Updated "Status of Knowledge" for Front Range Roundtable Fuel Treatment Goals and Objectives

Since the publication of the report, "Living with fire: protecting communities and restoring forests" was released in 2006, members of the Front Range Roundtable (FRRT) have been implementing fuel reduction-based forest vegetation management projects across landownerships, promoting community wildfire protection actions, and taking actions on lands and in communities impacted by recent wildfires. One of the primary values of the FRRT is that brings together organizations reflecting a broad diversity of interests, expertise, and capacities around the best available science, especially science related to forest and fire ecology and management. The 2006 "Living With Fire" report was based on the best available science at the time; the time is ripe to review and assess the status of knowledge of scientific research relative to the original 2006 goals, as scientific knowledge as evolved. The new, Front Range General Technical Report, titled "Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range" is scheduled to be published late 2017. The GTR contains a comprehensive repository of available knowledge that pertains to the restoration of ponderosa pine and dry mixed-conifer forests on the Front Range, and this document pulls from just a subset of that information to address the FRRT goals and expected outcomes.

The purpose of this document is to support FRRT members to communicate with a collective voice about the extent to which FRRT goals and management actions align with current science, the remaining uncertainties and challenges, and topics for future research. The document below is broken up into 3 sections: **(1)** goals and outcomes outlined by the FRRT, and a summary of current scientific knowledge to support such goals and outcomes, **(2)** detailed information on source of stated goals and how management actions by FRRT members are contributing to these goals, and **(3)** selected literature that guided the creation of this document.

1. Goals and Outcomes, Status of Knowledge, and Summary of Scientific Knowledge

Goal/Expected Outcome *Foundational Source*	**Status of Knowledge/ Degree of Confidence: High, Moderate, Speculative**	**Notes/Comments/Remaining Uncertainties*** *** Statements refer to consensus (or lack thereof) among the scientific community, not necessarily FRRT members**
(1) Restore forest structure and fire regime (primarily referring to forest density and low to mixed severity fire regime) *Living with Fire: Protecting Communities and Restoring Forests (p. 4 and p. 24)* *Front Range CFLR Proposal (Proposed Treatment, p. 2; Ecological Context, p. 1-2)* *2017 Ecological, Social, and Economic Monitoring Plan (p. 3 and throughout)*	High – lower montane Moderate – upper montane	• General agreement on need for the restoration of forest structure and fire regimes at lower montane and low productivity sites (surface fire regimes, more departed from HRV) • General agreement that low severity fires are less common than they were historically, but some debate on role of large, high-severity fire (Fulé, et al. 2014,Williams and Baker 2014) • More unclear as you increase in elevation/productivity, stands likely naturally denser with more mixed severity fire regimes – departure from HRV depends more on local context and physiographic gradients • The need for restoration of forest structure and fire regime should be assessed on a site-by-site basis, as past disturbance regimes and structures vary greatly with physiographic settings (elevation, slope, aspect) over small spatial scales in the Front Range, and target should be set to achieve landscape-scale goals.
(2) Restore complex mosaic, favoring ponderosa pine and diversifying age structure	High – lower montane Moderate – upper montane	• General agreement on the need for increasing openings of various sizes, breaking up large continuous patches of trees, preserving old growth characteristics

Living with Fire: Protecting Communities and Restoring Forests (p. 4, p. 10, and p. 24) *Front Range CFLR Proposal (Proposed Treatment, p. 2; Ecological Context, p. 1-2)* *2017 Ecological, Social, and Economic Monitoring Plan (p. 3 and throughout)*		• Better understood for lower montane, but montane zone likely has experienced homogenization in stand structure (data is a bit more limited for this) • Favoring ponderosa pine likely more appropriate in lower montane/less productive sites, upper montane/higher productivity sites historically more diverse with more Douglas-fir and other species
(3) Increase resilience to fire, insects, disease, drought, and climate change *Front Range CFLR Proposal (Proposed Treatment, p. 2; Ecological Context, p. 1-2)* *2017 Ecological, Social, and Economic Monitoring Plan (p. 3 and throughout)*	Moderate	• Treatment impacts on forest resilience to fire, insects and disease, and drought are well documented, although many examples include the greater Rocky Mountain region and not necessarily the Front Range. • Strong consensus that spatial heterogeneity across spatial scales is critical to forest resilience • Resilience to climate change more speculative as uncertainties in temperature and precipitation regimes will have different effects on forest dynamics. Many broad forecasts, but uncertain localized effects of climate change make it difficult to plan for uncertainties/specific conditions. ○ Despite uncertainties, useful frameworks are being developed to guide vulnerability assessments and management strategies
(4) Provide sustainable vegetation and watershed conditions	Speculative	• Well documented relationships between canopy cover, litter/duff loadings and understory cover, richness, and diversity

