Rural Fire Hazard in the Wellington Region

A Report Prepared for the Wellington Regional Council

WRC/RP-G-98/12

April 1998

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1. Executive Summary

The vegetation mapping in the LCDB allows the recognition of four classes of vegetation fire hazard. This is one less than used for the urban/rural interface model. The reduction is primarily due to the varied vegetation identified as shrubland.

A GIS model which describes the fire hazard of vegetation has been outlined for the Wellington Region. The model this provides is similar to the one used for the urban/rural interface of the Wellington, Hutt, Upper Hutt and Porirua Cities within the region.

Two options are presented for the model. The overlays involved are as given below:

1. Vegetation type
2. Curing and weather variables
    - aspect

   And either:
    - Option One
        - ⇒ rainfall
        - ⇒ temperature

   or:
    - Option Two
        - ⇒ soil water deficit
3. Slope
4. Light-up hazard.

The second option is considered to be better but will cost slightly more.

The earlier model for the urban/rural interface includes many of the same variables although the vegetation mapping for that model allowed one more hazard class. Despite this, the Wellington Region model could be used with only small changes to the curing and weather variables.

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2. Introduction

This report was produced for the Wellington Regional Council. The purpose of the report is to develop for the Wellington Region:

- a flammability assessment of the vegetation Land Cover Database (LCDB) classes
- a flammability hierarchy of vegetation LCDB classes
- a model that adequately represents fire hazard
- a weighting scheme that allows the vegetation LCDB classes to be incorporated into a model that adequately represents fire hazard

This work follows earlier work for the Regional Council in which a similar approach was used to determine high hazard areas of the urban/rural interface in the Wellington, Hutt, Upper Hutt and Porirua Cities.

3. Vegetation Flammability

In any wildfire hazard mapping fuel, which is largely vegetation and dead plant material, is an important consideration. The amount of vegetative material in a given area is important as is how readily it burns. Both of these are related to vegetation type. Gorse has higher volumes of fuel on a unit area than grazed pasture for example. Gorse burns more readily than most indigenous shrubs. This makes vegetation mapping an important component of wildfire hazard mapping.

3.1 Terralink LCDB vegetation classes

The Land Cover Database (LCDB) classes are derived from satellite images which have been orthorectified to the NZMS mapping grid. Key elements of the mapping include:

Minimum mapping unit of 1 hectare
Classification accuracy of 90%
Positional accuracy of +-25m

This puts a limit of the detail with which the model must cope.

3.1.1 Definition of the LCDB classes

The classes of vegetation and other land cover identified by the LCDB are as follows:

Cultural Landscapes

- Primarily pastoral - suitable for grazing, enclosure distinguishes this from grassland. Includes croplands.

Most of the grassland outside of the Tararua tussock grasslands are of this type. Except in very dry periods grazed pasture will not generally carry a fire. The resolution of the imagery, down to 1 hectare, means that the small areas of rank grass and shrubland, which are often significant in terms of being key areas where fire starts, are not identified in the maps.

- Primarily horticultural - orchards and vineyards
- Planted forest - plantation forest or exotic forest inclusive of recent replanting, eg *Pinus radiata*, *Pseudotsuga menziesii*.
  Includes areas with high weed growth and the full range of age classes. This includes very young stands, older stands with closed canopy and recently logged stands with the forest boundary.

Natural Landscapes

- Grassland - tussock, non-pastoral or un-enclosed grassland
  This category includes alpine tussock in the Tararua Range, tussock nearer the coast and areas of rough grass. Marram grass is included in the category.
- Shrubland - Woody vegetation in which the cover of shrubs and trees in the canopy is >20% and in which shrub cover exceeds that of any other growth form or bare ground. Shrubs are woody plants generally <10cm bdh eg Manuka, Kanuka, Gorse, Broom.
  The shrubland category covers a range of types. The principal criteria is the size of the individual plants. In some cases the shrubland will be younger examples of species that are classified as indigenous forest when the individual trees grow in size. Shrubland in the Wellington Region includes a range of different types including manuka, kanuka, gorse, broom, scrub hardwoods and sub-alpine types including leatherwood and *Dracophylum*.
- Indigenous forest - natural forest cover.
  Indigenous forest as recognised by the LCDB includes a range of different associations.
  Broad vegetation, especially forest, typing is available from forest park maps for the Tararua, Rimutaka and Haurangi Forest Parks[1] at 1:100,000 scale. The forest typing was carried out by the Forest Service and is still on the newer editions of the maps.
  Forest types identified by the Forest Service maps are:
  <u>Tararua Forest Park</u>
  1. Silver Beech
  2. Beech/kamahi
  3. Rimu/beech/kamahi
  4. Miro/kamahi
  5. Rimu/kamahi
  6. Beech kamahi with Hard or Black Beech
  7. Lowland Beech
  8. Lowland Forest
  9. Regenerating Forest

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[1] Tararua Forest Park Map, Rimutaka and Haurangi Forest Park Maps. In addition to the Forest Parks the maps cover some adjoining areas as follows:
Tararua Map - the foothills on the east of the Forest Park, Mt Bruce.
Rimutaka and Haurangi Map - Cape Palliser area as far north as Tora Road and White Rock Road, foothills of the Rimutaka Range.

Other vegetation types identified are alpine grassland, Subalpine scrub land, lowland and montane scrub land (generally under 3 m tall), exotic conifer and exotic other. Areas of kanuka/manuka on the sheet are largely mapped as lowland and montane scrub land rather than as forest. The LCDB forest category included all of 1 to 8 above plus the bulk of the 9. The remainder is mapped as shrubland in the LCDB.

Rimutaka and Haurangi Forest Parks

1. Podocarp Hardwood
2. Podocarp Hardwood Beech
3. Beech
4. Hardwood
5. Unidentified bush

Other vegetation types identified include scrub and exotic plantation. On this map much of the kanuka/manuka is mapped as scrub (ie shrubland) but some is included in the hardwood category, especially where it is mixed with other species.

- Bare ground - non-pastoral exposed soil and rock
- Inland wetlands - inundated by fresh water

  Inland wetlands include a number of vegetation types and include flax, willows and rushes.
- Coastal wetlands - inundated by salt water

  This includes areas in estuaries. Vegetation includes succulents as well as rushes.
- Coastal sands - beach sands and dunes

  This category covers sand without vegetation cover. This is generally not flammable, except where there are heavy accumulations of driftwood.
- Inland water - lakes, ponds and rivers

  These include Lake Wairarapa. Clearly these are not flammable.
- Mangrove - sea level mangrove swamp land

  These are not present in the Wellington Region and should not appear in the maps..

