Wells Gray Community Forest Landscape Fire Management Plan

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REGISTERED PROFESSIONAL SIGN AND SEAL

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Bruce A. Blackwell	RPF 2073
DATE SIGNED	
I certify that the work described herein fulfills the standards expected of a member of the Association of British Columbia Forest Professionals and that I did personally supervise the work.	
Registered Professional Forester Signature and Seal	

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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 (BC). This report provides a review and an unbiased opinion on wildfire risk associated with the Wells Gray Community Forest (Community Forest). The report also considers the appropriate mitigation measures to reduce the identified risk associated with long-term fire suppression, associated ingrown stands, and concerns related to climate change.

2.0 BRUCE BLACKWELL RPF – STATEMENT OF QUALIFICATIONS

The opinions and discussion contained in the enclosed report are based on 30 years of experience as a practicing Forest Professional in British Columbia. 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 BC 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 BC 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 License A82206 in the vicinity of Port Renfrew, BC.

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 BC 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.

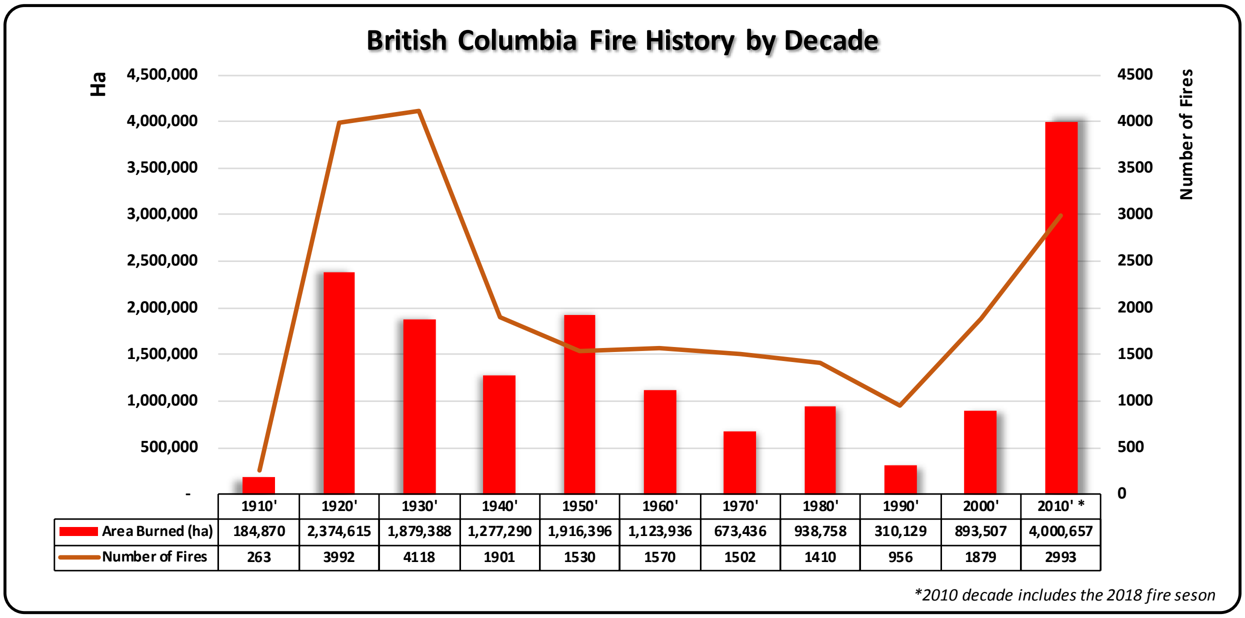
Work assignments have included detailed analyses of fire weather for prescribed burn prescriptions, fire history studies, and fire behaviour analyses. As part of the Firestorm 2003 Provincial Review[1] conducted by Gary Filmon P.C., O.M, I was retained to assist in the development of recommendations 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 B.C. 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 B.C. Forest Professionals[3].

3.0 INTRODUCTION

B.A. Blackwell & Associates Ltd. was retained to complete a Landscape Fire Management Plan (LFMP) for the Wells Gray Community Forest (the study area or Community Forest) located in the Thompson Rivers Natural Resource District. The LFMP process is aimed at determining the optimum location for fuel break locations and types of fuel treatments that will limit fire spread and growth and provide anchors for fire suppression operations including but not limited to aerial attack, direct attack on the ground, and or broadcast (back) burning. This report documents the rationale and results of the fuel break fuel treatment network design for the study area.

Wildfire seasons in BC, 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 of fires is greater than all other decades, with the exception of 1920-1930. 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 4.5 for a description of the effects of historic fire suppression); and 2) a period of increasing drought during the fire season.

[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



	1910'	1920'	1930'	1940'	1950'	1960'	1970'	1980'	1990'	2000'	2010' *
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).

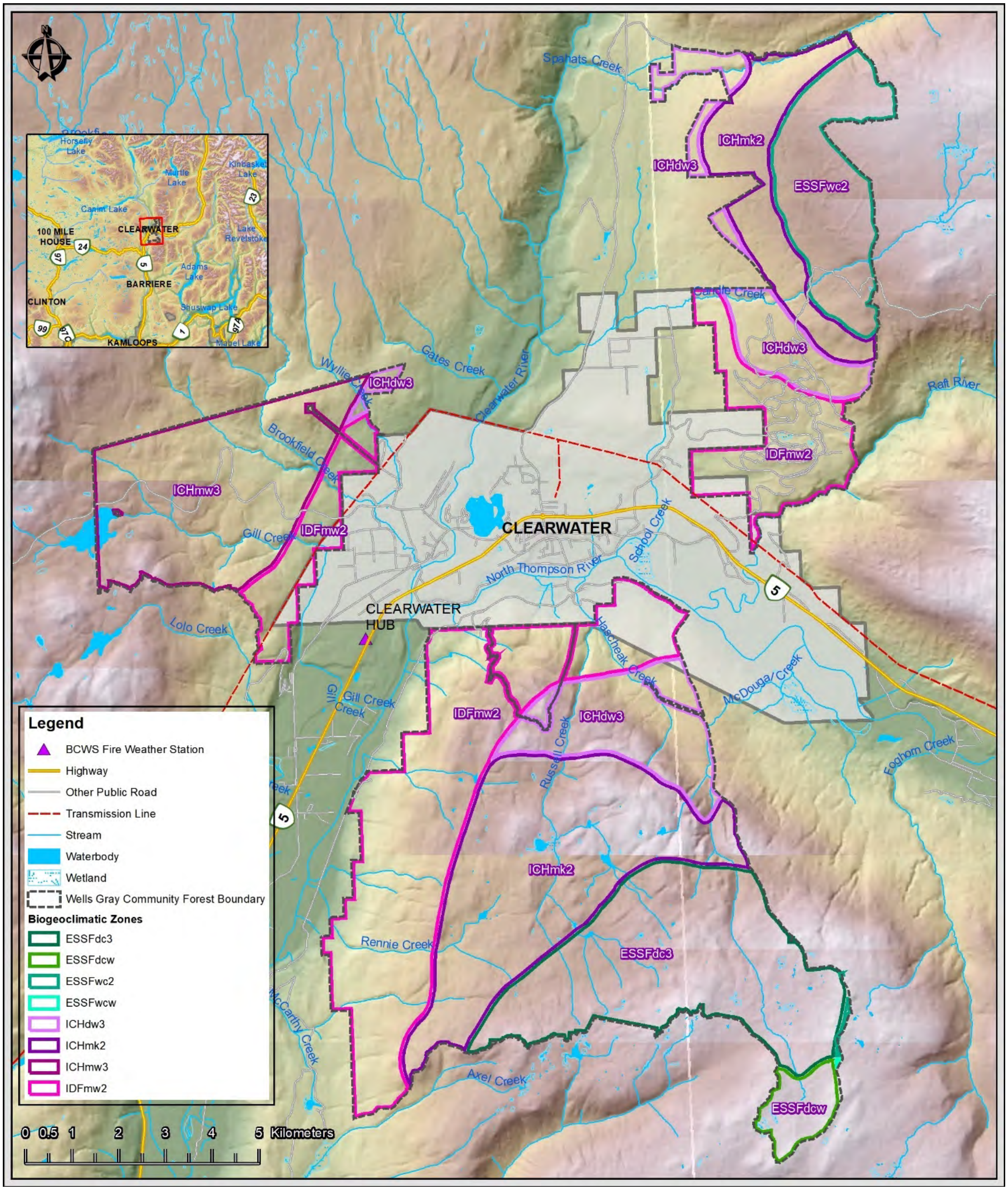


Figure 2. Study Area Overview including Biogeoclimatic Zones

4.0 THE FIRE ENVIRONMENT

Wildfire is a natural disturbance agent in the forest ecosystems of the Thompson Rivers Natural Resource District. Fire requires fuel (carbon), oxygen and heat. These three components make up the fire triangle and if one is not present, a fire will not burn. Oxygen is present in the air and as it is used up by a fire it is replenished quickly by wind. Heat is needed to start and maintain a fire and can be supplied through lightning or human sources such as misused campfires and discarded cigarettes. Fuel is generally available in adequate quantities in the forest and comes from living or dead plant materials (organic matter) and trees and branches lying on the ground are a major source of fuel in a forest. ***Fuel is the only component in the fire triangle that can be managed. Fuels can be managed through localized fuel treatments or through the establishment of fuel breaks or containment lines.***

4.1 FIRE WEATHER RATING

The Canadian Forestry Service developed the Canadian Forest Fire Danger Rating System (CFFDRS) to assess fire danger and potential fire behaviour. Fire Danger Classes provide a relative index of the ease of ignition and the difficulty of suppression. A network of fire weather stations is maintained during the fire season by MFLNRORD and the recorded data is used to determine fire danger, represented by Fire Danger Classes, on forestlands. The information can be obtained from the BC Wildfire Service (BCWS) and is most commonly utilized by forest tenure holders, municipalities and regional districts to monitor fire weather, restrict high risk activities when appropriate, and to determine hazard ratings associated with bans and closures.

The BC *Wildfire Act* [BC 2004] and *Wildfire Regulation* [BC Reg. 38/2005] specify responsibilities and obligations with respect to fire use, prevention, control and rehabilitation, and restrict high risk activities based on these classes. Fire Danger Classes are defined as follows:

- **Class 1 (Very Low)**: Fires are likely to be self-extinguishing and new ignitions are unlikely. Any existing fires are limited to smoldering in deep, drier layers.
- **Class 2 (Low)**: Creeping or gentle surface fires. Ground crews easily contain fires with pumps and hand tools.
- **Class 3 (Moderate)**: Moderate to vigorous surface fires with intermittent crown involvement. They are challenging for ground crews to handle; heavy equipment (bulldozers, tanker trucks, and aircraft) are often required to contain these fires.
- **Class 4 (High)**: High-intensity fires with partial to full crown involvement. Head fire conditions are beyond the ability of ground crews; air attack with retardant is required to effectively attack the fire’s head.
- **Class 5 (Extreme)**: Fires with fast spreading, high-intensity crown fire. These fires are very difficult to control. Suppression actions are limited to flanks, with only indirect actions possible against the fire’s head.

It is important when developing appropriate prevention programs to determine the average exposure to periods of high and extreme fire danger. 'High fire danger' encompasses Danger Class ratings of 4 (High) and 5 (Extreme). Danger class days for the study area were summarized to provide an indication of the fire weather in the Community Forest. Considering that fire danger varies from year to year, historical weather data can provide information on the number and distribution of days when the Community Forest is typically subject to high fire danger conditions, which is useful information in assessing fire risk.

Figure 3 displays the average frequency of Fire Danger Class days between the months of April and October. The data summarized comes from the 'Clearwater Hub' weather station (daily data for the years 1976-2018). According to Figure 3, the months with the highest average number of 'high' and 'extreme' fire danger class days are July and August. However; 'high' fire danger days are not uncommon in May and June (comparable to July) and September, and even extend into April and October. 'Extreme' fire danger class days also extend into May and June in the early season, and into September and October in the late season. August historically has the highest number of days in both the 'extreme' class and in the 'high' class.

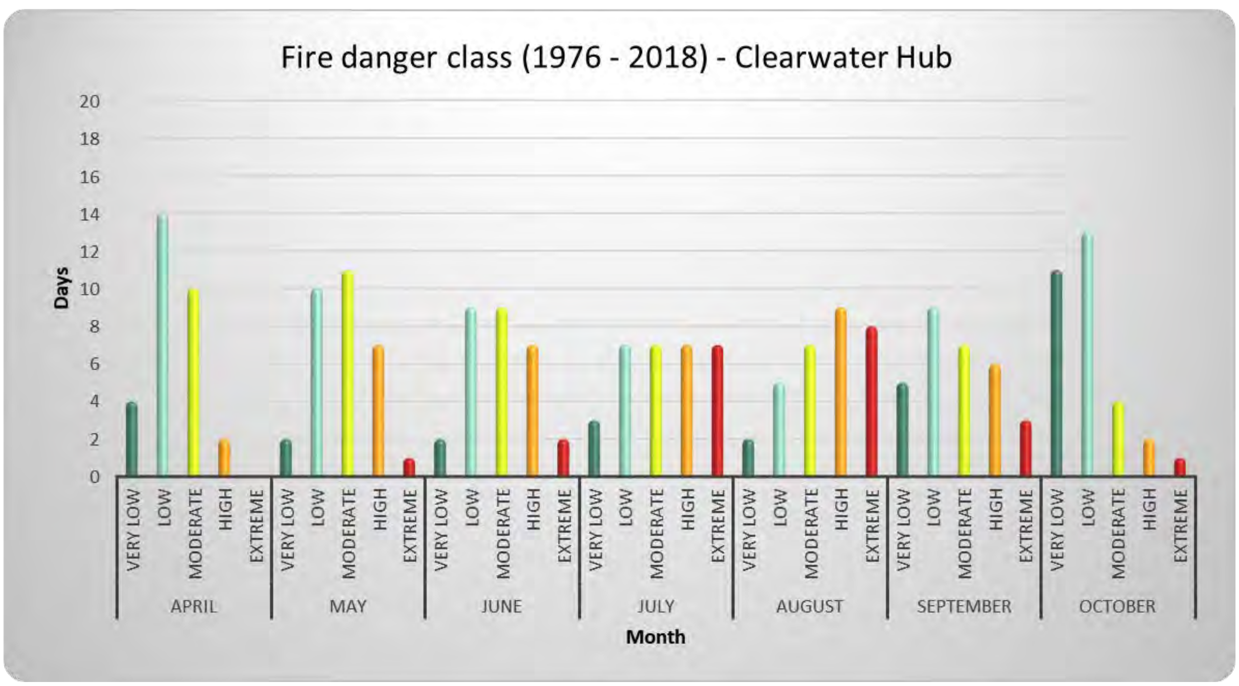


Figure 3. Average number of danger class days for the 'Clearwater Hub[4] weather station (summary of fire weather data for the years 1976-2018).

While there is considerable variability, Figure 4 highlights the trend of increasing high and extreme danger class days over the past 42 years. From 1976 to 1999, the number of high danger class days

[4] Source: BC Wildfire Service

exceeded 40 in 12 out of 24 years (50%) with an average of 38 high danger class days in this time period. Between 2000 and 2018, the number of high danger class days exceeded 40 in 16 out of 19 years (84%) with an average of 47 high danger class days. The number of days in the extreme danger class has increased more dramatically in recent years, with extreme danger days occurring in every year since 1994; prior to 1994, no extreme danger class days occurred in 6 out of 18 years. The average number of extreme danger class days in earlier decades (1976-1999) was 16. Since 2000, the average number of extreme danger class days has increased to 31. Combined, the number of high and extreme danger class days has increased since 1976, and has consistently exceeded 40 days since 2000, with the exception of 2011, and has exceeded 80 days in 10 years out of 19 since 2000. These trends demonstrate that the window of high wildfire probability is expanding and that once a wildfire has ignited that the potential for fire spread event days[5] is also greater, which in all likelihood will increase wildfire severity and the total area burned in any given season.

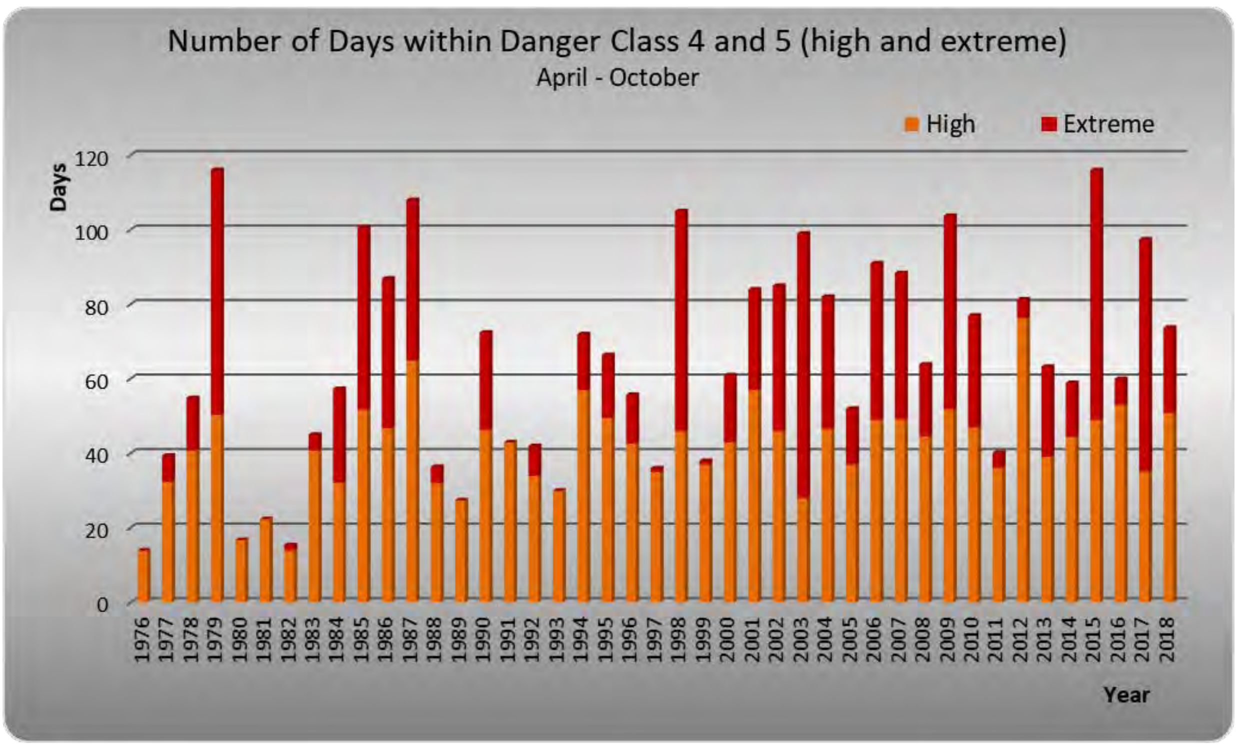


Figure 4. Number of high and extreme danger class days for the Wells Gray Community Forest 1976 - 2018.

The Drought Code (DC) is a numeric rating of average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smouldering in deep duff layers and large logs. The drought code has consistently been higher than 500 for most seasons over the period of record. A drought code above 500 will support high to extreme fire behaviour

[5] Most of a fire's growth typically occurs on a small number of days when burning conditions are conducive for spread (Podur and Wotton, 2011).

(Figure 5). That said over the last many years have been above 600 and extreme years have risen to levels between 700 to almost 1000. This indicates that the potential for extreme drought has been variable but overall supports the potential for periods of higher probabilities of ignition, higher severity wildfires, and a greater cumulative burn area.

