State and Transition Models of semi-arid forest landscapes in western North America: fire and fuel pathways

Authors:
Susan Prichard, Bob Gray, Paul Hessburg, Nicholas Povak, and Brion Salter

Introduction

As part of a study on burn mosaics and their effect on subsequent wildfires, we developed a series of State and Transition Models (STM) to represent vegetation, fuels and fire dynamics in mixed conifer forests of western North America. The central objective of our study was to evaluate fire, vegetation and fuel dynamics under a range of wildland fire management scenarios. Model development was based on three study areas focused on past large fire events included the 2003 Kootenay Complex fires in Kootenay National Park, British Columbia, the 2006 Tripod Complex fires in north-central Washington and the 2007 East Zone Complex fires of central Idaho (Figure 1). Although the three study areas are geographically distinct, they share similar vegetation types and historically complex mixed-severity fire regimes. Because fire is a dominant driver of vegetation within each of the three study areas, the fire and vegetation pathways reflect how fire events can reset succession back to stand initiation from high severity, stand replacement events or cause successional trajectories to branch under low to moderate severity events.

The STMs included in this guide trace successional pathways of vegetation as it interacts with fire across a range of fire timing and severities. Development of the STMs is described in Prichard et al. (in prep). In this guide, we present four major STMs, representing high elevation cold dry mixed conifer forests (CDC) and cold moist mixed conifer forests (CMC) and low to moderate elevation dry mixed conifer forests (DMC) and moist mixed conifer forests (MMC). Each state within the STMs provides a vegetation structural class (**Table 1**), a time step between stages, and surface and canopy fuel assignments including surface fire behavior fuel model (Anderson 1982, Scott and Burgan 2005), canopy cover (CC, %), canopy base height (CBH, m), and canopy bulk density (CBD, kg m^{-3}). Using structural characteristics summarized for representative subbasins within the Interior Columbia River Basin Ecosystem Management Project (Hessburg et al. 1999, 2000), we can also assign forest canopy layers and tree size distributions, shrubland characteristics (cover and height) and herbland characteristics (cover and height). Based on assigned vegetation type and structural attributes, each state within the STMs can be represented with the Fuel Characteristics Classification System (FCCS, Ottmar et al. 2007), and fuelbeds can be used to provide general wildlife habitat suitability under wildland fire scenarios, estimate aboveground carbon stores and wildland fire emissions under fire management scenarios. Fuelbed inputs are summarized in Appendix 1.

Table 1: Vegetation structural class definitions (after O'Hara et al. 1996).

Code	Definition
PFBG	Post-fire bare ground: immediately following a stand-replacing wildfire event
SI	Stand initiation: herb and/or shrub dominated with regenerating trees.
SECC	Stem exclusion closed canopy: dense tree regeneration with canopy closure.
SEOC	Stem exclusion open canopy: open-grown young forests with low canopy cover
UR	Understory reinitiation: maturing, young forests with some canopy gaps to allow recruitment of understory trees.
YFMS	Young forest multi-story: maturing, multi-layered young forests
OFMS	Old forest multi-story: old, multi-layered forests
OFSS	Old forest single-story: old forests characterized by a single overstory layer.

Study Areas

1) The 17,000-ha 2003 Kootenay Fire Complex was one of the largest fire events to have occurred in the Canadian Rockies in the past century and burned within Kootenay National Park. The study area, located in the Canadian Rockies within southeastern British Columbia, is dominated by high elevation mixed conifer forests of Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*) (ESSF) and lodgepole pine (*Pinus contorta*)(LP). Over 75% of the area burned at moderate to high severity. Pre-fire fuel complexes were comprised of mature mixed-conifer forests of lodgepole pine, Engelmann spruce, and subalpine fir. A striking feature of the post-burn landscape is the nearly uniform tree stand replacement within the burned area.

Figure 1: Post-fire photo of the 2003 Kootenay Complex fire in the distance along the Vermillion River. In the foreground is a portion of the 1994 Shank fire that was subsequently reburned by the 2012 Octopus Mountain fire.

2) The 2006 Tripod Complex burned over 70,000 ha of the Okanogan-Wenatchee National Forest (MTBS 2010' Prichard and Kennedy 2014). Approximately 65% of the area burned in stand replacement fires. The study area supports a mix of vegetation types from low-elevation ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) forests to high-elevation mixed conifer codominated by Engelmann spruce, subalpine fir, and lodgepole pine. At the highest elevations within this study area, forests yield to subalpine parklands of whitebark pine (*Pinus albicaulis*) and subalpine larch (*Larix lyallii*).

Figure 2: Post-fire photo of the 2006 Tripod Complex burn near Roger Lake in the foreground with regenerating forests from the 1970 Forks fire in the background.

3) In 2007, the East Zone Complex fires burned over 128,000 ha on the Boise and Payette National Forests in central Idaho (MTBS 2010; Hudak et al. 2011) and was active concurrently with adjacent large fires including the 128,000-ha Cascade Complex to the south and 40,000-ha Rattlesnake Complex to the North. The East Zone Complex study area was selected because it was in the center of the two other fires and supports a wide range of forest types and elevations from subalpine forests and meadows at high elevation to lower tree line dominated by ponderosa pine woodlands.

Figure 3: Large reburn area of the 1994 Porphyry South fire located within the East Zone Complex.

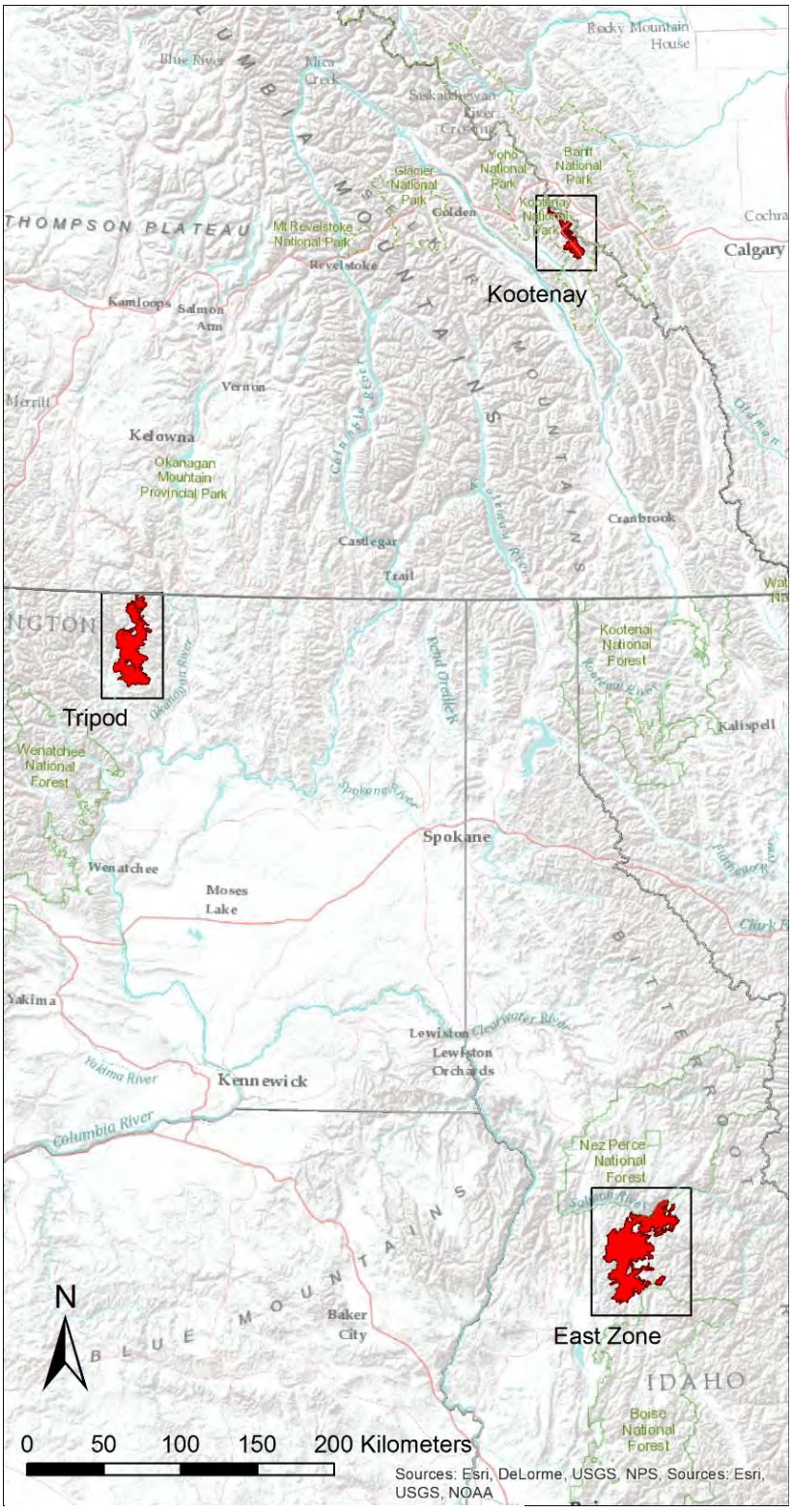


Figure 4: Study area locations.

State and Transition Models

Mixed severity fire STMs were developed to represent major vegetation within mixed conifer zones of the East Zone, Kootenay and Tripod landscapes. Based on site visits and consultations with local area managers, we developed separate models to represent the high-elevation subboreal forest of the Kootenay landscape. Although distributions of vegetation vary between the East Zone and Tripod landscapes, the two study areas share common vegetation types and were represented with the same models.

Single states were assigned to barren areas, grass and shrub vegetation types that were assumed to rapidly recover to pre-burn conditions following fire. These include bare ground, grassland/herbland, shrubland, hardwood forests and montane meadows (**Table 2**).

Table 2: Fuel types and properties that are represented by a single state. CC = canopy cover (%), CH = canopy height (m), canopy base height (m), crown bulk density (kg m^{-3}).

StateID	State	FBFM	CC	CH	CBH	CBD	Description
2111	1A	NB9	0	0.0	0.0	0.0000	Bare ground - rock/water/ice
2121	1B	GR4	0	0.0	0.0	0.0000	Grassland/herbland
2131	1C	GS2	0	0.0	0.0	0.0000	Shrubland
2141	1D	TU1	60	15.0	5.0	0.1314	Hardwood forest
2151	1E	TU1	0	0.0	0.0	0.0000	Montane meadow

Full STM pathways were developed to represent forested areas within each study area. Specialized STMs were developed for the Kootenay study area due to longer successional times required to represent the pathways.

1) Cold Dry Conifer
2) Cold Moist Conifer
3) Dry Mixed Conifer
4) Moist Mixed Conifer

Rates of forest succession in each STM pathway were calibrated using the Forest Vegetation Simulator (FVS)(https://www.fs.fed.us/fvs/). We first used tree list data from FIA plots within the Okanogan and central Idaho study areas to run forest development simulations in the FVS. Simulations included the structural class (keyword StrClass) and canopy fuels (keywords CanCalc, CanFProf) of the Fire and Fuels Extension. FVS simulations were run for 250 years and were used to validate and calibrate successional time steps for STM pathways. For high elevation Engelmann spruce subalpine fir (ESSF) stands, stand structural class definitions were adjusted to account for potentially lower stocking in stand initiation (changed from a minimum of 200 to 100 trees per acre) and lower tree diameter (transition diameter threshold was changed from 25 inches to 15 inches). Because the Kootenay study area is in Canada, a proxy

dataset from high elevation forests in the northern Rockies of Montana was developed to represent the Kootenay pathway.

