HAZARDOUS FUELS REDUCTION DEMONSTRATION IN CENTRAL AND SOUTHERN CALIFORNIA

Demo Locations:
Shaver Lake, CA (Southern California Edison)
Big Bear Lake, CA (San Bernardino National Forest)
Santa Rosa Indian Reservation (Riverside County, CA)

Prepared for:
Southern California Edison, US Forest Service Pacific Southwest Region, CAL FIRE, and the Santa Rosa Band of the Cahuilla Indians

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TSS Consultants typically conducts assessments and equipment demonstrations utilizing in-house personnel and resources, a business model our firm has utilized since it was founded in 1986. The Hazardous Fuels Reducion Demonstration project was unique in that our clients made available an array of knowledgeable individuals and networks that proved invaluable in the course of our work. The authors wish to thank a number of individuals and organizations for their significant efforts in support of this project.

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EXECUTIVE SUMMARY

The USDA Forest Service in conjunction with the University of California Center for Forestry, Southern California Edison and other partners, sponsored a series of three Hazardous Fuels Reduction Demonstrations (HFRD) at strategic locations in central and southern California. The demonstrations (demos) were one week in duration at each location and included a demo day (Friday of each week) for guests to view operations first hand. Demos were conducted at the following locations:

- Shaver Lake – Southern California Edison (Fresno County)
- Big Bear Lake – San Bernardino National Forest (San Bernardino County)
- Santa Rosa Indian Reservation (Riverside County)

The primary purpose of the demos was to raise awareness about different hazardous fuels treatment alternatives and provide interested parties with up-to-date information regarding resource impacts (soil disturbance, fire behavior), efficiencies and cost of fuels treatment systems ($ per acre and $ per hour) and available treatment techniques. The central/southern California region was selected for siting of the demos due to the high level of interest across three landownerships: Southern California Edison, US Forest Service, and the Santa Rosa Band of Cahuilla Indians. This region has also been severely impacted by four years of drought conditions that has heightened the need to proactively address hazardous fuels conditions.

Target audiences included fire agencies, natural resource managers, fuels treatment contractors, electric utilities, water conservation districts, homeowner associations, fire safe councils, resource conservation districts, tribal resource management staff, county and city planning departments, elected officials, and any others interested in fire safe practices. A total of 295 guests participated in the demos. Resource professionals were on site to answer questions and guide participants through the live demos.

Both conventional and innovative equipment and techniques were deployed across all three demos. A total of 11 different treatment systems were included in the HFRD to compare and contrast systems across a variety of vegetation cover types, soil types, and terrains. Treatment systems were selected for their ability to reduce hazardous fuels including shrubs, brush and small trees. These systems, broadly grouped, included mechanical mastication, hand treatments and livestock grazing (goats).

INTRODUCTION

Many research studies have investigated the mechanical treatment of hazardous fuels. However, very few have included the opportunity for a wide range of private and public land managers to observe an array of different treatment systems in the same location, interface with knowledgeable and experienced operators, and obtain a follow-up report regarding results and performance. One of the few known examples was a project involving a series of fuels treatment trials conducted in three western states (Washington, Idaho, and Oregon) in 2002.[1] These trials earned numerous positive reviews because of their focus on local situations and partner groups, and they provided information not previously available about effectiveness, site impacts and costs. The Hazardous Fuels Reduction Demonstrations (HFRD) conducted in central and southern California were focused on unique site conditions and vegetation management in these regions and the ability of selected treatment systems to address hazardous fuels conditions.

Targeted Outcomes

Expected short-term outcomes of the HFRD include improved ability of government agencies and partners to assess, plan and budget for future fuels treatment projects, heightened cooperator awareness about equipment options and impacts, and improved ability of local contractors to make informed business decisions about what equipment to buy or lease. Targeted long-term project outcomes include improved wildland and watershed health, enhanced ability to defend communities and other infrastructure from wildfires, mitigation of air emissions impacts (including greenhouse gas (GHG) releases during wildfires), improved reduction in hazardous fuel accumulation, reduced site impacts, potential increase in acres treated, and local job retention.

Participating Vendors and Contractors

Vendors and contractors that participated in the HFRD demos included:

- Access Limited
- Air Burners (exhibitor)
- Caterpillar
- California Conservation Corps (hand crew)
- Dyer All Terrain Excavation
- FAE - Prime Tech
- Fecon
- Global Machinery
- John Deere
- Ramona Band of Cahuilla (hand crew)
- Sullivan Logging
- Star Creek Land Stewards (goats)
- Takeuchi

[1] Dry Forest Mechanized Fuels Treatment Trials, TSS Consultants/ The Yankee Group, 2002. http://ucanr.edu/sites/WoodyBiomass/newsletters/Woody_Biomass_Related_Publications50962.pdf

The UC Center for Forestry created a webpage (http://ucanr.edu/HFRD) to provide information regarding registration for the HFRD demos and also to allow interested parties to view treatment systems and site conditions pre and post treatment.

Equipment vendors have continued to refine the design of vegetation treatment systems to improve efficiency of high fire hazard material reduction while minimizing resource impacts. These include promising technologies that both remove or rearrange (e.g., masticate, mulch, graze or pile/burn) excess vegetation from challenging topography and facilitate processing into value-added uses, such as low-value logs suitable for pallets and firewood, as well as feedstock for soil amendment, landscape cover, water treatment filters, or bioenergy. Due to very limited value-added utilization markets within central and southern California, the HFRD demos focused on rearranging excess vegetation (e.g., mastication) and not removal for value-added utilization. It is important to note that value-added processing of residual wood for regional markets can be an effective way to offset the relatively high cost of treating hazardous fuels.

Project Partners

Southern California Edison, USDA Forest Service and the Santa Rosa Band of Cahuilla Indians provided funding for this project. Significant in-kind services (equipment and staff mobilization, operator support, labor) were provided by all of the treatment system vendors and contractors (noted previously). Listed below are the project partners that provided wide-ranging support including outreach assistance, data collection, guides and docents, serving on the project Steering Committee and data analysis. These project partners were key to the successful implementation of the HFRD demos:

- Big Bear Fire Authority
- Bureau of Indian Affairs
- CAL FIRE
- California Conservation Corps (hand crew)
- California Forestry Association
- Natural Resources Conservation Service
- Pacific Southwest Research Station (Riverside Fire and Fuels Program)
- Ramona Band of Cahuilla (hand crew)
- Santa Rosa Band of the Cahuilla Indians
- Southern California Edison
- Southern California Society of American Foresters
- Stand Dynamics, LLC
- Sullivan Logging
- The Nature Conservancy
- The Watershed Research and Training Center
- University of California Center for Forestry
- University of California Davis Biological and Agricultural Engineering Department
- USDA Forest Service

ENVIRONMENTAL SETTING

A total of three demos were conducted across central/southern California in the fall of 2015.

- Shaver Lake – October 5 through 10
- Big Bear Lake – October 12 through 17
- Santa Rosa Indian Reservation – November 16 through 21

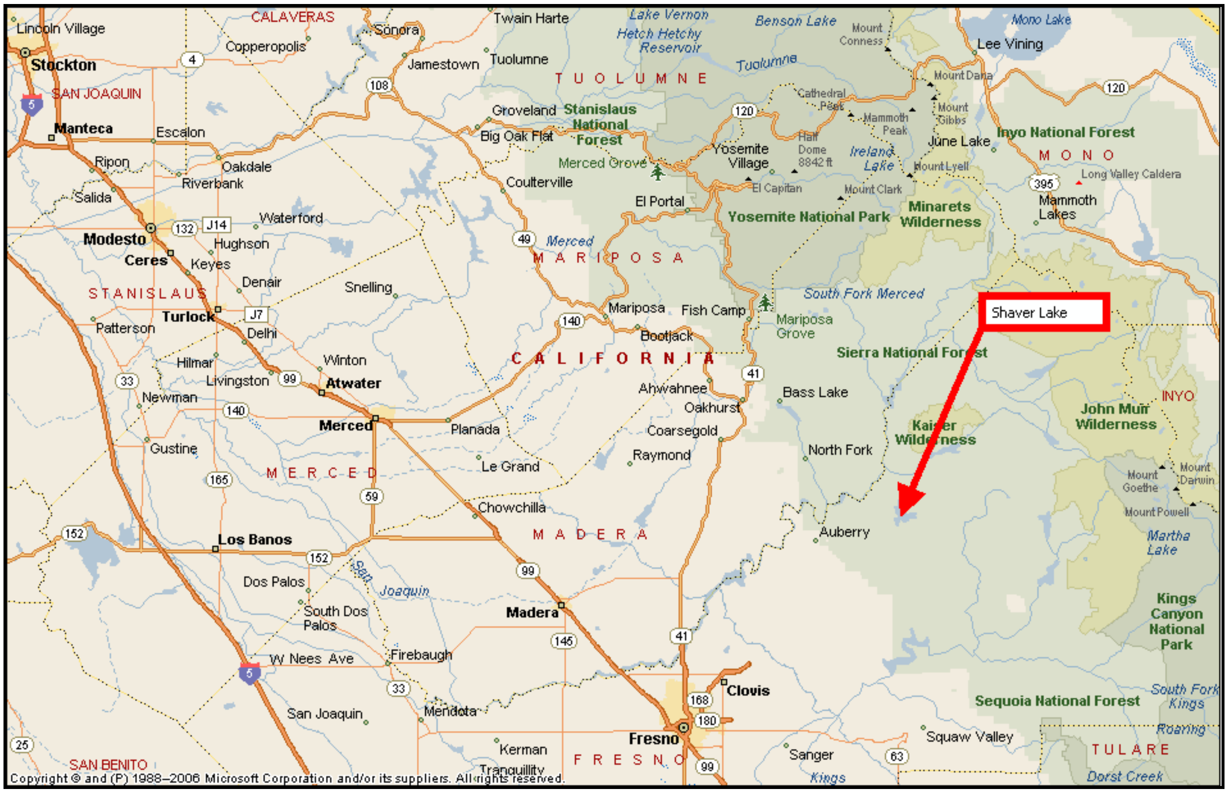
Each location represented different vegetation cover types, soils, terrain, and treatment prescriptions. Figure 1 highlights the locations of the demos.

Figure 1. Locations of HFRD Demos

Shaver Lake

The Shaver Lake location was selected due to its blend of vegetation cover types and terrain representative of the southern Sierra Nevada region within central California at mid-elevation (5,600’). Southern California Edison (SCE) owns and manages approximately 20,000 acres of mixed conifer forest near Shaver Lake. Known as the Shaver Forest, SCE has responsibility to manage this forestland based on an existing land management plan (LMP). The LMP provides guidance regarding stewardship objectives for the Shaver Forest including the reduction of hazardous forest fuels. Figure 2 highlights the general location of the Shaver Forest.

Figure 2. Shaver Lake Demo Location



Over 16,000 acres of the Shaver Forest are mixed conifer cover type with the balance made up of mixed chaparral, hardwood, and meadow. SCE foresters selected the target treatment area based on readily accessible landscape (good road system) with a blend of shrub and mixed conifer dominated acreage. As was the case with all three demo sites, logistics of safely guiding guests in groups of 10 to 12 dictates road access with safe treatment system viewing vantage points. Figure 3 is a detailed map of the Shaver Lake treatment area (courtesy of SCE Forestry).

Figure 3. Shaver Lake Treatment Area Detail

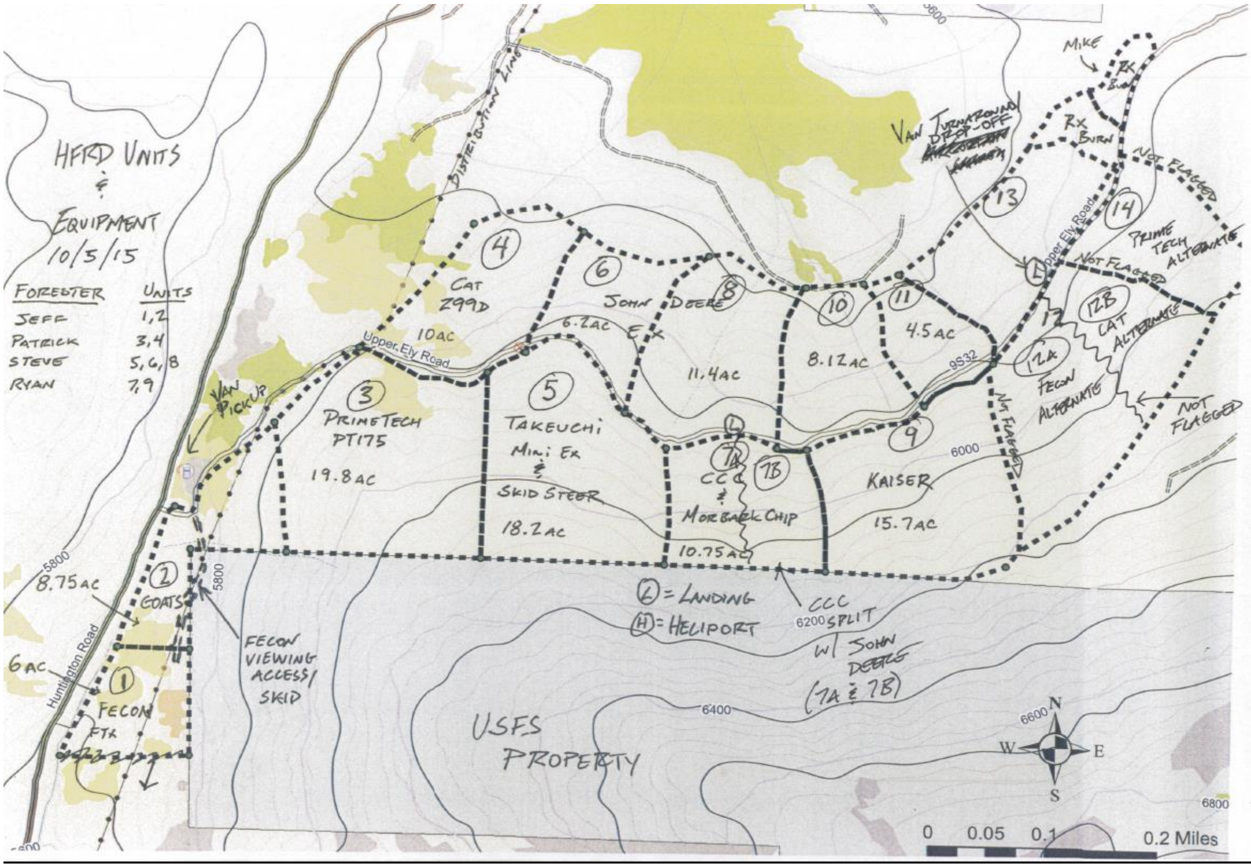


Figure 4 includes images of the dominant vegetation cover types in the Shaver Lake demo treatment area.

Figure 4. Dominant Vegetation Cover Image – Shaver Lake Demo

Table 1 lists treatment systems that were deployed at the Shaver Lake demo. Note that the Air Burner Burn Boss was deployed adjacent to the guest sign-in area and was included as a working exhibit and an alternative disposal method. No fuels treatment cost analysis was conducted on the Burn Boss, as it was primarily deployed at the demo as an exhibit.

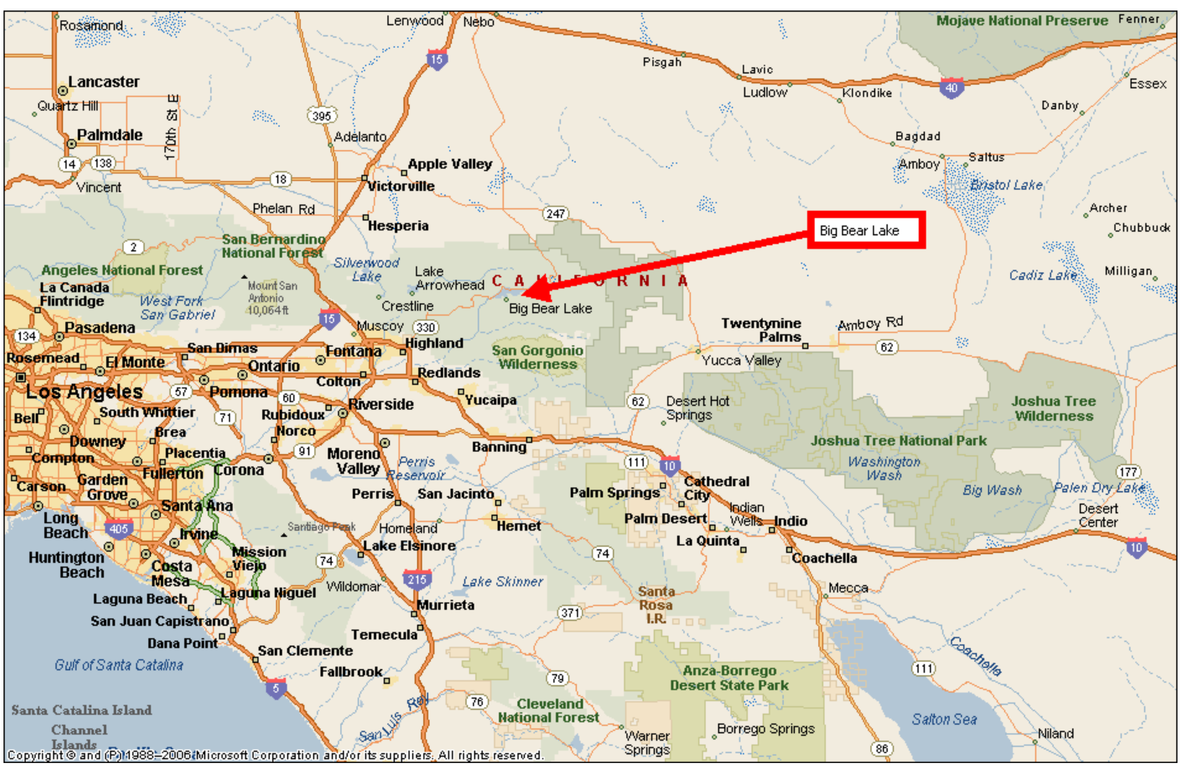
Table 1. Treatment Systems Deployed – Shaver Lake

Treatment System	Model and Attachment
Air Burner	Burn Boss (exhibitor)
Caterpillar	299D (skid steer) with CAT HM418C mastication head
FAE - Prime Tech	PT 175 (skid steer) with FAE 140/U 175 mastication head
Fecon	FTX 128L (skid steer) with Fecon BH 85 mastication head
Goats	Star Creek Land Stewards
Hand Crew	California Conservation Corp
John Deere	JD 210G (excavator) with Fecon BH 80 mastication head
Kaiser	Kaiser S2 (excavator) with FAE DML/HY 125 mastication head
Takeuchi	TB 290 (excavator) with FAE DML/HY/VT 100 mastication head
Takeuchi	TL 12 (skid steer) with FAE UML/SSL/VT 150 mastication head

Big Bear Lake

The Big Bear Lake location was selected due to its blend of vegetation cover types and terrain representative of the San Bernardino Mountain region within southern California at high elevation (6,700'). The Mountaintop Ranger District, San Bernardino National Forest, hosted the Big Bear Lake demo. The District has active fuels reduction projects in the upper Santa Ana Watershed, where the demo was sited. Under the authority of the Hazardous Forests Restoration Act of 2003, the District is in the process of treating several hundred acres over the next few years. Figure 5 highlights the general location of the Big Bear Lake demo.

Figure 5. Big Bear Lake Site Location



A significant portion of the Mountaintop Ranger District is made up of montane mixed conifer cover type with a balance of mixed chaparral, hardwood, and meadow. Most of the District is located within or adjacent to the Wildland Urban Interface (WUI) and is targeted for fuels treatment. Figure 6 is the hazardous fuels treatment area demonstration site location with finer detail (courtesy of the San Bernardino National Forest).

Figure 6. Big Bear Lake Treatment Area Detail

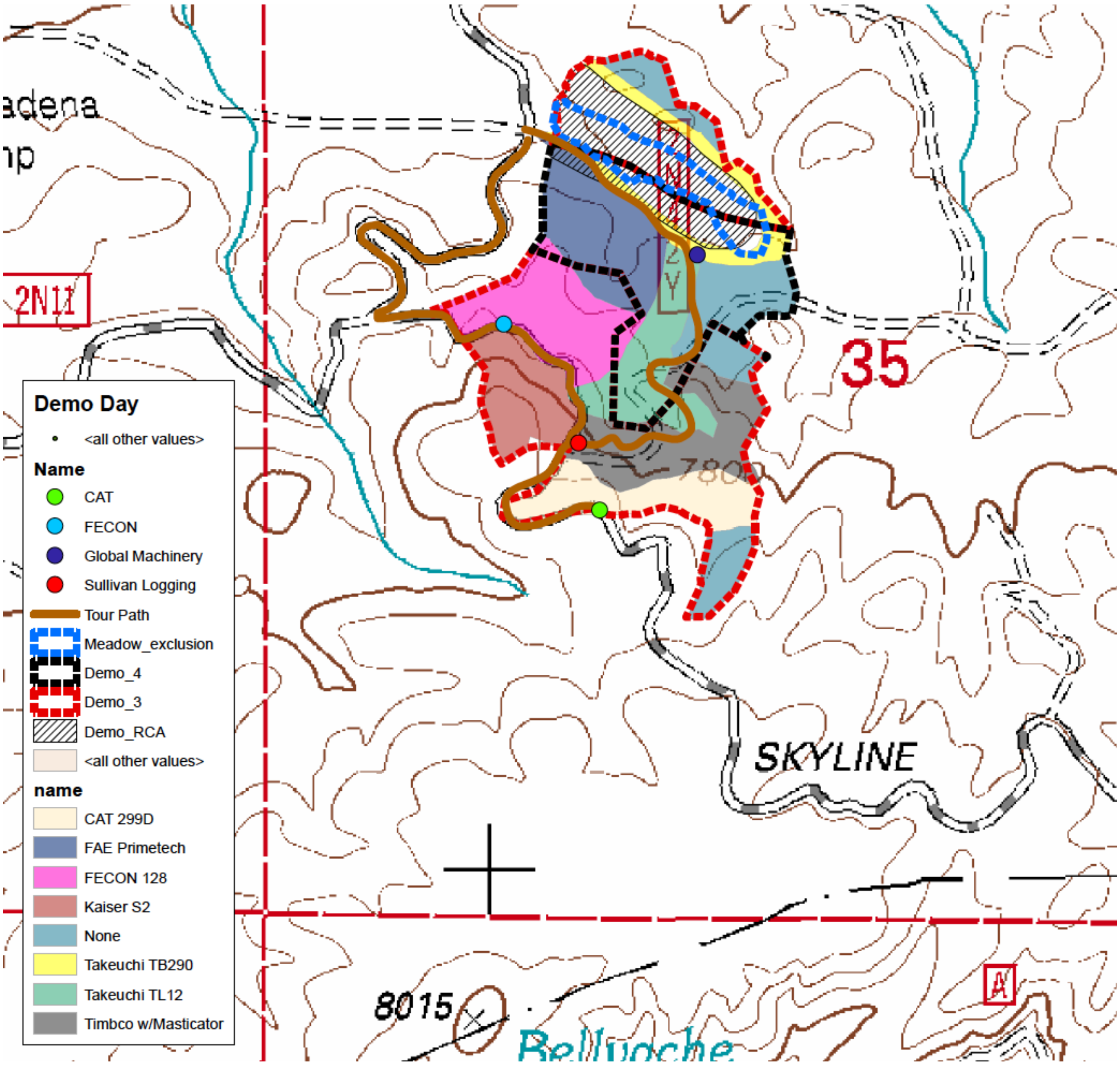


Figure 7 is an image of the dominant vegetation cover types in the Big Bear Lake treatment area.

Figure 7. Dominant Vegetation Cover Image – Big Bear Lake Demo

Table 2 lists treatment systems that were deployed at the Big Bear Lake demo.

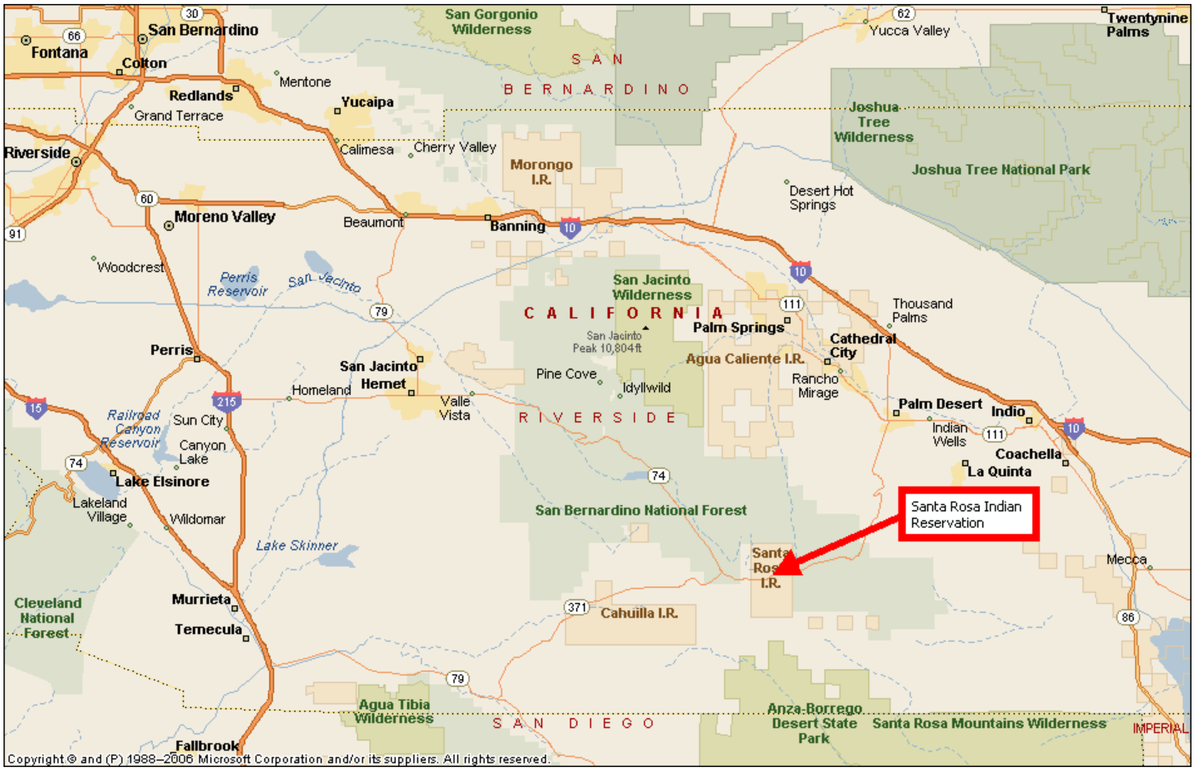
Table 2. Treatment Systems Deployed – Big Bear Lake

Treatment System	Model and Attachment
Caterpillar	299D (skid steer) with CAT HM415B mastication head
FAE - Prime Tech	PT 175 (skid steer) with FAE 140/U 175 mastication head
Fecon	FTX 128L (skid steer) with Fecon BH 85 mastication head
Takeuchi	TB 290 (excavator) with FAE DML/HY/VT 100 mastication head
Takeuchi	TL 12 (skid steer) with FAE UML/SSL/VT 150 mastication head
Timbco	425D (excavator) with FAE UMM/EX-150 mastication head

Santa Rosa Indian Reservation

The Santa Rosa Indian Reservation is home to the Santa Rosa Band of the Cahuilla Indian Tribe. Located along State Highway 74 near the community of Ribbonwood in Riverside County, the reservation is made up of 11,000 acres of primarily shrub and oak woodland dominated landscape ranging from 4,200' to 8,700' elevation. The treatment site was selected due to its blend of vegetation cover types and terrain representative of the San Jacinto Mountain region. Predominant vegetation cover at the site includes chemise, white thorn ceanothus, yucca and red shank manzanita. Figure 8 highlights the general location of the Santa Rosa demo.

Figure 8. Santa Rosa Indian Reservation Site Location



The Santa Rosa Band was an active participant in the HFRD project due primarily to the Tribe's interest in conducting fuels treatment activities on the Reservation to protect homes and community buildings. In the last five years, the Tribe has experienced several wildfires which started along Highway 74 due to vehicle fires. The most recent fire was the Anza Fire, which occurred August 2015 and impacted 500 acres adjacent to the Reservation. In recent years, the Tribe has been working closely with the Natural Resource Conservation Service to conduct strategic fuel treatment and woodland restoration activities on the Reservation. Figure 9 is the hazardous fuels treatment area demonstration site location with finer detail (courtesy of the Natural Resource Conservation Service).

Figure 9. Big Bear Lake Treatment Area Detail

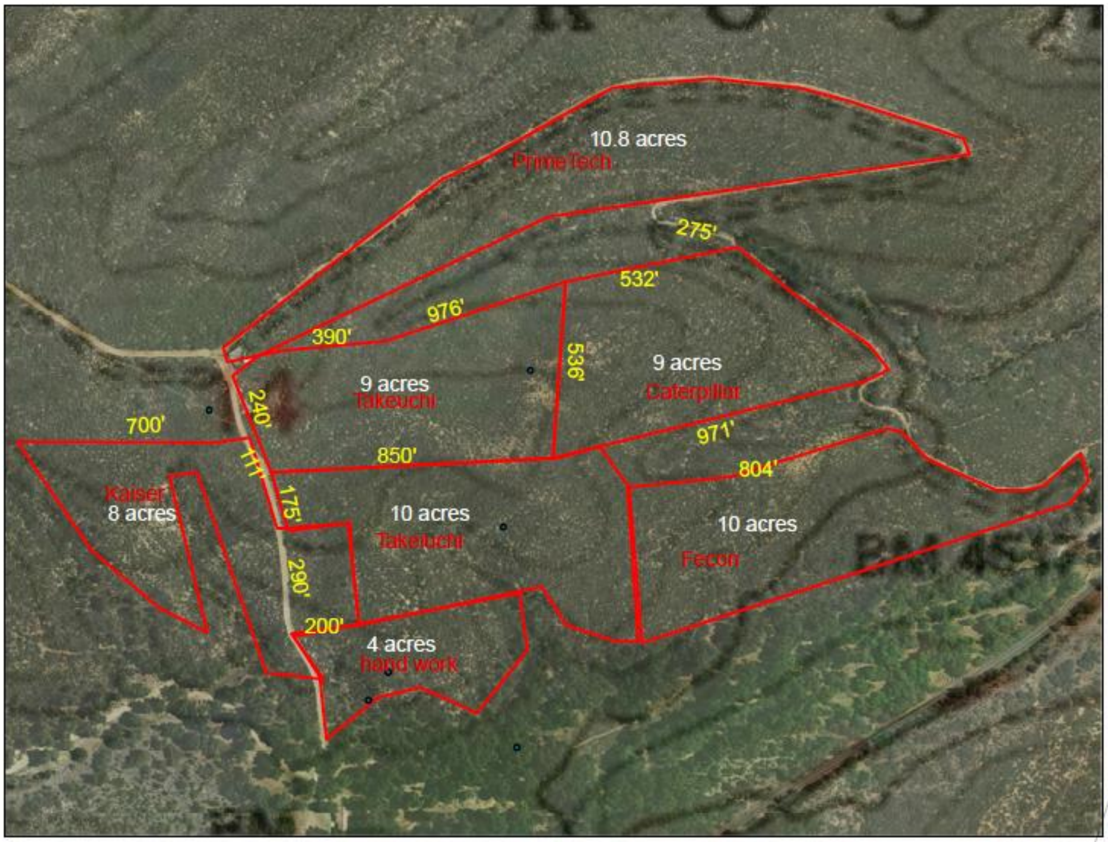


Figure 10 is an image of the dominant vegetation cover types in the Big Bear Lake treatment area.

