

Fire Research Report

NZ Fire Behaviour Toolkit: User Guide and Technical Report

Scion

June 2008

A *NZ Fire Behaviour Toolkit* has been developed to incorporate as much as possible of the current knowledge on fuels and fire behaviour in the New Zealand fire environment into a user-friendly software package. 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. The toolkit contains a number of separate modules, each developed for different purposes and levels of use. These include a calculator (for quick and easy determination of fire potential), worksheet (allowing more detailed calculations and prediction of fire behaviour over longer periods of time for specific fires), firebreak effectiveness tool (to either determine the likely effectiveness of an existing firebreak or the firebreak width required to contain a fire), fire intensity tool (calculates fire intensity from flame length and vice versa), and information sections on fire behaviour “rules of thumb” and the productivity of NZ fire suppression resources. Users can save calculations, and produce and print detailed reports. There is also a comprehensive “Help” module. This 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, and is an excellent example of creating user-friendly applications from science knowledge.

New Zealand Fire Service Commission Research Report Number 105
ISBN Number 978-1-877539-21-3 (on-line)
ISBN Number 978-1-877539-20-6 (paperback)
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NZ Fire Behaviour Toolkit: User Guide and Technical Report

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Client Report No. 12796

Date: June 2008
Client: New Zealand Fire Service Commission

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EXECUTIVE SUMMARY

The *NZ Fire Behaviour Toolkit* has been developed to incorporate as much as possible of the current knowledge on fuels and fire behaviour in the New Zealand fire environment into a user-friendly software package. 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)¹.

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

- i. **Fire Behaviour Calculator** – designed for quick and easy determination of fire potential for any of the NZ fuel types.
- ii. **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.
- iii. **Firebreak Effectiveness** – allows the user to either 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.
- iv. **Fire Intensity** – allows calculation of fire intensity based on an observed flame length, or calculation of flame length if the intensity is known.
- v. **Fire Behaviour Rules of Thumb** – a listing of these “rules of thumb” for quick and easy reference.
- vi. **Resource Productivity** – a table providing some general guidelines for resource productivity in NZ fuel types with different types of suppression resources.

This version of the NZ Fire Behaviour Toolkit is the first version, and the intention is to update relevant modules in the future as new information from the Scion Rural Fire Research Group becomes available. It 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.

¹ Pearce, H.G.; Anderson, S.A.J. 2008. A manual for predicting fire behaviour in New Zealand fuels. Scion, Rural Fire Research Group, Christchurch. June 2008.

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INTRODUCTION

The *NZ Fire Behaviour Toolkit* has been developed to incorporate as much as possible of the current knowledge on fuels and fire behaviour in the New Zealand fire environment into a user-friendly software package. 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.

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

- i. **Fire Behaviour Calculator** – designed for quick and easy determination of fire potential for any of the NZ fuel types.
- ii. **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.
- iii. **Firebreak Effectiveness** – this module allows the user to either 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.
- iv. **Fire Intensity** – allows calculation of fire intensity based on an observed flame length, or calculation of flame length if the intensity is known.
- v. **Fire Behaviour Rules of Thumb** – a listing of these “rules of thumb” for quick and easy reference.
- vi. **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 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 (refer to 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 outputs from these tables to better reflect conditions at the fire location.

SPECIFICATIONS AND SYSTEM REQUIREMENTS

NZ Fire Behaviour Toolkit will run on any computer that supports Microsoft .NET Framework 2.0. The .NET Framework is a development and execution environment that can be used by many Windows-based applications. The .NET Framework comes pre-installed on Windows Vista and can be installed on Windows 2000 and Windows XP systems².

If not already installed, .NET Framework 2.0 is available for download from the Microsoft website: [.NET Framework 2.0 Service Pack 1 \(x86\)](#)³. The NZ Fire Behaviour Toolkit installer will check for .NET presence.

In addition, to access some NZ Fire Behaviour Toolkit reference material, a PDF viewer is also required.

.NET Framework 2.0 Service Pack 1 System Requirements:

- **Supported Operating Systems:** Windows 2000 Service Pack 4; Windows Server 2003; Windows XP Service Pack 2; Windows Vista
- **Software:** On Windows Server 2000 SP4, install [KB 835732](#)⁴ before installing .NET Framework 2.0 Service Pack 1.
- **Processor:** 400 MHz Pentium processor or equivalent (Minimum); 1GHz Pentium processor or equivalent (Recommended)
- **RAM:** 96 MB (Minimum); 256 MB (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)

² To install and operate NZ Fire Behaviour Toolkit on Windows 98 operating systems, please contact the Scion Rural Fire Research Group for instructions (rural.fire@scionresearch.com)

³ <http://www.microsoft.com/downloads/details.aspx?familyid=79BC3B77-E02C-4AD3-AACF-A7633F706BA5&displaylang=en>