We used Surface and Tree Mortality modules within BehavePlus (Andrews et al. 2008) to predict flame length and probability of tree mortality across a range of weather scenarios, representing early season, mid-season and late-season fire weather for each study area based on 30-year climate summaries (Table 1). From our BehavePlus predictions, we then developed a set of flame length thresholds that were used to relate predicted flame length to burn severity. Following severity definitions in Perry et al. (2011), high severity was defined as 70-100% tree mortality, moderate severity as 20-70% tree mortality and low severity as burned with <20% mortality. In this paper, we use the term *moderate severity* to represent the middle range of severity for each state. The term *mixed severity* is applied to larger spatial scales and represents the range of low-, moderate- and high-severity fires at work within these STMs (Perry et al. 2011).

Surface and canopy fuel assignments were made for each state. The assignment of surface fire behavior fuel model for each pathway was informed by local fire managers, field observation of state examples, and published photo series. Canopy fuel assignments were informed by FIA data and FVS runs. To model the percent tree mortality for each state we chose a representative tree species and assigned a diameter that coincided with the mid-point of the structure stage of the state.

In addition to fuel assignments for fire behavior modeling, we also constructed fuelbeds to represent each state within the Fuel Characteristics Classification System (FCCS, Ottmar et al. 2007). The FCCS is a software application that catalogues and classifies fuelbed attributes by stratum (e.g., canopy, shrub, herbaceous, downed wood, litter-lichen-moss, and ground fuels) and fuel categories by stratum (e.g., trees, snags and ladder fuels for canopy layers and sound and rotten wood, stumps and piles for downed wood) and subcategory. Fuelbeds were constructed based on reference fuelbeds within FCCS that generally represent the major vegetation types, including low elevation mixed conifer dominated by Douglas-fir and ponderosa pine and high elevation ESSF-LP. Additional reference datasets included natural fuels photo series, activity photo series and field datasets. Based on previous work on constructing FCCS fuelbeds to represent forest successional pathways, disturbance agents and management activities, a chronosequence approach using existing plot data is not possible due to high site-to-site variance, and in this case, reference sites are not available to represent all of the pathways and states in our models of the historical mixed severity fire regime. The FCCS fuelbeds we developed for this exercise were informed as much as possible from reference data but relied on expert opinion for logical transitions between states and pathways.

Cold Dry Conifer

The cold dry conifer STM follows successional trajectories in lodgepole pine, Engelmann spruce and subalpine fir forests on dry, high elevation aspects. State look up tables, including canopy and surface inputs and burn severity definitions by flame length are in Tables 3 and 4, respectively. Forests are dominated by thin-barked trees and generally develop multi-layered canopies even in early stages of forest development. The fire exclusion pathway A follows vegetation recovery and succession after a stand replacement fire and no subsequent fire. The mixed severity pathway B represents moderate severity burns of young to old states in Pathway A. The reburn pathway C traces the trajectory of sites that were burned by a subsequent fire in early stages of forest recovery.

CDC Pathway A

In states 1A through 7A, a stand develops over >180 yr in the absence of subsequent moderate to high severity fires. Low severity fires are possible after the first 14 years but would be expected to creep through stands, partially consuming surface fuels and resulting in up to 20% tree mortality and not actually changing the state.

- State 1A (0-14 yr) represents post-fire bare ground following high-severity fire with mostly bare ground, snags and coarse wood remaining from the antecedent stand. Surface fuels are not continuous enough for fire spread, and after 14 yr, State 1A succeeds to State 2A.
- In state 2A (15-29 yr) a reburn is possible in light surface fuels dominated by compact timber litter, herbaceous fuels and low shrubs. Tree regeneration is slow and composed of lodgepole pine, Engelmann spruce and subalpine fir. Low severity fire does not shift the state. Because regenerating ESSF-LP stands have thin bark and low crowns, we assume that moderate and high-severity fires would both result in substantial mortality and consumption of antecedent snags, represented by state 1C. In the absence of fire, the site transitions to state 3A.
- In the continued absence of fire (3A, 30-49 yr), the regenerating forest has a closed canopy and surface fuels composed of low shrubs and herbs. This state represents high quality Canada lynx habitat with small regenerating high-elevation forests, understory fuels and coarse wood from the antecedent stand. A low severity fire does not shift the state. Moderate and high severity fire kills regenerating trees and consumes downed logs and snags, and as in state 2A, transitions to the reburn pathway at state 1C. In the continued absence of fire, the site transitions to state 4A.
- State 4A (50-79 yr) represents a continuation of SECC but with pole-sized, dense trees and sparse understories that are no longer high-quality Canada lynx habitat. A low severity fire does not shift the state. Moderate severity fire transitions to state 4B. High severity fire kills

regenerating trees and dead wood returning to state 1A. In continued absence of fire, the site transitions to state 5A.

- In state 5A (80-129 yr) the overstory canopy has started to thin, allowing understory spruce and fir to regenerate. This state is characterized by multiple canopy layers and a light timber-litter surface fuelbed. Low severity fire does not shift the state. Moderate to high severity fires return to state 1A. In the continued absence of fire, the site transitions to state 6A.
- State 6A (130-179 yr) represents forests that continue to accumulate surface fuels and develop multiple canopy layers in the absence of fire. In the absence of fire, the site transitions to 7A. Low severity fire does not shift the state. Moderate severity transitions to 6B, and high severity fires return to state 1A.
- In the continued absence of fire, old forests with multiple canopy layers have developed in state 7A (≥ 180 yr) with heavy surface fuel accumulations from individual or group tree mortality from natural thinning, insects and disease. Low severity fire does not shift the state. Moderate severity transitions to 7B, and high severity fires return to state 1A.

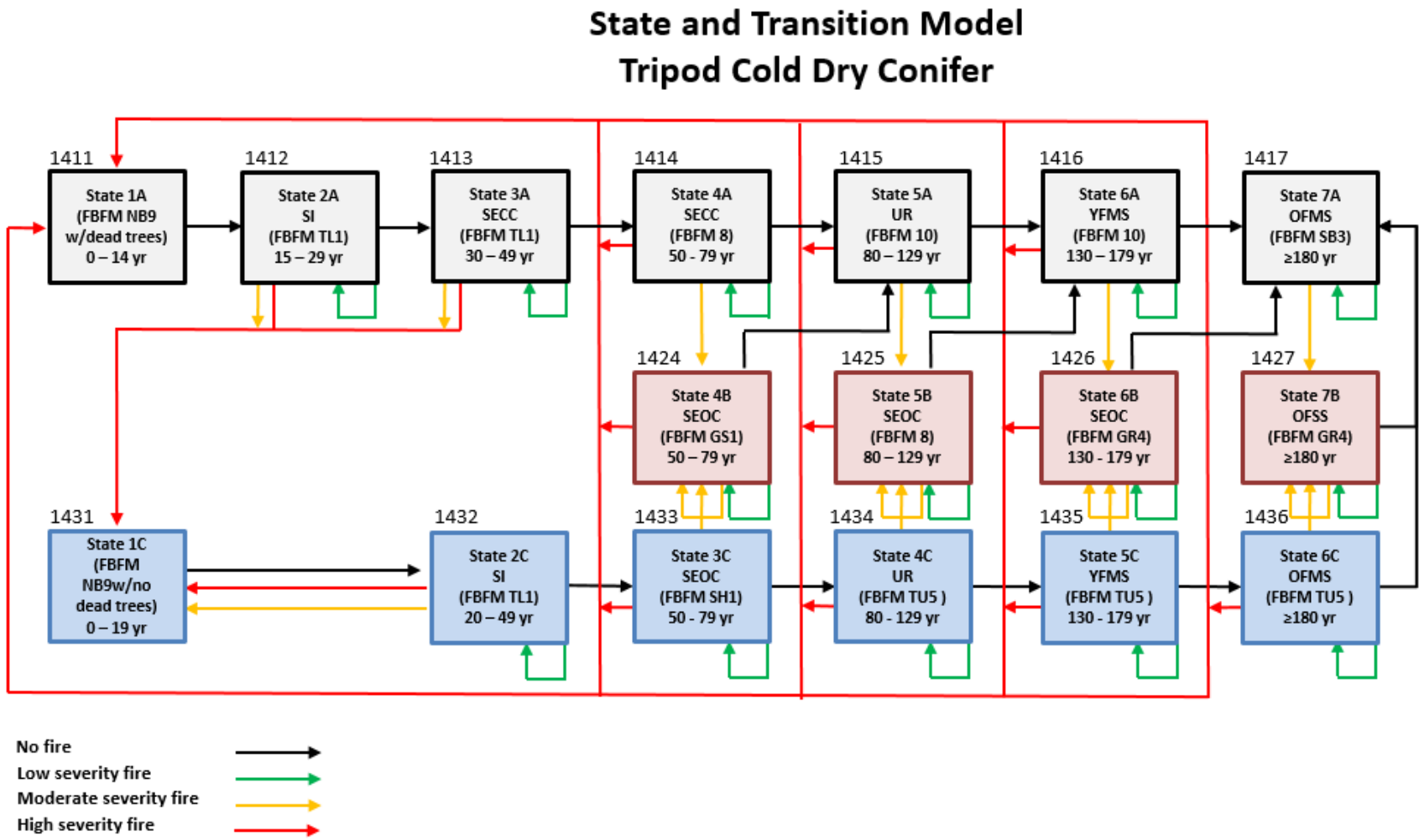


Figure 2: Cold dry conifer state and transition model for the Tripod study area, representing vegetation and fuel dynamics in Engelmann spruce, subalpine fir and lodgepole pine forests under low, moderate and high-severity fire pathways.

CDC PATHWAY A

State 1A: Post-fire bare ground. Fuel model NB9. 0-14 yr.

State 2A: Stand initiation. Fuel model TL1. 15-29 yr.

State 3A-4A: Stem exclusion closed-canopy. Fuel model TL1, 8. 30-79 yr.

State 5A: Understory reinitiation. Fuel model 10. 80-129 yr.

State 6A: Young forest multi-story. Fuel model 10. 130-179 yr.

State 7A: Old forest multi-story. Fuel model SB3. ≥ 180 yr.

CDC Pathway B

The Cold Dry Conifer moderate severity pathways 4B-7B represent altered surface fuels and open forest canopies associated with moderate severity fire events in states 4A through 7A. In the absence of fire, states 4B through 7B transition to the fire exclusion pathway (e.g., 4B transitions to 5A if there is no subsequent fire). Although in reality, moderate severity reburns of 4B through 7B would result in new states, for this simplified STM, repeat moderate severity fires return to their same state. High severity events in states 4A to 7A and 4B to 7B are defined as stand-replacement events with > 75% of trees killed by fire and reset vegetation and fuel succession back to state 1A.

CDC Pathway C

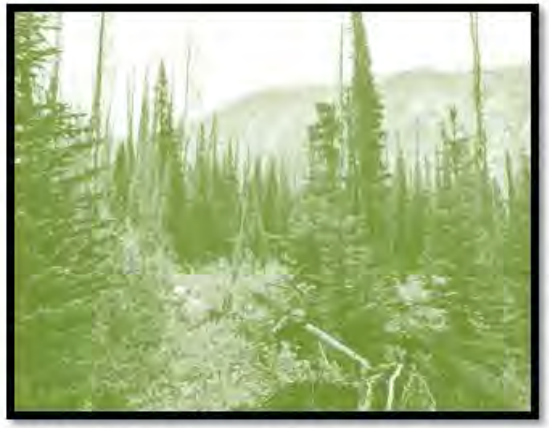
The CDC reburn pathway follows forest succession after a repeat stand-replacing fire event that removed antecedent snags and logs. Rates of tree recruitment and fuel accumulation are slow, reflecting a loss in seed source and that snags from the antecedent stand were consumed in the second fire event.

