Smoke from Outdoor Recreational Fires and Wildfires

Jurisdictional Review and Summary of Management Options

Public Health and Compliance
November 2018

Alberta

About this document:

This review summarizes the health impacts of wood smoke and provides a description of the regulatory measures that different provincial, state and municipal governments in Canada and the United States have implemented to manage it. For recreational fires, bylaws from various municipalities are reviewed. For wildfires, the guidelines used in different jurisdictions to manage wildfire smoke and reduce public exposure are summarized. The findings are based on information that was publicly available online as of September 2017.

Management options for regulation of smoke from recreational fires range from the strictest regulation which is a complete ban of outdoor wood-burning fire pits and fireplaces, to common regulations such as allowing fires for the purpose of cooking only, allowing fires in fireplaces only, and restrictions on size of fire, site of fire, permitted and prohibited fuels, wind conditions and time of day. Other less frequently used options include restrictions on frequency of usage, duration of fire, season of use, outside temperature and ventilation index (a measure of the ability of the atmosphere to disperse air pollutants).

Preventative approaches to managing wildfire smoke focus on reducing hazardous fuels in areas at risk of wildfire. Reducing any build-up of hazardous fuels, such as dead woody debris on a ground surface, lowers the risk of a future catastrophic wildfire. This can be achieved through the use of prescribed fires (planned, controlled fires conducted under carefully selected weather conditions) or by allowing a naturally-occurring wildfire to burn out. Other strategies for reducing hazardous fuels include physical removal or reduction of wildland fuel (by harvesting, mulching, mowing, grazing, removing flammable tree species or pruning low lying limbs) and species conversion (replacing flammable vegetation species with less flammable species).

The review identified public awareness and public communication as two important aspects of smoke management. Public tolerance for wildfire smoke is influenced by factors such as knowledge of origin of the smoke, advance public warning, community preparedness, personal and community health, and public knowledge of the steps taken to reduce smoke impacts. An understanding of the range of public opinions toward smoke, and the attitudes and values of the residents, can be used to tailor smoke management plans to the needs of the community.

This document may be cited as follows:

> Government of Alberta. (2018). Smoke from Outdoor Recreational Fires and Wildfires: Jurisdictional Review and Summary of Management Options. [PDF ISBN: 978-1-4601-4079-6] Environmental Public Health Science Unit, Health Protection Branch, Public Health and Compliance Division, Alberta Health. Edmonton, Alberta.

Statement of Availability:

As part of the Government of Alberta's commitment to open government, this publication is posted to and permanently retained in the Open Government Portal at https://open.alberta.ca/publications/9781460140796

ISBN: 978-1-4601-4079-6 (PDF)

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Executive Summary

Smoke generated from the burning of wood contributes to poor air quality. Common sources of wood smoke include wildfires, wood stoves, fireplaces, fire pits and open burning of agricultural material. During Alberta summers, wood-burning recreational fires (outdoor fire pits/fireplaces) and wildfires can cause wood smoke levels in the air to be elevated. This generates health and air quality concerns, particularly for residents in urban areas.

Wood smoke is a complex mixture of chemicals, many of which could be harmful to health. The main pollutants include particulate matter [fine particles ($PM_{2.5}$), coarse particles (PM_{10})], carbon monoxide, nitrogen oxides, sulphur dioxide, volatile organic compounds, polycyclic aromatic hydrocarbons and chlorinated compounds. $PM_{2.5}$ makes up ~80–90% of wood smoke and presents the greatest concern to human health.

Exposure to wood smoke can irritate the eyes, nose and throat. $PM_{2.5}$ can cause respiratory effects such as coughing and breathing difficulties. The particles are small enough to be inhaled deep into the lungs, and can remain embedded there for several months. Water-soluble particles can pass into the bloodstream, leading to systemic cardiovascular effects. Exposure to $PM_{2.5}$ has been linked to headaches, reduced lung function, bronchitis, exacerbation of asthma, aggravation of pre-existing lung/heart disease and premature mortality.

The objective of the current report is to review how smoke from outdoor wood-burning recreational fires and wildfires is managed in various jurisdictions in Canada and the United States. For recreational fires, bylaws from various municipalities are reviewed. For wildfires, the guidelines used in different jurisdictions to manage wildfire smoke and reduce public exposure are summarized. The findings are based on information that was publicly available online as of September 2017.

Smoke from Recreational Fires

There are a number of different management options currently being used to regulate smoke from recreational fires. The strictest regulation is a complete ban of outdoor wood-burning fire pits and fireplaces; this is observed in the three largest cities in Canada (Montreal, Toronto, Vancouver), and several smaller cities as well (e.g., Surrey, Waterloo).

There are many jurisdictions that prohibit recreational fires when air quality advisories are in effect. In Canada, these restrictions exist in Ontario (e.g., Burlington, Mississauga, Oakville) and British Columbia (e.g., Houston, Prince George). In areas of California, Oregon and Washington, recreational fires are not allowed during wood-burning bans, which are issued when ambient $PM_{2.5}$ levels are expected to exceed air quality standards.

For managing smoke complaints, many bylaws state that smoke from fires is not to create a nuisance (the definition of which varies between jurisdictions), and that fires may be ordered extinguished if there are smoke complaints from neighbours.

Common regulations used to manage outdoor recreational fires include: allowing fires for the purpose of cooking only, allowing fires in fireplaces only, and restrictions on size of fire, site of fire, permitted and prohibited fuels, wind conditions and time of day. Other management options used less frequently are those involving restrictions on frequency of usage, duration of fire, season of use, outside temperature and ventilation index (a measure of the ability of the atmosphere to disperse air pollutants).

Improved public awareness of the health effects of wood smoke and cleaner burning practices may help improve air quality and reduce nuisance issues related to recreational fires. For example, informing residents that propane and natural gas are cleaner, healthier fuel alternatives may promote the use of these fuels instead of wood for recreational fires.

Some jurisdictions have incorporated public education requirements into their recreational fire regulations. For example, in some areas of California, sellers of wood-burning devices are required to provide the purchaser a fact sheet outlining the health effects of wood smoke. Additionally, first-time violators of an air quality burn ban may complete an online or written wood smoke awareness course in lieu of paying a fine of $50.

Regardless of the method used, educating the public in matters related to recreational fires and wood smoke should be an important component of recreational fire management strategies. Public knowledge of the health effects of wood smoke also helps with gaining support from the community for implementing changes to recreational fire regulations.

Wildfire Smoke

Smoke management guidelines and protocols were reviewed for six provinces and states (British Columbia, Manitoba, Northwest Territories, California, Idaho and Oregon). From the review of these jurisdictions, the key aspects of wildfire smoke management relate to the public health response to smoke events (reducing public exposure to smoke during wildfire events) and smoke prevention (mitigation of wildfire smoke by reducing hazardous fuels).

For smoke response plans, the main components include:

Air quality: The main tools used to assess air quality and communicate health risk information to the public are the Air Quality Health Index (AQHI) in Canada and the Air Quality Index (AQI) in the United States. Health categories for the indices range from 'Low risk' to 'Very high risk' for the AQHI and 'Good' to 'Hazardous' for the AQI. The main pollutant of concern in wildfire smoke is PM. During a wildfire smoke event, air quality assessments may be supplemented by additional $PM_{2.5}$ and/or PM_{10} information, using existing ambient air monitors and portable monitors. PM concentrations can be

converted to a corresponding AQHI (or AQI) health risk category. In cases where PM monitoring is not available or not up-to date, a visibility index may be used to approximate PM level and health risk.

Smoke forecasting: A smoke forecasting system provides advance notice of the estimated intensity and duration of smoke exposure in affected communities. There are two different systems used in Canada: BlueSky and FireWork. Both systems use computer modeling to produce animated smoke forecasts for up to 48 hours into the future. Results are published on national websites throughout the wildfire season (April to September or October).The data are used to inform decisions regarding public health alerts and recommended actions to reduce smoke exposure.

Public health warnings and actions: For the jurisdictions reviewed, the public messages and actions in response to smoke tended to be similar for equivalent health risk categories. For example, *Moderate* categories typically trigger public health warnings or advisories, with suggestions on how to reduce exposure to smoke. *Unhealthy* categories tend to trigger the consideration of school closures and cancellation of events. *Very Unhealthy* and *Hazardous* categories tend to trigger the closure of schools and non-essential workplaces, cancellation of events and consideration of voluntary evacuations for sensitive populations.

Preventative approaches to managing wildfire smoke focus on reducing hazardous fuels in areas at risk of wildfire. Reducing any build-up of hazardous fuels, such as dead woody debris on a ground surface, lowers the risk of a future catastrophic wildfire. This can be achieved through the use of prescribed fires (planned, controlled fires conducted under carefully selected weather conditions) or by allowing a naturally-occurring wildfire to burn out. In both cases, fires are selected to burn in conditions that minimize production of smoke and the resulting impact on air quality. Other strategies for reducing hazardous fuels include physical removal or reduction of wildland fuel (by harvesting, mulching, mowing, grazing, removing flammable tree species or pruning low lying limbs) and species conversion (replacing flammable vegetation species with less flammable species).

Two important aspects of smoke management are public awareness and public communication. Public tolerance for wildfire smoke is influenced by factors such as knowledge of origin of the smoke, advance public warning, community preparedness, personal and community health, and public knowledge of the steps taken to reduce smoke impacts. An understanding of the range of public opinions toward smoke, and the attitudes and values of the residents, can be used to tailor smoke management plans to the needs of the community.

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Special thanks to our peer-reviewers for their valuable editorial comments:

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Abbreviations

AQHI: Air Quality Health Index
AQI: Air Quality Index
CCME Canadian Council of Ministers of the Environment
BAAQMD: Bay Area Air Quality Management District
CARPA: California Air Response Planning Alliance
CWFIS: Canadian Wildland Fire Information System
DEQ: Department of Environmental Quality
ECCC: Environment and Climate Change Canada
PM: Particulate matter
$PM_{2.5}$: Fine particulate matter
PM_{10}: Coarse particulate matter
SCAQMD: South Coast Air Quality Management District
SMAQMD: Sacramento Metropolitan Air Quality Management District
SO_2: Sulphur dioxide
USEPA: United States Environmental Protection Agency
VOC: Volatile organic compound

Chapter 1: Introduction

Smoke generated from the burning of wood contributes to poor air quality. Wood smoke contains harmful pollutants that can have deleterious effects on human health. Common sources of wood smoke include wildfires, fire pits, fireplaces and wood stoves. A 2011 air quality study found that ~12% of the total particulate pollution in Edmonton, Alberta was attributable to smoke from the burning of wood and other agricultural material [1].

Wildfires are a common occurrence during Alberta summers. The number of wildfires reported in Alberta was 1425 in 2014, 1819 in 2015 and ~1300 in 2016 [2, 3]. The resulting smoke levels have often triggered air quality and health advisories in communities throughout the province. Backyard fire pits/fireplaces (typically referred to as recreational fires) are also commonplace throughout the summer, at times leading to neighbour complaints of drifting smoke and concerns about health impacts [4].

1.1 Objective

Two sources of wood smoke that impact urban areas during Alberta summers include: (i) outdoor wood-burning recreational fires and (ii) wildfires. The objective of the current report is to review how smoke from these sources is managed in various jurisdictions in Canada and the United States. For recreational fires, bylaws from several municipalities are reviewed. For wildfires, various provincial and state guidelines used to manage wildfire smoke and reduce public exposure are summarized.

The aim is to provide an overview of some of the current practices in use (as of September 2017).

1.2 Limitations

This review is not intended to be comprehensive, but rather offers a snapshot of regulations used by different jurisdictions. While various management options for recreational fires and wildfires are presented and discussed, an evaluation of the effectiveness of the regulations, or enforcement of the regulations, is beyond the scope of the review.

For recreational fires, the information is limited to regulations governing outdoor wood-burning fire pits and fireplaces in backyards. Regulations for outdoor appliances fuelled by charcoal briquettes, natural gas, propane, or other liquid or gaseous fuels were considered out of scope and not reviewed. Regulations for indoor wood-burning appliances, such as indoor wood stoves and fireplaces, were also excluded, as these appliances are generally not used during the summer. Regulations for fires in campgrounds or public parks were also considered out of scope, as these are typically located away from urban residences.

Lastly, open burning of agricultural material, which typically occurs in non-urban areas, was considered out of scope. For a summary of open air burning regulations, readers are referred

to two recent Canadian Council of Ministers of the Environment (CCME) documents: a jurisdictional review of open air burning policies and an accompanying policy guidance document for Canadian jurisdictions [5, 6].

1.3 Sources of Smoke

Sources of smoke pollution are generally categorized as point and non-point. Point sources refer to large stationary facilities that emit pollutants and maintain an inventory of emissions [7]. Examples include power plants and petroleum refineries. Non-point sources are small sources of air pollution that individually do not emit large amounts of pollutants, but collectively contribute a large part to total air emissions [8]. The four types of non-point sources include [9]:

Line source (or one-dimensional source): an emission source that follows a straight line (e.g., roadways, railways, aircraft flight paths).

Area source (or two-dimensional source): an emission source where pollutants are released over a wide area (e.g., forest fires, landfills) or numerous individual emission sources that are spread out across an area and are inventoried collectively (e.g., gas stations, construction activity, residential heating).

Volume source (or three-dimensional source): an area source that has a third (height) dimension (e.g., buildings with multiple vents/windows/doors, wind erosion from gravel or sand piles).

Mobile source: a non-stationary emission source such as on-road vehicles (e.g., automobiles, buses) and non-road sources (e.g., ships, farm equipment).

Wildfires and backyard fire pits/fireplaces are non-point (area) sources of smoke. Table 1 lists the major non-point sources of wood smoke in Alberta.

Table 1. Non-point sources of wood smoke in Alberta

Recreational	Residential	Forest Fires	Agricultural Burning
-Outdoor fire pit -Outdoor fireplace -Bonfire -Fire for ceremonial or special purposes	-Fireplace -Chimney -Wood stove -Outdoor wood furnace	-Wildfire -Prescribed fire	-Slash burning -Open burning of agricultural material

(adapted from [10, 11])

1.4 Wood Smoke Pollutants and Health Impacts

Wood smoke is a complex mixture of pollutants that varies with the material burned and the combustion conditions. The primary pollutants in wood smoke include particulate matter

(PM), carbon monoxide, nitrogen oxides, sulphur dioxide (SO_2), volatile organic compounds (VOCs) and other compounds such as polycyclic aromatic hydrocarbons and chlorinated compounds [11-13]. Exposure to wood smoke can cause irritation of the eyes, nose and throat and worsen heart and lung conditions.

Some components of wood smoke undergo reactions in the atmosphere to form secondary pollutants [12]. Examples of secondary pollutants include ozone (produced when nitrogen oxides and VOCs react with sunlight) and secondary particles (e.g., conversion of SO_2 into particulate sulphate).

PM, which refers to the mixture of microscopic particles suspended in the air, is the main pollutant of concern in wood smoke. PM is classified based on size: coarse PM (or PM_{10}) includes particles with an aerodynamic diameter up to 10 μm; fine PM (or $PM_{2.5}$) includes particles up to 2.5 μm; and ultrafine PM (or $PM_{0.1}$) includes particles up to 0.1 μm. Wood smoke is primarily comprised of $PM_{2.5}$ (~80–90%), with most particles less than 1 μm in size [13].

PM in wood smoke can trigger adverse health effects, such as respiratory irritation and breathing difficulties. Fine particles can be inhaled deep into the lungs, and may remain embedded there for several months [14]. Water-soluble particles can also pass into the bloodstream, leading to systemic inflammation and oxidative stress [15]. This can increase the risk of adverse cardiovascular outcomes such as arrhythmia, heart failure and stroke, particularly in individuals with existing cardiovascular disease. $PM_{2.5}$ exposure has been linked to headaches, reduced lung function, bronchitis, exacerbation of asthma, aggravation of lung or heart disease, and premature mortality [12, 13].

Most healthy people exposed to wood smoke will only experience transient symptoms and recover quickly. However, certain individuals, such as children, the elderly, pregnant women and people with lung or heart diseases, may be more susceptible to the effects of wood smoke. These groups are often referred to as 'sensitive', 'vulnerable' or 'at-risk' populations, and are more likely to experience severe symptoms or persisting effects following wood smoke exposure [13].

Studies of past wildfire events have demonstrated a measurable impact of smoke PM on the health care system. In recent systematic reviews of wildfires and human health, PM was consistently associated with dispensation of medications, physician visits and respiratory-related emergency room visits or hospitalizations [16-19].

1.5 Public Concerns

Public concerns regarding recreational fires mainly arise from unwanted exposure to drifting wood smoke. Residents on neighbouring properties may complain of odours or nuisance[1] from wood smoke entering their yard and home, needing to shut their windows, and health impacts from smoke exposure. On the other hand, many people want to be able to enjoy a recreational fire in their backyard [20]. Several news articles discussing the possibility of stricter regulations for recreational fires in Edmonton and Calgary highlight the range of viewpoints on the topic [21-24]. Some residents are angered by the idea of stricter regulations, such as a complete ban, and feel that existing bylaws are sufficient for managing fire pits. Those in favour of stricter regulations discuss the air quality, nuisance and health impacts associated with drifting wood smoke. These opposing viewpoints have also been observed in other cities across Canada [25-27].

Regarding concerns about wildfires, several factors can influence the public's tolerance to wildfire smoke. One of the main factors is personal and community health. Individuals, families and populations with existing health conditions are likely to be more sensitive to the presence of wildfire smoke, and more vulnerable to negative health impacts [28]. These groups tend to have a lower tolerance for smoke and can be the most vocal about health concerns. Another factor influencing smoke tolerance is community preparedness; communities that are more prepared for wildfire have been found to be more tolerant of smoke than less-prepared communities [28].

There may also be public concerns related to tourism, recreation, outdoor activities and ecosystem health [28]. The presence of wildfire smoke can have negative aesthetic impacts on sceneries and reduce visits to national parks and recreational areas, causing an economic impact on tourism-related businesses.

1.6 Research Methods

The search for regulatory documents pertaining to recreational fires and wildfires consisted of government website searches and Google searches. The search was limited to information that was publicly available online as of September 2017. The methods did not include a search of academic databases; as such, any alternative approaches for smoke management discussed in the peer-reviewed literature have not been included in this report.

[1] The definition of nuisance may vary between jurisdictions. Alberta's *Public Health Act* defines nuisance as "a condition that is or that might become injurious or dangerous to the public health, or that might hinder in any manner the prevention or suppression of disease" [258].

1.6.1 Recreational Fires

Recreational fire bylaws were obtained from government websites of the most populated cities in each of the Canadian provinces and territories. Google searches were then conducted to find other cities or counties in each province/territory with smoke-related bylaws. The following terms were used for the search: [Canada/Province] AND (recreational fire OR outdoor fire OR fire pit OR fireplace) AND smoke AND bylaw. A total of 9–12 jurisdictions were included from each of the most-populated provinces (Alberta, British Columbia, Ontario, Quebec), and 3–6 jurisdictions from each of the remaining provinces and the territories.

The search of United States jurisdictions was targeted towards locations with regulations that discuss recreational fires in relation to smoke and air quality. A preliminary Google search was performed to identify US locations with air quality-related regulations; the first four states identified as having relevant regulations were selected for inclusion (California, Minnesota, Oregon and Washington). Google searches were conducted using the following terms: [United States/State] AND (recreational fire OR outdoor fire OR fire pit OR fireplace) AND smoke AND ordinance. A sample of 3–4 jurisdictions were included from each of the four US states.

The focus of the section was on regulations governing wood-burning recreational fires in backyards in urban or residential areas. Regulations for the following were therefore considered out of scope: fires in campgrounds or public parks; fires in indoor wood-burning appliances (e.g., wood stoves, fireplaces); and fires fuelled by charcoal, natural gas, propane or other liquid/gaseous fuels.

1.6.2 Wildfires

For wildfires, provincial government websites were searched for information related to management of smoke from wildfires. State government websites for the western United States were searched for similar material. Additional Google searches for national/ provincial/state documents or web pages pertaining to wildfire smoke management were conducted using the following terms: [Country/Province/State] AND wildfire AND smoke.

