Wildfire Risk Assessment for the West Kelowna Transmission (WKTP) Project Resiliency Alternative (1L244)

October 2019

Submitted by:

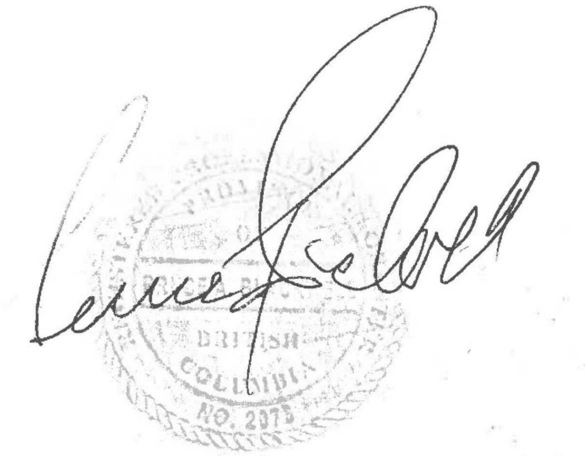
Bruce A. Blackwell, R.P.F., R.P. Bio.
B.A. Blackwell & Associates Ltd.
270 – 18 Gostick Place
North Vancouver, B.C. V7M 3G3
Phone: 604-986-8346
Email: bablackwell@bablackwell.com
GST No.: 132457983

Submitted to:

Guy Taylor, R.P.F.
Vegetation Project Manager
Program and Contract Management
BC Hydro
400 Madsen Road
Nanaimo, B.C. V9R 5M3

B.A. Blackwell
& Associates Ltd.

PROFESSIONAL SIGN-OFF



Bruce A. Blackwell, RPF 2073, RPBio
Date: October 24, 2019

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 IDENTIFICATION

The opinions contained in this report are those of Bruce A. Blackwell RPF of B.A. Blackwell & Associates Ltd. at 270 – 18 Gostick Place, North Vancouver, British Columbia. Mr. Blackwell is a recognized expert in fire science and fire management within the Province of British Columbia. This report provides a review and an unbiased opinion on wildfire risk associated with the Resiliency Alternative 1L244 for the West Kelowna Transmission Project (WKTP).

2.0 STATEMENT OF QUALIFICATIONS – BRUCE BLACKWELL

The opinions and discussion contained in the enclosed report are based on 32 years of experience as a practicing Forest Professional in British Columbia (B.C.). I am the individual responsible for the opinions expressed in this report.

My education includes a Bachelor of Science in Forestry (BSF) and a Master of Science (MSc.) from the University of British Columbia, specializing in Fire Science. My academic training has provided me with the opportunity to publish numerous research and contract reports related to fire management.

Specific work experience related to forest fire suppression, fire management and forest ecology includes:

- Three years with the B.C. Ministry of Forests Provincial Rapattack Program, specializing in fire suppression.
- Thirty years as a Professional Forester working in forest fire ecology, prescribed fire and fire management policy.
- Three years teaching the fire component of Forestry 320 (Abiotic Disturbance) at the University of British Columbia.
- Developing and teaching Applications of Fire in Ecosystem Restoration (RENR 8104) at the British Columbia Institute of Technology for the past seven years.
- Qualified as an expert in the B.C. Supreme Court to testify on wildfire behaviour, prescribed fire, fire suppression, fire ecology and fire management all related to the Greer Creek Fire (2010).
- Qualified as an expert to the Forest Appeals Commission to testify on wildfire hazard and mitigation related to the Anderson Pacific Forest Products Ltd. and harvesting abatement associated with Cutblock C059C3HT (Cutblock) pursuant to Timber Sale Licence A82206 in the vicinity of Port Renfrew, B.C.

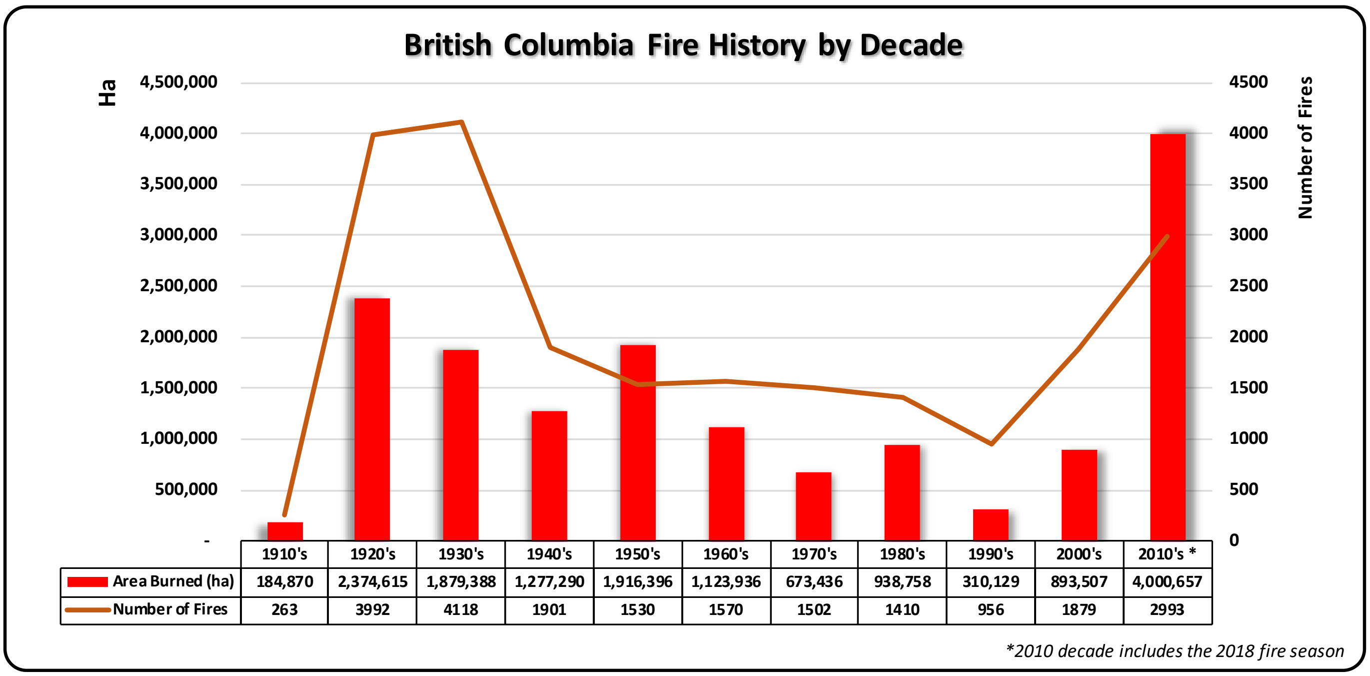
My consultancy has included fire related assignments throughout British Columbia on behalf of organizations that include the Ministry of Forest, Lands, Natural Resource Operations and Rural Development (MFLNRORD), Forest Practices Board, Ministry of Environment and Climate Change Strategy (MoECCS), Association of British Columbia Forest Professionals (ABCFP), BC Hydro, BC Transmission Corp, numerous forest tenure holders, local governments, the private sector, First Nations, KPMG, and PricewaterhouseCoopers. Additionally, my firm has completed fire related assignments in Alberta and the State of Alaska, USA.

Work assignments have included detailed analyses of fire weather for prescribed burn prescriptions, fire history studies, and fire behaviour analyses. As part of the Firestorm 2003 Provincial Review[1] conducted by Gary Filmon P.C., O.M, I was retained to assist in the development of recommendations on fuel and forest management practices. I was responsible for the development of a Provincial Strategic Threat Analysis[2] for the MFLNRORD Wildfire Management Branch, focusing on the identification of communities that were at risk from wildfire in British Columbia. Additionally, I co-authored a report entitled "Forest Health, Fuels, and Wildfire: Implications for Long-Term Ecosystem Health" for the British Columbia Forest Practices Board (Gray and Blackwell, 2005) and was the project lead for the development of a professional guidance document providing Interim Guidelines – Fire and Fuel Management for the Association of British Columbia Forest Professionals[3].

[1] https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/wildfire-management/governance/bcws_firestormreport_2003.pdf
[2] https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/fire-fuel-management/psta
[3] https://member.abcfp.ca/web/Files/policies/Fire_Fuel_Management-Interim_Guidelines.pdf

3.0 INTRODUCTION

Wildfire seasons in British Columbia, over the past two decades, have increased in numbers and the area burned across the province. Large expenditures in wildfire suppression and forest resource losses have occurred in 2003, 2004, 2009, 2010, 2014, 2015, 2017 and 2018. Figure 1 shows the number of wildfires and the total area burned by decade since 1910. The period 2010 to 2018 only represents 8 years of data, and yet the area burned is larger than any other decade and the number fires is greater than all other decades with the exception of the 1920s and 1930s. This is the result of two significant factors: 1) increases in fuel loads associated with long-term fire suppression and insects and disease, (see Section 4.0 for a description of the effects of historic fire suppression); and 2) a period of increasing drought during the fire season.



	1910's	1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's	2000's	2010's *
Area Burned (ha)	184,870	2,374,615	1,879,388	1,277,290	1,916,396	1,123,936	673,436	938,758	310,129	893,507	4,000,657
Number of Fires	263	3992	4118	1901	1530	1570	1502	1410	956	1879	2993

Figure 1. The number of fires and area burned summarized by decade in British Columbia (Source MFLNRORD, 2018)

BC Hydro has assessed alternative areas for development of a new secondary transmission line to deliver clean, reliable power to the communities of West Kelowna and Peachland. A previous preliminary wildfire risk assessment report (Blackwell, 2016) was completed for the WKTP Conceptual Design phase and evaluated three proposed project alternatives through the Okanagan and to Merritt. In late 2016, Alternative 2 (Nicola to Westbank) was identified as the leading alternative and was further studied, and Blackwell evaluated the relative wildfire risk of three corridor options for Alternative 2 (Blackwell, 2018). BC Hydro is further investigating the feasibility of improving the resiliency of the existing 1L244 circuit as an alternative to constructing a new secondary transmission line. This alternative is referred to as the West Kelowna Transmission Project (WKTP) – Resiliency Alternative (1L244).

Blackwell was retained to evaluate wildfire probability and associated wildfire risk of circuit 1L244 and include an assessment of the potential for a wildfire to impact the circuit resulting in an outage during a single wildfire event. Additionally, the assessment included reviewing two climate scenarios and fire behaviour analysis simulations to complement the risk assessment. The fire behaviour simulations estimate potential wildfire size, spread direction, and the impact of potential wildfire on the 1L244 transmission line in the absence of fire suppression. A final structure to structure assessment summary of Wildfire Probability and Associated Risk for 1L244 is provided in Appendix A.

The assessment considered two climate scenarios: the first based on the weather station data from 1977 to present day (2018); and the second based on only the data from 2000 to the present (2018). These two periods were selected based on significantly greater wildfire activity provincially within the last two decades and to identify if there was a significant change in the risk profile for the study area. The individual weather stations used and the date ranges of available data by station are provided in Section 7.0 (Table 1). Field assessments were completed within the 10 km study corridor to assess and calibrate fuel types with the Provincial fuel type inventory and assess identified vulnerabilities. Past vegetation maintenance history and the 2019 vegetation maintenance plan for 1L244 were also considered in the assessment. This report provides guidance to the vegetation maintenance team on areas of focus and options and considerations for improving resilience of the 1L244 circuit to wildfire, considering past and planned vegetation maintenance and the assessed wildfire risk as verified by ground truthing.

The existing 1L244 circuit (Figure 2) transects a broad range of Interior forest ecosystems. Wildfire is a natural disturbance agent in these forest ecosystems and, in addition to impacting the transmission line infrastructure, has the potential to negatively impact social and economic stability, and environmental quality. For the purpose of wildfire risk assessment, the 1L244 circuit was buffered by 5 km on either side of the centre line of the transmission line to establish a 10 km wide study corridor. The buffer was established to assess the vegetation and related fuel type, and access in close proximity to the transmission line. Additionally, the study corridor width needed to be large enough to account for large scale wildfires in the vicinity of the line and the variability in fuel type and associated fire behaviour.

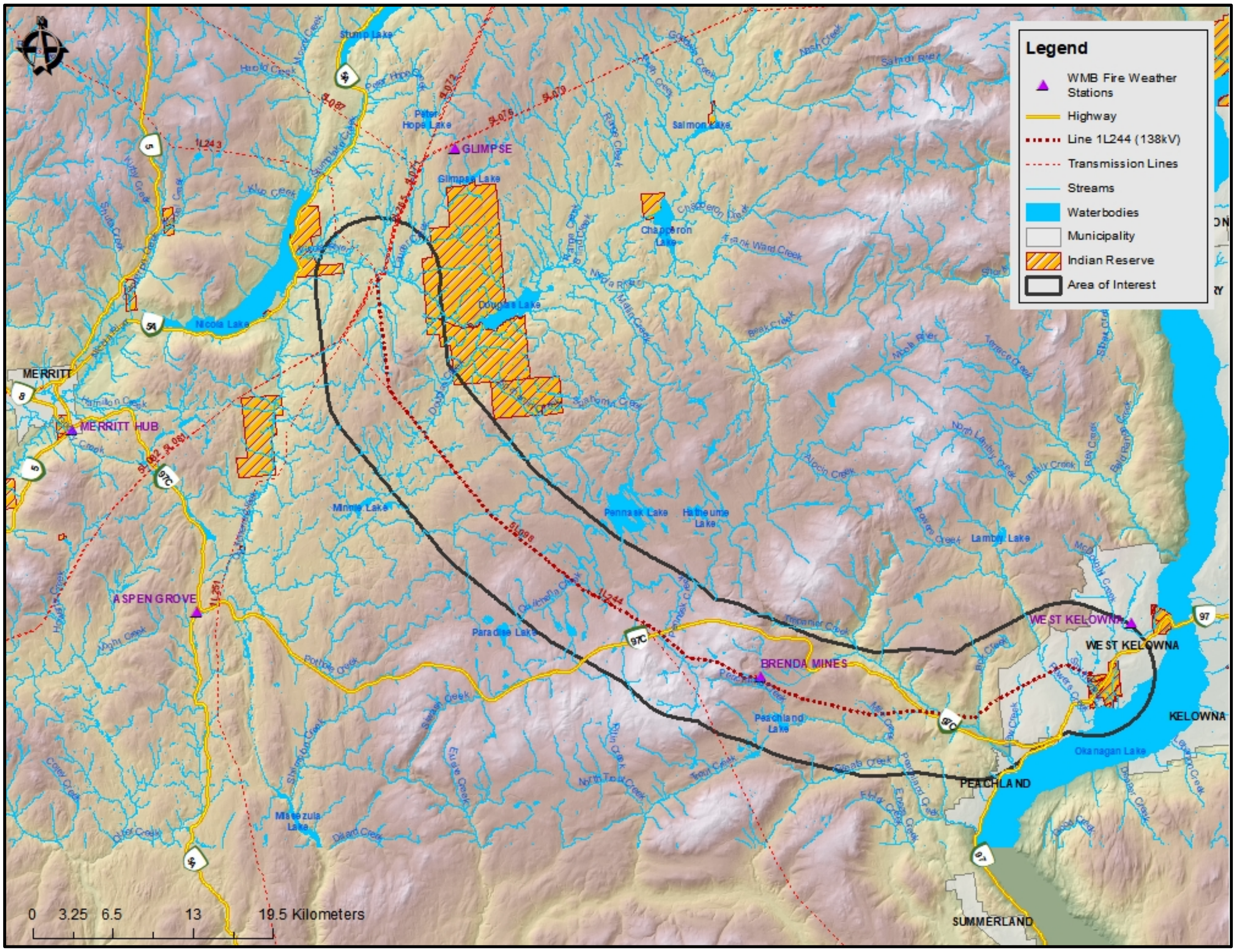


Figure 2. Overview of the study area.

Historically, the study area (Figure 2) has been exposed to high frequency, low severity surface fires and high severity stand replacement fires (fires that kill larger groups of trees) which occur every 20-120 years (Lloyd *et al.,* 1990) and have the potential to significantly alter the forests.

There are no supporting fire history publications that reference this specific study area. Regional fire history studies publish a return interval of 20-120-year range. However, the southern and central portions of B.C. are expected to become warmer and drier and hence experience more frequent, severe and more extensive area burned. The southern interior, in which the study area is located, is expected to experience the most significant increases in fire-related weather indices including fire frequency, mean fire size, and fire severity (Spittlehouse, 2008). Given these projections and fire behaviour patterns in recent seasons, it is likely to result in the increased potential for high-severity wildfires to occur more frequently, well below the 20-120-year range. In fact, a review of this specific study area shows a lower area burned in recent years, including 2018, in comparison to other locations in the region and it can be surmised from this that there is a significant probability of large fires in this study area in the near future.

The probability of large wildfires within these Interior forest ecosystems is generally considered high, and in many areas the consequences associated with a large wildfire would be very high to extreme. A Wildfire Risk Management System (WRMS) evaluation was completed for this study area and the 1L244 circuit to determine the wildfire risk profile of the area. The WRMS evaluation is aimed at determining the potential risk for the overall circuit (Figure 2), and potential risk mitigations including vegetation maintenance measures along the circuit segments. This report documents the methods and results of the WRMS analysis for the 1L244 and the individual component segments.

The methodology used to develop the WRMS for 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 B.C. in a number of different contexts and scales (Hawkes and Beck, 1997; Blackwell *et al.,* 2003). In older 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 by B.A. Blackwell & Associates Ltd. in collaboration with Compass Resource Management adopts a risk management approach to guide the quantification of discrete landscape-level probability and consequence ratings, using the same underlying data attributes.

4.0 STUDY AREA IGNITION AND SPATIAL FIRE HISTORY

Figure 3 provides a summary of ignitions (both human and lightning) by decade. The number of ignitions was largely stable between 1950 and 1969 and then increased from 1970 through 2009, and more recently (2010 to present) has decreased. Given the limited size of the study area (10 km wide corridor), there is potential for high variability in the number of lighting and human caused ignitions. For example, 2019 was a relatively wet fire season, with a low number of ignitions within the study area. The trends in lightning ignitions are relatively constant over time while the number of human caused ignitions has declined in the last decade. This is likely the result of increased efforts through public education and awareness and the impacts of recent large wildfires on the community. The last complete decade (2000-2009) showed a marked increase in ignitions which can largely be attributed to a prolonged period with dry summers and increasing lightning and human ignitions (related to population growth in the Okanagan valley).

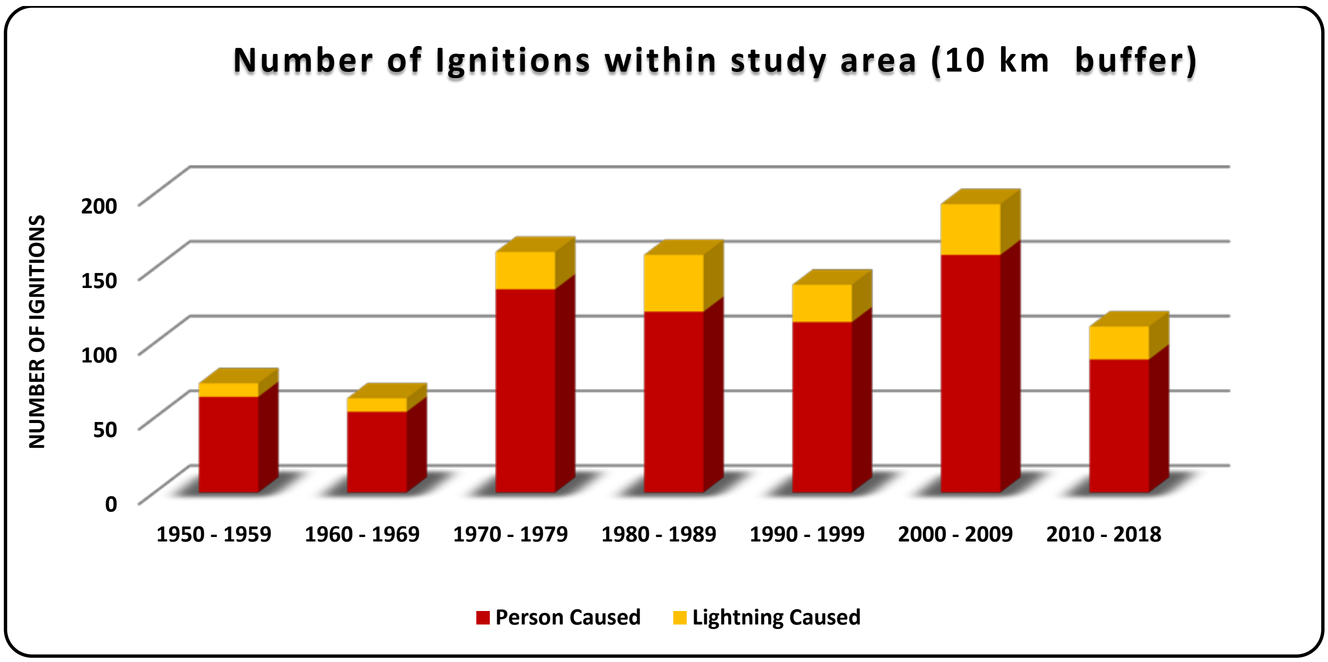


Figure 3. Number of ignitions by decade within a 10 km buffer of the 1L244 circuit.

Figure 4 shows the spatial distribution of ignitions (both human and lightning caused) within the study area and highlights the concentration of ignitions (largely human) within the developed areas of Okanagan Lake, recreation areas, and along the highway and road networks. This is consistent with ignition density in other parts of the southern Interior and the Province at large.

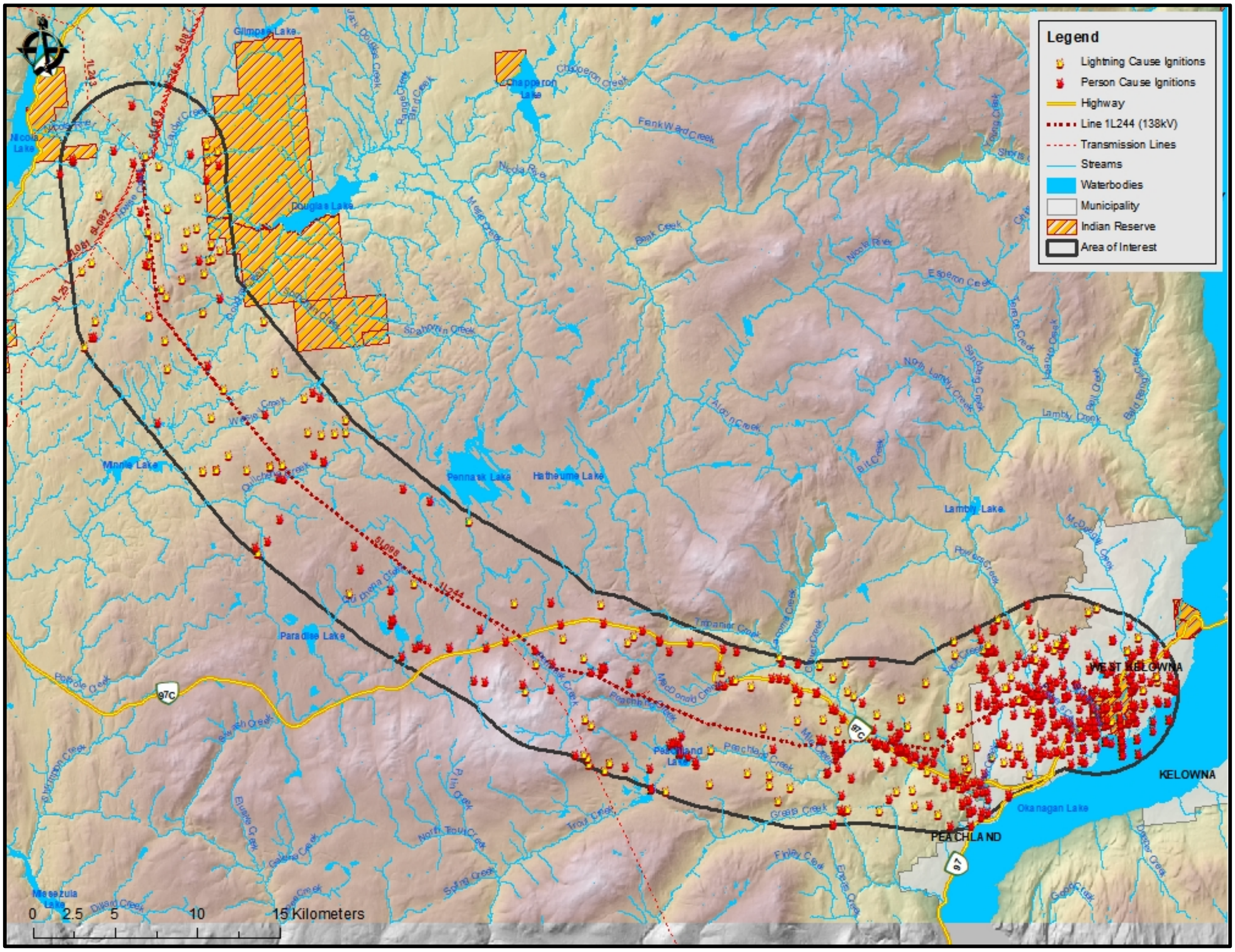


Figure 4. Spatial ignition history for the study area (1950 – 2018).

When the buffered 1L244 circuit area is considered, it is clear that there are a much higher number of ignitions along the circuit associated with more recent decades (2000-2009 and 2010-present) and that the ignition density has been steadily increasing over the last seven decades with the exception of the 2010 to 2018 period which is an incomplete record and shows a decline in human caused ignitions as discussed previously (Figure 5).

