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Production Rates for United States Forest Service Brush Disposal Planning in the Northern Rocky Mountains

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Abstract

Timber harvesting operations generate brush and other vegetative debris, which often has no marketable value. In many western U.S. forests, these materials represent a fire hazard and a potential threat to forest health and must be removed or burned for disposal. Currently, there is no established, consistent method to estimate brush disposal production rates in the U.S. Forest Service's Northern Region, which spans Montana and parts of Washington, Idaho, South Dakota, and North Dakota. Production rates developed specifically for one Northern Region national forest over a decade ago are the basis for many brush disposal production and cost estimates. Evidence suggests that these rates are applied incorrectly in many circumstances. Through a survey of experienced fuels specialists we have developed a Northern Region brush disposal production guide to serve as a baseline from which the required components of brush disposal plans, fuels treatment contracts, and force account planning can be further refined and tailored for individual burn units. Results capture variability in productivity across 10 districts on 5 national forests for hand and machine preparation work, and burning activity fuels and natural fuels. Average production rates are presented with the range and the number of respondents in each category. Results consistently demonstrate that the productivity of Northern Region specialists implementing brush disposal operations is far more efficient than the production estimates contained in other Northern Region guides. This new guide can be used to improve brush disposal planning for the region, and may serve as a model for other regions to collect and provide updated information that reflects current forest conditions, practices, and productivity.

Keywords: brush disposal, prescribed fire, timber sales, U.S. Forest Service Northern Region, fuel management

cover photos

Brian Firman Timber Sale, purchaser performance machine line, Superior Ranger District, Lolo National Forest (photo: Justin Singer)

Sunnyside Timber Sale, slash disposal understory burn, Superior Ranger District, Lolo National Forest (photo: Lorie Cotter)

Twomile Helo Timber Sale, slash disposal understory burn, Superior Ranger District, Lolo National Forest.

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Contents

Introduction

On many lands managed by the U.S. Department of Agriculture, Forest Service, insects, disease, and historically aggressive fire suppression in fire-adapted ecosystems have resulted in large tracts of forest lands that have accumulated heavy fuel loads and are in uncharacteristically severe fire regimes. Forest managers can introduce carefully planned human-ignited fire in forests to mimic natural fire and restore otherwise heavy fuel loads to historical reference conditions. Additionally, harvesting timber to meet society's demand for wood products continues, and harvest operations typically generate significant quantities of logging slash—conventionally referred to as "activity fuels" or "brush" by Forest Service managers—which often has no marketable value. If left onsite, these materials represent a fire and forest health hazard and require disposal (Ruth and Harris 1975). There are many options for brush disposal (BD) ranging from onsite mastication (i.e. crushed, chipped or chopped onto the ground), to removal for use for bioenergy or other bioproducts, and onsite disposal via open burning (Halbrook et al. 2006; Loeffler et al. 2010; Rhoades and Fornwalt 2015). When utilization or mastication is not an option, open burning is likely to be the only BD alternative on Forest Service-managed lands.

Brush disposal is a component of timber sale contracts, stewardship contracts, and permits. As part of the timber sale preparation process on Forest Service lands, a BD treatment plan is prepared "in accordance with Forest plan standards and guidelines and environmental analysis applicable to the sale area" (2409.19; USFS 2011, p. 3). The BD treatment plan outlines the responsibilities of all parties involved with the timber sale for disposing of the logging slash or other debris (i.e., brush) generated from the purchaser's operations and includes details of the BD methods, the activities associated with disposal, and related costs. During preparation of a BD treatment plan, consideration is given to site conditions as well as existing resource management plans developed in accordance with Federal laws such as the National Environmental Policy Act (NEPA 1969). Often, however, purchasers of Forest Service timber have no markets for the brush (such as use as fuel for bioenergy), lack adequate expertise in fuels reduction treatments, or cannot dispose of the brush within critical time requirements. In these instances, purchasers of Forest Service timber are required by Federal statute (16 USC 490) to pay the Federal Government for the estimated cost of disposing of the brush and debris, which is typically conducted by trained Forest Service personnel.

Background

The standardized document and format for preparing BD treatment plans on Forest Service lands is Form FS 2400-62 in the Forest Service Handbook, Series 2400, Chapter 40 (USFS 2011). The BD plan is developed at Gate 3 of the Timber Sale Planning Gate System. In contrast with the associated burn plan, which is not discussed here, the BD plan does not require much detail. Table 1 displays the information required in a BD plan. In addition to the BD plan, a Narrative Statement is required. This statement should include all of the NEPA-approved BD activities, treatment objectives, justification for the treatment, and cost computations. It also includes silvicultural prescriptions for the project and other relevant integrated resource plan information (USFS 2011).

Table 1—Required information in a Forest Service brush disposal treatment plan.

Form FS 2400-62 entries	Entry definitions
Forest	National Forest name
District or Unit	District or Unit name
Sale name	Name of sale
Award date	Contract award date
Compartments or GIS[a] reference	Geographic reference of sale location
Type of plan	Indicates whether the plan is original or a revision
Purchaser	Name of the timber sale purchaser
Contract number	Contract number
List of projects	Each type of project to be implemented
Work activity code	Forest Service Activity Tracking System database code
Unit of work	Applicable units of work, such as acres or miles
Cost per unit	From local experience, cost guides, or other supportable values, such as those contained here. Costs are adjusted for the expected rate of inflation to date of planned accomplishment
Number of units	The total number of units proposed for treatment by collected BD funds for this sale.
Cost	The total BD fund cost for the project (i.e. cost per unit multiplied by the number of units)
Total project cost	The sum of project costs
National program support cost	Total project cost multiplied by the National collection rate for program support
Remarks	Used for any appropriate explanations such as collection rates
Signatures	Signatures of the fuels specialist, District Ranger, and National Forest Supervisor

[a] Geographic information system.

In accordance with Federal law, the Forest Service Handbook also sets forth in great detail how to account for BD treatment costs and how Forest Service personnel should efficiently collect and use BD funds. Funds for BD activities can come from any number of sources, and the purchaser does not always solely bear the cost of implementing the BD treatment plan. For example, alternative funding sources may include nongovernmental or nonprofit organizations, such as wildlife and aquatic habitat conservation entities. These types of organizations often have an interest in the outcome of a timber sale because they expect the harvest and BD to benefit a particular species of concern. Alternatively, they may recognize improvements in other environmental or ecological values and are willing to subsidize BD to ensure the sale occurs. In this regard, accounting for and collecting BD treatment plan costs are well developed. Cost per unit associated with implementing BD treatment plans are a function of productivity, which is influenced by many variables. These factors include local experience and site conditions, in addition to the specific desired outcomes described in purpose and need statements for BD treatment plans. However, the Forest Service Handbook provides no direction for estimating the time required, number of personnel, and other resources to accomplish BD treatment plan objectives.