The typing carried out for the LCDB was checked against known vegetation in a number of areas. This was done both to check accuracy but also to check how the classifications separate different vegetation classes where the class boundaries and classifications could be arbitrary. Examples include many shrubland/forest boundaries and shrubland/planted forest mixtures.

This checking was done for parts of Masterton District, which has been mapped earlier, parts of the Carterton and South Wairarapa Districts which are currently being mapped. In addition selected areas, which show a range of particular problems, where checked in other parts of the country. The northern Kaimanawa Forest Park contains manuka which bounds onto beech forest. The manuka was classified as shrubland (owing to its size, while the beech was indigenous forest. This boundary is common in the Wairarapa. A similar check was made for an area west of Lake Taupo in the Waihaha catchment which contains regenerating forest, a matrix of manuka and frost flat vegetation and mature forest. The LCDB classes correctly identified these boundaries. The classification of older kanuka around Lakes Tarawera and Okataina near Rotorua were also checked. These areas have kanuka forest, which is being superseded by hardwoods, which is growing on areas cleared by the Tarawera eruption. These were classified as indigenous forest. Areas of smaller kanuka/manuka were classified as shrubland.

3.2 Issues relating to typing

3.2.1 Forest covers a multitude of types

The forest types identified by the Forest Service mapping show strong altitudinal and rainfall gradients. In general rainfall shows a strong altitudinal gradient as well as a west to east one. The forest types that are present in the wetter areas, specifically silver beech and the beech/hardwood/podocarp mixes are less prone to fire than some of the lowland forest types. Much of this is due to the forests being wetter.

Wardle[2] cites two opinions concerning the flammability of beech. The first notes that the beech remaining in the Canterbury Alps is not prone to fire otherwise the widespread use of fire would have removed it by the turn of the century. The second, held by Cockayne, was that beech was prone to fire when dry. As Wardle notes these two views are compatible if the effect of climate is factored in. Basically beech will burn when dry. In drier areas beech has been largely burnt. The types of beech found in drier areas is more restricted in distribution as a result. Experience with burning beech foliage and wood suggests that dry silver beech (the beech found in the wettest areas) will burn as well as most of the other beeches. Dry silver beech is less common as silver beech grows in the wettest areas. Silver beech and other montane forest in the Tararua Range is typically covered with epiphytic moss and small ferns which are extremely wet in normal conditions. In extremely dry conditions these are flammable.

Kamahi, a significant species in many of the wetter forest types, will burn well when dry.

A number of species flammability lists have been drawn up. Most of these are based on ratings by experienced people. It is not clear to what extent these are influenced by the normal wetness of the species. The ranking by species is not always consistent. However the main forest canopy species, including podocarps, beeches, tawa and kamahi, generally fall in the low to medium categories. Shrub hardwoods, such as mahoe and five finger fall into the low category while others such as cabbage trees and tree ferns are more flammable. Forest flammability is not just a function of the flammability of the individual trees within the forest; the arrangement of fuel both vertically and within the forest area is also important. Generally the higher the canopy is from the ground and the more the separation of the foliage from the ground the less likely there it is that fire will reach the crown.

If a rainfall factor is included in the model then the wetness of the vegetation is already included in the model and no distinction need be drawn between the vegetation types based solely on the typical wetness of the fuel.

If this is accepted, which means accepting the point made by Wardle in regard to the flammability of beech, then one general flammability class is sufficient for a variety of forest types with the same forest structure. Where this is likely to be weakest is where the forest is relatively close in structure to tall shrubland. Were the divide between shrubland and forest is not distinct the use of one flammability class for shrubland and one for forest is going to over-emphasise the change in flammability.

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[2] Wardle J (1984) The New Zealand Beeches Ecology Utilisation and Management. NZ Forest Service.

3.2.2 Shrubland covers a range of types

In areas there are shrublands comprising of hardwood regeneration including mahoe, five-finger, hebe, and rangiora. This mix is not very flammable. In areas low canopy regeneration, such as regeneration on the major slip systems in the Upper Waiohine Gorge, are mapped as shrubland. Here the shrubland comprises of a mix of species but horopito is prominent. Again the association is of low flammability except were manuka is common.

Some shrubland types are very flammable. One of these is gorse, especially taller gorse, which is common along the eastern foothills of the Tararua Range. Shrublands which are dominated by broom, which often include rank grass, are only slightly less flammable. Manuka shrubland is also a flammable association. The higher altitude shrublands, leatherwood dominated or *Dracophylum*/beech associations, are of high flammability. Of the two, the *Dracophylum* is the most flammable and, while still occurring in very wet areas, is common at some drier sites.

In terms of modelling fire hazard the shrubland category poses the most difficulty. In the drier areas of the Wellington Region shrubland types of a range of flammabilities are found on similar sites. On the eastern foothills of the Tararua Range shrubland can include highly flammable gorse or manuka/kanuka associations and less flammable hardwood regeneration. shrubland is however generally more flammable than taller forest.

3.2.3 Planted Forest Covers a Range of Flammabilities

This category includes areas with high weed growth and the full range of age classes. These cover a range of flammabilities which are traditionally recognised in fire hazard mapping[3].

In general, the younger age classes are at high risk than older age classes because : the foliage of the trees is in close proximity to weeds and the ground, younger age classes often carry heavy weed infestations, thinning and pruning often results in accumulation of dry dead material, and weeds often add to flammability. In older age classes the crown is often some height from the ground which provides a break in fuel, weeds are usually suppressed leaving the forest open near the ground, slash from tending has rotted and often humidity is higher or temperatures are lower near the ground due to the shading and sheltering effect of the crown.

Immediately after logging the hazard is also high owing to the high loading of dead logging debris. With younger forests the presence of some weed species, especially gorse, can greatly increase fuel loading and may add to flammability. Grazing in young forests will reduce the hazard by decreasing fuel loading and breaking fuel between individual trees.

The range of flammability found in planted forests is not able to be represented with one category. As tending operations occur stands will quite rapidly change in terms of flammability in any event. We have allocated a value reflecting the range we feel is present in the Wellington Region. Here there is a mix of young stands, some containing shrubland, older stands and logging activity.

3.2.4 Resolution - Vegetation in areas too small to map.

The minimum mapping unit for the Land Cover Database is around one hectare. This means that smaller areas are mapped as being part of the larger surrounding vegetation. In many

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[3] See National Rural Fire Authority (1995) Rural Fire Management Code of Practice. This recognises different hazard levels for different age classes of pine.

places this is not an issue for fire management. In these, the presence of , for example, small pockets of regenerating scrub on forested slopes or pockets of pine in a matrix of scrub on a hillside, does not broadly change the fire hazard which is posed by the slope. In other cases it will create a problem.

