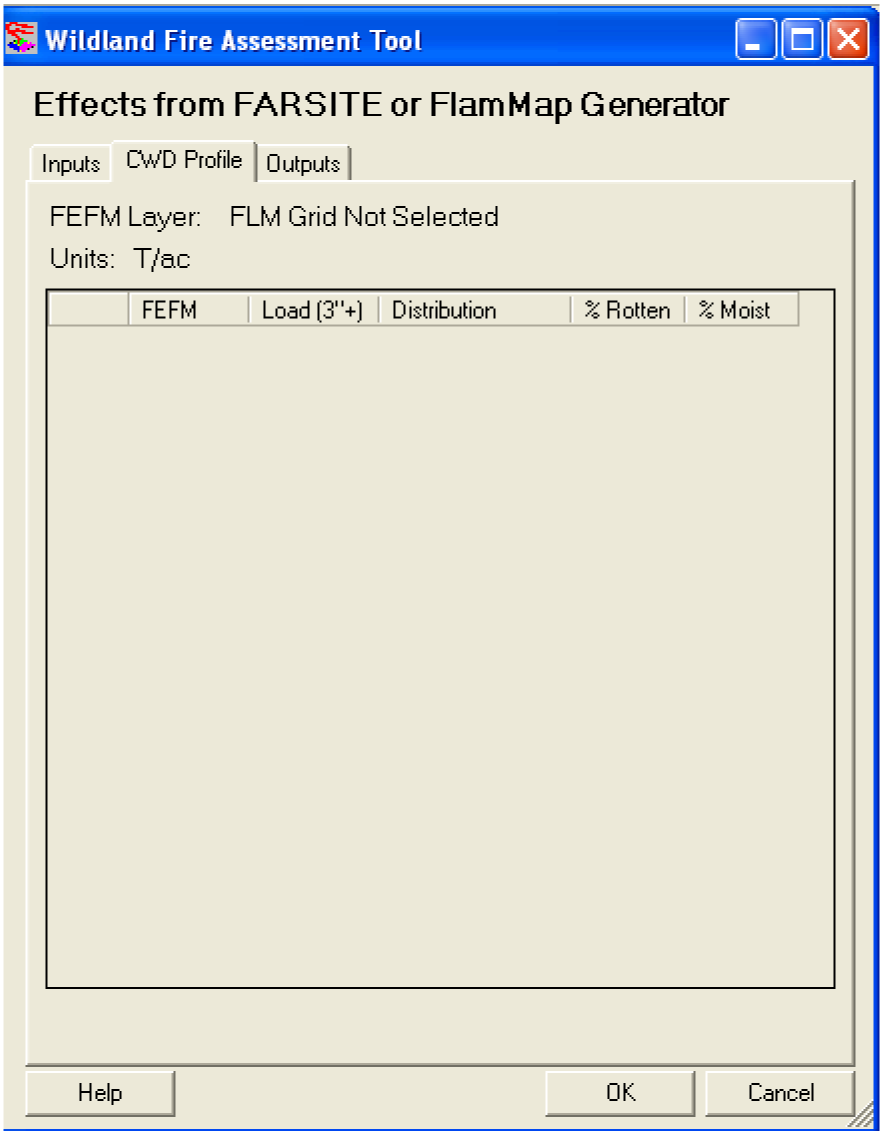


Figure 8-7. **Fire Behavior and Effects Output Generation Tool** dialog box showing **CWD Profile** tab.

Once you have identified a Fire Effects Fuel Model from the drop-down selection, on the **Inputs** tab, the **CWD Profile** tab is populated using the FEFM layer you specified.

An example CWD Profile for a FEFM layer (FLM) is shown below (fig. 8-8.):

