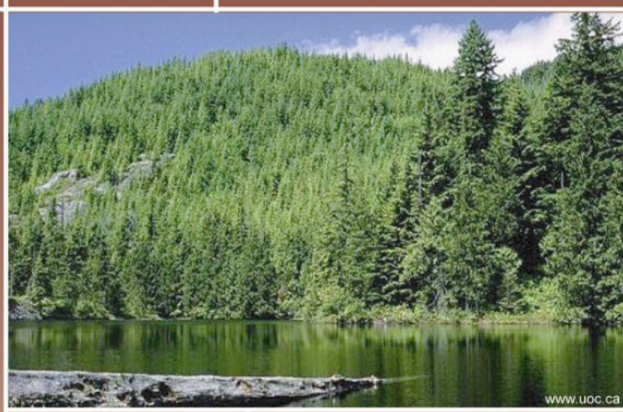
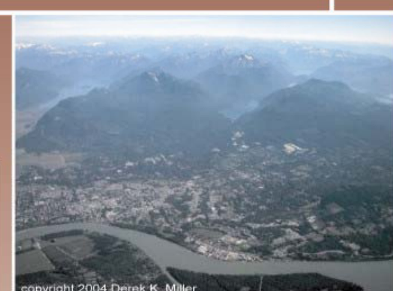
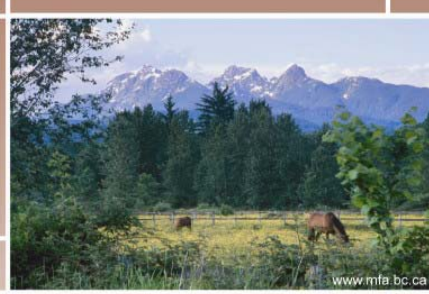
District of Maple Ridge
Wildfire Risk Management System



B.A. Blackwell & Associates Ltd.
August, 2006

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D I S T R I C T O F M A P L E R I D G E

W I L D F I R E R I S K M A N A G E M E N T S Y S T E M

An Assessment of Risk in Terms of the Probability and Consequence of Wildfire Occurrence Within in the District of Maple Ridge

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July 2006

Table of Contents

List of Figures

List of Tables

1.0 Introduction

In 2006 the District of Maple Ridge, hereinafter referred to as 'the District', began the development a Wildfire Risk Management System (WRMS). Wildfire is a natural disturbance agent in the forests that surround the District and has the potential to negatively impact social and economic stability, and environmental quality. Historically the mid to low elevation stands in this area have been exposed to high severity stand replacement wildfire that has the potential to significantly alter the forests adjacent to and within the District. The probability of large wildfires within this community is considered low to moderate, and the consequences associated with a large wildfire could be devastating. This report documents the methods and results of the WRMS analysis for the District.

This project builds on the wildfire threat analysis methodology that was initially pioneered in Australia (Muller 1993, Vodopier and Haswell 1995) and has since been adapted for use in British Columbia in a number of different contexts and scales (Hawkes and Beck 1997, Blackwell et al. 2003). In previous applications, all fire related factors (fire risk, suppression response capability, fire behaviour, and values at risk) were related equally without consideration of formal risk management theory. The revised system developed for this project adopts a risk management approach to guide the quantification of separate and discrete landscape-level probability and consequence ratings, using the same underlying data attributes. The resultant Wildfire Risk Management System better enables fire and forest managers to design strategies and tactics for fire management that vary from high probability-low consequence to low probability-high consequence fire risks across the landscape.

2.0 Wildfire Risk Management

Definitions of the term "risk" and all its derivatives (*i.e.*, risk management, risk assessment, risk evaluation) are inconsistent in the wildfire literature, perhaps as a legacy of the fact that most wildfire research has been broken down into specialty topics such as fire behaviour, fire effects, and fire history/occurrence. For the purposes of the WRMS, wildfire risk is defined as the probability and consequence of wildfire at a specified location under specified conditions. This definition is consistent with the generic definition of risk and its derivative terms being adopted in many jurisdictions worldwide (Canadian Standards Association 1997, Council of Standards Australia/New Zealand 1999, International Standards Organization 2002).

Analytically, the WRMS approach to wildfire risk assessment provides a spatial characterization of risk based on probability and consequence ratings. In other words, the WRMS can indicate, at any given location and under specified conditions, what the probability of wildfire occurring is and, for a given wildfire behaviour, what the potential consequences on valued resources are.

In other fields of risk management (*e.g.*, hazardous materials management), a single resultant quantification of probability and consequence is often derived mathematically. However, in the case of wildfire risk assessment it has been found more useful to keep these elements separate, since they may imply different management approaches spatially. Figure 1 shows how various combinations of probability and consequence can imply the basic management strategies. In practice, the implementation of this risk management approach requires a detailed spatial examination of assessment results across a full continuum from low to high ratings.

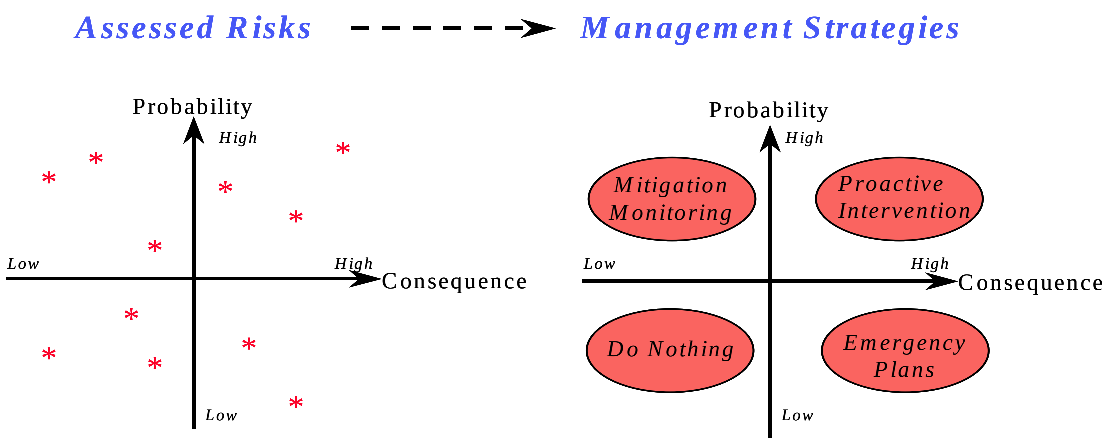

Figure 1. Conceptual representation of risk assessment/management as the resultant of two factors, Probability and Consequence

3.0 The District of Maple Ridge and Surrounding Area

The project study area includes the District of Maple Ridge (28,675 ha) and the surrounding 5 km perimeter (Figure 2). Elevations range from 0 to 1,642 meters. Forests in the lower elevations include western hemlock, amabilis fir, western red-cedar, Douglas-fir, lodgepole pine, big-leaf maple, red alder, black cottonwood and paper birch. With increasing elevation, yellow cedar and mountain hemlock become dominant tree species. In the harsh climate of the highest elevations, vegetation consists of herbs, lichens, and scattered low alpine shrubs and trees.

Wildfire is a natural disturbance agent in a portion of this heavily forested, coastal landscape. Historically these areas have been exposed to low frequency (300-600 years), high severity stand replacement fires (Green *et al.* 1998). Although the probability of large wildfires within the study area is considered generally low, the consequences associated with a large wildfire could be devastating to both the District and adjacent municipalities. Air quality, urban interface, recreation use, timber value, visual quality and biodiversity are important values that must be considered in a wildfire risk assessment of the District and surrounding area.

Figure 2. Overview of the study area.

In recent years, fire management within the study area has focused on initial attack and all wildfires have been actively suppressed.

4.0 Methods

4.1 Overview

The purpose of this WRMS was to create a spatial representation of all factors that influence the probability and consequence of wildfire in the study area. The basic model structure was similar to the one used in 2004 in the Greater Vancouver Watersheds (GVWD) (Blackwell and Ohlson, 2004) and in 2005 in the Resort Municipality of Whistler; it was further developed and refined through a workshop with District staff. The model was implemented in a GIS environment using ArcMap 8.2.1 (ESRI) and ArcInfo 8.0.2 (ESRI) using a raster grid at 50m by 50m cell resolution.

The final WRMS model structure is portrayed in Figure 3. The final spatial probability rating was derived from three major components: *Ignition Probability*, *Fire Behaviour*, and *Suppression Response Capability*. The final spatial consequence rating was derived from six major components that were significant within the study area: *Air Quality, Timber Value, Urban Interface, Recreation Use, Visual Quality* and *Biodiversity*. Each main model component was in turn derived from several subcomponents as shown in the Figure 3.

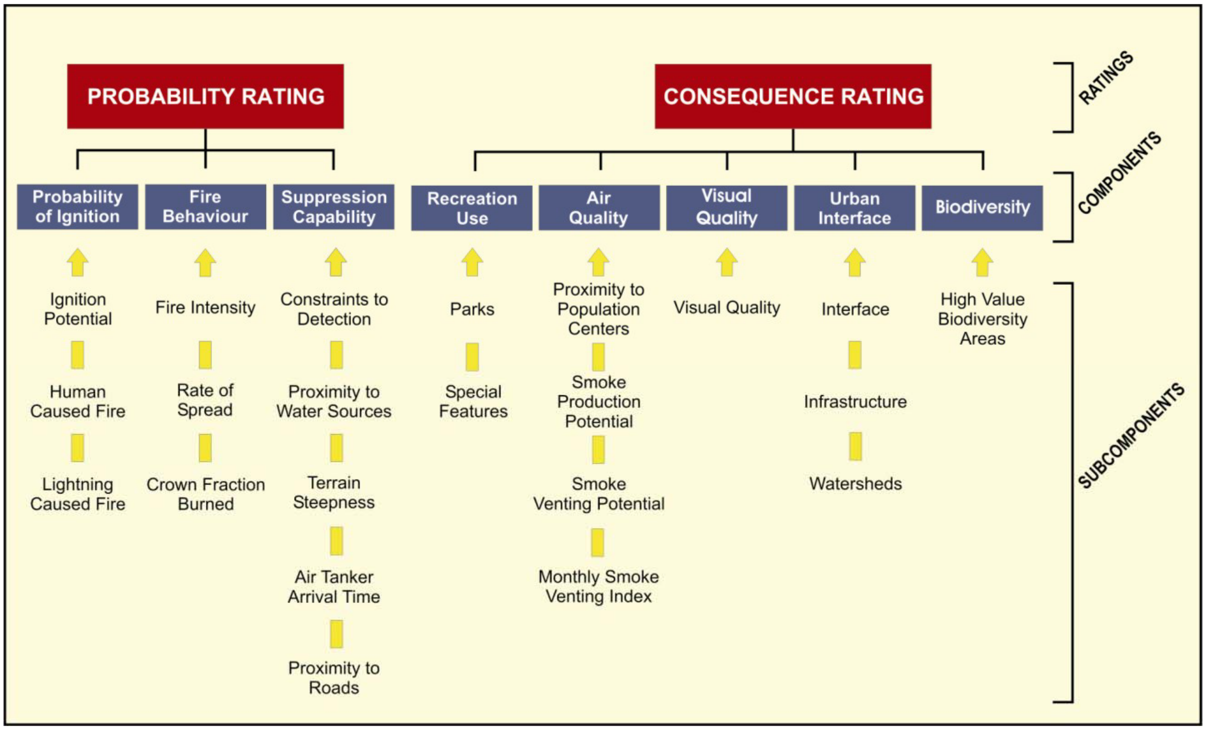

Figure 3. District of Maple Ridge Wildfire Risk Management System (WRMS) model structure.

At the subcomponent level, individual ratings for each raster cell were developed on 0-10 scales based on existing biophysical databases and, in some cases, the application of sub-models (*e.g.,* rate of fire spread calculated using the Canadian Fire Behaviour Prediction System and spatial fuel inventory data). An overview of each subcomponent method, database source and/or sub-model is provided in Table 1.

At the component level, the rating for each raster cell was calculated as a weighted sum of all its subcomponents.

Figure 4 provides an example of the rating scales and subcomponent weighting for the *Suppression Response Capability* component. All other components were derived in a similar manner (see Appendix 1). Similarly, at the overall rating level for probability or consequence, the rating for each raster cell was calculated as a weighted sum of all its components.

Wildfire Risk Management Component: **Suppression Response Capability**

The Suppression component provides a rating of the probability that a wildfire could be quickly exterminated in a given location given existing resources. The rating is calculated as a weighted sum rating using five attributes: **Contraints to Detection, Proximity to Water Sources, Air Tanker Arrival Time, Terrain Steepness,** and **Proximity to Roads**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Constraints to Detection *Indicator of the ability to detect a fire: reconnaissance at higher elevations is often constrained by cloud cover.*	elevation metres	> 1900	10	10%
		1401-1900	7	
		900-1400	2	
Proximity to Water Sources *Indicator of the ability to access water quickly for fire fighting. Based on distance from all season streams and lakes.*	distance metres	>300	10	10%
		101-300	7	
		0-100	2	
Air Tanker Arrival Time *Indicator of time for air tanker action measured as flight time (concentric) from nearest tanker base (300k/hr)*	minutes	> 40	10	30%
		31 - 40 (200km)	7	
		21 - 30 (150km)	5	
		11 - 20 (100km)	3	
		0 - 10 (50km)	0	
Terrain Steepness *Indicator of the difficulty of control/contain on the landscape.*	slope Class %	> 60	10	40%
		41 - 60	7	
		21 - 40	3	
		0 - 20	0	
Proximity to Roads *Indicator of the ability to get suppression resources into an area: based on a bush walking rate of 1 km / hour.*	minutes	> 120	10	10%
		61 - 120	7	
		31 - 60	5	
		16 - 30	3	
		0 -15	0	

Figure 4. Component level rating example: Suppression Response Capability.

