Effectiveness and longevity of fuel treatments in coniferous forests across California

Managers' Report: Mendocino National Forest

Prepared by

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Background

Longevity of fuel treatment effectiveness to alter potential fire behavior is a critical question for managers preparing plans for fuel hazard reduction, prescribed burning, fire management, forest thinning, and other land management activities. Results from this study will help to reduce uncertainty associated with plan prioritization and maintenance activities. From 2001 to 2006, permanent plots were established in areas planned for hazardous fuel reduction treatments across 14 National Forests in California. Treatments included prescribed fire and mechanical methods (i.e., thinning of various sizes and intensities followed by a surface fuel treatment). After treatment, plots were re-measured at various intervals up to 10 years post-treatment. Very few empirically based studies exist with data beyond the first couple of years past treatment, and none span the breadth of California's coniferous forests. With the data gathered, this research aimed to meet three main objectives:

Objective 1) *Determine the length of time that fuel treatments are effective at maintaining goals of reduced fire behavior, by*

- *a) measuring effects of treatments on canopy characteristics and surface fuel loads over time, and*
- *b) modeling potential fire behavior with custom fuel models.*

Objective 2) *Quantify the uncertainty associated with the use of standard and custom fuel models.*

Objective 3) *Assess prescribed fire effects on carbon stocks and validate modeled outputs.*

This managers' report is meant to compliment the final report to the Joint Fire Science Program and supply project specific information that is not included in the regional assessment. This report includes a summary of Key Findings and Management Implications from the regional study as well as individual Forest-level information for each plot (i.e., project history, map, navigation directions, plot level findings, and plot protocol). For your use, we included a number of supplementary files with the digital version of this report. Included on the thumb drive are the following also described in Appendix A:

- Final report to the JFSP
- FVS Input database for your Forest for all projects (database file)
- Photo pairs for the plots on your Forest (power point file)
- Plot maps for each project on your Forest (pdf file)
- GIS shapefile with the plots on your Forest

All datasets for the regional project were input into the FFI (Feat/FIREMON Integrated) tool (www.frames.gov/partner-sites/ffi/ffi-home/) for future use and comparisons. Please contact Nicole Vaillant (nvaillant@fs.fed.us) for more information on obtaining the FFI data or other questions.

Key Findings

Objective 1- Determine the length of time that fuel treatments are effective at maintaining goals of reduced fire behavior by measuring effects of treatments on canopy characteristics and surface fuel loads over time and modeling potential fire behavior with custom fuel models.

Results have shown initial reductions in surface fuels from fire treatments recover to pre-treatment levels by 10 yr post-treatment. Mechanical treatments continue to have variable effects on surface fuels. With the exception of mechanical treatments in red fir, both treatment types resulted in increased live understory vegetation by 8 yr post-treatment relative to pre-treatment. Mechanical treatment effects on stand structure remains fairly consistent through 8 yr post. Fire-induced delayed mortality contributes to slight decreases in canopy cover and canopy bulk density over time. For both treatment types, overall canopy base height decreases in later years due to in-growth of smaller trees, but it remains higher than pre-treatment. The changes in fuel loads and stand structure are reflected in fire behavior simulations via custom fuel modeling. Surface fire flame lengths were initially reduced as a result of prescribed fire, but by 10 yr post-treatment they exceeded the pre-treatment lengths. Though a low proportion of fire type, initial reductions in potential crown fire returned to pre-treatment levels by 8 yr post-treatment; passive crown fire remained reduced relative to pre-treatment for the duration. Mechanical treatments showed variable and minimal effects on surface fire flame length over time; however the incidence of active crown fire was nearly halved from this treatment for the duration.

Objective 2- Quantify the uncertainty associated with the use of standard and custom fuel models

The Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) was used to model potential fire behavior for plots treated with prescribed fire to determine the differences in modeled fire behavior using standard and custom fuel models. In general predicted fire behavior from custom versus standard fuel models were similar with mean surface fire flame lengths slightly higher using standard fuel models for all time steps until the 8 yr post-treatment. Similarly, custom fuel models predicted a higher instance of surface fire than standard fuel models with the exception of 8 yr post-treatment.

Objective 3- Assess prescribed fire effects on carbon stocks and validate modeled outputs.

To better understand the impact of prescribed fire on carbon stocks, we estimated aboveground and belowground (roots) carbon stocks using field measurement in FFE-FVS, and simulated wildfire emissions, before treatment and up to 8 yr post-prescribed fire. Prescribed fire treatments reduced total stand carbon by 13%, with the largest reduction in the forest floor (litter and duff) pool and the smallest reduction in the live tree pool. Combined carbon recovery and reduced wildfire emissions allowed the initial carbon source from simulated wildfire emissions and treatment to become a sink by 8 yr post-treatment relative to pre-treatment if both were to burn in a wildfire. In a comparison of field-derived versus FFE-FVS simulated carbon stocks, the total stand, tree, and belowground live carbon pools are highly correlated. However, the variability within the other carbon pools compared was high (up to 212%).

Management Implications

- ✓ Need more long term monitoring.
- ✓ The ability of a fuel treatment to maintain effectiveness in reducing fire behavior and effects depends on the accumulation rates and distribution of fuels, which are used as metrics to judge treatment longevity. Surface and understory fuel loading trends help inform managers' initial treatment and maintenance timelines, priorities, and adaptive management prescriptions.
- ✓ Stand and canopy structure trends help inform both fuel and silviculture integrated objectives and prioritizations.
- ✓ Despite extensive variability between plots, overall trends for treatment-forest combinations exist.
- ✓ Changes to modeled surface fire after prescribed fire treatment included an initial decrease in surface flame lengths, then an increase starting around 5 yr post-treatment.
- ✓ Overall, modeled fire behavior in mechanical treatments showed that goals of reduced fire behavior were initially reached, and then began diminishing around 5 to 8 yr post-treatment, with some positive changes still apparent through 8 yr post-treatment.
- ✓ In general, predicted fire behavior from custom versus standard fuel models was similar.
- ✓ Prescribed fire treatments reduced total stand carbon by about 13%, and total stand carbon stocks returned to 97% of pre-treatment levels after 8 yr post-treatment.
- ✓ Although the total stand carbon differences between field-derived and simulated carbon stocks are minimal, the variability within different carbon was great.

Project Websites

Please visit our project website in the next few months to year as reports are finalized and publications become available at http://www.fs.fed.us/adaptivemanagement/pub_reports/JFS_vaillant2.shtml.

The final report and many of our presentations and other deliverables will also be available via the Joint Fire Science Program website at http://www.firescience.gov/JFSP_advanced_search_results_detail.cfm?jdbid=%24%26Z%2F8W%20%20%20%0A.

Acknowledgements

We acknowledge funding for this research from the USFS Region 5 Fire Aviation and Management and Joint Fire Sciences program (JFS 09-01-1-01). This project would have never gotten off the ground without the passion and drive of Jo Ann Fites-Kaufman. We thank the countless number of field crew members over the past 12 years, especially T. Decker and K. McCrummen for serving as crew leads during the past four years. Thank you to all the fire and fuels specialists on all the National Forests in California for providing invaluable insight and information about their fuel treatments.

Howard Mill (Project 20, Upper Lake Ranger District)

Project history

The Howard Mill project had six plots set up pre-treatment in 2002 using the 2001 detailed plot style. For details about the protocol used, please see “Appendix B: Sampling Protocol” at the end of the report. Plots were sampled prior to treatment (P00), then 1 yr post (P01), 2 yr post (P02), 8 yr post (P08), and 10 yr post (P10) (Table 1). Due to additional treatments not all plots were read for all post-treatment visits; see the “Treatment information” section below.

For analysis at the regional level, plots from all projects were grouped into one of two treatment types (mechanical or prescribed fire) and one of three dominant forest types (yellow pine, red fir, or mixed conifer). All Howard Mill plots were grouped into the prescribed fire treatment category and the yellow pine forest type.

The High Glade RAWS was used for fire weather and fire behavior simulation modeling.

Table 1. Treatment visits completed by year for each of the plots in the project. ~Indicates that data was not collected for that plot and year.

Plot	2002	2003	2004	2010	2012
1	P00	P01	P02	P08	P10
2	P00	P01	P02	P08	P10
3	P00	P01	P02	~	~
5	P00	P01	P02	P08	P10
6	P00	P01	P02	P08	P10

Treatment information

Prior treatment: The project area is a 30 year old plantation that was established following the 1966 Round fire.

During the project treatment: The unit with Plots 1 to 4 was underburned on 3/7/03; however, Plot 4 did not actually burn. The unit with Plots 5 and 6 was underburned on12/2/2002. Additionally, Plot 3 had received a pre-commercial thin in 9/27/04 and a pile burn 12/15/08.