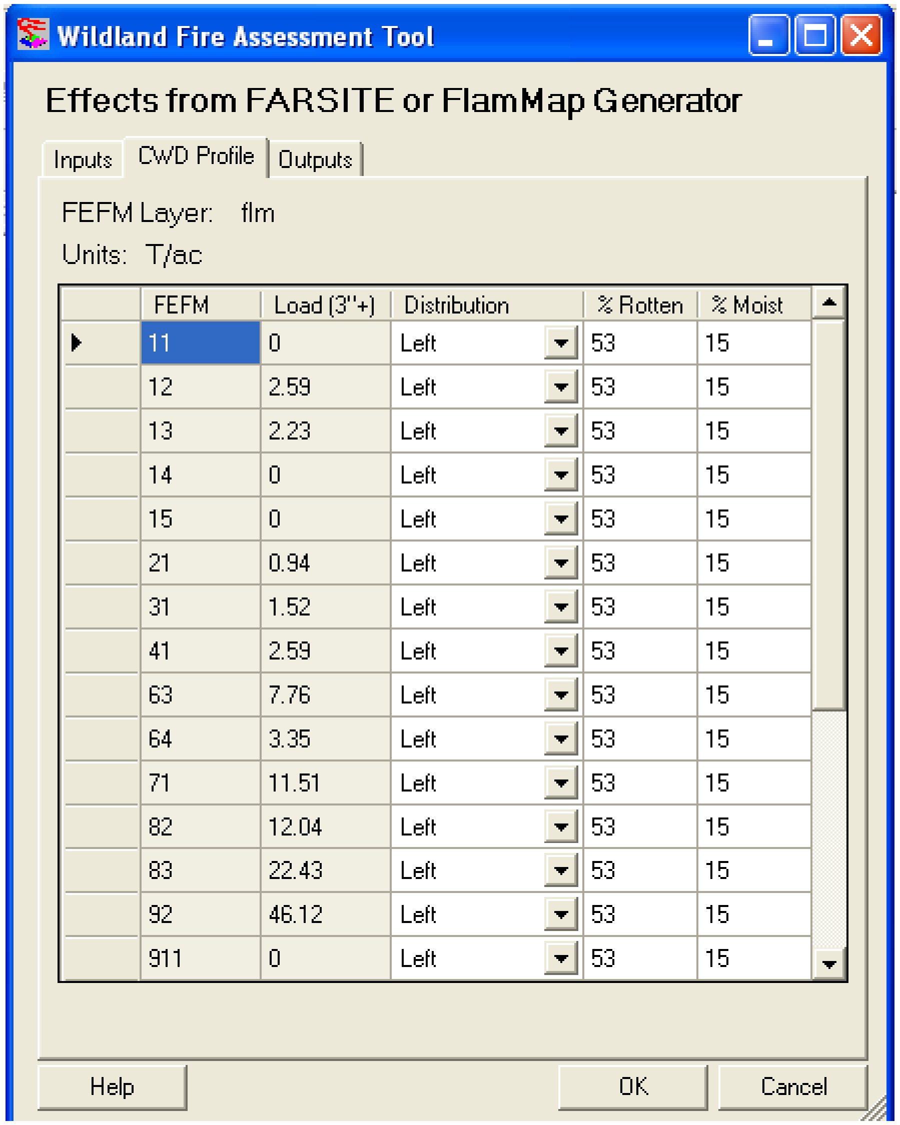


Figure 8-8. Example of completed **CWD Profile** tab in dialog box.

> ***Note**: The "Load (3"+)" column displays the total fuel load of the CWD. If an FLM or Custom FEFM is selected, a default "Left" distribution and 53% rot is applied to the load for each FEFM. FCCS fuelbeds include information on the distribution and percent rot of the CWD load and are shown in the dialog box. Any modifications made here will redistribute the load from its original values. (See section 3.4 for more information on this subject.)*

2. Use the **CWD Profile** tab to specify a CWD profile for each value in the FEFM layer. Values include fuel load 3 inch or greater (7.6 cm) in tons per acre, load distribution, percent rotten, and percent moisture (see section 3.4 for additional information).

3. To edit values, click in the cell within the FEFM that you would like to change.

4. Highlight the cell and type in a new value if desired.

5. The third column, "Distribution" contains a drop-down menu for convenience. Use the drop-down menu to select a new log distribution (**Left**, **Center**, **Right**, **Even**, or **End**) for each value you would like to edit (fig.8-9). (See section 3.4.1 for more information).

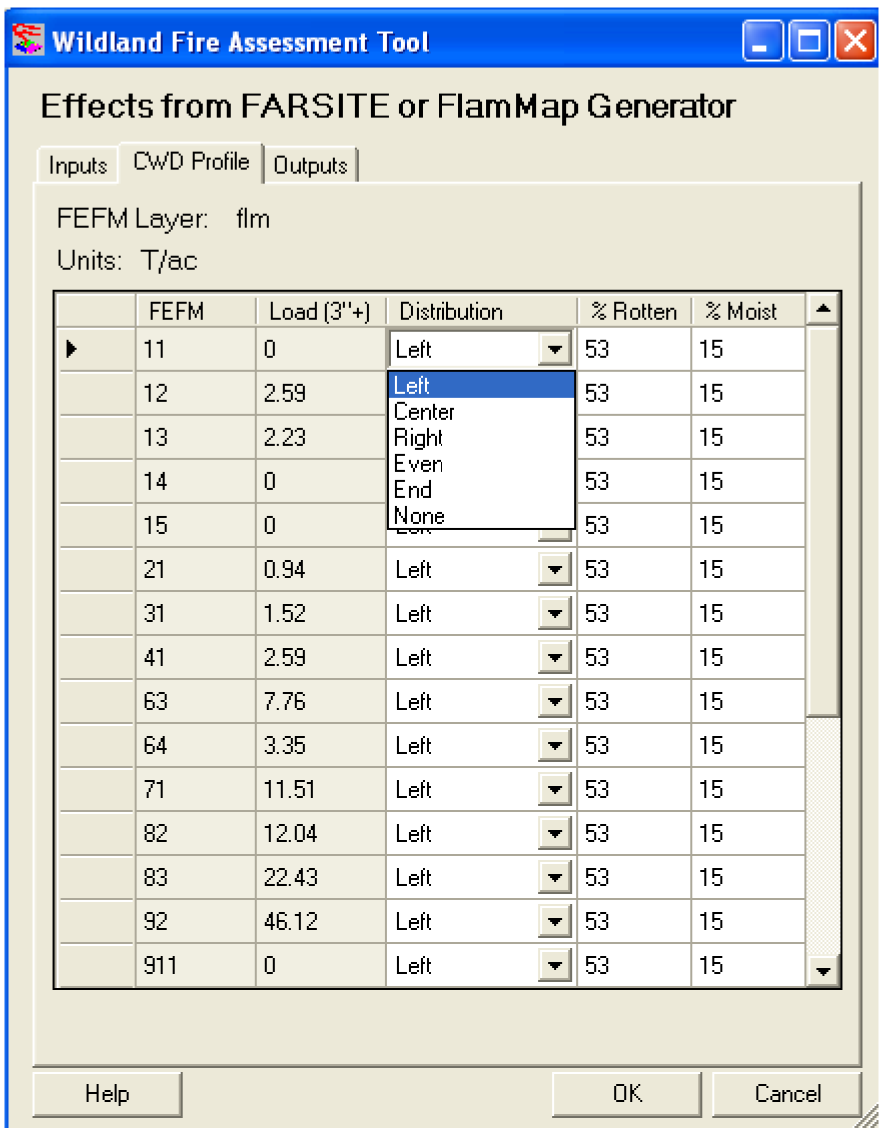


Figure 8-9. **Effects from FARSITE or FlamMap Generator** dialog box showing **CWD Profile** tab.

