FCCS Fuelbeds For The Lake Tahoe Basin Management Unit

Final Report P018

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Lake Tahoe Basin Mgt Unit

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Abstract

We used the Fuel Characteristic Classification System (FCCS) to develop a set of past, current, and future fuelbeds for the Lake Tahoe Basin Management Unit (LTBMU). Through group consensus of LBTMU managers, six major fuelbed types were identified that occur in the basin including: (1) jeffrey pine-white fir, (2) red fir, (3) wet lodgepole pine, (4) whitebark pine-lodgepole, (5) mountain hemlock, and (6) mixed confer. Fuelbed pathways were completed for each of the major fuelbed types and 88 fuelbeds were identified for development. Twenty additional fuelbeds were identified and developed to represent unique vegetation types that did not fall within the six fuelbed types. The fuelbeds were constructed using baseline fuelbeds provided within the FCCS and modified for local application using scientific and gray literature, photo series, plant association and forest community guides, and community descriptions. A fuelbed pathway handbook was compiled that includes the six fuelbed types, pathway schematics, fuelbed names and descriptions, fire behavior estimates and general photographs assigned to the fuelbeds. Thirty-one of the major fuelbeds and 20 of the unique fuelbeds were crosswalked to vegetation attributes from the CALVEG data set and mapped for the LTBMU. The fuelbed pathway handbook, FCCS fuelbeds, and fuelbed map were presented at the meeting "A Symposium on Forest Management Decision Support Tools" held in 2010 at Incline Village, Nevada and at a workshop conducted the following day. Defining and mapping important

fuelbeds for the LTBMU will enable managers to better plan restoration and wildlife habitat projects and account for potential fire hazard, smoke from wildland fire, and carbon.

Background and Purpose

As fire models become more sophisticated and widely used, there is an increasing need to accurately quantify and classify the structural and geographical diversity of wildland fuels. Defining these fuelbeds provides input data for current and future fire and fuel models, enabling managers to better plan restoration projects; quantify potential fire behavior, fire effects, and smoke emissions; account for carbon; and protect and enhance wildlife habitat throughout the Lake Tahoe Basin Management Unit (LTBMU). Although fire behavior fuel models have been assigned to the LTBMU for wildland fire risk assessments (U.S. Forest Service 2007), those do not provide a representation of realistic fuels required by today's planning processes. Consequently, the LTBMU collaborated with the Fire and Environmental Research and Applications (FERA) team of the Pacific Wildland Fire Research Laboratory to create a comprehensive set of Fuel Characteristic Classification System (FCCS) fuelbeds (Ottmar et al. 2007; Riccardi et al. 2007) representing the past, current and potential future conditions of major forest and rangeland types, management activities, and natural disturbances occurring within the LTBMU.

What is the FCCS? It is a software system to build fuelbeds with realistic fuels data and predict their relative fire hazard (Ottmar et al. 2007, Riccardi et al. 2007). The FCCS defines a fuelbed as a relatively homogeneous unit on the landscape, representing a unique combustion environment. The FCCS stratifies fuelbeds into 6 horizontal strata (canopy, shrubs, nonwoody vegetation, woody fuels, litter-lichen-moss, and ground fuels) to represent every fuel element that has the potential to combust. The fuelbeds are further separated into one or more fuelbed categories and subcategories. Users can modify FCCS fuelbeds to create a set of customized fuelbeds representing any scale of interest.

FCCS calculates the relative fire hazard of each fuelbed, including surface fire behavior, crown fire, and available fuel potentials, scaled on an index from 0 to 9 (Sandberg et al. 2007b). FCCS fire potentials facilitate communication of fire hazard among users by providing an index of the intrinsic capacity of each fuelbed for surface fire behavior, crown fire and fuels available for consumption. FCCS fire potentials also offer an easy way to evaluate fuels treatment effectiveness. The crown fire potential takes into account the predicted surface fire behavior and whether there is sufficient energy available to breach the gap between canopy layers carrying the fire into tree crowns, whether there are sufficient ladder fuels to carry the fire into the crowns, and finally, whether the trees crowns are close enough to carry fire through the canopy. So fuelbeds with higher than average surface fire behavior and dense canopies with either low live crowns or ladder fuels are likely to have a high crown fire potential. The surface fire potential considers the loading and arrangement of surface fuels (shrubs (including needle drape, if applicable), nonwoody fuels, litter and woody fuels <3 inches), and the species composition of the shrub layer, specifically, whether highly flammable species are present. The available fuel potential tends to be highest in fuelbeds with high total biomass. However, a fuelbed with higher loading of finer fuels might have a higher available fuel potential than a fuelbed with higher loading of coarse fuels, because the fine fuels are more likely to be consumed. These three fire potentials can be used to compare the potential fire behavior among fuelbeds. For example, as

Sandberg et al. (2007b) state, "an FCCS fire potential of 469 would represent a fuelbed with a modest surface fire potential, above-average crown fire potential, and extreme potential for biomass consumption." Comparing this to a fuelbed with a fire potential of 222 would indicate that the second fuelbed is predicted to have lower surface fire potential, much lower potential for crown fire and also much lower potential for biomass consumption than the first fuelbed.

In addition to the fire potentials, FCCS also predicts surface fire behavior, including reaction intensity (BTU ft^{-2} sec^{-1}), flame length (ft), and rate of spread (ft min^{-1}) based on benchmark and user-specified environmental conditions. Using a modified Rothermel spread equation (Sandberg et al. 2007a), FCCS evaluates each fuelbed stratum separately for reaction intensity and heat sink terms, accounting for changes that occur between fuelbed strata due to natural succession or a natural or human change agent (Sandberg et al. 2007a). By comparing predicted flame length and rate of spread between the fuelbed and fire behavior fuel models, FCCS provides a crosswalk to one of the original 13 Fire Behavior Prediction System fuel models and one of the 40 standard fuel models (Scott and Burgan 2005). Finally, the FCCS reports carbon storage by fuelbed category and subcategory.

Study Location and Description

Study Location

The study area is the 150,000-acre Lake Tahoe Basin Management Unit located on the California and Nevada border (fig. 1). Initially, the study area was to be confined to the Angora fire area. However, following discussions with the LTBMU managers, it was decided the study would include the entire unit.

Figure 1. Location of the Lake Tahoe Basin Management Unit.

<u>Study Description</u>

In collaboration with U.S. Forest Service, Pacific Southwest Region, the Fire and Environmental Research Applications Team (FERA) of the Pacific Northwest Research Station, and LTBMU managers, 108 fuelbeds were identified and constructed using the fuelbed pathway concept, FCCS, and data from both scientific and gray literature sources. The FCCS calculator provided fuelbed characteristics, a set of surface fire behavior, crown fire, and available fuel potential predictions based on established environmental criteria; and a report for each fuelbed. The fuelbeds were matched with CALVEG Lake Tahoe basin vegetation layer descriptions and attributes to map the fuelbeds across the region. A fuelbed pathway handbook was produced with fuelbed types, fuelbed pathways, fuelbed descriptions, and fuelbed fire potentials and fire behavior predictions.

