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Wildfire Adaptations for Resource Roads in British Columbia

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Innovative adaptations are needed to respond to increasing wildfire risks in British Columbia. This report reviews existing and potential adaptations for resource roads using approaches that include planned fuel management, proactive actions that protect infrastructure from oncoming wildfires, emergency firefighting, and considering post-wildfire risks. Following this review a discussion summarizes adaptation knowledge gaps that include a need for greater focus on stock management in fuel break design, evaluation and testing of existing and evolving adaptations to protect crossings, considering how road data can enhance reactionary and preplanned firefighting responses, and questioning if, and how, adaptations are appropriate in post-wildfire conditions. Improved understanding of adaptations that mitigate wildfire risks to resource roads can help identify options and strategies for project prioritization to enhance resilience.

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1 INTRODUCTION

Innovative adaptations are needed to mitigate the risks created by wildfire in British Columbia (B.C.) that continue to increase due to climate change impacts, fuel build up, and new rural housing developments (B.C. Wildfire Service, 2010; B.C. Government 2021a). This report focuses on B.C. resource roads and how they may be part of the mitigation of risks created by wildfire. Mitigations are actions that reduce or prevent a hazardous event or damage and are termed adaptations when they involve accounting for climate change (B.C. Government, 2016a). Adaptations for resource roads that respond to wildfire vulnerability can occur through physical measures that protect infrastructure serviceability or improve road functions, such as providing access for evacuations and firefighting (Kurowski and Bradley, 2022). Adaptations are often physical or involve maintenance activities; however, they also can be educational materials or policies aimed at mitigating impacts, reducing vulnerabilities, and increasing resilience (Partington et al., 2017).

Current wildfire adaptation efforts in B.C. have much of their origins with the 2003 Kelowna firestorms (Nikolakis and Roberts, 2021) that affected large areas of the wildland-urban interface (WUI) and impacted housing developments (Filmon, 2004). In 2004, the province partnered with the Union of British Columbia Municipalities (UBCM) to introduce the Strategic Wildfire Prevention Initiative – a funding program that allowed communities to plan fuel treatments by developing Community Wildfire Prevention Plans (CWPPs) (Copes-Gerbitz et al., 2020). By 2020, several funding sources had replaced the original program, CWPPs were updated to Community Wildfire Resilience Plans (CWRPs) (B.C. Government, 2021b) as part of synchronization to FireSmart standards (UBCM, 2021), and a tactical scale wildfire risk reduction (WRR) program for Crown land fuel treatments was introduced to complement CWRPs (B.C. Government, 2022a). CWRPs and WRR tactical plans must be completed by a qualified forestry professional (ABCFP, 2013) and are built upon a standardized framework that includes community outreach, risk identification using B.C. Provincial Strategic Threat Assessment (PSTA) risk maps, fuel treatment recommendations and prioritization based on the seven disciplines of FireSmart and professional judgement (B.C. Government, 2021b; UBCM, 2021). Once completed, components of these plans can inform other wildfire planning, assessment, and operations-related tasks (UBCM, 2021; B.C. Wildfire Service, 2022). Cumulatively, these plans span much of B.C. and have grown in number since 2004 and can therefore be useful documentation for identifying examples of wildfire adaptations to resource roads.

The objective of this report is to review existing and potential wildfire risk adaptations that are applicable to resource roads. Adaptations are considered from a perspective of districts, industry, and the planning and management of firefighting activities. An additional objective is to identify research needs to address identified gaps in knowledge, implementation, and understanding. Information for the report was gathered through a literature review of wildfires and resource road infrastructure; a review of available CWPPs, CWRPs, and WRR plans that specifically mention resource roads; and interviews with district officers, regional managers, forest industry professionals, wildfire scientists, and wildfire emergency response experts, including a program liaison with the First Nations Emergency Services Society of B.C. While the report focuses on B.C., the resulting information applies to all Canada.