Figure 10. Dominant Vegetation Cover Image – Santa Rosa Demo

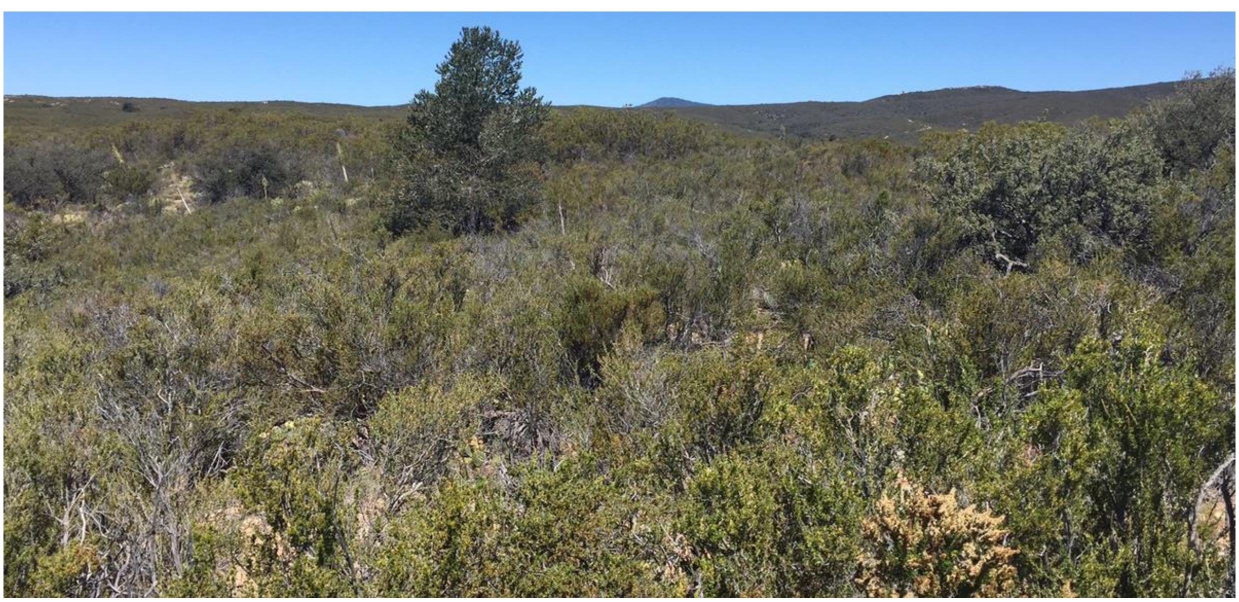


Table 3 lists treatment systems that were deployed at the Santa Rosa demo.

Table 3. Treatment Systems Deployed – Santa Rosa Indian Reservation

Treatment System	Model and Attachment
Caterpillar	299D (skid steer) with CAT HM415B mastication head
FAE - Prime Tech	PT 175 (skid steer) with FAE 140/U 175 mastication head
Fecon	FTX 128L (skid steer) with Fecon BH 85 mastication head
Hand Crew	Ramona Band
Kaiser	Kaiser S2 (excavator) with mastication head (fabricated by contractor)
Takeuchi	TB 290 (excavator) with FAE DML/HY/VT 100 mastication head
Takeuchi	TL 12 (skid steer) with FAE UML/SSL/VT 150 mastication head

COMMUNICATIONS AND OUTREACH

A primary focus of the HFRD project is coordinated communications and outreach, to a diverse set of audiences, the options available to treat excess vegetation in support of fire resilient landscapes. This may lead to more informed decisions regarding the selection of fuels treatment systems and activities, optimized for specific vegetation types and terrain found in central and southern California. The demos are designed to raise awareness about different hazardous fuels treatment alternatives and provide key stakeholders with up-to-date information regarding resource impacts, efficiencies and cost of fuels treatment equipment and techniques.

Communication Plan

A separate communications and outreach team was established for each of the three demos. Each team included a communications expert who had experience conducting outreach (including media outreach) in the vicinity of the targeted demo. Using the communications and outreach team's knowledge, experience, and local media contacts, a communications plan was developed for each of the demos. The communications plan for the Shaver Lake demo is included in Appendix A. Each communications plan provided a structured approach to outreach that included project objectives, list of target audiences, key messages, implementation plan, communication tools, evaluation tools, key contacts (including media), and contingency plans.

Outreach Objectives

The communications and outreach teams agreed on a variety of outreach objectives, both short term and long term.

Short-term objectives of this project include:

- Improved ability of agencies to plan and budget for future fuels treatment projects.
- Continued development of an informed cadre of local fuels treatment contractors and local stakeholder groups (e.g., fire safe councils, homeowner associations, resource conservation districts).
- Outreach to the general public (e.g., media, homeowners, forest landowners) with regards to fuels treatment opportunities, techniques and latest technology.
- Secure public support for increasing the pace and scale of fuels treatment activities.
- Promotion of cost effective, minimum impact fuels treatment alternatives.

Long-term objectives include:

- Significant increase in the number of acres treated in support of the reduction of hazardous fuels and improvement of the ecological health of at-risk landscapes.
- Reduction of site impacts from fuels treatment activities.

- Creation of long-term sustainable jobs.

- Promotion of an informed public, one that more fully appreciates the complexities of fuels treatment efforts and the statewide challenge of creating and maintaining fire resilient landscapes.

- Improved timber production and yield, which results in improved GHG reduction and better carbon retention.

A key objective of the HFRD project was targeted outreach to a very specific set of audiences including:

- Natural resource managers
- Fire safe councils
- Current and potential fuels treatment contractors
- Tribal staff
- Elected officials
- Media
- Homeowner associations
- Federal and state agency personnel
- County and city planning department staff
- Forest landowners
- Local schools

Outreach to these target audiences was conducted using a variety of communication tools including email blasts and posting in weekly and monthly newsletters. An HFRD announcement and registration form (Appendix B) were distributed widely and encouraged online registration using a site hosted by the University of California Division of Agriculture and Natural Resources (UCANR). A website[2] was established and maintained by UCANR and the University of California Extension staff that hosted key information regarding the HFRD project including schedule, treatment systems, pre and post-treatment images, and key contact information.

[2] http://ucanr.edu/sites/WoodyBiomass/Technical_Assistance/Hazardous_Fuels_Reduction_Demonstration_753/

MONITORING PROTOCOL

A monitoring protocol with detailed field procedures, data collection and analysis was developed by UC Extension staff to meet the HFRD goals and objectives. Several iterations of the draft protocol were reviewed and modified by the Science Advisory Committee[3] in consultation with forest, range, and fire specialists. The complete protocol is included in Appendix C.

Monitoring Objectives

The monitoring objective of the HFRD project is to track the efficacy and cost of each treatment system (one or several pieces of equipment or other means used within a treatment unit) in achieving the desired stand condition outlined in the treatment prescription. Pre and post-treatment sampling was conducted to monitor the following biotic and abiotic features for impacts from treatment:

- Live woody vegetation to assess ecosystem condition and disturbance impact from treatment. Monitoring was completed using static 1/10th acre circular plots.

- Fuel and vegetative volume to identify treatment impact in reducing risk of fire ignition, spread, and intensity. Monitoring was completed using Browns line (planar) transect[4] procedure.

- Soil condition to identify impact of treatment on topsoil disturbance and compaction as drivers of vegetation stress. Monitoring was implemented using line transect procedure derived from the USFS Forest Soil Disturbance Protocol (see Appendix D).

- Visual condition with photographs to identify impact of treatment on qualitative aspects of the ecosystem including but not limited to public perception of treatment impact and light availability.

- Time and cost efficacy of treatment was monitored during the treatment process to identify production rates for all treatment options.

- Geospatial positioning and activity tracking to identify location of equipment through the treatment period and reported operational and idle activity times.

Monitoring Design

A minimum of one randomly located 1/10th acre plot was measured for each treatment unit. Where time and resources were available, additional plots were laid out to increase sampling density. It is important to note that sampling was laid out to be a representative sample of the

[3] Science Advisory Committee included Peter Tittmann, Rick Satomi and Max Moritz, UC Extension; David Weise, Fire and Fuels Program, Pacific Southwest Research Station; and Tad Mason, TSS Consultants.
[4] Brown, James K. "Handbook for inventorying downed woody material." 1974.

vegetative conditions in the unit and was limited by budget, not driven by statistical rigor. Depending upon the vegetation type, equipment, and desired condition, the treatment may have operated on a greater or lesser percentage of the total treatment unit area.

Each 1/10th acre plot monitored a comprehensive suite of ecosystem features including (1) live and dead vegetation, (2) soil condition, and (3) photographic documentation. To monitor production efficiency of each treatment, (1) economic cost, (2) time, (3) geospatial position, and (4) activity was collected for every piece of treatment system included within a treatment unit over the entirety of the treatment period. See below for more details on sampling procedures.

To restrict operator and researcher bias, a single blind approach was used where plots were randomly located and operators were not informed of their location. Since operators were instructed to not specifically target plots for treatment, there are some gaps in coverage of treatment effects. A future trial would similarly replicate the single blind approach but implement more plot locations to capture better coverage of treatment effects.

Sampling Procedures

Vegetation

Vegetation characteristics were collected for each strata using a protocol adapted from the USFS FIREMON Density (DE)[5] method and UC Center for Forestry continuous forest inventory (CFI) methodology. This approach utilizes quadrats and belt transects to assess changes in plant species density and height. Herbaceous plant species composition was sampled using 1/100th acre microplot circular quadrats while shrubs were sampled at regular intervals along transects. Tree composition was measured with 1/10th acre macroplot circular quadrats. Stocking was measured for each vegetative type for use in assessing shift in fire behavior and fuel volume impacted by treatment.

<u>Vegetation Sampling Procedure</u>

1. Macroplot Measurements
    a. Percent cover of trees occupied by the following size classes were collected inside the 0.1 acre fixed radius plot (37.2 ft. radius circle) for:
        i. Seedlings are all trees <4.5’ in height
        ii. Saplings are all trees >4.5’ in height and < 5’ in diameter
        iii. Poles are all trees between 5” and 9” in diameter
        iv. Trees are all trees >9” in diameter
    b. Percent cover of shrubs occupied by the following size classes collected inside 0.1 acre fixed radius plot (37.2’ radius circle) for:
        i. Low shrubs are all woody shrub species <3’ in height
        ii. Medium shrubs are all woody shrub species between 3’ and 6’ in height
        iii. Tall shrubs are all woody shrub species >6’ in height

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[5] Lutes, Duncan C., Keane, Robert E., Caratti, John F., Key, Carl H., Benson, Nathan C., Sutherland, Steve, Gangi, Larry J. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 2006, p. DE-1-15.

c. Stocking inventory of mid to large trees (greater than 5" in diameter) captured the following characteristics of all trees within a 1/10th acre (37.2') fixed radius plot for:
    i. Species using a two letter common code (BO, SP, PP, JP, IC, WF, etc.)
    ii. Status of trees as (Healthy, Unhealthy, Sick, or Dead)
    iii. Diameter at Breast Height (DBH) to the nearest 1/10 inch
    iv. Height to the closest foot using a clinometer
    v. HTLCB to the closest foot. Balance heights to even crown height
    vi. Crown Class as either Dominant, Codominant, Intermediate, Suppressed

2. Microplot Measurements (1/100th acre)
    a. All seedling and sapling were tallied based on species and 1 ft. height increments. Seedlings are defined as trees under 4 feet in height and saplings as trees greater than 4 feet in height and less than 5 inches in diameter.
    b. For each size class of each species, average total height and average Height to Live Crown Base (HTLCB) was estimated to the nearest half foot.

Fuel Load

The Brown's Planar Intercept Method[6] was used to capture surface fuel loading of downed dead woody material of a variety of size classes. Litter and duff depths were estimated along the transect. Down woody debris was sampled using the line transect method.[7] Pieces were tallied in the standard fire size classes: 1-hour (0-0.635 cm), 10-hour (0.635-2.54 cm), and 100-hour (2.54-7.62 cm). Pieces greater than 7.62 cm were recorded by diameter and decay class. Duff and litter depth were measured at two points along each of 25-meter line transect segments. Litter depth was estimated as a proportion of total duff and litter depth.

Fuel Sampling Procedure

Three transects were collected at each plot location. The following fuel characteristics were measured along three predetermined azimuths (90, 270, 330) starting from plot center:

1. Number of downed woody pieces (twigs, branches, logs) intersecting the transect from the ground to a maximum height of 6' using a go-no-go gauge were tallied for:
    a. 1-hour fuel: At a distance between 15' and 21' along the transect, tally the pieces of wood <0.25" in diameter.
    b. 10-hour fuel: At a distance between 15' and 21' along the transect, tally the pieces of wood pieces 0.25" to 1" in diameter.
    c. 100-hour fuel: At a distance between 15' and 30' along the transect, tally the pieces of wood 1" to 3" in diameter.
    d. 1,000 hour fuel: At a distance between 15' and 75' along the transect, record the diameter of any piece of wood >3".

[6] Brown, James K. "Handbook for inventorying downed woody material." 1974.
[7] Ibid.

2. At a distance of 45’ and 75’ along the transect, litter depth, duff depth, and vegetation cover was measured.
    a. Litter: At 45’ and 75’, measure the litter (fresh needles, leaves, twigs, fruit, bark, etc.) to the nearest 0.25 inches from the bottom of the litter layer (top of duff) to the highest dead particle (not to exceed 72”) intersecting a 1’ wide vertical plane perpendicular to the transect.
    b. Duff: At 45’ and 75’, measure the duff (visibly decomposing organic material) (bottom of the litter layer down to the mineral soil) with a ruler to the nearest 0.25”.
    c. Tree and Shrub Cover: At 45’ and 75’, take a cylinder 6’ in diameter and measure the % of canopy (up to 6’ in height) occupied by live foliage and dead foliage from woody tree and shrub species. Average height of all cover to the nearest half foot.
    d. Herbaceous Cover: At 45’ and 75’, take a cylinder 6’ in diameter and measure the % of canopy (up to 6’ in height) occupied by live foliage and dead foliage from herbaceous species (non-woody vegetation). Average height of all cover to the nearest half foot.

Soil Disturbance

The Forest Soil Disturbance Monitoring Protocol (FSDMP) is a publication of the Rocky Mountain Research Station and describes how to monitor forest sites before and after ground disturbing management activities for physical attributes that could influence site resilience and long-term sustainability. (As noted earlier, the FSDMP is attached as Appendix D.) The attributes describe surface conditions that affect site sustainability and hydrologic function. Monitoring the attributes of surface cover, ruts, compaction, and platy structure can also be used to generate best management practices that help maintain site productivity.

The FSDMP provides specific techniques to sample for soil disturbance effects. The FSDMP protocol was implemented to evaluate soil impacts of fuels treatments. Field data collection followed the steps outlined beginning on page 11 of the FSDMP: Volume I: Rapid assessment.

<u>Soil Sampling Procedure</u>

Soil characteristics were collected before and after treatment along the same three transects as used in the fuel collection. At 15 foot increments along the transect (15’, 30’, 45’, 60, and 75’) a presence/absence assessment was applied across the following benchmarks. All observations were made within a 6” diameter circle on the surface at the increment.

a. Live Plant (Y/N): Plant containing green foliage rooted within the 6” circle.
b. Fine Wood (Y/N): Small diameter woody debris <3 inches in diameter.
c. Coarse Wood (Y/N): Large diameter woody debris >3 inches in diameter.
d. Bare Soil (Y/N): Exposed bare mineral soil.
e. Rock (Y/N): Large rocky material embedded in the soil substrate.
f. Topsoil Disturbance (Y/N): Whether or not the topsoil layer is disturbed.

g. Rutting (Y/N): Indicate presence of rutting at depths of <5 cm, 5-10 cm, and >10 cm.
h. Burning (L, M, H): Indicate presence/absence of burning. May come in the form of char or burned logs. Indicate Low, Medium, or High to confirm the quantity and level of burned material.
i. Erosion (Y/N): Indicate presence of erosion. May be identified by soil or gravel movement from outside factors such as water or wind.
j. Compaction (Y/N): Indicate presence of compaction. If compaction is evident, use a trowel or plot stake to identify which depth increment(s) the compaction covers (0-10 cm, 10-30 cm, >30 cm).
k. Platy/Massive (Y/N): Indicate presence of platy/massive soil structures. If present, indicate which size classes these structures are found in (0-10, 10-30, >30).
l. Disturbance (0, 1, 2, and 3): Indicate severity of disturbance with 0 as low and 3 as high.

System Productivity and Cost

Shift level and cycle level data was collected for each treatment system. Shift level data summarizes time spent in maintenance, repair, breaks, or other activities, so these can be separated from the time spent directly conducting fuels treatment operations. Cycle data quantifies the time components (moving, positioning, cutting, etc.) spent by a machine in conducting its intended function (harvesting, chipping, masticating, etc.). Shift reports were submitted by all equipment operators or crew foremen for all shifts (see Appendix E, Shift Report Template). In addition, electronic data recorders in combination with video cameras were attached to individual machines for a single shift to sample cycle data. Each system was sampled for cycle times using the data logger and video camera for at least one shift. Time and motion data was collected at the shift and cycle levels for each equipment configuration. System productivity was evaluated based on the acres treated (and terrain treated). Equipment costs were estimated based on standard methods from Miyata.[8] Vendors were asked to provide cost data via an online survey (see Appendix F, Equipment Cost Form). Cost data such as initial equipment cost, track or tire replacement cost, economic life, maintenance and repairs, and labor were provided using this online form.

<u>Time and Motion Sampling</u>

Each machine was monitored with a data logger package containing an accelerometer and GPS (global positioning system) tracker. The package collected vibration data at a rate of 100 per second and positioning at 5 second intervals. Video footage was taken to pair with accelerometer and positioning readings for each piece of equipment.

As noted earlier, each equipment operator or crew foreman also completed a shift report estimating the amount of time allocated to various activities during each shift. The shift report

[8] Miyata, ES. Determining fixed and operating costs of logging equipment. General Technical Report NC-55. 1980. Available from: http://www.nrs.fs.fed.us/pubs/gtr/gtr_nc055.pdf

captures time during a work shift taken by breaks, service, and repair and other activities not directly relating to its primary forestry purpose.

For each system, at least one shift was analyzed to provide cycle times. For each machine, cycle activity was timed as operational, idle, or non-operational.

Shift level production data was collected in terms of acres treated wherein the treatment objective was achieved. For the treatment techniques and equipment systems deployed with the HFRD (which do not include extraction of material), production data consists only of acres treated.

Cost Monitoring

Equipment costs were estimated based on methods from Miyata[9] and are reiterated generally here. Treatment costs for the fuels reduction operations include the cost of owning and operating each piece of equipment. Total equipment costs include all costs accrued from buying, owning, and operating equipment. For analysis, equipment costs can be grouped into fixed costs, operating costs, and labor costs. To estimate these costs we utilized the method presented by Miyata.[10]

Preliminary Data

- Equipment Costs (*P*)**.** This is defined as the actual equipment purchase cost, less the tire or track replacement cost, regardless of whether the equipment is purchased at full price or discounted:
    - Equipment costs with standard attachment
    - Optional attachment cost
    - Sales taxes (State and local)
    - Freight cost
    - Miscellaneous, including installation of attachments or modifications made to equipment.

  Vendors and contractors provided equipment cost (*P*) data.

- Salvage Value (*S*)**.** This is defined as the amount that equipment can be sold for at the time of its disposal. The actual salvage value of equipment is affected by current market demand for used equipment and the condition of the equipment at the time of disposal. However, estimating the future salvage value of equipment is very difficult because it is based on the future market value and the unknown condition of the equipment at the time of its disposal. The estimates come from owners themselves or from manufacturers or dealers. As a rule of thumb, the salvage value can be considered 20 percent of the initial investment cost.

[9] Miyata ES. Determining fixed and operating costs of logging equipment. General Technical Report NC-55. 1980. Available from: http://www.nrs.fs.fed.us/pubs/gtr/gtr_nc055.pdf
[10] Ibid.

- Economic Life (*N*). This is the period over which the equipment can operate at an acceptable operating cost and productivity. The economic life is generally measured in terms of years, hours, or mileages (trucks and trailers). It depends on two factors: physical and functional impairment.

- Scheduled Operating Time (*SH*). Scheduled operating time is the time during which equipment is scheduled to do productive work.

- Productive Time (*H*). Productive time is that part of scheduled operating time during which a machine actually operates.

Fixed Costs
Fixed costs do not vary with hours of operation. They are neither affected by the amount of equipment activity nor output and are incurred regardless of whether a piece of equipment is used or not. Fixed costs include depreciation, interest, insurance, and taxes.

- Depreciation charges were estimated using the straight-line or declining balance method. Straight-line is calculated as:
$$D_n = (P - SN)_n$$
where *n* is the year for which the depreciation charge is to be estimated.

    - Interest
    - Insurance
    - Taxes

  Declining balance method allows equipment owners to depreciate their asset more quickly in the earlier years of its useful life while still arriving at the same total depreciation as the straight-line method at the end of its economic life. Declining balance is calculated using the maximum depreciation rate for this method permitted by the Internal Revenue Service which is 2 times the depreciation rate derived from the straight-line method. A 40% depreciation is taken annually based on the depreciated value of the asset from the previous year.

Operating Costs
- Maintenance and Repair
- Fuel
- Lubricants
- Tires or Tracks

Labor Costs
- Social Security
- Unemployment Insurance
- Workmen's Compensation Insurance
- Other: Other employer contributions may include paid vacation, paid holidays, paid sick leave, health insurance, uniforms, safety equipment.

Photo Tracking

Photo tracking monitored immersive photographic spheres prior to and post treatment. Point photographic methods[11] have been developed in the past, but recent advances in image capture technology have led us to develop an alternative prescription. Use of photographic spheres is improved upon traditional photo monitoring in allowing for comprehensive capture of site assessment, including ocular representations of light availability, soil conditions, and general vegetation change.

Photo Sampling Procedure

1. A camera with photosphere functions such as an android or iOS smartphone with the google photo was used to capture hemispherical photos.
2. All photo sequences originate facing north to allow for replication and use in plot finding if all other means are exhausted.

[11] Hall, Frederick C. Ground-based photographic monitoring. Gen. Tech. Rep. PNW-GTR-503. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 2001, 340 p

DEMONSTRATION RESULTS

All three hazardous fuels reduction demos were conducted across different ownerships and vegetative cover types. Table 4 summarizes location, ownership, vegetation cover type and implementation schedule for the three demos.

Table 4. HFRD Site Location, Ownership, Vegetation Cover Type, Schedule

Location	Site Ownership	Vegetation Cover Type	Schedule
Shaver lake	Southern California Edison	High elevation Sierra Nevada mixed conifer	October 5-10, 2016
Big Bear Lake	USDA Forest Service, San Bernardino National Forest	High elevation San Bernardino mixed conifer	October 12-17, 2016
Santa Rosa Indian Reservation	Santa Rosa Band of the Cahuilla Indians	Mid elevation chaparral	November 16-21, 2016

Treatment Systems Deployed

TSS worked closely with the HFRD Steering Committee and site coordinators to select both conventional and innovative treatment systems that were appropriate for the terrain and vegetative cover at each site. A minimum of six treatment systems was deployed at each site. Not all of the systems resulted in acres treated.[12] Table 5 lists the treatment systems deployed by demo site and total acres targeted for treatment.

Table 5. Treatment Systems Deployed by Demo Site

Treatment System	Demo Site		
	Shaver Lake	Santa Rosa	Big Bear Lake
Air Burner Burn Boss	y (exhibit only)	No Treatment	No Treatment
Caterpillar 299D (Skid Steer)	y	y	y
FAE Prime Tech PT 175 (Skid Steer)	y	y	y
Fecon FTX 128L (Skid Steer)	y	y	y
Hand Crew	y	y	No Treatment
John Deere JD 210 (Excavator)	y	No Treatment	No Treatment
Kaiser S2 (Excavator)	y	No Treatment	y

[12] A Burn Boss unit was deployed at the Shaver Lake demo in order to highlight an innovative approach to pile and burn slash disposal.

Treatment System	Demo Site		
	Shaver Lake	**Santa Rosa**	**Big Bear Lake**
Star Creek (Goats)	y	No Treatment	No Treatment
Takeuchi TB290 (Excavator)	y	y	y
Takeuchi TL12 (Skid Steer)	y	y	y
Timbco 425D (Excavator)	No Treatment	No Treatment	y
Total Acres Targeted for Treatment at Site	**36.97**	**60**	**48.5**

A one-page summary description of each treatment system, with purchase cost data, demo site deployed, and sponsoring vendor, is provided in Appendix G.

Fire/Fuels

Fire behavior modeling provides an objective metric to compare the predicted and actual effects of fuel treatments. Since the 1970s, fuel managers have been able to use the Rothermel spread model[13] to provide objective predictions of potential fire behavior in treated and untreated fuel beds. The BehavePlus v. 5 software package[14] is the tool incorporating the Rothermel model that is widely used by managers to make point predictions of fire behavior for a wide variety of purposes. While the accuracy of the model has been described as a "factor of two,"[15] it readily provides a relative measure of expected fire behavior that enables comparison of fuel treatment effects on surface fuels.

Fire Behavior Modeling with BehavePlus v. 5

BehavePlus v. 5 consists of several modules with equations to predict a variety of fire behavior outputs including surface fire rate of spread, flame length, spotting distance, fire perimeter growth, crown fire spread, etc. The SURFACE module was used for the HFRD project. This module is designed to predict rate of spread, flame length, and heat released per unit area for fire in surface fuels within 6 feet of the ground. The interested reader is referred to Table 1 in

[13] Rothermel, R.C. "Predicting Behavior and Size of Crown Fires in the Northern Rocky Mountains." Research Paper INT-438. Ogden, UT: USDA Forest Service, Intermountain Research Station. 1991. http://www.treesearch.fs.fed.us/pubs/26696

[14] Heinsch, F.A., Andrews, P.L. BehavePlus fire modeling system, version 5.0: Design and Features. General Technical Report RMRS-GTR-249. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 2010. http://www.frames.gov/rcs/10000/10046.html

[15] Albini, F.A. "Estimating Wildfire Behavior and Effects." General Technical Report INT-30. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 1976. http://www.fs.fed.us/rm/pubs_int/int_gtr030.pdf.

Heinsch and Andrews[16] for details on the mathematical models included in the SURFACE module. The basic inputs needed to make a fire behavior prediction are fuels, weather, and topography.

Fuels data were sampled and the loading of dead and downed woody fuels were estimated following procedures outlined in Brown (1974).[17] Live fuel loading was estimated by taking the loading from fire behavior fuel model assigned to the closest weather station and multiplying by the cover measurement, which typically reduced the live woody loading. While numerous fuel models exist (Albini 1976, Scott and Burgan 2005, Prichard et al 2010),[18] the fuel models used were the original static models described in Albini (1976).[19] 90th percentile weather data from a reliable weather station near each treatment site were provided by the local national forest. These data described the weather, fuel moisture and topography associated with high fire danger conditions. While each fuel model has a wind adjustment factor associated with it to account for the presence/absence of an overstory to reduce the 20 ft wind speed to the "midflame" wind speed (Albini and Baughman 1979, Rothermel 1983),[20] we used the wind speed as the "midflame" wind speed and did not adjust it.

Rate of spread (chains per hour)[21] and flame length (feet) were predicted using the fuels and weather data for each site before treatment. Following treatment, each area had one or two dominant fuel types. When shrub cover exceeded 70 percent following treatment, fuel bed depth was determined by the shrub height. When shrub cover was less than 30 percent, fuel bed depth was determined by the litter/duff depth. When shrub cover was between 30 and 70 percent, both depths were used and two separate fire behavior calculations were made. The mean rate of spread was calculated using the two fuel model concept following Fujioka (1985)[22] which differs from the method described by Rothermel (1983).[23] Shrub and duff cover were used as the weighting factor to calculate mean rate of spread and flame length. Because of the sensitivity of

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16 Heinsch, F.A., Andrews, P.L. BehavePlus fire modeling system, version 5.0: Design and Features. General Technical Report RMRS-GTR-249. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 2010. http://www.frames.gov/rcs/10000/10046.html

17 Brown, James K. "Handbook for inventorying downed woody material." 1974.

18 Albini, F.A. "Estimating Wildfire Behavior and Effects." General Technical Report INT-30. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 1976. http://www.fs.fed.us/rm/pubs_int/int_gtr030.pdf.
Scott, J.H., and R.E. Burgan. "Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model." General Technical Report RMRS-GTR-153. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 2005. http://treesearch.fs.fed.us/pubs/9521

19 Ibid.

20 Albini, F. A., and R. G. Baughman. Estimating windspeeds for predicting wildland fire behavior. Research Paper INT-221. Ogden, UT, USDA Forest Service, Intermountain Forest and Range Experiment Station. 1979.
Rothermel, R. C. "How to Predict the Spread and Intensity of Forest and Range Fires." General Technical Report INT-143. Ogden, UT: USDA Forest Service, Intermountain Research Station. 1983. http://www.treesearch.fs.fed.us/pubs/24635

21 One chain = 66 feet on a horizontal plane.

22 Fujioka, F.M. "Estimating Wildland Fire Rate of Spread in a Spatially Nonuniform Environment." Forest Science 31 (1): 21–29. 1985.

23 Rothermel, R. C. "How to Predict the Spread and Intensity of Forest and Range Fires." General Technical Report INT-143. Ogden, UT: USDA Forest Service, Intermountain Research Station. 1983. http://www.treesearch.fs.fed.us/pubs/24635

the Rothermel model to fuel bed depth, if a rate of spread or flame length prediction was 0, a nominal value of 0.1 was used to enable calculation of the means. When comparing the predicted rates of spread and flame length, several factors should be considered. While some validation of the Rothermel model has occurred, the stated accuracy of the model predictions was estimated as within a "factor of two" (Albini 1976).[24] This means that the actual rate of spread could be as small as 50% of the prediction or as large as 200% of the prediction. The number of sample transects used to estimate fuel loading for each treatment system was generally small (2 or 3 points with 3 transects each) so 95% confidence intervals about the estimated mean loading are larger than if more samples had been collected. With this level of accuracy and sampling error, comparison of results becomes more difficult.

Findings

Summarized below by treatment site are results from the Behave Plus fire modeling assessment. In order to compare the potential pre and post treatment fire behavior, the predicted rate of spread, fireline intensity (Byram 1959)[25] and flame length were plotted on a Fire Characteristics Chart (sometimes referred to as a "hauling chart"). The Fire Characteristics Chart presents potential fire behavior in a form that also suggests the potential level of resources that would be needed to contain the fire (Andrews and Rothermel 1982, Rothermel 1991, Andrews et al 2011).[26] The charts in this report were prepared with the Fire Characteristics Chart 2.0 program.[27] Note that the ranges of rate of spread and heat per unit area differ between the three figures.

The "Site" treatment noted in the fire modeling results tables is an area weighted mean of the fire behavior estimates from each treatment and represents fire behavior results for the entire treatment site. The area treated by each treatment system was used as the weighting factor. The harmonic mean was calculated for rate of spread (Fujioka 1985)[28] and the standard weighted mean was used for flame length.

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[24] Albini, F.A. "Estimating Wildfire Behavior and Effects." General Technical Report INT-30. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 1976. http://www.fs.fed.us/rm/pubs_int/int_gtr030.pdf

[25] Byram, G.M. "Combustion of Forest Fuels." In Forest Fire: Control and Use, edited by K.P. Davis, 1st ed., 61–89. New York: McGraw-Hill. 1959.

[26] Andrews, P.L., and R.C. Rothermel. "Charts for Interpreting Wildland Fire Behavior Characteristics." General Technical Report INT-131. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station. 1982. http://www.treesearch.fs.fed.us/pubs/22647
Rothermel, R. C. "Predicting Behavior and Size of Crown Fires in the Northern Rocky Mountains." Research Paper INT-438. Ogden, UT: USDA Forest Service, Intermountain Research Station. 1991. http://www.treesearch.fs.fed.us/pubs/26696
Andrews, Patricia L., Faith Ann Heinsch, and Luke Schelvan. "How to Generate and Interpret Fire Characteristics Charts for Surface and Crown Fire Behavior." General Technical Report RMRS-GTR-253. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 2011. http://www.treesearch.fs.fed.us/pubs/37380

[27] Available at http://www.frames.gov/documents/behaveplus/software/FireChart20.msi

[28] Fujioka, F. M. "Estimating Wildland Fire Rate of Spread in a Spatially Nonuniform Environment." Forest Science 31 (1): 21–29. 1985.