Table 1. Overview of Methods, Databases and Sub-Models for each Subcomponent of the District of Maple Ridge Wildfire Risk Management System

	Component	Subcomponent	Overview Method	Database/Sub-Model
Probability Rating	Probability of Ignition	Ignition Potential	Calculation based on fuel type and fire weather indices	Wildfire Ignition Probability Predictor[1]
		Lightning Caused Fire	Inverse distance weighted interpolation of the number of lightning fire ignition points (since 1950) within a 500m buffer	- ESRI Spatial Analyst[2] - Ministry of Forests fire records
		Human Caused Fire	Inverse distance weighted interpolation of the number of human fire ignition points (since 1950) within a 500m buffer	- ESRI Spatial Analyst[2] - Ministry of Forests fire records
	Fire Behaviour	Fire Intensity	Calculation using fire weather, fuel type and topography	Fire Behaviour Predictor 97[3]
		Rate of Spread	Calculation using fire weather, fuel type and topography	Fire Behaviour Predictor 97[3]
		Crown Fraction Burned	Calculation using fire weather, fuel type and topography	Fire Behaviour Predictor 97[3]
	Suppression Response Capability	Constraints to Detection	Average elevation above valley bottom of forest inventory polygon	TRIM
		Proximity to Water Sources	Buffer distance from determinant streams and lakes	TRIM
		Air Tanker Arrival Time	Measured flight time (concentric) from air tanker base	Protection Branch data
		Terrain Steepness	Average slope of forest inventory polygon	TRIM
		Proximity to Roads	Buffer distance from roads	TRIM and District of Maple Ridge inventory
Consequence Rating	Recreation Use	Parks	Provincial, GVRD and Municipal park boundaries	Provincial and GVRD park boundaries, District of Maple Ridge Inventory
	Air Quality	Proximity to Population	Buffer distance from urban interface	TRIM
		Smoke Production Potential	Smoke production as a function of seral stage	TRIM
		Smoke Venting Potential	Average elevation above valley floor of forest inventory polygon	TRIM
		Smoke Venting Index	Smoke dispersion rating based on long-term monthly averages.	Ambient Air Analyst based on methods applied to the Greater Vancouver Regional District
	Visual Quality	Visual Quality	Visually sensitive polygons	District of Maple Ridge inventory
	Urban Interface	Interface	Buffer distance from interface areas	TRIM
		Infrastructure	Buffer distance from infrastructure	District of Maple Ridge inventory
		Watersheds	Watershed boundary	District of Maple Ridge inventory
	Biodiversity	High Value Biodiversity Areas	Areas containing ecologically sensitive areas or unique features	District of Maple Ridge inventory

[1]FORTester v1.0 (Canadian Forest Service 2002); [2]ESRI Spatial Analyst 8.1.2 (ESRI 2001); [3]Fire Behaviour Predictor 97 (Remsoft, 1997)

4.2 Development of Probability Theme

4.2.1 Probability of Ignition Component

The probability of ignition component was divided into three subcomponents: fires caused by lightning, fires caused by human activity and ignition potential (Figure 5). The subcomponent rating scales and assigned initial weights are shown in Appendix 1.

<u>Lightning and Human Caused Fire</u>

The first two subcomponents, lightning and human caused fires were based on historical fire frequency and cause in the study area from 1950 to 2004. Fire history records from the Ministry of Forest Protection Branch were translated into spatial points within the GIS framework. Five hundred meter radius buffers were then created around every fire location point. This buffer distance was chosen because some older fire location data was only considered accurate to the nearest kilometre and represented fire ignition origin, and not fire perimeter. The number of fire location points within these new buffer polygons was totalled. ESRI Spatial Analyst (2001) was then used to determine the final probability of ignition through the application of inverse distance weighted interpolation. The purpose of interpolation was to predict the value of cells that lack actual points. The simplest form of inverse distance weighted interpolation is sometimes called "Shepard's method" (Shepard 1968). The equation used is as follows:

$$F(x,y) = \sum_{i=1}^{n} w_i f_i$$

Where: n is the number of scatter points in the set; f_i are the prescribed function values at the scatter points (*e.g.,* the data set values), and; w_i are the weight functions assigned to each scatter point.

The classical form of the weight function is:

$$w_i = \frac{h_i^{-p}}{\sum_{j=1}^{n} h_j^{-p}}$$

Where: p is an arbitrary positive real number called the power parameter (typically, p=2), and; h_i is the distance from the scatter point to the interpolation point, or

$$h_i = \sqrt{(x - x_i)^2 + (y - y_i)^2}$$

Where: (x,y) are the coordinates of the interpolation point, and; (x_i,y_i) are the coordinates of each scatter point.

The weight function varies from a value of unity at the scatter point to a value-approaching zero as the distance from the scatter point increases. The weight functions are normalized so that the weights sum to unity.

The effect of the weight function was that the surface interpolated each scatter point and was influenced most strongly between scatter points by the points closest to the point being interpolated.

Ignition Potential

The third subcomponent, ignition potential, was an indicator of the potential for fire ignition based on fuel type and 90th percentile fire weather conditions (historic fire weather representing 90% of the most extreme conditions recorded). It was calculated using the Wildfire Ignition Probability Predictor (WIPP), a tool from FORTester v1.0 (Lawson et al. 1993, Bernie Todd personal communication.). The model determined the probability of sustained ignition from simulated people-caused fire brands (matches and camp fires) and predicted, in broad classes (“no-fire day” less than 50% probability of sustained ignition and “fire day” greater than 50% probability), from readily available indicators of fire danger based on benchmark fuel type groups applicable to British Columbia (Appendix 2). This revision of existing provincial fuel type data for use in this model included input from the Ministry of Forests and the Canadian Forest Service on applying boreal fuel types in coastal settings. Ignition probabilities expressed on an area basis provided a measure of people-caused fire potential from simple fire danger rating system components.

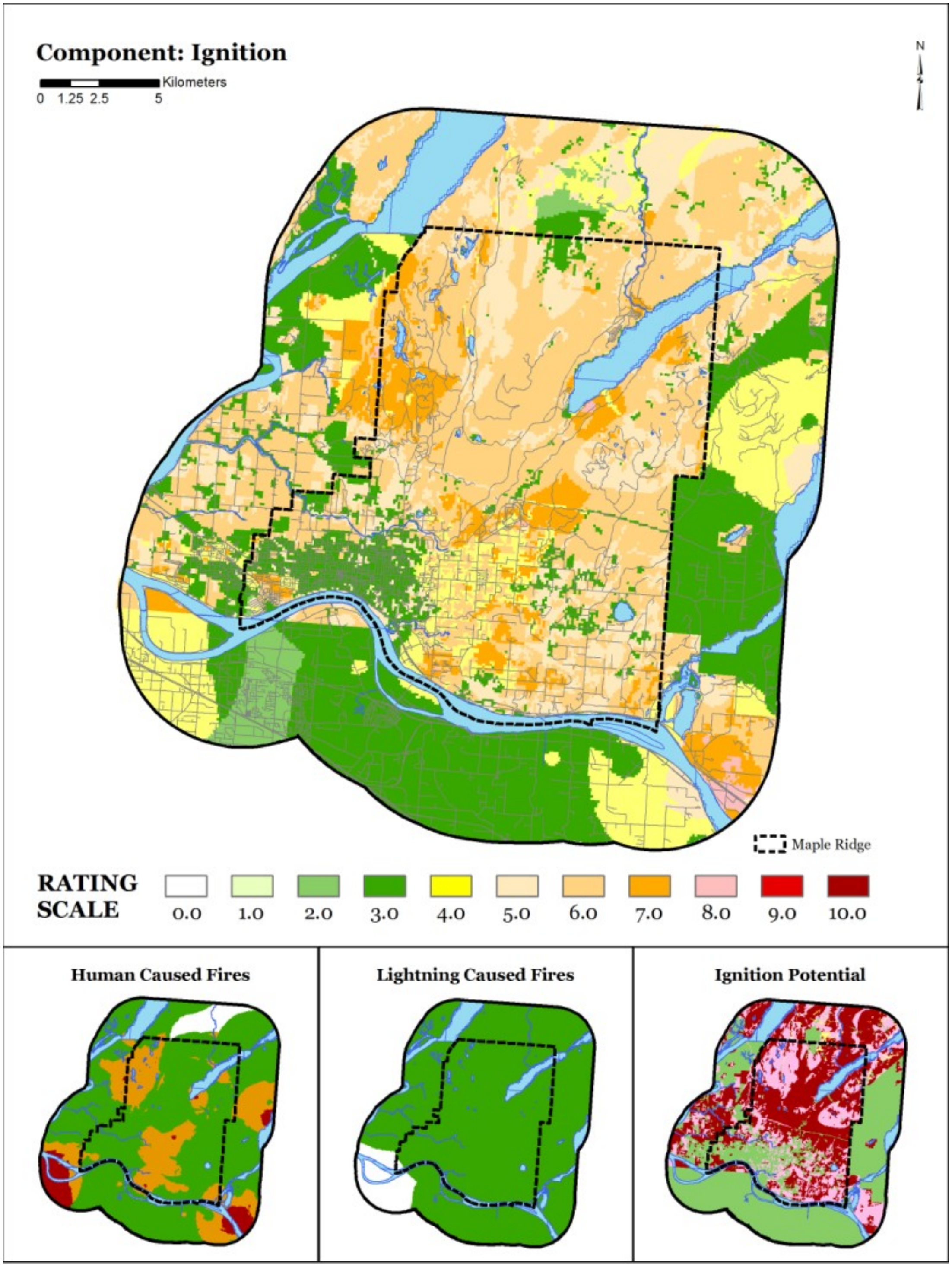

Figure 5. Probability of Ignition component and associated subcomponents.

4.2.2 Fire Behaviour Component

The fire behaviour component estimated how wildfire would behave under historic weather conditions that have occurred over the recorded climate record for the District. Information was compiled that related stand-level fuel types, slope, aspect, and fire weather for the study area. The resulting data was processed through the FBP97 (Fire Behaviour Predictor 97) program. Fire Behaviour Predictor 97 is a Windows™ based version of the Canadian Fire Behaviour Prediction System (Forestry Canada 1992) developed by Remsoft Inc. The fire behaviour outputs of FBP97 include: fire intensity; rate of spread; and, crown fraction burned. These outputs form the subcomponents of the fire behaviour component (Figure 6).

The Canadian Fire Behaviour Prediction System uses 16 national benchmark fuel types to predict fire behaviour. For the WRMS, seven of the 16 fuel types were selected to estimate fire behaviour based on species composition and stand structure attributes. The provincial fuel type database was adjusted to reflect changes in forest cover over the past eight years (since 1997) and to correct fuel-typing areas that did not match with fuel types verified by both field checking and aerial photography review.

Weather information was derived from historic records collected from weather stations associated with the study area. Depending on the element measured, the period of record was 1931 to 2005. Data for temperature and precipitation was only continuous from 1950. A look up table, with computed fire weather indices summarized by station and Biogeoclimatic Unit, was developed specifically for the District. This look-up table allows computation of fire percentiles for all possible permutations and combinations of fire weather indices for the period of record.

Fire weather data (temperature, relative humidity, precipitation, and wind speed) was used to calculate Fine Fuel Moisture Code (FFMC) and Build-Up Index (BUI). Fire behaviour was subsequently modeled in FBP97 using upslope winds calculated from the relevant aspect. The subcomponent rating scales and assigned initial weights are shown in Appendix 1.

<u>Fire Intensity</u>

The fire intensity subcomponent was a measure of the rate of heat energy released per unit time per unit length of fire front. It was based on the rate of spread and predicted fuel consumption of the fire, and was expressed in kilowatts per meter (Pyne 1984).

<u>Rate of Spread</u>

The rate of spread subcomponent was a measure of the speed at which fire expands its horizontal dimensions at the head of the fire. This was based on the hourly Initial Spread Index (ISI) value and was expressed in meters per minute. The rate of spread was adjusted for steepness of slope and interactions between slope direction and wind direction determined from the Build-Up Index (BUI).

<u>Crown Fraction Burned</u>

The crown fraction burned subcomponent was a measure of the proportion of the tree crowns consumed by fire and was expressed as a percentage value. It was based on rate of spread, crown base height and foliar moisture content.