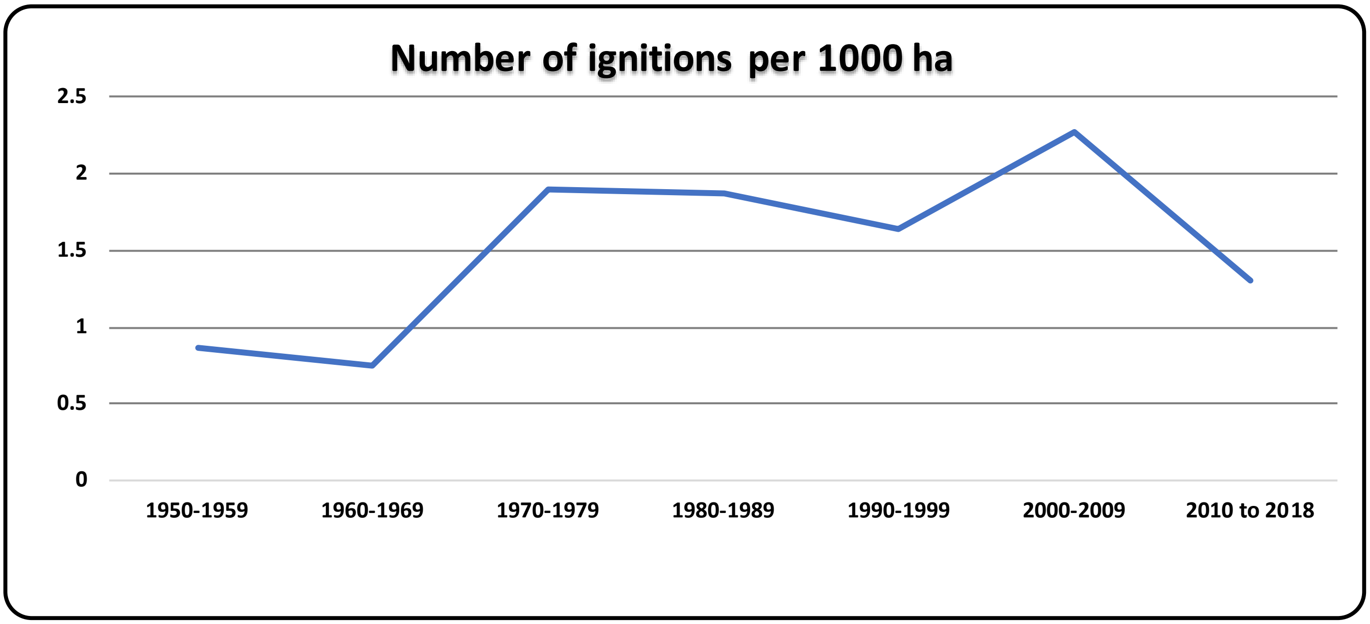


Figure 5. Number of ignitions per 1000 hectares for the 1L244 circuit study area.

Fire has frequently occurred within the study area over the last hundred years (Figure 6) with a significant number of large wildfires, and a resultant large area burned, having occurred prior to 1950. With the advent of advanced fire suppression following World War II the burned area footprint has been substantially reduced (Figure 6). Ecologically, this effective fire suppression has altered forest fuels such that there is ingrowth (increased tree density associated with long-term fire suppression) in forest stands and trees encroaching into grasslands which have resulted in an increase in the total fuel loading, resultant fire behaviour potential and the overall severity of wildfires within the region.

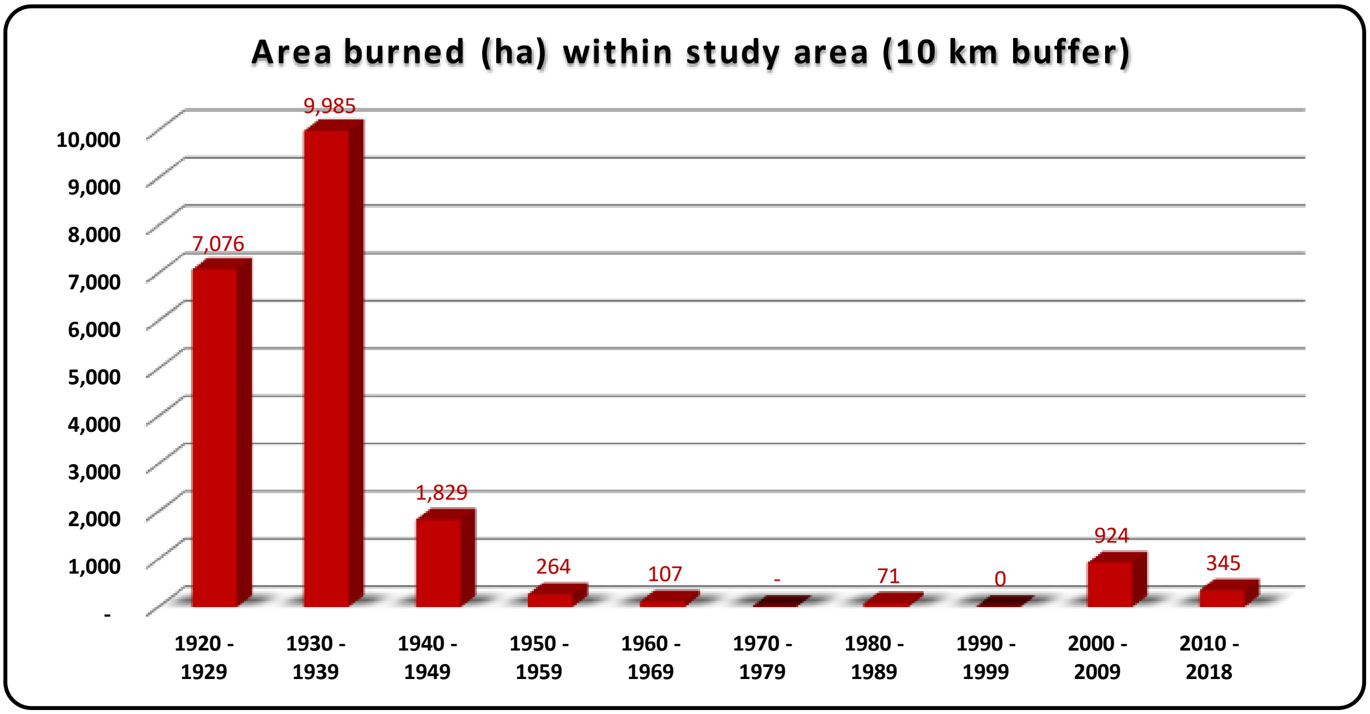


Figure 6. Area burned summarized by decade for the 1L244 study area.

Figure 7 below shows historically that a number of wildfires prior to 1950 have impacted the areas now occupied by the 1L244 circuit and intersect the buffered study area. However, it is also clear that the area closest to West Kelowna has experienced a larger footprint of area burned when compared with the other portions of the study area. This could be related to topography, climate and the location of both human and lightning ignitions. Other portions of the circuit within the study have not been impacted to the same extent as the area near West Kelowna. This could be related to lower ignition density, effective fire suppression and/or that parts of the circuit cross over higher elevation forest ecosystems, where the combination of snowpack, lower summer temperatures, and typically higher levels of precipitation during the fire season, results in a reduced probability of wildfire. The more recent Terrace Mountain (2009) and Okanagan Mountain Park (2003) wildfires (dark orange polygons in Figure 7), located on either side of Okanagan Lake, are examples of the changing wildfire conditions and the potential for damaging wildfires.

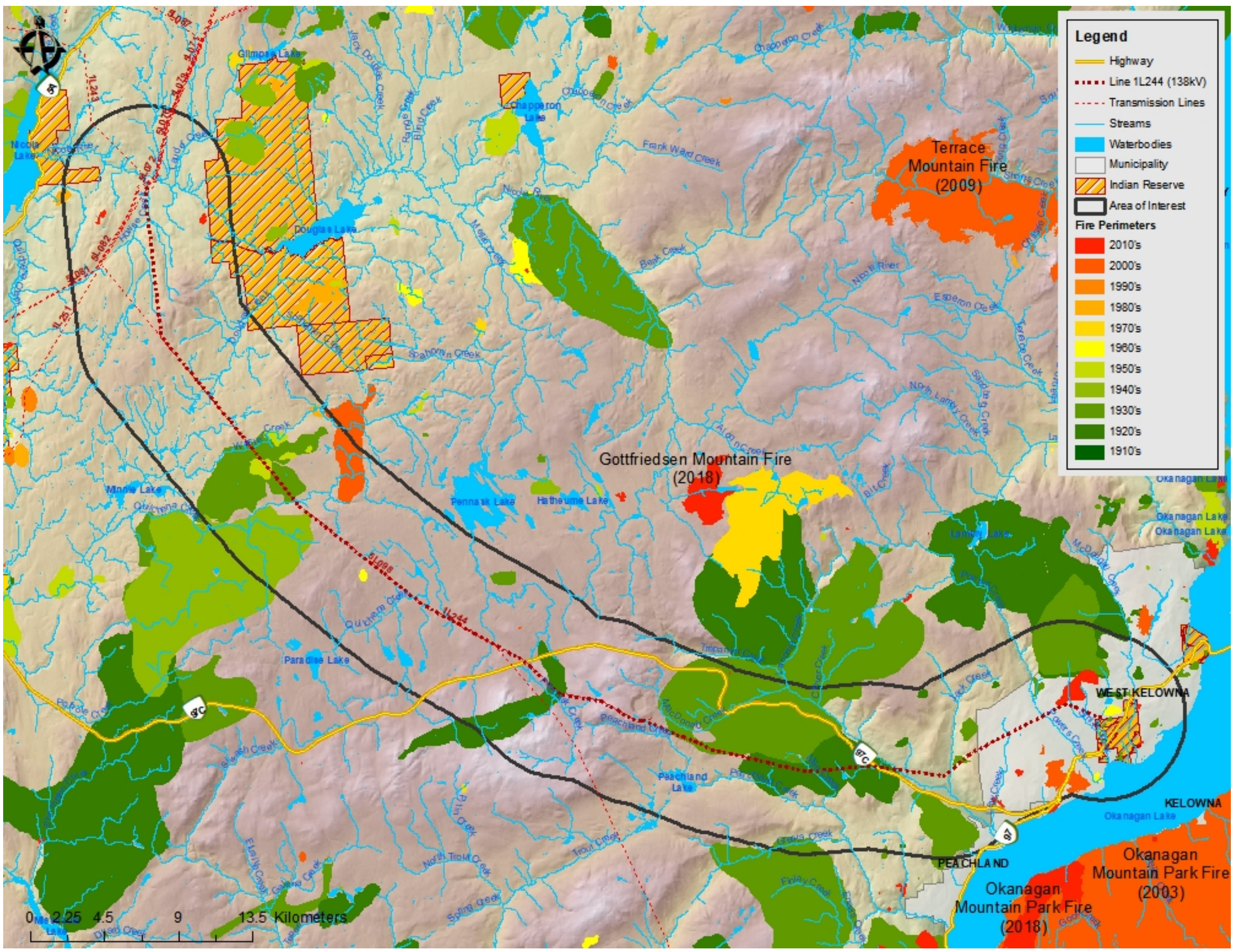


Figure 7. Spatial history, by decade, of fires that have occurred between 1919 and 2018.

5.0 WILDFIRE RISK MANAGEMENT

Definitions of the term "risk" and all its derivatives (*e.g.* risk management, risk assessment, risk evaluation, etc.) 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 (as in Bachmann and Allgower, 1998) more useful to keep these elements separate since they may imply different management approaches spatially. Figure 8 shows how various combinations of probability and consequence can imply 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.

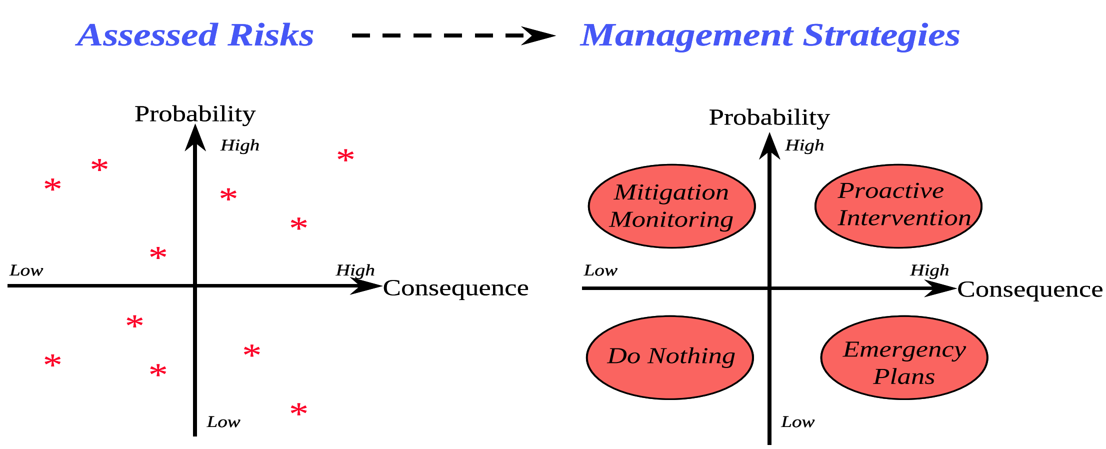


Figure 8. Conceptual representation of risk assessment/management as the resultant of two factors, Probability and Consequence.

6.0 THE WEST KELOWNA TRANSMISSION PROJECT ASSESSMENT AREA – RESILIENCE ALTERNATIVE 1L244

The assessment area encompasses 84,802 hectares. Elevations range from 339 meters to 1,984 meters. Forests in the lower elevations include ponderosa pine and Douglas-fir within the Ponderosa Pine (PP) and Interior Douglas-fir (IDF) Biogeoclimatic Zones. With increasing elevation, lodgepole pine and Engelmann spruce become the dominant tree species within the Montane Spruce (MS) and Engelmann Spruce Subalpine-fir (ESSF) Biogeoclimatic Zones.

Wildfire is a natural disturbance agent in this heavily forested, Interior landscape. Historically these areas have been exposed to high frequency, low severity surface fires and high severity stand replacement fires (fires that kill larger groups of trees) which occur every 20-120 years (Lloyd *et al.,* 1990). The probability of large wildfires within the study area is considered high, and the consequences associated with a large wildfire have the potential to damage BC Hydro infrastructure in this area.

As stated in Section 3.0, the 20-120-year fire return interval refers to the concept that the entire landscape within the study area will experience a fire within that timeframe. Since it is difficult to predict the occurrence of any single fire event, an average temporal range best represents a description of fire return intervals. The landscape of West Kelowna has a mosaic of vegetation and age classes in various stages of succession which are already predisposed to a large-scale landscape wildfire such as the Terrace Mountain fire (2009), and the Okanagan Mountain Park fire (2003). This means that a wildfire event can occur in any given year at any given location across the landscape and study area moving forward. Increased drought frequency and associated longer fire seasons, and growing populations of the West Kelowna community and region will result in a higher frequency of human ignitions, and a greater risk from both low and high severity fires.

A detailed description of the risk assessment methodologies and fire behaviour modelling that were applied to this project are located in APPENDIX B – Wildfire Risk Modelling Methods and Section 9.0 Fire Behaviour Analysis, respectively.

7.0 FIRE WEATHER DATA ANALYSIS

As discussed previously recent wildfire seasons have been more severe resulting in higher severity wildfires and a larger burned area. The decision to apply two climate scenarios was based on more recent wildfire activity provincially over the past two decades in comparison to the longer historic climate record, which on average had lesser wildfire activity associated with on average lower wildfire danger. For the purposes of evaluating wildfire risk the project team selected two separate fire weather analyses (i.e., two climate scenarios) to assess wildfire probability historically:

Climate Scenario 1: station start-up to present (2018); and

Climate Scenario 2: wildfire probability under current conditions (2000 to present (2018)).

Five weather stations were selected (locations are illustrated in Figure 9) to evaluate differences in 90th percentile fire weather conditions under the two scenarios, and potential changes in fire weather patterns. The 90th percentile conditions for each of the five stations are summarized in Table 1.

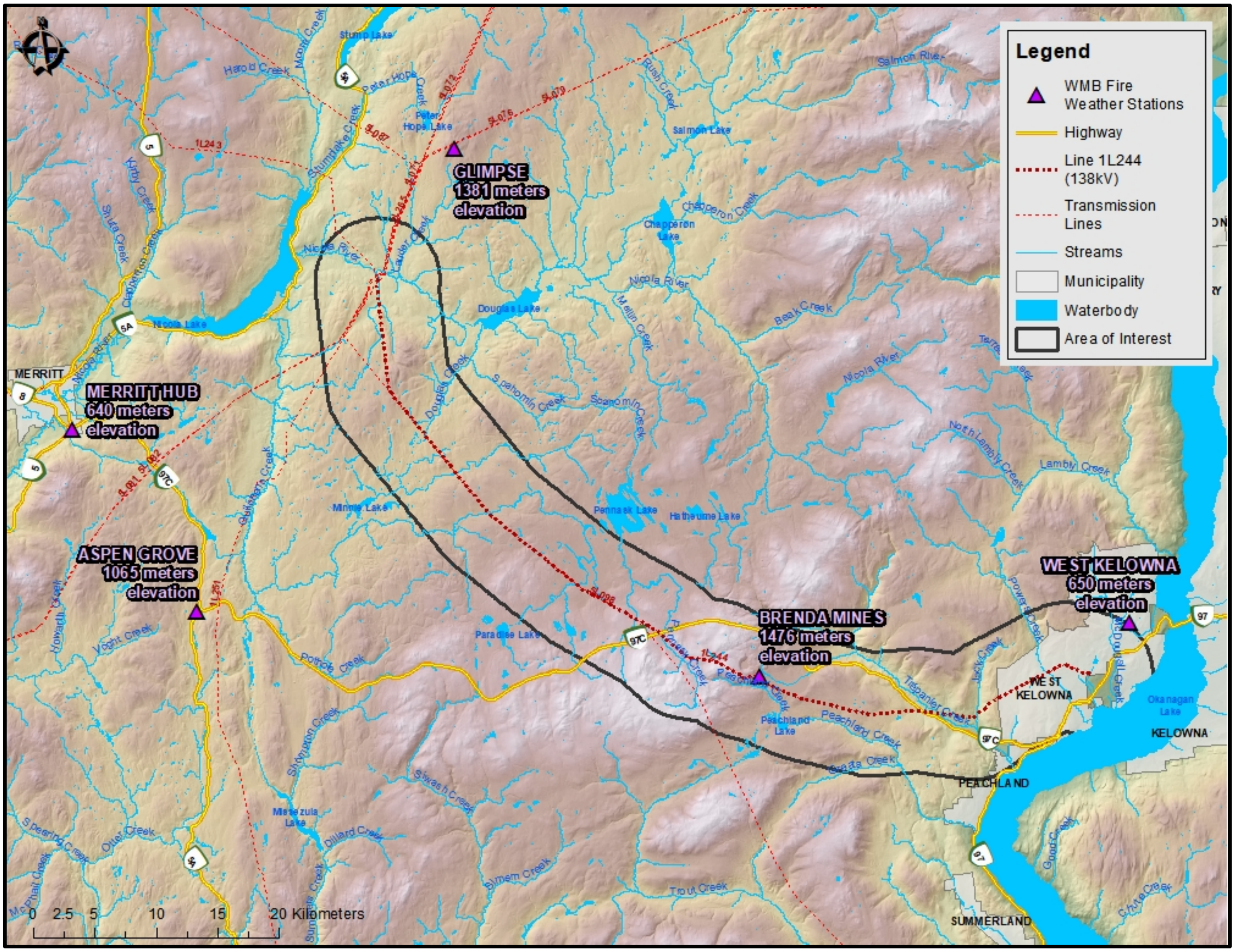


Figure 9. Location of fire weather stations used for analysis.

The Canadian Forest Fire Danger Rating System (CFFDRS), Natural Resources Canada, 2017) is the national system of rating fire danger in Canada. Under the CFFDRS, a number of codes and indices (fire weather parameters in Table 1) are used to obtain fire behaviour indices. These codes and indices include the following:

- *Fine Fuel Moisture Code (FFMC)* – a numeric rating of the moisture content of litter and other cured fine fuels (i.e., represents the moisture content of surface litter). This code is an indicator of the relative ease of ignition and the flammability of fine fuel.
- *Duff Moisture Code (DMC)* – a numeric rating of the average moisture content of loosely compacted organic layers of moderate depth (i.e., represents the moisture of shallow organic layers). This code is an indication of fuel consumption in these layers and medium size woody material.
- *Drought Code (DC)* – a numeric rating of the average moisture content of deep, compact organic layers. This code is an indicator of seasonal drought effects and fire smoldering in these layers and large logs.

- *Buildup Index (BUI)* – a numeric rating of total fuel available for consumption (it combines the DMC and the DC).
- *Initial Spread Index (ISI)* – a numeric rating of the expected rate of spread (it combines the effects of wind and the FFMC); and
- *Fire Weather Index (FWI)* – a numeric rating of fire intensity (it combines the ISI and the BUI and is a general index of fire danger).

The CFFDRS system codes and indices are used to measure the fire condition of various elements of the forest based on weather and fuel type. Their primary application is in the calculation of the Fire Weather Index (FWI) which is used to determine Fire Danger. The Fine Fuel Moisture Code (FFMC) is a measure of the drying conditions of the small fuel, the Duff Moisture Code (DMC) a measure of the drying condition of the forest floor and the Drought Code (DC) measures long-term drought. Overall the Drought Code is the most meaningful measure of longer-term trends of potential wildfire behaviour both when comparing season to season and over a longer-term record such as those available for the stations included in this study.

Table 1. Ninetieth percentile of fire weather parameters by fire weather station.

Fire Weather Parameter	WEST KELOWNA		ASPEN GROVE		GLIMPSE		BRENDA MINES		MERRITT HUB	
	2017-2018	Before 2000	2000-2018	1998-2018	2000-2018	1978-2018	2000-2018	1977-2018	2000-2018	1978-2018
Fine Fuel Moisture Code (FFMC)	94.5	NA*	93.5	93.4	92.5	92.2	92.9	91.8	94.0	93.8
Duff Moisture Code (DMC)	271.4	NA	122.7	119.6	79.3	78.9	84.6	68.9	138.8	140.4
Drought Code (DC)	970.2	NA	837.6	825.0	586.5	573.8	565.9	521.6	922.3	874.3
Buildup Index (BUI)	319.4	NA	179.6	175.5	118.5	117.4	123.2	103.6	201.7	200.4
Initial Spread Index (ISI)	17.1	NA	15.0	14.8	13.0	12.4	13.7	11.8	16.0	15.6
Fire Weather Index (FWI)	10.5	NA	9.7	9.7	8.6	8.5	8.9	8.0	10.1	10.0

*NA = data Not Available (weather station was not in operation).

Overall, when comparing the weather records for the two climate scenarios the variation in codes and indices calculated for fire weather were largely similar for the four stations with long records (Figure 10 to Figure 12). The Glimpse and Aspen Grove weather stations were almost identical in the results for the two periods. However, the drought code (DC) at the Merritt Hub and Brenda Mines stations, and the fine fuel moisture code (FFMC) at Brenda Mines station were noticeably different when the two scenarios were compared.

The drought code at the Merritt Hub and Brenda Mines weather stations were approximately 5% higher (44-48) and the fine fuel moisture code at the Brenda Mines weather station was higher by 1.1 for the 2000-2018 period when compared to the whole station record. This translated into higher fire behaviour in the results discussed in the next sections of the report. The higher drought code (DC) likely contributed the most to variation in the fire behaviour calculations when the two scenarios were compared to each other for each of the stations.

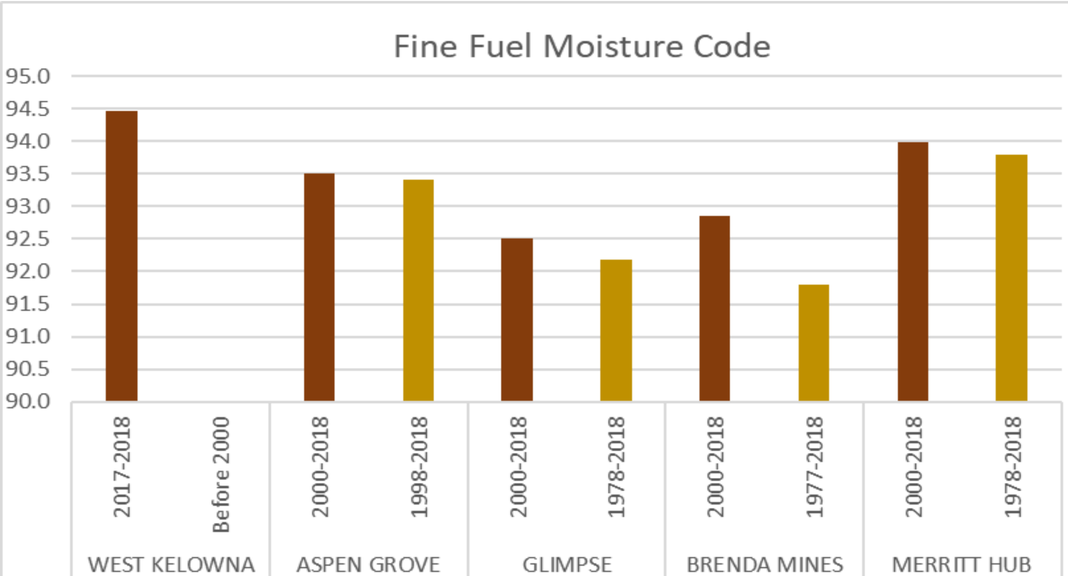


Figure 10. FFMC values calculated as 90th percentiles.[4]

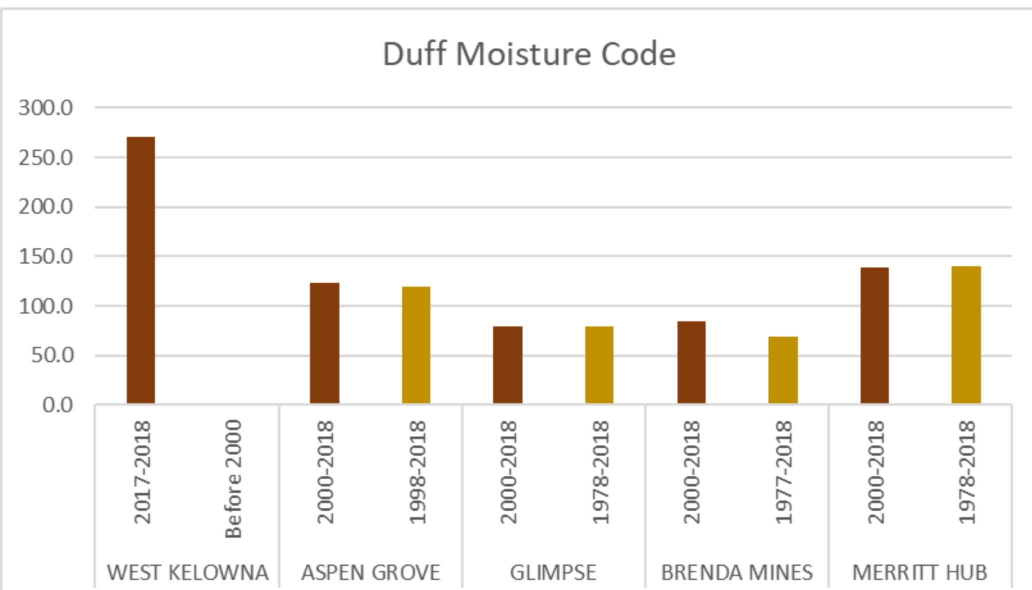


Figure 11. DMC values calculated as 90th percentiles.[4]

[4] Data for the West Kelowna weather station was not available before 2000 (the weather station was not in operation).