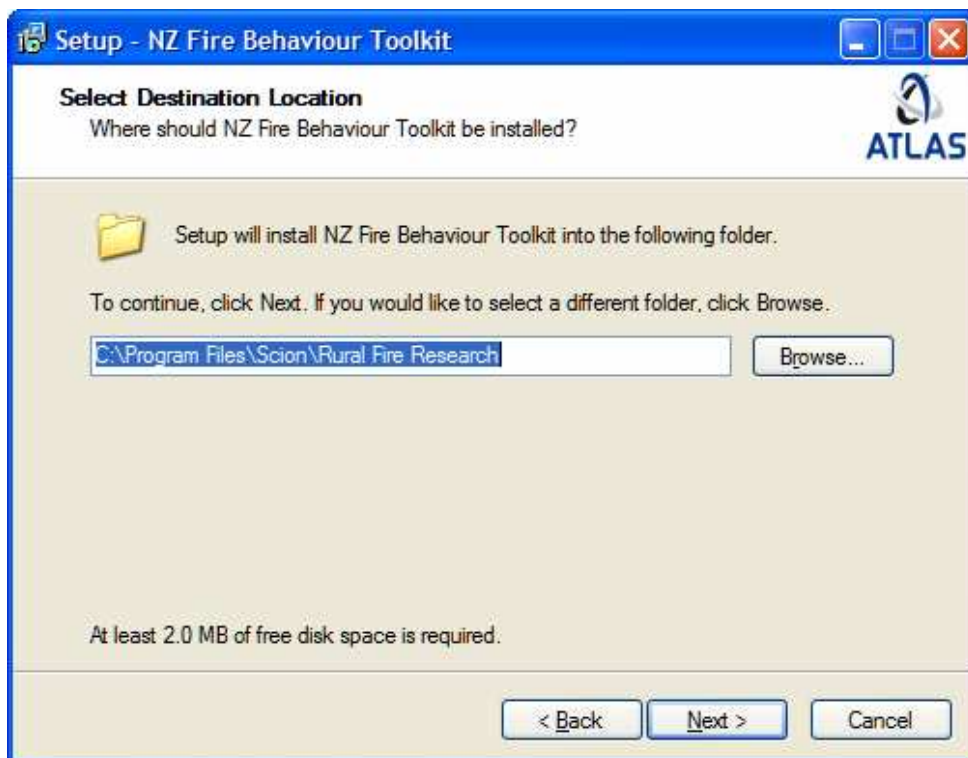
⁴ <http://www.microsoft.com/downloads/details.aspx?FamilyId=0692C27E-F63A-414C-B3EB-D2342FBB6C00&displaylang=en>

INSTALLATION

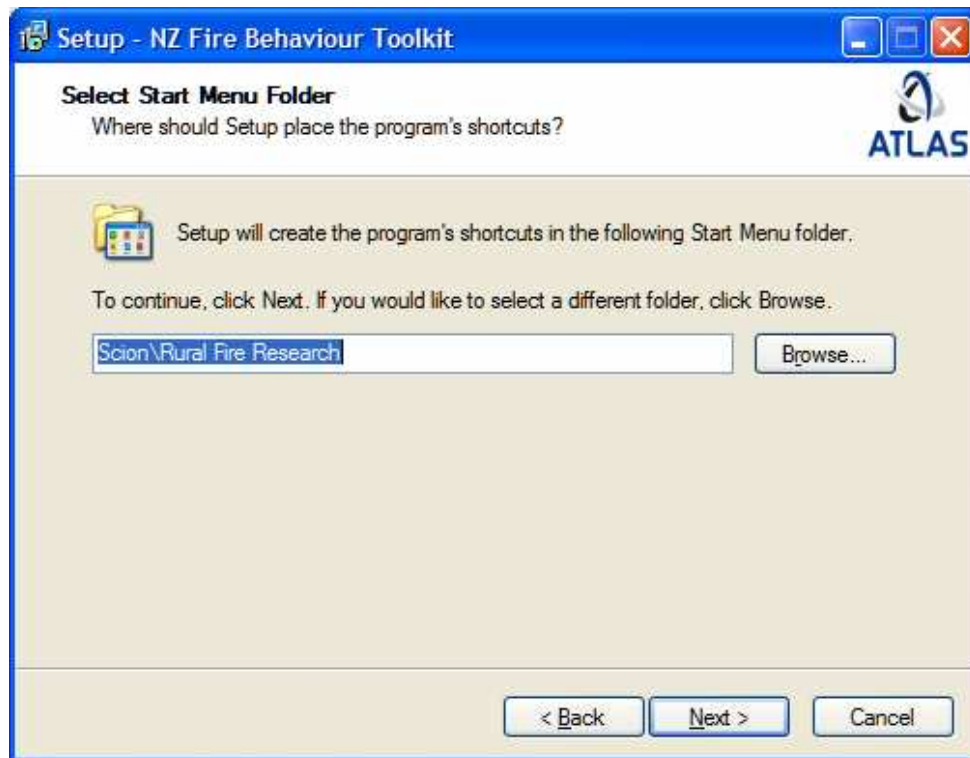
To install the NZ Fire Behaviour Toolkit, run the setup program SetupNZFireBehaviourToolkit.exe:



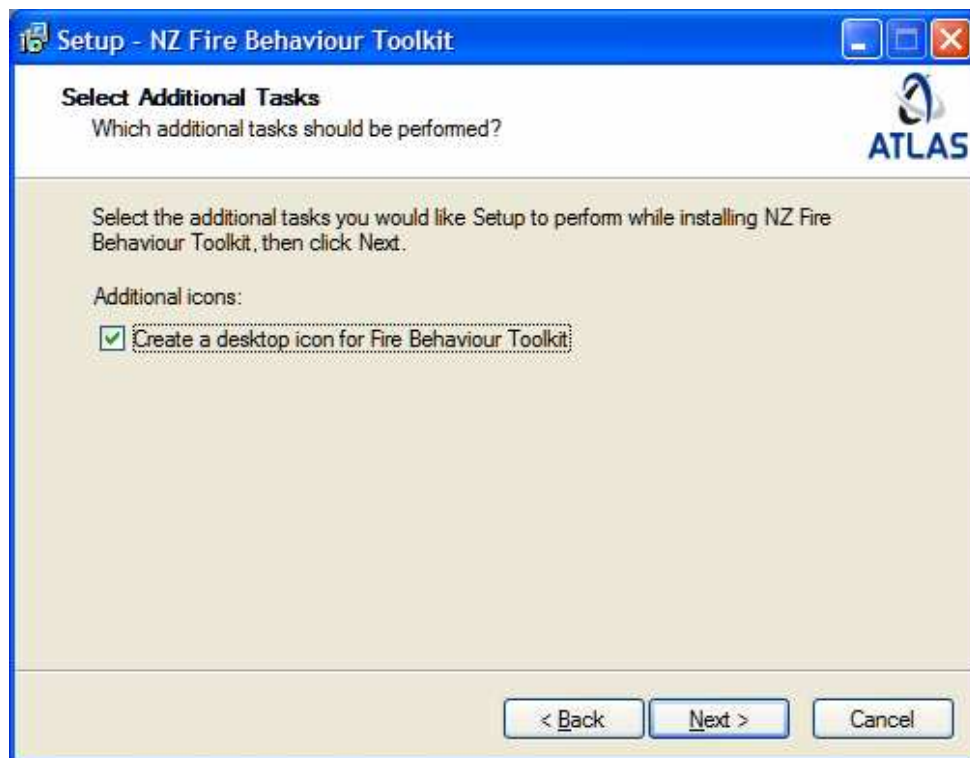
Click on Next.



