# NZ Fire Behaviour Toolkit

# Table of Contents

# 1   Introduction

The NZ Fire Behaviour Toolkit has been developed to incorporate into a user-friendly software package as much as possible of the current knowledge of fuels and fire behaviour in the New Zealand fire environment. It is based on the fuel and fire behaviour models developed by the Scion Rural Fire Research Group that are also available in paper (tabular) format in "A Manual for Predicting Fire Behaviour in New Zealand Fuels" (Pearce & Anderson 2008). The user is referred to this manual for further details on the fuel and fire behaviour models that form the basis of this toolkit.

This toolkit comprises a number of separate modules, each developed for different purposes and levels of use:

1. Fire Behaviour Calculator – designed for quick and easy determination of fire potential for any of the NZ fuel types
2. Fire Behaviour Prediction Worksheet – based on the paper-based worksheet available for use in NZ, and contained in the Fire Behaviour Manual (Pearce & Anderson 2008). This worksheet is used for predicting fire behaviour over a period of time for a specific fire, and/or to evaluate the effects on fire behaviour of different conditions during the period the forecast is being prepared for (such as changes in weather conditions, fuel type or slope). The worksheet can be saved and exported for printing, to allow it to be incorporated into Incident Action Plans and as the basis for preparing a written fire behaviour forecast.
3. Firebreak Effectiveness – this module allows the user either to determine the probability of an existing firebreak (of given width) being breached by a fire where the head fire intensity is known, or to calculate the width of firebreak required to contain a head fire of known intensity
4. Fire Intensity – allows calculation of fire intensity based on an observed flame length, or calculation of flame length if the intensity is known
5. Fire Behaviour Rules of Thumb – a listing of "rules of thumb" for quick and easy reference.
6. Resource Productivity – a table providing some general guidelines for resource productivity in NZ fuel types with different types of suppression resources

**Assumptions**

A reasonable level of understanding of fire behaviour and fire danger rating on the part of the user is assumed, and it is expected that users will have the underlying knowledge and experience to confidently use this toolkit and apply the outputs correctly. This also applies to selection of the appropriate fuel models for calculating available fuel load and fire rate of spread.

Users must also be careful not to apply model outputs beyond their useful range. Fire behaviour models that are incorporated into this toolkit are based on a fire spreading

during a single burning period, assuming that (after Taylor et al. 1997):

- The fire is spreading as a line-source fire at its equilibrium or steady-state rate of spread (i.e. no allowance is made for point-source ignitions undergoing a period of acceleration). In addition, no allowance has been made for the effect of head fire width (Cheney and Gould 1997).
- The fire spreads as a surface fire only (i.e, no allowance has been made for the overall increase to fire rate of spread associated with crowning). Due to a lack of knowledge on stand characteristics (e.g. live crown base height, crown bulk density, foliar moisture content) for New Zealand plantation fuels, the models for pine plantation fuel types do not currently include the effects of crown fire development on rate of spread. However, an indication of likely fire type (i.e. surface or crown fire) in pine plantation fuels can be gained from crown fire initiation thresholds (see the Fire Behaviour Rules of Thumb).
- Fuel conditions are similar to one of the 16 identified New Zealand fuel types for which fuel load and/or rate of spread models are presently available.
- The fuel moisture code values used (from the FWI System) are representative of site conditions.
- Fuels are uniform and continuous, topography is simple and homogeneous, and wind is constant and uni-directional.
- The fire is wind- or wind/slope-driven, and spread is not affected by a convection column.
- Wind (speed and direction) is represented by the 10-m open wind.
- The fire is unaffected by suppression activities (i.e. it is free-burning).
- A fire originally starting from a point-source will have an elliptical shape under the above conditions.
- The effect of short- and medium-range spotting on a fire's overall rate of advance is directly accounted for in the mathematical rate of spread relationships.

These assumptions have been made in the interests of simplicity, and for ease of use by operational personnel (in the field).

## Caution

Fire behaviour predictions represent a combination of art and science. They are intended to assist in fire management decision making, and are not a substitute for experience, sound judgement, or observations of actual fire behaviour. Fire behaviour can change rapidly due to changes in fuel conditions, slope and exposure to wind, and no model can ever fully account for all the variables that affect fire behaviour. Operational personnel must be aware of the limitations of the models that form the basis of this toolkit, and be able to recognise unique or unusual situations as

fires can be potentially dangerous at any level of fire danger (e.g., Bucklands Crossing Fire, Pearce et al. 2004). It is therefore essential to combine one's local knowledge and experience with the outputs from these tables to better reflect conditions at the fire location.

# 2    System Requirements

- Supported Operating Systems: Windows Vista, Windows 7, Windows 8, Windows 10
- Processor: 800 MHz  (Minimum); 1GHz  (Recommended)
- RAM: 512 MB (Minimum); 1 GB (Recommended)
- Hard Disk: Up to 500 MB of available space may be required
- CD or DVD Drive: Not required
- Display: 800 x 600, 256 colours (Minimum); 1024 x 768 high colour, 32-bit (Recommended)

To access some reference material, a PDF viewer is also required.

Support for Windows operating systems older than Vista starting with v2.3 has been removed.

# 3     Version History

- Version 1.0.0 (June 2008)

- Version 1.0.1 (July 2008)
    - add missing pdf component dll to installer.

- Version 2.0.0 (February 2012)
    - updated Available Fuel Load and Rate of Spread models for grass and scrub fuel types,
    - addition of new fuel type selection box,
    - corrections to equations based on revisions to the Canadian FBP System (Wotton et al. 2009),
    - changed "elapsed time" input to "prediction interval" and have it calculate automatically,
    - added new secondary output " total elapsed time" and calculate automatically,
    - modified how "back fire spread distance" is used to calculate "total spread distance", with the option to make this zero where no actual backing occurs
    - minor bug fixes

- Version 2.1.0 (September 2012)
    - Updated Rate of Spread calculation for Tussock (grazed and ungrazed)

- Version 2.2.0 (December 2014)
    - Added Guide to New Zealand Fuels reference.

- Version 2.3.0 (March 2019)
    - Updated to Microsoft .NET Framework 4.6. Support for Windows operating systems older than Vista has been removed.

# 4    Installation

To install the NZ Fire Behaviour Toolkit, run the setup program
SetupNZFireBehaviourToolkit.exe:
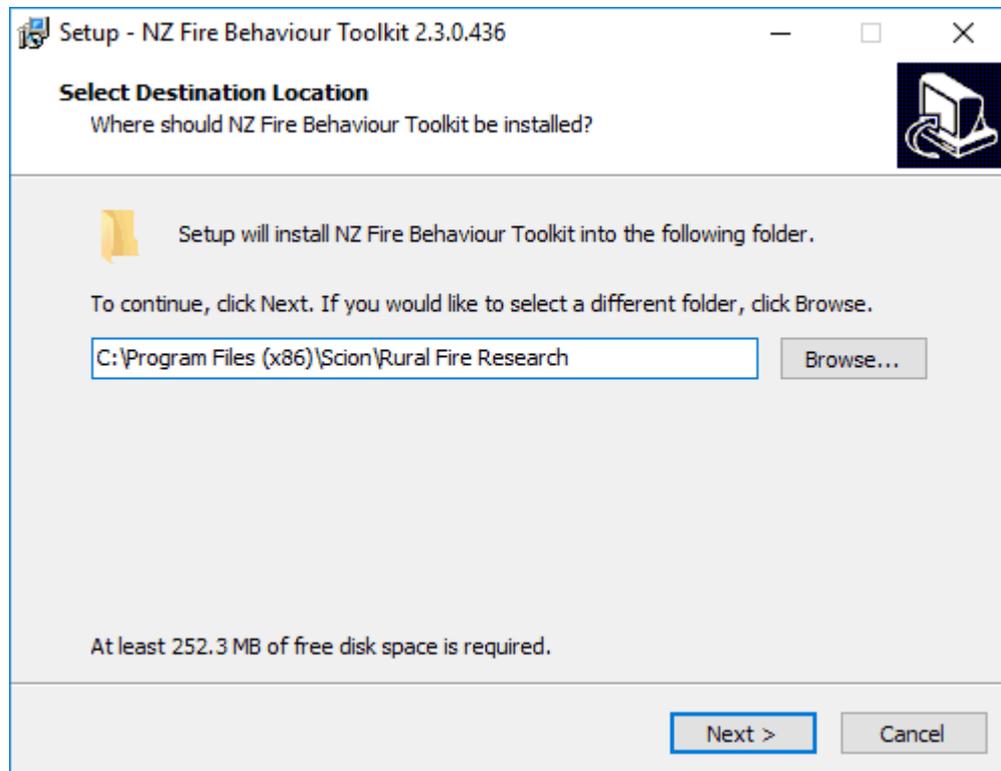