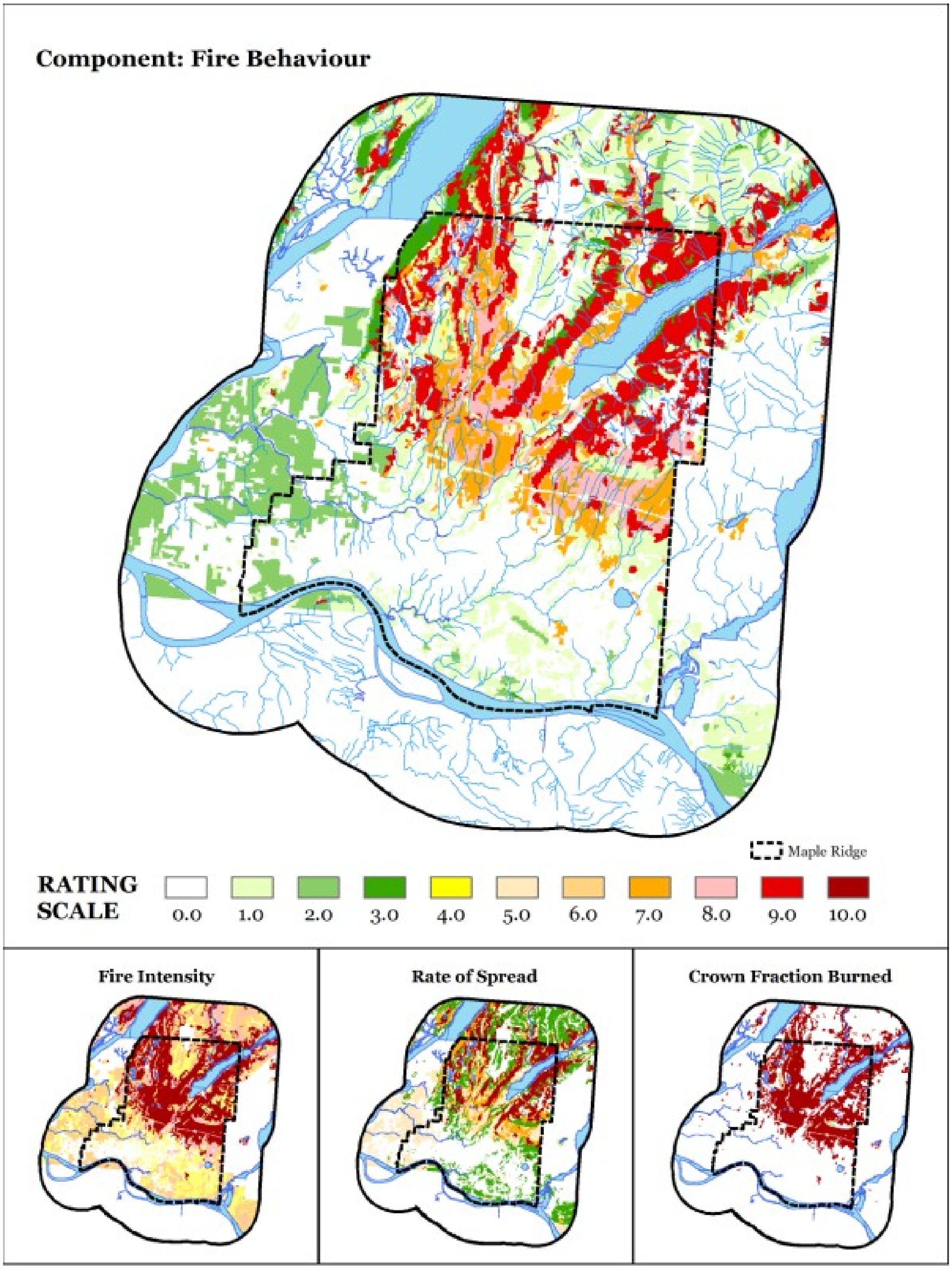

Figure 6. Fire Behaviour component and associated subcomponents for the 90% percentile July/August weather conditions applying a windspeed of 16 km/h

Calculation of Spotting Distances

The calculation of spotting distance for individual forest polygons was based on the predictive spotting models contained within BEHAVE (USDA Forest Fire Behaviour prediction software). Spotting models were originally devised to predict the maximum distance burning embers would travel over flat and regularly undulating terrain. The balance between particle size, burnout rate, and time or distance traveled determines maximum spotting distance (Figure 7). Smaller particles are lofted higher and transported further, but burnout sooner than larger particles.

Forest polygon size was an important consideration in determining the threshold of fuel necessary to create spotting. For the purpose of this analysis within the urban area, forest polygons (parks and greenways) less than 20 hectares in area were not included in the spotting assessment. For forest polygons outside of the urban area, areas less than 20 hectares were not included in the assessment. The purpose of this analysis was to compute the maximum spotting distance over complex landscapes, for a given windspeed and fuel type, that particles of different sizes would travel (Figure 7). The spotting distance across the interface assumed that wind direction was down slope and into the urban area. In general, it is believed that these models are conservative and underestimate the actual spotting distances under conditions of running crown fire.

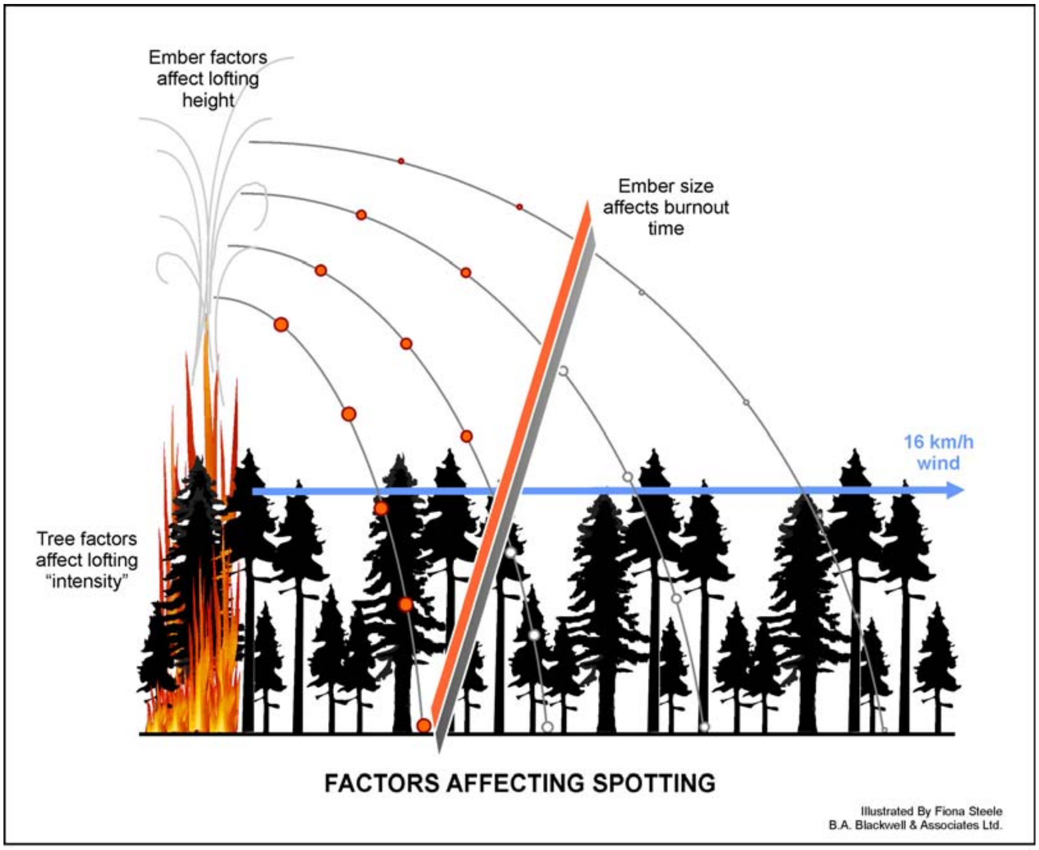

Figure 7. Graphic that shows factors affecting spotting.

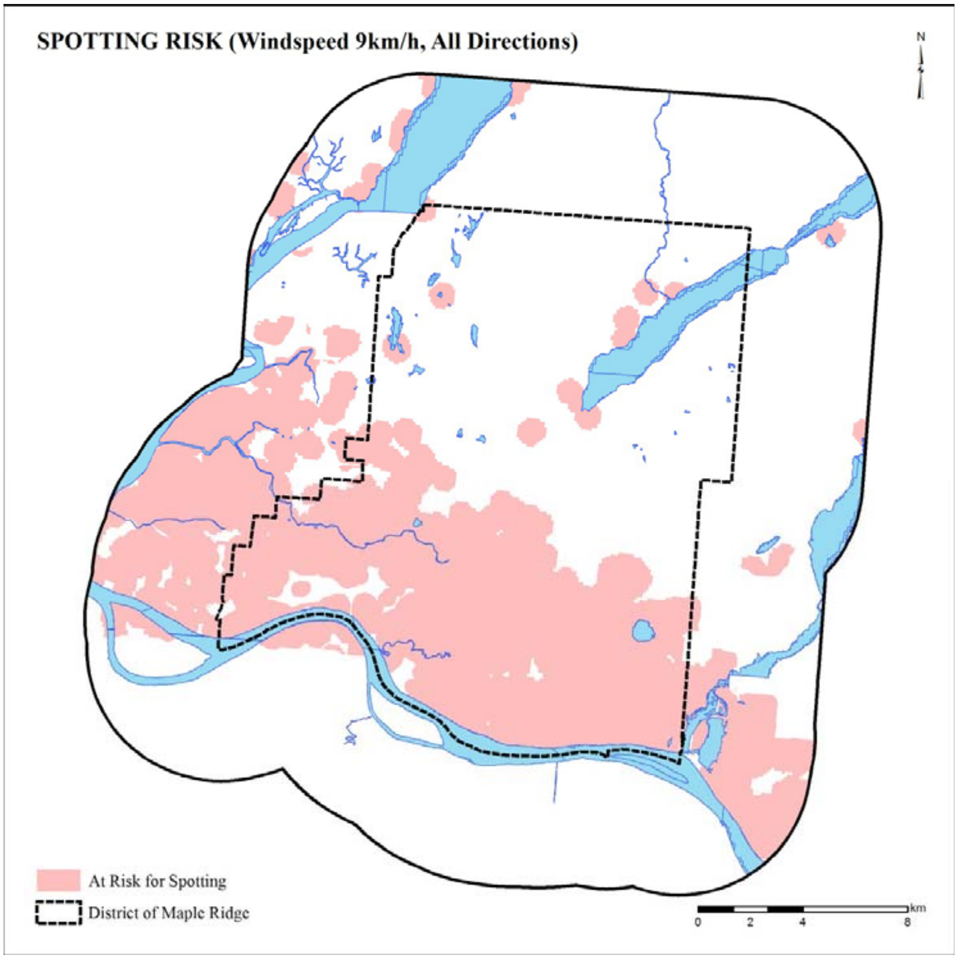

Figure 8. Map showing the polygon assignment of spotting distances based on fuel type, and fire behaviour potential for a 9-km/h windspeed.

4.2.3 Suppression Response Capability Component

Ability to suppress wildfire was dependent on the speed of detection, terrain, accessibility and availability of resources. Five subcomponents were used to determine overall suppression response capability. These included constraints to detection, proximity to water sources, air tanker arrival time, steepness of terrain, and proximity to roads (Figure 9). The subcomponent rating scales and assigned initial weights are shown in Appendix 1.

<u>Constraints to Detection</u>

In British Columbia, fires are detected by three primary methods that include a provincial lightning location system, aircraft, and/or by the public. Due to the unpredictability of flight frequency and public response, it was not possible to quantify the speed of detection. Detection is primarily a function of visibility limitations associated with high elevation cloud in specific parts of the study area. A storm front with varying amounts of precipitation can follow an active lightning period. This storm front creates cloud and fog within higher elevations zones of the study area during a 12 to 24 hour period following the storm. This cloud and fog cover inhibits the critical detection period; since most fire ignitions within the study area occur during the transition from a high to low-pressure weather system. The constraints to detection subcomponent were therefore based on elevation classes. The higher the elevation, the more likely detection will be constrained by cloud and fog cover. Elevation classes were assigned in increments of 500 m and were measured from sea level. Elevations greater then 1000 m were given the highest rating.

Proximity to Water Sources

Proximity to water sources was delineated using the hydrological base and only included determinant (perennial) water sources. Proximity to water sources for fire suppression (an indicator of the ability to access water quickly for fire fighting) was evaluated by creating a 100 m and 300 m buffer around all determinant rivers, creeks and lakes. Areas outside of the 300 m buffer were given the maximum subcomponent rating.

Air Tanker Arrival Time

The air tanker arrival time subcomponent was determined based on the distance from the closest air tanker base to the study area, the Abbotsford base. The ratings increased with greater distance from the base.

Terrain Steepness

Steepness of terrain influences the ability of a ground crew to build fireguards and carry out ground suppression. Average slope class was determined from the terrain data and ratings were assigned according to slope class.

Proximity to Roads

Proximity to roads was used to evaluate the accessibility of suppression resources reaching areas within a given landscape unit. It was evaluated based on a bush-walking rate of 1 km/h. Proximity to roads and helipads was rated by creating buffers around all roads in the study area and assigning weights relative to walking time from these areas. Alpine tundra was included as area accessible by helicopter.