2 RESOURCE ROADS AND ADAPTATIONS

Adaptations for resource roads on Crown land outside of the WUIs of CWRPs/WRR plans are the responsibility of districts. Wildfire adaptations led by districts that support the function of resource roads normally are done reactively, during emergencies. Some districts in more wildfire-prone areas may create proactive, forward-looking adaptations, often in collaboration with the B.C. Wildfire Service or the forest industry. However, most areas in B.C. have no experience with resource road-related wildfire risk adaptations (past or ongoing), especially outside of more wildfire-prone districts. Numerous groups may be engaged with planning and implementing adaptations including Indigenous groups, communities and municipalities, the B.C. Wildfire Service, the Ministry of Forests, and the forest industry (B.C. Wildfire Service, 2010).

There are several types of resource roads in B.C. with differing adaptation needs for wildfire risks. In B.C., higher traffic volume resource roads are known as Forest Service Roads (FSRs) and may serve any combination of industrial based activities, human settlement, and recreational traffic (B.C. Government, 2022b). Lower traffic volume roads include active permit roads (used for hauling), cut block roads, and inactive roads that may be wilderness roads or decommissioned roads (Pickup, 2020). Most resource roads are classified as being inactive (Forest Practices Board, 2015a) and may or may not be passable.

For FSRs that provide access to rural and Indigenous communities, adaptation needs may include protection of key crossing infrastructure, fuel management along the road corridor, and removal of potential road hazards, such as trees that could fall onto the road during or after a wildfire. For FSRs and permit roads that provide industrial access to resources, adaptation needs may include measures that minimize damage to key crossings and, in so doing, avoid costly bridge repairs or changes to harvesting plans. All types of resource roads can support adaptations to enhance wildfire resilience including efforts that improve planning for firefighting operations; minimize damage to inactive roads from the traffic of firefighting crews; and enhance community evacuation planning as part of alternate route identification.

2.1 Planned fuel management for wildfire risks

Planned fuel management adaptations are forward-thinking and have time periods on the order of years. B.C. government funded community and district led wildfire adaptation initiatives with longer time horizons centre on fuel removal that involve planning, creating, and maintaining fuel breaks. Fuel break treatments can involve techniques like commercial thinning, burning, pruning, and soil mastication (Fitzgerald and Bennett, 2013). In B.C., burning as a longer-term fuel management strategy is uncommon, in part due to legal restrictions; however, planned legislative changes aim to make prescribed burning and cultural burning more available (B.C. Government, 2021c). Treatments can also involve species management.

2.1.1 Fuel removal

Fuel management prescriptions along resource roads may be informed by components of the CWRP, WRR plans, or any other planning process that can identify target treatment sites.

Prescriptions to remove fuel adjacent to road right-of-ways create fuel breaks that also contain firebreak areas (the road prism) where there is no vegetation (Partners in Protection, 2003). Fuel breaks along resource roads may be a component of landscape scale plans that seek to slow wildfires while also providing safe zones for firefighting crews and equipment can be hundreds of meters wide. The narrower a fuel break, the less effective it is for slowing wildfires at the landscape scale, but it remains useful for local scale firefighting and protection of infrastructure (Day et al., 2010).

At the landscape scale, fuel breaks are located strategically near communities where they may be referred to as primary fuel breaks or fireguards. Roads, and terrain features such as streams, valleys, and ridges are natural choices for establishing fireguards near communities (Agee, 2000). In Canada, fireguards are usually at least 100 m wide; however, Mooney (2010) maintains that they should be at least 300 m wide to be effective at the landscape scale and, ideally, much wider given that embers can spot as far as 2 km ahead of a wildfire. A review of CWPPs and CWRPs found that a shaded, 300 m-wide, fuel break was the widest design in use seeking to balance cost and benefit. A shaded fuel break refers to a reduced fuel area with residual larger trees that have been left to reduce moisture evaporation from the soil's exposure to sun (Ascoli et al., 2018). The practice to incorporate FSR's within fireguards in the B.C. Interior has been identified but is not widespread.