Specify a folder for the software to be installed into, or just click Next to use the
default (recommended).
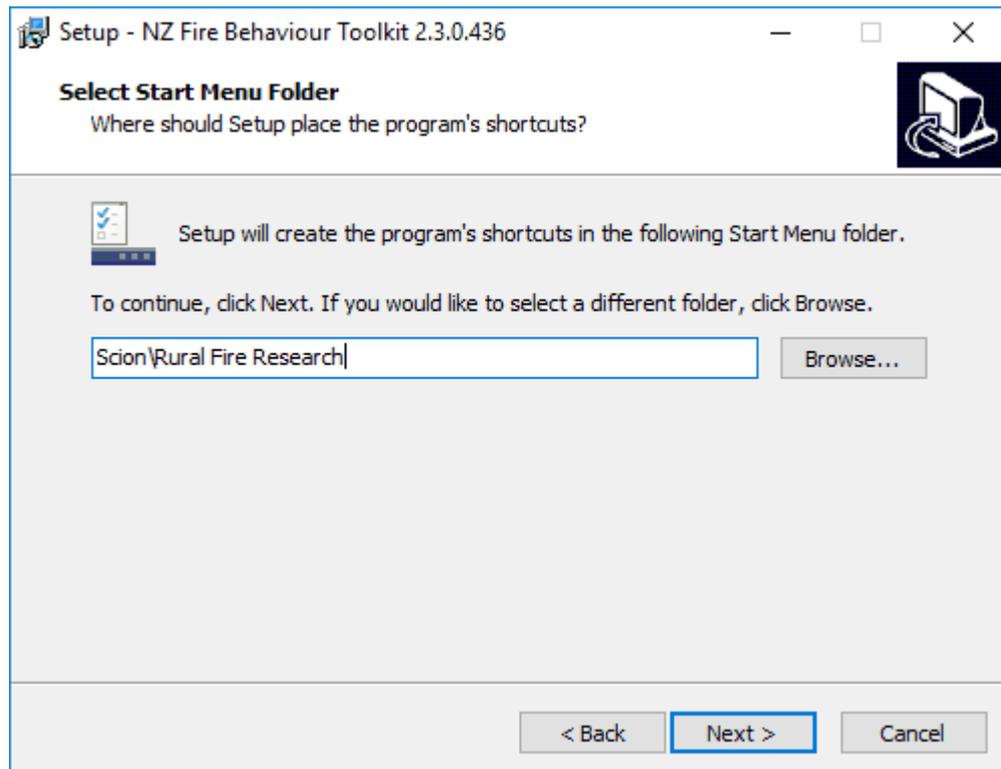
Specify a Start Menu folder for the software to be run from, or just click Next to use the default (recommended).
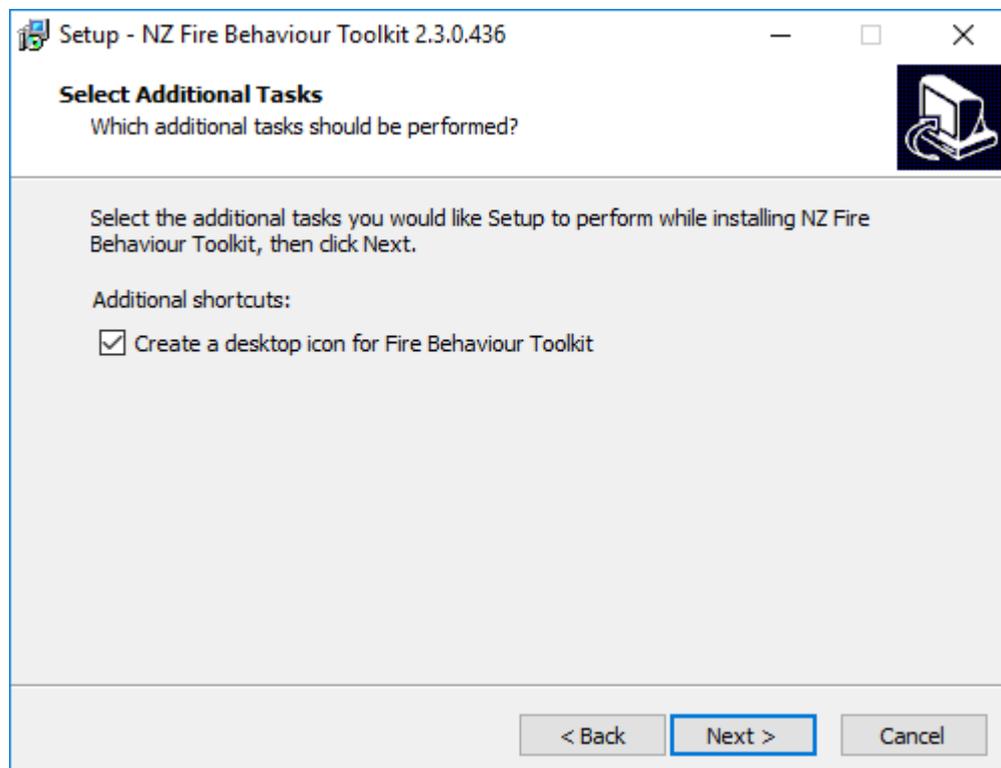