Specific objectives of the project were:

1) Consult with LTBMU ID-team to determine critical fuelbed types, fuelbed pathways, and fuelbeds that will represent past, current and future vegetation states of the LTBMU.
2) Build fuelbeds using previously collected data and scientific and gray literature.
3) Run each fuelbed for fuelbed characteristics, fire potentials, fire behavior, and total carbon.
4) Use CALVEG existing vegetation layer to map the FCCS fuelbeds for the LTBMU.
5) Prepare required quarterly progress reports.
6) Complete a final report with fuelbed handbook, pathway diagrams, FCCS predicted fire outputs, and FCCS fuelbed files.
7) Complete FCCS fuelbed map for the LTBMU.
8) Prepare a draft manuscript(s) to be submitted to a refereed journal.
9) Present a minimum of one conference and one mini-workshop

Methods

Fuelbed Identification and Development

A team of fire ecologists and fire and fuel experts were gathered to list a set of important fuelbed types for the Lake Tahoe Basin Management Unit. A fuelbed pathway (similar to a successional forest pathway, but for fuelbeds as they change over time) was created for each fuelbed type. The fuelbed pathways were developed from consensus of land managers and the project leads based on (1) fuelbed types that were important, (2) years for a fuelbed to change significantly, (3) common management and natural change agents that occur in the LTBMU.

The pathways highlighted fuelbeds which needed to be constructed to represent major forest types, natural succession, common management activities, and natural disturbances over time. In addition, 20 fuelbeds were added to the fuelbed list that did not fall within the key fuel types identified by the LTBMU managers, but would allow a more complete assignment of fuelbeds to vegetation classes found in the LTBMU (fig. 2).

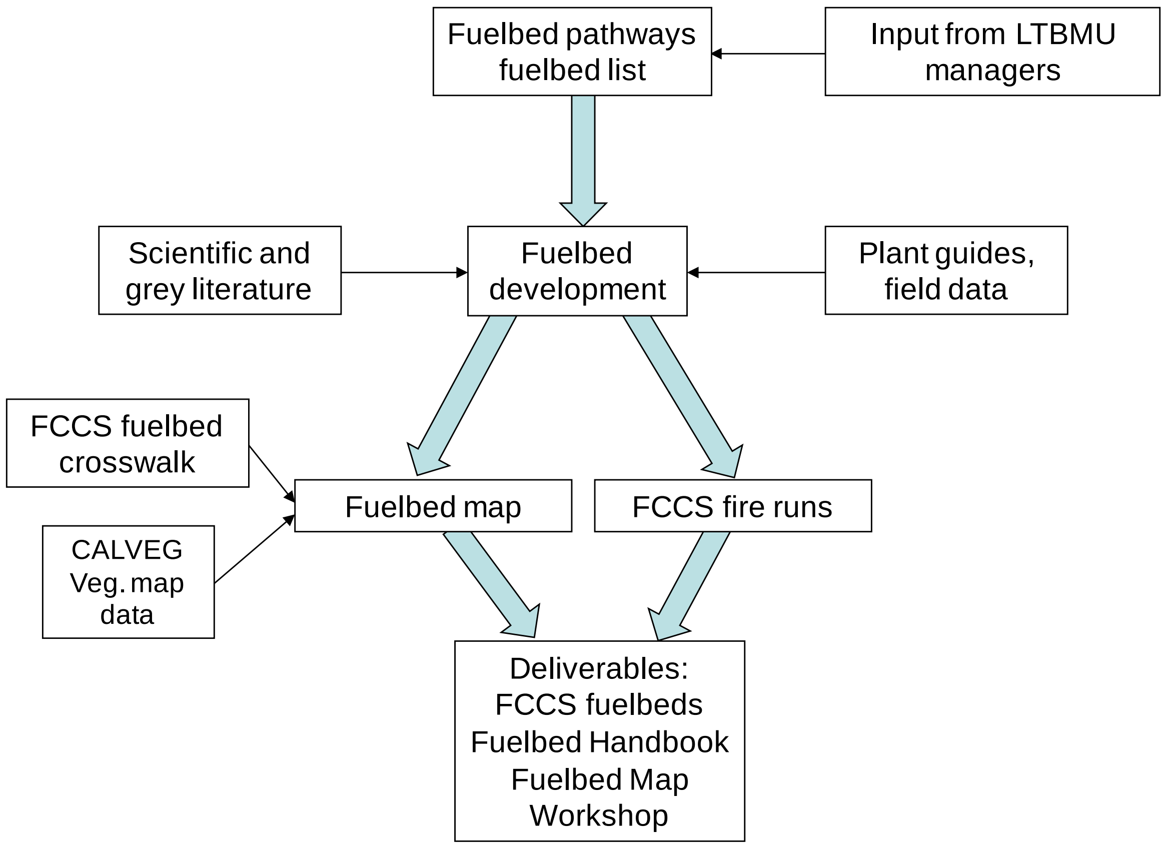

Figure 2. Study process.

Fuelbeds provided in the FCCS library (Ricarrdi et al. 2007, http://www.fs.fed.us/pnw/fera/fccs/fuelbed_references.shtml) or from other projects (i.e. Okanogan/Wenatchee National Forest project and central Oregon project, http://www.fs.fed.us/pnw/fera/fccs/downloads.shtml#sf) were used as starting points for creating LTBMU fuelbeds. Plant association and forest community guides (Fites 1993; Smith 1994; Potter 1994), photo series (Ottmat et al. 1998, Ottmar et al. 2000a, Ottmar et al. 2000b, Ottmar et al. 2007), inventory databases (http://www.fs.fed.us/pnw/fera/fccs/fuelbed_references.shtml), experimental results (Stephens and Moghaddas 2005) and expert opinion were used to modify the fuelbed descriptions and adjust fuelbed inputs including loading, depths, percentage cover, and species to represent the fuelbeds identified in the pathways and that fell outside the six important fuelbed types. Field data from the LTBMU was not collected for building the fuelbeds because resources and time were limited. However, the fuelbeds provided by the FCCS library and other national forest projects were developed from measured data acquired through scientific literature, regional data bases, or actual field measurement.

Fuelbed Characteristics

Some fuelbed characteristics such as woody fuel loading, litter depths, and shrub heights are assigned to each fulebed during the fuelbed building process. However, other fuelbed characteristics use input variables to calculate other characertistics that were not measured. Fuelbed characteristics, including shrub loading, litter loading, and carbon by fuelbed strata, categories, and subcategories, were calculated for each fuelbed using the FCCS.

Fire Behavior

FCCS version 2.1 was used to calculate (1) surface fire behavior, crown fire, and available fuel potentials; (2) reaction intensity, rate of spread, and flame length (Sandberg et al. 2007a; Sandberg et al. 2007b) for each fuelbed at three moisture scenarios (low, medium, and high),and (3) mid-flame windspeeds (0, 3,and 7 mph) and slopes (0, 30, and 70%). These environmental variables and slopes were selected by LTBMU managers and scientists to provide results at a wide range of conditions. Suggested crosswalks to the original Fire Behavior Prediction System (Rothermel 1972, Albini 1976, Andrews et al. 2005) and standard fuel models (Scott and Burgan, 2005) were also determined at three moisture scenarios (low, medium, high), mid-flame windspeeds (0, 3, and 7 mph) and slopes (0, 30, and 70%).