Shaver Lake

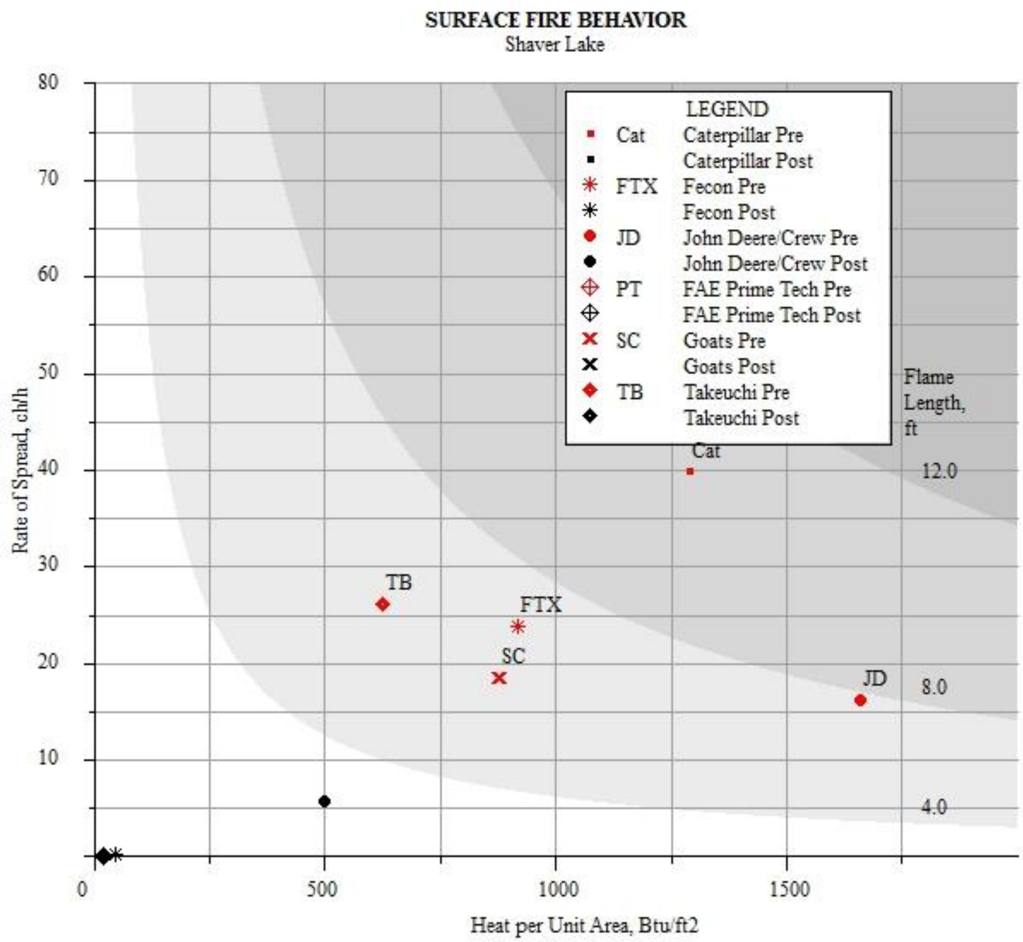
Fuel model 10 (Timber – litter and understory) was used to estimate the pre treatment fire behavior. The 90th percentile weather data for the Shaver Lake RAWS (NESDIS ID CA256792) were provided by the High Sierra Ranger District, Sierra National Forest. The time period used was May 15-Oct 1, 2015 and the data are as follows: fuel moistures (%) - woody = 70, herbaceous = 45, 100 hour = 9, 10 hour = 4, 1 hour = 3, wind speed = 6 mph, relative humidity = 17 %, and air temperature = 88 °F. The John Deere and Hand Crew treatments were applied on the same plot (on separate halves) and at this point the fuel loading estimates are combined as shown in Table 6. Since all treatment systems drastically reduced the understory component, the post treatment fire behavior calculations were essentially made for a chip or duff fuel bed (Table 6). The resulting fire spread predictions ranged from 0.1 to 0.5 chain[29]/hour with the exception of the Caterpillar and John Deere/Hand Crew treatments. Mean flame lengths were similar; mean flame length for the Caterpillar, Hand Crew and Goat treatments reflect the higher shrub cover in these treatments. The Fire Characteristics Chart for Shaver Lake, shown as Figure 11, also illustrates the dramatic change in predicted fire behavior post treatment. Note the range in pre treatment potential fire behavior and the small range in the post treatment fire behavior. Fire behavior in the Hand Crew treatment differed from the other treatments. Since the fuel sampling transects were established prior to treatment and there were some constraints placed on the treatment systems after this establishment, the fuels along the transects may not have been treated or only a portion of the fuels received treatment. This is likely the case for the Caterpillar treatment, which only reduced shrub cover in the fuel plots to 62 percent even though visual observation of areas outside of the fuel plots indicated a greater reduction in shrub cover. This complication occurred at all three sites. Based on the sampled fuel loadings, all treatment systems substantially reduced fire behavior potential.

[29] 1 chain = 66 feet. 80 chains/hr = 1 mile/hr.

Table 6. Shaver Lake Data and Fire Modeling Results

Treatment System	Shrub Cover (Percent)		1 Hour Fuel (Tons/Acre)		10 Hour Fuel (Tons/Acre)		100 Hour Fuel (Tons/Acre)		Live Woody Fuel Load (Tons/Acre)		Fuel Depth (Feet)		Rate of Spread (Chains/Hour)		Flame Length (Feet)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Caterpillar 299D	90	62	1.53	1.90	3.54	3.54	3.22	3.13	1.80	1.24	2.7	2.0	39.9	2.3	10.5	6.3
FAE-Prime Tech PT 175	100	1	0.83	0.59	4.78	3.39	8.98	11.84	1.85	0.05	5.5	0.2	20.1	0.1	10.0	0.1
Fecon FTX 128L	95	4	0.55	1.07	2.55	6.76	2.12	5.33	1.90	0.08	2.3	0.2	23.9	0.2	7.1	0.2
Goats	70	46	0.36	0.59	2.32	3.17	3.83	7.07	1.40	0.91	2.4	2.2	18.6	0.2	6.2	3.2
John Deere JD210 Hand Crew	30	20	0.17	1.28	2.35	3.52	8.33	0.00	0.60	0.40	1.8	0.3	16.2	5.8	7.8	2.8
Takeuchi TL12	10	4	0.75	0.63	3.66	3.02	2.43	2.37	0.20	0.08	1.8	0.1	26.2	0.1	6.2	0.1
Entire Site													**23.6**	**0.2**	**8.4**	**1.8**

Figure 11. Predicted Surface Fire Characteristics at Shaver Lake Site



Big Bear Lake

Fuel model TU1 (Scott and Burgan 2005)[30] was used to provide initial fuel parameters. Fuel loading and fuel depth were based on measured quantities as shown in Table 7. The 90th percentile weather data for the Fawnskin RAWS (NESDIS ID 3230F3EE) were provided by the San Bernardino National Forest. The data are as follows: fuel moistures (%) - woody = 69, herbaceous = 29, 100 hour = 5, 10 hour = 3, 1 hour = 2, 20 ft wind speed = 6 mph, relative humidity = 8 %, and air temperature = 82 °F. Note that the pre treatment spread rates and flame lengths at Big Bear Lake are similar to those at Shaver Lake. With the exception of the Caterpillar 299D treatment, predicted fire behavior was significantly reduced by the treatments. The fuel sampling plot for the Caterpillar treatment still contained a significant amount of shrub vegetation after treatment due to the application method. Because the treatment increased the amount of dead woody fuels and reduced depth slightly, the amount of heat released per unit area

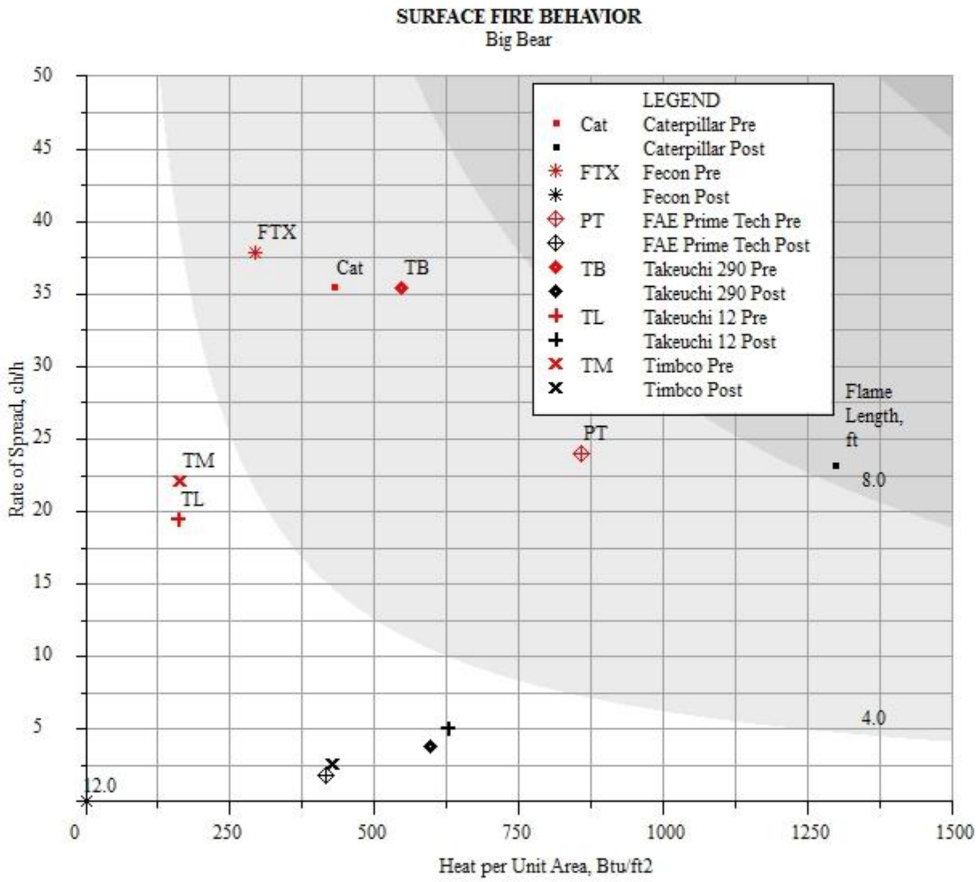
[30] Scott, J.H., Burgan R.E. "Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model." General Technical Report RMRS-GTR-153. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 2005. http://treesearch.fs.fed.us/pubs/9521

and thus flame length increased potentially making fire control more difficult. However, visual observation of the fuels outside of the measurement plot showed that the Caterpillar treatment reduced fuels to similar levels as the other treatments and thus was likely as effective as the other treatments.

Table 7. Big Bear Lake Data and Fire Modeling Results

Treatment System	Shrub Cover (Percent)		1 Hour Fuel (Tons/Acre)		10 Hour Fuel (Tons/Acre)		100 Hour Fuel (Tons/Acre)		Live Woody Fuel Load (Tons/Acre)		Fuel Depth (Feet)		Rate of Spread (Chains/Hour)		Flame Length (Feet)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Caterpillar 299D	80	45	0.08	0.22	0.94	4.30	2.57	1.50	0.72	0.41	3.60	1.43	35.4	23.1	6.0	8.2
Fecon FTX 128L	65	5	0.17	0.47	1.27	5.88	0.97	5.47	0.59	0.05	2.93	0.13	37.9	0.0	5.2	0.1
FAE-Prime Tech PT 175	50	5	0.27	0.23	1.05	3.84	6.22	2.6	0.45	0.05	2.25	0.20	24.0	1.8	6.9	1.5
Takeuchi TB290	50	10	0.07	0.49	1.91	5.45	0.97	3.29	0.45	0.09	2.25	0.35	35.4	3.8	6.7	2.5
Takeuchi TL12	40	5	0.13	0.5	0.58	4.76	0.88	1.78	0.36	0.05	1.80	0.35	19.5	5.0	2.9	2.9
Timbco 425D	75	5	0.05	0.49	0.12	5.88	1.89	1.37	0.68	0.05	3.25	0.23	22.1	2.6	3.1	1.8
Entire Site													**26.3**	**4.1**	**6.2**	**2.9**

Figure 12. Predicted Surface Fire Characteristics at Big Bear Lake Site



<u>Santa Rosa</u>

Fuel model 4 (chaparral – 6 ft deep) was used to predict fire behavior at Santa Rosa and the fuel loading and height were adjusted using the field data. The 90th percentile weather data for the Keenwild RAWS (NESDIS ID 32675560) were provided by the San Bernardino National Forest. The data are as follows: fuel moistures (%) - woody = 69, herbaceous = 29, 100 hour = 6, 10 hour = 3, 1 hour = 2, 20 ft wind speed = 7 mph, relative humidity = 8 %, and air temperature = 92 °F. Since all treatment systems drastically reduced the shrub component, the post treatment fire behavior calculations were essentially made for a chip or duff fuel bed. The resulting fire spread predictions ranged from 0.1 to 0.5 chain/hr. For comparison purposes, prescribed burns in masticated fuels in northern California were observed to spread 2 to 3 chain/hr (Knapp et al 2011).[31] Mean flame lengths were similar; mean flame length for the Caterpillar and the Hand Crew treatments reflects the higher shrub cover in these two treatments. While the rate of spread was not appreciably affected, a predicted increase in flame length when a fire burns into a shrub dominated area is not surprising. The Fire Characteristics Chart for Santa Rosa also illustrates

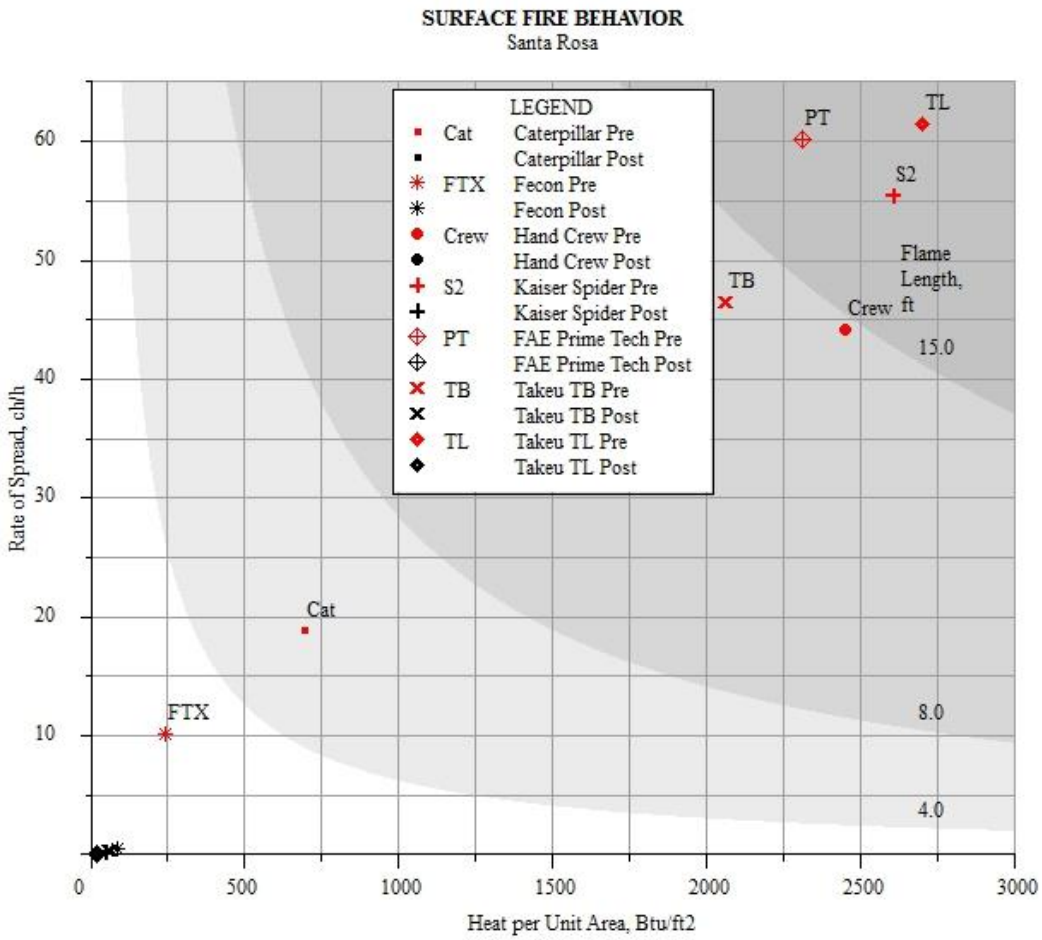
[31] Knapp, Eric E., J. Morgan Varner, Matt D. Busse, Carl N. Skinner, and Carol J. Shestak. "Behaviour and Effects of Prescribed Fire in Masticated Fuelbeds." International Journal of Wildfire 20: 932 – 945. doi:10.1071/WF1Q110. 2011.

the dramatic change in predicted fire behavior. Note the range in pre treatment potential fire behavior and the small range in the post treatment fire behavior. Based on the sampled fuel loadings, all treatment systems substantially reduced fire behavior potential.

Table 8. Santa Rosa Data and Fire Modeling Results

Treatment System	Shrub Cover (Percent)		1 Hour Fuel (Tons/Acre)		10 Hour Fuel (Tons/Acre)		100 Hour Fuel (Tons/Acre)		Live Woody Fuel Load (Tons/Acre)		Fuel Depth (Feet)		Rate of Spread (Chains/Hour)		Flame Length (Feet)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Caterpillar 299D	100	32	0.23	1.31	1.44	9.10	6.10	2.97	5.01	1.60	4.5	1.5	18.8	0.1	5.5	3.3
Fecon FTX 128L	92	0	0.21	1.00	1.14	7.95	2.48	1.81	4.61	0.00	4.0	0.0	10.2	0.5	2.6	0.4
Hand Crew	93	40	0.37	1.28	4.59	6.42	6.66	10.60	4.66	2.00	4.0	2.0	44.2	0.2	14.8	3.8
Kaiser S2 Spider	95	20	0.24	1.91	5.07	9.99	5.45	4.72	4.76	1.00	4.5	1.5	55.4	0.2	16.9	0.2
FAE - Prime Tech PT175	95	20	0.42	0.93	5.40	6.99	1.82	1.98	4.76	1.00	4.0	1.0	60.1	0.1	16.6	0.1
Takeuchi TB290	100	0	0.46	1.24	3.64	7.92	6.66	0.00	5.01	0.00	4.5	0.0	46.5	0.4	14.0	0.3
Takeuchi TL12	95	15	0.71	1.69	7.16	13.69	3.65	3.55	4.76	0.75	4.5	1.0	61.4	0.1	18.0	0.1
Entire Site													**27.3**	**0.2**	**12.4**	**0.9**

Figure 13. Predicted Surface Fire Characteristics at Santa Rosa Site



Observations

In summary, all of the fuel treatments significantly altered the fuel profiles at all three sites. The amount of dead woody material in the 10 and 100 hour time lag size classes generally increased. Predicted rates of spread, flame length, and heat released per unit area under 90th percentile weather conditions were reduced by all treatment systems – often to levels where direct attack using hand crews may be possible. The increase in dead woody fuel loading on these sites may increase the potential for below ground damage to root systems and other soil heat effects in the event that a smoldering, creeping type of fire was to become established at these sites (e.g., Preisler et al 2000, Busse et al 2005).[32] However, as dead woody debris decomposes over time, and is incorporated into the soil, this potential damage will be reduced.

[32] Preisler, Haiganoush K., Sally M. Haase, and Stephen S. Sackett. "Modeling and Risk Assessment for Soil Temperatures beneath Prescribed Forest Fires." 2000. Environmental and Ecological Statistics 7 (3): 239–54. doi:10.1023/A:1009615032159.
Busse, Matt D., Ken R. Hubbert, Gary O. Fiddler, Carol J. Shestak, and Robert F. Powers. "Lethal Soil Temperatures during Burning of Masticated Forest Residues." 2005. International Journal of Wildland Fire 14: 267–76. doi:10.1071/WF04062.

Soil Impacts

To determine impact of treatment on physical attributes that influence site resilience and hydrologic function, soil condition was monitored using the Forest Soil Disturbance Monitoring Protocol (FSDMP) developed by the Rocky Mountain Research Station (Appendix D). Pre-treatment soil monitoring was captured immediately prior to treatment to establish a baseline to compare with the current study and avoid the influence of any legacy soil impacts.

Soil characteristics (live plant, fine wood, coarse wood, bare soil, rock), disturbance indicators (rutting, burning, erosion, compaction, platy), and qualitative rankings were collected at regular 15 foot (5 meter) intervals along three 75 foot (15 meter) transects. Live vegetation and woody material cover provides obstacles to decrease impact pressure from precipitation and overland flow, improving soil stability. Rutting, ash, and compaction can also channelize overland flow, increasing the cutting power of water to erode soil and cause sedimentation of watercourses. These reported findings are based on probability of occupancy across each treatment site. A 10% increase implies that 10% of the sampled area has increased in the associated cover type as a result of treatment.

Overall qualitative ranking has a ranking of soil disturbance as none (0), low (1), medium (2) or high (3) as defined in the FSDMP. This ranking combines the soil characteristic and disturbance indicator metrics into a single relative value for comparison. Appendix D provides detail descriptions of the soil disturbance classes.

To avoid operator bias, operators were not informed of plot locations prior to treatment. As a result, monitoring data was unavailable for some treatment systems.

Findings

<u>Shaver Lake</u>

Overall post-treatment soil disturbance rankings indicated that no significant disturbance occurred from mastication treatments at the Shaver Lake site. The treatment system with the highest average soil disturbance rating was the Caterpillar 299D at 0.26, which is below the first ranking level of “low” soil disturbance as defined by faint wheel tracks or slight depressions less than five centimeters in depth (per FSDMP).

Only the Takeuchi TB290 treatment system had a significant loss in wood material cover at 16.7%, increasing exposure of soil to erosive elements. Woody material cover increased by 40% from the FAE – Prime Tech PT175 treatment system, likely from an increase in masticated residue being distributed over the treatment area. All other treatments demonstrated insignificant post treatment changes to wood material cover, suggesting neutral to positive benefits from treatment.

Live vegetative cover was reduced in all the treatments. Most treatments had a low impact on existing live vegetative cover with the exception of the Caterpillar 299D (40% reduction), Fecon FTX 128L (73.33% reduction) and FAE Prime Tech PT175 (73.33% reduction). Since post-treatment monitoring surveys were captured immediately after treatment, we are unable to determine if the loss of vegetation is a short-term or long-term impact from treatment.

Exposed bare soil for the California Conservation Corps (CCC) Hand Crew and John Deere JD 210 treatment significantly decreased (33%) over the course of the treatment while the other treatments showed nominal increases in bare soil cover. Loss of bare soil coverage in these treatments are likely attributed to increases in woody material coverage while increased bare soil coverage suggests surface scraping from treatment. The FAE Prime Tech PT175 treatment had a significant increase in bare soil cover (20%), exposing greater surface area to hydrological processes and increasing erosion potential of the soil.

Overall, soil disturbance findings are consistent with expected outcome. Significant reductions were made in the live vegetative cover from the treatments but were not correlated with significant increases in exposed bare soil cover. Similarly, post-treatment soil disturbance rankings did not identify any significant rutting, burning, erosion, compaction, or platy soil disturbance indicators. No soil impact results were available for the Kaiser and Takeuchi TL12 treatment systems, as these treatments did not treat area that included soil disturbance plots. Table 9 summarizes the Shaver Lake soil impact results.

Table 9. Shaver Lake Soil Impact Analysis Results

Treatment System	Woody Material Cover (Initial)	Woody Material Cover (Post Treatment)	Change in Woody Material Cover	Live Vegetative Cover (Initial)	Live Vegetative Cover (Post Treatment)	Change in Live Plant Cover	Exposed Bare Soil (Initial)	Exposed Bare Soil (Post Treatment)	Change in Exposed Bare Soil Cover	Post-treatment Disturbance Ranking
Caterpillar 299D	70.00%	73.33%	3.33%	86.67%	46.67%	-40.00%	0.00%	6.67%	6.67%	0.26
FAE Prime TechPT175	46.67%	86.67%	40.00%	86.67%	13.33%	-73.33%	6.67%	26.67%	20.00%	0.06
Fecon FTX 128L	51.67%	50.00%	-1.67%	76.67%	20.00%	-56.67%	23.34%	10.00%	-13.33%	0.04
Hand Crew	60.00%	70.00%	10.00%	60.00%	40.00%	-20.00%	33.33%	0.00%	-33.33%	0.00
Goats	70.00%	63.33%	-6.67%	93.33%	66.67%	-26.67%	6.67%	20.00%	13.33%	0.00
John Deere JD 210G	60.00%	70.00%	10.00%	60.00%	40.00%	-20.00%	33.33%	0.00%	-33.33%	0.00
Takeuchi TB290	70.00%	53.33%	-16.67%	60.00%	6.67%	-53.33%	26.67%	33.33%	6.67%	0.00

Big Bear Lake

Overall post-treatment soil disturbance rankings indicated that no significant disturbance occurred from mastication treatments at the Big Bear Lake site. The treatment system with the highest average soil disturbance rating was the Fecon FTX 128L at 0.8, which approaches the first ranking level of "low" soil disturbance as defined by faint wheel tracks or slight depressions less than five centimeters in depth (per FSDMP). While the remaining treatments did demonstrate topsoil disturbance, none were greater than 0.5 suggesting negligible impact from treatment.

Only the FAE – Prime Tech PT 175 treatment system had a significant loss in wood material cover at 40%, increasing exposure of soil to erosive elements. Woody material also decreased by 26% from the Takeuchi TB290 treatment system, but had low impact on overall disturbance ranking. All other treatments demonstrated insignificant post-treatment changes to wood material cover, suggesting neutral to positive benefits from treatment.

Most treatments had a low impact on existing live vegetative cover with the exception of the Caterpillar 299D (33.33% reduction), Fecon FTX 128L (53.33% reduction) and Timbco 425D (66.67% reduction). Of note is that these three treatments had a higher percent coverage of live vegetation initially. Since post-treatment monitoring surveys were captured immediately after treatment, we are unable to determine if the loss of vegetation is a short-term or long-term impact from treatment.

Exposed bare soil for the Fecon FTX 128L (33.33%) and Timbco 425D (40%) significantly increased over the course of the treatment while the other treatments showed nominal changes to bare soil cover. The Timbco 425D was a highly productive treatment and increases in exposed bare soil coverage may be due to surface scraping from treatment.

Overall, soil disturbance findings are consistent with expected outcome. Post-treatment soil disturbance rankings did not identify any significant rutting, burning, erosion, compaction, or platy soil disturbance indicators. Table 10 summarizes the Big Bear soil impact results.

Table 10. Big Bear Lake Soil Impact Analysis Results

Treatment System	Woody Material Cover (Initial)	Woody Material Cover (Post Treatment)	Change in Woody Material Cover	Live Vegetative Cover (Initial)	Live Vegetative Cover (Post Treatment)	Change in Live Plant Cover	Exposed Bare Soil (Initial)	Exposed Bare Soil (Post Treatment)	Change in Exposed Bare Soil Cover	Post-treatment Disturbance Ranking
Caterpillar 299D	30.00%	33.33%	3.33%	60.00%	26.67%	-33.33%	26.67%	33.33%	6.67%	0.27
FAE - Prime Tech PT175	100.00%	60.00%	-40.00%	46.67%	53.33%	6.67%	20.00%	20.00%	0.00%	0.40
Fecon FTX 128L	36.67%	53.33%	16.67%	53.33%	0.00%	-53.33%	13.33%	46.67%	33.33%	0.80
Takeuchi TB290	76.67%	50.00%	-26.67%	13.33%	33.33%	20.00%	6.67%	13.33%	6.67%	0.13
Takeuchi TL 12	46.67%	60.00%	13.33%	46.67%	53.33%	6.67%	33.33%	20.00%	-13.33%	0.33
Timbco 425D	66.67%	50.00%	-16.67%	80.00%	13.33%	-66.67%	20.00%	60.00%	40.00%	0.27

Santa Rosa

Overall post-treatment soil disturbance rankings at the Santa Rosa site indicated significant soil disturbance with a disturbance ranking between “low” and “medium.” Only the Fecon FTX 128L and Kaiser S2 treatment had a disturbance ranking less than 1. The remaining treatments resulted in moderate levels of disturbance.

Treatment at Santa Rosa resulted in a significant reduction of live plant cover at the site, in line with the target treatment prescription. The Cat 299D treatment had minimal impact on bare soil cover while the Takeuchi TL12 treatment resulted in the most exposed bare soil. Both treatments created similar post treatment conditions in vegetative and woody material coverage.

The treatments did not result in any significant change in woody material cover post treatment. The highest change was a 10% increase in woody material cover at the FAE Prime Tech PT 175 treatment.

Live vegetative cover was significantly reduced for all treatments at the Santa Rosa site. The Kaiser S2 and Caterpillar 299D treatment retained the highest quantity of live vegetative at 13.3% and 20% (respectively). All other treatments were occupied by less than 10% residual live vegetative cover post treatment. The treatment prescription for the Santa Rosa site specifically called for removal of all brush except for culturally relevant species (e.g., pinyon, manzanita, ribbonwood).

Exposed Bare Soil was decreased for most of the treatments. All post treatment conditions show less than 14% exposed bare soil remaining. Loss of bare soil coverage in these treatments are likely due to increases in woody material coverage from the mastication treatment.

Overall, soil disturbance findings are consistent with expected outcome. Significant reductions in the live vegetative cover are correlated with decreases in exposed bare soil. Data identified a moderate erosion impact as a result of treatment operations that could be taken into consideration when planning for fuel treatments. Table 11 summarizes the Santa Rosa soil impact results.

Table 11. Santa Rosa Soil Impact Analysis Results

Treatment System	Woody Material Cover (Initial)	Woody Material Cover (Post Treatment)	Change in Woody Material Cover	Live Vegetative Cover (Initial)	Live Vegetative Cover (Post Treatment)	Change in Live Plant Cover	Exposed Bare Soil (Initial)	Exposed Bare Soil (Post Treatment)	Change in Exposed Bare Soil Cover	Post-treatment Disturbance Ranking
Caterpillar 299D	50.00%	50.00%	0.00%	60.00%	20.00%	-40.00%	6.67%	6.67%	0.00%	1.60
FAE - Prime Tech PT175	40.00%	50.00%	10.00%	73.33%	0.00%	-73.33%	46.67%	6.67%	-40.00%	1.80
Fecon FTX 128L	53.33%	53.33%	0.00%	80.00%	0.00%	-80.00%	40.00%	13.33%	-25.67%	0.4
Hand Crew	46.67%	50.00%	3.33%	66.67%	6.67%	-60.00%	46.67%	13.33%	-33.33%	1.2
Kaiser S2 Spider	53.33%	53.33%	0.00%	80.00%	13.33%	-66.67%	53.33%	6.67%	-46.67%	0.80
Takeuchi TB290	53.33%	53.33%	0.00%	80.00%	6.67%	-73.33%	20.00%	0.00%	-20.00%	1.13
Takeuchi TL 12	50.00%	50.00%	0.00%	66.67%	0.00%	-66.67%	60.00%	0.00%	-60.00%	1.47

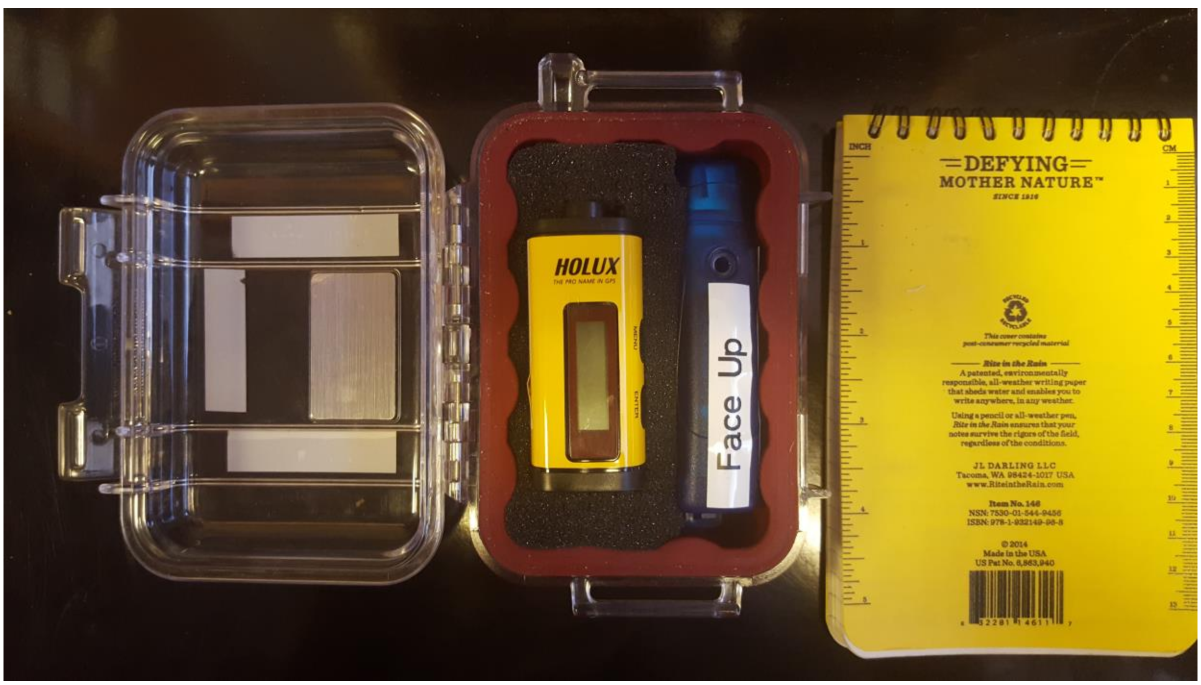
Treatment System Production and Cost Estimates

To determine machine productivity and cost, it was critical to differentiate the effects of machine capability from extraneous environmental variables. To achieve this, we focused on measuring production rate (hours per acre) and cost rate ($/acre) of each treatment system.

Production rate was measured using GPS sensors to track time spent operating within each “complete” treatment area. “Complete” treatment areas were defined as study areas that achieved the land manager’s prescription. Further parsing of treatment area along percent slope bands allowed for detailed analysis of each method’s productivity as it relates to slope.