6. Finish all edits on the **CWD Profile** tab, but do not click **OK** until you have completed required information on all tabs and have specified an output folder name and location on the **Outputs** tab.

7. Next click on the **Outputs** tab and the following dialog box will open.

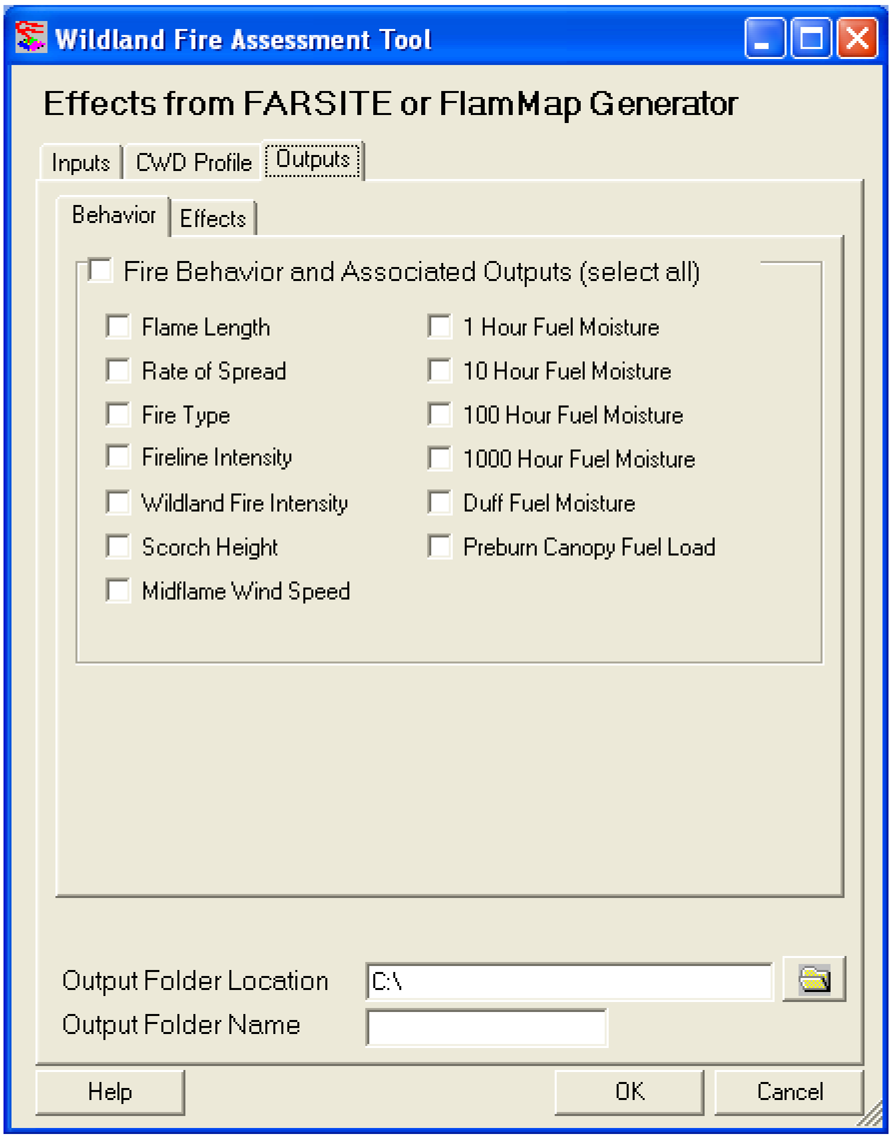


Figure 8-10**. Effects from FARSITE or FlamMap Generator** showing **Outputs** tab.

8. Next you will select all layers to be generated in each category (both Behavior and Effects). (Chapter 4 provides a detailed discussion of available output layers.) Click on the **Behavior** tab and begin with the desired Fire Behavior Outputs. Select the top box **Fire Behavior and Associated Outputs (select all)** to select all of the available fire behavior outputs.

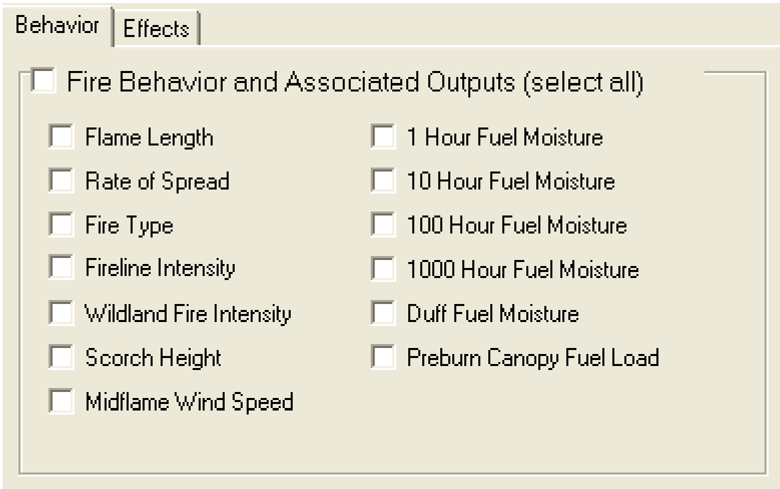


Figure 8-11. **Fire Behavior** tab showing outputs.