The two most common situations where resolution down to 1 hectare will give problems are:

1. Where small pockets of flammable scrub occupy the location where a fire is likely to start, for example along a roadside. In some cases the scrub burning could ignite a neighbouring less flammable type, such as older plantation of indigenous forest. This mix poses more of a hazard than if the plantation or indigenous forest had a clean edge. In other cases the flammable vegetation could be along a road in a pasture area and pose a risk to buildings despite covering only a small area.
2. Where tracking, firebreaks and small clear areas break up fuel in the more flammable types. Exposed ridges in reverting pasture often carry very little fuel and when tracks broadly follow the ridge these can very effectively break fuel.

In both these cases there are implications for fire management. In the first the hazard is under-stated and in the second, while the hazard of the vegetation on any one patch is high, the changes of a very large rapidly spreading fire are greatly reduced.

Addressing both of these issues requires some more detailed mapping of particular locations. This is only likely to be worthwhile in areas which are identified as being high hazard and where particular values are at risk, or where past fire history suggests there is a problem.

3.3 Flammability of vegetation

The ranking of vegetation classes for flammability draws on the ranking implicit in the National Rural Fire Authority's Code of Practice[4] in Table 1.

Table 1: Fire Flammability Classes - Drawn from the National Rural Fire Authority Code of Practice.

Flammability	Exotic vegetation	Indigenous Vegetation
Highest	-	Wetlands vegetation
	Bracken Rank dry grass Pampas Gorse Mixed age exotic pruned/thinned to waste in last 10 years	Manuka Kanuka Coastal Bracken Tussock Low scrub
	Exotic forest - age 10 - 18	-
	Grain crops	-
	Exotic forest over age 18	Beech forest
Lowest	Grazed pasture Horticulture	Podocarp forest

Some amendments have been made to reflect the wide range of types included in some of the LCDB classes. The ranking as carried out is given in Table 2.

[4] National Rural Fire Authority (1995) Rural Fire Management Code of Practice. Page 6.

<u>Table 2 : Ranking of Flammability by LCDB Classification</u>

Wellington Region Model - LCDB Classes
<u>Low</u> Primarily pastoral Primarily horticultural Coastal sands Bare ground Inland water
<u>Medium</u> Indigenous forest
<u>High</u> Planted forest Shelterbelts Coastal wetlands
<u>Very High and Extreme</u> Shrubland Grassland - non-pastoral Inland wetlands

The major LCDB classes which show a range of flammabilites are as follows:

<u>Primarily Pastoral</u>

While this includes small pockets of other vegetation the bulk of the class as typed is of low flammability. As the pockets of other vegetation are small, and usually isolated, the areas ranking recognises the low flammability of the bulks of the area.

<u>Indigenous forest</u>

Indigenous forest comprises of a range of types. These are typically regarded as being of low flammability the medium flammability. The two types mentioned in the NRFA Code are podocarp forest which is similar to pasture and beech forest which is only one category higher. In addition there are some forest which in species and structure is similar to shrubland. However the higher canopy makes this less flammable and the under-story is often sparse. Taken as a whole indigenous forest is given a medium fire danger rating. Note that much of the range in forest flammability found in the Wellington Region is expected to be accounted for by rainfall gradient rather than vegetation patterns.

<u>Planted Forest</u>

The planted forest class covers areas in three of the categories in the NRFA Code. Young forest containing slash from tending operations is of very high hazard. The code allows 10 years after the operation before the effect of the slash is gone due to decay. If regimes for clearwood are followed, as they are by most major growers in the Wellington Region, tending is carried out up to about age 8 to 10 years. Even where a framing regime is followed late thinning to waste often occurs. In weed infested sites tending is often minimal and the weeds provide a heavy loading of fuel. This is loading remains as for some time after canopy closure during which time the weeds are suppressed and eventually die. Once the stand is past this stage, taken as age 18 in the NRFA Code, and there is little undergrowth and the foliage is well above the ground the stand is less flammable.

Normal rotations for radiata pine, which comprise of 95% of the planted forest in the Wairarapa[5] and 98% of the planted forest in the remainder of the region, are between 25 and 30 years. Therefore the low flammability of mature forests is only short lived on a site. Once harvesting begins dead branches and foliage greatly increase the hazard. The hazard should therefore be in the higher categories. In addition the Wellington resource has a large area of younger trees following the high levels of new planting over the last 20 years. Only some 14% of the radiata pine in the Wairarapa and 9% in the remainder of the region is over 20 years of age.

Shrubland
This covers vegetation which is largely classified by the NRFA Code in the higher grouping for flammability. For the most part this is justified. It will overstate the flammability of the hardwood regeneration which is often found in damper gullies. This type is also found in forested areas where canopy gapes have formed. In these cases the higher rainfall in the areas will show these as being of lower hazard than the drier associations elsewhere. The grouping does not allow the most extreme categories to be separated out.

Grassland - non-pastoral
This group is highly flammable and, while not having as heavy a fuel loading as shrubland it often dries more rapidly. The rating reflects the NRA Code's ranking.

4. Fire Hazard Model

4.1 Introduction to fire models

Fire hazard models are used to assess the hazard in a particular area. The model provides a consistent framework for doing this. The main elements of fire hazard are include fuel, weather conditions (both during the fire and before in that curing of the fuel occurs), topography and a variable reflecting the relative probability of light-up. The exact combination of variables will differ between regions, reflecting different conditions and differing availability of data.

A number of models and data sets are drawn on in the proposed model.

4.2 NRFA Model

The National Rural Fire Authority[6] rating for minimum standards of fire control protection cover uses the following criteria to assess the fire danger score:

1. Fuel (vegetation) type and topography - slopes are higher hazard
2. Fire Climate - frequency of high and extreme fire weather index scores
3. Additional factors - these cover a list of attributes including:
    - forest operations
    - illegal activity
    - industry

[5] Ministry of Forestry (1996) National Exotic Forest Description as at 1 April 1996.
[6] National Rural Fire Authority (1995) Rural Fire Management Code of Practice.

rubbish tips
population
land clearance - controlled burns
Also included with other items is a catch-all “other factors” item.

Fire weather index scores[7] are calculated from tables which integrate past weather patterns and current conditions. The month of the year also impacts on parts the index. This provides recognition of the differing period and intensity of sunlight between the months. The raw weather observations which are used to construct the index are regular readings of:

air temperature
relative humidity (measured by use of dry and wet bulb thermometers)
wind speed
rainfall (for 24 hour periods)

Within the Fire Weather Index system there are other indices measuring different aspects of fire weather, such as the Fine Fuel Moisture Code which gives an indication of curing in fine fuels, which are based on current weather conditions plus the relevant values for immediate past.

Generally higher rainfall, higher humidity, low wind speeds and low air temperatures are associated with low FWI readings while low rainfall, low humidity, higher winds and high air temperatures are associated with high FWI readings.