In fact, like many other Forest Service regions, the Northern Region (which covers Montana and parts of Washington, Idaho, North Dakota, and South Dakota) has no standardized guidelines for estimating production rates associated with BD treatment plan activities. Although many experienced personnel on national forests in the Northern Region have acute knowledge of local conditions and the experience necessary to estimate BD treatment plan costs, many national forests have also developed spreadsheet-based cost calculators to complement expert opinion and facilitate accurate cost estimation. Yet very little information about production rates is required for these models. Whether used individually or in combination, productivity estimates are obtained almost exclusively from two sources: the local experience of fire and fuels management personnel and estimates available in a set of guidelines developed in 2002 for the Nez Perce-Clearwater National Forest, the Clearwater-Nez Perce Fuel Treatment Allowance Collection Guide 2010 (USFS 2010).

Since 2002, at least two additional national forests have adopted the structure, activity production rates, and cost estimates of the Clearwater-Nez Perce guide. Although it has been reported that BD treatment plan production and cost estimates are routinely updated, as of the time of this publication the production and cost estimates are almost identical across all of the guides developed by individual national forests in the Northern Region. Today these guides are consulted for definitive information across much of the region. Yet applying rates developed for a single forest across many Northern Region forests is not ideal for several reasons. Productivity and costs of BD treatment plan implementation are based on highly variable and dynamic field conditions. Forest Service personnel time requirements to implement the BD treatment plan, the accuracy of BD treatment plan costs and purchaser deposits, and efficiency in allocating funding for brush disposal could vary widely across national forests.

Purpose and Need

Some evidence suggests that production rates found in the Clearwater-Nez Perce guide or spreadsheet-based models developed by other Northern Region national forests are not representative of the entire Northern Region. Additionally, productivity and costs for only a few work activities associated with BD production rates are described in the scientific literature. Currently, individual national forests continue to develop BD treatment plans using local knowledge, and to date no study has been conducted to quantify the inherent variability across national forests and Ranger Districts and to propose a consistent method of estimating BD productivity. Costs to implement BD treatment plans are currently developed by using whatever means available, whether local expertise or values from the Clearwater-Nez Perce guide, or a combination of the two. This effort was designed to develop production rates associated with BD treatment plan implementation that can be used in conjunction with known labor and materials costs to inform BD cost development for the Forest Service Northern Region. This work provides baseline production rates for the many work activity components included in BD treatment plans, which can be appropriately adapted based on site conditions, expert opinion, and other variables. This effort is intended to fill the knowledge gap in the forest operations literature pertaining to BD treatment plan work activities and implementation.

This document is intended to inform fire and fuels specialists with baseline estimates from which final production estimates can be developed. This document is not intended to be considered a standard, but rather to provide specialists with insight into calculated average production rates and a sense of the range of production values that peer specialists consider reasonable. To be clear, local experience and conditions should continue to be given great weight in BD treatment plan development. We further acknowledge vast ranges in productivity among the many different work activities reported here and contained in the existing guides, which use the values contained in the Clearwater-Nez Perce guide. Unfortunately, these differences cannot be examined here because the Clearwater-Nez Perce guide does not contain the methods used in its development, or references to specific sources of productivity and cost estimation. It is likely the guide was developed based on local experience and conditions specific to the forest, and does not reflect the varying conditions across the Northern Region.

Literature Review

Aside from the Forest Service Handbook (USFS 2011), we found little publicly available information related specifically to BD treatment plan implementation, or any information for many of the component work activities required for BD treatment plan implementation (for example, lopping, slashing, and slash pile covering). There is, however, much information about machine productivity and machine rates, such as hourly costs, for other purposes, including estimating productivity and costs during logging, fuel reduction or bioenergy operations, and road construction (Loeffler et al. 2009, 2010). As noted by Berry and Hesseln (2004), fuel reduction cost studies are often focused on mechanical fuels treatments or prescribed burning, for which there is abundant technical literature. For example, research exists that explains costs associated with prescribed fire (Berry and Hesseln 2004; Calkin and Gebert 2006; Cleaves et al. 2000; Hesseln 2000). There is also abundant research examining the impacts of prescribed fire on people and communities, smoke management, ecosystem health and sustainability, water, carbon, nutrient cycling, and fuelbeds, as well as the uncertainty of using prescribed fire to reduce fuels (Butry et al. 2002; Hardy et al. 2001; Jain et al. 2014; Knapp et al. 2011; Page-Dumroese et al. 2015; Vose 2000; Wright et al. 2010). Other research explains various uses of brush for bioenergy or bioproducts if brush is removed from the forest (Loeffler et al. 2010). However, very little published information exists to describe the productivity and costs of many of the work elements for which BD production rates are estimated in this effort.

Estimates of production, and consequently project costs, in BD treatment plans are highly correlated to the fire behavior fuel model (FBFM) of the burn unit (Broyles 2011). Initially developed for use in the Rothermel (1972) surface fire spread model, FBFMs are a collection of fuel properties and represent a “quantitative basis for rating fire danger and predicting fire behavior” (Anderson 1982, p. 1). FBFMs are based on fuelbed characteristics including fuel load, fuelbed depth, surface area-to-volume ratios by component and size class, heat content by category, and dead fuel moisture of extinction (Scott and Burgan 2005). The use of FBFMs to categorize fuels with various characteristics into four primary groups—grass, shrub, timber, and slash—has become standard procedure in the U.S. wildland fire, fuels, and BD community. To date, most of the published production estimates that are available to authors of BD treatment plans or prescribed fire crews relate to fireline construction during wildland fire suppression efforts in various FBFM conditions (Barney et al. 1992; Broyles 2011; Broyles et al. 2006; Fried and Gilless 1989; Haven et al. 1982; Lindquist 1970). It is uncertain how exactly wildland fireline production rates relate to production rates for other activities, but they have served as a useful proxy.