Tick the check box if you would like an icon for the Toolkit on your desktop. Click on the Next button.
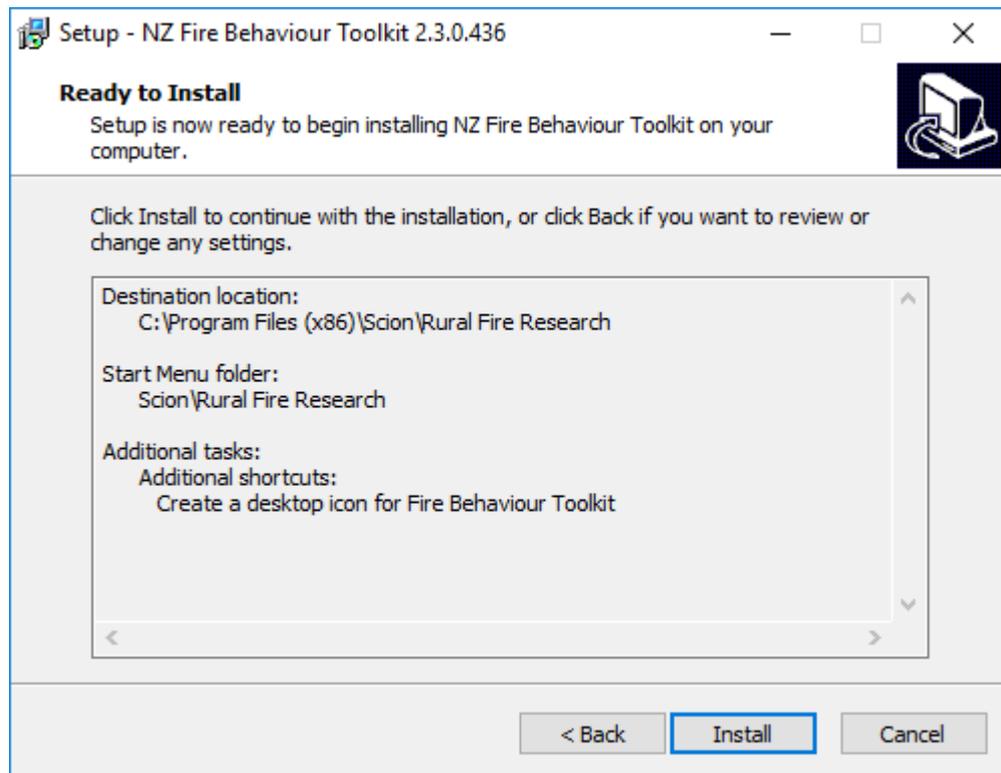
Click the Install button, and the Toolkit will be installed.
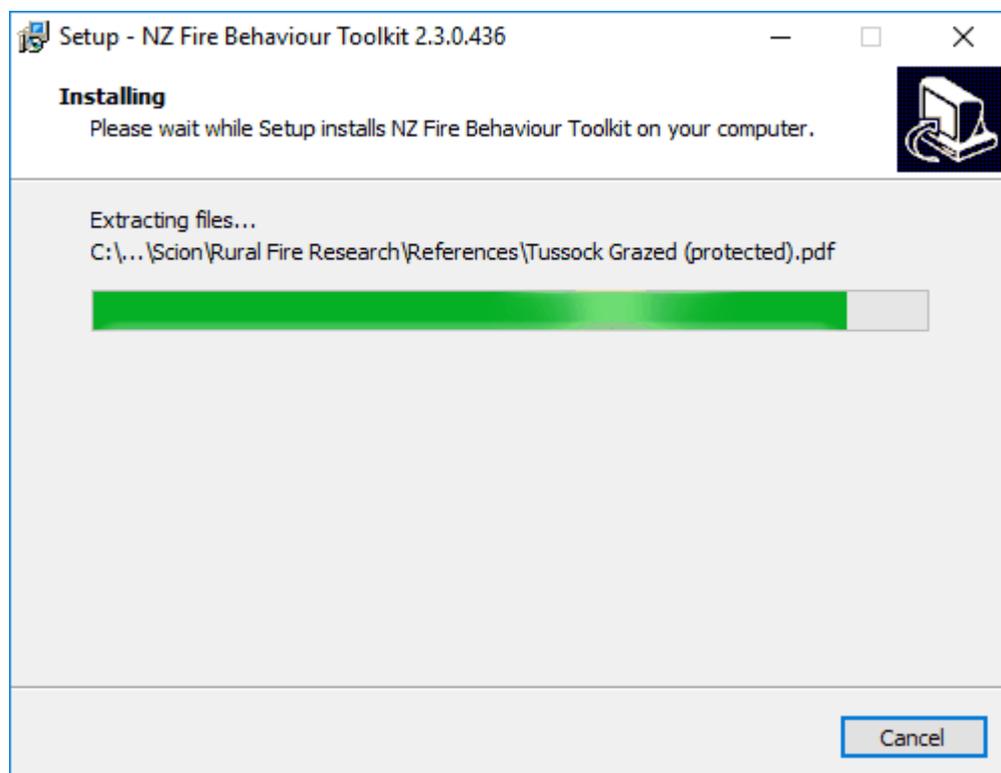
Click on the Finish button to exit the Setup process.

The Toolkit can now be run via the Start menu:

**Start | Programs | Scion | Rural Fire Research | NZ Fire Behaviour Toolkit**

or via the Toolkit icon on your Windows Desktop (if specified during the Installation).

# 5    Getting Started

Once the installation procedure has completed and the NZ Fire Behaviour Toolkit is installed on the system, it can accessed by either clicking on the icon that was installed on the desktop, or through the menu **Start | Programs | Scion | Rural Fire Research | NZ Fire Behaviour Toolkit**. Starting the program will open up the main window:
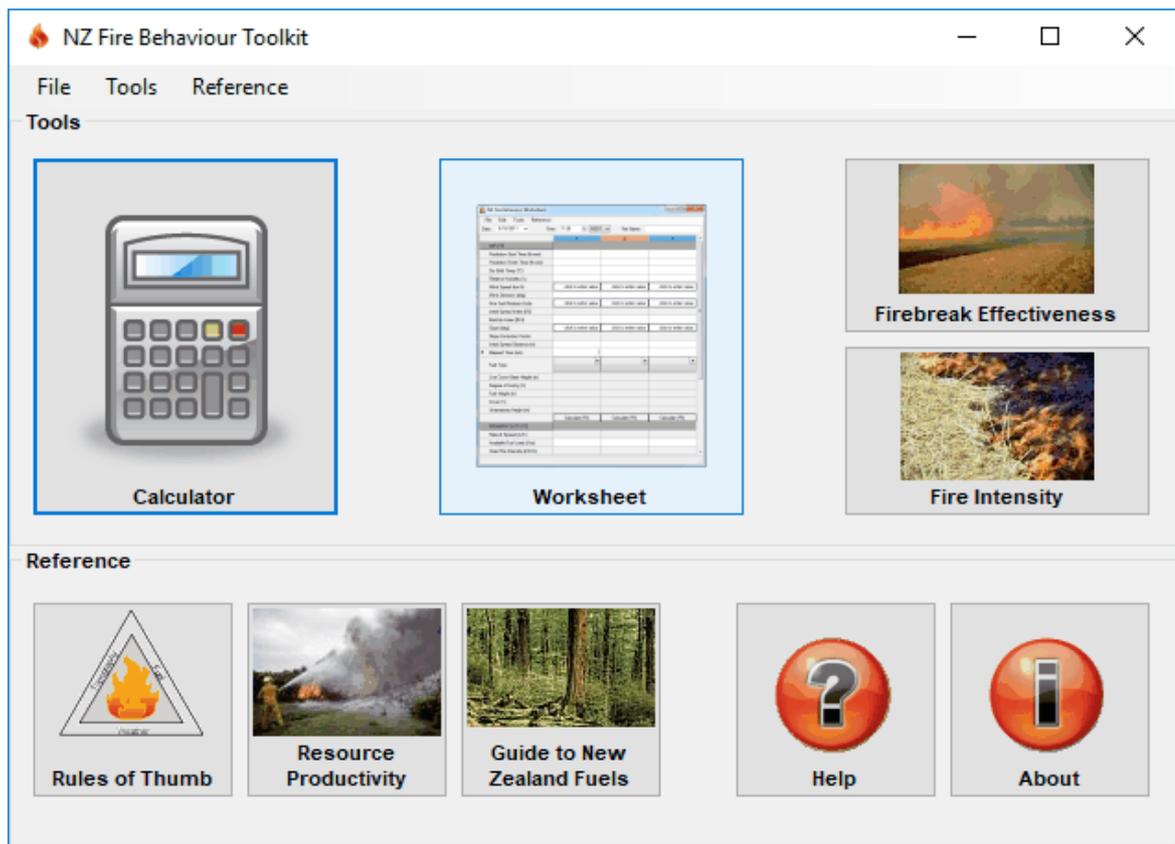


From here the user clicks on the buttons to start the relevant modules, or they can be accessed via the menu at the top of the screen.

Any of the modules can be opened and used simultaneously, i.e. no modules need to closed down before another one can be opened. It is also possible to open and run multiple versions of the Calculator and Worksheet modules, should the user wish to perform calculations for a number of different scenarios at the same time.

# 6    Fire Behaviour Calculator

The Fire Behaviour Calculator is designed for quick and easy determination of fire potential for any of the NZ fuel types.