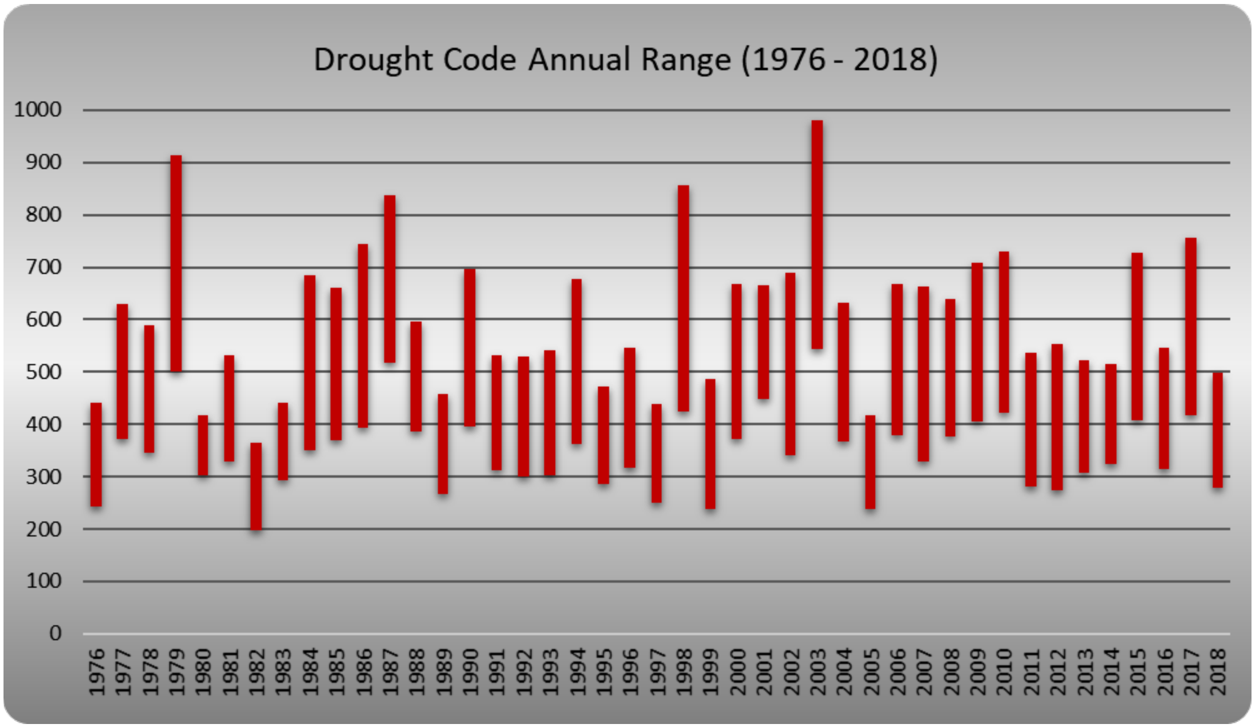


Figure 5. Annual range of the Drought Code for the Wells Gray Community Forest 1976 -2018.

The Fine Fuel Moisture Code (FFMC) is a numeric rating of the moisture content of litter and other cured fine fuels. The code is an indicator of the relative ease of ignition and the flammability of fine fuel. When the trends in the fine fuel moisture code (FFMC) are investigated, the summary of moderate, high and extreme FFMC show similar trends in July, and August (Figure 6). This suggests that there are significant periods of fine fuel curing that could contribute to ignition and spread of wildfires within the study area. They are; however, not a good indicator of wildlife severity and/or area burned when compared to the other variables investigated above.

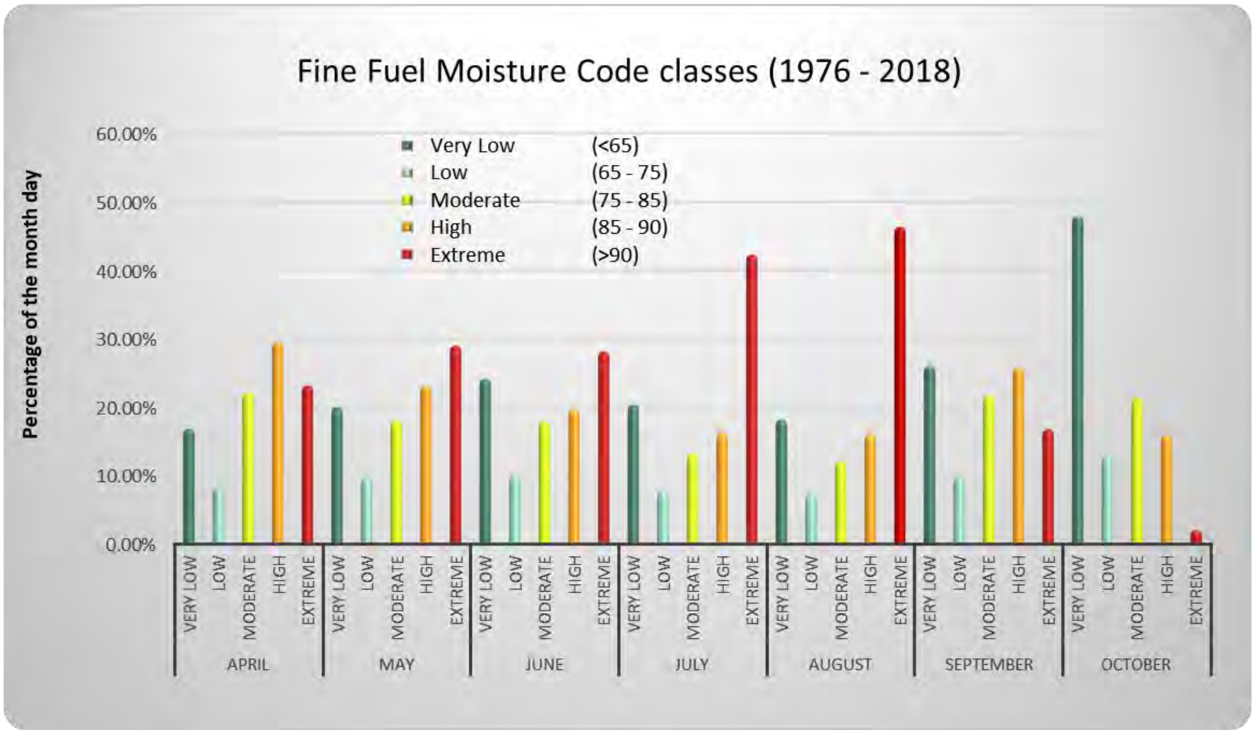


Figure 6. Probability of fine fuel moisture code classes summarized for each month of the fire season (April to October 1976 -2018).

Overall the fire weather parameters discussed above all suggest that the probability of wildfire ignition is increasing during the wildfire season based on both the number of high and extreme danger class days and the trend towards increasing drought codes. These parameters are also good indicators of increasing fire severity and increased area burned. Additionally, these results are consistent with what has been reported in other parts of BC and western North America.

4.2 CLIMATE CHANGE

Climate change is a serious and complex consideration for wildfire management planning. Warming of the climate system is unequivocal, and since the 1950s, each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere (International Panel on Climate Change, 2014).

Numerous studies outline the nature of these impacts on wildland fire across Canada, and globally. Although there are uncertainties regarding the extent of the impacts of climate change on wildfire, it is clear that the frequency, intensity, severity, duration and timing of wildfire and other natural disturbances is expected to be altered significantly with the changing climate (Dale *et al.*, 2001). Despite the uncertainties, trends within the data are visible. According to the Pacific Climate Impacts Consortium (www.plan2adapt.ca), the following climate change projections are made from the baseline historical period of 1961-1990 to the 2050s for the Thompson-Nicola region:

- Annual average temperature is expected to increase by 1.8 ˚C[6].
- Precipitation is projected to increase on an annual basis, with the majority of the increase in the winter months, but generally decrease by 8%[6] in the summer (ranging from a 17% decrease to a 2% increase).
- Snowfall is projected to decrease by 10%[6] in the winter and by 54%[6] in the spring.
- The number of frost-free days is projected to increase by 23 days[6].

Overall, the projections indicate a decrease in snowpack, increase in hot and dry conditions, and a longer dry season into the 2050s that may result in increased forest fire severity and longer fire season.

Climate change projections for the Central Interior were also summarized by the BC Agriculture & Food Climate Action Initiative (2012)[7] drawing on regional modeling supplemented with broader scale studies. Similar temperature and precipitation projections for the Central Interior were reported in the aforementioned summary. These were noted to be generally consistent with projections for the province on average; however, the Central Interior is expected to experience a greater decrease in summer precipitation than the provincial average. Warming in winter and spring is expected to result in an increasing amount of precipitation falling as rain and less as snow, particularly in spring.

In the province as a whole, as average winter temperatures increase, more intense winter precipitation is expected to fall as rain during extreme events, and less falling as snow, potentially influencing watershed and groundwater storage ability, timing and amount of run-off, and soil and fuel moisture during early fire season.

An increased frequency of natural disturbance events is expected to occur as a result of climate change with coincident impacts to ecosystems. These include:

- Storm events, including catastrophic blowdown and damage to trees from snow and ice;
- Wildfire events and drought;
- Increased winter precipitation may result in slope instability, mass wasting, increased peak flows (loss of forest cover from fire or other disturbance may increase the chance of mass wasting); and

Other research regarding the intricacies of climate change and potential impacts on wildfire threats to Canadian forests has found that:

- Fuel moisture is highly sensitive to temperature change and projected precipitation increases will be insufficient to counteract the impacts of the projected increase in temperature. Results conclude that future conditions will include drier fuels and a higher frequency of extreme fire weather days (Flannigan *et al.*, 2016).

[6] Median value
[7] https://www.bcagclimateaction.ca/wp/wp-content/media/AdaptROseries-CentralInterior.pdf

- The future daily fire severity rating (a seasonally cumulative value) is expected to have higher peak levels and head fire intensity is expected to increase significantly in western Canada. A bi-modal (spring-late summer) pattern of peak values may evolve to replace the historical late summer peak which is the current norm (DeGroot et al., 2013). The length of fire seasons is expected to increase and the increase will be most pronounced in the northern hemisphere, specifically at higher latitude northern regions. Fire season severity seems to be sensitive to increasing global temperatures; larger and more intense fires are expected and fire management will become more challenging (Flannigan *et al.*, 2013; Jandt, 2013).

In summary, climate scientists expect that the warming global climate will trend towards wildfires that are increasingly larger, more intense and difficult to control. Furthermore, it is likely that these fires will be more threatening to Wildland Urban Interface (WUI) communities due to increased potential fire behaviour, fire season length, and fire severity. This trend is expected to be disproportionately felt in northern latitudes.[8]

4.3 FIRE WEATHER ZONES

In addition to stand characteristics such as species composition and fuel type, weather also influences fire behaviour. Weather attributes that contribute to fire behaviour include precipitation, relative humidity, wind and temperature. Weather can be affected by terrain and topography, resulting in changes in fire behaviour or occurrence. The topography of the study area is variable, dominated by flat and rolling terrain, but having limited and isolated areas (>60%) that are considered steep. Topography plays a substantial role in determining fire behaviour given the variation in slope, aspect and elevation. Slope accelerates fire behaviour, aspect influences solar radiation loading and the effects on seasonal drying trends, and elevation has a substantial influence on seasonality, with higher elevations staying snow covered into June/July and lower elevations susceptible to wildfire during the early parts of the fire season (April/May).

A network of fire weather stations throughout BC is established, and maintained by MFLNRORD and Environment Canada. The data from these stations is typically used to determine fire danger on forestlands and weather data can be used to predict future forecasts and track trends. Additionally, it is a beneficial tool for Fire and Resource Managers for decision making and managing resources to suppress wildfires. The nearest and most representative MFLNRORD weather station located in Clearwater ('Clearwater Hub') was used in the analysis.

To enhance fire hazard risk assessments for the Province, in coordination with MFLNRORD, B.A. Blackwell & Associates Ltd. (2013) developed fire weather zone classifications for the Province using the BEC system. These weather regions reflect differences in seasonality, mid-summer conditions and outflow

[8] All research noted was completed for Canada or globally, not for the study area. Direct application of trends may not be appropriate, although general expectations for Canada were noted to be consistent across multiple studies.

characteristics. Four fire weather zones have been identified for the Wells Gray Community Forest, within the Thompson Rivers Resource District (Figure 7) These include the following:

Fire Weather Zone	Area (Ha)	Percent
8.02: INTERIOR WET - Columbia - Shuswap	1,693	13%
7.04: INTERIOR SUBALPINE - Columbia Mountains	966	7%
7.01: INTERIOR SUBALPINE - Thompson - Okanagan Plateau	1,990	15%
5.02: INTERIOR DRY - Thompson - Okanagan Plateau	8,252	63%
1.01: ALPINE - Parkland	247	2%

Overall, the complexity of climate and weather within the Wells Gray Community Forest is considered high and it is expected that these weather zones would be quite variable in their fire behaviour potential. The topography in combination with these weather zones indicates that the majority of the area is quite heterogenous in fire weather both on a daily and seasonal basis, however, with the exception of the North Thompson River, there are few topographic barriers to limit wildfire spread. Given the extensive area of Interior Dry zone; one could suggest that under extreme fire weather conditions these areas of the landscape have the highest probability of a large catastrophic wildfire with limited control points that could be used as anchors fore wildfire suppression. The other zones would be more vulnerable later in the wildfire season (late July to August) but snowmelt and aspect would play a significant role in determining the potential of these areas.

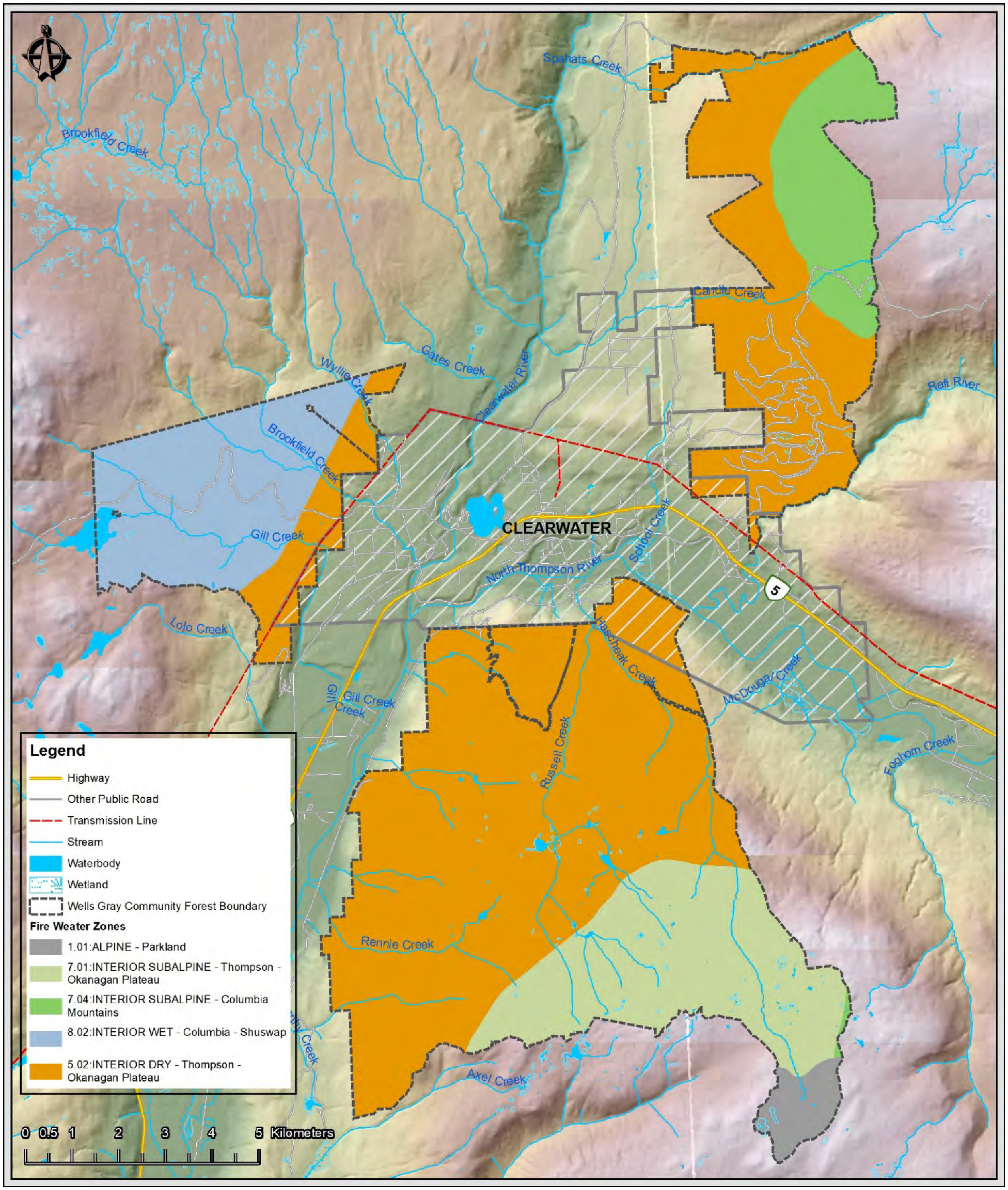
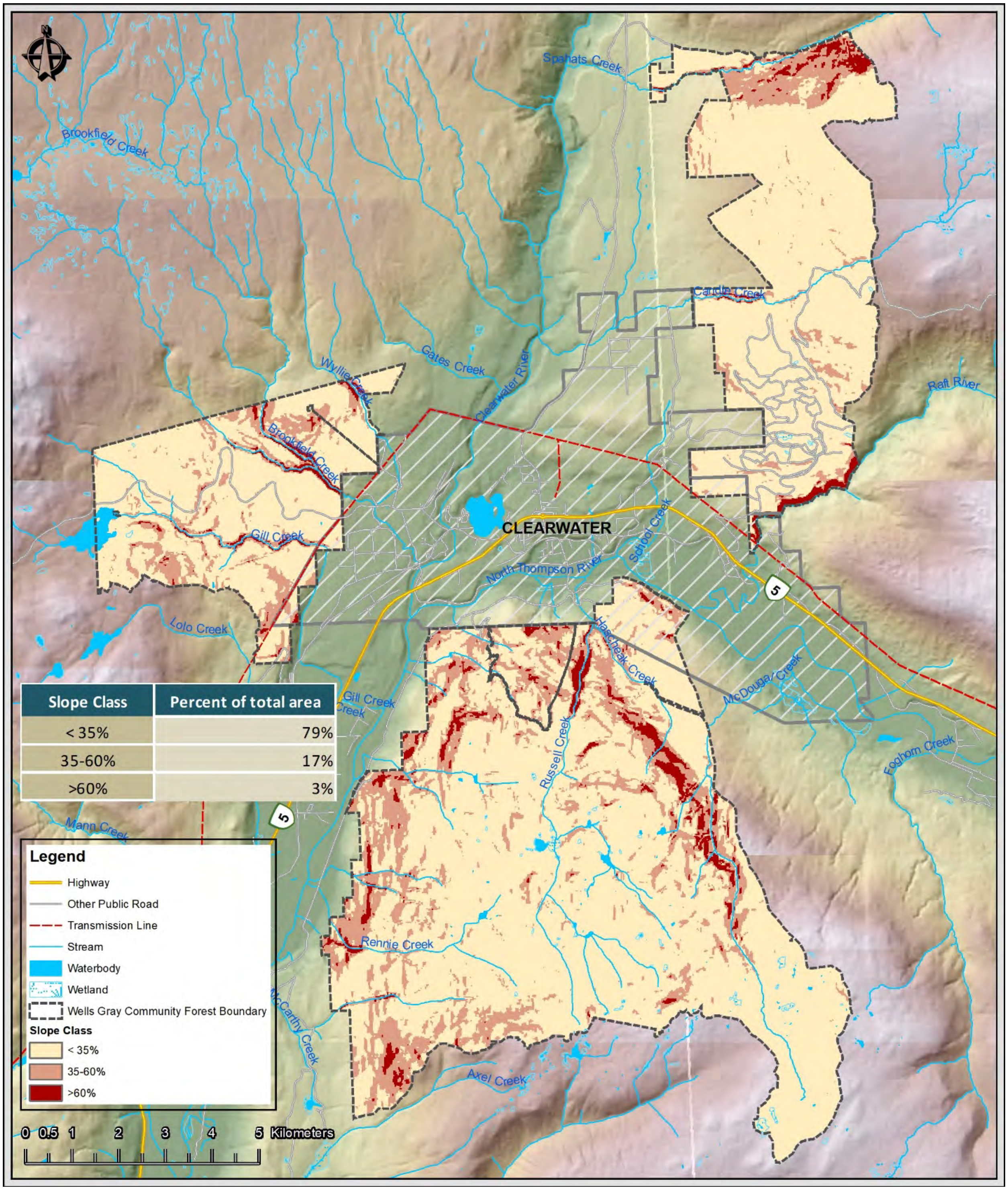


Figure 7. Fire Weather Zones for the Wells Gray Community Forest

4.4 TOPOGRAPHY

The topography of the Wells Gray Community is dominated by gradual slopes (most are <35%) and elevation ranging from approximately 400 m to 2000 m. Aspects are variable. Overall the topography of the Community Forest provides no significant topographic barriers (ridges, rock dominated areas, large deciduous dominated areas, and areas of non-fuel) that will limit fire spread and growth through the study area. Slope classes within the Community Forest are illustrated in Figure 8.