9. Click on the **Effects** tab and select the **Fuel** tab at the top left to view selections for Fuel Consumption outputs (fig. 8-12). You can select postburn fuel load (Post), the amount of fuel load that is consumed (Consumed) or both options by checking the appropriate boxes. (The default selection is "Post"). See section 4.2.1 for further information. All Fuel Loading output options will be chosen if you check the **Fuel Loading (select all)** box.

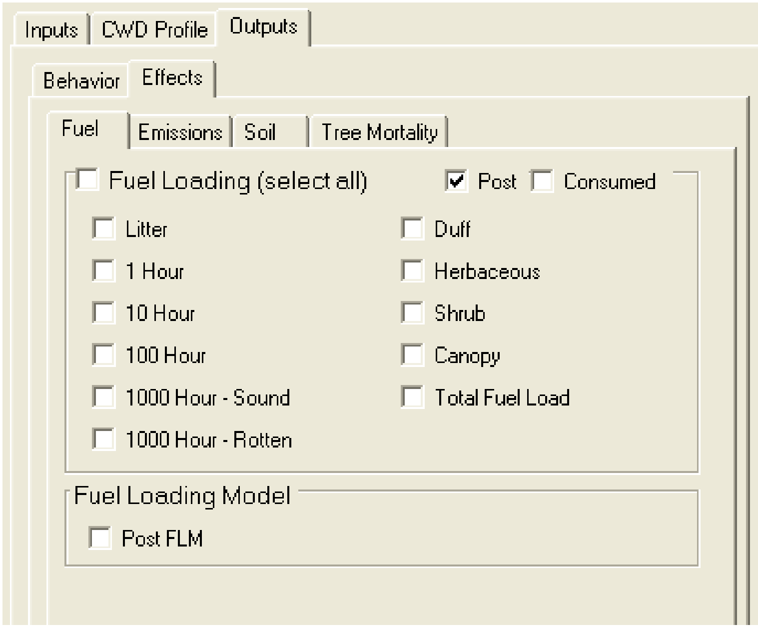


Figure 8-12. **Effects** tab showing outputs.

10. You can select individual fuel consumption layers. Select all layers of interest by checking the appropriate boxes.

11. Select the **Emissions** tab to view all available emissions options (see section 4.2.2.3). Check the boxes to the left of the emission layers you would like to generate (fig. 8-13). Click the box to the left of **Emissions (select all)** to select all emission layers shown.

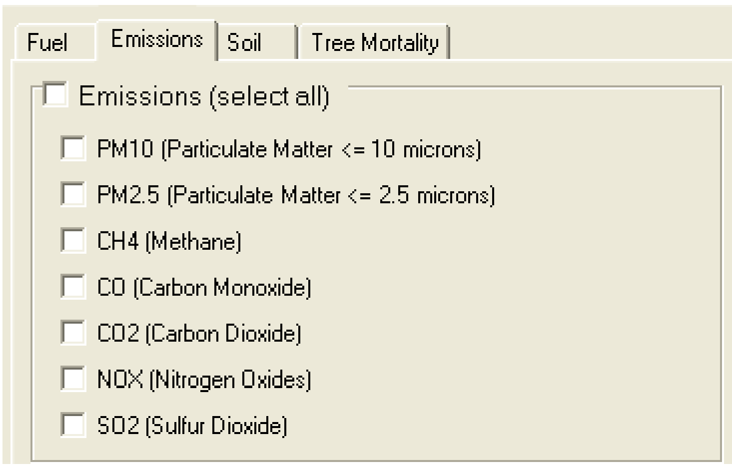


Figure 8-13. **Effects** tab showing **Emissions**.

12. Click on the **Soil** tab under **Effects**. The following output layers address soil heating and the percent of mineral soil exposed.

13. Select the soil heating layers you would like to generate by checking the boxes to the left of each (fig. 8-14). Click the box to the left of **Soil (select all)** to select all soil layers shown. (For additional information refer to section 4.2.2.4).

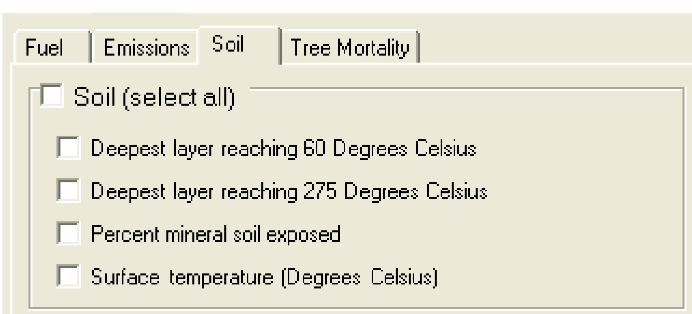


Figure 8-14. **Effects** tab showing **Soil** tab.

14. Select the **Tree Mortality** tab as shown (fig. 8-15). Check the **Tree Mortality (select all)** box at the top to select all mortality options or click on the individual boxes to choose the layers you would like to generate.

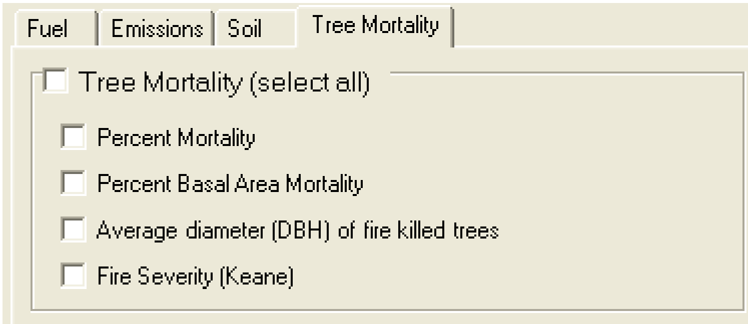


Figure 8-15. **Effects** tab showing **Tree Mortality**.