Future treatment: Unknown

Project location map

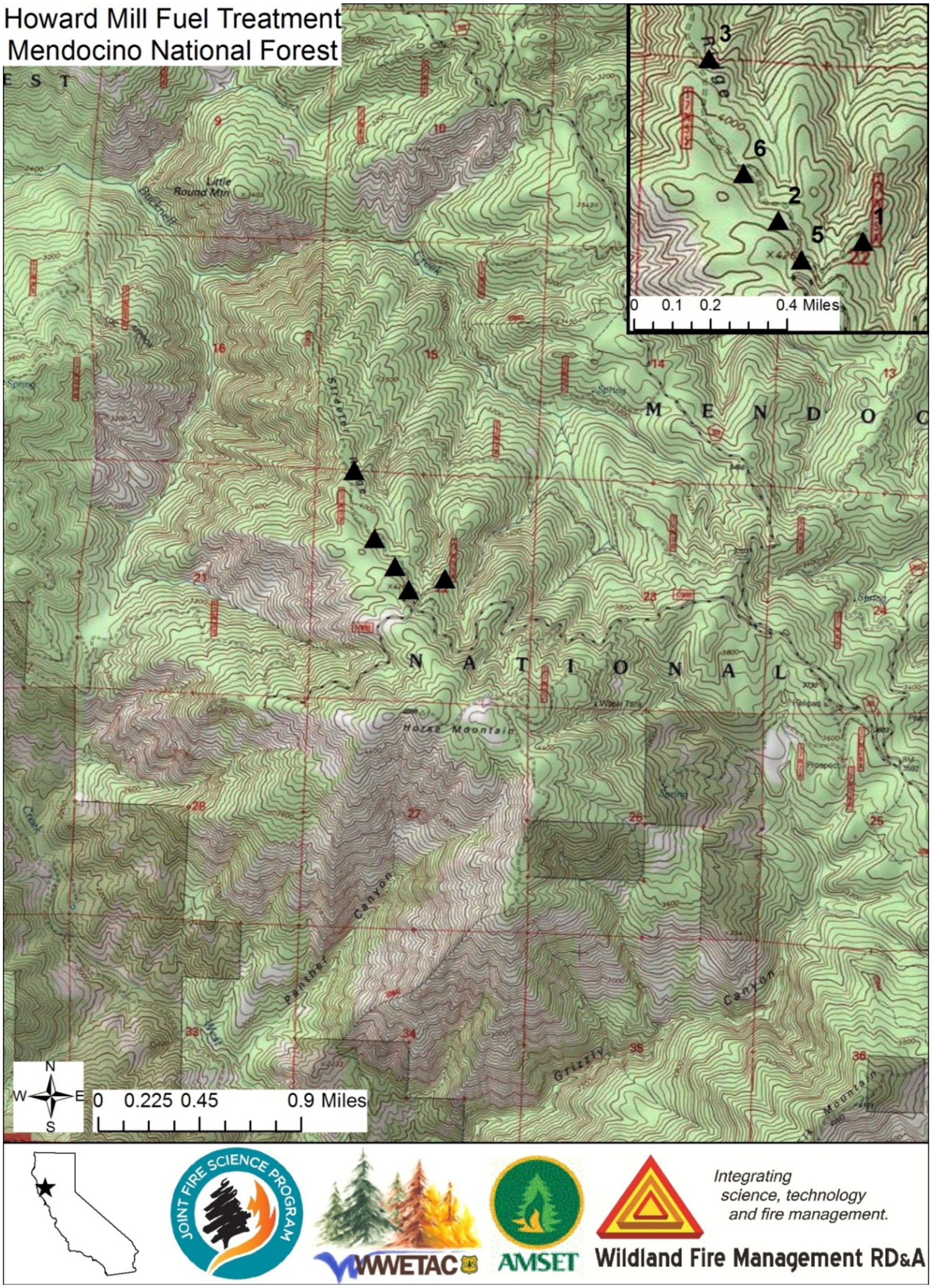


Figure 1. Location map for the Howard Mill fuel treatment plots, showing general location of plots, and inset displaying increased detail of plot locations.

Driving directions/GPS/plot layout

Driving directions

Plot 1- From Road M1, take 17N99 to the west for 2.2 miles. Make a right onto Road M55 for approximately 0.05 miles. Park at the first bend in the road.

Plot 2- From Road M1, go west on 17N99 for approximately 2.2 miles. Make a right onto M55 and follow for approximately 0.2 miles. Park at OHV Road 24 junction.

Plot 3- From Road M1, take 17N99 to the west for 2.2 miles. Make a right onto M55 and follow for 0.9 miles. Park at OHV Road 25.

Plot 5- From Road M1, go west onto 17N99 for approximately 2.3 miles. Park just before a hairpin bend.

Plot 6- From Road M1, go west onto 17N99 for approximately 2.2 miles. Make a right onto Road 55. Follow Road 55 for approximately 0.6 miles. Park at the bend in the road.

Table 2. Directions (distance and azimuth) for walking from the "start tree" to each plot. The azimuth takes into account the local declination. Distance and azimuth are approximate as they were recorded by crews walking in from the start tree (usually tagged tree near road edge).

Plot	Start tree (DBH and species)	Azimuth °	Distance
1	38cm DBH ponderosa pine	35	250 m
2	25cm DBH ponderosa pine	250	100 m
3	44cm DBH ponderosa pine	120	75 m
5	20cm DBH ponderosa pine	350	50 m
6	32cm DBH ponderosa pine	210	100 m

Table 3. GPS coordinates for each plot (decimal degrees, datum NAD 1983, projection NAD_1983_California_Teale_Albers).

Plot	Latitude	Longitude
1	39.315253	-122.971631
2	39.315948	-122.975801
3	39.322004	-122.979432
5	39.314479	-122.974607
6	39.317683	-122.977566

Table 4. Plot layout line azimuths (degrees). See Appendix A for plot diagrams. AB and CD are the main transects, and F1, F2, F3, and F4 are the fuels transects.

Plot	Plot Type	AB	CD	F1	F2	F3	F4
1	Detail 2001	90	360	224	315	45	138
2	Detail 2001	10	280	145	235	335	56
3	Detail 2001	55	325	190	280	10	101
5	Detail 2001	20	290	160	245	338	65
6	Detail 2001	40	130	177	259	87	88

Paired pictures

Below is an example of pictures paired or matched over the time steps the plots were visited. All of the paired pictures are available in the supplied power point file.

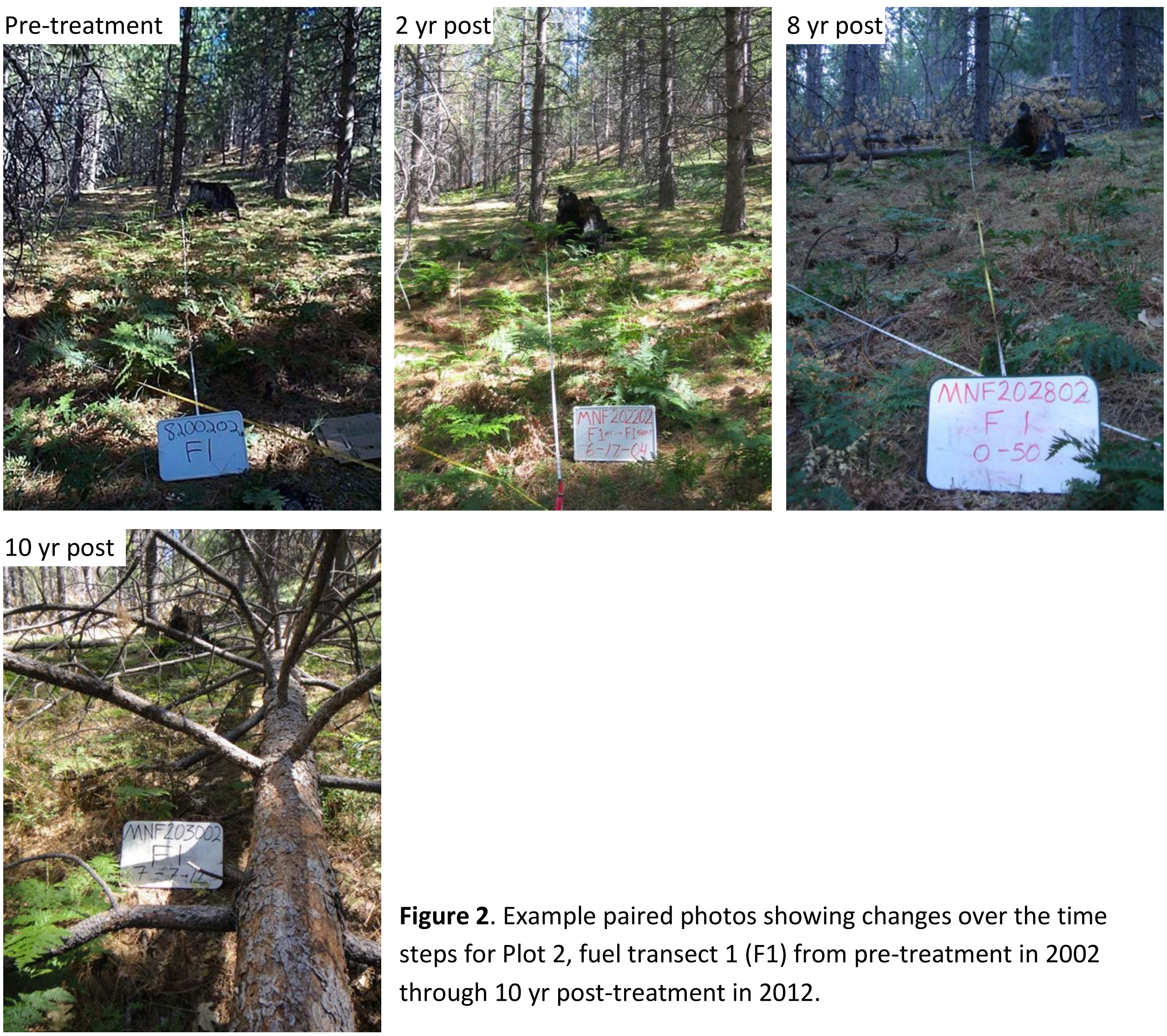
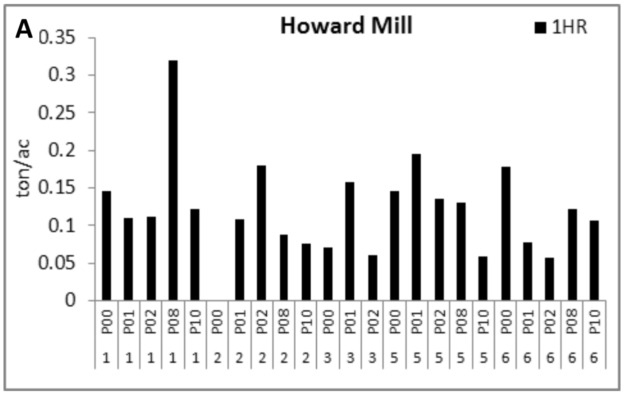
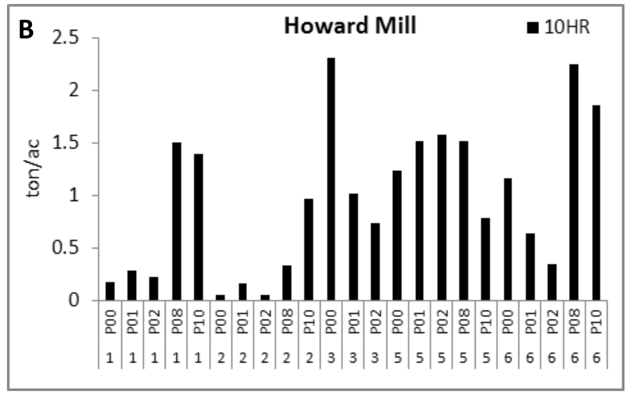