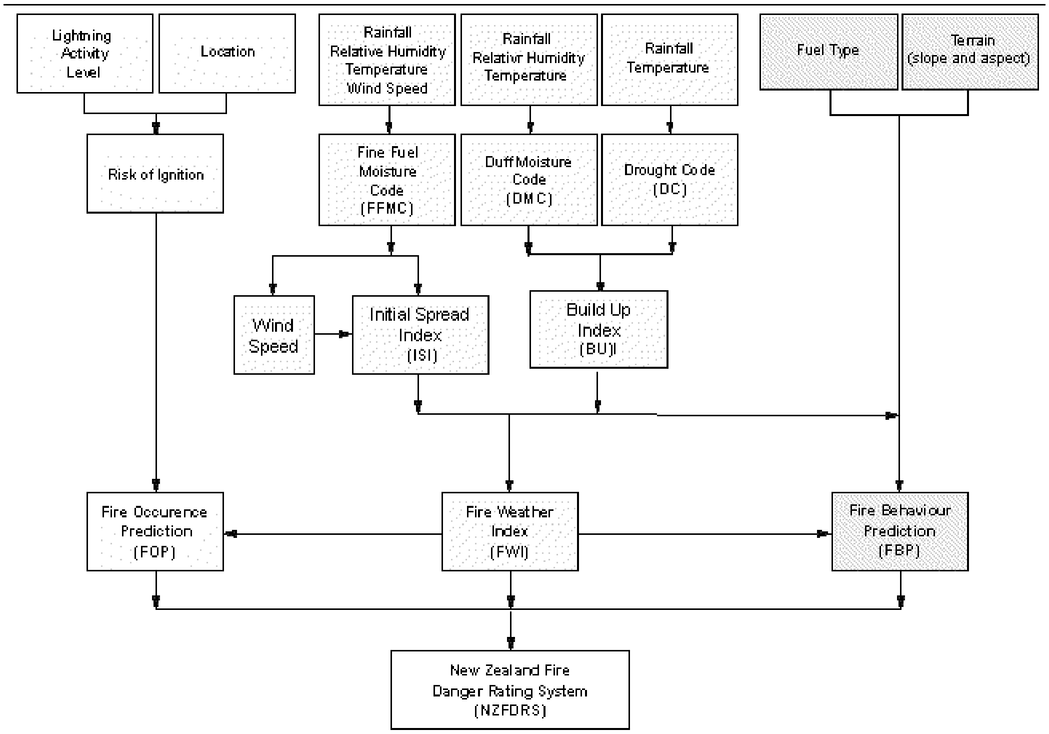
The fire danger score is calculated by multiplying a the score for topography and fuel by the climate score and then adding a score for the additional factors. The fire danger score is used in conjunction with a rating of the value and people at risk to determine required fire suppression cover.

4.3 Other Developments in New Zealand

There are initiatives under way to develop a more comprehensive system for hazard analysis. Research at the NZ Forest Research Institute is outlined by Fogerty and Pearce[8]. They state that “The aim of this research programme is to interpret and adapt the CFFDRS (Canadian Forest Fire Danger Rating System) to the New Zealand fire environment to produce a comprehensive New Zealand Fire Danger Rating System (NZFDRS)”. A schematic of the NZFDS is given below in Figure 1.

Figure 1 : Schematic of the New Zealand Fire Danger Rating System

[7] National Rural Fire Authority (1993) Fire Weather Index System Tables for New Zealand.
[8] Fogerty L and Pearce G (1998) Forest and Rural Fire Research in New Zealand. Fire Technology Transfer Notes. Number 6. National Rural Fire Authority. See page 8 for quote.



FFMC A numerical rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and flammability of fine fuel.

DMC A numerical rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.

DC A numerical rating of the average moisture content of deep, compact, organic layers. This code is a useful indicator of seasonal effects on forest fuels, and amount of smouldering in deep duff layers and large logs.

ISI A numerical rating of the expected rate of fire spread. It combines the effects of wind and FFMC on rate of spread without the influence of variable quantities of fuel.

BUI A numerical rating of the total amount of fuel available for combustion that combines DMC and DC.

FWI A numerical rating of fire intensity that combines ISI and BUI. It is suitable as a general index of fire danger.

Source : Fogerty L and Pearce G (1998) Forest and Rural Fire Research in New Zealand. Fire Technology Transfer Notes. Number 6. National Rural Fire Authority. They adapted it from a Canadian reference outlining the Canadian system - Hirsch KG (1993) A Brief Overview of the Canadian Forest Fire Behaviour Prediction (FBP) System. International Association of Wildland Fire Hotsheet.

The Fire Weather Index (FWI) System is basically a Canadian system (outlined by Van Wagner[9]) which uses basic weather data to provide a standard indicator of fire danger. More recently The FWI System components have been combined with fuel type and terrain factors to determine expected fire behaviour using the Fire Behaviour Prediction (FBP) System[10]. This approach is being used for the development of the New Zealand system. To date the NZ Fire Weather Index system only directly relates to pine plantations, and then the underlying empirical data are for Canadian species[11]. A major objective of the NZFRI research programme is the modelling of fire behaviour in key fuel types to develop the NZFDRS.

[9] Van Wagner CE (1987) Development and Structure of the Canadian Fire Weather Index System. Canadian For. Serv., Forestry Technical Report 35.
[10] Forestry Canada Fire Danger Group (1992) Development and Structure of the Canadian Forest Fire Behaviour Prediction System. For. Canada Fire Danger Group, Information Report ST-X-3.
[11] See Fogerty and Pearce, Van Wagner and Forestry Canada Fire Danger Group.

Once these models are developed, in a few years time, then the mapping of the fire hazard in the Wellington Region could make use of these. In the interim any mapping should include either all of the variables outlined in figure 1 or those that can be meaningfully mapped. The variables in figure 1 include:

In the current FWI system
- rainfall
- relative humidity
- temperature
- wind-speed

In the risk of ignition model
- lightning activity
- location

Fuel type
Terrain (slope and aspect or exposure to sunlight)

There are three approaches to the FWI variables :
1. these could either be incorporated in the index and the incidence of extreme values mapped
2. overlays of the individual variables could be prepared and used in the final weighting system.
3. an alternative but related measure, such as soil moisture deficit which measures drought stress in grass, could be used for the FWI.