Note: *Important – do not click **OK** until you have completed the **Outputs** tab and specified an output folder name and.*

The option of copying a spatial reference (in other words, coordinate system and projection information) from an existing layer becomes available only if you have not specified an FEFM layer in the **Fire Effects Model Inputs** box on the **Inputs** tab. Since ASCII files do not contain a spatial reference (coordinate system and projection information), the user must specify the appropriate coordinate system and projection needed to derive spatial outputs either by entering an FEFM layer on the Inputs tab, or by selecting a layer from the "Copy Spatial Ref From" drop-down menu. If spatial inputs include a pre-existing landscape file, then one of the original spatial layers used to create the landscape file should be selected. This will ensure that the spatial outputs have the same spatial reference as the layers used to create the landscape file.

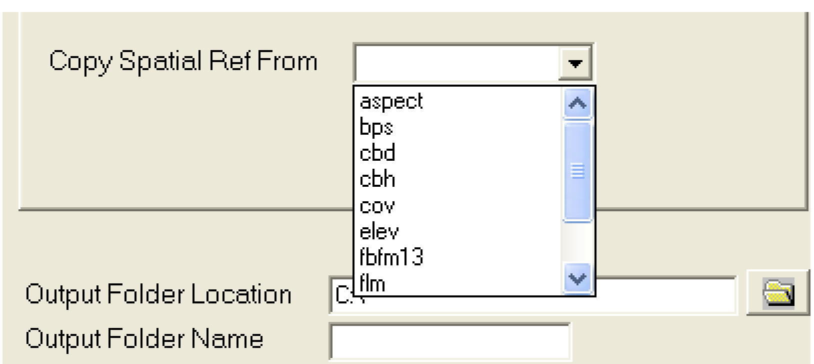


Figure 8-16. **Copy Spatial Ref From** drop-down menu.

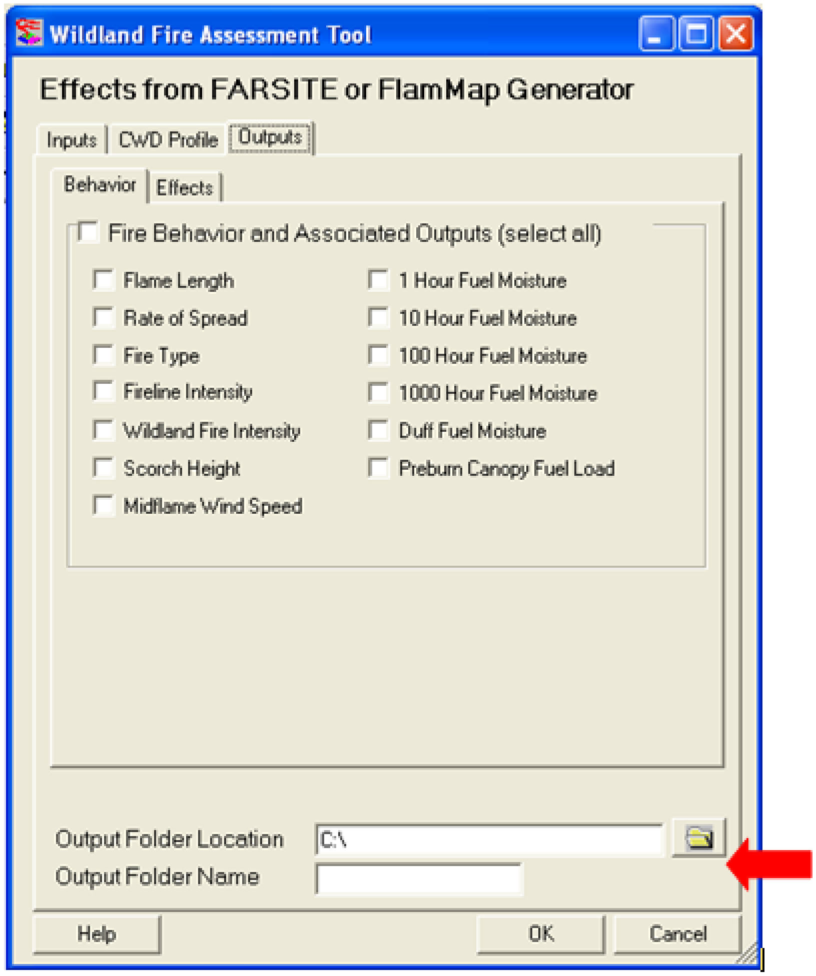


Figure 8-17. **Effects from FARSITE or FlamMap Generator** showing Output Folder Location and Name.

8.3 Selecting project folder location and name

Once your output layer selections have been made, you will need to specify an output folder name and path for your run. All WFAT outputs are stored in an output folder with the name you specified (fig.8-21).

1. Click on the browse button to the right of the **Output Folder Location** box and navigate to a folder of your choice.

2. Next, enter an **Output Folder Name** for your WFAT run. The folder will be located in the pathway identified here (fig 8-17). WFAT outputs will be stored in this folder.

Click **OK** after providing all of the appropriate information on each of the three tabs. The resulting spatial layers will automatically appear in the ArcMap Table of Contents as well as in your designated project folder.

> ***Note**: Be patient. The run may take several minutes.*

Chapter 9: Troubleshooting WFAT – Common Errors, Symptoms, and Solutions

> ***Tip**: Make sure that you are using ArcGIS 9.2, 9.3, or 9.3.1.*

Perhaps the most common WFAT user issue is that modeled potential fire behavior does not coincide with observed fire behavior. The discrepancy between simulated and observed fire behavior can generally be attributed to WFAT input parameters. These parameters can include fuel input data as well as environmental conditions such as wind speed and direction.