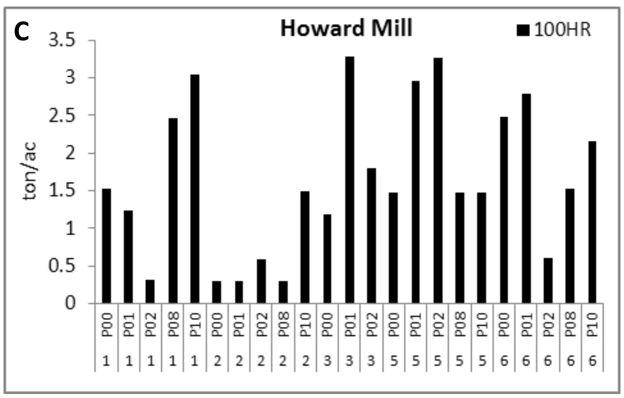
Figure 2. Example paired photos showing changes over the time steps for Plot 2, fuel transect 1 (F1) from pre-treatment in 2002 through 10 yr post-treatment in 2012.

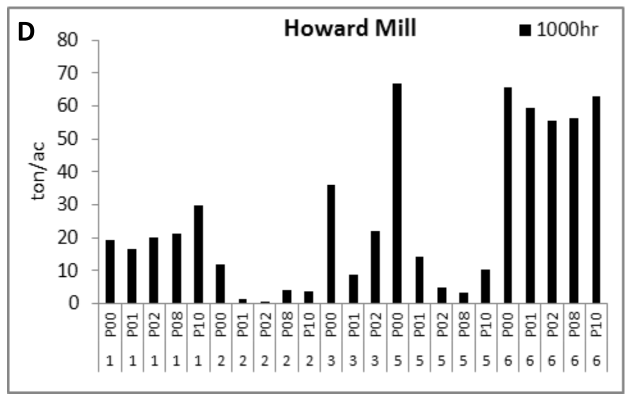
Plot findings

Below are graphs and data tables of key metrics from the data gathered in the field for each plot and time period within the project.









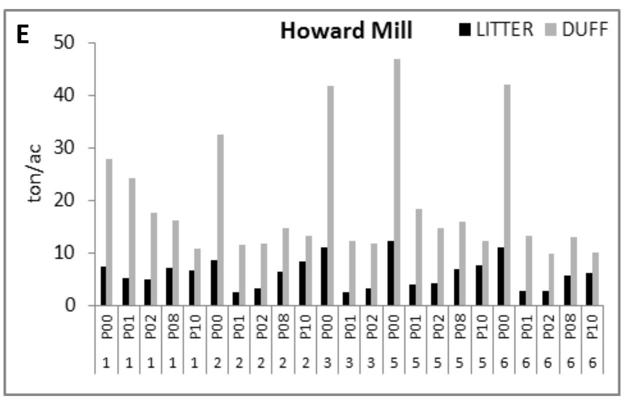


Figure 3. Fuel loading (ton/ac) for the 1-hr (A), 10-hr (B), 100-hr (C), and 1000-hr (D) time lag fuel classes, and litter and duff (E) for each plot at each sampling time period.

P00-pre-treatment, P01-1 yr post-treatment, P02-2 yr post-treatment, etc.

Table 5. Fuel loading (ton/ac) for the 1-hr, 10-hr, 100-hr, and 1000-hr time lag fuel classes, and litter and duff by time period for all the plots in the Howard Mill fuel treatment project.

Plot	Time period	1-hr	10-hr	100-hr	1000-hr	Litter	Duff
1	P00	0.15	0.2	1.5	19.3	7.4	27.9
1	P01	0.11	0.3	1.2	16.5	5.2	24.1
1	P02	0.11	0.2	0.3	20.0	5.1	17.6
1	P08	0.32	1.5	2.5	21.1	7.2	16.3
1	P10	0.12	1.4	3.0	29.8	6.7	10.8
2	P00	0.00	0.1	0.3	11.8	8.6	32.5
2	P01	0.11	0.2	0.3	1.4	2.5	11.6
2	P02	0.18	0.1	0.6	0.4	3.4	11.9
2	P08	0.09	0.3	0.3	4.0	6.5	14.8
2	P10	0.08	1.0	1.5	3.8	8.3	13.3
3	P00	0.07	2.3	1.2	36.1	11.0	41.8
3	P01	0.16	1.0	3.3	8.7	2.6	12.3
3	P02	0.06	0.7	1.8	22.1	3.4	11.8
5	P00	0.15	1.2	1.5	66.8	12.4	46.9
5	P01	0.20	1.5	3.0	14.1	4.0	18.3
5	P02	0.14	1.6	3.3	4.7	4.2	14.8
5	P08	0.13	1.5	1.5	3.1	7.0	15.8
5	P10	0.06	0.8	1.5	10.3	7.6	12.2
6	P00	0.18	1.2	2.5	65.7	11.1	41.9
6	P01	0.08	0.6	2.8	59.4	2.9	13.3
6	P02	0.06	0.3	0.6	55.7	2.8	9.9
6	P08	0.12	2.3	1.5	56.4	5.7	13.0
6	P10	0.11	1.9	2.2	63.0	6.3	10.1