Guideline documents addressing management of wildfire smoke were not found for many of the jurisdictions searched, including Alberta. Therefore, the review focuses on seven provinces and states (British Columbia, Manitoba, Newfoundland and Labrador, Northwest Territories, California, Idaho, and Oregon) for which wildfire smoke guideline documents were available (as of September 2017).

Chapter 2: Smoke from Recreational Fires

This chapter presents a summary of the various bylaws and regulations[2] used to manage outdoor wood-burning recreational fires in backyard fire pits and fireplaces in Canada and the US, focusing on those regulations that manage smoke.

Different jurisdictions may use varying definitions and terminology when discussing outdoor recreational fires, fire pits and fireplaces, which can lead to some confusion if not properly defined. The terms and definitions used in this report (adapted from various bylaw documents from jurisdictions in Alberta) are presented below [29-33]:

> **Recreational fire:** A fire confined to an outdoor non-combustible container and set for the purpose of cooking, obtaining warmth or viewing for pleasure. Other common names include campfire, cooking fire and outdoor fire.
>
> **Fire pit:** An outdoor installation which has enclosed sides made from bricks, concrete blocks, heavy gauge metal or other non combustible materials, and does not have a flue, chimney or duct. Fire pits may be portable or permanently affixed.
>
> **Fireplace:** An enclosed outdoor fire receptacle which incorporates a permanently affixed chimney or flue, and is constructed of brick, rock or other masonry. Fireplaces may be portable or permanently affixed. Common names include chiminea and patio fireplace.

This chapter reviews recreational fire regulations from a sample of 90 jurisdictions in Canada and the United States. The information is current as of September 2017; readers are advised to contact their local municipality or regional district office for official bylaw information. Tables summarizing the recreational fire regulations of the 90 jurisdictions are included in Appendices A (Canada) and B (United States).

The main management options for recreational fires include: complete ban, fires banned during fire bans, fires banned during air quality advisories, fires are allowed with restrictions on size/site/time of use, fires are allowed for cooking purposes only, and fires are allowed in fireplaces only.

There are several regulations that are common to most of the bylaws reviewed. For example, the majority of bylaws state that dry (seasoned), untreated wood and charcoal are the only solid fuels permitted in a fire pit or fireplace. Most bylaws also provide a list of prohibited

[2] For the purposes of this report, the term 'bylaw' refers to an entire bylaw document, and the term 'regulation' refers to the subparts or components within a bylaw that define a specific legislative guideline. For example, the City of Edmonton Community Standards Bylaw (Bylaw 14600) is made up of several regulations governing outdoor fires, noise and property maintenance [38].

fuels, which typically includes garbage, yard waste, treated wood, rubber, plastic, animal carcass or any material that might create dense black smoke or offensive odour. Table 2 lists the permitted and prohibited fuels found in the reviewed bylaws.

Table 2. Permitted and prohibited fuels listed in recreational fire bylaws

Permitted Fuels	Prohibited Fuels			
Charcoal	Accelerants	Clothing	Manure	Stubble
Firewood	Animal carcass/parts	Construction waste	Oil	Styrofoam
Seasoned wood	Asphalt	Electrical wiring	Paint	Tar
Untreated wood	Automobile materials	Fuel containers	Petroleum products	Tires
Butane	Biomedical waste	Furniture	Plastic	Toxic
Gel Fuel	Cardboard	Garbage	Recyclable material	substances
Natural gas	Chemicals	Glue	Rubber	Treated wood
Propane	Chemical containers	Leaves	Straw	Unseasoned wood
				Yard waste

For the jurisdictions imposing site limitations, the bylaws typically state that fire pits and fireplaces are to be a minimum of 3 metres from any building, property line or combustible material. Some jurisdictions have more lenient restrictions (e.g., minimum of 1 metre from any combustible material), while others have stricter restrictions (e.g., minimum of 5 metres from any combustible material). Regarding size limitations for fire pits, jurisdictions typically allow a maximum fire pit diameter of 0.3–1 metres and maximum height of 0.3–0.75 metres. For jurisdictions with fireplace size restrictions, the maximum allowed size is typically in the range of 1–1.25 metres in width and 0.4–0.6 metres in depth.

Other common regulations related to fire prevention include: fires are to be supervised, a means of extinguishing the fire must be kept nearby, fires are not allowed in windy conditions and no more than one fire is permitted on a property at any time.

The remainder of this chapter focuses on the various other regulations related to management of smoke from recreational fires, such as the requirement for permits, restrictions on season/time of use, fire bans, air quality burn bans, nuisance statements and any other alternative regulations. Data are presented for each province in Canada, and four states in the US (California, Minnesota, Oregon and Washington).

2.1 Canada

This section summarizes the various bylaws and regulations used to manage outdoor wood-burning recreational fires in backyard fire pits and fireplaces in each province in Canada. A total of 9–12 jurisdictions were included from each of the most-populated provinces (Alberta, British Columbia, Ontario, Quebec), and 3–6 jurisdictions from each of the remaining provinces and the territories.

2.1.1 Alberta

There are several municipalities in Alberta that require permits for fire pits and/or fireplaces, such as Grande Prairie, Medicine Hat, St. Albert and the Regional Municipality of Wood Buffalo [34-37]. However, many do not require a permit, including Edmonton, Calgary, Lethbridge and Red Deer [31, 38-40].

Some jurisdictions limit the time of day that fires are permitted. For example, the City of Lethbridge allows fires between 8 am and 1:30 am [30]. In Calgary, fires are permitted from 10 am to midnight during the week, and 10 am to 1 am on weekends [39].

Bylaws for many jurisdictions state that the use of fire pits and fireplaces is prohibited during fire bans; examples include Edmonton, Calgary, Airdrie, Banff, Lethbridge, Red Deer, and Wood Buffalo [29-31, 38, 39, 41-43]. Fire bans are issued during times of high fire danger, and factors considered when issuing a fire ban in Alberta typically include recent precipitation, water shortages or restrictions, air quality, availability of fire fighters and the overall fire danger [30, 31, 39].

With regard to smoke management, bylaws for several jurisdictions stipulate that smoke from fires is not to create a nuisance. For example, the City of Edmonton states that fires should be small and burn clean, dry fuels to limit the amount of smoke drifting on to neighbours' properties [44], and fires are not permitted if they are reasonably likely to disturb the peace of any other individual [38]. In St. Albert and Grande Prairie, fires may be ordered extinguished if smoke is a nuisance to other properties [34, 45]. Similarly, the Medicine Hat bylaw states that a permit for a fire pit or fireplace may be revoked if smoke creates a nuisance for neighbours [35]. In Carstairs and Wood Buffalo, smoke-related nuisance is specifically defined as the emitting of opaque or dense smoke into the atmosphere for more than 6 minutes in any 1-hour period [46, 47].

2.1.2 British Columbia

In 2015, the BC Ministry of Environment published an inventory of open air burning bylaws used in local governments across the province [48]. The report provides a tabulated summary of regulations for recreational fires for 188 municipalities and regional districts.

Many of the larger urban areas in BC have a complete ban on recreational fires, including Vancouver [49-51], Abbotsford [52, 53], Burnaby [54, 55], Richmond [56], Surrey [57, 58]

and Victoria [59]. The City of Vancouver states that the burning of wood "creates a substantial amount of smoke, noxious fumes, or flaming embers and thus does not meet the fire protection and health objectives of the Fire By-law" [51]. In Kamloops, fires are allowed (with a permit) on residential properties ≥ 0.4 hectare (1 acre), which results in a ban for most of the Kamloops urban area [60].

A number of jurisdictions allow recreational fires, but with restrictions on the time of use and purpose of use. For example, in Kimberley, fires are only allowed between 3:30 pm and 11 pm, and for the sole purpose of cooking food [61]. In the Okanagan-Similkameen Regional District, fires are permitted between 6 am and midnight [62].

Several jurisdictions, such as Kimberley, Prince George and Houston, have regulations in place that ban outdoor wood-burning recreational fires during air quality advisories [61, 63, 64]. The BC Ministry of Environment issues air quality advisories when "pollutant concentrations approach or exceed predetermined limits, or when degraded-air-quality episodes are expected to continue or worsen" [65].

Regarding smoke management, the bylaw for the Regional District of Okanagan-Similkameen states that fires are not to cause a nuisance, with nuisance being defined as "the emission into the atmosphere of smoke by any means, which disturbs the comfort or convenience of persons in the vicinity" [62]. Similarly, the bylaw for Chase states that fires are not to create excessive smoke, defined as "any visible smoke persistently crossing the property line of the subject fire, not including initial start-up or extinguishing of the fire" [66]. In Prince George, the bylaw stipulates that recreational fires shall not be maintained "in such a manner as to discharge air contaminants that are likely to cause or significantly contribute to the cause or injury of or damage to human health, plant or animal life, or so as to unreasonably interfere with the enjoyment of life or property" [63]. To help prevent 'smoking out' of neighbours, the city provides tips for reducing smoke from fires: burn small hot fires, use small pieces of split wood rather than whole logs, and leave gaps when stacking wood to ensure adequate air flow [67].

The bylaws in Chase, Kimberley and the Okanagan-Similkameen Regional District indicate that recreational fires are prohibited when a fire ban is in effect [61, 62, 66].

2.1.3 Manitoba

In Manitoba, many municipalities allow the use of fire pits and fireplaces, and do not require a permit; examples include Winnipeg, Springfield and Winkler [68-70]. Brandon also allows fire pits and fireplaces, but a permit is required [71].

For smoke management, bylaws from Brandon, Springfield and Winkler state that smoke from fires shall not create a nuisance for neighbouring properties, and fires may be ordered extinguished if there are smoke complaints [69-71].

2.1.4 New Brunswick

In New Brunswick, some municipalities allow recreational fires in both fireplaces and fire pits, such as Saint John (no permit required) and Shediac (permit required) [72, 73]. Other municipalities allow recreational fires in fireplaces only, such as Moncton (no permit required) and Fredericton (permit required) [74, 75].

For Shediac and Dieppe, fires are only permitted from the third week of April until October 31 [73, 76]. Both areas also limit the time of day that fires are allowed (4 pm to midnight for Dieppe, 6 pm to 11 pm for fire pits in Shediac, and 4 pm to 11 pm for fireplaces in Shediac).

Regarding smoke management, bylaws for Moncton and Shediac stipulate that fires are not to interfere with the use and enjoyment of other properties [73, 75].

2.1.5 Newfoundland and Labrador

Labrador City, Mount Pearl, Paradise and St. John's allow recreational fires in fireplaces only, with Labrador City requiring a permit [77-80]. Bylaws from these four municipalities state that fires are prohibited when a fire ban is in effect, and smoke from fires is not to cause a nuisance or annoyance to neighbouring properties.

2.1.6 Nova Scotia

In the Cape Breton and Halifax Regional Municipalities, the bylaws differ for the urban and rural areas. In Cape Breton, fire pits and fireplaces are prohibited in the urban areas (e.g., Sydney, Glace Bay), except if used for cooking [81]. In rural areas, fire pits and fireplaces require a permit, except if used for cooking.

In the rural areas of Halifax, fire pits and fireplaces are permitted throughout the year [82]. In the urban areas of Halifax (areas serviced by municipal water and sewer), fire pits are not allowed at any time of year, and fireplaces are permitted from October 16 to March 14. These dates are in line with the fire season dates (March 15 to October 15) used by the Province of Nova Scotia, as set out in the Forest Fire Protection Regulations [83].

In Pictou and Truro, fire pits and fireplaces are allowed without a permit [84, 85]. Bylaws for both areas stipulate that smoke from fires is not to create a nuisance, by interfering with a neighbouring property owner's enjoyment of his or her property. Additionally, the Pictou bylaw states that a fire may be ordered extinguished if the fire causes a nuisance exceeding two minutes in succession (except during start up) or if the fire has a smoke opacity exceeding 20%, determined using the Ringelmann method [84].[3]

[3] Smoke opacity is the degree to which visibility of a background is reduced by smoke, which can be visually estimated by a trained observer using the Ringelmann method [259]. A smoke plume at its point of greatest opacity is compared to the five-step Ringelmann Smoke Chart, where Ringelmann values of 0 (clear), 1, 2, 3, 4 and 5 (black) correspond to opacities of 0, 20, 40, 60, 80 and 100%.

2.1.7 Ontario

Several jurisdictions in Ontario cite the Ontario Fire Code in their bylaws governing fire pits and fireplaces, but with varying interpretations. Section 2.6.3.4 of the Fire Code states that "open-air burning shall not be permitted unless approved, or unless such burning consists of a small, confined fire, supervised at all times, and used to cook food on a grill or a barbecue" [86].

Toronto and Waterloo have a complete ban on fire pits and fireplaces, as does Oshawa and Ottawa in the urban (and most suburban) areas [87-91]. Burlington and Hamilton prohibit fire pits and fireplaces in urban areas, but do allow small, contained cooking fires [92, 93].

Other jurisdictions in Ontario allow the use of fire pits and fireplaces, but only during specified hours. For example, fires are allowed between 7:30 pm and 1 am in North Bay, 6 pm and 11 pm in Kitchener, 4 pm and midnight in London and Strathroy-Caradoc, and 10 am and 11 pm in Oakville [94-99]. In Mississauga, only fireplaces and small cooking fires are allowed between sunrise and 11 pm [100].

The bylaw for Strathroy-Caradoc states that recreational fires are not allowed when a "Poor Air Quality Advisory" has been issued by Environment Canada or any other recognized agency [97]. Similarly, bylaws for Burlington, Hamilton, Mississauga, North Bay and Oakville state that fires are not allowed when a smog alert has been declared [92, 93, 98, 100-102]. Smog and Air Health Advisories are issued jointly by Environment Canada and the Ontario Ministry of the Environment and Climate Change when "the Air Quality Health Index is forecast to reach, or has reached, the high risk category, and is expected to last for at least three hours" [103].

Of the municipalities that allow fire pits and fireplaces, most bylaws stipulate that fires are not to cause a nuisance by creating excessive smoke, smell or embers that are likely to disturb others or interfere with the enjoyment or use of a property; examples include Kitchener, London, Mississauga, North Bay, Oakville and Strathroy-Caradoc [94-101, 104]. The bylaw in Hamilton states that burning is prohibited when winds will cause smoke to be an annoyance to nearby properties [93, 102].

2.1.8 Prince Edward Island

Limited information on regulations for recreational fires was found for municipalities in Prince Edward Island. Bylaws for Cornwall and Stratford indicate that only enclosed fireplaces are allowed [105, 106]. Stratford allows the use of fire pits for cooking with written permission from the fire chief.

No bylaw documents or municipal websites discussing recreational fires were found for Charlottetown or Summerside.

2.1.9 Quebec

In the urban agglomeration of Montreal, fire pits and fireplaces are prohibited [107, 108]. In the urban agglomeration of Longueuil, fire pits are prohibited, and regulation of fireplaces lies with the individual cities/boroughs [109]. For example, Saint-Lambert allows the use of fireplaces, while Boucherville does not [110-112]. Similar to Saint-Lambert, some other cities of Quebec (Laval, Gatineau, Quebec City, Sainte-Julie, Sherbrooke) allow the use of fireplaces, but prohibit fire pits [113-117].

With regard to smoke management, the Saint-Lambert, Laval and Sainte-Julie regulations indicate that fires are not permitted if the smoke causes a major nuisance or impacts the comfort or well-being of neighbours [111, 112, 116, 118, 119].

2.1.10 Saskatchewan

The larger cities in the province (Regina, Saskatoon and Prince Albert) do not require permits for fire pits and fireplaces [120-123]. Contrarily, some smaller communities, such as Meadow Lake and Melfort, require permits [124, 125].

For smoke management, bylaws for several municipalities (Regina, Saskatoon, Prince Albert, Meadow Lake and Melfort) include a nuisance statement indicating that fires are to be extinguished if the smoke interferes with the enjoyment of another person's property [121-125].

In Moose Jaw, open air fires are not allowed, except for cooking fires in fireplaces, grills or barbecues [120, 126].

2.1.11 Territories (Northwest Territories, Nunavut, Yukon)

Recreational fires are permitted in Whitehorse and Yellowknife, with Whitehorse requiring a permit [127-130]. Bylaws for both cities stipulate that fires may be ordered extinguished if smoke is a nuisance for neighbours. In Dawson, fires are allowed for the purpose of cooking and a permit is not required [131, 132].

No information was found for the City of Iqaluit (Nunavut).

2.2 United States

Many of the regulations reviewed for cities and states in the United States were similar to those found across Canada - site restrictions, size restrictions and permitted/prohibited fuels. Thus, the search for regulations in the United States was focused towards jurisdictions that specifically discuss recreational fires and air quality, or jurisdictions that use alternative smoke management options to those used in Canada. The states included in this section are California, Minnesota, Oregon and Washington (with a sample of 3–4 jurisdictions from each state).

2.2.1 California

Several air quality management districts throughout California have regulations restricting the use of wood-burning devices during winter burning curtailments. The South Coast Air Quality Management District (SCAQMD) and the Bay Area Air Quality Management District (BAAQMD) issue mandatory curtailments when $PM_{2.5}$ is forecast to exceed 30 $\mu g/m^3$ and 35 $\mu g/m^3$, respectively [133-135]. Recreational fires are prohibited during these periods. In the BAAQMD, cooking fires are exempt from this regulation.

The Sacramento Metropolitan Air Quality Management District (SMAQMD) issues Stage 1 and Stage 2 mandatory curtailments when $PM_{2.5}$ is forecast to exceed 31 $\mu g/m^3$ and 35 $\mu g/m^3$, respectively [136]. Recreational fires are prohibited in both stages. The SMAQMD also issues a voluntary curtailment when $PM_{2.5}$ is expected to exceed 25 $\mu g/m^3$.

The wood-burning rules for the three districts discussed above [133, 136, 137] also indicate that first-time violators can complete a wood smoke awareness course in lieu of paying a fine of $50.

2.2.2 Minnesota

In St. Louis Park, recreational fires are allowed from 11 am to 10 pm (Sunday–Thursday) and 11 am to midnight (Friday–Saturday), and a permit is required [138]. In Minneapolis and Coon Rapids, fires are allowed without a permit between the hours of 9 am and 10 pm (Minneapolis) or 8 am and midnight (Coon Rapids) [139, 140]. Coon Rapids also limits the duration of a fire to 6 hours.

The City Codes for the three municipalities state that smoke is not to create a nuisance or be offensive to any nearby residents. Additionally, fires are prohibited when an air pollution health advisory for $PM_{2.5}$ (Minneapolis) or air quality alert (Coon Rapids, St. Louis Park) is in effect. For $PM_{2.5}$, the Minnesota Pollution Control Agency issues an advisory or alert when the 24-hour concentration is forecast to approach or exceed 35 $\mu g/m^3$, respectively [141, 142].

2.2.3 Oregon

The City of Portland and Clackamas County both permit recreational fires, but state that fires are not allowed if there are complaints of smoke disturbances from neighbours [143-146]. Additionally, Clackamas County restricts fire pits and fireplaces to occasional use, which is defined as less than four times per month.

In the City of Eugene, only cooking fires are allowed under the air pollution regulations of the City Code [147]. In the Eugene/Springfield Urban Growth Boundary and the City of Oakridge, recreational fires are permitted; however, during the winter (October–May), recreational fires are prohibited on yellow (deteriorating air quality) and red (poor air quality)

wood-burning advisory days [148, 149]. Advisories are determined based on $PM_{2.5}$ levels, weather forecasts and the Air Quality Index (AQI).

In both the urban and rural areas of Medford, recreational fires are also prohibited on yellow and red advisory days during the winter (Oct–May) [150]. Days are designated as yellow when $PM_{2.5}$ is expected to approach (but not exceed) unhealthy levels, and red when $PM_{2.5}$ is expected to exceed unhealthy levels [151]. Additionally, from October through February, fires are not permitted when the ventilation index, a measure of the ability of the atmosphere to disperse air pollutants, is low [152, 153]. Permits are required for fire pits, but not for fireplaces.