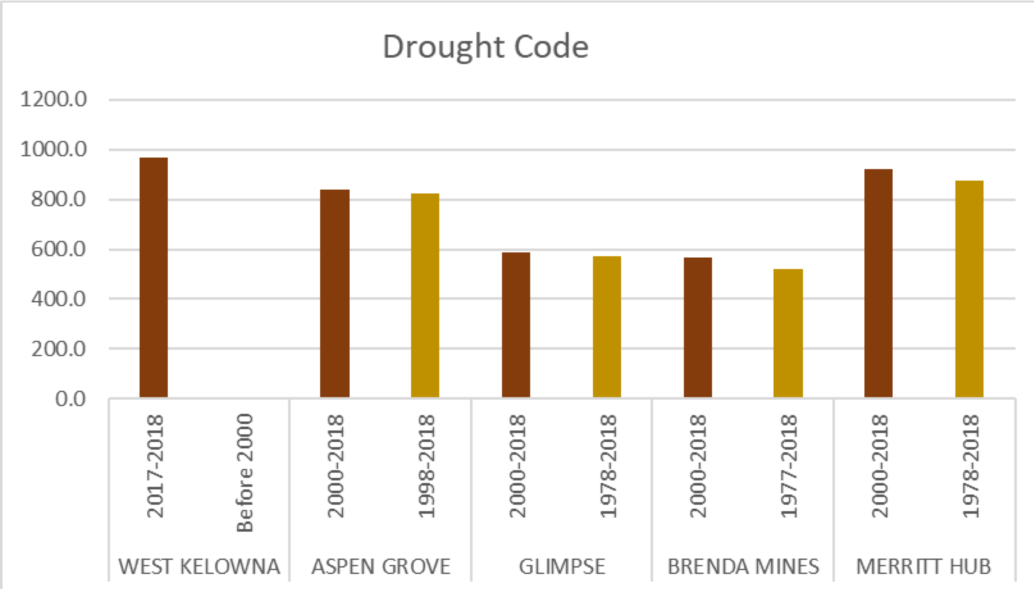


Figure 12. DC values calculated as 90th percentiles[5]

The fire weather index (FWI) and buildup index (BUI) are used to determine the fire danger class. Fire danger class days are the number of days in each danger class (expressed from very low to extreme) for a specified period. For the purposes of this evaluation, fire danger class days are expressed as monthly averages (percentage of days of the month) for the specified range of weather data. When the number of fire danger class days were evaluated for the Brenda Mines station (Figure 13 and Figure 14) there was a noticeable difference in both the moderate and extreme fire danger days for July and August, when comparing between the period 1977-2018 (climate scenario 1) and 2000-2018 (climate scenario 2), and this is likely due to the variation in the drought code (DC) for this station. This is consistent with observations that periods of drought in both the Okanagan and other regions of the Province have been increasing during the fire season and that this is resulting in an increase in the number of days in which fires will burn and the number of days where extreme fire behaviour is probable.

[5] Data for the West Kelowna weather station was not available before 2000 (the weather station was not in operation).

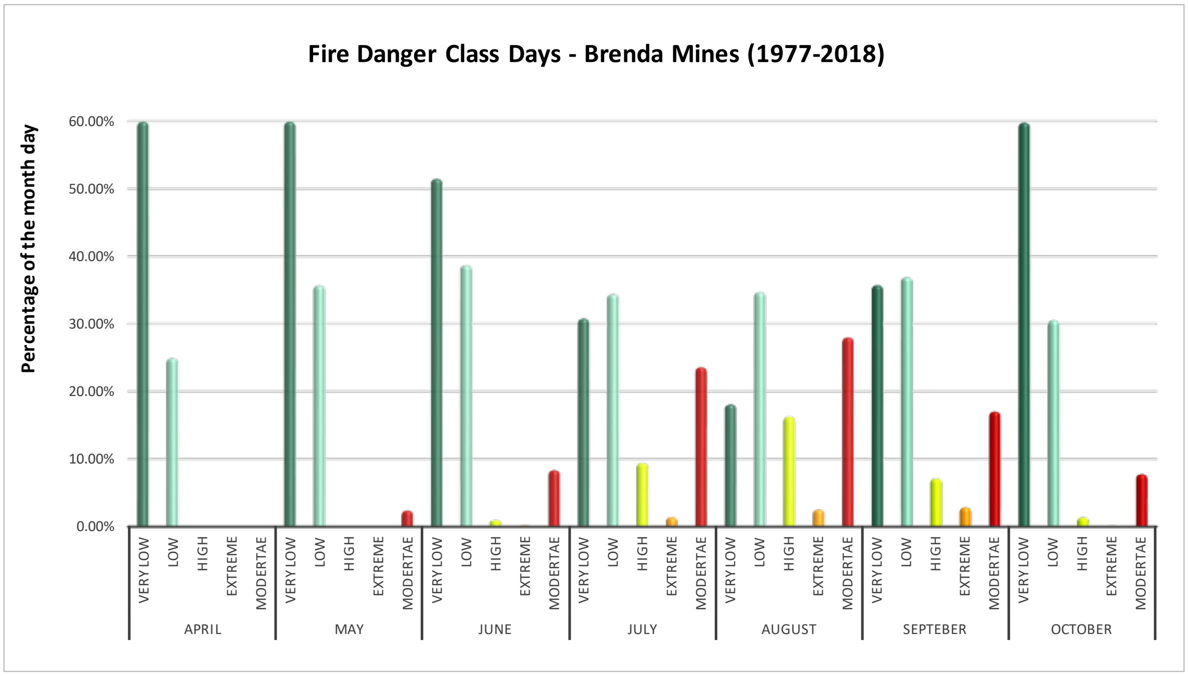


Figure 13. Fire Danger Class Days (averages as percentage of days of the month for Brenda Mines between 1977 and 2018 - climate scenario 1)

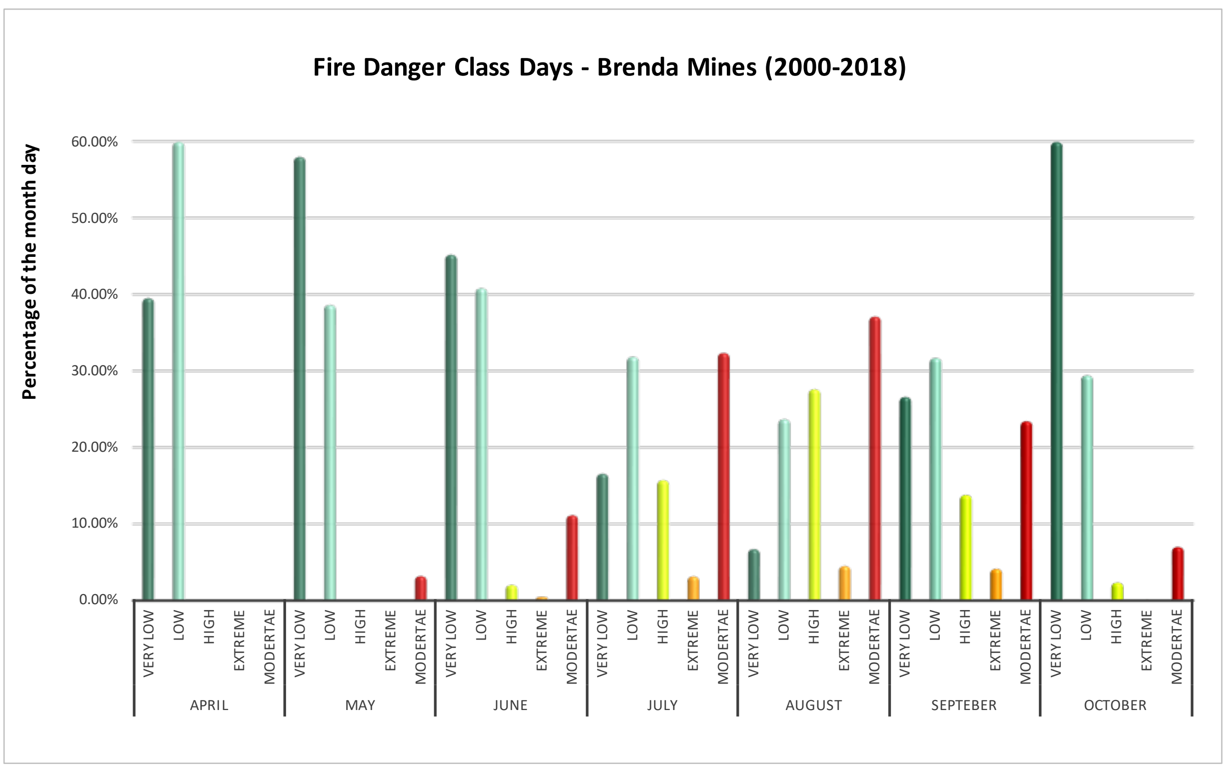


Figure 14. Fire Danger Class Days (averages as percentage of days of the month for Brenda Mines after year 2000 – climate scenario 2)

8.0 PROBABILITY AND RELATED WILDFIRE RISK

A Wildfire Risk Management System (WRMS) was completed for the study area including the 1L244 circuit and the results were evaluated within the entire 10 km buffered area and for 5 km segments along the transmission corridor. This wildfire risk profile is intended to support design of transmission line mitigation strategies with respect to wildfire risk ensuring that the circuit is more resilient to large and destructive wildfires. The WRMS methods employed are described in Appendix B, including the model components, subcomponents and related attributes and their relative weighting. The fire behaviour modelling completed in support of the WRMS is described in Section 9.0.

8.1 IGNITION PROBABILITY

CLIMATE SCENARIO 1:

As illustrated in Figure 15 below, the ignition probability was highest in close proximity to West Kelowna. The high probability of ignition for this portion of the study area is related to its proximity to West Kelowna and the influence of historic human ignitions in this portion of the study area. High human ignitions along this portion of the circuit may also be related to both human ignitions associated with the Coquihalla highway corridor in close proximity to West Kelowna, and at higher elevations, due to lightning. Similarly, within the northern portion of the study area, there appears to be a higher lightning ignition probability associated with higher elevation forested areas (spatial ignition history illustrated in Figure 4) and human ignitions near both Douglas Lake and Pennask Lake roads.

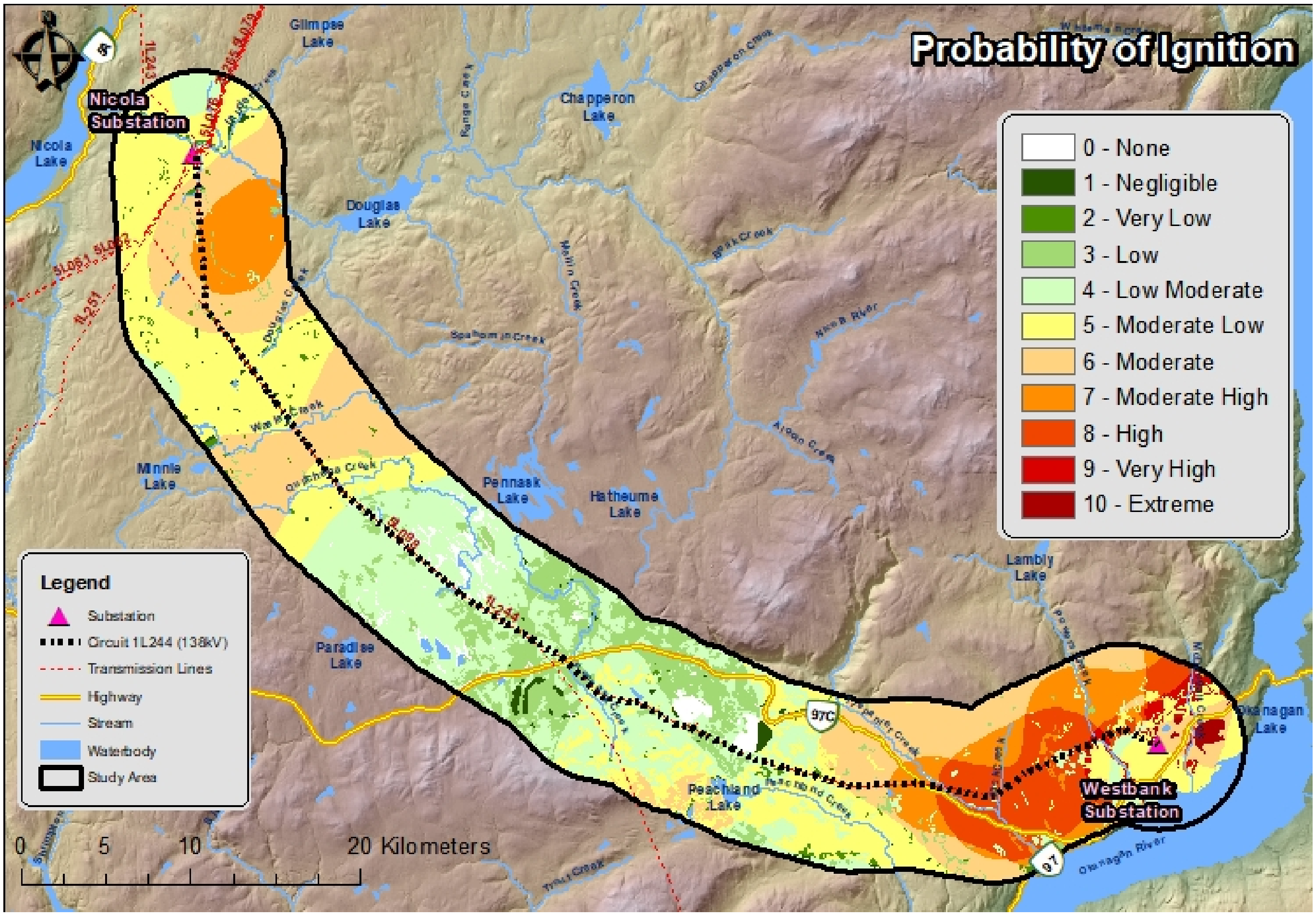


Figure 15. Probability of Ignition using 90th percentiles calculated using the full range of weather records (1977 – 2018) of the fire weather stations (climate scenario 1).

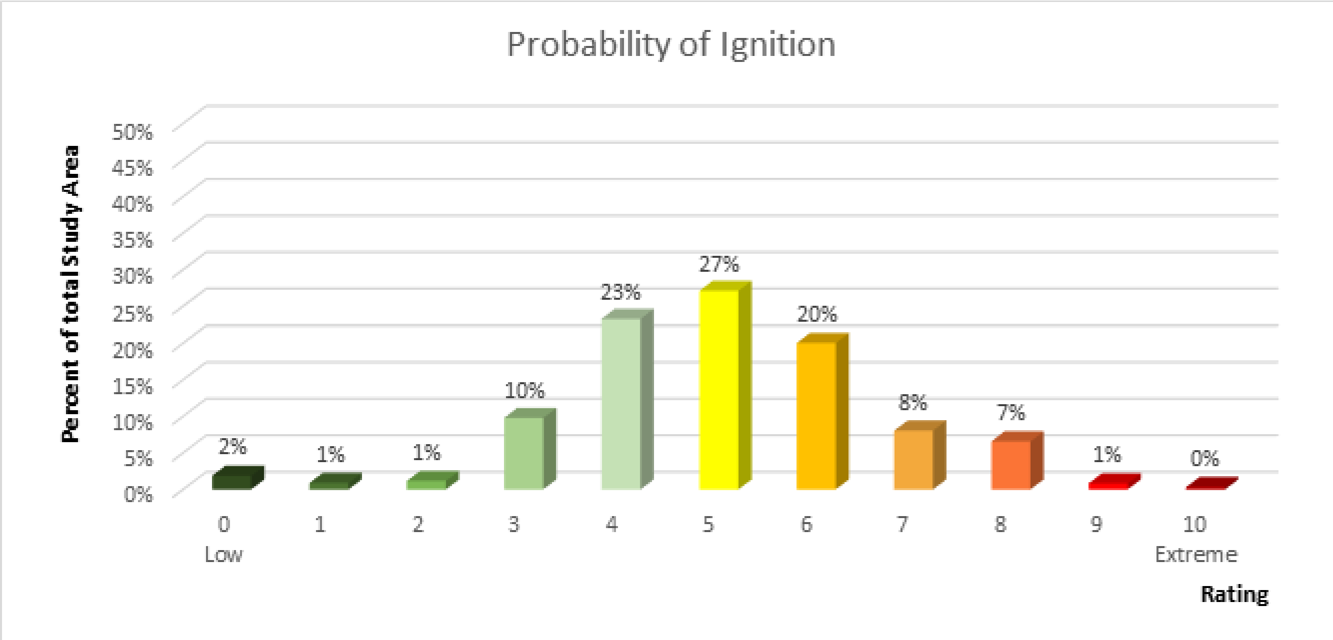


Figure 16. Distribution of the probability of ignition classes as percentage of the study area (climate scenario 1).

CLIMATE SCENARIO 2:

The probability ignition theme for the recent climate record (2000 to present, Figure 17) was almost the same when comparing the longer fire weather record (Figure 15). This was not a surprise as the ignition probability is the result of density of ignitions within the study area and this has not likely changed over the climate periods measured. While periodic numbers of ignitions may have changed, the pattern of ignitions has likely remained similar. If the ignition density has changed, it is not measurable within this type of analysis.

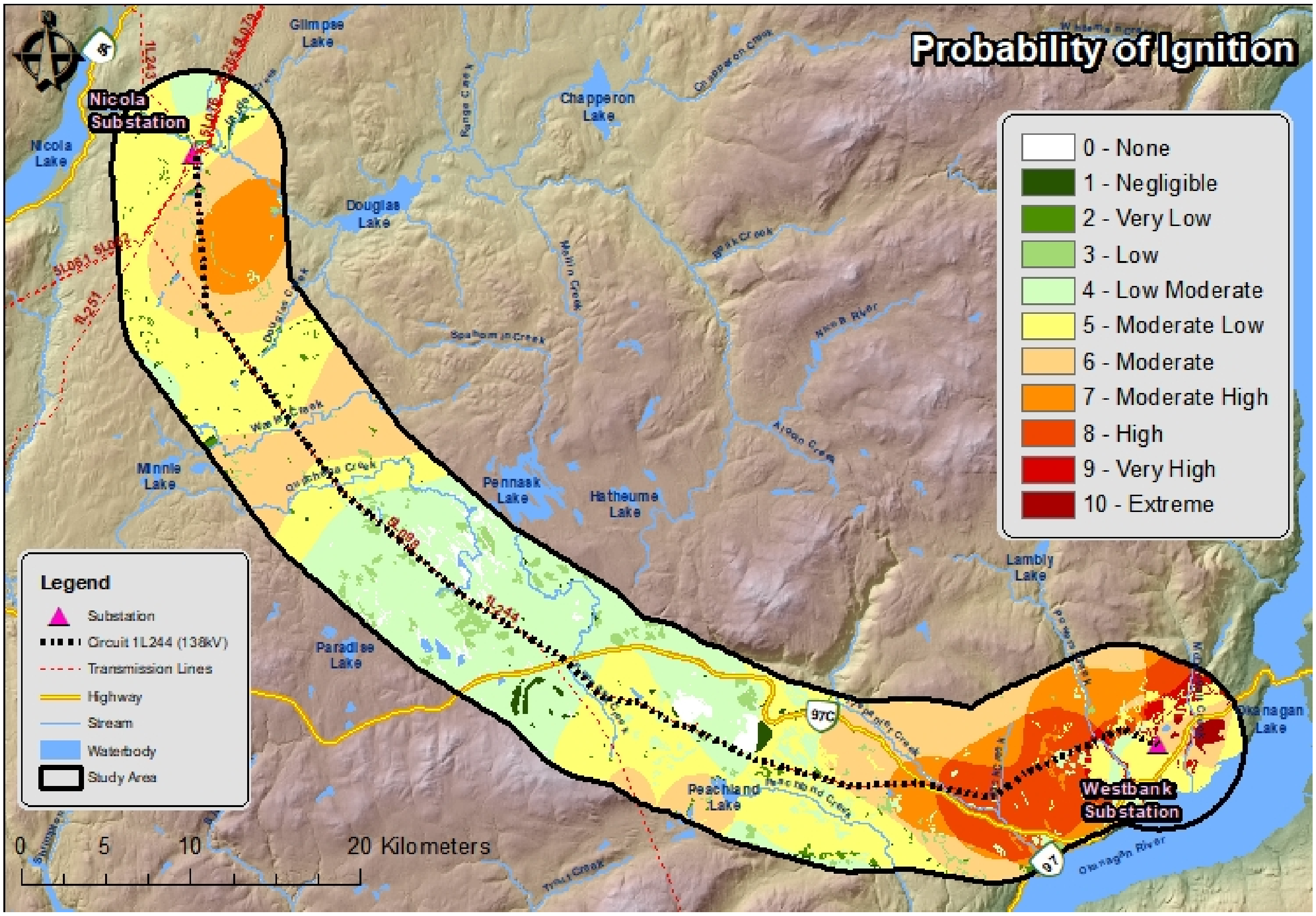


Figure 17. Probability of Ignition using 90th percentiles calculated using only the values recorded after year 2000 of the fire weather stations (climate scenario 2).

When the probability of ignition classes was compared as a percentage of the total study area, classes 4, 5, and 6 accounted for 78% of the study area (Figure 18). The higher ignition probability classes 7-10, only accounted for approximately 16% of the study area. What this suggests is that approximately 78% of the study area is vulnerable to wildfire ignitions and that 16% of the study area is highly vulnerable to wildfire ignitions.

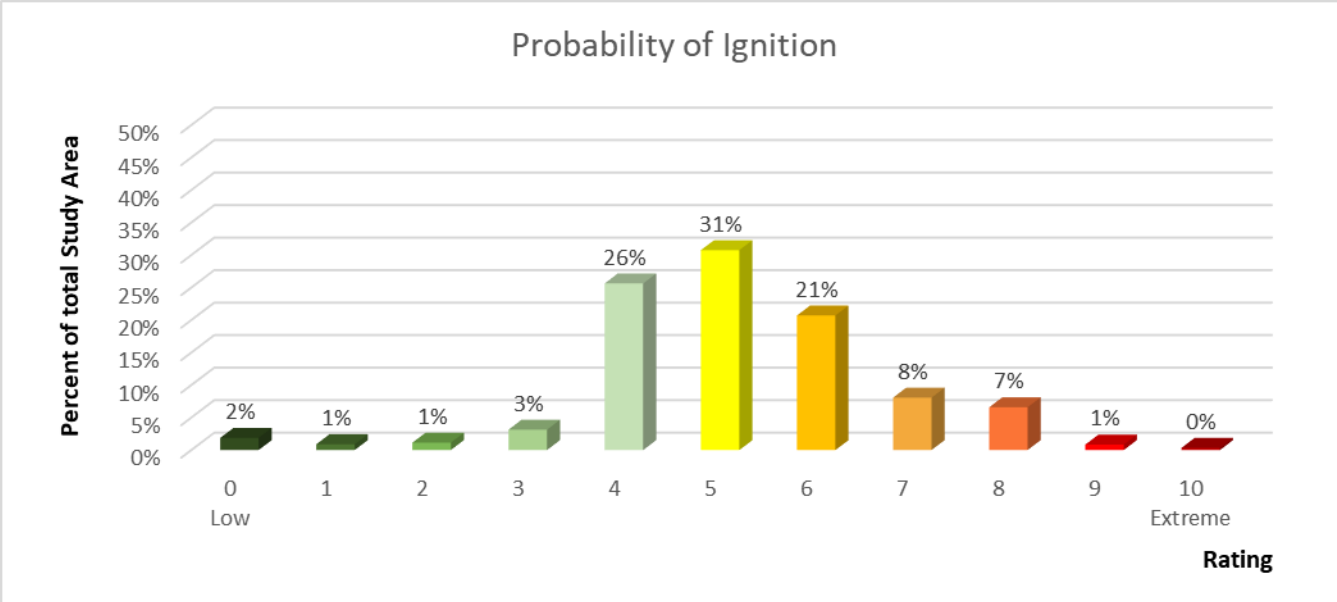


Figure 18. Distribution of the probability of ignition classes as percentage of the study area (climate scenario 2).

The last 15 kilometers of the corridor approaching West Kelowna have the highest relative probability of ignition. This area has complex terrain, a significant area of high hazard fuels and therefore it is expected that fire control in this area could be difficult even though there is very good suppression capability close to Kelowna. The area closest to Merritt has relatively moderate to high probability of ignition, while the area through the middle of the circuit is rated the lowest probability of ignition relative to the study area as a whole.

8.2 FIRE BEHAVIOUR

CLIMATE SCENARIO 1:

Under climate scenario 1, a large portion of the study area has fire behaviour potential that is ranked moderate to high with isolated patches of low and very high to extreme fire behaviour (Figure 19 and Figure 20). There are no large scale recently burned areas along any portion of the right-of-way which also elevates the potential for fire spread and fire intensity within the study area. The fire behaviour potential in the immediate vicinity of West Kelowna (white on the map) is rated as none largely due to the development footprint in this area. Only small areas of forest cover/fuel types that contribute to fire behaviour are present, so this area has nil measured fire behaviour.

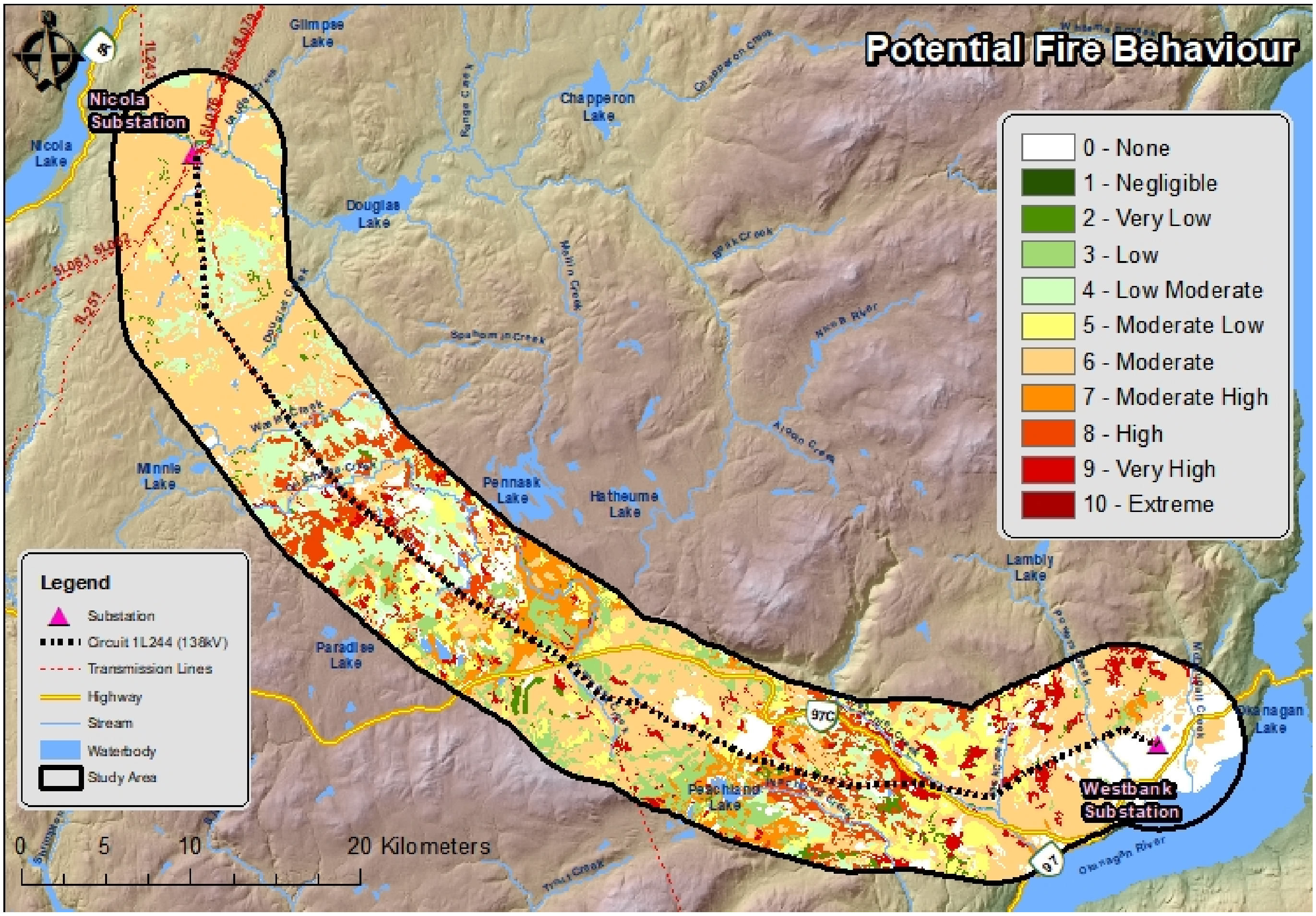


Figure 19. Potential Fire Behaviour using 90th percentiles calculated using the full range of records (1977 – 2018) of the fire weather stations (climate scenario 1).