In 2014 the National Wildfire Coordinating Group (NWCG) updated the widely distributed Fireline Handbook, now titled the Wildland Fire Incident Management Field Guide (NIFC 1993, NWCG 2013). This guide addresses many aspects of wildland fire suppression. It contains fireline production rates and ranges for Type I and Type II 20-person hand crews and dozer and tractor plow fireline construction for many FBFMs, including those estimated for the Northern Region in the present study. However, those estimates were derived for production during conditions for wildland fire suppression rather than for BD treatment plan implementation. Furthermore, it is noted in the Wildland Fire Incident Management Field Guide that production rates for the logging slash FBFMs are "based on various sources from pre-1980" (p. 121), and those sources are not provided. Additionally, the NWCG has published material for prescribed fire planning and implementation (NWCG 2014). The NWCG's Interagency Prescribed Fire Planning and Implementation Procedures Guide describes in detail how to organize and conduct prescribed fire operations, whether for BD or other purposes, but does not contain production estimates for any aspect of prescribed fire implementation.

Broyles (2011) estimated hand fireline construction rates through shift-level field observations of wildland firefighters over 5 years. Results show statistical differences between direct and indirect fireline construction and indicate that crews spend about 34 percent of a shift constructing fireline; most of the remaining time is spent for support purposes related to the operational period. An inverse relationship was found between interagency hotshot crew size and production; that is, as the number of crew members increased, the fireline production rate decreased. Fried and Gilless (1989) used an expert opinion survey approach to estimate fireline production in California in varying fuels and conditions. Perhaps more notable than the actual production estimates are several stated conclusions. First, fireline construction rates found in the literature vary widely even when resources and operating conditions are similar; second, many previously published hand crew fireline production rates appear optimistic. Finally, the source of the production rates is important. Rates derived from expert opinion are perceived as accurate and are more likely to be accepted. In other words, data and results stemming from in-person interviews of experienced fire and fuels specialist peers are expected to increase acceptance within the fire, fuels, and BD community.

Survey Methods

In this effort, we addressed the lack of standardized baseline BD production estimates for the Forest Service Northern Region. In 2013 the Northern Region's fuels specialist and personnel from the Rocky Mountain Research Station began a collaborative project with 5 Northern Region national forests across 10 districts to better understand time requirements and production output associated with many aspects of BD treatment plan implementation. Specifically, we designed and carried out a study to capture and describe a large portion of the variability that exists in BD treatment plan implementation across the Northern Region. We focused on collecting production rate estimates for preparation work activities necessary before burning, and for burning activity fuels and natural fuels. To collect data, we used a questionnaire that closely followed the structure of the Idaho Panhandle National Forests Fuel Treatment and Allowance Collection Guide 2012 (USFS 2012).

Ten experienced fire or fuels specialists, two each from five national forests in Idaho and Montana, were identified by the Northern Region fuels specialist to complete the questionnaire. Participants were from the Flathead, Idaho Panhandle, Kootenai, Lolo, and Nez Perce-Clearwater National Forests. The specialists were selected for their extensive experience with BD activities, and the group consisted of two fire management officers, six assistant fire management officers, and two fuels specialists. In spring 2015, one researcher administered the questionnaire in person and conducted all of the interviews for consistency.

Before the questionnaire was administered, a standard questionnaire pretest was conducted with several fire or fuels specialists not included in the sample frame (Dillman 1978). The Northern Region fuels specialist further refined the questionnaire based on input from pretest respondents. Although the overall response rate was 100 percent for returned questionnaires, not every respondent could complete all questions on the questionnaire, further highlighting regional variability in local experience and conditions. Data from the questionnaire are summarized and aggregated to protect confidentiality of responses.

Results and Discussion

Tables A1 through A28 in the Appendix contain selected summary statistics for all work activities that the regional fuels specialist determined to be important to BD treatments. Table 2 provides descriptions of each preparation work activity and the overall mean productivity value of each activity. Table 3 describes each burning activity. For each activity in the Appendix, we report the average response, the minimum and maximum response values, and the number of respondents who provided estimates (n). As previously noted, not all respondents had familiarity or experience with every activity in the questionnaire, and there were some activities for which there were zero, one, or two responses. We report summary statistics for those activities for which there were two or more responses. Because the summarized responses presented here were provided by experienced fire and fuels specialists from several Northern Region forests, they reflect local experience and conditions from many Northern Region locations. Thus, they capture a portion of the variability in the Northern Region. Results are generally categorized as BD preparation work activities, and burning and associated activities, such as mop-up and patrol.

In general, results indicate that for most work items, fire and fuels personnel on Northern Region national forests are completing the burn preparation work and burns at a much more productive rate than is reported in the Clearwater-Nez Perce guide.

Table 2—Definitions and overall averages associated with preparation work activities for brush disposal on U.S. Forest Service Northern Region lands.

Activity	Definition	Overall mean
Spot excavator pile	Concentrated machine piling of fuels used primarily in intermediate harvests	4.1 Acres/day
Excavator pile	Any mechanical piling of fuels	4.0 Acres/day
Excavator fireline and fuelbreak	Fireline scraped or dug to mineral soil around an area that is to be treated for fuel reduction by burning	0.068 Miles/hour
Hand fuelbreak construction	Vegetative treatment to change fuel characteristics in such a way that expected fire behavior would be reduced	0.082 Miles/hour/10 person crew
Hand fireline	Control line that is scraped or dug to mineral soil by hand around an area that is to be treated for fuel reduction by burning	0.005 Miles/hour/person
Hand slashing	Cutting back unwanted, competing fuels such as limbs, tops, or brush to reduce fuel bed depth or speed up decomposition	2.0 Acres/day/person
Hand/windrow piling	Fuel treated by hand piling slash	0.5 Acres/day/person
Hand lopping	Method of reducing average fuel height of limbs, tops, or brush to reduce fuel bed depth or speed up decomposition	2.7 Acres/day/person
Pile covering	Hand covering piled fuels with wax-coated paper	29.9 Piles/day/person
Survey fuel inventory	Surveying the inventory of hazardous fuel loading on a site	13.8 Plots/day
Pre and postburn evaluation	Pre and posttreatment exam for fuels management	81.3 Acres/day
Landing cleanup	Mechanical piling of fuels at landing	9.9 Landings/day
Leave tree protection	Protection of residual trees to reduce damage from subsequent activities	5.2 Acres/day

Additionally, as previously stated, the production and cost rates contained in the guide are from unknown methods and origin, which makes it difficult to adequately compare estimates or understand the possible sources of differences. The differences between rates in previous guides and those provided here may be attributable to factors other than methodology, such as scheduled rates compared to productive rates. Scheduled rates are calculated based on the time when personnel and equipment are scheduled to work, and productive rates are calculated based on the time during the scheduled work period when

Table 3—Definitions of burning activities for brush disposal on U.S. Forest Service Northern Region lands.