- In State 1C (0-19 yr) remains a barrier to fire for 20 years due to sparse fuels and slow rates of tree recruitment and fuel accumulation and then transitions to State 2C.
- State 2C (20-49 yr) represents a long stand initiation phase associated with slow rates of tree regeneration and delayed canopy closure. Fire spread is possible in the light surface fuels of timber litter and sparse shrubs. Low severity fires are assumed to not shift the state, but moderate and high severity fires transition the state back to 1C.
- State 3C (50-79 yr) represents an open-grown, uneven-aged young forest. Low severity fire does not shift the state. Moderate severity fires are represented by 4B with lighter surface fuels and more open canopy conditions. High severity fires return to state 1A, which represents recent stand replacement with standing dead trees. In the continued absence of fire, the site transitions to state 4C.
- State 4C (80-129 yr) represents a maturing forest with understory reinitiation. Low severity fire does not shift the state. Moderate severity fires are represented by 5B with lighter surface fuels and more open canopy conditions. If no fire occurs, the state transitions to 5C, and high severity fires return to state 1A.
- State 5C (130-179 yr) represents a maturing, multi-storied forest that has developed in the absence of fire with accumulations of live and dead surface fuels. Low severity fire does not shift the state. Moderate severity fires transition to State 6B, and high severity fires return to state 1A. If no fire occurs, the state transitions to 6C.
- State 6C (≥ 180 yr) represents an old, multi-storied forest that has developed in the absence of fire with heavy live and dead fuel accumulation. Moderate severity fires transition to State 7B, and high severity fires return to state 1A.

CDC PATHWAY B

State 4B: Stem exclusion open canopy. Fuel model GS1. 50-79 yr.

State 5B: Stem exclusion open canopy. Fuel model 8. 80-129 yr.



State 6B: Stem exclusion open canopy. Fuel model GR4. 130-179 yr.

State 7B: Old forest multi-story. Fuel model GR4. ≥ 180 yr.

CDC PATHWAY C

State 1C: Post-fire bare ground. Fuel model NB9. 0-19 yr.

State 2C: Stand initiation. Fuel model TL1. 20-49 yr.

State 3C: Stem exclusion closed-canopy. Fuel model SH1. 50-89 yr.

State 4C: Understory reinitiation. Fuel model TU5. 90-129 yr.

State 5C: Young forest multi-story. Fuel model TU5. 130-179 yr.

State 6C: Old forest multi-story. Fuel model TU5. ≥ 180 yr.

Table 3: Surface and canopy fuel properties of cold dry conifer (CDC) states for the Tripod and East Zone study areas. State assignments are identical between the two study areas, but successional time steps differ. CC = canopy cover (%), CH = canopy height (m), canopy base height (m), crown bulk density (kg m^{-3}).

State	Tripod State ID	Time period (yr)	Structure	FBFM	CC	CH	CBH	CBD	East Zone State ID	Time period (yr)
1A	1411	0-14	PFBG	NB9	10	2	0.0	0.0010	2411	0-14
2A	1412	15-29	SI	TL1	25	4	0.5	0.0500	2412	15-24
3A	1413	30-49	SECC	TL1	45	12	0.8	0.0800	2413	25-39
4A	1414	50-79	SECC	8	50	15	0.8	0.0993	2414	40-59
5A	1415	80-129	UR	10	55	18	1.0	0.1000	2415	60-119
6A	1416	130-179	YFMS	10	55	28	0.2	0.1185	2416	120-179
7A	1417	≥ 180	OFMS	SB3	65	30	0.2	0.1185	2417	≥ 180
4B	1424	50-79	SEOC	GS1	40	14	0.5	0.0535	2424	40-59
5B	1425	80-129	SEOC	8	45	25	0.2	0.0750	2425	60-119
6B	1426	130-179	SEOC	GR4	50	25	0.2	0.0800	2426	120-179
7B	1427	≥ 180	OFSS	GR4	55	25	0.2	0.0950	2427	≥ 180
1C	1431	0-19	PFBG	NB9	5	1	0.0	0.0005	2431	0-19
2C	1432	30-49	SI	TL1	25	4	0.5	0.0500	2432	20-39
3C	1433	50-79	SECC	SH1	45	14	0.8	0.0800	2433	40-59
4C	1434	80-129	UR	TU5	50	22	0.8	0.0993	2434	60-119
5C	1435	130-179	YFMS	TU5	55	30	1.0	0.1000	2435	120-179
6C	1436	≥ 180	OFMS	TU5	55	30	0.2	0.1185	2436	≥ 180

Table 4: Fire severity thresholds to classify burn severity by predicted flame length (m).

StateID	State	Low	Moderate	High
1411	1A			> 0.0
1412	2A	≤ 0.4	> 0.4 but ≤ 0.7	> 0.7
1413	3A	≤ 0.4	> 0.4 but ≤ 0.7	> 0.7
1414	4A	≤ 0.7	> 0.7 but ≤ 1.1	> 1.1
1415	5A	≤ 0.3	> 0.3 but ≤ 1.1	> 1.1
1416	6A	≤ 0.3	> 0.3 but ≤ 1.1	> 1.1
1417	7A	≤ 0.3	> 0.3 but ≤ 1.6	> 1.6
1424	4B	≤ 0.2	> 0.2 but ≤ 0.7	> 0.7
1425	5B	≤ 0.15	> 0.15 but ≤ 0.6	> 0.6
1426	6B	≤ 0.3	> 0.3 but ≤ 1.6	> 1.6
1427	7B	≤ 0.3	> 0.3 but ≤ 1.6	> 1.6
1431	2C	≤ 0.9	> 0.9 but ≤ 1.6	> 1.6
1432	3C	≤ 0.7	> 0.7 but ≤ 1.6	> 1.6
1433	4C	≤ 0.4	> 0.4 but ≤ 1.5	> 1.5
1434	5C	≤ 0.4	> 0.4 but ≤ 1.6	> 1.6
1435	6C	≤ 0.4	> 0.4 but ≤ 1.6	> 1.6

Cold Moist Conifer

The cold moist conifer STM follows successional trajectories in lodgepole pine, Engelmann spruce and subalpine fir forests on moist sites that are somewhat more productive than the cold dry conifer STM but with the same states and pathways.

Table 5: Surface and canopy fuel properties of cold moist conifer (CDC) states for the Tripod and East Zone study areas. State assignments are identical between the two study areas, but successional time steps differ. CC = canopy cover (%), CH = canopy height (m), canopy base height (m), crown bulk density (kg m^{-3}).

State	Tripod State ID	Time period	Structure	FBFM	CC	CH	CBH	CBD	East Zone State ID	Time period
1A	1511	0-9	PFBG	NB9	10	2.0	0.0	0.0010	2511	0-9
2A	1512	10-19	SI	TL1	30	6.1	0.5	0.0673	2512	10-19
3A	1513	20-34	SECC	TL1	50	14.0	0.5	0.0700	2513	20-29
4A	1514	35-59	SECC	8	70	16.2	0.8	0.0800	2514	30-49
5A	1515	60-119	UR	10	60	22.3	0.8	0.0800	2515	50-109
6A	1516	120-179	YFMS	10	65	33.2	0.8	0.0950	2516	110-169
7A	1517	≥ 180	OFMS	SB3	70	35.0	0.4	0.1185	2517	≥ 170
4B	1524	35-59	SEOC	GS1	45	16.2	1.0	0.0800	2524	30-49
5B	1525	60-119	SEOC	8	50	22.3	1.0	0.0900	2525	50-109
6B	1526	120-179	SEOC	GR4	55	30.0	1.0	0.1000	2526	110-169
7B	1527	≥ 180	OFSS	GR4	55	33.2	1.0	0.1000	2527	≥ 170
1C	1531	0-19	PFBG	NB9	5	1.5	0.0	0.0010	2531	0-19
2C	1532	20-35	SI	TL1	20	10.0	0.5	0.0700	2532	20-29
3C	1533	35-59	SEOC	SH1	55	16.2	0.8	0.0800	2533	30-49
4C	1534	60-119	UR	TU5	50	22.3	0.8	0.0993	2534	50-109
5C	1535	120-179	YFMS	TU5	60	30.0	0.8	0.1000	2535	110-169
6C	1536	≥ 180	OFMS	TU5	60	33.2	1.0	0.1185	2536	≥ 170

Table 6: Fire severity thresholds to classify burn severity by predicted flame length (m).

StateID	State	Low	Moderate	High
1511	1A			> 0.0
1512	2A	≤ 0.4	> 0.4 but ≤ 0.7	> 0.7
1513	3A	≤ 0.4	> 0.4 but ≤ 0.7	> 0.7
1514	4A	≤ 0.7	> 0.7 but ≤ 1.1	> 1.1
1515	5A	≤ 0.3	> 0.3 but ≤ 1.1	> 1.1
1516	6A	≤ 0.3	> 0.3 but ≤ 1.1	> 1.1
1517	7A	≤ 0.3	> 0.3 but ≤ 1.6	> 1.6
1524	4B	≤ 0.2	> 0.2 but ≤ 0.7	> 0.7
1525	5B	≤ 0.15	> 0.15 but ≤ 0.6	> 0.6
1526	6B	≤ 0.3	> 0.3 but ≤ 1.6	> 1.6
1527	7B	≤ 0.3	> 0.3 but ≤ 1.6	> 1.6
1531	2C	≤ 0.9	> 0.9 but ≤ 1.6	> 1.6
1532	3C	≤ 0.7	> 0.7 but ≤ 1.6	> 1.6
1533	4C	≤ 0.4	> 0.4 but ≤ 1.5	> 1.5
1534	5C	≤ 0.4	> 0.4 but ≤ 1.6	> 1.6
1535	6C	≤ 0.4	> 0.4 but ≤ 1.6	> 1.6

Kootenay Cold Dry Conifer

The Kootenay Cold Dry Conifer (CDC) STM represents fire and fuel dynamics on dry sites, generally on exposed ridges and slopes with southern or western exposures in the southern Canadian Rockies. There are two key differences in the cold dry and cold moist ESSF-LP forests of the Kootenay study area that required separate STMs for this area. The first is that herbaceous vegetation, including *Calamagrostis* spp. and *Carex* spp., quickly recolonizes sites and creates a continuous surface fuelbed that supports reburns within 5 years of an original fire. Second, historically, forests in the Kootenay landscape were older (> 250 to 300 years) and justified a longer successional timeframe in these models (Table 7).

Table 7: Surface and canopy fuel properties of cold dry conifer (CDC) pathways for the Kootenay study area. CC = canopy cover (%), CH = canopy height (m), canopy base height (m), crown bulk density (kg m^{-3}).

State	State ID	Time period (yr)	Structure	FBFM	CC	CH	CBH	CBD
1A	2411	0-5	PFBG	NB9	5	1.0	0.0	0.0010
2A	2412	5-29	SI	TL1	5	4.6	0.5	0.0500
3A	2413	30-59	SECC	TL1	45	12.0	0.8	0.0800
4A	2414	60-119	SECC	8	50	15.0	0.8	0.0993
5A	2415	60-119	UR	8	55	18.0	1.0	0.1000
6A	2416	120-179	YFMS	10	55	28.0	0.2	0.1185
7A	2417	≥ 180	OFMS	SB3	65	30.0	0.2	0.1185
3B	2423	25-39	SEOC	GS1	20	12.0	1.0	0.0400
4B	2424	40-59	SEOC	GS1	40	14.0	0.5	0.0535
5B	2425	60-119	SEOC	8	45	25.0	0.2	0.0750
6B	2426	120-179	OFSS	GR4	50	25.0	0.2	0.0800
7B	2427	≥ 180	OFSS	GR4	55	25.0	0.2	0.0950
1C	2431	0-19	PFBG	NB9	10	2.0	0.0	0.0010
2C	2432	20-39	SI	TL1	25	4.0	0.5	0.0500
3C	2433	40-59	SECC	SH1	45	14.0	0.8	0.0800
4C	2434	60-119	SECC	TU5	50	22.3	0.8	0.0993
5C	2435	120-179	UR	TU5	55	30.0	1.0	0.1000
6C	2436	≥ 180	YFMS	TU5	55	30.0	0.2	0.1185

Kootenay Cold Moist Conifer

The Kootenay Cold Moist Conifer (CMC) STM represents fire and fuel dynamics on moist sites, generally in moist valleys and north and eastern slopes in the southern Canadian Rockies (Table 8).