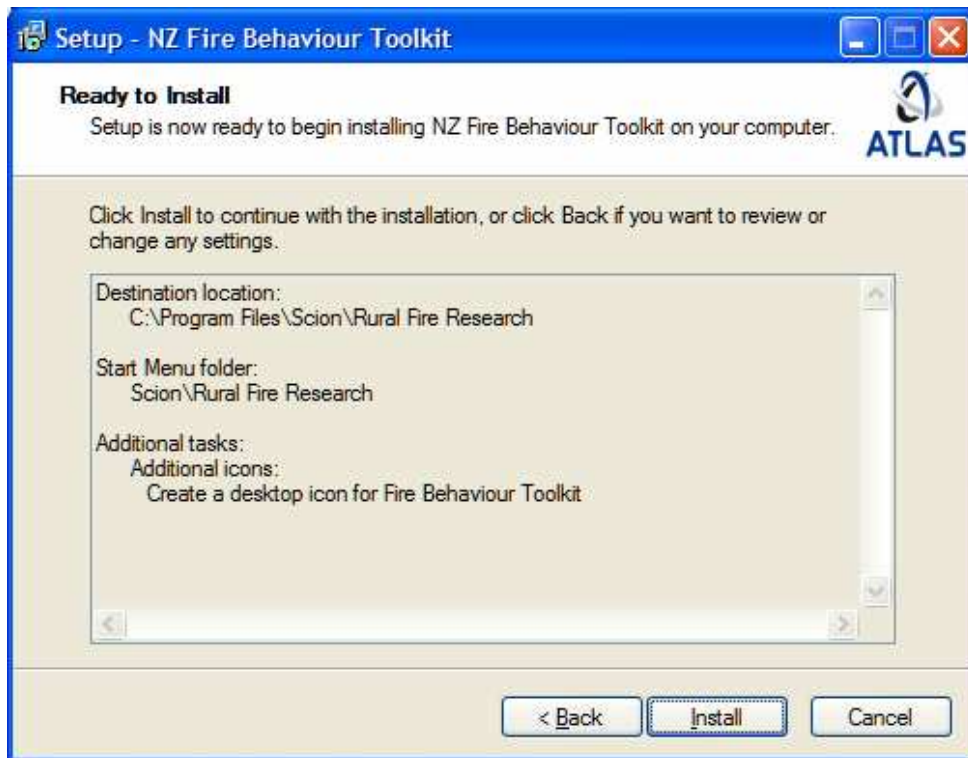
Specify a folder for the software to be installed into, or just click Next to use the default (recommended).



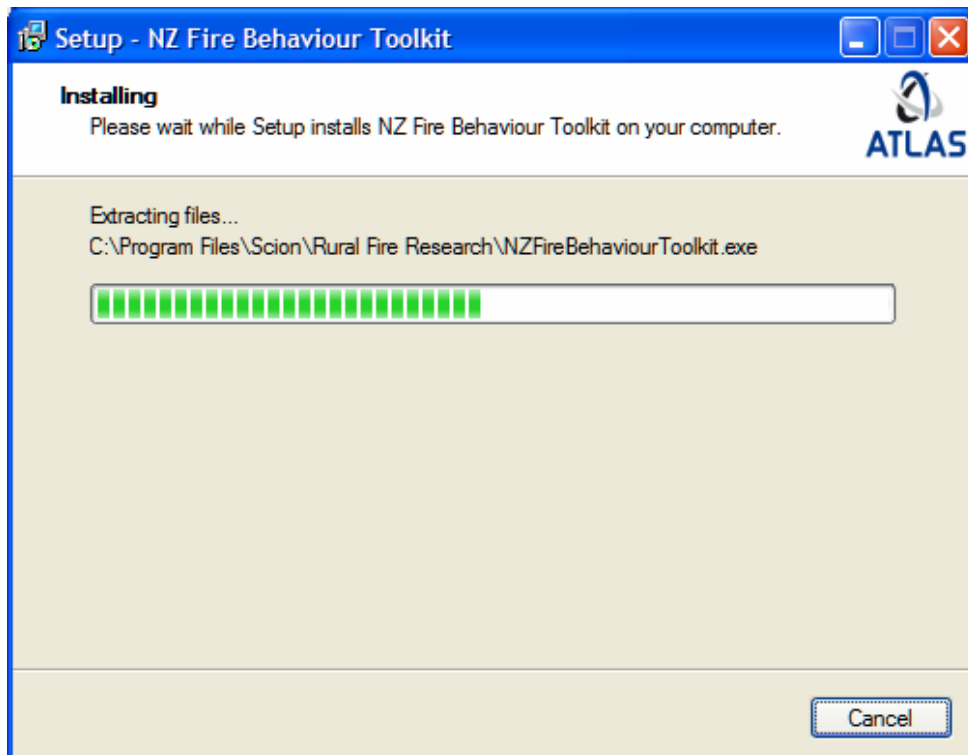
Specify a Start Menu folder for the software to be run from, or just click Next to use the default (recommended).