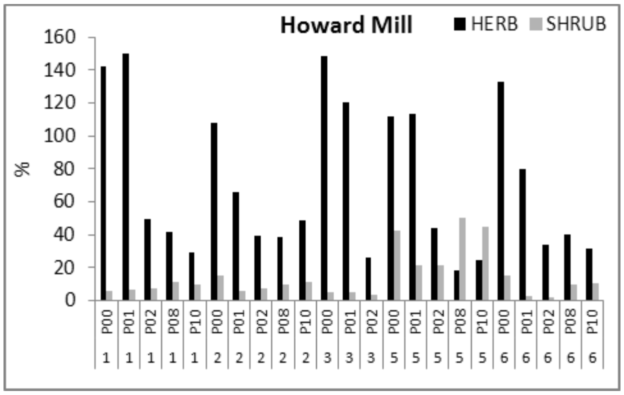
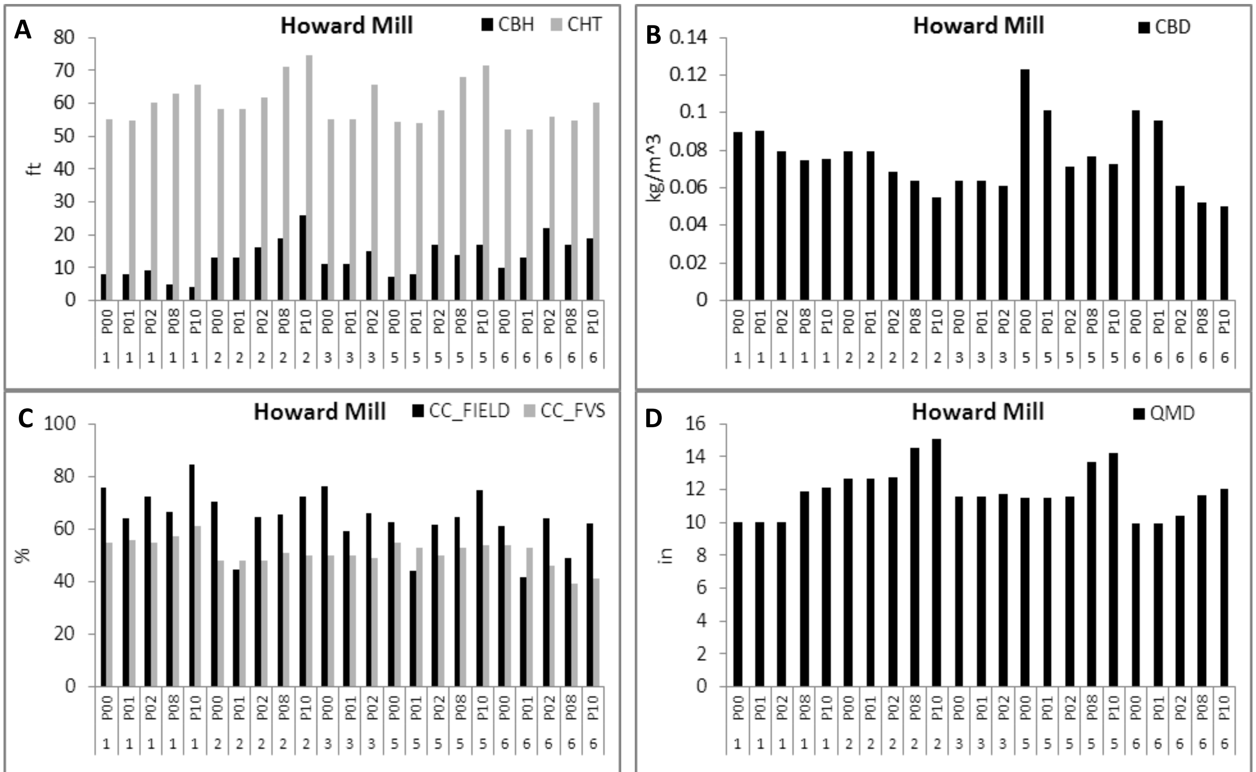


Figure 4. Average herbaceous plant and shrub cover for each plot at each sampling time period.

Table 6. Understory vegetation cover by time period for all the plots in the Howard Mill fuel treatment project.

Plot	Time period	Herbaceous cover (%)	Shrub cover (%)
1	P00	142	6
1	P01	150	7
1	P02	50	8
1	P08	42	11
1	P10	30	10
2	P00	108	15
2	P01	66	6
2	P02	40	8
2	P08	39	10
2	P10	48	11
3	P00	149	5
3	P01	120	5
3	P02	26	3
5	P00	112	42
5	P01	113	21
5	P02	44	22
5	P08	18	50
5	P10	24	45
6	P00	133	15
6	P01	80	2
6	P02	34	2
6	P08	40	9
6	P10	32	10



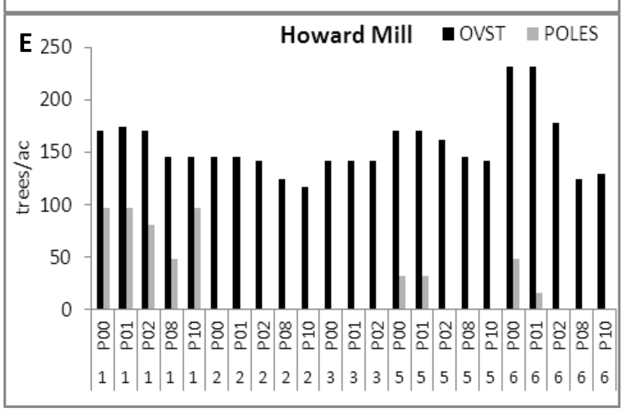


Figure 5. Canopy height and canopy base height (A), canopy bulk density (B), canopy cover from field data and FVS (C), quadratic mean diameter (D), and overstory and pole-sized tree density (E) for each plot at each sampling time period.

Table 7. Canopy characteristics by time period for all the plots in the Howard Mill fuel treatment project.

Plot	Time period	Canopy cover (%) - field	Canopy cover (%) - FVS	Canopy height (ft)	Canopy base height (ft)	Canopy bulk density (kg/m^3)	Quadratic mean diameter (in)	Overstory (trees/ac)	Pole-sized (trees/ac)
1	P00	76	55	55.0	8.0	0.090	10.0	170	97
1	P01	64	56	54.7	8.0	0.090	10.1	174	97
1	P02	72	55	60.1	9.0	0.080	10.0	170	81
1	P08	66	57	62.8	5.0	0.075	11.9	146	49
1	P10	85	61	65.5	4.0	0.075	12.2	146	97
2	P00	70	48	58.1	13.0	0.079	12.7	146	0
2	P01	45	48	58.1	13.0	0.079	12.7	146	0
2	P02	64	48	61.8	16.0	0.069	12.7	142	0
2	P08	65	51	71.2	19.0	0.064	14.5	125	0
2	P10	72	50	74.6	26.0	0.055	15.1	117	0
3	P00	76	50	55.2	11.0	0.064	11.6	142	0
3	P01	59	50	55.2	11.0	0.064	11.6	142	0
3	P02	66	49	65.9	15.0	0.061	11.7	142	0
5	P00	62	55	54.5	7.0	0.123	11.5	170	32
5	P01	44	53	53.9	8.0	0.102	11.5	170	32
5	P02	62	50	58.0	17.0	0.071	11.6	162	0
5	P08	65	53	68.1	14.0	0.077	13.7	146	0
5	P10	75	54	71.5	17.0	0.073	14.2	142	0
6	P00	61	54	52.2	10.0	0.102	10.0	231	49
6	P01	41	53	52.2	13.0	0.096	10.0	231	16
6	P02	64	46	55.8	22.0	0.061	10.4	178	0
6	P08	49	39	54.6	17.0	0.052	11.7	125	0
6	P10	62	41	60.0	19.0	0.050	12.0	130	0

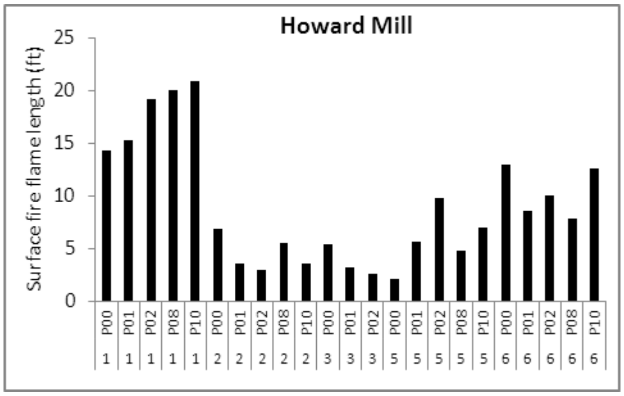


Figure 6. Surface fire flame length from custom fuel models using NEXUS for each plot at each sampling time period under 90th percentile fire weather conditions.

Table 8. Surface fire flame length (modeled in NEXUS with custom fuel models) and type of fire for 90th percentile fire weather conditions for all the plots in the Howard Mill fuel treatment project.

Plot	Time period	Surface fire flame length (ft)	Type of fire
1	P00	14.36	Passive crown
1	P01	15.25	Passive crown
1	P02	19.2	Surface
1	P08	20.04	Passive crown
1	P10	20.93	Passive crown
2	P00	6.90	Passive crown
2	P01	3.62	Surface
2	P02	3.03	Surface
2	P08	5.53	Surface
2	P10	3.60	Surface
3	P00	5.39	Passive crown
3	P01	3.20	Surface
3	P02	2.56	Surface
5	P00	2.14	Active crown
5	P01	5.62	Passive crown
5	P02	9.77	Surface
5	P08	4.83	Surface
5	P10	6.95	Surface
6	P00	12.92	Active crown
6	P01	8.55	Conditional crown
6	P02	10.05	Surface
6	P08	7.84	Passive crown
6	P10	12.58	Passive crown

Trough Ridge (Project 40, Grindstone Ranger District)

Project history

The Trough Ridge project had five plots set up pre-treatment in 2003 using two different plot styles (detailed and fuels 2003). For details about the protocol used, please see "Appendix B: Sampling Protocol" at the end of the report. We had an additional chaparral sub-plot protocol that was no longer continued, but rebar may remain on site beyond both ends of the main transect (CD) line.