2.2.4 Washington

Under Washington State Legislature, recreational fires are prohibited during air quality burn bans [154]. Burn bans typically occur during the colder fall and winter months, when stagnant weather combined with increased smoke from wood stoves and fireplaces result in the build-up of air pollution. The Puget Sound Clean Air Agency issues burn bans for the King, Kitsap, Pierce and Snohomish Counties [155]. In the King and Kitsap Counties, Stage 1 burn bans are issued when forecasted meteorological conditions are predicted to cause $PM_{2.5}$ levels to reach 35 $\mu g/m^3$ (24-hour average) within two days; in the Pierce and Snohomish Counties, this value is 30 $\mu g/m^3$. If conditions are expected to continue or worsen, a Stage 2 burn ban may be issued. In both cases, recreational fires are not allowed.

2.3 Management Options

2.3.1 Summary of Management Options

There are a number of different management options that are currently being used to regulate recreational fires in Canada and the United States. Table 3 presents a summary of these management options, and provides examples of jurisdictions utilizing each option.

Several jurisdictions have implemented complete bans for recreational fires, primarily for reasons of fire prevention but also air quality and health. For example, fires are not permitted in Vancouver, as the smoke and embers created during the burning of wood do not satisfy the fire protection and health objectives of their Fire By-law [51]. For Montreal, the city website states that the toxic substances in wood smoke constitute a health hazard, and thus, outdoor fires are prohibited [108]. Other cities with a complete ban on recreational fires include Burnaby, Surrey, Toronto and Waterloo [54, 57, 87, 88].

A number of jurisdictions prohibit recreational fires when air quality advisories are in effect. For example, bylaws for several areas in Ontario (e.g., Burlington, Mississauga, Oakville) and British Columbia (e.g., Houston, Prince George) state that fires are not allowed when a smog alert or air quality advisory has been issued [92, 98, 100]. Similarly, recreational fires are prohibited in Minnesota (Minneapolis, Coon Rapids, St. Louis Park) during air quality advisories or alerts [138-140]. In areas of California, Oregon and Washington, recreational

fires are not allowed during wood-burning bans, which are issued when ambient $PM_{2.5}$ levels are expected to be elevated (in the range of 30–35 $\mu g/m^3$) [133, 135, 136, 148-150, 155]. Additionally, in Sacramento, voluntary wood-burning bans are issued when $PM_{2.5}$ is expected to exceed 25 $\mu g/m^3$.

For managing smoke nuisance complaints, bylaws for many jurisdictions include a statement stipulating that smoke from fires is not to create a nuisance, and that fires may be ordered extinguished if there are smoke complaints from neighbours [34, 36, 156]. There are various definitions of nuisance used, some of which are specific and measurable, and others that are somewhat vague. For example, the Carstairs bylaw defines nuisance as the emission of opaque or dense smoke from any fire for a period in excess of 6 minutes in any 1 hour [46], while the City of Edmonton bylaw defines a nuisance fire as one that is reasonably likely to disturb the peace of any other individual [38].

Another management option for recreational fires is the stipulation that fires are to be used for cooking purposes only. Communities using this regulation include Cape Breton (Sydney, Glace Bay), Kimberley and Moose Jaw [61, 81, 120]. Some jurisdictions have additional requirements, such as the size and duration of fire must be appropriate for the food being cooked. However, the definitions for cooking fires are often vague and left open to interpretation.

Table 3. Summary of management options for recreational fires

Management Option	Purpose of Regulation	Example Jurisdictions*			Ref.
Complete ban of recreational fires	-	Abbotsford BC Montreal QC Richmond BC Vancouver BC	Boucherville QC Oshawa ON (urban) Surrey BC Victoria BC	Burnaby BC Ottawa ON (urban) Toronto ON Waterloo ON	[51, 52, 54, 56, 57, 59, 87-91, 107, 108, 110]
Bans during a Fire Ban	Fire	Burlington ON Dieppe NB Kimberley BC Prince Albert SK	Calgary AB Edmonton AB Labrador City NL Regina SK	Chase BC Halifax NS Ottawa ON Shediac NB	[38, 39, 61, 66, 73, 76, 78, 82, 90, 92, 121, 123]
Bans during an Air Quality Advisory	Air Quality	Bay Area CA - winter (Nov–Feb) burning curtailments are issued when $PM_{2.5}$ is forecast to exceed 35 µg/m^3			[134, 135]
		Lane County OR - winter (Oct–May) advisory days are issued when air quality is deteriorating (yellow) or poor (red)			[148]
		Minneapolis MN - air pollution health advisories for $PM_{2.5}$ are issued when the 24-hour concentration is forecast to approach 35 µg/m^3			[139]
		Mississauga ON - smog alerts are issued when the air quality health index is forecast to reach, or has reached, the high risk category			[100, 103]
		Prince George BC - air quality advisories are issued when pollutant levels approach or exceed predetermined limits, or when poor air quality episodes are expected to continue or worsen			[63, 67]
		Puget Sound WA - burn bans are issued when $PM_{2.5}$ (24-hour average) is expected to exceed 30 µg/m^3 (Pierce and Snohomish Counties) or 35 µg/m^3 (King and Kitsap Counties) within two days			[155]
		Sacramento CA - winter (Nov–Feb) burning curtailments are issued when $PM_{2.5}$ is forecast to exceed 31 µg/m^3 (Stage 1) and 35 µg/m^3 (Stage 2)			[136]

Management Option	Purpose of Regulation	Example Jurisdictions*			Ref.
Permit required	Fire/Nuisance	Brandon MB Fredericton NB Medicine Hat AB Ottawa ON	Chase BC Kimberley BC Melfort SK St. Albert AB	Dieppe NB Labrador City NL Oshawa ON Sydney NS	[36, 61, 66, 71, 74, 76, 78, 81, 89, 90, 125, 156]
Smoke from fires is not to create a nuisance (fires may be ordered extinguished if there are smoke complaints)	Nuisance	Banff AB Edmonton AB Laval QC Portland OR St. Albert AB	Bellevue WA Kamloops BC London ON Regina SK St. John's NL	Brandon MB Kitchener ON Moncton NB Saskatoon SK Truro NS	[36, 38, 42, 60, 71, 75, 80, 85, 94, 96, 118, 121, 122, 146, 157]
Cooking fire only	Air Quality/Fire	Burlington ON (urban) Kimberley BC Moose Jaw SK	Eugene OR Glace Bay NS (urban) Sydney NS (urban)	Kamloops BC Melfort SK	[60, 61, 81, 92, 120, 125, 147]
Fireplace only (fire pits not permitted)	Fire/Nuisance	Cornwall PE Halifax NS (urban) Moncton NB Quebec City QC	Fredericton NB Labrador City NL Moose Jaw SK St. John's NL	Gatineau QC Laval QC Paradise NL Stratford PE	[74, 75, 78-80, 82, 105, 106, 118, 120, 158, 159]
Frequency of usage	Fire/Nuisance	Clackamas County OR - less than 4 fires per month			[143]
Duration of fire	Fire/Nuisance	Kamloops BC - 3 hours maximum duration Coon Rapids MN - 6 hours maximum duration			[60] [140]
Season	Air Quality/ Fire	Fires are permitted year-round in most jurisdictions. Some areas have seasonal restrictions: Halifax NS (urban): fireplaces permitted in winter only (Oct 16 to Mar 14) Dieppe NB, Shediac NB: permitted in summer only (3rd Monday in April to Oct 31)			[82] [73, 76]
Time of day (permitted fire times)	Fire/Nuisance	Dieppe NB (4pm–12am) Oshawa ON (dawn–dusk)	Kitchener ON (6pm–11pm) Regina SK (12pm–1am)	Melfort SK (8am–11pm) Sydney NS (8am–9pm)	[76, 81, 89, 94, 121, 125]
Outside temperature	Fire	Medford OR – fires are prohibited when temperature is >90°F (32°C)			[153]
Ventilation index	Air Quality/ Nuisance	Medford OR - during the winter (Oct–Feb), fires are prohibited when the ventilation index is low			[153]

Management Option	Purpose of Regulation	Example Jurisdictions*	Ref.
Wind conditions	Fire	Fires are prohibited when wind is > 15–32 km/h: Lethbridge AB (30 km/h) — Oakville ON (30 km/h) St. John's NL (25 km/h) — Winnipeg MB (25 km/h)	[30, 68, 80, 98, 128, 139]
Size of fire	Fire	Fire pit, maximum diameter range 0.3–1 m, height range 0.3–0.75 m: Airdrie AB — Mississauga ON Prince Albert SK — Winnipeg MB	[29, 61, 68, 73, 100, 123]
		Fireplace burning area, maximum width of 1–1.25 m, maximum depth of 0.4–1 m: Airdrie AB — Moncton NB	[29, 38, 75]
		General restriction on size of fuel area (typically 0.5–1 m in any direction): Dieppe NB — Prince George BC — London ON Minneapolis MN — Oshawa ON — Portland OR	[63, 89, 96, 139, 145, 160]
Site of fire	Fire/Nuisance	Minimum distance requirements to any building/structure, property line or combustible material (typical range is between 1 and 7.6 m): Brandon MB (1.5 m) — Halifax NS (4.75 m) — Lethbridge AB (1.5 m) Moose Jaw SK (3 m) — Oakville ON (3 m) — Pictou NS (7.6 m)	[30, 71, 82, 84, 98, 120]
Backyard size	Fire/Nuisance	Kamloops BC - properties must be ≥0.4 hectare (1 acre) Oshawa ON - properties must be >10 acres	[60] [89]
Permitted fuels	Air Quality/ Nuisance	Dry untreated wood and charcoal are listed as the permitted solid fuels in most bylaws	-
Prohibited fuels	Air Quality/ Nuisance	Most bylaws provide a list of prohibited fuels. The list typically includes garbage, leaves, yard waste, treated wood, rubber, plastic, construction debris or anything that might create dense smoke or offensive odour	-
Wood Smoke Awareness Course	Air Quality	First time violators of an air quality burn ban can choose to complete a wood smoke awareness course instead of paying a fine: Bay Area CA — Sacramento CA — South Coast CA	[133, 136, 137]

* Based on a sample of 90 jurisdictions in Canada and four US states

Many jurisdictions restrict recreational fires by allowing fireplaces but prohibiting fire pits. Examples include Halifax (urban area), Fredericton, Labrador City and Quebec City [74, 78, 82, 158]. Fireplaces typically have better drafting than fire pits, resulting in a hotter fire and less smouldering (i.e., less smoke). Additionally, the presence of chimneys on fireplaces allows smoke to be directed up and away, which, compared to a fire pit, may lead to fewer smoke complaints from neighbours.

Bylaws for most jurisdictions include restrictions on size of fire, site of fire, permitted and prohibited fuels, wind conditions, time of day and smoke causing a nuisance to neighbours. Other management options used less frequently were those involving frequency of usage, duration of fire, season of use, outside temperature and ventilation index.

The CCME recently published a guidance document to assist local and provincial governments with the development of open air burning policies [6]. For recreational fires, the document covers many of the regulations discussed above in Table 3 (e.g., size of fire, site of fire, permitted fuels, smoke causing a nuisance, bans during a fire ban or air quality advisory, complete bans). The CCME document also includes sample bylaws and templates for public education campaigns.

2.3.2 Public Education and Awareness

Some important questions to consider in the management of recreational fires relate to public awareness:

- Is the public aware of the bylaw and the consequences of violating the bylaw?
- Is the bylaw accessible and easy to understand?
- Are the reasons for the bylaw understood?

In some cases, residents may not be aware of the bylaws governing fire pits and fireplaces; for this reason, first-time violators of a bylaw may be issued warnings, rather than fines, along with information about the bylaws.

Many bylaws are available online and easily accessible; however, the language can sometimes be confusing or difficult to interpret. To facilitate understanding, some jurisdictions have websites that summarize the bylaw in plain language. Clear definitions for fire pits, fireplaces, cooking fires and nuisance also help to ensure the public properly understands the regulations.

Various types of outdoor fires (e.g., fire pits, fireplaces, bonfires, open burning) are often regulated under the same bylaw, and it may be difficult for the public to identify which regulations apply to recreational fires. The City of Medford, Oregon developed a helpful flow-chart (Appendix C) to clarify their regulations for the different categories of outdoor burning [150]. The tool is intended to help individuals decide if and when burning is permitted, and what can be burned.

Improved public awareness of the health effects of wood smoke and cleaner burning practices may help improve air quality and reduce nuisance issues related to recreational fires. Informing residents that propane and natural gas are cleaner, healthier fuel alternatives may promote the use of these fuels instead of wood for recreational fires. Educational campaigns may be in the form of fact sheets, brochures, television/radio commercials, newspaper articles and websites. For example, the Government of Alberta has developed a wood smoke fact sheet and a Frequently Asked Questions document that provide information on the composition of wood smoke, human exposure to wood smoke and potential health concerns [11, 161].

A recreational fire/wood smoke awareness program may include information such as:

- Plain language summary of the bylaws governing recreational fires;
- The process for reporting smoke and nuisance complaints;
- The health effects of wood smoke;
- Tips on proper burning techniques to limit wood smoke (e.g., burn small hot fires, use wood that has been dried for at least 6 months); and
- Suggestions for cleaner alternatives to wood fires (gas or propane-fuelled appliances).

The United States Environmental Protection Agency (USEPA) has implemented a Burn Wise Program to help educate the public on how to burn clean [162]. The website offers information on the importance of burning the right wood, the right way, in the right wood-burning appliance, and also discusses the health effects of wood smoke. The website focuses on wood-burning associated with residential heating, though much of the information also applies to recreational fires (e.g., best burn practices, health effects of wood smoke).

Some jurisdictions have incorporated public education requirements into their recreational fire regulations. For example, in California, the BAAQMD requires that sellers of a wood-burning device provide to the purchaser a fact sheet outlining the health effects of wood smoke [135]. The fact sheet must include the following statement: "*Wood smoke contains harmful particulate matter (PM) which is associated with numerous negative health effects.*" Additionally, sellers of solid fuels or wood are required to attach a label to the packaging stating: "*Use of this and other solid fuels may be restricted at times by law. Please check 1-877-4-NO-BURN or http://www.8774noburn.org/ before burning.*" The BAAQMD, as well as other air quality districts in California, allow first-time violators of an air quality burn ban to complete a wood smoke awareness course instead of paying a fine of US$50 [133, 136, 137].

Regardless of the methods used, educating the public in matters related to recreational fires and wood smoke is an important component of recreational fire management plans. Public knowledge of the health effects of wood smoke also helps with gaining support from the community for implementing changes to recreational fire regulations [163].

Chapter 3: Wildfire Smoke

Wildfires are a common occurrence in Alberta, with more than one thousand reported every summer [2]. Some wildfires are caused naturally by lightning, but the majority are caused by human activity (e.g., unattended campfires, discarded cigarettes, arson). Information on wildfire status and air quality in Alberta is available from a number of sources. Government of Alberta websites provide wildfire status maps (wildfire.alberta.ca/wildfire-status), fire ban notices (albertafirebans.ca) and Air Quality Health Index (AQHI) maps (airquality.alberta.ca/map). Additionally, wildfire and AQHI apps are available for Android and iOS devices [164, 165]. For national wildfire information, Natural Resources Canada manages the Canadian Wildland Fire Information System (CWFIS; cwfis.cfs.nrcan.gc.ca). The CWFIS monitors fire danger conditions and produces daily fire weather and fire behaviour maps [166].

There are a number of guidelines and tools that can be used to manage smoke emitted from wildfires. This chapter presents a summary of the wildfire smoke management guidelines used in seven jurisdictions in North America (British Columbia, Manitoba, Northwest Territories, Newfoundland and Labrador, California, Idaho and Oregon). For comparison purposes, information on air quality monitoring in Alberta is also included.

The key components of a smoke response plan are (1) air quality monitoring; (2) smoke forecasting and modeling; (3) communication and issuing of health warnings; and (4) public actions and trigger values. Section 3.1.1 summarizes the main practices used for air quality monitoring and smoke forecasting. Section 3.1.2 reviews the public health warnings and actions used at various trigger levels (thresholds).

Another aspect of wildfire smoke management pertains to preventative approaches, which focus on the mitigation of wildfire smoke by reducing hazardous fuels in areas at risk of wildfire. Reducing the build-up of hazardous fuels, such as dead woody debris on a ground surface, lowers the risk of a future catastrophic wildfire. This can be achieved through options such as prescribed fires (planned, controlled fires conducted under carefully selected weather conditions) or allowing a naturally-occurring wildfire to burn out. Section 0 discusses these management options further.

3.1 Response to Wildfire Smoke

In this section, the main practices used for air quality monitoring and smoke forecasting are summarized. Additionally, the public health warnings and actions used at different trigger levels in various jurisdictions are presented.

3.1.1 Air Quality Monitoring

The main pollutant of concern in wildfire smoke is PM. Air quality conditions during a wildfire are typically assessed based on $PM_{2.5}$ and/or PM_{10} levels (using existing ambient PM

monitors supplemented by portable PM monitors). Data for other pollutants regularly measured at permanent monitoring stations (e.g., carbon dioxide, nitrogen oxides, ozone, SO_2) are also considered in air quality assessments.

Deployment of portable PM monitors often involves multiple agencies, particularly for larger wildfires affecting multiple counties. To assist with coordination of the air monitoring response, some agencies recommend the use of an air emergency response template. For example, the California Air Resources Board (of the California Environmental Protection Agency) provides an emergency response template to keep track of monitoring objectives, the pollutants to be monitored, monitoring locations, agency personnel and resources deployed, and any other relevant information [167, 168]. Additionally, the 'Wildfire Smoke Response Coordination' published by the California Air Response Planning Alliance (CARPA) provides information on the steps required and agencies responsible for the request and coordination of portable air monitor deployment in California [167].

3.1.1.1 Air Quality Health Index

The AQHI is a tool used in Canada to communicate the health risk associated with air quality [169]. The AQHI uses a scale of 1 to 10+ (values above 10 are reported as 10+), and is based on measurements of $PM_{2.5}$, ozone and nitrogen dioxide (3-hour average concentrations). AQHI values are grouped into four health risk categories: Low, Moderate, High and Very High (

Table 4). For each category, there are customized health messages for the general population and at-risk population. The AQHI is available for over 100 locations across Canada [170]. Current conditions are updated hourly, and forecast bulletins are issued twice a day.

One limitation of the AQHI is that it may not be sufficiently sensitive to the short-term peaks in $PM_{2.5}$ that may occur during smoky conditions [171]. For this reason, some jurisdictions, such as Alberta and BC, have AQHI override programs in place [172, 173]. When the $PM_{2.5}$ concentration reaches a specified threshold, the conventional AQHI value is overridden by an AQHI value based solely on $PM_{2.5}$.

Table 4. AQHI categories and health messages

Health Risk	Air Quality Health Index	Health Messages	
		At Risk Population	General Population
Low Risk	**1 – 3**	**Enjoy** your usual outdoor activities.	**Ideal** air quality for outdoor activities
Moderate Risk	**4 – 6**	**Consider** reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	**No need to modify** your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High Risk	**7 – 10**	**Reduce or reschedule** strenuous activities outdoors. Children and the elderly should take it easy.	**Consider** reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation
Very High Risk	**Above 10**	**Avoid** strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	**Reduce or reschedule** strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

Government of Alberta [174]

3.1.1.2 Air Quality Index

In the United States, an Air Quality Index (AQI) tool is used to communicate daily air quality information. The AQI is calculated for five pollutants (PM, ozone, carbon monoxide, nitrogen dioxide and SO_2) and the value of the single worst pollutant is reported [175]. The AQI uses a normalized scale of 0 to 500 (

Table 5); for $PM_{2.5}$, an AQI value of 100 corresponds to a 24-hour average concentration of 35 $\mu g/m^3$ [176]. The index is categorized into six levels of health concern: Good, Moderate, Unhealthy for Sensitive Groups, Unhealthy, Very Unhealthy and Hazardous. Section 3.1.2 provides additional information on the recommended public health messages and actions for each AQI category.