Once all of the required input data has been entered, click the "Calculate" button (or press F5), and all of the output values will be calculated and displayed. If any of the input data are considered to be in error, e.g. are outside of an acceptable range, then an error message such as the following will be displayed:
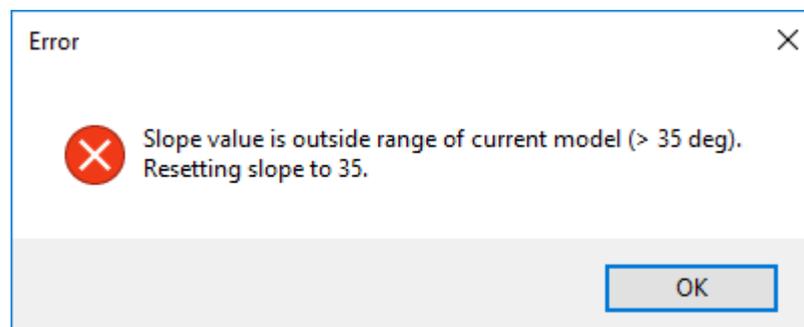


Once a calculation has been successfully completed, if the user then chooses to re-enter or change any of the input values, the "Calculate" button will be coloured red (in bold) to indicate that the outputs need to be re-calculated.

A new scenario can be started by selecting the menu item **File | Clear**, which will clear all of the fields on the calculator.

## 6.1    Inputs

### 6.1.1    Wind Speed

If a wind speed value in km/h is available, it can be entered directly into the calculator, or one can be derived from other forms of measurement.
A value measured at 10m from the nearest Remote Automatic Weather Station (RAWS) can be entered into the Wind Speed field on the calculator, or by clicking on the button marked with an ellipsis ("...") to the right of the field, the Wind Speed form is displayed:
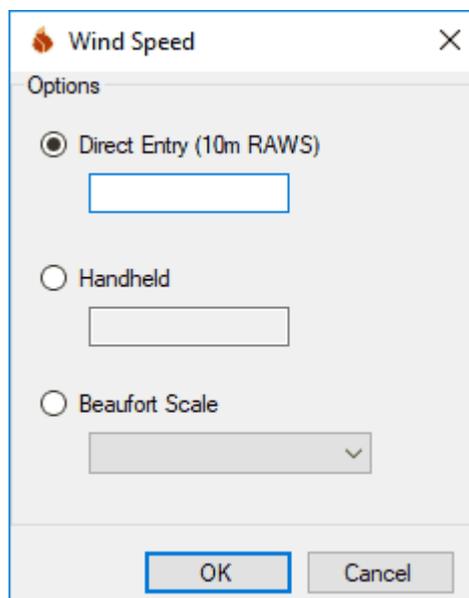


The Wind Speed form allows a value to be entered in any of three ways:

- Direct entry (10m RAWS) – the 10m wind speed measured at the nearest RAWS.
- Handheld – wind speed measured using a handheld weather instrument such as a Kestrel (http://www.nkhome.com/ww/wwindex.html). The value entered will then be converted to a 10m wind speed equivalent for use in subsequent calculations.
- Beaufort Scale – if the user does not have access to any other readings of wind speed, the Beaufort Scale can be used. The descriptors for the various classes of wind speed are listed in the drop-down box, and the midpoint of the wind speed range for this class is used in subsequent calculations.

### 6.1.2    Fine Fuel Moisture Code (FFMC)

If the Fine Fuel Moisture Code (FFMC) value is known, it can be entered directly into the calculator, or an hourly value can be derived from the standard noon value. The standard noon, or hourly, FFMC value can be entered into the Fine Fuel Moisture

Code field, or by clicking on the button marked with an ellipsis ("...") to the right of the field, the Fine Fuel Moisture Code form is displayed:



An FFMC value can then be entered in one of three ways:

1. Use Noon value – this is the 1200 (NZST) FFMC value calculated from the nearest RAWS, or by using manual or other computer calculations.
2. Convert Noon value to hour – this option adjusts the standard daily FFMC, based on the time of the day, in accordance with Canadian diurnal FFMC adjustment equations (Lawson et al. 1996). Apart from relative humidity (RH) for calculations between 0600-1159 NZST, this FFMC adjustment does not require additional weather observations, but *it does assume that normal diurnal weather conditions exist*. This option is the least accurate in that the relationships have not been validated for New Zealand latitudes and fuels. It is also not appropriate in situations where a normal diurnal weather pattern does not arise (e.g., peak burning conditions do not occur around 1600 NZST). Users also need to be aware that, when selecting a prediction time for the FFMC that falls between 0600-1159 NZST, that the noon FFMC value from the **previous day** is required. A warning message appears when these conditions apply:

FFMC Adjustment ✕

⚠ Remember - calculations for 0600-1159 NZST require yesterday's Noon FFMC

OK
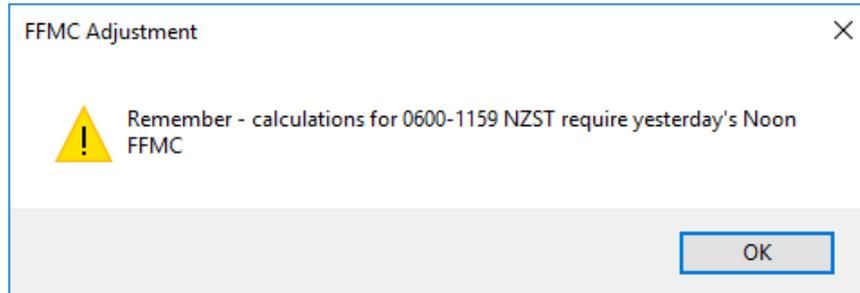
3. Use Hourly value – the FFMC value that relates to the hour of calculation. This requires the use of a computer program to calculate the hourly FFMC value from a starting standard daily FFMC value or an initial diurnal FFMC value, as well as consecutive hourly observations of temperature, relative humidity, wind speed and hourly rainfall (or forecasted values from, for example, the MetService's MetConnect website http://www.metconnect.co.nz).

### 6.1.3 Initial Spread Index (ISI)

The Initial Spread Index (ISI) is calculated from the wind speed and FFMC – no direct input is required.

### 6.1.4 Buildup Index (BUI)

This is the BUI value calculated at 1200 (NZST) from the nearest RAWS, or using manual or other computer-based calculations.

### 6.1.5 Slope

Enter the slope angle (in degrees) into the Slope field, if known, otherwise, for alternative input options, click on the ellipsis button to the right of the field to display the Slope form:

🔥 Slope ✕

Options

● Direct Entry

[ ]

○ Use Rise and Run

Rise [ ]

Run [ ]

OK    Cancel
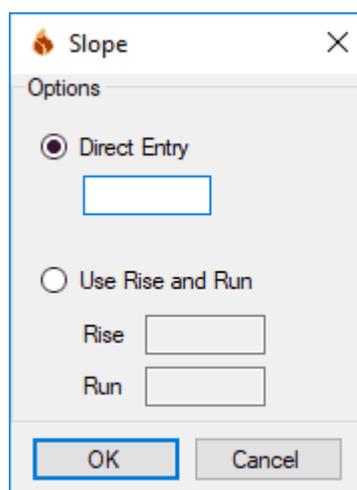
The Slope form allows a value to be entered in either of two ways:

- Direct Entry – when the slope angle (in degrees) is known.
- Use Rise and Run – where the slope angle needs to be calculated from

a topographical map sheet. This option requires entry of values in the same units (usually metres, m) for both rise (change in elevation, determined by counting contour intervals) and run (by measuring the distance using the map scale), and it will then calculate and display the slope angle.

Refer to the "Slope Calculation" text below for further explanation of the assumptions and procedures in calculation of slope for fire behaviour prediction.