Table 8: Surface and canopy fuel properties of cold moist conifer (CMC) pathways for the Kootenay study area. CC = canopy cover (%), CH = canopy height (m), canopy base height (m), crown bulk density (kg m^{-3}).

State	State ID	Time period (yr)	Structure	FBFM	CC	CH	CBH	CBD
1A	2511	0-9	PFBG	NB9	10	2.0	0.0	0.0010
2A	2512	10-19	SI	TL1	30	6.1	0.5	0.0673
3A	2513	20-29	SECC	TL1	50	14.0	0.5	0.0700
4A	2514	30-49	SECC	8	70	16.2	0.8	0.0800
5A	2515	50-109	UR	8	60	22.3	0.8	0.0800
6A	2516	110-169	YFMS	10	65	33.2	0.8	0.0950
7A	2517	≥ 170	OFMS	SB3	70	35.0	0.4	0.1185
3B	2523	20-29	SEOC	TL1	36	14.0	1.0	0.0673
4B	2524	30-49	SEOC	TU5	45	16.2	1.0	0.0800
5B	2525	50-109	SEOC	TU5	50	22.3	1.0	0.0900
6B	2526	110-169	OFSS	TU5	55	30.0	1.0	0.1000
7B	2527	≥ 170	OFSS	TU5	55	33.2	1.0	0.1000
1C	2531	0-19	PFBG	NB9	5	1.5	0.0	0.0010
2C	2532	20-29	SI	TL1	20	10.0	0.5	0.0700
3C	2533	30-49	SEOC	SH1	55	16.2	0.8	0.0800
4C	2534	50-109	UR	TU5	50	22.3	0.8	0.0993
5C	2535	110-169	YFMS	TU5	60	30.0	0.8	0.1000
6C	2536	≥ 170	OFMS	TU5	60	33.2	1.0	0.1185

KOOTENAY CDC PATHWAY "A"

State 1A: Post-fire bare ground. Fuel model NB9. 0-14 yr.

State 2A: Stand initiation. Fuel model GS1. 15-49 yr.

State 3A: Stem exclusion closed-canopy. Fuel model 2. 50-89 yr.

State 4A: Understory reinitiation. Fuel model TU5. 90-129 yr.

State 5A: Young forest multi-story. Fuel model TU5. 130-179 yr.

State 6A: Old forest multi-story. Fuel model TU5. ≥ 180 yr.

Kootenay Avalanche Tracks

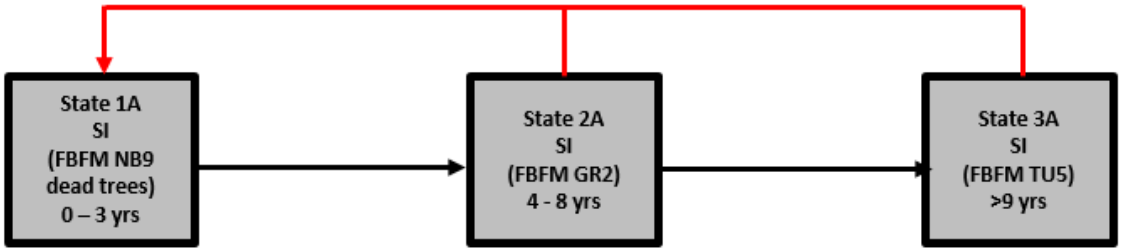
Avalanche tracks are a prominent feature of the mountainous Kootenay landscape. Vegetation and fuels are quite variable within avalanche tracks but are generally composed of grasses, sedges, broadleaf deciduous shrubs and dead wood. Three states are supported with a relatively short time interval between states (Table 9). Due to the extreme topography and influence of snow avalanches, succession within tracks is often curtailed by a subsequent avalanche event.

- State 1A (0-3 yr) represents a short-term barrier to fire and is mostly bare ground with some concentrations of recently dead trees and logs following avalanche and/or fire.
- In State 2A (4-8 yr) is dominated by grasses and dead wood with some early conifer regeneration. Cured herbaceous fuels will carry surface fires.
- State 3A (> 9 yr) supports dense grass, herb and shrubs with heavy downed wood accumulations and some conifer regeneration. Cured herbaceous fuels will carry surface fires, and large fuel accumulations, which are often associated with avalanche tracks, burn aggressively and facilitate fire spread across/around avalanche tracks.

Table 9: Kootenay avalanche tracks.

ID	State	Time period (yr)	Stand structure class	Surface fuel model	Canopy bulk density (kg/m³)	Canopy base height (m)	Crown closure (%)	Canopy height (m)
1611	1A	0-3	PFBG	NB9	n/a	0.0	0	n/a
1612	2A	4-8	SI	GR2	0.001	0.5	5	1
1613	3A	>9	SI	TU5	0.001	0.5	10	7

Kootenay Avalanche Tracks



Dry Mixed Conifer

The Dry Mixed Conifer (DMC) STM models vegetation and fire pathways on drier biophysical settings within ponderosa pine and Douglas-fir dominated forests of the East Zone and Tripod study areas (Table 10). The DMC STM has four pathways to represent a complex mixed severity fire regime and uneven-aged forest development (Figure 3). By supporting a limited number of states and aligning time periods between pathways, the STM offers a simplified representation of the interaction of fire and vegetation with a range of burn severities, including low-severity, moderate severity, and high-severity fires as defined by the relationship of predicted flame length to probable tree mortality (Table 11). In reality, combinations of low and moderate severity fires would result in a continuum of states, reflecting diverse fire effects and forest and fuel structures.

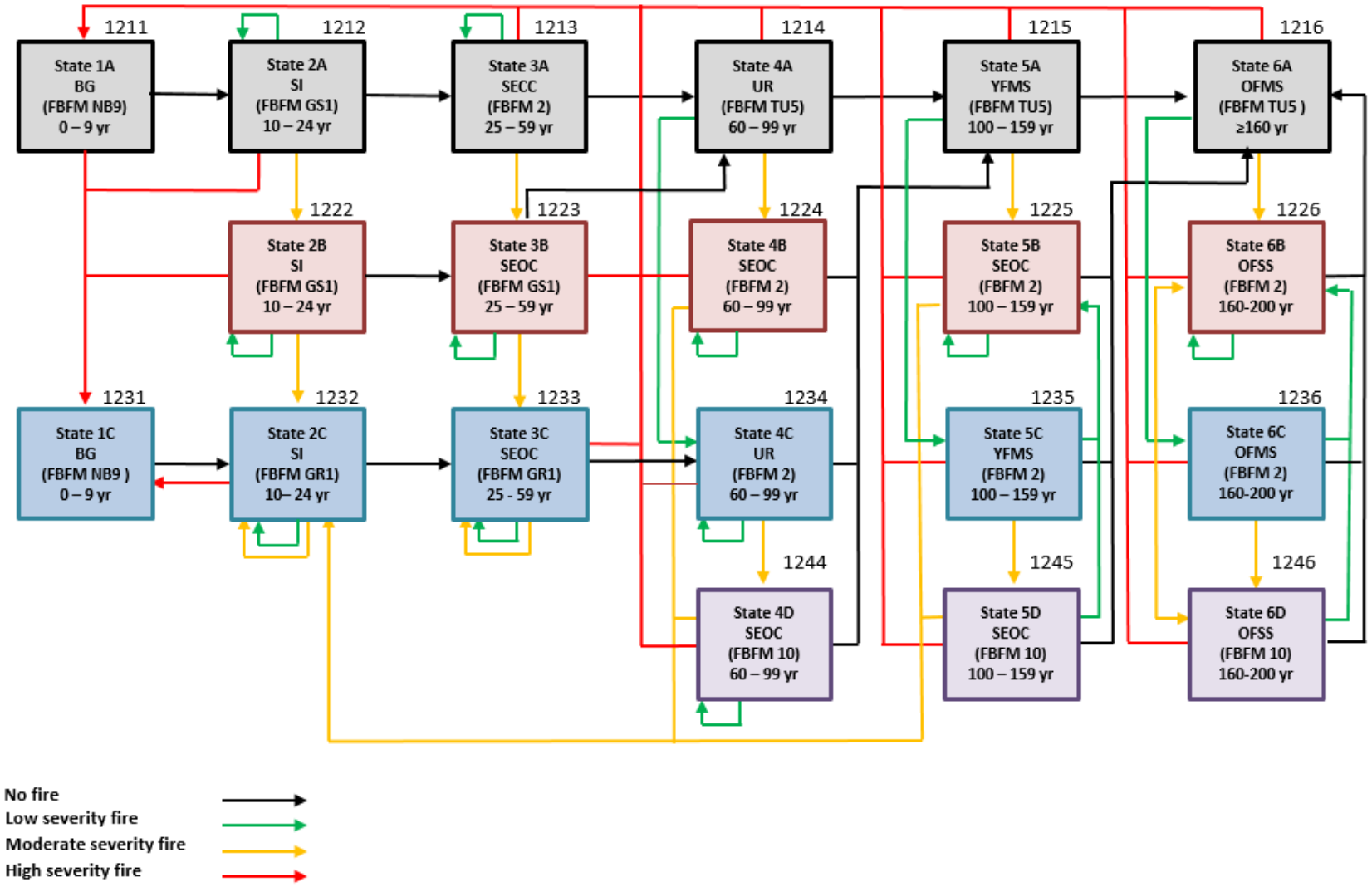
Table 10: Surface and canopy fuel properties of dry mixed conifer (DMC) states for the Tripod and East Zone study areas. State assignments are identical between the two study areas, including successional time steps. CC = canopy cover (%), CH = canopy height (m), canopy base height (m), crown bulk density (kg m^{-3}).

State ID Tripod/ East Zone	State ID	Time period (yr)	Stand structure class	Surface fuel model	Canopy bulk density (kg/m^3)	Canopy base height (m)	Crown closure (%)	Canopy height (m)
1211/2311	1A	0-9	PFBG	NB9	0.0019	0.0	1	2.1
1212/2312	2A	10-24	SI	GS1	0.0320	0.6	18	6.4
1213/2313	3A	25-59	SECC	2	0.0298	0.8	60	14.6
1214/2314	4A	60-99	UR	TU5	0.0275	1.0	34	19.8
1215/2315	5A	100-159	YFMS	TU5	0.0275	1.0	45	27.4
1216/2316	6A	≥ 160	OFMS	TU5	0.0320	1.5	55	36.6
1222/2322	2B	10-24	SI	GS1	0.0205	0.6	15	5.5
1223/2323	3B	25-59	SEOC	GS1	0.0228	1.5	25	13.7
1224/2324	4B	60-99	SEOC	2	0.0259	1.0	30	18.3
1225/2325	5B	100-159	SEOC	2	0.0275	2.0	40	27.4
1226/2326	6B	160-200	OFSS	2	0.0275	3.0	55	36.6
1231/2331	1C	0-9	PFBG	NB9	0.0019	0.0	1	2.1
1232/2332	2C	10-24	SI	GR1	0.0205	0.6	15	5.5
1233/2333	3C	25-59	SEOC	GR1	0.0228	1.5	25	13.7
1234/2334	4C	60-99	UR	2	0.0259	1.0	30	18.3
1235/2335	5C	100-159	YFMS	2	0.0275	1.5	40	27.4
1236/2336	6C	≥ 160	UR	2	0.0275	1.0	55	36.6
1244/2344	4D	60-99	SEOC	10	0.0275	1.5	34	19.8
1245/2345	5D	100-159	SEOC	10	0.0275	1.5	45	27.4
1246/2346	6D	160-200	OFSS	10	0.0320	2.5	55	36.6

Table 11: Fire severity thresholds to classify burn severity by predicted flame length (m).