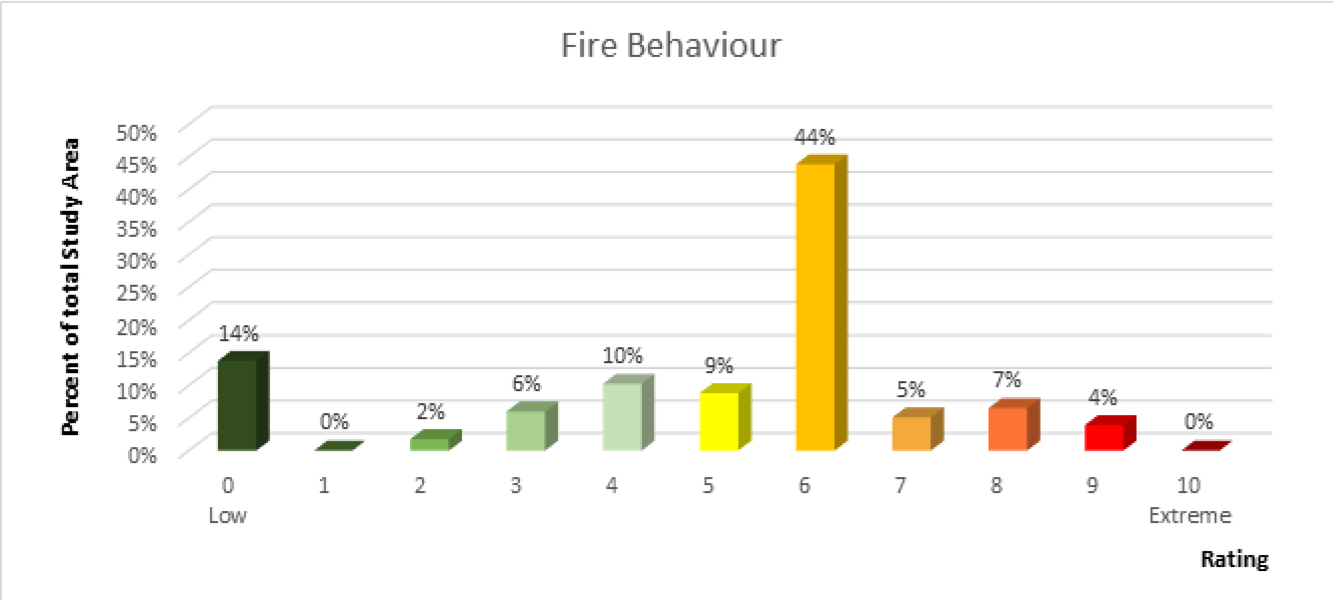


Figure 20. Distribution of the fire behaviour classes as a percentage of the study area (climate scenario 1).

CLIMATE SCENARIO 2:

Compared with climate scenario 1, climate scenario 2 has a larger proportion of the study area in the high to extreme potential fire behaviour classes (Figure 21 and Figure 22). This is largely a function of the increased drought code (DC) and fine fuel moisture code (FFMC) associated with the Brenda Mines station. It appears that the more extended periods of drought during the 2000-2018 period have increased the potential fire behaviour in the higher elevation portions of the study area. Under the longer term record these areas showed an overall lower fire behaviour potential and did not appear to be as vulnerable to large scale catastrophic wildfire. This is no longer the case under scenario 2 and more due diligence is potentially required to protect the transmission line and corridor within this area.

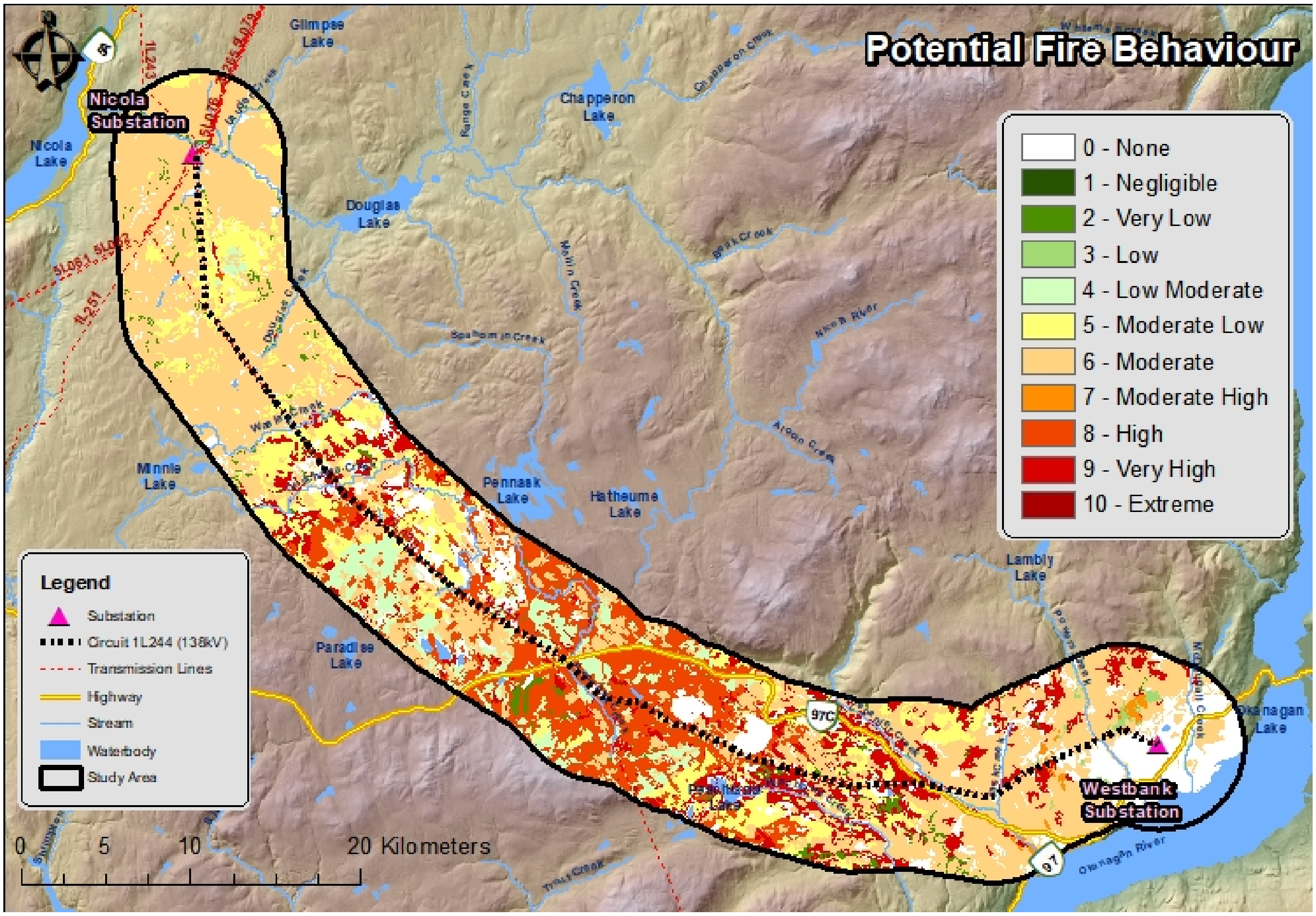


Figure 21. Potential Fire Behaviour using 90th percentiles calculated using only the values recorded after year 2000 of the fire weather stations (climate scenario 2).

When the fire behaviour potential is evaluated as a percentage of the total study area for scenario 2, almost 70% of the study area is vulnerable to fire behaviour ranging from high to extreme using 90th percentile conditions for the period of record from 2000-2018. This suggests that there are significant areas within the study area that could sustain and contribute to a large catastrophic wildfire that could impact a significant section of the transmission line.

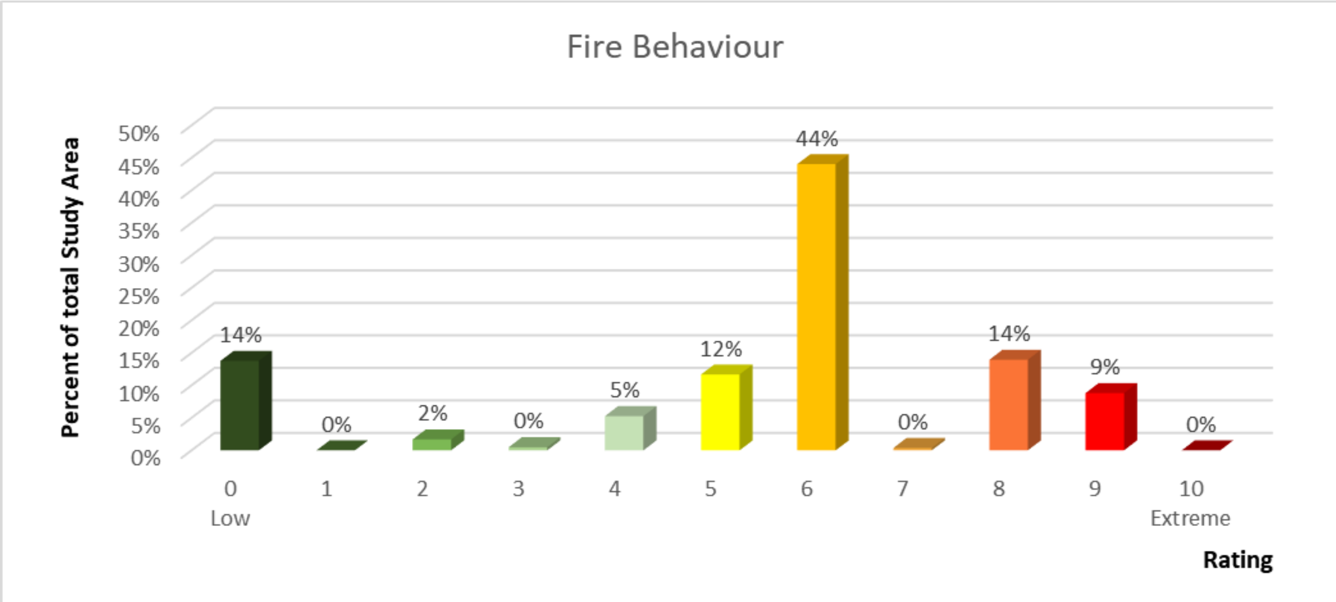


Figure 22. Distribution of the fire behaviour classes as a percentage of the study area (climate scenario 2).

Relative to the study area as a whole, the area closest to West Kelowna has the lowest relative fire behaviour potential, due to areas with no forest cover and development. However, within the immediate forested area next to development the fire behaviour jumps to high. The remainder of the transmission line is rated as relatively high to highest fire behaviour potential and only a small area is rated as relatively moderate fire behaviour potential. As pointed out previously, this suggests that a large portion of the transmission line is vulnerable to an outage from a wildfire and must be considered for some form of mitigation if BC Hydro decides to move forward with the WKTP Resiliency Alternative (1L244) as opposed to constructing a new transmission line for redundancy.

8.3 SUPPRESSION RESPONSE CAPABILITY

The overall suppression capability for the majority of the study area and the 1L244 circuit is good to very good. This makes sense in that most of the study area has good access (high road density network), is relatively close to suppression resources (both ground and aerial in both West Kelowna and Merritt), and with the exception of the area just outside West Kelowna (which has steeper sections with broken terrain and difficult access), the majority of the terrain is relatively uniform and can be described as rolling topography. The best suppression capability is associated with the area of homes and development at the eastern end of the circuit due to proximity to West Kelowna (Figure 23). The poorest suppression capability rated as moderate (yellow area on the map) is associated with areas where the road density is lower comparatively and distances to suppression resources are longer. During a period where the fire load is high (i.e., there may be multiple priority fires within the region) suppression capability may be substantially reduced such that human life and property becomes a priority and BC Hydro assets may not be an immediate priority for suppression. This map represents the best-case suppression capability where no recourses are constrained by other wildfire activity.

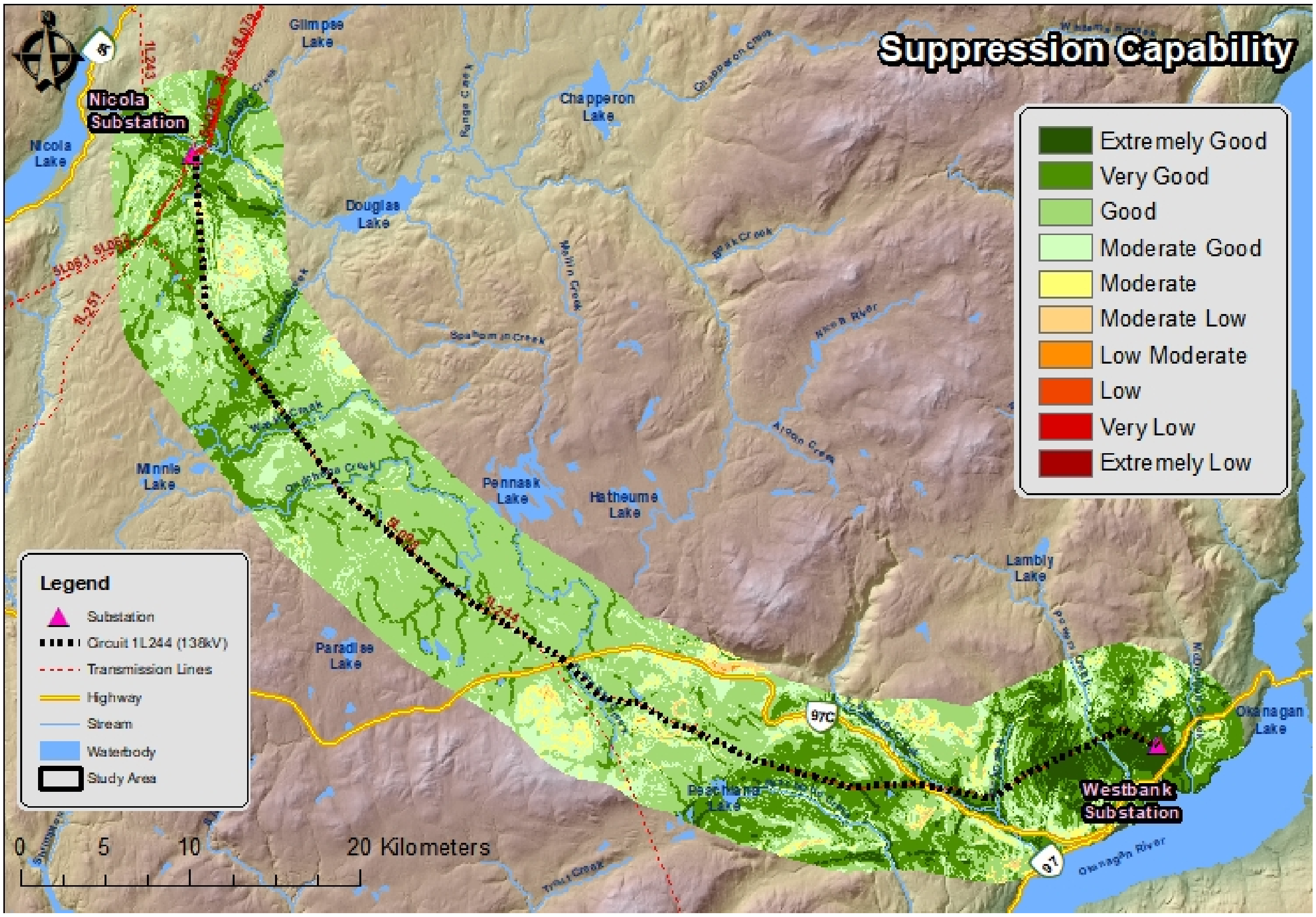


Figure 23. Suppression response capability.

The discussion above is further supported when the distribution of suppression capability classes represented by area is evaluated. More than 90% of the study area falls within areas classified with extremely good to good suppression capability (Figure 24).

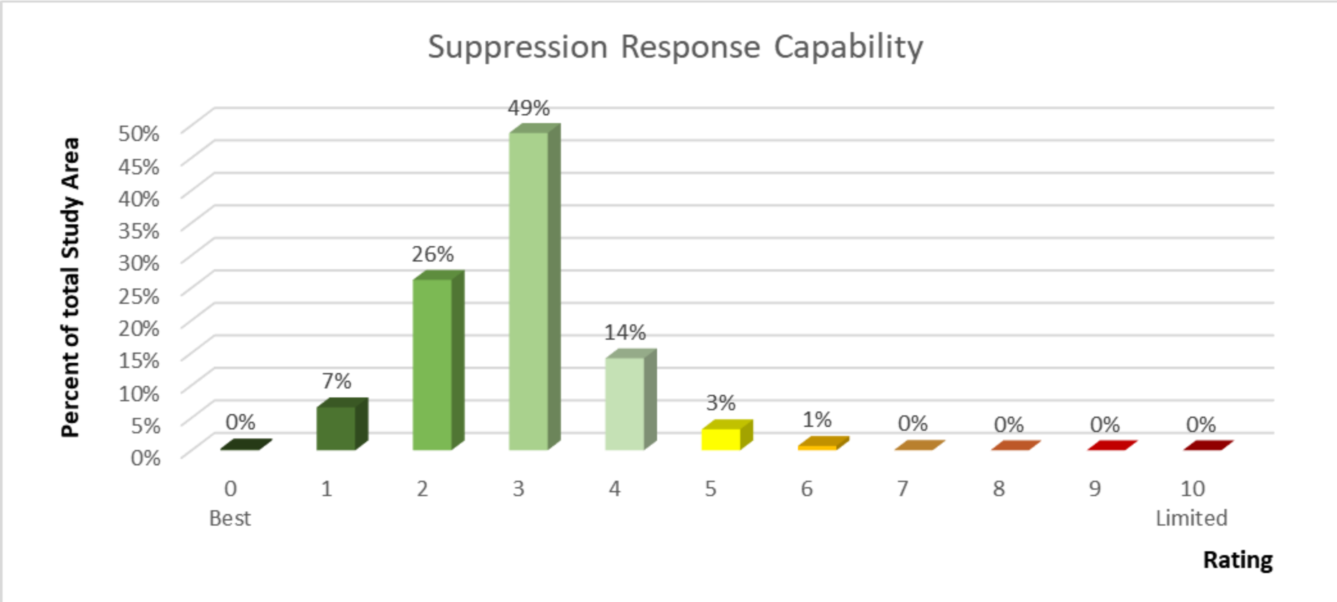


Figure 24. Distribution of the suppression response capability classes as percentage of the study area.

The poorest suppression response capability relative to the study area as a whole is located in the middle of the transmission line where both West Kelowna and Merritt are the greatest distance away. Generally, suppression response capability ranks relatively better for segments closest to West Kelowna, reflecting the very good suppression capability.

8.4 OVERALL WILDFIRE PROBABILITY

CLIMATE SCENARIO 1:

The wildfire probability and risk under climate scenario 1 provides a comprehensive assessment of the probability of wildfire within and adjacent to the study area footprint (Figure 25). In general, under this scenario the western and eastern ends of the circuit are at highest risk of wildfire. The middle section of the study area has a lower risk profile due the climate scenario used and the related fire behaviour potential in this portion of the study area. The overall probability is characterized by Figure 26, which summarizes the area of different probability classes described as low, moderate, high and extreme. Areas of high fire probability occur in varying proportions along sections of the entire circuit and are largely related to all of the factors considered, which include, fuel type and associated fire behaviour, human and lightning caused ignitions, and suppression capability.

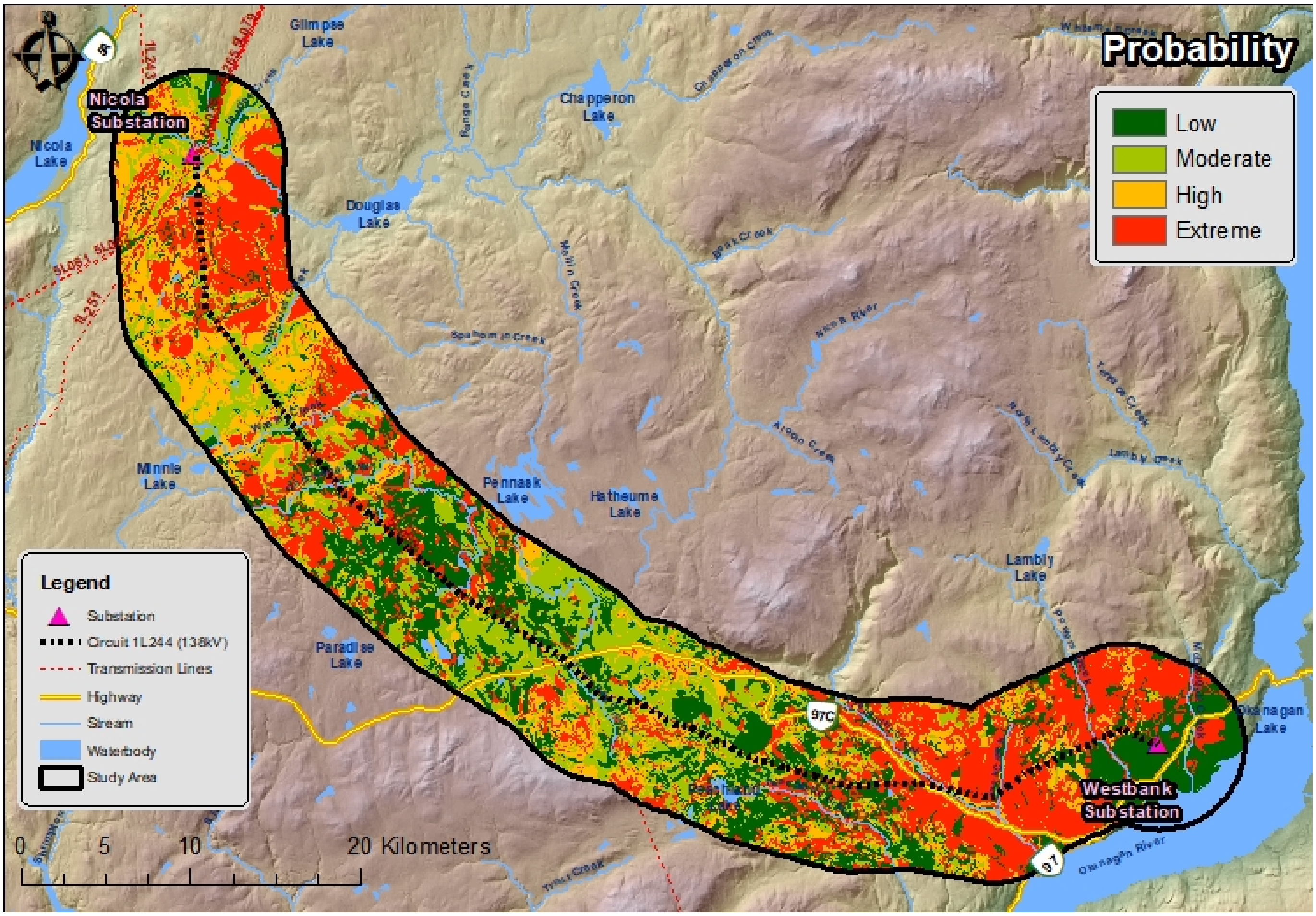


Figure 25. Fire Probability using 90th percentiles calculated using the full range of records (1977 – 2018) of the fire weather stations – climate scenario 1.

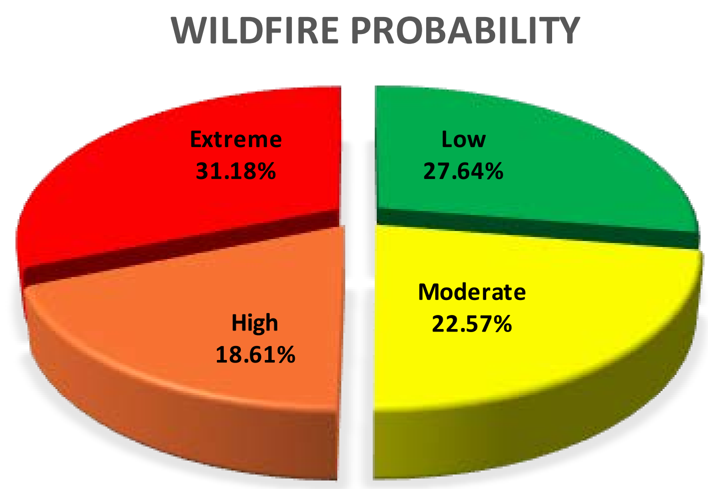


Figure 26. Wildfire probability - climate scenario 1.

CLIMATE SCENARIO 2:

When climate scenario 2 is considered the proportion of the area in extreme probability is increased (Figure 27 and Figure 28). As discussed for the fire behaviour theme under climate scenario 2, the higher elevation portion of the study area represented by the Brenda Mines station has elevated levels of drought as compared to climate scenario 1 and therefore there is an increase in the overall fire behaviour potential that contributes to higher levels of wildfire probability and resultant overall risk.