Fuelbed Handbook

General information on the fuelbed types, fuelbed pathways and their related fuelbeds, fire potentials, surface fire behavior prediction, and fire behavior fuel model crosswalk were compiled into the Lake Tahoe Basin Fuelbed Pathway Handbook. Fuelbed types and pathway information is summarized in schematics and tables that include the fuelbed names, description, age class, and any management actions or natural change agents associated with each fuelbed. All fuelbed outputs are presented in summary tables. Representative photos for many fuelbeds were collected and provided in the handbook to illustrate general structural features of the fuelbeds only and were not intended to represent actual species composition or fuel loadings.

Fuelbed Map

To map FCCS fuelbeds we used CALVEG data for the Lake Tahoe Basin Management Unit (U.S. Forest Service 2008). The vegetation type (Regional Dominance type) and overstory tree size class were used to create unique classes. These unique vegetation classes matched closely with the fuelbed type, age, and characteristics of the pathways and fuelbeds, so a simple crosswalk was created. Once a fuelbed map was produced, it was discovered that there were more vegetation classes than fuelbed types developed for the basin and the map coverage was less than 90 percent. To improve map coverage, 20 additional fuelbeds outside the fuelbed types were constructed and added to the map to achieve a +99.5 % fuelbed coverage of the Lake Tahoe Basin Management Unit.

Results

The majority of the results are presented in the Fuelbed Pathway Handbook (a separate deliverable) and the Fuelbed Map. These were two major deliverables for the project.

Fuelbeds

There were 6 fuelbed types identified by the LTBMU managers and 6 fuelbed pathways developed to account for natural succession, fuels management activities, and natural and human change agents. Harvest types, fuel treatments, and natural change agents were considered when constructing the pathways and included: clearcut, pre-commercial thin, select-cut, salvage, pile and burn, pile and no burn, prescribed fire, mastication; crown wildfire, ground wildfire, insect and disease, avalanche, and none. A total of 88 fuelbeds were developed.

The fuelbed types and number of fuelbeds constructed for each type include:

- Jeffrey pine and white fir (24 fuelbeds)
- Red fir (18 fuelbeds)
- Wet lodgepole pine (8 fuelbeds)
- Whitebark pine, lodgepole pine (8 fuelbeds)
- Moutain hemlock (6 fuelbeds)
- Mixed conifer (24 fuelbeds)

Twenty additional fuelbeds were identified and constructed to account for vegetation not covered by the 6 fuelbed types but that represented a significant portion of the landscape. These included: (1) huckleberry oak shrub, (2) green leaf manzanita, (3) short hair reed grass-thread leaf sedge, (4) sapling aspen, (5) pole aspen, (6) medium aspen, (7) black cottonwood, (8) chamise chaparral, (9) sagebrush, (10) western juniper/sagebrush/bitterbrush, (11) willow-mountain alder, (l2) low sagebrush, (13) mountain mahogany, (14) avalanche-disturbed aspen, (15) large ponderosa pine, (16) sapling Douglas-fir/ponderosa pine, (17) sapling ponderosa pine, (18) bitterbrush and rabbit brush, (19) western juniper savanna, and (20) old sagebrush.

The 108 fuelbeds are available from the FERA website for input into the FCCS allowing additional outputs to be observed including fuel loading and available carbon by fuelbed category (http://www.fs.fed.us/pnw/fera/fccs/downloads.shtml#sf).

Fuelbed Characteristics

Over 300 input variables and calculated characteristics are available for each fuelbed. In this report, we provide only loading (t a^{-1}) for each major fuel category and total aboveground carbon (appendix 1). Additional characteristics can be calculated or reported by running the fuelbeds in the FCCS. The total loading ranged from 1.5 t a^{-1} for the low sagebrush additional fuelbed LF308 with only shrub biomass, to 1240 t a^{-1} for the mixed conifer LT064 fuelbed, 80-120 years old, with a substantial tree bole and woody fuel mass. The shrub, grass, woody fuel, and litter fuelbed categories drive surface fire behavior reaction intensity, spread rate, and flame length for surface fire behavior. Total biomass for these 4 categories ranged from 1.1 t a^{-1} for the additional bitterbrush fuelbed CO208 with no litter and small woody fuels to 17.7 t a^{-1} for the mixed conifer fuelbed LT088 120+ years.

Fuelbed Map

There were more fuelbeds developed for the Lake Tahoe Basin area than were vegetation classes in the CALVEG data set. Furthermore, the data set did not distinguish between human or natural change agents so fuelbeds that naturally progressed from one age class to the next without a change agent were the only fuelbeds mapped. This allowed only 31 of the 100 fuelbeds developed for the six fuelbed types to be mapped. To achieve a more complete coverage of the LTBMU, 20 additional fuelbeds were constructed for vegetation classes without a matched fuelbed and added to the fuelbed list. Appendix 2 displays the CALVEG vegetation classes and FCCS fuelbed crosswalk. The fuelbed map and legend are displayed in figs. 3 and 4. A majority of the mapped coverage was in the mixed conifer and yellow pine categories (55.2%), followed by montane chaparral and red fir (24.1 %). Grass and forbs, subalpine, lodgepole pine, great basin shrub types, riparian hardwoods, aspen and other accounted for the remaining area (20.8%).

Modeled Fire Behavior

FCCS surface fire behavior, crown fire, and available fuels potentials; reaction intensity, rate of spread, and flame length; and suggested crosswalks to the original Fire Behavior Prediction System and standard fuel models are presented in summary tables of the Lake Tahoe Fuelbed Pathway Handbook. FCCS fire potentials ranged from **1 0 5** for the red fir fuelbed LT033 (120+ years old that has been select cut, piled and burned at moisture scenario high, 0% slope, and 0 mph wind speed) to **9 6 9** for the red fir fuelbed LT032 (120+ years old with no management at moisture scenario low, 70% slope and 7 mph wind). The reaction intensity ranged from 560 BTUs ft^{-2} sec^{-1} for the wet lodgepole pine fuelbed LT038 (0-10 years old with no management action at high fuel moisture content, 0% slope and 0 mph wind speed), to 119 BTUs ft^{-2} sec^{-1} for the mixed conifer fuelbed LT062 (25-50 years old with no management at a low moisture, 70 % slope and 7 mph wind). Flame length ranged from 0.2 feet for the wet lodgepole pine fuelbed LT042 (40-80 year old with no treatment, high moisture content, 0 % slope and 0 mph wind speed) to 25.3 feet for mixed conifer fuelbed LT062 (25-50 years old with no treatment, at low fuel moisture content, 70% slope, and 7 mph wind speed). The rate of spread ranged from 0 ft min^{-1} for the wet lodgepole pine fuelbed LT042 (40-80 years old with no treatment, high moisture content, 0 % slope and 0 mph wind speed) to 81.4 ft/min^{-1} for fuelbed LT062 (with no treatment at 25-50 years old, at low fuel moisture content, 70% slope, and 7 mph wind speed). In general, the FCCS fire potentials and surface fire behavior increased over time if there were no treatment activities in place or if there was a change agent such as logging without subsequent fuels treatment.