Front Range CFLR Proposal (Proposed Treatment, p. 2; Ecological Context, p. 1-2) *2017 Ecological, Social, and Economic Monitoring Plan (p. 3 and throughout)*		• Enhancing spatial heterogeneity can facilitate long term forest dynamics such as tree regeneration and resilience, thus providing sustainable watershed conditions • Commonly assumed that fire-adapted understory species have not benefited from fire-exclusion • Links between forest management and erosion are predominately model based and rarely include the Front Range setting (but see (Jones, et al. 2017)
(5) Provide improved fish and wildlife habitat *Front Range CFLR Proposal (Proposed Treatment, p. 2; Ecological Context, p. 1-2)* *2017 Ecological, Social, and Economic Monitoring Plan (p. 3 and throughout)*	Speculative	• Response can be positive or negative, depending on individual species habitat requirements, life history, trophic interactions, and severity of disturbance • Very few long term (e.g. 5+ years post-treatment) studies • Commonly assumed that fire-adapted wildlife species have not benefited from fire-exclusion • Generally agreed upon that having the full suite of forest structural conditions (e.g. large openings → closed canopy forest) on the landscape will benefit wildlife communities. • Minimal Colorado representation in published literature
(6) Decrease probability of life and property loss from wildfire *Living with Fire: Protecting Communities and Restoring Forests (p. 4 and p. 24)* *Front Range CFLR Proposal (Proposed Treatment, p. 2-4*	Speculative	• Controlled empirical studies of fuel treatment effectiveness are rare. Many qualitative, post fire reports • Fuel treatment effectiveness depends greatly on specific management activities, including size, location, treatment of activity fuels, and age of treatment. • Some instances where fuel treatments may even exacerbate fire effects • Fuel treatments will not stop fire, but may change behavior under favorable environmental conditions

Collaboration, p. 1-2, *Wildfire, p. 1)*		

Confidence levels (derived from prior status-of-knowledge reports by Bill Romme and Merrill Kaufmann):

<u>High</u>:
- Multiple, independent sources of peer-reviewed published research using accepted scientific methods and directly relevant to local ecosystems and management contexts;
- Ideally replicated or replicable
- Reflects general consensus of research community

<u>Moderate</u>:
- Isolated, limited sources of peer-reviewed published research – one-off case studies, for example; not replicated; still questions about methods, data sources
- Non-peer reviewed technical reports or white papers

<u>Speculative</u>:
- Peer-reviewed research using accepted scientific methods, but indirectly relevant to local ecosystems and contexts – general similarities but not local data (e.g., Ponderosa pine in northern Arizona or New Mexico);
- No published research;
- Anecdotal narratives based on experience or limited observations – information not based on accepted scientific methods, replicated or replicable

2. History of Goals, How Do Management Actions Contribute to Goals?

(1) Restore forest structure and fire regime (primarily referring to forest density and low to mixed severity fire regime)

<u>Foundational Sources</u>

(1) Living with Fire: Protecting Communities and Restoring Forests (**p. 4** and p. 24) – *"…Partnership's goals are to reduce wildfire risks… protect communities from wildland fire;* ***and to restore fire-adapted ecosystems****"*

(2) Front Range CFLR Proposal (Proposed Treatment, p. 2; **Ecological Context, p. 1-2**) – *"The purpose of ecological restoration treatments implemented through this proposal will be to* ***substantially decrease the density of ponderosa pine and Douglas-fir in the lower montane*** *favoring ponderosa pine, create a more diverse age structure. Treatments would increase meadows, patchiness, and herbaceous understory across the landscape while maximizing ponderosa pine old growth. These treatments will result in* ***lower severity wildland fires…****"*