Activity	Definition
Broadcast burning	Prescribed burning applied to the majority or all of an area within well-defined boundaries for reduction of fuel, as a resource management treatment, or both
Jackpot burning	Prescribed burning of fuels in scattered concentrations that does not cover a majority of the unit
Underburn	Prescribed burns of low intensity covering a majority of the burn unit consuming surface fuels, but not the overstory canopy
Burning mechanically piled material at landings	Burning of piled material including machine piles and decks created as a result of a logging operation
Burning mechanically piled material in units	Burning activity fuels piled by an excavator with a grapple
Burning hand piled material in units	Burning hand piles of either natural or activity fuels
Mop-up	Extinguishing or removing burning material near control lines, felling snags, or trenching logs to make a fire safe or to reduce residual smoke

personnel and equipment are actually accomplishing work tasks (Brinker et al. 2002). Results presented here describe productive rates, which do not account for time lost to operational, mechanical, and personal delays. Delay time may be spent on maintenance, breakdowns, rest, meals, waiting for other machines in the system, and other activities that reduce the amount of scheduled time that results in productive work. If earlier guides were based on scheduled rates, that would explain at least some of the difference.

However, the previous guides all state that "Forest Service production rates are for actual on-the-ground work and have been adjusted downward to cover travel time allowing for a five-hour effective workday." This statement implies that the estimates are productive rates, but we have no basis on which to make that conclusion. Therefore, it is difficult to confidently attribute some of the large differences to the reporting of scheduled rates in the previous guides. Regardless, we believe reporting productive rates for actual on-the-ground work is of more value and further allows for travel or other anticipated nonproductive time adjustments to be made during preparation of the BD treatment plan. Such adjustments vary widely over different activities conducted under different conditions.

Conclusions

Across timber sales, BD treatment plans are highly variable for many reasons. All aspects of the timber sale for which a BD treatment plan is prepared influence disposal of unmarketable brush. As previously stated, burning is the primary BD activity, and Forest Service personnel perform most of the burning work. In part because of the variable nature of timber sale BD, there are currently no clear guidelines for Forest Service managers and specialists to reference when estimating the productivity of BD activities, including the length of time, number of personnel, and other requirements based on attributes of the associated timber sale. In this effort we have surveyed highly experienced fire and fuels specialists and collected their best estimates of production rates for the many activities associated with BD treatment plan implementation. The estimates presented here were provided by personnel on five national forests and are reflective of varying landscape and operational conditions across areas of the Northern Region with active BD programs.

Management Implications

These estimated production rates can be used to improve brush disposal planning for the northern Rocky Mountains, and may serve as a model for other regions to collect and provide updated information that reflects current forest conditions, practices, and productivity. While conducting this research, we discovered that BD treatment plans are vitally important for successful timber sale outcomes. If a BD treatment plan is too costly, a timber sale could receive no bids; conversely, if a BD treatment plan has underestimated costs, the deficit has to be funded from other accounts. Given the importance of BD treatment plans, we recommend that Forest Service personnel and others collect additional data and information to guide BD treatment plan activities, with complementary analyses performed to refine time and cost estimates. In this regard, more contributions to both the forest operations literature and Forest Service management resources can be made. Real-time, post-BD data collection, facilitated by accurate log book or online database entries, would allow, over time, expansion of a BD activity dataset and allow for more sophisticated analysis and refined estimates. Those results would decrease error associated with estimating BD costs, which has direct implications for timber sale success.

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APPENDIX: Selected Summary Statistics for all Work Activities That the Regional Fuels Specialist Determined to be Important to BD Treatments.

Table A1—Excavator spot piling production rates by site condition and excavator size (Type).

Site condition	Summary statistics	Type II	Type III	Type IV
		Acres/day		
More than 40 leave trees/acre, ≤33 feet spacing between leave trees, slope <35%	Mean	2.8	5.3	5.2
	Minimum	2	3	1
	Maximum	4	12	12
	Count[a]	3	6	3
More than 40 leave trees/acre, ≤33 feet spacing between leave trees, slope >35%	Mean	1.8	3.4	–
	Minimum	2	2	–
	Maximum	2	7	–
	Count[a]	2	4	–
Less than 40 leave trees/acre, ≥33 feet spacing between leave trees, slope <35%	Mean	3.5	6.5	7.0
	Minimum	2	4	2
	Maximum	5	16	16
	Count[a]	3	2	3
Less than 40 leave trees/acre, ≥33 feet spacing between leave trees, slope >35%	Mean	1.5	3.6	–
	Minimum	1	2	–
	Maximum	2	5	–
	Count[a]	2	4	–

[a] Units are the number of responses (n).

Table A2—Excavator piling production rates by site condition and excavator size (Type).

Site condition	Summary statistics	Type II	Type III	Type IV
		Acres/day		
Light fuel loading (25–35 tons/acre), residual trees do not restrict excavator movement, 0–35% slope	Mean	5.5	6.6	5.5
	Minimum	3	3	2
	Maximum	9	9	8
	Count[a]	4	6	4
Light fuel loading (25–35 tons/acre), residual trees are restricting excavator movement and production, 0–35% slope	Mean	4.4	5.0	4.9
	Minimum	2	2	2
	Maximum	7	7	7
	Count[a]	4	6	4
Moderate fuel loading (35–50 tons/acre), residual trees do not restrict excavator movement, 0–35% slope	Mean	4.4	5.4	4.0
	Minimum	2	2	2
	Maximum	8	8	5
	Count[a]	4	6	3
Moderate fuel loading (35–50 tons/acre), residual trees are restricting excavator movement and production, 0–35% slope	Mean	3.5	4.3	3.5
	Minimum	2	2	2
	Maximum	6	6	5
	Count[a]	4	6	3
Heavy fuel loading (50+ tons/acre), residual trees do not restrict excavator movement, 0–35% slope	Mean	3.0	3.8	2.0
	Minimum	2	2	2
	Maximum	6	6	3
	Count[a]	3	5	2
Heavy fuel loading (50+ tons/acre), residual trees are restricting excavator movement and production, 0–35% slope	Mean	2.2	2.7	1.5
	Minimum	1	2	1
	Maximum	4	4	2
	Count[a]	3	5	2

[a] Units are the number of responses (n).

Table A3—Excavator fireline and fuelbreak production rates by site condition and excavator size (Type).