Due to distortion from poor signal quality and non-treatment activity, we limited productivity analysis to periods of “active” treatment where masticator treatment of fuels could be confirmed using activity tracking from accelerometer sensors and operator shift reports. By comparing activity tracking with GPS position, we expunged GPS data collected during non-operational periods from the production rate analysis. Figure 14 shows images of the Holux Logger and Acceleromenter.

Figure 14. Holux GPS Logger (Left) and Accelerometer (Right) Seated in Protective Case

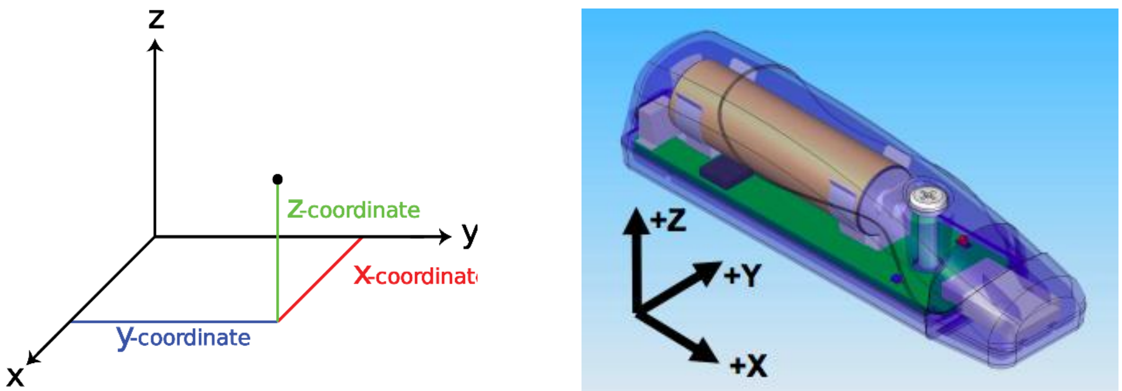


Cost per machine hour rates ($/MH) were independently calculated for each treatment system, then factored with production rate to identify system specific production cost rates ($/acre). A thorough breakdown of the data alignment, cleaning, and analysis methodology for each step is discussed below.

Treatment Activity Tracking

Gulf Coast Data Concepts X16-1D accelerometer activity sensors were attached to each treatment system to record machine vibration. Each accelerometer was positioned on the prime mover body to minimize the effects of vibration dampening devices during operation. The X16-1D accelerometer sensor captures acceleration up to 16 g (514.784 ft/second) in the x, y, and z coordinate direction with a frequency of 100 observations per second. Figure 15 includes a diagram showing coordinate reference and a rendering of the accelerometer tool.

Figure 15. Coordinate Reference and Accelerometer Tool



To isolate data noise from acceleration directionality, the three acceleration bands were merged into an acceleration index to gauge acceleration magnitude.

$$Acceleration\ Index\ (t) = \sqrt{x_{t+1}^2 + y_{t+1}^2 + z_{t+1}^2} - \sqrt{x_t^2 + y_t^2 + z_t^2}$$

By applying a minimum threshold to the acceleration band, we were able to isolate and remove periods of non-work equipment activity (traveling, maintenance check, shut down period, etc.) and limit time and cost efficiency analysis to periods of active operation. To further reduce data noise from outlier shocks (device being kicked) and simplify comparison with GPS data, the acceleration index was down sampled to one point per second. Due to the high sampling frequency, vibration response from accelerometers more strongly indicated intensity of machine activity than direction of machine movement.

Self-reported shift activity (Appendix E) was also collected from treatment operators to ground-truth accelerometer signal response. Operators were asked to self-identify periods of operation, inactivity, repair, maintenance, and any other breaks. Using visual inspection of the acceleration index alongside self-reported activity from machine operators allowed us to isolate "work time" behavior classifications demonstrative of conventional operational behavior.[33] "Work time" activity periods were then combined with GPS location to validate completed treatment area.

[33] Björheden, Rolf, Jeremy Rickards, Reidar Skaar, Sigfred Haberle, and Karl Apel. *Forest Work-Study Nomenclature*. Edited by Rolf Björheden. *Swedish University of Agricultural Sciences*. 1995. Garpenberg: Swedish University of Agricultural Sciences, Department of Operational Efficiency.

Geospatial Tracking

Holux M-241 GPS loggers tracked latitude, longitude, and elevation position at five-second intervals to monitor movement pattern and speed for the duration of treatment. Despite having high data density (~ 30,000 points for each treatment), some data gaps or misalignment occurs due to loss of satellite signal strength. The Holux loggers have an inherent 10 foot circular error probability and any signal movement beyond that error margin was removed to enhance data quality. By analyzing speed and movement behavior, we identified non-operational periods including staging, maintenance, refueling, and operator breaks. To facilitate tracking of multiple units without constant researcher supervision, sensors were left on overnight and during idle periods (restroom/lunch breaks, refueling, maintenance sessions, and site relocation). These periods were subsequently removed from the final analysis to ensure that production rates reflected true "work time" activity.

Productivity Analysis

In practice, operational logistics and vegetative structure results in non-linear movement patterns. Operators are required to occasionally retrace their steps (overnight parking, refueling, heavy brush reentry) while avoiding others (large rock formations, lack of existing vegetation). To accurately measure completed treatment area, GPS movement paths were buffered by cutting head width (Table 12) to identify traversed area. Small untreated gaps less than 400 square feet located within treatment polygons were considered to have met treatment prescription and been avoided due to operator choice and merged into the final treatment area with GIS software.

Table 12. Treatment System Equipment Attachment Specifications

Treatment System	Attachment	Attachment Cutting Width (Inches)	Attachment Number of Teeth
Caterpillar 299D	CAT HM41HC	72	38
FAE - Prime Tech PT175	FAE 140/U 175	72	30
Fecon FTX 128L	Fecon BH 85	72	36
John Deere JD 210G	Fecon BH 80	56	33
Kaiser S2	FAE DML/HY 125	60	22
Takeuchi TB290	FAE DML/HY/VT 100	62	28
Takeuchi TL12	FAE UML/SSL/VT 150	72	36
Timbco 425D	FAE UMM/EX 150	62	34

In addition, final treatment area was categorized into slope bands to identify volume of treatment completed under each slope condition. GPS point density was also measured within each slope condition to derive an hour per acre calculation for each treatment. In total, roughly 5,760 GPS points and 2,880,000 accelerometer points were collected each day for each of the 22 treatments over the 5-day study periods.

Cost Analysis

We requested general treatment system data from participating vendors and contractors. Equipment-specific information was provided via a web form (Appendix F). A total of 11 different treatment systems were deployed. Vendors were asked to provide prices for equipment base system, necessary attachments and miscellaneous setup costs to provision the specific configuration used in the demo(s). Table 13 summarizes these costs.

Table 13. Equipment Purchase and Setup Prices

Treatment System	Base Cost	Attachment Cost	Miscellaneous Setup Cost	Total Cost
Caterpillar 299D	$111,000	$32,500	$700	$144,200
FAE - Prime Tech PT175	$250,000	N/A[34]	$0	$250,000
Fecon FTX 128L	$154,000	$38,300	$1,000	$193,300
John Deere JD 210G	$200,000	$50,000	$10,000	$260,000
Kaiser S2	$450,000	$85,000	$1,500	$536,500
Takeuchi TB290	$120,000	$25,000	$1,200	$146,200
Takeuchi TL12	$87,000	$32,000	$1,000	$120,000
Timbco 425D	$450,000	$55,000	$5,000	$510,000

To calculate depreciation for each piece of equipment, an expected economic life span is necessary. Vendors were asked to provide an expected economic life span for the equipment. If none was provided, a default of five years was assumed. Salvage value is also necessary to calculate depreciation. If vendors did not provide salvage value at the end of the economic life span of the investment, we assumed 20% of the initial value. Scheduled (planned) and productive time on an annual basis were used to derive a utilization rate for each piece of equipment. If vendors did not provide planned and productive hours, we assumed a utilization rate of 65% based on the average values for equipment presented by Miyata.[35] The utilization rate reflects the percent of scheduled hours during which the equipment was actually used to perform its intended function.

Several basic ownership and utilization metrics were used to calculate equipment costs using the following:

- Salvage value at the end of equipment economic life.
- Economic life in years.
- Scheduled operating time in hours per year.
- Productive time in hours per year.
- Utilization rate.

Table 14 summarizes ownership and utilization metrics by treatment system.

[34] Cost of attachment is included in the base equipment cost.
[35] Miyata, E.S. Determining fixed and operating costs of logging equipment. General Technical Report NC-55. Houghton, MI: USDA Forest Service, North Central Forest Experiment Station. 1980.

Table 14. Ownership and Utilization Metrics by Treatment System

Treatment System	Salvage Value	Economic Life (Years)	Scheduled Hours (Per Year)	Productive Time (Per Year)	Utilization Rate
Caterpillar 299D	$30,000	5	1,872	1,215	64.9%
FAE - Prime Tech PT175	$51,000	7.5	1,872	1,215	64.9%
Fecon FTX 128L	$40,000	5	1,872	1,215	64.9%
John Deere JD 210G	$54,000	20	1,872	1,560	83.3%
Kaiser S2	$74,800	5	1,872	1,215	64.9%
Takeuchi TB290	$27,589	8	1,872	1,215	64.9%
Takeuchi TL12	$23,611	8	1,872	1,248	66.7%
Timbco 425D	$101,000	10	1,872	1,755	93.8%

Fixed Costs

Depreciation, interest, insurance and taxes are all considered fixed costs, as they do not vary regardless of operating hours. We asked vendors to select between three methods used to calculate depreciation:[36]

- Straight line assumes constant annual depreciation over the life span of the equipment.
- Declining balance weights depreciation toward the early years of the equipment economic life.
- Sum of the years digits which is an alternate way of weighting depreciation toward the earlier years.

Other fixed costs such as interest, insurance and taxes were estimated on the basis of the average value of yearly investment accounts for annual investment in the equipment over its economic life. We estimate interest insurance and taxes on the basis of the Average Value of Yearly Investment (AVI). AVI is calculated as follows.

$$AVI = \left(\frac{(P-S)(N+1)}{2N}\right) + S$$

Where P = Initial Investment
S = Salvage value
N = Economic life in years

We estimate interest, insurance and taxes as 12%, 3% and 3% of AVI respectively based on Miyata.[37] Table 15 summarizes depreciation, AVI and fixed costs by treatment system.

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[36] See Miyata for a more detailed discussion of the different methods of estimating depreciation.
[37] Ibid.

Table 15. Annual Depreciation and Fixed Cost Data by Treatment System

Treatment System	Depreciation	Dep. Method	AVI	Interest	Insurance	Taxes
Caterpillar 299D	$25,102	declining balance	$98,520	$11,822	$2,956	$2,956
FAE - Prime Tech PT175	$27,200	Straight line	$166,600	$19,992	$4,998	$4,998
Fecon FTX 128L	$32,000	Straight line	$136,000	$16,320	$4,080	$4,080
John Deere JD 210G	$10,800	Straight line	$167,400	$20,088	$5,022	$5,022
Kaiser S2	$59,840	Straight line	$254,320	$30,518	$7,630	$7,630
Takeuchi TB290	$13,795	Straight line	$89,667	$10,760	$2,690	$2,690
Takeuchi TL12	$11,806	Straight line	$76,736	$9,208	$2,302	$2,302
Timbco 425D	$40,400	Straight line	$323,200	$38,784	$9,696	$9,696

Operating Costs

Operating costs, unlike fixed costs, will vary with the number of operating hours the equipment is utilized. Operating costs include fuel, lubricants and maintenance. Maintenance and repair is calculated based on Miyata as 110% of annual depreciation. Based on sales of diesel during the demos, we assume a fuel cost of $2.61/gallon and 0.24/gal in taxes. We estimate fully loaded labor costs of $15.82 for equipment operators based on US Bureau of Labor statistics for 2015.[38]

Table 16 summarizes hourly operating costs by treatment system.

Table 16. Hourly Operating Costs by Treatment System

Treatment System	Maintenance and Repair	Diesel Fuel	Lubricants	Total Operating Cost
Caterpillar 299D	$22.70	$11.10	$0.0147	$54.10
FAE - Prime Tech PT175	$24.60	$16.80	$0.0128	$57.60
Fecon FTX 128L	$29.00	$13.40	$0.0327	$62.10
John Deere JD 210G	$7.60	$16.70	$0.0282	$45.90
Kaiser S2	$54.20	$16.40	$0.0107	$88.50
Takeuchi TB290	$12.50	$7.20	$0.0207	$35.90

[38] Occupational Employment and Wages, May 2015 45-4029 Logging Workers, All Other. http://www.bls.gov/oes/current/oes454029.htm#(2)

Treatment System	Maintenance and Repair	Diesel Fuel	Lubricants	Total Operating Cost
Takeuchi TL12	$10.40	$11.50	$0.0143	$38.20
Timbco 425D	$25.30	$27.80	$0.0407	$71.90

Additional equipment-specific information is necessary to calculate equipment costs. Table 17 summarizes horsepower and lubricant data for each piece of equipment.

Table 17. Equipment Horsepower and Lubricant Data

Treatment System	Rated HP	Lubricant Reservoir (Gallons)	Oil Change Cycle (Hours)
Caterpillar 299D	106	3.5	500
FAE - Prime Tech PT175	160	3.04	500
Fecon FTX 128L	128	4.0	250
John Deere JD 210G	159	6.875	500
Kaiser S2	156	1.0	200
Takeuchi TB290	69	2.5	250
Takeuchi TL12	110	3.4	500
Timbco 425D	265	5.0	250

Total Hourly Costs

Using key economic data presented in Tables 13 through 16, total costs per Productive Machine Hour ($/PMH) were calculated for each piece of equipment. Table 18 summarizes costs per productive machine hour for each of the treatment systems.

Table 18. Total Hourly Costs for each Treatment System

Treatment System	Total Hourly Costs per Productive Machine Hour
Caterpillar 299D	$61.10
FAE - Prime Tech PT175	$74.60
Fecon FTX 128L	$74.10
John Deere JD 210G	$61.90
Kaiser S2	$115.80
Takeuchi TB290	$42.60
Takeuchi TL12	$43.00
Timbco 425D	$101.80

Findings

Summarized in Table 19 by demo site are results from the treatment systems deployment. Treatment production rate (Hours per Acre) and treatment cost rate ($ per Acre) are provided as standard metrics for comparison. Additional analyses were performed on production metrics as affected by slope, but trends were inconclusive due to limited availability of slope gradient ranges for treatment. Future work could address this issue if additional treatment acres with more varied slope conditions were included.

Production rates differ based on treatment system and application site. The cost per acre rate was lowest for nearly all equipment options at the Santa Rosa site, indicating it as the location with highest overall productivity. This is not surprising considering the homogeneous vegetation cover and slope conditions at Santa Rosa. The Big Bear Lake site contrasted in having the most expensive treatment cost rate for most equipment options. This is likely due to the varied vegetation cover, slope gradients and complex treatment prescription at Big Bear. Of notable exception is the Takeuchi TB290, which was least costly to operate at the Big Bear Lake site and most expensive at the Santa Rosa Site. This may be due to the low volume of acres treated by the Takeuchi TB290 at Santa Rosa (<0.5 acres) which may be a poor indicator of its true production rate.

Table 19. Treatment Cost per Acre by Production Site

Treatment System	Treatment Type	Shaver Lake ($/Acre)	Big Bear Lake ($/Acre)	Santa Rosa ($/Acre)	Hourly Rate ($/PMH)
Caterpillar 299D	Skid Steer	$122.81	$274.16	$76.89	$61.10
CCC Hand Crew	Biological	$1,681.63	-	-	$225.24
FAE - Prime Tech PT175	Skid Steer	$166.21	$192.34	$107.41	$74.60
Fecon FTX 128L	Skid Steer	$203.48	$253.88	$73.54	$74.10
John Deere JD 210G	Excavator	$614.50	-	-	$61.90
Kaiser S2	Excavator	$426.46	-	$398.97	$115.80
Ramona Tribe Hand Crew	Biological	-	-	$2,713.78	$189.28
Star Creek Land Stewards (goats)	Biological	$1,948.05	-	-	$41.00
Takeuchi TB290	Excavator	$348.37	$233.64	$385.43	$42.60
Takeuchi TL 12	Skid Steer	$112.12	$168.70	$77.13	$43.00
Timbco 425 D	Excavator	-	$166.56	-	$101.80

<u>Shaver Lake</u>

Cost rates showed that the goat treatment is the most expensive treatment option. While goats were fairly effective at reducing vegetation cover, the cost to transport and manage a herd dispersed over only three acres is not cost effective. If treating larger acreage, transport costs can be amortized across more acres. Herds operate continuously throughout the contract period and do not require daily transportation to and from the treatment site. While it is not possible to disassociate "work time" from idle time in goat treatments, goats are left on site well beyond the safe operating period (eight hours per day) of heavy machinery. Personal communication with the herders suggests that goat productivity may be increased by agitating the herd to increase hunger and concentrating the herd into smaller treatment areas.

Second most costly treatment was the CCC hand crew. Hand crews have relatively low production rates but may be guided towards specific treatment goals too complex for mastication equipment to achieve. For example, in this study, hand crews were instructed to pile woody material, effectively reducing surface fuel volume in contrast to mechanical masticators, which distributed fuels across the forest floor.

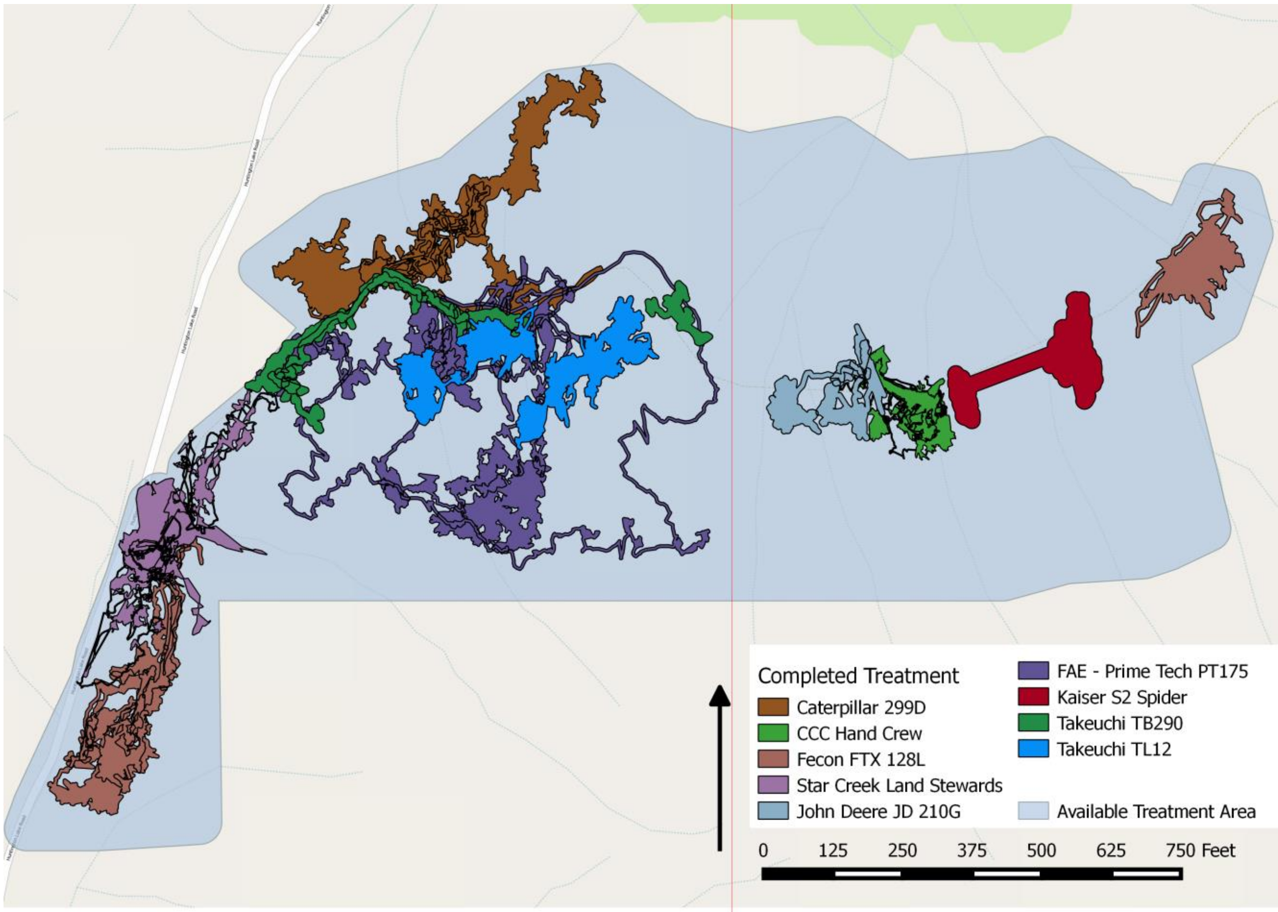
With equal masticating heads and prime mover size classes, it appears that boom mounts are a key factor in increased cost and decreased production rate. The John Deere was the most expensive mechanical treatment option at $614.50 per acre. While its cost per machine hour was among the lowest three methods reviewed (Table 19), it had the slowest production rate. This may be due to the operator not being fully conversant with this equipment. Being significantly larger than purpose built forestry machines, the John Deere had higher ground pressure and required careful operator control to minimize damage to soil and residual trees during treatment, decreasing production rate. The Kaiser's operating cost also exceeded $400 per acre, ranking it just below the John Deere among the most expensive mechanical methods tested. While it had the highest production rate among boom-mounted mastication equipment, cost per machine hour for the Kaiser treatment system was the highest of all equipment studied (Table 19). The Takeuchi TB290, although having the lowest cost per machine hour, also had a low production rate as is common among boom-mounted excavators, resulting in a higher cost rate than the remaining skid steer configurations. Considering the relatively gentle terrain and shrub dominated treatment areas, skid steer equipment was the most cost efficient treatment system. Biological treatments have low production rates and high hourly costs. Whereas boom-mounted excavators operate in discrete intervals (and have the ability to "reach-in" with boom mounted attachment to treat sensitive areas) and are better adapted to treat steep and rugged terrain, skid steer attached masticating heads can treat continuously as they move, boosting productivity. Table 20 summarizes acres treated (that were monitored), cost per acre, and hours per acre for the Shaver Lake site.

Table 20. Shaver Lake Site Acres Treated by Treatment System

Treatment System	Acres Treated	Cost per Acre	Hours per Acre
Caterpillar 299D	6.05	$122.81	2.01
CCC Hand Crew	1.46	$1,681.63	7.47
FAE - Prime Tech PT175	8.56	$166.21	2.23
Fecon FTX 128L	5.14	$203.48	2.74
John Deere JD 210G	1.57	$614.50	9.92
Kaiser S2	1.97	$426.46	3.68
Star Creek Land Stewards (goats)	3.08	$1,948.05	N/A
Takeuchi TB290	2.56	$348.37	8.18
Takeuchi TL 12	3.54	$112.12	2.60

Figure 16 is a map showing treatment system locations for the Shaver Lake demo.

Figure 16. Shaver Lake Site Treatment System Deployment Locations



<u>Big Bear Lake</u>

Cost rate analysis showed most treatment systems operating at similar cost rates. While generally more expensive than Shaver Lake on a per equipment basis, the variation in cost between mechanical treatment options at the Big Bear Lake site are much more closely aligned. This may be attributed to the more restrictive prescription applied at the Big Bear Lake site, equalizing some of the production efficiencies that might have otherwise been achieved at Shaver Lake and Santa Rosa.

Overall, the most efficient treatment equipment was the Timbco 425D. This may have been due to operator familiarity[39] with the treatment prescription, region and local practices. While having the highest production acres and fastest production rate, the cost per acre was closely followed by the Takeuchi TL12. With a lower $/PMH rate, the Takeuchi was able to treat the Big Bear Lake site at a similar cost rate, at half the production rate of the Timbco. The FAE Prime Tech PT 175, while capable of treating the landscape at a faster rate than the Takeuchi TL12, returned

[39] Sullivan Logging has completed several fuels treatment projects in the Big Bear Lake area.

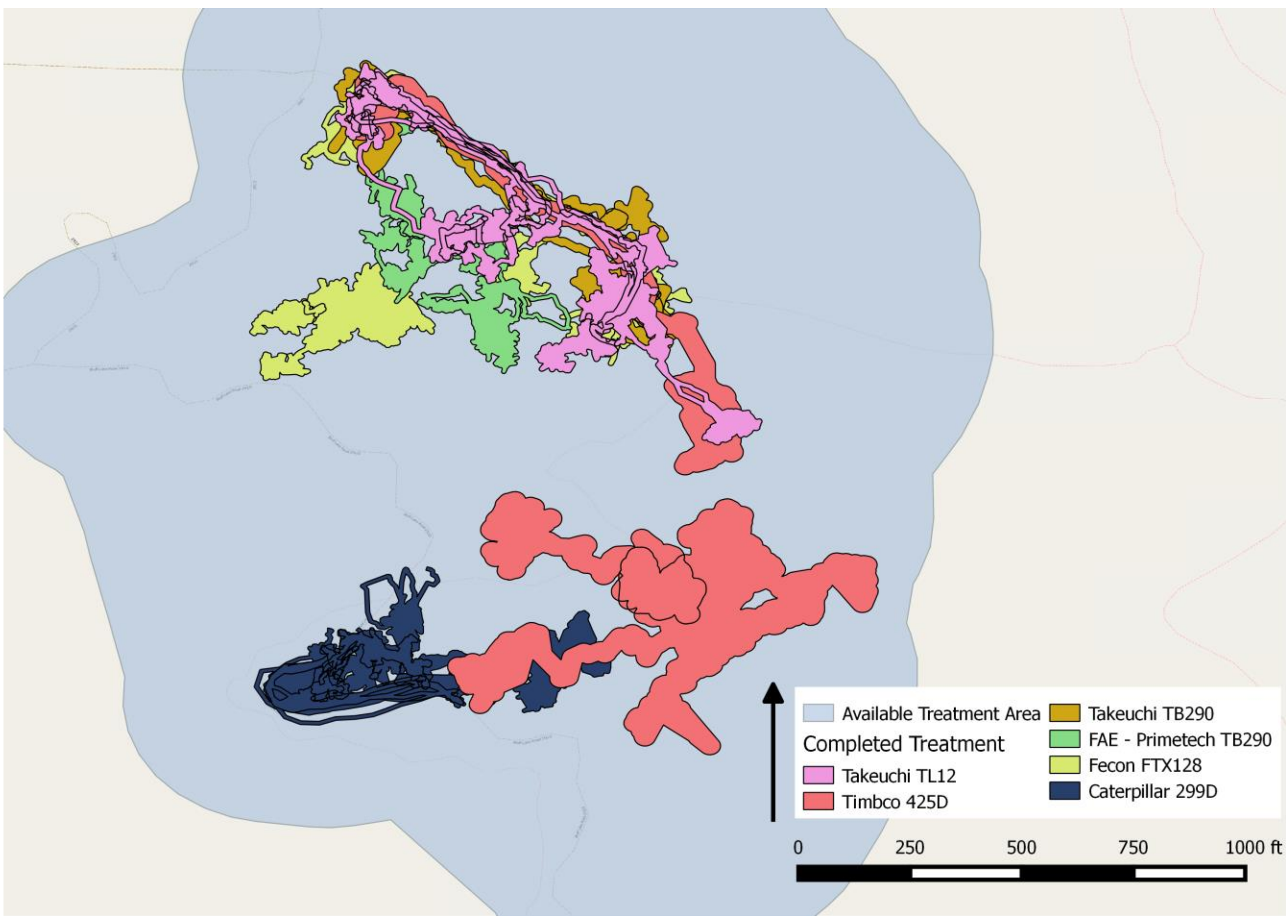
a higher Cost per Acre due to higher costs per machine hour. A more detailed breakdown of how these costs are calculated is provided in Table 21. Table 21 summarizes acres treated (that were monitored), cost per acre, and hours per acre for the Big Bear Lake site.

Table 21. Big Bear Lake Site Acres Treated by Treatment System

Treatment System	Acres Treated	Cost per Acre	Hours per Acre
Caterpillar 299D	2.96	$274.16	4.48
FAE - Prime Tech PT175	1.70	$192.34	2.58
Fecon FTX 128L	3.37	$253.88	3.42
Takeuchi TB290	2.74	$233.64	5.48
Takeuchi TL 12	3.34	$168.7	3.92
Timbco 425D	8.42	$166.56	1.64

Figure 17 is a map showing treatment system locations for the Big Bear Lake demo.

Figure 17. Big Bear Lake Site Treatment System Deployment Locations



Santa Rosa

All skid steer and integrated mastication equipment treatment systems were able to operate near or less than $100 per acre, a much lower rate than any of the other treatment sites. Boom-mounted masticators were more costly at just under $400/acre and biological treatment (hand crew) was the most expensive. This reinforces the results from the Shaver Lake site of boom-mounted equipment being a prime determinant in cost difference. Santa Rosa is additionally unique in that it had a heavy brush component with little species variation, which allowed operators to treat landscape with relatively little concern for retention species. This likely contributed towards increased production rate and lower cost. The advantages of boom-mounted masticators no longer play a role under these conditions except on steeper slopes or operating in sensitive locations. Table 22 summarizes acres treated (that were monitored), cost per acre, and hours per acre for the Santa Rosa site.

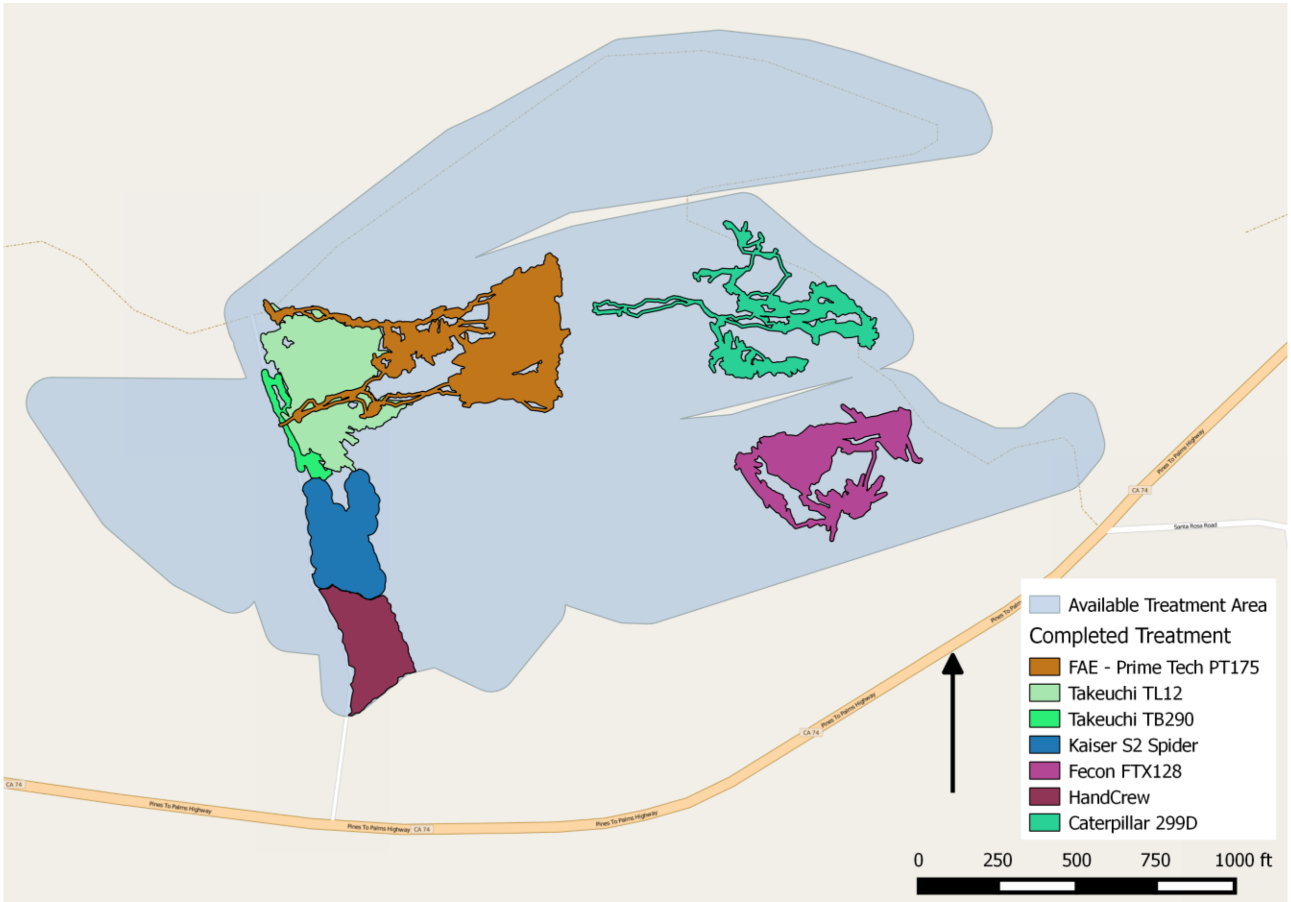
Table 22. Santa Rosa Site Acres Treated by Treatment System

Treatment System	Acres Treated	Cost per Acre	Hours per Acre
Caterpillar 299D	2.04	$76.86	1.26
FAE Prime Tech PT175	4.05	$107.41	1.44
Fecon FTX 128L	2.30	$73.54	.99
Kaiser S2	1.60	$398.97	1.44
Ramona Tribe Hand Crew	1.95[40]	$2,713.78	14.0
Takeuchi TB290	0.47	$385.43	9.05
Takeuchi TL 12	3.06	$77.13	1.79

Figure 18 is a map showing treatment system locations for the Santa Rosa demo.