Slope Class	Percent of total area
< 35%	79%
35-60%	17%
>60%	3%

Figure 8. Slope classes in the Wells Gray Community Forest.

4.5 FIRE HISTORY

Fire history data was summarized by fire cause for the period between 1950 and 2018 (with no gaps between years) for the Wells Gray Community Forest. It is worthy to note that data summarized for the latest decade (2010s) is not a complete decade (up to 2018) and therefore estimates may appear lower in comparison to the other (complete) decades. Fire history data was obtained from the BC Wildfire Service. The point ignition data used in this summary represents ignitions located, as per MFLNRORD methodology, on a grid rather than exact location; therefore, some points are located in water and multiple points are often located on top of one another.

Figure 9 provides a summary of ignitions within 10 kilometers of the study area (both human and lightning) for the period 1950-2018. The number of lightning ignitions has largely been stable over the length of record. However; human ignitions have been higher in recent decades, although this trend is less pronounced in the incomplete decade period of 2010-2018. Overall the trend is consistent with other regions of the Province where increased summer drought and careless human behaviour has resulted in increasing wildfire ignitions.

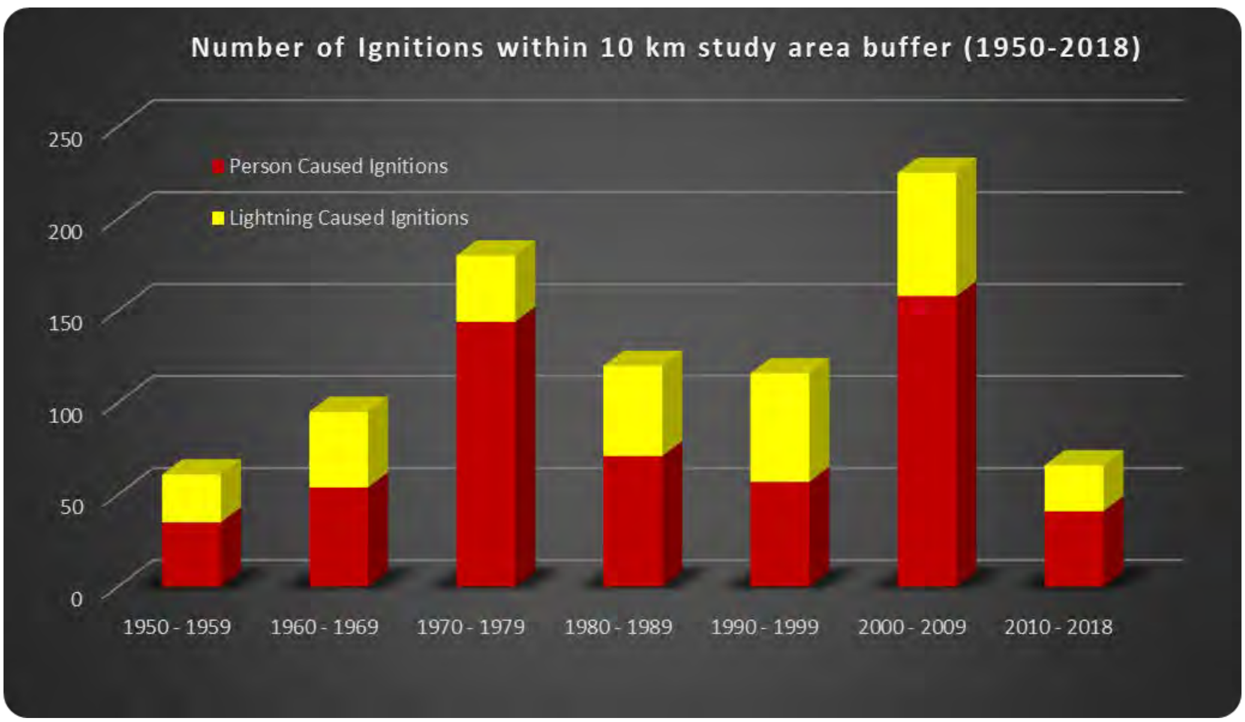


Figure 9. Number of ignitions within a 10-kilometer buffer of the study area buffer.

Figure 10 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, adjacent to the Thompson River, and along the highway and road networks.

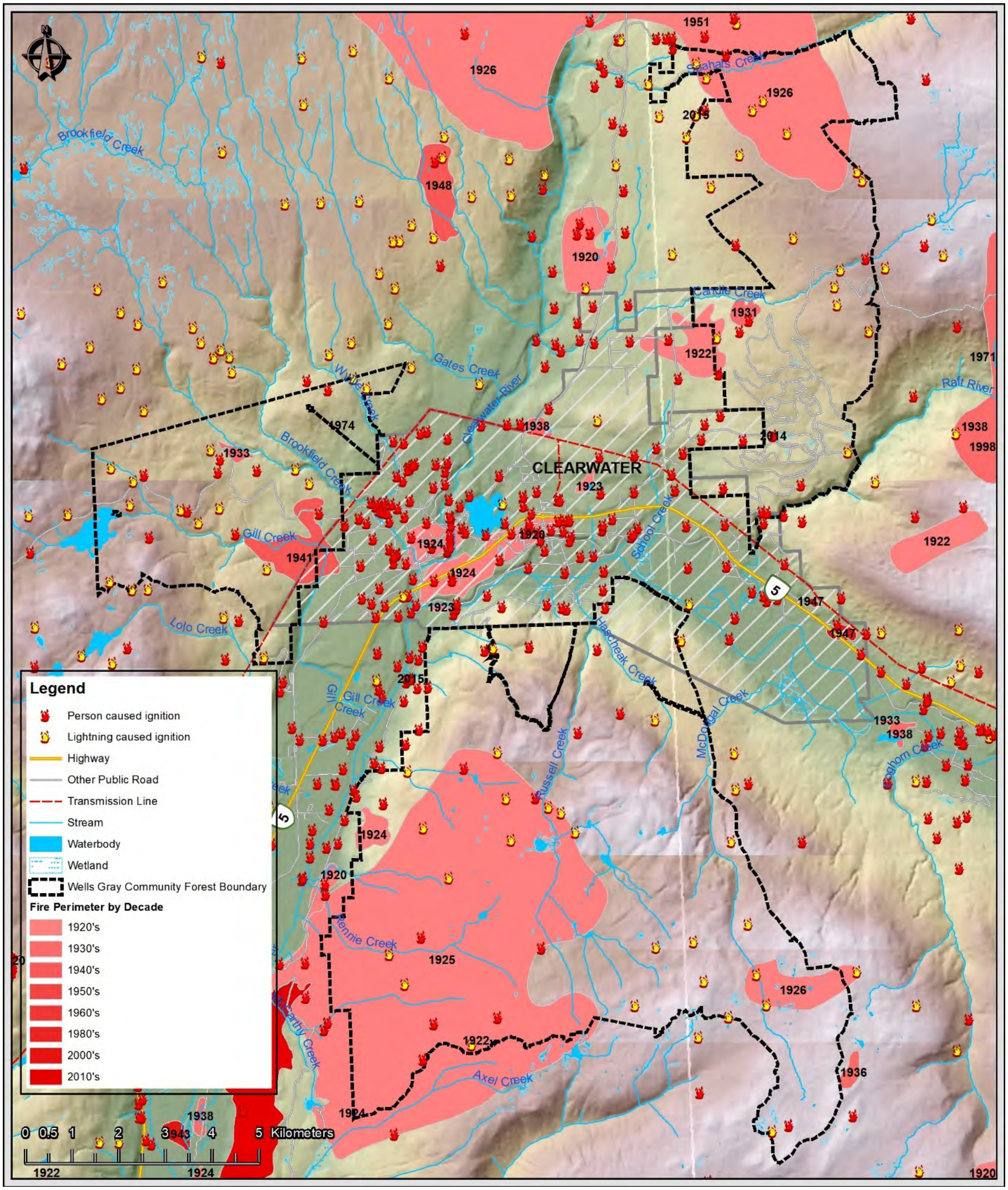


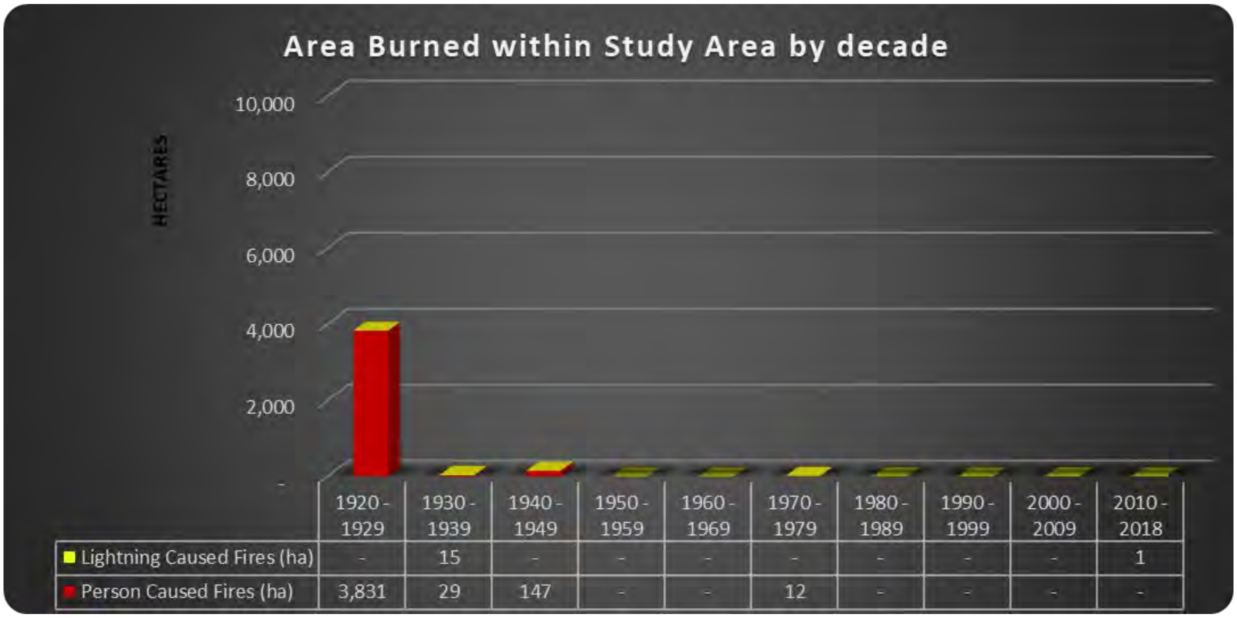
Figure 10. Study Area Ignition and Spatial Fire History

The study area has been impacted by one significant wildfire 2800 ha (1925) in size over the past century; with the exception of one lightning caused wildfire all were human caused. A summary of individual wildfires by fire year is provided in Table 1. Other wildfire activity was largely concentrated in the 1920's, but since that time wildfire activity with the tenure has been limited to small single starts in any give year. The data emphasizes the success of wildfire suppression during the period of record.

Table 1. Summary of fire size and area burned within Wells Gray Community Forest for individual wildfires between 1920 and 2018.

Fire Number	Fire Cause	Fire Year	Total Fire Size (ha)	Burned within Study Area (ha)
20a	Person	1922	146	33.8
63	Person	1922	300	151.6
31b	Person	1924	46	41.4
50	Person	1924	31	10.5
39a	Person	1925	3,746	2,819.2
27	Person	1926	12,527	620.9
91	Person	1926	167	153.3
452	Person	1931	29	28.9
245	Lightning	1933	15	14.6
5	Person	1941	172	146.9
K20624	Person	1974	13	12.4
K10097	Lightning	2015	2	0.8

The area burned by decade within the study area is summarized in Figure 11. There has not been a significant wildfire within the study area since the 1930's. Of the total study area only 31% has burned within the last 100 years. Prior to 1930's just under 4,000 ha burned within the Wells Gray Community Forest tenure. One human caused fire resulted in the largest area burned in the 1920s within the Community Forest. Since 1929, effective fire suppression has likely resulted in a growing fuel buildup associated with forest in-growth within the IDF forests of the tenure. Overall it is the author's opinion that this area is susceptible to a large wildfire of the size and behaviour that has occurred within other regions of the Thompson Rivers Natural Resource District. Preventative work is a must if wildfire impacts are to be limited within the Community Forest tenure and to protect the WUI associated with the town of Clearwater and the surrounding rural community.



	1920 - 1929	1930 - 1939	1940 - 1949	1950 - 1959	1960 - 1969	1970 - 1979	1980 - 1989	1990 - 1999	2000 - 2009	2010 - 2018
Lightning Caused Fires (ha)	-	15	-	-	-	-	-	-	-	1
Person Caused Fires (ha)	3,831	29	147	-	-	12	-	-	-	-

Figure 11. Area burned summary for the study area by decade.

4.6 SUMMARY OF FOREST FUELS

The probability of large wildfires occurring within interior forest ecosystems is generally high to very high within this region of the Province, and the associated consequences associated with a large wildfire can be catastrophic to a small tenure like the Wells Gray Community Forest. Fire behaviour is generally influenced by fuel type, weather and topography. The Canadian Fire Behaviour Prediction System (FBP System)[9] uses 17 national benchmark fuel types to predict fire behaviour. The FBP fuel layer is primarily based on forest inventory data from the Provincial Vegetation Resource Inventory (VRI) layer (polygons a minimum of 1 ha in size) and their respective land cover attributes. The Wells Gray Community Forest includes the majority of the defined fuel types – this includes area covering non-fuel and water (NF) (Table 2). The fuel types represented in the Community Forest are described and summarized by total area and by percentage of the study area in Table 2. Additionally, the fuel type distribution (by percent of the total study area) is summarized graphically in Figure 12. The most extensive forested fuel types are C3 (fully-stocked, mature forest) which comprises approximately 24% of the study area, followed by C7 (open uneven-age forest, crowns separated from the ground) which comprises approximately 19% of the study area. M-1/2 (moderately well-stocked mixed stand of conifers and deciduous species) comprises 17% of the study area, C5 (well-stocked, mature forest, crowns well separated from ground) comprises 16% of the study area and C2 (moderately dense regeneration to pole-sapling forest with crowns almost to the ground) comprises 8%. The remaining classes of fuel types in combination make up approximately 15% of the total fuel type inventory.

[9] Forestry Canada (1992)

Table 2. Provincial fuel type summaries for the Wells Gray Community Forest.

Fuel Type	Description	Wildfire Behaviour Under High Wildfire Danger	Area (ha)	Percent	Hazard
C-2	Moderately dense regeneration to pole-sapling forest with crowns almost to the ground.	Almost always crown fire, high to very high fire intensity and rate of spread	1,027	8%	High
C-3	Fully stocked, mature forest, crown separated from ground.	Surface and crown fire, low to very high fire intensity and rate of spread.	3,157	24%	High
C-5	Well-stocked, mature forest, crowns well separated from ground.	Low to moderately fast spreading, low to moderate intensity surface fire.	2,160	16%	Mod
C-7	Open uneven-aged forest, crowns separated from ground except in conifer thickets, understory of discontinuous grasses, herbs.	Surface, torching, rarely crowing (slopes > 30%), moderate to high intensity and rate of spread.	2,548	19%	Low
D-1/2	Moderately well-stocked deciduous stands.	Always a surface fire, low to moderate rate of spread and fire intensity.	642	5%	Low
M-1/2	Moderately well-stocked mixed stand of conifers and deciduous species, low to moderate dead, down woody fuels, crowns nearly to the ground.	Surface, torching and crowning, moderate to very high intensity and spread rate (depending on slope and percent conifer).	2,242	17%	Low - Mod
O-1a/b	Continuous short grass.	Rapid spreading, moderate to high intensity surface fire.	555	4%	Low - Mod
S-1	Continuous, deep slash from mature jack pine or lodgepole pine. Slash is typically one or two seasons old, retaining up to 50% of the foliage.	Surface fire, low to moderate intensity.	491	4%	Low - Mod
S-2	Moderate slash fuel loading, cured slash, one to two years old with little foliage remaining.	Surface fire, low to moderate intensity.	124	1%	Low - Mod
S-3			147	1%	
Water	Water	N/A	47	<1%	N/A
No Fuel	No fuel	N/A	9	<1%	N/A

Figure 12. Summary of the hectares and percentage of each fuel type inventory class represented in the Wells Gray Community Forest.

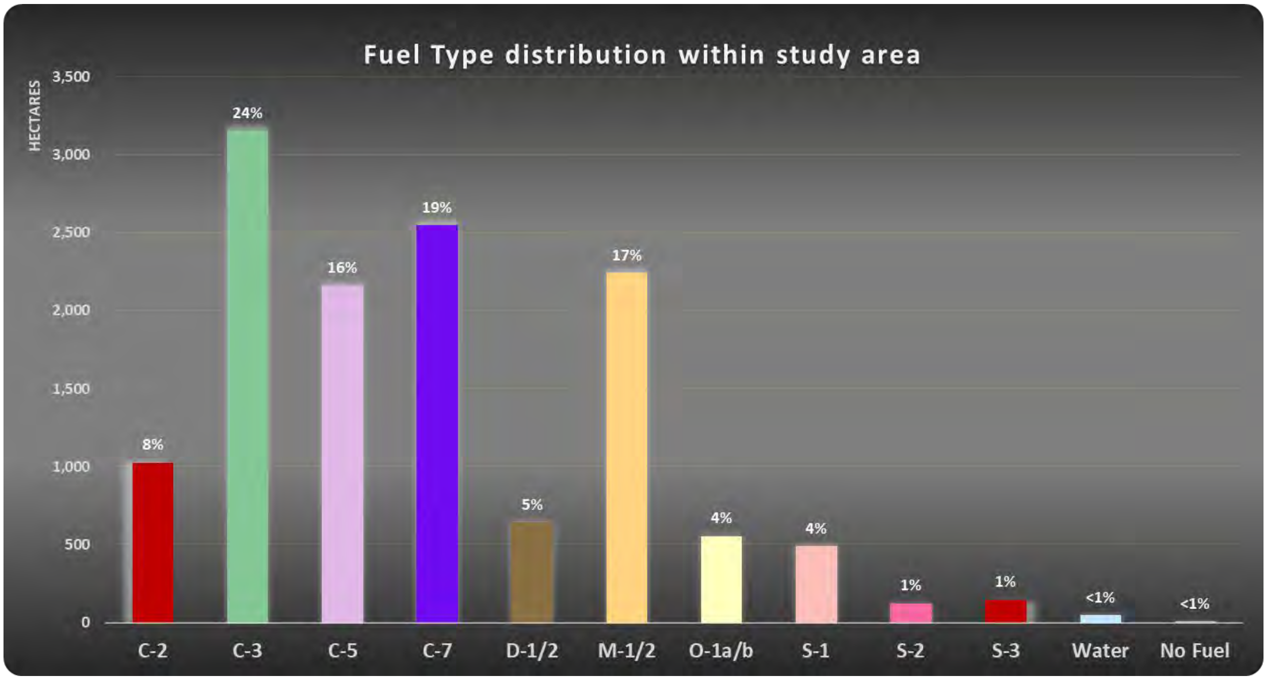


Figure 13 below illustrates the spatial distribution of fuel types for the Community Forest.