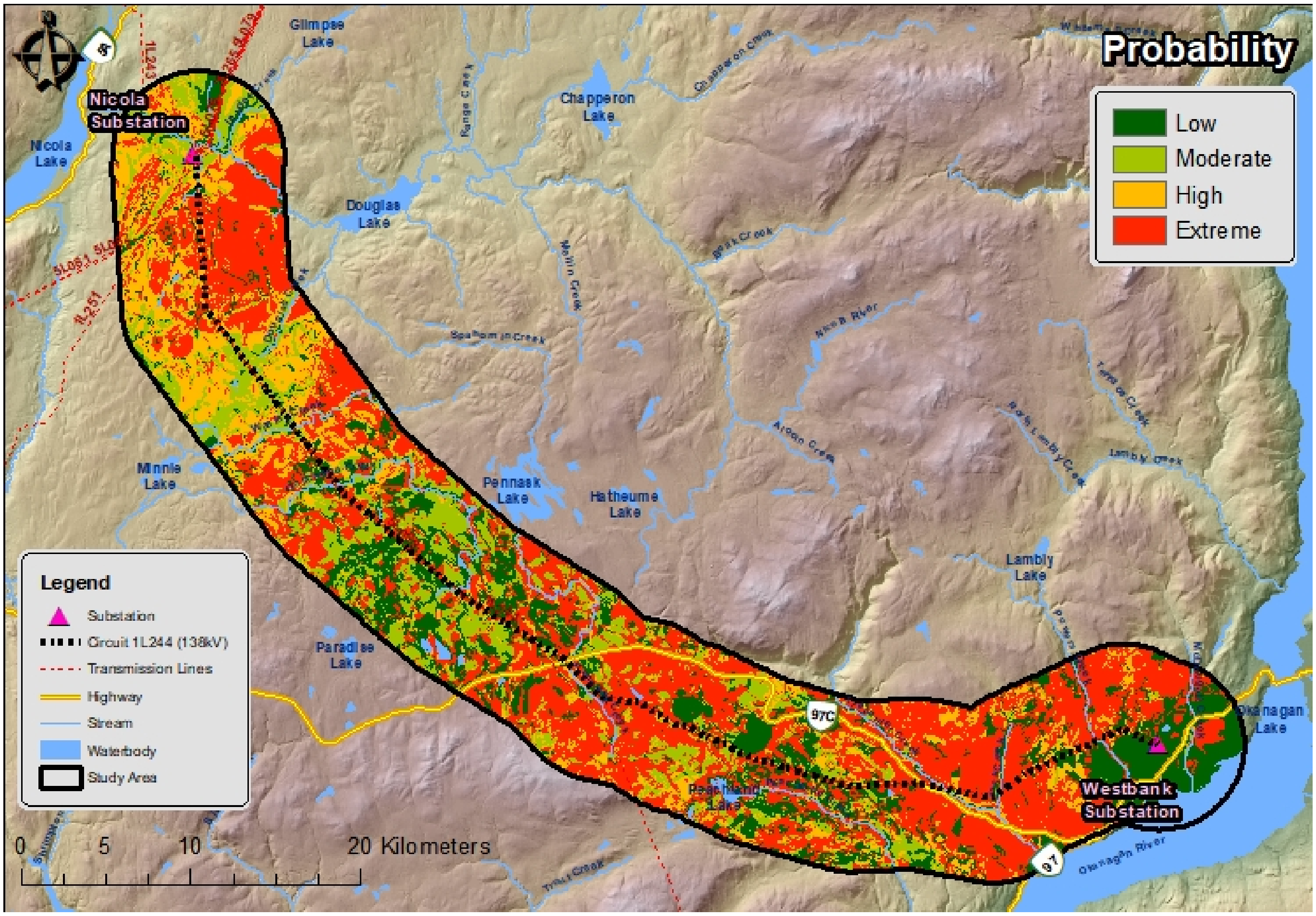


Figure 27. Fire Probability using 90th percentiles calculated using only the values recorded after year 2000 of the fire weather stations – climate scenario 2.

When the distribution of fire probability classes within the study area were compared for the two climate scenarios 1 and 2 there were significant changes in the percentages of each class (Figure 26 and Figure 28). For climate scenario 1 the contribution of the low and moderate classes was 50% of the study area, while high and extreme classes represented 50% of the study area. When the distribution of classes was compared for climate scenario 2 the area of low and moderate classes represented 39% and high and extreme represented 61%, which represented an overall increase in probability in the high and extreme classes of approximately 11%. It seems quite evident that increases in codes and indices of the Canadian Forest Fire Danger Rating System at the Brenda Mines station have significantly influenced the analysis and suggest that the wildfire probability has increased, specifically within higher elevation areas of the study area. An additional consideration in evaluating the probability and risk to the transmission line is associated with changes related to mountain pine beetle salvage harvesting, and the increased future wildfire hazard (closed canopy condition) of these areas as the young plantations approach the 30-40 years of age. During this 30-40-year period the probability of wildfire will increase incrementally to an even higher percentage of high to extreme probability as the plantations grow and fuel types become more hazardous (vertically and horizontally integrated). While this analysis is not statistical in nature and cannot be easily validated it makes intuitive sense that there is a trend to higher wildfire probability conditions along specific sections of the transmission corridor.

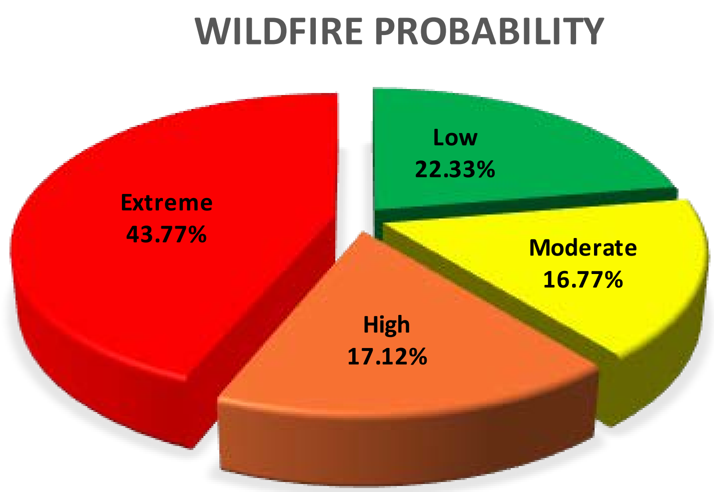


Figure 28. Wildfire probability - climate scenario 2.

The wildfire probability ranges from moderate to extreme for the majority of the transmission line. There are specific sections of the line that are rated extreme and high, with the remaining area rated moderate. The areas rated low are largely a function of fuel type and/or the proximity to communities where there are no fuels and a build-up of development. The areas rated moderate to high are largely a function of the fuel types present and the topography. Given the wide distribution of the moderate, high and extreme wildfire probability areas, much of the transmission corridor is vulnerable to wildfire and a resiliency strategy focused on protection of the structures and reduction of fine and dead fuels along the right-of-way corridor will be important to help reduce the potential damage to the circuit in the event of a wildfire.

9.0 FIRE BEHAVIOUR ANALYSIS

9.1 PURPOSE OF THE ANALYSIS

A spatial fire growth model was used to assess projected fire behaviour in fuels adjacent to the 1L244 using fire weather data from active stations during the 2018 wildfire season (B.C. Wildfire Service (BCWS)). Prometheus was used to complete the fire behaviour analyses as described in Section 9.2.1.

As discussed previously, circuit 1L244 is located within an area with high wildfire probability. Of importance to BC Hydro is where and how a wildfire could grow, and how it could impact this transmission line, which would impact the electricity supply to the communities of West Kelowna and Peachland. To better understand these issues, fire behaviour simulations (modelling), using potential ignition points and historic hourly weather data were used to understand how wildfires might grow both spatially and temporally, within this study area.

9.2 FUEL TYPES AND FIRE BEHAVIOUR

Blackwell derived fuel type polygons based on B.C. Vegetation Resource Inventory (VRI) data, and then updated the data using ground-truthing and orthophoto interpretations. VRI data was obtained from the B.C. Geographic Warehouse Database (DataBC). Fuel typing may contain some errors due to factors such as recent natural/human disturbance and heterogeneity within fuel type polygons, but the data accuracy was considered acceptable for the scale of this analysis. A targeted ground sampling program was conducted to validate the fuel type inventory and to adjust incorrectly assigned fuel types. The most significant issue was that fuel types that were assigned to the C7 classification were incorrect. This was largely attributed to the in-growth of trees in the understory that was not recognized or unidentified within the inventory. Fuel types that occur in the study area are listed in Table 4, Appendix C. Graphics and data illustrating the spatial distribution of the fuel types in the study area can be found in Figure 46 and Figure 47 in Appendix C.

The highest risk from wildfire is to young plantations in the 30-40-year age class and maturing young forest types up to 80 years old where the stocking level (density) has significant ladder fuel components with varying loadings of slash that have high surface and crown fire behaviour potential. Since 1995, salvage harvesting activities related to the Mountain Pine Beetle (*Dendroctonus ponderosae*) epidemic have resulted in additional areas of conifer regeneration plantations which are less than 30 years old, and will soon be entering the 30-40-year age class. This means that an increasing proportion of the project area will be entering these higher risk fuel types.

9.2.1 Prometheus

In total, 4 ignition points, using applicable weather station hourly fire weather, were modelled. The only fuel breaks were the existing road network in the study area. Although numerous wetlands, lakes, rivers and streams exist across the landscape, they are relatively small in area and still vulnerable to long-distance spotting. They have been included in the Non-Fuel portion of the fuel type classification. Therefore, they do not show up in the Prometheus modelling. It is important to note that Prometheus fire behaviour modelling does not simulate spotting of fires; hence modelled outputs are for individual ignition points only. Specific scenario parameter settings were 2-hour time steps. Otherwise, default model settings were retained.

The results from the four Prometheus model runs are based on fire weather data from weather stations nearest to the point of ignition as illustrated in Appendix E – Prometheus Runs. The Prometheus fire behaviour model outputs illustrate that the scale of fire growth and potential impacts increase with higher wind speeds over the multi-day simulation. These simulations cannot incorporate the impacts of fire suppression and likely represent a worst-case scenario with the exception of spotting, given that any of these simulations would be reduced by aggressive fire suppression. Fire perimeters in certain areas of the landscape are also significantly influenced by wind direction, whereas some individual ignition points result in fire growth that is similar under simulations with different wind directions. The range of fire size is variable when individual ignitions are compared for the same direction and wind speed.

Overall the Prometheus runs demonstrate the following:

- Fire growth and area of fire perimeters is very dependent on the location of the ignition point and wind direction;
- Fires originating from the eastern and western portions of the study area have the greatest potential to impact the circuit close to the Merritt Hub and or West Kelowna;
- Fires originating along the southern flank of the study area closer to Nicola substation have similar potential to spread over a wide portion of the circuit; and
- The results validate and support the efforts considered to date to mitigate wildfire risk primarily through segment selection (increased separation), or specified design decisions such as structure type. Vegetation management plays a subsidiary role with regards to wildfire hazard mitigation and is focused within the maintained right-of-way and can help slow spread rates, reduce the chance of potential ignition from within the right-of-way and along the edges, and aid suppression strategies such as facilitating the development of a wide fuel break that can be used effectively to set up fire guards.

10.0 VEGETATION MAINTENANCE

BC Hydro's vegetation management program has and may play a significant future role in mitigating/managing wildfire risk, which is an important consideration in protecting the 1L244 transmission line from wildfire. BC Hydro controls vegetation under, above, and near its power lines in order to maintain safe and reliable transmission and distribution of electricity to its customers. BC Hydro utilizes the principles of Integrated Vegetation Management to control target vegetation and manages the vegetation on its power lines on a cyclical basis using a variety of manual, mechanical, cultural, biological, and chemical control methods.

Vegetation management for 1L244 is completed on an approximate 10-year cycle. Planning is informed by regular patrols and inspections of the transmission system to determine when and where vegetation needs to be managed based on electrical clearance requirements and also to determine the location of hazard trees along the edge of the right-of-way. Specific vegetation treatments are prioritized taking into consideration site specific conditions, environmental constraints, target species growth rates, electrical clearance requirements, and worker and public safety. Consequently, the timing of treatments along the line will vary. During the current vegetation maintenance cycle (fiscal 2011-2020) for 1L244, approximately 114 ha of vegetation maintenance treatment has been completed (85 ha of this completed and/or in progress in 2019 as illustrated in Figure 29). Additionally, approximately 6,050 hazard trees have been removed or treated so far during the current 10-year cycle.

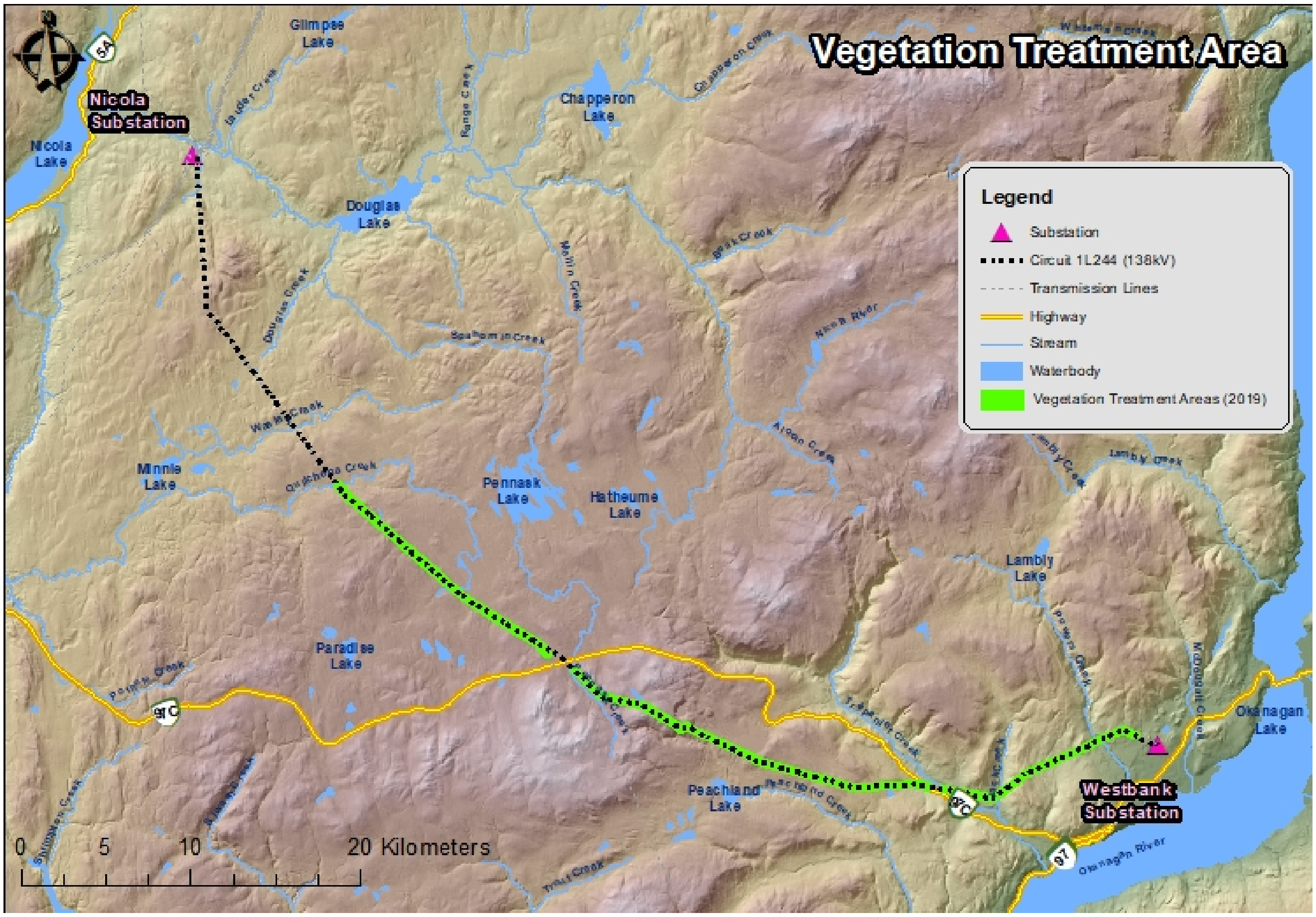


Figure 29. Vegetation maintenance treatments completed in 2019.

Site specific prescriptions for managing vegetation include protection of riparian areas and retention of vegetation for other values. Recent (2019) pre and post vegetation treatment conditions in the study area are illustrated in Figure 30 to Figure 33. Conifer re-growth prior to treatment on two sections of 1L244 is illustrated in Figure 30. Completed treatments in right-of-way sections with riparian features are illustrated in Figure 31. Additional recent vegetation maintenance treatment areas are illustrated in Figure 32 and Figure 33.

Figure 30. Pre-treatment condition west of structure 15-05 (top) and east of structure 20-08 (bottom), illustrating areas with conifer regrowth.

Figure 31. Post-treatment condition west of structure 19-05 (top, with a linear riparian feature); and west of structure 20-08 (bottom, with larger wetland riparian features), illustrating site-specific protection of riparian areas and retention of vegetation for other values.

Figure 32. Post-treatment site conditions east of structure 19-03 (top) and east of structure 31-05 (bottom).

Figure 33. Post-treatment site conditions east of structure 31-08 (top) and east of structure 29-02 (bottom).

Currently vegetation management for 1L244 is focused on the immediate right-of-way and trees that could fall onto the conductors. If BC Hydro elects to move forward with the resiliency alternative; given the current fire probability and the future expected increase of wildfire risk along the 1L244 circuit, BC Hydro should, in specific locations where risk is high to extreme, consider expanding the vegetation management foot print (wider right-of-way) as an option to reduce the overall risk to the line. This may be on a structure by structure basis or could include specific sections of the transmission corridor.

The current *Wildfire Act* and *Wildfire Regulation* define a number of obligations which require BC Hydro to conduct vegetation management to a high standard in both carrying out high risk activities (use of power saws and equipment) and managing forest fuels post vegetation treatment. These requirements contribute to other measures, such as hardening off structures, that in effect reduce the overall wildfire risk. Additionally, these types of actions will assist in reducing future climate induced risk and impacts, similar to those that have been experienced in recent years in British Columbia and other jurisdictions such as California.

With regards to wildfire risk, the most important consideration in protection of the 1L244 line is fire behaviour potential. The only approach that BC Hydro has to modify or control fire behaviour is through vegetation management within the right-of-way. As discussed in Appendix B (Wildfire Risk Modelling Methods) there are three elements to fire behaviour including crown fraction burned, rate of spread, and head fire intensity that make up the overall fire behaviour analysis. The rate of spread describes how fast a fire can spread under specific fire weather conditions, and the crown fraction burned describes where the fire is expected to move into the tree crowns. These are important measures specifically for fire suppression. The head fire intensity (HFI) describes the energy output of the fire, and is also important for fire suppression. However, the head fire intensity can also be used to assess where there is significant potential for fire related damage of BC Hydro infrastructure.

Figure 34 shows the 90th percentile head fire intensity (HFI) for climate scenario 2. The analysis shows that for the majority of the 1L244 right-of-way, the line would be impacted by high and extreme head fire intensity. It is expected that wherever the HFI is high along the transmission corridor, wood poles will likely be damaged by the wildfire. Where the HFI is extreme there is the possibility that both wood pole structures and lower hanging conductors may be compromised by the wildfire. Overall the analysis indicates that the majority of the transmission line has the potential under an extreme wildfire event to have damaging impacts to BC Hydro infrastructure.

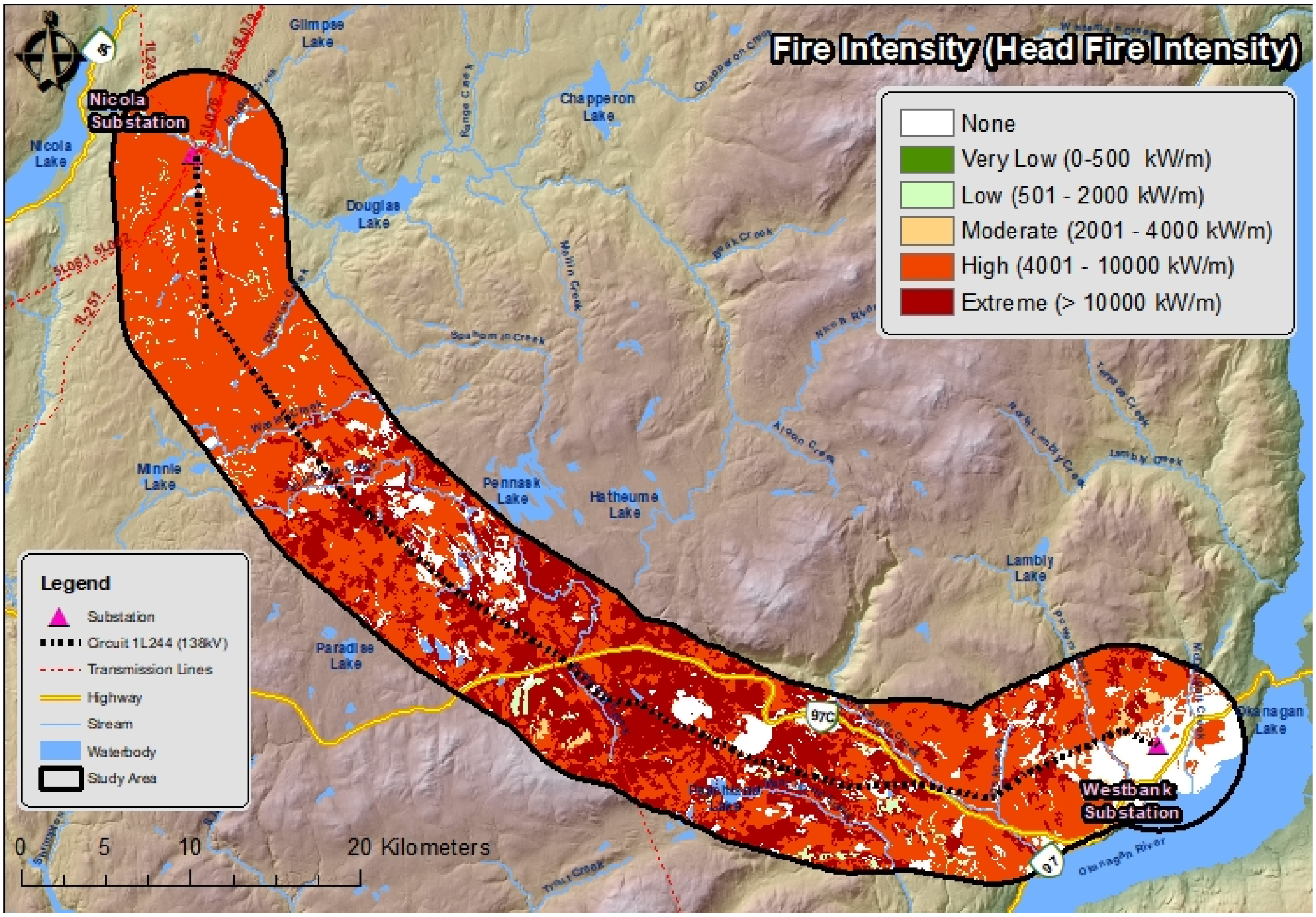


Figure 34. Head fire intensity classes for the study area – climate scenario 2.

The results of the analysis suggest that BC Hydro consider increasing the vegetation maintenance treatment frequencies based on the high and extreme risk areas, and areas with more significant conifer ingress, particularly those areas associated with the high hazard fuel types C2, C3, C4, and C7. A summary of the fuel types occurring in the study area (Table 4) and a map of the distribution of fuel types in the study area (Figure 46) are provided in Appendix C.

If the resiliency alternative is selected rather than constructing a new transmission line for redundancy, BC Hydro should consider the wildfire probability associated with the 1L244 corridor (see Section 8.4) and apply vegetation management strategies or mitigation options for the 1L244 line such that higher risk areas of the right-of-way are treated to a higher standard in order to lower fire behaviour potential to a level that improves wildfire resiliency. A final structure to structure assessment summary of wildfire probability and associated risk for 1L244 is provided in Appendix A.

Additional recommendations specific to the WKTP Resiliency Alternative (1L244) include the following:

- All forested edges should be located a minimum of 10 m[6] away from the closest conductor such that radiant heat from any crown fire can dissipate across a fuel free zone between the forest edge and the conductors. The width of the right-of-way should be wide enough to allow for this additional clearance between the outer conductors and the forest edge. Consider clearing additional right-of-way (widening) as required to provide the additional clearance.
- In the extreme and possibly high probability areas, consider replacing wood structures with steel structures to reduce the risk of damage to the structures in the event of a wildfire.
- Consider more frequent vegetation treatments nearer to wood poles in areas with a moderate and higher risk to reduce the risk of damage to wood poles in the event a wildfire spreads across the right-of-way.
- Consider regularly scheduled application of wood pole fire-guard[7] protection in areas with a moderate and higher risk to reduce the risk of damage to wood poles in the event a wildfire spreads across the right-of-way.
- Vegetation within BC Hydro's right-of-way is maintained to keep it a safe distance from the conductors. It is recommended that where possible, vegetation under the conductors be maintained as required to provide a clearance (based on expected flame height)[8] between the conductors and the tops of conifer vegetation to help reduce the risk of damage from flames should a wildfire occur within the right-of-way. The clearance can be a lesser distance over deciduous fuel types with little or no conifer component as these forest types have lower fire behaviour potential and are unlikely to impact the conductors. Minimum clearance distances need to be evaluated based on vulnerability assessments of BC Hydro structures and conductors, engineering requirements and recommendations related to these assets.
- Increase the frequency of vegetation maintenance treatments within the right-of-way, as required to maintain recommended clearance (as determined above).
- On steeper terrain where vegetation maintenance must be completed using manual hand treatments, consider implementing mini-pile and burn techniques where appropriate for final hazard abatement to help prevent buildup of woody debris over time. Where appropriate, the selective use of herbicide on tall-growing deciduous trees is another effective tool that can be used to limit the rate of regrowth on these areas and reduce the frequency of successive treatments and fuel loading potential within the maintained right-of-way.
- Maintain permanent access in a good condition along the right-of-way where possible to improve accessibility for vegetation maintenance and for fire suppression in the event of a wildfire.

---

[6] Based on Blackwell professional opinion, 10 m equates to the distance for radiant heat to dissipate to a temperature threshold that limits damage to structures and infrastructure. A 10 m priority fire-resistant zone is the FireSmart Canada standard (https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/wildfire-status/prevention/prevention-home-community/bcws_homeowner_firesmart_manual.pdf).

[7] Fire-guard protection could include engineered protection for the poles or application of proprietary fire-retardant materials.

[8] Flame height is dependent on fuel type, fire weather and topography.

The WRMS tool has been used to determine the wildfire risk profile of public and private assets and forms a spatial foundation on which to build a fire management plan focused on risk reduction along the right-of-way. By following the guidelines above, BC Hydro will be able to:

1) Minimize the risk of damage to the conductors and structures in the event of a wildfire;
2) Plan and schedule vegetation maintenance treatments to help minimize the potential fire intensity within the right-of-way;
3) Help reduce the likelihood of fire escaping off, or onto the right-of-way; and,
4) Protect critical infrastructure from fire related damage.