Site condition	Summary statistics	Fuel break width (feet)					
		Type II		Type III		Type IV	
		0–10 ft.	11–20 ft.	0–10 ft.	11–20 ft.	0–10 ft.	11–20 ft.
		Miles/hour					
Slope is <35%, Fire Behavior Fuel Model 11	Mean	0.095	0.078	0.122	0.088	0.100	0.124
	Minimum	0.050	0.038	0.066	0.038	0.073	0.110
	Maximum	0.139	0.139	0.188	0.150	0.139	0.139
	Count[a]	3	3	4	6	3	2
Slope is >35%, Fire Behavior Fuel Model 11	Mean	0.067	0.025	0.123	0.071	–	–
	Minimum	0.038	0.025	0.096	0.031	–	–
	Maximum	0.096	0.096	0.150	0.125	–	–
	Count[a]	2	2	2	4	–	–
Slope is <35% Fire Behavior Fuel Model 12	Mean	0.064	0.052	0.083	0.062	0.067	0.086
	Minimum	0.044	0.031	0.060	0.025	0.063	0.074
	Maximum	0.074	0.074	0.125	0.100	0.074	0.099
	Count[a]	3	3	4	6	3	2
Slope is >35%, Fire Behavior Fuel Model 12	Mean	0.049	0.043	0.087	0.048	–	–
	Minimum	0.025	0.013	0.074	0.019	–	–
	Maximum	0.074	0.074	0.100	0.075	–	–
	Count[a]	2	2	2	4	–	–
Slope is <35%, Fire Behavior Fuel Model 13	Mean	0.038	0.023	0.059	0.030	–	–
	Minimum	0.019	0.013	0.056	0.015	–	–
	Maximum	0.056	0.034	0.063	0.050	–	–
	Count[a]	2	2	2	4	–	–
Slope is >35%, Fire Behavior Fuel Model 13	Mean	–	–	–	0.024	–	–
	Minimum	–	–	–	0.009	–	–
	Maximum	–	–	–	0.050	–	–
	Count[a]	–	–	–	3	–	–

[a] Units are the number of responses (n).

Table A4—Hand fuelbreak production rates by site condition and personnel.

Site condition	Summary statistics	Purchaser or contractor	Forest Service rate
		Miles/hour/10-person crew	
0–19 tons/acre. Clearing 6 inches and less diameter to a width of 15 feet	Mean	0.135	0.079
	Minimum	0.069	0.016
	Maximum	0.175	0.125
	Count[a]	3	5
20–39 tons/acre. Clearing 6 inches and less diameter to a width of 15 feet	Mean	0.115	0.057
	Minimum	0.069	0.010
	Maximum	0.150	0.100
	Count[a]	3	5
>40 tons/acre. Clearing 6 inches and less diameter to a width of 15 feet	Mean	0.072	0.034
	Minimum	0.063	0.008
	Maximum	0.084	0.063
	Count[a]	3	5

[a] Units are the number of responses (n).

A5—Hand fireline production rates by site condition, personnel, and accessibility.

Site condition	Summary statistics	Purchaser or contractor		Forest Service rate	
		Accessible[a]	Inaccessible[a]	Accessible	Inaccessible
		Miles/hour/person			
Slope is <40%, Fire Behavior Fuel Model 11	Mean	0.012	0.007	0.006	0.005
	Minimum	0.009	0.004	0.004	0.003
	Maximum	0.013	0.010	0.013	0.010
	Count[b]	4	4	5	6
Slope is >40%, Fire Behavior Fuel Model 11	Mean	0.008	0.006	0.005	0.004
	Minimum	0.003	0.003	0.002	0.001
	Maximum	0.013	0.010	0.013	0.010
	Count[b]	4	4	6	7
Slope is <40%, Fire Behavior Fuel Model 12	Mean	0.007	0.005	0.005	0.003
	Minimum	0.004	0.003	0.002	0.001
	Maximum	0.013	0.010	0.013	0.010
	Count[b]	4	4	5	6
Slope is >40%, Fire Behavior Fuel Model 12	Mean	0.005	0.004	0.004	0.003
	Minimum	0.003	0.002	0.002	0.001
	Maximum	0.013	0.010	0.013	0.010
	Count[b]	4	4	6	7
Slope is <40%, Fire Behavior Fuel Model 13	Mean	0.005	0.003	0.003	0.002
	Minimum	0.003	0.003	0.001	0.001
	Maximum	0.006	0.004	0.006	0.004
	Count[b]	3	3	3	3
Slope is >40%, Fire Behavior Fuel Model 13	Mean	0.004	0.002	0.003	0.002
	Minimum	0.002	0.001	0.001	0.001
	Maximum	0.006	0.004	0.006	0.004
	Count[b]	3	3	3	3

[a] Accessible = <¼ mile from drivable road; Inaccessible = >¼ mile from drivable road.

[b] Units are the number of responses (n).

Table A6—Hand slashing production rates by site condition and personnel.

Site condition	Summary statistics	Purchaser or contractor	Forest Service rate
		Acres/day/person	
<50 cut trees/acre	Mean	4.8	2.2
	Minimum	3	2
	Maximum	7	4
	Count[a]	6	10
50–99 cut trees/acre	Mean	3.2	1.5
	Minimum	2	1
	Maximum	4	3
	Count[a]	6	10
100–200 cut trees/acre	Mean	2.3	0.9
	Minimum	2	0
	Maximum	4	2
	Count[a]	6	10
>200 cut trees/acre	Mean	1.5	0.6
	Minimum	1	1
	Maximum	3	2
	Count[a]	6	10
Scattered large residual cut cull trees >7 inches and <100 trees/acre <7 inches	Mean	2.9	1.5
	Minimum	1	0
	Maximum	4	3
	Count[a]	4	7
Scattered large residual cut cull trees >7 inches and >100 trees/acre <7 inches	Mean	2.0	0.8
	Minimum	1	0
	Maximum	3	2
	Count[a]	5	8

[a] Units are the number of responses (n).

Table A7—Hand/windrow production rates by site condition and personnel.

Site condition	Summary statistics	Purchaser	Contractor	Forest Service rate
		Acres/day/person		
Light: <20 piles/acre >45 feet spacing	Mean	0.9	0.9	0.6
	Minimum	0	0	0
	Maximum	2	2	1
	Count[a]	5	6	8
Moderate: 20–40 piles/acre 33–45 feet spacing	Mean	0.6	0.6	0.3
	Minimum	0	0	0
	Maximum	1	1	1
	Count[a]	5	6	8
High: >40 piles/acre <33 feet spacing	Mean	0.4	0.4	0.2
	Minimum	0	0	0
	Maximum	1	1	0
	Count[a]	5	6	8

[a] Units are the number of responses (n).