Fuel data are often derived from vegetation attributes, which can be poor correlates of fuel characteristics. In addition, accurate identification of the input parameters (such as fuel moisture, wind speed, and wind direction) that result in observed fire behavior can also be problematic. For example, it may be difficult (after the fact) to identify the actual 20-ft wind speed and direction that occurred during an active crown fire.

We recommend that users review Stratton (2006) for guidance on evaluating input data and fire behavior outputs as well as for guidance on calibrating models to observed local fire behavior. The discussion of climatology and fire analysis is particularly useful for identifying appropriate environmental parameters for modeling specific fire scenarios.

The following guidelines can be used if you have doubts regarding the accuracy of your output.

9.1 Evaluating input data

1. **Evaluate the fire behavior fuel model layer**. Does it seem appropriate for your particular analysis scenario? For example, a fuel model layer developed from observations taken during the green-up period will probably not be suitable if you are trying to simulate fire behavior to reflect conditions during the peak of the fire season. The appropriate fuel model on a given site can vary according to plant phenology as well as with

yearly fluctuation in available moisture. In addition, accurate simulation of expected fire behavior is unlikely if the fuel model has been misclassified. For example, crown fire simulation cannot generally be modeled using the Anderson (1982) Fuel Model 8: Closed Timber Litter, which is often characterized under common burning conditions by slow-burning ground fires with low flame lengths.

2. **Evaluate the canopy base height layer**. Canopy base height is a critical variable for determining the transition between surface fire and crown fire. Do the values seem reasonable for your analysis area? Simulating crown fire may be troublesome if the values for canopy base height are too high.

3. **Evaluate the canopy bulk density layer.** Canopy bulk density serves as a critical variable for determining the transition from passive to active crown fire. Do the values seem reasonable for your analysis area? Simulating active crown fire may be troublesome if the values for canopy bulk density are too low.

4. **Evaluate the canopy cover layer.** Canopy cover and effective midflame wind speed are inversely related. Thus, dense canopy cover will substantially decrease midflame wind speed, which subsequently reduces flame length, which in turn reduces the likelihood of transition from surface fire to crown fire. Be suspicious of canopy cover values exceeding 70 percent (see Scott and Reinhardt [2005]).

5. **Evaluate the slope layer**. Typically, slope layers are derived from digital elevation models (DEMs). A poor quality DEM can be recognized by the occurrence of "spikes" or "troughs." Using a poor quality DEM to derive a slope layer will result in unrealistic slope values.

   Tip: *Many of the errors discussed above can often be detected by simply viewing the layers and zooming-in when necessary.*

9.2 Evaluating input parameters

1. **Consider which crown fire calculation algorithm you used.** Use of the Scott and Reinhardt (2001) algorithm will increase the amount of active crown fire relative to passive crown fire.

2. **Evaluate the surface fuel moisture file used for the simulation**. Do the fuel moisture values truly reflect the scenario that you were trying to simulate? See Stratton (2006) for a detailed discussion on obtaining fuel

moisture parameters from local remote automated weather stations (RAWS).

3. **Evaluate the wind speed and direction used for the simulation**. (See Stratton [2006] for information on how to obtain wind speed and direction parameters). Because WFAT does not currently allow the use of wind vectors, we encourage users to use the "uphill" option as this will maximize fire behavior. However, using upslope winds does not adequately simulate actual fire weather. Wind vectors, on the other hand, vary wind speed and direction according to topography to provide a more realistic simulation.

4. **Evaluate the canopy fuel moisture used for the simulation**. Many people use the default of 100 percent. This may underestimate the transition to crown fire during cumulative drought conditions or in areas with short-needled conifer species.

5. **Review the environmental parameters used for your WFAT run**. Open the param.txt file located in the output folder you specified for your simulation. Ensure that a mistake was not made when selecting the fuel moisture file, wind speed, wind direction, and/or foliar moisture content. In addition, check to make sure that you selected the correct input layers. For example, unrealistic simulations may result if you inadvertently used the canopy height layer to represent canopy base height.

   ***Note**: For WFAT to function properly, the analysis area that you select is currently limited to approximately 4 million pixels in size.*

   To report a bug, please contact helpdesk@niftt.gov.

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Appendix B: Introduction to FlamMap

B.1 About FlamMap

(from http://www.fire.org)

FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics (such as spread rate, flame length, and fireline intensity) over an entire FARSITE landscape for constant weather and fuel moisture conditions.

FlamMap is widely used by the National Park Service (U.S. Department of the Interior), Forest Service (U.S. Department of Agriculture), and other federal and state land management agencies in support of fire management activities. It is designed for those familiar with fuel, weather, topography, wildfire situations, and the associated terminology. Because of FlamMap's complexity, only those with proper fire behavior training and experience should use the application when outputs are to be used in support of fire and land management decisions.

B.2 Using FlamMap

- FlamMap software creates raster maps of potential fire behavior characteristics (spread rate, flame length, crown fire activity, etc.) and environmental conditions (dead fuel moistures, midflame wind speeds, and solar irradiance) over the entire FARSITE landscape. These raster maps can be viewed in FlamMap or exported for use in a geographic information system, image, or word processor.

- FlamMap is not a replacement for FARSITE or a complete fire growth simulation model. There is no temporal component in FlamMap. It uses spatial information on topography and fuel to calculate fire behavior characteristics at one instant.

- FlamMap uses the same spatial and tabular data as FARSITE.