At a local scale, fuel break adaptations can protect vulnerable crossings or structures, or be located with future firefighting operations in mind, or be maintained along important resource roads to protect access for community evacuations and wildfire crews. Fuel breaks that protect critical watercourse crossings ideally would be at least 100 m wide to avoid potential ignition by thermal irradiation (Bénichou et al., 2021); however, using this distance as part of an adaptive fuel treatment would extend beyond the 37.5 m-wide buffer to either side of centreline that defines an FSR (B.C. Government, 2022b). Fuel breaks that serve firefighting purposes require anchor points (safe staging areas for firefighter crews) that are 30 m or wider depending on terrain, fuels, historic fire regimes, and expected weather (Agee et al., 2000; Bénichou et al., 2021). Fuel breaks for firefighting, if built as shaded fuel breaks, can more easily be transitioned to anchor points during a wildfire. Fuel treatments are not planned primarily to support firefighting as this is not practical; all firefighting-centric mitigation is done at the time of the emergency and seeks to take advantage of natural and designed fuel breaks in topography. Fuel breaks that maintain corridor functionality can be found in the B.C. Interior, with treatment widths of 10 m past the ditch being a common distance in reviewed community plans. Fuel break prescriptions frequently involve thinning by removing a given percentage of [small] coniferous trees and any current or potential danger trees. This type of fuel management can improve the access function of a road but also may have a primary aim of suppressing fires that may start at roadside (Thompson et al., 2021). Districts generally do not brush or manage the right-of-way for wildfire mitigation purposes, including danger trees, unless they are fire-prone areas.

2.1.2 Species management

Deciduous or mixed stands can be an effective and desirable way to reduce stand flammability during summer months (B.C. Wildfire Service, 2022). Implementing changes to species requires processes that consider ecological considerations (B.C. Government, 2021b) as well as aligning with landscape-level strategies (B.C. Government, 2022a). The conversion process of a stand can involve species removal as well as planting. The B.C. Government (2016b) describes the stocking standards that must be met when reducing stand density or adding deciduous and/or fire-resilient coniferous species to fuel breaks.

Converting and then managing deciduous or mixed stands is applicable to both landscape and stand scale fuel breaks (Matute, 2021). Reviews of CWPPs and CWRPs revealed the presence of deciduous-related treatments of both landscape and local scale fuel breaks. The review further found a larger focus on mechanical thinning and mulching compared to treatments involving introduction and management of less flammable species. This mirrors the observation that use of deciduous stands for wildfire suppression is uncommon in North America (Wang et al., 2021).

Species management research areas applicable to local scale fuel breaks along resource roads include the conversion of conifer stands into trembling aspen by removing all vegetation then using suckering (Matute, 2021); assessing how well grasses that are more fire-resistant grasses can establish in place of native ones (Baxter and Woosaree, 2013), and learning from the knowledge of Indigenous peoples.

2.2 Proactive reactions to oncoming wildfire threats

Industry and district led adaptations have several options with shorter time horizons that focus on protection of infrastructure. Some may be accomplished weeks before expected wildfire activity, while others may be done a day or less before an approaching wildfire is projected to impact the area.

2.2.1 Sprinkler systems

Setting up sprinklers at vulnerable bridges ahead of when a wildfire may arrive is a common practice in some districts. There is interest in the ability to remotely activate multiple protective sprinkling systems shortly before a wildfire is expected to arrive at key infrastructure, which can be accomplished through the development of remote start water pumps and sprinkler systems. Technical advantages would include optimized fuel consumption of the unit, as well as water (if no plentiful source exists at site).

WASP Wildfire Inc., a wildfire sprinkler kit supplier, is actively developing this technology in Canada. Waterax Canada had a remote start pump but no longer carry it – possibly because previous generations of this technology were unable to be remotely re-started after being turned off. Being unable to be remotely restart the system commits the entire water supply to a one-time use in the case of a water reservoir tank (instead of being able to alternate sprinkling with refilling the water tank). Currently, WASP Wildfire is developing a battery-powered pump that can be remotely started, stopped, and restarted. Another remote start pump system is offered by an Australian company, Davey (Remote Start Davey Firefighter® MkII | Davey Water). The system can be activated manually, with a timer, or via SMS; however, its remote start ability requires cellular connectivity and does not have satellite capability.