Table A8—Hand lopping production rates by site condition and personnel.

Site condition	Summary statistics	Purchaser	Contractor	Forest Service rate
		Acres/day/person		
Slope is <40%, Fire Behavior Fuel Model 11	Mean	4.8	5.3	3.1
	Minimum	4	4	3
	Maximum	6	8	3
	Count[a]	4	4	4
Slope is >40%, Fire Behavior Fuel Model 11	Mean	3.5	4.7	2.3
	Minimum	2	3	2
	Maximum	5	7	3
	Count[a]	4	3	4
Slope is <40%, Fire Behavior Fuel Model 12	Mean	3.1	4.0	1.8
	Minimum	2	2	2
	Maximum	5	7	2
	Count[a]	4	3	4
Slope is >40%, Fire Behavior Fuel Model 12	Mean	2.1	3.0	0.9
	Minimum	1	1	1
	Maximum	4	6	1
	Count[a]	4	3	4
Slope is <40%, Fire Behavior Fuel Model 13	Mean	2.3	2.9	0.8
	Minimum	1	1	1
	Maximum	4	6	1
	Count[a]	3	3	3
Slope is >40%, Fire Behavior Fuel Model 13	Mean	1.5	2.2	0.4
	Minimum	1	1	0
	Maximum	3	5	1
	Count[a]	3	3	3

[a] Units are the number of responses (n).

Table A9—Pile covering production rates by piling method.

Summary statistics	Pile types: Machine	Pile types: Hand
	Piles/day/person	
Mean	28.8	31.0
Minimum	5	2
Maximum	60	60
Count[a]	4	7

[a] Units are the number of responses (n).

Table A10—Survey fuel inventory production rates by site condition.

Site condition	Summary statistics Plots/day	
Natural fuels (uncut) slope <40%	Mean	16.1
	Minimum	8
	Maximum	33
	Count[a]	8
Natural fuels (uncut) slope >40%	Mean	11.8
	Minimum	6
	Maximum	22
	Count[a]	8
Slope is <40%, Fire Behavior Fuel Model 11	Mean	18.6
	Minimum	10
	Maximum	43
	Count[a]	7
Slope is >40%, Fire Behavior Fuel Model 11	Mean	15.3
	Minimum	8
	Maximum	38
	Count[a]	7
Slope is <40%, Fire Behavior Fuel Model 12	Mean	15.4
	Minimum	7
	Maximum	32
	Count[a]	7
Slope is >40%, Fire Behavior Fuel Model 12	Mean	11.7
	Minimum	6
	Maximum	27
	Count[a]	7
Slope is <40%, Fire Behavior Fuel Model 13	Mean	11.8
	Minimum	5
	Maximum	21
	Count[a]	5
Slope is >40%, Fire Behavior Fuel Model 13	Mean	9.5
	Minimum	4
	Maximum	20
	Count[a]	5

[a] Units are the number of responses (n).

Table A11—Pre and post burn evaluation production rates by site condition.

Site condition	Summary statistics Acres/day	
Understory burning, natural fuels prescription	Mean	110.2
	Minimum	20
	Maximum	250
	Count[a]	10
Understory burning, seed tree or shelter wood prescription	Mean	75.0
	Minimum	20
	Maximum	200
	Count[a]	10
Broadcast burning, clear-cut prescription	Mean	81.1
	Minimum	11
	Maximum	200
	Count[a]	10
Jackpot burning, light uneven aged harvest	Mean	58.8
	Minimum	15
	Maximum	100
	Count[a]	9

[a] Units are the number of responses (n).

Table A12—Landing cleanup production rates by logging system.

Logging system	Summary statistics Landings/day	
Ground based	Mean	6.2
	Minimum	2
	Maximum	10
	Count[a]	5
Cable based	Mean	13.7
	Minimum	1
	Maximum	20
	Count[a]	3

[a] Units are the number of responses (n).

Table A13—Leave tree protection production rates by site condition and personnel.

Site conditions	Summary statistics	Purchaser	Contractor	Forest Service rate
		Acres/day		
<5 trees/acre	Mean	14.3	–	6.5
	Minimum	7	–	2
	Maximum	20	–	20
	Count[a]	3	–	6
5–10 trees/acre	Mean	4.3	–	4.7
	Minimum	3	–	1
	Maximum	7	–	15
	Count[a]	3	–	6
10–20 trees/acre	Mean	3.2	–	3.0
	Minimum	2	–	1
	Maximum	5	–	10
	Count[a]	3	–	6
>20 trees/acre	Mean	2.0	–	1.9
	Minimum	1	–	1
	Maximum	3	–	5
	Count[a]	3	–	5

[a] Units are the number of responses (n)

Table A14—Daily personnel requirements for broadcast burning activity fuels on <35 percent slope.

Unit size (acres)	Position	Burn organization: Small Fall	Small Spring	Medium Fall	Medium Spring	Large Fall	Large Spring
		Average personnel/day					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	3	3	4	4	4	4
	Holders	3	2	5	3	7	6
	Engines[a]	1	1	1	1	2	2
	Tenders[a]	0	0	0	0	0	0
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	4	4	5	5	5	5
	Holders	4	3	7	5	10	8
	Engines[a]	1	1	2	1	3	2
	Tenders[a]	0	0	1	1	1	1
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	5	5	7	8	7	7
	Holders	6	6	8	7	11	10
	Engines[a]	1	1	2	2	3	3
	Tenders[a]	1	0	1	1	1	1
>40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	7	6	8	8	8	8
	Holders	6	6	10	8	12	9
	Engines[a]	2	2	3	2	3	2
	Tenders[a]	1	1	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

Table A15—Daily personnel requirements for broadcast burning activity fuels on >35 percent slope.

		Burn organization					
		Small		Medium		Large	
Unit size		Fall	Spring	Fall	Spring	Fall	Spring
(acres)	Position	Average personnel/day					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	3	3	4	4	4	4
	Holders	3	2	5	3	7	6
	Engines[a]	1	1	1	1	2	2
	Tenders[a]	0	0	0	0	0	0
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	4	4	5	5	5	5
	Holders	4	3	6	5	9	8
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	0	0	0	0	0	0
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	5	6	8	7	8	8
	Holders	7	7	8	7	12	11
	Engines[a]	2	1	2	2	3	2
	Tenders[a]	1	0	1	0	1	0
>40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	7	7	9	9	9	10
	Holders	6	5	10	8	13	10
	Engines[a]	2	2	3	2	3	3
	Tenders[a]	1	1	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

A16—Daily personnel requirements for jackpot burning activity fuels on <35 percent slope.