(3) 2017 Ecological, Social, and Economic Monitoring Plan (**p. 3** and throughout) –
- Desired Condition Number 2: "Establish a more characteristic fire regime.
- Desired Condition Number 6: "Establish a complex mosaic of forest density, size and age"
→ *Desired trend: "Decreased basal areas, Decreased trees per acre"*

<u>How do Management Actions Contribute to Goals?</u>

From the 2017 Landscape Restoration Team Monitoring JAM Session, Cannon et al. forthcoming:

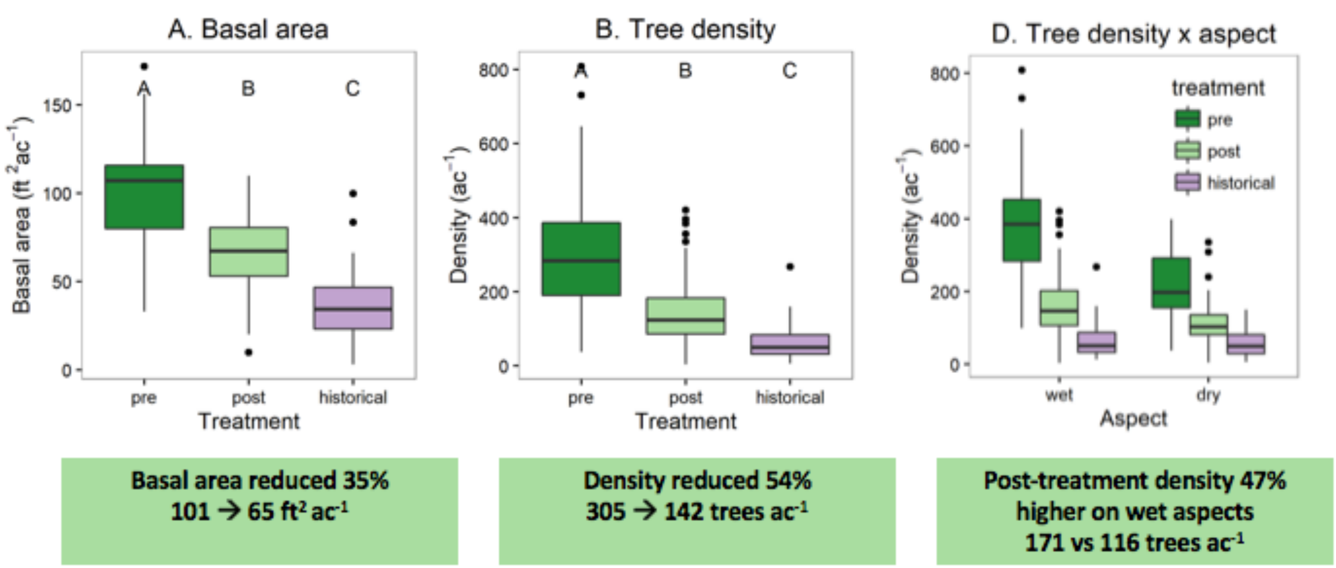

Figure 1. Analysis of 7 early CFLR projects, showing **(A) decreases in basal area and (B) tree density following forest management activities relative to reconstructed data, as well as (C) comparisons of forest conditions among wet and dry aspects,** in which residual density was more similar to historical conditions on dry aspects relative to wet aspects. Reconstructed data courtesy of the Front Range Forest Reconstruction Network (Brown, et al. 2015).

