Preface

The Fire Behavior Assessment Tool (FBAT) provides an interface between the ArcMap geographic information system (GIS) and FlamMap3 (Finney and others 2006), a fire behavior mapping and analysis program that computes potential fire behavior characteristics (flame length, rate of spread, crown fire activity [in other words, fire type], and fireline intensity) at a pixel level (see Appendix B). In summary, FBAT runs FlamMap in the background from an ArcMap platform while producing many of the same fire behavior characteristics that are output by FlamMap (such as flame length, fireline intensity, rate of spread, and crown fire activity). FBAT also includes several additional functions that are not currently available in FlamMap (explained later in this document).

A primary objective behind the creation of FBAT was to develop a tool that would assist managers in prioritizing fuel treatments on the basis of fire behavior and in assessing the effectiveness of fuel treatment proposals. In addition, FBAT can also be used to support the analysis of prescribed and wildland fires and to calibrate fuel input layers for more complex FlamMap or FARSITE (Finney 1998) applications.

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. As opposed to FlamMap, FBAT uses spatial layers that are in the ArcGRID format and automatically saves all outputs in the ArcGRID format as well. Consequently, there is no longer any need to convert files back and forth between ASCII and ArcGRID formats as required by FlamMap.

We assumed that most fire behavior issues could be adequately addressed by working with predictions of potential flame length, rate of spread, crown fire activity, and fireline intensity. Thus, by default, FBAT outputs these four fire behavior characteristics as individual layers. In addition, FBAT has two options that allow the user to query specific fire behavior conditions that may occur within an analysis area based upon user-defined thresholds of potential flame length, rate of spread, and crown fire activity. That is, FBAT can be used to integrate flame length, rate of spread, and crown fire activity into a single metric based upon user-defined queries.

Certain photos courtesy of Fire Management Today
FBAT is a planning tool that can be used to help:

- Identify the location of hazardous fuels
- Prioritize, design, and evaluate fuel treatment projects
- Develop burn plans for prescribed fire
- Infer fire effects
- Assess appropriate management response to wildland fire
- Develop suppression strategies and tactics for wildland fire
- Calibrate fuel data layers based upon observed fire behavior

FBAT outputs can be used to help identify the location of hazardous fuels within an analysis area and to prioritize, design, and evaluate the effectiveness of proposed fuel treatments in altering fire behavior. For example, the tool can help answer the question “Where on a landscape is potential fire behavior likely to be most problematic in regards to specific land management objectives?” And after a fuel treatment prescription is developed, FBAT can be used to address the question “Will the fuel treatment prescriptions actually achieve the desired fire behavior characteristics?”

FBAT outputs – such as maps showing potential fire behavior characteristics under different weather conditions and fuel moisture scenarios – can also be used to develop burn plans for prescribed fires. For example, the tool can help answer the question “What wind and fuel moisture conditions will result in controllable fire behavior characteristics?” Moreover, fire behavior characteristics, such as flame length, fireline intensity, rate of spread, and crown fire activity, can be used to infer potential first-order fire effects. For example, flame length can be used to estimate scorch height.

FBAT can also be used to assess the appropriate management response to wildland fire. Response to wildland fire depends on land management objectives and on whether a fire can be managed within a defined boundary with no adverse outcomes to life or property values. FBAT output maps showing potential fire behavior characteristics and inferences to potential fire effects can be used to support these decisions. FBAT output maps showing potential fire behavior characteristics can also be used to help develop suppression strategies. For example, fire managers can use FBAT outputs to prioritize suppression resources based on potential spread rates, natural barriers to fire spread, and the location of potential burnout areas.

Lastly, one of the most powerful applications of FBAT is that the fire behavior outputs can be used to calibrate fuel input layers used in FARSITE, FlamMap, and FBAT. For example, fuel layers are commonly developed using vegetation characteristics as correlates; however, vegetation attributes alone can be poor predictors of the fuel complex. FBAT 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 appropriate fire behavior is simulated by FBAT.

This version of FBAT (version 1.2.0) was released in March 2007. Future versions may incorporate additional features, so be sure to check the NIFTT website (www.nifft.gov) for possible tool updates and enhancements as well as associated updates to this user's guide.
What’s new in version 1.2.0?

A beta version of the Fire Behavior Assessment Tool was released for review and testing in 2005. We have fixed all reported bugs and have incorporated many of the ideas suggested by users into FBAT version 1.2.0. The most notable changes include the following:

- Incorporated FlamMap3 executable
- Deleted Absolute fire behavior metric from outputs
- Deleted Relative fire behavior metric from outputs
- Added Scott and Reinhardt (2001) method for calculating the transition between passive and active crown fire
- Added canopy foliar moisture content as an input parameter
- Added Scott’s (in press) wildland fire intensity metric (see Appendix C)
- Added a text file that documents run parameters
- Omitted need for ASCII grids for the creation of the landscape (LCP) file

Prerequisites

FBAT serves as an interface between ArcMap and FlamMap, so users should be familiar with both of these software tools. More importantly, users should have at least a basic understanding of fire behavior, including knowledge pertaining to fuels (such as fire behavior fuel models), weather (such as wind and fuel moisture), topography, and wildfire situations. Moreover, users should also understand the relationships between disturbance, vegetation attributes, and fuel characteristics. This understanding should be accompanied by an ability to use a non-spatial fire behavior prediction system such as BehavePlus or NEXUS. FBAT users should be capable of using fire behavior 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 training and experience should use FBAT whenever the outputs are to be used in fire and land management decisions.

FBAT requires ArcGIS 9.0 software (or higher) and the necessary computer hardware for operation. Specific computer requirements are described in detail in Chapter 1 of this guide. Note that FBAT has not yet been tested with the Microsoft Vista operating system or with ArcGIS version 9.2.

Obtaining copies
To obtain additional copies of this FBAT User’s Guide or to obtain the FBAT Tutorial (available spring 2008), follow these steps:

1. Go to the NIFTT website at [www.niftt.gov](http://www.niftt.gov)
2. Click on NIFTT Tools and User Documents in the menu. Select NIFTT User Documents, and you will then be routed to the fire.org site where NIFTT tools and associated documents are housed.
3. In the menu on the left, go to NIFTT > User Documents
4. Click on the material you wish to download (User’s Guide, Tutorial, or the latest version of FBAT).

Credits

FBAT was developed for the National Interagency Fuels Technology Team (NIFTT) by Dale Hamilton (NIFTT member) of Systems for Environmental Management (SEM), Missoula, Montana. Technical guidance was provided by Mark Finney, Jeff Jones, and Wendel Hann of the USDA Forest Service.

Support for the development of FBAT was provided by the National Interagency Fuels Coordination Group through NIFTT. Funding was provided by the U.S. Department of Agriculture Forest Service and the U.S. Department of Interior.

This Fire Behavior Assessment Tool User’s Guide was written by NIFTT members Jeff Jones of the USDA Forest Service and Deb Tirmenstein of Systems for Environmental Management.

Lastly, we thank Christine Frame of Systems for Environmental Management (and NIFTT member) for her editorial proficiency.

Your input

We value your input. Please forward any questions, comments, reports of bugs, or ideas to the National Interagency Fuels Technology Team (NIFTT) at helpdesk@niftt.gov.
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Chapter 1: About the FBAT User’s Guide

1.1 Before you begin
This user’s guide describes the basic operation of FBAT, which serves as an interface between ArcMap and FlamMap. Because we assume that FBAT users have experience operating and understanding the ArcMap and FlamMap applications (as well as ArcGIS and Microsoft Windows in general), this user’s guide will not repeat specific instructions for using either of these two software packages. Instead, we encourage users to refer to the excellent help functions available with ArcMap and FlamMap should any questions arise.

1.2 How to use this guide
You need not read the entire guide to carry out a specific task. Once you are familiar with the basic concepts associated with FBAT, you can quickly locate commonly performed tasks by reviewing the headings in the Table of Contents located near the beginning of this guide. You can then refer to the specific section pertaining to your needs. Whenever possible, screen captures are used to illustrate the steps required to complete a task.

Note that the FBAT 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 FBAT tutorial, available spring of 2008 at www.niftt.gov, will provide such step-by-step instructions with examples.

1.3 System requirements

1.3.1 Computer hardware
Your choice of hardware will greatly affect FBAT’s performance. In general, computers having faster processors, more memory, and more free hard drive space will process data faster. With respect to FBAT, the major determinant in selecting a system is the size of landscapes to be analyzed – larger landscapes will take longer to process. A computer system having the minimum requirements identified in table 1-1 will likely suffice for applications involving relatively small landscapes, such as tens of thousands of acres. However, a computer system should have the recommended requirements (table 1-1) if users will be frequently processing relatively large landscapes, such as hundreds of thousands of acres.

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows operating system</td>
<td>2000/XP</td>
<td>2000/XP</td>
</tr>
<tr>
<td>Memory</td>
<td>1GB</td>
<td>At least 1.5GB</td>
</tr>
<tr>
<td>Processor: P4 or equivalent</td>
<td>1.0GHz</td>
<td>At least 2.0GHz</td>
</tr>
<tr>
<td>Free hard drive space</td>
<td>5GB</td>
<td>At least 10GB</td>
</tr>
<tr>
<td>Display resolution</td>
<td>800 x 600</td>
<td>At least 1280 x 1024</td>
</tr>
<tr>
<td>Mouse or pointer</td>
<td>Required</td>
<td>Required</td>
</tr>
</tbody>
</table>

### 1.3.2 Computer software

FBAT users need ArcMap versions 9.0 or 9.1 and the Spatial Analyst extension.

**Note:** As mentioned above, FBAT has not yet been tested with ArcMap 9.2 or with the Microsoft Windows Vista operating system.
Chapter 2: FBAT Function

2.1 What does FBAT do?

FBAT provides an interface that allows FlamMap to be run from the ArcMap platform. Accordingly, many (but not all) of the input and output options available with FlamMap are also available with FBAT. Key limitations pertaining to input options are as follows: 1) the current version of FBAT cannot utilize wind grids or fuel moisture conditioning; 2) in respect to fire behavior outputs, FBAT does not derive heat per unit area, horizontal movement rate, mid-flame wind speed, or spread vectors; and 3) FBAT does not incorporate the Minimum Travel Time (MTT) or the Treatment Optimization Model (TOM) fire growth models that are currently available in FlamMap (see Appendix B for additional information on FlamMap).