- FlamMap incorporates the following fire behavior models:
    - a Landscape (.lcp) File,
    - Initial Fuel Moistures (.FMS) File,
    - optional Custom Fuel Model (.FMD),
    - optional Conversion (.CNV) File,
    - optional Weather (.WTR) File, and
    - optional Wind (.WND) File.
    - Rothermel's 1972 surface fire model,
    - Van Wagner's 1977 crown fire initiation model,
    - Rothermel's 1991 crown fir spread model, and
    - Nelson's 2000 dead fuel moisture model.

- FlamMap runs under Microsoft Windows operating systems (Windows 95, 98, ME, NT, 2000, and XP) and features a graphical user interface.

  ***Note**: FlamMap has not yet been tested with the Microsoft Windows VISTA operating system.*

- Users may need the support of a geographic information system (GIS) analyst to use FlamMap. Rasters must be in the same projection system and pixel size must also match.

- In addition to the usual menus, commands, and toolbar buttons, FlamMap has a hierarchical tree interface that makes it easy to navigate throughout a fire behavior analysis.

- Instead of using the same dead fuel moisture values for all cells of a fuel model, FlamMap has the ability to use weather data so as to estimate dead fuel moisture based on slope, shading, elevation, aspect, and the weather stream.

- Because FlamMap uses fuel moisture values at one point in time, and of course topography does not change, FlamMap is an ideal tool to compare relative fire behavior changes resulting from fuel modifications. However, FlamMap will not simulate temporal variations in fire behavior caused by weather and diurnal fluctuations, nor will it display spatial variations caused by backing or flanking fire behavior. These limitations need to be considered when viewing FlamMap output in an absolute rather than relative sense.

B.3 What's new in FlamMap version 3.0?

FlamMap version 3.0 (FlamMap3) was released in March 2006. Major recent feature additions include support for the Scott and Burgan (2005) Fire Behavior Fuel Models, the Minimum Travel Time fire growth model (described below), and the Treatment Optimization Model (also described below). In addition, a second method for calculating crown fire behavior has been added. All of the features found in FlamMap2 are still available in this newer version.

The Minimum Travel Time (MTT) fire growth model is a two-dimensional fire growth model. It calculates fire growth and behavior by searching for the set of pathways with minimum fire spread times from point, line, or polygon ignition sources. In theory, the results are identical to those of the wave-front expansion simulation technique used in FARSITE with the exception that all weather and fuel moisture conditions are held constant over time in MTT but allowed to vary in time in FARSITE.

The Treatment Optimization Model's (TOM) calculations rely on the MTT calculations to identify major fire travel routes, and then the model attempts to efficiently block these routes with fuel treatments. Given target weather conditions, the model will select the fuel treatments that best reduce fire growth rates.

> ***Tip**: See "What's New in FlamMap3" in online help for more information on these features.*

B.4 Downloading FlamMap

To download FlamMap, go to http://www.fire.org and click on **FlamMap > Downloads >** FlamMap3Setup.msi.

FlamMap3Setup.msi (6.4 MB) is a Windows installer module containing all files as well as Help and Tutorial data. Download this file to a temporary directory and install by using the Add/Remove Programs control panel or by simply double-clicking.

> ***Note**: The msi file referenced above requires the latest version of Windows Installer. During the installation process, you will be notified if your system does not contain the most recent Windows Installer distribution from Microsoft, and your computer system will attempt to update Windows Installer from Microsoft's website.*

If you select the full installation package as shown above, you will get the FlamMap install, a helpful tutorial with sample data, as well as full on-line help.

Appendix C: Decision Key; Decision Dependency from FOFEM

This section details the algorithm decision key used by FOFEM to select the most appropriate algorithm for predicting the consumption of the herbaceous, shrub, and duff fuel components.

Herbaceous Calculations:
- Cover Type
- Season

Shrubs Calculations:
- Cover Type
- Season
- Region

Duff Calculations:
- Region
- Cover Type
- Fuel Category
- Moisture Method

Litter, Crown Branch/Foliage, Down Woody
These fuel components are always calculated using the same equations regardless of Cover Type, Season, etc.

Herbaceous

Herbaceous fuel: Herbaceous fuel is generally a small component of the total fuel load. However, for completeness, especially in modeling emission production, their consumption is computed by FOFEM. Generally, all the herbaceous fuel is assumed to burn (equation 22). If the cover type is a grass type, and the season of burn is spring, only 90% of the herbaceous fuel is consumed (equation 221).

Shrubs

Shrub consumption is modeled with rules of thumb that will eventually be replaced when additional shrub consumption work is available. General rules can be summarized as follows:

- If the cover type is sagebrush and the season is fall, shrub consumption is 90% (equation 233); for all other seasons, 50% (equation 232).

- For other cover types dominated by shrubs (except in the southeast), shrub consumption is assumed to be 80% (equation 231).
- For cover types not dominated by shrubs, shrub consumption is set to 60% (eq 23).
- For the southeastern region, for the pocosin cover type, in spring or winter shrub consumption is 90% (eq 233), in summer or fall 80% (equation 235).
- For non-pocosin types in the southeast, Hough's (1968, 1978) research was used to predict shrub consumption (eq 234): percent consumption = ((3.2484 + 0.4322 * preburn litter and duff loading + .6765 * preburn shrub and regeneration loading - .0276* duff moisture – (5.0796 / preburn litter and duff loading) – litter and duff consumption) / preburn shrub and regeneration loading) * 100%.

Duff

A number of different duff consumption algorithms are incorporated into FOFEM5. Separate predictions are made of percent duff consumption and duff depth consumed. These equations, their sources, and the circumstances under which each is used by FOFEM are summarized below.