(2) Restore complex mosaic, favoring ponderosa pine and diversifying age structure

<u>Foundational Sources</u>

(1) Living with Fire: Protecting Communities and Restoring Forests (p 4., **p. 10,** and p. 24) – *"… Instead, treatments should **achieve a complex mosaic** of forest structures with patches of variable tree densities and **ages that favor retention of the older trees**."*

(2) Front Range CFLR Proposal (Proposed Treatment, p. 2; **Ecological Context, p. 1-2** – "*Treatments would increase meadows, patchiness and herbaceous understory across the landscape while maximizing ponderosa pine old growth."*

(3) 2017 Ecological, Social, and Economic Monitoring Plan (**p. 3** and throughout) –
- *Desired Condition Number 1: Establish a more favorable species composition favoring lower montane species over other conifers*
  → *Desired trend: Increase ratio of ponderosa pine to other conifers, where appropriate*
- *Desired Condition Number 6: Establish a complex mosaic of forest density, size and age*
  → *Desired trend: Increased spatial heterogeneity (stand and landscape scale)*

<u>How do Management Actions Contribute to Goals?</u>

From the 2017 Landscape Restoration Team Monitoring JAM Session, Cannon et al. forthcoming:

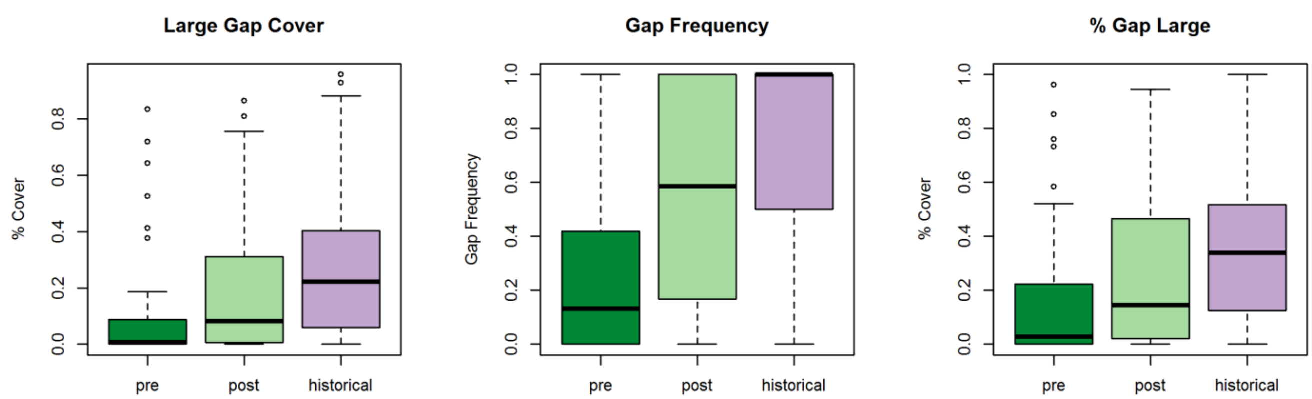

Figure 2. Analysis of 7 early CFLR projects, showing **(A) increases in the percent cover of large gaps (>59 ft), (B) the frequency of plots containing large gaps, and (C) the proportion of large gaps relative to the total area of openings** following forest management activities relative to reconstructed data. Reconstructed data courtesy of the Front Range Forest Reconstruction Network (Brown, et al. 2015).

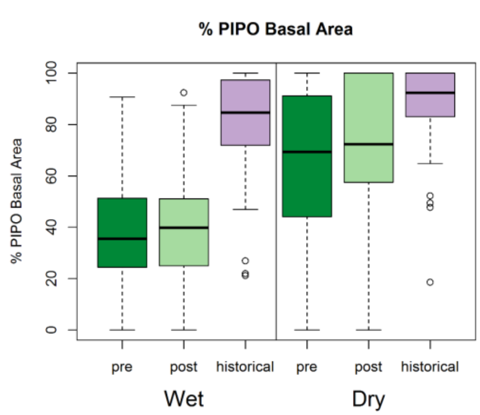

Figure 3. Analysis of 7 early CFLR projects, showing **slight (not significant) changes in the proportion of ponderosa pine by basal area resulting from forest management, on both wet and dry aspects, relative to reconstructed data.** Reconstructed data courtesy of the Front Range Forest Reconstruction Network (Brown, et al. 2015).