FBAT incorporates three main processing steps. First, FBAT builds the landscape (LCP) file required to run FlamMap (or FARSITE). Next, FBAT runs FlamMap and produces layers depicting potential flame length, fireline intensity, rate of spread, and crown fire activity. FBAT also has an option to derive wildland fire intensity, which is the common logarithm of fireline intensity (Scott, in press – see Appendix C). FBAT then classifies the floating point grids denoting flame length and rate of spread into three classes using a classification scheme adapted from Scott and Burgan (2005). (Note: a floating point grid is a layer whose values are denoted by a type of numeric field for storing real numbers with a decimal point. The decimal point can be in any position in the field and, thus, may "float" from one location to another for different values stored in the field.) Lastly (and the primary advantage of using FBAT rather than FlamMap to assess fire behavior), FBAT contains two querying options for synthesizing flame length, rate of spread, and crown fire activity into a single fire behavior metric. All of the FBAT outputs are in ArcGRID format.

2.2 Synthesizing fire behavior characteristics into a single metric

Fire and fuel managers are commonly interested in assessing the cumulative hazard associated with several characteristics of fire behavior. For example, managers may be concerned with potential flame length, as well as with the likelihood that torching might
occur (in other words, passive or active crown fire). Or, perhaps they are concerned with flame length, rate of spread, and the likelihood of torching. FBAT contains two different options for assessing the cumulative hazard associated with flame length, rate of spread, and crown fire activity. That is, FBAT offers an easy means to query fire characteristics predicted by FlamMap, allowing managers to customize their analyses to address fire behavior issues specific to their assessment areas.

**Note:** Fireline intensity was not included as a characteristic to be integrated with other fire behavior characteristics because it is directly related to flame length. As flame length increases, fireline intensity increases exponentially. Consequently, it would be redundant to include both flame length and fireline intensity. Fireline intensity is a metric for heat output in the flaming front and is useful in its own right as a measure of fire behavior, and as a correlate with frontal fire effects.

FBAT’s Simple Query is a binary query in which the user defines the characteristics of interest, the thresholds of interest for each characteristic, and whether the query involves an AND or an OR conditional statement. The query is binary because only two values are contained in the output layer: those conditions meeting the conditions of the query (Value = 1) and those conditions not meeting the conditions of the query (Value = 0). For example, perhaps a manager is interested in knowing where potential flame length would exceed 2.4 m (8 ft) or where torching would likely occur. Alternatively, the manager might want to know where flame length would exceed 2.4 m (8 ft) and torching would likely occur. Both questions could be answered using the Simple Query.

On the other hand, the Classification Query classifies the entire assessment area into four categories indicating different levels of hazard (very low, low, moderate, and high). The user again identifies the characteristics of interest, as well as the thresholds of each characteristic that distinguish between classes. The Classification Query also includes options for either an AND or an OR conditional statement. For example, a manager may want to identify high hazard areas where potential flame length would exceed 3.7 m (12 ft) and the rate of spread exceeds 16.8 m/min (55 ft/min). Moderate hazard areas would be identified where flame length exceeds 1.2 m (4 ft) and the rate of spread exceeds 1.7 m/min (5.6 ft/min); low hazard areas would be identified where flame length exceeds 0.3 m (1 ft) and rate of spread exceeds 0.3 m/min (1 ft/min). All remaining areas not meeting these conditions would be classified as very low hazard.
Chapter 3: Input Data

3.1 Description of input data

The prediction of potential fire behavior requires site-specific information pertaining to fuels and topography, as well as information relating to fuel moisture and the fire weather scenario of interest. In FBAT, fuel and topographic information is provided by spatial input layers. Environmental factors describing a particular fuel moisture and fire weather scenario are provided by an initial fuel moisture file and a user interface that requires the user to specify the wind speed at 6.1 m (20 ft) above the canopy, wind direction, and percent foliar moisture.

3.2 Spatial layers

Before it can predict potential fire behavior, FBAT must first build a landscape (LCP) file that characterizes topography and fuels from eight rasters (see table 3-1). These layers must all be in ArcGRID format.

In order to successfully build a landscape file, FBAT uses the same input theme requirements as FlamMap and FARSITE. That is, the input grids must have identical coordinate systems, spatial extents, cell resolutions, and cell alignments. However, unlike FlamMap and FARSITE, FBAT does not have flexibility in the units used to characterize each input layer. The units used in FBAT must correspond to those shown in table 3-1.
### Table 3-1. Input grids.

<table>
<thead>
<tr>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>Meters</td>
</tr>
<tr>
<td>Slope</td>
<td>Degrees</td>
</tr>
<tr>
<td>Aspect</td>
<td>Degrees</td>
</tr>
<tr>
<td>Fire Behavior Fuel Model</td>
<td>Class</td>
</tr>
<tr>
<td>Canopy Cover</td>
<td>Percent</td>
</tr>
<tr>
<td>Canopy Height</td>
<td>Meters*10</td>
</tr>
<tr>
<td>Canopy Base Height</td>
<td>Meters* 10</td>
</tr>
<tr>
<td>Canopy Bulk Density</td>
<td>Kilograms/cubic meter * 100</td>
</tr>
</tbody>
</table>

*Slope and aspect layers are optional as they can be derived from the elevation layer.

**Note:** Slope and aspect layers are optional inputs. If these layers are not selected by the user, FBAT will automatically derive the slope and aspect layers from the elevation layer. However, be careful when using elevation data that contain any values other than elevation. For example, slope will be calculated inaccurately if your data set contains a value of “-9999,” which denotes NoData. We have also observed that the extents of the FBAT-generated slope and aspect layers will be slightly different from extents derived from the elevation layer if you are using ArcGIS 9.1 without the latest service pack (available at www.esri.com under Support > Downloads).

FBAT can also be executed using a pre-existing landscape file that was derived by using FlamMap, FARSITE, or FBAT. However, remember that the landscape file must have been derived from input grids having the units specified in table 3-1.

**Note:** FlamMap does not currently have a means for changing the units within a landscape file. Thus, users must first convert the input layers to the desired units prior to building the landscape file. The Raster Calculator can easily be used to convert data – simply multiply the grid values by the conversion factor. However, in FARSITE, the user can change the units of the landscape file from English to metric by using the Landscape Calculator and Editor dialog box.

With the exception of the layers denoting fire behavior fuel models, the ArcGRIDs used for running FBAT must be formatted so that the cell value represents the thematic value as a continuous or discrete variable. For example, the grid value of the elevation grid must denote the actual elevation in meters (see fig. 3-1). The grid value can also denote an ordered class of data in which the grid value denotes the midpoint of the class (see fig. 3-6).

The grid value of the fuel model layer must denote the actual fuel model class unless the grid value denotes a non-fuel class (such as water, rock, or agriculture). For canopy fuel, remember that the grid value corresponds to a specific unit. Therefore, the grid value of 10 in the canopy base height grid actually represents a canopy base height of...
one meter (3.3 ft), whereas a grid value of 10 in the canopy bulk density grid represents a canopy bulk density of 0.1 kg/m³ (0.01 lbs/ft³).

### 3.2.1 Elevation

The elevation layer must represent meters above sea level, and zero values are used for those areas that are at or below sea level. Figure 3-1 shows the Value Attribute Table of an elevation layer. FlamMap and FARSITE use the elevation theme for the fuel conditioning utility to adjust fuel moistures using adiabatic lapse rates. The elevation layer is also used for conversion of fire spread between horizontal and slope distances. In addition, FBAT can derive slope and aspect layers from the elevation layer, if desired.

![Figure 3-1. Example Value Attribute Table of an FBAT Elevation layer. The Value field must depict elevation in meters above sea level.](attachment:image.png)
3.2.2 Slope

FlamMap uses the slope layer for computing slope effects on flame length, fire spread, and solar radiance. The slope layer can have cell values represented by either floating point numbers (decimals) or integers. Figure 3-2 displays the Value Attribute Table of a slope layer. FBAT requires that slope units to be given in degrees rather than in percent. Note that FBAT will derive the slope layer from the elevation layer if it is not provided by the user.

![Figure 3-2. Example Value Attribute Table of an FBAT Slope layer. The Value field must show slope in degrees.](image)

3.2.3 Aspect

The aspect layer is used for the fuel conditioning function in FlamMap and FARSITE. (Fuel conditioning varies fuel moisture with respect to solar radiance). The FBAT aspect layer denotes slope azimuth in degrees clockwise from the
north (fig. 3-3). 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. Note that FBAT will derive the aspect layer from the elevation layer if it is not provided by the user.

<table>
<thead>
<tr>
<th>ObjectID</th>
<th>Value</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-1</td>
<td>46487</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>14438</td>
</tr>
<tr>
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</tr>
<tr>
<td>20</td>
<td>19</td>
<td>16949</td>
</tr>
</tbody>
</table>

Figure 3-3. Example Value Attribute Table of an Aspect layer. The Value field must depict aspect in degrees. (A value of -1 denotes flat areas that have no aspect).

### 3.2.4 Fire Behavior Fuel Model

FBAT can use either the fire behavior fuel models characterized by Anderson (1982) or those characterized by Scott and Burgan (2005). However, FBAT 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. 3-4). Non-burnable fuels 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 FBAT layer.

![Fire behavior fuel model code]

**Figure 3-4.** Example Value Attribute Table for a Fire Behavior Fuel Model layer using the Scott and Burgan (2005) models. The Value field must correspond to numeric fire behavior fuel model codes of Anderson (1982) or Scott and Burgan (2005).

### 3.2.5 Canopy Cover

Canopy cover is a stand attribute that corresponds to the proportion of the ground that is covered directly overhead by the overstory canopy (that is, the vertical projection of the 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 mid-flame height. The canopy cover layer is also used to modify solar radiance with the fuel conditioning function of FlamMap and FARSITE. FBAT requires that the canopy cover layer be expressed in percent
A cell value of 0 indicates a non-forested setting. The cell values can be denoted by either floating point numbers (decimals) or integers.