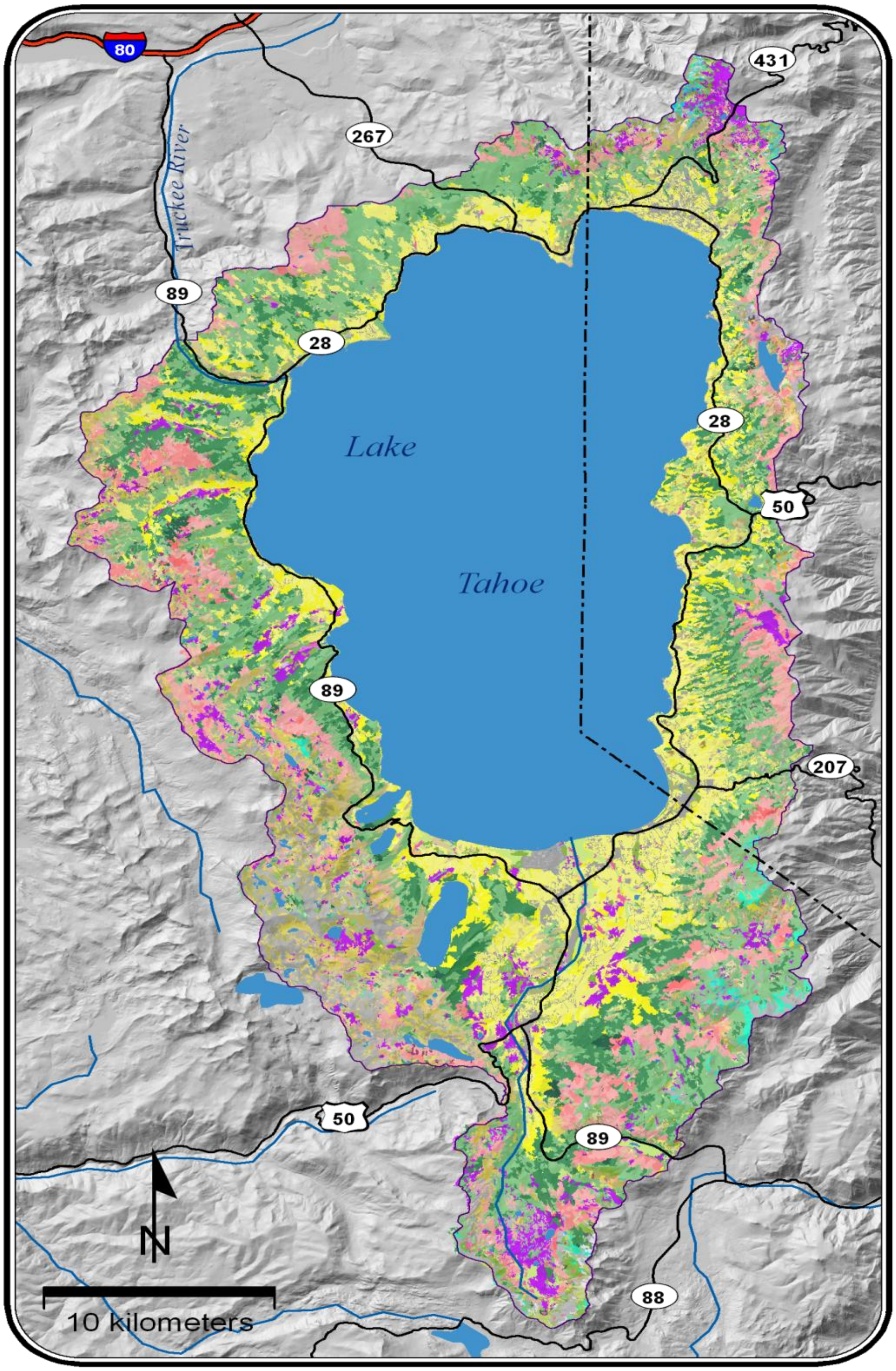
80
431
267
Truckee River
89
28
Lake
Tahoe
28
50
89
207
50
89
N
88
10 kilometers

Figure 3. FCCS fuelbed map for the Lake Tahoe Basin Management Unit.

Figure 4. Legend for Lake Tahoe Basin Management Unit FCCS fuelbed map.

Discussion

Each FCCS fuelbed developed for the LTBMU represents a relatively uniform unit on the landscape that is a unique combustion environment. These fuelbeds provide realistic physical fuel properties for a range of applications in fire, fuel, smoke, wildlife habitat, and carbon assessments. The fuelbeds can be input into Consume or other software tools to calculate fuel consumption, emissions, and potential fire effects. In addition, users can assess the effects of human and natural disturbances on a range of fuelbed characteristics. These can lead to a rigorous framework for planning, decision making, and policy analysis. Because the fuelbed list was developed from important fuelbed types and pathways, the fuelbeds will be especially beneficial for fuel treatment planning and evaluating the effectiveness of the fuel treatments through space and time.

The FCCS LTBMU fuelbeds were developed using baseline fuelbeds established from field measurements that were in the proximity of the LTBMU, contained similar vegetative structures, age classes, and change agents. These fuelbeds were modified and species adjusted using photo series, plant association and forest community guides, experimental results, and expert opinion. Although the fuelbeds developed during this study have not been verified against field measurements, the attention to detail and customizing the fuelbeds to best represent the LTBMU with available local information, we feel they will be accurate enough for most management planning. A simple evaluation could be performed to assess the fuelebds with measured fuels information collected from recent studies.

Each fuelbed can be customized with collected data to improve the representation of a particular fuelbed. Similarly, the fire behavior predictions are within the range of Rothermel’s equations and have been verified by anecdotal evidence. However, they have not been validated with a scientifically collected data set since no quality data set exists. In fact, no fire models have been rigorously evaluated. A plan for testing the FCCS fuelbeds and calculated fire potentials and surface fire behavior values has been proposed for 2014.

The FCCS fire potentials calculated for each fuelbed represent the capacity of a specific fuelbed to support a surface fire and crown fire, and to consume and smolder fuels at benchmark environmental conditions. The fire potentials can be used to evaluate and map fire hazard, compare and communicate the degree of fire hazard, and measure the change in fire hazard caused by fuel management, natural events, or the passage of time. For example, an FCCS fuelbed with a fire potential of #466 will have a surface fire behavior potential index of 4 (modest reaction potential, surface spread, and flame height), a crown fire potential index of 6 (above average crowning potential representing 6 on a scale of 10), and an available fuel potential index of 6 (above average available fuel representing 60 t a^{-1} consumed).

In addition, the FCCS predicts actual surface fire behavior of reaction intensity (btu ft^{-2} sec^{-1}, flamelength (ft), and rate of spread (ft min^{-1}) for specific environmental variables of moisture content, wind speed and slope. This allows managers to evaluate a specific fuelbed for actual surface fire behavior rather than using the simplified FCCS potential index. Finally, the

FCCS assigns each fuelbed to the closest matched 13 and 40 fire behavior fuel models. This would allow managers to assign a fire behavior fuel model to the landscape and run FLAMAP (Finney 2006).

Each fuelbed contains over 300 input variables and fire and carbon prediction outputs. Although the fuelbed map completed for this study only delineates fuelbeds, various input variable layers or output value layers for each fuelbed could be added to the map. For example, it would be relatively easy to display the fire behavior and crown fire potential, reaction intensity, flame length, and rate of spread presented in the Fuelbed Pathway Handbook across the LTBMU.