[40] Acreage treated is an estimate.

Figure 18. Santa Rosa Site Treatment System Deployment Locations



Demo Attendance

Public participation in the HFRD project was significant, with a total of 295 guests in attendance across all three demos. Most of the participation was concentrated (by design) on demo day of the week-long implementation period at each demo site. Appendix H provides a detailed head count showing all vendor representatives, operators, volunteers and support staff, and participation by affiliation.

The HFRD demos attracted significant participation from a wide range of affiliations. Overall, the HFRD outreach goal of reaching a variety of target audiences was met. Media participation was not as strong as hoped, with media representation only at the Shaver Lake demo. Tribal participation at the Santa Rosa demo was significant, primarily due to effective outreach and assistance from the Bureau of Indian Affairs and the Natural Resources Conservation Service.

OBSERVATIONS

Fire/Fuel Impact

In summary, all of the fuel treatments significantly altered the fuel profiles at all three sites. The amount of dead woody material in the 10 and 100 hour time lag size classes generally increased. Predicted rates of spread, flame length, and heat released per unit area under 90th percentile weather conditions were reduced by all treatment systems – often to levels where direct attack using hand crews may be possible. The increase in dead woody fuel loading on these sites may increase the potential for below ground damage to root systems and other soil heat effects in the event that a smoldering, creeping type of fire were to become established. However, as dead woody debris decomposes over time, and is incorporated into the soil, this potential damage will be reduced.

Soil Impacts

Different terrain and ecosystem types result in site specific treatment prescriptions, which result in different post treatment results. For example, treatments at the Santa Rosa site, (a dense shrub dominated site) the results were much more inclined to have more significant effects on the soil due to more deliberate treatment. Overall soil impacts were minimal across all there sites.

Treatment Efficacy

Production rates differ based on treatment system and application site. The cost per acre rate was lowest for nearly all equipment options at the Santa Rosa site, indicating it as the location with highest overall equipment productivity. This was likely due to very consistent vegetation cover types, gentle terrain and treatment prescription that was simple to implement. The Big Bear Lake site contrasted in having the most expensive treatment cost rate for most equipment options. This was likely due to variable vegetation types, inconsistent terrain and complex treatment prescription. The Shaver Lake site demonstrated slightly lower costs per acre treated compared to Big Bear, and is likely reflective of a less complex treatment prescription. Like Big Bear Lake, the Shaver Lake vegetation cover and terrain were variable. The two most costly treatment systems were the goats and the hand crews. Balancing differences in production and cost rate are important features in contracting decisions, as limited time is available in any given field season to implement fuels treatment activities.

Demo Attendance

Public participation in the HFRD project was significant, with a total of 295 guests in attendance across all three demos. Most of the participation was concentrated on demo day of the week-long implementation period at each demo site. A key factor in achieving a successful attendance outcome was the use of online registration. Regarding media attendance, past experience (2002 Dry Forest Mechanized Treatment Trials) confirms that attracting media participation can be particularly challenging. Only four media representatives were in attendance (all at the Shaver Lake demo).

LESSONS LEARNED

Summarized below are lessons learned that can be applied to future fuels treatment demonstrations.

Post-Treatment Monitoring Expansion

Future opportunities include monitoring site conditions annually over an extended period of time, such as five or ten years. Soil conditions, vegetative response and woody debris decomposition rates over time are some of the key variables that the Science Advisory Committee felt deserved further study. Due to funding constraints, post treatment site conditions were only measured once.

Steep Terrain Trials

Consider replicating the HFRD demo to capture a greater variability in terrain range. Much of the landscape considered at risk to wildfire in California is located on steep terrain (over 35% slope gradient). Treatment systems have continued to evolve and innovate over time, with several systems having the capacity to treat vegetation cover on steeper terrain.

Woody Material Collection and Processing

Fuels treatment activities in California have the potential to provide forest biomass material as feedstock to support the State's renewable energy mandate (Renewable Portfolio Standard) and climate change mitigation goals (California Global Warming Solutions Act of 2006). More information is needed to determine optimized harvest, collection, processing and transport of excess forest biomass. Cost, effectiveness and impacts across numerous vegetation cover types in California would assist numerous efforts now underway to deploy community-scale biomass power generation facilities[41] at locations considered at risk to wildfire. In addition, expanding the analysis to evaluate potential removal of merchantable logs, as a possible revenue source, where feasible, could further assist land managers in evaluating strategies to reduce treatment costs. Though limited opportunities currently exist for adding value to residual material harvested, identification of alternative utilization strategies for further evaluation and investment in technology development and emerging markets could extend the reach and value of vegetation treatment options.

[41] Consistent with Senate Bill 1122, BioMAT program.

Appendix A

Shaver Lake Communications Plan

HAZARDOUS FUELS REDUCTION DEMONSTRATION COMMUNICATION PLAN SHAVER LAKE SITE

The USDA Forest Service and other partners, is sponsoring a series of hazardous fuels treatment demonstrations (demos) at strategic locations in Central and Southern California. Target audiences include fire agencies, natural resource managers, electric utilities, water conservation districts, homeowner associations, fire safe councils, county and city planning departments, fuels treatment contractors, and other stakeholders.

September 21, 2015 Update

DEVELOPMENT AND REVIEW TEAM

Developed by:	Tad Mason	Date: 2/1/15
Reviewed by:	Paul Griffo	Date: 6/8/15
	Calvin Rossi	Date: 2/20/15
	Ted Luckham	Date: 2/20/15
	Rich Bagley	Date: 2/20/15
	Iveth Hernandez	Date: 9/1/15
Accepted by:	Ted Luckham	Date: 2/24/15

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EXECUTIVE SUMMARY

The Hazardous Fuels Reduction Demonstration project (HFRD) will evaluate fuels treatment techniques and equipment used to treat hazardous fuels on landscapes that are indicative of areas currently at risk to catastrophic wildfire. The project will conduct realistic fuels treatment demonstrations at three locations in Central and Southern California and synthesize and disseminate the results.

Treatment demonstrations will be approximately one week in duration at each location and will provide equipment vendors the opportunity to demonstrate conventional and innovative equipment and techniques that might not be currently utilized in a local area. Equipment and techniques used for the demos will be monitored for effectiveness, efficiency, cost, and resource impacts (e.g., soil disturbance, fire behavior mitigation). Once completed, results of the demos will be synthesized and disseminated to previously identified target audiences and others.

This communication plan provides a comprehensive framework for actions that will support successful outreach and communication. The goals are to facilitate appropriate media coverage; ensure interested local groups, organizations and contractors can observe the demos and ask questions; and ensure the results reach interested parties.

The primary target audience includes natural resource professionals, community-based stakeholders (e.g., fire safe councils) and potential contractors for mechanized fuels reduction work. The goal is to inform them of the demos, engage their interest, encourage their participation, and inform them of the results. They will gain the following:

- More information about fuel treatment technologies including conventional and innovative equipment;
- Treatment capabilities;
- Treatment costs and;
- Resource (e.g., soil, habitat) impacts.

Secondary audiences include forest landowners, local schools, media, and non-government organizations involved in small wood and biomass utilization efforts, and industry associations. The goal is to inform them of the following:

- Hazardous fuels treatment opportunities;
- Techniques;
- Technologies – both conventional and innovative;
- Concurrent costs and impacts.

Finally, communication with stakeholders interested in natural resource management, in general, will increase their understanding of the complexities of fuel treatment activities.

The communication goals will be achieved using a variety of methods including media releases, tours, industry contacts and networks, public meetings, and publication/dissemination of results.

BACKGROUND

Throughout much of the West, concentrations of hazardous forest fuels are placing rural communities, critical infrastructure (e.g., roads, power lines), sensitive habitat and entire watersheds at significant risk to catastrophic wildfire. Between 2006 and 2010 over 900,000 acres per year were impacted by wildfires in the state of California. Fire suppression costs alone averaged over $1.2 billion per year in this same time period.[1] California is now in the fourth year of an extended drought and is currently anticipating one of the most active fire seasons on record.

A primary factor influencing the intensity of these wildfire events is the unnaturally high concentrations of vegetation. As noted in the April 1999 General Accounting Office report (GAO/RCED-99-65) *Western Forests: A cohesive Strategy is Needed to Address Catastrophic Wildfire Threats*, ***"The most extensive and serious problem related to the health of national forests in the interior West is the over-accumulation of vegetation"***

A century of successful fire exclusion efforts have facilitated a serious and unnatural concentration of vegetation - mostly small trees and brush. To restore the health of at risk landscapes and reduce the risk of wildfire, these dense stands require treatment. This treatment of non-commercial trees and brush – also know as biomass, is fast becoming the fuel management option of choice for land managers throughout the West. In many cases the removal or mastication of excess forest biomass is a pre-treatment technique used to prepare the landscape for the introduction of prescribed fire.

Many studies have looked at the mechanical treatment of hazardous fuels. However, very few have included the opportunity to observe an array of different treatment techniques and equipment in the same location, interface with knowledgeable and experienced operators, and obtain a follow-up summary about results and performance. One of the few known examples was a project involving a series of fuels treatment trials conducted in three western states (Washington, Idaho, and Oregon) in 2002 (Dry Forest Mechanized Fuels Treatment Trials, TSS Consultants/The Yankee Group).
http://ucanr.edu/sites/WoodyBiomass/newsletters/Woody_Biomass_Related_Publications50962.pdf

These trials earned numerous positive reviews because of their focus on local situations and partner groups, and they provided information not previously available about effectiveness and costs. The demos planned for central and southern California would be focused on unique site conditions and vegetation management in this region and the ability of the most suitable equipment or processes to address excess fuel buildup.

Results from the HFRD project will be processed, synthesized and distributed to interested parties including natural resource managers, local contractors, community organizations, media, and other interested parties to aid on the ground efforts in the pro-active treatment of hazardous fuels.

Outlined below is a summary of the HFRD project administrative structure:

- **PRIMARY FUNDING SUPPORT:** Southern California Edison, USDA Forest Service, Natural Resource Conservation Service

- **ADMINISTRATION:** TSS Consultants and The Watershed Research and Training Center

[1] Data provided by Cal Fire, USDA Forest Service and Bureau of Land Management.

- **IMPLEMENTATION - CONTRACTORS:** TSS Consultants
- **IMPLEMENTATION – AGENCY PRIMARY SUPPORT:**
  - Southern California Edison
  - Sierra National Forest
  - Natural Resource Conservation Service
- **IMPLEMENTATION – NGO/AGENCY ADDITIONAL SUPPORT:**
  - UC Berkeley Extension
  - Norcal Society of American Foresters - High Sierra Chapter
  - Highway 168 Fire Safe Council
  - Dinkey Collaborative
  - Sierra Resource Conservation District
  - Cal Fire

PROBLEM OR OPPORTUNITY STATEMENT

Problem Statement:

1. Throughout much of Central and Southern California, concentrations of hazardous forest fuels are placing rural communities, sensitive habitat (including threatened and endangered species), entire watersheds and strategic infrastructure at significant risk to catastrophic wildfire events. Hazardous fuels include a high concentration of biomass[2] and/or small trees.

2. To aid in restoration of the ecological health of at risk landscapes, unnaturally high concentrations of biomass material requires treatment. Some information exists addressing treatment and removal of biomass. More information needs to be gathered about effectiveness, cost of treatment, and on site impacts.

3. Public perceptions to fuels treatment and harvest activities are not always positive.

Opportunity Statement:

1. Southern California Edison and the USDA Forest Service are sponsoring forest fuels reduction demonstrations at three locations in central and southern California. It is anticipated that information from this work will aid efforts to proactively treat hazardous fuels, in the West.

2. Hazardous fuels reduction projects could potentially contribute additional economic opportunities for local contractors and communities.

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[2] Biomass – the living or dead weight of organic matter in a tree, stand or forest (Dictionary of Forestry, Society of American Foresters, 1998).

3. Reducing excess fuels on at risk landscapes will mitigate wildfire behavior thus protecting communities, habitat, and valuable infrastructure from the impacts of catastrophic wildfire.

4. Reducing excess fuels on at risk landscapes will mitigate wildfire behavior thus reducing greenhouse gas emissions associated with wildfire events.

5. California's watersheds are at significant risk to wildfire events (e.g., 2013 Rim Fire impacted city of San Francisco's domestic watershed and power generation assets near Yosemite National Park).

6. Field demonstration of conventional and innovative techniques and equipment will contribute to the reduction of the relatively high financial cost of hazardous fuels reduction. An ancillary benefit is the potential to cost effectively remove and utilize excess woody biomass material for value-added uses such as soil amendment products and feedstock for bioenergy production.

7. Fire suppression costs (financial and societal costs) are significant. Investing on a pre-fire basis has proven to be very cost effective.

8. Returning our watersheds to a more fire resilient state will protect them from potential impacts of wildfire. Healthy, functioning watersheds typically yield high volumes of water.

PRIMARY GOAL

Successfully demonstrate to natural resource managers, landowners, private contractors, agency personnel and other stakeholders, the options available to treat excess biomass material and return landscapes to a more natural and fire resilient condition. This will lead to more fuels treatment activities that will decrease fire risk and provide economic opportunities to local communities.

The primary purpose of the demos is to raise awareness about different hazardous fuels treatment alternatives and provide key stakeholders with up-to-date information regarding resource impacts, efficiencies and cost of fuels treatment equipment and techniques. Both conventional and innovative equipment and techniques will be deployed and resource professionals will be on site to answer questions.

OBJECTIVES

Short term objectives of this project include:

- Improved ability of agencies to plan and budget for future fuels treatment projects.

- Development of an informed cadre of local fuels treatment contractors and local stakeholder groups (e.g., fire safe councils, homeowners association, resource conservation districts).

- Outreach to the general public (e.g., media, homeowners, forest landowners) with regards to fuels treatment opportunities, techniques and latest technology.

- Secure public support for increasing the pace and scale of fuels treatment activities.

- Promotion of cost effective, minimum impact fuels treatment alternatives.

Long-term objectives include:

- Significant increase in the number of acres treated in support of the reduction of hazardous fuels and improvement of the ecological health of at risk landscapes.
- Reduction of site impacts from fuels treatment activities.
- Creation of long-term sustainable jobs.
- Promotion of an informed public, one that more fully appreciates the complexities of fuels treatment efforts and the statewide challenge of creating and maintaining fire resilient landscapes.
- Improved timber production and yield which results in this improved GHG reduction and better carbon retention.
- Improved water yeilds, timimg and quality.

AUDIENCES

Key Audiences

1. Independent Contractors – Interested in purchasing equipment and or fiber purchasers (small diameter logs, biomass). Appendix A
2. Small Woodland Associations – Forest Landowners of California
3. Professional organizations – Associated California Loggers, California Licensed Foresters Association, Norcal Society of American Foresters, SoCal Society of American Foresters, Sierra Cascade Logging Conference, Redwood Regional Logging Conference.
4. Key State and Federal Agencies – USDA Forest Service, Cal Fire, Bureau of Land Management, Natural Resource Conservation Service, National Park Service, California State Parks.
5. Other Agencies – US Fish and Wildlife Service, California Fish and Wildlife Service, National Marine Fisheries Service, Bureau of Indian Affairs, California Department of Water Resources, California Air Resources Board, Resource Conservation Districts, Resource Conservation and Development Councils, Elected Officials – Federal, State, County
6. NGO's - Watershed Councils, Advisory Councils, Conservation organizations, Dinkey Collaborative (list may not be available), Central Sierra Historical Society, California Forestry Association, Fire Safe Councils.
7. Media and general public. (Database from SCE Local Public Affairs staff? Add as Appendix?)
8. Local schools – Shaver Lake area and Central Valley. Reedley Com College. Local High School (Sierra HS) – vocational classes and science oriented classes. Maybe Cal Poly?
9. Local fire district. (Deploy fire truck on site).
10. Other utilities: PG+E, SDG+E, SMUD, Cooperatives, other?

KEY MESSAGES

- The HFRD is intended to raise awareness about different hazardous fuel treatment alternatives and provide key stakeholders with up-to-date information regarding resource impacts, efficiencies, and cost of fuels treatment equipment and techniques.

- The HFRD will improve the ability of natural resource managers to plan and budget for fuel treatment projects, increasing their ability to reduce wildfire risks and improve the overall health of watersheds and vegetative ecosystems in central and southern California.
- Information learned from these demonstrations, will help public and private land managers be better equipped to conduct fuel treatments that reduce impacts on other resources and are cost effective.
- Mechanized fuels treatment techniques are one of many different tools used to help restore ecosystem health and reduce the risk of wildfire. Mechanized fuels treatments often work in conjunction with other methods.

IMPLEMENTION PLAN

Outlined below is the draft implementation plan.

Completion Date	Activity	Purpose	Responsible Parties
2/1/15	Draft Final of Shaver Lake Com Plan.	Meet HFRD objectives	Tad Mason
2/23/15	Finalize Com Plan, generate key contacts/target audience list.	Assure info reaches target audience	Tad Mason Rich Bagley Ted Luckham Calvin Rossi Paul Griffo
3/15/15	Outreach to key target audience (e.g., Fire Safe Councils) to save the date.	Solicit support and participation	Rich Bagley Tad Mason
7/15/15	Issue Project Announcement with registration form and Project Overview.	Assure target audience participation	Peter Tittmann (UC Extension) Tad Mason
8/1/15	Issue Media Advisory with Briefing Paper targeting print media (long-lead publications). Request that they embargo the publication – like trade publications (not release article until close to date of the demo).	Assure media participation. Paul to develop short list of targeted publications.	Tad Mason
8/15/15	Make personal contact with target audiences.	Assure target audience participation	Tad Mason Rich Bagley
9/22/15	Contact local officials and staff	Recommend they attend Media day	Calvin Rossi
9/22/15	Contact area print Media – Mountain	Request public notice of	Tad Mason

	Press	HFRD Demo day – 10/9	
9/28/15	Issue Media Alert (who, what, where, why). Include description of visual possibilities (equipment, landscape, etc.). Conduct follow-up calls (to assure participation).	Assure media participation. Paul Griffo to help pitch local media.	Tad Mason Paul Griffo Iveth Hernandez
10/05/15	Equipment is mobilized to Shaver Lake site.		Tad Mason
10/8/15	Conduct Media Day (may coordinate this with Demo Day so that Media can interview guests and participants). Issue Press Release.	Assure media participation	Tad Mason Calvin Rossi Rich Bagley Iveth Hernandez Paul Griffo
10/9/15	Demonstration Day - Invite SCE video crew to document (story for online Newsroom?).	Assure target audience participation	Tad Mason Calvin Rossi Rich Bagley
10/9/15	Interview guests (post-demo) using evaluation form.	Confirm what was effective and where to improve communications	Tad Mason
10/10/15	Equipment is de-mobilized from Shaver Lake site.		Tad Mason
10/12/15	Communications Team de-brief.	Evaluate communications effectiveness	Tad Mason Calvin Rossi Rich Bagley Ted Luckham Others?

COMMUNICATION TOOLS/PRODUCTS

			Target Audience					
Communication Tool	**Prepared By**	**Reviewed By**	**Independent Contractors**	**NGO's**	**Land Management Agencies**	**Other Agencies**	**Elected Officials**	**Media & Public**
Media Alerts/Media Advisories	Tad Mason	Calvin Rossi Paul Griffo Ted Luckham	X	X	X	X	X	X
Fact Sheet/Project Overview	Tad Mason	Calvin Rossi Paul Griffo Ted Luckham Iveth Hernandez	X	X	X	X	X	X
Website Updates (Camp Edison, Hwy 168 FSC, Dinkey Collaborative and UC Extension)	Peter Tittmann Rich Bagley		X	X	X	X	X	X
Media Briefing Paper	Tad Mason	Calvin Rossi Paul Griffo Ted Luckham						X
Evaluation Form(s) (for guests as they exit the demo)	Tad Mason		X	X	X	X		

Other communication tools include:

Establish a web site or link for participating agency home page showing digital photos of the equipment and final report results.

http://ucanr.edu/HFRD

And the on-line registration site:

http://ucanr.edu/register_hfrd

EVALUATION

Did we accomplish the objectives of plan? There are two ways to evaluate the plan's effectiveness:

Nominal evaluation

Communication Tool	Completed Tasks
Talk Points	Yes
Media Advisory	Yes
Media Alert	
Website updates	Yes
Briefing Paper	
Evaluation Form	
Media Contacts	
# Of web site hits and media spots/articles	

Effectiveness or outcomes evaluation

Include participant evaluation/feedback

Attitude change, and opinion change

KEY CONTACTS – COMMUNICATIONS PLAN

Rich Bagley, SCE Forestry
Paul Griffo, SCE Corporate Communications
Iveth Hernandez, Public Affairs Assistant, Sierra National Forest
Calvin Rossi, SCE Local Public Affairs
Ted Luckham, SCE Regulatory Affairs
Tad Mason, TSS Consultants

CONTINGENCY CONSIDERATIONS

- *The major variable here is weather. Rain or shine the demo will proceed. Snow will likely force cancellation or delay.*

- *Safety considerations – parking, sanitation, safety equipment, sunscreen, hat, sturdy shoes, and field wear.*

REFERENCES

- National Fire Plan – http://www.fs.fed.us/rm/science-application-integration/national-fire-plan/

- GAO Report – "*Western Forests: A Cohesive Strategy is Needed to Address Catastrophic Wildfire Threats"* – http://www.gao.gov/products/GAO/rced-99-65

- GTR 220 An Ecosystem Management Strategy for Sierra Mixed-Conifer Forests http://www.fs.fed.us/psw/publications/documents/psw_gtr220/

LIST OF CONTACTS

USDA Forest Service:

- USDA Forest Service – Region 5 staff
- Sierra NF – Supervisor Office staff and local Ranger Districts
- Pacific Southwest Research Station Research Station

Industry Contacts:

- California Forestry Association
- Sierra Forest Products
- Sierra Pacific Industries
- Local logging and fuels treatment contractors (Appendix A)
- Others?

Professional Associations:

- Norcal SAF High Sierra Chapter
- California Licensed Foresters Assoc
- Associated California Loggers
- Sierra Cascade Logging Conf
- Redwood Regional Logging Conf
- California Forest Soils Council
- Other?

Elected Officials Contacts:

- Federal Congressional Offices
- State Legislative Offices
- County Supervisors

State Senator Tom Barryhill (R-8th District)
Contact: Mary Alice Kaloostian
Phone: 559-253-7122
e-mail: maryalice.kaloostian@sen.ca.gov

Assemblyman Jim Patterson
Contact: Jane Metcalf
Phone: 559-446-2029
e-mail: jane.metcalf@asm.ca.gov

Debbie Poochigian, 5th District Supervisor and Chairman of the Board
Contact: Susan Lambedian
Phone: 559-600-5000
e-mail: dpoochigian@co.fresno.ca.us

Media Contacts: (Include news release, fact sheet, website address, briefing paper)

- Valley Gold, PBS – (Elizabeth Laval)
- Television Stations – Local, PBS Amy Osterburg (559.301.0783)
- Fresno Bee
- Radio Stations AM, FM, NPR
- News Papers.
- Loggers World Pub
- Timber Harvesting Pub
- Timber West Pub
- Other?

Mountain Press
Reporter: Tom Catchpole
Phone: 559-855-2194
e-mail: Treecookies@netptc.net

Fresno Bee
Reporter: Tim Sheehan
e-mail: tsheehan@fresnobee.com

KSRW-TV, Bishop
Contact: Bennett Kessler
(760) 873-5329
Email: bkessler@sierrawave.net

KBAK-TV, Bakersfield
661-327-7955
news@bakersfieldnow.com

KERO-TV, Bakersfield
661-637-2323

news@kero.com

KFAZ-TV, Fresno
559-738-8880

KFSN-TV, Fresno
559-442-1170

KFTV-TV, Fresno
559-222-2121
kvtvnews@univision.net

KGMC-TV, Fresno
559-=435-7000
info@cocolatv.com

KGET-TV, Bakersfield
661-283-1700
17news@kget.com

KGPE-TV, Fresno
559-222-2411
newsdesk@cbs47.tv

KMPH-TV, Fresno
559-255-2600
newsdesk@kmph.com

KNSO-TV, Fresno
559-252-5101
publicidad@holacuidad.com

KSEE-TV, Fresno
559-222-2411
newsdesk@ksee.com

Mammoth Times
760-934-3929
editor@mammothtimes.com

Mariposa Gazette
209-966-2500
editor@mariposagazette.com

Mid-Valley Publications
209-358-5311
info@midvalleypub.com

Sierra Star
559-683-4464
editorial@sierrastar.com

Visalia Times Delta
559-735-3200
news@visaliatimesdelta.com

Other Land Management and other agency contacts:

- Cal Poly SLO
- Humboldt State
- UC Berkeley
- Rural Homeowner Association Officers – Wilderness Ranch
- BLM
- USFWS
- NMFS
- USFWS
- Resource Conservation and Development Councils

Local Agencies/Organizations:

- Sierra Resource Conservation District
- Yosemite-Sequoia Resource Conservation and Development Council
- Local Fire Departments
- Other?

Shaver Lake Visitors Bureau
Contact: Keith Davis
Phone: 559-841-2923
e-mail: ck.dj@live.com

Huntington Lake Big Creek Historical Conservancy/Huntington Lake Association
Contact: Chris Oberti
Phone: 559-299-7030
e-mail: twico@earthlink.net

Conservation/Sportsman/Recreation Organizations:

- Primary contact with be the Dinkey Collaborative
- Other?

Other State/Federal/local Agencies:

- Cal Fire
- Dept. of Fish and Wildlife
- US Fish and Wildlife
- NOAA
- NMFS

- Local Air Districts
- Other?

Other Utilities:
- PG+E
- SDG+E
- SMUD
- Other?

Appendix B

HFRD Participant Registration Form

Hazardous Fuels Reduction Demonstrations in Central and Southern California

Background

The USDA Forest Service, in conjunction with the University of California Center for Forestry, TSS Consultants and other partners, is sponsoring a series of hazardous fuels reduction demonstrations (demos) at strategic locations in central and southern California. Demos are one week in duration at each location (three locations total) and will include a demo day (Friday of each week) for guests to view operations first hand. The primary purpose of the demos is to raise awareness about different hazardous fuels treatment alternatives and provide key stakeholders with up-to-date information regarding resource impacts, efficiencies and cost of fuels treatment equipment and techniques. Both conventional and innovative equipment and techniques will be deployed and resource professionals will be on site to answer questions. Vendors that will be showcasing their equipment include Caterpillar, FAE - Prime Tech, Fecon, John Deere, Kaiser, Morbark, Star Creek Land Stewards (goats) and Takeuchi. For a complete list of equipment go to the HFRD webpage: http://ucanr.edu/HFRD Once completed, results of the demos will be summarized and disseminated.

Demo Day - Where & When

- Shaver Lake, CA (high elevation Sierra Nevada mixed conifer) – October 9, 2015
- Big Bear Lake, CA (high elevation San Bernardino mixed conifer) – October 16, 2015
- Santa Rosa Indian Reservation, Mountain Center, CA (mid elevation chaparral) – November 20, 2015

Who Should Attend

Target audiences include fire agencies, natural resource managers, fuels treatment contractors, electric utilities, water conservation districts, homeowner associations, fire safe councils, resource conservation districts, tribal staff, county and city planning departments, elected officials, and any others interested in fire safe practices.

How to Register

Additional information, including demo locations and an online registration form, can be accessed using this link:
http://ucanr.edu/register_hfrd Alternatively, the attached registration form can be used and returned via USPS. However, online registration is preferred. Please register early (no later than October 1) as space will be limited.
There is no registration fee to attend the demos.

What to Bring

- Field clothes including long-sleeved shirt, pants, hiking boots
- Sunscreen, water, lunch
- Safety gear such as hard hats and goggles (these will be provided if you do not have them)

Contacts

Tad Mason, TSS Consultants, 916.600.4174 tmason@tssconsultants.com
Peter Tittmann, UC Center for Forestry, 510.665.3518 pwt@berkeley.edu
Larry Swan, Region 5, USDA Forest Service, 707.562.8917 lswan01@fs.fed.us
Ted Luckham, Southern California Edison, 626.302.1752 theodore.luckham@sce.com

Project Partners

- USDA Forest Service
- Southern California Edison
- University of California Center for Forestry
- TSS Consultants
- Big Bear Fire Authority
- California Conservation Corps
- California Forestry Association
- CAL FIRE
- Natural Resources Conservation Service
- Santa Rosa Band of Cahuilla Indians
- Stand Dynamics, LLC
- Sullivan Logging
- The Nature Conservancy
- The Watershed Research and Training Center
- University of California Davis Biological and Agricultural Engineering

Hazardous Fuels Reduction Demonstration Registration Form

Use this link to Register Online: **http://ucanr.edu/register_hfrd**

Print Form Below to Register by Mail (note: online registration is preferred)

Mail-In Registration Form

Name: ____

(One name per form. This is how your name will appear on your nametag.)

Organization: ______________________________________

Address: ____

City: __________________________ **State:** _______________

Zip Code: ___________________

Email Address: _______________________________________

Which demos do you plan to attend, and when would you arrive?

(Please circle all that apply)

Shaver Lake, CA – Oct 9, 2015 – 9am 10am 11am 12noon 1pm 2pm

Big Bear Lake, CA – Oct 16, 2015 – 9am 10am 11am 12noon 1pm 2pm

Santa Rosa Indian Res, Mountain Center, CA – Nov 20, 2015 - 9am 10am 11am 12noon 1pm 2pm

Mail This Registration Form To:

Peter Tittmann

UC Cooperative Extension

1301 South 46th Street

Richmond, CA 94804

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Appendix C

Monitoring Protocol

Site Condition and Productivity Monitoring Protocol

Designed for use in the 2015 Hazardous Fuels Reduction Demonstration

Fuels, Soils, Grazing/Vegetation, Photography, Time and Motion

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Ricky Satomi, UC Berkeley, Center for Forestry
Peter Tittmann, UC Berkeley, Center for Forestry

Table of Contents

Overview

The objective of data collection from the Hazardous Fuels Treatment Demonstration is to evaluate the efficacy and cost of each treatment system (one or many pieces of equipment or other means used within a treatment unit) in achieving the desired stand condition. In addition to evaluating treatment effect on vegetation, secondary goals are to:

1. Evaluate the impact of treatment operations on soil conditions
2. Systematically document through photos and video

Monitoring of this project involves analysis of several biotic and abiotic features that may be impacted by operational treatment including:

- Live woody vegetation to parameterize ecosystem type
- Fuel and vegetation analysis will be performed for the purpose of identifying impact of treatment on reducing risk of fire ignition as well as fire spread and intensity. Modeling will be performed by the USFS using data from the Brown[1] line (planar) transect procedure.
- Soil monitoring will be performed for the purpose of identifying impact of treatment on soil disturbance as a factor of compaction and vegetation stress. The USFS Forest Soil Disturbance Monitoring Protocol will be followed to collect data before and after treatments.
- Photographic monitoring will be performed for the purpose of identifying impact of treatment on qualitative aspects of the ecosystem including but not limited to: public perception of treatment impact, soil disturbance severity, and light availability.
- System Productivity and Cost will be monitored to provide quantitative benchmarks assisting landowners in selecting equipment to optimize management objectives and cost.

Location	**Mountaintop Ranger District**	**Santa Rosa Band of Cahuilla Indian Tribe**	**Southern California Edison**
Treatment Size	~ 50 Acres	~ 60 acres	~ 60 acres
Ecosystem Type	Montane Mixed Conifer, Mixed Chaparral, Hardwood, Meadow	Chamise, White Thorn, Red Shank, and Oak	Mixed Conifer, Mixed Chaparral, Hardwood, Meadow
Treatment Types	Mastication	Mastication, Goats	Mastication, Goats, Hand Treatment

Sampling Design

Plot sampling intensity varies at each HFRD site based on availability of personnel to collect data. A minimum of one randomly located 1/10th acre plot is measured for each geospatial stratum. Each plots will monitor a comprehensive suite of live and dead vegetation, soil characteristics, and photographs. Strata are defined with the following classifiers:

[1] https://www.frames.gov/partner-sites/firemon/sampling-methods/

1. Treatment unit boundaries (UB)
2. Forest structure (FS)
3. Slope (S)
4. Vegetation Type (VT)

Production sampling will be completed for every piece of equipment for any period of time of operation. Operation status, cost, rate, and completeness will be collected regardless of geospatial location.