Surprisingly, effective protection for structures can be provided after even a short period of wetting. Adequate protection results when surfaces are wet enough to prevent heat transfer from embers; most structure ignitions are from embers, and not from direct flame contact from the fire. Providing short but frequent watering can provide adequate protection. The number of sprinklers needed depends on the surface area to be wetted. It is important to create overlapping sprinkler coverage (i.e., allow no gaps in coverage). Sprinklers should be concentrated on buildings and infrastructure locations where embers and fuels can accumulate. In buildings, this can include re-entrant (corners), eaves, decks, and roofs (Figure 2). In bridges, this often includes timber decks, curbs, and cross ties.

Figure 2. Gutter-mounted sprinkler used to protect against wildfire embers.

Currently wildfire services are interested in applying the remote start technology to portable pumps which are small, relatively light (one or two-person lift), high pressure, pumps popular with firefighting crews. Pumps are used to fight fire in numerous ways including wetting fuels to prevent spotting, putting out hot spots, protecting zones or infrastructure, and pumping water uphill between a series of water bladders (Figure 3).

Figure 3. The lightweight MK III pump allows for easy transport into the forest.

Like the use of sprinklers in structure protection, the motivation is to allow one crew to manage and deploy multiple portable pumps. Currently, because pumps must be monitored in pe rson and crews cannot (generally) be broken up, entire crews are dedicated to monitor just a single pump. This is highly inefficient and problematic in areas where there are remote assets and few crews (e.g., in N.W.T, Sask.). Fuel availability for these portable pumps is less of an issue because you can connect multiple jerry cans of fuel in series. The general advantage of portable pumps is their versatility to be deployed quickly, especially in areas with difficult access.

2.2.2 Chemicals

Most knowledge about fire fighting chemicals comes from the field of aviation safety. These fire fighting chemicals are generally classified as either suppressants or retardants. Suppressants (e.g., water, foam, water-enhancers, or gels) are dropped from the air directly onto the fire (direct-attack) whereas retardants are dropped from the air onto vegetation or structures ahead of the fire (indirect-attack) as an adaptive measure. Unlike suppressants which are applied directly to wildfires to cool them down, retardants facilitate different tactics by decreasing fire intensity and slowing the advancement of the fire. It is important to note that the main objective when using these chemicals is to buy time for ground crews to arrive at the fire and start their work.

When fighting wildfire in wildlands little other than water is used. However, to harden their infrastructure against climate-driven wildfires, utility companies and railway companies have promoted research into retardants and other technology to apply to power poles and railway trestle bridges and these may prove viable options for protecting other types of infrastructure. Figure 4 shows an example of an FPInnovations ignition test for timber with various fire suppression treatments.

Figure 4. FPInnovations bridge timber treatment ignition test (Razim 2020).

Technologies include coatings (e.g., paints, intumescent paint, gels), wraps (e.g., welding blanket wrap, intumescent wrap), and barriers (metal shielding). Three products familiar to FPInnovations wildfire researchers are intumescent paint and wraps (these bubble up to become a barrier when heated but don’t withstand prolonged heat exposure), welding blanket wraps (embers fall off), and gels (become ineffective when the water evaporates, can be sensitive to water quality, are corrosive, toxic, and very expensive).

To be effective the application of some ground treatments must be timed to the arrival of the wildfire and selected based on the type of fire exposure expected. Crown fires expose infrastructure to intense heat but only for about 2 minutes whereas ground fires are cooler but provide longer exposure.