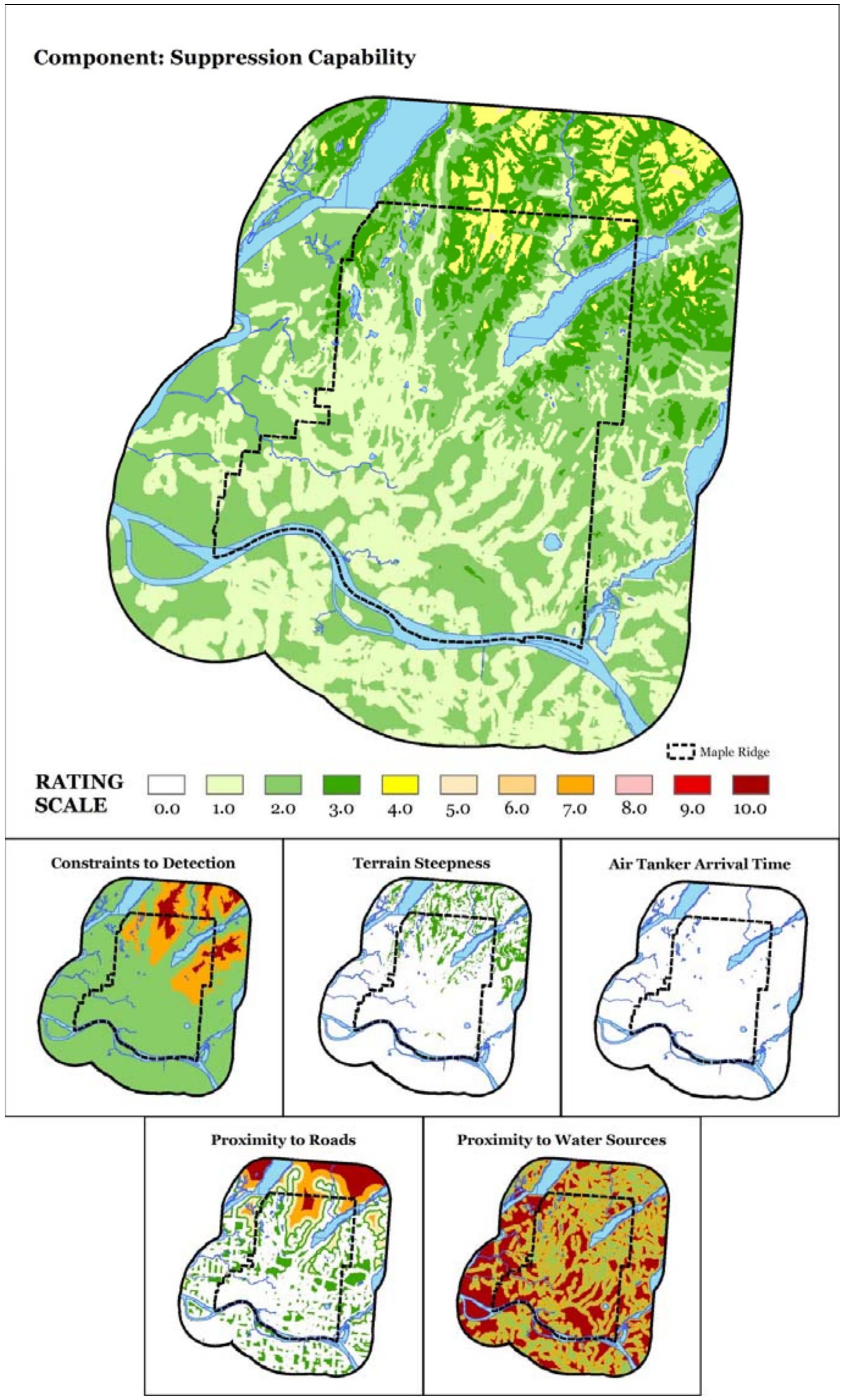

Figure 9. Suppression response capability component and associated subcomponents.

4.3 Development of Consequence Theme

4.3.1 Recreation Use Component

Providing recreation opportunity is an important mandate of the District. Although the probability of lightning caused forest fires within the study area is considered low, human caused fires present a substantial threat to the community. Overall, the consequence of fire impact on recreation use would be considerable.

The recreation use consequence component was developed using information on one sub-component that encompassed important areas for recreation (Figure 10). The subcomponent rating scales and assigned initial weights are shown in Appendix 1.

Parks

Regional parks and provincial parks were given the maximum rating of 10. Municipal parks were rated as 5.

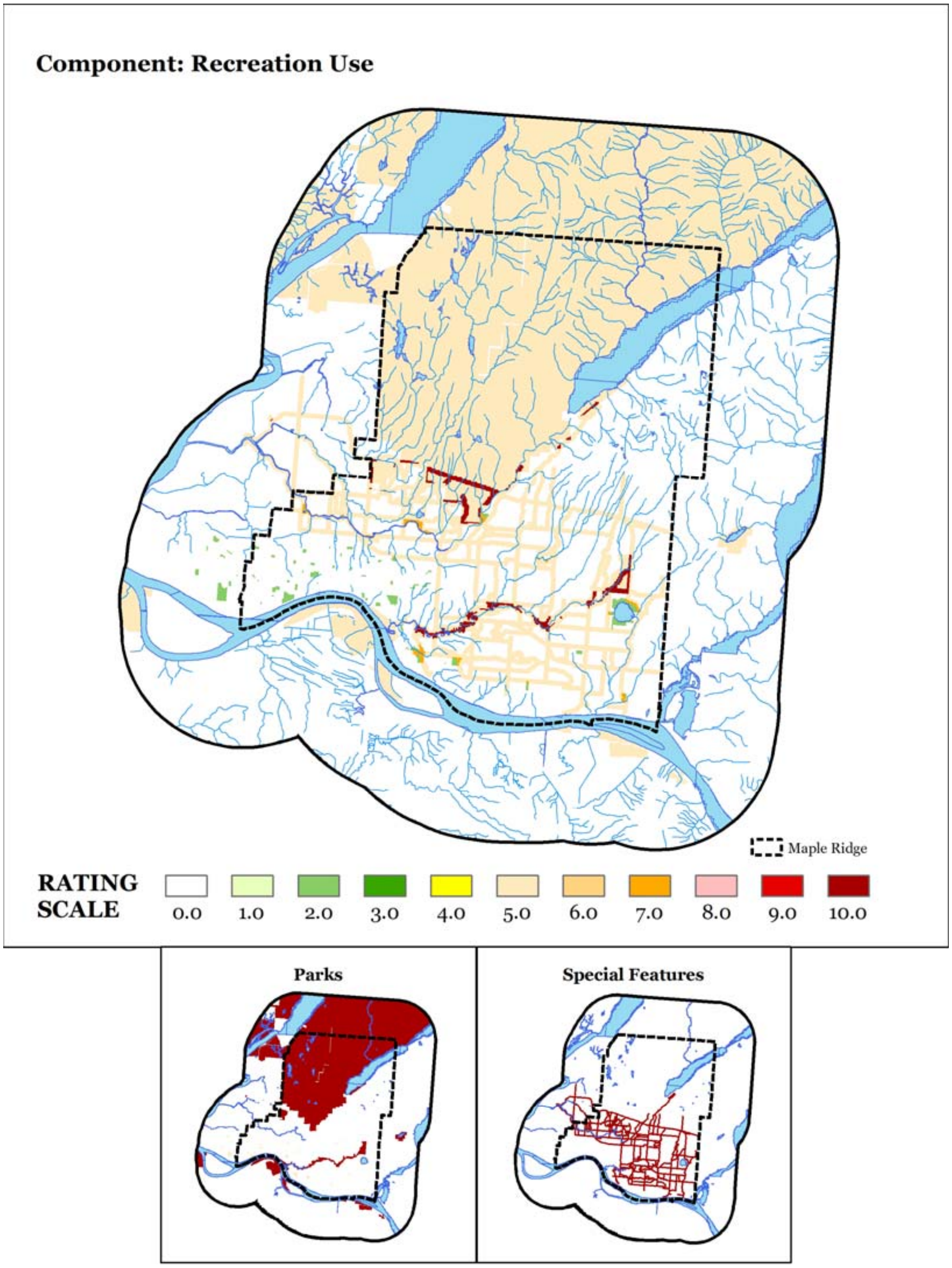

Figure 10. Recreation Use component

4.3.2 Air Quality Component

Wildfire within, and/or, adjacent to the District has the potential to substantially impact the air quality of the community. Wildfire caused smoke emissions could force a large-scale evacuation of the District lasting several days to a week. Smoke related air pollution is not a problem that can be confined to one location; it must be examined at a broader, landscape level. Because the forest landscape is in close proximity to the populated areas of the community, smoke and forest fire related emissions have the potential to notably impact regional air quality. The air quality component of the WRMS system was developed considering a number of related factors including proximity to population, smoke production potential, and smoke venting potential (Figure 11).

The WRMS system is considered useful for identification of potential air quality impacts of wildfires. However, given the complex topography of the area, actual air quality impacts from wildfires are difficult to accurately predict without detailed knowledge of airflow and other atmospheric parameters (*i.e.,* stability and mixing height) in the region, particularly near the areas of smoke release and the surrounding airshed. The subcomponent rating scales and assigned initial weights are shown in Appendix 1.

Proximity to Population

The proximity to population subcomponent was based on distance to population centres (urban interface). The ratings in this subcomponent were assigned with the assumption that wildfire in close proximity to residential areas would have more potential to impact air quality (with smoke emissions, ash and embers) than wildfire occurring far from residential areas.

Smoke Production Potential

Smoke production is based on several factors including the moisture content of the fuel, the heat of combustion and, most importantly, the amount of fuel present on a given site. Available biomass (a function of structural stage) was used as a surrogate for smoke production potential. It was assumed that higher amounts of biomass (forest floor and dead and living vegetation) contributed to increased amounts of smoke production. Smoke production potential was greatest in old forest of the Coastal Western Hemlock (CWH) zone, followed by young forest, pole sapling, and finally, shrub herb. Old and mature forest in the Mountain Hemlock (MH) was treated separately than the CWH old forest because the amount of available biomass that contributes to flaming combustion is potentially lower in the MH zones compared to the CWH zone.

Smoke Venting Potential

The ability of the atmosphere to disperse and transport smoke is commonly estimated using the ventilation index (VI), which is forecast daily by Environment Canada. Smoke venting potential is an indicator of potential smoke dispersion based on mixing height during poor VI days. Within the District WRMS, the smoke venting potential was rated as a function of elevation; where higher elevations had a higher smoke venting potential than lower elevations. Typically, fires that are sufficiently upslope of the valley bottom have a greater likelihood of transporting the smoke plume above the mixed layer and or the valley re-circulations, thereby allowing smoke to be mixed to higher elevations without being transported down the valley into nearby communities.

Monthly Smoke Venting Index

On any given day any range of ventilation conditions can occur, however, there is some seasonality to the ventilation index that makes the occurrence of good to poor ventilation index days more likely depending on the time of year. This subcomponent was included in the air quality component to provide a relative monthly comparison of smoke venting potential. During the fire season, September and October have poor venting conditions compared to May and June when the venting index is generally good. For the hotter months of July and August, smoke venting potential is average compared to other times during the year.

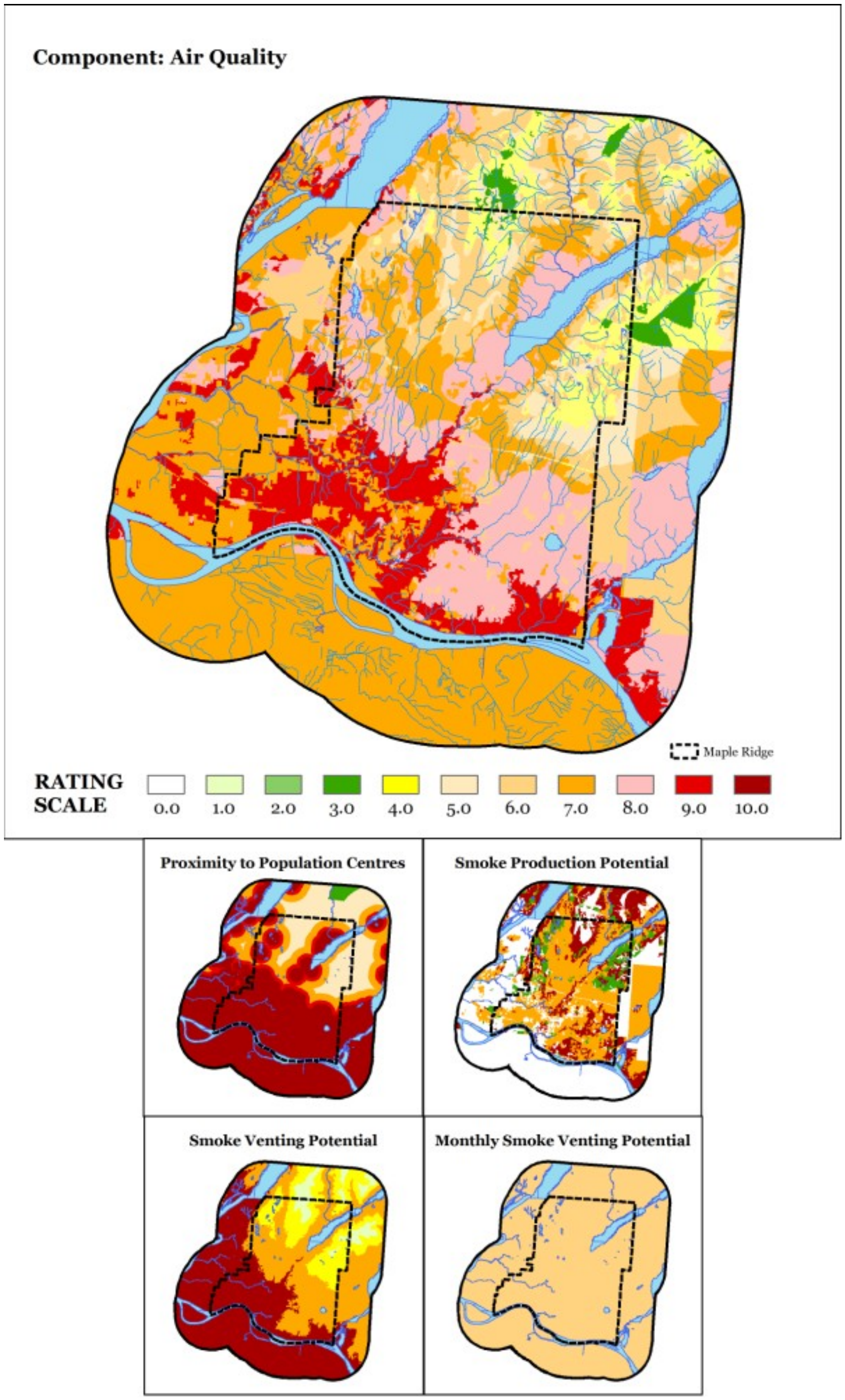

Figure 11. Air Quality component and associated subcomponents.

