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Retrieving Residue After Overstory Removal in True Fir, Northeastern California

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Overstory removal cutting, the most common means of converting old-growth stands to young-growth stands in California, can produce excessive residues that pose management problems. Utilization is an attractive option for managing residues. However, the cost of residue retrieval and utilization is often prohibitive. Residue retrieval by a private contractor was studied to determine production rates and effectiveness after overstory removal on three blocks in true fir stands in northeastern California. Residues were inventoried before and after residue retrieval to determine the amount removed. The contractor removed 97 percent of the residue specified for retrieval and 68 percent of residue smaller than specifications, for a total of 136 dry tons (123 t). Residues down to about 3 inches (8 cm) in diameter were utilized for fuelwood. Production rates—0.53 ton (0.48 t) per man-hour and 0.67 ton (0.61 t) per equipment-hour—were low (costs high) for several reasons, including the small size of residues and restricted yarding patterns. Damage to the residual stand was negligible.

Retrieval Terms: overstory removal, forest residues, residue utilization, true firs, salvage rights, northern California

Overstory removal cutting is the most common means for converting old-growth stands with adequately stocked understory to young-growth stands in California. The Pacific Southwest Region of the Forest Service, U.S. Department of Agriculture, harvests about 20,000 acres (8100 ha) yearly using overstory removal. Slash from overstory trees often exceeds 15 dry tons per acre (34 t/ha), and—depending on stand and harvesting variables—substantial additional amounts of residue may result from damaged and cut understory trees. If left untreated, these residues can pose significant management problems, including high fire hazard.

Treating residue that remains after overstory removal is often difficult and expensive due to the need to protect the understory. Utilization of the residue is an attractive alternative to treatment; however, costs of removal, processing, and transportation often exceed the value of the delivered material. Where the economics are not favorable otherwise, land managers may be able to improve the feasibility of utilization by paying for residue removal to the extent that treatment and resource costs are thereby avoided or reduced.

Most studies of production rates and costs of residue harvesting have involved high loadings and large pieces of residue.¹⁻⁸ Both of these characteristics tend to lower costs of residue retrieval.^{1,8} We know of a few such studies reported from California,⁵⁻⁷ but none documents residue retrieval after overstory removal cutting. A study designed to test the effectiveness

of special logging requirements for reducing damage to understory crop trees during overstory removal cutting provided an opportunity to study residue retrieval.

This note reports a case study of residue retrieval after harvesting true fir by overstory removal on three blocks in northeastern California. Contract specifications required removal of slash and sound natural debris 6 inches (15 cm) or greater in large-end diameter and 6 feet (2 m) or more in length. The contractor had salvage rights to this and any smaller material. Residue was inventoried with the planar intersect technique before and after retrieval to estimate the amount removed.

Over 97 percent of residue that met contract specifications and 68 percent of other material was removed. A total of 136 dry tons (123 t) of residue was removed at average rates of 0.53 ton (0.48 t) per man-hour and 0.67 ton (0.61 t) per equipment-hour. These production rates were relatively low (costs high), and the value of the residue removed would not have covered the full costs of retrieval, transportation, and processing under conditions of the study. Factors that contributed to the observed production rates included these: retrieval was a separate procedure from harvesting, restrictions were imposed to reduce damage to the residual stand, and pieces of residue were small.

Results of the study apply directly only to the stand conditions, timber sale provisions, and residue retrieval contract specifications described. However, the results can provide a useful starting point for managers wishing to estimate residue re-

trieval effectiveness and production rates in a variety of overstory removal harvest situations on sites that can be logged with ground-based equipment.

SITE AND STAND CHARACTERISTICS

The case study reported here was conducted on the Swain Mountain Experimental Forest in northeastern California, where elevation ranges from 5700 to 7000 feet (1740 to 2130 m). Slopes are generally less than 10 percent, and all but southerly aspects are represented. Soils are derived from Pleistocene andesitic rock and ash. Precipitation, falling mostly as snow, averages around 50 inches (1270 mm) per year.