(3) Increase resilience to fire, insects, disease, drought, and climate change

Foundational Sources

(1) Front Range CFLR Proposal (Propo**sed Treatment, p. 2**; **Ecological Context, p. 1-2**) – *"This proposal is based on a collaboratively designed ecological restoration strategy to return the Front Range ponderosa pine forests to a condition that reduces the threat of catastrophic fire;* ***increases forest resilience to fire, insects, disease, drought, and climate change…****"*

(1b) "*The purpose of ecological restoration treatments implemented through this proposal will be to substantially decrease the density of ponderosa pine and Douglas-fir in the lower montane favoring ponderosa pine, create a more diverse age structure.* ***Treatments would increase meadows, patchiness and herbaceous understory across the landscape while maximizing ponderosa pine old growth.*** *These treatments will result in lower severity wildland fires,* ***increased resistance to insects and disease,*** *reduced threats to communities and watersheds, and improved habitat for fish and wildlife species.* ***These more resilient forests will also have increased capacity to adapt to the impacts of a changing climate****."*

(2) 2017 Ecological, Social, and Economic Monitoring Plan (**p. 5**) – *"The broad goal of the FRRT, as described in Aplet, et al. (2014), is to bring the dry montane forests of the Front Range into a condition* ***that can sustain desired ecosystem values*** *in the presence of inevitable wildfire."*

How do Management Actions Contribute to Goals?

This has not been directly monitored on CFLR projects. However, the assumption that increasing heterogeneity in Front Range forests will increase forest resiliency holds for both the FRRT community (see foundational documents) as well as the scientific community (see selected literature). Given this assumption, much of what is presented above (complex mosaic) tends to support increasing forest resilience. Additional spatial heterogeneity monitoring shows **the increase in large gaps** in project areas resulting from forest management.

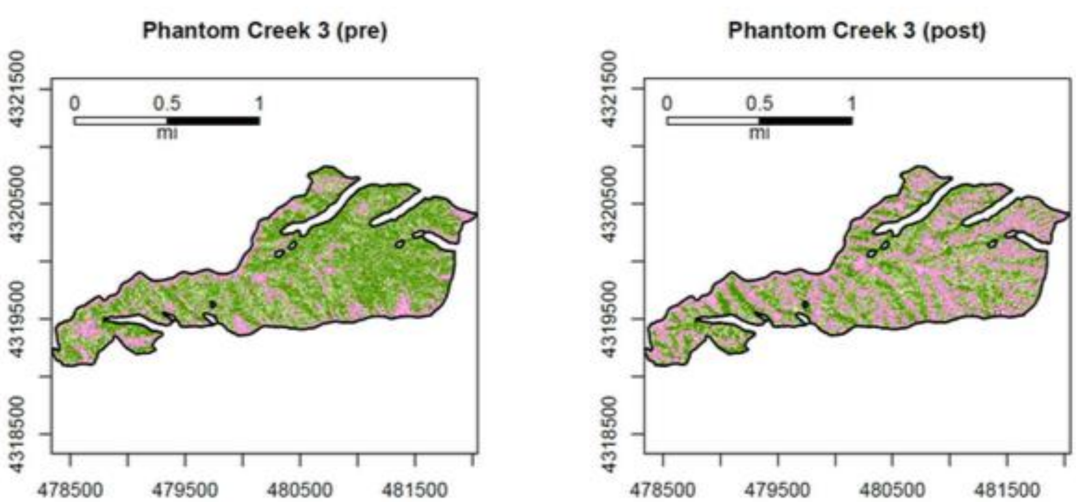

Figure 4. Example of additional spatial heterogeneity monitoring show the increase in large gaps (pink regions) resulting from forest management at Phantom Creek. Literature suggests these types of patterns can increase forest resiliency to disease, insects, wildfire, and climate change, as well as help sustain other ecosystem services such as regeneration, wildlife habitat, and carbon sequestration.