4.3.3 Visual Quality Component

Visual quality within the District is considered fundamental to the maintenance and integrity of community aesthetics and values. Large-scale fire has the potential to blacken much of the landscape, which would impair visual quality and therefore impact the aesthetic and recreational character of the District. The visual quality component provided a rating of the impact of a fire on visual quality from the vantage point of the District. It utilized the 1999 Visual Landscape Inventory done by Warren Fox. Areas rated most visually sensitive were assigned the maximum weighting of ten and areas not designated as visually sensitive were given a rating of zero (Figure 12).

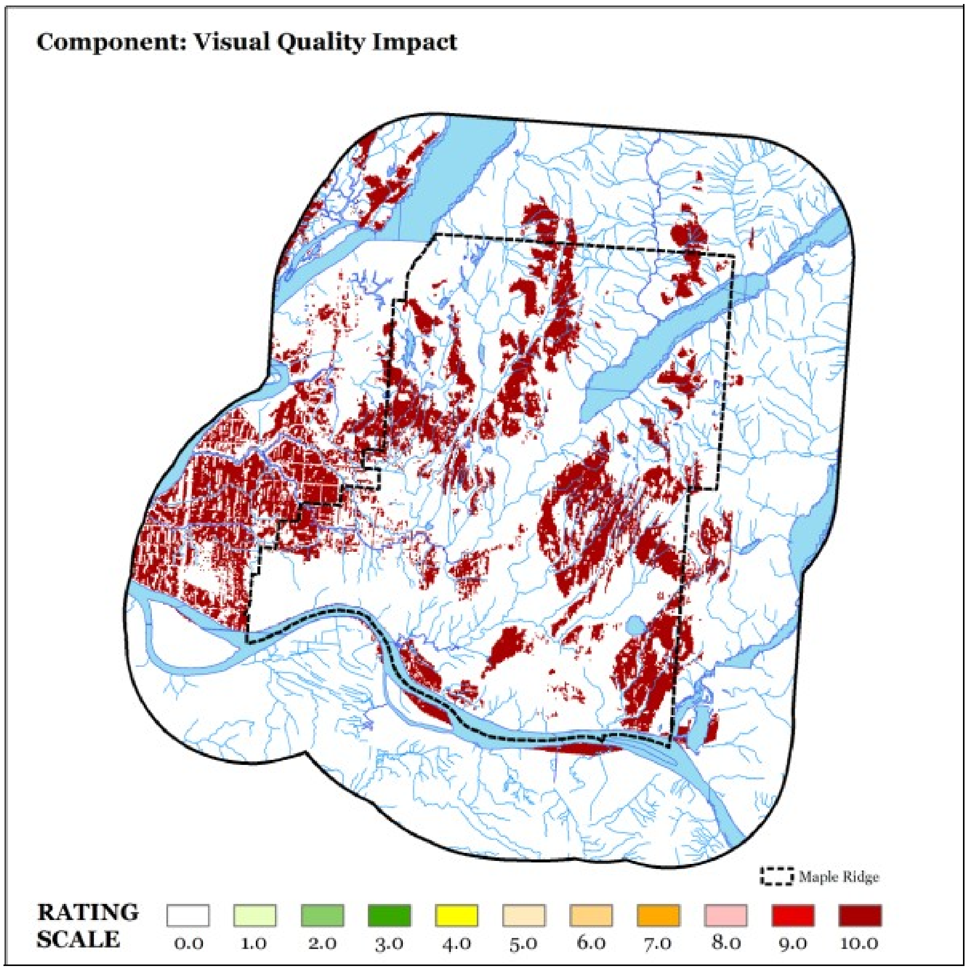

Figure 12. Visual Quality component.

4.3.4 Urban Interface Component

The Urban Interface component provided a rating of the potential for fire to pose a direct threat to people and property located in and around the District. It contained three subcomponents: interface, infrastructure and watersheds (Figure 13). The subcomponent rating scales and assigned initial weights are shown in Appendix 1.

Interface

The interface subcomponent was an indicator of threat to property and was based on structure density determined using TRIM. All anthological building features were extracted from this data set and buffered such that structural classes could be assigned based on their density on the District control, including building materials (*i.e.,* unrated roofing materials), defensible space around structures, access, water availability and vegetation within the proximity of homes.

Interface density classes were delineated as follows:

- Undeveloped 0-1 structures/km^2
- Isolated =1-10 structures/km^2
- Mixed = 10-100 structures/km^2
- Developed = 100-1000 structures/km^2
- Urban = > 1000 structures/km^2

The urban class was assigned a maximum rating, while area with no structures was assigned a rating of zero.

Infrastructure

The infrastructure subcomponent was an indicator of fire risk to key infrastructure within the District. The District established a list of key infrastructure which included: city hall, public works yard, fire stations, the hospital, RCMP detachment, federal prisons, BC Hydro dams (Ruskin and Stave Lake), microwave repeater towers, BCTC transmission lines, BC Government fish hatchery facility, BC Hydro Lodge, Mission Rod and Gun Club, and the Zajak Foundation Camp. All point locations were buffered by 500m and given maximum ratings.

Watersheds

The watershed component was developed as an indicator of the risk to water supply and water quality. The District's water supply is serviced by surface water from three community watersheds within the District. Given the importance of water quality to the community, the watersheds were given maximum ratings.

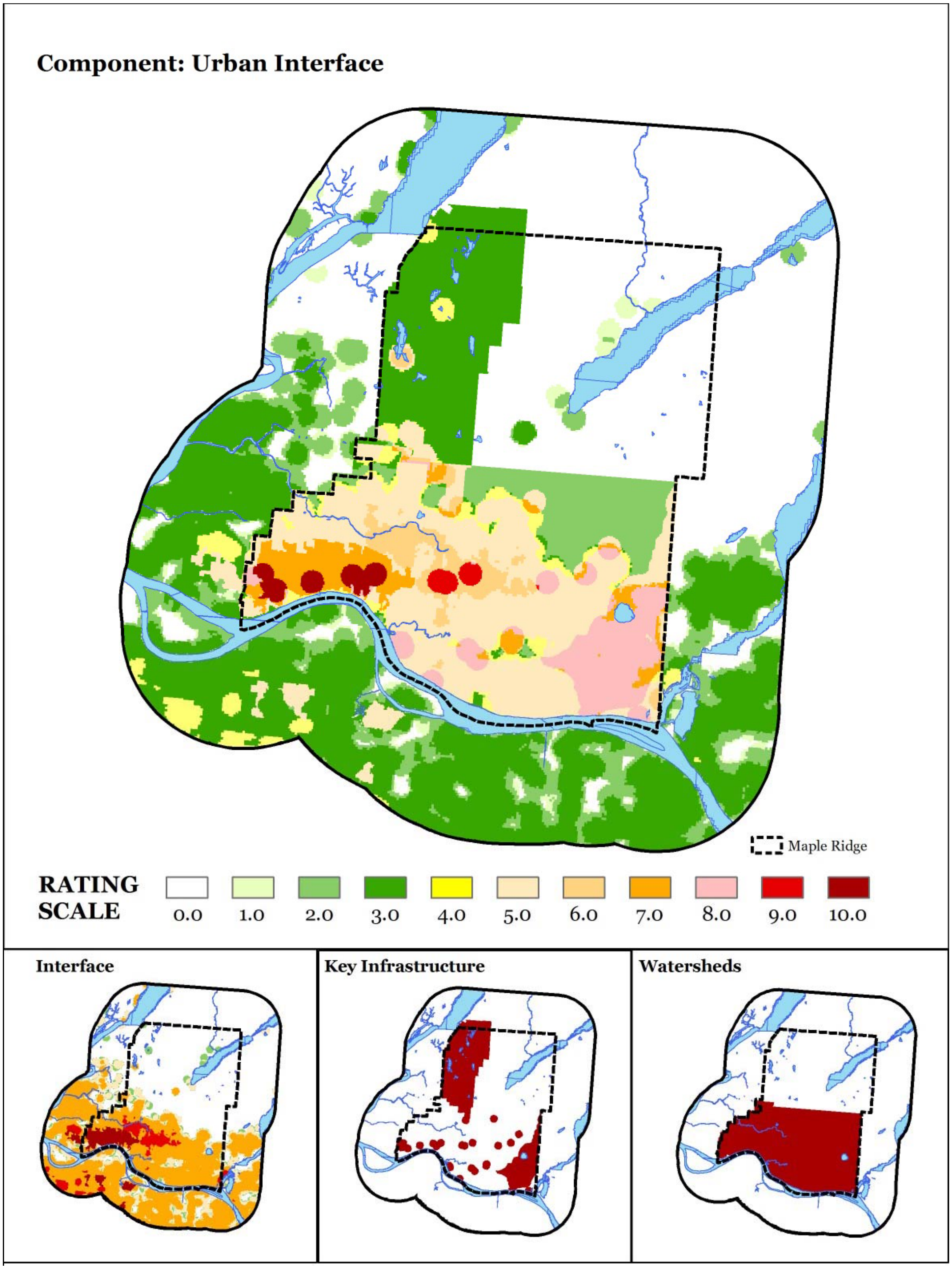

Figure 13. Urban Interface component and associated subcomponents.

4.3.5 Biodiversity Component

The biodiversity component was developed using one subcomponent: high value biodiversity areas from regional data provided by the District of Maple Ridge (originally provided by the GVRD). The subcomponent rating scales and assigned initial weights are shown in Appendix 1.

<u>High Value Biodiversity Areas</u>

The District encompasses ecologically sensitive areas including grasslands and riparian areas. In addition, unique habitat features have been identified in various locations within the District.

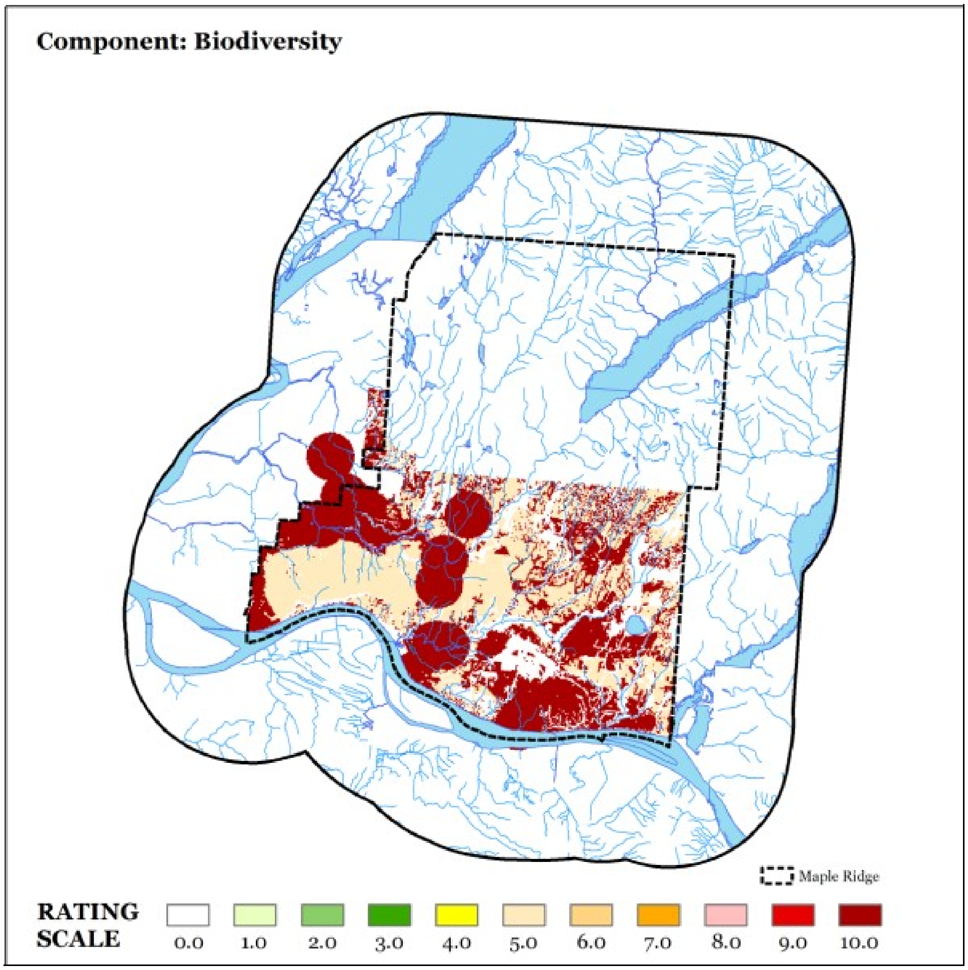

Figure 14. Biodiversity component.