State ID	State	Low	Moderate	High
1211	1A			> 0.01
1212	2A	< 0.5	> 0.5 but ≤ 0.85	> 0.85
1213	3A	< 0.75	> 0.75 but ≤ 1.4	> 1.4
1214	4A	< 1.6	> 1.6 but ≤ 1.8	> 1.8
1215	5A	< 1.75	> 1.75 but ≤ 1.85	> 1.85
1216	6A	< 1.7	> 1.7 but ≤ 1.85	> 1.85
1222	2B	< 0.85	> 0.85 but ≤ 0.95	> 0.95
1223	3B	< 0.85	> 0.85 but ≤ 0.95	> 0.95
1224	4B	< 1.35	> 1.35 but ≤ 1.45	> 1.45
1225	5B	< 1.4	> 1.4 but ≤ 1.48	> 1.48
1226	6B	< 1.45	> 1.45 but ≤ 1.7	> 1.7
1231	1C			> 0.01
1232	2C	< 0.6	> 0.6 but ≤ 0.68	> 0.68
1233	3C	< 1.0	> 1.0 but ≤ 2.0	> 2.0
1234	4C	< 1.3	> 1.3 but ≤ 1.5	> 1.5
1235	5C	< 1.35	> 1.35 but ≤ 1.48	> 1.48
1236	6C	< 1.4	> 1.4 but ≤ 1.7	> 1.7
1244	4D	< 1.25	> 1.25 but ≤ 1.38	> 1.38
1245	5D	< 1.25	> 1.25 but ≤ 1.4	> 1.4
1246	6D	< 1.3	> 1.3 but ≤ 1.7	> 1.7

State and Transition Model
Tripod Dry Mixed Conifer Model



DMC Pathway A: In states 1A through 6A, a ponderosa pine and Douglas-fir stand develops over 160 yr after a stand-replacing fire event from early successional state (1A) to an old multistory forest (6A).

- State 1A (0-9 yr) represents post-fire bare ground with mostly exposed mineral soil, snags and coarse wood remaining from the antecedent stand. Surface fuels are not continuous enough for fire spread. After 9 yr State 1A transitions to State 2A.
- In State 2A (10-24 yr), a reburn is possible in light surface fuels dominated by grass and litter. Low severity fire does not shift the state. Moderate severity fire results in patchy mortality represented by state 2B (moderate severity pathway). High severity fire transitions to State 1C (reburn pathway with no remaining antecedent snags or coarse wood). If no fire occurs the site transitions to 3A.
- In State 3A (25-59 yr) heavy accumulations of dead wood from the antecedent stand are present. Low severity fire does not shift the state. Moderate severity fire shifts to state 3B. High severity fire results in 1A (stand initiation).In the absence of fire the site transitions to 4A.
- In State 4A (60-99 yr) understory trees and accumulations of litter and fine wood have accumulated in the maturing forest. Low severity fire shifts to state 4C, and moderate severity fire results in state 4B. High severity fire returns state 1A. If no fire occurs the site transitions to 5A.
- In the continued absence of moderate or high severity fire, state 5A (100-159 yr) forests accumulate surface fuels and develop multiple canopy layers. Low severity fire transitions the site to 5C, and moderate severity fire results in State 5B. High severity fire returns to State 1A. In the absence of fire the site transitions to 6A.
- State 6A (≥ 160 yr) represents an old forest with multilayered canopies and heavy surface fuels that have developed in the absence of fire. Low and moderate fires are represented by 6C and 6B, respectively. High severity fire returns to State 1A.

DMC PATHWAY A

State 1A: Post-fire bare ground. Fuel model NB9. 0-9 yr.

State 2A: Stand initiation. Fuel model GS1. 10-24 yr.

State 3A: Stem exclusion closed-canopy. Fuel model 2. 25-59 yr.

State 4A: Understory reinitiation. Fuel model TU5. 60-99 yr.

State 5A: Young forest multi-story. Fuel model TU5. 100-159 yr.

State 6A: Old forest multi-story. Fuel model TU5. 80-120 yr.

DMC Pathway B: The moderate severity DMC pathway (2B to 6B) represents reburn scenarios in which subsequent fires support patchy, open stand structures and modified surface fuels.

- State 2B (10-24 yr) represents an open-grown regenerating stand with a sparse understory following a moderate severity reburn of State 2A. Low severity fire does not result in a state change. Moderate severity burns reduces surface and canopy fuels of the regenerating stand and dead trees from the antecedent stand, best represented in this simplified STM by state 2C. High severity fire transitions to the reburn pathway at 1C. No fire transitions to State 3B.
- States 3B (25-59 yr) and 4B (60-99 yr) support open, patchy forest structure created from moderate severity burns at State 3A and 4A respectively. A subsequent low severity fire does not change the state, but moderate severity fires further reduce canopy fuels and surface fuels, transitioning to State 3C and 4C, respectively. High severity fires return to State 1A. No fire transitions to the fire exclusion pathway at 4A and 5A, respectively.
- In State 5B (80-160 yr) mature open and patchy forests are created via low severity fires in states 5C and 5D or a moderate severity fire in State 5A. A subsequent low-severity burns does not shift the state. Moderate severity burns further reduce canopy fuels and result in state 2C, reflecting that the site is mostly in stand initiation. High severity fire in this state resets burned areas to State 1A, and if no fire occurs, the site enters the fire exclusion pathway at 6A.
- State 6B (160-200 yr) represents open-grown, old forests that have developed after a moderate severity reburn event from state 6A or a low severity event from states 6C or 6D. A subsequent low-severity burn does not change the state. Moderate severity fire results in state 6D in which reduced canopy fuels temporarily increase surface fuels. High severity fire returns burned areas to State 1A. If no fire occurs, the site enters the fire exclusion pathway at 6A.

DMC PATHWAY B

State 2B: Stand initiation. Fuel model GS1. 10-24yr.

State 3B: Stem exclusion open canopy. Fuel model GS1. 25-59 yr.

State 4B: Stem exclusion open canopy. Fuel model 2. 60-99 yr.

State 5B: Stem exclusion open canopy. Fuel model 2. 100-159 yr.

State 6B: Old forest single story. Fuel model 2. 160-200 years

DMC Pathway C: The DMC reburn pathway follows forest and fuel succession after a high severity fire at early stand development stages (2A, 2B, and 2C), consuming antecedent snags and logs and creating an open-grown regenerating forest with delayed canopy and surface fuel succession due to reduced seed source and/or competition with established grasses. Due to recent fires or delayed tree regeneration and fuel accumulation, light grass and timber litter fuels characterize surface fuels in each state.

- State 1C (0-9 yr) represents initial bare ground following stand-replacing fires in States 1A or 2A or 2C in which antecedent snags and logs are absent and stand initiation is sparse due to lack of seed source. Subsequent fires are not possible at this state, and after 9 years, stand transition to State 2C.
- State 2C (10-24 yr) represents an open-grown regenerating stand with a sparse understory following succession from 2A or a moderate severity fire at state 2B. Subsequent low or moderate severity fire do not change the state. High severity fire returns to 1C. No fire succeeds to State 3C.
- State 3C (25-59 yr) represents an open-grown young stand that either develops from State 2C or a moderate severity reburn of State 3B. Subsequent low or moderate severity fire do not change the state. High severity fire returns to 1A. No fire succeeds to 4C.
- In State 4C (60-99 yr) an open forest has developed with understory tree recruitment following the absence of fire in States 2C and 3C. Low severity fire does not change the state, but moderate severity fire causes tree mortality, resulting in a temporary increase in surface fuels, as represented by State 4D. High severity fires return to State 1A. No fire transitions to the fire exclusion pathway at 5A.
- State 5C (100-159 yr) represents older forests with understory tree recruitment and reduced surface fuels from a low-severity fire State 5A. Subsequent low-severity fire transitions the site to State 5B. Moderate severity fire transitions to 5D, reflecting open canopy conditions. High severity fires return to State 1A. In the absence of fire, the site transitions to the fire exclusion pathway at 6A.
- State 6C (160-200 yr) represents an old forest with understory tree recruitment and reduced surface fuels, resulting from a low severity fire in 6A. A subsequent low-severity fire transitions to State 6B. Moderate severity fire results in state 6D, reflecting recent tree mortality and a temporary increase in surface fuels. High severity fires return to State 1A. In the absence of fire, the site transitions to the fire exclusion pathway at 6A.

DMC PATHWAY C

State 1C: Post-fire bare ground. Fuel model NB9. 0-9 yr.

State 2C: Stand initiation. Fuel model GR1. 10-24 yr.

State 3C. Stem exclusion open canopy. Fuel model GR1. 25-59 yr.

State 4C: Understory reinitiation. Fuel model 2. 60-99 yr.

State 5C: Young forest multi-story. Fuel model 2. 100-159 yr.

State 6C: Old forest multi-story. Fuel model 2. 160-200 yr.

DMC Pathway D: This pathway represents multi-aged forests that result from multiple low and moderate severity fires. In reality, myriad bifurcations of states within B, C and D would exist within a mixed severity fire regime but have been limited to simplify this STM.

- State 4D (60-99 yr) follows a moderate severity fire in State 4C. A subsequent low severity fire does not change the state. Moderate severity burns create additional tree mortality and transition to state 2C, reflecting that the site is mostly in stand initiation. High severity fires return to State 1A. In the absence of fire, the site transitions to the fire exclusion pathway at 5A.
- State 5D (100-159 yr) represents an open-grown, maturing forest following moderate severity fire in 5C. A subsequent low severity fire transitions to State 5B. Moderate severity fire further reduces canopy fuels and results in state 2C, reflecting that the site is mostly in stand initiation. High severity fires return to State 1A, and in the absence of fire, the site transitions to the fire exclusion pathway at 6A.
- State 6D (160-200 yr) represents an uneven-aged, open-grown stand of ponderosa pine following a moderate severity burn in State 6B. Subsequent low and moderate severity fires are best represented by 6B, reflecting open stand conditions and reduced surface fuels. High severity fires reset to State 1A, and in the absence of fire, the site transitions to the fire exclusion pathway at 6A.

DMC PATHWAY D

State 4D: Stem exclusion open canopy. Fuel model 10. 60-99 yr.

State 5D: Stem exclusion open canopy. Fuel model 10. 100-159 yr.

State 6D: Old forest single story. Fuel model 10. 160-200 yr.

Moist Mixed Conifer

The low elevation moist mixed conifer (MMC) STM has four pathways to represent a complex mixed severity fire regime resulting from forest succession on productive, low-elevation sites within the East Zone and Tripod study areas (Tables 12, 13). Forests are dominated by ponderosa pine, Douglas-fir with associated lodgepole pine, Engelmann spruce and western larch. The STM shares the same pathways and states as the DMC but with shorter times between states, representing greater productivity and more rapid vegetation development.

Table 12: East Zone/Tripod MMC surface and canopy fuel assignments by state.