The availability of reliable weather data poses some problems for the first two approaches. In order to avoid problems with short term variations in weather patterns it is best if measures are based on at least 20 years of observation. In terms of the variables contributing to the fire weather index both relative humidity and wind-speed are available from only a few sites. Rainfall is reasonably well covered and coverage for temperature is sufficient to allow a map to be prepared. Overlays of individual weather variables could be used. If this done the effect of unmapped (for example relative humidity) variables is ignored. This will only result in misleading results from the final hazard mapping is the unmapped variable follows a significantly different pattern from the mapped variables.
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The risk of ignition model outlined above is not comprehensive. In fires involving arson and escaped burns fuel type is an important determinant as well as location. Arsonists light vegetation that will burn and not just in a location. Mapping of past fire in Wellington[12] showed that gorse was one of the vegetation types most frequently lit by arsonists. Similarly fires lit to clear vegetation only generally occur where there is scrub, logging slash, wheat stubble and other unwanted vegetation. These are both land use/cover determined as well being determined by location. Both of these comments suggest that higher hazard weightings should apply to some vegetation types, at least until a robust arson/land-use model is available.

[12] Forme Consulting Group Ltd (1997) Recent Urban Interface Fires In the Wellington Region. Contract Report for the Wellington Regional Council.

In the New Zealand context lightning is not significant[13] and modelling it is not warranted.

4.4 Overseas Models

4.4.1 Introduction

There are numerous overseas examples of fire hazard modelling. Among the most comprehensive are those developed in the US, Canada and Australia.

4.4.2 United States

In the United States fire hazard analysis must be undertaken within specified guidelines contained in the US Forest and Rural Fire Protection Committee's "Standard for Protection of Life and Property from Wildfire"[14]. This states that any hazard analysis must include consideration of:

1. Weather History
2. Fuels (vegetation and other)
3. Structures
4. Slope and aspect
5. Fire history
6. Access and evacuation
7. Additional factors

There are a number of models are available so the exact form of the model used is left to the authority covering the area concerned. This acceptance of a range of models recognises the variability in data availability as well as the differing critical elements being faced in different circumstances.

Of the identified factors structures (item 3) and access and evacuation (item 6) are beyond the scope of this study. Fire history (item 5) and additional factors (item 7), while related, are also largely beyond the scope of this report.

An earlier 1991 version[15] of the US standard contained a prescribed model which included the a number of hazard ratings:

1. Fuel hazard rating
2. Slope hazard rating
3. Structure hazard rating
4. Additional factors rating

Scores are determined for each of these factors. These are combined to get an overall hazard rating by multiplying the slope and vegetation scores and then adding the other scores to this to determine a total score for the area. These total hazard ratings are used for each part of the urban/wildland interface area (this division into mapping units and the terminology is listed as a component of the analysis in the standard). The additional factors assessed by them

[13] Fogerty L and Pearce G (1998) Forest and Rural Fire Research in New Zealand. Fire Technology Transfer Notes. Number 6. National Rural Fire Authority. They cite lightning as being responsible for only 2% of all fires in New Zealand (p7). Of major fires discussed only one in Canterbury, at Dunsandel, was caused by lightning. (see p7)

[14] Forest and Rural Fire Protection Committee (1997) Standard for Protection of Life and Property from Wildfire. 1997 Edition. NFPA 299. Approved by US National Standards Institute 15 August 1997.

[15] Forest and Rural Fire Protection Committee (1991) Standard for Protection of Life and Property from Wildfire. NFPA 299. Approved by US National Standards Institute.

include topography (especially canyons), high fire risk activities, fuel breaks and management, and fire protection infrastructure.

Complementing this detailed hazard rating approach the United States has a nation wide National Fire Danger Rating System (NFDRS)[16] which assesses fire danger from weather variables as well as generalised fuel types. The weather information makes use of current and recent past weather data to derive indices which indicates different aspects of fire behaviour. A large number of different fuel type models are used to derive danger ratings in each general locality. The fire danger rating maps being updated daily. Currently the system produces maps with a 10km grid square resolution. Work is being undertaken to develop this for a one kilometre grid square resolution. Tools have been developed to assist in determining the most appropriate fuel models of the NFDRS system to apply in a locality and to assist in interpreting the NFDRS system[17].

4.4.3 Australia

In Australia the are a number of models in use. Victoria provides an example which contains the following elements in a GIS overlay system[18]:

Fire behaviour index - calculated from:
- vegetation map
- slope - contours
- weather

Damage potential index - calculated from:
- population density
- dwelling density
- agricultural productivity

Fire statistics index - which is:
- frequency of fires (>50 ha) for each district (calculated since 1980)

The final wildfire threat index is calculated by summing these three indices for each location. The weightings between the different overlays and indices can be arbitrary. As the system is computer based, however, the assumptions used are the same for all areas and the impact of varying the weightings has been examined.

The Victorian Fire Behaviour Index measures the same aspects of fire that the Wellington Region model (excluding light-up hazard) does.

4.5 Earlier WRC Urban/Rural Interface Fire Model

[16] USDA Forest Service (1998) Wildland Fire Assessment System. Intermountain Fire Services Laboratory. Internet document http://www.fs.fed.us/land/wfas/
An earlier technical report also provides information on the system : Deeming, John E.; Burgan, Robert E.; Cohen, Jack D. 1977. The National Fire Danger Rating System - 1978. Gen. Tech. Rep. INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 63 p.

[17] Andrews, Patricia L.; Bradshaw, Larry S. 1997. FIRES: Fire Information Retrieval and Evaluation System - a program for fire danger rating analysis. Gen. Tech. Rep. INT-GTR-367. Ogden, UT; U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 64 p.

[18] Garvey M (1997) Drawn from notes from a presentation to NZ Fire Service.

This model[19] was developed for the urban/rural interface of the Wellington urban area for the Regional Council. The model used there has four elements:

1. Vegetation type
2. Curing and weather
    - aspect
    - rainfall
3. Slope
4. People

The weather variables reflected the availability of mapped information, the scale at which the mapping was done and the importance of the spatial variation of the variable over the area being assessed. The model used detailed vegetation mapping for the area covered. As a larger area, the whole region, is to be covered by the current model a different vegetation map, the LCDB map is to be used. As the model will be different in this respect the opportunity to revise other aspects to it has been taken.

4.6 Model for Wellington Region

For the current model the main areas to be modelled are as follows:

1. Vegetation type - from the LCDB
2. Curing and weather variables
    - intensity of solar radiation - this is related to aspect.

    and either:
    - Option One
        - ⇒ rainfall
        - ⇒ temperature

    or:
    - Option Two
        - ⇒ soil water deficit
3. Slope - from contours
4. Light-up hazard - basically people related.

Option one is the easier of the two to derive.

The vegetation classes are discussed above.

4.6.1 Curing and Weather Variables

There are a number of options available for the derivation of the curing and weather component of the model. Should data availability and quality change in the future there may be a case for amending this part of the model at a later date.