5.0 Results

5.1 Overview

A schematic compilation of mapping outputs from the initial implementation of the District Wildfire Risk Management System is presented in Figure 15. The mapping outputs parallel the description of the model in the previous section. In other words:

- Subcomponents maps are generated using 0-10 rating scales derived from existing GIS databases and/or sub-model outputs;
- Component maps are generated using user-defined weights on each subcomponent (see Appendix 1); and,
- Final probability and consequence rating maps are generated using user-defined weights on each component (Figure 15).

A final probability/consequence overlay map is generated by overlaying the final rating maps (Figure 16).

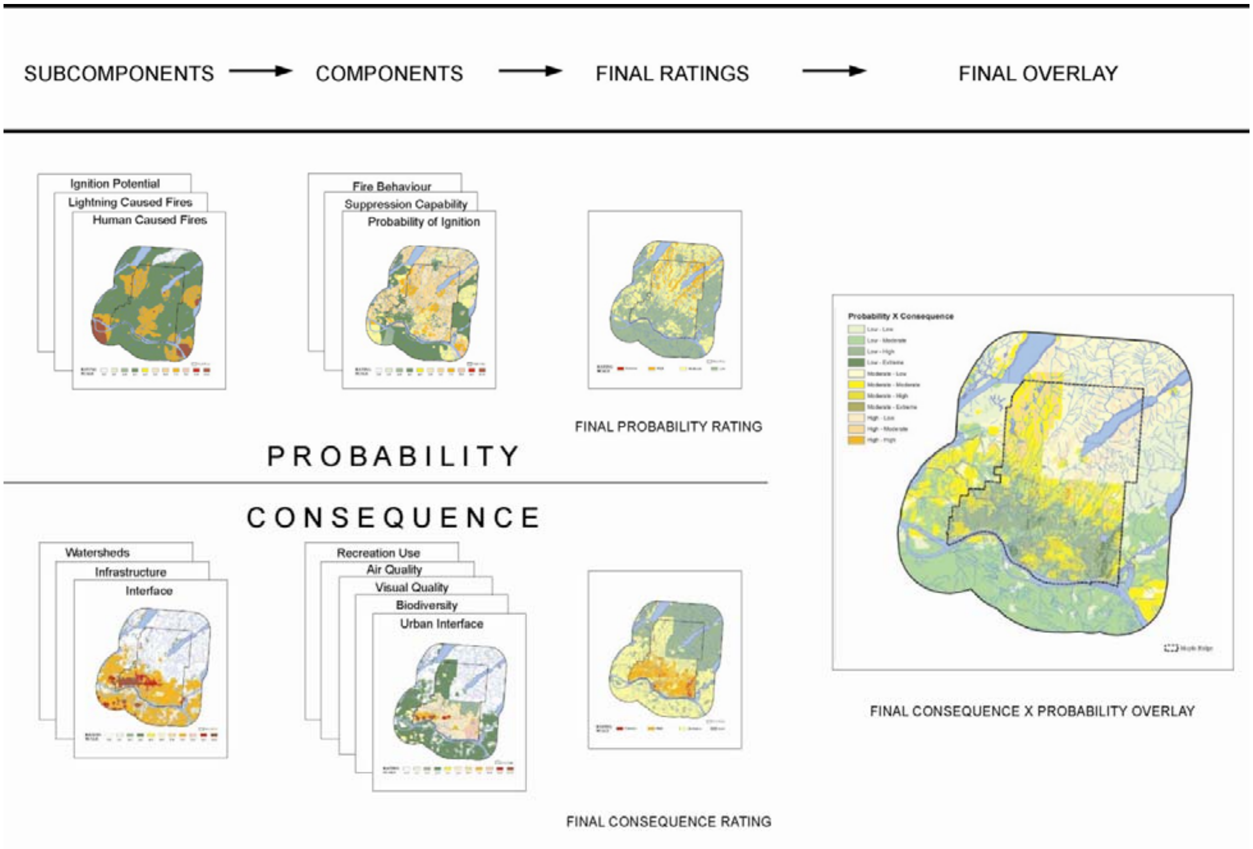

Figure 15. Summary mapping outputs from the District Wildfire Risk Management System.

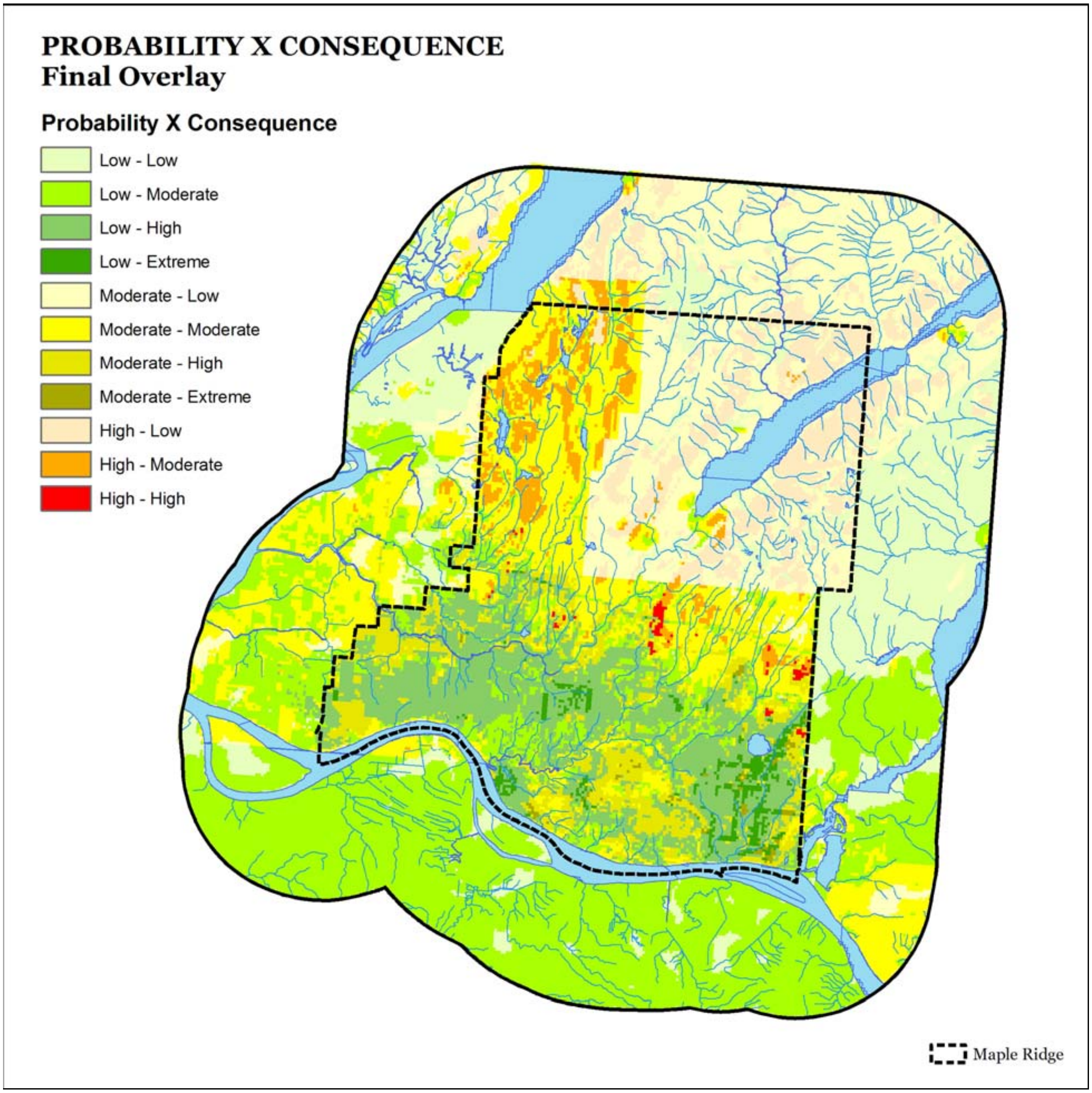

Figure 16. Final overlay of probability and consequence.

As shown in Figure 15 and all of the maps in Section 4, each component and subcomponent map applies a similar white-green-yellow-orange-red colour scheme depicting ratings on 0 – 10 scales. An expanded colour scheme was used to show all probability/consequence combinations for the final interpretation. In this manner the final probability/consequence overlay map in Figure 16 reflects the full range of risk spatially, within and adjacent to the District, from 'low probability- high consequence' areas through to 'high probability-low consequence' areas for extreme fire conditions.

These final mapping outputs are the result of multiple interactive workshops, during which the project team evaluated the accuracy and consistency of each subcomponent and component. The weights used to generate these outputs at the component level are shown in Figure 17.

In overview, the area of highest consequence is located within and adjacent to the interface areas of the District. This was expected given the identified values at risk. In terms of wildfire probability, there is a relatively large area of moderate to high fire probability in the lower elevations where the District and the UBC Research Forest are located. This probability declines with increasing elevation out of the valley bottom. These probability ratings are driven largely by human ignitions and the fire behaviour potential of young forest stands established by historic logging. The probabilities of ignition and fire behaviour are offset by good suppression capability afforded by roads, water sources and the gentle terrain associated with the valley bottom.

Probability Component (PC)	Scale	Weight (W)
Ignition	0 - 10	30%
Fire Behaviour	0 - 10	30%
Suppression	0 - 10	40%
		100%

Consequence Component (CC)	Scale	Weight (W)
Urban Interface	0 - 10	50%
Visual Quality	0 - 10	10%
Air Quality	0 - 10	20%
Recreation Use	0 - 10	10%
Biodversity	0 - 10	10%
		100%

Figure 17. Initialized weights on all components.

Overall, the community has a moderate to high probability of fire within and adjacent to the community and the consequence of fire within District limits is moderate to high given that resource values included in the analysis.

5.2 Data Quality Issues

The data provided by the forest cover inventory was fundamental to the development of many of the underlying spatial GIS databases. The forest cover inventory databases (MOF) included substantial validation efforts and therefore we are confident in the overall accuracy of this data.

However, one concern directly related to the fire management data used, as part of this project was fuel typing. Since these data sources are fundamental to the development of the fire behaviour themes, we expand on these concerns below.

5.2.1 Fuel Typing

As part of the provincial fuel type classification program, the Ministry of Forests Protection Branch completed fuel typing of the provincial forest land adjacent to the District of Maple Ridge (Hawkes et. al. 1995). This classification applies the Canadian Fire Behaviour Prediction (FBP) System fuel type classification using a detailed algorithm that relates specific attributes of standard forest cover inventory data to specific fuel types within the FBP classification scheme (Taylor et. al. 1997).

For most of the fuel types present in the study area there is was a good fit with FBP types. For example, we used C4 for pole sapling forests and C3 for young forest, which have worked well. The qualitative attributes of these FBP fuel types are similar and representative of the structural attributes present within these forest types of the adjacent landscape

However for other fuel types, the relationship is considered to be poor. In particular, the old forests of the District, which represent a significant portion of the total area, do not correspond well with any of the FBP types. In discussion with CFS and the Ministry of Forests Protection Branch fire behaviour specialists, it was determined that C5 should be substituted for M2 in an attempt to alter these fire behaviour outputs to levels considered more realistic for both the weather and fuel conditions present within the District. The substitution of C5 for M2 resulted in an improved result, particularly for the old forest types in the CWHvm2 and MHmm1. However, it was felt that for CWHvm1 and CWHdm old forests the fire behaviour prediction might now under-predict the overall fire behaviour potential. Figure 19 below provides a comparison of MOF fuel typing and updated fuel types for the study area.