Canopy height is a stand attribute that reflects the average height of the overstory dominant and co-dominant 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 mid-flame height. In FARSITE, the canopy height layer is also used for estimating spotting distances from torching trees. FBAT requires the canopy base height layer units to be in meters*10 (fig. 3-6). A cell value of 0 indicates a non-forested setting. The cell values can be denoted by either floating point numbers (decimals) or integers.
3.2.7 Canopy Base Height

Canopy base height is a stand attribute that denotes the lowest height above the ground above which there is sufficient canopy 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 (in other words, lower heights increase the likelihood of passive crown fires). FBAT requires canopy base height layer units to be expressed in meters*10 (see fig. 3-7). A cell value of 0 characterizes a non-forested setting. Cell values can be denoted by either floating point numbers (decimals) or integers.
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 canopy fuel is that of a size and type that would be consumed in the flaming front. FARSITE and FlamMap use canopy bulk density to determine the transition between passive and active crown fire. (See Scott and Reinhardt [2001] for discussion on the derivation of crown fire activity). FBAT requires the units of the canopy bulk density layer to be expressed in kg/m$^3$ *100 (fig. 3-8). Cell values can be represented by floating point numbers (decimals) or integers.
3.3 Fuel Moisture File

Like FlamMap, FBAT requires a text file (.fms) that specifies the initial fuel moisture values (1-hr, 10-hr, 100-hr, live herbaceous, and live woody fuels) for each of the fire behavior fuel models (see fig. 3-9). 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 seasons. We recommend using data provided by Weather Information Management System (WIMS) at http://famweb.nwcg.gov/ and FireFamily Plus software (http://www.fire.org) to identify fuel moisture values that are appropriate for the specific geographic area and simulation scenario.
Unlike FlamMap, FBAT cannot vary fuel moisture by elevation, slope, aspect, and shading. Consequently, FBAT uses the same fuel moisture values for a fuel model, regardless of where that fuel model is located in the landscape.

The fuel moisture file used by FBAT 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 (1-hr) fuel moisture, 10-hour (10-hr) fuel moisture, 100-hour (100-hr) fuel moisture, live-herbaceous fuel moisture (LH), and live-woody fuel moisture (LW), respectively (see fig. 3-9). 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).

![Figure 3-9](image)

**Figure 3-9.** An example FBAT fuel moisture file that includes the first 10 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).

### 3.4 Wind Speed (6.1 m; 20 ft)

The FBAT user must input the 6.1 m (20 ft) wind speed he or she wishes to use for predicting potential fire behavior. The wind speed refers to the speed of the wind that occurs 6.1 m (20 ft) above the canopy of the dominant vegetation. Thus, in grasslands, the wind speed denotes winds at 6.1 m (20 ft) above the herbaceous canopy, whereas in forests, the value represents winds 6.1 m (20 ft) above the canopy. Values must be integers that reflect wind speed in miles per hour.
3.5 Wind Direction

Two options are available for entering wind direction. FBAT users may specify that the wind is blowing uphill, 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.

3.6 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 FBAT. A value of 80 percent typically reflects the effects of cumulative drought in systems where average annual precipitation is less than 76 cm (30 in), while 100 percent would reflect those same areas having recovered 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. In general, short needle species appear to have lower foliar moisture than long needle species and dry faster during dry seasons.
Chapter 4: Obtaining Input Data

4.1 Obtaining input data

Data sources for FBAT include remote sensing, such as satellite imagery or photo interpretation, stand exam data, and field-level mapping. You can also download geospatial data layers from www.landfire.gov.

Users can download LANDFIRE National layers representing fire regimes, fire behavior, and vegetation as well as LANDFIRE Rapid Assessment layers from the LANDFIRE website (www.landfire.gov). The West has been mapped and mapping progress continues across the country (check landfire.gov for mapping status). The LANDFIRE team is scheduled to complete mapping of the entire nation (including Alaska and Hawaii) by the end of 2009.

Note: Because the LANDFIRE data have the same units of measurement required by FBAT, no data conversions are required.

4.2 Steps

1. Navigate to www.landfire.gov and click on Data Products.
2. Under the Data Product Access menu item, you will see an overview followed by four options for downloading LANDFIRE data (shown below). Note these are also located in the right-hand column of the page. The first option links to the National Map LANDFIRE, LANDFIRE’S data dissemination website managed by the U.S. Geological Survey. The second option allows you to download the LANDFIRE Data Access Tool, which is run from ArcMap and can be used to download data layers (see http://www.landfire.gov/datatool.php). The third option provides information on how to obtain the latest LANDFIRE data via DVD, and the fourth explains how to access the data from an ftp site (note: this option is reserved for rare, time-sensitive situations – see website for details).

The following steps will detail the process necessary for downloading data directly from the National Map LANDFIRE.
3. Click on National Map LANDFIRE for a description of the data dissemination site and then click on the link in the right-hand column of that page to link to the National Map LANDFIRE. You can also access the National Map LANDFIRE website directly at http://landfire.cr.usgs.gov/viewer/.

4. Click on View User Instructions to open a page with tips for using the map interface. After reviewing, click on the approximate geographic location of your assessment area.
**Note:** Layers are available for all mapping zones colored green on the website’s front page (visit the National Map LANDFIRE for current mapping status).

5. The next web page will display a shaded relief map of the approximate geographic location that you selected in the previous step. At this point, you can zoom in, zoom out, and pan until the specific area of interest is within view. Note also that under the Display tab, you can access the Places and Boundaries menus to help locate your area of interest.

---

**Figure 4-4.** National Map LANDFIRE front page.
6. Click on the **Download** tab to identify the LANDFIRE layers that you wish to download. Check all of the layers to be downloaded.

7. Under **Downloads** in the left-hand column, click on either of the two download options: Define Rectangular Download Area or Define Download Area by Coordinates.
Click on either of the 2 download options

Figure 4-7. Data viewer download tools.

8. When you have finished drawing a rectangle or selecting coordinates, a summary page identifying all layers selected for download will appear. The data format default is ArcGRID_with_attib. However, in the event that you want to download additional layers with the existing selection or you have forgotten to select layers from the download tab, you can use the Modify Data Request option (found at the top of the Request Summary Page).
9. First, select the additional grids by checking the box next to the layer name. Then, click on the dropdown menu next to each data layer you have chosen and select ArcGRID_with_attribs. Notice that ArcGRID (no attributes) is the default format.

10. Click the Save Changes and Return to Summary button at the bottom of the page, which will bring you back to the Request Summary Page. You are now ready to continue downloading your data.

11. Once you have selected the desired layers, click on the Download button for the first layer in your summary report. The file will download as a .zip file with a random numeric name. The .zip file will contain a grid identified by the same
random number as the .zip file. We recommend that you change the name of the grid in ArcCatalog to reflect the thematic nature of the layer.

4.3 Tips

- Users should regularly check [www.landfire.gov](http://www.landfire.gov) for data versioning alerts – notices that appear when layers have been updated – and data notifications that identify known issues with specific data layers.

![Figure 4-9. Link on LANDFIRE website homepage to access important user information pages: Data Versioning Alerts and Data Notifications.](image)

- Users should be aware of some issues surrounding LANDFIRE canopy fuel data. As noted on the Data Notifications page of [www.landfire.gov](http://www.landfire.gov), external review has suggested that LANDFIRE forest canopy cover estimates are too high. As a consequence, the adjusted mid-flame wind speeds may be underestimated, thereby lessening predicted fire behavior.
Chapter 5: Output Data

5.1 Utility of outputs
5.2 Description of outputs
  5.2.1 Flame length class (flcls)
  5.2.2 Rate of spread class (roscls)
  5.2.3 Wildland fire intensity (firintn)
  5.2.4 Fire behavior simple query (fbquery)
  5.2.5 Fire behavior classification query (fbclass)

5.1 Utility of outputs

FBAT outputs can be used to spatially identify problematic areas from a fire behavior perspective based on fireline intensity, flame length, rate of spread, and crown fire activity. Outputs may be useful for assessing the appropriate management response to wildland fires (including wildland fire use), locating fuel treatment opportunities, evaluating fuel treatment effectiveness, and for calibrating fuel input layers to mimic observed fire behavior. For example, potential spread rate, flame length, and crown fire activity may provide useful information when deciding on the appropriate management response to wildland fire or when prioritizing suppression resources. Outputs are also helpful in assessing fire risk relative to ecological and social values and in subsequent prioritization of fuel treatment opportunities.

Once a project is identified, FBAT outputs can be used to help formulate fuel treatment prescriptions. For example, a potential fuel treatment might involve changing the surface fuel model to reduce potential flame length and/or rate of spread, changing the canopy base height to reduce the likelihood of surface to crown fire transition, or decreasing canopy bulk density to lessen the possibility of active crown fire. After a project is designed, pre-treatment fire behavior characteristics can be compared to post-treatment characteristics to evaluate whether the proposed fuel treatment produced the desired outcome. In some instances, a fuel treatment prescription may produce unintended consequences. For example, an objective to decrease flame length by altering the fire behavior fuel model may result in reduced canopy cover, which subsequently decreases fuel moisture and increases mid-flame wind speed. As a consequence of changing the fire behavior fuel model, flame length may actually increase rather than decrease.

FBAT outputs can also be useful for calibrating fuel and fire weather inputs. For example, if the outputs do not resemble the observed behavior of a historical or current fire, the fuel and fire weather inputs must be modified so that the simulated and
observed fire behaviors are similar. These refined outputs will then improve the predictive capabilities of fire behavior systems such as FlamMap and FARSITE.

## 5.2 Description of outputs

Nine spatial layers are generated by FBAT: six layers are produced automatically and three layers are optional (table 5-1). Four layers are direct outputs from FlamMap: flame length, fireline intensity, rate of spread, and crown fire activity. These outputs will not be discussed further here as they are fully described in the user guides and help systems of FlamMap, FARSITE, and BehavePlus. All other outputs are FBAT derivatives and will be discussed individually.

Table 5-1. Spatial outputs generated by FBAT characterizing potential fire behavior.