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).

GETTING STARTED

Once the installation procedure has completed and the NZ Fire Behaviour Toolkit is installed on the system, it can be 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 these can also be accessed through the toolbar at the top of the screen.

MODULES

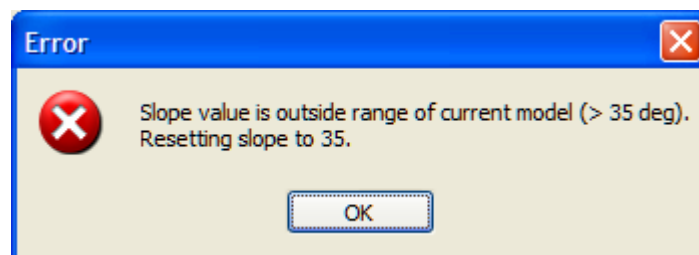
Any of the modules can be opened and used simultaneously, i.e. no modules need to be closed down before another one can be opened. It is also possible to open and run multiple versions of the Calculator and Worksheet modules, e.g. should the user wish to perform calculations for a number of different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

1. FIRE BEHAVIOUR CALCULATOR

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

The screenshot shows the 'NZ Fire Behaviour Calculator - [Untitled]' window. It features a menu bar with 'File', 'Tools', and 'Reference'. The interface is divided into three main sections: 'Inputs', 'Primary Outputs', and 'Secondary Outputs'. The 'Inputs' section includes fields for Wind Speed (km/h), Fine Fuel Moisture Code, Initial Spread Index [ISI], BuildUp Index [BUI], Slope (deg), Slope Correction Factor, Initial Spread Distance (m), Elapsed Time (min) (set to 0), and Fuel Type (a dropdown menu). The 'Primary Outputs' section displays Rate of Spread [ROS] (m/h), Available Fuel Load (t/ha), Head Fire Intensity (kW/m), Flame Length (m), and Type of Fire. The 'Secondary Outputs' section displays Head Spread Distance (m), Back Spread Distance (m), Total Spread Distance (m), Back Rate of Spread (m/h), Back Fire Intensity (kW/m), Fire Area (ha), Perimeter Length (m), Perimeter Growth Rate (m/h), and Length/Breadth Ratio. A 'Calculate (F5)' button is located at the bottom center. The status bar at the bottom left indicates 'Wind Speed @ 10m (kph)'.

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, i.e. are outside of an acceptable range, then an error message such as the following will be displayed:



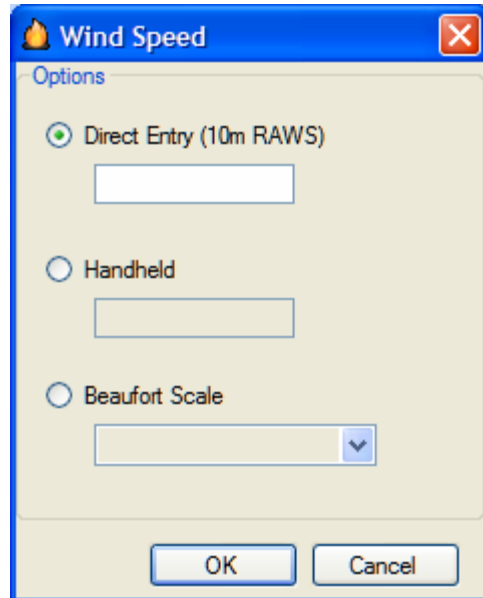
If a calculation has been carried out and the user then chooses to re-enter (or change) input values, the “Calculate” button will colour red (in bold) to indicate to the user that the calculation needs to be repeated.

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

Inputs

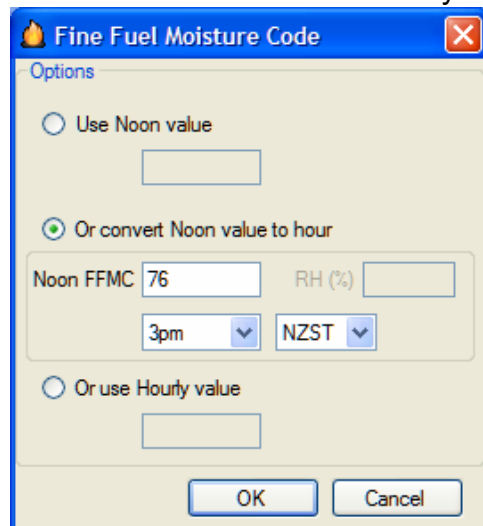
- i. Wind speed – if a wind speed value in km/h is available, it can be entered directly into the Calculator, or one can be derived from other forms of measurement. A value measured at 10m from nearest Remote Automatic Weather Station (RAWS) can be entered into the Wind Speed field, or by clicking on 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 Remote Automatic Weather Station (RAWS).
- Handheld – wind speed measured using a handheld weather instrument such as a Kestrel®⁵. 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, a Beaufort Scale estimate 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.