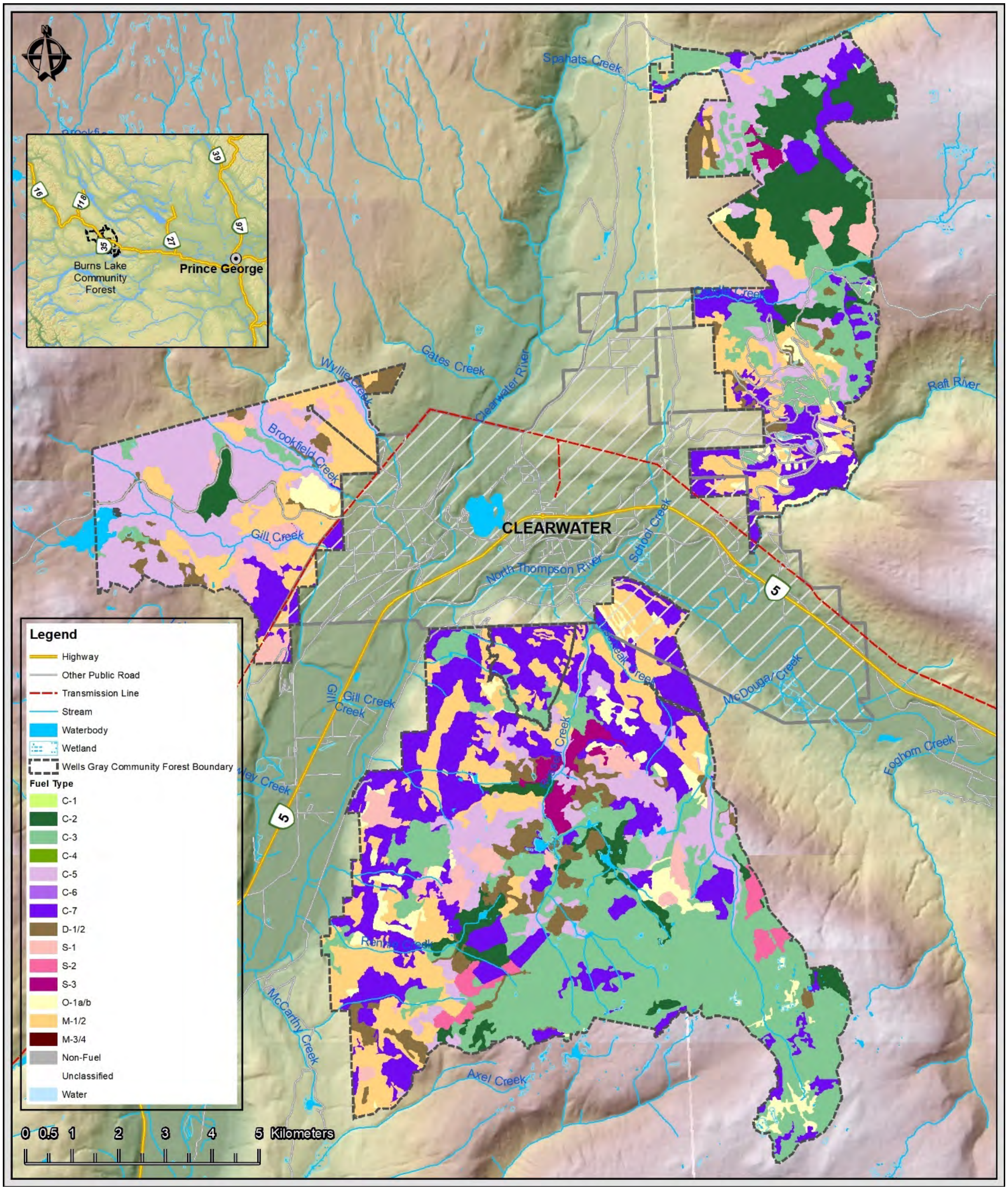


Figure 13. Fuel type spatial distribution for the Wells Gray Community Forest.

Fuel types considered hazardous in terms of dangerous fire behaviour and spotting (lofting burning embers) are C2, C3, C7, and M1/2. These hazardous fuel types comprise 68% of the total study area (inclusive of water and non-fuel). It is worthy to note that C2 fuels, the highest hazard fuel type, account for approximately 8% of the fuel type inventory within the Community Forest(Table 2 and Figure 12). The spatial distribution of hazardous fuel types is illustrated in Figure 14. The following summarizes why these fuels have been classified;

- C3 (particularly if there are large amounts of woody fuel accumulations or denser understory ingrowth)
- M-1/2 fuel type can sometimes be considered hazardous, depending on the proportion of conifers within the forest stand; conifer fuels include those in the overstory, as well as those in the understory.
- C-3 and C-7 can sometimes represent hazardous fuels, particularly if there are large amounts of woody fuel accumulations or denser understory ingrowth.

Overall fire management planning needs to be concerned about the accuracy of the fuel typing primarily because of the quality of the inventory and the application of the FBP system to fuels that have been heavily modified by fire suppression and related forest in-growth. It is recommended that more detailed ground truthing and coordination in the assignment of fuel type, with the BC Wildfire Service Fuel Specialist, be a priority to improve fire behavior potential and wildfire risk assessment as part of working to implement this plan. Specifically the M and C7 fuel types should be targeted for ground truthing.

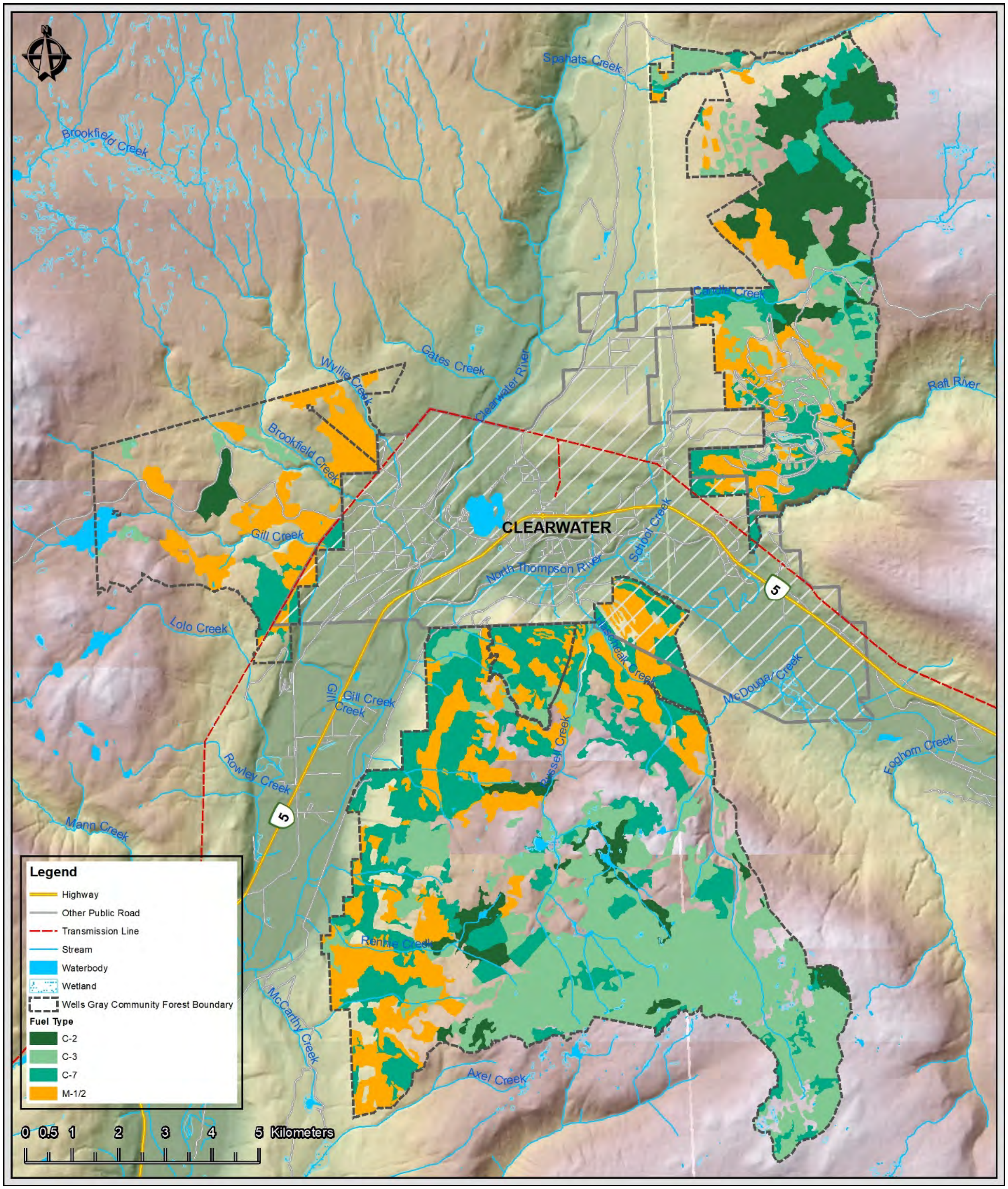


Figure 14. Spatial distribution of hazardous fuels in the Community Forest – C2, C3, C7; and M1/2 (75% conifer and 25% deciduous).

4.6.1 CURRENT CONDITIONS

The lack of prescribed fire since the mid-eighties has resulted in accumulations of post-harvest slash. Previously after burning, low fuel loadings prevented the spread of wildfires through cutblocks and acted as a barrier to fire spread. The accumulations of harvest slash in the absence of prescribed fire now facilitates easy spread and growth of wildfires within recent cutblocks. This has been further exacerbated by insect and disease salvage which typically has resulted in even higher slash loads associated with the mortality and economics salvage harvesting. Moving forward harvest abatement needs to be more focused on the removal of fine slash (<12.5 cm) to limit both the ignition potential and the rapid spread and growth of surface fire. Particular attention to travel corridors and areas of heavy human use is required to prevent careless human ignitions.

5.0 OVERVIEW FIRE HAZARD AND RISK ASSESSMENT

The Province has developed a standardized approach (tools including mapping) to help assess fire risk which is the combination of fire threat and impact to values at risk. The tools provided by the Province incorporate provincial scale data inventories associated with various factors including fire density, spotting, head fire intensity and the PSTA. The goal of a standardized approach is to provide both a regional context to fire management and to aid in the decision-making priorities of land managers. Although it is recognized that each District is unique, the fire risk in any given District may be lower or higher in relation to other Districts based on the threat and/or associated values at risk. Additionally, this standardized approach quantifies and prioritizes management activities within the context of the District risk profile.

5.1 PROVINCIAL STRATEGIC THREAT ASSESSMENT

The PSTA Fire Threat Analysis (FTA) is meant to inform the wildfire threat portion of the LFMP and Community Wildfire Protection Plan (CWPP) processes. It was also developed to aid strategic level planning at a coarse resolution for the District. The PSTA FTA combines three inputs to produce an overall fire threat layer that integrates many different aspects of fire hazard and risk. The three-layer classes were combined through a weighted averaging process:

- Historical Fire Density (25% weighted average);
- Head Fire Intensity (90th percentile) (60% weighted average); and
- Spotting Potential/Impact (15% weighted average).

Weighted values were added to produce a final FTA percentage value (0 – 100) where values of zero represent areas that have a zero value in all three categories (alpine rock, glaciers, oceans, etc.). This weighting integrates the three distinct elements of fire threat or risk – fire occurrence (Fire Density layer), suppression difficulty and fire impacts (Head Fire Intensity) and spotting. The final FTA data was then classed into five categories to produce a map. The classification was done based on equal-interval classes using an expert opinion iterative process. These five categories of fire threat represent the best estimate of relative fire threat across the Province, taking into account fire occurrence and history, predicted fire intensity under extreme conditions, and spotting potential. It is important to note that all models are limited by the data inputs and have built in assumptions and limitations with respect to their utility. The PSTA Fire Threat analysis is sensitive to certain elements most notably the fuel layer which drives the fire behavior elements. A number of important assumptions and limitations to be aware of include:

1. Fire history (based on the reliability of Provincial fire records);
2. Fuel typing (an approximation and is limited by the availably and reliability of the of VRI data in addition to the determination of the final fuel type); and
3. Fire threat layer (used 90th percentile Head Fire Intensity which represents the worst-case scenario).

The PSTA FTA is a snapshot in time and does not make projections for changes to the land base or to climate over time. The intent is to run the final threat model with updates to inputs every year or as fuels change and assumptions are refined. The maps are only intended to help with the identification of areas where the risk to values (including communities) is high, and to prioritize where proactive investment is required to mitigate the impact. Subsequent ground truthing and field inspections are required to determine the final threat and develop the appropriate prescription for action.

Input 1 – Fire Density

Fire density is the first input into the PSTA Fire Threat Layer. The numbers represent the thresholds of the Kernel density function for fires > 4 ha. Kernel density is not fully described here, but essentially fits a smooth surface to a spatial point frequency dataset. For this purpose, a search radius of 10 km was used. This therefore represents the approximate density of historic fires 4 ha and greater. The threshold of 4 ha, by convention, discriminated between small 'initial attack' fires and larger 'escaped' fires (MFLNRORD, 2017).

Overall historical fire density is low throughout the Wells Gray Community Forest (Figure 15); these areas are associated with gently sloping, rolling to hummocky topography, that is heavily roaded and easily accessed from Clearwater with moderate to good suppression capability.

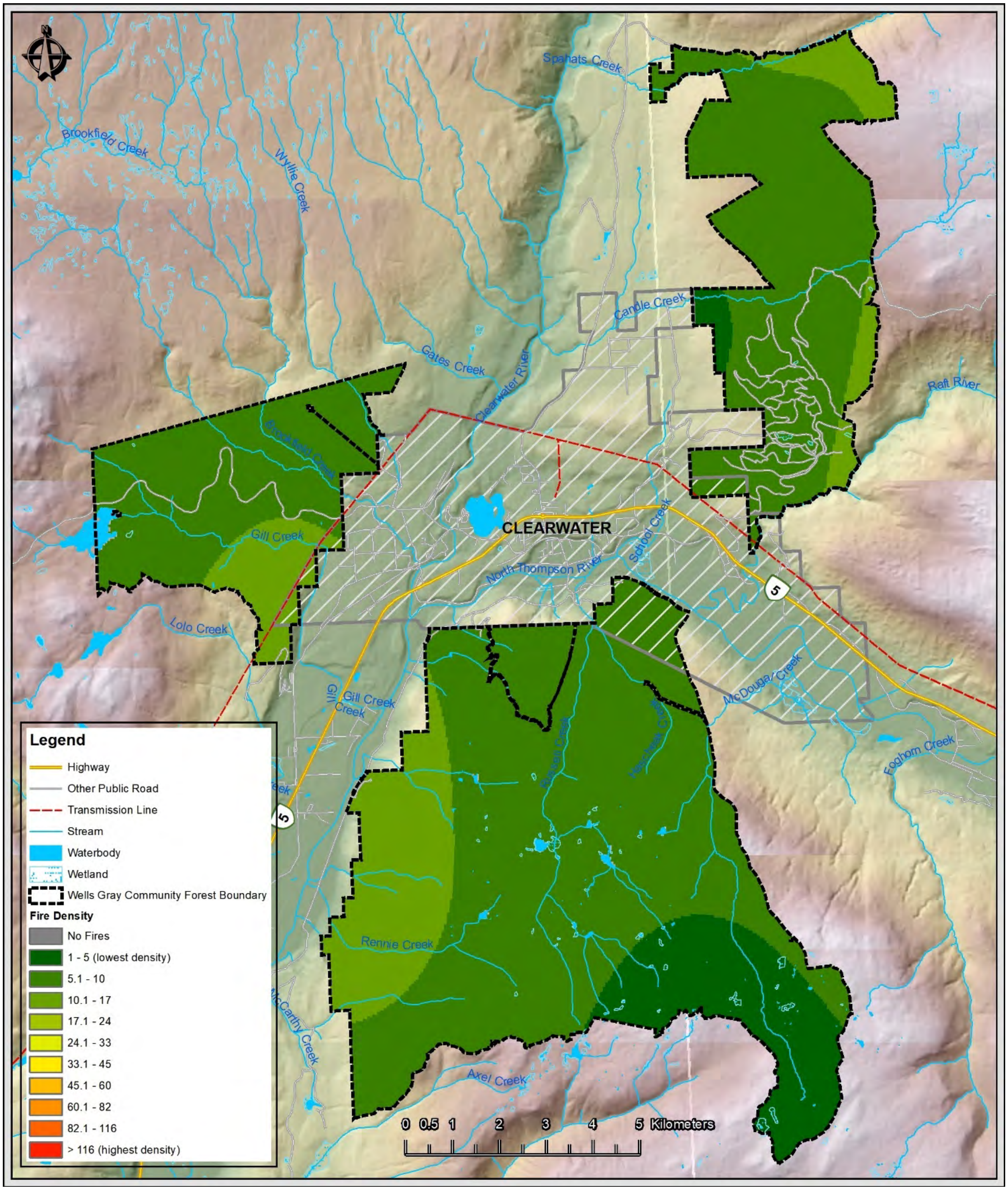


Figure 15. Provincial Strategic Threat Analysis Historical Fire Density.

Input 2 – Head Fire Intensity

Head Fire Intensity (HFI) is the heat output of the flaming front of a wildfire. HFI is a good indicator of fire severity as it is a function of the combustion of organic materials on the landscape and is measured in kilowatts/metres (kW/m). The HFI layer was developed using three different fire weather percentiles (55%, 75% and 90%). These percentiles are identified values of weather variables at which 45%, 25% and 10% of all-weather observations for a station exceed the value identified for the percentile in question. The 90th percentile HFI layer was used for this analysis. There are nine HFI class limits and the values represent peak burning conditions (mid-afternoon) during a small number of days (~1 – 15) in an average year. These represent extreme values for any given location. It is important to note that the accuracy of these forecast intensity values depends strongly on the fuel typing (MFLNRORD, 2017).

The study area contains some large concentrated areas of moderate to high HFI intensity classes. Otherwise the HFI potential is quite variable and mixed with smaller to medium size polygons of low HFI ranging to moderate and high HFI. Throughout the Community Forest tenure HFI classes are high enough that suppression capability would be classified as moderate to difficult for ground crews attacking a wildfire under 90 percentile weather conditions. This assumes that the windspeed is below 10km/hr. Where these fuels are subjected to higher windspeeds (>10km/hr) the majority of the forest area would have suppression capability that was classified as difficult (Figure 16).