<table>
<thead>
<tr>
<th>Layer Name</th>
<th>Description</th>
<th>Grid Format</th>
<th>Units</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cfa</td>
<td>Crown fire activity (fire type)</td>
<td>Integer</td>
<td>Class</td>
<td>Automatic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 = non-burnable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = surface fire</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 = passive crown fire</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 = active crown fire</td>
<td></td>
</tr>
<tr>
<td>Flameln</td>
<td>Flame length</td>
<td>Floating point</td>
<td>meters</td>
<td>Automatic</td>
</tr>
<tr>
<td>Flcls</td>
<td>Flame length class</td>
<td>Integer</td>
<td>Class</td>
<td>Automatic</td>
</tr>
<tr>
<td></td>
<td>Flame length is divided into four classes</td>
<td></td>
<td>0 = non-burnable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = low (0.1 to 1.22 m)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 = moderate (1.2 to 3.66 m)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 = high (exceeds 3.66 m)</td>
<td></td>
</tr>
<tr>
<td>Lineintn</td>
<td>Fireline intensity</td>
<td>Floating point</td>
<td>Kilowatts/meter</td>
<td>Automatic</td>
</tr>
<tr>
<td>ros</td>
<td>Rate of spread</td>
<td>Floating point</td>
<td>Meters/minute</td>
<td>Automatic</td>
</tr>
<tr>
<td>roscls</td>
<td>Rate of spread class</td>
<td>Integer</td>
<td>Class</td>
<td>Automatic</td>
</tr>
<tr>
<td></td>
<td>Rate of spread is divided into four classes</td>
<td></td>
<td>0 = non-burnable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = low (0.1 to 1.68 m/min)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 = moderate (1.68 to 16.76 m/min)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 = high (exceeds 16.76 m/min)</td>
<td></td>
</tr>
<tr>
<td>firintn</td>
<td>Wildland fire intensity (common log of fireline intensity)</td>
<td>Floating point</td>
<td>Log10(kW/meter)</td>
<td>Optional</td>
</tr>
<tr>
<td>fbquery</td>
<td>Fire behavior – simple binary query</td>
<td>Integer</td>
<td>Class</td>
<td>Optional</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 = does not meet query specs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = meets query specs</td>
<td></td>
</tr>
<tr>
<td>fbclass</td>
<td>Fire behavior – classification query</td>
<td>Integer</td>
<td>Class</td>
<td>Optional</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 = very low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 = low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2 = moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3 = high</td>
<td></td>
</tr>
</tbody>
</table>
5.2.1 Flame Length Class (flcls)

Flame Length Class is derived by classifying flame length observations into four flame length classes: non-burnable, low, moderate, and high. Class thresholds (table 5-2) were modified from the Scott and Burgan (2005) six-class system. Converting the flame length layer from a continuous variable (floating point grid) to a categorical variable (integer grid with four classes) simplifies its use for those who are not interested in precise estimates of potential flame length.

Table 5-2. The classification of potential flame length (FL) used by FBAT.

<table>
<thead>
<tr>
<th>Flame Length Class</th>
<th>Flame Length (meters)</th>
<th>Class Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Non-burnable</td>
</tr>
<tr>
<td>1</td>
<td>0 &lt; FL &lt; 1.219</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>1.219 &lt; FL &lt; 16.764</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>16.764 &lt; FL</td>
<td>High</td>
</tr>
</tbody>
</table>

The Flame Length Class layer (fig. 5-1) uses a default color scheme of gray, blue, green, and red, which corresponds to non-burnable, low, moderate, and high flame lengths, respectively.

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.
5.2.2 Rate of Spread Class (roscls)

Rate of spread observations are grouped into four classes representing non-burnable, low, moderate, and high spread rates. The class thresholds defined by Scott and Burgan (2005) were modified to fit our four-class system (see table 5-3). Converting the rate of spread layer from a continuous variable (floating point grid) to a categorical variable (integer grid having four classes) simplifies its use by those who are not interested in precise estimates of potential rate of spread.

<table>
<thead>
<tr>
<th>ROS Class</th>
<th>ROS (m/min)</th>
<th>Class Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Non-burnable</td>
</tr>
<tr>
<td>1</td>
<td>0 &lt; ROS &lt; 1.676</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>1.676 &lt; ROS &lt; 16.764</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>16.764 &lt; ROS</td>
<td>High</td>
</tr>
</tbody>
</table>

Note: The ROS Class layer (fig. 5-2) uses the same default color scheme as the Flame Length Class layer: gray, blue, green, and red, which correspond to non-burnable, low, moderate, and high spread rates, respectively.
5.2.3 Wildland Fire Intensity (firintn)

The Wildland Fire Intensity metric was proposed by Scott (in press – see Appendix C) 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.

The Wildland Fire Intensity layer is a floating point grid (see fig. 5-3). Consequently, there is no way to view the Value Attribute Table in ArcMap.
5.2.4 Fire Behavior Simple Query (fbquery)

The Fire Behavior Simple Query is a user-defined query that produces output with multiple fire behavior characteristics but which allows users to focus on a single set of thresholds. The FBAT user must first identify all combinations of flame length, rate of spread, and crown fire activity that are applicable to his or her assessment. The FBAT user must then specify the threshold of each fire behavior characteristic that is meaningful to the application. And lastly, the user must specify whether the query should include an And or an Or conditional statement.

For example, a manager may want to prioritize fuel treatment unit locations in areas where potential fire behavior is especially problematic from a suppression perspective. These conditions could be identified by querying for those areas where potential flame length would exceed four meters or where passive or active crowning could potentially occur.

The Fire Behavior Simple Query is a binary query. Those conditions meeting the query parameters are mapped with a cell value of 1; all other values (not meeting the query parameters) are assigned a cell value of 0 (see fig. 5-4). Consequently, the output is “simple” – a cell is identified by whether it meets the conditions of
the query. The Fire Behavior Simple Query can be used to characterize potential fire behavior within an analysis area based on the interaction of multiple fire behavior characteristics. The Simple Query also enhances user understanding of the interaction between fuels and multiple fire behavior characteristics. For example, a user concerned about crown fire activity, flame length, and rate of spread might observe that a certain fuel treatment prescription alters the crown fire activity as intended (such as passive crown fire is changed to surface fire), but with the unintended consequences of increasing potential flame length and rate of spread. Thus, a user may find that a proposed prescription actually increases fire behavior concerns.

![Attribute table]

**Figure 5-4.** An example Fire Behavior Simple Query output. The spatial output contains two values: 0 (yellow) identifies those areas that do not satisfy the parameters of the query; 1 (black) identifies those areas that do satisfy the parameters of the query. In this example, the query identifies those areas that have the potential for crown fire (passive or active) OR areas where potential flame length will exceed 1.2 meters, OR areas where potential spread rate will exceed 1.7 m/min.

By default, the Simple Query uses an OR conditional statement and the threshold values shown in table 5-4. However, users can easily change any of the threshold values and can select an AND conditional statement, if desired.
Table 5-4. Default parameters of the Simple Query.

<table>
<thead>
<tr>
<th>Fire Behavior Characteristic</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flame length</td>
<td>1.2-meter &lt; FL</td>
</tr>
<tr>
<td>Rate of Spread</td>
<td>1.7-meter/minute &lt; ROS</td>
</tr>
<tr>
<td>Crown Fire Activity (Fire Type)</td>
<td>2 &lt; CFA (i.e., passive or active crown fire)</td>
</tr>
</tbody>
</table>

*FL = flame length; ROS = rate of spread; CFA = crown fire activity.

**Note:** Simple Query results can be used to compare and prioritize different assessment areas only if the query parameters are consistent across the areas to be compared.

5.2.5 Fire Behavior Classification Query (fbclass)

The Fire Behavior Classification Query is also designed by the FBAT user. The user must identify applicable fire behavior characteristics (in other words, flame length, rate of spread, and crown fire activity) and their respective thresholds that are of interest to analysis objectives. Unlike the Simple Fire Behavior Query which classifies the landscape into two classes (meets the conditions of the query or does not), the Fire Behavior Classification Query classifies the landscape into four user-defined classes that indicate very low, low, moderate, and high fire behavior activity.

For example, a manager may want the high class to denote those areas where flame lengths would likely exceed 7 m (23.0 ft) or where active crowning is likely to occur, the moderate class to denote areas where flame lengths would likely exceed 4 m (13.1 ft) or where torching would be expected to occur, and the low class to denote where flame lengths would likely exceed 1 m (3.3 ft) or where surface fire would be expected, and the very low class to denote the remaining areas that did not meet the specifications of the low class. This example uses the conditional OR statement to define class thresholds; however, a query could also use the conditional AND statement.

**Note:** The Classification Query is set up with default thresholds suggesting very low, low, moderate, and high fire behavior classes (table 5-5) and uses an OR conditional statement. However, users can easily change any of the thresholds and can select an AND conditional statement, if preferred.
Table 5-5. Default thresholds used in the Classification Query to derive very low, low, moderate, and high fire behavior classes.

<table>
<thead>
<tr>
<th>Flame length (meters)</th>
<th>Rate of spread (meters per min.)</th>
<th>Crown fire activity (fire type)</th>
<th>Fire behavior class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
<td>None</td>
<td>0 (very low)</td>
</tr>
<tr>
<td>0.1 to 1.2</td>
<td>0.1 to 1.7</td>
<td>Surface</td>
<td>1 (low)</td>
</tr>
<tr>
<td>1.2 to 3.7</td>
<td>1.7 to 16.8</td>
<td>Passive crown fire</td>
<td>2 (moderate)</td>
</tr>
<tr>
<td>&gt; 3.7</td>
<td>&gt; 16.8</td>
<td>Active crown fire</td>
<td>3 (high)</td>
</tr>
</tbody>
</table>

The output layer is a simple integer grid containing four values (0,1,2,3) that represent the four fire behavior classes as defined by the user (fig. 5-5). This layer can be used to help prioritize fuel treatment projects and to evaluate the effectiveness of a proposed treatment by comparing pre-treatment fire behavior with post-treatment fire behavior. Classification Query output may also be useful for assessing wildland fire use scenarios for Fire Management Planning or for designing suppression tactics during a wildland fire incident.

**Figure 5-5.** An example Classification Query output layer. Note that the attribute table contains values 0 through 3 which represent very low, low, moderate, and high fire behavior, respectively.