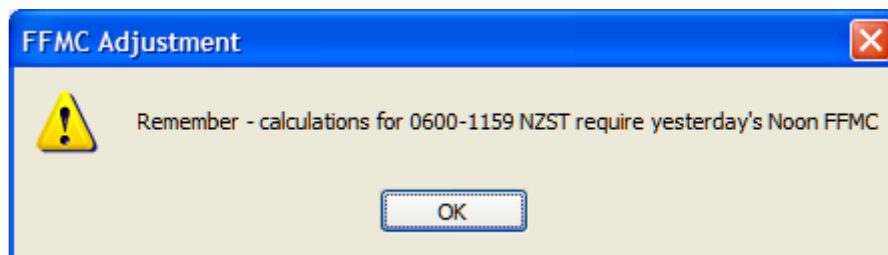
- ii. Fine Fuel Moisture Code – if the Fine Fuel Moisture Code (FFMC) value is known, it can be entered directly into the Calculator, or an hourly value can be derived from the standard noon value. The standard noon, or hourly, FFMC value can be entered into the Fine Fuel Moisture Code field, or by clicking 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:

- Use Noon value – this is the 1200 (NZST) FFMC value calculated from the nearest RAWS, or by using manual or other computer calculations.
- Or 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

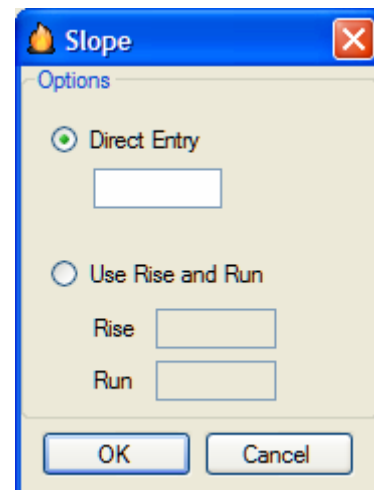


⁵ <http://www.nkhome.com/ww/wwindex.html>

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 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, that the noon FFMC value from the **previous day** is required. A warning box appears when this option is selected:



- Or use Hourly value – this is the FFMC value that relates to the hour of calculation. It 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 (RH), wind speed and hourly rainfall (or forecasted values from, for example, the MetService’s MetConnect website⁶).
- iii. Initial Spread Index (ISI) – this is calculated from the wind speed and FFMC (no direct input is required).
- iv. Buildup Index (BUI) – BUI calculated at 1200 (NZST) from the nearest RAWS, or using manual or other computer calculations.
- v. Slope (deg) – enter the slope angle (in degrees) if known, otherwise click on the button marked with an ellipsis ("...") to the right of the field to display the Slope form with alternative input options:
 - Direct Entry – if 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



⁶ www.metconnect.co.nz

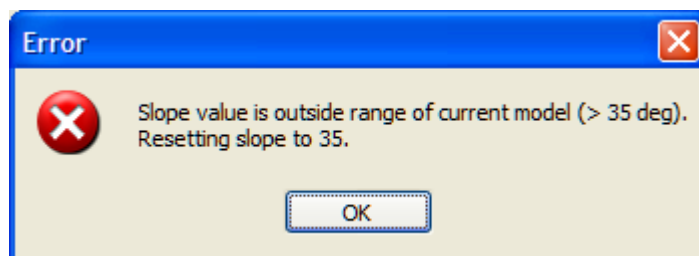
will then calculate and display the slope angle.

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

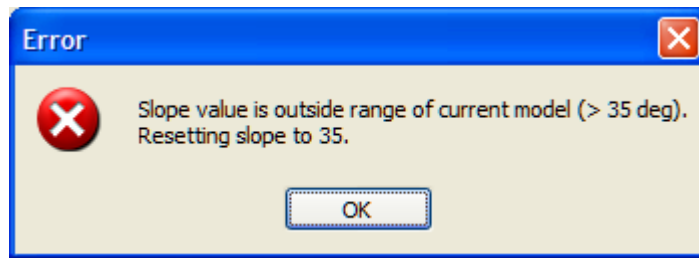
- vi. Slope Correction Factor (SCF) – is calculated based on the slope angle (no direct input required).
- vii. Initial Spread Distance (m) – this option allows the user to predict fire behaviour for an active fire that has already spread a certain distance by the time the calculations or predictions 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.
- viii. Elapsed Time (min) – enter an elapsed time (in minutes) to specify the time period for which the calculations are required.
- ix. 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, percentage 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 the Available Fuel Load (AFL) and Rate of Spread (ROS) values. Similarly, for a pine stand with a dominant gorse understorey, the gorse scrub fuel type is likely to provide more accurate estimates of fire behaviour.

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 higher than this value will default to the SCF that relates to a 35° slope (SCF of 10). A warning message will appear notifying 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). 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 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.

NOTE:

It is always important to be aware of the limitations of the models and the assumptions that are embedded in the calculation routines, and to apply the results with caution (or modify them appropriately using experience and local knowledge) if local conditions are different.

Primary Outputs

- i. Rate of Spread (ROS) – the (head) fire rate of spread in m/h.
- ii. Available Fuel Load – 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 the fuel load (based on local knowledge) is available. Should this field be left blank, then the fuel load is calculated based on the fuel characteristics and other inputs provided.
- iii. Head Fire Intensity – 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 available fuel load in t/ha and 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.
 - iv. Flame Length – 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 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).
 - v. Type of fire – 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.