## Slope Calculation

Equations for calculating the Slope Correction Factor (SCF) for upslope fire spread are based on the Canadian slope effect relationship (Forestry Canada Fire Danger Group 1992). The maximum slope angle for this relationship is 35°, therefore any slope angle entered that is greater than this value will default to the SCF that relates to a 35° slope (SCF of 10). A warning message will notify the user of this:
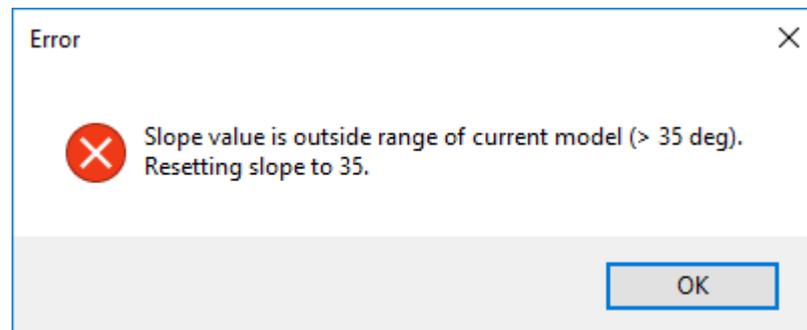


Downslope SCF values are derived from the Australian downslope spread reduction factors (Cheney 1981), as these are not included in the Canadian Fire Behavior Prediction System. The maximum downslope angle for this relationship is -20°, so any downslope angle entered that is less than this value will default to -20° (SCF of 0.25). Once again, a warning message will appear notifying the user of this:
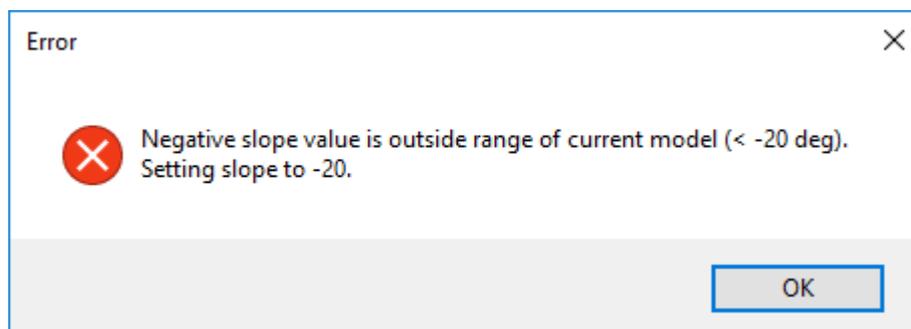


When a **positive** value for slope angle is entered, the calculated Slope Correction Factor (SCF) will only apply to situations where wind (if present) and slope are aligned; i.e., wind is blowing for the most part directly upslope (i.e. within 30° either side of the maximum upslope direction). The combination of different wind directions with slope direction can complicate the determination of slope effects on fire rate of spread. A vectoring approach is required to properly integrate cross-slope winds to determine cross-slope spread rates and direction, which is beyond the current scope

of this toolkit. In addition, the Back Fire ISI and a downslope SCF (not displayed) will be used to determine the Back Fire Spread Rate and Spread Distance. In other words, the calculator assumes that the Head Fire is spreading upslope, with the wind blowing upslope and aligned with the slope direction, and that the Back Fire outputs represent the fire that is "backing" down the slope.

When a **negative** value for slope angle is entered, it is assumed that the user is only interested in predicting the behaviour of a fire that is spreading downslope, e.g., a spot fire on a slope that is burning downslope only (has burned to the ridge top), or a fire that has reached the ridge top and is now backing down the slope. In other words, it is assumed that there is no head fire present, and that the fire is backing down the slope. If wind is present in this scenario, it is again assumed that the wind direction is aligned with the direction of the slope and that the wind is blowing downslope. For these reasons, if a negative slope value is entered, only the Primary Outputs will be displayed for fire behaviour calculations, as it is assumed that the fire is a backing fire only. The Rate of Spread output thus refers to the rate of spread of this fire backing down the slope. It is therefore not possible to determine many of the Secondary Outputs (since the assumption of a spreading fire being driven by the wind on level terrain or upslope is not valid), and they are therefore not calculated or displayed.

### 6.1.6    Slope Correction Factor

The Slope Correction Factor (SCF) is calculated from the slope angle, no direct input is required.

### 6.1.7    Initial Spread Distance

Entering an Initial Spread Distance (in metres) allows the user to predict fire behaviour for an active fire that has already spread a certain distance by the time the calculations or predictions are commenced. This initial spread distance is then added to the outputs for the calculation period to provide a more accurate determination of total fire spread distance, fire area and perimeter etc.

### 6.1.8    Elapsed Time

Enter an Elapsed Time (in minutes) to specify the time period for which the calculations are required..

### 6.1.9    Fuel Type

Enter the appropriate fuel type from the dropdown list. Depending on the fuel type selected, additional fuel characteristics such as degree of curing, % cover, height, etc. may be required. When selecting the fuel type for fire behaviour predictions, carefully consider what fuels will carry the fire – this is the fuel type that should be used in fire behaviour calculations. For example, in an immature pine plantation dominated by rank grass, the grass is the dominant fuel type supporting the fire, and should be used to derive Available Fuel Load (AFL) and Rate of Spread (ROS) values. Similarly, for a pine stand with a dominant gorse understorey, the scrub fuel type is likely to provide more accurate estimates of fire behaviour.

## 6.2 Primary Outputs

### 6.2.1 Rate of Spread (ROS)

The Rate of Spread (ROS) is the (head) fire rate of spread in m/h.

### 6.2.2 Available Fuel Load (AFL)

The Available Fuel Load (AFL) is the total fuel available for consumption in t/ha, based on fuel load models for NZ fuel types (Fogarty & Pearce 2000). This calculated value can be over-written if a more accurate estimation of fuel load (based on local knowledge) is available. Should this field be left blank, the fuel load is calculated based on the fuel characteristics, and other inputs provided.

### 6.2.3 Head Fire Intensity

The Head Fire Intensity is the intensity of the head of the fire, based on the formula:

$$I = (w \times r)/2$$

where:

I is the intensity in kW/m
w is the fuel load in t/ha
r is the fire rate of spread in m/h.

Intensity will be lower than this calculated value for parts of the fire that are not at the head. For more information refer to Pearce & Anderson (2008) and the Fire Behaviour Rules of Thumb.

### 6.2.4 Flame Length

The Flame Length is calculated from the Head Fire Intensity using Byram's (1959) formula, and represents the flame length at the head of the fire. Users need to be aware of the difference between the flame *length* and flame *height*. Flame height is the maximum vertical extension of the flame front, and flame length and height are only equal to each other in still air conditions (no wind).

### 6.2.5 Type of Fire

The fire type is either surface (S) or crown (C). Fire type will always be "S" for all fuel types other than Pine (11-20 yrs) and Mature Pine (20+). Crown fire (C) will not apply to any of the other fuel types. This is because the relationships for crown fire development have thus far only been recommended for use in NZ's mature pine plantation fuel types (Alexander 1994). The underlying equation for determining fire type for pine plantations assumes a live crown foliar moisture content of 145%. If the calculated Head Fire intensity exceeds the critical surface fire intensity required for crowning, then conditions are suitable for crown fire development.

## 6.3 Secondary Outputs

- Head Spread Distance – the distance of spread of the head fire (m), based on the head fire rate of spread and the elapsed time.
- Back Spread Distance – the distance of spread of the back fire (m),

based on the back fire rate of spread and the elapsed time.

- Total Spread Distance – the total spread distance of the fire, calculated by adding the head and back fire spread distances, as well as the initial spread distance, if one was entered in the inputs.
- Back Rate of Spread – calculated using the back fire ISI in the rate of spread model for the relevant fuel type.
- Back Fire Intensity – calculated using the same formula for head fire intensity (as explained previously), but based on the back fire rate of spread and available fuel load.
- Fire Area – the area (ha) of the fire, based on the fire spread distance and wind speed.
- Perimeter Length – based on the area of the fire.
- Perimeter Growth Rate – the rate at which the perimeter of the fire is growing for every hour of active burning/fire spread.
- Length/Breadth Ratio – based on the wind speed, and provides an indication of the shape of the fire.