State ID (Tripod/ East Zone)	State	Time period (yr)	Stand structure class	Surface fuel model	Canopy bulk density (kg/m³)	Canopy base height (m)	Crown closure (%)	Canopy height (m)
1311/2211	1A	0-9	PFBG	NB9	0.0096	0.0	2	5.0
1312/2212	2A	10-19	SI	GS1	0.0416	0.6	24	9.0
1313/2213	3A	20-39	SECC	2	0.0465	1.0	70	24.0
1314/2214	4A	40-79	UR	TU5	0.0430	1.0	70	24.0
1315/2215	5A	80-139	YFMS	TU5	0.0405	0.8	70	37.0
1316/2216	6A	≥140	OFMS	TU5	0.0500	1.0	80	37.0
1322/2222	2B	10-19	SI	GS1	0.0350	0.6	20	7.0
1323/2223	3B	20-39	SEOC	GS1	0.0301	2.0	51	24.0
1324/2224	4B	40-79	SEOC	2	0.0284	2.0	53	24.0
1325/2225	5B	80-139	SEOC	2	0.0284	0.8	70	24.0
1326/2226	6B	140-180	OFSS	2	0.0350	12.0	75	30.0
1331/2231	1C	0-9	PFBG	NB9	0.0096	0.0	2	5.0
1332/2232	2C	10-19	SI	GR1	0.0333	0.6	20	12.0
1333/2233	3C	20-39	SEOC	GR1	0.0372	2.0	40	23.0
1334/2234	4C	40-79	UR	2	0.0405	2.0	60	23.0
1335/2235	5C	80-139	YFMS	2	0.0500	1.0	70	30.0
1336/2236	6C	140-180	OFMS	2	0.0550	1.0	75	35.0
1344/2244	4D	40-79	SEOC	10	0.0250	3.0	40	23.0
1345/2245	5D	80-139	SEOC	10	0.0250	6.0	34	30.0
1346/2246	6D	140-180	OFSS	10	0.0350	12.0	50	30.0

Table 13: Fire severity thresholds to classify burn severity by predicted flame length (m).

State ID	State	Low	Moderate	High
1311	MMC	1A		
1312	MMC	2A	< 0.5	> 0.5 but ≤ 0.7
1313	MMC	3A	< 1.0	> 1.0 but ≤ 1.75
1314	MMC	4A	< 1.0	> 1.0 but ≤ 1.3
1315	MMC	5A	< 1.2	> 1.2 but ≤ 1.75
1316	MMC	6A	< 1.3	> 1.3 but ≤ 1.8
1322	MMC	2B	< 0.6	> 0.6 but ≤ 0.75
1323	MMC	3B	< 0.8	> 0.8 but ≤ 1.2
1324	MMC	4B	< 1.2	> 1.2 but ≤ 1.75
1325	MMC	5B	< 0.9	> 0.9 but ≤ 1.3
1326	MMC	6B	< 1.8	> 1.8 but ≤ 1.9
1331	MMC	1C		
1332	MMC	2C	< 0.4	> 0.4 but ≤ 0.7
1333	MMC	3C	< 0.5	> 0.5 but ≤ 0.7
1334	MMC	4C	< 1.0	> 1.0 but ≤ 1.4
1335	MMC	5C	< 1.1	> 1.1 but ≤ 1.4
1336	MMC	6C	< 1.3	> 1.3 but ≤ 1.7
1344	MMC	4D	< 1.0	> 1.0 but ≤ 1.3
1345	MMC	5D	< 1.35	> 1.35 but ≤ 1.45
1346	MMC	6D	< 1.8	> 1.8 but ≤ 1.9

Other assignments

For cover types that would either not be changed by fire or would rapidly recover, we assigned a no-path state with associated surface and canopy fuel properties (Table 14). Herblands and shrublands are categorized as within biophysical settings that do not support forest cover.

Table 14: East Zone/Tripod MMC surface and canopy fuel assignments by state.

State ID	State	Time period (yr)	Stand structure class	Surface fuel model	Canopy bulk density (kg/m³)	Canopy base height (m)	Crown closure (%)	Canopy height (m)
1111	1A	n/a	Bare ground (rock/water/ice)	NB9	0.0000	0.0	0	0.0
1121	1B	n/a	Herbland	GR4	0.0000	0.0	0	0.0
1131	1C	n/a	Shrubland	GS2	0.0000	0.0	0	0.0
1141	1D	n/a	Hardwoods	TU1	0.1314	5.0	60	15.0
1151	1E	n/a	Montane meadow	TU1	0.0000	0.0	0	0.0

References

Anderson, H.E. 1982. Aids to determining fuel models for estimating fire behavior. GTR-INT-122. USDA Forest Service Intermountain Forest and Range Experiment Station, Ogden, UT.

Andrews, P.L., Bevins, C.D. and Seli, R.C. 2008. BehavePlus fire modeling system Version 4.0 User's Guide. USDA Forest Service RMRS-GTR-106WWW.

Hessburg, P.F., Smith, B.G., Kreiter, S.G., Miller, C.A., Salter, R.B., McNicholl, C.H., Hann, W.J. 1999. Historical and current forest and range landscapes in the Interior Columbia River Basin and portions of the Klamath and Great Basins. PNW-GTR-458. U.S. Forest Service, Pacific Northwest Research Station, Portland, OR, 357 p.

Hessburg, P.F., Smith, B.G., Salter, R.B. Ottmar, R.D., and Alvarado, E. 2000. Recent changes (1930s-1990s) in spatial patterns of interior northwest forests, USA. Forest Ecology and Management 136: 53-83.

Hudak, A.T., Rickert, I., Morgan, P., Strand, E., Lewis, S.A., Robichaud, P.R., Hoffman, C., Holden, Z.A. Review of fuel treatment effectiveness in forests and rangelands and a case study from the 2007 megafires in central Idaho USA. RMRS-GTR-252. U.S. Forest Service, Rocky Mountain Research Station, Fort Collins, CO, 60 p.

Perry, D.A, Hessburg P.F., Skinner, C.N., Spies, C.N., Spies, T.A., Stephens, S.L., Taylor A.H., Franklin, J.F., McComb, B. and Riegel, G. 2011. The ecology of mixed-severity fire regimes in Washington, Oregon and northern California. Forest Ecology and Management 262: 703-717.

O'Hara et al. 1996. A structural classification for Inland Northwest Forest Vegetation. Western Journal of Applied Forestry 11(3): 97-102.

Ottmar, R.D., Sandberg, D.V., Riccardi, C.L. and Prichard, S.J. 2007. An overview of the Fuel Characteristic Classification System – quantifying, classifying and creating fuelbeds for resource planning. Canadian Journal of Forest Research 37: 2383-2393.

Prichard, S.J., and Kennedy, M.C. 2014. Fuel treatments and landform modify landscape patterns of burn severity in an extreme fire event. Ecological Applications 24(3): 571-590.

Scott, J.H. and Burgan, R.E. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. GTR-RMRS-153. USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Appendix 1 – FCCS Fuelbed Inputs

We constructed fuelbeds to represent each state within the Fuel Characteristics Classification System (FCCS). The FCCS is a software application that catalogues and classifies fuelbed attributes by stratum (e.g., canopy, shrub, herbaceous, downed wood, litter-lichen-moss, and ground fuels) and fuel categories by stratum (e.g., trees, snags and ladder fuels for canopy layers and sound and rotten wood, stumps and piles for downed wood) and subcategory (Ottmar et al. 2007). Fuelbeds were constructed based on reference fuelbeds within FCCS that generally represent the major vegetation types, including low elevation mixed conifer dominated by Douglas-fir and ponderosa pine and high elevation ESSF-LP. Additional reference datasets included natural fuels photo series, activity photo series and field datasets. Based on previous work on constructing FCCS fuelbeds to represent forest successional pathways, disturbance agents and management activities, a chronosequence approach using existing plot data is not possible due to high site-to-site variance, and in this case, reference sites are not available to represent all of the pathways and states in our models of the historical mixed severity fire regime. The FCCS fuelbeds we developed for this exercise were informed as much as possible from reference data but relied on expert opinion for logical transitions between states and pathways. To date, fuelbeds have been constructed to represent dry mixed conifer (DMC) and cold dry conifer pathways and are also applied to moist mixed conifer (MMC) and cold moist conifer (CMC) pathways, respectively.

Appendices A1: List of FCCS fuelbeds and the source FCCS reference fuelbed.

State	Fuelbed Description
CDC 1A	Tripod Cold Dry Conifer State 1A BG 0-14 yr. Source FB OW073.
CDC 2A	Tripod Cold Dry Conifer State 2A SI 15-29 yr. Source FB OW074.
CDC 3A	Tripod Cold Dry Conifer State 3A SECC 30-49 yr. Source FB OW075.
CDC 4A	Tripod Cold Dry Conifer State 4A SECC 50-79 yr. Source FB OW076.
CDC 5A	Tripod Cold Dry Conifer State 5A UR 80-129 yr. Source FB OW078.
CDC 6A	Tripod Cold Dry Conifer State 6A YFMS 130-179 yr. Source FB OW112.
CDC 7A	Tripod Cold Dry Conifer State 7A OFMS >180 yr. Source FB OW112.
CDC4B	Tripod Cold Dry Conifer State 4B SEOC 50-79 yr. Source FB OW076.
CDC 5B	Tripod Cold Dry Conifer State 5B SEOC 80-129 yr. Source FB OW078.
CDC 6B	Tripod Cold Dry Conifer State 6B SEOC 130-179 yr. Source FB OW112.
CDC 7B	Tripod Cold Dry Conifer State 7B OFSS >180 yr. Source FB OW112.
CDC 1C	Tripod Cold Dry Conifer State 1C BG 0-19 yr. Source FB OW074.
CDC 2C	Tripod Cold Dry Conifer State 2C SI 20-49 yr. Source FB OW074.
CDC 3C	Tripod Cold Dry Conifer State 3C SEOC 50-79 yr. Source FB OW075.
CDC 4C	Tripod Cold Dry Conifer State 4C UR 80-129 yr. Source FB OW077.
CDC 5C	Tripod Cold Dry Conifer State 5C YFMS 130-179 yr. Source FB OW112.
CDC 6C	Tripod Cold Dry Conifer State 6C OFMS >180 yr. Source FB OW112.
DMC1A	Dry Mixed Conifer State 1A BG 0-9 yr. Source FB OW003.
DMC2A	Dry Mixed Conifer State 2A SI 10-24 yr. Source FB OW010.
DMC3A	Dry Mixed Conifer State 3A SECC 25-59 yr. Source FB OW017.
DMC4A	Dry Mixed Conifer State 4A UR 60-99 yr. Source FB OW022.
DMC5A	Dry Mixed Conifer State 5A YFMS 100-159 yr. Source FB OW028.
DMC6A	Dry Mixed Conifer State 6A OFMS >160 yr. Source FB OW030.
DMC2B	Dry Mixed Conifer State 2B SI 10-24 yr. Source FB OW006.
DMC3B	Dry Mixed Conifer State 3B SEOC 25-59 yr. Source FB OW014.
DMC4B	Dry Mixed Conifer State 4B SEOC 60-99 yr. Source FB OW020.
DMC5B	Dry Mixed Conifer State 5B SEOC 100-159 yr. Source FB OW025.
DMC6B	Tripod Dry Mixed Conifer State 6B OFSS 160-200 yr. Source FB OW030.
DMC1C	Dry Mixed Conifer State 1C BG 0-9 yr. Source FB OW006.
DMC2C	Dry Mixed Conifer State 2C SI 10-24 yr. Source FB OW012.
DMC3C	Dry Mixed Conifer State 3C SEOC 25-59 yr. Source FB OW018.
DMC4C	Dry Mixed Conifer State 4C UR 60-99 yr. Source FB OW023.
DMC5C	Dry Mixed Conifer State 5C YFMS 100-159 yr. Source FB OW028.
DMC6C	Dry Mixed Conifer State 6C OFMS 160-200 yr. Source FB OW030.
DMC4D	Dry Mixed Conifer State 4D SEOC 60-99 yr. Source FB OW020.
DMC5D	Dry Mixed Conifer State 5D SEOC 100-159 yr. Source FB OW025.
DMC6D	Dry Mixed Conifer State 6D OFSS 160-200 yr. Source FB OW030.

Table A2. Overstory, midstory and understory canopy variables for the Cold Dry Conifer STM.