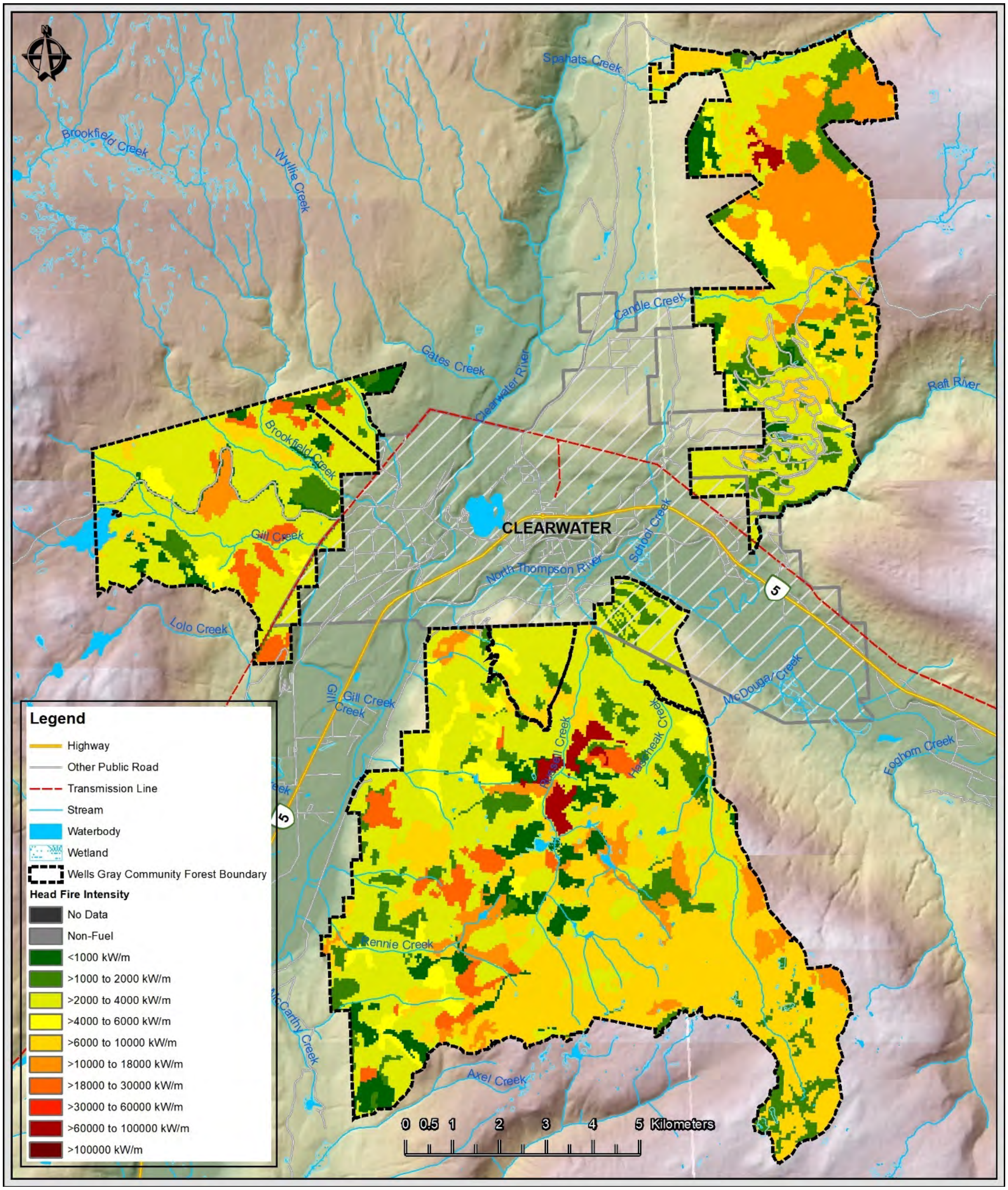


Figure 16. Provincial Strategic Threat Analysis Head Fire Intensity

Input 3 – Spotting Potential / Impact

Spotting is the physical movement of firebrands and embers from the main fire perimeter to areas outside of the fire perimeter. This process is a function of torching trees, tree height and wind speed. The spotting calculation is based on the ability of burning biomass fuel to loft embers over a distance on the landscape and start new fires. For fuel types that do not produce extensive lofted embers, spotting and spotting distances tend to be much lower. Spotting values for this input were assigned in order to represent the relative danger of each spotting distance for 12 fuel type distance classes. They were also adjusted to normalize the areas considering larger, concentric circles cover much greater area than smaller ones. Each pixel (25 m x 25 m) was then assigned a score based on its location from the spotting source (MFLNRORD, 2017).

The total spotting risk associated with a pixel was calculated as the sum of the spotting values of the pixels in the surrounding concentric circles. This iterative process was completed for the complete landscape with each pixel receiving a total score. Based on this total score, the landscape was categorized into Spotting Classes of low to high. This process best describes the landscape's ability to be affected by spotting from a wildfire. The spotting impact layer is experimental and has not been extensively tested. It is meant to represent the threat provided by spotting (ember lofting) alone from a wildfire nearby (upwind), regardless of the impact of the actual fire. The values and classes represent relative differences between the risks of spotting across different portions of the provincial landscape. They were created by automatic classification (the 'natural breaks' [Jenks]) setting of the ArcGIS 10.1 Spatial Analyst extension. Differences are caused by different fuel type classes and distances (MFLNRORD, 2017).

Areas identified with high spotting impact within the study area are associated with hazardous fuel types with moderate to high HFI classes. Areas of high spotting potential are identified in three areas of the study area and none of these areas suggest they will impact the adjacent community of Clearwater. (Figure 17). It is important to note that the PSTA Spotting Impact Layer illustrates where spots will land and not where they will originate; hence this is currently not useful for evaluating potential fuel treatment areas.

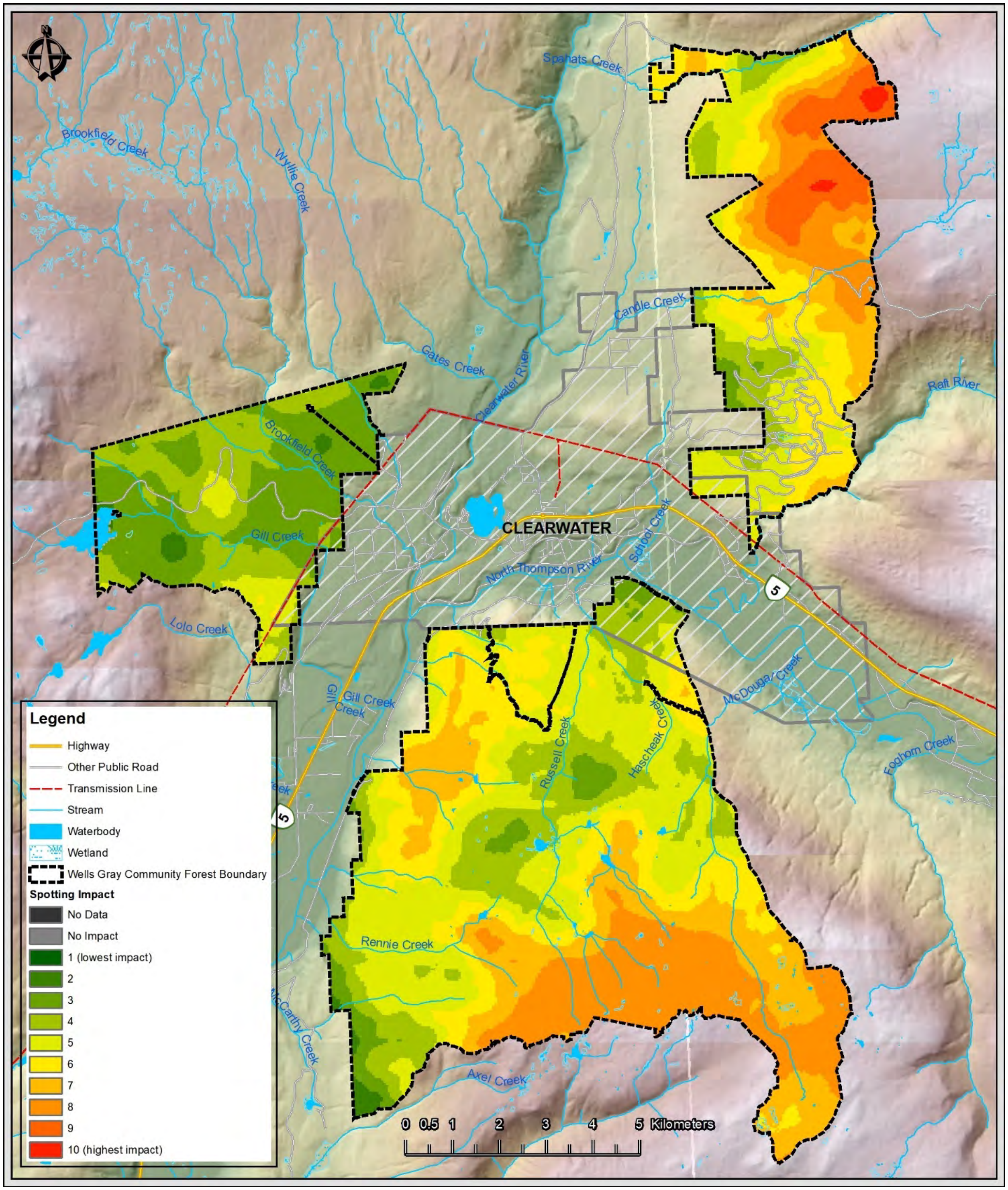


Figure 17. Provincial Strategic Threat Analysis Spotting Impact

Overall Fire Threat Rating

A summary of the PSTA inputs is provided below in Table 3 and Figure 18. The overall PSTA fire threat rating is spatially represented in Figure 19. The overall PSTA ratings for the Community Forest are consistent with the hazardous fuel types previously described in section 4.6. There are significant areas (approximately 4,428 ha) of 'high' Threat (classes 8-10,) which represent approximately 34% of the total Community Forest land base (Table 3 and Figure 18).

Table 3. Distribution summary of PSTA inputs: Fire Density, Head Fire Intensity and Spotting Impact.

Class	Fire Density (ha)	Head Fire Intensity (ha)	Spotting Impact (ha)	PSTA Fire Threat (ha)
0	47	77	64	69
1	1,319	666	0	0
2	9,722	1,199	108	3
3	2,060	5,636	1,495	230
4	0	583	2,337	587
5	0	3,163	3,125	1,975
6	0	1,250	2,110	4,628
7	0	433	1,778	1,230
8	0	0	1,694	2,789
9	0	143	403	1,399
10	0	0	35	240

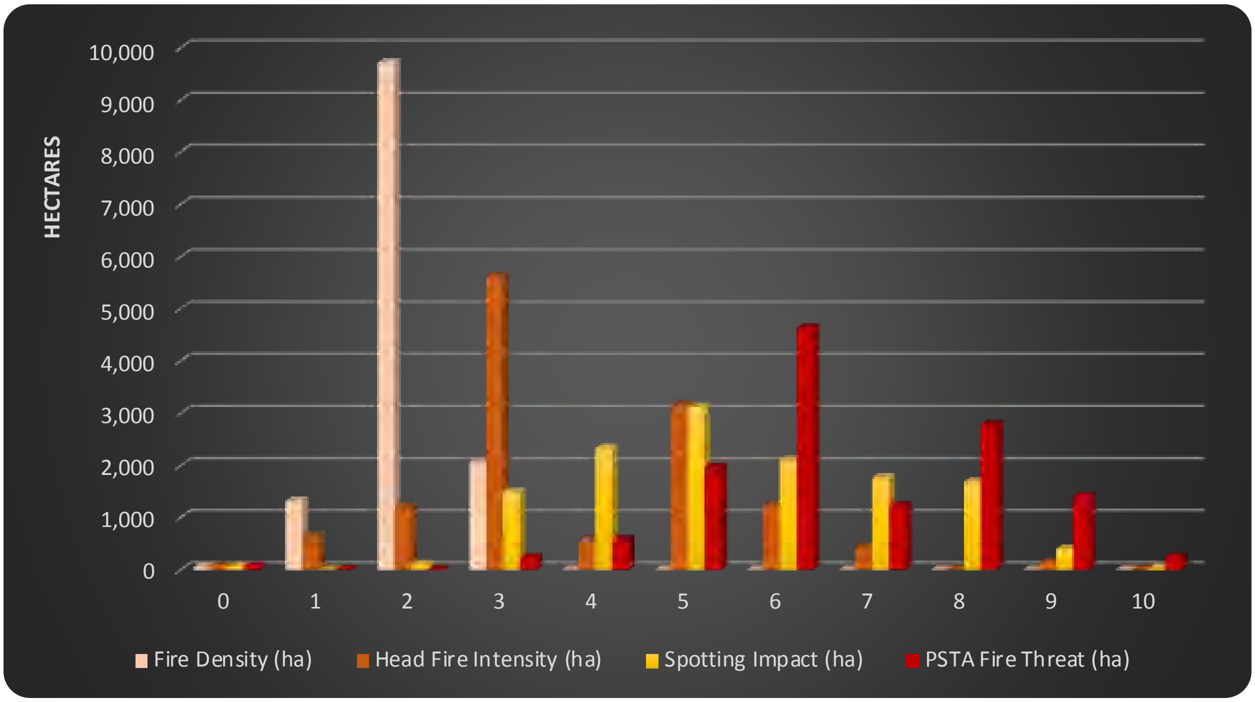


Figure 18. Distribution summary of PSTA inputs: Fire Density, Head Fire Intensity and Spotting Impact.

The overall PSTA fire threat rating is spatially represented in Figure 19 below.

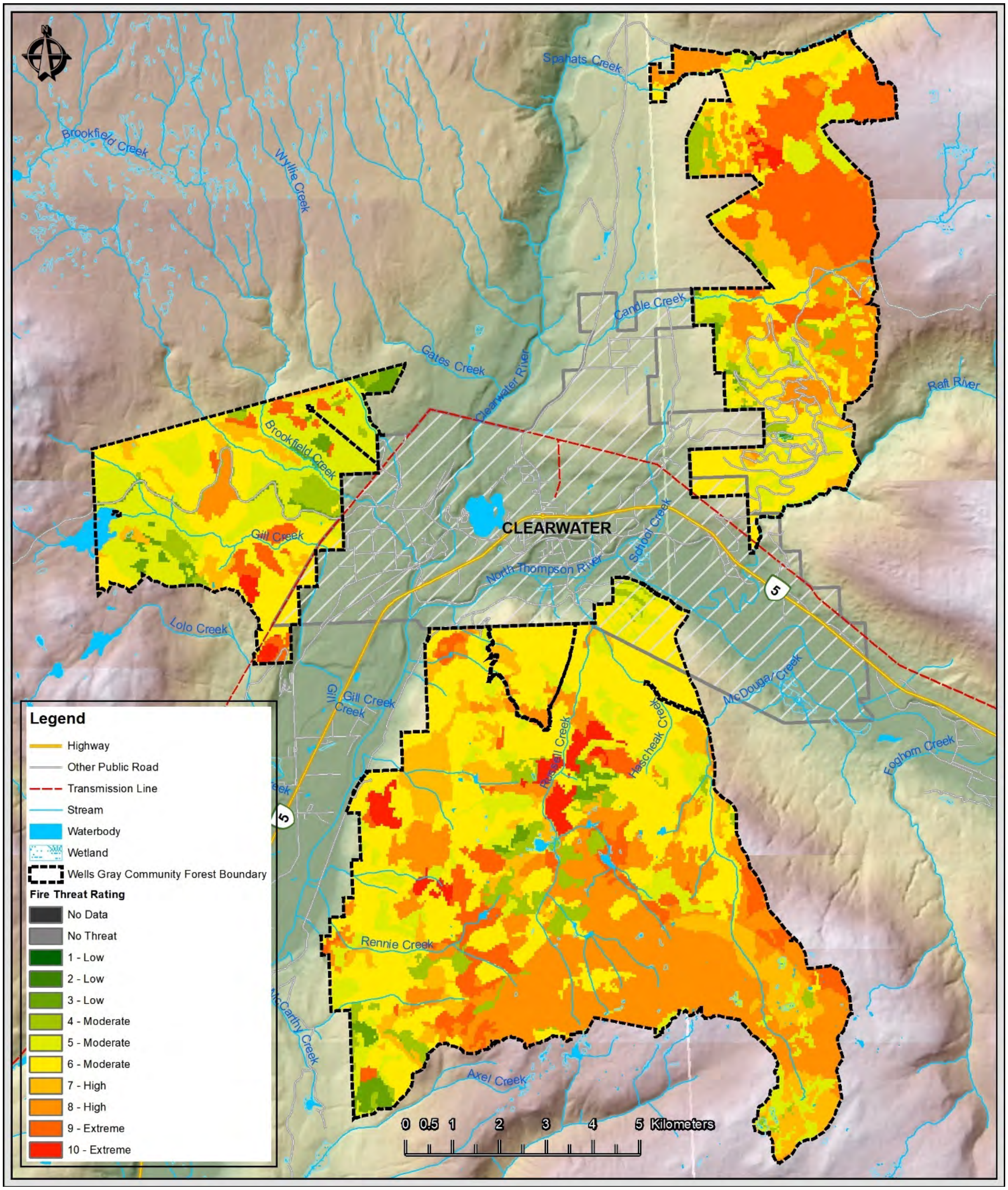


Figure 19. Overall PSTA fire threat rating.

6.0 RISK MITIGATION

To date within the Community Forest, there have only been small scale fuel treatment projects that are focused primarily on protecting the interface. Given the last two wildfire seasons (2017 and 2018) and the trend over the last twenty years of increase wildfire size and severity it is necessary for the Community Forest to focus more attention on limiting catastrophic wildfire through modifying portions of the landscape to improve and create anchors to modify wildfire behaviour and for more effective wildfire suppression. In the absence of these landscape modifications and treatments it is likely that suppression efforts to control large wildfires will be extremely difficult and likely unsuccessful.

In addition to fuel treatments, fire hazard mitigation can be achieved through improved fire prevention and fuel management (both stand level and landscape level). Fire prevention can be achieved through communication and education initiatives, as well as through the development and implementation of policies and regulations, including operational guidelines and restrictions. Fire prevention can be addressed at the community level through various avenues. Danger class rating signs within fire protection zones, public communication, industrial work restrictions and fire bans are examples of public fire prevention measures. Fire hazard and risk mitigation, and opportunities identified in this plan are not designed to replace other prevention recommendations; rather they target silvicultural and harvesting activities to reduce fire hazard and risk within the Community Forest. Potential treatment areas are described in Section 6.3.

6.1 FUEL MANAGEMENT

Fuel management is generally considered a key element of fuel hazard mitigation for high risk areas. Fuel management is the planned manipulation and/or reduction of living and dead forest fuels. Stand level fuel management is generally focused on protecting the WUI and is not necessarily effective in completely stopping fire spread but to ensure that fire severity is low enough that fire suppression crews have a high probability of success in suppressing the wildfire and that wildfire damage is limited. Additionally, fuel management can be supported with communication and education where land managers are made aware of and understand the benefits of managing fuels on the landscape. Fuel management can also be linked with other physical features to create fuel breaks similar to those identified within this report.

6.2 LANDSCAPE LEVEL FUEL BREAK DEVELOPMENT

Fuel breaks can be defined as strategically placed continuous areas with low volume fuel, and where firefighters can make a stand against wildfire and provide safe access for fire crews in the vicinity of wildfires (often for the purpose of lighting backfires). Fuel breaks are an important tool for protecting communities and other values at risk (such as timber supply and habitat features) from wildfire. Fuel breaks can be created by utilizing existing physical features such as areas of non-fuel, cleared land for rights-of-way, roads, recent cutblocks, burned areas, *etc*., or through a combination of physical features, and by implementing fuel management treatments that minimize hazardous vegetation and woody debris. General considerations for landscape level fuel break establishment include:

- Areas where fire control activities can be focused to limit or stop a large wildfire.
    - Utilize topography, harvesting and fuel management to create larger-scale treatment areas.
    - Utilize existing physical features (*e.g.*, road, power lines, non-forested or deciduous forest types, *etc*.).
    - Requires coordination at the community level:
        - Coordination with the local municipality and regional governments.