Table 5. AQI categories

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51 to 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health alert: everyone may experience more serious health effects.
Hazardous	301 to 500	Health warnings of emergency conditions. The entire population is more likely to be affected.

USEPA [175]

3.1.1.3 Smoke Forecasting and Modeling

The forecasting and modeling of smoke conditions is an important component of wildfire smoke response. A smoke forecasting system provides advance notice of the estimated intensity and duration of smoke exposure in affected communities. There are two smoke forecasting systems used in Canada: BlueSky and FireWork. Data from these forecasting systems inform decisions regarding public health alerts and recommended actions to reduce smoke exposure.

BlueSky

Using complex computer modeling, the BlueSky system integrates wildfire locations, wildfire emissions (using fuel and consumption estimates), meteorological data (e.g., wind speed, temperature, humidity) and smoke transport and dispersion information to estimate smoke concentrations (as $PM_{2.5}$) at ground level [10, 177]. Animated smoke forecasts are produced at a 4 to 12 km spatial resolution across Canada for every hour, for up to 48 hours into the future.

The BlueSky system is a collaborative effort between several federal and provincial agencies. Smoke forecasts are produced at the University of British Columbia, and results are published on FireSmoke Canada (www.firesmoke.ca) throughout the wildfire season (April to September).

In the United States, BlueSky smoke forecasts are produced by the National Weather Service, and are available online through the AirFire Research Team of the United States Forest Service (www.airfire.org/data/bluesky-daily/).

FireWork

FireWork is a wildfire emissions prediction system developed by Environment and Climate Change Canada (ECCC) in 2012 and made available to the public in 2016 [178, 179]. The system provides an indication of expected wildfire smoke behaviour across North America for the upcoming 48 hours at a 10 km horizontal resolution, based on the estimated level of fine particles emitted to the air. FireWork combines biomass burning data (from Canada and the United States) from the CWFIS with ECCC's Regional Air Quality Deterministic Prediction System to determine the contribution of wildfire emissions to forecasted pollution levels [178].

Animated forecast maps are published twice daily on the Government of Canada weather website (weather.gc.ca/firework/) during the wildfire season (April through October).

3.1.2 Public Health Actions

The following section provides a summary of the recommended public health actions and air pollution trigger levels (if available) for several provinces and states. The methods used for issuing and communicating health warnings are also discussed.

3.1.2.1 Alberta

The air quality monitoring network in Alberta consists of approximately 110 stations operated by Alberta Environment and Parks, airsheds, Environment and Climate Change Canada, and industry [180]. During a wildfire smoke event, mobile air monitoring labs may be deployed for additional pollutant monitoring [181].

The AQHI is used to inform the public about air quality and health risk, and is currently available for 34 communities across the province [182]. As discussed in Section 3.1.1.1, Alberta has an AQHI override program in place that accounts for peaks in $PM_{2.5}$ that may occur during smoky conditions. When the hourly $PM_{2.5}$ concentration reaches the Alberta Ambient Air Quality Objective of 80 $\mu g/m^3$, the conventional AQHI value is overridden with a High or Very High risk value (7 or higher) [173].

When communities are impacted by wildfire smoke, air quality advisories may be issued by Alberta Health Services [11, 183]. Additionally, special air quality statements may be issued by Environment Canada [184].

Special messaging may also be used for odour or visibility events in a community [173]. These events occur when the AQHI is rated as Low or Moderate risk and a specified pollutant [hydrogen sulphide (or total reduced sulphur), SO_2 or $PM_{2.5}$] reaches its odour or

visibility threshold. The odour thresholds used for hydrogen sulphide and SO_2 are 10 and 100 parts per billion, respectively, and the visibility threshold for $PM_{2.5}$ is 25 $\mu g/m^3$. An example of a special message may be: *While you may detect an odour or change in visibility or clarity, enjoy your outdoor activities unless you experience symptoms*.

There was no publicly available guideline document or tool specifically discussing wildfire smoke responses in Alberta.

3.1.2.2 British Columbia

The 'British Columbia Provincial Coordination Plan for Wildland Urban Interface Fires' describes the responsibilities of different agencies during a wildfire [185]. With regard to smoke issues, the Ministry of Environment is responsible for monitoring and reporting air quality, while the Ministry of Health and regional health authorities provide leadership and direction on public health issues related to smoke and air quality. The Ministry of Transportation and Infrastructure monitors provincially owned highways and inland ferries for safety, and closes transportation routes if there is poor visibility caused by smoke.

The recently published 'BC Health Wildfire Smoke Response Coordination Guideline' outlines the roles and responsibilities of the Health Wildfire Smoke Response Coordination Group [186]. The group is made up of members from various regional, provincial and federal agencies, and supports regional efforts aimed at reducing the public health impact of wildfire smoke events. Prior to each wildfire season, the group convenes to review guidance documents and response capacities. During wildfire events, the group provides recommendations to reduce the health risk posed by wildfire smoke, based on an evaluation of weather and wildfire data, wildfire smoke modeling maps, air quality ratings, and health and environmental surveillance data. The health surveillance data is obtained from the BC Asthma Monitoring System, a program that retrospectively integrates $PM_{2.5}$ concentrations and smoke modeling information with two smoke-related health outcomes (asthma-related physician visits and dispensations of the asthma medication salbutamol). Data are evaluated to determine if physician visits or salbutamol dispensations have exceeded expected daily values [187]. These two health outcomes may not always be attributable to wildfire smoke exposure; for this reason, the Asthma Monitoring System summary reports include visual displays of health outcomes and exposure which allows users to disregard excursions not associated with $PM_{2.5}$ exposure.

Air quality and health risk information is communicated to the public using the AQHI, which is available for 25 locations in BC [170]. To account for peaks in $PM_{2.5}$ that may occur during smoky conditions, the conventional AQHI value may be overridden by an AQHI value that is based solely on $PM_{2.5}$ [172, 186]. Using this approach, termed 'AQHI Plus' in BC, the AQHI will be reported as 7 (high risk) when the hourly concentration of $PM_{2.5}$ exceeds 60 $\mu g/m^3$ or the 24-hour moving average exceeds 25 $\mu g/m^3$.

If air quality monitoring is unavailable or not up-to-date, a visibility index (Table 6) may be used to approximate smoke level ($PM_{2.5}$) and AQHI [186]. Using landmarks at known distances, visibility is determined as the point at which the landmark can no longer be seen.[4] Several assumptions were made in the development of the visibility index, and the values obtained should be considered as approximate.

Table 6. Visibility index used for estimating AQHI in British Columbia

Visibility Distance	Approximate $PM_{2.5}$ (3-hour average)	AQHI
>35 km	0 – 15 µg/m^3	Low risk 1 to 3
8 – 35 km	15 – 65 µg/m^3	Moderate risk 4 to 6
3.5 – 8 km	65 – 150 µg/m^3	High risk 7 to 10
<3.5 km	>150 µg/m^3	Very High risk > 10

Province of British Columbia [186]

The 'Guidance for BC Public Health Decision Makers During Wildfire Smoke Events' document discusses the interventions that can be used to help reduce public exposure to wildfire smoke [171]. The main interventions include: (1) communications (such as public service announcements) advising the public to stay indoors, reduce outdoor activity, wear a respirator mask, activate their asthma (or other respiratory disease) action plan and use a home clean air shelter; (2) cancellation of outdoor events (school activities, sporting events, mass gatherings); (3) providing community clean air shelters; (4) augmentation of air filtration in institutions (hospitals, nursing homes, schools); and (5) evacuation. Trigger values for the interventions were not indicated; however, it was stated that decision makers should prepare individualized response plans that include interventions, thresholds and timelines for response. In addition to interventions, the document offers various measures for preparedness prior to wildfire smoke events. The main preparedness steps include: identifying regions or communities at risk for wildfire smoke events and the susceptible populations in those areas; determining and preparing appropriate interventions for different scenarios; preparing communications for the general and susceptible populations; and agreeing on the data streams and data thresholds that will guide decisions (e.g., PM concentrations and durations).

In 2011, the Province published a smoke management framework outlining their approach for managing biomass smoke in BC [10]. The report is a compilation of existing smoke management measures into a single framework. With regard to managing smoke from

[4] Visibility indices should not be used at night or during dawn or dusk. Additionally, visibility indices should not be used in humid conditions (>70% humidity), as visibility is reduced in high humidity [186, 202].

wildfires, the province aims to limit public exposure to smoke by issuing air quality advisories and advising actions to be taken to reduce exposure.

Air quality advisories, or Wildfire Smoke Advisories, are based primarily on 24-hour $PM_{2.5}$ concentrations, and are used when air pollutants are predicted to exceed provincial standards. The advisories are issued by local/regional authorities, the BC Ministry of Environment and/or Environment Canada, and also include information on how the public can reduce their exposure.

In the Thompson and Okanagan Regions, a newer type of air quality advisory, called the Smoky Skies Advisory, is used by the Ministry of Environment and Interior Health Authority [171, 186, 188]. Smoky Skies Advisories are issued when smoke concentrations reach levels that are of concern for human health. Decisions are based on satellite information, smoke transport models, visibility photographs, first-hand observations from the area and $PM_{2.5}$ concentrations. The main objective of a Smoky Skies Advisory is to "respond to the rapidly changing nature of wildfire smoke, in which smoke concentrations can vary significantly over short distances and periods of time that may not be well-characterized by the existing air quality monitoring network or responded to in a timely manner by Wildfire Smoke Advisories" [171, 186].

To assist with communication to the public, the Government Communications and Public Engagement maintains the Emergency Info BC website and twitter feed [185, 189]. The sites contain current alerts and advisories, as well as information on emergency preparedness.

3.1.2.3 Manitoba

The Manitoba Health document titled 'Smoke Exposure from Wildland Fires: Interim Guidelines for Protecting Community Health and Wellbeing' outlines the steps involved in wildfire smoke response for the province [190]. Responsible agencies include local authorities, Manitoba Conservation, Manitoba Public Health, Office of Disaster Management, Emergency Measures Organization, Emergency Social Services, and local and regional health authorities.

The local municipal government is responsible for decisions regarding the best course of action, with assistance from the Emergency Measures Organization, Manitoba Health or other involved agencies. Manitoba Public Health is responsible for coordinating the provincial public health response and communicating with the public and health care providers.

During a wildfire smoke event, air quality information may be communicated using the AQHI (available for Brandon and Winnipeg) or special air quality statements issued by Environment Canada [191].

Manitoba Health also provides a list of public health recommendations for five air quality categories based on $PM_{2.5}$ concentration (1- to 3-hour average) or a visibility index (Table 7)

[190]. For each category, there are various recommended health messages (for at-risk populations and the general population) and actions for the health team. The guidelines are adapted from an earlier version of the 'Wildfire Smoke Guide' used in California [192].

Table 7. Recommended public health messages and actions for Manitoba

Air Quality Category (1- to 3-hour $PM_{2.5}$ conc)	Visibility	Health messages for at-risk populations	Health messages for general population	Actions for health team
Good (0 – 40 µg/m^3)	>15 km	**Enjoy** your usual outdoor activities.	**Ideal** air quality for outdoor activities.	-Be aware of forecast (current, daily, tomorrow).
Moderate/ Unhealthy for Sensitive Groups (41 – 175 µg/m^3)	5 – 14 km	**Reduce** or reschedule prolonged strenuous activities and limit time spent outdoors.	**Be aware** of health effects of smoke and related symptoms.	-Advise public about: health effects of smoke, related symptoms and ways to reduce exposure. -If the smoke event is projected to be prolonged, evaluate and notify possible cleaner air shelter sites and prepare evacuation plans for at-risk populations.
Unhealthy (176 – 300 µg/m^3)	2.5 – 4 km	**Avoid** prolonged strenuous activities and stay indoors if possible.	**Reduce** or reschedule prolonged strenuous activities outdoors, especially if you experience symptoms.	-Consider cancelling public events, based on public health and travel considerations (e.g., number of people, level of physical exertion, etc.).
Very Unhealthy (301 – 500 µg/m^3)	1.5 – 2 km	**Avoid** all strenuous activities and stay indoors if possible.	**Avoid** prolonged strenuous activities and stay indoors if possible.	-Consider having at-risk populations go to cleaner air shelters in the community.
Hazardous (>500 µg/m^3)	< 1 km	**Avoid** all strenuous activities and stay indoors.	**Avoid** all strenuous activities and stay indoors.	-Cancel public and outdoor events. -If smoke event is projected to be prolonged, consider evacuation of at-risk populations.

Manitoba Health [190]

3.1.2.4 Newfoundland and Labrador

The 'Forest Fire Smoke and Air Quality Public Health Guidelines', published by the Department of Health and Community Services, summarizes the agencies and tools involved in wildfire smoke management in the province [193].

The Regional Medical Officer of Health in an affected area, in consultation with regional environmental health officials, meteorologists, emergency management officials and air quality regulators, is responsible for assessing air quality and health impacts and preparing health messages and precaution measures. The Regional Health Authority communicates this information to the public, typically via website postings and media releases.

When wildfire smoke affects more than one Regional Health Authority, health messages and precaution measures are prepared by the Chief Medical Officer of Health and Provincial Director of Environmental Health, in consultation with the Department of Health and Community Services, and other Departments/Agencies as required. The Department of Health and Community Services is responsible for issuing media releases and postings of health messages and precaution measures on the Department's website. Municipal councils and event emergency management teams are consulted if wildfire smoke exposure is part of an ongoing emergency situation such as a forest fire event.

Air quality and health risk information is also communicated to the public using the AQHI (available in five cities/towns) and special air quality statements (or e-smog bulletins) issued by Environment Canada.

When AQHI information is not available, $PM_{2.5}$ monitoring data or a visibility index may be used by public officials to determine health risk. Public health recommendations for six health risk levels are listed in Table 8. The guidelines are adapted from an earlier version the 'Wildfire Smoke Guide' used in California [194].

If a smoke event is expected to be prolonged, evacuations may be considered. Decisions regarding evacuations are made by municipal officials in consultation with the event emergency management team, Regional Health Authority (Regional Medical Officer of Health) and the Department of Health and Community Services (Chief Medical Officer of Health). The trigger for consideration of evacuations is continued exposure to $PM_{2.5}$ in the range of 250–500 $\mu g/m^3$.

Table 8. Recommended public health actions for Newfoundland and Labrador

$PM_{2.5}$ or PM_{10} (average in µg/m^3)			Risk Category	Visibility	Recommendations
1- to 3-hour	8-hour	24-hour			
0 – 38	0 – 22	0 – 12	Good	17.7 km (≥11 miles)	-If smoke event forecast, implement communication plan.
39 – 88	23 – 50	12.1 – 35.4	Moderate	9.6 – 16 km (6 – 10 miles)	-Issue public service announcements advising public about health effects and symptoms and ways to reduce exposure. -Distribute information about exposure avoidance.
89 – 138	51 – 79	35.5 – 55.4	Unhealthy for Sensitive Groups	4.8 – 8 km (3 – 5 miles)	-If smoke event projected to be prolonged, evaluate and notify possible sites for cleaner air shelters. -If smoke event projected to be prolonged, **prepare evacuation plans**.
139 – 350	80 – 200	55.5 – 150.4	Unhealthy	2.4 – 4.4 km (1.5 – 2.75 miles)	-Consider "Smoke Day" for schools (i.e. no school that day), possibly based on school environment and travel considerations. -Consider cancelling public events, based on public health and travel considerations.
351 – 526	201 – 300	150.5 – 250.4	Very Unhealthy	1.6 – 2 km (1 – 1.25 miles)	-Consider closing some or all schools (newer schools with a central air cleaning filter may be more protective than older, leakier schools). -Cancel outdoor events (e.g., concerts, sports events).
>526	>300	>250.5	Hazardous	<1.6 km (<1 mile)	-Close schools. -Cancel outdoor events (e.g., concerts, sports events). -Consider closing workplaces not essential to public health. -If PM level is projected to remain high for a prolonged time, **consider evacuation of sensitive populations**.

Government of Newfoundland and Labrador [193]

3.1.2.5 Northwest Territories

In the Northwest Territories, the 'Smoke Exposure from Wildfire: Guidelines for Protecting Community Health and Wellbeing' document outlines the preparation and planning activities to be undertaken by the local authorities (local emergency coordinator), Department of Health and Social Services, Health and Social Services Authority, health emergency management officers and local health facilities [195]. Community Health Centres and Community Emergency Response Committees are to designate someone to evaluate smoke-related health risks to determine the appropriate course of action.

During a wildfire smoke event, air quality may be communicated using the AQHI (available for Fort Smith, Inuvik and Yellowknife), special air quality statements issued by Environment Canada or a visibility index. The visibility index and recommendations for public health messages/actions for five air quality categories are the same as those used in Manitoba (Section 3.1.2.3; Table 7).

3.1.2.6 California

CARPA recently published a report outlining the best practices and tools used by federal, state and local agencies for wildfire smoke response in California [167].

Decisions regarding public actions are made at the local level, in consultation with the California Air Resources Board, air resource advisor, federal land manager, California Department of Public Health, Office of Environmental Health Hazard Assessment and other involved agencies. During major wildfire events, a "1400" conference call, conducted at 2 pm daily, facilitates sharing of information and coordination of actions between the agencies involved.

For recommendations on public health actions to mitigate exposure to smoke, the CARPA report refers authorities to a companion document titled 'Wildfire Smoke: A Guide for Public Officials' [13, 167]. Recommended actions for six AQI categories, based on 24-hour $PM_{2.5}$ averages, are presented in Table 9. The guide also references the use of the USEPA's activity guidance for schools, which provides instructions on how to modify children's outdoor physical activities based on the AQI [196]. Public health authorities are advised to consider fluctuations in PM levels, duration of elevated PM and potential indirect effects (e.g., risk of traffic accidents) in the decision-making process.

County health departments, in coordination with the air resource advisor, federal land manager, California Air Resources Board, California Department of Public Health, Office of Environmental Health Hazard Assessment, air pollution control officer and local governments, are responsible for issuing advisory announcements and updates to the public [167]. Information is provided to the public via agency websites, press releases to media and the California Smoke Blog (californiasmokeinfo.blogspot.com). The California Smoke Blog is a 'one-stop' website for information on air quality conditions and forecasts, as well as links to agency websites [167, 197].

For guidance on cautionary statements to use in public advisories, the CARPA report again refers local agencies to the guidelines in the 'Wildfire Smoke: A Guide for Public Officials' document [13, 167]. Recommendations for cautionary statements for each AQI category are provided in Table 10.

Table 9. Recommended public health actions for California

AQI Category (AQI Value)	$PM_{2.5}$ * (24-hour average)	Recommended Actions
Good (0 – 50)	0 – 12 µg/m^3	-If smoke event forecast, implement communication plan.
Moderate (51 – 100)	12.1 – 35.4 µg/m^3	-Prepare for full implementation of the USEPA's school activity guidelines (www3.epa.gov/airnow/flag/school-chart-2014.pdf). -Issue public service announcements advising public about health effects and symptoms and ways to reduce exposure. -Distribute information about exposure avoidance.
Unhealthy for Sensitive Groups (101 – 150)	35.5 – 55.4 µg/m^3	-Evaluate implementation of school activity guidelines. -If smoke event projected to be prolonged, evaluate and notify possible sites for cleaner air shelters. -If smoke event projected to be prolonged, prepare evacuation plans.
Unhealthy (151 – 200)	55.5 – 150.4 µg/m^3	-Full implementation of school activity guidelines. -Consider "Smoke Day" for schools (i.e. no school that day), possibly based on school environment and travel considerations. -Consider cancelling public events, based on public health and travel considerations.
Very Unhealthy (201 – 300)	150.5 – 250.4 µg/m^3	-Schools move all activities indoors or reschedule them to another day. -Consider closing some or all schools (newer schools with a central air cleaning filter may be more protective than older, leakier schools). -Cancel outdoor events that involve activity (e.g., sports events). -Consider cancelling outdoor events that do not involve activity (e.g. concerts).
Hazardous (> 300)	> 250.5 – 500 µg/m^3	-Close schools. -Cancel outdoor events (e.g., concerts, sports events). -Consider closing workplaces not essential to public health. -If PM level is projected to remain high for a prolonged time, consider evacuation of sensitive populations.