Razim (2020) presents a literature review of wildfire and bridges conducted on behalf of the B.C. government to clarify how bridges are damaged by wildfires, if any pro-active protection methods and strategies have been employed or studied, and, if so, their efficacy. Literature indicates that wooden bridges are susceptible to more damage in wildfires than concrete or steel bridges, however, steel bridges may collapse when burnt. Embers have been a chief cause of wooden bridge ignitions from wildfires, especially if the embers are able to collect on cross ties and decking. Various coatings, wraps, and barriers have been evaluated but results are not conclusive or were conducted for private bridge owners (i.e., railways) and have not been made public. Razim (2020) notes that intumescent coating and wrap tests have shown mixed results and that product performance depends on the mode and intensity of heat transfer. Similarly, sprinklers have been successful in protecting bridges from crown fires, but information is lacking about the maximum delay between wetting and the fire, and how to ensure overlapping full coverage of the structure. Lastly, steel barriers or welding blankets are expected to be effective against embers but their performance against prolonged heat exposure or rainfall (if installed long before the fire) is unknown.

2.2.3 Reactive fuel management treatments

Reactive fuel management around vulnerable crossings before a wildfire is projected to arrive is another short-term treatment that could also complement chemical and sprinkler systems. As noted by Day et al. (2010) narrow fuel breaks can be useful for firefighting and protection of infrastructure. Fuel breaks can be created through backburns, if conditions permit, by burning grasses in the right-of-way, by removing ladder fuels through chainsaw delimbing, and by tree felling or mulching to physically increase the clearance between forest and structures.

Razim (2020) provides specific recommendations for decreasing fuel loading around and under bridges and can include stand thinning, pruning, cleaning, and complete removal of grasses (manually digging, excavating with heavy equipment, or by burning within the right-of-way). Another quick method is mulching brush and small trees near the bridge to convert vertical fuels into horizontal fuels to make it easier for crews to fight fires. Government of B.C. (2018) notes that the vertical clearance between bridge members and burning materials underneath influences the likelihood of damage and deflection – steel girders that are directly in contact with flames will reach much higher temperatures and are more at risk of expansion, distortion, buckling, and degradation of steel properties. Removal of fuels from under bridges, including removal of any stored flammable materials, thus should be a priority.

2.2.4 Access management

Access management for resource roads is required as part of wildfire management due to existing wildfires or the increased potential for them. Road function access restrictions can protect the public from the wildfire, reduce congestion and the potential for crashes on the resource road, prevent looting of evacuated residences, and relieve fire crews from having to rescue public road users who have become endangered by the wildfire. They can also close FSRs to public as a precautionary measure to reduce the chances of human-caused fire. Plans for road closures would normally be initiated in consultation with local communities and would be announced with portable signage and in public radio broadcasts during the wildfire. Given the vital role played by roads for community access, it is important that this type of measure be done as transparently as possible and be maintained for only as long as absolutely necessary.

2.3 Emergency responses for firefighting

Resource roads, especially inactive roads, often become important ground access for firefighting activities. Adaptations for how resource roads can help mitigation efforts are centred on ensuring safe function for fire crews. The lack of information about the status of inactive roads (FBP, 2015a) creates numerous challenges including lack of road condition data.

A resource road that is near a wildfire can provide access and then facilitate the establishment of an anchor – a 30 m or wider firebreak that acts as a safe area and a new base of operations for firefighting crews. This 30 m width includes the firebreak (road surface) with vegetation stripped beyond it as part of the initial preparations. Most heavy equipment and equipment operators working in firefighter crews are hired from local forest industry contracting companies. In accessing locations to place anchors, on-the-fly planning includes having or hiring a local expert that knows the crossings in the area to try to make up for the general lack of information about inactive roads and crossings.

To support ground firefighting procedures, B.C. Wildfire Service works with GeoBC to receive live data feeds and analysis for its firefighter crews. Real-time analysis extends to support for finding the most suitable anchor locations. Considerations include known resource road locations, a digital elevation model of local terrain, and the latest fire behavior model projections. The same real-time system also sends warnings to the crew to leave if projected conditions are not looking favorable.