The LTBMU is unique in that the CALVEG layer contains specific classes that allowed a detailed cross-walk to be developed and enabled more fuelbeds to be assigned to the landscape than many mapping projects in the west. The only other project that had detailed vegetation attributes comparable was the Interior Columbia River Basin Assessment (Huff et al. 1995, Ottmar et al. 1998) that used historic and current aerial photo interpretation for assigning vegetation attributes and FCCS fuelbeds.

There are several enhancements that would improve the usefulness of this project. First, a more thorough examination of available fuel measurements would allow improved fuelbed construction. Second, Forest Vegetation Simulator runs (Reinhardt and Crookston 2003) could be used to improve stand data for fuelbeds as they move through time. Third, specific fuelbed inputs and outputs such as fuel loading, carbon, snag density, etc. could be mapped for the LTBMU. Fourth each LTBMU fuelbed could be run through Consume and estimates of fuel consumption and emissions for low, medium, and high moisture contents could be calculated and those values mapped. Fifth, photos could be taken to generally represent each FCCS fuelbed. Finally, there are numerous measured fuel data sets representing areas of the LTBMU that are currently available from other research projects. These data could be used to (1) evaluate the FCCS approach, (2) provide information on the accuracy of the fuelbed map, and (3) used to modify individual fuelbeds to better represent the LTBMU.

Conclusion

This project has provided a robust set of fuelbeds that represent the past, current and potential future conditions of major forest and rangeland types, management activities, and natural disturbances occurring within the LTBMU. These fuelbeds can be used to evaluate the landscape for fire potential, smoke production, fuel loading, carbon storage, and wildlife habitat across time and space. This project is only the initial stage, providing a solid baseline of fuelbeds to assist in land management planning. As management actions change or the landscape changes due to succession or natural and human change agents, additional fuelbeds may need to be developed or the original fuelbeds modified. This will be a relatively easy process with the fuelbed pathways and initial fuelbeds in place. Finally, there are several fuel data sets representing areas of the LTBMU that are currently available from other research projects that could be used to evaluate the FCCS approach, provide information on the accuracy of the fuelbed map, and be used to modify individual fuelbeds to better represent the LTBMU.

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U.S. Forest Service, 2007. Lake Tahoe Basin multi-jurisdictional fuel reduction and wildfire prevention strategy—10 year plan. On file at USDA Forest service, Lake Tahoe Basin Management Unit, 35 College Drive, South Lake Tahoe, CA 96105. 60 p.; http://resources.ca.gov/tahoefirecommission/downloads/Final_Draft_LTB-FUELS-10_YEAR_PLAN.pdf

Deliverables

The study has completed the majority of deliverables stated in the proposal. Several additional tasks beyond the scope of the original proposal were also completed. Tables 1 and 2 list the proposed and actual deliverables and additional deliverables provided. A detailed list of websites, presentations, consultations, lesson plans and training are also presented.

Table 1. Comparison of proposed and actual deliverables.

Proposed	Delivered	Status
Scientific manuscript draft		Initiated
Final report	Final Report	Complete
Fuelbed handbook	Fuelbed handbook	Complete
Fuelbed map	Fuelbed map delivered	Complete
Final FCCS fuelbeds for LTBMU	http://www.fs.fed.us/pnw/fera/fccs/downloads.shtml#sf	Complete
Workshop	A FCCS, photo series, and Consume Workshop was held at Incline Village, NV on November 5, 2010. The FCCS fuelbed handbook, fuelbeds, and fuelbed map were distributed. Approximately 20 participants attended.	Complete
Forest Management Decision Support Tools Conference at Incline Village, NV	Three presentations were conducted at the conference: (1) FCCS fuelbed project, (2) Smoke Management Tools, and (3) Digital Photo Series.	Complete
Training	Lake Tahoe FCCS fuelbeds were presented at 8 RX 410 (smoke management) and RX 310 (fire effects) national and regional training sessions, two Technical Fire Management classes, and in an 8-hour and a 4-hour regional and conference workshop.	Complete
Quarterly reports	Completed required quarterly reports	Complete
FCCS fuelbeds	Constructed FCCS fuelbeds and incorporated review comments.	Complete
FCCS fuelbed pathways	Constructed fuelbed pathways	Complete
Kick-off meeting	Met with LTBMU managers July 17-18, 2008 and drafted fuelbed type list and fuelbed pathways	Complete

Table 2. Additional deliverables completed that were not included in the original proposal.

Additional Deliverables Completed But Not Originally Proposed
A web page was established to distribute the Lake Tahoe Basin Management Fuelbed handbook and FCCS fuelbeds: http://www.fs.fed.us/pnw/fera/fccs/downloads.shtml#sf
The scope of the project increased significantly from the Angora fire perimeter to the Lake Tahoe Basin Management Unit. This required approximately 50 additional fuelbeds to be developed than were originally planned and reorganization of fuelbed pathway handbook and fuelbed map.

POSTERS, ABSTRACTS, AND PRESENTATIONS

Ottmar, Roger D. Lake Tahoe FCCS Fuelbed Development. A presentation at the Forest Management Decision Support Tools Conference, Incline Village, NV, November 4, 2010.

Ottmar, Roger D. Smoke Management Tools. A presentation at the Forest Management Decision Support Tools Conference, Incline Village, NV, November 4, 2010.

Wright, Clint S. The photo series. A presentation at the Forest Management Decision Support Tools Conference, Incline Village, NV, November 4, 2010.

Ottmar, Roger D. The Fuel Characteristic Classification System, 4th International Fire Ecology and Management Congress, Savannah, GA, 2009

CONSULTATIONS

Over the past year, the principle investigator consulted with many land managers, regulators, and scientists with regard to the development of FCCS fuelbeds and used the Lake Tahoe project as the practical case study for managers. These included fuel and fire managers of the USDI Fish and Wildlife Service and National Park Service, US Forest Service, Department of Defense, Army and Air Force, and the Division of Forestry in the States of Minnesota and Michigan.

LESSON PLANS AND TRAINING

The FCCS fuelbed development project for the LTBMU has been used as a case example in several local and regional training classes including:

- Technical Fire Management, Bothell, WA, March 2011
- Smoke Modeling Workshop, Kinston, NC, 2011
- Rx410 in Albuquerque, NM:, Redmond, OR; Missoula, MT; Grand Rapids, MN,; and Chattanooga, TN, in 2010 and 2011
- Technical Fire Management, Bothell, WA, May 2010

- Rx310, Redmond, 2011

In addition, the protocols and process from the project will be demonstrated and applied to assist in the ongoing project to develop and map FCCS fuelbeds for northeastern Oregon.

Appendix 1. Loading (tons/acre) for each major fuel category and total aboveground carbon (tons/acre) estimated for the Lake Tahoe Basin Management Unit fuelbeds.