* If only PM_{10} measurements are available during smoky conditions, it can be assumed that the PM_{10} is composed primarily of $PM_{2.5}$, and that the AQI and associated cautionary statements and advisories for $PM_{2.5}$ may be used.

('2016 Wildfire Smoke: A Guide for Public Officials' [13])

Table 10. Recommendations for public advisory cautionary statements for California

AQI Category (AQI Value)	Health Effects	Cautionary Statements*	Other Protective Actions
Good (0 – 50)	None expected	None	None
Moderate (51 – 100)	Possible aggravation of heart or lung disease.	Unusually sensitive individuals should consider limiting prolonged or heavy exertion. -People with heart or lung disease should pay attention to symptoms. -If you have symptoms of lung or heart disease, including repeated coughing, shortness of breath or difficulty breathing, wheezing, chest tightness, palpitations, nausea, fatigue or light-headedness, contact health care provider.	If symptomatic, reduce exposure to particles by following advice in box below.
Unhealthy for Sensitive Groups (101 – 150)	Increasing likelihood of respiratory or cardiac symptoms in sensitive individuals, aggravation of heart or lung disease, and premature mortality in persons with cardio-pulmonary disease and the elderly.	*Sensitive Groups* (people with heart or lung disease, the elderly, children, pregnant women) should limit prolonged or heavy exertion. -Limit time spent outdoors. -Avoid physical exertion. -People with asthma should follow asthma management plan. -If you have symptoms of lung or heart disease (see box above), contact health care provider.	-Keep doors and windows closed, seal large gaps as much as possible. -Avoid using exhaust fans (kitchen, bathrooms, dryer, and utility room). -If cooling is needed, turn air conditioning to recirculate mode in home and car, or use ceiling fans or portable fans. -Install higher efficiency filters in central heating and air conditioning systems. If a filter upgrade has been performed, the system's circulating fan can be set to operate continuously to obtain maximum particle removal by the system's filter. -Operate portable air cleaners to reduce indoor particle levels. -Avoid indoor sources of pollutants (e.g., tobacco smoke, wood stoves, frying foods, candles, vacuum, paint, cleaning product). -Keep 5-day supply of medication. -Have supply of non-perishable foods.

AQI Category (AQI Value)	Health Effects	Cautionary Statements*	Other Protective Actions
Unhealthy (151 – 200)	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population.	*Sensitive Groups*: should avoid prolonged or heavy exertion. -Stay indoors; avoid exertion. *General Population*: should limit prolonged or heavy exertion. -Limit time spent outdoors. -If you have symptoms of lung or heart disease, contact health care provider.	*Sensitive Groups*: Stay in a "clean room" at home (where there are no indoor smoke or particle sources, and use a non-ozone producing air cleaner). -Go to a "cleaner air" shelter or possibly out of area. *General Population*: Follow advice for sensitive groups in box above. -Identify potential "cleaner air" shelters in the community.
Very Unhealthy (201 – 300)	Significant aggravation of heart or lung disease, premature mortality in persons with cardio-pulmonary disease and the elderly; significant increase in respiratory effects in general population.	*General Population*: should avoid prolonged or heavy exertion. -Stay indoors, avoid exertion.	*General Population*: If symptomatic, evacuate to cleaner air shelter or leave area, if safe to do so.
Hazardous (> 300)	Serious aggravation of heart or lung disease, premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	*General Population*: should avoid any outdoor activity.	*General Population*: If symptomatic, evacuate to cleaner air shelter or leave area, if safe to do so.

* Higher advisory levels automatically incorporate all guidance offered at lower levels.

('2016 Wildfire Smoke: A Guide for Public Officials' [13])

3.1.2.7 Idaho

The 'Idaho Wildfire Smoke Event Response Protocol' outlines the guidelines used in Idaho to mitigate public exposure to wildfire smoke [198]. Several agencies are involved in the response, including the Idaho Department of Health and Welfare, Idaho Department of Environmental Quality (DEQ), Idaho Office of Emergency Management, tribal governments, public health districts, local authorities, air resource advisors, federal land managers and any other involved parties. The key actions required during a smoke event are air monitoring, smoke forecasting and modelling, issuing of health warnings and recommendations, and public actions. Table 11 presents the recommended public health actions based on AQI category and smoke forecasts [198].

The lead agencies involved in the communication of health warnings are the Idaho DEQ, Idaho Department of Health and Welfare, public health districts and the USEPA (or Tribes) [198]. A daily interagency conference call, generally initiated when air quality reaches the Unhealthy for Sensitive Groups category, ensures participating agencies have the same information regarding smoke severity and potential health impact. Information is provided to the public via agency websites, press releases to media and the Idaho Smoke Blog (idsmoke.blogspot.com). The Idaho Smoke Blog provides a 'one-stop' access point for information such as wildfire status, air quality conditions and forecasts, school and activity closures, burn bans, location of clean air shelters and travel restrictions due to visibility [198, 199]. Additionally, the Idaho Department of Health and Welfare has developed recommended guidelines for children's outdoor activities at schools (Table 12) that can be used during wildfire events [200].

The Idaho DEQ also follows the protocol outlined in the 'Montana-Idaho Interagency Smoke Management Coordination Strategy' to facilitate coordination and communication when wildfire smoke impacts both states [201]. The document outlines three coordination levels based on the potential impact (minor, moderate and major) of smoke on public health, with each level triggering specific management actions to be undertaken by fire management agencies and DEQs.

Table 11. Recommended public health actions for Idaho

AQI Category (AQI Value) [smoke forecast conditions]	**Recommended Public Health Actions**
Good (0 – 50) [ignitions have occurred or are forecasted to occur]	-Federal land managers to notify Idaho DEQ, Tribes and USEPA of wildfires that are expected to be of long duration or under a management strategy other than full suppression (i.e., Resource Benefit or Multiple Objectives). -Idaho DEQ to initiate Idaho Smoke Blog and post info on smoke impacts. -USEPA (or Tribes) to track ignitions and potential for smoke impacts.
Moderate (51 – 100) [and is forecasted to remain at or deteriorate for the next 24–72 hrs]	Above actions, plus: -Idaho DEQ to initiate daily wildfire smoke forecast (agency and public), identify wildfires of concern, and determine if an 'Air pollution Forecast and Caution' is required. -Idaho Department of Health and Welfare or public health districts to issue news release for public health warnings and recommendations. -USEPA (or Tribes) to issue air quality advisory, and issue a burn ban if $PM_{2.5}$ (24-hour average) is expected to reach 26 µg/m^3. -USEPA (or Tribes) to past air quality advisory and burn ban info to Idaho Smoke Blog.
Unhealthy for Sensitive Groups (101 – 150) [or air quality is in the Unhealthy category for part of the day and forecasted to remain or deteriorate for the next 24–72 hrs]	Above actions, plus: -Idaho DEQ to initiate daily conference calls with agencies. USEPA (or Tribes) to participate. -Idaho DEQ and USEPA to evaluate if emergency monitors need to be deployed. -Idaho DEQ to issue 'Air Pollution Forecast and Caution.' -Federal land managers to evaluate if an air resource advisor is needed.
Unhealthy (151 – 200) [air quality has reached the Unhealthy or Very Unhealthy category for part of the day and is forecasted to remain or deteriorate for the next 24–72 hrs]	Above actions, plus: -Idaho Department of Health and Welfare or public health districts to evaluate whether other actions are needed to protect public health (e.g., clean air shelters).
Very Unhealthy (201 – 300)	Same as above
Hazardous (301+)	Same as above

Idaho Department of Environmental Quality [198]

Table 12. Recommendations for schools and others responsible for children during a wildfire smoke event in Idaho

Activity	GOOD (10+ miles visibility)	MODERATE (6 – 10 miles visibility)	UNHEALTHY Sensitive Groups* (3 – 6 miles visibility)	UNHEALTHY (1.5 – 3 miles visibility)	VERY UNHEALTHY / HAZARDOUS (<1.5 miles visibility)
Recess (15 minutes)	No restrictions	No restrictions	Keep children with asthma or other respiratory problems indoors. Make indoor space available for all children.	Keep all children indoors.	Keep all children indoors.
P.E (1-hour)	No restrictions	Monitor kids with asthma or other respiratory problems and limit their vigorous activities.	Keep children with asthma or other respiratory problems indoors. Make indoor space available for all children. If outdoors, limit vigorous activities. Individual with asthma or other respiratory illness should be medically managing their condition.	Conduct P.E. indoors. If outdoors, only allow light activities for all participants. Individuals with asthma or other respiratory illness should be medically managing their condition.	Keep all children indoors.
Scheduled Sporting Events	No restrictions	Monitor kids with asthma or other respiratory problems and limit their vigorous activities.	Individuals with asthma or other respiratory illness should be medically managing their condition. Increase rest periods and substitutions for all participants to lower breathing rates.	Consider rescheduling or relocating event.	Reschedule or relocate event.
Athletic Practice, Training & Games (2-4 hours)	No restrictions	Monitor kids with asthma or other respiratory problems and limit their vigorous activities.	Individual with asthma or other respiratory illness should be medically managing their condition. Increase rest periods and substitutions for all participants to lower breathing rates.	Conduct practice and games indoors. If outdoors, allow only light activities for all participants. Add rest breaks or substitutions to lower breathing rates. Individuals with asthma or other respiratory illness should be medically managing their condition.	Conduct practice and games indoors only.
Example of light activities: • Walking • Carrying school books • Hanging out with friends		Examples of moderate activities: • Skateboarding • Slow pitch softball • Shooting basketballs		Examples of vigorous activities: • Running, jogging • Playing football, soccer, and basketball	

* If your child has lung or heart problems he or she may be more sensitive to air pollution and it is recommended that you talk with a doctor about his or her condition.

Idaho Department of Health and Welfare [200]

3.1.2.8 Oregon

The Oregon DEQ, in collaboration with other health and environmental agencies, developed the 'Oregon Wildfire Response Protocol for Severe Smoke Episodes' [202]. The document provides protocol guidelines for use during severe smoke events, and outlines the roles and responsibilities of local, state and federal agencies.

Decisions regarding public actions are made by local authorities, in consultation with the Oregon DEQ, air resource advisor, federal land manager, Oregon Health Authority and other involved agencies. Table 13 summarizes the recommended public health actions for each AQI category, based on $PM_{2.5}$ concentration or 5-3-1 visibility index [202]. Recommended actions are provided for two different smoke exposure durations (<24 hours, >24 hours) for the general population and sensitive populations.

The issuing of smoke updates and health warnings is a coordinated effort between the Oregon DEQ, air resource advisor, Oregon Health Authority, county health department and local government [202]. Information is provided to the public via agency websites, press releases to media, the 211info health information website (211info.org) and the Oregon Smoke Blog (oregonsmoke.blogspot.com). The Oregon Smoke Blog provides information on wildfire status, air quality conditions and forecasts, school and activity closures, burn bans, location of clean air shelters, travel restrictions due to visibility and links to agency websites [202-204]. The Oregon Wildfire Communications Group, consisting of public affairs staff from various agencies, coordinates dissemination of wildfire smoke information to the public and media.

To assist local health departments with public messaging and risk communication during a wildfire response, the Oregon Health Authority developed a 'Crisis and Emergency Risk Communication Toolkit for Wildfire Smoke' [205]. The toolkit includes communication materials such as sample press releases and social media messages, and provides information on how to reduce exposure to smoke during a wildfire. A guide for schools on how to determine the appropriate student activity levels during wildfire smoke events is also available [206]. The guide is similar to that used in Idaho, presented above in Table 12.

In addition to the recommended actions discussed in Table 13, the State of Oregon has an 'Air Pollution Emergency Rule' that identifies emission reduction actions to be taken when pollutants reach emergency levels that are extremely hazardous to public health [207-209]. Particulate trigger levels and examples of emission reduction actions required at each stage are presented in Table 14.

Table 13. Recommended public health actions for Oregon

		Recommended Public Health Actions	
AQI Category (24-hour $PM_{2.5}$ conc)	**5-3-1 Visibility Index**	**Smoke exposure periods of <24 hours**	**Smoke exposure periods of >24 hours**
Good (0–12 µg/m³)	**>5 miles**	If a smoke event is forecast in your area, review documents pertaining to wildfire response (e.g., Oregon Wildfire Response Protocol for Severe Smoke Episodes, Crisis and Emergency Risk Communication Toolkit for Wildfires, Oregon Smoke Blog).	
Moderate (13–35 µg/m³)	**>5 miles**	-Distribute information to public health partners and the public. -Focus on identifying and getting the information to vulnerable populations. -Refer people to the Oregon Smoke Blog for more information. -Recommend sensitive groups use an air cleaner at home during wildfires.	*Follow recommended actions to the left and above, plus*: -Respond to media inquiries. (Use the 'Crisis and Emergency Risk Communication Toolkit for Wildfires' [205] for guidance).
Unhealthy for Sensitive Groups (36–55 µg/m³)	**3 – 5 miles**	*Above, plus*: -Issue a press release, outlining sensitive groups and encouraging them to reduce exposure. (Use the 'Crisis and Emergency Risk Communication Toolkit for Wildfires' for guidance). -If school is in session, refer to the 'Public Health Guidance for School Outdoor Activities during Wildfire Events' [206].	*Follow recommended actions to the left and above, plus*: -In the release, include consideration of sensitive groups leaving area until air quality improves or if that is not feasible, using air cleaner at home or spending time in a clean air setting in the community (e.g., air conditioned library). -Consider opening a clean air shelter for sensitive groups.
Unhealthy (56–150 µg/m³)	**1 – 3 miles**	*Above, plus*: -Consider cancelling outdoor public events. -Recommend public limit strenuous outdoor activities. -Recommend that sensitive groups consider leaving the area until air quality improves. If they can't, recommend spending time in a clean air setting in the community or shelter-in-place.	*Follow recommended actions to the left and above, plus*: -Open and publicize clean air shelters for sensitive groups. -Review health benefits for sensitive groups of leaving area until air quality improves, and that intermittent time in clean-air shelters or sheltering in-place might not be as protective.
Very Unhealthy (151–250 µg/m³)	**1 mile**	*Above, plus*: -Cancel outdoor public events. -If school is in session, measure indoor air quality if possible, discuss school closure with school administrators. -Recommend shelter-in-place for general population. -Share info about periods of improved air quality to guide essential outdoor activity and ventilation of dwellings.	*Follow recommended actions to the left and above, plus*: -Open and publicize clean air shelters for sensitive groups.
Hazardous (>251 µg/m³)	**<1 mile**	*Above, plus*: -Recommend voluntary evacuation for sensitive groups.	*Follow recommended actions to the left and above, plus*: -Open and publicize clean air shelters for the general public.

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Table 14. Episode stages, activation levels and emission reduction actions for air pollution emergencies in Oregon

Air Pollution Episode	Activation Level for PM (24-hour average)	Emission Reduction Actions
Pre-Episode Standby	PM levels are within standards or only moderately exceed standards	-Increased sampling frequency of particulates may be required during times of air stagnation or if ambient levels exceed ambient air standards.
Air Pollution **Alert**	$PM_{2.5}$: 140.5 µg/m^3 PM_{10}: 350 µg/m^3	-No open burning. -Public is requested to refrain from the use of uncertified woodstoves and fireplaces.
Air Pollution **Warning**	$PM_{2.5}$: 210.5 µg/m^3 PM_{10}: 420 µg/m^3	In addition to above: -Prohibit use of woodstoves and fireplaces (except if sole source of heat). -Reduce emissions as much as possible. -Use of incinerators for disposal of solid or liquid waste is prohibited.
Air Pollution **Emergency**	$PM_{2.5}$: 280 µg/m^3 (**2-hour average**) PM_{10}: 500 µg/m^3 (**2-hour average**)	In addition to above: -Prohibit all use of woodstoves and fireplaces. -Cease non-essential business/government operations. -Prohibit non-essential operation of motor vehicles. -Reduce heat in occupied spaces and turn off heat to all other spaces.

(adapted from [207-209])

3.2 Mitigation of Wildfire Smoke (Reduction of Hazardous Fuels)

The following section reviews two practices used to mitigate wildfire smoke: prescribed fires and management of existing wildfires. As these practices also lead to smoke production, they must be managed properly to ensure that burning occurs only under favourable conditions. This section also discusses the vegetation management strategies recommended as part of Alberta's FireSmart Program.

3.2.1 Prescribed Fires

Prescribed fires are planned, controlled fires that are used to achieve natural resource management objectives, and offer a preventative approach to managing wildfire smoke [210]. Prescribed fires, also known as hazard reduction burns, reduce the build-up of hazardous fuels in areas at risk of wildfire, which helps to reduce the size and intensity of any future wildfires. Prescribed fires produce less smoke than equivalent wildfires, as burns are shorter, less intense and planned for periods when smoke emissions would be minimized [10, 211].

Smoke produced from prescribed fires must be managed responsibly to prevent negative impacts on health and safety, air pollution and visibility [212, 213]. These impacts are minimized by conducting prescribed fires under carefully selected fuel and weather conditions. Factors influencing the production of smoke include fuel type, relative moisture of fuels (greenness), burning techniques, humidity, temperature, wind and air mass stability [212, 214]. Table 15 describes the favourable and unfavourable conditions for each of these factors. Smoke modeling programs, such as the BlueSky Playground web application, utilize fuel and weather information to estimate the emissions and projected pathways of smoke from prescribed fires [215, 216]. This helps determine the potential impact of smoke on air quality and the optimal conditions for burning.

Approval for a prescribed burn requires submission of a burn plan to the appropriate local, provincial or state wildfire management agency [213, 217, 218]. A burn plan documents all details of the burn, smoke emissions, nearby sensitive areas (towns, cities) and public notification procedures. In the United States, the 'Interagency Prescribed Fire Planning and Implementation Procedures Guide', published by the National Wildfire Coordinating Group, describes standardized procedures for planning and implementing prescribed fires, including the specific elements required for a burn plan [219].

Other important factors to consider in the management of smoke from prescribed fires are public awareness and public communication. Smoke tolerance has been found to increase with community preparedness and public knowledge of the smoke origin, steps taken to reduce smoke impacts and the ecological benefits of wildfire [28]. For example, a recent study of residents in Montana, Idaho, Texas and Louisiana found public tolerance of smoke to be significantly influenced by knowledge of origin of the smoke and advance public warning [220]. In terms of communication methods, a 2012 mail survey conducted in four sites across the United States found the most useful forms of public smoke communication to be official websites, public service announcements, road signage and conversations with agency personnel [221].

3.2.2 Management of Existing Wildfires

There are two main options for management of active natural wildfires: suppressing the fire, or managing the fire for resource benefit. Managing fires for resource benefit allows the natural ecological benefit of fires to be maintained [222]. Additionally, managing fires helps to remove build-up of hazardous surface fuels, thereby reducing future wildfire potential. In the United States, wildfire response may be referred to as 'managing wildfires for multiple objectives'; this strategy emphasizes the use of both fire suppression and managing the fire for resource benefit in wildfire response to satisfy protection and resource objectives [223].