Except for some lodgepole pine (*Pinus contorta* Dougl. ex Loud.) at lower elevations and in wet areas, and a few scattered Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) and sugar pine (*Pinus lambertiana* Dougl.), the Experimental Forest consists of virtually pure old-growth true fir. Composition varies from predominantly California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.) at the lowest elevations to pure California red fir (*Abies magnifica* A. Murr.) near the top of Swain Mountain. A Dunning site class II (150 ft at 300 years) is common.⁹ A wide variety of age classes and understory stocking conditions typical of true fir are present. Mature and overmature stands lacking a stocked understory have standing volumes averaging around 60 to 80 thousand board feet (MBF) per acre (800 to 1100 m³/ha). In contrast, lower overstory volumes are

usually necessary for development of manageable understories—the stand condition for which overstory removal cuttings may be desirable. The blocks used in this study (table 1) are fairly typical of this latter stand condition on Swain Mountain, with overstory volumes ranging from 19 to 45 MBF per acre (270 to 630 m³/ha).

METHODS

Harvesting

In spring and summer 1981, all overstory trees were removed from the three study blocks by overstory removal cutting. Merchantability standards specified a minimum 10-foot (3.0-m) log with a small end diameter of 6 inches (15 cm) inside bark.

The following requirements and restrictions on the harvesting operations, mostly designed to lessen damage to the residual stand, were enforced:

- All skid trails were designated or approved by the Forest Service and were clearcut and skidded before felling any other timber.
- Overstory trees had to be felled into designated beds that were clearcut before any other felling.
- Directional felling was required, using hydraulic jacks where necessary.
- Merchantable pieces were limbed before skidding. Tops were limbed down to a bole diameter of about 3 inches (8 cm), and bucked into sections of 15 feet (4.6 m) or less.
- Skidding equipment—either track-laying tractors or rubber-tired skidders—

was limited to a maximum width of 115 inches (292 cm), and was confined to approved skid trails and beds only.

- Stage logging was required.

A standard provision required removal from the blocks of all unutilized material developed by the harvesting operation that was 10 inches (25 cm) or larger in large-end diameter and 10 feet or more in length.

Many submerchantable stems (less than 8 inches [20 cm] in diameter at breast height [d.b.h.]) were damaged or destroyed during logging (table 1). All stems over 5 feet (2 m) in height damaged beyond recovery were felled and limbed to a stem diameter of about 3 inches, at which point the top was cut from the remainder of the stem. Boles were bucked into lengths not exceeding 20 feet (6.1 m).

Residue Retrieval

A nonpersonal service contract was prepared for removal of the residue from the study blocks. The contract was awarded on September 22, 1983, and all contractual requirements were completed by October 19, 1983. Pertinent contract specifications can be summarized as follows:

- Residue included both slash resulting from overstory removal cutting operations (from damaged understory as well as harvested overstory trees) and naturally occurring woody debris sufficiently sound to remain intact when handled by equipment.
- Residue was to be removed only from existing skid trails and prepared felling beds (where most of the slash was located). Equipment was restricted to these areas.

Table 1—Stand characteristics for test blocks before overstory removal harvest and changes associated with logging

Block	Size	Species composition (overstory/ understory) ¹	Before logging				Trees removed or lost		
			Average d.b.h. ²		Trees per acre		Overstory removed	Understory lost ³	
			Overstory	Understory	Overstory	Understory			
	<i>Acres</i>		<i>Inches</i>			⁴ <i>MBF/acre</i>	<i>Trees/acre</i>		
1	3.2	RF/RF	39.0	4.2	20.9	3326	45.4	20.9	937
2	7.1	RF/RF	35.9	4.9	14.4	1823	29.3	14.4	590
3	5.0	WF,JP/WF	37.9	7.8	8.8	628	18.5	8.8	47

¹ RF = red fir; WF = white fir; JP = Jeffrey pine.

² D.b.h. = diameter at breast height.

³ Trees damaged or destroyed during logging.

⁴ Thousand board feet per acre.

- Within skid trails and beds, residue 6 inches (15 cm) or greater in large-end diameter and 6 feet (2 m) or longer was to be removed.

- Residue specified for removal was to be piled in designated locations or hauled off and utilized by the contractor. The contractor also had salvage rights to any smaller residue he wished to remove from permitted areas.

- Equipment had to be able to load and forward the material free of the ground and dump it at designated locations. Maximum width of any equipment and its load was 115 inches (292 cm).

Laborers with chain saws bucked the residue into lengths less than 115 inches, beginning with the material that was over about 3 inches in diameter. This material was then hand piled in a parallel arrangement. A backhoe was used to speed the piling of any heavy concentrations of this 3-inch and larger residue. After all this size material was piled, a Caterpillar 977 loader with modified brush forks forwarded the residue to a concentration point adjacent to each block.¹⁰ The material was bucked into stove lengths (12 to 18 inches [30 to 46 cm]), loaded into 10-yard dump trucks with a backhoe, and then transported about 50 miles (80 km) to the contractor's home for use or sale as fuelwood.