Taking the three approaches for curing and weather variables and discounting a map of spatial variations based on FWI readings the two main remaining options for mapping are:

1. To use a soil moisture deficit map as a measure of curing intensity and of very high to extreme fire weather.

[19] Forme Consulting Group Ltd (1997) Recent Urban Interface Fires In the Wellington Region. Contract Report for the Wellington Regional Council.

2. To use maps of a mix of rainfall and other variables which are available and are related to fire weather index. Key overlays would include measures of : intensity of solar radiation, rainfall, wind-speed, temperature and relative humidity.

Depending on the scale of the mapping undertaken for each of these options a map of aspect could be used to include the effect that aspect has on curing. If the maps used, for example for the soil moisture deficit option, are at a scale which has detail sufficient to pick up the impact of aspect then the aspect overlay is unnecessary. If it does not then the addition of this overlay will give an improved representation of curing. At this stage aspect is included as neither the temperature nor the water deficit maps are sufficiently detailed to include the impact of aspect.

4.6.1.1 Intensity of Solar Radiation

Aspect has traditionally been used to provide an indication of this. Of the models outlined above it is the approach taken in the earlier urban/rural interface model, the US Standard and proposed for development work by FRI (see fig 1). Work undertaken for the Department of Conservation[20] provided a map of the intensity of sunlight on Kapiti Island based on a terrain model (contour map) and the path of the sun mid summer and mid winter. Intensity of sunlight is a critical element of aspect for fire modelling due to its impact on drying. This approach is adopted for the proposed model for the Wellington Region. The contour model used will be drawn from the 1:50,000 map series and sunlight intensity will be calculated for mid summer (summer solstice).

The results of the calculation provide a continuous range of values for the region with each location having a unique value. Dividing the range in categories and providing scores for each category is unnecessary and would lose some of the variation between different localities. The values have, therefore, been converted a linear scale.

4.6.1.2 Other Curing and Weather Variables - Option One

Under this option maps of rainfall and other available variables which contribute to fire weather index are included in the model.

The availability of reliable weather data poses some problems. In order to avoid problems with short term variations in weather patterns it is best if measures are based on at least 20 years of observation.

Of the variables contributing to Fire Weather Index, two (rainfall and temperature) can mapped with some reliability. The other two (wind speed and relative humidity) cannot. Using the two variables only will only result in misleading results from the final hazard mapping is the unmapped variables follows a significantly different pattern from the mapped variables. Relative humidity is probably related most closely to the rainfall overlay. Wind is different as there are only a few reliable, long-term datasets for wind and these relate to individual points. In the Wairarapa, for example, there are long term data for only six points. Some limited other wind data also exists.

4.6.1.2.1 Rainfall

[20] Paul Hughes (1997) Department of Conservation, Wellington Conservancy Office. Pers comm

Areas were placed in five categories according to mean annual rainfall, from lowest hazard (highest rainfall) to highest hazard, as shown in Table 3.

Table 3 : Rainfall Hazard Categories

	Mean Annual Rainfall
Extremely high rainfall	>2200 mm
Very high rainfall	1800-2200 mm
High rainfall	1400-1800 mm
Moderate rainfall	1200-1400 mm
Lowest rainfall	<1200mm

This variable can be mapped from data held by the Regional Council which was sourced from the Meteorological Service.

4.6.1.2.2 Temperature

Temperature is a factor which affects both how dry a fuel is and a high temperature at the time of a fire contributes to conditions in which the exacerbates the intensity of any fire. Temperature is included in the model with a simple overlay as shown on Table 4. Temperature is generally recorded daily or more frequently . The most meaningful measure of temperature for fire hazard purposes is probably the mean summer maximum temperature. Summer is when most drying occurs and is when extreme values are found.

Table 4 : Temperature Hazard Categories

	Mean Summer Maximum temperature
Extremely high temperature	30^o +
Very high temperature	28^o -30^o
High temperature	25^o -28^o
Moderate temperature	20^o -25^o
Lowest temperature	Below 20^o

Temperature data are also held by the Regional Council from the Meteorological Service.

4.6.1.2.3 Wind and Relative Humidity

Neither of these two variables can be easily mapped. Relative humidity is probably related most closely to the rainfall overlay. In high humidity situations fire will be less intense than otherwise and the fuel will not be as dry prior to the fire.

There is probably no such simple relationship with wind. The limited data that exists suggests broadly that the high areas in the axial ranges are subject to extremely high wind. The coast is also subject to extremely high winds, especially along the south coast. Maps which are good enough for use are not available however. A wind overlay could be calculated. This involves the use of modelling air flows over a terrain model and is extremely expensive to develop a wind frequency model.

4.6.1.3 Other Curing and Weather Variables - Option Two

The other option for modelling curing and weather is to use an existing approach. Soil moisture deficit is calculated from weather data, basically rainfall patterns through time, calculated evapo-transpiration and soil moisture retention. The measure is designed to indicate when grass, and hence pastoral farming, is affected by drought stress. This can be calculated for about 30 sites in the Wairarapa and then interpolation used to fill the gaps. Similar interpolation is used for the rainfall and temperature maps above. The interpolation makes use of a terrain model. The range of values expected for the average annual number of days of soil moisture deficit is expected to be from 10 days per year to 150 days per year.

The frequency of soil moisture deficit is used to indicate relative fire hazard.

Table 5 : Soil Moisture Deficit Categories

	No. of days deficit
Lowest hazard	10 - 49
	50 - 79
	80 - 99
	100 - 119
Highest hazard	120 +

4.6.1.4 Slope

Overseas standards, such as the 1991 US Standard[21], use five hazard classes for slope.

Slope affects fire with fire spread being much faster up hill. This is due to the fire pre-heating fuels further up the slope. A fire will travel up a 10^o slope 1.5 times the speed it will travel on the flat, 2.5 to 3 times as fast on a 20^o slope, 6 times as fast on a 30^o slope and 10 times as fast on a 35^o slope[22].

Slope is calculated from contours. This provides a value for each location. The slope variable is continuous and as a result grouping into categories is unnecessary. The results, in degrees, is converted to a relative hazard rating each location by use of a curve which reflects the much more rapid spread of fires on a slope. Note that the curve being fitted to is an approximation. The relative hazard values are then corrected to give a slope hazard value by a linear transformation.

The curve is obtained by:

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[21] Forest and Rural Fire Protection Committee (1991) Standard for protection of Life and Property from Wildfire. NFPA 299. Approved by US National Standards Institute.

[22] Forestry Canada Fire Danger Group (1992) Development and Structure of the Canadian Forest Fire Behaviour Prediction System. For. Canada Fire Danger Group, Information Report ST-X-3. Values taken from slope correction graph.

slope /(60-slope)^2 (where slope is in degrees)

This is then converted to a 1 to 5 scale by multiplying by 8.93 (ie 5/value @60^o)

Topography has a number of other impacts. Hills and valleys can greatly influence wind speeds by funnelling winds and creating turbulence. Where the topography results in a chimney effect wind speeds can be different when there is a fire. This aspect requires detailed information on wind and topography, often at mapping scales beyond which mapping has been carried out in this exercise.