Table 15. Factors influencing production of smoke during prescribed fires

Fuels and Burning Techniques	
Fuel type	-Finer fuels (e.g., leaves, grass) produce less smoke compared to heavier woodland or timber fuels (e.g., logs, branches, shrubs). -Fuels in open areas (e.g., grass) tend to have more rapid smoke dispersion compared to woodlands. Canopies can reduce air movement and trap smoke, resulting in a lingering of smoke in the area.
Relative moisture (greenness)	-Fuels with a higher moisture content will produce more smoke and a darker dense smoke, which can be more irritating to those exposed. -Prescribed burns occurring during the dormant season, when less moisture is present in fuels, will produce less smoke.
Presence of noxious or irritating plants	-Smoke from plants such as poison ivy may cause severe reactions to fire personnel.
Burning technique	**Backing fire** (fire burns perpendicular to wind direction or downslope) -Fire moves slowly through the fuelbed area, and burns hotter with more complete combustion of fuels. The resulting smoke is finer, lighter and less dense. **Headfire** (fire burns with wind or upslope) -Fire moves rapidly through the fuelbed area, with less heat, and less complete combustion of fuels. The resulting smoke is thicker and darker, and can be more irritating to people; however, smoke is produced for a shorter time period. **Flank fire** (fire burns parallel to wind or slope; includes both backing fire and headfire) -Smoke produced is a mixture of smoke from backing fires and headfires.
Weather	
Relative humidity **Temperature**	-Days with lower humidity and warmer temperatures tend to produce relatively less smoke than cooler, damper days. However, fire behaviours in warm dry conditions may be more difficult to manage.
Wind	-The direction/speed of winds at the surface (ground level) and aloft influence smoke dispersion. -Winds speed helps disperse smoke plumes; however, strong surface winds keep smoke low to the ground. -Prescribed burns should occur on days with persistent winds from a constant direction, with wind direction moving smoke away from sensitive areas (towns, cities). -Wind should move smoke away from power lines (dense PM can create an arc of electricity between power lines, potentially shorting them out).
Air mass stability	-Smoke tends to rise and disperse more favourably in unstable air mass conditions; this usually occurs under lower atmospheric pressure. -Smoke may be trapped near the ground in stable air mass conditions; this usually occurs under higher atmospheric pressure.

(adapted from [212, 214])

A decision to suppress a fire or let it burn out naturally will depend on the area of the fire and the priorities of the government agency responsible for managing the fire [224]. Fires occurring near residential areas, critical infrastructure, high-value commercial forests and recreational sites will typically be suppressed, while fires in wilderness parks and remote forests may be allowed to burn out. The decision involves consideration of weather and smoke forecasts, expected fire behaviour, public and firefighter safety, availability of resources and the potential impact on air quality and public health [185, 222].

3.2.3 Alberta FireSmart Program

The Government of Alberta's *FireSmart Guidebook for Community Protection* ("FireSmart Guidebook") discusses various proactive measures that Alberta communities can use to reduce the risk of wildfire [225]. The FireSmart Guidebook focuses on wildfire preparedness in communities, as well as wildfire mitigation strategies (including prescribed fires and management of existing wildfires).

The FireSmart Guidebook recommends various vegetation management strategies to reduce wildfire potential, including fuel removal, fuel reduction and species conversion (to less flammable species). Removal or reduction of wildland fuel may be achieved by harvesting, mulching, mowing, grazing, removing flammable tree species, pruning low lying limbs or participating in prescribed fires. Prescribed burning may be used on a regular basis to manage buildup of fine fuels (e.g., annual burning of dry grasses).

Species conversion (i.e., replacing flammable vegetation species with less flammable species) is recommended to reduce the flammability of surrounding vegetation. This may be achieved through the establishment of parks, open spaces, recreational fields and golf courses, or through forest management and land disposition planning. Flammability may also be reduced by irrigating and maintaining grassy areas and deciduous trees near structures.

For management of existing wildfires, the FireSmart Guidebook indicates that while protection of the public and communities is the main priority, allowing naturally-occurring wildfires to burn in certain scenarios may be used to achieve resource benefit objectives.

3.3 Summary

This chapter summarizes the practices and guidelines used in the management of smoke from wildfires, focusing on responses to smoke events and reduction of hazardous fuels.

For smoke response plans, the provinces and states reviewed tended to follow similar guidelines and protocols. The main components of the guidelines were PM monitoring (using existing monitors and portable monitors), smoke forecasting (using BlueSky and FireWork) and public health warnings and actions.

With regard to public health warnings and actions, responses for the provinces/states tended to be similar for equivalent health risk categories. For example, *Moderate* categories typically

trigger public health warnings or advisories and suggestions on how to reduce exposure to smoke. *Unhealthy* categories tend to trigger the consideration of school closures and cancellation of events. *Very Unhealthy* and *Hazardous* categories trigger the closure of schools and non-essential workplaces, cancellation of events and consideration of evacuations. Table 16 compares the PM concentrations and visibility distances used for each health risk category in six jurisdictions (British Columbia (BC), Manitoba (MB), Newfoundland and Labrador (NL), Northwest Territories (NT), California (CA) and Oregon (OR)).

The guidelines reviewed stressed the importance of coordination between involved agencies and effective communication with the public. In California, Idaho and Oregon, special smoke-related websites ('smoke blogs') are used as 'one stop' resources for all information related to wildfires, smoke conditions, school and activity closures, burn bans, location of clean air shelters, travel restrictions and evacuations. Similarly, the Province of BC hosts an Emergency Info website to relay air quality advisories and emergency preparedness information. These websites help to ensure the public has access to complete and coordinated information.

As a proactive approach to managing wildfire smoke, hazardous fuels reduction to lower the potential for future wildfires is an important element of smoke management plans. This can be achieved through prescribed fires or by managing an existing naturally-occurring fire. In both cases, fires are selected to burn in conditions that minimize production of smoke and the impact on air quality in sensitive areas. The decision to burn or not burn is based on several influencing factors, including fuel type, greenness of fuels, temperature, humidity, wind speed and wind direction. Other vegetation management strategies include physical removal or reduction of wildland fuel (by harvesting, mulching, mowing, grazing, removing flammable tree species or pruning low lying limbs) and vegetation species conversion (to less flammable species).

Providing the public with relevant information, in a clear and effective manner, is critical during smoke events. Public tolerance for smoke may be influenced by community preparedness and advance public warning of smoke, as well as public knowledge of smoke origin, steps taken to reduce smoke impacts and the ecological benefits of wildfire. An understanding of the range of public opinions toward smoke, and the attitudes and values of the residents, can be used to tailor smoke management plans to the needs of the community.

Table 16. Summary of PM concentration ranges and visibility distances for different health risk categories

Risk Category	Time Range	PM Concentration Range	Visibility Distance
Moderate / Unhealthy for sensitive groups	**1- to 3-hour average**	39 – 138 µg/m^3 *(NL)* 41 – 175 µg/m^3 *(MB, NT)*	5 – 16 km *(NL)* 5 – 14 km *(MB, NT)*
	3-hour average	15 – 65 µg/m^3 *(BC)*	8 – 35 km *(BC)*
	24-hour average	12.1 – 55.4 µg/m^3 *(CA, NL)* 13 – 55 µg/m^3 *(OR)*	5 – 16 km *(NL)* 5 – >8 km *(OR)*
Unhealthy or High	**1- to 3-hour average**	139 – 350 µg/m^3 *(NL)* 176 – 300 µg/m^3 *(MB, NT)*	2.4 – 4.4 km *(NL)* 2.5 – 4 km *(MB, NT)*
	3-hour average	65 – 150 µg/m^3 *(BC)*	3.5 – 8 km *(BC)*
	24-hour average	55.5 – 150.4 µg/m^3 *(CA, NL)* 56 – 150 µg/m^3 *(OR)*	2.4 – 4.4 km *(NL)* 1.6 – 5 km *(OR)*
Very Unhealthy or Very High	**1- to 3-hour average**	351 – 526 µg/m^3 *(NL)* 301 – 500 µg/m^3 *(MB, NT)*	1.6 – 2 km *(NL)* 1.5 – 2 km *(MB, NT)*
	3-hour average	> 150 µg/m^3 *(BC)*	<3.5 km *(BC)*
	24- hour average	150.5 – 250.4 µg/m^3 *(CA, NL)* 151 – 250 µg/m^3 *(OR)*	1.6 – 2 km *(NL)* 1.6 km *(OR)*
Hazardous	**1- to 3-hour average**	>526 µg/m^3 *(NL)* >500 µg/m^3 *(MB, NT)*	<1.6 km *(NL)* <1 km *(MB, NT)*
	24-hour average	>250.5 µg/m^3 *(CA, NL)* >250 µg/m^3 *(OR)*	<1.6 km *(NL)* <1.6 km *(OR)*

Based on guidance documents from six jurisdictions: British Columbia (BC), Manitoba (MB), Newfoundland and Labrador (NL), Northwest Territories (NT), California (CA) and Oregon (OR) [13, 186, 190, 193, 195, 202].

Chapter 4: Overall Summary

Wood smoke is a major contributor to air pollution in Alberta. Exposure to wood smoke has been linked to several health effects, ranging from eye irritation and coughing to exacerbation of respiratory conditions and premature mortality. This report summarizes various management options for regulating wood smoke from two important sources: recreational fires and wildfires. Current regulations used in jurisdictions across Canada and the United States are discussed.

4.1 Recreational Fires

There are a number of different management options that can be used to regulate smoke from recreational fires. The strictest regulation is a complete ban of wood-burning fire pits and fireplaces; this is utilized in the three largest cities in Canada (Montreal, Toronto, Vancouver), as well as several smaller cities (e.g., Kelowna, Surrey, Waterloo).

There are many jurisdictions that prohibit recreational fires when air quality advisories are in effect. In Canada, these regulations are found in Ontario (e.g., Burlington, Mississauga, Oakville) and British Columbia (e.g., Houston, Prince George). In areas of California, Oregon and Washington, recreational fires are not allowed during wood-burning bans, which are issued when ambient $PM_{2.5}$ levels are expected to exceed air quality standards.

For managing smoke complaints, many bylaws state that smoke from fires is not to create a nuisance (the definition of which varies between jurisdictions), and that fires may be ordered extinguished if there are smoke complaints from neighbours.

Common regulations used to manage recreational fires include: allowing fires for the purpose of cooking only, allowing fires in fireplaces only and restrictions on size of fire, site of fire, permitted and prohibited fuels, wind conditions and time of day. Other management options used less frequently were those involving restrictions on frequency of usage, duration of fire, season of use, outside temperature and ventilation index.

In some cases, residents may not be aware of the bylaws governing fire pits and fireplaces; for this reason, first-time violators of a bylaw may be issued warnings, rather than fines, along with information about the bylaws.

Improved public awareness of the health effects of wood smoke and cleaner burning practices may help improve air quality and reduce nuisance issues related to recreational fires. Informing residents that propane and natural gas are cleaner, healthier fuel alternatives may promote the use of these fuels instead of wood for recreational fires.

A recreational fire/wood smoke awareness program may include information such as:

- Plain language summary of the bylaws governing recreational fires;

- The process for reporting smoke and nuisance complaints;
- The health effects of wood smoke;
- Tips on proper burning techniques to limit wood smoke (e.g., burn small hot fires, use wood that has been dried for at least 6 months); and
- Suggestions for cleaner alternatives to wood fires (gas or propane-fuelled appliances).

Some jurisdictions have incorporated public education requirements into their recreational fire regulations. For example, in some areas of California, sellers of wood-burning devices are required to provide to the purchaser a fact sheet outlining the health effects of wood smoke. Additionally, first-time violators of an air quality burn ban may opt to complete an online or written wood smoke awareness course instead of paying a US$50 fine.

Regardless of the methods used, educating the public in matters related to recreational fires and wood smoke should be an important component of recreational fire management strategies. Public knowledge of the health effects of wood smoke also helps with gaining support from the community for implementing changes to recreational fire regulations [163].

4.2 Wildfires

Smoke management guidelines and protocols were reviewed for seven provinces and states (British Columbia, Manitoba, Newfoundland and Labrador, Northwest Territories, California, Idaho and Oregon). From the review of these jurisdictions, the key aspects of wildfire smoke management relate to the public health response to smoke events (reducing public exposure to smoke during wildfire events) and smoke prevention (mitigation of wildfire smoke by reducing hazardous fuels).

For smoke response plans, the main components include:

Air quality: The main tools used to assess air quality and communicate health risk information to the public are the AQHI in Canada and the AQI in the United States. Health categories for the indices range from 'Low risk' to 'Very high risk' for the AQHI and 'Good' to 'Hazardous' for the AQI. The main pollutant of concern in wildfire smoke is PM. During a wildfire smoke event, air quality assessments may be supplemented by additional $PM_{2.5}$ and/or PM_{10} information, using existing ambient air monitors and portable monitors. PM concentrations can be converted to a corresponding AQHI (or AQI) health risk category. In cases where PM monitoring is not available or not up-to date, a visibility index may be used to approximate PM level and health risk.

Smoke forecasting: A smoke forecasting system provides advance notice of the estimated intensity and duration of smoke exposure in affected communities. There are two different systems used in Canada: BlueSky and FireWork. Both systems use computer modeling to produce animated smoke forecasts for up to 48 hours into the future. Results are published on national websites throughout the wildfire season (April to

September/October).The data are used to inform decisions regarding public health alerts and recommended actions to reduce smoke exposure.

Public health warnings and actions: For the jurisdictions reviewed, the public messages and actions in response to smoke tended to be similar for equivalent health risk categories. For example, *Moderate* categories typically trigger public health warnings or advisories, with suggestions on how to reduce exposure to smoke. *Unhealthy* categories tend to trigger the consideration of school closures and cancellation of events. *Very Unhealthy* and *Hazardous* categories tend to trigger the closure of schools and non-essential workplaces, cancellation of events and consideration of voluntary evacuations for sensitive populations.

With regard to preventative approaches for managing wildfire smoke, the reduction of hazardous fuels to lower the potential for future wildfires is typically incorporated into fire or smoke management plans. This can be achieved through prescribed fires or by managing an existing naturally-occurring fire. In both cases, fires are selected to burn in conditions that minimize production of smoke and the resulting impact on air quality in sensitive areas. The decision to burn or not burn is based on several influencing factors, including fuel type, greenness of fuels, temperature, humidity, wind speed and wind direction. Other vegetation management strategies include physical removal or reduction of wildland fuel (by harvesting, mulching, mowing, grazing, removing flammable tree species or pruning low lying limbs) and vegetation species conversion (to less flammable species).

Two important aspects of smoke management are public awareness and public communication. Public tolerance for wildfire smoke is influenced by factors such as knowledge of origin of the smoke, advance public warning, community preparedness, personal and community health, and public knowledge of the steps taken to reduce smoke impacts. An understanding of the range of public opinions toward smoke, and the attitudes and values of the residents can help to tailor smoke management plans to the needs of the community.

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Appendix A: Summary of Regulations for Recreational Fires in Canada

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Alberta						
Airdrie [Bylaw B-13/2008]	Fire pit is ≥3 m from any building, property line or combustible material; (≥1 m for Fireplace)	-Fire pit opening ≤1 m, Fire pit height ≤0.6 m above surrounding grade -Fireplace base of burning area is ≥0.3 m above surrounding grade -Fireplace burning area is ≤1.25 m wide and 0.4–0.6 m deep -Fireplace chimney extends ≥2.5 m above base of fire burning area	No	-	-Fires are prohibited when a fire ban is in effect.	[29, 41]
Banff [Bylaw 260]	Fire pit is ≥3 m from any building/structure and ≥2 m from any combustible material; (≥2 m for Fireplace)	-Fire pit opening ≤1 m, Fire pit height ≤0.75 m above surrounding grade -Flames do not exceed 1 m	No	-The Nuisances bylaw states that "No owner or occupier of a premises shall engage in an activity likely to allow smoke, dust or other airborne matter likely to disturb another person, to escape the premises without taking precautions to ensure that the smoke, dust or other airborne matter does not escape the premises."	-Fires are prohibited when a fire ban is in effect.	[42]
Calgary [Bylaw 5M2004]	≥2 m from any building, combustible material or trees/branches	-Fire pit opening ≤1 m, Fire pit height ≤0.75 m above floor of fire pit -Flames do not exceed 1 m	No	-Fires prohibited from 12 am to 10 am (weekdays) and 1 am to 10 am (weekends); -Citizens should not engage in any activity that is likely to allow smoke, dust or other airborne matter, which may disturb any other person, to escape a premises without taking reasonable precautions.	-Fires are prohibited when a fire ban is in effect.	[39, 226, 227]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Carstairs [Bylaw 838]	Fire pit is ≥3 m from any building, property line or combustible material; (≥1 m for Fireplace)	-Fire pit opening ≤1 m, Fire pit height ≤0.6 m above floor of fire pit -Fireplace base of burning area is ≥0.3 m above surrounding grade -Fireplace burning area is ≤1.25 m wide and 0.4–0.6 m deep -Fireplace chimney extends ≥2.5 m above base of fire burning area.	No	-Fires shall not create a nuisance that is offensive to others (defined as "the causing of opaque or dense smoke by or from any fire…and permitting such smoke to be emitted into the atmosphere for a period in excess of 6 minutes in any 1 hour").	-	[46]
Edmonton [Bylaw 14600]	Fire pit is ≥3 m from any building, property line or combustible material; (≥1 m for Fireplace)	-Fire pit opening ≤1 m, Fire pit height ≤0.6 m above surrounding grade -Fireplace base of burning area is ≥0.3 m above surrounding grade -Fireplace burning area is ≤1.25 m wide and 0.4–0.6 m deep -Fireplace chimney extends ≥2.5 m above base of fire burning area	No	-The bylaw states that "a person shall not cause or permit an outdoor fire…that is reasonably likely to disturb the peace of any other individual"; -The production of excessive smoke is considered a nuisance; -The city website states that fires should be small and burn clean, dry fuels to limit the smoke drifting on to neighbours' properties.	-Fires are prohibited when a fire ban is in effect.	[38, 44]
Grande Prairie [Bylaw C-1312]	≥3 m from all combustible material	Fire pit opening ≤1 m	Yes	-The fire department will extinguish fires if smoke is a nuisance to other properties.	-	[34, 228]
Leduc [Bylaw 351-95]	Fire pit is ≥3 m from any building, property line or combustible material; (≥1 m for Fireplace)	-Fire pit opening ≤1 m, Fire pit height ≤0.6 m above surrounding grade -Fireplace base of burning area is ≥0.3 m above surrounding grade -Fireplace burning area is ≤1.25 m wide and 0.4–0.6 m deep -Fireplace chimney extends ≥2.5 m above base of fire burning area	No	-The city website advises that fire pit users note where the wind is taking the smoke and suggests avoiding having a fire if the smoke is entering a neighbour's house.	-	[229, 230]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Lethbridge [Bylaw 5858]	≥1.5 m from any structure or combustible material	-Fire pit opening ≤1 m, Fire pit height ≤0.75 m above floor of fire pit -Flames do not exceed 1 m	No	-Fires prohibited from 1:30 am to 8 am; -The city website advises that fire pit users take precautions to prevent smoke from disturbing neighbours.	-Fires are prohibited when the wind is >30 km/h; -fires are prohibited when a fire ban is in effect.	[30, 40]
Medicine Hat [Bylaw 2703]	≥3 m from any building, property line, vegetation or combustible material; Backyard only	-Fire pit opening ≤0.9 m, Fire pit height ≥0.45 m above ground level	Yes	-A permit may be revoked if, in the opinion of the fire department, the fire or smoke creates a nuisance for other property owners.	-	[35, 156]
Red Deer [Bylaw 3387/2007]	≥3 m from any building, property line, vegetation or combustible material	-Fire pit opening ≤1 m, Fire pit height ≤0.75 m above floor of fire pit -Flames do not exceed 1 m	No	-Fires shall not create a nuisance that is offensive to others.	-Fires are prohibited when a fire ban is in effect.	[31, 231]
St. Albert [Bylaw 21/2002]	≥3 m from any building/structure, property line or vegetation; Backyard only	-Fire pit opening ≤0.61 m, Fire pit height ≥0.45 m above floor of fire pit -Flames do not exceed 1 m.	Yes	-Fires may be ordered extinguished if smoke from the fire creates a nuisance for other property owners.	-	[36, 45]
Wood Buffalo [Bylaw 01/084]	≥3 m from property line, ≥2 m from any combustible material, ≥0.6 m from underground utility.	-Fire pit opening ≤1 m	Yes (fire pit) No (portable fireplace)	-The emitting of opaque or dense smoke into the atmosphere for more than 6 minutes in any 1-hour period is considered a nuisance.	-Fires are prohibited when a fire ban is in effect.	[37, 43, 47]
British Columbia						
Abbotsford [Bylaw 1513]	-	-	-	-Fire pits and fireplaces are prohibited.	-	[52, 53]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Burnaby [Bylaw 11860]	-	-	-	-Fire pits and fireplaces are prohibited.	-	[54]
Chase [Bylaws 730 and 800]	No burning is to occur near standing timber, bush, buildings or flammable material (specific distances not indicated).	-Fire pit opening ≤0.5 m -Fire area may not exceed 1 m (diameter) and 1 m (height)	Yes	-Fires are not to create excessive smoke (defined as "any visible smoke persistently crossing the property line of the subject fire, not including initial start up or extinguishing of the fire").	-Fires are prohibited during high winds; and -Fires are prohibited when a fire ban is in effect.	[66, 232]
Houston [Bylaw 947]	-	-Fire pit opening ≤0.9 m	No	-Fires are prohibited if an air quality advisory has been issued.	-	[64]
Kamloops [Bylaw 10-37]	≥5 m from any structure; permitted only on properties ≥0.4 hectare (1 acre).	-Fire area may not exceed 0.6 m (diameter) and 0.5 m (height)	Yes	-Fires are permitted for cooking only; -Fires are to be extinguished by 10 pm; -Fires shall not burn for more than 3 hours; -A permit may be refused or revoked if the fire or smoke creates a nuisance.	-	[60]
Kimberley [Bylaw 2364]	≥3 m from any structure, fence or combustible material.	-Fire pit opening ≤0.6 m, Fire pit height ≥0.45 m above floor of fire pit.	Yes	-Fires are permitted for cooking only; -Fires allowed between 3:30 pm and 11 pm; -Fires are prohibited if an air quality advisory has been issued.	-Fires are prohibited when a fire ban is in effect.	[61, 233]
Prince George [Bylaw 8266]	≥3 m from any building, property line or vegetation.	-Fire area may not exceed 0.6 m (diameter)	No	-Fires are prohibited if an air quality advisory has been issued.	-	[63, 67]
Okanagan-Similkameen Regional District [Bylaw 2364]	≥5 m from any building or property line, ≥3 m from any combustible material.	-Fire pit opening ≤1 m, Fire pit height ≥0.30 m above floor of fire pit -Fire area does not exceed 0.75 m (diameter) and 0.75 m (height)	No	-Fires prohibited between 12 am and 6 am; -Fires are not to cause a nuisance (defined as "the emission into the atmosphere of smoke by any means, which disturbs the comfort or convenience of persons in the vicinity").	-Fires are prohibited when a fire ban is in effect.	[62]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Richmond [Bylaw 8306]	-	-	-	-Fire pits and fireplaces are prohibited.	-	[56]
Surrey [Bylaw 10771]	-	-	-	-Fire pits and fireplaces are prohibited.	-	[57, 58]
Vancouver [Bylaw 8191]	-	-	-	-Fire pits and fireplaces are prohibited.	-	[49-51]
Victoria [Bylaw 96-10]	-	-	-	-Open air fires are prohibited.	-	[59]
Manitoba						
Brandon [Bylaw 6476]	≥1.5 m from any building, property line or combustible material.	-Fire pit opening ≤0.61 m, Fire pit height ≤0.36 m above surrounding grade	Yes	-Fires are to be extinguished if smoke from a fire causes unreasonable interference to another person's property.	-Fires are prohibited in windy conditions.	[71, 234]
Springfield [Bylaw 16-18]	≥3 m from any building, property line or combustible material.	-	No	-Smoke from fires shall not impact on neighbouring properties by releasing offensive odours that are annoying, unpleasant or a nuisance.	-Fires are prohibited in severe wind conditions.	[69]
Winkler [Bylaw 2079-12]	≥3 m from any building, property line or combustible material.	-Fire pit opening ≤0.91 m, Fire pit height ≤0.61 m	No	-Fires may be ordered to be extinguished if there are smoke complaints; and -Users are to obtain permission from neighbours if smoke travels into their yard.	-Fires are prohibited when the wind is >25 km/h.	[70, 235]
Winnipeg [Bylaw 1/2008]	≥3 m from any building, fence, tree, overhead wires or combustible material.	-Fire pit opening ≤0.75 m, Fire pit height 0.15–0.6 m above surrounding grade -Fire area does not exceed 0.75 m in any direction -Fireplace side opening ≤0.75 m	No	-	-Fires are prohibited when the wind is >25 km/h.	[68, 236]
New Brunswick						