		Burn organization					
		Small		Medium		Large	
Unit size		Fall	Spring	Fall	Spring	Fall	Spring
(acres)	Position	Average personnel/day					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	3	3	3	3	3	3
	Holders	3	3	3	2	4	4
	Engines[a]	1	1	2	1	2	1
	Tenders[a]	0	0	1	1	1	1
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	4	4	4	4	4	4
	Holders	4	3	4	4	7	6
	Engines[a]	1	1	1	1	2	2
	Tenders[a]	0	0	1	1	1	1
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	6	7	5	6	6	6
	Holders	5	4	6	5	9	8
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	1	0	1	1	1	1
>40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	9	9	8	8	8	9
	Holders	6	5	7	6	10	9
	Engines[a]	2	2	2	2	2	2
	Tenders[a]	1	0	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

Table A17—Daily personnel requirements for jackpot burning activity fuels on >35 percent slope.

		Burn organization					
		Small		Medium		Large	
Unit size		Fall	Spring	Fall	Spring	Fall	Spring
(acres)	Position	Average personnel/day					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	3	3	3	3	3	3
	Holders	3	3	3	2	4	4
	Engines[a]	1	1	2	1	2	1
	Tenders[a]	0	0	1	1	1	1
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	4	4	4	4	4	4
	Holders	4	3	4	4	7	6
	Engines[a]	1	1	1	1	2	2
	Tenders[a]	0	0	1	1	1	1
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	8	8	5	5	7	7
	Holders	6	6	6	5	10	9
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	1	0	1	1	1	1
>40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	11	11	8	8	9	9
	Holders	7	6	7	7	11	10
	Engines[a]	2	2	2	2	2	2
	Tenders[a]	1	0	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

Table A18—Daily personnel requirements for underburning activity fuels on <35 percent slope.

		Burn organization					
		Small		Medium		Large	
Unit size		Fall	Spring	Fall	Spring	Fall	Spring
(acres)	Position	Average personnel/day					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	3	3	4	4	4	4
	Holders	3	3	5	3	7	6
	Engines[a]	1	1	1	1	2	2
	Tenders[a]	0	0	1	1	1	1
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	4	4	5	5	5	5
	Holders	4	3	7	5	10	9
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	0	0	1	1	1	1
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	5	5	7	7	8	7
	Holders	6	6	8	7	11	10
	Engines[a]	2	1	2	2	3	2
	Tenders[a]	1	0	1	1	1	1
>40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	6	6	9	8	9	9
	Holders	7	7	10	8	12	10
	Engines[a]	2	2	3	2	3	2
	Tenders[a]	1	1	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

Table A19—Daily personnel requirements for underburning activity fuels on >35 percent slope.

		Burn organization					
		Small		Medium		Large	
Unit size		Fall	Spring	Fall	Spring	Fall	Spring
(acres)	Position	Average personnel/day					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	3	3	4	4	4	4
	Holders	3	3	5	4	7	6
	Engines[a]	1	1	1	1	2	2
	Tenders[a]	0	0	1	1	1	1
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	4	4	5	5	6	5
	Holders	4	3	6	5	10	8
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	0	0	1	1	1	1
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	0	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	5	5	7	7	8	8
	Holders	7	7	8	7	12	11
	Engines[a]	2	1	2	2	3	2
	Tenders[a]	1	0	1	1	1	1
>40	Burn boss	1	1	1	1	1	1
	Firing boss	1	1	1	1	1	1
	Holding boss	1	1	1	1	1	1
	Ignitors	7	7	9	9	10	9
	Holders	7	6	10	9	13	11
	Engines[a]	2	2	3	2	3	3
	Tenders[a]	1	1	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

Table A20—Pile burning at landing production rates by activity.

Summary statistics	Activity: Chunking	Activity: No chunking
	Acres/day/person	
Mean	2.4	8.3
Minimum	0	1
Maximum	9	30
Count[a]	6	10

[a] Units are the number of responses (n).

Table A21—Burning mechanically piled materials in the unit production rates by slope.

Site condition	Summary statistics	Slope: <35%	Slope: >35%
		Piles/day/person	
Shelterwood: 15–40 leave tree/acre, <20 acres	Mean	27.6	25.3
	Minimum	5	4
	Maximum	60	50
	Count[a]	7	5
Shelterwood: 15–40 leave tree/acre, >20 acres	Mean	28.5	25.7
	Minimum	5	4
	Maximum	60	50
	Count[a]	7	5
Clearcut/seedtree: <20 acres	Mean	32.9	32.3
	Minimum	5	4
	Maximum	60	60
	Count[a]	7	5
Clearcut/seedtree: >20 acres	Mean	33.8	32.7
	Minimum	5	4
	Maximum	60	60
	Count[a]	7	5
Commercial thin/intermediate harvest: <20 acres	Mean	26.0	22.7
	Minimum	5	4
	Maximum	60	50
	Count[a]	7	5
Commercial thin/intermediate harvest: >20 acres	Mean	26.3	23.3
	Minimum	5	4
	Maximum	60	50
	Count[a]	7	5

[a] Units are the number of responses (n).

Table A22—Burning hand piled materials in the unit production rates by complexity.

Site condition	Summary statistics	Complexity: High	Moderate	Low
		Acres/day/person		
0–20 tons/acre, <20 piles/acre	Mean	1.3	1.8	3.5
	Minimum	1	1	1
	Maximum	3	4	10
	Count[a]	3	4	8
20–40 tons/acre, 20–40 piles/acre	Mean	0.8	1.4	2.5
	Minimum	1	1	1
	Maximum	3	4	8
	Count[a]	3	4	8
40–60 tons/acre, >40 piles/acre	Mean	0.5	0.9	1.4
	Minimum	0	1	0
	Maximum	3	4	8
	Count[a]	3	4	8

[a] Units are the number of responses (n).

Table A23—Daily personnel requirements for mop-up of activity fuels on <35 percent slope.