FB#	Age range	Treatment / change agent	Tree	Snag	Ladder fuel	Shrub	NW fuel	Total woody fuel	Small woody fuel	Pile & stump	LLM	Duff	BA	Total carbon
						Jeffery pine – white fir forest								
LT001	0-7 years shrub	WF	33.3	93.8	0.0	3.5	0.1	10.3	3.7	0.0	0.3	0.5	0.0	70.1
LT082	0-7 years shrub	Salvage, WF	0.1	1.2	0.0	3.5	0.1	10.3	3.7	0.0	0.3	0.5	0.0	7.8
LT013	0-10 years grass	WF	33.3	89.6	0.0	0.6	0.3	5.4	1.2	0.0	0.5	0.0	0.0	64.4
LT002	7-25 years	None	36.9	6.9	3.0	1.7	0.1	8.4	3.7	0.0	1.5	1.5	0.0	28.9
LT083	7-25 years	None	3.6	1.2	3.0	1.7	0.1	8.4	3.7	0.0	1.5	1.5	0.0	10.0
LT014	10-25 years	None	42.3	6.9	3.0	1.5	0.1	12.1	4.7	0.0	2.1	1.5	0.0	33.6
LT003	25-50 years	None	72.7	0.7	3.0	3.0	0.1	12.5	3.6	0.0	2.9	1.7	0.3	47.7
LT004	50-80 years	None	385.1	0.9	0.5	2.7	0.0	9.2	3.6	0.1	3.0	2.8	0.3	201.7
LT005	80-120 years	None	573.0	5.4	3.0	2.3	0.1	14.5	5.1	0.0	4.5	4.6	0.3	302.5
LT007	80-120 years	SC, RX or WF	216.8	0.6	3.0	0.9	0.2	3.5	1.6	0.5	1.4	0.3	0.0	113.7
LT008	80-120 years	SC	216.9	0.6	3.0	1.2	0.2	21.9	6.9	0.5	2.9	4.1	0.0	124.5
LT009	80-120 years	SC, P&B	216.8	0.6	3.0	1.3	0.2	3.5	2.0	0.5	1.4	0.3	0.0	113.7
LT010	80-120 years	SC, pile	216.8	0.6	3.0	1.2	0.2	3.5	2.0	0.5	1.5	0.5	0.0	113.7
LT084	80-120 years	SC, mastication	216.8	0.6	3.0	0.4	0.1	19.9	8.9	0.5	2.9	4.1	0.0	123.2
LT006	over 120 years	None	602.5	18.0	0.5	1.5	0.1	20.0	5.1	0.1	4.5	2.8	0.3	323.1
LT011	over 120 years	SC, RX	109.8	1.9	0.5	1.5	0.1	4.1	2.6	1.0	1.3	0.3	0.3	60.1
LT012	over 120 years	SC	109.8	1.9	0.5	1.5	0.1	14.5	4.5	1.6	2.4	5.7	0.3	68.1
LT015	over 120 years	None	400.7	7.5	3.0	0.8	0.2	4.6	2.1	0.2	2.6	5.7	0.0	212.0
LT016	over 120 years	SC	109.8	1.9	3.0	1.2	0.1	25.9	6.9	2.9	2.6	5.7	0.0	74.8
LT017	over 120 years	SC, RX, P&B	345.5	7.5	3.0	0.9	0.2	4.6	2.1	8.8	1.4	2.6	0.0	186.9
LT018	over 120 years	SC	345.5	4.1	3.0	0.8	0.1	24.0	7.0	8.8	2.6	5.7	0.0	196.0
LT019	over 120 years	SC, pile	345.5	4.1	3.0	0.8	0.1	3.5	2.0	8.8	1.4	0.5	0.0	183.7
LT020	over 120 years	SC, pile	109.8	1.9	0.5	2.3	0.1	3.5	2.0	1.6	1.3	0.5	0.3	60.6
LT087	over 120 years	None	400.7	7.5	3.0	0.8	0.1	26.3		0.2	2.6	10.6	0.0	224.1

FB#	Age range	Treatment / change agent	Tree	Snag	Ladder fuel	Shrub	NW fuel	Total woody fuel	Small woody fuel	Pile & stump	LLM	Duff	BA	Total carbon
							Red fir forest							
LT021	0-10 years	WF	14.2	123.3	0.0	2.5	0.0	17.1	3.3	0.0	1.4	3.1	0.0	78.1
LT022	10-25 years	None	12.6	72.3	3.0	1.1	0.0	27.7	1.3	0.0	0.6	3.1	0.0	52.2
LT023	25-50 years	None	41.6	28.8	0.5	0.1	0.0	25.7	6.1	0.0	3.0	8.9	0.0	49.9
LT024	50-80 years	None	142.8	5.4	3.0	0.1	0.0	20.1	5.5	0.0	3.0	6.6	0.0	89.3
LT025	50-80 years	PCT, P&B	38.7	1.3	0.5	0.4	0.1	5.4	2.9	0.6	1.2	1.7	0.0	24.7
LT026	50-80 years	PCT, pile	38.7	1.3	0.5	0.4	0.1	35.0	10.0	0.6	6.6	22.0	0.0	49.6
LT027	80-120 years	None	170.7	65.2	0.5	0.3	0.0	33.6	4.2	0.0	3.6	16.2	0.0	142.1
LT028	80-120 years	SC, RX, P&B	51.0	1.3	0.5	0.3	0.0	3.8	0.8	1.0	0.6	0.9	0.0	29.3
LT029	80-120 years	None	40.6	8.4	3.0	0.0	0.0	18.5	3.6	0.1	2.4	7.9	0.0	38.7
LT030	80-120 years	None	82.7	10.5	0.5	0.1	0.0	40.0	10.0	0.1	6.9	28.9	0.0	86.8
LT031	80-120 years	SC, pile	51.0	1.7	0.5	0.3	0.1	16.0	6.0	0.3	4.4	8.8	0.0	40.1
LT086	80-120 years	SC, mastication	51.0	1.7	0.5	0.2	0.0	24.0	12.5	0.3	4.4	8.8	0.0	44.1
LT032	over 120 years	None	139.2	28.4	0.5	0.2	0.0	48.0	8.0	0.0	7.5	35.6	0.0	124.4
LT033	over 120 years	SC, RX, P&B	89.5	3.0	3.0	0.3	0.1	9.1	1.1	0.6	0.6	2.1	0.0	53.3
LT034	over 120 years	SC, pile	89.5	3.0	3.0	0.3	0.0	16.5	6.5	0.9	3.0	8.8	0.0	60.9
LT035	over 120 years	None	85.0	1.7	0.5	0.2	0.0	16.0	6.0	0.2	4.5	17.6	0.0	60.6
LT036	over 120 years	None	85.0	5.0	0.5	0.3	0.1	16.0	6.0	0.2	7.5	7.7	0.0	59.8
LT089	over 120 years	None	85.0	1.7	0.5	0.2	0.0	27.9	13.0	0.2	4.5	17.6	0.0	66.6
							Lodgepole pine forest							
LT037	0-10 years	WF	1.2	8.9	3.0	0.0	0.0	15.4	4.3	0.1	1.5	0.4	0.0	14.6
LT038	0-10 years	CC, RX	1.2	0.4	3.0	0.0	0.0	4.5	0.7	1.2	1.5	0.4	0.0	6.1
LT039	10-20 years	None	10.0	2.7	3.0	0.0	0.0	20.4	4.3	0.1	1.5	0.8	0.0	18.9
LT040	20-40 years	None	15.6	1.4	3.0	0.0	0.0	19.7	3.2	0.1	2.1	2.6	0.0	21.7
LT041	20-40 years	PCT	6.0	1.4	3.0	0.0	0.0	15.4	9.2	2.9	1.5	2.6	0.0	16.0
LT042	40-80 years	None	60.3	20.3	3.0	0.0	0.0	21.6	3.2	0.1	0.0	5.3	0.0	54.6
LT043	40-80 years	None	43.6	20.3	3.0	0.0	0.0	14.5	5.7	0.0	1.8	4.8	0.0	43.4
LT044	over 80 years	I&D	59.6	36.3	3.0	0.0	0.0	49.2	3.2	0.1	3.0	8.6	0.0	77.7