**Note:** The Classification Query can be used to compare different analysis areas only if the query parameters are consistent across the multiple areas.
Chapter 6: Installing FBAT

6.1 Installation instructions
   6.1.1 Installing the complete NIFTT tool package
   6.1.2 Single-tool (FBAT) installation
6.2 Troubleshooting FBAT installation

6.1 Installation instructions

Currently, all NIFTT tools can be installed at once as a package. For most NIFTT tool users, the complete or package installation is most convenient.

    Note: The following instructions apply to installation of the entire NIFTT package. Single tool installation will be addressed later in this chapter.

Before you begin installation, it is important to note that both Microsoft .Net Framework 1.1 and Service Pack 1 have been installed. You can obtain Microsoft .Net Framework 1.1 from ftp://fire.org/dotnetfxsp1 or by searching at http://www.microsoft.com.

The folder dotnetfxsp1 contains three required files, and they must be installed in the following order (the install programs provide help in the form of warnings):

1. dotnetfx.exe (Microsoft .Net Framework 1.1).
2. NDP1.1sp1-KB8867460-X86.exe – (Microsoft .Net Framework 1.1 Service Pack 1).
3. NDP1.1sp1-KB886903-X86.exe - (Microsoft .Net Framework 1.1 Hotfix).

You will need to reboot after installation. However, only one reboot is necessary.

    Note: To confirm that these programs are installed on your computer, check Add/Remove Programs. You should see the following if the necessary programs are present:

- Microsoft .Net Framework 1.1
- Microsoft .Net Framework 1.1 Hotfix (886903)

6.1.1 Installing the complete NIFTT tool package
If you have earlier versions of any of the NIFTT tools (Area Change Tool [ACT], FRCC Mapping Tool [FRCC MT], Multi-scale Resource Integration Tool [MRIT], or Fire Behavior Assessment Tool [FBAT]) installed on your computer, you will first need to un-install these tools before proceeding with installation of the current versions.

To determine which version is currently installed on your computer, go to **Start > Control Panel > Add or Remove Programs**. View the version of the NIFTT tool you are interested in (fig. 6-1).

**Figure 6-1.** Version 1.2.0 of FBAT.

*Note:* NIFTT naming conventions are as follows: **FBAT_120_070119** indicates that this “install” is version 1.2.0 which was completed on 01/19/2007.

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

Follow these steps to install the complete NIFTT tool package:

1. From the NIFTT website at [www.niftt.gov](http://www.niftt.gov), click on **NIFTT Tools & User Documents** in the menu. Select **NIFTT Tools**. You will be routed to Fire.org where the NIFTT tools are housed.
2. To download the self-extracting WinZip file, **NIFTT_Install_(date).exe**, select **NIFTT > Downloads** from the menu.
3. Click on the NIFTT Install Executable file as shown in figure 6-2: **NIFTT Install Executable** (FBAT, FRCC, MRIT and ACT)
4. Next, double-click on `NIFTT_Install_070226.exe` to begin downloading the most recent tool installation package (note that the date in the file name may have changed). You will see the dialog box shown in figure 6-3:
5. Click **OK** to download the installation file and then save it to a convenient location on your computer.

The following box will open as soon as the download is complete.

![WinZip Self-Extractor NIFTT install dialog box.](image)

**Figure 6-4.** WinZip Self-Extractor NIFTT install dialog box.

6. Unzip the file to either the default location (**C:\NIFTT** as shown above in figure 6-4) or the location of your choice by selecting the **Browse** button.

**Note:** do not install the tools to any pathways that may contain a space in the folder name such as *My Documents* or *Program Files*.

7. A folder labeled **NIFTT\_Install\_070123** will be created within the **NIFTT** (default) folder. Locate and then double click on the folder labeled **NIFTT\_Install\_070123** as shown in figure 6-5 to begin the installation process. (Again, dates in folder names may have changed.)

![NIFTT\_Install folder](image)

**Figure 6-5.** NIFTT\_Install folder
8. When the NIFTT_Install folder opens, you will see the following files. Next, double-click on the installation batch file NIFTT_setup.bat.

![NIFTT Install folder contents](image)

Figure 6-6. NIFTT Install folder contents.

9. You’ll see a number of dialog boxes such as the one in figure 6-7. Click Yes to install the Microsoft.NET Framework package.

![Microsoft .NET Framework 1.1 Setup](image)

Figure 6-7. Microsoft Framework Setup dialog box.

Follow instructions as directed in a series of tool installation screens. Finally, you’ll see the following dialog box:
10. Click **OK** to install the **Microsoft.NET Framework Service Pack 1**, which is necessary for proper operation of the NIFTT tools.

11. You will be directed to reboot your computer after installation of each service pack. However, do not reboot the first time you see the following message box:

![Microsoft .NET Framework dialog box](image)

Figure 6-9. Microsoft .NET Framework dialog box.

When prompted a second time, click **Yes** to reboot.

**Note:** If for some reason you do not see a second message box asking if you want to reboot your computer, reboot your computer after the installation is complete.

In addition, during installation of the MRIT tool, you may be asked to specify whether the tool is to be installed for **Everyone** or **Just Me**. Select the radio button next to the **Just Me** option.

Installation of the NIFTT tool package should now be complete. The following NIFTT tools should now be installed on your computer:

- Area Change Tool (ACT)
- Fire Behavior Assessment Tool (FBAT)
- FRCC Mapping Tool (FRCC MT)
- Multi-scale Resource Integration Tool (MRIT)

Two other applications, Microsoft.NET Framework and the Microsoft.NET Framework 1.1 Service Pack 1, should now also be installed.

**Note:** For NIFTT tools to function properly, ensure the following:

- The Spatial Analyst Extension must be installed and activated
- The Ethernet cable must be unplugged from your computer
- The wireless network card (if you have one) must be turned off.

Now, open ArcMap and make sure that all of the NIFTT toolbars are visible as shown in figure 6-10:

![Figure 6-10. ArcMap showing NIFTT toolbars.](image)

**Note:** Toolbars may be “floating” and you may need to anchor them in convenient locations by dragging them to toolbars at the top of your screen.

### 6.1.2 Single tool (FBAT) installation

If you wish to install or reinstall the FBAT as a single tool without the entire NIFTT package, follow these steps:

1. Download the individual tool (FBAT) from the website at: [www.fire.org](http://www.fire.org)
Go to **NIFTT > Downloads** located at the left margin of the screen and select **FBAT** from the table as shown in figure 6-11:

![Software Installation](image)

**Figure 6-11.** Downloading individual FBAT tool.

2. Navigate to the directory in which you have copied NIFTT tool files and downloaded FBAT (see figs. 6-4 and 6-5).

3. If the installer determines a previous version of FBAT is already installed, go to the **Control Panel (Start > Settings > Control Panel)** and select **Add/Remove Programs**. Uninstall **Fire Behavior Assessment Tool** and then rerun **Setup.exe**.

4. If the installer determines that Microsoft Data Access Components (MDAC) are not up-to-date, run **mdac_type.exe** from the distribution source and rerun **Setup.exe**.

5. If the installer determines the setup needs the **.NET Framework**, double click on the **dotnetfx.exe** file and follow the prompts. When complete, double click **Setup.exe** to continue.
Tip: If the `dotnetfx.exe` file is already present on your computer, the downloaded .zip file will contain everything needed to install FBAT on your computer. If it is not already installed, you must download and install `dotnetfx.exe`.

6. Once the installation begins, choose to install FBAT for a single user (Just Me) and then select your install location. Follow the defaults and then select Close.

7. Open ArcMap with your desired map document. Go to the Tools menu and select Extensions. Make sure that the Fire Behavior Assessment Tool Extension and Spatial Analyst are checked and select Close. Next, go to the View menu and select Toolbars. Make sure that the Fire Behavior Assessment Tool Toolbar is checked and visible.

6.2 Troubleshooting FBAT installation

If the FBAT toolbar as shown at right does not install automatically, you will need to select View > Toolbars in ArcMap and check the box to the left of Fire Behavior Assessment Tool as shown in figure 6-12:
The FBAT toolbar should now be enabled and ready for use. Direct any questions to helpdesk@nifft.gov.
Chapter 7: Running FBAT

7.1 The FBAT toolbar

7.2 How to run FBAT

7.2.1 Selecting FBAT input parameters
7.2.2 Selecting spatial parameters
7.2.3 Selecting environmental parameters
7.2.4 Selecting crown fire calculations
7.2.5 Selecting output layers
7.2.6 Selecting outputs
7.2.7 Designing queries
7.2.8 Copying spatial reference
7.2.9 Selecting output location and name of output folder

7.1 The FBAT toolbar

The FBAT toolbar contains four icons (commands). Placing your cursor on each icon will display associated tool tips as shown in figure 7-1. We will briefly discuss the function of each icon.

**Fire Behavior Assessment Tool** – This command initiates FBAT. Clicking on this button will open a dialog box, which allows the FBAT user to select desired inputs and outputs.

**Generate Landscape (LCP) File** – This command is used when an FBAT simulation is not required. It allows creation of a landscape file for later use with...
FlamMap, FARSITE, or FBAT. Clicking on this icon will open a dialog box in which the user can specify the required inputs for creating a landscape file.

**Launch FlamMap Application** – This command will initiate FlamMap and is provided for users who want to build a landscape file using FBAT but then wish to use FlamMap utilities that are not available in FBAT (such as MTT, TOM, fuel conditioning, and wind vectors).

*Note*: Users will need to first install FlamMap separately for this function to operate.

**Generate Fire Behavior Assessment Reports** – This command is used to run new queries from an existing FBAT run. Clicking on this button will open a dialog box that is used to identify input layers and to design new queries – it does not build a new landscape file, nor does it rerun FlamMap. The command is typically used when the user merely wants to adjust the query parameters but not the FlamMap inputs.

### 7.2 How to run FBAT

To run FBAT, follow these steps:

1. Start ArcMap and create a new project by selecting **A new empty map** as shown in figure 7-2:

![Figure 7-2. Creating a new project in ArcMap.](image)
2. Next, load input layers into your ArcMap project by clicking the **Add Data** icon (fig. 7-3):

![Add Data icon](image1.png)

**Figure 7-3.** Loading input layers.

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

*Tip:* At this point, you may see several **Create pyramids** dialog boxes similar to the box shown in figure 7-4. 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.