Unit size (acres)	Position	Burn organization: Small, Fall	Small, Spring	Medium, Fall	Medium, Spring	Large, Fall	Large, Spring
		Average personnel/day					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	0	0	1	1	1	1
	Ignitors	0	0	0	0	0	0
	Holders	4	3	4	4	5	4
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	0	0	1	1	1	1
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	0	0	1	1	1	1
	Ignitors	0	0	0	0	0	0
	Holders	5	5	6	5	7	6
	Engines[a]	1	1	1	1	2	2
	Tenders[a]	1	0	1	1	1	1
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	0	0	1	1	1	1
	Ignitors	0	0	0	0	0	0
	Holders	7	7	7	7	8	8
	Engines[a]	2	2	2	2	2	2
	Tenders[a]	1	0	1	1	1	1
>40	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	1	1	1	1	1	1
	Ignitors	0	0	0	0	0	0
	Holders	9	8	9	8	9	9
	Engines[a]	2	2	2	2	2	2
	Tenders[a]	1	1	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

Table A24—Daily personnel requirements for mop-up of activity fuels on >35 percent slope.

		Burn organization					
		Small		**Medium**		**Large**	
Unit size		**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**
(acres)	**Position**	**Average personnel/day**					
<10	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	1	0	1	1	1	1
	Ignitors	0	0	0	5	0	0
	Holders	4	3	4	4	5	4
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	0	0	1	1	1	1
10–20	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	1	0	1	1	1	1
	Ignitors	0	0	0	0	0	0
	Holders	6	5	6	5	7	6
	Engines[a]	1	1	2	1	2	2
	Tenders[a]	0	0	1	1	1	1
21–40	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	1	1	1	1	1	1
	Ignitors	0	0	0	0	0	0
	Holders	8	7	8	8	9	9
	Engines[a]	2	2	2	2	2	2
	Tenders[a]	1	0	1	1	1	1
>40	Burn boss	1	1	1	1	1	1
	Firing boss	0	0	0	0	0	0
	Holding boss	1	1	1	1	1	1
	Ignitors	0	0	0	0	0	0
	Holders	10	10	10	9	11	10
	Engines[a]	2	2	2	2	2	2
	Tenders[a]	1	1	1	1	1	1

[a] Units are the number of engines and tenders and do not reflect the number of personnel staffing each piece of equipment.

Table A25—Days required for mop-up and patrol of activity fuels on <35 percent slope.

		Burn organization					
		Small		Medium		Large	
Unit size	Summary	Fall	Spring	Fall	Spring	Fall	Spring
(acres)	statistics	Average days/mop-up					
<10	Mean	6.6	6.4	7.0	6.5	7.5	6.9
	Minimum	1	1	1	1	1	1
	Maximum	2	2	3	3	5	5
	Count[a]	5	5	6	6	7	7
10–20	Mean	6.8	6.6	7.5	6.7	8.2	7.2
	Minimum	1	1	1	1	1	1
	Maximum	2	2	4	3	5	5
	Count[a]	5	5	6	6	7	7
21–40	Mean	7.4	6.8	8.2	7.0	9.0	7.5
	Minimum	1	1	1	1	1	1
	Maximum	4	2	6	3	6	5
	Count[a]	5	5	6	6	7	7
>40	Mean	7.8	6.8	8.4	7.2	9.1	7.8
	Minimum	1	1	1	1	1	1
	Maximum	5	2	6	3	6	5
	Count[a]	5	5	6	6	7	7

[a] Units are the number of responses (n).

Table A26—Days required for mop-up and patrol of activity fuels on >35 percent slope.

		Burn organization					
		Small		Medium		Large	
Unit size	Summary	Fall	Spring	Fall	Spring	Fall	Spring
(acres)	statistics	Average days/mop-up					
<10	Mean	6.5	6.4	7.1	6.5	7.6	7.0
	Minimum	1	1	1	1	1	1
	Maximum	2	2	2	1	5	5
	Count[a]	6	5	7	6	8	8
10–20	Mean	6.7	6.6	7.5	6.7	8.3	7.2
	Minimum	1	1	1	1	1	1
	Maximum	2	2	4	2	5	5
	Count[a]	6	5	7	6	8	8
21–40	Mean	7.2	6.8	8.1	7.0	9.0	7.5
	Minimum	1	1	1	1	1	1
	Maximum	4	2	6	2	6	5
	Count[a]	6	5	7	6	8	8
>40	Mean	7.5	6.8	8.2	7.2	9.0	7.7
	Minimum	1	1	1	1	1	1
	Maximum	5	2	6	2	6	5
	Count[a]	6	5	7	6	8	8

[a] Units are the number of responses (n).

Table A27—Daily personnel requirements for jackpot burning natural fuels.

Fire behavior fuel model	Unit size (acres)	Summary statistics	Complexity: High	Moderate	Low
			Average personnel/day		
Fire Behavior Fuel Model 2 or 5	<100	Mean	16	11	8
		Minimum	8	8	7
		Maximum	25	15	10
		Count[a]	5	5	5
	100–300	Mean	21	16	12
		Minimum	12	12	7
		Maximum	35	25	16
		Count[a]	5	5	5
	>300	Mean	22	19	13
		Minimum	12	12	7
		Maximum	35	30	18
		Count[a]	5	5	4
Fire Behavior Fuel Model 8 or 10	<100	Mean	17	13	10
		Minimum	8	7	7
		Maximum	25	20	16
		Count[a]	5	5	5
	100–300	Mean	21	17	12
		Minimum	12	12	7
		Maximum	35	30	16
		Count[a]	5	5	4
	>300	Mean	23	19	13
		Minimum	12	12	7
		Maximum	35	30	18
		Count[a]	5	5	4

[a] Units are the number of responses (n).

Table A28—Daily personnel requirements for underburning natural fuels.

Fire behavior fuel model	Unit size (acres)	Summary statistics	Complexity: High	Complexity: Moderate	Complexity: Low
			Average personnel/day		
Fire Behavior Fuel Model 2 or 5	<100	Mean	16	14	8
		Minimum	8	8	7
		Maximum	25	24	10
		Count[a]	6	7	5
	100–300	Mean	23	20	14
		Minimum	12	12	7
		Maximum	35	30	16
		Count[a]	6	7	5
	>300	Mean	25	21	14
		Minimum	16	12	7
		Maximum	35	30	18
		Count[a]	5	6	4
Fire Behavior Fuel Model 8 or 10	<100	Mean	17	15	11
		Minimum	8	8	7
		Maximum	25	24	16
		Count[a]	6	7	5
	100–300	Mean	22	19	13
		Minimum	12	12	7
		Maximum	35	30	16
		Count[a]	6	7	4
	>300	Mean	25	21	15
		Minimum	16	12	7
		Maximum	35	30	22
		Count[a]	5	6	4

[a] Units are the number of responses (n).

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