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Dieppe [Bylaw S-12]	≥6 m from any main building on an adjacent property, ≥3 m from any main building, vegetation, roadway, overhead wire or combustible material	-Fire area may not exceed 1 m in any direction	Yes	-Fires are allowed between 4 pm and 12 am.	-Fires are allowed from April (3rd Monday)–Oct 31; and -Fires are prohibited when a fire ban is in effect.	[76, 160]
Fredericton [Bylaw S-2]	-	-Fireplace only	Yes	-	-	[74, 237]
Moncton [Bylaw H-602]	≥3 m from any building/structure, property line, vegetation, roadway, overhead wire or combustible material	-Fireplace only; Fire area may not exceed 1 m in any direction	No	-Smoke, smell, airborne sparks or embers from the fire are not to infringe on the use and enjoyment of other properties.	-	[75, 238]
Saint John [Bylaw number not found]	≥15 m wooded area, ≥3 m from tall grass, ≥1.5 m from any combustibles	-	No	-	-Fires are prohibited in windy conditions.	[72]
Shediac [Bylaw F-13-50]	Fire pit is ≥6 m from any building, ≥4 m from any roadway or combustible material, and ≥3 m from any accessory building; Fireplace is ≥4 m from any building, and ≥3 m from any accessory building, roadway or combustible material	-Fire pit opening ≤0.6 m, Fire pit height 0.3–0.6 m -Fireplace fire area may not exceed 1 m in any direction	Yes	-Fires allowed between 6 pm and 11 pm (4 pm–11 pm for fireplaces); -Fire pit fires are prohibited if wind direction causes smoke to create a discomfort to neighbours; -Fires shall not interfere with a person's reasonable and comfortable use and enjoyment of property and should not impede the traffic, through the emission of offensive or annoying smoke or ash.	-Fires are allowed from April (3rd Monday)–Oct 31; -Fires are prohibited when a fire ban is in effect.	[73]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Newfoundland and Labrador						
Labrador City [Open Air Burning Regulations]	≥4.6 m from any combustible material; Permitted in backyard only	-Fireplace only	Yes	-Smoke, smell, airborne sparks or embers shall not infringe on the use and enjoyment of other properties or become a nuisance (defined as "any obnoxious substance, smoke or other unsanitary matter that has an unpleasant effect on the senses or affects an individual's health, well-being or property").	-Fires are prohibited in high wind conditions; -fires are prohibited when a fire ban is in effect.	[78]
Mount Pearl [Open Air Burning Regulations]	≥3 m from any combustible material	-Fireplace only	No	-Fires shall not become a nuisance to neighbours (defined as "any obnoxious substance, smoke or other unsanitary matter that has an unpleasant affect on the senses or affects an individual's health and well-being").	-Outdoor fires are prohibited in any area within the city designated as a "no burn zone"; -Fires are prohibited when a fire ban is in effect.	[77]
Paradise [Open Air Burning Regulations]	≥3 m from any combustible material	-Fireplace only	No	-Smoke, smell, sparks or embers shall not infringe on the use and enjoyment of other properties or become a nuisance (defined as anything that endangers health, gives offence to the senses, or obstructs the comfortable use of property).	-Fires are prohibited when a fire ban is in effect.	[79]
St. John's [Bylaw 1306]	≥3 m from any building/structure or combustible material	-Fireplace only	No	-Smoke is not to cause an annoyance to adjacent properties.	-Fires are prohibited when the wind is >25 km/h; -Fires are prohibited when a fire ban is in effect.	[80]
Nova Scotia						

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Cape Breton Regional Municipality [Bylaw B-400]	≥15 m from combustible material; Permitted in rural areas only	-	Yes	-Fires are allowed between 8 am and 9 pm; -In the larger cities (e.g., Sydney, Glace Bay), fires are prohibited except for cooking fires; -In the rural areas, fires require a permit except for cooking fires	-Fires not permitted in windy conditions .	[81]
Halifax Regional Municipality (Permit required zone) [Bylaw O-109]	≥4.75 m from any structure or property line	-Fireplace only	No	-Fires are prohibited between 12:01 am and 2 pm (Mar 15–Oct 15) and 12:01 am and 8 am (Oct 16–Mar 14); -Fire pits are prohibited in the 'Permit required zone' (areas serviced by municipal water and sewer); -Fireplace burning is not permitted from Mar 15–Oct 15 in the 'Permit required zone'; and -Use of fire pits and fireplaces is allowed year-round in the 'No permit required zone.'	-Fires should not be ignited in windy conditions; -Fires are prohibited when a fire ban is in effect.	[82]
Halifax Regional Municipality (No permit required zone) [Bylaw O-109]	≥4.75 m from any structure or property line	-Fire pit: Material being burned does not exceed 0.5 m (diameter)	No			
Pictou [Outdoor Fire Bylaw]	≥7.6 m from any building/structure, property line or combustible material	-	No	-Fires are not to create a nuisance (defined as the causing of any smoke that adversely affects the reasonable enjoyment by other persons of their property); -The Fire Chief shall order extinguished any fire with a smoke opacity exceeding 20%, or if the fire causes a nuisance exceeding 2 minutes in succession except during start-up.	-Fires are prohibited in windy conditions.	[84]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Truro [Bylaw B140-001]	Fire pit is ≥5 m from any building/structure, property line or combustible material; Fireplace is ≥5 m from any building, ≥1 m from any wooden surface (not fire-proofed)	-Fire pit opening ≤1 m	No	-Fires are not to create a nuisance (defined as any "unreasonable interference with a neighbouring property owner's enjoyment of his or her property").	-	[85]
Ontario						
Burlington [Ontario Reg. 213/07]	-	-	Yes	-Fires are prohibited in urban areas (except small, confined cooking fires); -fires are prohibited when a smog alert has been declared.	-Fires are prohibited when a fire ban is in effect.	[86, 92]
Hamilton [Bylaw 02-283]	≥3 m from any building or combustible material	-Fire pit diameter ≤0.6 m	Yes	-Fires are prohibited in urban areas (except small, confined cooking fires); -Fires are prohibited when a smog alert has been declared; -Burning is prohibited when winds will cause smoke to be a safety hazard or annoyance to nearby properties or roadways; and -Permits may be revoked if smoke complaints are received.	-	[93, 102]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Kitchener [Chapter 711]	≥5 m from any building/structure, property line, vegetation, roadway, overhead wire or combustible material	-Material being burned does not exceed 1 m in any direction	No	-Fires are allowed between 6 pm and 11 pm; -Fires are not to create a nuisance (defined as "smoke, smell, airborne sparks, ash, particles or embers that are likely to disturb a person, are likely to interfere with the enjoyment or use of a property, or negatively and unreasonably affect a person due to a medical condition").	-	[94, 95]
London [Bylaw F-7]	≥4 m from any building/structure, property line, vegetation, roadway, overhead wire or combustible material	-Material being burned does not exceed 0.46 m (diameter) and 0.3 m (height)	No	-Fires allowed between 11 am and 12 am (4 pm to 12 am for non-cooking fires); -Fires shall not create a nuisance (defined as "excessive smoke, smell, airborne sparks or embers that is likely to disturb others, or that is likely to reduce visibility on roads").	-	[96]
Mississauga [Bylaw 49-03]	≥5 m from any building/structure, property line, fence, vegetation, roadway, overhead wire or combustible material	-Fire pit opening ≤0.3 m, Fire pit height ≤0.3 m -Fireplace fire area may not exceed 1 m in any direction	No	-Only fireplaces and cooking fires allowed, and only between sunrise and 11 pm; -Fires are prohibited when a smog alert has been declared; -Fires shall not create a nuisance (defined as "excessive smoke, smell, airborne sparks or embers that is likely to disturb others").	-Fires are prohibited when the wind exceeds 24 km/h.	[100, 104]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
North Bay [Bylaw 2015-115]	≥6 m from any property line, ≥2 m from any combustible material	-Fireplace dimensions not to exceed 0.61 m by 0.61 m, or a volume of 0.26 cubic metres	Yes	-Fres allowed between 7:30 pm and 1 am; -Fires are prohibited when a smog alert has been declared; -Fires are not to create a nuisance (defined as a fire which "causes discomfort, irritation or danger to any person occupying in the area of the fire through sparking, smoke or unpleasant odour from the fire").	- Fires are prohibited when the wind exceeds 15 km/h; -Fires are prohibited when a fire ban is in effect.	[101, 239]
Oakville [Bylaws 2006-174 and 2014-044]	≥3 m from any combustible material or property line	-Fire pit opening ≤0.61 m, Fire pit height ≤0.21 m above floor of fire pit (max depth 0.42 m)	No	-Fires are allowed between 10 am and 11 pm; -Fires are prohibited when a smog alert has been declared; -Smoke and odour from the fire is to be contained to the property of origin and cannot impact a neighbours' ability to enjoy their property	-Fires are prohibited when the wind is >30 km/h.	[98, 99, 240]
Oshawa [Bylaw 73-2012]	>15 m from any building/structure or forested area; permitted only in rural areas on properties >10 acres	-Fire area may not exceed 1 cubic metre	Yes	-Fires are prohibited in the urban area; -Fires are prohibited between dusk and dawn; -Fires are prohibited in weather conditions that prevent the rapid dispersion of smoke.	-	[89, 241]
Ottawa [Bylaw 2004-163]	Fire pit is ≥10 m from any building, hedge, fence, overhead wiring, highway or combustible material; (≥5 m for Fireplace)	-Fire pit height ≥0.3 m; Fire area may not exceed 0.6 m (diameter) and 0.5 m (height) -Fireplace fire area may not exceed 1 m in any direction	Yes	-Fires are prohibited in urban/suburban areas.	-Fires are prohibited when a fire ban is in effect.	[90, 91]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Strathroy-Caradoc [Bylaw 17-12]	≥3 m from any combustible material or property line	-Fire pit opening ≤0.6 m	No	-Fires are allowed between 4 pm and 12 am; -Fires are prohibited when a "Poor Air Quality Advisory" has been issued (by Environment and Climate Change Canada or other recognized agency) -Fire users must ensure that adjacent properties are protected and that the by-products of fires do not have a negative impact on persons, pets or the environment.	-Fires are prohibited when the wind is >15 km/h.	[97]
Toronto [Ont Reg. 213/07]	-	-	-	-Fire pits and fireplaces are prohibited (under Article 2.4.4.4 of the Fire Code)	-	[86, 87]
Waterloo [2011-124]	-	-	-	-Fire pits and fireplaces are prohibited.	-	[88, 242]
Prince Edward Island						
Charlottetown [No Bylaw found]	-	-	-	-	-	-
Cornwall [Bylaw 221]	-	-Fireplace only	No	-	-	[106]
Stratford [Bylaw 30]	-	-Fireplace only; must be equipped with a chimney	No	-Fire pit for outdoor cooking allowed with prior written consent of the fire chief.	-	[105]
Summerside [No Bylaw found]	-	-	-	-	-	-
Quebec						

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Boucherville (Longueuil) [Reglement 1414]	-	-	-	-Fireplaces are prohibited. -Fire pits are also prohibited, as per the urban agglomeration of Longueuil.	-	[110]
Gatineau [Reglement 774-2015]	≥20 m from property line, ≥16 m from main buildings, ≥6 m from accessory buildings, ≥3 m from vegetation	-Permanent fireplace only	Yes	-Fires may be ordered extinguished if smoke is a bother to neighbours	-	[115, 159]
Laval [Reglements L-12137 and L-11465]	≥3.05 m from any building or property line, ≥1.5 m from trees, hedges or other combustible material; Backyard only	-Fireplace only; Fireplace height ≤3.05 m	No	-Fires are prohibited when smoke causes a major nuisance (the nuisance bylaw stipulates that emission of soot or smoke that disturbs one or more persons is prohibited).	-	[114, 118, 119]
Longueuil [Bylaw not found]	-	-	-	-Fire pits are prohibited in the urban agglomeration of Longueuil. -Regulation of fireplaces falls under the individual cities and boroughs (see Boucherville and Saint-Lambert).	-	[109]
Montreal [RCG 12-003]	-	-	-	-Fire pits and fireplaces are prohibited in the urban agglomeration of Montreal.	-	[107, 108]
Quebec City [RVQ 1207]	≥3 m from any building, property line or combustible material; Backyard or sideyard only	-Fireplace only; must be equipped with a chimney	No	-	-	[113, 158, 243]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Sainte-Julie [Reglements 1101 and 964]	≥6 m from property line, ≥4 m from main buildings, ≥2 m from accessory buildings or construction equipment	-Fireplace only	No	-Smoke or odour from a fireplace shall not disturb people or prevent the normal use of adjacent properties.	-	[116, 244]
Saint-Lambert (Longueuil) [Reglement 2006-19]	-	-Fireplace only	No	-Emission of dense smoke from a fireplace is considered a nuisance and prohibited. -Fire pits are prohibited, as per the urban agglomeration of Longueuil.	-	[111, 112]
Sherbrooke [Règlement no 1, Titre 5, chapitre 8]	≥6 m from any buildings, ≥3 m from property line or combustible material; Backyard or sideyard only	-Fireplace only	No	-Fires are not permitted during a smog episode.	-Fires are prohibited when wind is >20 km/h or when the Fire Weather Index is "Extreme."	[117, 245]
Saskatchewan						
Meadow Lake [Bylaw 15/2015]	≥3 m from any building/structure, property line or combustible material, and ≥6 m from the outside wall of any dwelling	-Size of fire pit does not exceed 0.76 m in any direction, or a volume of 0.91 cubic metres	Yes	-Fires are to be extinguished if the fire causes a nuisance (adversely affects neighbours' use and enjoyment of their property). -A permit may be revoked if the fire or smoke creates a nuisance.	-	[124]
Melfort [Bylaw 04-10]	≥3.1 m from any building/structure, property line or vegetation	-	Yes	-Fires are permitted for cooking only; -Fires are allowed between 8 am and 11 pm; -Fires are to be extinguished if smoke causes an unreasonable interference with the use and enjoyment of another person's property.	-Fires are prohibited in windy conditions; -Fires are prohibited when a fire ban is in effect.	[125]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Moose Jaw [Bylaw 5070]	≥3 m from any building, vegetation or combustible material	-Fireplace only; must have a chimney ≥0.6 m.	No	-Fires are prohibited, except for cooking fires in fireplaces, grills or barbecues.	-	[120, 126]
Prince Albert [Bylaw 22 of 2008]	≥2 m from any building/structure, property line or combustible material; (≥3 m for Fireplace)	-Fire pit opening ≤0.75 m, Fire pit height ≤0.51 m -Flame does not exceed 1 m.	No	-Fires are prohibited when the weather conditions contribute to smoke from the fire creating a nuisance to another person; -Fires are to be extinguished if smoke causes a nuisance, or interferes with the enjoyment of another person's property.	-Fires are prohibited in windy conditions; -Fires are prohibited when a fire ban is in effect.	[123]
Regina [Bylaw 2005-18]	≥3 m from any building/structure, property line or combustible material	-Size of fire pit does not exceed 0.75 m in any direction.	No	-Fires prohibited between 1 am and 12 pm; -Fires are to be extinguished if smoke causes an unreasonable interference with the use and enjoyment of another person's property.	-Fires are prohibited in windy conditions; -Fires are prohibited when a fire ban is in effect.	[121, 246]
Saskatoon [Bylaw 7990]	-	-Fire pit opening ≤0.61 m.	No	-Fires are to be adequately ventilated to ensure proper combustion and to prevent an unreasonable accumulation of smoke. -Fires are to be extinguished if smoke causes an unreasonable interference with the use and enjoyment of another person's property.	-Fires are prohibited in windy conditions.	[122]
Territories (Northwest Territories, Yukon)						
Dawson [Bylaw 13-02]	≥3 m from any building/structure	-Size of fire pit does not exceed 1 m in any direction -Flame does not exceed 0.5 m.	No	-Fires are permitted for cooking only.	-Fires are prohibited when a fire ban is in effect.	[131, 132]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Whitehorse [Bylaw 2000-01]	≥3 m from any building/structure, property line or combustible material	-Size of fire pit does not exceed 1 m in any direction -Flame does not exceed 0.5 m.	Yes	-Fires may be ordered extinguished if smoke enters neighbouring buildings.	-Fires are prohibited if wind is >20 km/h or during a fire ban; -Fire department must be notified prior to starting a fire.	[127, 128, 247]
Yellowknife [Bylaw 4502]	≥3 m from any combustible structure, ≥5 m from flammable fuel tanks	-Size of fire pit does not exceed 1 m (diameter) and 0.5 m (height) -Fireplace does not exceed 0.5 m (depth) and 1.5 m (height)	No	-Smoke from fires is not to cause discomfort to nearby persons; fires may be ordered extinguished if the fire creates a nuisance.	-Fires are prohibited in excessive wind conditions; -Fires are prohibited when a fire ban is in effect.	[129, 130]