![Create pyramids dialog box](image2.png)

**Figure 7-4.** Create pyramids dialog box.

4. 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.
5. Save your project and rename the data frame by clicking the **Save** icon in the toolbar

6. Rename the data frame as shown in figure 7-5 with a slow double click on the default Data Frame name Layers:

![Figure 7-5. Renaming the data frame.](image)

Slowly double left click on **Layers** and rename the **Data Frame**

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

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

7.2.1 Selecting FBAT input parameters

Click on the **Fire Behavior Assessment Tool** icon on the FBAT toolbar in ArcMap as shown in figure 7-6:
The following **Fire Behavior Assessment Tool** dialog box will open:

*Note: First click on the Inputs tabs if this screen is not already active.*

*Figure 7-7. The FBAT dialog box with the Inputs tab selected. Notice the spatial inputs required for FBAT.*
The **Inputs** tab of the dialog box is used to select the topographic and fuels spatial layers, environmental parameters, and the crown fire algorithm used for calculating active crown fire. Although eight spatial layers are required, the slope and aspect layers are considered optional. FBAT will derive slope and aspect layers from the elevation layer if these two layers are not provided.

### 7.2.2 Selecting spatial parameters

The first step is to identify the spatial layers from your ArcMap project that will be used to build the landscape file and subsequently for calculating fire behavior characteristics. Select the appropriate layer from the drop-down list located to the right of each layer. Clicking on the drop-down list will display all raster layers that are currently loaded in your ArcMap project.

![Figure 7-8. Selecting spatial inputs from drop-down list.](image)

**Note**: As mentioned, slope and aspect layers are optional inputs. If these layers are not selected by the user, FBAT will automatically derive the slope and aspect layers from the elevation layer. However, be careful when using elevation data containing any values other than elevation. For example, slope will be calculated inaccurately if your data set contains a value of “-9999,” which denotes NoData. We have also observed that the extents of the FBAT-generated slope and aspect layers will be slightly different from extents derived from the elevation layer if you are using ArcGIS 9.1 without the latest Service Pack. Consequently, you may get an error message while generating the
landscape file. Thus, we recommend that users NOT run ArcGIS 9.1 without first installing the latest Service Pack and input all eight spatial layers rather than allowing FBAT to generate slope and aspect.

A substantial portion of FBAT's processing time is spent creating the landscape file. Thus, run times can be significantly shortened by using previously created landscape files whenever appropriate. If such a landscape file is available, click on the radio button to the left of Landscape File and browse to the desired file.

Figure 7-9. Selecting an existing landscape file, if appropriate.
Click the **ArcGRIDs** radio button to build the LCP file. Spatial layers needed for creating the LCP file

Click on the **Landscape File** radio button and browse to an existing LCP file that is appropriate for your analysis.

**Figure 7-10. Fire Behavior Assessment dialog box.**

You have now completed the fuel and terrain inputs necessary for running FBAT. The next step will involve selecting environment parameters for your run.

### 7.2.3 Selecting environmental parameters

The environmental parameters necessary for running FBAT include values for fuel moisture, wind speed, wind direction, and foliar moisture content. Start by selecting an appropriate Fuel Moisture File by clicking on the browse button to the right of the **Fuel Moisture File** box.
Recall that the Fuel Moisture File is a text file that identifies both dead and live fuel moisture for each fire behavior fuel model (see Chapter 3 for a description of the Fuel Moisture File).

**Note:** The Fuel Moisture File must contain the fire behavior fuel models that correspond to the fuel model layer used in the analysis. For example, if the landscape file was created using Scott and Burgan (2005) fuel models, then the Fuel Moisture file must also contain Scott and Burgan (2005) fuel models. In addition, it is imperative that the Fuel Moisture File characterizes the environmental conditions that are appropriate for your analysis scenario. For example, you might want to use 60th to 90th percentile conditions for predicting potential fire behavior for a prescribed burn or wildland fire use scenario, but you may want to use 97th percentile conditions for modeling a wildfire scenario. See Chapter 3 for more information.

Now enter a 20-foot 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. Remember that this parameter represents the wind speed occurring 20 feet above the vegetation’s canopy as expressed in miles per hour. The default wind speed is 5 miles per hour.

**Tip:** Make sure that you have entered the wind speed you want to model or the default value will be used automatically.

Next enter the wind direction (see fig. 7-11 below). There are two options for entering wind direction. Check the **Uphill** box if you want to maximize potential fire behavior on any particular site. Alternatively, uncheck the **Uphill** box if you would rather enter an azimuth in degrees for the wind direction.

**Tip:** Enter the direction the wind is blowing from in degrees.

Lastly, select an appropriate value in percent for **Foliar Moisture Content** (see fig. 7-11 below). Foliar moisture content usually ranges between 80 and 130 percent. Typical conditions are commonly represented by a value of 100 percent foliar moisture content.
7.2.4 Selecting crown fire calculations

Two different algorithms are available for modeling the transition between passive and active crown fire. The primary difference between the two is that the Scott and Reinhardt (2001) equation will result in more active crown fire relative to the Finney (1998) equation. Select the radio button to the left of the algorithm that you wish to use.
Select the appropriate crown fire calculation algorithm.

![Figure 7-12. Selecting the most appropriate Crown Fire Calculation algorithm.](image)

**Note:** Important—do not click OK until you have completed the outputs tab.

### 7.2.5 Selecting output layers

Next, select the FBAT outputs of your choice. Click on the Outputs tab at the top of the Fire Behavior Assessment dialog box as shown in figure 7-13:
Figure 7-13. Outputs tab on Fire Behavior Assessment dialog box.

The Outputs dialog box allows four primary functions:

1. Selecting the optional output layers
2. Designing the Simple and Classification queries
3. Copying the spatial reference from an existing layer
4. Selecting a location and name for the output folder

7.2.6 Selecting outputs
Three types of optional outputs are available with FBAT: (1) Wildland Fire Intensity, (2) Fire Behavior Simple Query, and (3) Fire Behavior Classification Query. (See Chapter 5 for more information on FBAT output). All optional outputs are selected by default. Simply uncheck the boxes to the left of the outputs that are not desired as shown in figure 7-14:

![Figure 7-14. Selecting optional outputs.](image)

If none of the optional outputs are selected, FBAT will derive only flame length (FL), flame length class, rate of spread (ROS), rate of spread class, fireline intensity, and crown fire activity (CFA).

7.2.7 Designing queries

If the Fire Behavior Simple Query or Classification Query is selected, the user must then complete three general steps for designing a query.

1. The first step involves identifying fire behavior characteristics of interest for your query (such as flame length, rate of spread, and crown fire activity). Selecting any combination of the three characteristics is permissible. Select the desired characteristics by checking the box located to the left of the characteristics you wish to use (fig. 7-15).
2. The second step requires that the user specify whether the query will use an AND or an OR conditional statement. An AND conditional statement requires all of the conditions of the query to be met, whereas an OR conditional statement requires that only one of the conditions be met. Note that FBAT uses the OR conditional statement as a default. Select the appropriate conditional statement by checking the AND or OR radio buttons located on the right side of the dialog box.

3. The third step requires that the user specify threshold values for each fire behavior characteristic selected. The dialog box contains default threshold values, which are intended to characterize at least a “moderate” fire behavior hazard; the thresholds are the same used for deriving the moderate Flame Length Class (1.2 m; 4 ft) and moderate Rate of Spread Class (1.7 m/min; 5.6 ft/min). Similarly, default thresholds used in the Classification Query were selected so that Class 3 would denote a “high” fire behavior hazard, Class 2 would denote a “moderate” fire behavior hazard, and Class 1 would denote a “low” fire behavior hazard. Any conditions not meeting the specifications of Class 1 would be considered a “very low” fire behavior hazard.

Tip: Select the appropriate conditional statement cautiously as the results of the query will vary substantially depending on which conditional statement is used.
Figure 7-17. Specifying threshold values for each fire behavior characteristic selected.

**Note:** Thresholds for flame length and rate of spread, including all default values, must be given in metric units (meters and meters/minute, respectively).

**Simple Query**

Recall that the Simple Query was designed to partition an analysis area into two classes: Class 1 represents those conditions that meet or exceed the query parameters, and Class 0 represents those conditions that fail to meet the query parameters. FBAT users will need to change the default parameters if they do not meet analysis objectives for a particular assessment. The query parameters can be changed by typing the desired threshold directly into the box or by using the spinner to the right of the box to adjust values up or down.

As an example, the Simple Query displayed in figure 7-18 will produce an output layer containing two classes (0 and 1). Class 1 will identify those areas where potential flame length would exceed 1.2 m (4 ft) OR where potential spread rates would exceed 1.7 m/min (5.6 ft/min) OR where potential crown fire activity would likely be passive or active crown fire. Class 0 would apply to those areas that do not meet the minimum requirements of Class 1.
Fire Behavior Assessment Tool User's Guide  Chapter 7

Simple Query
Select the appropriate fire behavior characteristics, thresholds, and an AND or OR conditional statement.

Figure 7-18. Example of completed Fire Behavior Simple Query.