## 6.4    Other Calculator Options

*Saving and Loading files*

Calculations can be saved as scenarios, for reference or use at a later stage. Selecting **File | Save** will open the Save Inputs form, asking the user for relevant information:
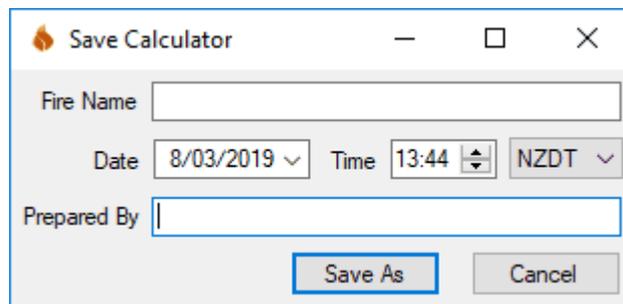
Clicking "Save As" allows the user to specify a relevant directory in which to store the file. Calculator files will be saved as *.calc files, and they can be opened (**File | Open**) and used in subsequent calculations or forecast preparations as required.

Selecting **File | Save As** allows an existing scenario (already saved as a file) to be saved under a different file name.

If the user attempts to exit the Calculator (**File | Exit**) without saving the file (or after making amendments to an existing file without saving), a reminder message will appear to prompt the user to save the work.

*Creating Reports*

Selecting **File | Print Preview** will open the Print Preview form, asking the user for further information:
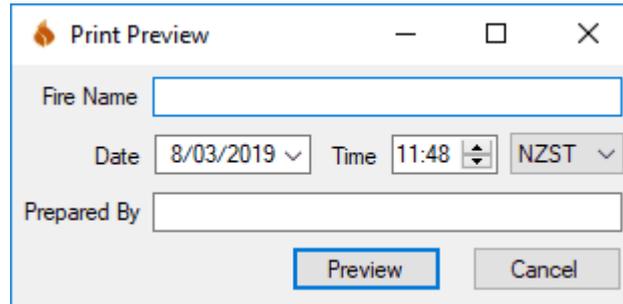
The data entered into these fields are then added to the report form which is created as a PDF file. This PDF file can then be saved to the user's hard drive in an appropriate directory, and/or printed, for use in subsequent fire behaviour forecast planning, prescribed burn planning, fire investigation reports, etc.

# Fire Behaviour Calculator

## NZ Fire Behaviour Toolkit

**Fire Name**     Crop fire                                    Prepared by J. Doe

**Date**     8/3/2019 13:44 NZDT

| INPUTS | |
|---|---:|
| Wind Speed (km/h) | 20 |
| Fine Fuel Moisture Code | 89 |
| Initial Spread Index [ISI] | 10.1 |
| BuildUp Index [BUI] | 80 |
| Slope (deg) | 0 |
| Slope Correction Factor | 1.0 |
| Initial Spread Distance (m) | 400 |
| Prediction Interval (min) | 60 |
| Fuel Type | Crop stubble - unbaled |
| Degree of Curing (%) | 100 |
| Fuel Height (m) | 0.2 |
| **PRIMARY OUTPUTS** | |
| Rate of Spread (m/h) | 3355 |
| Available Fuel Load (t/ha) | 6 |
| Head Fire Intensity (kW/m) | 9980 |
| Flame Length (m) | 5.4 |
| Type of Fire | S |
| **SECONDARY OUTPUTS** | |
| Head Spread Distance (m) | 3355 |
| Back Spread Distance (m) | 2816 |
| Total Spread Distance (m) | 6570 |
| Back Rate of Spread (m/h) | 2816 |
| Back Fire Intensity (kW/m) | 8376 |
| Fire Area (ha) | 767.7 |
| Perimeter Length (m) | 13916 |
| Perimeter Growth Rate (m/h) | 13069 |
| Length/Breadth Ratio | 4.4 |

*Clear contents*

Selecting **File | Clear** will erase all of the cell contents on the calculator, allowing the user to start again with calculations.

*Export inputs to a Worksheet*

On opening the Worksheet module from the Calculator (**Tools | Worksheet**), the user is asked whether the input values from the Calculator are to be carried across into the new Worksheet:

NZ Fire Behaviour     ✕

Copy values to worksheet?

[ Yes ] [ No ] [ Cancel ]
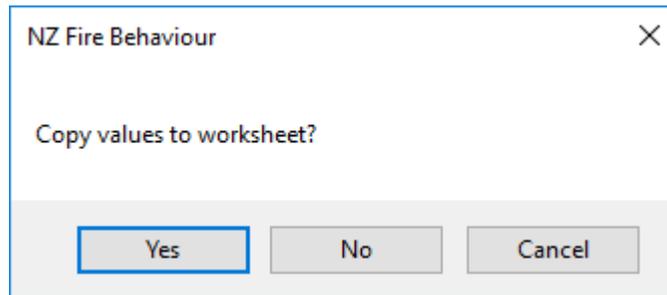
If the user answers "Yes" to this, the Calculator inputs will be inserted into the first column of the new Worksheet, allowing the user to continue using the Worksheet for more detailed calculations or predictions.

# 7 Fire Behaviour Prediction Worksheet

The Fire Behaviour Prediction Worksheet is intended to be used as the basis for more detailed fire behaviour predictions, particularly where there is a need to extend the predictions over a number of different time periods or scenarios, for example where there is a need to determine fire behaviour predictions for the duration of an active burning period or shift. Such a scenario may involve extending a fire over a number of different time periods (with changes in weather conditions and/or fuel type and topography), or the ability to compare the effects of changes in fire environment conditions (weather, fuel type, topography) during the same time period.



On opening the worksheet, only the first column will appear. Once this first column is complete, the user has the option to enter subsequent columns.

The worksheet can be saved, exported to a report and printed, and then used as the basis to prepare a fire behaviour forecast, prescribed burn plan, fire investigation report, etc.

## 7.1 Worksheet Inputs

The procedure for entry of inputs is the same as for the Fire Behaviour Calculator.

The Start and Finish times for the prediction period also need to be selected. The elapsed time is then determined from these start and finish times, for use in the calculation of total spread distance, fire area, perimeter length, etc. The Elapsed

Time can also be manually entered, to replace the calculated value from Start and Finish times.

Once the Fuel Type is selected, the required fields to determine fuel load and other fire behaviour outputs will appear unshaded (shaded fields indicate that the parameter is not required for that fuel type). As with the Calculator, a value for Available Fuel Load (in t/ha) can be manually entered if a more accurate estimation of fuel load (based on local knowledge) is available. If no value is entered by the user, then the fuel load is calculated based on the fuel characteristics and other inputs provided.

## 7.2    Worksheet Outputs

Once all the inputs are entered, the "Calculate" button needs to be clicked (or F5 pressed) to calculate the outputs. As with the Fire Behaviour Calculator, if the user chooses to re-enter (or change) input values after a calculation has been executed, the "Calculate" button will be coloured red to indicate to the user that the output values need to be re-calculated.

The Primary and Secondary outputs listed are the same as those in the Calculator. The "Warnings" field (last row of the worksheet) allows the user to type in any safety warnings or comments related to the predicted fire behaviour.

This procedure should be repeated for each prediction period, or for different fuel types or slope changes encountered during the prediction period. Predictions can also be made for subsequent time intervals using forecasted weather and fire danger information, if available.

## 7.3    Other Worksheet Options

*Inserting additional columns*

Once the first column is complete, additional columns can be inserted into the worksheet from the **Edit** menu. There are two options for inserting new columns:

- Insert Time Sequence Column – select this option if the intention is to continue the fire behaviour prediction into a subsequent time period. Upon selecting this option, the user will be asked "Copy values from column(#)?" If "Yes" is selected, the input values from the previous column will be copied into this column. These input values can of course then be altered for this subsequent fire behaviour calculation. The Finish Time field will be left empty, prompting the user to define the prediction period for this new column. A new Elapsed Time is then calculated for this period. For a Time Sequence column, the Initial Spread Distance field will be filled with the Total Spread Distance value from the preceding column, and added to the spread distance for this

time period to determine total spread distance, fire area, perimeter length, etc.

- Insert Alternative Column – select this option to evaluate different fire environment scenarios during the same time period, such as a change in weather (wind speed, relative humidity, temperature), fuel type or slope. Once again the user will have the option to "Copy values from Column(#)?". If the user chooses to copy the input values from the previous column, the Elapsed Time will also be copied over. However, altering either the Start or Finish Time in this new column will result in the Elapsed Time being recalculated to match the new time interval.