Monitoring Design

Vegetation

The FIREMON Density (DE) method is used to assess changes in plant species density and height for a macroplot. This method uses quadrats and belt transects, transects having a width, to sample within stand variation and quantify statistically valid changes in plant species density and height over time. Herbaceous plant species are sampled with quadrats while shrubs and trees are sampled with belt transects. Quadrats for sampling herbaceous plants are placed systematically along randomly located transects. Belt transects for sampling shrub and tree density use the same randomly located transects. The number of individuals for each plant species in a quadrat or belt transect are calculated. Density is calculated as the number of individuals per unit area using the area of the sampling unit, quadrat or belt transect. This method is primarily suited for grasses, forbs, shrubs, and small trees in which individual plants or stems can be distinguished. However, we recommend using the FIREMON TD sampling methods for estimating tree density.

- ➢ Density Sampling Methods (PDF)
- ➢ Density Sampling Equipment (PDF)
- ➢ Density Field Descriptions (PDF)
- ➢ Density Sampling Form (PDF)
- ➢ Density Sampling Cheatsheet (PDF)

Fuel Load

A line transect technique which estimates loadings of downed dead woody in a variety of size classes (Brown 1979). Litter and duff depths will be estimated along the transect using methods outlined in Keane (1999). The Fuel Load methods (FL) are used to sample dead and down woody debris, depth of the duff/litter profile and estimate the proportion of litter in the profile. Down woody debris is sampled using the line transect method (Brown 1974). Pieces are tallied in the standard fire size classes: 1-hour (0-0.635 cm), 10-hour (0.635-2.54 cm), 100-hour (2.54-7.62 cm). Pieces greater than 7.62cm are recorded by diameter and decay class. Duff and litter depth are measured at two points along each of 25-meter line transect segments. Litter depth is estimated as a proportion of total duff and litter depth.

- ➢ Fuel Load Sampling Methods (PDF)
- ➢ Fuel Load Sampling Equipment (PDF)
- ➢ Fuel Load Field Descriptions (PDF)
- ➢ Fuel Load Sampling Form (PDF)

➢ Fuel Load Sampling Cheatsheet (PDF)

Soil Disturbance

The Forest Soil Disturbance Monitoring Protocol (FSDMP) is a publication of the Rocky Mountain Research Station and describes how to monitor forest sites before and after ground disturbing management activities for physical attributes that could influence site resilience and long-term sustainability. The attributes describe surface conditions that affect site sustainability and hydrologic function. Monitoring the attributes of surface cover, ruts, compaction, and platy structure can also be used to generate best management practices that help maintain site productivity.[2][3]

The FSDMP provides specific techniques to sample for soil disturbance effects. We will implement the FSDMP protocol to evaluate impacts of fuels treatments. Field data collection will follow the steps outlined beginning on page 11 of the FSDMP: Volume I: Rapid assessment. ***If additional time and resources are available***, the following shear strength and moisture data will be collected at each FSDMP sample location.

Photo Tracking

Photo Tracking will be completed by utilization of photographic spheres. Alternative photographic methods have been developed in the past, but recent advances in image capture technology has led us to develop an alternative prescription. Photos will be taken pre and post management as an ocular estimate. Use of photographic spheres will allow for a comprehensive capture of site assessment, including canopy cover, soil conditions, and general vegetation change. Previously developed protocols are as follows, but are only provided as comparison points to the current model being used.

➢ Point Photo Monitoring (PDF)

Field Monitoring Procedure (Pre and Post Treatment)

Complete the attached datasheet (appendix ?) at each plot. Collect data in the order of appearance shown below. ✎ Denotes critical areas where data is to be recorded.

Equipment Checklist

Required for Plot Establishment ONLY

- ❏ 1 Roll Tivek flagging
- ❏ Steel Spikes for Plot Center
- ❏ Hatchet
- ❏ High Precision GPS (Trimble)
- ❏ Zip Ties
- ❏ Orange Spray Paint

[2] 1. Page-Dumroese DS, Abbott AM, Rice TM. Forest Soil Disturbance Monitoring Protocol: Volume I: Rapid assessment. General Technical Report - USDA Forest Service. United States Department of Agriculture, Forest Service; 2009 http://www.fs.fed.us/t-d/programs/im/soil_compaction/MonitoringManualVolume_II.pdf

[3] http://naldc.nal.usda.gov/naldc/download.xhtml?id=13042&content=PDF

Required for every individual

- ❏ Cruiser Vest
- ❏ Compass
- ❏ Go/No-Go Gauge
- ❏ Clinometer
- ❏ Map
- ❏ 100' Diameter Tape
- ❏ Flagging

Required for every 2 individuals

- ❏ GPS (Garmin)
- ❏ Clipboard w/ Plot Sheets
- ❏ Laser Hypsometer
- ❏ PhotoSphere compatible phone

Plot Establishment

1. Navigate to the plot using the provided map and a GPS unit. If the plot will overlap with an existing plot, main road, or boundary, offset the plot by moving one chain (66') in the nearest cardinal direction.
2. Establish plot center by driving a steel spike into the plot center. Secure a strip of Tivek to the head of the spike using zip ties.
3. On the Tivek strip, mark out:
    a. Plot ID (Example BB_8_tl3_10)
    b. Est. Date (establishment date);
    c. Est. Crew # (crew number establishing plot)
    d. Record Date (date plot data collected)
    e. Record Crew # (crew name) crew collecting plot data.
4. Mark the site with spray paint for future surveyors. Apply paint to high, visible areas on tree trunks, rocks, and other features that will be minimally affected by cultural treatments.
5. ✎ Record Site Name
6. ✎ Record Plot Number
7. ✎ Record plot slope along the aspect of the plot
8. ✎ Record the Date and Time of day.

Vegetation

1. For all vegetation measurements, begin measurements by starting in a northerly direction and moving clockwise. This is to ensure repeatability of plot data
2. Measure small vegetation (trees less than 4 feet in height and less than 5 inches in diameter) within a 1/100th acre (11.7 feet radius) fixed radius circular plot originating at the plot center stake.

a. ✎ Seedlings: For all trees under 4 feet in height, **tally** the number of seedlings of each species in 1 foot height increments. If there are more species variety than available slots, add additional information in the comments box

b. ✎ Saplings: **Tally** all trees greater than 4 feet in height and less than 5 inches in diameter. Tally the number of trees of each species within 1 inch diameter increments. For each size class of each species, estimate average total **height** and average Height to Live Crown Base (**HTLCB**) to the nearest half foot.

3. Measure mid to large trees (trees greater than 5" in diameter) within a 1/10th acre (37.2') fixed radius plot originating at the plot center stake.
   a. Start in a northerly direction
   b. ✎ Record **Species** using a two letter common code (BO, SP, PP, JP, IC, WF, etc)
   c. ✎ Record **Status** of trees as (**H**ealthy, **U**nhealthy, **S**ick, or **D**ead)
   d. ✎ Record Diameter at Breast Height (**DBH**) to the nearest 1/10 inch. Measure diameter of trees at a height of 4.5' on the high side of the tree.
   e. ✎ Record Height to the closest foot using a clinometer.
   f. ✎ Record HTLCB to the closest foot. Balance heights to even crown height
   g. ✎ Record Crown Class as either **D**ominant, **C**oDominant, **I**ntermediate, **S**uppressed.

Fuels

1. Start at plot center and orientate your compass to one of three predetermined azimuths (90, 270, 330)
2. Stake your tape at plot center and pull it to 75 feet along the selected azimuth.
3. ✎ Use your clinometer to measure the % slope of the transect you are on.
4. **AS YOU WALK ALONG**, tally the number of downed *woody* pieces (twigs, branches, logs) intersecting the transect from the ground to a maximum height of 6' using a go-no-go gauge. Pieces must be severed from the original source of growth and their central axes must be above the duff layer. Do not count needles, grass, bark, or cones.
   a. ✎ **1-hour fuel**: At a distance between 15' and 21' along the transect, tally the pieces of wood < .25" in diameter .
   b. ✎ **10-hour fuel**: At a distance between 15' and 21' along the transect, tally the pieces of wood pieces .25" to 1" in diameter .
   c. ✎ **100-hour fuel**: At a distance between 15' and 30' along the transect, tally the pieces of wood 1" to 3" in diameter.
   d. ✎ **1000 hour fuel**: At a distance between 15' and 75' along the transect, record the diameter of any piece of wood >3".

5. AT A DISTANCE OF 45’ AND 75’ along the transect, measure litter depth, duff depth, and vegetation cover. Use a trowel to expose a vertical plane down to bare mineral soil. If a log or stump is in the way, offset by 1’ in a direction perpendicular to the transect orientation.
    a. ✎ **Litter**: At 45’ and 75’, measure the litter (fresh needles, leaves, twigs, fruit, bark, etc.) to the nearest 0.25 inches from the bottom of the litter layer (top of duff) to the highest dead particle (not to exceed 72”) intersecting a 1’ wide vertical plane perpendicular to the transect.
    b. ✎ **Duff**: At 45’ and 75’, measure the duff (visibly decomposing organic material) (bottom of the litter layer down to the mineral soil)with a ruler to the nearest 0.25”.
    c. ✎ **Tree and Shrub Cover**: At 45’ and 75’, take a cylinder 6’ in diameter and measure the % of canopy (up to 6’ in height) occupied by live foliage and dead foliage from woody tree and shrub species. Average height of all cover to the nearest half foot.
    d. ✎ **Herbaceous Cover**: At 45’ and 75’, take a cylinder 6’ in diameter and measure the % of canopy (up to 6’ in height) occupied by live foliage and dead foliage from herbaceous species (non-woody vegetation). Average height of all cover to the nearest half foot.
6. Repeat steps 3-5 for the remaining two transects

Soil Disturbance

1. Conduct soil disturbance analysis along the same three transects as used above. At 15 foot increments along the transect (15’, 30’, 45’, 60, and 75’) assess the following benchmarks within a 6” diameter circle on the surface. There are two stages within each transect.
2. Stage 1: Assess the presence or absence of the following indicators within a 6” diameter circle of soil at each increment along the transect.
    a. ✎ Live Plant (Y/N): Plant containing green foliage rooted within the 6” circle
    b. ✎ Fine Wood (Y/N): Small diameter woody debris <3 inches in diameter
    c. ✎ Coarse Wood (Y/N): Large diameter woody debris >3 inches in diameter
    d. ✎ Bare Soil (Y/N): Exposed bare mineral soil
    e. ✎ Rock (Y/N): Large rocky material embedded in the soil substrate.
    f. ✎ Topsoil Disturbance(Y/N): Whether or not the topsoil layer is disturbed.
3. Stage 2: If topsoil disturbance is absent, ignore this stage and move on to general site characteristics.
    a. ✎ Rutting (Y/N): Indicate presence of rutting at depths of <5cm, 5-10cm, and >10cm
    b. ✎ Burning (L, M, H): Indicate presence absence of burning. May come in the form of char or burned logs. Indicate Low, Medium, or High to indicate the quantity and level of burned material.

c. ✎ Erosion (Y/N): Indicate presence of erosion. May be identified by soil or gravel movement from outside factors such as water or wind.

d. ✎ Compaction (Y/N): Indicate presence of compaction. If compaction is evident, use a trowel or plot stake to identify which depth increment(s) the compaction covers. (0-10cm, 10-30cm, >30cm)

e. ✎ Platy/Massive (Y/N): Indicate presence of platy/massive soil structures. If present, indicate which size classes these structures are found in (0-10, 10-30, >30)

f. ✎ Disturbance (0,1,2,3): Indicate severity of disturbance with 0 and low and 3 to high.

General Site Characteristics

9. Assess the % cover of trees occupied by the following size classes inside the 1/10th acre fixed radius plot. (37.2' radius circle). Estimate cover percentage to the nearest 5%.
    a. ✎ **Seedlings** are all trees < 4.5' in height
    b. ✎ **Saplings** are all trees >4.5' in height and < 5' in diameter
    c. ✎ **Poles** are all trees between 5" and 9" in diameter
    d. ✎ **Trees** are all trees > 9" in diameter

10. Assess the % cover of trees occupied by the following size classes inside the 1/10th acre fixed radius plot. (37.2' radius circle). Estimate cover percentage to the nearest 5%.
    a. ✎ **Low Shrubs** are all woody shrub species < 3' in height
    b. ✎ **Medium Shrubs** are all woody shrub species between 3' and 6' in height
    c. ✎ **Tall Shrubs** are all woody shrub species >6' in height

Photographic Monitoring

1. Use a camera with a photosphere function such as an android or ios smartphone with the google photo application
2. Position the camera directly over the spike at the center of the plot at a height of 4.5 feet
3. Orientate the camera so that the first photo is facing North.
4. Rotate the camera **IN PLACE** as you move around the camera to take other photographic angles. Moving the phone around you as you take photos will create irreparable distortion.
5. ✎ When the photosphere is completed, take a picture of the completed plot data sheet.

System Productivity and Cost (During Treatment)

Time and motion data, combined with production (acres treated, volume harvested), and equipment costs collected during this study will provide useful information to land managers evaluating strategies for timber harvesting and fuels reduction. In analyzing system productivity and cost, it is important to be able to differentiate the effects of machine capability and operator proficiency *(Will there be a means of differentiating operator effects? If not, drop the "and operator proficiency.")* from the effects of the operating conditions. *Stand conditions recorded from the other sections of this protocol as well as stand conditions (Not sure what the previous sentence should be.)* Time and motion data will be collected at the shift and cycle levels for each equipment configuration. System productivity will be evaluated based on the acres treated and volume of material produced. Equipment cost will be estimated based on standard methods.

Data Collection Equipment

- ❏ 10x Gulf Coast Data Concepts X16-1D three-axis accelerometers
- ❏ 10x Holux 241 GPS data loggers
- ❏ 4x GoPro Video Cameras
- ❏ 1 Laptop
- ❏ Clipboard (one for each unit) with printed copies of shift report and pen/pencil

Data logger configuration

The accelerometer/GPS data logging kit should be positioned on the equipment such that the accelerometer axes are aligned with the chassis of the equipment. Additionally, the axes should be aligned with the equipment consistently across all equipment. Figure 1 indicates label positioning on the GPS/Accelerometer logging kits.

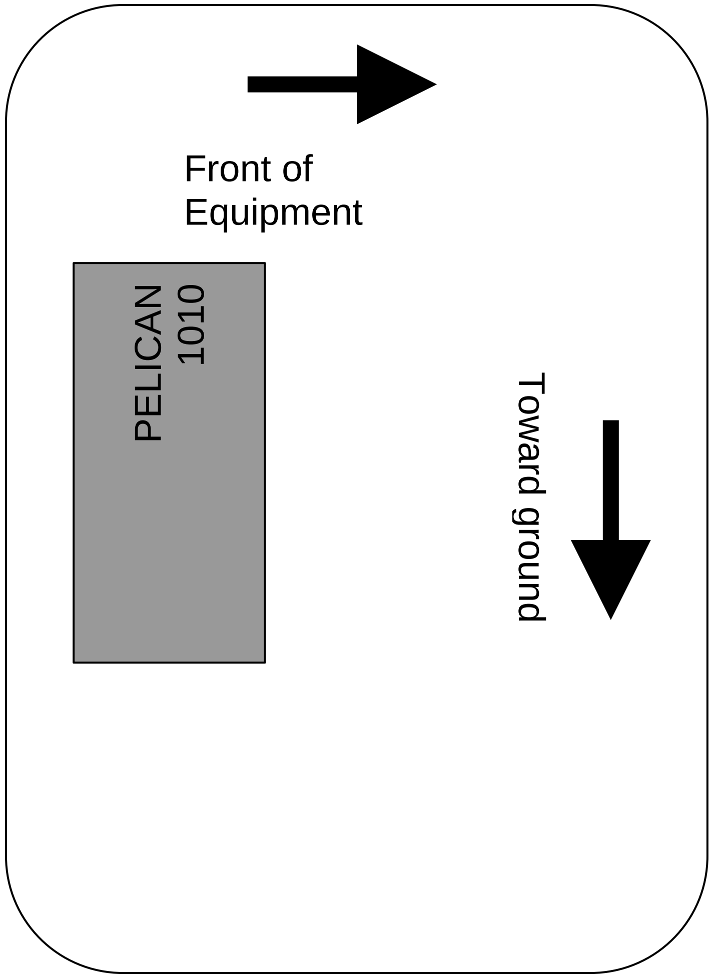


Image 1: Orientation of labels on the data logger case.

The GPS data logger orientation should be such that the circular protrusion from one of the ends is pointing toward the sky. The accelerometer should be oriented such that the X axis is recording positional change on the vertical axis of the equipment, the Y axis should be recording the positional change side to side (transverse of the front-to-back axis), and the Z axis should be recording the positional change forward and backward. Image X indicates the placement of the GPS and Accelerometer data loggers in the Pelican 1010 case.

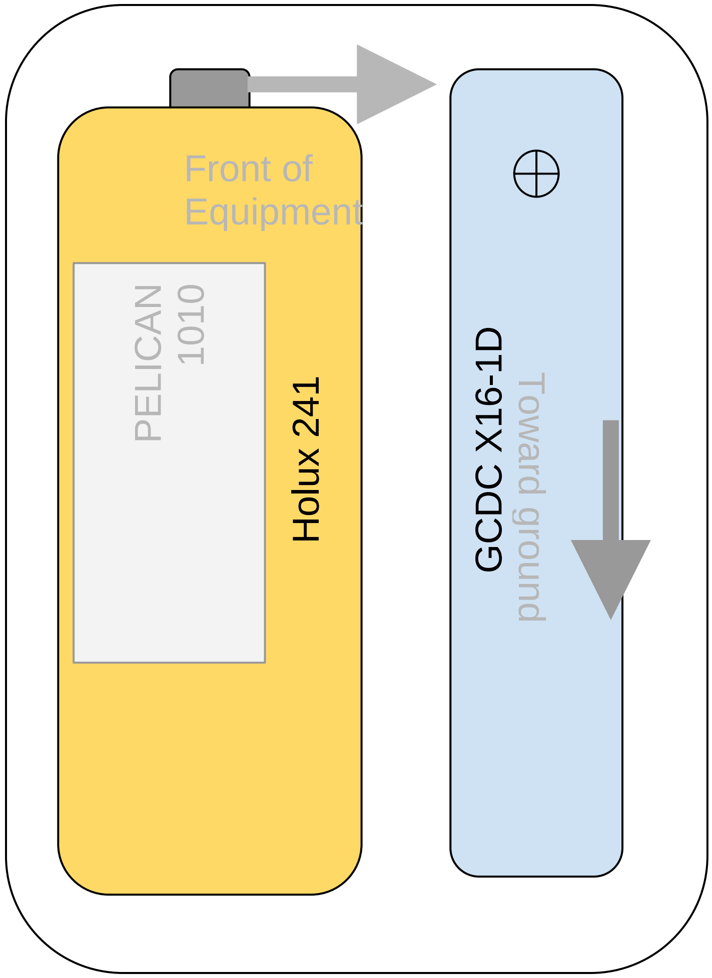


Image 2: Orientation of Holux 241 GPS data logger and GCDC X16-1D accelerometer in the case.

Time and Motion Sampling

Shift level and cycle level data will be collected for each system. Shift level data summarizes time spent in maintenance, repair, breaks or other activities, so these can be separated from the time spent directly conducting forest operations. Cycle data quantify the time components (moving, positioning, cutting, etc.) spent by a machine in conducting its intended function (harvesting, chipping, masticating, etc.). Shift reports will be submitted by all equipment operators or crew foremen for all shifts. In addition, electronic data recorders in combination with video cameras will be attached to individual machines for a single shift to sample cycle data. Each system will be sampled for cycle times using the data logger and video camera for at least one shift.

Shift data collection

Each equipment operator or crew foreman will complete a shift report estimating the amount of time during each shift. The shift report captures time during a work shift taken by breaks, service, and repair and other activities not directly relating to its primary forestry purpose and can can be downloaded here (See Appendix for shift report template). *In addition to the operator report, simultaneous data logging and machine-mounted video will be* *captured for at least 1 shift for each piece of equipment. The MultiDAT[4] heavy equipment production management platform collects machine vibration data that can be associated with cycle and shift activities. (Previously, the electronic recorders were proposed for cycle data collection. I would suggest sticking with that in the protocol, as only one shift will be recorded. In practice, the recorder can be used as a check on the operator's report.*

Delays

Equipment Loading/Unloading

Time required to maneuver equipment from highway transport configuration to operational condition. Cycle level data will be collected for:

- Unloading
- Assembly (if elements of the functional unit have been detached for transport, ie mastication heads, etc)

On-site travel (between stands)

If travel between stands or treatment sites at the same location is necessary, transit time will be recorded. Cycle level data for on-site travel will include

- Travel time
- Travel distance from road entry to exit.

Service and repair

Time taken for service and repair will be monitored, distinguishing between:

- Regular service/maintenance (greasing,etc)
- Repair

Cycle data collection

For each system, at least one shift will be analyzed to provide cycle times. For each machine, cycle activity will be timed in each of the following categories. Some pieces of equipment do not perform some functions listed below. In such a case, no time data will be recorded for that function for that equipment.

(Need to define the production unit (cycle) for each of the following activities. For felling and processing, the tree is the obvious cycle. For skidding and yarding, the turn is the best unit, while for chipping it is a van load. Mastication is more difficult; you might have to use a whole treated area as the cycle, or maybe it will be possible to flag subunits to be treated individually?)

Mastication

For equipment conducting mastication activities the following cycle level activity categories will be monitored:

- In-stand travel
- Mastication

Production Unit: Area (acres)

Tree felling

[4] Forest Engineering Research Institute of Canada. MultiDAT 5 [Internet]. 1st ed. Pointe-Claire, Quebec. 2006. 1-20 p. Available from: http://www.castonguay.biz/

For equipment used to fell trees, the following cycle-level activities will be recorded:

- In-stand travel
- Felling head positioning
- Bole cutting
- Tree handling (bunching, etc.) after cutting

Production Unit: Tree

Tree processing

Tree processing may be conducted at the stump in a cut-to-length (CTL) system or at the landing in a whole-tree system. For equipment capable of limbing and bucking felled trees, cycle level data will be recorded for:

- Travel within stand (CTL only)
- Limbing
- Log bucking

Production Unit: Tree

Skidding/yarding

For equipment used in extraction of merchantable roundwood or residual biomass material to a landing for further processing or transportation, cycle level data will be recorded for:

- Travel unloaded
- Load
- Travel in stand with a partial load
- Travel loaded (return to landing)
- Unload
- Decking (piling)

Production Unit: Turn

Chipping

For stationary or mobile equipment used to chip material, cycle level data will be recorded for:

- Travel (not chipping, for mobile chippers)
- Chipping
- Idling

Production

Shift level production data will be collected in terms of volume produced and acres wherein the treatment objective was achieved. For systems which do not include extraction of material (merchantable or not) to the landing, production data will consist only of acres treated. *(Will the fuels and woody vegetation be measured both pre- and post-treatment? If so, could they be used to develop productivity in terms of volume of material treated?)*

Chipped material

Chipped material produced during a shift will be reported by truck drivers using the load reporting sheet available here. The following will be recorded for each load:

- Unit id
- Start loading time
- End loading time
- *Start driving time to the destination?*
- *Arrival time at destination or back in the field?*

- *(Do you want to know how much time is spent at the destination so it can be separated from actual travel time?) (Similar questions for the merchantable material.)*
- Load weight
- Destination
- Comments

Merchantable material

Merchantable log volume produced during a shift will be reported by truck drivers using the load reporting sheet available here. The following will be recorded for each load:

- Unit id
- Start loading time
- End loading time
- Start driving time
- End driving time
- Log Volume
- Destination
- Comments

Landing residuals

For systems which produce piled logging slash at the landing, data will be collected after all equipment has departed from the unit. Slash piles will be measured and biomass residual volume estimated based on methods from Wright et.al.[5]

Equipment Cost

Equipment costs will be estimated based on methods from Miyata (1980)[6] and is reiterated generally here. To evaluate treatment costs for the fuels treatment operations the cost of owning and operating each piece of equipment must be estimated. Total equipment costs include all costs accrued from buying, owning, and operating equipment. For analysis, equipment costs can be grouped into fixed costs, operating costs, and labor costs. To calculate these costs we will use the method presented by Miyata.

Preliminary Data

Equipment Costs (P)

This is defined as the actual equipment purchase cost, less the tire cost, regardless of whether the equipment is purchased at full price or discounted

- Equipment costs with standard attachment
- Optional attachment cost
- Sales taxes (State and local)

[5] 1. Wright CS, Balog CS, Kelly JW. Estimating Volume, Biomass, and Potential Emissions of Hand-Piled Fuels [Internet]. PNW-GTR-805. Portland, OR; 2010. Available from: http://www.firescience.gov/projects/07-2-1-57/project/07-2-1-57_wright_etal_pnw-gtr-805_2010.pdf

[6] 1. Miyata ES. Determining fixed and operating costs of logging equipment [Internet]. General Technical Report NC-55. 1980. Available from: http://www.nrs.fs.fed.us/pubs/gtr/gtr_nc055.pdf?

- Freight cost
- Miscellaneous: Including installation of attachments or modifications made to equipment.

P is calculated as:

$$P = \sum_{i..n} \quad - t$$

where *i* is a vector of are the discrete costs listed above, and *t* is the value of the tires if they are included.

Salvage Value (*S*)
This is defined as the amount that equipment can be sold for at the time of its disposal. The actual salvage value of equipment is affected by current market demand for used equipment and the condition of the equipment at the time of disposal. However, estimating the future salvage value of equipment is very difficult because it is based on the future market value and the unknown condition of the equipment at the time of its disposal:The estimates come from owners themselves or from manufacturers or dealers. As a rule of thumb,the salvage value can be considered 20 percent of the initial investment cost.

Economic Life (*N*)
This is the period over which the equipment can operate at an acceptable operating cost and productivity. The economic life is generally measured in terms of years, hours, or mileages (trucks and trailers).It depends on two factors---physical and functional impairment.

Scheduled Operating Time (*SH*)
Scheduled operating time is the time during which equipment is scheduled to do productive work.

Productive Time (*H*)
Productive time is that part of scheduled operating time during which a machine actually operates.

Fixed Costs

Fixed costs do not vary with hours of operation. They are neither affected by the amount of equipment activity nor output and are incurred regardless of whether a piece of equipment is used or not. Fixed costs include depreciation,interest, insurance, and taxes.

- Depreciation: Depreciation charges will be estimated using the strait-line method:

$$D_n = (\frac{P - S}{N})n$$

where:
n is the year for which the depreciation charge is to be estimated

- Interest
- Insurance
- Taxes

Operating Costs

- Maintenance and Repair
- Fuel
- Lubricants

- Tires

Labor Costs

- Social Security
- Unemployment Insurance
- Workmens Compensation Insurance
- Other: Other employer contributions may include paid vacation, paid holidays, paid sick leave, health insurance, uniforms, safety equipment.

Equipment Configuration

Appendix

Machine Shift Report

:	Shift Start Time	Unit	
:	Shift End Time	Date	
		Operator	
		Machine	

Please fill out a new report for each shift or when changing to a different unit.

For each delay event 10 minutes or longer,
record either the (Start Time and End Time), or the (Total Time).

Start Time	End Time	Total Time	Circle Event Type	Comments
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	
:	:	:	Ld Unld Brk Srv Rep Other	

Please explain anything unusual about the shift.
(Example: The engine ran poorly which made the machine slow.)

(Write on back of page if needed.)

Start Time	Time of day when event started (Hour : Minute)
End Time	Time of day when event ended (Hour : Minute)
Total Time	Total time of event (Hours : Minutes)
Ld	Loading (including any disassembly)
Unld	Unloading (including any assembly)
Brk	Break (lunch, coffee, smoke, etc.)
Srv	Service (any routine maintenance or service: fuel, lubrication, etc.)
Rep	Repair (any breakdowns or problems with machine: broken hose, etc.)
Other	Other (describe event: talked to supervisor, etc.)

FireMON: Sample Approach Classification Key

Question	Shaver	Big Bear	Santa Rosa
1. **Sufficient sampling resources are available.** There is plenty of funding, ample time and sufficient personnel (with necessary skills) to complete a detailed monitoring effort.	No	No	No
2. **NP < SP. There are sufficient resources to sample the entire landscape.** Sampling resources allow more than one plot in each	Yes	No	No

stand.			
3. **An estimate of across and within stand variation is not important.** The project objectives are not concerned with the variability of ecosystem characteristics or the statistical comparisons of sampled attributes.	No	No	No
4. **A statistician or statistics expert is available for consultation.** Someone can easily be contacted to answer questions about your sampling design. There is sufficient expertise for designing a valid statistical sampling scheme.	Yes	Yes	Yes
5. Navigation across the sample landscape is difficult. Steep, dangerous terrain, long travel distances or other features prevent plot establishment in major portions of the landscape.	No	No	Yes
6. Few ecosystem components are being measured for assessing fire effects. The monitoring objectives are concerned with just one or two ecosystem attributes whose variation must be quantified.	Yes	Yes	Yes
Approach	**Statistical**	**Releve**	**Releve**

Appendix D

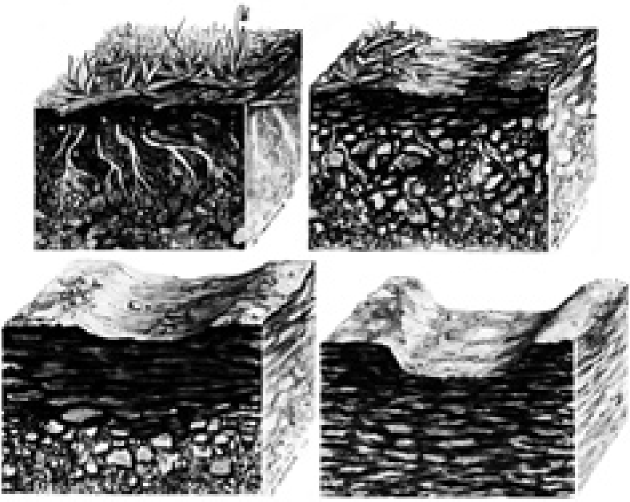
Forest Soil Disturbance Monitoring Protocol

United States Department of Agriculture
Forest Service
Gen. Tech. Report WO-82a
September 2009

Forest Soil Disturbance Monitoring Protocol

Volume I: Rapid Assessment

By Deborah S. Page-Dumroese,
Ann M. Abbott, and Thomas M. Rice



Schematics from Napper et al. (N.d.)

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CONTENTS

Acknowledgments

The monitoring approach and methods in volume I and volume II are the result of extensive collaboration between the Forest Service, U.S. Department of Agriculture National Forest System and Research and Development. The Forest Service Rocky Mountain Research Station in cooperation with the Northern Region led the effort. Although the development of this protocol has been guided by suggestions from a large number of regional soil program leaders, forest soil scientists, research soil scientists, university professors, and British Columbia Ministry of Forests and Range soil scientists, we particularly want to acknowledge the input and guidance from Sharon DeHart[1], Sue Farley[2], and Randy Davis[3]. Countless reviewers, workshop participants, students, and technicians have tested this protocol and offered input on how to make it more user friendly. Their input has been extraordinarily beneficial.

General Summary

This document—Volume I: Rapid Assessment—outlines a framework for monitoring soil disturbances from forest management preactivity and postactivity. Volume II: Supplementary Methods, Statistics, and Data Collection defines key terms, explains the development of a statistically sound data collection method, and describes how data should be stored. Volume III: Scientific Background for Soil Monitoring on National Forests and Rangelands includes the proceedings from a workshop held to define the state of the science. This volume outlines the step-by-step field protocols to get a rapid assessment of the disturbance characteristics before and after land management.

[1] Former Soil Program Leader, Northern Region, Missoula, MT.
[2] Forest Soil Scientist, Helena National Forest, Helena, MT.
[3] National Soil Program Leader, Washington Office, Washington, DC.

Introduction

This volume of the Forest Soil Disturbance Monitoring Protocol (FSDMP) describes how to monitor forest sites before and after ground disturbing management activities for physical attributes that could influence site resilience and long-term sustainability. The attributes describe surface conditions that affect **site sustainability** and **hydrologic function.** Monitoring the attributes of surface cover, ruts, compaction, and platy structure can also be used to generate best management practices that help maintain **site productivity.**

Key Monitoring Points

The Forest Soil Disturbance Monitoring Protocol describes surface conditions that affect—

- Site sustainability.
- Hydrologic function.
- Site productivity.