					---------- Overstory ----------					---------- Midstory ----------					---------- Understory ----------				
State	State	Struct Class	Age	Total CC	Cover	Height	HLC	Density	DBH	Cover	Height	HLC	Density	DBH	Cover	Height	HLC	Density	DBH
ID			(yr)	(%)	(%)	(m)	(m)	(#/ha)	(cm)	(%)	(m)	(m)	(#/ha)	(cm)	(%)	(m)	(m)	(#/ha)	(cm)
1411	1A	PFBG	0-14	10	5	2	0	5	35		0	0	0	0	10	0.5	0	200	1
1412	2A	SI	15-29	25	5	4	0.5	5	35		0	0	0	0	35	3	0.5	800	5
1413	3A	SECC	30-49	45	45	13	0.8	750	25		0	0	0	0	5	8	0	20	14
1414	4A	SECC	50-79	50	50	16	0.8	500	28	10	12	1	80	22	20	1	0	200	2
1415	5A	UR	80-129	55	55	20	0.8	500	33	15	15	1	80	25	20	1	0	200	2
1416	6A	YFMS	130-179	55	55	23	1	330	37	25	18	1	100	32	20	1.5	0	200	3
1417	7A	OFMS	≥180	65	65	28	0.2	350	45	30	20	1	100	35	20	1.5	0	200	3
1424	4B	SEOC	50-79	15	15	16	1.5	250	28	0					2	1	0	50	2
1425	5B	SEOC	80-129	25	25	20	2	250	33	0					2	1	0	50	2
1426	6B	SEOC	130-179	25	25	23	2	160	37	0					2	1.5	0	50	3
1427	7B	OFSS	≥180	30	30	28	2	175	45	0					2	1	0	50	3
1431	1C	PFBG	0-19	0	0	0	0	0	0		0	0	0	0	5	0.5	0.5	50	1
1432	2C	SI	20-49	0	0	0	0	0	0	0	0	0	0	0	30	2.5	0	350	5
1433	3C	SECC	50-79	45	40	13	1	400	20	12	8	1	60	14	5	0.5	0	20	1
1434	4C	UR	80-129	50	40	20	0.5	350	30	15	12	1	60	22	20	1	0	150	2
1435	5C	YFMS	130-179	55	45	23	0.5	350	38	20	18	1	80	32	20	1.5	0	150	3
1436	6C	OFMS	≥180	55	40	25	0.2	290	46	25	20	1	80	35	20	1.5	0	150	3

CC – canopy cover

HLC – height to live crown base

DBH – diameter at breast height

Table A3. Snag variables for the Cold Dry Conifer STM.

				Snag class 1 with foliage					Snag class 1			Snag class 2			Snag class 3		
StateID	State	Structure class	Age yr	Cover %	Ht m	HCL m	Dens #/ha	DBH cm	Ht m	Dens #/ha	DBH cm	Ht m	Dens #/ha	DBH cm	Ht m	Dens #/ha	DBH cm
1411	1A	PFBG	0-14		0	0	0	0	27	350	40	0	0	0	0	0	0
1412	2A	SI	15-29		0	0	0	0	0	0	0	20	800	40	0	0	0
1413	3A	SECC	30-49	1	14	2	20	15	14	80	15	0	0	0	15	20	35
1414	4A	SECC	50-79	1	16	5	20	18	16	60	18	12	40	15	12	20	10
1415	5A	UR	80-129	2	18	5	35	25	18	60	25	14	40	20	12	20	15
1416	6A	YFMS	130-179	2	20	2	60	30	20	60	30	16	80	25	13	20	18
1417	7A	OFMS	≥180	2	25	2	60	40	25	60	40	18	80	30	14	20	20
1424	4B	SEOC	50-79	5	16	5	50	18	16	80	18	12	80	15	12	40	15
1425	5B	SEOC	80-129	5	16	5	50	18	16	80	18	12	80	15	12	40	15
1426	6B	SEOC	130-179	5	20	2	70	30	20	80	30	16	100	15	8	40	10
1427	7B	OFSS	≥180	5	25	2	70	40	25	80	40	25	100	15	14	40	12
1431	1C	PFBG	0-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1432	2C	SI	20-49		0	0	0	0	0	0	0	0	0	0	0	0	0
1433	3C	SECC	50-79	1	9	5	10	15	9	5	10	0	0	0	0	0	0
1434	4C	UR	80-129	1	9	5	10	15	12	10	15	8	2	8	8	20	10
1435	5C	YFMS	130-179	2	18	2	20	25	18	100	25	16	80	15	14	20	12
1436	6C	OFMS	≥180	2	30	2	60	40	30	60	40	25	80	15	14	20	12

DBH – diameter at breast height
HLC – height to live crown base
Ht – height
Dens – density

Table A4. Shrub stratum variables for the Cold Dry Conifer STM.

				Shrub		
State ID	State	Stand structure class	Age (yr)	Cover (%)	Height (m)	Percent Live (%)
1411	1A	PFBG	0-14	30	0.3	100
1412	2A	SI	15-29	40	0.5	100
1413	3A	SECC	30-49	20	0.3	100
1414	4A	SECC	50-79	20	0.5	100
1415	5A	UR	80-129	20	0.5	100
1416	6A	YFMS	130-179	20	1	100
1417	7A	OFMS	≥180	20	1	100
1424	4B	SEOC	50-79	30	0.5	100
1425	5B	SEOC	80-129	30	0.5	100
1426	6B	SEOC	130-179	30	1	100
1427	7B	OFSS	≥180	30	1	100
1431	1C	PFBG	0-19	30	0.3	100
1432	2C	SI	20-49	40	0.5	100
1433	3C	SECC	50-79	40	0.8	100
1434	4C	UR	80-129	20	1	100
1435	5C	YFMS	130-179	20	1	100
1436	6C	OFMS	≥180	20	1	100

Note: shrub species in 1141-1143 and 1431-1432 are *Vaccinium scoparium* and *Salix scouleriana*; in 1414, 1415, 1424-1426, and 1433 shrubs are *V. scoparium, S. scouleriana* and *Menziesia ferruginea*; in 1516, 1417, 1426, 1427, and in 1434-1436 shrubs are *V. scoparium, V. membranacium* and *M. ferruginea*.

Table A5. Herb stratum variables for the Cold Dry Conifer STM.

				Herb			
						Percent	
State ID	State	Stand structure class	Age (yr)	Cover (%)	Height (m)	Live (%)	Loading (Mg/ha)
1411	1A	PFBG	0-14	7	0.3	100	0.1
1412	2A	SI	15-29	7	0.3	100	0.1
1413	3A	SECC	30-49	3	0.3	100	0.05
1414	4A	SECC	50-79	7	0.3	100	0.1
1415	5A	UR	80-129	10	0.3	100	0.1
1416	6A	YFMS	130-179	10	0.3	100	0.1
1417	7A	OFMS	≥180	10	0.3	100	0.1
1424	4B	SEOC	50-79	15	0.3	100	0.15
1425	5B	SEOC	80-129	20	0.3	100	0.15
1426	6B	SEOC	130-179	20	0.3	100	0.15
1427	7B	OFSS	≥180	20	0.3	100	0.1
1431	1C	PFBG	0-19	10	0.3	100	0.67
1432	2C	SI	20-49	7	0.3	100	0.45
1433	3C	SECC	50-79	7	0.3	100	0.45
1434	4C	UR	80-129	10	0.3	100	0.7
1435	5C	YFMS	130-179	8	0.3	100	0.6
1436	6C	OFMS	≥180	5	0.3	100	0.3

Note: herb species composition in 1411 is *Chamerion angustifolium*; in 1412 herbs are *Arnica latifolia*, *Carex concinnoides*, *Chamerion angustifolium* and *Calamagrostis rubescens*; in 1413-1427 and 1433-1436 herbs are *A. latifolia*, *C. concinnoides*, and *Luzula hitchcockii*.

Table A6. Downed wood stratum variables for the Cold Dry Conifer STM.

				Sound wood						Rotten wood		
StateID	State	Cover %	Depth cm	1 hr	10 hr	100 hr	1000 hr	10k hr	>10k hr	1000 hr	10k hr	>10k hr
				Mg/ha								
1411	1A	0	0	0	0	1	1.7	7.3	0.9	0.6	0.2	0.9
1412	2A	8	5	0.4	1.6	2.7	24	38.1	4.5	7.7	1.3	4.5
1413	3A	8	5	0.7	0.7	3.4	3.8	16.4	16.5	10.3	0.4	16.5
1414	4A	8	5	0.7	1.55	5.05	8.95	14.1	6	3	0.1	6
1415	5A	8	8	0.7	3.1	10.1	17.9	14.1	8	5	0.22	8
1416	6A	10	10	0.7	1.8	0.9	16.8	27.6	2.1	3.4	1.8	2.1
1417	7A	10	10	0.7	1.8	0.9	16.8	27.6	2.1	3.4	1.8	2.1
1424	4B	2	1.25	0.2	0.4	1.3	4.5	7.1	0.0	1.5	0.8	0.0
1425	5B	2	2	0.2	0.8	2.5	9.0	7.1	3.5	2.0	1.3	0.1
1426	6B	2.5	2.5	0.2	0.5	0.2	8.4	13.8	7.3	0.5	0.9	0.5
1427	7B	2.5	2.5	0.2	0.5	0.2	8.4	13.8	7.3	0.5	0.9	0.5
1431	1C	0	0	0	0	0	0	0	0	1.61	4.5	0
1432	2C	5	1	0.2	0.7	1.2	0	0	0	0	0	0
1433	3C	5	2	0.5	1.6	2	1.8	0	1.3	0.4	0.3	0
1434	4C	8	5	0.7	3.1	4	5	8	4	3	2	0.1
1435	5C	5	5	0.7	1.8	0.9	16.8	27.6	14.6	2.1	3.4	1.8
1436	6C	5	5	0.7	1.8	0.9	16.8	27.6	14.6	2.1	3.4	1.8

Table A7. Litter and duff strata variables for the Cold Dry Conifer STM.

				Litter		Upper duff		Lower duff	
State ID	State	Stand structure class	Age (yr)	Cover (%)	Depth (cm)	Cover (%)	Depth (cm)	Cover (%)	Depth (cm)
1411	1A	PFBG	0-14	30	0.25	0	0	0	0
1412	2A	SI	15-29	30	1	80	0.5	0	0
1413	3A	SECC	30-49	80	1.5	90	1	90	0.5
1414	4A	SECC	50-79	90	1.78	100	1	90	0.5
1415	5A	UR	80-129	100	2	100	2	100	1
1416	6A	YFMS	130-179	100	2.54	100	3	100	1.5
1417	7A	OFMS	≥180	100	2.54	100	4	100	2.54
1424	4B	SEOC	50-79	70	0.5	50	0.5	0	0
1425	5B	SEOC	80-129	70	0.5	50	0.5	0	0
1426	6B	SEOC	130-179	70	0.5	50	0.5	0	0
1427	7B	OFSS	≥180	70	0.5	50	0.5	0	0
1431	1C	PFBG	0-19	10	0.25	50	0.5	0	0
1432	2C	SI	20-49	30	1	50	0.5	0	0
1433	3C	SECC	50-79	80	1.5	70	0.75	50	0.5
1434	4C	UR	80-129	90	1.78	90	1	90	0.5
1435	5C	YFMS	130-179	100	2.54	100	1.5	100	1.5
1436	6C	OFMS	≥180	100	2.54	100	3	100	2.54

Note: Litter arrangement is normal in all states of the CDC STM.

Table B1. Overstory, midstory and understory canopy variables for the Dry Mixed Conifer STM.