4.6.1.5 Light-up Hazard

This aspect of the model basically concerns people. High fire hazard areas are accessible to people. A study of past fire frequency is most useful at identifying the key causes of wild fire.

Experience in Wellington and fire records nationally[23] indicate that principal causes of fire are:

- controlled fire, for land clearance, spreading and becoming uncontrolled. This is the biggest single cause of wildfire.
- vehicles and industrial activity (including logging)
- arson
- smokers/picnics/hunters - recreation

For a large proportion of fires no cause is established.

Both controlled fires and arson are most common in scrub and rank grass. Landowners generally only burn vegetation that will burn. Similarly arsonists only light vegetation that will burn. Industrial activities affect only areas near to the plant or, in the case of logging, plantation forest. Vehicle fires affect areas next to formed roads as a general rule. The recreational use of fire affects areas that are accessible far more than less accessible areas.

For this model a simple two category approach is suggested as an approximation. This follows a two category approach taken earlier in Wellington. The experience of wildfires around the Wellington region indicates that most are near areas were people live or frequently visit. Beyond this the pattern of fires appears to be determined more by vegetation, aspect and other environmental factors rather than by social factors. For this reason the overlay is a simple two class one, with a high hazard area and low hazard area. Low hazard areas occur away from roads and human habitations while high hazard areas are close to roads and habitations. Areas with the higher hazard have a score of 2 while the low hazard area has a score of 0.

Should the fire history show other patterns these should be incorporated. A three category overlay which uses a higher hazard class for shrubland and plantation areas within the zone near all roads in addition to the two category model suggested could be used.

4.7 Weightings for the Wellington Region Model

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[23] Cooper AN (1989) History of Fires and Legislation: Fires Within and Outside Forests: Costs, Statistics, Overall Causes. Introduction Paper Prevent Rural Fires Convention, Ministry of Forestry.

The weightings have been developed based on the literature plus a selected site approach. Under this approach clear rankings are established for a number of sites. These are then scored and any adjustments that are made to the scoring are then made. This intuitive approach has been used with success in Australia and is behind the Victorian model. The approach differs from that used elsewhere in that where information allows, as it does for slope and incident solar radiation, the variables used are continuous rather than discrete. Ideally the other variables would be continuous as well with the weightings being reflected in the values for the range of scores given to the variable.

The final fire hazard is mapped by overlaying the different hazard variable maps. The different categories in each map have scores associated with them and these are summed to give a total wildfire hazard score for each point on the map.

Table 6 : Ranking Scores

Option One

Hazard Category	LCDB Class	Slope	Rainfall	Summer Temperature	Incident solar radiation	Light-up
Lowest to highest hazard category	1 2 3 4	1 to 5	0 2 4 6 8	0 1 2	0 to 4	0 2

Note : Incident solar radiation and slope are continuous variables whilst the remainder are discrete.

Option Two

Hazard Category	LCDB Class	Slope	Soil Moisture Deficit Temperature	Incident solar radiation	Light-up
Lowest to highest hazard category	1 2 3 4	1 to 5	0 2 4 6 8	0 to 4	0 2

For some of the variables more detailed groupings could be used. For example the temperature overlay could use more categories for the map. If this is done then ranking scores non-integer values could be used for the groupings between the outer values given here. For example additional temperature categories could be included and scores in the range 0 to 2 assigned.

The scores for the different attributes are combined to give a final score for each location which provides a relative ranking for fire hazard. To combine the score the LCDB class score is multiplied by the slope hazard score to give a combined rating for slope and fuel. This follows the approach used in the US Standard[24] (outlined above in section 4.4.2). This score is then added to the sum of the scores for the remaining variables to arrive at an overall rating for all of the scores combined. The fire hazard map is derived from the total scores as given in Table 7. The maximum score possible is 38 and the lowest is 1.

Table 7 : Wildfire Hazard Classes - Total Ranking Scores - Option One

	Total Score
Low wildfire hazard	Up to14.9
Medium wildfire hazard	15 to 19.9
High wildfire hazard	20 to 24.9
Very high wildfire hazard	25 to 29.9
Extreme wildfire hazard	30 and above

For option two total ranking scores two should be taken off of these to reflect the lower scores due to there being one less variable.

4.8 Data sources

4.8.1 Topographical Information

This is available in GIS form to the Regional Council already through its arrangements with Terralink NZ Limited.

Slope ; This derived from contour mapping over the area. The most detailed contour maps available should be used. The 1:50,000 scale NZMS 260 series will give adequate results for the scale of the land cover database mapping. This is available to the Wellington Regional Council on its GIS system from Terralink.

Incident Solar Radiation ; this can be calculated from the contours as outlined in material supplied by the Department of Conservation.[25]

4.8.2 Curing and Weather Information

This data is based on past weather records. At least twenty years of data should be used to obtain averages otherwise year-to-year weather variations will influence the final hazard map. Thirty years of data are preferable.

The data and subsequent analysis can be obtained from the National Institute of Water and Atmospheric Research Limited (NIWA). A contact address is included in the references. Costs vary. Two overlays (rainfall and mean summer maximum temperatures) could be obtained for some $3000 to $5000. A soil moisture deficit map would cost more, possibly in the range $4500 to $6000. These values are based on very rough estimates of the work

[24] Forest and Rural Fire Protection Committee (1991) Standard for protection of Life and Property from Wildfire. NFPA 299. Approved by US National Standards Institute.

[25] Paul Hughes (1997) Department of Conservation, Wellington Conservancy Office. Pers comm

involved (at NIWA charging out at $150 per hour). They are not firm quotes and a separate quote should be obtained prior to any work commencing.

Rainfall : an average annual rainfall overlay can be obtained for the region.

Temperature : mean summer temperatures.

Soil Moisture Deficit: the annual average length of time a location is in deficit can be obtained.

Wind : detailed mapping based on wind parameters are not available. Modelling could be undertaken by NIWA but the expense is not considered to be justified at this stage.
In order to do interpolation at an appropriate scale NIWA would need access to the terrain model (Terralink 20m 1:50000 scale contours). NIWA use ArcInfo as a GIS system so there should be no difficulty in transferring data to the Regional Council.