This protocol is intended to be used by field soil scientists and watershed specialists when evaluating physical soil disturbance in a forested setting. This *rapid assessment tool* can also be useful, however, for timber sale administrators, logging contractors, hydrologists, and the general public to help them understand how to monitor soil disturbance using standardized visual disturbance classes. Monitoring soil disturbance preactivity and postactivity enables the Forest Service to assess the success of management activities in meeting legal, regulatory, and policy objectives. By using a consistent monitoring approach, forests in every Forest Service region can build soil resource programs to meet their specific requirements in accord with their soil quality standards and guidelines. Table 1 provides common definitions of frequently used soil descriptors.

Table 1.—*Visual indicators and their definitions.*

Forest floor impacted	Forest floor material includes all organic horizons above the mineral soil surface.
Topsoil displacement	The surface mineral soil primarily includes the A horizons, but if the A horizon is shallow or undeveloped, it may include other horizons. This disturbance is usually due to machinery but does not include "rutting" described below.
Rutting	Ruts vary in depth but are primarily the result of equipment movement. Ruts are defined as machine-generated soil displacement or compression. Often soil puddling is also present within the rut.
Burning (light, moderate, severe) severity	Burn severity includes only effects on the forest floor and mineral soil, not on above-ground vegetation.
Compaction	Compaction by equipment results in either a compression of the soil profile or increased resistance to penetration.
Platy structure/ massive/puddled	Flat-lying or tabular structure in the mineral soil. "Massive" indicates no structural units are present and soil material is a coherent mass. Puddled soil is often found after wet weather harvest operations. Soil pores are usually smeared and prevent water infiltration.

Objective

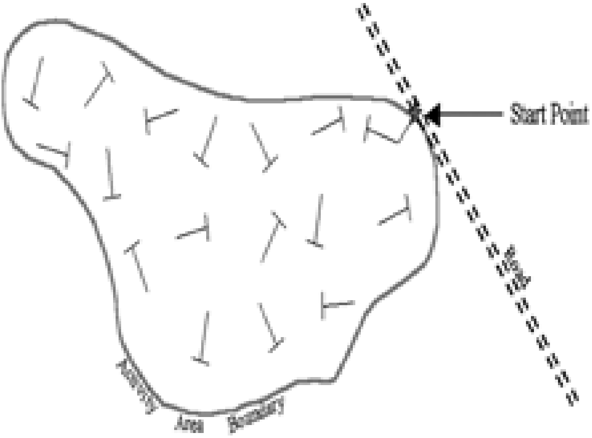
The FSDMP defines indicators that can be measured consistently, efficiently, and economically. It is intended for use in any forested activity area to set the stage to address and report project effects. The FSDMP provides estimates of soil disturbance and confidence intervals around the monitoring results. The estimates are based on sample sizes calculated from the onsite variability estimated from the first 30 monitoring points in the sample and a predetermined confidence level. The following chart shows the rapid assessment steps.

Rapid Assessment Steps

Steps
Define the monitoring objective (preactivity, postactivity, short-term monitoring, long-term monitoring, etc.).
Gather the necessary background information—soil survey, maps, photos, etc.—and determine if the site should be stratified. Enter site description data on FSDMPSoLo worksheet #1 (SoLo Info).
Decide on confidence level (FSDMP worksheet #3 – Data Entry), transect design, and indicators needed (FSDMP worksheet #2 – Variable Selection).
Describe site management, slope, soil texture, soil depth, aspect, landform or topography, and elevation (FSDMP worksheet #1 – Data Entry).
Begin monitoring (FSDMP worksheet #3 – Data Entry).
Summarize results (FSDMP worksheet #4 - Results).

Transect Options

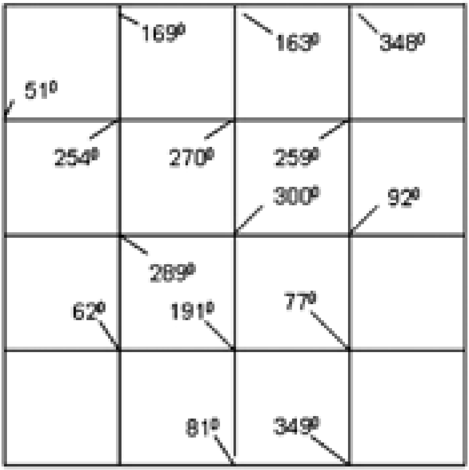
Option 1. Randomly Oriented Transects



In this option transects are laid out randomly on a site map before going to the field. Monitoring points can be collected along these randomly established transects to collect the minimum number of points needed. At each intersection, a 30 m (~100 ft) transect is established. The attributes are then noted at monitoring points located along each transect.

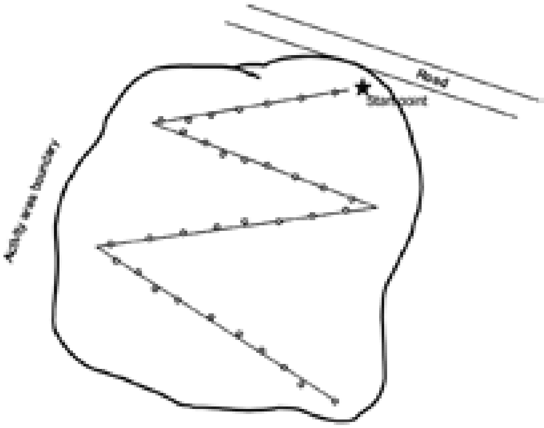
Option 2. Systematic Grid Points

In this option the protocol calls for establishing a systematic grid of monitoring points arrayed on a map or aerial photograph of the activity area to be monitored. The entire grid is randomly located and oriented, and the distance between monitoring points is constructed to provide a sample size that meets precision requirements or cost limitations specified in the objectives for monitoring. Each grid intersection locates a monitoring point that radiates in a random chosen direction and distance from the grid point (Howes 2006).



Option 3. A Random Transect

In this option the protocol calls for randomly locating a start point and traversing a transect that covers the entire unit so that the first 30 monitoring points (the minimum required) are spaced to provide an adequate assessment of the site. The entire transect is randomly located and oriented, and the distance between monitoring points is constructed to provide a sample size that meets precision requirements or cost limitations specified in the objectives for monitoring. Turning points are usually located within the activity area so that the last monitoring point before a turn is not within an area of influence of the surrounding stand (usually the height of the tallest trees). Additional transects at random directions are often needed to reach the appropriate sample size. If the transect begins to follow a skid road, either offset from the skid road or start a new random transect. Record offset or new direction.



How Many Monitoring Points Do I Need?

The *minimum* number of monitoring points is 30. This minimum number is required to get site-specific variability for statistically valid sample size, and these 30 points should be conducted as a rapid assessment using the soil indicators selected. Only when the variability within the site is very small will the minimum of

30 be the final number of monitoring points. As the variability in disturbance within the site increases, so does the sample size required to achieve a confidence interval using a predetermined confidence level and interval width. If fewer than 30 monitoring points are taken, the sample sizes and confidence intervals calculated in the spreadsheet may be incorrect. The consequence of using more than 30 samples, but fewer than the number that the spreadsheet recommends, is that the confidence interval will be wider than the predetermined width, as indicated by the "Lower Bound" and "Upper Bound" values on the spreadsheet. Volume II addresses details of the formulas used for calculating sample size, the available confidence levels, and alternatives for varying sampling intensity.

We strongly recommend entering the data into the electronic spreadsheet rather than using the paper data collection form, because calculation of the intervals by hand is tedious and error prone. Summary levels of disturbance classes are also provided in the electronic *Results* worksheet (see appendix C-4 in volume II). Because disturbance class is an ordinal variable (meaning that levels of this variable are ordered categories), confidence intervals are not calculated.

For details on how to stratify sample points within a project area or about stratifying the number of project areas to sample, see volume II.

What Is a Monitoring Point?

For the FSDMP, a monitoring point is defined as a 15-cm (6-in) diameter circular area around the end of your toe. The presence or absence of each disturbance indicator at the point is noted. The visual disturbance class of each sample point is determined using the most limiting visual indicator at the point (table 2). Areas outside the monitoring point can be used for determining the general context of the disturbance but should not be used to decide the class of the point. Using the surrounding areas to determine the disturbance class would bias the sample system, especially if applied differently to different visual attributes.

Table 2.—*Soil disturbance classes used in the Forest Soil Disturbance Monitoring Protocol. Soil disturbance classes increase in severity of impact from class 0 to class 3. (1 of 2)*

Soil disturbance class 0	**Soil disturbance class 1**
Soil surface: • No evidence of compaction; i.e., past equipment operation, ruts, skid trails. • No depressions or wheel tracks evident. • Forest floor layers present and intact. • No soil displacement evident. • No management-generated soil erosion. • Litter and duff layers not burned. No soil char. Water repellency may be present.	Soil surface: • Faint wheel tracks or slight depressions evident and are <5 cm deep. • Forest floor layers present and intact. • Surface soil has not been displaced and shows minimal mixing with subsoil. • Burning light: Depth of char <1 cm. ***Accessory****: Litter charred or consumed. Duff largely intact. Water repellency is similar to preburn conditions. Soil compaction: • Compaction in the surface soil is slightly greater than observed under natural conditions. • Concentrated from 0 to 10 cm deep. Observations of soil physical conditions: • Change in soil structure from crumb or granular structure to massive or platy structure; restricted to the surface 0 to 10 cm. • Platy structure is noncontinuous. • Fine, medium, and large roots can penetrate or grow around the platy structure. No “J” rooting observed. • Erosion is slight.

Table 2.—*Soil disturbance classes used in the Forest Soil Disturbance Monitoring Protocol. Soil disturbance classes increase in severity of impact from class 0 to class 3. (2 of 2)*

Soil disturbance class 2	Soil disturbance class 3
Soil surface: • Wheel tracks or depressions are 5 to 10 cm deep. • ***Accessory****: Forest floor layers partially intact or missing. • Surface soil partially intact and may be mixed with subsoil. • Burning moderate: Depth of char is 1 to 5 cm. ***Accessory****: Duff deeply charred or consumed. Surface soil water repellency increased compared with the preburn condition. Soil compaction: • Increased compaction is present from 10 to 30 cm deep. Observation of soil physical condition: • Change in soil structure from crumb or granular structure to massive or platy structure; restricted to the surface, 10 to 30 cm. • Platy structure is generally continuous. • ***Accessory*:*** Large roots may penetrate the platy structure, but fine and medium roots may not. • Erosion is moderate.	Soil surface: • Wheel tracks and depressions highly evident with depth >10 cm. • ***Accessory****: Forest floor layers missing. • Evidence of surface soil removal, gouging, and piling. • Most surface soil displaced. Surface soil may be mixed with subsoil. Subsoil partially or totally exposed. • Burning severe: Depth of char is >5 cm. ***Accessory*:*** Duff and litter layer completely consumed. Surface soil is water repellent. Surface is reddish or orange in places. Soil compaction: • Increased compaction is deep in the soil profile (>30 cm deep). Observations of soil physical conditions: • Change in soil structure from granular structure to massive or platy structure extends beyond 30 cm deep. • Platy structure is continuous. • ***Accessory****: Roots do not penetrate the platy structure. • Erosion is severe and has produced deep gullies or rills.

**Accessory items are those descriptors that may help identify individual severity classes.*

Unique Monitoring Strategies

Volume II outlines the details of unique monitoring strategies. These strategies provide a standardized protocol for assessing large and small units; determining how many activity areas to monitor; and deciding how to count rocks, roots, downed wood, stumps, fallen trees, slash piles (containing tree tops, branches, brush, etc.) and so on that fall on a sample point. Volume II also standardizes descriptions of how to assess prescribed fire and wildfire areas and defines landings and temporary and permanent roads that fall within the scope of the FSDMP.

Soil Disturbance Classes

Table 2 shows a four-level soil disturbance classification system. Disturbance classes used in the FSDMP are defined primarily by morphological (visual) attributes, not quantitative measures. In this visual class system, an increased severity of soil surface disturbance indicates a change in the disturbance class. Some changes (such as compaction and rutting), however, are linked to an increase in that property at depth. Evidence of deep soil compaction (e.g., deep ruts) is often present but not always. A shovel or metal probe may be needed if deep soil compaction is questionable. Because the results of management activities on soil productivity vary by soil type (Fleming et al. 2006, Gomez et al. 2002, Page-Dumroese et al. 2000, Page-Dumroese et al. 2006, Powers et al. 1998), this document does not prescribe any disturbance class as detrimental soil disturbance. Each Forest Service administrative region should determine where and when a detrimental call should be made based on local knowledge, research, and experience. Often, the definition of detrimental disturbance is tied to existing soil quality standards and guidelines. After the determination of detrimental disturbance is defined and noted, then this FSDMP can be used to calculate the amount of detrimental disturbance (e.g., if 5 out of 100 sample points are considered in a detrimental condition, then 5 percent of the area has been detrimentally disturbed).

As the activity area is walked, each monitoring point is placed in one of the predefined classes. The monitoring point may represent soil indicators from more than one soil disturbance class, and the soil scientist or other observer must decide which disturbance class best describes the monitoring point.

Local, forest-level class descriptors can be added to table 2, but the core descriptors outlined in this volume cannot be removed. For classes to remain consistent among administrative units, core descriptors cannot be changed. If a core classification descriptor is found to be lacking applicability across many forests, the classification descriptor will undergo a regional and research review and the protocol will be updated if needed. (See volume II for information about change management.)

Safety

A sample job hazard analysis has been included in this volume as appendix A. Each national forest is encouraged to modify the job hazard analysis to suit local conditions and safety concerns.

What Data Should I Collect?

Data To Collect While in the Office

Before starting a field evaluation of soil disturbance on an activity area, study available existing information sources and record applicable information in the *SoLo Info* electronic worksheet (see appendix C-1 in volume II and additional details in appendix G in volume II). Having information on soil texture, landform, aspect, and so on will provide a context for the data and provide information for long-term monitoring (if needed). In general, the following steps should be followed before going into the field:

1. Consult the most current subsection map (McNab et al. 2007) and available landtype association maps for general site characteristics. The SoLo database may require some of this information, which can help stratify the area for sampling. It is important to note, however, that such broad-scale maps are not appropriate for the more detailed site information needed to assess soil quality.

2. Consult available soil surveys and terrestrial ecological unit inventories (TEUIs) for more detailed site information and for the description and morphology of the soils that occur in the project area. Soil surveys may have been done by the Forest Service or by the Natural Resources Conservation Service (NRCS) and may be referred to as soil resource inventories, TEUIs, or landtype inventories. This information can help establish soil reference conditions for the activity area. It is critical, however, to confirm the actual soil type after you are in the field.

3. Check previous field review and soil monitoring reports and use available data.

4. For postharvest assessments, consult the harvest plan and contract information to determine where existing skid trails, landings, or changes in harvest operations may have occurred.

Step-by-Step Field Survey Method

Before starting field work, ensure that the *SoLo Info* worksheet (see appendix C-1 in volume II) is as complete as possible, then determine the intensity of sampling (confidence level and interval width) with input from a line officer. As noted earlier, the area for the visual assessment is a 15-cm (6-in) diameter circular area around the monitoring point. Continuous variables such as ruts, skid trails, or landings can be measured (using a tape measure, laser measure, etc.) and the total area and areal extent of the disturbance can be calculated using the "ONSITE" feature of the database. If a survey of skid trails, landings, or ruts indicates excess (based on regional soil quality standards and guidelines) detrimental soil disturbance, then it is likely that further assessment is not necessary because the applicable soil quality standard has already been exceeded. If the large features do not exceed the maximum area for disturbance, however, the FSDMP assessment may be warranted. If no large features are in the activity area, a rapid assessment may be sufficient on some activity areas to confirm that the applicable soil quality standards have been met.

Choose the visual disturbance category by selecting the one best fitting the monitoring point. This protocol is to be used in cases in which activity areas are defined and discrete. For assessment of areas in a watershed context, without defined and discrete activity units, see this volume's section titled "Unique Monitoring Strategies."

Baseline (Preactivity) Assessment

Step 1. Prework—Determine why you are monitoring (goals) and if the FSDMP is the most efficient method for accomplishing those goals. As noted in the section titled "Data To Collect While in the Office," fill out as much of the electronic or paper form as possible using existing documentation and interviews with other team members (see also appendix G in volume II). Inspection of topographic maps and areal photography can reveal basic landform information, such as slope and drainage patterns that affect soil productivity or hydrologic function. Select the variables you want to use for monitoring the activity area (*Variable Selection* worksheet, appendix C-2 in volume II). Determine the size of the activity area. Determine which option for monitoring point layout will work best for your site (see appendix A in volume II). If choosing a random transect, select the length of transect needed and the distance between points. If choosing a grid point survey, select a random orientation for the grid points. If using an electronic portable data recorder, predetermine grid point locations and save them onto the recorder.

Step 2. Select the *Data Entry* worksheet (see appendix C-3 in volume II). If past ground-disturbing activities (e.g., stumps, skid trails, roads, differences in vegetation age or composition, or trash) are evident, continue to use the FSDMP for a quantitative estimate of the amount and extent of disturbance. Often, aerial photos and other maps can be used to determine the extent of effects. Field verification of compaction, displacement, or change in hydrologic state is necessary on sites with legacy effects. From preactivity assessments, determination of cumulative effects may be facilitated. Conversely, if records of previous management resulted in minimal soil disturbance and the activity area has similar soils, vegetation, aspect, and slope throughout the unit, then space a *minimum* of 30 monitoring points to cover the entire unit. When using the sample size calculator and appropriate confidence level, more points may be necessary. Take note of preactivity forest floor depth and composition, mineral soil horizon depth(s), and depth to bedrock (if applicable).

Step 3. Document a preactivity starting point using a Global Positioning System or other method of precise point location documentation. Using the sampling scheme selected from step 1, start sampling 5 m (~15 ft) inside the unit to avoid edge effects. If using a portable data recorder (see appendix F in volume II), upload a map of the site and add predetermined monitoring point locations before going into the field. Predetermining monitoring point locations can also be done with paper copies of available maps.

Step 4. After locating the starting point within the activity area, calculate the distance between points based on activity area size. To avoid bias, sample point distances must be predetermined and documented before starting. Points must be evenly spaced to cover the entire activity area. For instance, if the activity area is ~1,000 m (3,300 ft) long and you need to take 30 sample points, points should be at least 35 m (110 ft) apart along the random transect. If the transect (or point grid) does not adequately cover the range of variability, then take more transects (or grid points) to confirm the presence or absence of dispersed disturbance and the nature of the dispersed disturbance.

Step 5. Walk to the first point and assess the soil surface condition using the *Data Entry* worksheet (see appendix C-3 in volume II). On the data form, record a “1” if the indicator is present and a “0” if the indicator or statement is absent, ending with a general Soil Disturbance Class (using table 3). For assistance with visual class determinations, use the *Soil Disturbance Field Guide* Napper et al. N.d.). Continue collecting data at each monitoring point along the transect (grid). When you reach the edge of the activity area, select another transect direction (a predetermined grid point sampling scheme should be placed entirely within the activity area boundary) at an appropriate angle (toward the inside of the activity area) from the previous transect and continue data collection on the same spreadsheet. Note that, as you make observations at each monitoring point, the required sample size will likely change as the estimated variability changes.

Step 6. Continue the assessment until you reach the appropriate sample size. On the data form, record a “1” if the indicator is present and a “0” if the indicator or statement is absent, ending with a general soil disturbance class (table 2). *Take AT LEAST 30 monitoring points in the activity area that has disturbance.* Use aerial photos, ONSITE, or activity area maps to measure temporary roads and landings within or contiguous to the activity area, but take additional notes. Estimate disturbance on temporary roads or landings not in the activity area separately and manually add after completing this method.

Step 7. Use the comment field at the bottom of each column (or a field notebook) to document noteworthy existing disturbance. Use these comments to document unusual spatial features related to the disturbances or to record the type and severity of erosion features.

Step 8. In the last row of the *Data Entry* worksheet (see appendix C-3 in volume II) indicate if the soil disturbance is detrimental. This row of information is based on the professional judgment of a qualified soil scientist, literature, or other local studies.

Table 3.—*Examples of soil visual indicators and management activities. (1 of 3)*

Disturbance type	**Severity class**			
	0	**1**	**2**	**3**
Equipment impacts				
Past operation	None.	Dispersed.	Faint.	Obvious.
Wheel tracks or depressions	None.	Faint wheel tracks or slight depressions evident (<5 cm deep).	Wheel tracks or depressions are >5 cm deep.	Wheel tracks or depressions highly evident with a depth being >10 cm.
Equipment trails from more than two passes	None.	Faintly evident.	Evident, but not heavily trafficked.	Main trails that are heavily used.
Excavated and bladed trails[1]	None.	None.	None.	Present.

Table 3.—*Examples of soil visual indicators and management activities. (2 of 3)*

Disturbance type	Severity class			
	0	1	2	3
Penetration and resistance[2]	Natural conditions.	Resistance of surface soils may be slightly greater than observed under natural conditions. Increased resistance is concentrated in the surface (10 cm).	Increased resistance is present throughout the top 30 cm of soil.	Increased resistance is deep into the soil profile (>30 cm).
Soil physical condition	Natural conditions.	Change in soil structure from crumb or granular structure to massive or platy structure in the surface (10 cm).	Change in soil structure in the surface (30 cm). Platy (or massive) structure is generally continuous. On older sites, large roots may penetrate the platy structure, but fine and medium roots may not.	Change in soil structure extends beyond the top 30 cm. Platy (or massive) structure is continuous. On older sites, roots do not penetrate the platy structure.
Displacement				
Forest floor	None.	Forest floor layers present and intact.	Forest floor layers partially intact or missing.	Forest floor layers missing.

Table 3.—*Examples of soil visual indicators and management activities. (3 of 3)*

Disturbance type	Severity class			
	0	1	2	3
Mineral soil	None.	Soil surface has not been displaced and shows minimal mixing with subsoil.	Mineral topsoil partially intact and may be mixed with subsoil.	Evidence of topsoil removal, gouging, and piling. Soil displacement has removed most of the surface soil. Surface soil may be mixed with subsoil or subsoil may be partially or totally exposed.
Erosion	None.	Slight erosion evident (i.e., sheet erosion[3]).	Moderate amount of erosion evident (i.e., sheet and rill erosion[3]).	Substantial amount of erosion evident. Gullies, pedestals, and rills noticeable.
Burning	None.	Fire impacts are light. Forest floor is charred but intact. Gray ash becomes inconspicuous and surface appears lightly charred to black. Soil surface structure intact.	Fire impacts are moderate. Litter layer is consumed and humus layer is charred or consumed. Mineral soil not visibly altered, but soil organic matter (OM) has been partially charred.	Fire impacts are deep. The entire forest floor is consumed and top layer of mineral soil is visibly altered. Surface mineral structure and texture are altered. Mineral soil is black due to charred or deposited OM or is orange from burning.

[1] Evaluate on main trails but not necessarily for wheel tracks or depressions.

[2] Soil resistance to penetration with a tile spade or probe is best done when the soil is not moist or wet.

[3] See USDA NRCS (1993).

Postactivity Assessment

Step 1. Before starting work in an activity area, examine the soil in a nearby undisturbed unit for forest floor thickness, composition, mineral soil horizon depth(s), and depth to bedrock (if applicable). If baseline data have been collected (as in baseline assessment step 2), then this examination procedure may not be necessary. Examining an undisturbed area is essential, however, if one observer recorded the preactivity data and another observer is collecting the postactivity data. If an undisturbed site is not available, examine the undisturbed soil around stumps to become familiar with uncompacted soil conditions. Decide on the type of monitoring transect needed and locate a starting point using a method similar to that used for the preactivity assessment. It is not necessary to replicate transect locations from the previous assessment. The required sample size is likely to be different because of the increased variability of the site postactivity. It is better to complete two different assessments within the activity area.

Step 2. Using the procedure described for preactivity assessments, determine the soil surface disturbance. Record data points until you have taken enough monitoring points to reach the sample size calculated by the electronic spreadsheet or shown on the paper sample size table.

As in steps 7 and 8 (in the preactivity assessment), indicate the disturbance class for each point and indicate which points are considered detrimentally disturbed and would affect long-term site sustainability.

Filling Out the Field Form

The worksheet forms for the FSDMP provide for a core set of attributes that are important for linking soil disturbance to changes in site productivity. Although these forms represent a core data set, however, on some sites they may not be an expected attribute of the site. The soil indicators may also represent a more intense sampling scheme than is required for the monitoring objectives. By varying the sampling intensity and turning some attributes “off,” you can still collect some of the soil indicators but be more efficient at data collection. The forms were designed so that a rapid assessment of soil disturbance would consistently look at a standard set of soil disturbance indicators; collecting this standard set of data is the reason why you must fill out each column completely before moving on to the next monitoring point. Do not modify the soil indicators on either the electronic or paper forms; the forms were designed to make data entry into the SoLo database quick and easy.

Site Descriptors and Soil Indicators

Each monitored activity area must have the required site descriptors included on the reports. These descriptors and their definitions are located in appendix G of volume II.

Detailed definitions about soil indicators used in the FSDMP appear in volume II. Table 3 illustrates the visually recognizable attributes of each indicator. When assessing soil indicators, each indicator can place the monitoring point into a different soil disturbance class. You must decide which feature is the overriding concern (based on soil texture, expected vegetative response, or site sensitivity) and to which soil disturbance class the monitoring point will be assigned.

Machine Traffic Disturbances

Use the ONSITE worksheet to calculate large features and determine the areal extent of skid trails, ruts, and landings. If the areal extent of these features is over the regional limit for detrimental disturbance, additional monitoring may or may not be needed.

Compaction

The *Data Entry* worksheet (see appendix C-3 in volume II) has three rows that list compaction (by depth). Determine the maximum extent of compaction and record a “1” (present) in the appropriate cell for that monitoring point. Record a “0” in each of the other two rows. If compaction occurs throughout the profile (not at one depth), then place a “1” in each cell for compaction. Visual indicators of change in compaction level are past operations (from aerial photos or databases), wheel tracks or depressions (ruts), equipment trails (e.g., from more than two passes), excavated or bladed trails, penetration resistance, and a change in structure.

Insert a metal rod or shovel into the ground to determine changes in the compaction level of a monitoring point. This surrogate for bulk density sampling can be effective if undisturbed soils are nearby to calibrate this “push” test. You must calibrate yourself to the physical resistance of each soil type. Although a change in compaction is often measured by pushing a rod or spade into the soil (or taking a bulk density core), the visual attributes listed previously (wheel tracks, equipment trails, etc.) may be all that is necessary to determine a change in surface disturbance.

Placing compaction into a soil disturbance class (disturbance class 1, 2, or 3) is based on depth of compaction change into the mineral soil. Because of this depth relationship, it is important to know the undisturbed condition (at depths) of the soil preactivity.

Rutting and/or Wheel Track Impressions

The *Data Entry* worksheet (see appendix C-3 in volume II) has three rows in which ruts are listed (by depth). Determine the maximum extent of the rut and record a “1” (present) in the cell for that monitoring point. Record a “0” in each of the other two rows. To measure the depth of the rut, you may need to determine where the approximate surface of the undisturbed soil is (or was). As mentioned previously, you can measure these physical features for area (length multiplied by the average width) and enter them into ONSITE to determine areal extent.

Wheel tracks or ruts (impressions in the soil caused by heavy equipment) vary in depth and width. On sites that have a high compaction hazard (e.g., fine-textured soils, steep slopes), a shallow rut may cause degradation in site quality by altering the flow of water and gasses in the soil and/or increasing soil penetration resistance. On sites that have a low compaction hazard (e.g., coarse-textured soils), deeper ruts may not cause a detrimental change to water and gas flow but may represent displacement of fertile topsoil layers. Regardless of texture, however, wheel tracks and ruts can cause water to be routed off a site, making it unavailable for plant growth. Within a rut or wheel track could also be altered soil structure, increased soil density, puddling, compacted deposits of forest floor, fine slash, and woody debris (not readily excavated with a shovel). Placing ruts and wheel tracks into a soil disturbance category (disturbance class 1, 2, or 3) is based on their depth on the soil surface and their extension into the mineral soil profile.

Soil Structure

Record massive/platy/puddled soil on the *Data Entry* worksheet (see appendix C-3 in volume II). Determination of a change in structure is by depth and can sometimes be linked to the change in compaction level at the same depth. Determine the maximum extent of the change in structure and record a "1" (present) in the cell for that monitoring point. Record a "0" in each of the other two rows, unless these structural changes extend beyond one depth. In that case, record a 1 in each field.

Massive, platy, and puddled structures are indicators of a change in soil structure and a reduction in pore sizes that will change pore size distribution. Massive soil can be naturally occurring or can be caused by management activities. Massive structure means structural units are not present and the soil is a coherent mass. Platy structure can also be naturally occurring, but coarse-platy structure that has flat or tabular-like (dinner plate) units within the profile is usually caused by harvesting equipment. Puddled soils occur when equipment operates when the soil is too wet; soil is smeared along a wheel track or rut and causes water to pond on the surface. The change in soil physical conditions and their depth into the mineral soil profile will determine in which soil disturbance category (severity class) you will place it.

Surface Organic Matter

The *Data Entry* worksheet (see appendix C-3 in volume II) has a row for recording the depth of the forest floor (all surface organic horizons combined). Forest floor depth can be used to determine loss of nutrients from the organic layers. If the organic layers are piled and burned, nutrients are lost from the site. Page-Dumroese et al. (2000) describe how to use the NRCS soil data to determine approximate nutrient amounts and potential losses. Depending on site variability, you can collect this value for some (e.g., every 10 points) or all of the points. Measure the forest floor depth with a pocket ruler.

Displacement

Forest Floor

Record if the forest floor is impacted (e.g., if the surface organic matter has been moved from one place to another) on the *Data*

Entry worksheet (see appendix C-3 in volume II). The item reads "forest floor impacted." Record either a "0" (forest floor is not impacted) or a "1" (forest floor is impacted) in this row for each monitoring point. Large areas of displaced forest floor can lead to changes in nutrient cycling or erosion. Changes in the distribution and depth of the forest floor will change the soil disturbance severity rating. If the area of forest floor displacement is large, measure the area (length times average width) and enter the result into the ONSITE portion of the database to determine areal extent.

Mineral Soil

Record removal of the top mineral soil under "topsoil displacement." Record either a "0" (displacement is absent) or a "1" (displacement is present) in this row for each monitoring point. Mineral top soil displacement and gouging can result in degradation of site quality by exposing unfavorable subsoil material (e.g., denser, lower in nutrients, less organic matter, calcareous), altering slope hydrology, and causing excessive erosion and, therefore, a loss of nutrients. Displacement that has removed most of the surface soil and exposed the subsoil is considered severity class 3. The impacts of mineral soil displacement on long-term productivity are governed by slope gradient, slope complexity, and subsoil conditions.

Changes in the soil disturbance categories are based on mixing of topsoil with the subsoil, topsoil removal, and evidence of gouging and piling. This attribute is the only one specifically linked to an areal extent in most regional soil quality standards and guidelines. Document the areal extent used by individuals before monitoring and list it in the comment field. Because the electronic field form is used to calculate ongoing sample size using "0s" and "1s," areal extent size must be listed elsewhere. For example, if the regional soil quality standards lists an areal extent (e.g., >1.5 m (5 ft) in diameter), then use that areal extent for counting mineral soil displacement (counted as "1" [present] on the worksheet). In addition, if areas of mineral soil displacement are extraordinarily large, measure them for area (length multiplied by the average width) and enter the result into the ONSITE calculator.

Point Attributes

After recording information about forest floor impacted, use the section on the *Data Entry* worksheet (see appendix C-3 in volume II) that asks for information about live plants, invasive species, fine woody material, coarse woody material, bare soil, and rock. These attributes are meant to help describe site conditions that may indicate a change in site sustainability or erosion potential. These attributes are not automatically included in the sample size calculation on the *Variable Selection* worksheet (see appendix C-2). If these attributes are important for particular sites, however, they may be included in the sample size calculation.

Erosion

Record erosion in the *Data Entry* worksheet (see appendix C-3 in volume II) under "erosion." Record either a "0" (absent) or a "1" (present) in this row for each monitoring point. Soil erosion is the movement of soil by water and wind. Accelerated erosion (erosion caused by human activity that is more than the historic erosion rate) causes both onsite (soil loss, nutrient loss, lower productivity, shallower mineral soil) and offsite (reduced stream water quality, increased sedimentation, loss of aquatic habitat) impacts.

Erosion noted in the FSDMP is for surface soils within an activity area. It is not designed for roads, ditches, or places where the subsoil is exposed. The degree and extent (slight, moderate, or severe) of erosion will place this attribute into different soil disturbance (severity) categories.

Prescribed Fire and Pile Burning

Record fire severity on the *Data Entry* worksheet (see appendix C-3 in volume II) in the three rows that list fire severity (light, moderate, and severe). Determine the fire severity of the monitoring point and record a "1" (present) in the cell for that point. Record a "0" in each of the other two rows.