(4) Provide sustainable vegetation and watershed conditions

Foundational Sources

(1) Front Range CFLR Proposal (**Proposed Treatment, p. 2**, Ecological Context, p. 1-2) – "*This proposal is based on a collaboratively designed ecological restoration strategy to return Front Range ponderosa pine forests to a condition that reduces the threat of catastrophic fire; increases forest resilience to fire, insects, disease, drought, and climate change; and* ***provides sustainable vegetation and watershed conditions****, wildlife habitat, and community needs."*

(2) 2017 Ecological, Social, and Economic Monitoring Plan (**p. 3** and throughout) –

- Desired Condition Number 3: Increase coverage of native understory plant communities

→ *Desired trend: Increased cover and diversity of grasses, forbs, and shrubs*

→ *Desired trend: Similar (or decreased) occurrence and cover of noxious or invasive plant species*

- Desired Condition Number 5: Reduced potential for damaging post-fire erosion and sedimentation to municipal water supplies

How do Management Actions Contribute to Goals?

Understory vegetation monitoring results are still preliminary from the Landscape Restoration team, as many plots have just been, or are awaiting treatment. However, in a study of 7 Front Range restoration sites, Briggs, et al. (2017) found:

> *"Understory plant metrics of richness and cover* ***were largely unimpacted by restoration treatments*** *in the first post-treatment year…. To some extent, this lack of change may be considered in line with CFRLRI project objectives (Clement and Brown, 2011); for example,* ***treatments did not promote an undesirable increase in the (already low) abundance of exotic plants, and did not negatively affect understory plant diversity.*** *Furthermore, longer-term (5+ years post-treatment) studies commonly document an increase in many understory plant metrics as understory plants respond to the reduction in competition with overstory trees, suggesting that we may see positive understory plant responses in our plots in the future"*

Additionally, monitoring is not currently taking place to evaluate erosion potential. However, a recent simulation study of two sub-watersheds of the Upper South Platte, Jones, et al. (2017) found that prioritizing preventative management activities (e.g., fuel hazard reduction) can reduce potential sediment loadsfollowing a catastrophic fire when 40% of the potential treatment units were treated. Conversely, accessibility-based management activities had no effect on sediment load.

> "*Accessibility-based treatment scenarios had no effect on sediment load given the limited extent of treatment… When >40% of treatment units were treated under the priority-based scenario, sediment load for the 1-year storm event was less than 1000 m^3 of sediment, but this value increased to 10,000 m^3 when <40% of the area was treated. Far higher sediment loads resulted from the 10-year and 100-year storms for scenarios with <40% treated (680,000 and 2,500,000 m^3 respectively). Sediment loads declined steeply for these storms following 40%-80% fuel treatment extent…"*

(5) Provide improved fish and wildlife habitat

Foundational Sources

(1) Front Range CFLR Proposal (Proposed Treatment, p. 2; **Ecological Context, p. 2) – "***Although forest thinning can have short-term negative effects to some wildlife species, **restoring the landscape to a more historic range of conditions and reducing the potential for stand-replacing, high severity wildfire will have an overall positive impact on the majority of species.***

(2) 2017 Ecological, Social, and Economic Monitoring Plan (**p. 3**) –

- *Desired Condition Number 4: Increase the occurrence of wildlife species that would be expected in a restored lower montane forest*
  - → *Desired trend: Focal species occupying restored sites*

How do Management Actions Contribute to Goals?

Monitoring results are pending from the Landscape Restoration Team, which seek to evaluate trends in 7 focal avian species, in addition to the Abert's squirrel and pine squirrel resulting from forest management. However, in a recent study of 7 Front Range restoration sites, Briggs, et al. (2017) did not detect significant differences in ungulate and squirrel use metrics attributable to forest management.

Table 5

Means (and standard errors) of wildlife use metrics before and one year after restoration treatments in ponderosa pine forests of the Colorado Front Range; n = 34 treated plots and n = 32 untreated plots in seven treatment units and seven nearby untreated areas. Values represent fresh or active signs of use recorded for 2 guilds of species (tree squirrels and ungulates). Significant (α = 0.050) p-values are shown in bold. No interactions of treatment × time were significant for any metric, so pairwise comparisons between groups were not performed.