11.0 CONCLUSIONS

In reviewing the assessment of the 1L244 transmission corridor, it is my professional opinion that there are significant sections of the line with high and extreme wildfire probability and associated risk. This conclusion is based on the fire environment (climate, fuels and topography), historic ignitions and fire history. The climate scenarios modelled, including over the past decade, demonstrated an increased probability of wildfire associated with higher codes and indices of the Canadian Forest Fire Danger Rating System and the resultant increase in wildfire behaviour. If the resiliency alternative is selected rather than constructing a new transmission line for redundancy, the analysis emphasizes the need for BC Hydro to consider changes to its maintenance program specific to 1L244 including more frequent evaluation of high risk portions of the line, vegetation maintenance treatments, and potentially increasing the corridor width in specific locations where there are hazardous fuel types and a higher potential for damage to structures and the conductors.

12.0 REFERENCES

Bachmann, A. and B. Allgower. 1998. Framework for the assessment of wildfire risk. In: Proceedings of the 3rd International Conference on Forest Fire Research/ 14th Conference on Fire and Forest Meteorology, Luso, 2:2177-2190.

B.A. Blackwell & Associates Ltd. 2018. West Kelowna Transmission Project – Alternative 2. Identification Phase – Wildfire Risk Assessment - Preliminary Study Corridors. Contract Report to BC Hydro.

B.A. Blackwell & Associates Ltd. 2016. West Kelowna Transmission Project Wildfire Risk Assessment. Contract Report to BC Hydro.

Blackwell, B.A., Gray, R.W., Steele, F.M., Needoba, A.J., Green, R.N., and K. MacKenzie. 2003. A wildfire threat rating system for the Birkenhead and Gates Landscape Units, British Columbia. in: R.T. Engstrom and W.J. de Groot (eds.) Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Canadian Standards Association, 1997. Risk Management: Guideline for Decision-Makers: A National Standard of Canada. CAN/CSA-Q850-97. Etobicoke, Canada.

Council of Standards Australia / Council of Standards New Zealand, 1999. Risk Management. AZ/NZS 4360:1999. Strathfield, Australia.

Hawkes, B. and Beck, J. 1997. A wildfire threat rating system. 1997. Forest Service, Pacific Forestry Centre, Victoria, B.C. Technology Transfer Note 01.

International Standards Organization, 2002. Risk Management Vocabulary, Guidelines for use in Standards. First Edition. ISO/IEC Guide 73:2002(E/F). Geneva, Switzerland.

Lawson, B.D., O.B. Armitage, and G.N. Dalrymple. 1993. Ignition probabilities for simulated people-caused fires in British Columbia's lodgepole pine and white spruce-subalpine fir forests. Paper presented at the 12 International Conference on Fire and Forest Meteorology, Oct. 26-29, 1993, Jekyll Island, Georgia.

Lloyd, D, K. Angove, G. Hope and C. Thompson. 1990. A Guide to Site Identification and Interpretation for the Kamloops Forest Region. Land Management Handbook No. 23. ISSN 0229-1622.

Muller, C. 1993. Wildfire threat analysis: A decision support system for improved fire management. Paper presented at "The Burning Question: Fire Management in NSW", Coffs Harbour, Aug. 1993, UNE, Armidale, NSW, Australia.

Natural Resources Canada. 2017. Canadian Forest Fire Danger Rating System. http://cwfis.cfs.nrcan.gc.ca/background/summary/fdr

Pyne, S.J. 1984. Introduction to Wildland Fire: Forest Management in the U.S. John Wiley and Sons. New York, NY.

Silverman, B. W. *Density Estimation for Statistics and Data Analysis*. New York: Chapman and Hall, 1986.

Spittlehouse, D.L. 2008. Climate change, impacts, and adaptation scenarios: climate change and forest and range management in British Columbia. B.C. Ministry of Forests and Range, Resources Branch, Victoria, B.C. Technical Report 045. Accessed December 12, 2018: https://www.for.gov.bc.ca/hfd/pubs/docs/Tr/Tr045.htm

Vodopier, J.; Haswell, D. 1995. The application of wildfire threat analysis in forests of southwestern Australia. In: BUSHFIRE '95, Australian Bushfire Conference, Sept. 27-30, 1995, Hobart, Tasmania (no pagination in proceedings).

APPENDIX A – WKTP RESILIENCY ALTERNATIVE (1L244) WILDFIRE RISK ASSESSMENT

As part of the evaluation of wildfire probability, analysis was used to assign a risk class to the assessment of each structure on the 1L244 transmission corridor (Figure 35 and Table 2). The assignment of risk class was based on creating a 200 m buffer around each structure to determine its weighted probability (contribution of each probability class within the buffer) of damage and its associated risk class. Once probabilities were assigned to structures an overlay of structure probability and orthophotography was used to evaluate the probability and risk. For the majority of the corridor the probability class and the predicted risk class were the same (Table 2). Where the probability was moderate for grass fuel types (O1-a/b fuel types[9]) and there was a high probability that structures in around this fuel type would be damaged, the risk class was increased to high (Table 2). Where the probability was high and the structures were located within recently harvested clear cuts (S1/S2 fuel types) surrounded by extreme probability fuel types, the risk class was increased to extreme. The rationale for this increase is founded on the knowledge that as these plantations grow over the next 30 years they will become horizontally and vertically integrated, in all likelihood representing either C3 or C4 fuel types. Therefore, during the life of the transmission line, it is expected that these areas would also be exposed to extreme wildfire probability conditions. This emphasizes the importance of considering the evolving, succession related condition of vegetation and fuel types over the longer term in relation to the life cycle of 1L244 and the associated risk from wildfire.

[9] Fuel types for the study area are described and summarized in Appendix C

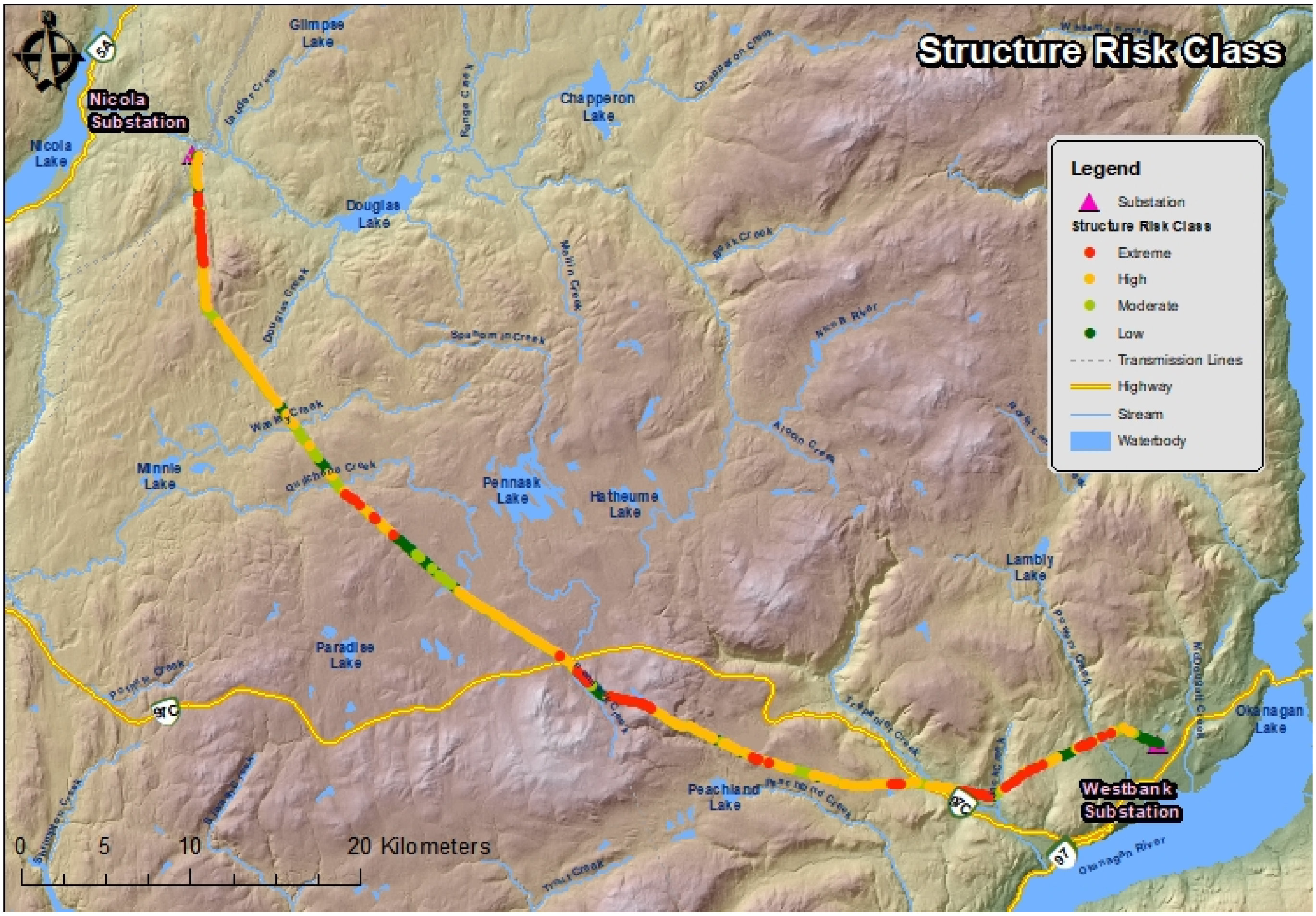


Figure 35. Structure wildfire risk classes along the length of 1L244.

Table 2. Wildfire risk assessment summary (weighted probability rating and risk class) for structures along 1L244.

Structure	Probability Rating	Risk Class	Structure	Probability Rating	Risk Class	Structure	Probability Rating	Risk Class	Structure	Probability Rating	Risk Class
00-SUB	Low	Low	**11-05**	Moderate	Moderate	**23-04**	High	High	**35-02**	High	High
00-01	Low	High	**11-06**	Moderate	Moderate	**23-05**	Extreme	Extreme	**35-03**	High	High
00-02	Low	High	**11-07**	Moderate	Moderate	**23-06**	High	High	**35-04**	High	High
00-03	Low	High	**11-08**	Moderate	Moderate	**23-07**	High	High	**35-05**	Moderate	High
00-04	Moderate	High	**12-01**	Moderate	Moderate	**23-08**	Moderate	High	**35-06**	Moderate	High
00-05	Moderate	High	**12-02**	Low	Low	**24-01**	High	High	**35-07**	High	High
00-06	High	High	**12-03**	Low	Low	**24-02**	High	High	**36-01**	Moderate	High
00-07	High	High	**12-04**	Low	Low	**24-03**	Extreme	Extreme	**36-02**	Low	High
00-08	High	High	**12-05**	Low	Low	**24-04**	Extreme	Extreme	**36-03**	Moderate	High
00-09	Moderate	High	**12-06**	High	High	**24-05**	Extreme	Extreme	**36-04**	High	High
00-10	Low	Low	**12-07**	High	High	**24-06**	Extreme	Extreme	**36-05**	High	High
01-01	Extreme	Extreme	**12-08**	Moderate	Moderate	**24-07**	Extreme	Extreme	**36-06**	High	High
01-02	Extreme	Extreme	**13-01**	Moderate	Moderate	**24-08**	Extreme	Extreme	**36-07**	Moderate	High
01-03	Extreme	Extreme	**13-02**	Moderate	Moderate	**25-01**	Moderate	High	**36-08**	Extreme	Extreme
01-04	Extreme	Extreme	**13-03**	Moderate	Moderate	**25-02**	Low	High	**37-01**	Extreme	Extreme
01-05	High	High	**13-04**	Moderate	High	**25-03**	Low	High	**37-02**	Extreme	Extreme
01-06	Extreme	Extreme	**13-05**	High	High	**25-04**	Low	High	**37-03**	Extreme	Extreme
01-07	High	High	**13-06**	Extreme	Extreme	**25-05**	Low	High	**37-04**	High	High
01-08	Extreme	Extreme	**13-07**	Extreme	Extreme	**25-06**	Low	High	**37-05**	Moderate	Moderate
02-01	High	High	**14-01**	Extreme	Extreme	**25-07**	High	High	**37-06**	High	High
02-02	Extreme	Extreme	**14-02**	High	High	**26-01**	Extreme	Extreme	**37-07**	High	High
02-03	Extreme	Extreme	**14-03**	Extreme	Extreme	**26-02**	Extreme	Extreme	**37-08**	High	High
02-04	Extreme	Extreme	**14-04**	High	High	**26-03**	Extreme	Extreme	**37-09**	Moderate	Moderate
02-05	Extreme	Extreme	**14-05**	Moderate	Moderate	**26-04**	Extreme	Extreme	**38-01**	Moderate	Moderate
02-06	Extreme	Extreme	**14-06**	High	High	**26-05**	Extreme	Extreme	**38-02**	Moderate	Moderate
02-07	Extreme	Extreme	**14-07**	High	High	**26-06**	Extreme	Extreme	**38-03**	High	High
02-08	Extreme	Extreme	**15-01**	Extreme	Extreme	**26-07**	Extreme	Extreme	**38-04**	Extreme	High
03-01	Extreme	Extreme	**15-02**	Extreme	Extreme	**26-08**	Extreme	Extreme	**38-05**	Extreme	High
03-02	Extreme	Extreme	**15-03**	High	High	**26-09**	Extreme	Extreme	**38-06**	Extreme	High
03-03	Extreme	Extreme	**15-04**	High	High	**27-01**	Extreme	Extreme	**38-07**	High	High
03-04	Extreme	Extreme	**15-05**	High	High	**27-02**	Extreme	Extreme	**38-08**	High	High
03-05	Extreme	Extreme	**15-06**	High	High	**27-04**	Extreme	Extreme	**38-09**	High	High
03-06	High	High	**15-07**	High	High	**27-05**	Extreme	Extreme	**39-01**	High	High
03-07	High	High	**16-01**	Extreme	Extreme	**27-06**	Extreme	Extreme	**39-02**	High	High
03-08	High	High	**16-02**	Low	Low	**27-07**	High	High	**39-03**	Extreme	Extreme
04-01	High	High	**16-03**	Low	Low	**28-01**	High	High	**39-04**	Extreme	Extreme
04-02	High	High	**16-04**	Low	Low	**28-02**	High	High	**39-05**	Extreme	Extreme
04-03	High	High	**16-05**	Low	Low	**28-02A**	High	High	**39-06**	Extreme	Extreme
04-04	High	High	**16-06**	Low	Low	**28-03**	High	High	**40-01**	Extreme	Extreme
04-05	High	High	**16-07**	Low	Low	**28-04**	High	High	**40-02**	Extreme	Extreme
04-06	High	High	**16-08**	Low	Low	**28-05**	Moderate	High	**40-03**	Extreme	Extreme
04-07	High	High	**17-01**	Moderate	Moderate	**28-06**	Moderate	High	**40-04**	Extreme	Extreme
04-08	High	High	**17-02**	Moderate	Moderate	**28-07**	High	High	**40-05**	Extreme	Extreme
04-09	High	High	**17-03**	Moderate	Moderate	**28-08**	High	High	**40-06**	Low	Low
04-10	High	High	**17-04**	Low	Low	**29-01**	Moderate	Moderate	**40-07**	Moderate	Moderate
05-01	High	High	**17-05**	Low	Low	**29-02**	Moderate	Moderate	**41-01**	High	High

Structure	Probability Rating	Risk Class	Structure	Probability Rating	Risk Class	Structure	Probability Rating	Risk Class	Structure	Probability Rating	Risk Class
05-02	High	High	**17-06**	Low	Low	**29-03**	High	High	**41-02**	Extreme	Extreme
05-03	Moderate	Moderate	**17-07**	Low	Low	**29-04**	Moderate	High	**41-03**	Extreme	Extreme
05-04	Moderate	Moderate	**17-08**	Moderate	Moderate	**29-05**	Moderate	High	**41-04**	Extreme	Extreme
05-05	Moderate	Moderate	**18-01**	Low	Low	**29-06**	Moderate	High	**41-05**	Extreme	Extreme
05-06	Moderate	Moderate	**18-02**	Moderate	Moderate	**29-07**	Moderate	High	**41-06**	High	High
05-07	High	High	**18-03**	Moderate	Moderate	**29-08**	Moderate	High	**42-01**	Extreme	Extreme
05-08	High	High	**18-04**	Moderate	Moderate	**29-09**	Moderate	High	**42-02**	High	High
06-01	High	High	**18-05**	Moderate	Moderate	**29-10**	Moderate	High	**42-03**	Extreme	Extreme
06-02	High	High	**18-06**	Moderate	Moderate	**30-01**	High	High	**42-04**	Extreme	Extreme
06-03	Moderate	High	**18-07**	Moderate	Moderate	**30-02**	Low	High	**42-05**	Extreme	Extreme
06-04	Moderate	High	**18-08**	Low	Low	**30-03**	Low	High	**42-06**	High	High
06-05	Moderate	High	**19-01**	Moderate	High	**30-04**	Moderate	High	**42-07**	Extreme	Extreme
06-06	Moderate	High	**19-02**	Moderate	High	**30-05**	High	High	**43-01**	High	High
06-07	Moderate	High	**19-03**	Moderate	High	**30-06**	High	High	**43-02**	High	High
07-01	Moderate	High	**19-04**	Moderate	High	**30-07**	Moderate	High	**43-03**	High	High
07-02	Moderate	High	**19-05**	Moderate	High	**30-08**	High	High	**43-04**	High	High
07-03	Moderate	High	**19-06**	Moderate	High	**30-09**	Moderate	High	**43-05**	Low	Low
07-04	Moderate	High	**19-07**	Moderate	High	**31-01**	Moderate	High	**43-06**	Low	Low
07-05	Moderate	High	**19-08**	Moderate	High	**31-02**	Low	Low	**43-07**	Low	Low
07-06	Moderate	High	**20-01**	Moderate	High	**31-03**	Moderate	High	**43-08**	Low	Low
07-07	Moderate	High	**20-02**	High	High	**31-04**	Low	High	**44-01**	High	High
08-01	Moderate	High	**20-03**	High	High	**31-05**	Moderate	High	**44-02**	Extreme	Extreme
08-02	Moderate	High	**20-04**	Moderate	High	**31-06**	Extreme	Extreme	**44-03**	Extreme	Extreme
08-03	Moderate	High	**20-05**	Low	High	**31-07**	Extreme	Extreme	**44-04**	Extreme	Extreme
08-04	Moderate	High	**20-06**	Low	High	**31-08**	Extreme	Extreme	**44-05**	Extreme	Extreme
08-05	Moderate	High	**20-07**	Low	High	**32-01**	High	High	**44-06**	Extreme	Extreme
08-06	Moderate	High	**20-08**	Low	High	**32-02**	Extreme	Extreme	**44-07**	High	Extreme
08-07	Moderate	High	**21-01**	Moderate	High	**32-03**	High	High	**45-01**	Extreme	Extreme
09-01	Moderate	High	**21-02**	High	High	**32-04**	Moderate	High	**45-02**	Extreme	Extreme
09-02	Moderate	High	**21-03**	High	High	**32-05**	Moderate	High	**45-03**	High	High
09-03	Moderate	High	**21-04**	Moderate	High	**32-06**	Moderate	High	**45-04**	Moderate	Moderate
09-04	Moderate	High	**21-05**	Moderate	High	**33-01**	Moderate	High	**45-05**	Moderate	Moderate
09-05	Low	Low	**21-06**	Moderate	High	**33-02**	High	High	**46-01**	High	High
09-06	Low	Low	**21-07**	Moderate	High	**33-03**	Moderate	Moderate	**46-02**	High	High
09-07	Low	Low	**21-08**	High	High	**33-04**	Moderate	Moderate	**46-03**	High	High
10-01	Moderate	High	**22-01**	Moderate	High	**33-05**	Low	Moderate	**46-04**	Moderate	Moderate
10-02	Moderate	High	**22-02**	High	High	**33-06**	Moderate	Moderate	**46-05**	Low	Low
10-03	Moderate	High	**22-03**	Moderate	High	**33-07**	Moderate	Moderate	**46-06**	Low	Low
10-04	Moderate	High	**22-04**	Moderate	High	**33-08**	Low	High	**46-07**	Low	Low
10-05	Moderate	Moderate	**22-05**	Moderate	High	**34-01**	Low	High	**47-01**	Low	Low
10-06	Moderate	Moderate	**22-06**	Moderate	High	**34-02**	Low	Low	**47-02**	Low	Low
10-07	Moderate	Moderate	**22-07**	Moderate	High	**34-03**	Moderate	High	**47-03**	Low	Low
11-01	Moderate	Moderate	**22-08**	Moderate	High	**34-04**	Moderate	High	**47-04**	Low	Low
11-02	Moderate	Moderate	**23-01**	Moderate	High	**34-05**	Moderate	High	**47-99**	Low	Low
11-03	Moderate	Moderate	**23-02**	Moderate	High	**34-06**	High	High			
11-04	High	High	**23-03**	High	High	**35-01**	Moderate	Moderate			

APPENDIX B – WILDFIRE RISK MODELLING METHODS

OVERVIEW

The purpose of this assessment was to create a spatial representation of factors that influence the probability and the potential consequence of wildfire to BC Hydro transmission infrastructure for the WKTP Resiliency Alternative study area. The model was implemented in a GIS environment using ArcGIS 10.6. (ESRI – Geographic Information System software developer) using a raster grid at 25 m by 25 m cell resolution (a raster consists of a matrix of cells organized into a grid, with each cell containing values representing the attributes of a corresponding physical space).

The WKTP model structure is portrayed in Figure 36. The final spatial probability rating was derived from three major components: *Probability of Ignition*, Potential *Fire Behaviour*, and *Suppression Capability*.

Probability Rating		Attribute Rating	Attribute Weight	Weighted Sum	Component Weight	Weighted Sum
Probability of Ignition	Lightning Caused Fires		30%			
	Human Caused Fires		30%			
	Ignition Potential		40%			
					30%	
Potential Fire Behaviour	Fire Intensity		50%			
	Rate of Spread		25%			
	Crown Fraction Burned		25%			
					30%	
Suppression Capability	Constraints to Detection		10%			
	Proximity to Water Sources		10%			
	Helicopter Arrival Time		20%			
	Air Tanker Arrival Time		20%			
	Terrain Steepness		30%			
	Proximity to Roads		10%			
					40%	

Figure 36. West Kelowna Transmission Project Resiliency Alternative WRMS model structure, showing major components and their subcomponents10

Within each major model component, subcomponents are assigned individual ratings for each raster cell using a 0-10 scale 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).

At the component level, the rating for each raster cell was calculated as a weighted sum of all its subcomponents. All the data sources used to compile this analysis are listed in Table 3. All other subcomponents were derived in a

[10] Crown Fraction Burned (CFB) is the predicted fraction of the tree crowns consumed by the fire. It is based on Buildup Index, Foliar Moisture Content, Surface Fuel Consumption, and Rate of Spread.

similar manner. The overall rating levels for probability and consequence were analogously constructed by calculating the weighted sum of their respective components.

Table 3. Overview of Methods, Databases and Sub-Models for each Subcomponent of each Component

	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	Kernel point density of the number of lightning fire ignition points (since 1950) with a natural distribution into 4 classes	- ESRI Spatial Analyst[2] - Ministry of Forests fire records
		Human Caused Fire	Kernel point density of the number of human fire ignition points (since 1950) with a natural distribution into 4 classes	- ESRI Spatial Analyst - Ministry of Forests fire records
	Potential 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
		Crown Fraction Burned	Calculation using fire weather, fuel type and topography	- Fire Behaviour Predictor 97
	Suppression Capability	Constraints to Detection	Average elevation above valley bottom of forest inventory polygon	- Terrain Resource Information Management (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
		Helicopter Arrival Time	Measured flight time (concentric) from heli base	- Protection Branch data
		Terrain Steepness	Average slope of forest inventory polygon	- TRIM
		Proximity to Roads/Helipads	Buffer distance from roads, helipads, and alpine tundra/parkland	- TRIM

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

DEVELOPMENT OF PROBABILITY THEME

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 38). The subcomponent rating scales and assigned initial weights are shown (Figure 37).

The following figures represent the Probability of Ignition Component Tables.

Wildfire Risk Management Component: **Probability of 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*		Extreme	10	30%
		High	7	
		Moderate	3	
		Low	0	
Human Caused Fires *Indicator of historical frequency of human caused fires*		Extreme	10	30%
		High	7	
		Moderate	3	
		Low	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	
		Very Low	0	

Figure 37. Probability Component Table: Probability of Ignition.

LIGHTNING AND HUMAN CAUSED FIRE

The first two subcomponents, lightning and human caused fires, were based on historical fire frequency and cause in the study area from 1950 to 2018. Fire history records from the BCWS were translated into spatial points within the GIS framework. A surface kernel function was used to generate the ignition density. Kernel density calculates the density of point features around each output raster cell.

Conceptually, a smoothly curved surface is fitted over each point. The surface value is highest at the location of the point and diminishes with increasing distance from the point, reaching zero at the search radius distance from the point. Only a circular neighborhood is possible. The volume under the surface equals the population field value for the point, or 1 if "NONE" is specified. The density at each output raster cell is calculated by adding the values of all the kernel surfaces where they overlay the raster cell center. The kernel function is based on the quartic kernel function described in Silverman (1986, p. 76, equation 4.5).

If a population field setting other than “NONE” is used, each item's value determines the number of times to count the point. For example, a value of 3 would cause the point to be counted as three points. The values can be integer or floating points.

The resulting raster was classified using the Natural Breaks (Jenks) method into 4 classes: low, moderate, high and extreme.

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 where 90th percentile weather represents 10% of the historic fire weather extreme. It was calculated using the Wildfire Ignition Probability Predictor (WIPP), a tool from FORTester v1.0 (Lawson *et al.* 1993). The model determined the probability of sustained ignition from simulated people-caused fire brands (matches and camp fires) and predicted, in broad classes (a “no-fire day” if probability of sustained ignition was less than 50% and a “fire day” if probability was greater than 50%), from readily available indicators of fire danger based on benchmark fuel type groups applicable to B.C. Ignition probabilities expressed on an area basis provided a measure of people-caused fire potential from simple fire danger rating system components.