Using the existing road network and existing transmission lines right of way in the Community Forest, thinned stands and other physical features, fuel breaks were identified and are based on fire behaviour modelling of hazardous fuel types and fire behaviour potential using the Prometheus fire growth model. The modelling methods employed and the results of the modelling are described in Appendix A (including spatial representations of fire growth projections for five separate scenarios modelled). In designing fuel breaks it is assumed that at a minimum, fuels will be thinned or removed within a 300 m zone either straddling each side of the linear feature centerline or alternatively on one side depending on the predominate wind direction.

6.2.1 FUEL BREAK DESIGN PRINCIPLES

Fuel breaks act as staging areas where fire suppression crews can anchor their fire suppression efforts, thus increasing the likelihood that fires can be stopped, or fire behaviour minimized, so that the potential for a fire to move fluidly through the wildland and into the WUI is substantially reduced. The effectiveness of fuel breaks has been questioned considering they are generally constructed to varying standards, have not been tested under a wide variety of wildland fire conditions, and have been measured by varying standards of effectiveness. Factors influencing the effectiveness of fuel breaks include construction standards, potential fire behaviour and the level of suppression. Generally, wider fuel breaks are more effective than narrow ones. There is no absolute standard for fuel break width, however, a minimum width of 300 m was identified as an adequate break by Agee, *et al.,* in 2000 and for the purposes of this project and based on professional opinion, fuel breaks of approximately 300 m are utilized. Fuel breaks are generally tailored to the terrain, fuels, historic fire regimes and expected weather conditions of the area (Mooney, 2007). An effective fuel break will significantly alter fire behaviour (slow fire spread, reduce fire intensity, reduce flame length, and reduce torching and crown fire probability). By reducing fire behaviour, fuel breaks can: allow suppression response to safely reduce the spread of fire and as noted above; serve as an anchor point for indirect and direct attack and facilitate the rapid construction of a fireline; provide safe access for ground suppression; and provide greater opportunity for aerial response (air tankers), use of sprinklers and back burning operations.

Fuel breaks are an important tool for protecting communities and other values at risk from wildfire. They must be strategically located and can be created by utilizing existing physical features (*e.g*. areas of non-fuel, cleared land for right-of-ways, roads, recent cut blocks and wildfires, *etc*.) and by implementing fuel reduction treatments to minimize hazardous vegetation and woody debris. This can be achieved through prescribed fire, and manual and/or harvesting treatments. Generally, the goals of fuel break treatments are to reduce stand density, increase the height to live crown, remove saplings and reduce the amount of surface fuels (Figure 20).

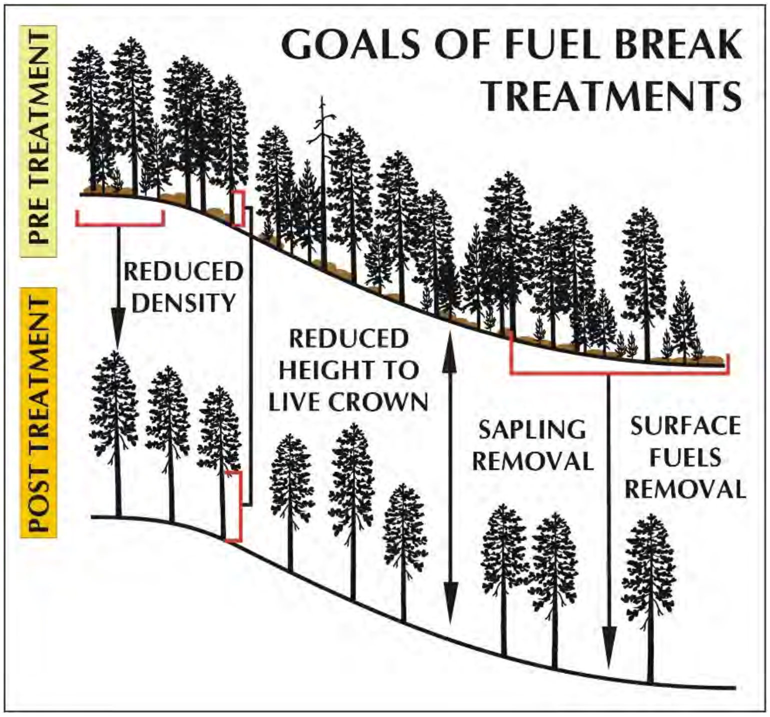


Figure 20. Goals of fuel break treatments.

Where the overstory is dead or dying fuel removal may be required to construct an effective fuel break. In this case careful consideration of the fuel removal standard is required and reforestation standards should consider reduced stocking standards to limit the growth of a fuel layer that will compromise the fuel break over time. Where natural regeneration and fill is a concern, future fuel maintenance may be required.

Reducing the number of dead trees and shrubs on the ground will limit the fire intensity and rate of spread of a surface fire, enhancing the effectiveness of fire suppression. Some coarse woody debris should be retained for ecosystem health (*e.g*., wildlife habitat and soil nutrition). Removing small conifer trees and pruning the lower branches of large trees will reduce ladder fuels (stratification between the ground and tree crown) that can contribute to crown fire. The density of larger trees is reduced to help minimize ladder fuels and to create separation among tree crowns. This further limits the potential for crown fires. The number of trees thinned from a stand to reduce density depends on the stand characteristics (e.g. species, density, age). Deciduous trees do not possess the same level of volatility as conifer trees and, therefore, are generally not considered for removal. Some areas may require extensive removal of vegetation and trees to establish an effective fuel break. Why and how fuel breaks are created depends on the ecosystem of the area. In some ecosystems shaded fuel breaks may be more beneficial. Shaded fuel breaks are generally utilized where forests grow quickly, are dense and have a wide range of shrubs and tree species (coniferous and deciduous). These high productivity and diverse stands create challenges for both creating and maintaining effective fuel breaks.

The principle objective behind the development of fuel breaks within the Community Forest is to alter fire behaviour over the area of treatment and to give suppression crews time to take action to prevent fire spread and mitigate risks to values. This includes an objective to create a heterogeneous landscape. Additionally, opportunities for integrating ecosystem restoration (removal and management of beetle impacted stands into fuel break establishment) are considered in addition to the use of existing physical features (*e.g*., roads, transmission corridors, etc.) or existing natural fuel breaks.

Considerations for fuel break development included but were not limited to:

- A review of the full range of forest values;
- Opportunities for inter-agency cooperation and collaboration;
- Consideration of climate change on future dynamics; and
- Requirements for future/ongoing maintenance.

Fuel breaks are considered for Crown lands that are within the Timber Harvesting Landbase (THLB) (with a few exceptions on non-THLB). Types of fuel breaks considered for the Community Forest included linear breaks up to 300 m wide and existing physical features that were considered or incorporated into fuel break establishment include:

- Defined classes of non-fuel (water, rock, snow and ice);
- Areas of deciduous forest cover (*i.e*., D1/D2 fuel types/predominantly aspen);
- Areas of mixedwood forest cover (i.e. with greater than 80% deciduous);
- Non-vegetated linear features (*e.g*., transmission lines, roads, pipelines, etc.); and
- Cut blocks harvested within the last 10 years.

The 300 m wide breaks are based on topographic positioning, existing physical features that would constrain fire movement, the potential fire behaviour based on the 90th percentile Head Fire Intensity (HFI), specific fuel types, and constraints with a focus on protection and communities. In addition to the complete removal of the overstory to create a fuel break, another appropriate treatment is to utilize shaded fuel breaks. Shaded fuel breaks need to be wider (300m recommended) than cleared fuel breaks to ensure enough area of low fuel loading to slow the rate of spread. Shaded fuel breaks are initially created through manual and/or timber harvesting and followed by broadcast under burning of the understory or, alternatively, piling and burning debris. These breaks need to be maintained to ensure they meet wildfire protection objectives, if applicable, and the timing/frequency of maintenance is determined based on stand characteristics (site productivity, species composition, density and stand response).

6.3 PROPOSED FUEL TREATMENTS

Considering all of the above principles and criteria in the context of the hazardous fuels present in the Community Forest and the risk to the community of Clearwater and the Highway 5 transportation corridor, four major fuel breaks (total of 3,909.2 ha) (total of 966 ha) have been identified and are the priority focus of this fire management plan (Table 4). The location of these fuel breaks is illustrated in Figure 21.

This is a significant area of proposed treatment areas, however if the landscape is to be protected from large scale wildfire damage and loss this is likely the required scale of treatment. It is recognized that other areas of hazardous fuels have been identified but these should be considered in future harvest planning and the pattern and type of harvest required to reduce the overall landscape hazard. It is not feasible within the economic capability and the sustainability of harvest within the Community Forest to address all hazardous fuel types. Therefore, this plan has attempted to identify treatments that can be implemented over a reasonable timeframe (10 years) within the financial and resource capabilities of the Community Forest. The treatment plan is focused on both the protection of the Community Forest resource values and the protection of the community of Clearwater and the Highway 5 corridor.

Table 4. Summary of landscape level fuel breaks identified as priority fuel treatments within for the Wells Gray Community Forest

Id	Type	Area (ha)	C-2	C-3	C-4	C-5	C-7	D-1/2	M-1/2	S-1	S-2	O-1a/b	No Fuel
1	Primary Fuel Break - 300 m width	533.6	0.0	31.0	0.0	13.0	208.5	11.7	173.6	17.2	33.7	45.0	0.0
2	Primary Fuel Break - 300 m width	117.8	0.0	0.0	0.0	2.6	18.3	2.3	62.2	17.0	0.0	15.3	0.0
3	Primary Fuel Break - 300 m width	191.5	0.0	6.5	0.0	4.1	86.1	14.6	71.2	0.0	0.0	9.0	0.0
4	Primary Fuel Break - 300 m width	123.1	1.1	37.3	0.0	69.7	9.7	1.5	0.6	0.0	0.0	0.1	3.0

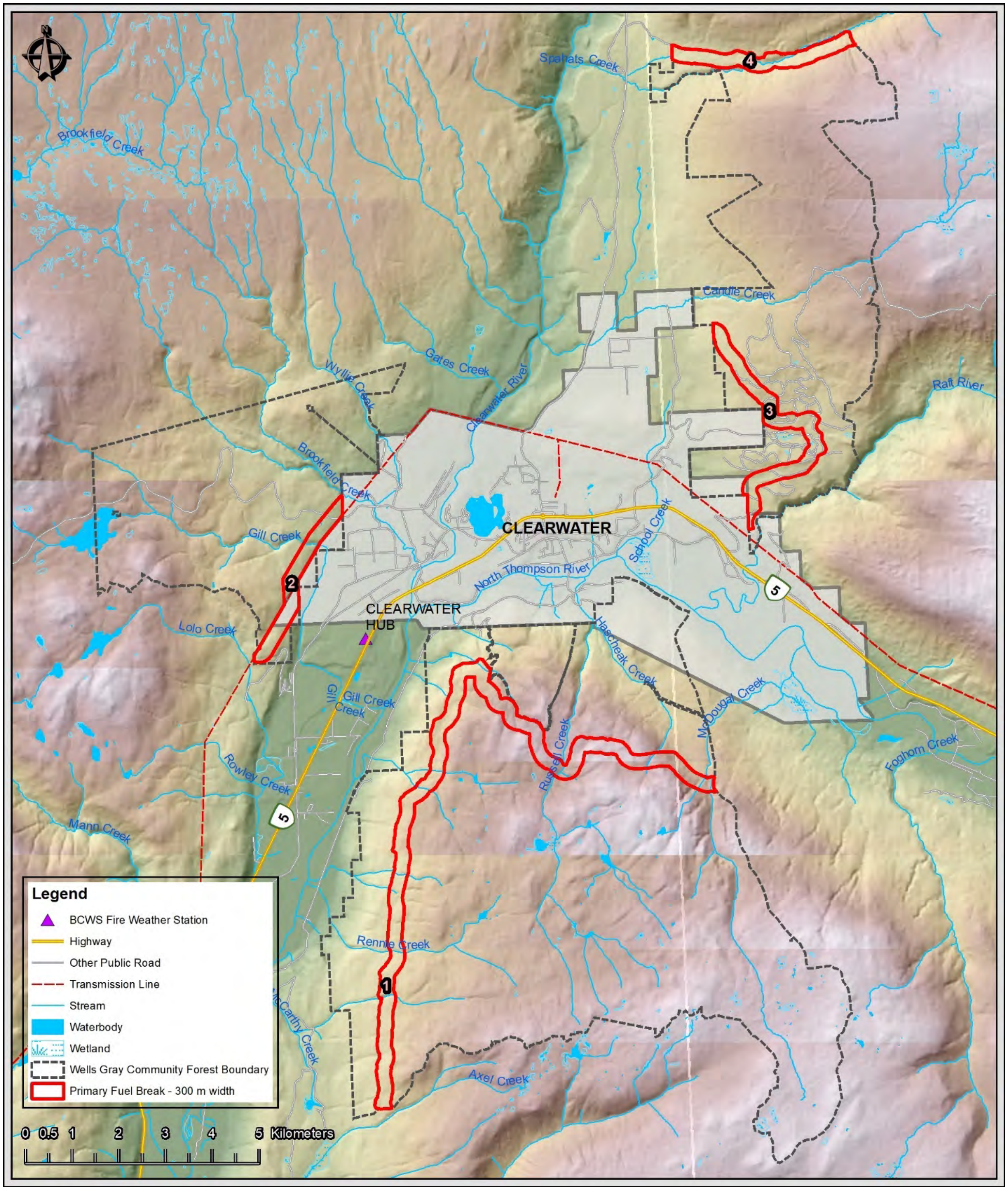


Figure 21. Fuel breaks identified as a priority for treatment within the Wells Gray Community Forest.

6.4 PRIORITY AREAS FOR CONSIDERATION

Priority areas for wildfire mitigation (fuel breaks and priority areas for operational fuel management) are delineated in Figure 22. Priority areas have been identified for recommended implementation over the near term (2019-2022) based on discussions with the Community Forest Manager as follows:

- Year 1 (2019-2020 action areas) – Very high priority;
- Year 2 (2020-2021 action area) – High priority; and
- Year 3 (2021-2022) – High priority.

These areas were assigned based on the following factors considered in prioritization:

- Implementation of the creation of fuel breaks is the top priority
- Shifting harvest focus to the priority areas for operation fuel management should be the second priority – these areas should become part of operational planning for the forest.
- To address potential catastrophic fire behaviour associated with hazardous fuel types, fire behaviour analysis and overall protection of the Community Forest tenure and the community of Clearwater;
- Ensure that the highway corridor remains safe during a wildfire event.
- Provide protection for areas around communities, particularly from wildfires approaching from the south and north;
- Protect key Clearwater critical infrastructure within the Community Forest tenure;
- Protect critical infrastructure such as powerlines; and
- Where constraints are in conflict with fuel management guidelines, they should be evaluated relative to the values at risk. For example, initiatives defined to support habitat may override fuel management where the protection area is small or the risk to other parts of the Community Forest can be mitigated around the feature area.

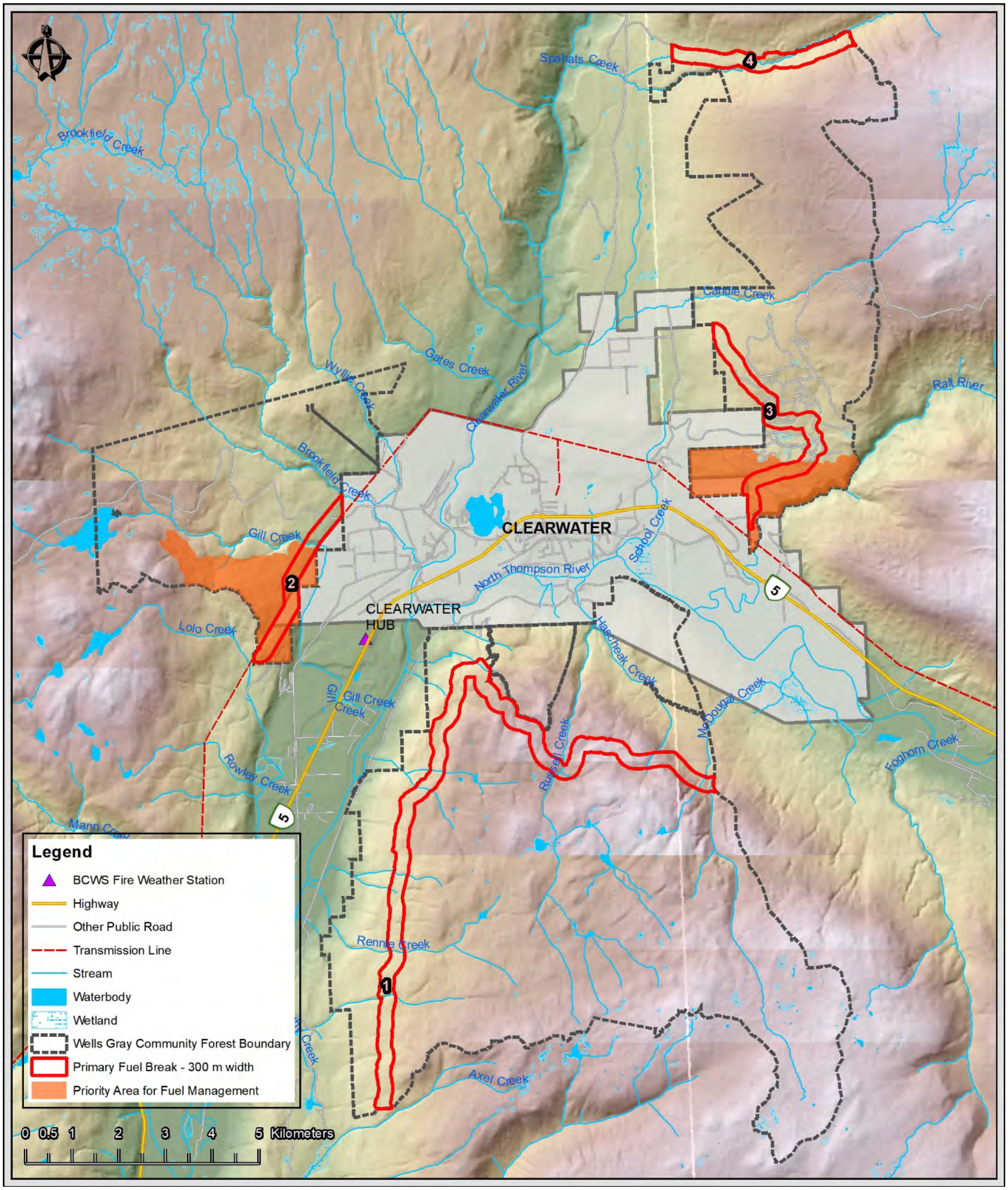


Figure 22. Priority fuel management and harvest zones.

6.5 SILVICULTURE REGIME GUIDELINES

The recommended silviculture regime for addressing the proposed fuel breaks is summarized in Table 5. Additionally, target silviculture standards for stands with components of dead pine (priority fuel management and harvest zones delineated in Figure 22 above) are included, in consideration of stand-level fuel management for Community Forest harvest areas, outside of proposed fuel breaks.

Table 5. Silviculture regime for fuel breaks and operational harvest (outside of fuel treatment areas) in stands with components of dead pine.