2.4 Considering post-wildfire risks

After a wildfire, burned over soils may be hydrophobic and, thereby, increase the time of concentration of a watershed for several years following (FPB, 2005). There also can be large flush of sediment from denuded slopes during heavy rainfall events, which can deposit in ditches and drainage structures reducing their function and redirecting drainage. After a decade or more, as roots decay and dead trees start to fall over on the slopes, the risk of mass wasting and debris torrents becomes elevated.

While B.C. Wildfire Services is responsible for repairing any damage it causes to forests and roads during firefighting, resizing of a culvert would only be considered if it were damaged by excessive traffic loads and needed replacement. Currently, adaptions to damaged roads within burned areas are either not common or not occurring in terms of addressing possible hydrologic issues. While a watercourse crossing design should account for how changes in landscape can change hydrology (EGBC and ABCFP, 2021), there are few recommendations in design approaches for crossing designs in burned over watersheds.

Resizing a crossing due to temporary hydrophobic soil upstream may not be practical unless the site has elevated risk (high values to protect or high likelihood of failures). A related or alternative adaptation may be to install guarding or instream structures to protect the crossing from stream borne bedload and large woody debris.

3 IMPROVING OUR UNDERSTANDING

Planned adaptations currently are focused on the removal of fuels – a reflection of the funding systems in B.C. that are set up to improve wildfire mitigation. This practice is not economically feasible for long lengths of road corridor as fuel removal costs are in the order of $10 000 / hectare. A few options exist that may help this situation.

- Increased attention to local scale fuel breaks that retain or introduce deciduous or other identified vegetation is recommended, especially for species that require less effort to maintain.
- The ongoing work by the B.C. government to adjust legislation to streamline approvals for prescribed and cultural burns may reduce treatment costs and promote burning along resource roads as a central tool for creating fuel breaks.
- A system for prioritizing funding for local scale fuel breaks could complement funding mechanisms available for communities. If district annual budgets are allocated without specific requirements for wildfire adaptation, current trends may continue in which many districts have no program for adaptation.
- There are opportunities for industry and districts to consider various adaptations involving strategic, multi-year budgeting. This already occurs in some more fire-prone districts, such as one where a strategic multi-year budget policy has allowed for replacing timber bridges when needed with more fire-resistant structures. Multi-year budget plans can support plans to replace or increase in total supply of technology supporting proactive reactions to shorter term oncoming wildfire threats.

Adaptations that can protect resource road crossings on short notice have many ongoing developments that are progressing rapidly. Fully remote-controlled sprinklers are close to being fully realized, and chemical retardant treatments exist but require more validation under B.C. conditions. Knowledge gaps include quantification of their effectiveness, understanding how treatments degrade over time, and investigating resistance to different types of heat exposure. It is anticipated that sprinkler and chemical adaptations, along with others based on quick fuel management and access policy, may become more important in the future; districts and industry may need to become more self-resilient because B.C. Wildfire Service resources may increasingly be overextended as climate changes increase wildfire activity (i.e., more frequent, larger, and faster moving wildfires, longer fire seasons, and more frequent multiple ignition events (Kurowski and Bradley, 2022)).

Emergency response adaptations that support firefighting would be improved with more complete and up-to-date inventory information about resource road assets, notably smaller crossings and inactive roads. Having this information can help firefighters to use resource road networks more safely and efficiently during firefighting activities. Furthermore, existing data could be used outside the context of on-the-fly analysis. That is, analyzing for potential anchor point locations as a planning exercise rather than emergency activity (a recommendation mentioned in some community plans). Improving asset inventories also helps in assessing wildfire risks (Kurowski and Bradley, 2022) and therefore, also would support any type of province-wide risk analysis involving the resource road network.

Post-wildfire adaptations to resulting risks can better address issues surrounding increased storm flows, and the occurrence of debris floods or debris flows which are more likely to occur in the years following a wildfire event. It is unclear how important this type of adaptation would be when prioritizing between other potential projects for areas not affected by wildfire. It is also unclear whether it is better to restore or upgrade damaged crossings immediately after the wildfire season (late fall or winter) or to postpone this activity until after the spring freshet. In the longer term, improved asset inventory also would help with deciding whether mitigation is needed for burn-affected crossings because original and newly estimated design flows may be part of the database.