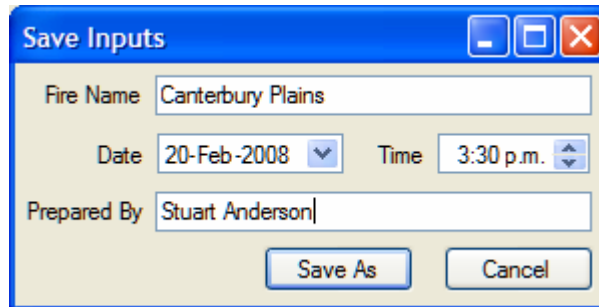
Secondary Outputs

- i. Head Spread Distance – the distance of spread of the head fire (m), based on the head fire rate of spread and the elapsed time.
- ii. Back Spread Distance – the distance of spread of the back fire (m), based on the back fire rate of spread and the elapsed time.
- iii. 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 entered in the inputs).
- iv. Back Rate of Spread – calculated using the Back Fire ISI in the rate of spread model for the relevant fuel type.
- v. 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.
- vi. Fire Area – the area (in ha) of the fire, based on the fire spread distance and wind speed.
- vii. Perimeter Length – based on the area of the fire.
- viii. Perimeter Growth Rate – the rate at which the perimeter of the fire is growing for every hour of active burning/fire spread.
- ix. Length/Breadth Ratio – based on the wind speed, and provides an indication of the shape of the fire.

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:



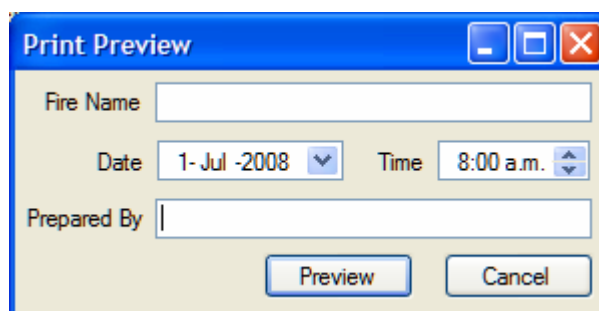
Clicking “Save As” allows the user to then select a relevant directory in which to store the file. Calculator files will be saved as *.calc files. This file can then be opened (**File | Open**) and used in subsequent calculations or forecast preparations as required.

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 window 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:



These fields are then captured and 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 Calculator		NZ Fire Behaviour Toolkit	
Fire Name	Canterbury Plains	Prepared by Stuart Anderson	
Date	20/02/2008 3:30 p.m.		
INPUTS			
Wind Speed (km/h)		20	
Fine Fuel Moisture Code		89	
Initial Spread Index [ISI]		10.1	
BuildUp Index [BUi]		80	
Slope (deg)			
Slope Correction Factor			
Initial Spread Distance (m)		400	
Elapsed Time (min)		60	
Fuel Type		Crop stubble	
Degree of Curing (%)		100	
Fuel Height (m)		0.2	
PRIMARY OUTPUTS			
Rate of Spread (m/h)		1813	
Available Fuel Load (t/ha)		3	
Head Fire Intensity (kW/m)		2303	
Flame Length (m)		2.7	
Type of Fire		S	
SECONDARY OUTPUTS			
Head Spread Distance (m)		1813	
Back Spread Distance (m)		130	
Total Spread Distance (m)		2343	
Back Rate of Spread (m/h)		130	
Back Fire Intensity (kW/m)		165	
Fire Area (ha)		97.6	
Perimeter Length (m)		4962	
Perimeter Growth Rate (m/h)		4115	
Length/Breadth Ratio		4.4	
<hr/> <div style="display: flex; justify-content: space-between;"> NZ Fire Behaviour Toolkit 0.7.6.0 Page 1 / 1 27/06/2008 3:13 p.m. </div>			

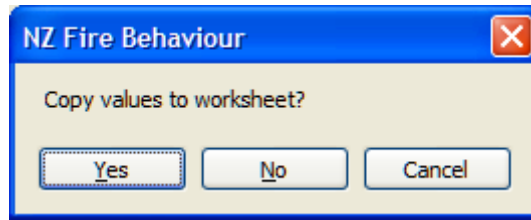
Figure 1. Example of a printed Calculator report output created as a PDF file.

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 Worksheet

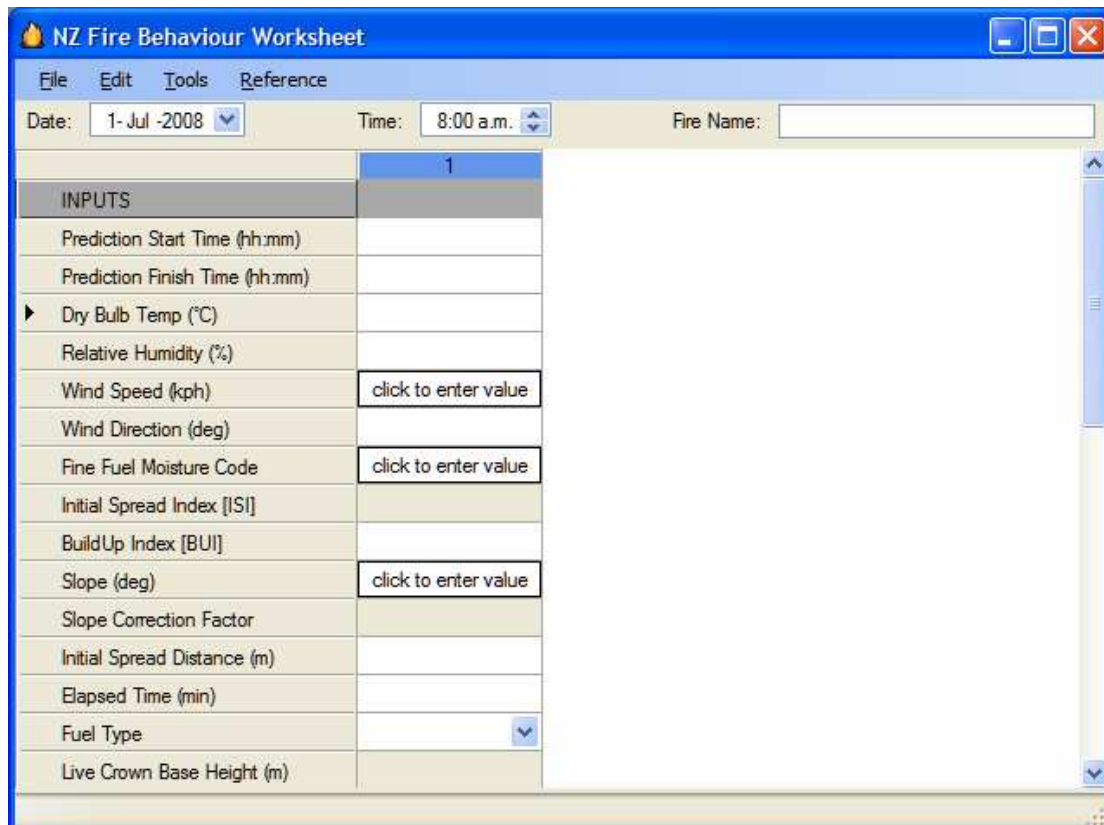
On opening the Worksheet module from the Calculator (Tools | Worksheet), a message will appear with the option to copy the input values from the Calculator into the Worksheet:



These inputs from the Calculator will then be inserted into the first column of the Worksheet, allowing the user to continue using the Worksheet for more detailed calculations or predictions.

2. 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. An example is 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 be able 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 will have 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.

Inputs

The procedure for entry of inputs is the same as for the Fire Behaviour Calculator (see previous section for detailed descriptions).

The Start and Finish times for the prediction period also need to be selected. The Elapsed Time (in minutes) 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 value can also be manually entered (to replace the calculated value from Start and Finish times) by the user.

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.

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 colour red to indicate to the user that the calculation needs to be repeated.

The Primary and Secondary outputs listed are the same as those in the Calculator (refer to the previous section for explanation of these outputs). 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.

Other Worksheet options

Inserting additional columns

Once the first column is complete, additional columns can be inserted into the worksheet from the “Edit” option on the toolbar. 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 the question “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 has 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.

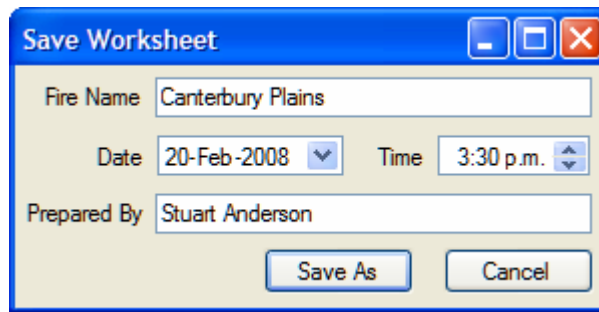
It is possible for combinations of the above two column types to be inserted into the worksheet, e.g., a Time Sequence column could be followed by a number of Alternative columns and then a Time Sequence could be resumed. However, users need to be aware that whenever a Time Sequence column is inserted, 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 worksheet to be saved as a *.wsht file. This file can then be opened (**File | Open**) and used in subsequent calculations or forecast preparations as required. The Save Worksheet form will appear, asking the user for relevant information:

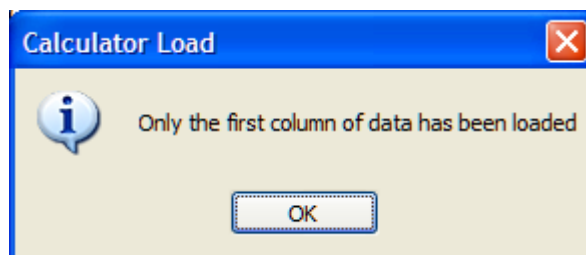


Clicking “Save As” allows the user to then select a relevant directory in which to store the file.

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.

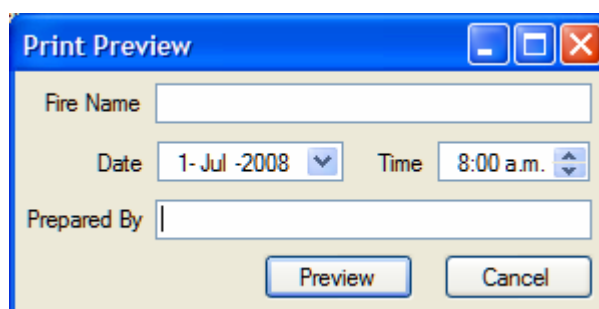
Files created from the Calculator (*.calc) or Worksheet (*.wsht) can be opened in either module. However, if the user attempts to open a Worksheet file in the Calculator, and the Worksheet scenario contains more than one column, only the first column’s values will be inserted into the Calculator. A warning 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	
NZ Fire Behaviour Toolkit 0.7.2.0		Page 1 / 1	27/06/2008 12:34 p.m.	

Figure 2. Example of a printed Worksheet report output created as a PDF file.

3. FIREBREAK EFFECTIVENESS

This module allows the user to determine either:

1. the effectiveness of an existing firebreak of given width, or
2. the width of firebreak required to contain a fire of known head fire intensity or flame length.