Treatment Type	Target Fine Surface Fuel <12.5 cm	Target crown base height	Crown Closure Target	Target Living sph	Target Dead sph	Deciduous
Fuel break silviculture treatment standards						
Shaded Fuelbreak (35-40% green leave trees)	10 tons/ha or 1 kg/m^2 [10]	2-3 m	35-40% or 3 m crown to crown spacing	300-600 sph depending on size and crown to crown spacing	25-50 sph	All living deciduous with the exception of birch preferred
Community Forest harvest areas – fuel management guidelines						
Harvest treatment	30 tons/ha or 3 kg/m^2	For partial cut blocks -target >2 m for all remaining living trees	non-applicable	non-applicable	non-applicable	All living deciduous with the exception of birch preferred
Hazardous fuel treatment areas	30 tons/ha or 3 kg/m^2	Target >2 m for all remaining living trees	35-40% crown closure or 3 m crown spacing	Prescription specific	Prescription specific	All living deciduous with the exception of birch preferred

[10] 1 ton per ha is the equivalent of 10,000 kg/m^2 and there are 10,000 m^2 per ha. and 1000 kg in a ton

Other fuel management treatment considerations include the following:

- To avoid independent crown fire, the shaded fuelbreak crown closure must be between 35-40% crown closure.
- Mixed dead and living stands – partial cut, leaving all green that meet the criteria of shaded fuel break conditions.
- For M fuel types within fuel breaks remove understory and overstory conifers to convert these to deciduous dominated stands (except where the deciduous is birch)
- For any OGMA or EVQO area where there are signs of significant wildlife activity and/or use, a biological assessment should be conducted and the treatment modified to maintain or enhance the habitat in conjunction with wildfire hazard reduction/mitigation.

7.0 FIRE MANAGEMENT AND FOREST MANAGEMENT OBJECTIVES – THE TENSION ZONE

7.1 SUMMARY OF FOREST MANAGEMENT OBJECTIVES

Within the current forest land management framework in BC there are a number of objectives and related requirements that protect specific forest values under the *Forest and Range Practices Act* (FRPA). These measures ensure protection of wildlife, fisheries, viewscapes, recreation, and other environmental values that have been deemed important to society and foster sustainable forest management. Typically, these areas are statically managed and are excluded from the THLB. While the current land management framework was developed with considerable analysis, review, and consultation it inadequately recognizes that forests are living, changing and dynamic systems that are periodically (either frequently or infrequently) disturbed by abiotic factors (such as wind and snow) and biotic factors (such as forest health agents and wildfire). One of the outcomes of disturbance is that it often results in partial or complete stand mortality resulting in unintended consequences of increased fuel loads and resulting increased fire behaviour potential. The current legislation and management paradigm often restrict the intervention and management of these areas to reduce risk and yet they often contribute to a significant portion of the hazard and risk that threatens other values including communities, watersheds, and other forest related values.

Forest managers need to recognize when forest stands have been compromised by disturbance, and no longer provide the objectives that they were intended to be managed for, and instead represent a hazard and risk to the greater landscape.

This is currently the case in the Wells Gray Community Forest where, as described previously, 68 percent of the landscape is composed of hazardous fuel types. The overlaps of Established Visual Quality Objectives (EVQOs) and Old Growth Management Areas (OGMAs) within fuel breaks are spatially represented in Figure 23. The proposed treatment areas will impact 6 percent of the total 1,287 ha

OGMA area in the Community Forest. Of the total EVQO (both partial and full retention areas totaling 7,080 ha in the Community Forest), 9 percent will be impacted.

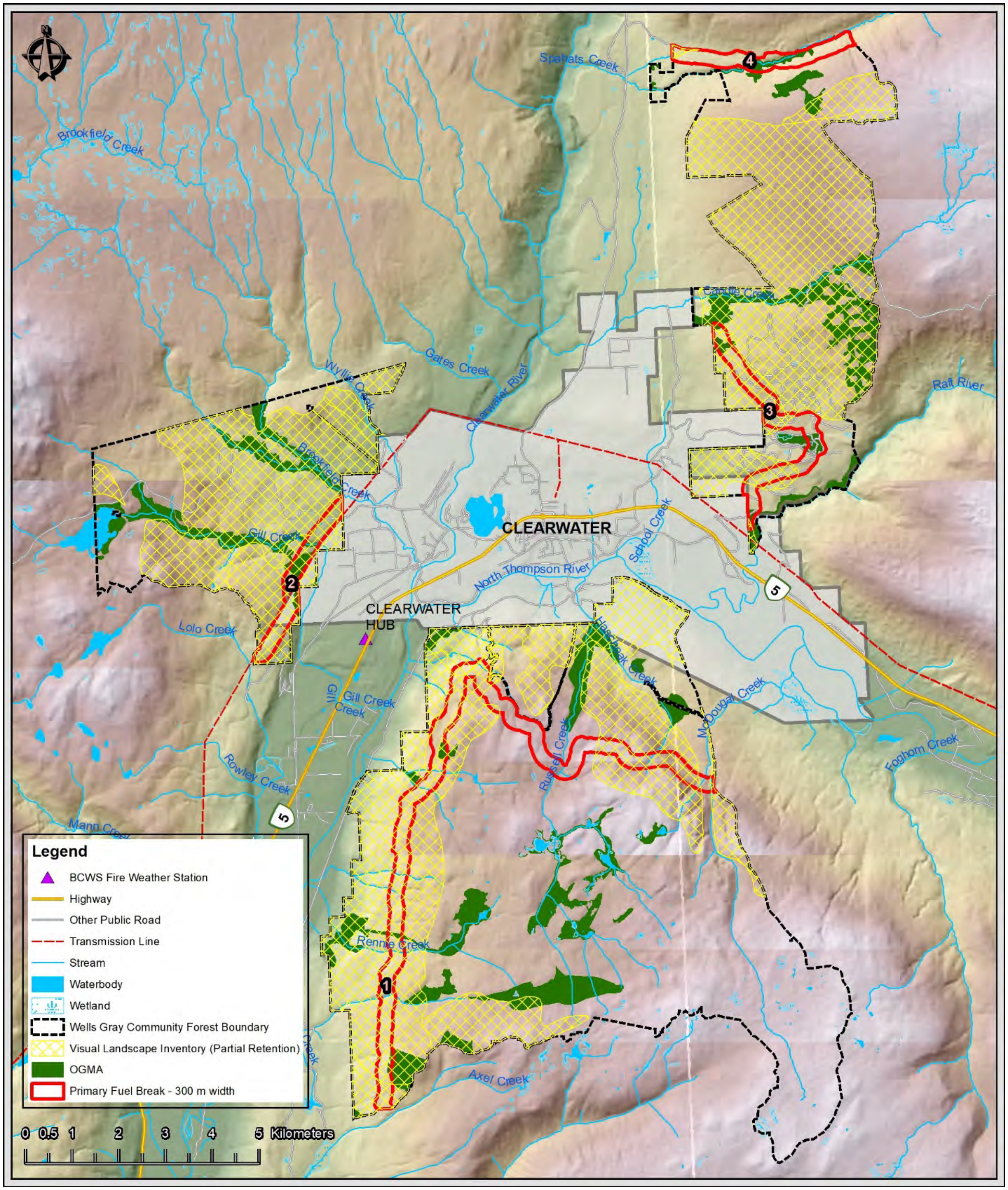


Figure 23. Current forest management FRPA objectives overlapped with proposed fuel breaks within the Wells Gray Community Forest.

Table 6 shows the overlap, by each individual proposed fuel break, with the specific impacted EVQOs and OGMAs. Table 7 summarizes the area of hazardous fuel types identified within each of the proposed fuel breaks and treatment areas that have been prioritized which represent significant wildfire risk in close proximity to the Community Forest, Clearwater and the Highway 5 corridor.

The fuel treatment impacts on OGMAs and EVQOs are not considered significant. Thinning from below treatment regime is not likely to impact the objectives of old growth protection and or visual landscape management. Furthermore, within the existing Government Actions Regulation (GAR) orders for OGMAs, fire hazard treatments are permitted within the legislation where a hazard has been clearly identified. Where the areas identified contain a significant proportion of deciduous, no treatment will be considered or a conversion from a mixed conifer/deciduous forest to deciduous should be the priority. Deciduous dominated areas (>75% deciduous) should be considered as functioning fuel breaks and should be maintained as such.

Table 6. Summary of legislated management objectives including Established Visual Quality Objectives (EVQO) and Old Growth Management Areas (OGMA) in proposed fuel break areas.

Id	Type	Total Area	OGMA				EVQO					
			No		Yes		Other		PR		R	
			ha	%	ha	%	ha	%	ha	%	ha	%
1	Primary Fuel Break - 300 m width	534	521	98%	12	2%	154	29%	380	71%	0	0%
2	Primary Fuel Break - 300 m width	118	98	83%	20	17%	0	0%	118	100%	0	0%
3	Primary Fuel Break - 300 m width	191	163	85%	28	15%	74	39%	117	61%	0	0%
4	Primary Fuel Break - 300 m width	123	103	84%	20	16%	117	95%	6	5%	0	0%
TOTAL		**966**	**885**	**92%**	**81**	**8%**	**345**	**36%**	**621**	**64%**	**0**	**0%**

Table 7. Summary of hazardous fuel types (C2, C3, C7 and M1/2) within proposed fuel breaks and priority fuel management harvest zones.

Id	Type	Total Area	Hazardous Fuel Type								Other Fuel Type	
			C-2		C-3		C-7		M-1/2			
			ha	%	ha	%	ha	%	ha	%	ha	%
1	Primary Fuel Break - 300 m width	534	0	0%	31	6%	208	39%	174	33%	329	62%
2	Primary Fuel Break - 300 m width	118	0	0%	0	0%	18	16%	62	53%	56	47%
3	Primary Fuel Break - 300 m width	191	0	0%	7	3%	86	45%	71	37%	114	59%
4	Primary Fuel Break - 300 m width	123	1	1%	37	30%	10	8%	1	0%	84	68%
TOTAL		966	1	0%	75	8%	323	33%	308	32%	583	60%

8.0 CONCLUSIONS AND RECOMMENDATIONS

A comprehensive review of the fire environment (weather, fuels and topography) was completed as part of this plan. Overall this review suggests that the Wells Gray Community Forest has not been impacted by a significant wildfire in recent history, and is vulnerable to a large and catastrophic wildfire based on the following;

- Recent climate trends suggest that periods of drought are increasing with increasing probability of human and lightning ignitions;
- The entire Community Forest is dominated (>50%) by hazardous fuels;
- The Strategic Threat Analysis developed by the Province also validates the hazard and risk to this area with a large distribution of the study area contained within high Threat classes.

The analysis and summaries provided in this report suggest that there are prudent actions that need to be taken to address the current landscape hazard to protect values at risk, including the town of Clearwater and the Yellowhead highway corridor. The overall risk profile of this area is considered high.

Four large fuel breaks and hazardous fuel treatments have been identified throughout the Community Forest. These areas should be the primary focus of fuel management efforts over the next decade. Some of these treatments will provide revenues that will partly pay for, or completely pay for the treatments. Other areas identified will be uneconomic and will require additional funds to facilitate treatment. The primary focus of all treatments is to ensure that surface fuel (<12.5 cm) is reduced to below 1kg/m^2 over the majority of treatment area, as this material increases ignition probability and promotes the rapid spread and growth of wildfires. If this is not the focus of treatment this will compromise the effectiveness of treatment and not reduce the fire behaviour to acceptable level to facilitate direct attach of wildfires.

An additional fuel management consideration is that future harvesting should also be focused on a high level of abatement such that fuel loadings of fine slash within cut blocks is reduced to the lowest level economically feasible. In the absence of significant post-harvest fuel abatement, practices such as processing at the stump should not be considered as they typically create large accumulations of fine surface fuels.

The current forest legislative framework in BC promotes static management to protect important forest values. Over the past 15 years (2003-2015) wildfire seasons in British Columbia have demonstrated that wildfires are not selective in the areas that they impact. Many of the important static reserves (wildlife habitat, riparian corridors, visually sensitive areas *etc.*.) have been impacted by both abiotic and biotic disturbance that has compromised the values that they were set aside to protect and has increased the risk of wildfire. In consideration of fuel treatments, forest land managers in BC, need to recognize changes in these areas (compromised forest values and increased wildfire risk) and support the fuel treatment planning and implementation to reduce this risk.

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APPENDIX A – FIRE BEHAVIOUR MODELLING

OVERVIEW

The Prometheus spatial fire growth model was used to assess projected fire behaviour in hazardous fuels adjacent to the community of Clearwater and the Highway 5 corridor. Five wildfire scenarios were modelled to support fuel break identification and design in the Community Forest. Prometheus is a nationally applied inter-agency sponsored fire growth model in Canada and is accepted as one of the dominant fire growth models used in Canada. It is a mathematically-based, elliptical fire growth model used in forest fire control planning that simulates and describes the growth of a forest fire front over time for variable fuel, weather, and topographical conditions. The descriptor 'elliptical' refers to the fan-shaped area that develops as a fire head burns and that generally widens as the fire front advances (Van Wagner, 1969[11]). The overall width of the fan remains relatively elliptical throughout the burn time. Prometheus uses both the Fire Weather Index (FWI) values and the Fire Behaviour Prediction (FBP) calculations from the Canadian Forest Fire Danger Rating System (CFFDRS) to estimate changes in the fire perimeter over time. In addition, a Geographic Information System (GIS) enable the inputs and outputs to be presented spatially.

PROMETHEUS FIRE BEHAVIOUR MODELLING METHODS

Prometheus[12] is based on the Canadian Forest Fire Danger Rating System (CFFDRS)[13]. The CFFDRS consists of two main subsystems; the Fire Weather Index (FWI) system and the Fire Behaviour Prediction (FBP) system (Figure 24). With respect to fuels, vegetation must be represented, as defined by the FBP System.

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[12] http://www.firegrowthmodel.com/index.cfm
[13] http://fire.cfs.nrcan.gc.ca/research/environment/cffdrs/cffdrs_e.htm

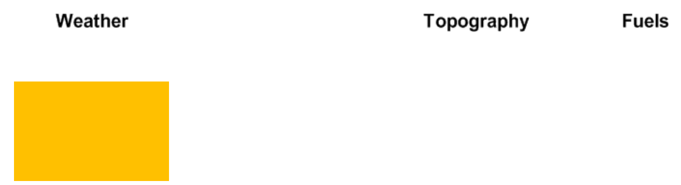

Figure 24. Diagrammatic representation of CFFDRS and Prometheus

FIRE WEATHER INDEX

The FWI system uses dry-bulb temperature, relative humidity, 10-meter open wind speed and 24-hour accumulated precipitation at noon local standard time as inputs to derive three fuel moisture codes:

1. Fine Fuel Moisture Code (FFMC): Moisture content of litter and fine fuels in a closed forest stand.
2. Duff Moisture Code (DMC): Moisture content of loosely compacted decomposing matter on the forest floor.
3. Drought Code (DC): Moisture content in deep, compact organic matter.

These in turn are used to derive:

4. Initial Spread Index (ISI): Wind speed with FFMC as an indicator of fire rate of spread.
5. Build-up Index (BUI): A combination of DMC and DC that has a longer response time to changes in humidity/precipitation. BUI is used to indicate the total fuel available for combustion.

The resulting FWI is:

6. A combination of generalized ISI and BUI indicators used to derive a relative estimate of the potential intensity of the fire.

The FWI indicates the potential intensity of a fire on level terrain in a stand of mature pine and assesses relative fire potential (Van Nest and Alexander 1999[14]). Variation in fire behaviour by fuel type is addressed in the FBP system. More comprehensive technical information on the FWI can be found in Van Wagner (1987)[15].

FIRE BEHAVIOUR PREDICTION SYSTEM

The FBP system assesses fire behaviour and uses inputs including topography, fuels, weather, foliar moisture content and duration of prediction. The FBP system is primarily based on empirical data from 495 observations of experimental fires and wildfires. Data from observations made during these fires was analyzed using statistical correlation techniques to derive fire behaviour predictions for 16 generalized boreal fuel types. Comprehensive technical information on the FBP can be found in the Forestry Canada Fire Danger Group (FCFDG) (1992). Primary outputs include:

1. Rate of Spread (ROS): speed of fire spread usually expressed in metres per second.
2. Head Fire Intensity (HFI): energy output of the flaming fire front usually expressed as kilowatts per metre.
3. Fuel Consumption (surface and crown): expressed in kilograms per square metre.
4. Fire Description (surface, intermittent and crown): Surface fire burns through surface fuels, intermittent fire refers to surface fire that periodically switches to crown fire via torching trees, and crown fire refers to fire burning continuously from the surface to the crown.

Secondary outputs from FBP include:

1. Flank and back fire rates of spread;
2. Flank and back fire intensity;
3. Head, flank and back fire spread distances;
4. Elliptical fire area;
5. Fire perimeter;
6. Rate of perimeter growth; and
7. Length-to-breadth ratio.

[14] Van Nest, T.A.; Alexander, M.E. Systems for rating fire danger and predicting fire behavior used in Canada. 1999. Pages 1-13 in National Interagency Fire Behavior Workshop, March 1-5, 1999, Phoenix, Arizona, USA. National Interagency Fire Centre, Boise, Idaho, USA. 13 p.

[15] Van Wagner, C.E. Development and structure of the Canadian Forest Fire Weather Index System. 1987. Canadian Forestry Service, Headquarters, Ottawa. Forestry Technical Report 35. 35 p.

MODEL INPUTS

Weather and Fuel Moisture Model Inputs

For weather inputs, existing data for August 1, 2018 real time weather from the Clearwater Hub weather station was used. The burn period modeled was 240 hours for real wind speeds (provided by the Clearwater Hub weather station on August 1, 2018.

Landscape Inputs

Elevation, aspect and slope were derived from a digital elevation model for the Community Forest study area. Text files for input into each of the models were generated using GIS.

Fuel Type Inputs

Fuel types that occur within the study area and which were used for this analysis are illustrated in Figure 13 and show the spatial distribution of the fuel types.

Ignition Inputs

Five scenarios were selected at key locations along Highway 5 based on potential for human-caused ignitions and sloped terrain which contributes to wildfire spread and head fire intensity under certain wind driven conditions. This included one scenario at higher altitude based on potential for lightning caused ignitions. The locations of the ignitions modelled are summarized below:

Ignition ID	Longitude	Latitude
1	120° 9' 7.129" W	51° 34' 34.684" N
2	119° 57' 46.185" W	51° 38' 31.408" N
3	120° 1' 56.289" W	51° 40' 31.111" N
4	120° 6' 28.800" W	51° 37' 1.200" N
5	119° 58' 40.800" W	51° 33' 32.400" N

RESULTS

In total, five ignition points were modeled without the proposed fuel breaks. Additionally, Prometheus does not incorporate the potential effects of suppression efforts and as such is considered a worst-case scenario. It is important to note that Prometheus fire behaviour modeling does not simulate spotting of fires; hence modeled outputs are for individual ignition points only.

The fire modelling results from the Prometheus runs are illustrated in Figure 25 to Figure 29 and include the following simulations:

- Fire growth simulation with an ignition point along Highway 5 South of Clearwater;
- Fire growth simulation with an ignition point along Highway 5 East of Clearwater;
- Fire growth simulation with an ignition point North of Clearwater;

- Fire growth simulation with an ignition point along Highway 5 South of Clearwater (nearer to the community); and
- Fire growth simulation with an ignition point south of Clearwater at higher altitude North of Foghorn Mountain.

The Prometheus fire behaviour model outputs illustrate the scale of fire growth and potential impacts with summer diurnal wind variation over a (10-day) 240-hour period in the absence of any fire suppression. Fire perimeters in certain areas of the landscape are also significantly influenced by wind direction and the topography (valley outflow and inflow winds), whereas some individual ignitions points result in fire growth that is driven more by location and terrain and yet are similar even under conditions with changing diurnal wind directions. A fire greater than 500 ha has the potential to create significant smoke, which would be highly visible to the general public, distress visitors, and has the potential to impact the highway corridor. Depending on the proximity the community, it would also create the potential for evacuation while generating a significant ember shower that could accelerate fire spread before an advancing fire front).