It is possible for combinations of the above two column types to be inserted into the worksheet, e.g., a Time Sequence column could be followed by a number of Alternative columns, and then a Time Sequence could be resumed. However, users need to be aware that whenever a Time Sequence column is inserted, only the input values (and total spread distance) from the immediately preceding column will be used as input values for the column, i.e. there is no ability to instruct the worksheet to copy values from a column that is not the immediately preceding column.

*Clear contents and delete column*

The input values for a column can be cleared by selecting **Edit | Clear column(#)**. Any column from a series of Alternative Scenario columns can be deleted by selecting **Edit | Delete column(#)**. However, in the case of Time Sequence columns, only the last (most recent) column to the right can be deleted.

*Saving and Loading files*

Selecting **File | Save** allows the scenario to be saved as a *.wsht file. This file can then be opened (using **File | Open**) and used in subsequent calculations or forecast preparations as required. The Save Worksheet form will appear, asking the user for relevant information:
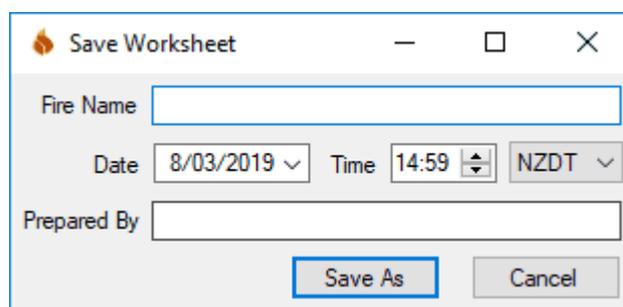


Clicking "Save As" allows the user to then select a relevant directory in which to save the file.

**File | Save As** allows an existing worksheet (already saved as a file) to be saved under a different file name.

If the user attempts to exit the Worksheet (**File | Exit**) without saving the file (or after

making amendments to an existing file without saving), a reminder window will appear to prompt the user to save the work.

Files created from the Calculator (*.calc) or Worksheet (*.wsht) can be opened in either module. However, if the user attempts to open a Worksheet file in the Calculator, and the Worksheet scenario contains more than one column, only the first column's values will be inserted into the Calculator. A warning message will appear when this is attempted:
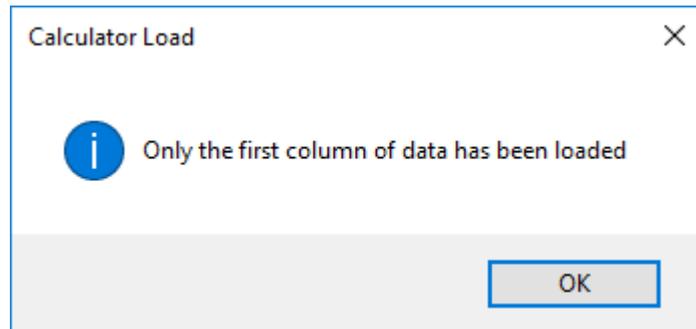


However, it would not be a common action to seek to load a multi-column worksheet scenario into the Calculator.

*Creating Reports*

Selecting **File | Print Preview** will open the Print Preview form, asking the user for further information:
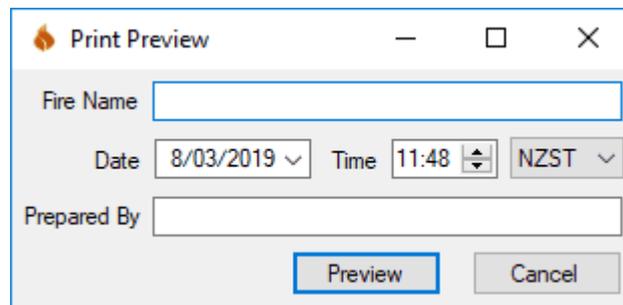


The Date, Time and Fire Name fields from the top row of the Worksheet will automatically be inserted into the fields of the Print Preview form, and then inserted into the report form which is created as a PDF file. This PDF file can then be saved to the user's hard drive in an appropriate directory and/or printed, and the report used in subsequent fire behaviour forecast planning, prescribed burn planning, fire investigation reports, etc.

## Fire Behaviour Prediction Worksheet    NZ Fire Behaviour Toolkit

| | | | |
|---|---|---|---|
| Fire Name | Wairarapa Forest Fire | Prepared by Stuart Anderson | |
| Date | 12/03/2008 12:00 p.m. | | |

| INPUTS | 1 | 2 | 3 |
|---|---|---|---|
| Prediction Start Time (hh:mm) | 12:00 p.m. | 02:00 p.m. | 03:00 p.m. |
| Prediction Finish Time (hh:mm) | 02:00 p.m. | 03:00 p.m. | 05:00 p.m. |
| Dry Bulb Temp (°C) | 30 | 32 | 25 |
| Relative Humidity (%) | 38 | 30 | 45 |
| Wind Speed (km/h) | 15 | 30 | 15 |
| Wind Direction (deg) | 315 | 315 | 200 |
| Fine Fuel Moisture Code | 95 | 96 | 89 |
| Initial Spread Index [ISI] | 18.3 | 44.7 | 7.9 |
| BuildUp Index [BUI] | 80 | 80 | 80 |
| Slope (deg) | 10 | 15 | 0 |
| Slope Correction Factor | 1.6 | 2.1 | 1.0 |
| Initial Spread Distance (m) | 0 | 2685 | 6250 |
| Elapsed Time (min) | 120 | 60 | 120 |
| Fuel Type | Pine 11-20 yrs | Pine mature (20+ years) | Pine - logging slash |
| Live Crown Base Height (m) | 2.5 | 4 | |
| Degree of Curing (%) | | | |
| Fuel Height (m) | | | |
| Cover (%) | | | |
| **PRIMARY OUTPUTS** | | | |
| Rate of Spread (m/h) | 1323 | 3562 | 713 |
| Available Fuel Load (t/ha) | 24 | 20 | 72 |
| Head Fire Intensity (kW/m) | 15993 | 36301 | 25654 |
| Flame Length (m) | 6.7 | 9.7 | 8.3 |
| Type of Fire | C | C | S |
| **SECONDARY OUTPUTS** | | | |
| Head Spread Distance (m) | 2646 | 3562 | 1426 |
| Back Spread Distance (m) | 39 | 3 | 224 |
| Total Spread Distance (m) | 2685 | 6250 | 7900 |
| Back Rate of Spread (m/h) | 20 | 3 | 112 |
| Back Fire Intensity (kW/m) | 238 | 27 | 4034 |
| Fire Area (ha) | 286.1 | 799.9 | 2476.7 |
| Perimeter Length (m) | 6520 | 13441 | 19184 |
| Perimeter Growth Rate (m/h) | 3260 | 7667 | 2004 |
| Length/Breadth Ratio | 2.0 | 3.8 | 2.0 |
| Warnings | Crown fire, extreme fire intensity | Crown fire, spotting | Southerly change - flank fire may become head |

# 8 Firebreak Effectiveness

The Firebreak Effectiveness module allows the user to determine either:

1. the probability of an existing firebreak of given width being breached by a fire, where the head fire intensity is known, or
2. the width of firebreak required to contain a head fire of known intensity

The form has two tabs, for different fuel types. Select the one most appropriate:

**1. Grass fuels**



The probability of a grass fire breaching a mineral earth firebreak is a function of fire intensity, firebreak width, and the absence or presence of trees _within 20m of the upwind side of the firebreak_ to provide a firebrand source (based on Wilson 1988). There are two calculation options:

- Enter the fire intensity, mark the presence or absence of trees, and enter the existing firebreak width. Press Calculate (**F5** or the **Enter** key) to calculate the probability of the firebreak being breached, or
- Enter the fire intensity, mark the presence or absence of trees, and enter the desired probability of the firebreak being breached ie. the probability of breaching that is an acceptable level of risk to the user. Press Calculate (**F5** or **Enter**) to calculate the width of firebreak associated with the specified probability of breaching.