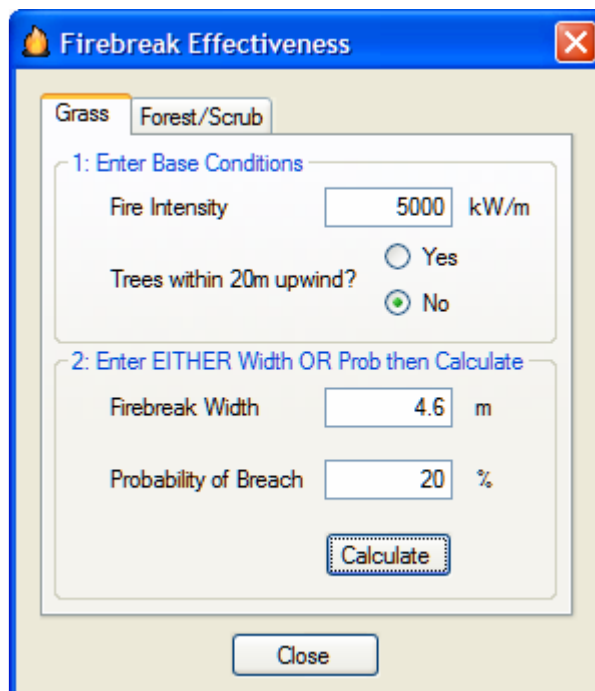
The first step is to select the tab relating to the relevant fuel type (Grass or Forest/Scrub).

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:

- i. 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
- ii. Enter the fire intensity, mark the presence or absence of trees, and enter the desired probability of the firebreak being breached, i.e., 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 (for practical purposes a firebreak width of 5m would be recommended).



The screenshot shows a software window titled "Firebreak Effectiveness" with a blue header bar and a close button (X) in the top right corner. The window has two tabs: "Grass" (selected) and "Forest/Scrub". The main content area is divided into two sections:

- 1: Enter Base Conditions**
 - Fire Intensity: 5000 kW/m
 - Trees within 20m upwind?: Yes, No
- 2: Enter EITHER Width OR Prob then Calculate**
 - Firebreak Width: 4.6 m
 - Probability of Breach: 20 %
 - Calculate button

A "Close" button is located at the bottom center of the window.

Forest/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:

- i. Enter either the flame length or the fire intensity, then press Calculate (F5 or Enter) to calculate the required firebreak width; or
- ii. 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.

For 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.

The screenshot shows a software window titled "Firebreak Effectiveness" with a blue header and a close button (X) in the top right corner. Below the title bar, there are two tabs: "Grass" and "Forest/Scrub", with "Forest/Scrub" being the active tab. The main content area is divided into three sections:

- 1a. EITHER enter Flame Length or Intensity**: This section contains two input fields. The first is labeled "Flame Length" and has the value "4.5" entered, followed by "m". The second is labeled "Fire Intensity" and has the value "6836" entered, followed by "kW/m".
- 1b. OR enter Firebreak Width**: This section contains one input field labeled "Firebreak Width" with the value "6.8" entered, followed by "m".
- 2. THEN press Calculate**: This section contains a single button labeled "Calculate".

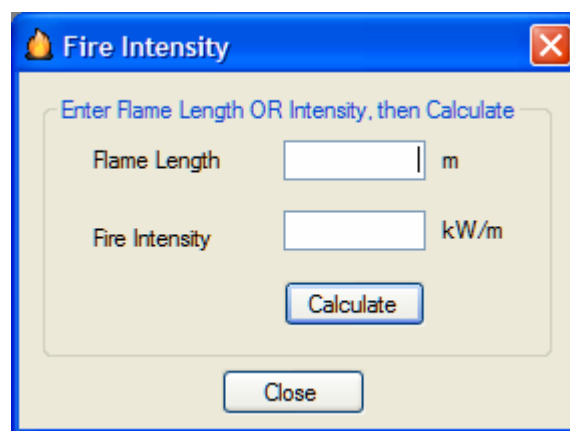
At the bottom center of the window, there is a "Close" button.

4. FIRE INTENSITY

This module allows the calculation of fire intensity based on an observed flame length, or calculation of flame length if 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:

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



5. FIRE BEHAVIOUR RULES OF THUMB

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

6. 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).

7. HELP

A comprehensive Help module is contained in the Toolkit, which provides users with readily-accessible information and assistance regarding the use of the Toolkit and its different modules. The content of the Help module is searchable, printable and easily navigable.

8. ABOUT

The About module contains information for the user on the NZ Fire Behaviour Toolkit version number, and contact details for support, queries, feedback and access to future versions or updates.

UPDATES AND SUPPORT

This version of the NZ Fire Behaviour Toolkit is the first 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

ACKNOWLEDGEMENTS

This toolkit has been developed by the Scion Rural Fire Research Group in conjunction with Scion's ATLAS Technology Group.

The Scion Rural Fire Research Group receives funding and "in kind" support from the following organisations:

- Foundation for Research, Science and Technology
- National Rural Fire Authority
- New Zealand Forest Owners Association
- Department of Conservation
- New Zealand Defence Force
- members of Local Government New Zealand
- Federated Farmers of NZ Inc.

Additional funding for the development of this toolkit was provided by the New Zealand Fire Service Commission's Contestable Research Fund.

Thanks are extended to members of the Project Team, made up of representatives from the rural fire sector, who provided input into the development of the toolkit and review and testing of prototype versions:

- Mark Bang (South Canterbury Rural Fire District)
- Rodney Chambers (Christchurch City Council)
- Kevin Fletcher (Manawatu District Council)
- Mike Grant (Southern Rural Fire Authority)
- Kirby MacLeod (Wainuiomata Bushfire Force)
- Trevor Mitchell (Department of Conservation)
- John Rasmussen (National Rural Fire Authority)
- Rachael Thorp (Department of Conservation)
- Phill Wishnowsky (Wairarapa Rural Fire District)

Steve Taylor (Canadian Forest Service) also kindly provided access to the computer code for the diurnal Fine Fuel Moisture Code lookup routine.

Input into the development of the Toolkit and review comments on the technical documentation by Grant Pearce (Scion Rural Fire Research Group) are also acknowledged.

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