4.9 Model Limitations

The key limitations of the model are:

1. In precision. The topographical data are no better than the mapping of contours which are for :50,000 scale. Limitations in the LCDB mean that precision is in terms of +-25m while areas smaller than 1 hectare (or a 100 by 100m square are not mapped separately. This means the small areas of high hazard, such as rank grass/scrub on road verges, will not be mapped.
2. In distributions of weather. The weather variables used are surrogates for a map showing the frequency of very high and extreme fire weather index readings for the vegetation in any given location. There are insufficient data to map these as a distribution so the distribution of principal weather variables have been used instead.
3. No map of fire history has been prepared. This prevents development of a robust model of the likelihood of light-up and the testing of the model as developed here.

4.10 Comparison With Earlier WRC Urban/Rural Interface Model

The model used in 1997[26] for the urban/rural interface is compared with the one proposed for the Wellington Region. There are some significant differences in weather within the Wellington Region. In terms of rainfall some of the area is drier that the driest part of Wellington west of the Rimutaka Range. With mean temperatures the is also a greater range. This means that more variables can be used in the Wellington Region as distributions exist for them.

These variables could be used in the urban interface area by adding them to the model used there and adjusting the weightings used in that model.

As a guide the classification in Table 8 was used in the vegetation hazard mapping.

Table 8 : Vegetation Hazard Categories

[26] Forme Consulting Group (1997) Interface Fire Hazard Susceptibility. Separate reports for Wellington City, Porirua and the Hutt. Reports for the Wellington Regional Council

Wellington Region Model - LCDB Classes	Urban/Rural Interface WRC Model (1977)
<u>Low</u> Primarily pastoral Primarily horticultural Coastal sands Bare ground Inland water	<u>Low</u> Mowed grass Grazed grass Bare ground
<u>Medium</u> Indigenous forest	<u>Medium</u> Native forest - mature trees Mature Pine
<u>High</u> Planted forest Shelterbelts Coastal wetlands	<u>High</u> Pine - after canopy closure to 18 years Large kanuka/kamahi Scrub hardwoods (eg mahoe, five finger)
<u>Very High and Extreme</u> Shrubland Grassland - non-pastoral Inland wetlands	<u>Very High</u> Young pines on clean site Manuka scrub Swamp vegetation Dry scrub (eg Tutu)
	<u>Extreme</u> Bracken Rank grass/broom Gorse Young pines with gorse and/or slash Marram grass and tussock

Note : Mangrove is not applicable in the Wellington Region as this not present in the district.

The slope and incident solar radiation variables for the Wellington Region Model are improvements on the variables used the earlier Urban/Rural Interface WRC Model (1977) for aspect and slope. Slope is more accurately portrayed as a continuous variable and solar radiation is modelled rather than a the crude four category aspect scoring of the earlier model. If option one is followed then the rainfall categories are the same but the scoring for aspect differs. If option two is followed then soil moisture deficit replaces rainfall and temperature.

The weightings from the earlier Urban/Rural Interface WRC Model (1977)[27] are given below in Table 9. These can be compared with those now proposed for the Wellington Region which are shown in Table 6.

The final fire hazard is mapped by overlaying the different hazard variable maps. The different categories in each map have scores associated with them and these are summed to give a total wildfire hazard score for each point on the map.

These scores could be varied if different weighting to the variables are to be applied.

<u>Table 9 : Ranking Scores - Earlier Urban/Rural Interface WRC Model (1977)</u>

	Hazard variable				
Hazard Category	Vegetatio n	Rainfall	Aspect	Slope	People

[27] Forme Consulting Group (1997) Interface Fire Hazard Susceptibility. Separate reports for Wellington City, Porirua and the Hutt. Reports for the Wellington Regional Council.

	Score				
Lowest to highest hazard category	2 4 6 8 10	-4 -2 0 2 4	0 2 4	0 2 3 4	0 2

Table 10 : Wildfire Hazard Classes - Total Ranking Scores - Earlier Urban/Rural Interface WRC Model (1977)

	Total Score	Total Score
	Wellington Region Model	Urban/Rural Interface WRC Model (1977)
Low wildfire hazard	10 and below	10 and below
Medium wildfire hazard	11 to 13	11 to 13
High wildfire hazard	14 to 17	14 to 17
Very high wildfire hazard	17 to 19	17 to 19
Extreme wildfire hazard	20 and above	20 and above

5. Conclusion

The vegetation mapping in the LCDB allows the recognition of four classes of vegetation fire hazard. This is one less than used for the urban/rural interface model. The reduction is primarily due to the varied vegetation identified as shrubland.

A model which describes the fire hazard of vegetation has been outlined for the Wellington Region part of the Wellington Region. The model this provides has similarities with the one used for the urban interface of the Wellington, Hutt, Upper Hutt and Porirua Cities within the region.

Two options are presented for the model. The overlays involved are as given below:

1. Vegetation type
2. Curing and weather variables
    - aspect

    And either:
    - Option One
        - ⇒ rainfall
        - ⇒ temperature

    or:
    - Option Two
        - ⇒ soil water deficit
3. Slope
4. Light-up hazard.

The second option is considered to be better but will cost slightly more.

The earlier model for the urban/rural interface includes many of the same variables, although the vegetation mapping for that model allowed one more hazard class. Despite this, the

Wellington Region model could be used with only small changes to the curing and weather variables.

6. References

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7. Appendices

7.1 Terms of Reference

The report is to contain:

- a flammability assessment of the vegetation LCDB classes
- a flammability hierarchy of vegetation LCDB classes
- a model that adequately represents fire hazard
- a weighting scheme that allows the vegetation LCDB classes to be incorporated into a model that adequately represents fire hazard

7.2 Vegetation Classes

Landcover Database

Artificial landscapes

- Urban - built up areas, includes any contiguous group of buildings larger than the MMU (1ha)
- Mines, gravel pits and dump sites
- Urban open space - eg sports fields, parklands etc

Cultural Landscapes

- Primarily pastoral - suitable for grazing, enclosure distinguishes this from grassland. Includes croplands.
- Primarily horticultural - orchards and vineyards
- Planted forest - plantation forest or exotic forest inclusive of recent replanting, eg *Pinus radiata*, *Pseudotsuga menziesii*.

Natural Landscapes

- Grassland - tussock, non pastoral or unenclosed grassland
- Shrubland - Woody vegetation in which the cover of shrubs and trees in the canopy is >20% and in which shrub cover exceeds that of any other growth form or bare ground. Shrubs are woody plants generally <10cm bdh eg Manuka, Kanuka, Gorse, Broom
- Indigenous forest - natural forest cover
- Bare ground - non-pastoral exposed soil and rock
- Inland wetlands - inundated by fresh water
- Coastal wetlands - inundated by salt water
- Coastal sands - beach sands and dunes
- Inland water - lakes, ponds and rivers
- Mangrove - sea level mangrove swamp land

Linear features

- Shelterbelts - major shelterbelts (visible on imagery)