For analysis at the regional level, plots from all projects were grouped into one of two treatment types (mechanical or prescribed fire) and one of three dominant forest types (yellow pine, red fir, or mixed conifer). For this project all plots were grouped into the mechanical treatment category, and the mixed conifer forest type. Plots were sampled prior to treatment (P00), then 1 yr post (P01), 2 yr post (P02), and 5 yr-post (P05)(Table 9).

The Stonyford RAWS was used for fire weather and fire behavior simulation modeling.

Table 9. Treatment visits completed by year for each of the plots in the project. ~Indicates that data was not collected for that plot and year.

Plot	2003	2005	2006	2009
1	P00	P01	P02	P05
2	P00	P01	P02	~
3	P00	P01	P02	~
4	P00	P01	P02	P05
5	P00	P01	P02	P05

Treatment information

Prior treatment: There are records of several timber sales that occurred in the 1980's, located in the general area of the monitoring plots, but according to records none of those projects should have included harvesting where the plots are located. However, there are stumps in the pre-treatment pictures.

During the project treatment: This site was mechanically thinned with a dozer in 2004. This was a commercial harvest contract where some portions of sub-merchantable understory trees were removed. Then understory material was piled and burned in October of 2004. In 2006, after the 2 yr post-treatment monitoring occurred, plots 2 and 3 (within unit "C5") were also thinned, burn piled, and the unit was underburned.

Future treatment: Unknown (the plots might have burned during a wildfire in July 2012, the Mill Fire (?))

Project location map

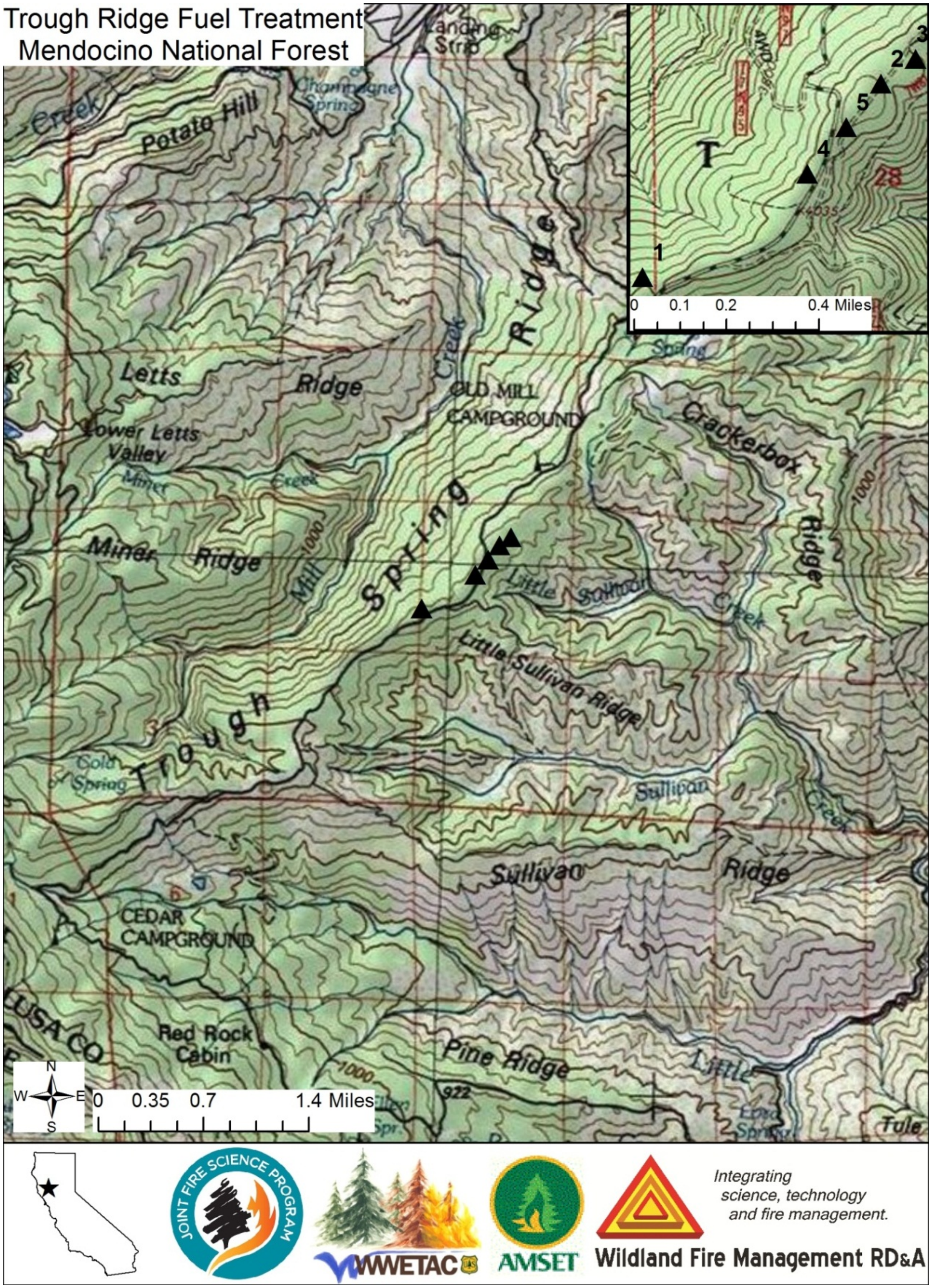


Figure 7. Location map for the Trough Ridge fuel treatment plots, showing the general location of plots, and inset displaying increased detail of plot locations.

Driving directions/GPS/plot layout

Driving directions

Plot 1- Take the M5 road to the Trough Ridge area. Park 0.1 miles west of where the Little Sullivan Ridge road junctions the M5. The reference tree is at the parking spot (a slash road pull out). The plot tag/placard is not facing the road and is on a medium sized ponderosa pine.

Plot 2- From the intersection of 17N02 and M5, continue east/northeast on M5 for 2.65 miles to the intersection of OHV trail 22 or 17N82. Continue 130 meters east on the OHV trail to the start tree on the south side of the road.

Plot 3- From the intersection of 17N02 and M5, continue east/northeast on M5 for 2.65 miles to the intersection of OHV trail 22 or 17N82. Continue 148 meters east on OHV trail to the start tree on the south side.

Plot 4- Park near mile marker 8 off of M5. On the NW side of the road is a large diameter oak. The start tree is 2 meters off of the road.

Plot 5- From the intersection of M5 and 17N82, travel 0.3 miles to the start tree. Start tree is a stump with the plot placard/tag nailed to the top.

Table 10. Directions (distance and azimuth) for walking from the" start tree" to each plot. The azimuth takes into account the local declination. Distance and azimuth are approximate as they were recorded by crews walking in from the start tree (usually tagged tree near road edge).

Plot	Start tree (DBH & species)	Azimuth °	Distance
1	44cm DBH ponderosa pine	304	75 m
2	44cm DBH ponderosa pine	196	78 m
3	46cm DBH oak	129	75 m
4	69cm DBH oak	305	90 m
5	Stump w/ tag nailed on top	86	74 m

Table 11. GPS coordinates for each plot (decimal degrees, datum NAD 1983, projection NAD_1983_California_Teale_Albers).

Plot	Latitude	Longitude
1	39.295889	-122.656474
2	39.302181	-122.647029
3	39.30299	-122.645652
4	39.299289	-122.649916
5	39.305424	-122.642612

Table 12. Plot layout line azimuths (degrees). See Appendix A for plot diagrams. Where CD is the main transect and F1 and F2 are the fuels transects.

Plot	Plot Type	CD	F1	F2
1	Fuels 2003	323	188	277
2	Detailed 2003	244	200	20
3	Fuels 2003	345	300	20
4	Detailed 2003	228	187	277
5	Detailed 2003	180	336	66