Metric	Untreated		Treated		Treatment	Time	Treatment × time
	Pre	Post	Pre	Post		P-value	
Plots with sign (%)							
Tree squirrels	93.8 (4.3)	65.6 (8.5)	70.6 (7.9)	26.5 (7.7)	0.060	**<0.001**	0.828
Ungulates	25.0 (7.8)	21.9 (7.4)	23.5 (7.4)	29.4 (7.9)	0.625	0.862	0.524
Number of signs (0.04 ha^{-1})							
Tree squirrels	66.1 (12.7)	27.8 (8.3)	29.7 (12.1)	23.4 (14.7)	0.159	**0.010**	0.612

Figure 5. Results from Briggs, et al. (2017), showing that although tree squirrel habitat use declined after forest management activities, habitat use metrics changed significantly with time but not treatment (e.g. declines in habitat use were observed on both treated and untreated plots). This indicates that changes in habitat use were likely due to inter-annual variation in squirrel populations rather than restoration activities. Ungulate use remained constant across treatments and time.

(6) Decrease probability of life and property loss from Wildfire

Foundational Sources

(1) Living with Fire: Protecting Communities and Restoring Forests (**p. 4** and p. 24) – *"…Partnership's goals are to* ***reduce wildland fire risks*** *through fuels treatment projects that are economically feasible, socially acceptable, and ecologically sustainable;* ***to protect communities from wildland fires****…"*

(2) Front Range CFLR Proposal (*Collaboration, p. 1-2,* ***Wildfire, p. 1****)* – *"There are tens of thousands of homes in the Wildland Urban Interface within the proposal. Most of the treatments included in this proposal will serve to* ***reduce the wildfire hazard and reduce wildfire management costs****. As a result of treatments, we will* ***increase the likelihood of suppressing fire with initial attack****. Millions of dollars* ***and many homes will likely be saved*** *if even one Hayman-type fire is caught in initial attack."*

How do Management Actions Contribute to Goals?

Monitoring has not been implemented to evaluate this goal.

3. Selected Literature

Goal/Expected Outcome	Sources	Notes
Restore forest structure and fire regime	Brown, et al. (2015) Fornwalt, et al. (2002) Kaufmann, et al. (2006) Kaufmann, et al. (2003) Kaufmann, et al. (2000) Platt and Schoennagel (2009) Sherriff and Veblen (2006) Sherriff, et al. (2014) Fulé, et al. (2014) Williams and Baker (2012) Veblen, et al. (2012) Veblen, et al. (2000) Romme (2005)	• Brown, et al. 2015 – Hall/Heil dendrochronological forest stand reconstruction • Fornwalt, et al. 2002 – Cheesman Lake, FVS back-casting exercise for canopy cover • Kauffmann, et al. 2003 – Cheesman Lake, tree age and fire history • Platt and Schoennagel 2009 – aerial imagery analysis N Front Range, canopy cover increased on avg 4% • Veblen et al. 2012 – summarized “then/now” comparison of “default” southwest model and mixed/variable severity regime. • Veblen et al. 2000 – In addition to talking about mixed severity, mentions importance of climate shaping pre-settlement structure • Sheriff et al. 2014 – increased mixed severity with increased elevation. 28% of Front Range forests burned low-severity, while 72% of the study area was mixed-severity fire • Romme 2005 – importance of spatial heterogeneity and multiple scales in fire occurrence and effects
Restore complex mosaic, favoring ponderosa pine and diversifying age structure	Dickinson (2014) Kaufmann, et al. (2000) Kaufmann, et al. (2003) Kaufmann, et al. (2006) Romme, et al. (2003) Dickinson, et al. (2014)	• Dickinson 2014 – Current conditions: reduced abundance of openings, predominately losing small openings rather than large ones • Kauffmann et al. 2000 – Old growth important characteristic historically