Equation 2:

%DR (duff depth reduction, %) = 83.7 - 0.426 EDM (entire duff moisture, %)

Brown and others 1985

Used for predicting percent duff consumption from entire or average duff moisture content in the Interior West and Pacific West. This equation is also the default equation that FOFEM uses when it cannot find another duff consumption algorithm.

Equation 6

DR = (duff depth reduction in inches) 0.8811 - 0.0096 EDM + 0.439 DPRE

Brown and others 1985

Used for predicting duff depth consumption from entire or average duff moisture content in the Interior West and Pacific West. This equation is also the default equation that FOFEM uses when it cannot find another duff consumption algorithm.

Equation 10

MSE (mineral soil exposure, %) = 167.4 - 31.6 log (EDM)

Brown and others 1985

Used for predicting mineral soil exposure from average duff moisture content in the West. This is also the default equation FOFEM uses for predicting mineral soil exposure.

Equation 14

MSE = -8.98 + 0.899 %DR

Brown and others 1985

Used for predicting mineral soil exposure from percent duff reduction – a robust equation used when other information is lacking.

Equation 15

RD (residual duff depth in inches) = -0.791 + .004 EDM + 0.8 DPRE + 0.56 PINE (PINE = 1 if long needle type, 0 if otherwise)

Reinhardt and others 1991

Used for predicting residual duff depth from average duff moisture and preburn duff depth, this equation was based on data assimilated from many studies and is used where a more site specific equation is lacking.

Equation 16

W (loading of forest fuel consumed – litter plus duff in tons per acre) = 3.4958 + 0.3833 WPRE (WPRE = preburn loading of forest fuel litter plus duff in tons per acre) - 0.0237 EDM - 5.6075/WPRE

%DR = 0 if W ≤ L (preburn loading of litter in tons per acres)

= ((W-L)/ (WPRE-L))*100%, if W > L

Hough 1978

Used in the Southeast except in pocosin cover types.

Equation 19

%DR = 100% (chaparral)

Equation 20

DR = DPRE - 4 (pocosin)

Hungerford 1996

For deep organic soils in the pocosin type, preburn duff depth is defined to be the depth above the water table. This depth is set to be 1 inch if moisture conditions are wet, 5 inches if moderate, 14 inches if dry, and 25 inches if very dry. These defaults can be changed by changing the preburn duff depth. It is assumed that the duff is consumed to within 4 inches of the water table.

Equation 201

%DR (pocosin)

Hungerford 1996

It is assumed that the top 8 inches of the duff is root mat with a bulk density of 0.1, and the muck below has a bulk density of 0.2. The duff loading consumed and percent duff consumption are calculated by assuming that this material burns from the top down to within 4 inches of the water table.

Equation 202

MSE = 0% (pocosin)

Hungerford 1996

For deep organic soils in the pocosin type, we assume mineral soil is never exposed.

From Reinhardt and others, 1997.

Appendix D: Default Fuel Moisture File (.fms)

Dead fuel moisture content values (percent) for the dead fuel moisture scenarios.

	Very low	Low	Moderate	High
1-hr	3	6	9	12
10-hr	4	7	10	13
100-hr	5	8	11	14
Live herbaceous	30	60	90	120
Live woody	60	90	120	150

From Scott and Burgan, 2005.

Appendix E: FOFEM Parameters Calculated by WFAT

Crown Branch Load = Crown Fuel Load * .1

Crown Foliage Load = Crown Fuel Load * .9

Duff Depth – FCCS includes this attribute, FLM WFAT assumes DuffLoad / 10

Soil Type = Coarse Silt (which is common in the west)

100-hr Fuel Moisture is used to calculate the Duff Moisture.

Moisture Condition – based off DuffMoisture
    If (DuffMoisture >= 130)
        MoistureCondition = Wet

    Else if (DuffMoisture < 130 && DuffMoisture >= 75)
        MoistureCondition = Moderate

    Else if (DuffMoisture <= 75 && DuffMoisture >= 20)
        MoistureCondition = Dry

    Else if (DuffMoisture < 20)
        MoistureCondition = VeryDry

Duff Moisture – based on 100-hr Fuel Moisture

    If (100FuelMoisture > 6.96)
        Duff Moisture = round((100FuelMoisture * 6.42) - 34.7)

    Else
        Duff Moisture = 10

Duff Moisture Method is always set to Entire

What is WFAT using for 1000 Hr moisture? 1000-hr Fuel Moisture Grid or CWD Profile?

    If we ran Fuel Moisture Conditioning (Effects Generator assumes that we did)
        Pull 1000-hr Moisture from 1000-hr Fuel Moisture Grid (with a min of 1)

Else // didn't run Fuel Moisture Conditioning

If FLM is in CWD profile (should be)
Get it from CWD profile (for that flm)

Else
1000-hr Fuel Moisture = 15

Cover Group is set based on the FEFM

If FefmType = Custom
CoverGroup = NO_CVRGRP ("")

Else if FefmType = FLM

If (flm = 66 or flmValue = 54 or flmValue = 15)
CoverGroup = SHRUB ("SG")

Else if (flmValue = 65 or flmValue = 14 or flmValue = 53)
CoverGroup = SAGEBRUSH ("SB")
Else
CoverGroup = NO_CVRGRP ("")
Else if FEFMType = FCCS
pull Cover Group from Ctg column in FCCS table in WFAT's

Fuel Loading database

Mapping of FCCS.Ctg values to cover group:

GG	Grass
SB	Sagebrush
SG	Shrub
PC	Pocosin
PN	Ponderosa
WPH	White Pine Hemlock
RJP	Red, Jack Pine
BBS	Balsam, Black, Red, White Spruce