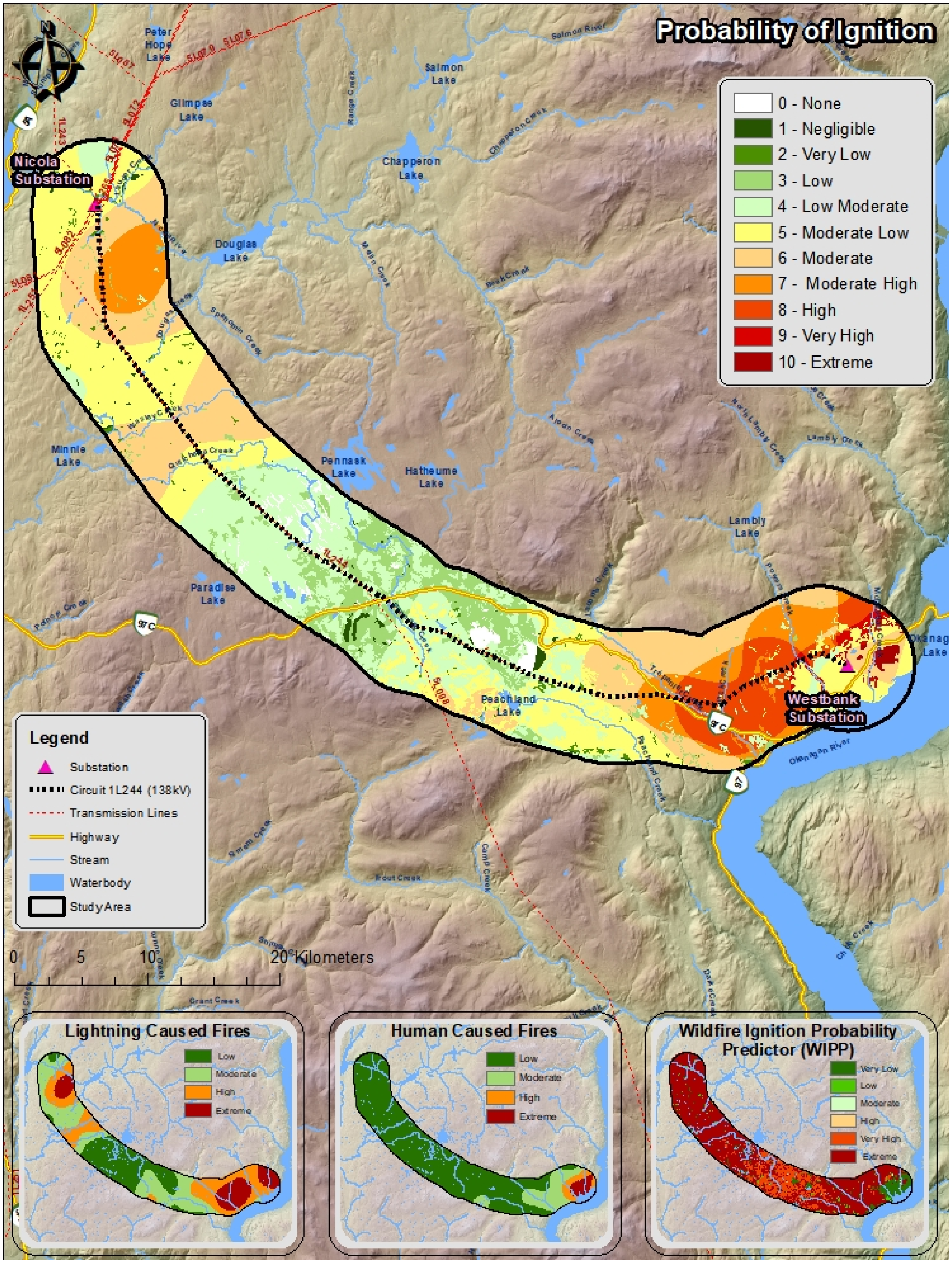


Figure 38. Probability of Ignition Component and associated subcomponents (climate scenario 1).

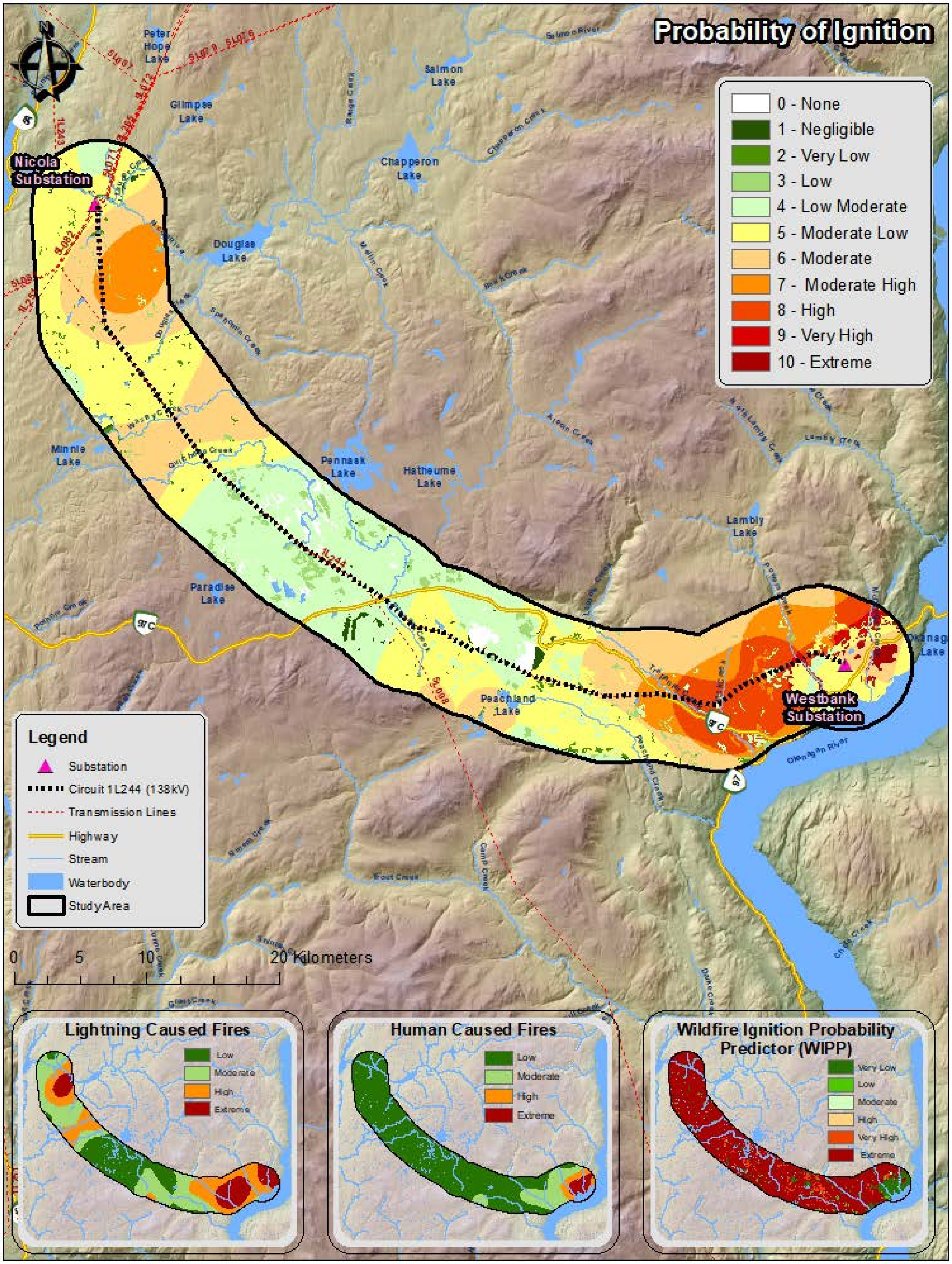


Figure 39. Probability of Ignition Component and associated subcomponents (climate scenario 2)

Fire Behaviour Component

The model developed for the WKTP Resiliency Alternative was designed using 90th percentile fire weather conditions[11]. The fire behaviour component (Figure 41) estimated how wildfire would behave under the study area's historic weather conditions that have occurred over the recorded climate record. 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 40 and Figure 41).

The Canadian Fire Behaviour Prediction System uses 16 national benchmark fuel types to predict fire behaviour. For the assessment, all of the 16 fuel types were selected to estimate fire behaviour based on species composition and stand structure attributes. Forest cover from the Vegetation Resource Inventory data was used by MFLNRORD to produce a standardized fuel type map that describes the 16 benchmark fuel types. A fuel type map of the study area is provided in Figure 46.

Weather information was derived from historic records collected from weather stations associated with the study area's Biogeoclimatic ecosystem classification. A provincial lookup table with computed fire weather indices summarized by station and Biogeoclimatic unit was used to determine 90th percentile weather conditions for the study area.

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.

[11] 90th percentile weather represents the historic fire weather extreme that is representative of 10% of the fire weather record.

Wildfire Risk Management Component: **Potential 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	50%
		4,001 - 10,000	8	
		2,001 - 4,000	6	
		501 - 2,000	4	
		1-500	2	
		0	0	
Rate of Spread *Indicator of speed at which fire extends horizontally.*	metres per minute	> 40	10	25%
		21 - 40	8	
		11 - 20	6	
		6 - 10	4	
		1 - 5	2	
		0	0	
Crown Fraction Burned *Indicator of the proportion of tree crowns consumed by fire (i.e., a measure of tree mortality).*	%	76 - 100	10	25%
		51 - 75	8	
		21 - 50	6	
		11 - 20	4	
		1 - 10	2	
		0	0	

Figure 40. Probability Component Table: Fire Behaviour probability

FIRE INTENSITY

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).

RATE OF SPREAD

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).

CROWN FRACTION BURNED

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.

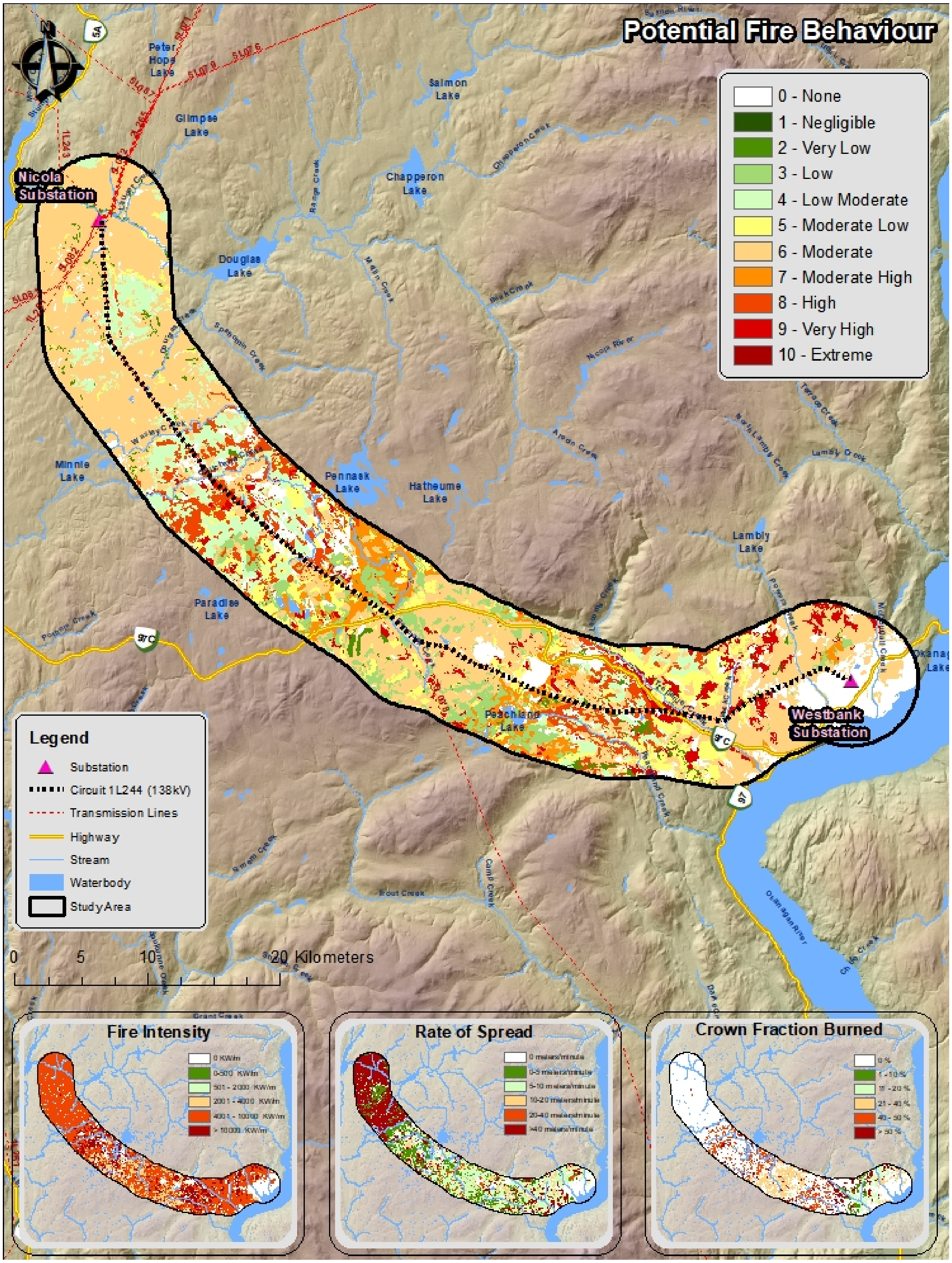


Figure 41. Fire Behaviour component and associated subcomponents for the 90th percentile July/August weather conditions applying a windspeed of 9 km/hour (climate scenario 1).

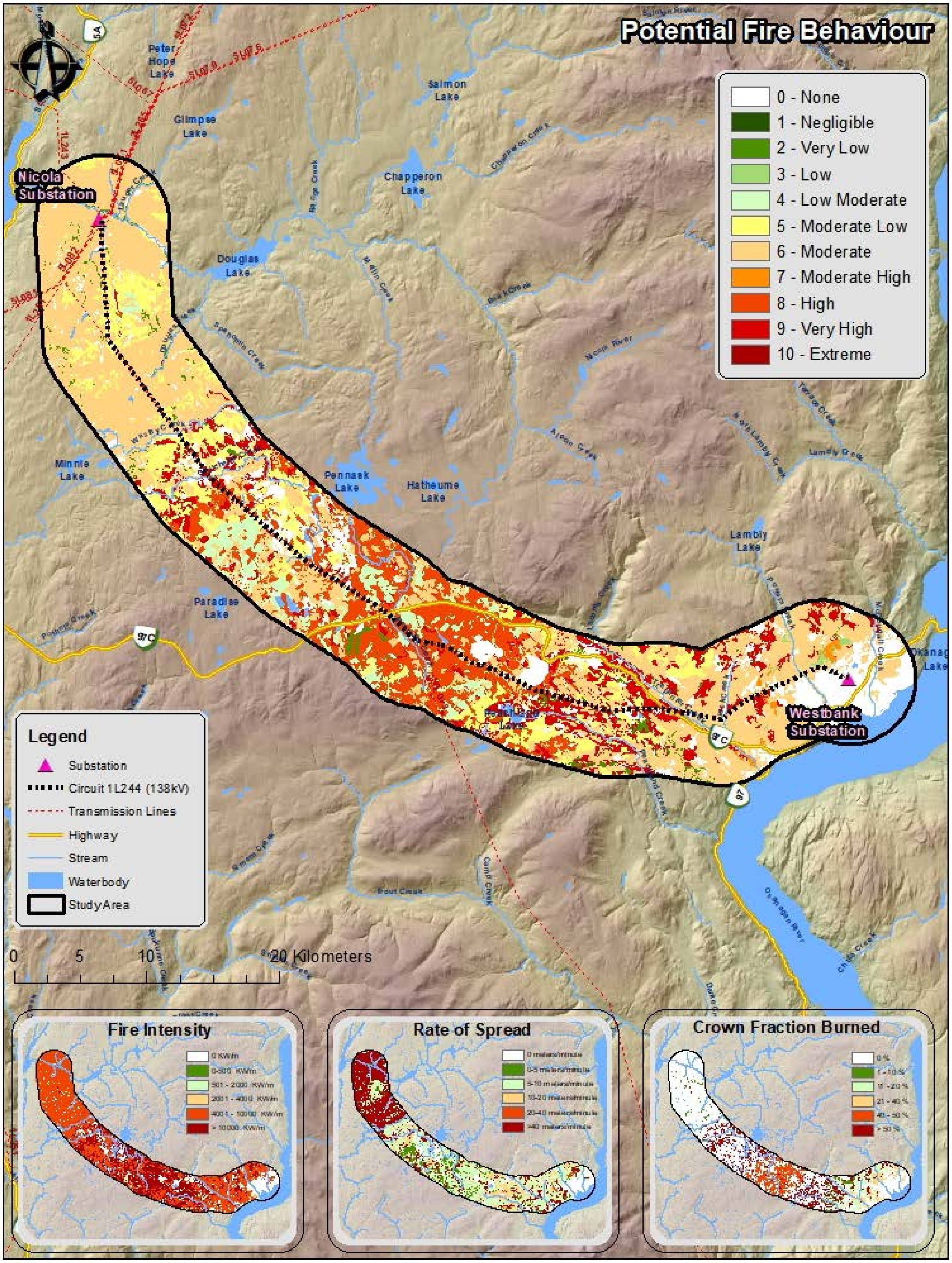


Figure 42. Fire Behaviour component and associated subcomponents for the 90th percentile July/August weather conditions applying a windspeed of 9 km/hour (climate scenario 2).

Suppression Response Capability Component

The ability to suppress wildfire is 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 and helipads (Figure 43 and Figure 44). An updated road network (provided by BC Hydro for the study area), was used for the suppression capability to reflect current access and resultant enhanced suppression capability.

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 Attack Time, Helicopter Arrival Time, Terrain Steepness,** and **Proximity to Roads**

Component Attributes:

Attribute	Indicator / Units	Rating Scale		Weight
Constraints to Detection		> 1700	10	10%
Indicator of the ability to detect a fire: reconnaissance at higher elevations is often constrained by cloud cover.	elevation metres	1250 - 1700	7	
		750 - 1250	3	
		<750	0	
Proximity to Water Sources		>300	10	10%
Indicator of the ability to access water quickly for fire fighting. Based on distance from all season streams and lakes.	distance metres	101-300	7	
		0-100	2	
Air Tanker Arrival Time		> 40	10	20%
Indicator of time for air tanker action measured as flight time (concentric) from nearest tanker base (300k/hr)	minutes	31 - 40 (200km)	7	
		21 - 30 (150km)	5	
		11 - 20 (100km)	3	
		0 - 10 (50km)	0	
Helicopter Arrival Time		> 70	10	20%
Indicator of the time for initial attack, measured as flight time (concentric) from nearest base PLUS fixed assumptions about time of travel to the base.	minutes	51 - 70 (210 km)	7	
		31 - 50 (150 km)	5	
		11 - 30 (90 km)	3	
		0 - 10 (30 km)	0	
Terrain Steepness		> 60	10	30%
Indicator of the difficulty of control/contain on the landscape.	slope Class %	41 - 60	7	
		21 - 40	3	
		0 - 20	0	
Proximity to Roads		> 120 (>2km)	10	10%
Indicator of the ability to get suppression resources into an area: based on a bush walking rate of 1 km / hour.	minutes	61 - 120 (2 km)	7	
		31 - 60 (1km)	5	
		16 - 30 (0.5km)	3	
		0 -15 (0.25km)	0	

Figure 43. Probability Component Table: Suppression Response Capability.

CONSTRAINTS TO DETECTION

In British Columbia, fires are detected by three primary methods: a provincial lightning location system, aircraft, and identification 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 typically follows 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 inhibit 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 the detection subcomponent were therefore based on elevation classes. The higher the elevation, the more likely detection will be constrained by cloud and fog cover. Four classes were created based on the elevation range in the study area as follows:

- less than 1000 meters;
- 1000 – 1250 meters;
- 1250 – 1700 meters; and
- Over 1700 meters.

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 firefighting) 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.

HELICOPTER ARRIVAL TIME

The helicopter arrival time subcomponent was determined based on the distance from the closest heli base to the study area. 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 and helipads in the study area and assigning weights relative to walking time from these areas. Alpine tundra was included as area accessible by helicopter.

Figure 45 summarizes all the mapping outputs required to develop the final probability theme as per the methods described above, for ignition probability, fire behaviour and suppression capability.

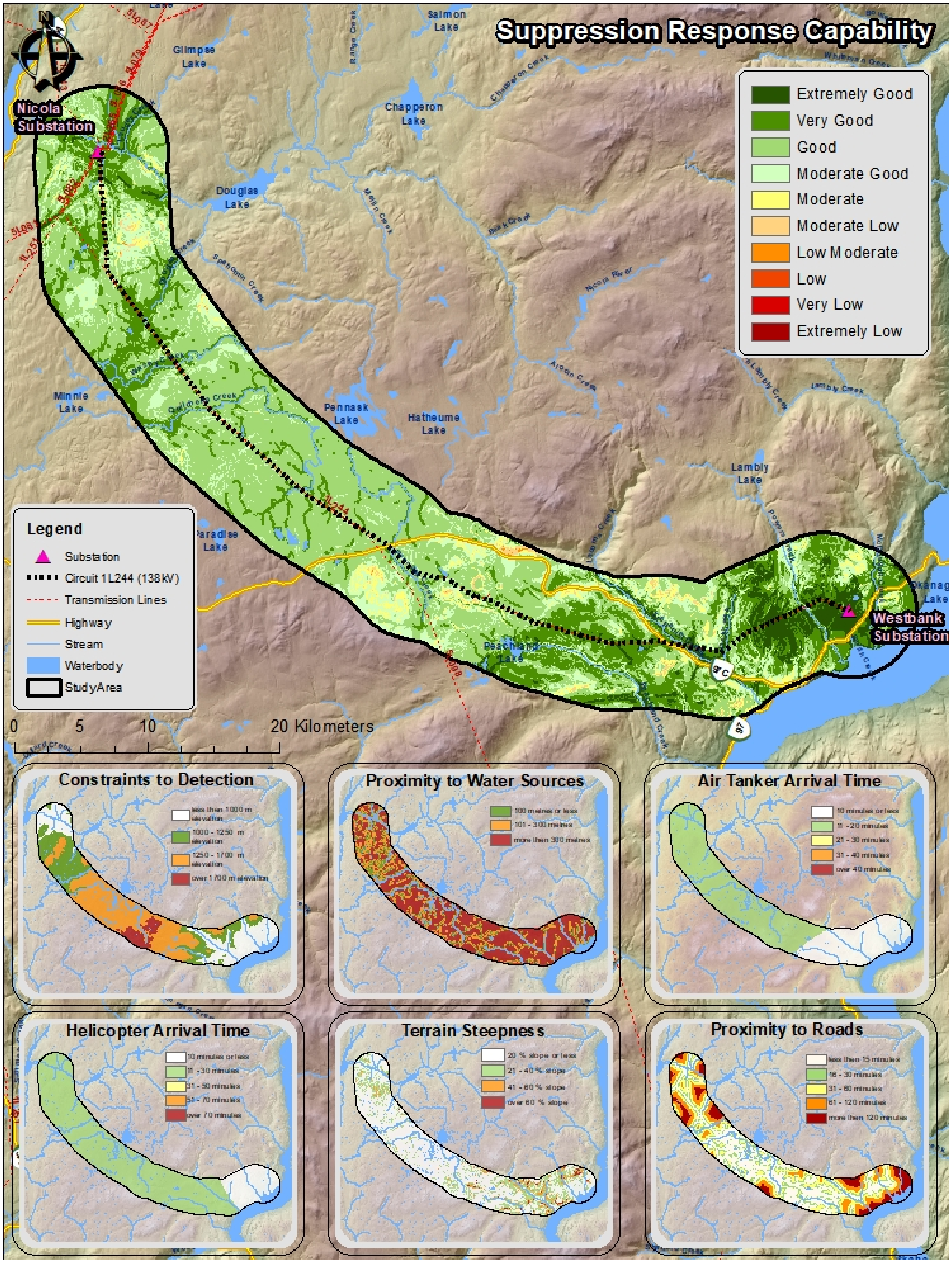


Figure 44. Suppression Response Capability and associated subcomponents.

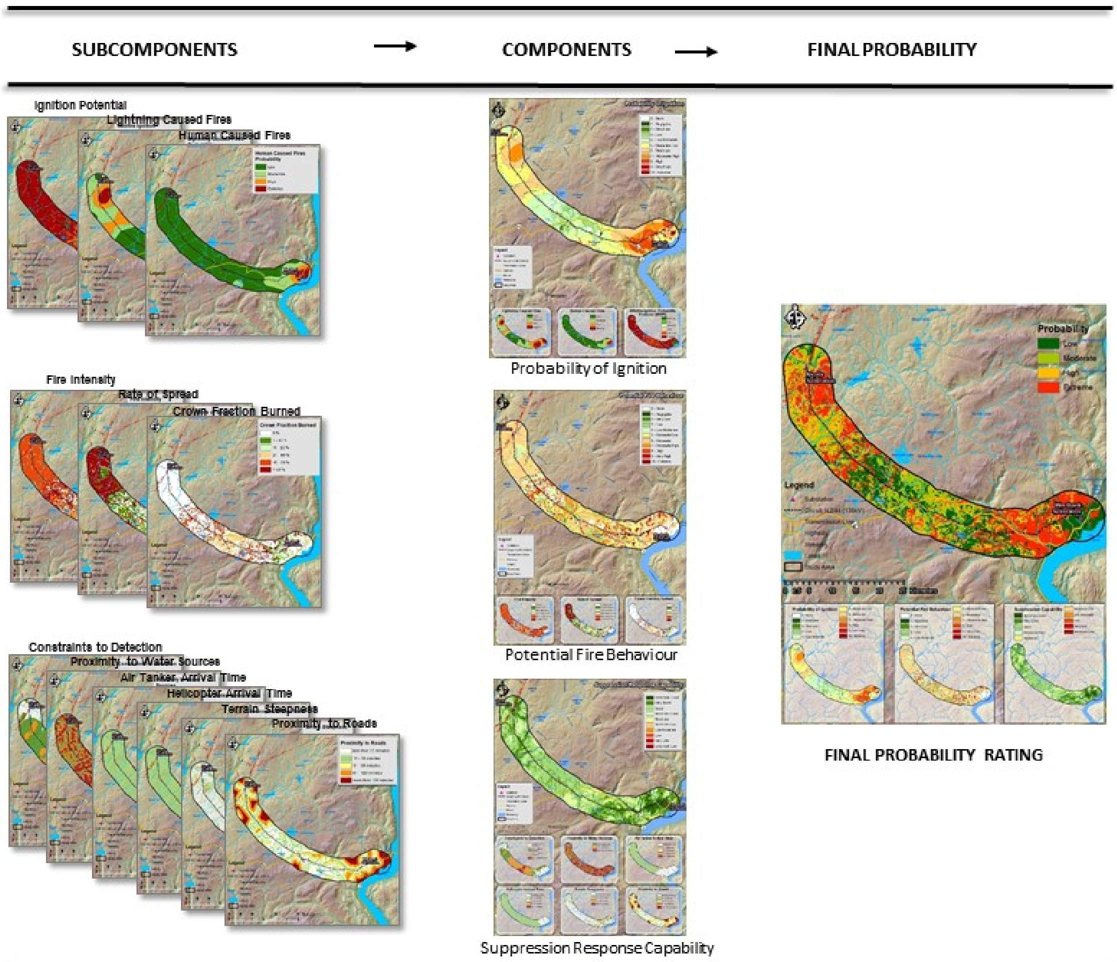


Figure 45. Wildfire Risk Management System analysis workflow illustrating the components (Ignition Probability, Fire Behaviour, and Suppression Capability) and their subcomponents used to derive final probability.