	Huckaby, et al. (2001) Brown, et al. (2015) Veblen, et al. (2012) Schoennagel, et al. (2011) Peet (1981) Larson and Churchill (2012) Dickinson, et al. (2016) Briggs, et al. (2017) Chambers, et al. (2016)	• Kauffmann et al. 2003 – Create openings of various sizes, reduce density, remove more DF (especially south aspects) • Romme et al 2003 – in addition to lower montane discussion, also talks about increased homogeneity in stand structure in montane zone – but availability of data is limited for this zone • Brown et al. 2015 – found very few (2) Douglas-fir in Hall/Heil reconstruction (albeit this is very lower montane) • Schoennagel et al. 2011 – Douglas-fir "encroachment" not as pronounced in upper montane • Larson and Churchill 2012 – Moasic structure of fire-frequent manifests between scales of 0.4 to 4.0 ha. Local pattern analysis (ICO) may be incorporated into prescriptions to improve spatial outcomes. • Dickinson et al. 2016 – Restoration treatments can improve some aspects of fine-scale spatial heterogeneity as measured via remote sensing. • Briggs et al. 2017 – restoration treatments in Front Range forests may not always create heterogeneity in forest structure. • Chambers et al. 2016 – post-fire spatial patterns are important drivers of tree regeneration; thus, spatial patterns be closely considered in restoration endeavors.
Increase resilience to fire, insects, disease, drought, and climate change	Hood, et al. (2016) Negrón and Popp (2004) Turner, et al. (2013) Fulé (2008) Rocca, et al. (2014) Churchill, et al. (2013) Janowiak, et al. (2014)	• Hood et al. 2006 – Reduction in tree density increases bark beetle resistance in W. Montana • Turner et al. 2013 – Importance of maintaining spatial heterogeneity for numerous ecosystem services (regeneration, primary production, carbon sequestration, wildlife, natural hazard regulation) through the lens of a changing future. Focused on Greater Yellowstone and PNW, responses depend on context. • Fule 2008 – Adapting reference conditions that already reflect a long history of fire can be used to plan for climate change resiliency

		(albeit it may mean treating areas that some argue are not out of their HRV) • Rocca et al 2014 – Characterizes likely effects of climate change throughout Rockies • Churchill et al. 2013 – provides many examples of spatial heterogeneity enhancing resilience and facilitate sustainable vegetation conditions (below) on the landscape
Provide sustainable vegetation and watershed conditions	Abella and Springer (2015) Laughlin, et al. (2011) Mitchell and Bartling (1991) Turner, et al. (2013) Jones, et al. (2017) Briggs, et al. (2017)	• Abella and Springer 2015 – systematic review, understory recovers after ~5 years. NO studies from Front Range • Lauglin et al. 2011 – comparison with 1912 data (N. Arizona), overall shift in composition to shade tolerant species, decreased cover, richness, and diversity as basal area increased • Mitchell and Bartling 1991 – linear and nonlinear overstory-understory models along Front Range • Turner et al. 2013 – maintaining vegetative conditions and related watershed benefits • Jones et al. 2017 –strategic placement of fuel reduction treatments can improve landscape-scale outcomes related to avoided soil erosion and sedimentation in stream networks. • Briggs et al. 2017 – short-term impacts of restoration treatments in Front Range on showed no increase in exotics nor decreases in native understory plants
Provide improved fish and wildlife habitat	Fontaine and Kennedy (2012) Hutto (2008) Kalies, et al. (2010) Reynolds, et al. (1992) Pilliod, et al. (2006) Briggs, et al. (2017)	• Fontaine and Kennedy 2012 – meta-analysis, full range of "fire-based disturbances (or their surrogates)" necessary to maintain full complement of wildlife species. Only one included study from CO • Hutto 2008 – strong relationship between black-backed woodpecker and high severity burn areas in MT suggests historical component of high severity fire • Kalies 2010 – mixed response to different activities for small mammals and passerine birds. Small diameter harvest and burning (positive), thin/burn and selective harvest (neutral), overstory

		removal and wildfire (negative). Also, species dependent (foraging guild). Arizona and NM • Pilliod 2006 – response depends on life history of species or groups of species. Talks about potential response of certain guilds. • Briggs et al. 2017 – short-term impacts of restoration treatments in Front Range showed no evidence of decreased use by tree squirrels or ungulates.
Decrease probability of life and property loss from wildfire	Graham, et al. (2012) Stephens, et al. (2009) Martinson, et al. (2003)	• Graham et al. 2012 – 4 Mile Canyon Fire Report, fuel treatments may not have moderated fire behavior, but may have exacerbated the fire. • Martinson et al. 2003 – Hayman Fire Report, some treatments (e.g. Polhemus) changed fire behavior, variable effects of other treatments (e.g. fuelbreaks etc).

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