Broadcast Burning

Broadcast burns across the activity area will likely create a mosaic of site conditions. Low-severity burns will likely not alter soil processes for an extensive period of time. Hotter burns may impact both the forest floor and mineral soil material. As burn severity increases, the soil disturbance class (1, 2, or 3) also increases.

Pile Burning

Piles of waste logging materials, brush, or tree tops (slash) that remain after harvest activities are often burned in the activity area or on landings and skid trails. It may be difficult to describe conditions under the burned area if substantial slash remains, but it is critical to assess the size (width multiplied by the length or diameter) of the area. Use ONSITE to help calculate the size of these features. Because monitoring points may land on different piles, assess them independently for severity. Assess burn piles similarly to broadcast burning severity.

Although wildfires are not considered as part of the FSDMP, record the impacts of fire on the soil resource during preactivity assessments to help determine if mitigation measures may be necessary.

Assigning a Disturbance Class

Soil disturbance classes are assigned using visual surface characteristics and they are recorded for each monitoring point in the survey. The disturbance classes are defined in the previous sections and table 2. Table 3 also provides a list of the visual attributes of each soil indicator and some potential management-induced changes. Data collected at each monitoring point provide a representative sample of the activity area. The percentage of the activity area in each soil disturbance class is automatically calculated in the electronic worksheets and the results are displayed on the *Results* worksheet (see appendix C-4 in volume II). Reliability is estimated from the variance among estimated point proportions of each condition class. At some points, there may be a variety of soil disturbances. The observer must evaluate these overlapping indicators so that the soil disturbance class best represents the point.

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Appendix A. Safety of Hazard Analysis

1. WORK PROJECT/ ACTIVITY Soil Quality Monitoring	2. LOCATION
4. NAME OF ANALYST	5. JOB TITLE
8. HAZARDS	9. ABATEMENT ACTIONS Engineering Controls • Substitution • Administrative Controls • PPE
Communication breakdown	Never travel or work alone in isolated areas without preparing and discussing a detailed JHA that includes emergency evacuation procedures and a communication plan. Talk to each other. Let other crew members know when you see a hazard. Avoid working near known hazard trees. Yell "ROCK!" if you see one start to roll down the hill. Always know the whereabouts of fellow crew members. Review emergency evacuation procedures (see below). Carry a radio and spare batteries. Ensure that local frequencies and repeaters are programmed in radios. Contact local districts or resource areas prior to field work to determine appropriate communication protocols. If going to a remote area alone, let someone know specifically where you will be; be sure someone knows you have returned.
Overdue, no contact, missing	File itinerary of planned routes of travel, destination, ETD/ETA, employee names, emergency phone numbers/communication system and contact points, and checkin/checkout system.
Falling down, twisted ankles and knees, poor footing, and general slips, trips, and falls	Always watch your footing. Slow down and use extra caution around logs, rocks, and animal holes. Steep slopes (>20%) can be hazardous under wet or dry conditions. Wear laced boots with nonskid, Vibram®-type soles for ankle support and traction. Stretch before hiking.

Crossing creeks, seeps, bogs, wet logs, wet rocks, wet vegetation slopes, and wet ash slopes	Watch where you walk in streams, expect rocks to be slippery, and do not cross if you feel unsafe. Cross facing upstream so knees do not buckle; use a stick for extra balance. Expect mud and vegetation-covered water to be deeper than it appears. Expect logs to be slippery, especially when the bark is worn off. Expect trails in wet areas to give way to pressure near toe slopes. Keep limber and alert at all times. Be aware in areas of wet ash, loose rocks, and unstable slopes. Slopes with wet vegetation are frequently slick and hazardous.
Stobs, sharp limbs, and other puncturing objects	Long pants, good boots, and cautious attention will mitigate the danger of possible punctures and tears associated from stobs. Puncture wounds are particularly difficult to clean completely in the field; monitor closely for swelling and throbbing. Obtain medical treatment if these conditions persist. Always expect hidden stobs in dense vegetation. Learn to roll; do not use arms to break a fall. As an option, cutting pant legs may reduce falls associated with stobs.
Falling objects	When applicable, wear a hardhat for protection from falling limbs and pinecones and from tools and equipment carried by other crew members. Always wear a hardhat in burned areas, high snag density areas, falling rock areas, and high wind situations. Try to stay out of the woods during extremely high winds.
Damage to eyes	Watch where you walk, especially around trees and brush with limbs sticking out. Exercise caution when clearing limbs from tree trunks. Wear eye protection.
Bee and wasp stings	Watch for respiratory problems. Notify dispatcher/other crew members/supervisor and get person to a doctor immediately if he/she has trouble breathing. Always know where the first aid kit is. Gently scrape stinger off if one is present. Apply analgesic swab and cold pack, if possible, and watch for infection. Flag the location of any known nests and inform other crew members. Carry antihistamine and asthma inhaler for bee stings. If known allergy, carry proper medication and instruct co-workers in administration.

Ticks and infected mosquitoes	Wear long-sleeved shirts. Tuck pants into socks/ boots. Visually check each other for ticks while in the field. Check yourself carefully at home at day's end. Use repellent at your discretion. If a tick is imbedded in you: • Gently pull the tick out with tweezers or fingernails, using a quick tug. • Ensure tick head is removed. • Wash the infected area and monitor for a red rash. • Monitor the tick bite for inflammation, color alteration, or swelling. See a doctor if problems present themselves.
Heat stress	Remain constantly aware of the four basic factors that determine the degree of heat stress (air temperature, humidity, air movement, and heat radiation) relative to the surrounding work environmental heat load. Drink enough water or sports drinks to keep hydrated and prevent heat exhaustion or heat stroke (at least 2 quarts in summer). Consumption of caffeine and alcohol greatly increase susceptibility to dehydration. Limit these intakes before and during exposure to heat stress. Know the signs and symptoms of heat exhaustion, heat cramps, and heat stroke. Heat stroke is a true medical emergency requiring immediate emergency response action. NOTE: The severity of the effects of a given environmental heat stress is decreased by reducing the work load, increasing the frequency and/or duration of rest periods, and introducing measures that will protect employees from hot environments.
Cold extremes	Cover all exposed skin and be aware of frostbite. Although cold air will not freeze the tissues of the lungs, slow down and use a mask or scarf to minimize the effect of cold air on air passages. Additional measures to take to avoid cold weather problems— a. Dress in layers with wicking garments (those that carry moisture away from the body) and a weatherproof slicker. A wool or breathable synthetic outer garment is recommended.

	b. Take layers off as you heat up; put them on as you cool down. c. Wear head protection that provides adequate insulation and protects the ears. d. Maintain your energy level. Avoid exhaustion and overexertion, which causes sweating, dampens clothing, and accelerates loss of body heat and increases the potential for hypothermia (the lowering of the body's core temperature). e. Acclimate to the cold climate to minimize discomfort. f. Maintain adequate water/fluid intake to avoid dehydration.
Wind	Windchill greatly affects heat lose. Avoid working in old, decomposed timber, especially hardwoods, during periods of high winds due to snag hazards. Wind also exacerbates the likelihood of hypothermia. Always carry appropriate rain gear (both jacket and pants), because rain gear greatly mitigates the effects of windchill.
Rain	Always carry appropriate rain gear (both jacket and pants). Hypothermia is much more likely when moisture is directly on or near the skin.
Sun rays	Ultraviolet light from the sun can be damaging to the eyes; look for sunglasses that specify significant protection from UV-A and UV-B radiation. Ultraviolet light from the sun can be damaging to the skin and lead to sunburn or skin cancer; on bright, sunny days and overcast days, always carry and apply to exposed skin, SPF 15-rated sun block lotion, a wide-brimmed hat, long-sleeved shirt, and pants to mitigate harmful light rays on the skin.
Lightning	Check weather report; stay off ridge tops and open slopes during lightning storms. If stuck in open, keep radio and metallic objects away from you, squat down with only feet on ground using insulating pad if possible, and keep as much of your body off the ground as possible. Never use radios or cell phones in lightning. Stay away from large trees that may act as lighting rods. Look for cover in even-aged tree stands. Above all else, stay out of streams during lighting activity, and do not carry stadia rods or other survey tools—graphite, fiberglass, aluminum, and wood can all attract lighting, especially when wet. Never use any electronic devices during lightning activity.

Environmental hazards	Choose campsites that are free of snags and leaning green trees and that have no danger of rolling rocks, slides, and flash floods.
Animal problems	Do not camp in areas with known animal problems. Hang food and follow food and cooking guidelines when in bear country. Keep a clean camp, do not leave food out, and clean up spills.
Ecological impacts	Follow "leave no trace" guidelines to minimize impacts from camping.
Giardia cryptosporidium and other parasites	Drink filtered or tap water at all times. Boil water if you do not have a filter or access to clear potable tap water, or use iodine tablets.
Fatigue, carelessness	Get plenty of sleep at night. Be careful and do the job right the first time, safely.
Wounds, scrapes, bruises, sprains, rashes, burns, infections, and general ailments	Carefully clean all cuts, punctures, scrapes, and such with antiseptic. Dress with clean bandages, replacing as necessary. Closely monitor all wounds, taking caution not to worsen them by continued physical activity. If ill, do not continue exertion and worsen the ailment. Take special care not to pass contagious ailments to fellow workers. Notify other crew members and immediate supervisor of all accidents, illnesses, and wounds, including those obtained before going on a tour. If applicable, this notification should take place before departing into the backcountry.
Toilet paper and feminine hygiene waste materials	These items, when used or unused, and if scented, must be considered attractants for animals, but carry the added weight of being considered biohazardous waste when used. Handle disposal of these items in one of two ways: (1) pack it in, pack it out—dedicate two plastic zipping or Ziploc® bags for this method or (2) dig a 4-in by 6-in cat hole to bury items along with waste.
Blisters and other foot injuries	These wounds are quite common in the back-country and should be planned for. Plenty of clean, dry socks should be on hand (two for each day if you are prone to blisters). Regular changing of socks prevents blisters and reduces infection of existing ones. In addition, thick moisture-wicking socks with thin, nylon liners are quite useful for preventing blisters. Break in boots before the start of the field season as well. Proper-fitting boots are essential. Always carry moleskin, rubbing alcohol, and duct tape for mitigating these problems.

Trash	The survey crew will pack out all trash. Treat all food-oriented trash the same as food in terms of wildlife attraction.
Other trash, left by other people	It is encouraged to pick up other trash found during surveys, but exercise extreme caution when doing so. Broken glass and the edges of tin cans can be hazardous. There are reports of bottles fermenting in the sun and building pressure, only to shatter and send glass fragments flying when disturbed by trash collection. Thus, gloves, eye protection, and long-sleeved shirt and pants are good ideas when handling trash.
Methamphetamine remains	It has come to the attention of law enforcement that many illegal drug producers are using national forests as ground upon which to make illegal drugs. Specifically, methamphetamine, also known as crystal meth, remains or trash have been found on a much more frequent basis. Thus, any trash that may appear suspicious or that emits toxic odors should be avoided and located on the map. A report to the local LEO is in order for such suspicious trash. The Forest Service course on recognizing and dealing with methamphetamine hazards is recommended.
Marijuana	Forest Service employees are advised, when encountering marijuana growing on national forest property, to leave the vicinity carefully, cautiously, and immediately. In some cases, these areas have been known to be guarded and/or booby-trapped. Notify local LEO immediately.
Communication	For cases in which evacuation is needed, communication procedures are essential. Know how to use the radio and who to contact in an emergency.
Medical evacuation	For cases in which injury, illness, or accident initiates the need to evacuate a person, the first priority is to contact other crews in the area for assistance, and then contact emergency crews from the district office or supervisor's office. If the wounded person is mobile, the crew should calmly and steadily proceed by the most direct and easy route to the vehicles in an effort to get to professional medical care. If the hurt crew member is not mobile, make preparations for backcountry extraction by a search and rescue team. In either case, if there is no radio contact, a crew member should be dedicated to hiking to the ridge to get

	a radio signal out. If search and rescue must intervene, be prepared with GPS coordinates and legal description of the location. Also plan to send a healthy crew member to the vehicles to assist search and rescue in locating the wounded crew member. Always remember your backcountry safety training during these times, and remember to think cool, calm, and collected. The atmosphere of the accident often instills shock, so mitigate shock by providing a relaxed, attentive, and well-thought-out atmosphere.
Danger evacuation	If weather, wildlife, human, or other dangers cause a need for evacuation, the group should stay together and proceed to safe quarters. Use your safety briefings about shelter areas and communication in case of these events; you will be trained for such occasion.
Once to the vehicle	Look at additional evacuation measures regarding vehicle safety, but always remember that driving should be cautious, even in the face of an accident or dangerous situation.
10. LINE OFFICER SIGNATURE	**11. TITLE**

ETA = estimated time of arrival. ETD = estimated time of departure. GPS = Global Positioning System. JHA = job hazard analysis. LEO = law enforcement organization. SPF = sun protection factor.

Appendix E

Shift Report Template

HFRD Machine Shift Repo

Unit ____________

Date ___/___/___

Operator ____________

Machine ____________

Fuel Consumption ____________

___:___ **Shift Start Time**

___:___ **Shift End Time**

For each delay event 10 minutes or longer, fill out Start Time, End Time, and Event Type.
Please fill out a new report for each shift or when changing to a different unit.

Start Time	End Time	Total Time	Circle Event Type	Comments
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	
:	:	:	Ld | Unld | Brk | Srv | Rep | Other	

Please explain anything unusual about the shift.
(Example: The engine ran poorly which made the machine slow.)

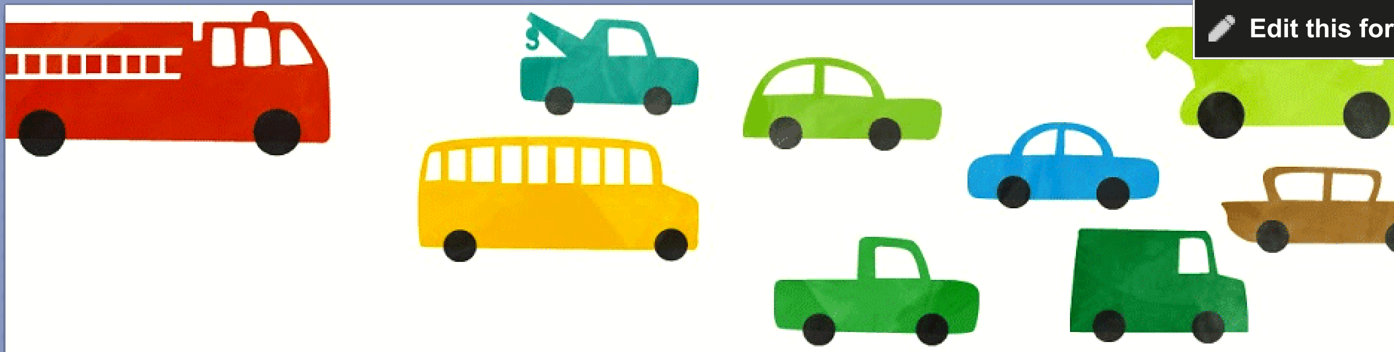
(Write on back of page if needed.)

Start Time Time of day when event started (Hour : Minute)
End Time Time of day when event ended (Hour : Minute)
Total Time Total time of event (Hours : Minutes)
Ld Loading (including any disassembly)
Unld Unloading (including any assembly)
Brk Break (lunch, coffee, smoke, etc.)
Srv Service (any routine maintenance or service: fuel, lubrication, etc.)
Rep Repair (any breakdowns or problems with machine: broken hose, etc.)
Other Other (describe event: talked to supervisor, etc.)

Appendix F

Equipment Vendor Equipment Form

Edit this form



Equipment Cost

This form should be filled out by equipment vendors for specific pieces of equipment that will be used in the demonstration at any of the three locations. Several key fields are required. If you do not feel you can provide accurate estimates for one or more of the optional fields, leave them blank. Keep in mind these numbers will be used to estimate hourly cost on the HFRD sites.

* Required

Contact

Please fill this out so we can follow up if necessary

Name *

First and last

Affiliation

Who you work for

E-mail address *

Phone # *

Equipment information

Descriptive information.

Equipment Mfg. *

Please give manufacturer name

Equipment model number *

Model number for the equipment

Equipment description *

Brief description of the equipment including any non-standard attachments

Rated Horsepower *

combined horsepower of the equipment

Lubricant reservoir *

Size of engine oil reservoir (gal)

Lubricant hours *

Reccomended hours between oil change

Sites *

At which sites will this equipment be deployed?

- [ ] Shaver Lake (October 3-10)
- [ ] San Bernardino NF (October 12-17)
- [ ] Santa Rosa Indian Reservation (November 16-21)

Preliminary Data

Total equipment costs include all costs accrued from buying, owning, and operating equipment. For analysis, equipment costs can be grouped into fixed costs, operating costs, and labor costs. To calculate these costs, the user needs preliminary information and understanding of the following definitions.

Equipment cost with standard attachments *

Not including tires. FOB factory price

Optional attachment.

Optional attachment for equipment (eg: masticating head for skid steer)

Optional attachment cost.

Optional equipment attachment cost (falling head for feller-buncher, masticating head for skid steer)

Miscellaneous

such as for installation or adaptation of the equipment to the logging system, should be included in the initial investment cost.

Salvage Value

The amount that equipment can be sold for at the time of its disposal. If not estimated this will be calculated as 20% of the initial investment cost.

Economic life

This is the period over which the equipment can operate at an acceptable operating cost and productivity (years)

Scheduled operating time

Scheduled operating time is the time during which equipment is scheduled to do productive work. The time during which a machine is on standby is not considered scheduled operating time. (hours/year)

Productive Time

Productive time is that part of scheduled operating time during which a machine actually operates (hrs/year). This can be caculated easily by multiplying an estimate of the percentage of the scheduled operating time that the machine is productive.

Fixed costs

Fixed costs do not vary with hours of operation. They are neither affected by the amount of equipment activity nor output and are incurred regardless of whether a piece of equipment is used or not. Fixed costs include depreciation, interest, insurance, and taxes.

Depreciation method

A piece of equipment loses its value with time and possesses only salvage value (or trade-in value) at the time of trade-in. The basic objective of the depreciation schedule is to recover the initial investment cost of equipment each year over its estimated economic life. The method for calculating depreciation is ordinarily determined by its planned or desired effect on profit and income taxes through the economic life of equipment. The three common methods generally used to compute depreciation are: (1) straight line: value decreases at a constant rate, (2) declining balance: depreciates at a higher rate in the early years, and lower rate later, (3) sum-of-years-digits depreciation decreases at a decreasing fraction each year

- ◯ strait line
- ◯ declining balance
- ◯ sum-of-years digits

Interest rate

On borrowed captial for purchase, percent (eg: 0.04)

Insurance

Annual cost to insure equipment ($/year)

Taxes

Annual property or usage taxes ($/year)

Operating Cost

Operating costs, unlike fixed costs, change in proportion to hours of operation or use. They depend on a host of factors, many of which are under control of the operator or the equipment owner to a certain extent.

Maintenance and repairs

Includes everything from simple maintenance to the periodic overhaul of engine, transmission, clutch, brakes, and other major equipment components. Storage costs and preventive maintenance are also included ($/year)

Fuel

$/hour

Lubricants

$/hour

Tires

$/hour

Labor Cost

Labor cost is the cost to keep an operator on the job on an hourly basis. Includes Social Security, Federal Unemployment Insurance, State Unemployment Insurance, Workmen's Compensation, etc.

Wages

$/hour

Social Security

$/hour

Unemployment insurance

$/hour

Workmens compensation

$/hour

Other

Sum of any other condtibutions (401k, uniform, etc.) on an hourly basis ($/hour)

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Appendix G

Treatment System Descriptions

System: **Caterpillar 299D**

Attachment: Caterpillar HM418C mulching head

Description: The Cat 299D is a compact skid steer track loader that features a suspended undercarriage for lower ground pressures and superior traction. The ergonomic operator station and easy-to-use pilot operated joystick controls facilitate operation throughout the workday. The advanced hydraulic system accommodates a range of attachments. The Cat HM418C mulching attachment used for the HFRD demo features fixed teeth that are easily serviced.

Price: Cat 299D - $111,000
Cat HM418C mulching attachment - $32,500

Demos: Shaver Lake, Big Bear Lake, Santa Rosa

Vendor: Contact local Caterpillar dealer for sales and support.
www.catresourcecenter.com

System: **FAE – Prime Tech PT-175**


Attachment: FAE 140/U-175 mulching head

Description: The Prime Tech PT-175 is the smallest purpose built track carrier by FAE. It is designed to operate on steep terrain. The PT-175 is a compact size tracked carrier with 160 HP, designed to perform light to medium duty forestry work and vegetation management, with a grinding diameter up to 10 inches. It has a BERCO undercarriage available with either a standard single grouser or LGP (3.65 psi) single grouser pad.

Price: FAE – Prime Tech PT-175 - $250,000.00
FAE 140/U-175 mulching attachment
(cost is included in equipment purchase)

Demos: Shaver Lake, Big Bear Lake, Santa Rosa

Vendor: Global Machinery
3321 Airport Road
Sacramento, CA 95834
877-541-6702
www.Globalmachinery.com

System: **Fecon FTX 128L**

Attachment: Fecon BH85SD-4 mulching head

Description: The Fecon FTX128L is a dedicated steel track mulching tractor with loader arms to reach up to 10 feet in the air. It comes equipped with a severe duty Fecon BH85SD-4 mastication head with FGT double carbide tools for durability in rocky environments. The oversized coolers with reversing fans allow it to operate in high ambient temperatures continuously. It can run a variety of skid steer attachments as well.

Price: Fecon FTX128L - $154,000.00
Fecon BH85SD-4 mulching attachment $38,300.00

Demos: Shaver Lake, Big Bear Lake, Santa Rosa

Vendor: Fecon Inc.
3460 Grant Drive
Lebanon, OH 45036
513-696-4430
www.Fecon.com

***System*: Goats**


Contractor: Star Creek Land Stewards

Description: Star Creek Land Stewards prescribes goats and/or sheep in our grazing programs to meet the vegetation management and fuel reduction goals. The primary breeds in our herds are Dorper sheep and Spanish Boer cross goats. Portable low voltage electric fencing is used to create appropriate sized controlled paddocks. Herd size from about 400 – 800 is typically prescribed and is based upon project size and scope. Areas in size of 5 acres or more is generally required to justify overall costs. Grazing is most effective generally between February and September in California. Re-treatment intervals can range from every 1-3 years, depending upon vegetation management goals as well as annual precipitation and re-growth.

Price: \$300 - \$2,000 per acre dependent upon the following considerations: time of year, water accessibility, total acreage, steepness of terrain, vegetation type, and transportation type required for site accessibility of livestock.

Demo: Shaver Lake

Contractor: Star Creek Land Stewards, Inc.
1232 California Avenue
Los Banos, CA 93635
209-704-1790
www.starcreeklandstewards.org

System: **Hand Crew – California Conservation Corps**

Description: Thin fuels and pile for burning. Crew falls trees, trims ladder fuels, limbing, bucking, and hand piling for burning. Crews include 14 crew members and one crew supervisor. For test project, approximately 2 acres were treated using basic hand tools (rakes, loppers, McLeods), 4 Stihl chainsaws, and 1 Stihl pole saw. Sloping to steep terrain was treated with little to no soil disturbance. Minimum number of acres for a treatment project (to justify mobilization costs) is 4 to 5 acres**.** Time of year for treatments is when area is free of snow.

Price: 14 Person Hand Crew (including 4 sawyers) $2,000 - $2800 per acre treated depending on fuel type and terrain.

Demo: Shaver Lake

Contractor: California Conservation Corps
2536 N. Grove Industrial Drive
Fresno, CA 93727
559-458-0914
www.ccc.ca.gov

***System*: Hand Crew – Ramona Band of Cahuilla Indians**

Description: The Ramona Band of Cahuilla provided a 12-man fuel module to target the reduction of fuels for the HFRD project. The goal was to eliminate unnaturally large amounts of fuel and the "fuel ladder" through the selective removal of trees, limbs, and shrubs on the approximately 5 acre parcel. Cut fuels were gathered and chipped in place. The Ramona Band can provide a crew as small as 10 men up to a full crew of 20. The crew comes equipped with all their own equipment including chain saws, hand tools, and a chipper. All crew members are qualified as Wildland Fire Fighter 2 (FF2) with several having additional qualifications. The crew has previously contracted with several federal agencies and tribal nations to work on wildland urban interface projects; invasive species eradication projects; fuels reductions projects; Burned Area Emergency Rehabilitation (BAER) projects; and fire ready projects which required compliance with a project imposed fire plan.

Price: Approximately $1,200-$2,000/acre treated (dependent on treatment prescription, terrain, and crew size).

Demo: Santa Rosa Indian Reservation

Contractor: Ramona Band of Cahuilla
56301 Highway 371, Suite B
Anza, CA 92539
951-763-4105
www.ramona-nsn.gov

***System:* John Deere 210G**

Attachment: Fecon BH80EXC mulching head

Description: The combination of a traditional John Deere 20 ton excavator with a Fecon BH80EXC severe duty mulcher offers the benefit of a versatile machine that has extended reach and mobility for work along roadsides, steep banks, and waterways. The power offered by the John Deere 210 is matched to the BH80 mulcher attachment with variable displacement motors for optimum performance and a 56" cutting width.

Price: John Deere 210 Excavator $200,000
Fecon BH80EXC Severe duty mulcher attachment - $50,000

Demo: Shaver Lake

Vendor: Fecon Inc.
3460 Grant Drive
Lebanon, OH 45036
513-696-4430
www.fecon.com
www.deere.com

***System:* Kaiser S2**

Attachment: Fabricated mastication attachment (by Access Limited Construction, Inc.)

Description: This excavator is designed to operate on steep and difficult access terrain. The telescopic outrigging legs are capable of moving up, down, in and out from the chassis, allowing the S2 to navigate steep and uneven terrain. Permanent all-wheel drive offers extra mobility, but this is also available in two-wheel drive. The wheels can be removed for increased stability in extreme terrain. The mastication attachment demonstrated with the S2 consists of swinging knives mounted in the center of a guarded attachment head.

Price: Kaiser S2 - $450,000 (all wheel drive model)
FAE DML/HY 125 mastication attachment - $85,000 (example)

Demo: Shaver Lake
Contractor: Dyer All Terrain Excavation
Truckee, CA 96161
530-386 - 5228
www.dyerallterrainexcavation.com

Demo: Santa Rosa
Contractor: Access Limited Construction Inc.
San Luis Obispo, CA 93401
www.accesslimitedconstruction.com

Vendor: GS Equipment
Tampa, FL 33619
866-586-8956
www.gsequipment.net

***System:* Takeuchi TB290**


Attachment: FAE DML/HY/VT 100 mastication head

Description: The Takeuchi TB290 excavator is a compact hydraulic excavator with the capacity to accommodate a variety of attachments. The TB290 has a maximum reach of just over 24 feet, which gives it the capability of working roadside or reaching into sensitive areas being treated for fuels reduction. The FAE DML/HY/VT 100 mastication head has fixed teeth, either carbide or reversible. The optional front and rear hood allows the operator to control the size of the finished product and helps control the direction of material leaving the head. The VT version is rated for treatment of material up to 5” in diameter.

Price: Takeuchi TB290CL - $120,000.00
FAE DML/HY/VT 100 mastication head - $25,000

Demo: Shaver Lake, Big Bear Lake, Santa Rosa

Vendor: Global Machinery
3321 Airport Road
Sacramento, CA 95834
877-541-6702
www.globalmachinery.com

***System:* Takeuchi TL12**

Attachment: FAE UML/SSL/VT-150 mulching head

Description: The Takeuchi TL12 is one of the most compact skid steer loaders manufactured by Takeuchi. It has a purpose built track frame and features integrated cross members to maximize strength. The TL has planetary drives that are positioned rearward to allow more contact points between the sprocket and track. It also has 13.5 inches of ground clearance that allows the TL12 to traverse terrain and obstacles. The FAE UML/SSL/VT mulcher has fixed carbide tipped teeth and a reengineered mulching chamber that allows more material to enter at once, thus increasing productivity. The VT version increases productivity while decreasing fuel consumption and is rated for material up to 8 inches in diameter.

Price: Takeuchi TL12CRH - $87,000.00
FAE DML/HY 125 - mulching head - $32,000

Demo: Shaver Lake, Big Bear Lake, Santa Rosa

Vendor: Global Machinery
3321 Airport Road
Sacramento, CA 95834
877-541-6702
www.globalmachinery.com

***System:* Timbco 425D**

Attachment: FAE UML/EX-150 mastication head

Description: The Timbco 425D is a track mounted excavator that incorporates an operator controlled leveling cab and upper chassis. This provides stability when performing on steep terrain and allows treatment roadside or along sensitive areas such as creeks or sensitive habitat. The masticating head is mounted on the end of a boom giving the machine a working radius of 25 feet. Timbco equipment is no longer manufactured and has been replaced by Timberpro.

Price: Timberpro (replacement for Timbco 425D) - $450,000
FAE UML/EX-150 attachment - $55,000

Demo: Big Bear Lake

Contractor: Sullivan Logging Company, Inc.
P.O. Box 1382
Idyllwild, CA 92549
sullivanlogging@gmail.com

Vendor: Bejac Corporation
5501 East Street
Redding, CA 96007
www.bejac.com

Appendix H

Public Attendance

Shaver Lake Participation Results

Affiliation	Vendor Reps & Operators	Volunteers & Support	Media Day (10/8)	Demo Day (10/9)	Comments
Equipment Vendors & Reps	36				Includes CCC crew of 16
SCE		10			Includes 6 forestry staff members
SAF		6			Includes UC Merced, local USFS, local consultant
Media			4		Local newspaper, local TV and Ag Alert publication
Private Landowner				18	Ages 30 to 70
Native American				2	
Logging Contractor				2	
Private Consultant				2	
Other Private Businesses				8	Livestock, orchard growers, landscaping, local tree co.
USFS, Regional Office			1	1	
USFS Local				6	
CAL FIRE BOF				2	
CAL FIRE Local				7	
CA State Parks				1	
CA Dept of Forest & WL				2	
CA State & Regional Water Quality Control Board				3	
Sierra Nevada Conservancy				4	
Industry Association				1	California Forestry Association
CSU Humboldt				3	
CSU Fresno				1	
CSU Cal Poly				28	
Reedley College			25		Includes two instructors
UC Berkeley				1	
Sierra High School			50		Includes two instructors
USDA NRCS				1	
USDA Other				2	
RCD or Other				2	
Unknown Affiliation				16	
PGE				1	
TOTALS	**36**	**16**	**80**	**114**	

Big Bear Lake Participation Results

Affiliation	Vendor Reps & Operators	Volunteers & Support	Media Day (10/15)	Demo Day (10/16)	Comments
Equip Vendors & Reps	15				
USFS		20			Includes fire crews, forestry techs, specialists, foresters
SAF		3			Members, SoCal Society of American Foresters
Media					
CA Highway Patrol			2		
City of Big Bear Lake			3		
Tree Care Contractor				3	
Private Consultant				3	
Other Private Businesses				3	
USFS, Regional Office			1	1	
USFS Local			1	4	
CAL FIRE Local				3	
Fuels Treatment Contractor Local				1	
National Park Service				2	
Bureau of Indian Affairs				2	
The Wildlands Conservancy				3	
SB Valley Water Conservation District				2	
Desert View Biomass Plant				2	
Camp De Benneville Pines				1	
Fire District				2	
Community Service District				2	
County Waste Department				1	
TOTALS	**15**	**23**	**7**	**35**	

Santa Rosa Participation Results

Affiliation	Vendor Reps & Operators	Volunteers & Support	Demo & Media Day (11/20)	Comments
Equip Vendors & Reps	14	3		
SAF		4		Members, SoCal Society of American Foresters
SCE			1	
Cahto Tribe of Laytonville Rancheria			1	
Pala Tribe of Mission Indians			2	
29 Palms Band of Mission Indians			2	
Ramona Band of Cahuilla Indians			2	
Morongo Band of Mission Indians			2	
La Jolla Band of Luiseno Indians			1	
Santa Rosa Band of Cahuilla Indians			2	
San Manuel Band of Mission Indians			1	
Bureau of Indian Affairs			2	
Fuels Treatment Contractor			3	
Local Equipment Dealer			1	
Private Consultant			2	
Env Planning Consultants			2	
County Department of Waste Resources			1	
City Waste Management			1	
USFS, Regional Office			1	
USFS Local			12	Included fire crews
CAL TRANS			1	
Non-Profit Organizations			2	
National Park Service			1	
Local Law Enforcement			1	
Idyllwild Energy Project			4	
Local fire agencies			2	
UC Berkeley			1	
USDA NRCS			8	
Unknown Affiliation			3	
TOTALS	**14**	**7**	**62**	