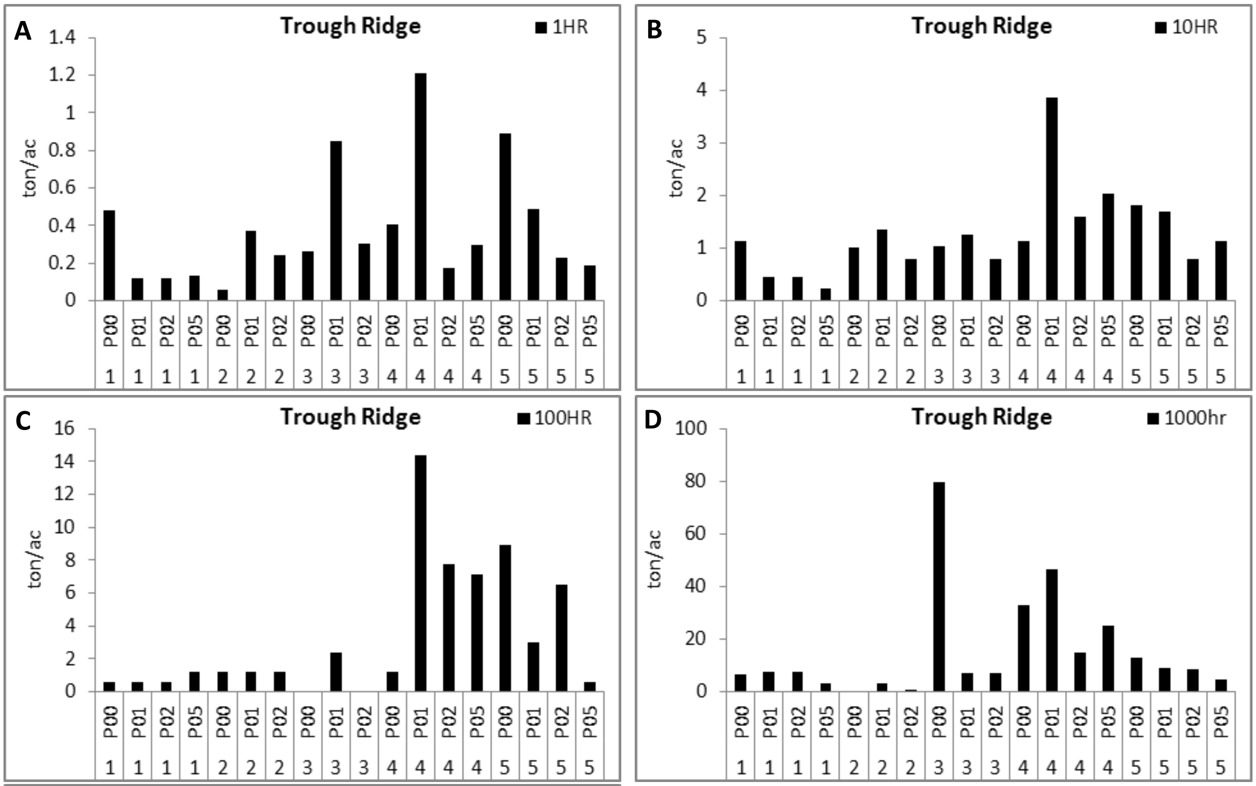
Paired pictures

Below is an example of pictures paired or matched over the time steps the plots were visited. All of the paired pictures are available in the supplied power point file.

Figure 8. Example paired photos showing changes over the time steps for Plot 5 on the CD or main transect line from pre-treatment in 2003 through 5 yr post-treatment in 2009.

Plot findings

Below are graphs and data tables of key metrics from the data gathered in the field for each plot and time period within the project.



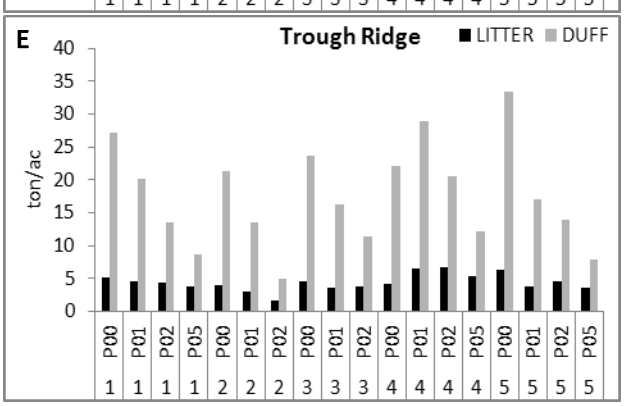


Figure 9. Fuel loading (ton/ac) for the 1-hr (A), 10-hr (B), 100-hr (C), and 1000-hr (D) time lag fuel classes, and litter and duff (E) for each plot at each sampling time period.

P00-pre-treatment, P01-1 yr post-treatment, P02-2 yr post-treatment, etc.

Table 13. Fuel loading (ton/ac) for the 1-hr, 10-hr, 100-hr, and 1000-hr time lag fuel classes, and litter and duff for by time period for all the plots in the Trough Ridge fuel treatment project.

Plot	Time period	1-hr	10-hr	100-hr	1000-hr	Litter	Duff
1	P00	0.48	1.1	0.6	6.7	5.2	27.2
1	P01	0.12	0.5	0.6	7.4	4.5	20.1
1	P02	0.12	0.5	0.6	7.4	4.4	13.6
1	P05	0.13	0.2	1.2	3.4	3.9	8.7
2	P00	0.05	1.0	1.2	0.0	4.1	21.3
2	P01	0.37	1.4	1.2	3.0	3.0	13.5
2	P02	0.24	0.8	1.2	0.9	1.6	5.0
3	P00	0.26	1.0	0.0	79.8	4.5	23.7
3	P01	0.85	1.3	2.4	7.0	3.7	16.3
3	P02	0.31	0.8	0.0	6.9	3.7	11.4
4	P00	0.40	1.1	1.2	33.0	4.2	22.1
4	P01	1.21	3.9	14.4	46.7	6.5	28.9
4	P02	0.18	1.6	7.8	15.1	6.7	20.5
4	P05	0.30	2.0	7.2	24.9	5.3	12.1
5	P00	0.89	1.8	8.9	12.9	6.4	33.5
5	P01	0.49	1.7	3.0	8.8	3.8	17.0
5	P02	0.23	0.8	6.5	8.6	4.5	14.0
5	P05	0.18	1.1	0.6	4.7	3.5	8.0

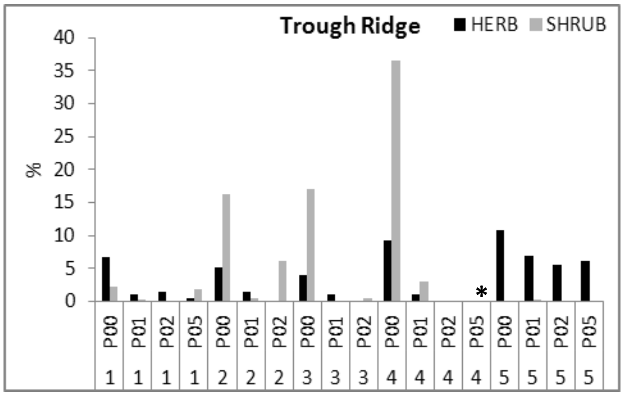


Figure 10. Average herbaceous plant and shrub cover for each plot at each sampling time period.

*Indicates the data was not collected, not a zero value (see Table 14).

Table 14. Understory vegetation cover by time period for all the plots in the Trough Ridge fuel treatment project. *Indicates the data was not collected for the given plot and time period.

Plot	Time period	Herbaceous cover (%)	Shrub cover (%)
1	P00	7	2
1	P01	1	0
1	P02	2	0
1	P05	1	2
2	P00	5	16
2	P01	2	0
2	P02	0	6
3	P00	4	17
3	P01	1	0
3	P02	0	0
4	P00	9	37
4	P01	1	3
4	P02	0	0
4	P05	0	0
5	P00	11	*
5	P01	7	0
5	P02	6	0
5	P05	6	0