FB#	Age range	Treatment / change agent	Tree	Snag	Ladder fuel	Shrub	NW fuel	Total woody fuel	Small woody fuel	Pile & stump	LLM	Duff	BA	Total carbon
							Whitebark pine – lodgepole pine forest							
LT045	0-10 yrs	WF	0.3	29.7	3.0	0.8	0.1	5.9	2.2	0.0	0.3	0.0	0.0	19.9
LT046	10-40 yrs	None	12.2	23.3	0.5	0.6	0.1	14.2	6.7	0.0	1.5	8.2	0.0	27.0
LT047	40-90 yrs	None	37.0	10.0	0.5	0.6	0.1	11.5	3.5	0.0	2.1	11.7	0.0	34.3
LT048	90-120 yrs	None	81.7	6.4	0.5	0.4	0.1	19.0	3.0	0.0	3.0	18.7	0.0	62.1
LT049	over 120 yrs	None	40.5	9.5	0.5	0.4	0.2	20.0	2.0	0.3	3.0	26.0	0.0	46.4
LT050	over 120 yrs	None	50.2	10.8	0.5	0.4	0.2	30.0	3.0	0.3	3.0	26.0	0.0	56.3
LT051	Dry site (no age)	None	38.1	1.1	3.0	0.1	0.3	10.3	3.3	0.0	1.5	5.2	0.0	28.9
LT052	Quaking aspen	Avalanche	3.3	0.0	3.0	0.1	0.3	2.8	1.6	0.0	3.7	14.8	0.0	12.5
							Mountain hemlock forest							
LT054	0-10 yrs	WF	0.6	48.7	3.0	0.4	0.1	18.3	4.3	0.0	0.3	0.0	0.0	35.4
LT055	10-40 yrs	None	37.2	191.2	0.5	0.3	0.1	22.4	8.4	0.0	1.5	8.2	0.0	110.4
LT056	40-90 yrs	None	220.5	112.3	3.0	0.3	0.1	18.0	4.0	0.0	2.1	11.7	0.0	171.2
LT057	90-120 yrs	None	373.8	44.5	0.5	0.2	0.1	18.6	2.6	0.0	3.0	18.7	0.0	226.8
LT058	over 120 yrs	None	377.9	33.1	0.5	0.1	0.1	29.9	1.9	0.3	3.0	26.0	0.0	231.1
LT059	over 120 yrs	None	450.1	39.3	0.5	0.1	0.1	42.0	3.0	0.3	3.0	26.0	0.0	274.8
							Mixed conifer forest							
LT060	0-7 yrs	WF	113.4	93.8	0.0	6.3	0.1	10.3	3.7	0.0	0.3	0.5	0.0	111.5
LT080	0-7 yrs	Salvage, WF	0.1	1.2	0.0	6.3	0.1	10.3	3.7	0.0	0.3	0.5	0.0	9.2
LT072	0-10 yrs	WF	113.3	89.6	0.0	1.0	0.3	5.4	1.2	0.0	0.5	0.0	0.0	104.7
LT061	7-25 yrs	None	121.2	58.2	3.0	4.7	0.1	8.4	3.7	0.0	1.5	1.5	0.0	93.1
LT081	7-25 yrs	None	8.0	1.2	3.0	4.7	0.1	8.4	3.7	0.0	1.5	1.5	0.0	13.7
LT073	10-25 yrs	None	133.3	58.6	3.0	2.0	0.1	12.1	4.7	0.0	1.7	1.5	0.0	99.9
LT062	25-50 yrs	None	214.4	23.5	3.0	4.6	0.1	12.5	3.6	0.0	3.0	1.7	0.3	128.5
LT063	50-80 yrs	None	1006.5	0.9	0.5	0.4	0.0	9.2	3.6	0.1	3.0	2.8	0.3	511.3
LT064	80-120 yrs	None	1202.3	5.4	3.0	0.2	0.1	14.5	5.1	0.0	4.5	4.6	0.3	616.1
LT066	80-120 yrs	SC, RX or WF	540.1	0.6	3.0	0.8	0.2	3.5	1.6	0.4	1.5	0.3	0.0	275.1
LT067	80-120 yrs	SC	540.2	0.6	3.0	1.2	0.2	21.9	6.9	0.4	3.0	4.1	0.0	286.2
LT068	80-120 yrs	SC, P&B	540.1	0.6	3.0	1.2	0.2	3.5	2.0	0.4	1.5	0.3	0.0	275.3

FB#	Age range	Treatment / change agent	Tree	Snag	Ladder fuel	Shrub	NW fuel	Total woody fuel	Small woody fuel	Pile & stump	LLM	Duff	BA	Total carbon
LT069	80-120 yrs	SC, pile	540.1	0.6	3.0	1.2	0.2	3.5	2.0	0.4	1.5	0.5	0.0	275.3
LT085	80-120 yrs	SC, mastication	540.1	0.6	3.0	0.4	0.1	19.9	8.9	0.4	3.0	4.1	0.0	284.8
LT065	over 120 yrs	None	1495.2	18.0	0.5	0.0	0.1	20.0	5.1	0.0	4.5	2.8	0.3	768.6
LT070	over 120 yrs	SC, pile	537.1	1.6	0.5	0.0	0.1	4.1	2.6	1.2	1.4	0.3	0.0	272.9
LT071	over 120 yrs	SC	536.7	1.9	0.5	0.0	0.1	14.5	4.5	1.9	2.6	5.7	0.3	281.0
LT074	over 120 yrs	None	986.2	30.3	3.0	0.8	0.1	4.6	2.1	0.2	2.6	5.7	0.0	513.8
LT075	over 120 yrs	SC	536.7	1.9	3.0	1.2	0.1	25.9	6.9	3.3	2.6	5.7	0.0	288.4
LT076	over 120 yrs	SC, RX, P&B	1021.5	7.5	3.0	0.8	0.2	4.6	2.1	10.5	1.4	2.6	0.0	525.7
LT077	over 120 yrs	SC	1021.5	4.1	3.0	0.8	0.1	24.0	7.0	10.5	2.6	5.7	0.0	534.8
LT078	over 120 yrs	SC, pile	1021.5	4.1	3.0	0.8	0.1	3.5	2.0	10.5	1.4	0.5	0.0	522.5
LT079	over 120 yrs	SC, pile	536.7	1.9	0.5	0.8	0.1	3.5	2.0	1.6	1.4	0.5	0.3	273.4
LT088	over 120 yrs	None	986.1	7.5	3.0	0.8	0.1	26.3	11.6	0.2	2.6	10.6	0.0	516.8
							Additional fuelbeds							
LT090	Huckleberry oak	None	0.0	0.0	0.0	2.3	0.0	1.0	1.0	0.0	1.6	0.3	0.0	2.5
LT091	Greenleaf Manzanita	None	0.0	0.0	0.0	5.6	0.0	2.0	1.8	0.0	1.6	0.8	0.0	4.9
LT092	Shorthair reedgrass - threadleaf sedge	None	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.2	0.0	0.0	1.3
LT093	Quaking aspen sapling	None	2.5	0.0	3.0	0.1	0.1	2.8	1.6	0.0	3.1	14.0	0.0	11.4
LT094	Quaking aspen pole	None	33.8	0.0	0.0	0.1	0.5	14.1	2.6	0.0	3.1	14.0	0.0	31.0
FCCS 001	Black cottonwood - Douglas-fir - quaking aspen	None	418.9	2.3	0.0	1.2	0.2	17.5	4.5	0.0	1.8	37.0	0.0	234.4
FCCS 046	Chamise chaparral	None	0.0	0.0	0.0	5.3	0.0	2.5	2.5	0.0	0.5	3.1	0.0	5.4
FCCS 056	Sagebrush	FE, grazing, exotic species	0.0	0.0	0.0	1.6	0.7	0.0	0.0	0.0	0.2	0.0	0.0	1.2