State ID	State	Stand structure class	Age	Total CC	Overstory					Midstory					Understory				
					Cover	Height	HLC	Density	DBH	Cover	Height	HLC	Density	DBH	Cover	Height	HLC	Density	DBH
			(yr)	(%)	(%)	(m)	(m)	(#/ha)	(cm)	(%)	(m)	(m)	(#/ha)	(cm)	(%)	(m)	(m)	(#/ha)	(cm)
1211	1A	PFBG	0-9	1	1	22	9	7.33	40		0	0	0	0	1	22	9	7.33	40
1212	2A	SI	24-Oct	18	1	22	9	7.33	40		0	0	0	0	1	22	9	7.33	40
1213	3A	SECC	25-59	60	60	11	1	7327	20		0	0	0	0	60	11	1	7327	20
1214	4A	UR	60-99	34	30	19.8	1	2014.9	38	5	12	1	122.12	16	30	19.8	1	2014.9	38
1215	5A	YFMS	100-159	45	40	25	0.9	1526.5	48	20	12	1	610.58	16	40	25	0.9	1526.5	48
1216	6A	OFMS	≥ 160	55	55	36.6	1.4	1099.1	55	10	12	1	488.47	22	55	36.6	1.4	1099.1	55
1222	2B	SI	24-Oct	15	0	0	0	0	0		0	0	0	0	0	0	0	0	0
1223	3B	SEOC	25-59	25	25	11	4	2442.3	20		0	0	0	0	25	11	4	2442.3	20
1224	4B	SEOC	60-99	30	30	18.3	1.8	1709.6	38		0	0	0	0	30	18.3	1.8	1709.6	38
1225	5B	SEOC	100-159	40	35	25	10.7	1282.2	48		0	0	0	0	35	25	10.7	1282.2	48
1226	6B	OFSS	160-200	55	45	36.6	12.2	915.88	55	2	12	3	61.06	22	45	36.6	12.2	915.88	55
1231	1C	PFBG	0-9	1	0	0	0	0	0		0	0	0	0	0	0	0	0	0
1232	2C	SI	24-Oct	15	0	0	0	0	0		0	0	0	0	0	0	0	0	0
1233	3C	SEOC	25-59	25	25	11	5	1526.5	20		0	0	0	0	25	11	5	1526.5	20
1234	4C	UR	60-99	30	25	18.3	15.2	1526.5	38		0	0	0	0	25	18.3	15.2	1526.5	38
1235	5C	YFMS	100-159	40	40	25	12.2	1099.1	48	5	12	3	122.12	16	40	25	12.2	1099.1	48
1236	6C	UR	≥ 160	55	45	36.6	12.2	732.7	55	5	12	3	183.18	22	45	36.6	12.2	732.7	55
											0	0	0	0					
1244	4D	SEOC	60-99	34	34	19.7	1.8	915.88	35		0	0	0	0	34	19.7	1.8	915.88	35
1245	5D	SEOC	100-159	45	40	27.4	10.7	915.88	48		0	0	0	0	40	27.4	10.7	915.88	48
1246	6D	OFSS	160-200	55	45	36.6	12.2	488.47	52	5	12	1	122.12	16	45	36.6	12.2	488.47	52

Table B2. Snag variables for the Dry Mixed Conifer STM.

				Snag class 1 with foliage					Snag class 1			Snag class 2			Snag class 3		
StateID	State	Structure class	Age yr	Cover %	Ht m	HCL m	Dens #/ha	DBH cm	Ht m	Dens #/ha	DBH cm	Ht m	Dens #/ha	DBH cm	Ht m	Dens #/ha	DBH cm
1211	1A	PFBG	0-9		0	0	0	0	22	2747.63	40	0	0	0	0	0	0
1212	2A	SI	10-24		0	0	0	0	0	0	0	37	610.58	50	30	305.29	40
1213	3A	SECC	25-59	2	15	1	366.35	15	15	366.35	15	0	0	0	12	24.42	25
1214	4A	UR	60-99	2	18	1	244.23	32	18	244.23	32	12	122.12	10	12	61.06	9
1215	5A	YFMS	100-159	2	25	1	244.23	40	25	244.23	40	15	122.12	20	15	61.06	15
1216	6A	OFMS	≥ 160	2	35	1	244.23	50	35	244.23	50	20	122.12	35	18	61.06	30
1222	2B	SI	10-24		0	0	0	0	0	0	0	30	122.12	50	25	61.06	40
1223	3B	SEOC	25-59	2	11	1	244.23	15	15	244.23	15	0	0	0	0	0	0
1224	4B	SEOC	60-99	2	17	1	183.18	30	17	183.18	30	12	61.06	9	0	0	0
1225	5B	SEOC	100-159	2	25	1	122.12	40	25	122.12	40	15	61.06	30	0	0	0
1226	6B	OFSS	160-200	2	35	1	122.12	50	35	122.12	50	20	61.06	40	0	0	0
1231	1C	PFBG	0-9		0	0	0	0	0	0	0						
1232	2C	SI	10-24		0	0	0	0	0	0	0						
1233	3C	SEOC	25-59	1	10	3	122.12	15	15	793.76	15						
1234	4C	UR	60-99	1	18	3	122.12	30	18	1099.05	30	12	366.35	15	10	183.18	15
1235	5C	YFMS	100-159	2	25	3	122.12	40	25	488.47	40	15	488.47	30	13	244.23	30
1236	6C	UR	≥ 160	2	35	3	122.12	45	35	488.47	45	22	244.23	38	20	122.12	38
1244	4D	SEOC	60-99	2	18	3	122.12	30	18	488.47	30	15	366.35	32	13	244.23	30
1245	5D	SEOC	100-159	2	25	3	122.12	46	25	488.47	40	20	366.35	46	18	244.23	33
1246	6D	OFSS	160-200	1	35	3	61.06	50	35	244.23	45	22	152.65	40	20	152.65	35

DBH – diameter at breast height
HLC – height to live crown base
Ht – height
Dens – density

Table B3. Shrub stratum variables for the Dry Mixed Conifer STM.

				Shrub		
State ID	State	Stand structure class	Age (yr)	Cover (%)	Height (m)	Percent Live (%)
1211	1A	PFBG	0-9	10	0.3	80
1212	2A	SI	10-24	30	0.5	80
1213	3A	SECC	25-59	2	0.6	80
1214	4A	UR	60-99	10	0.6	80
1215	5A	YFMS	100-159	10	0.6	80
1216	6A	OFMS	≥ 160	10	0.6	80
1222	2B	SI	10-24	10	0.3	80
1223	3B	SEOC	25-59	30	0.6	80
1224	4B	SEOC	60-99	45	0.6	80
1225	5B	SEOC	100-159	15	0.6	80
1226	6B	OFSS	160-200	10	0.6	80
1231	1C	PFBG	0-9	10	0.3	80
1232	2C	SI	10-24	20	0.5	80
1233	3C	SEOC	25-59	30	0.6	80
1234	4C	UR	60-99	40	0.6	80
1235	5C	YFMS	100-159	10	0.6	80
1236	6C	UR	≥ 160	10	0.6	80
1244	4D	SEOC	60-99	45	0.6	80
1245	5D	SEOC	100-159	15	0.6	80
1246	6D	OFSS	160-200	10	0.6	80

Table B4. Herb stratum variables for the Dry Mixed Conifer STM.

				Herb			
State ID	State	Stand structure class	Age (yr)	Cover (%)	Height (m)	Percent Live (%)	Loading (Mg/ha)
1211	1A	PFBG	0-9	10	0.3	65.62	0.22
1212	2A	SI	10-24	20	0.3	65.62	0.34
1213	3A	SECC	25-59	5	0.3	65.62	0.1
1214	4A	UR	60-99	10	0.3	65.62	0.22
1215	5A	YFMS	100-159	10	0.3	65.62	0.22
1216	6A	OFMS	≥ 160	10	0.3	65.62	0.22
1222	2B	SI	10-24	80	0.3	65.62	1.12
1223	3B	SEOC	25-59	30	0.49	65.62	0.45
1224	4B	SEOC	60-99	20	0.61	65.62	0.22
1225	5B	SEOC	100-159	92	0.15	65.62	1.12
1226	6B	OFSS	160-200	15	0.15	65.62	0.22
1231	1C	PFBG	0-9	80	0.3	65.62	1.12
1232	2C	SI	10-24	80	0.3	65.62	1.12
1233	3C	SEOC	25-59	40	0.3	65.62	0.34
1234	4C	UR	60-99	20	0.3	65.62	0.22
1235	5C	YFMS	100-159	15	0.15	65.62	0.22
1236	6C	UR	≥ 160	15	0.15	65.62	0.22
1244	4D	SEOC	60-99	20	0.61	65.62	0.22
1245	5D	SEOC	100-159	50	0.15	65.62	1.12
1246	6D	OFSS	160-200	50	0.15	65.62	1.12

Note: herb species composition in most fuelbeds includes *Calamagrostis rubescens*, *Pseudoroegneria spicata*, *Balsamorhiza sagittata*, and in 6D *Festuca idahoensis* is also included.

Table B5. Downed wood stratum variables for the Dry Mixed Conifer STM.

				Sound wood						Rotten wood		
StateID	State	Cover %	Depth cm	1 hr	10 hr	100 hr	1000 hr	10k hr	>10k hr	1000 hr	10k hr	>10k hr
				Mg/ha								
1211	1A	5	0.76	0	0	22	2747.63	40	0	0	0	0
1212	2A	10	20	0	0	0	0	0	37	610.58	50	30
1213	3A	10	2.54	1	15	15	366.35	15	0	0	0	12
1214	4A	20	5	1	32	18	244.23	32	12	122.12	10	12
1215	5A	20	7.6	1	40	25	244.23	40	15	122.12	20	15
1216	6A	20	10	1	50	35	244.23	50	20	122.12	35	18
1222	2B	10	5	0	0	0	0	0	30	122.12	50	25
1223	3B	35	0.5	1	15	15	244.23	15	0	0	0	0
1224	4B	10	3	1	30	17	183.18	30	12	61.06	9	0
1225	5B	5	5	1	40	25	122.12	40	15	61.06	30	0
1226	6B	5	5	1	50	35	122.12	50	20	61.06	40	0
1231	1C	0	0	0	0	0	0	0				
1232	2C	5	5	0	0	0	0	0				
1233	3C	20	2.54	3	15	15	793.76	15				
1234	4C	10	5	3	30	18	1099.05	30	12	366.35	15	10
1235	5C	5	5	3	40	25	488.47	40	15	488.47	30	13
1236	6C	5	1	3	45	35	488.47	45	22	244.23	38	20
1244	4D	10	8	3	30	18	488.47	30	15	366.35	32	13
1245	5D	5	2.54	3	46	25	488.47	40	20	366.35	46	18
1246	6D	5	2	3	50	35	244.23	45	22	152.65	40	20

Table B6. Litter and duff strata variables for the Dry Mixed Conifer STM.

				Litter		Upper duff	
State ID	State	Stand structure class	Age (yr)	Cover (%)	Depth (cm)	Cover (%)	Depth (cm)
1211	1A	PFBG	0-9	10	0.25	0	0
1212	2A	SI	10-24	30	1	50	0.5
1213	3A	SECC	25-59	100	1.27	100	1.5
1214	4A	UR	60-99	100	2.54	100	2.5
1215	5A	YFMS	100-159	100	3	100	3
1216	6A	OFMS	≥ 160	100	3.8	100	4
1222	2B	SI	10-24	50	0.5	50	0.5
1223	3B	SEOC	25-59	85	1.27	80	1
1224	4B	SEOC	60-99	88	2	80	1
1225	5B	SEOC	100-159	90	0.5	80	1
1226	6B	OFSS	160-200	100	3.8	80	1
1231	1C	PFBG	0-9	10	0.25	0	0
1232	2C	SI	10-24	30	1	50	0.5
1233	3C	SEOC	25-59	55	0.5	80	1.5
1234	4C	UR	60-99	100	2.54	80	1.5
1235	5C	YFMS	100-159	100	3	100	3
1236	6C	UR	≥ 160	100	3.81	100	4
1244	4D	SEOC	60-99	88	2	50	1
1245	5D	SEOC	100-159	90	0.5	50	1
1246	6D	OFSS	160-200	100	3.8	50	1

Note: Litter arrangement is normal and lower duff is not present in all states of the DMC STM.