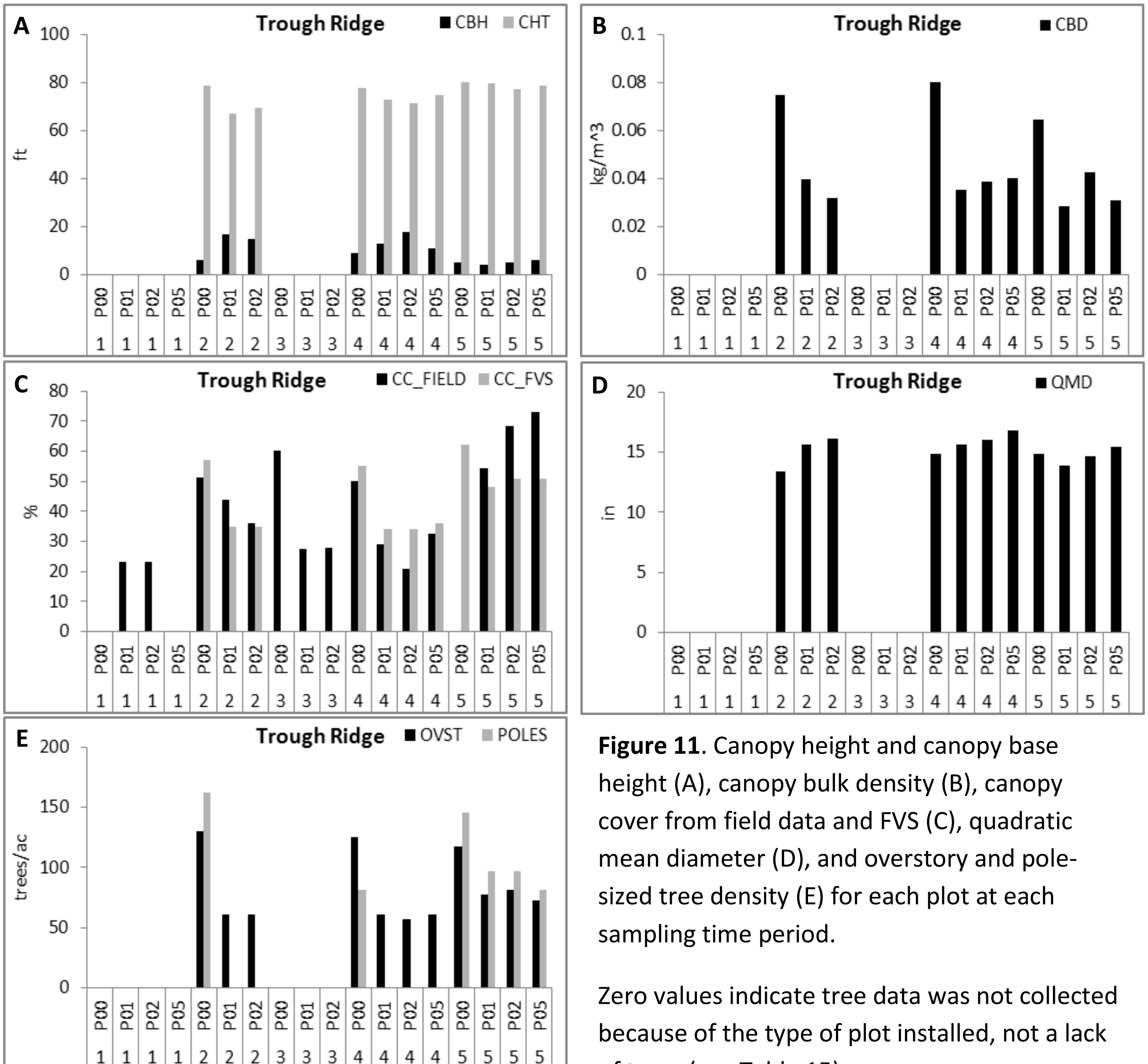


Figure 11. Canopy height and canopy base height (A), canopy bulk density (B), canopy cover from field data and FVS (C), quadratic mean diameter (D), and overstory and pole-sized tree density (E) for each plot at each sampling time period.

Zero values indicate tree data was not collected because of the type of plot installed, not a lack of trees (see Table 15).

Table15. Canopy characteristics by time period for all the plots in the Trough Ridge fuel treatment project. *Indicates the data was not collected for the given plot and time period.

Plot	Time period	Canopy cover (%) - field	Canopy cover (%) - FVS	Canopy height (ft)	Canopy base height (ft)	Canopy bulk density (kg/m^3)	Quadratic mean diameter (in)	Overstory (trees/ac)	Pole-sized (trees/ac)
1	P00	*	*	*	*	*	*	*	*
1	P01	23	*	*	*	*	*	*	*
1	P02	23	*	*	*	*	*	*	*
1	P05	*	*	*	*	*	*	*	*
2	P00	51	57	78.6	6.0	0.075	13.4	130	162
2	P01	44	35	67.2	17.0	0.040	15.6	61	0
2	P02	36	35	69.4	15.0	0.032	16.1	61	0
3	P00	60	*	*	*	*	*	*	*
3	P01	28	*	*	*	*	*	*	*
3	P02	28	*	*	*	*	*	*	*
4	P00	50	55	77.5	9.0	0.080	14.8	125	81
4	P01	29	34	73.0	13.0	0.035	15.6	61	0
4	P02	21	34	71.2	18.0	0.039	16.0	57	0
4	P05	33	36	74.9	11.0	0.040	16.8	61	0
5	P00	*	62	79.9	5.0	0.065	14.8	117	146
5	P01	54	48	79.5	4.0	0.029	13.9	77	97
5	P02	68	51	77.4	5.0	0.043	14.7	81	97
5	P05	73	51	78.6	6.0	0.031	15.5	73	81

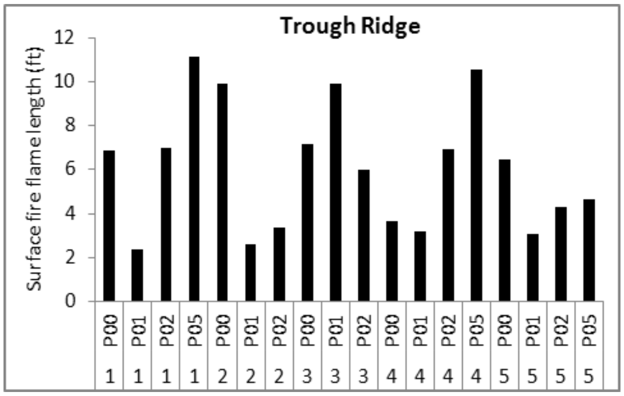


Figure 12. Surface fire flame length from custom fuel models using NEXUS for each plot at each sampling time period under 90th percentile fire weather conditions.

Table 16. Surface fire flame length (modeled in NEXUS with custom fuel models) and type of fire for 90th percentile fire weather conditions for all the plots in the Trough Ridge fuel treatment project. * Indicates the tree data was not collected and fire type was not modeled.

Plot	Time period	Surface fire flame length (ft)	Type of fire
1	P00	6.87	*
1	P01	2.38	*
1	P02	6.96	*
1	P05	11.11	*
2	P00	9.89	Passive crown
2	P01	2.62	Surface
2	P02	3.35	Surface
3	P00	7.17	*
3	P01	9.89	*
3	P02	6.00	*
4	P00	3.66	Passive crown
4	P01	3.16	Surface
4	P02	6.92	Surface
4	P05	10.56	Surface
5	P00	6.46	Surface
5	P01	3.04	Passive crown
5	P02	4.29	Surface
5	P05	4.64	Surface

Appendix A: Description of Supplied Files

For your use we included a number of supplementary files with the digital version of this report (see the supplied thumb drive).

Final report to the JFSP

We included a digital version of the Final Report we submitted to the Joint Fire Science Program for the entire regional assessment.

FVS input database

For each Forest we included an FVS-ready database with all the plots from all the projects (*.mdb). The database includes two different StandInit and TreeInit tables depending on the plot types within the Forest; separate StandInit and TreeInit tables were created for the "detailed" plots and the "fuels" plots. We did this so one would not assume there was tree data available for all plots when it might not have been sampled. The fuel loading data was collected on all plots and is included by size class in both StandInit tables. For the detailed plots, the tree data collected is within the TreeInit table. For the fuels plots, a "dummy" tree list (a single white fir seedling) was created so the plots can be run through FVS, but caution should be used with these because of the lack of real tree data. If data was missing it is represented as a blank in the data tables.

Photo pairs

Most of the photos taken for each plot is included in the supplied Power Point file (*.pptx). Photos were taken along the main transect line(s) and fuel lines each time the plot was visited.

Plot maps

In addition to the imbedded maps in this report, we have supplied PDF versions of the project maps.

GIS shapefile

We supplied a GIS file with all the plots for the Forest.

Appendix B: Sampling Protocol

Data collection protocol (inclusive of all plot layouts)

Plot information naming example

1. Forest name: *"Tahoe NF"*
2. Forest ICS code: *"TNF"*
3. Project name: "Jaybird"
4. Project number: pre-determined for tracking purposes
5. Status: P00=pre-treatment, P01=1st year post, P02=2nd year post, etc.
6. Plot number: *"1"*
7. Surveyors: *"last name, first initial"*
8. Date: *"5/8/09"*
9. Notes: general notes about the area, treatment, anything that stands out

Shrub transect(s) (50 m)

Collect shrub information (for any shrubs that intersect the transect tape) along the length of the transect(s): transect, species, status (live/dead), shrub range in decimeters (dm, distance along transect, i.e. 0.6-0.9 m=3 dm), average height (cm).

Herbs (1x1 m quadrats)

Collect herbaceous species information for all plants rooted in the quadrat. Record the transect, frame, life form (fern, forb, grass, vine, other, unknown), status (live/dead), average height (cm), species (if you know it), and cover class (1=0-5%; 2= 6-25%; 3= 26-50%; 4=51-75%; 5=76-95%; 6=96-100%). Also please take general botany notes for the plot, such as species observed in the plot overall but not captured in the quadrats, and general observations about how much of the plot has weeds or herbaceous plant dominance.

Seedlings (<2.5 cm DBH)

Tally seedlings by species code, status (live/dead), and height class (15=1-15 cm; 30=16-30 cm; 60=31-60 cm; 100=61-100 cm; 200=101-200 cm; 300=201-300 cm, etc.).

Pole-sized trees (>2.5 to <15 cm DBH, and > 4.5 ft (1.37 m) tall)

Live poles: tag #, species, DBH (cm), status (live/dead), partial crown height (m), total tree height (m), canopy class (D=dominant, CD=codominant, I=intermediate, S=suppressed).

Dead poles: tag#, species, DBH (cm), status (live/dead), total tree height (m), decay class (1 newly dead thru 5 long dead).

Overstory trees (>15 cm DBH and > 4.5 ft (1.37 m) tall)

Live trees: tag #, species, DBH (cm), status (live/dead), partial crown height (m), total tree height (m), canopy class (D, CD, I, S).

Dead trees: tag#, species, DBH (cm), status (live/dead), total tree height (m), decay class (1 newly dead thru 5 long dead).

Canopy cover

Collect and record canopy cover, using the moosehorn (canopy sight tube) along the main transects (AB and/or CD) every 1m, starting at 1m and ending at 50m. The moosehorn should be held at the meter mark on the tape, standing on the side of the shrub transect opposite to the side where the herb quadrats are being place. Count the number of hits or intersections, out of 25, where canopy overlaps the grid intersections.