APPENDIX C – FUEL TYPES FOR THE STUDY AREA

Table 4. Canadian fuel types used for the analysis

Fuel Type	Description	Area (ha)	Percent of Total Study Area
C2	Moderately dense regeneration to pole-sapling forest with crowns almost to the ground.	914.0	1%
C3	Fully stocked, mature forest, crowns separated from ground.	18009.2	21%
C4	Dense, pole-sapling forest, heavy standing dead and down, dead woody fuel, continuous vertical crown fuel continuity.	366.5	0%
C5	Well stocked, mature forest, crowns well separated from ground.	2.1	0%
C7	Open, uneven-aged forest, crowns separated from ground except in conifer thickets, understory of discontinuous grasses, herbs.	22152.7	26%
D1	Moderately well-stocked deciduous stands.	1936.9	2%
M2	Moderately well-stocked mixed stand of conifers and deciduous species, low to moderate dead, down woody fuels, crowns nearly to the ground.	4204.0	5%
O1 - a/b	Matted and standing continuous grass	26442.5	31%
S1/S2	lodgepole pine slash	3348.5	4%
NF	Non-fuel	4872.9	6%
W	Water	2552.7	3%
	TOTAL:	**84802.0**	**100%**

The distribution of fuel types was mapped for the study area and illustrated in Figure 46. Hazardous fuel types (C2, C3, C4, and C7) are shown in Figure 47. These fuel types within the corridor buffer, that were sampled and validated, represent approximately 48% of the total study area and cover 41,443 ha.

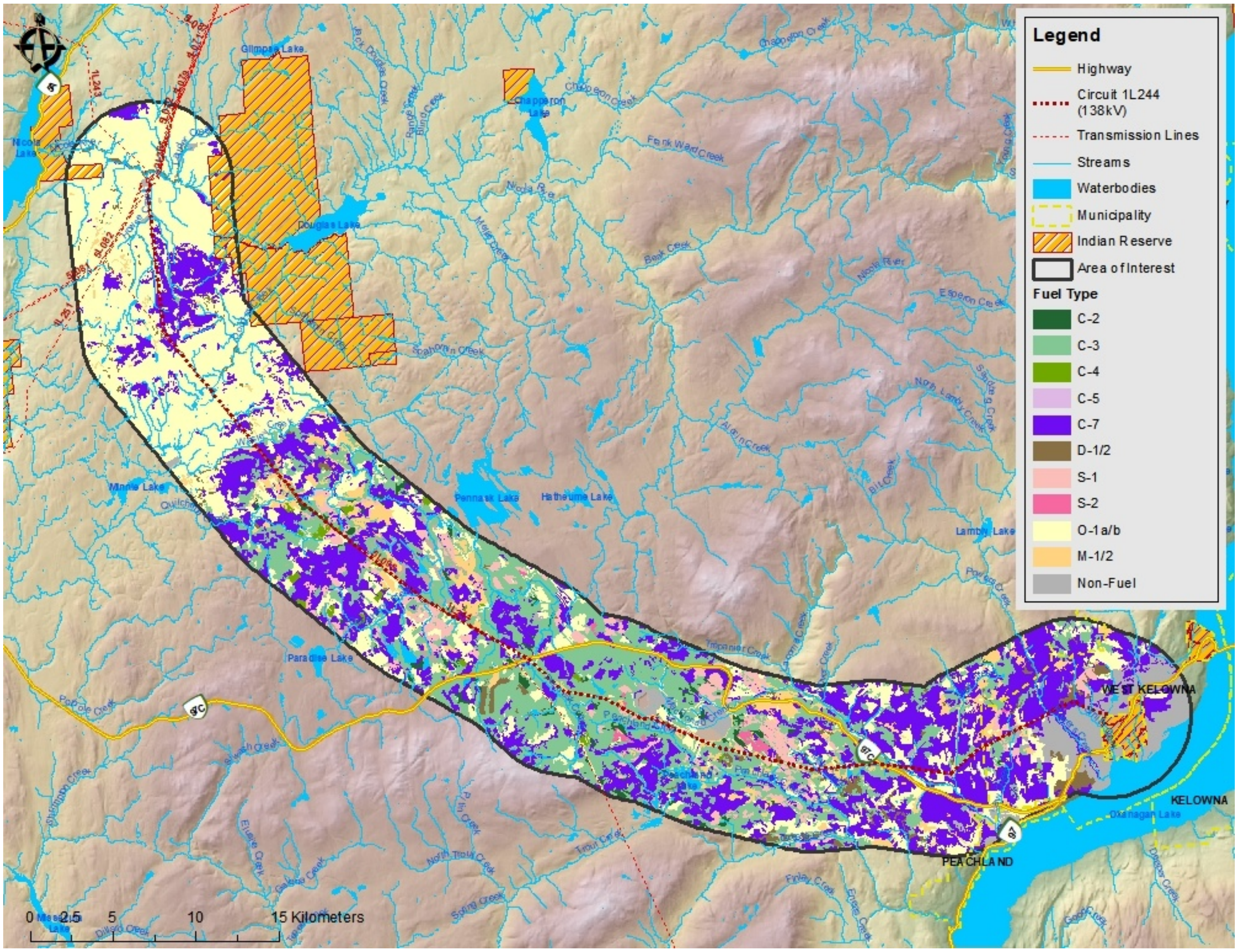


Figure 46. Fuel type distribution in the study area

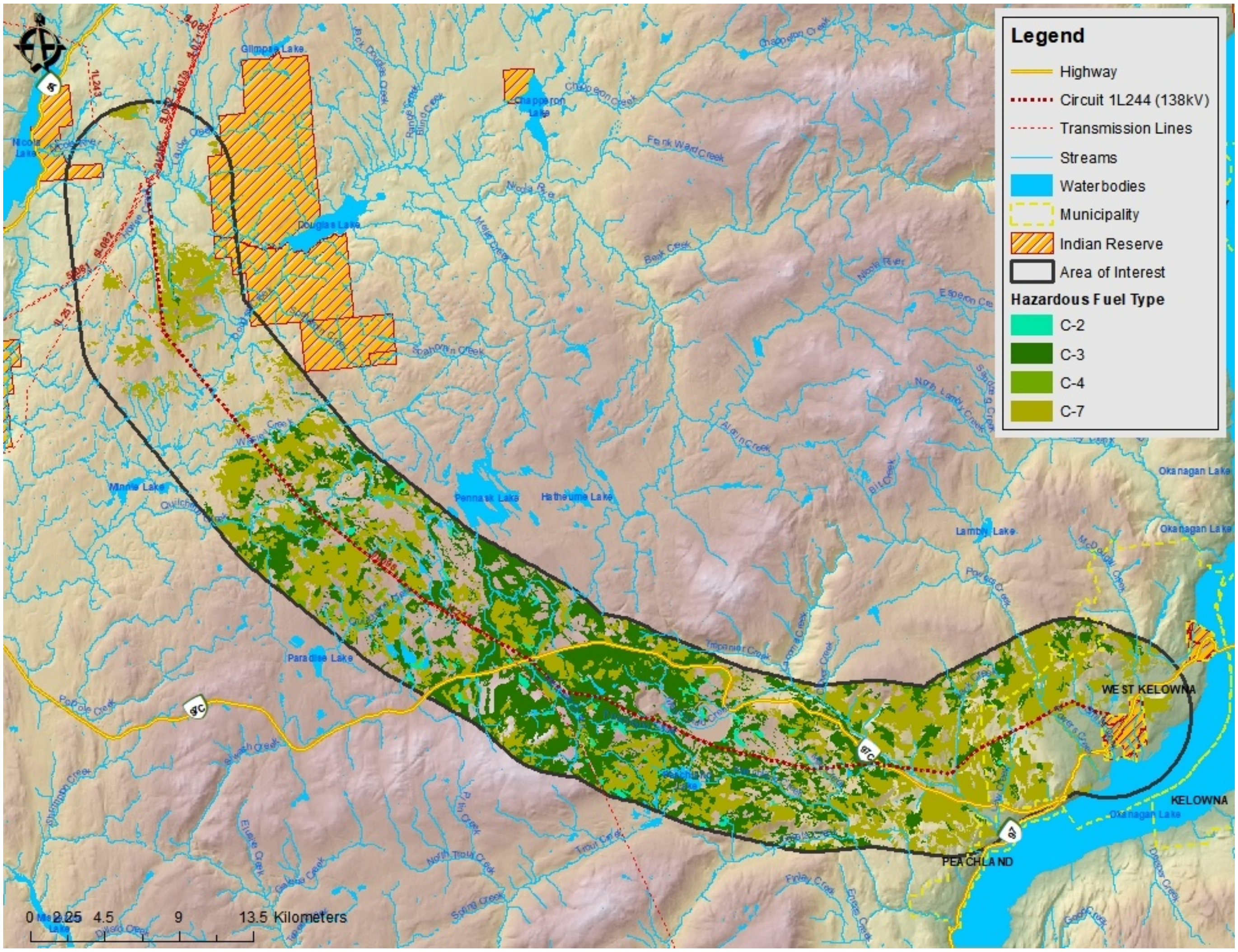


Figure 47. Hazardous fuel types in the study area

The highest wildfire hazards are young plantations in the 30-40-year age class, and young forest types up to 80-years old where the stocking levels (density) represent a significant ladder fuel component with varying loadings of slash that have high fire behaviour potential for both surface and crown fires. The majority of these stand types would be considered C-3 fuel types. Note: Figure 47 shows high hazard fuel types (C-2, C-3, C-4 and C-7 only; lower hazard vegetation types have been omitted for clarity.

APPENDIX D – THE WILDFIRE IGNITION PROBABILITY PREDICTION SYSTEM (WIPP)

(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 5 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 6. These possible associations are from Lawson and Armitage (1997)

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

Table 7 details the general fuel types and provincial test sites that were used to create the individual WIPP equations.

References

Lawson, B.D., O.B. Armitage, and G.N. Dalrymple. 1994a. Ignition probabilities for simulated people-caused fires in B.C.'s lodgepole pine and white spruce-alpine fir forests. Pages 493-505 in Proc.12th Conf. On Fire & Forest Meteorology. Oct 26-28, 1993. Jekyll Is. GA., Soc. Am. Foresters. Bethesda, MD.

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 5. 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 6. 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))

FBP Fuel	WIPP Eqn	WIPP Equation
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))

FBP Fuel	WIPP Eqn	WIPP Equation
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))
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))

FBP Fuel	WIPP Eqn	WIPP Equation
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 7. 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)

FBP Fuel	WIPP Eqn	General Fuel Type(s)	Provincial Site(s)
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	

FBP Fuel	WIPP Eqn	General Fuel Type(s)	Provincial Site(s)
C6	6-5012	Jack Pine (JY2)	MB (501-2)
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)

FBP Fuel	WIPP Eqn	General Fuel Type(s)	Provincial Site(s)
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)
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)

APPENDIX E – PROMETHEUS RUNS

Prometheus fire behaviour modelling does not simulate spotting of fires (modelled outputs are for individual ignition points only) and cannot incorporate the impacts of fire suppression (Figure 48 to Figure 51).

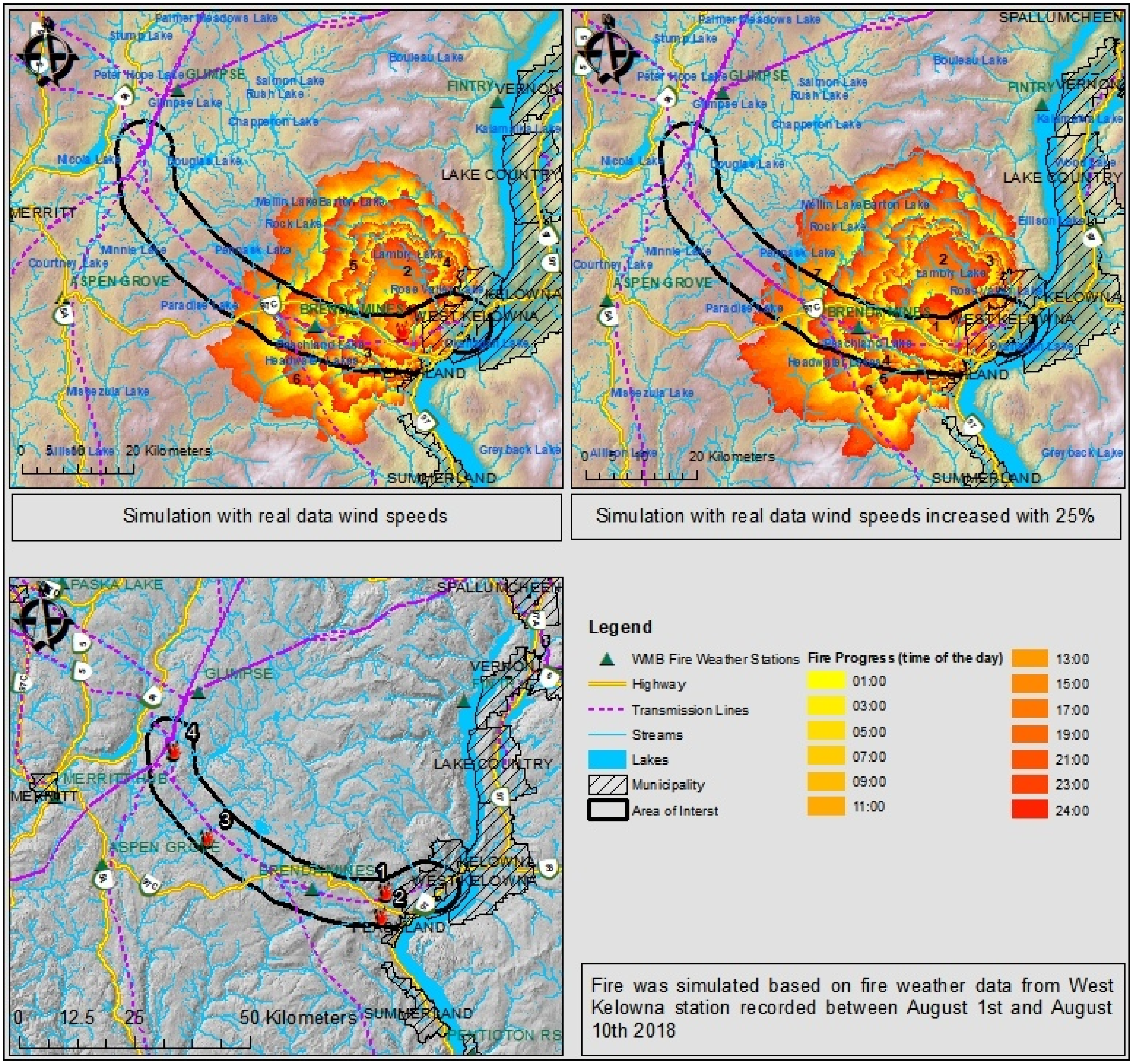


Figure 48. Prometheus Run #1: Ten days simulating an ignition point close to West Kelowna with real data wind speeds and real data wind speeds increased by 25%.

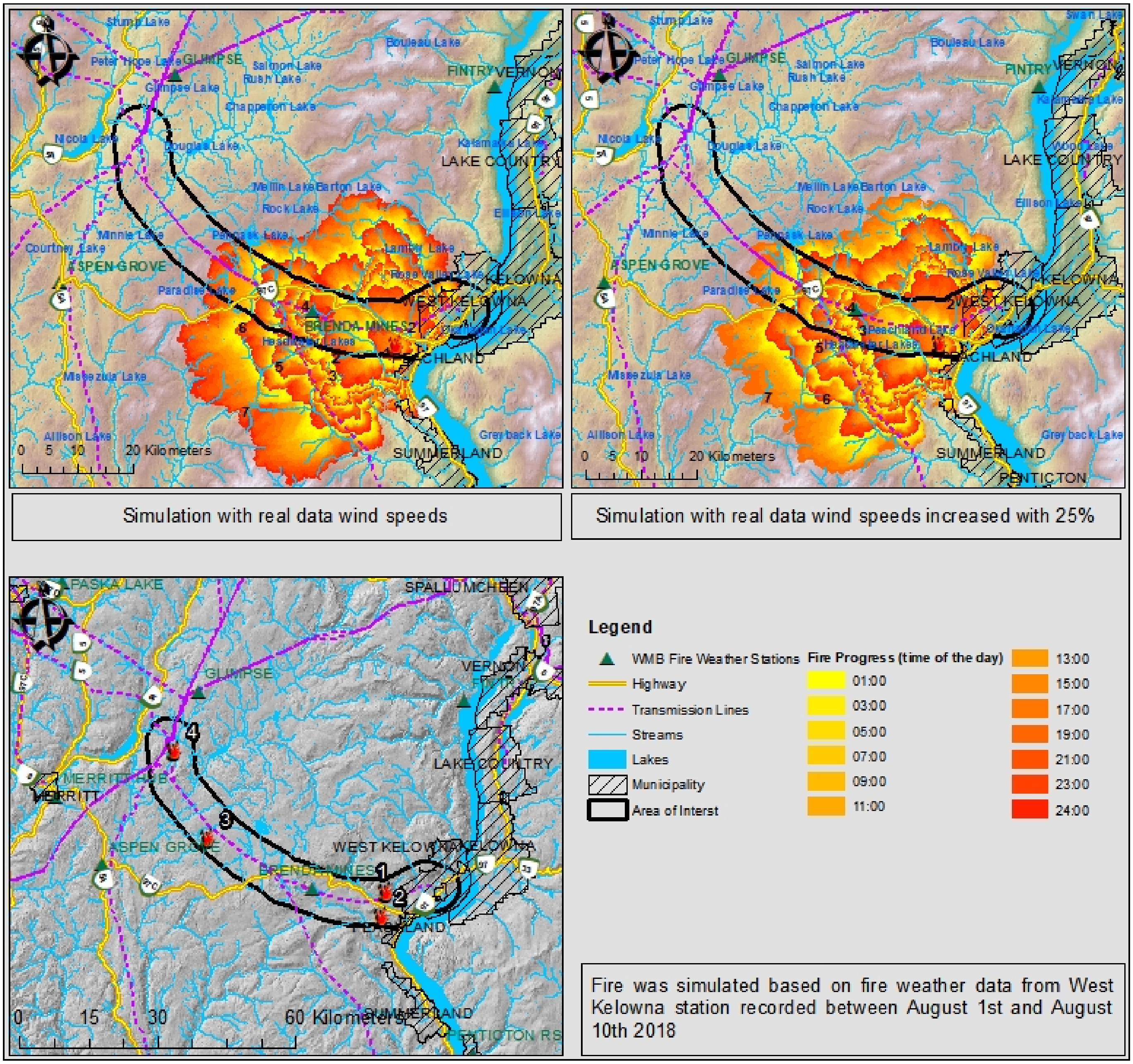


Figure 49. Prometheus Run #2: Ten days simulating an ignition point close to West Kelowna with real data wind speeds and real data wind speeds increased by 25%.

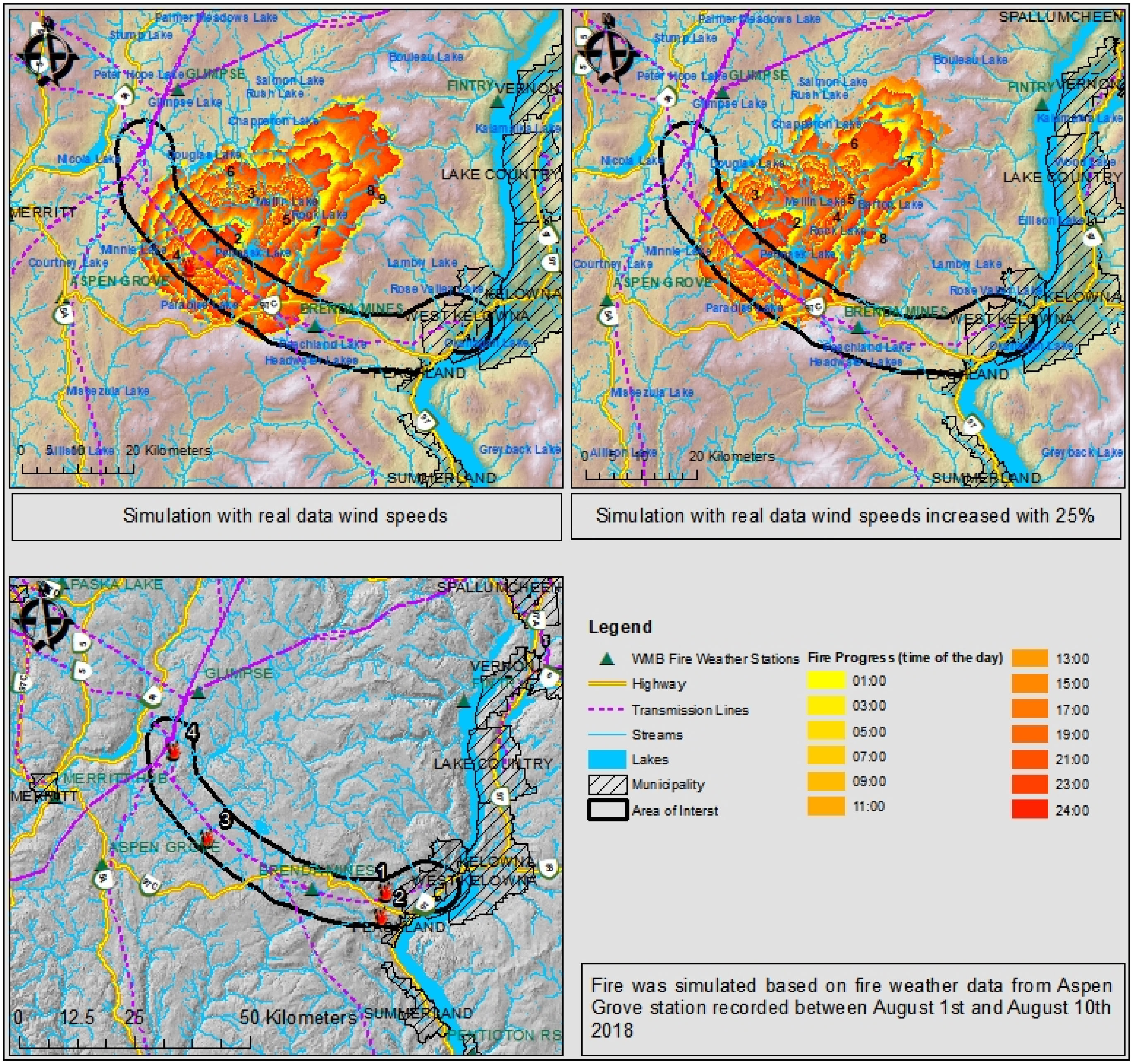


Figure 50. Prometheus Run #3: Ten days simulating an ignition point close to Aspen Grove weather station with real data wind speeds and real data wind speeds increased by 25%.

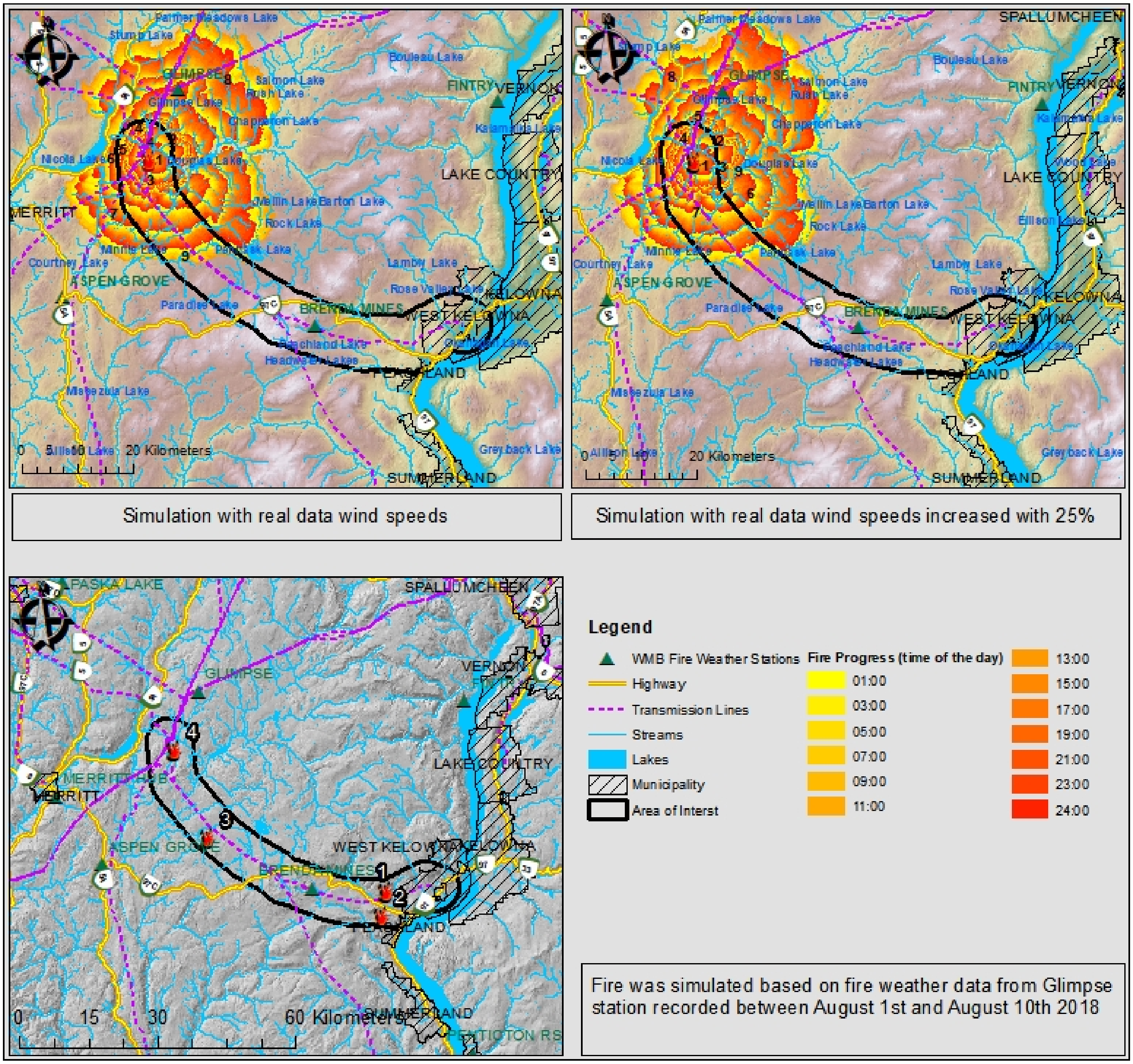


Figure 51. Prometheus Run #4: Ten days simulating an ignition point close to Glimpse weather station with real data wind speeds and real data wind speeds increased by 25%.