Many knowledge exchange opportunities exist between regions, districts, and various groups within B.C. that can support wildfire risk mitigation. A considerable amount of knowledge exists within districts that have high wildfire exposure that is undocumented or is documented but not organized or contextualized for other users. For example, a more exhaustive and comprehensive review of adaptations mentioned in CWPPs and CWRPs could distinguish regional trends, and follow-ups could be initiated to investigate which plans have moved forward. Knowledge transfer is especially important as wildfire risk increases in B.C., which could disproportionately affect districts that may not be expecting high increases to risk in their area and may, therefore, find themselves looking for solutions on short notice.

Overall, this report reveals a lacking perspective of resource road risks to wildfire as they relate to their function as access to communities, industry, and firefighting. There is further a lack of technical solutions that use more advanced technologies to protect crossings, but as these technologies mature, case studies, tests, and validations will be required. Best practices and procedures will also need development for the use of associated equipment, techniques, and assessments. Communities, districts, and industry that participate in implementing solutions that can adapt to oncoming wildfires would increase resilience and potentially complement ongoing wildfire mitigation funded by the province based on fuel reduction.

4 CONCLUSIONS

The objective of the report was to review adaptations applicable to resource roads that can mitigate wildfire risk adaptations now and in the future. The views of the various groups that may be involved in resource road adaptations were considered through the four sections of the report that correspond to adaptations that plan fuel treatments, are proactive in the short-term to protect crossings from oncoming wildfires, react to emergency firefighting, and respond to post-wildfire conditions. Additionally, an overall objective was to identify research needs to address identified gaps in knowledge, implementation, or understanding.

The report identified practices in B.C. that range from very sophisticated to basic, or even non-existent, through a literature review and interviews. Planned adaptation focused on the removal or modification of fuel in fuel breaks, and management of growing stock within the fuel breaks. Adaptations that can protect structures on short notice use approaches based on wetting, chemical agents, local fuel removal treatments, and management of access. Emergency response adaptations reviewed how roads and their metadata help on-the-fly analysis by support staff. Post-wildfire adaptations to increased risks focused on those that are related to increased runoff in the first few years, and growing slope instability in the decade following.

The discussion identified that opportunities to improve planned adaptations for fuel treatment include greater focus on deciduous stock and fuel removal with burning as a treatment along important resource roads and considering methods to prioritize district funding specifically for wildfire mitigation. Shorter term adaptation reactions for structure protection are numerous and may become increasingly important if B.C. Wildfire Service resources become less available or overextended in the future. Adaptation practices to support for emergency response has needs for improved asset inventory to help firefighting efforts that use inactive roads. Post-wildfire adaptations should investigate options and rationale for responding to maintaining the resilience of affected crossings. There are opportunities to enhance BC wildfire mitigation efforts by developing educational-based adaptations that can embrace knowledge exchange between districts and other groups. Furthermore, emerging technical solutions that can protect crossings need to be championed, tested, and protocols made as the technology matures. The list of adaptation options that this report provides is a resource for the many affected groups and includes mitigation based on education and working with technologies, rather than emphasizing fuel management only.

Adapting resource roads to wildfire is necessary to ensure resource roads can function to support access to communities, industry, and firefighting activities. Combining fuel removal with other less common adaptations along with PSTA wildfire hazard and risk maps, among other spatial wildfire or road inventory data, could assemble a clearer understanding of where adaptations might be best suited and, therefore, prioritized. Enhanced integration of wildfire adaptations that leverage technological solutions alongside fuel load management has potential to improve B.C.'s wildfire resilience by making local groups less reliant on B.C. Wildfire Service to protect infrastructure. While the capacity of resource roads to help B.C. adapt to climate change are numerous there are currently few resources that can assist communities, districts, and industry with this. In this regard, B.C. has an opportunity to provide leadership by supporting many types of wildfire adaptations.

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