The range of fire size is quite similar when individual ignitions are compared against one another. This is expected as the pattern and distribution of fuel types within the ignitions zones is all quite similar. With the exception of the last ignition simulation (Figure 28) all of the ignitions significantly impact the highway corridor and the associated highest concentration of values at risk.

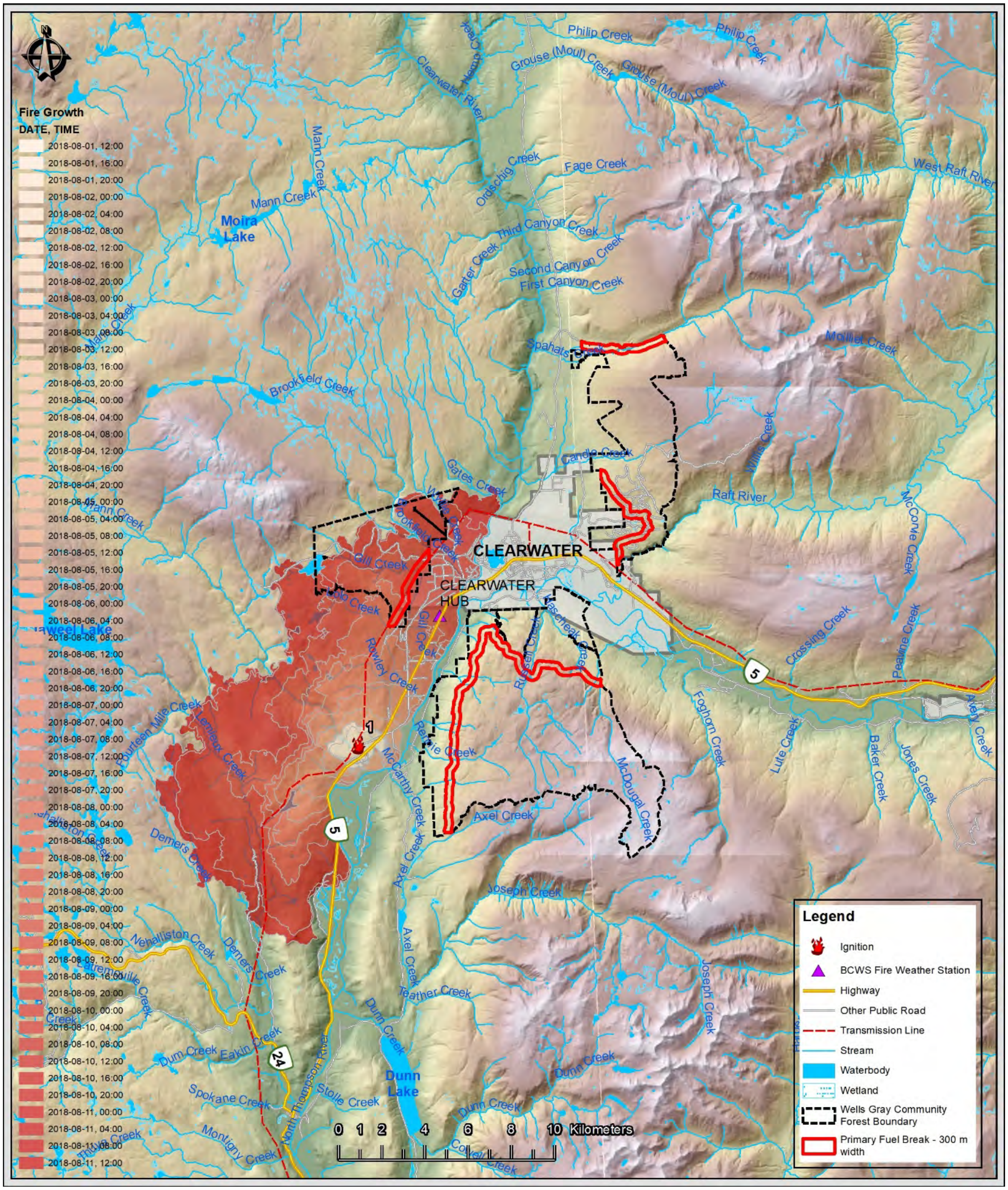

Figure 25. Fire growth simulation with an ignition point along Highway 5 South of Clearwater.

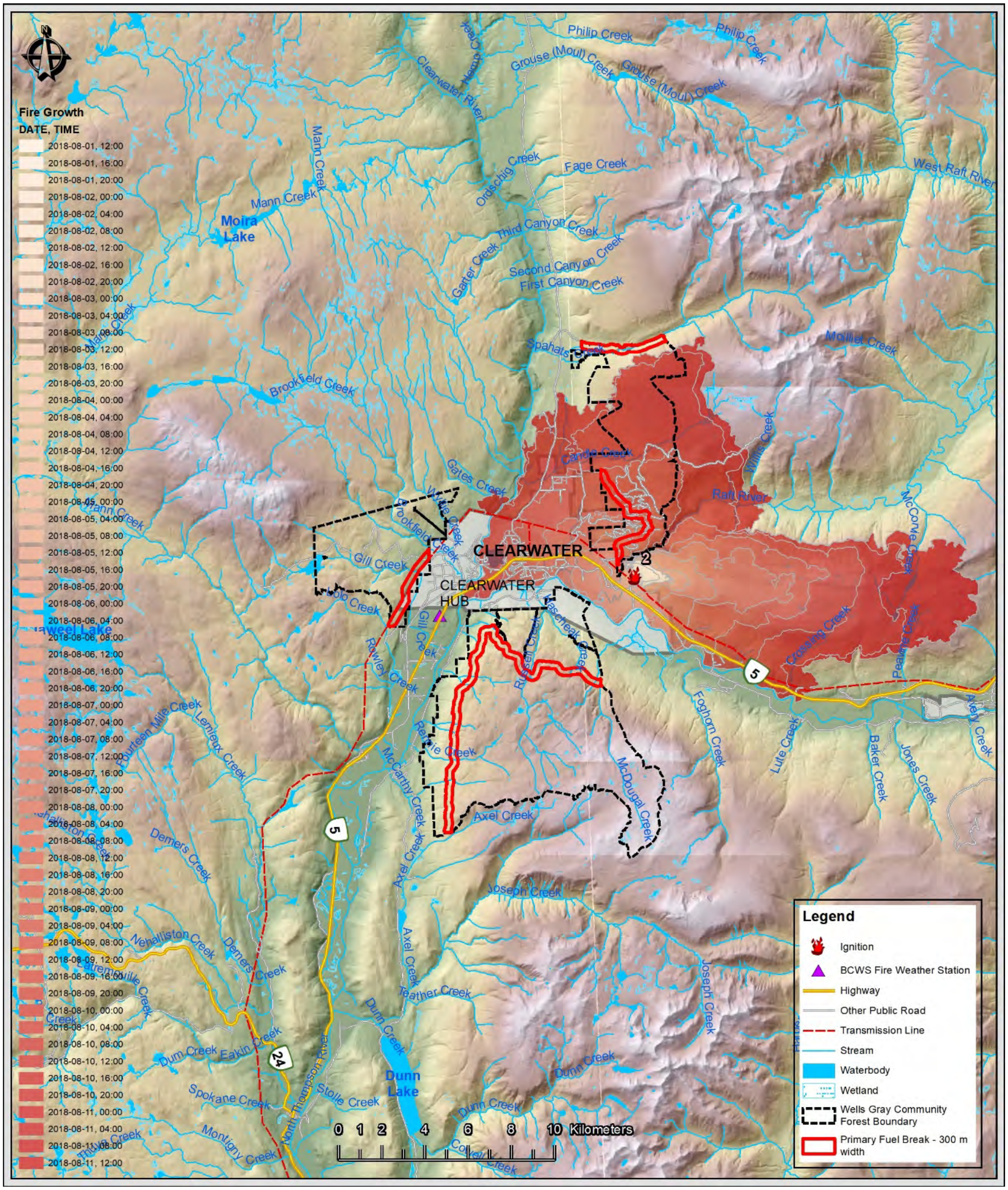

Figure 26. Fire growth simulation with an ignition point along Highway 5 East of Clearwater.

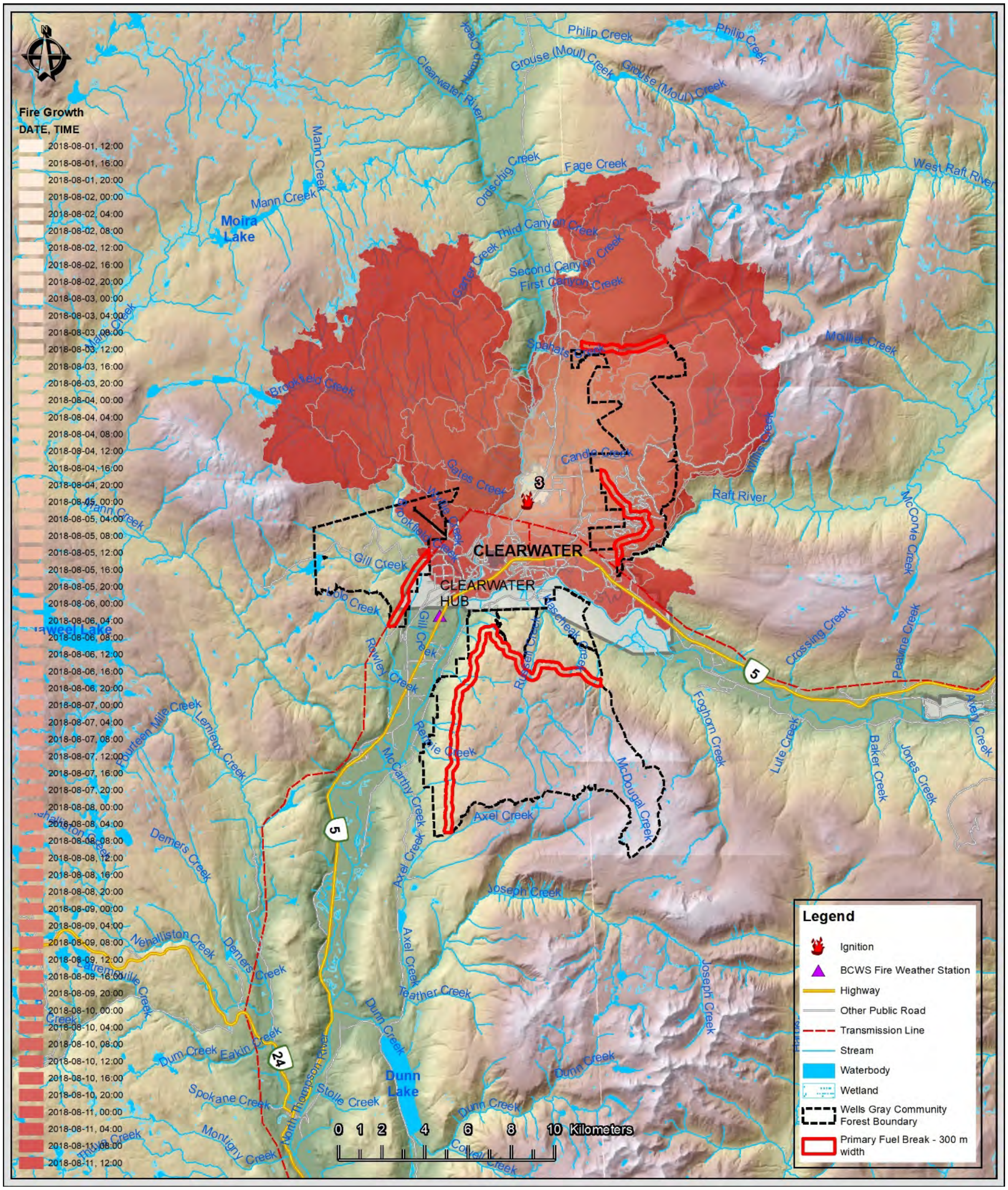

Figure 27. Fire growth simulation with an ignition point North of Clearwater.

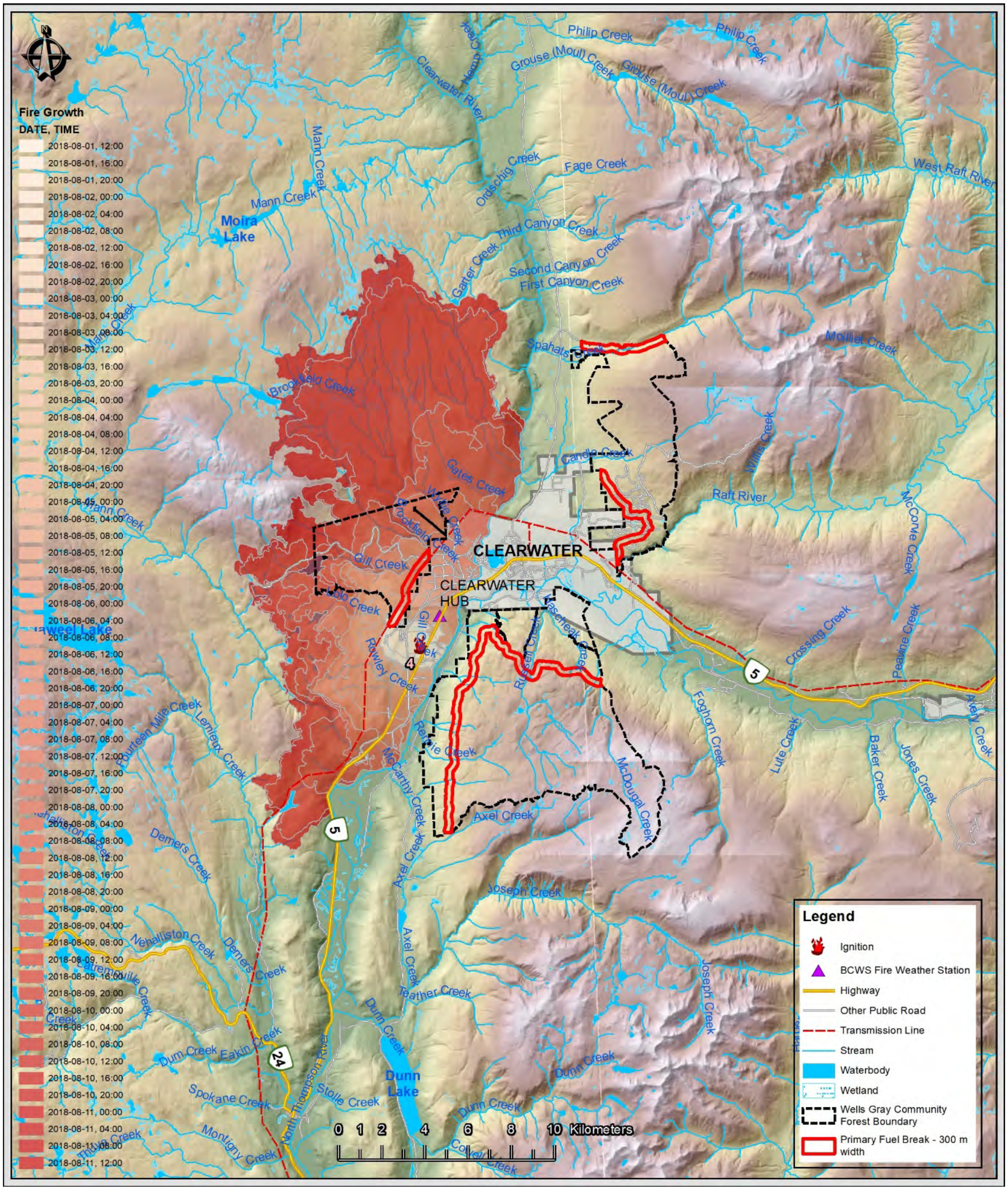

Figure 28. Fire growth simulation with an ignition point along Highway 5 South of Clearwater (nearer to the community).

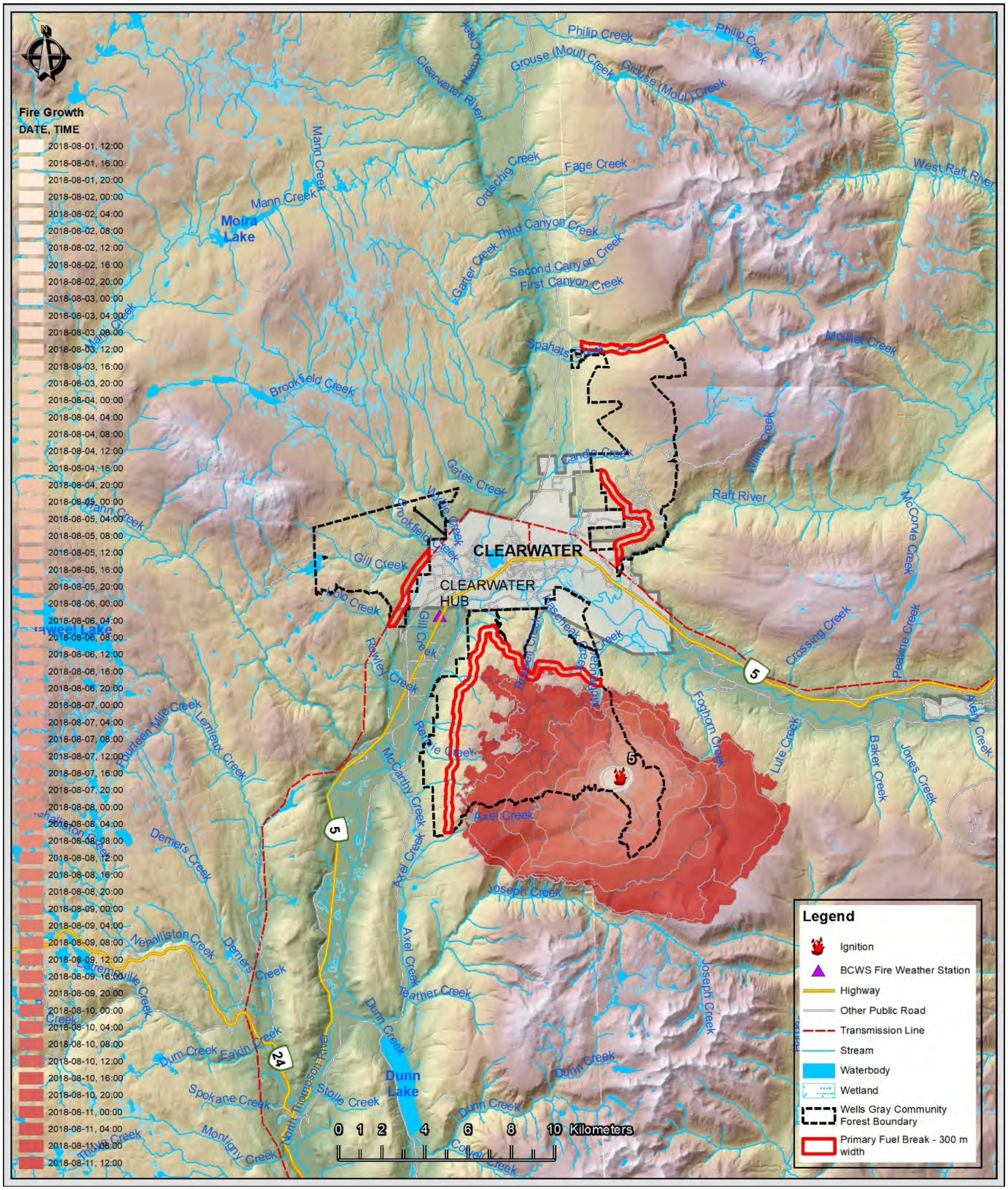

Figure 29. Fire growth simulation with an ignition point south of Clearwater at higher altitude North of Foghorn Mountain.