Classification Query

The Classification Query is designed so that Class 3 denotes a “high” fire behavior class, Class 2 a “moderate” fire behavior class, and Class 1 a “low” fire behavior class. The thresholds entered in the dialog box represent the minimum thresholds for a particular class. We recommend that when FBAT users select threshold values, they either start from the top with Class 3 and then work down to Class 1, or they start from the bottom with Class 1, and then work their way up to Class 3. The query parameters can be changed by typing the desired threshold value directly into the box or by using the spinner located to the right of the box to adjust values up or down.
As an example, the Classification Query displayed in figure 7-20 will produce an output layer containing four classes (0 through 3). Class 3 (high) will identify those areas where potential flame length would exceed 3.7 m (12 ft) OR where potential spread rates would exceed 16.8 m/min (55 ft/min) OR where potential crown fire activity would likely be an active crown fire. Class 2 (moderate) will denote those areas that do not meet the minimum requirements of Class 3, but where potential flame length would exceed 1.2 m (4 ft) OR where potential spread rates exceed 1.7 m/min (5.6 ft/min) OR where crown fire activity (CFA) would likely be at least a passive crown fire. Class 1 (low) will identify those areas that do not meet the minimum requirements of Class 2, but where flame length would exceed 0.1 m (0.3 ft) OR where spread rates exceed 0.1 m/min (0.3 ft/min) OR where crown fire activity would likely be at least a surface fire. Any other conditions not meeting the minimum requirements of Class 1 would be assigned to Class 0 (very low).
7.2.8 Copying spatial reference
The option of copying a spatial reference (in other words, a coordinate system and projection information) from an existing layer becomes available only if the FBAT input includes a previously created landscape file. Since the landscape file itself does not contain any information about spatial references, the user must “inform” FBAT of the appropriate coordinate system and projection needed to derive spatial outputs. If spatial inputs include a pre-existing landscape file, then one of the spatial layers that was originally used to create the landscape file should be selected. This will ensure that the spatial outputs will have the same spatial reference as the layers used to create the landscape file.

![Copy Spatial Ref From drop-down menu](image)

**Figure 7-21.** Copy Spatial Ref From drop-down menu.

**Tip:** The Copy Spatial Ref From drop-down menu (fig. 7-21) will be active and available for your use ONLY if the Landscape File was selected in the Inputs tab of the Fire Behavior Assessment Tool dialog box (see Spatial Parameters for more information on completing the Inputs tab).

### 7.2.9 Selecting output location and name of output folder

Now you will need to select an output path and an appropriate folder name for your run. All of the FBAT outputs will be stored in the output folder. Click on the browse button to the right of the Output Folder Location box and navigate to an existing folder of your choice. Then, enter an Output Folder Name to identify your FBAT run. The folder will be located within the pathway identified under Output Folder Location, as shown in figure 7-22.
Figure 7-22. Selecting output location and name of output folder.

**Tip:** The file name you select should not exceed ten characters in length and should not contain any spaces, leading numbers, or special characters (such as `~! @#$%^+-=[]\{}\|?/:;"'< >, .)
After having completely filled-out both the **Inputs** and **Outputs** dialog boxes, click **OK**. FBAT will now begin processing and will take a few minutes to run. FBAT has three main processing steps: (1) create the landscape file, (2) initiate FlamMap and derive fire behavior characteristics, and (3) derive results for the Simple and Classification queries.

After the landscape file has been created, a black window entitled `C:\NIFTT\Fire Behavior Assessment Tool\Tools\flammapx2.exe` (fig. 7-24) will appear on your monitor, indicating that FlamMap is running in the background.

![Figure 7-24. Flammapx2.exe window, indicating that FlamMap is running.](image)

The individual output layers will begin to appear in your ArcMap Table of Contents shortly after the `FlamMap.exe` window disappears (see fig. 7-25 below). The FBAT user interface will also disappear automatically when the FBAT run is complete.

![Figure 7-25. FBAT output layers in Table of Contents.](image)

**Tip:** FBAT documents the input and output parameters used in a file named `param.txt`, which can be found in your **Output Folder Location** folder.
We recommend that users save their ArcMap project as soon as the FBAT run has finished. Saving the ArcMap project will preserve the label and color schemes for each output layer.

Figure 7-26. Example flame length classification legend from ArcMap table of contents.

**Note:** The names of the output layers that appear within ArcMap’s Table of Contents are descriptive labels; they are NOT the layer names that will appear in the output folder (specifically, the **Output Folder Name** you identified in the **Output Folder Location**). (See Chapter 5, table 5-1 for the layer names as they will appear in ArcCatalog). Moreover, the thresholds used to derive ArcMap’s legend for the classified outputs (flame length class and rate of spread class) and query outputs can be identified in the **param.txt** file located within the output folder.
Chapter 8: Generating a Landscape File

8.1 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 an FBAT-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 FBAT.

8.2 Steps

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

2. Next, load input layers into your ArcMap project by clicking on the Add Data icon:
3. Navigate to the directory where your data layers are stored and add the following eight input layers: elevation, slope, aspect, fire behavior fuel model, canopy cover, canopy height, canopy base height, and canopy bulk density. These eight layers provide the direct input for FBAT.

**Tip:** At this point, you may see several Create pyramids dialog boxes similar to that shown in figure 8-3:

![Create pyramids dialog box](image)

*Click on 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.*

4. Ancillary layers can also 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.
5. Rename the data frame as shown in figure 8-4 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 8-4. Renaming the data frame.](image)

8.3 Selecting input layers

To generate a landscape file, you will need to add the following eight spatial layers:

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

**Note:** All eight 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 Chapter 3, table 3-1).
After you have finished loading the input layers into ArcMap, click on the **Generate Landscape (LCP) File** icon located second from the left on the FBAT toolbar:

![Generate Landscape (LCP) File icon](image)

**Figure 8-5. Generate Landscape (LCP) File icon.**

Selecting this command will open the **Landscape (LCP) File Creation** dialog box as shown in figure 8-6 below.

![Landscape (LCP) File Creation dialog box](image)

**Figure 8-6. Landscape (LCP) File Creation dialog box.**

First, select the appropriate input layers from the drop-down list located to the right of each layer (fig. 8-7). Clicking on the drop-down list will display all raster layers that are currently loaded in your ArcMap project.
Note: As mentioned, slope and aspect layers are optional inputs. If these layers are not selected by the user, FBAT will automatically derive the slope and aspect layers from the elevation layer. However, be careful when using elevation data that contain any values other than elevation. For example, slope will be calculated inaccurately if your data set contains a value of “-9999,” which denotes NoData. We have also observed that the extents of the FBAT-generated slope and aspect layers will be slightly different from extents derived from the elevation layer if you are using ArcGIS 9.1 without the latest Service Pack. Thus, we recommend that users NOT run ArcGIS 9.1 without first installing the latest Service Pack, and instead input all eight spatial layers rather than allowing FBAT to generate slope and aspect.

Next, select a Project Folder Location by using the browse button located to the right of the box to navigate to the appropriate location.
Enter a folder name for storing the landscape file in the **Project Folder Name** box.

**Note:** The file name that you select cannot exceed ten characters in length and should not contain any spaces, leading numbers, or special characters (such as: `~! @#$%^()+-}{][\|?/:;"'<,.`)

Click **OK** to generate the landscape file.
Chapter 9: Launching FlamMap

Chapter 9 explains how to use the FBAT command Launching FlamMap Application. The FBAT command that launches FlamMap was added so that users can open FlamMap from the ArcMap platform. This function will prove useful for those who want to compare FBAT outputs to FlamMap outputs and for those who want to run some of FlamMap’s more advanced applications that cannot be run using FBAT alone (such as MTT and TOM). See Appendix B for more information on this subject.

Click the third icon from the left on the FBAT toolbar as shown in figure 9-1 to open FlamMap:

![Figure 9-1. Icon for launching FlamMap application.](image)

**Note:** The FlamMap application must be installed separately for this command to work. To learn more about downloading FlamMap, see Appendix B.

At this point, you will see the following screen:
FlamMap is now open and available for use. As mentioned, Appendix B provides information on using FlamMap.

**Note:** If you select the full installation package as described in Chapter 6, you will get the FlamMap install file, a helpful tutorial with sample data as well as full on-line help.

To work with the tutorial, open FlamMap and from the Toolbar, select **Help > Contents > Tutorial**. The following screen will open:
Lesson 1
Load Landscape and Themes

The data files for this tutorial are found in your ...FlamMap2\Tutorial\ folder (directory). The ...FlamMap2\ folder is where you chose to place the FlamMap programs during installation. The default folder for installing FlamMap on Forest Service computers is C:\fsapps\fsprod\flam\FlamMap2. The default for most other computers would be C:\Program Files\FlamMap2.

When you first start FlamMap it opens a default project window named "FlamMap1".

Figure 9-3. FlamMap tutorial.
Chapter 10: Generating Fire Behavior Assessment Reports

10.1 Selecting inputs
10.2 Copying spatial references
10.3 Selecting project folder location and name
10.4 FBA metrics tab
10.5 FBA queries tab

The FBAT command to generate assessment reports (Generate Fire Behavior Assessment Reports) is typically used to adjust parameters for the Simple and Classification queries for an existing FBAT run. This command does not build a new landscape file, nor does it rerun FlamMap. You should therefore not use this command if you plan to change any of the inputs to FlamMap.

To begin, click on the last icon on the FBAT toolbar as shown in figure 10-1:

![Figure 10-1. Icon for generating fire behavior assessment reports.](image)

Selecting this icon will open the dialog box displayed in figure 10-2. This dialog box has three tabs: Inputs, FBA Metrics, and FBA Queries.
10.1 Selecting inputs

First, make sure that the Inputs tab is selected (fig. 10-3). FBAT requires that input layers be in ASCII format. The ASCII-formatted layers can be found within the results folder of previous FBAT 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.
Click on the browse button to the right of the required input layer as shown in figure 10-4 and navigate to the output folder of a previous FBAT run.
Click on browse button
Select an appropriate layer and click on Open

Figure 10-4. Navigating to output folder.

You can choose between the following four default layers: **FlamMap.CFR**, **FlamMap.FML**, **FlamMap.ROS**, or **FlamMap.FLI**. Only one of these layers, the correct choice, will be available for each parameter. You must include all four input layers even if some of those layers will not be used in your modified query(s).
10.2 Copying spatial reference

ASCII files do not contain a spatial reference (coordinate system and projection information). You will therefore need to select a layer with the appropriate spatial reference from your ArcMap Table of Contents. The option of copying a spatial reference from an existing layer becomes available only if your FBAT input includes previously created files. We recommend that you select one of the layers used to generate your landscape file.

To load layers into ArcMap, follow these steps:

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

2. Next, load input layers into your ArcMap project by clicking on the **Add Data** icon as shown in figure 10-6:
3. Navigate to the directory where your data layers are stored and add the following eight input layers: elevation, aspect, slope, fire behavior fuel model, canopy cover, canopy height, canopy base height, and canopy bulk density. These eight layers provide the direct input for FBAT.

**Tip:** At this point, you may see several Create pyramids dialog boxes. Click on 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.