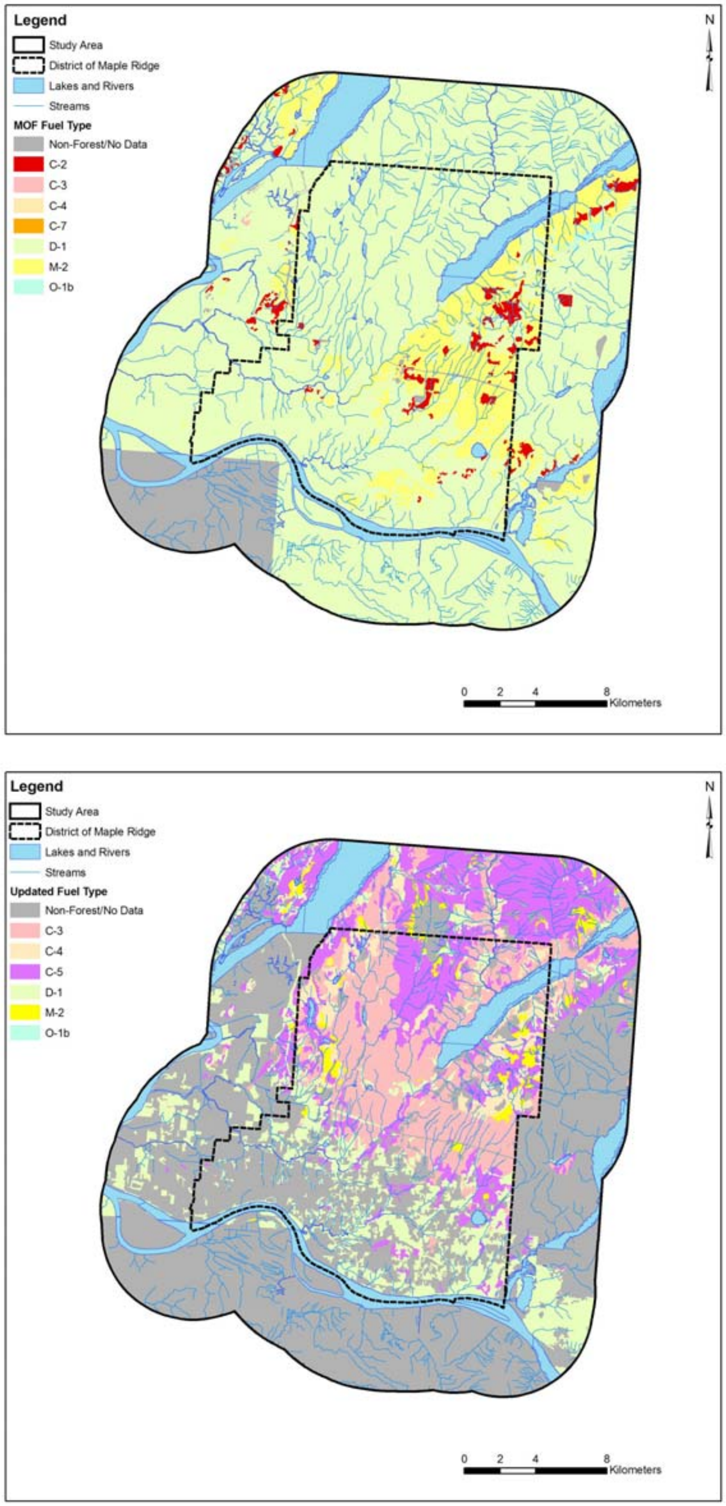

Figure 18. Comparison of original MOF fuel typing (top) and updated fuel typing (bottom) for the District.

6.0 Applications in the Fire Management Plan for the District of Maple Ridge

The development of the District of Maple Ridge WRMS has benefited from the collaborative approach of the District. This translated to a willingness to learn and explore the fire risk elements that could impact the District. The process will allow interested parties to understand the various phases of model development and will create an education to tool for public education and overall fire management planning. The model provides useful outputs to assist in developing strategic fire management strategies.

The District WRMS provides a comprehensive assessment of the wildfire risk within and adjacent to the community. The assessment can be used to further develop strategic fire management zones for the fire management program as described within the Fire Management Plan.

Fire protection resources can undergo a detailed evaluation of suppression response capability. The level of risk, as identified by the WRMS, can prioritize efficient use of these resources. By improving the fire suppression capability, the risk of wildfire can be reduced. This may require the acquisition of more resources (water delivery systems) or modification of existing practices (helicopter contract response times).

The current WRMS has utilized the most appropriate fuel types from the Canadian Fire Behaviour Prediction System for District lands. Modified stands from fuel hazard treatments (wildland/urban interface) or other disturbance such as insects (mountain pine beetle) produce a unique fuel type in the short-term. The development of new model algorithms is required to properly assess how fire behaviour and ignition potential in these stands would change in the future. A change in fire behaviour and ignition potential may reflect a higher or lower risk of wildfire.

7.0 Acknowledgements

We acknowledge the active participation of Peter Grootendorst (Fire Chief) and David Cooke (GIS Department) from the District of Maple Ridge. Judi Beck, BC Ministry of Forests Protection Branch provided provincial fuel typing algorithms. Amelia Needoba of B.A. Blackwell and Associates Ltd. implemented the system. Claire Tweedsdale of Forest Ecosystem Solution Ltd. did the GIS programming for spotting.

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9.0 Appendix 1: WRMS model subcomponent rating scales and weights

9.1 Probability Component Tables

Wildfire Risk Management Component: **Ignition**

The Ignition component provides a rating of the probability of wildfire occurring in a given location based on historical fire frequency. The rating is calculated as a weighted sum rating using two attributes: **Lightning Caused Fires,** and **Human Caused Fires.**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Lightning Caused Fires *Indicator of historical frequency of lightning caused fires*	# of fires/500m buffer	>4	10	30%
		3 - 4	7	
		1 - 2	3	
		0	0	
Human Caused Fires *Indicator of historical frequency of human caused fires*	# of fires/500m buffer	>4	10	30%
		3 - 4	7	
		1 - 2	3	
		0	0	
Ignition Potential *Indicator of the potential for fire ignition based on fuel type and weather, calculated using WIPP (Wildfire Ignition Probability Predictor)*	Probability Class	Extreme	10	40%
		Very High	8	
		High	6	
		Moderate	4	
		Low	2	

Wildfire Risk Management Component: **Fire Behaviour**

The Fire Behaviour component provides a rating of the probability of a wildfire exhibiting extreme behaviour in a given location given existing fuel types and 90th percentile weather conditions. The rating is calculated as a weighted sum rating using three attributes that are output from the FBP system: **Fire Intensity, Rate of Spread,** and **Crown Fraction Burned.**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Fire Intensity *Indicator of the rate of heat energy released.*	kilowatts per metre	> 10,000	10	45%
		4,001 - 10,000	8	
		2,001 - 4,000	6	
		501 - 2,000	4	
		10 - 500	2	
		0 - 9	0	
Rate of Spread *Indicator of speed at which fire extends horizontally.*	metres per minute	> 20	10	45%
		16 - 20	7	
		11 - 15	5	
		6 - 10	3	
		0 - 5	0	
Crown Fraction Burned *Indicator of the proportion of tree crowns consumed by fire (i.e., a measure of tree mortality).*	%	50 - 100	10	10%
		40 - 50	8	
		20 - 39	6	
		10 - 19	4	
		1 - 9	2	
		0	0	

Wildfire Risk Management Component: **Suppression Response Capability**

The Suppression component provides a rating of the probability that a wildfire could be quickly exterminated in a given location given existing resources. The rating is calculated as a weighted sum rating using five attributes: **Contraints to Detection, Proximity to Water Sources, Helicopter Attack Time, Terrain Steepness,** and **Proximity to Roads and Helipads.**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Constraints to Detection *Indicator of the ability to detect a fire: reconnaissance at higher elevations is often constrained by cloud cover.*	elevation metres	> 1000	10	10%
		501 - 1000	7	
		0 - 500	2	
Proximity to Water Sources *Indicator of the ability to access water quickly for fire fighting. Based on distance from all season streams and lakes.*	distance metres	>300	10	10%
		101-300	7	
		0-100	2	
Air Tanker Arrival Time *Indicator of time for air tanker action measured as flight time (concentric) from Abbotsford (300k/hr)*	minutes	> 40	10	30%
		31 - 40 (200km)	7	
		21 - 30 (150km)	5	
		11 - 20 (100km)	3	
		0 - 10 (50km)	0	
Terrain Steepness *Indicator of the difficulty of control/contain on the landscape.*	slope Class %	> 60	10	40%
		41 - 60	7	
		21 - 40	3	
		0 - 20	0	
Proximity to Roads and Helipads *Indicator of the ability to get suppression resources into an area: based on a bush walking rate of 1 km / hour.*	minutes	> 120 (>2km)	10	10%
		61 - 120 (2 km)	7	
		31 - 60 (1km)	5	
		16 - 30 (500m)	3	
		0 -15 (250m)	0	

9.2 Consequence Component Tables

Wildfire Risk Management Component: **Urban Interface**

The property component provides a rating of the potential for a fire to pose a direct threat to people and property. The impact is calculated as a weighted sum rating using three attributes; **Interface Density, Key Infrastructure** and **Watersheds**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Interface *Indicator of threat to private and public property. Density class (from TRIM) = Build-up areas and # of structures/km*2*	Weight by density class	Urban	10	50%
		Developed	9	
		Mixed	7	
		Isolated	5	
		Undeveloped	2	
		None	0	
Key Infrastructure *Indicator of the threat to critical community infrastructure: buffer 500m*	Community Importance	High	10	30%
			0	
Watershed	Community Watershed	High	10	20%

Wildfire Risk Management Component: **Visual Quality Impact**

The Visual Quality Impact component provides a rating of the impact that a fire would have on visual quality from both regional and local vantage points. The impact is calculated based on ratings of **Existing Visual Quality.**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Existing Visual Quality *Indicator of the visual quality rating for Visual Sensitivity Units as delineated from important local vantage points.*	Visually Sensitive Polygons	Visually Sensitive	10	100%

Wildfire Risk Management Component: **Air Quality Impact**

The Air Quality Impact component provides a rating of the impact that a fire would have on regional air quality within the Maple Ridge airshed. The impact is calculated as a weighted sum rating using four attributes: **Proximity to Population Centres, Smoke Production Potential, Smoke Venting Potential** and **Monthly Smoke Venting Potential.**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Proximity to Population Centres *Indicator of the distance to populated areas.*	distance (D) kilometres	D <=500 m	10	30%
		1 km > D > 500 m	9	
		2 km > D > 1 km	7	
		5 km > D > 2 km	5	
		10 km > D > 5 km	3	
		25 km > D > 10 km	1	
		D > 25 km	0	
Smoke Production Potential *Indicator of the potential for smoke production as a function of seral stage (overall biomass, forest floor depth, etc.)*	N/A	Old & Mature	10	20%
		Young	7	
		Old & Mature MH	5	
		Pole Sapling	3	
		Shrub / Herb	0	
Smoke Venting Potential *Indicator of the potential for smoke dispersion based on the mixing height during poor ventilation index days*	by elevation (E) metres	height < 100m	10	30%
		500m > H > 100m	7	
		1000m > H > 500m	4	
		H > 1000m	1	
Monthly Smoke Venting Potential *Indicator of the potential for smoke dispersion based on month*	by month	Jan	10	20%
		Nov, Dec	9	
		Feb	8	
		Sept, Oct	7	
		Aug	6	
		Mar	4	
		May	3	
		Jun, July	2	
		Apr	1	

Wildfire Risk Management Component: **Recreation Use**

The Recreation component provides a rating of the potential for a fire to pose a direct threat to people and property in and around the District of Maple Ridge and or impact special features within the community. The impact is calculated as a weighted sum rating using two attributes: **Parks** and **Special Features**.

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Parks *Indicator of the threat to recreation use areas*	Park boundary	Municipal	5	50%
		Regional	10	
		Provincial	10	
Special Features *Special features identified within the study area and rated as extreme, high, moderate, or low*	Buffer 100m around feature	Buffer	10	50%

Wildfire Risk Management Component: **Biodiversity**

The biodiversity component provides a rating of the potential for a fire to pose a direct threat to valued ecosystem resources in the District. The impact is calculated as a weighted sum rating using **High Value Biodiversity Areas.**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
High Value Biodiversity Areas		Unique Featurese SARA	10	100%
		Ecologically Sensitive Areas Moderate	10	
		Ecologically Sensitive Areas Low	5	

10.0 Appendix 2: The Wildfire Ignition Probability Prediction System (WIPPs)

(1) Format of the Standard WIPP Equation is :

P = 1 / {1 + exp[B0 + B1*FFMC + B2*DMC + B3*DC + B4*BUI + B5*FWI + B6*ISI] }

(2) Standard Association of FBP Fuel Types and WIPP Equations:

Table 1 provides the suggested standard association of WIPP equation to FBP Fuel types.

(3) Possible Association of WIPP Equations to FBP Fuel Types

The option exists to change the choice of the WIPP equation, which is used for each FBP fuel type. The default option, which is the first equation listed, and the subsequent possible options are listed in Table 2. These possible associations are from Lawson and Armitage (1997)

(4) Relationship of WIPP Equations to General Fuel Type and Provincial Experimental Sites

Table 3 details the general fuel types and provincial test sites that were used to create the individual WIPP equations.

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Lawson, B.D., O.B. Armitage. 1997. Ignition Probability Equations for some Canadian Fuel Types. Report submitted to the Canadian Committee on Forest Fire Management. (Draft report).