In the example below, for a fire with a head fire intensity of 5000 kW/m, trees absent from the upwind side of the firebreak, and a desired firebreak breaching probability of 20%, the calculated firebreak width is 4.6m. This means that for the fire manager to be 80% confident that the fire will be held by a firebreak, it is necessary to construct a firebreak of at least 4.6m width:
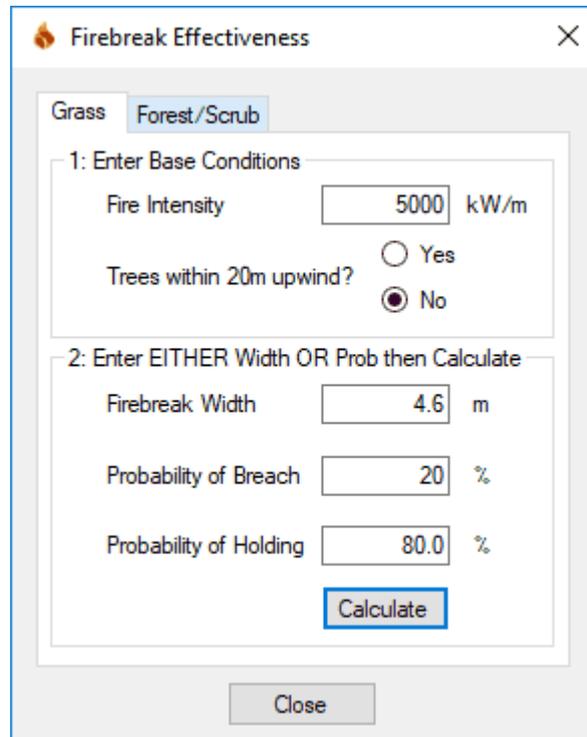


## 2. Forest and scrub

The firebreak width required to halt the spread of a fire burning in forest or scrub fuels, where spotting is not prevalent (where the fire breaches the firebreak by radiant heating or direct flame contact), is dependent on the fire intensity and associated flame length. This is based on a simple rule of thumb where the required firebreak width is equal to the flame length multiplied by a factor of 1.5 (Byram 1959).

There are two calculation options available:

- Enter either the flame length or the fire intensity, then press Calculate (**F5** or **Enter**) to calculate the required firebreak width, or
- Enter the existing firebreak width (m), then press Calculate (**F5** or **Enter**) to calculate the maximum flame length and intensity that the firebreak can withstand.

In the example below, an observed flame length of 4.5m means that a firebreak of at least 6.8m (7m for practical purposes) is required to contain a fire that may be burning in either forest or scrub fuels, in the absence of spotting:

# 9 Fire Intensity

The Fire Intensity module allows the calculation of fire intensity based on an observed flame length, or the calculation of flame length when the intensity is known. Flame length is the most visible manifestation of fire intensity, and is a key determinant of fire effects (e.g. scorching, crowning), and of control difficulty and fire suppression requirements.
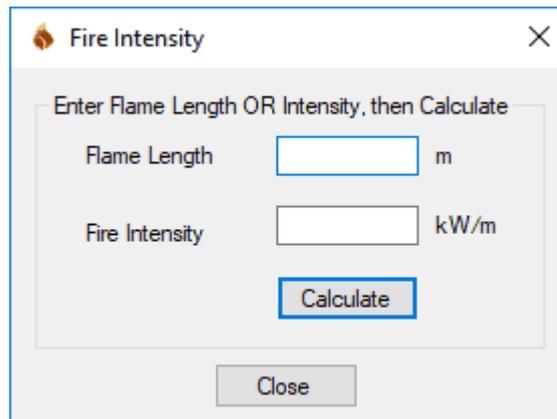


There are two calculation options available:

- Enter the flame length (m), then press Calculate (**F5** or **Enter**) to calculate the fire intensity (kW/m), or
- Enter the fire intensity (kW/m), then press Calculate (**F5** or **Enter**) to calculate the flame length (m)

# 10    Fire Behaviour Rules of Thumb

This is a listing of the fire behaviour "Rules of Thumb", which are provided for quick and easy reference, as contained in the NZ Fire Behaviour Manual (Pearce and Anderson 2008).

# 11 Resource Productivity

This section provides some general guidelines for resource productivity in NZ fuel types with different types of suppression resources. The table currently included is based on earlier work by Fogarty and Smart (1994). It is based on the best available New Zealand resource productivity data to date, but will be added to and updated as new information becomes available (Parker et al. 2007).

# 12    Guide to New Zealand Fuels

This guide to New Zealand fuel types has been prepared to assist with the selection of the most appropriate fuel models for fire behaviour predictions
The guide has been broken into fuel type sections and subsections and will use the default pdf viewer to view..

Two hard copy user guides also exist:
• a technical guide to determine available fuel loads and rates of spread,
• and a field guide that fits as an insert in the Orange fire behaviour field manual.

Both guides can be ordered here through Scion publications.
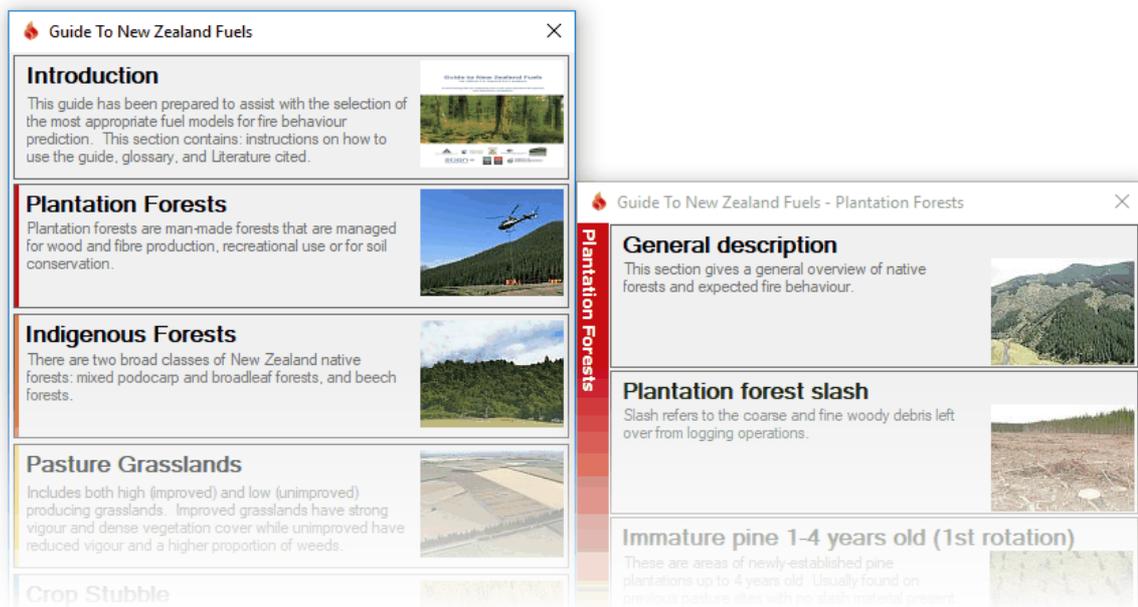
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# 14    Contact Us

This version of the NZ Fire Behaviour Toolkit is the second major version, and it is intended to update relevant modules in the future as new information from the Scion Rural Fire Research Group becomes available. The Toolkit represents a significant improvement in the level of tools that are available to assist fire managers across the country in incorporating fire behaviour information into fire management decision-making.

We also intend to make improvements to subsequent versions of this Toolkit as its use becomes more extensive, and the need for either new features or enhancements is identified. To this end, we welcome any feedback or suggestions for improvements.

For support queries or feedback, please contact:  rural.fire@scionresearch.com

The NZ Fire Behaviour Toolkit is available for download (free of charge) from the Scion website, and updates and subsequent versions will also be posted on the website: www.scionresearch.com/fire