4. Once these layers have been added to ArcMap’s Table of Contents, click on the drop-down menu to select a layer with an appropriate spatial reference, as shown in figure 10-7.

The Copy Spatial Ref From drop-down list will not be populated if you do not have layers already loaded into ArcMap. If you fill out all of the FlamMap ASCII Rasters boxes and click OK to run the Generate Fire Behavior Assessment Reports without first loading files into ArcMap, you will see the error message in figure 10-8:
10.3 Selecting project folder location and name

FBAT outputs will be stored in the project folder. Use the browse button to the right of the Project Folder Location box to navigate to a location where you wish to store the project folder. Type in a name for the project folder in the Project Folder Name box.

**Note:** The file name cannot exceed ten characters in length and should not contain any spaces, leading numbers, or special characters (such as: `~! @#$%^()+={ }|\/?;'":'< >, .)

**Tip:** Do not click OK until you have completed all three tabs of the dialog box.

10.4 FBA Metrics tab

Select the FBA (Fire Behavior Assessment) Metrics tab to open the dialog box displayed in figure 10-9. This tab allows you to select metrics that you may not have selected in your earlier simulation. Wildland Fire Intensity is currently the only metric available. There is no need to create a new Wildland Fire Intensity metric if it was derived in a previous FBAT run. Check the box to the left of the Wildland Fire Intensity metric only if you did not create this layer previously but would like to create it now.
10.5 FBA Queries tab

Select the FBA (fire behavior assessment) Queries tab to open the dialog box displayed in figure 10-10. Check the box to the left of those queries that you would like to rerun. Edit the query parameters (such as Flame Length, Rate of Spread, and Crown Fire Activity) to match your analysis objectives. (See Chapter 7 for guidance on designing queries).

Tip: Do not click on OK until you have completed all three tabs of the dialog box.
Click **OK** after providing all of the appropriate information in each of the three dialog boxes. The resulting spatial layers will automatically appear in the ArcMap Table of Contents as well as in your designated project folder.

*Note: The run may take several minutes.*
Chapter 11: Troubleshooting FBAT – Common Errors, Symptoms, and Solutions

11.1 Evaluating input data
11.2 Evaluating input parameters

Perhaps the most common FBAT (and FlamMap) 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 FBAT 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 checklists can be used if you have doubts regarding the accuracy of your output data.

11.1 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 according to 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 mid-flame wind speed are inversely related. Thus, dense canopy cover will substantially decrease mid-flame 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.

### 11.2 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 pertaining to the acquisition of 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 FBAT 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. **Recognize that FBAT does not allow for fuel moisture conditioning:** therefore, moisture values within a given fuel model do not vary despite differences in elevation, aspect, and canopy cover. This limitation can result in unrealistic fire behavior simulations.

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

6. **Review the environmental parameters used for your FBAT 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.

   To report a bug, please contact helpdesk@niftt.gov.
Appendix A: References


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 fuels, 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, mid-flame wind speeds, and solar irradiance) over the entire FARSITE landscape. These raster maps can be viewed in FlamMap or exported for use in a global 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 fuels to calculate fire behavior characteristics at one instant.

- FlamMap uses the same spatial and tabular data as FARSITE:
  o a Landscape (.LCP) File,
  o Initial Fuel Moistures (.FMS) File,
  o optional Custom Fuel Model (.FMD),
optional Conversion (.CNV) File, 
optional Weather (.WTR) File, and 
optional Wind (.WND) File.

- FlamMap incorporates the following fire behavior models:
  - Rothermel's 1972 surface fire model,
  - Van Wagner's 1977 crown fire initiation model,
  - Rothermel's 1991 crown fire 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 because it requires spatial coincident landscape raster information to run.

- 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 ingest 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 the online help system (included with the installation package) for more information on these new features.

### B.4 Downloading FlamMap

To download FlamMap, go to [http://www.fire.org](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: Off the Richter: magnitude and intensity scales for wildland fire

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Introduction

Quantitative scales of wildland fire magnitude and intensity are needed to assess and publicly communicate the unbiased potential of wildland fire to cause effects—harm, damage, and ecological change. Such scales already exist for earthquakes (Richter Scale and Mercalli Scale), hurricanes (Saffir-Simpson Scale), tornadoes (Fujita Scale), and even near-Earth objects (Torino Impact Hazard Scale). Standard quantitative scales of wildland fire magnitude and intensity would (1) set a standard for communicating important fire characteristics to the public, and (2) provide a context for public understanding of the potential for a fire to cause harm or damage (see Binzel 1997). The magnitude of a natural event like wildland fire—its potential to cause effects—is a function of energy release rate. Magnitude is a measure of an event as a whole; a high-magnitude event has great potential as a whole to cause harm or damage. That potential is not necessarily uniform. Some parts of a high-magnitude event have little potential to cause effects—the rear of a large fire, for example—whereas other parts have great potential. The potential for causing effects at any particular place is measured as intensity, the rate of energy release at that place and time. Magnitude and intensity are measures of potential to cause effects; actual effects are also a function of exposure—the presence of susceptible values in a hazardous situation. A high-magnitude event can cause no damage if no susceptible values are exposed to it.

A wildland fire intensity scale

Byram (1959) defines fireline intensity (IB) is the rate of heat release per unit length of fire front (kW · m⁻¹), regardless of flame front depth. IB is a fundamental fire characteristic variable containing “…about as much information about a fire’s behavior as can be crammed into one number” (Van Wagner 1977).

\[ I_B = H \cdot w_f \cdot \left( \frac{R}{60} \right) \]  

[1]

where H is the low heat of combustion (kJ · kg⁻¹), w_f is the load of fuel consumed in the flaming fire front (kg · m⁻²), and R is the linear rate of spread (m · min⁻¹). IB can be
estimated or simulated for any spatially explicit landscape element on a past or future fire. The resulting values of IB span nearly five orders of magnitude, from less than 10 kW m\(^{-1}\) for a slow-spreading fire in light fuel to more than 100 000 kW m\(^{-1}\) for a fast-spreading fire in heavy fuel. This very large range of IB makes communication and interpretation difficult. As a simple scale for communication with the media and public, I propose to use the common logarithm of IB (kW \cdot m\(^{-1}\)) as a scaled measure of wildland fire intensity (I)

\[ I = \log_{10}(I_B) \]

For the range of IB noted above, I ranges from less than 1 to just greater than 5 (six classes).

### A wildland fire magnitude scale

The rate of energy release of a fire as a whole is termed total fire flux (Catchpole and others 1982). Total fire flux, \(\int IB\), is the integral of fireline intensity around the perimeter of a fire. If a fire perimeter is broken down into \(n\) segments of uniform IB, then \(\int IB\) (kW) is the sum-product of IB and segment length for all segments around the perimeter. Total fire flux can also be calculated as (Catchpole and others 1982)

\[ \int I_B = \left( \frac{dA/dt}{60} \right) Hw_f \]

where \(dA/dt\) is the rate of fire area increase (m\(^2\) \cdot min\(^{-1}\)). For example, if a fire's area is known at two points in time, average area growth rate is simply the difference in area divided by the time interval. For an elliptical fire in uniform conditions

\[ dA/dt = 2\pi abt \]

where \(t\) is the time (min) since start of point-source fire growth, and

\[ a = \frac{R_{head}}{1 + \sqrt{1 - L_B^{-2}}} \]

\[ b = \frac{a}{L_B} \]

where \(R_{head}\) is the linear rate of fire spread in the heading direction and \(L_B\) is the length-to-breadth ratio of the fire. Andrews (1986) estimated \(L_B\) as a simple function of effective mid-flame wind speed (\(U_e\)).
\[ L_B = 1 + 0.155 * U_e \]  \hspace{1cm} [7]

for \( U_e \) measured in km \( \cdot \) h\(^{-1} \). It is not necessary to know \( t \) explicitly (which requires an unrealistic assumption of constant fire growth conditions throughout the time period) as long as current fire size is known, because for an elliptical fire the effective time required to achieve a given size is

\[ t = \sqrt{\frac{A}{\pi ab}} \]  \hspace{1cm} [8]

and therefore

\[ \frac{dA}{dt} = \sqrt{4\pi abA} \]  \hspace{1cm} [9]

where \( A \) is the area (m\(^2\)) of the fire.

Like \( I_B \), total fire flux ranges over many orders of magnitude. An incipient fire of 1 m\(^2\) with \( L_B = 1.0 \) that consumes 0.1 kg \( \cdot \) m\(^{-2}\) in the flaming front and spreads at 0.5 m \( \cdot \) min\(^{-1}\) produces 55 kW (\( I_B = 15 \) kW \( \cdot \) m\(^{-1}\) around all portions of the perimeter). In contrast, a 100 000 ha fire of \( L_B = 4.0 \) that consumes 4.0 kg \( \cdot \) m\(^{-2}\) in the flaming front and spreads 100 m \( \cdot \) min\(^{-1}\) at the head produces a theoretical 3.5 billion kW (with corresponding \( I_B = 125 \) 000 kW \( \cdot \) m\(^{-1}\), and \( I = 5.1 \)). Because of the huge theoretical range of \( \int I_B \), and to satisfy the need for a simple measurement for communication with the media and public, I propose to use the common logarithm of total fire flux (kW) as a scaled measure of wildland fire magnitude (\( M \)), and to categorize magnitude by factors-of-ten.

\[ M = \log_{10}(\int I_B) \]  \hspace{1cm} [10]

For the range of total fire flux noted above, \( M \) ranges from less than 1 for an incipient fire to greater than 9 for a large, fast-growing fire in heavy fuel (resulting in ten classes).

**Summary and Conclusions**

The magnitude and intensity scales defined here standardize the measurement and communication of two important fire characteristics with the public: intensity of any portion of a fire and its magnitude as a whole. Like the Richter Scale for earthquake magnitude, the wildland fire scales are logarithmic, which minimizes the effects of measurement error and fully exposes the wide range of variability of both \( I_B \) and \( \int I_B \). The intensity scale relates to a particular point on a fire’s perimeter at a particular time; it can be mapped for a past or potential fire. The magnitude scale applies to the whole fire at a particular point in time.

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**Literature cited**