Fuel loading

Each planar fuel transect is 50 ft in length and information is gathered to characterize surface and ground fuels and fuel bed depth.

Surface fuels (1, 10, 100, 1000-hr)

Record the project, plot, transect and tallies for small fuel classes (1, 10, 100-hr), and take notes on the **dominant trees or shrub species** contributing to the fuel load for each transect.

Tally: 1-hr (>0.25”) from 0-6 ft, 10-hr (0.25-<1”) from 0-6 ft, 100-hr (1-<3”) from 0-12 ft.

Record the species, diameter (cm), and status (rotten/sound) for each 1000-hr (> 3’) from 0-50 ft.

Ground fuels (litter/duff/chips)

Measure and record litter and duff depth (thickness) measurements to the nearest 1 cm (measure thickness of each layer, not depth from surface). Starting at 1 foot, take 10 readings, one every 5 ft on each transect: (1 ft, 5 ft, 10 ft… 45 ft). Duff begins where the litter layer organic materials have begun to decompose, and duff ends where the composition is greater than 50% mineral soil. If a sampling spot lands exactly on a log, rock, or other obstruction, take the reading immediately adjacent to the obstruction. If you hit bare soil, your reading will be 0.

If there was mastication/chipping completed, record the depth of the chipped materials as well.

Fuel bed depth

Measure and record the height of the **tallest** downed and dead woody fuel for ten 5 ft collection point intervals (0-5 ft, 5-10 ft, 10-15 ft, up to 45-50 ft) along the planar transect. Measure from the **base of the litter layer to the top of the fuel particle**; measure to the nearest whole cm. If you do not have any dead and downed fuels, your measure will be based on the maximum litter depth in that interval.

Photos

Avoid people and gear in the photos. Line up with the photos supplied from previous plot visits to the best of your ability. Use a photo board to document the photo location within the photos, matching the plot naming protocol example above. **Always take the photos in a portrait orientation (up and down) with the transect tape in the bottom middle of the image**. Photos were only taken from 0 to 50 ft for each fuels transect (labeled F1, F2, etc.), from C to D (and A to B if applicable) for the shrub transect, and one general picture of the plot (this one will not have an old photo to match).

2001 detailed plot specifics

Shrub transects (50 m)

There are two perpendicular transects (AB and CD) for these plots. They **should** be contour and up/down slope, but they **might** be shifted.

Herb quadrats

There are 10 quadrats for these plots. They are located from 9-10 m, 19-20 m, 29-30 m, 39-40 m, and 49-50 m along the **left hand side** looking from 0 to 50 m for both the AB and CD transects.

Seedlings

This is a circular plot starting at the pole/seedling origin rebar (at 33.92m on transect CD) extending out and around 3.99 m in all directions.

Pole-sized trees

This is a circular plot starting at the pole/seedling origin rebar (at 33.92m on transect CD) extending out and around 8.92 m in all directions.

Overstory trees

This is a circular plot starting from the origin (at 25 m on transect CD) extending out and around 17.85 m in all directions.

Canopy cover

A total of 100 canopy cover readings will be measured. They will start at 1m and continue every meter until the ends of each transect (50 m). This is to be done along **both** transect AB and CD.

Fuel loading

There are four 50 ft fuel transects for this layout. They start at 7.15 m and 42.85 m along the AB and CD transects extending out at a 45º angle. See the diagram for number convention and general layout.

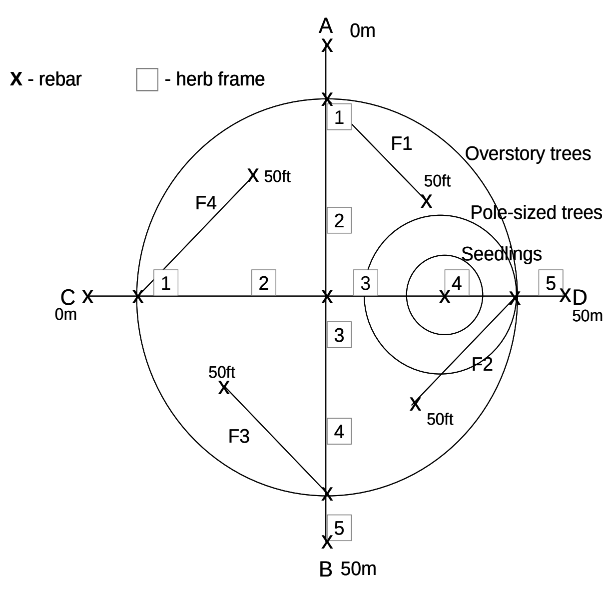


Figure 13. Plot layout diagram for the detailed plots installed in 2001 and 2002.

2003 detailed plot specifics

Shrub transects (50 m)

There is one transect (CD) for these plots. It **should** be contour to the slope.

Herb quadrats

There are five quadrats for these plots. They are located from 9-10 m, 19-20 m, 29-30 m, 39-40 m, and 49-50 m along the uphill side of CD transect.

Seedlings

This is a circular plot starting at the pole/seedling origin rebar (at 33.92 m on transect CD) extending out and around 3.99 m in all directions.

Pole-sized trees

This is a circular plot starting at the pole/seedling origin rebar (at 33.92 m on transect CD) extending out and around 8.92 m in all directions.

Overstory trees

This is a circular plot starting from the origin (at 25 m on transect CD) extending out and around 17.85 m in all directions.

Canopy cover

A total of 50 canopy cover readings will be measured. They will start at 1 m and continue every meter until the end of the transect CD (50 m).

Fuel loading

There are two 50 ft fuel transects for this layout. They both start at 7.15 m along the CD transect and have a rebar labeled "F1/F2 0ft". F1 extends uphill at a 45º angle toward the center of the plot, F2 extends downhill at a 45º angle toward the center of the plot.

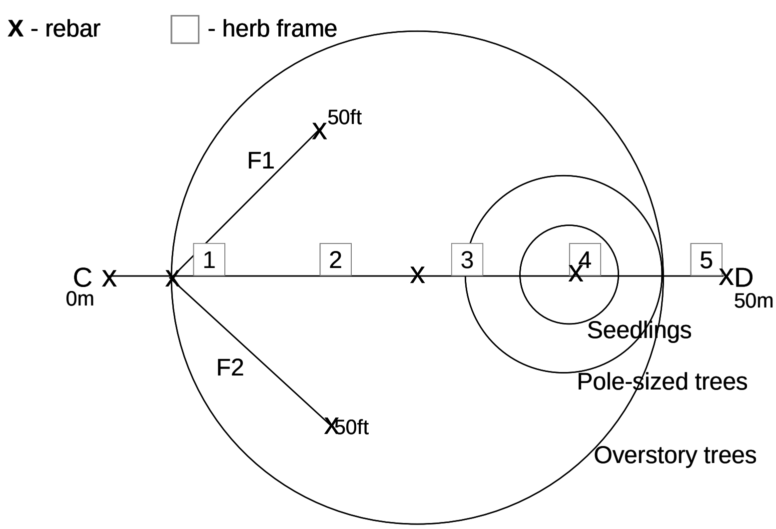


Figure 14. Plot layout diagram for the detailed plots installed from 2003 to 2006.

2003 fuels plot specifics

Starting in 2012 tree data was collected on Fuels '03 plots that were visited. You need to establish the pole/overstory and seedling rebar and tag all pole & overstory trees and gather data on all size classes!

Shrub transect

There is one transect (CD) for these plots. It **should** be contour to the slope.

Herb quadrats

There are 5 quadrats for these plots. They are located from 9-10 m, 19-20 m, 29-30 m, 39-40 m, and 49-50 m along the uphill side of CD transect.

Canopy cover

A total of 50 canopy cover readings will be measured. They will start at 1 m and continue every meter until the end of the transect CD (50 m).

Fuel loading

There are two 50 ft fuel transects for this layout. They both start at 7.15 m along the CD transect and have a rebar labeled "F1/F2 0 ft". F1 extends uphill at a 45º angle toward the center of the plot, F2 extends downhill at a 45º angle toward the center of the plot.

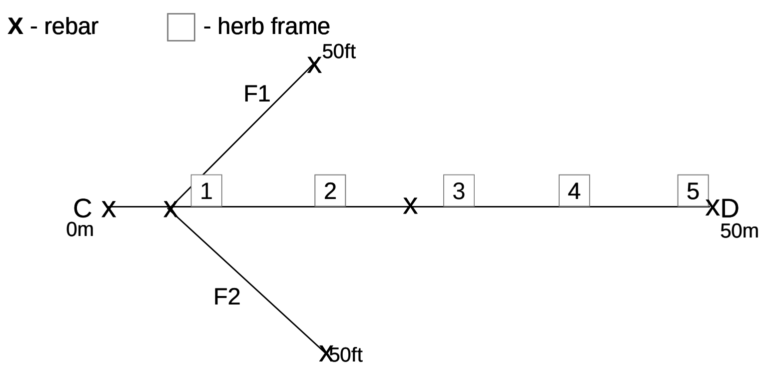


Figure 15. Plot layout diagram for the fuels plots installed from 2003 to 2006.