FB#	Age range	Treatment / change agent	Tree	Snag	Ladder fuel	Shrub	NW fuel	Total woody fuel	Small woody fuel	Pile & stump	LLM	Duff	BA	Total carbon
FCCS 069	Western juniper / sagebrush – bitterbrush	FE	0.6	0.0	0.0	1.3	0.2	0.8	0.8	0.0	0.5	0.1	0.3	1.9
FCCS 095	Willow - mountain alder	None	0.0	0.0	0.0	2.6	0.1	2.1	1.2	0.0	3.1	23.4	0.0	13.3
FCCS 224	Quaking aspen	FE	98.3	12.1	3.0	0.4	1.1	14.1	2.6	0.0	0.9	11.9	0.0	68.5
LF308	Low sagebrush	None	0.0	0.0	0.0	1.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.7
LF313	Mountain mahogany	None	32.4	0.0	0.0	0.3	0.1	1.9	1.4	0.0	1.6	1.2	0.0	18.6
OW072	Subalpine forest	Avalanche	10.1	0.0	3.0	0.0	0.3	2.8	1.6	0.0	3.7	14.8	0.0	15.8
OW140	Ponderosa pine80-150 yrs	None	597.7	5.4	3.0	2.0	0.1	14.5	5.1	0.0	4.4	4.6	0.3	314.6
CO005	Douglas-fir - ponderosa pine 0-15 yrs	CC, salvage, RX or WF	16.9	4.1	0.0	4.0	0.1	20.5	2.7	0.8	0.6	0.0	0.0	22.8
CO114	Ponderosa pine forest 0-15 yrs	CC, salvage, P&B, RX or WF	7.1	2.8	0.0	2.5	0.3	11.4	4.7	0.7	0.6	0.5	0.0	12.4
CO208	Bitterbrush – rabbitbrush 10-20 yrs	None	0.0	0.0	0.0	0.6	0.4	0.1	0.1	0.0	0.4	0.0	0.0	0.7
CO216	Western juniper / bitterbrush / bunchgrass 20-40 yrs	None	2.6	0.3	0.0	0.5	0.4	0.2	0.2	0.0	0.3	0.4	0.0	2.3
CO228	Sagebrush 20-40 yrs	None	0.0	0.0	0.0	0.9	0.2	0.3	0.3	0.0	1.2	0.0	0.0	1.3

NW = nonwoody; LLM = litter, lichen and moss; BA = basal accumulations; WF = wildfire; SC = select cut; RX = prescribed fire; P&B = pile and burn; CC = clearcut; I&D = insects and disease; PCT -= pre-commercial thin; FCCS = fuel characteristic classification system; LF = landfire; OW = Okanogan-Wenatchee; CO = central Oregon.

Appendix 2. CALVEG class and FCCS fuelbed crosswalk for mapping LTBMU fuelbeds.

CALVEG Category	FCCS Fuelbed	CALVEG Category	FCCS Fuelbed	CALVEG Category	FCCS Fuelbed
Mixed conifer		**Yellow pines**		**Montane chaparral**	
Mixed conifer sapling	LT061	Jeffrey pine/White fir poles	LT003	Upper montane mixed chaparral	FCCS046
Mixed conifer poles	LT062	Jeffrey pine/White fir small	LT004	Huckleberry oak	LT090
Mixed conifer small	LT063	Jeffrey pine/White fir medium	LT005	Upper montane mixed shrub	FCCS046
Mixed conifer medium	LT064	Jeffrey pine/White fir large/giant	LT006	Pinemat manzanita	LT091
Mixed conifer large/giant	LT065	Eastside pine poles	CO005	snowbrush	**
Red fir		Eastside pine small	CO114	Bush chinquapin	**
Red fir poles	LT023	Eastside pine medium	OW140	Curleaf mountain mahogany	LF313
Red fir small	LT024	**Lodgepole pine**		Gr. Basin=mixed chaparral trans.	**
Red fir medium	LT027	Lodgepole saplings	LT037	Green leaf manzanita	LT091
Red fir large/giant	LT032	Lodgepole poles	LT039	Mountain whitehorn	**
Grass/Forbs		Lodgepole small	LT040	Snowberry	**
Perrenial grasses and forbs	LT092	Lodgepole medium	LT042	**Aspen**	
Wet meadow	LT092	Lodgepole large/giant	LT044	Quaking aspen saplings	LT093
Alpine grasses and forbs	**	**Great Basin shrub types**		Quaking aspen poles	LT094
Non-native/ornamental grass	**	Mountain sagebrush	FCCS069	Quaking aspen small	FCCS224
Annual grasses and forbs	LT092	Low sagebrush	LF308	Quaking aspen medium	FCCS224
Subalpine		Bitterbrush	CO208	Aspen (shrub)	FCCS095
Mountain hemlock small	LT056	Great Basin mixed shrub	CO228	**Other**	
Western white pine saplings	**	Basin sagebrush	FCCS056	Alpine mixed scrub	**
Western white pine poles	**	**Riparian hardwoods**		Western Juniper	CO216
Western white pine small	**	Mountain alder	OW072	Barren	None
Western white pine medium	**	Willow (shrub)	FCCS095	Snow/ice	None
Western white pine large/giant	**	Willow sapling	**	Urban-related bare soil	None
White bark pine saplings	LT045	Willow poles	**	Urban/developed (general)	None

White bark pine poles	LT046	Black cottonwood sapling	**	Non=native/ornamental conifer/hardwood	**
White bark pine small	LT047	Black cottonwood poles	FCCS001		
White bark pine medium	LT048	Riparian mixed hardwoods	FCCS001		

****** CALVEG class coverage was less than 0.2% and did not develop a representative fuelbed.

LT = Lake Tahoe fuelbed
FCCS = FCCS standard fuelbed
CO = Central Oregon fuelbed
OW = Okanogan/Wenatchee fuelbed
LF = LANDFIRE fuelbed