Table 1 : Standard Association of FBP Fuel Types and WIPP Equations

FBP Fuel	WIPP Eqn	WIPP Equation
C1	1A	P = 1/(1+EXP(5.061 - 0.086*FFMC))
C2	9C	P = 1/(1+EXP(33.299 - 0.353*FFMC - 0.057*DMC))
C3	6A	P = 1/(1+EXP(2.199 - 0.021*DMC - 0.265*ISI))
C4	6-5012	P = 1/(1+EXP(3.731 - 0.079*DMC - 0.185*ISI))
C5	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
C6	BC Dry Pine	P = 1/(1+EXP(2.107 - 0.727*ISI))
C7	4BC	P = 1/(1+EXP(1.563 - 0.005*BUI - 0.478*ISI))
D1	8C	P = 1/(1+EXP(12.781 - 0.121*FFMC - 0.032*DMC))
D2	8	P = 1/(1+EXP(14.0 - 0.121*FFMC - 0.010*DMC))
M1	7A	P = 1/(1+EXP(25.540 - 0.264*FFMC - 0.036*DMC))
M2	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
M3	9A	P = 1/(1+EXP(2.144 - 0.423*ISI))
M4	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
S1	2A	P = 1/(1+EXP(7.219 - 0.107*FFMC))
S2	2A	P = 1/(1+EXP(7.219 - 0.107*FFMC))
S3	2A	P = 1/(1+EXP(7.219 - 0.107*FFMC))
O1a	SaA	P = 1/(1+EXP(0.161 - 0.016*DMC -0.240*ISI))
O1b	SaA	P = 1/(1+EXP(0.161 - 0.016*DMC -0.240*ISI))

Table 2: Possible Association of WIPP Equations to FBP Fuel Types

FBP Fuel	WIPP Eqn	WIPP Equation
C1	1A	P = 1/ (1+EXP(5.061 - 0.086*FFMC))
C1	1B	P = 1/ (1+EXP(1.965 - 0.704*ISI))
C1	1C	P = 1/ (1+EXP(0.837 - 1.020*ISI))
C2	9C	P = 1/(1+EXP(33.299 - 0.353*FFMC - 0.057*DMC))
C2	9A	P = 1/(1+EXP(2.144 - 0.423*ISI))
C2	9B	P = 1/(1+EXP(10.675 - 0.112*FFMC - 0.100*DMC))
C2	9D	P = 1/(1+EXP(11.677 - 0.123*FFMC - 0.027*DMC))
C2	9E	P = 1/(1+EXP(6.438 - 0.077*DMC – 0.357*ISI))
C2	9BC	P = 1/(1+EXP(2.766 - 0.005*DC - 0.396*ISI))
C3	6A	P = 1/(1+EXP(2.199 - 0.021*DMC - 0.265*ISI))
C3	6-5012	P = 1/(1+EXP(3.731 - 0.079*DMC - 0.185*ISI))
C3	6-6017	P = 1/(1+EXP(1.754 - 0.021*DMC - 0.282*ISI))
C3	6B	P = 1/(1+EXP(14.424 - 0.171*FFMC - 0.017*DMC))
C3	BC Dry Pine	P = 1/(1+EXP(2.107 - 0.727*ISI))
C3	BC Moist Pine	P = 1/(1+EXP(2.146 - 0.009*BUI -0.349*ISI))
C4	6-5012	P = 1/(1+EXP(3.731 - 0.079*DMC - 0.185 ISI))
C4	6A	P = 1/(1+EXP(2.199 - 0.021*DMC - 0.265*ISI))
C4	6-7015	P = 1/(1+EXP(2.199 - 0.022*DMC - 0.119*ISI))
C4	6B	P = 1/(1+EXP(14.424 - 0.171*FFMC - 0.017*DMC))
C4	BC Dry Pine	P = 1/(1+EXP(2.107 - 0.727*ISI))
C4	BC Moist Pine	P = 1/(1+EXP(2.146 - 0.009*BUI -0.349*ISI))
C5	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
C5	6A	P = 1/(1+EXP(2.199 - 0.021*DMC - 0.265*ISI))
C5	9A	P = 1/(1+EXP(2.144 - 0.423*ISI))
C5	9E	P = 1/(1+EXP(6.438 - 0.077*DMC – 0.357*ISI))
C6	BC Dry Pine	P = 1/(1+EXP(2.107 - 0.727*ISI))
C6	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
C6	6A	P = 1/(1+EXP(2.199 - 0.021*DMC - 0.265*ISI))
C6	6-5012	P = 1/(1+EXP(3.731 - 0.079*DMC - 0.185*ISI))
C6	9C	P = 1/(1+EXP(33.299 - 0.353*FFMC - 0.057*DMC))
C6	9D	P = 1/(1+EXP(11.677 - 0.123*FFMC - 0.027*DMC))
C7	4BC	P = 1/(1+EXP(1.563 - 0.005*BUI - 0.478*ISI))
D1	8C	P = 1/(1+EXP(12.781 - 0.121*FFMC - 0.032*DMC))
D1	8A	P = 1/(1+EXP(3.503 - 0.044*DMC - 0.407*ISI))

FBP Fuel	WIPP Eqn	WIPP Equation
D1	8B	P = 1/(1+EXP(5.026 - 0.233*ISI))
D2	8	P = 1/(1+EXP(14.0 - 0.121*FFMC - 0.010*DMC))
M1	7A	P = 1/(1+EXP(25.540 - 0.264*FFMC - 0.036*DMC))
M1	7B	P = 1/(1+EXP(45.827 - 0.491*FFMC))
M2	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
M2	9A	P = 1/(1+EXP(2.144 - 0.423*ISI))
M2	9B	P = 1/(1+EXP(10.675 - 0.112*FFMC - 0.100*DMC))
M2	9C	P = 1/(1+EXP(33.299 - 0.353*FFMC - 0.057*DMC))
M2	9D	P = 1/(1+EXP(11.677 - 0.123*FFMC - 0.027*DMC))
M2	9E	P = 1/(1+EXP(6.438 - 0.077*DMC – 0.357*ISI))
M3	9A	P = 1/(1+EXP(2.144 - 0.423*ISI))
M3	9B	P = 1/(1+EXP(10.675 - 0.112*FFMC - 0.100*DMC))
M3	9C	P = 1/(1+EXP(33.299 - 0.353*FFMC - 0.057*DMC))
M3	9D	P = 1/(1+EXP(11.677 - 0.123*FFMC - 0.027*DMC))
M3	9E	P = 1/(1+EXP(6.438 - 0.077*DMC – 0.357*ISI))
M3	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
M4	9BC	P = 1/(1+EXP(2.766 - 0.005*DC -0.396*ISI))
M4	9A	P = 1/(1+EXP(2.144 - 0.423*ISI))
M4	9B	P = 1/(1+EXP(10.675 - 0.112*FFMC - 0.100*DMC))
M4	9C	P = 1/(1+EXP(33.299 - 0.353*FFMC - 0.057*DMC))
M4	9D	P = 1/(1+EXP(11.677 - 0.123*FFMC - 0.027*DMC))
M4	9E	P = 1/(1+EXP(6.438 - 0.077*DMC – 0.357*ISI))
S1	2A	P = 1/(1+EXP(7.219 - 0.107*FFMC))
S2	2A	P = 1/(1+EXP(7.219 - 0.107*FFMC))
S3	2A	P = 1/(1+EXP(7.219 - 0.107*FFMC))
O1a	SaA	P = 1/(1+EXP(0.161 - 0.016*DMC -0.240*ISI))
O1a	SbA	P = 1/(1+EXP(46.942 - 0.508*FFMC -0.063*DMC))
O1b	SaA	P = 1/(1+EXP(0.161 - 0.016*DMC -0.240*ISI))
O1b	SbA	P = 1/(1+EXP(46.942 - 0.508*FFMC -0.063*DMC)

Table 3: Relationship of WIPP Equations to General Fuel Type and Provincial Experimental Sites

FBP Fuel	WIPP Eqn	General Fuel Type(s)	Provincial Site(s)
C1	1A	Cladonia	NF (101-5), MB (501-6)
C1	1B	Pine-Cladonia, Spruce-Cladonia	AB-Whitecourt (702-2,702-8)
C1	1C	Cladonia	SK (601-6)
C2	9C	Spruce	NWT (901-3)
C2	9A	Spruce-Fir	NF (101-3)
C2	9B	Spruce	NF (101-4)
C2	9D	Pine-Spruce,Spruce,Spruce-Pine	MB (501-1),SK (601-4), AB-Kananaskis (701-9)
C2	9E	Spruce, Spruce	AB-Whitecourt (702-6, 702-7)
C2	9BC	White Spruce-Subalpine Fir	BC-Prince George
C3	6A	Closed Jack Pine/Lodgepole Pine, Pine-Spruce, Balsam Fir	NF (101-1), SK (601-7, 601-8), MB (501-2, 501-5, 501-9), AB-Kananaskis (701-5, 701-6), AB-Whitecourt (702-3) NWT (901-2)
C3	6-5012	Jack Pine (JY2)	MB (501-2)
C3	6-6017	Pine	SK (601-7)
C3	6B	Pine, Jack Pine	AB-Whitecourt (702-1), NWT (901-1)
C3	BC Dry Pine	Lodgepole Pine (Dry)	BC-Prince George
C3	BC Moist Pine	Lodgepole Pine (Moist)	BC-Prince George
C4	6-5012	Jack Pine (JY2)	MB (501-2)
C4	6A	See C3 – 6A above	
C4	6-7015	Lodgepole Pine (L4)	AB-Kananaskis (701-5)
C4	6B	Pine, Jack Pine	AB-Whitecourt (702-1), NWT (901-1)
C4	BC Dry Pine	Lodgepole Pine (Dry)	BC-Prince George
C4	BC Moist Pine	Lodgepole Pine (Moist)	BC-Prince George
C5	9BC	White Spruce-Subalpine Fir	BC-Prince George
C5	6A	See C3 – 6A above	
C5	9A	Spruce-Fir	NF (101-3)
C5	9E	Spruce, Spruce	AB-Whitecourt (702-6, 702-7)
C6	BC Dry Pine	Lodgepole Pine (Dry)	BC-Prince George
C6	9BC	White Spruce-Subalpine Fir	BC-Prince George
C6	6A	See C3 – 6A above	
C6	6-5012	Jack Pine (JY2)	MB (501-2)

FBP Fuel	WIPP Eqn	General Fuel Type(s)	Provincial Site(s)
C6	9C	Spruce	NWT (901-3)
C6	9D	Pine-Spruce,Spruce,Spruce-Pine	MB (501-1),SK (601-4), AB-Kananaskis (701-9)
C7	4BC	Interior Douglas Fir (open w/grass)	BC
D1	8C	Poplar-Birch, Poplar, Aspen	MB (501-4,501-8), NWT (901-6)
D1	8A	Pine-Poplar, Aspen	AB-Whitecourt (702-4, 702-5)
D1	8B	Aspen	SK (601-1)
D2	8	See Note	
M1	7A	Spruce-Aspen-Pine	NWT (901-5)
M1	7B	Poplar-Spruce-Pine	NWT (901-4)
M2	9BC	White Spruce-Subalpine Fir	BC-Prince George
M2	9A	Spruce-Fir	NF (101-3)
M2	9B	Spruce	NF (101-4)
M2	9C	Spruce	NWT (901-3)
M2	9D	Pine-Spruce,Spruce,Spruce-Pine	MB (501-1),SK (601-4), AB-Kananaskis (701-9)
M2	9E	Spruce, Spruce	AB-Whitecourt (702-6, 702-7)
M3	9A	Spruce-Fir	NF (101-3)
M3	9B	Spruce	NF (101-4)
M3	9C	Spruce	NWT (901-3)
M3	9D	Pine-Spruce,Spruce,Spruce-Pine	MB (501-1),SK (601-4), AB-Kananaskis (701-9)
M3	9E	Spruce, Spruce	AB-Whitecourt (702-6, 702-7)
M3	9BC	White Spruce-Subalpine Fir	BC-Prince George
M4	9BC	White Spruce-Subalpine Fir	BC-Prince George
M4	9A	Spruce-Fir	NF (101-3)
M4	9B	Spruce	NF (101-4)
M4	9C	Spruce	NWT (901-3)
M4	9D	Pine-Spruce,Spruce,Spruce-Pine	MB (501-1),SK (601-4), AB-Kananaskis (701-9)
M4	9E	Spruce, Spruce	AB-Whitecourt (702-6, 702-7)
S1	2A	Cutover-Bracken, Fir regen-open	BC-L Cowichan (802-2, 802-3)
S2	2A	Cutover-Bracken, Fir regen-open	BC-L Cowichan (802-2, 802-3)
S3	2A	Cutover-Bracken, Fir regen-open	BC-L Cowichan (802-2, 802-3)

FBP Fuel	WIPP Eqn	General Fuel Type(s)	Provincial Site(s)
O1a	SaA	Grass, Fir-grass-open	BC-100 Mile (801-3, 801-8)
O1a	SbA	Grass	AB-Whitecourt (702-10)
O1b	SaA	Grass, Fir-grass-open	BC-100 Mile (801-3, 801-8)
O1b	SbA	Grass	AB-Whitecourt (702-10)