Appendix B: Summary of Regulations for Recreational Fires in Four US States

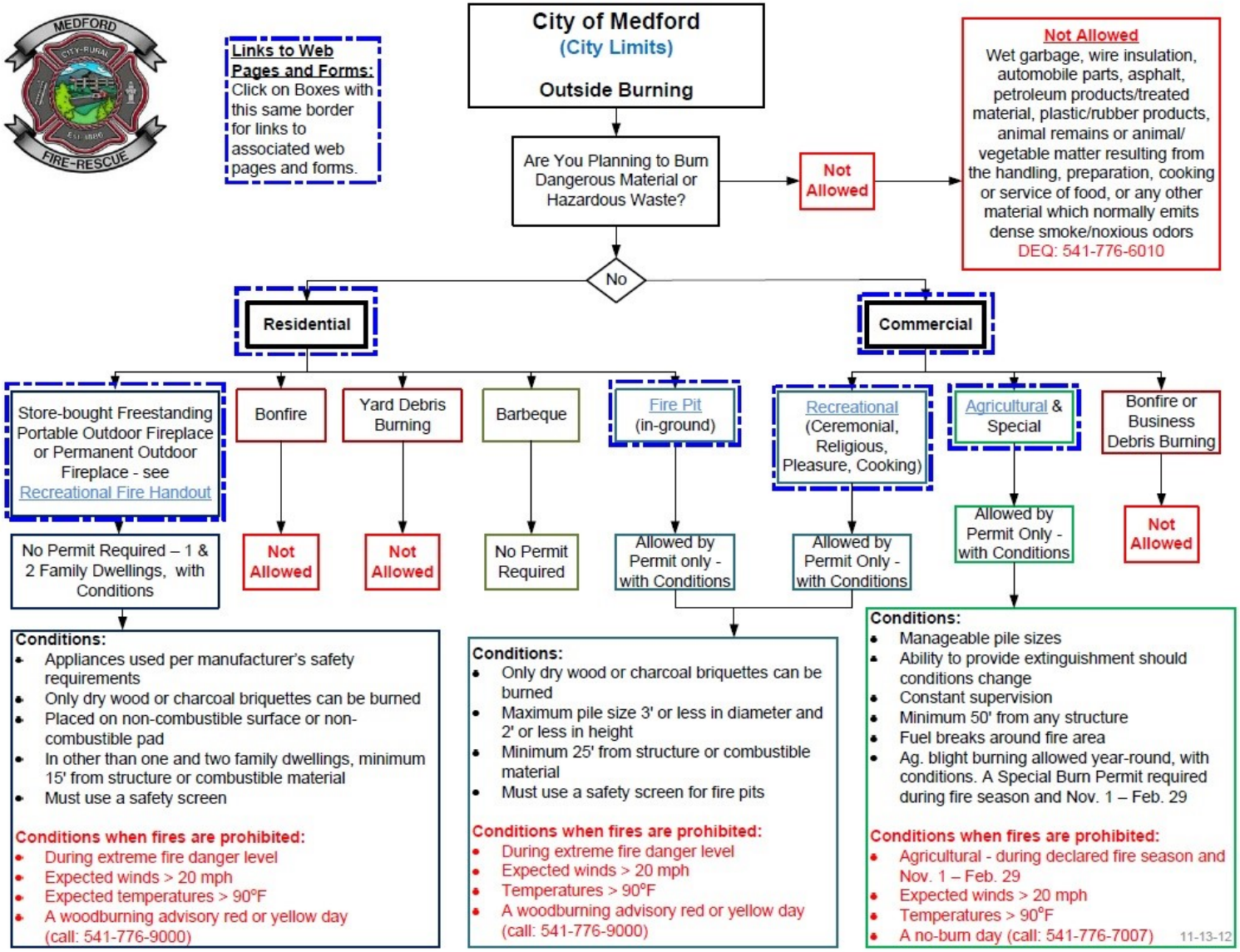
Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
California						
BAAQMD, Bay Area [Regulation 5]	-	-	-	-Fires are prohibited during mandatory winter curtailment periods (issued when $PM_{2.5}$ is forecast to exceed 35 µg/m^3). -Cooking fires are exempt from above rule.	-	[134, 135, 248]
California Legislature [California Fire Code Section 307]	≥7.6 m from any structure or combustible material (≥4.5 m for Portable Fireplaces; one- and two-family dwellings are exempt from this restriction)	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	-	-	-	[249]
SCAQMD, South Coast [Rule 445]	-	-	-	-Fires are prohibited during mandatory winter curtailment periods (issued when $PM_{2.5}$ is forecast to exceed 30 µg/m^3)	-	[133]
SMAQMD, Sacramento [Rule 421]	-	-	-	-Fires are prohibited during mandatory winter curtailment periods (Stage 1 and Stage 2 mandatory curtailments are issued when $PM_{2.5}$ is forecast to exceed 31 µg/m^3 and 35 µg/m^3, respectively; a voluntary curtailment is issued at 25 µg/m^3).	-	[136]

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Minnesota						
Coon Rapids [City Code 12-415]	≥7.6 m from any structure or combustible material	-Size of fire does not exceed 0.91 m in any direction	No	-Fires are allowed between 8 am and 12 am; -Fires shall not burn for more than 6 hours; -Fires are prohibited when an air quality alert has been issued; -Fires are not to create objectionable smoke beyond the property line.	-Fires are prohibited when the wind is >24 km/h; -Fires are prohibited when a fire ban is in effect.	[140, 250]
Minneapolis [City Code 178.20]	≥7.6 m from any structure or combustible material	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	No	-Fires are allowed between 9 am and 10 pm; -Fires are prohibited when an Air Pollution Health Advisory for $PM_{2.5}$ has been issued; -Fires may be ordered to be extinguished if smoke creates a nuisance for any neighbour.	-Fires are prohibited when the wind is >16 km/h.	[139, 251]
St. Louis Park [City Code Chapter 14]	≥7.6 m from any structure; ≥3 m from any property line	-Size of fire does not exceed 0.91 m in any direction	Yes	-Fires are allowed from 11 am to 10 pm (Sun–Thurs) and 11 am to 12 am (Fri–Sat); -Fires are prohibited when an air quality alert has been issued; -Fires may be ordered extinguished if the smoke emissions are offensive to occupants of surrounding properties.	-Fires are prohibited when the wind is >16 km/h; -Fires are prohibited when a fire ban is in effect.	[138, 252]
Oregon						

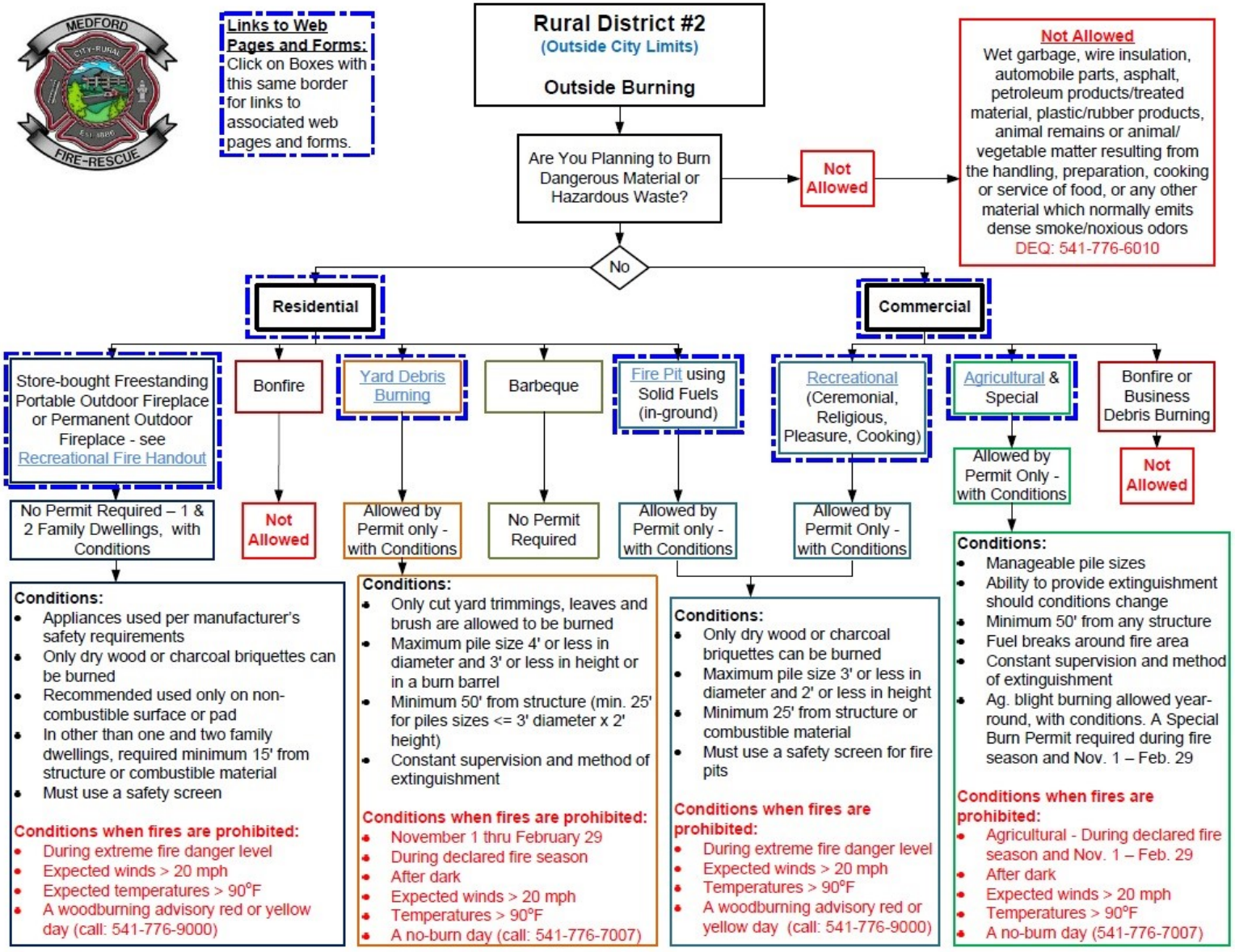
Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Clackamas County [Oregon Fire Code; Clackamas County Fire Defense Board]	≥7.6 m from any structure or combustible material (≥4.6 m if contained in a non-combustible fire pit)	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height) -Fire pit: diameter ≤1.2 m and height ≥0.30 m	No	-Only occasional use of fire is permitted (less than four per month); -Fires are to be extinguished if neighbours complain of smoke disturbances.	-Fires are prohibited during "Extreme Fire Danger Level" days.	[143, 144]
Eugene [City Code 6.200]	-	-	-	-Fires are permitted for cooking only.	-	[147]
Lane County [Title 47]	-	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	No	- In the Eugene/Springfield Urban Growth Boundary and Oakridge city limits, fires are prohibited on yellow (deteriorating air quality) and red (poor air quality) advisory days in winter (Oct–May).	-	[148, 149, 253]
Medford	≥7.6 m from any structure or combustible material (≥4.6 m for Portable Fireplace)	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	Yes (fire pits) No (fire-places)	-Fires are prohibited when ventilation index is below 400 (only applies Oct–Feb); -Fires are prohibited during red and yellow wood-burning advisories.	-Fires are prohibited when wind is >32 km/h or temperature is >90°F (32°C). -Fires are prohibited during "Extreme Fire Danger Level" days.	[150, 153]
Portland [FIR-3.08]	≥7.6 m from any structure (≥4.6 m for Fireplace)	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	No	-Smoke from the fire must not be of a noxious quality or amount that causes complaints from the neighbours.	- Fires are prohibited when the wind is >24 km/h.	[145, 146]
Washington						

Region [Bylaw]	Regulation					Ref.
	Site	Size	Permit Req'd	Smoke Management	Other	
Bellevue [Recreational and Cooking Fire Regulations]	≥7.6 m from any combustible structure (≥4.6 m for Fireplaces; fireplaces at single-family homes and duplexes are exempt from this restriction)	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	No	-Fires are prohibited during air quality burn bans; -fires are to be extinguished if smoke causes a nuisance.	-	[157]
Puget Sound Clean Air Agency (King, Kitsap, Pierce and Snohomish Counties)	-	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	No	-Fires are prohibited during Stage 1 and Stage 2 air quality burn bans. Stage 1 burn bans are issued when $PM_{2.5}$ levels are predicted to exceed 30 µg/m^3 (Pierce and Snohomish Counties) or 35 µg/m^3 (King and Kitsap Counties) within two days; -fires are to be extinguished if smoke causes a nuisance to any neighbours.	-Fires are prohibited when a fire ban is in effect.	[155, 254]
Washington State [WAC 173-425 and 51-54A-0307; RCW 70.94.473 and 70.94.65]	≥7.6 m from any structure or combustible material	-Size of fire does not exceed 0.91 m (diameter) and 0.61 m (height)	No	-Fires are prohibited during Stage 1 and Stage 2 air quality burn bans.	-	[154, 255-257]

Appendix C: Outside Burning Flowchart - Medford, Oregon



City of Medford, Oregon [150]



City of Medford, Oregon [150]

Appendix D: Glossary

Air Quality Health Index (AQHI)

An air quality scale used in Canada to help the public understand the impact of current air quality on health. It represents the health risk posed by the mixture of three air pollutants: particulate matter, ozone, and nitrogen dioxide. The AQHI has four categories describing the level of health risk (Low, Moderate, High, Very High), and each category has customized health messages for the general population and at-risk population (e.g., people with heart or lung conditions).

Air Quality Index (AQI)

A scale used in the United States to communicate daily air quality information. AQI is calculated for five major air pollutants (carbon monoxide, nitrogen dioxide, ozone, particulate matter, sulphur dioxide), and the highest AQI of the five pollutants is used as the overall AQI value.

Backing fire

A burning technique for prescribed fires in which the fire burns perpendicular to the prevailing wind direction or downslope. Backing fires move relatively slow through a fuelbed area resulting in a more complete burning of fuels. The smoke tends to be less dense and lighter in colour compared to smoke produced from other burning techniques.

Bonfire

A large, controlled outdoor fire such as those used for signaling or ceremonial purposes.

Burn ban (or air quality burn ban)

A temporary restriction or prohibition on most or all types of burning within a given area during periods of poor air quality. A fire ban may sometimes be referred to as a burn ban.

Fire ban

A temporary restriction or prohibition on most or all types of fire use within a given area during periods of high fire danger. A fire ban may sometimes be referred to as a burn ban.

Fire pit

An installation which has enclosed sides made from bricks, concrete blocks, heavy gauge metal, or other non-combustible materials, and does not have a flue, chimney or duct. Fire pits may be portable or permanently affixed.

Fireplace

An enclosed outdoor fire receptacle which incorporates a permanently affixed chimney or flue, and is constructed of brick, rock or other masonry. Fireplaces may be portable or permanently affixed. Common names include chiminea and patio fireplace.

Flankfire

A burning technique for prescribed fires in which the fire burns parallel to wind or slope. A flankfire is both a backing fire and a headfire, and thus produces a combination of fine, thin smoke and dark, dense smoke.

Headfire

A burning technique for prescribed fires in which the fire burns with the prevailing wind direction or upslope. Headfires move rapidly through a fuelbed area resulting in a less complete burning of fuels. The smoke tends to be thicker and darker compared to smoke produced from other burning techniques.

Nuisance

Anything that endangers health, gives offence to the senses, or obstructs the comfortable use of property. In Alberta's *Public Health Act*, nuisance is defined as "a condition that is or that might become injurious or dangerous to the public health, or that might hinder in any manner the prevention or suppression of disease" [258].

Open burning

The burning of any agricultural or waste material, such as leaves, wood, or garbage, in an open flame exposed to the environment. Recreational fires are a form of open burning; however, recreational fires are typically exempt from open burning regulations.

Particulate matter (PM)

The complex mixture of tiny solid or liquid particles suspended in the air. PM is typically classified based on size of aerodynamic diameter: PM_{10}, or coarse PM, refers to particles with an aerodynamic diameter up to 10 μm; $PM_{2.5}$, or fine PM, refers to particles up to 2.5 μm in size; and $PM_{0.1}$, or ultrafine PM, refers to particles up to 0.1 μm in size.

Permitted fuels

Material that is permitted for burning in recreational fires. Examples of permitted fuels include charcoal, firewood, seasoned wood, untreated wood, natural gas, and propane.

Polycyclic aromatic hydrocarbon

A class of organic compounds consisting of two or more benzene rings. Polycyclic aromatic hydrocarbons are formed from the incomplete combustion of organic material, such as coal, gasoline or wood, and are ubiquitous throughout the environment. Examples include benzo(a)pyrene and fluorene.

Prescribed fire

The knowledgeable and controlled application of fire on a specific land area to accomplish planned and well-defined resource management objectives. Prescribed fires are applied under select weather conditions and managed in such a way as to minimize the emission of smoke and maximize the benefits to the site.

Prohibited fuels

Material that is not permitted for burning in recreational fires. Examples of prohibited fuels include garbage, yard waste, treated wood, rubber, plastic, animal carcass, or any material that might create dense black smoke or offensive odour.

Recreational fire

A fire confined to an outdoor non-combustible container and set for the purpose of cooking, obtaining warmth or viewing for pleasure. Other common names include campfire, cooking fire and outdoor fire.

Ringlemann method

A visual method for estimating smoke opacity. A smoke plume at its point of greatest opacity is compared to the five-step Ringelmann Smoke Chart by a trained observer. Ringlemann values of 0 (clear), 1, 2, 3, 4 and 5 (black) correspond to opacities of 0, 20, 40, 60, 80 and 100% [259].

Seasoned wood (or seasoned firewood)

Wood that has been split and dried for an extended period of time (~6–12 months). The moisture content generally ranges between 20 and 25%. Seasoned wood burns cleaner and produces more heat than unseasoned wood.

Slash burning (or slash-and-burn)

A method of land clearing that involves the cutting down and burning of trees and other vegetation. Typically used for cultivation or wildfire mitigation.

Smoke opacity

The degree to which visibility of a background is reduced by smoke. Smoke opacity can be visually estimated by a trained observer using the Ringelmann method [259].

Species conversion

A vegetation management strategy that involves removing flammable vegetation species and replacing them with less flammable species.

Treated wood

Wood that has been treated with chemical preservatives, pressure processes, or non-pressure processes to extend the usable life of the wood.

Unseasoned wood (or green wood)

Fresh cut wood that has not been split and dried. The moisture content of freshly cut wood is typically greater than 40%. When burned, it produces less heat and more smoke than seasoned wood.

Untreated wood

Natural wood that has not been treated with chemical preservatives, pressure processes, or non-pressure processes.

Ventilation index

A measure of the ability of the atmosphere to disperse air pollutants. It is derived by multiplying the wind speed in the mixing layer and the mixing height.

Volatile organic compound (VOC)

A large class of carbon-containing chemicals that easily evaporate or volatilize into the air. VOCs are frequently encountered in both indoor and outdoor environments. Many VOCs are odorous and/or toxic; examples include benzene and formaldehyde.

Wildfire

A rapidly spreading wildland or brush fire.