Remanufacturing slash into fuelwood generated considerable amounts of small material. This material, usually less than 3 inches in diameter, consisted of limbs and tops (from merchantable trees, or damaged submerchantable trees that had not been properly limbed and bucked) attached to pieces of residue which met minimum specifications requiring removal. Therefore, under the contract this smaller material also had to be removed from the blocks. The contractor elected to limb and top the larger pieces to facilitate their removal, which resulted in the small material being removed separately. This material was hand piled, and removed from the blocks by the loader. The loader carried it to another 10-yard dump truck which transported it to a designated location outside the study blocks.

Residue Inventory

Using the planar intersect technique,¹¹ we inventoried woody residue before and

after residue retrieval on each block. Independent sets of sample points were used on the two occasions. Number of points sampled in each block before and after residue retrieval ranged from 19 to 30, and was sufficient to yield standard errors for residue loading of 11 to 19 percent of the mean. The difference in calculated loadings before and after residue retrieval provided an estimate of the amount of residue removed. The residue inventoried was that specified for removal in the contract with respect to type (both slash and natural residues) and location (skid trails and felling beds).

Three size classes of residue were sampled: (1) residues specified for removal (at least 6 inches in diameter and 6 ft long), (2) residues smaller than specifications and at least 3 inches in diameter, and (3) residues between 1/4 (0.6 cm) and 3 inches in diameter. Size classes 2 and 3 were measured to document removal of material smaller than that specified, either incidental to removal of specified residue or under salvage rights provisions of the contract. Size class 3 was segregated because these fuels are of interest from the standpoint of fire behavior prediction.¹² Residues smaller than 1/4 inch in diameter were not inventoried because the inevitable mixing of small particles with soil by equipment activity probably would have precluded an accurate assessment of the amount removed.

RESULTS AND DISCUSSION

Loadings of residues removed from the study blocks were calculated as the difference between pre- and post-retrieval inventories (*fig. 1, table 2*). Some of this observed difference undoubtedly was caused by trampling of small material into the soil by the backhoe and loader, instead of actual removal from the site. This component of "removed" residue, however, probably was quite small, and almost totally restricted to the 1/4- to 3-inch size class. Subsequent discussion, therefore, will attribute the difference between inventories to residue removed from the site.

Over 97 percent of the residue specified for removal was in fact removed (*table 2*). In addition, 68 percent of the smaller material not meeting specifications was re-

moved by the contractor, leading to an overall average of 80 percent removal of sound woody residue. The proximity of a potential fuelwood market to the contractor's residence accounted for the removal of much of this smaller residue. Residue down to about 3 inches in diameter was used by the contractor for fuelwood. Under the salvage rights provision of the contract, the contractor took 44 dump truck loads of fuelwood.

Another 31 truck loads of residue too small to convert into fuelwood (less than 3 inches) were hauled to a disposal site for burning. Much of this unutilized small material had to be removed from the blocks because it was originally attached to larger residue, removal of which was required. Apparently, however, the estimated removal of 58 percent of the 1/4- to 3-inch residue substantially exceeded the required removal. One possible reason may be the enthusiasm of a new contractor to make a good impression.

Both residue retrieval activities and the inventories upon which residue loadings (*table 2*) were based were restricted to skid trails and felling beds within the blocks. Using large-scale aerial photographs taken after the overstory removal logging, we estimated the proportion of total area occupied by skid trails and beds as 25 percent in Block 1, 25 percent in Block 2, and 23 percent in Block 3. Applying these percentages to the acreage and loading of residue removed in each block (*table 2*), a calculated total of 136 dry tons (123 t) of residue (fuelwood plus unutilized material) was removed from these three blocks.

All retrieved residue that met specifications for required removal was converted to fuelwood. In addition, about 90 percent of the retrieved residue at least 3 inches in diameter but not meeting specifications for removal was used for fuelwood. On the basis of this estimate, 97 tons (88 t) were salvaged for fuelwood, and the remaining 39 tons (35 t) were transported to the disposal site.

The time required to remove these amounts of residue from the unit, buck fuelwood into stove lengths, and load all material into dump trucks, was

Frontend loader—136 hours

Backhoe—68 hours

Laborer—256 hours

For total residue removed, therefore, pro-

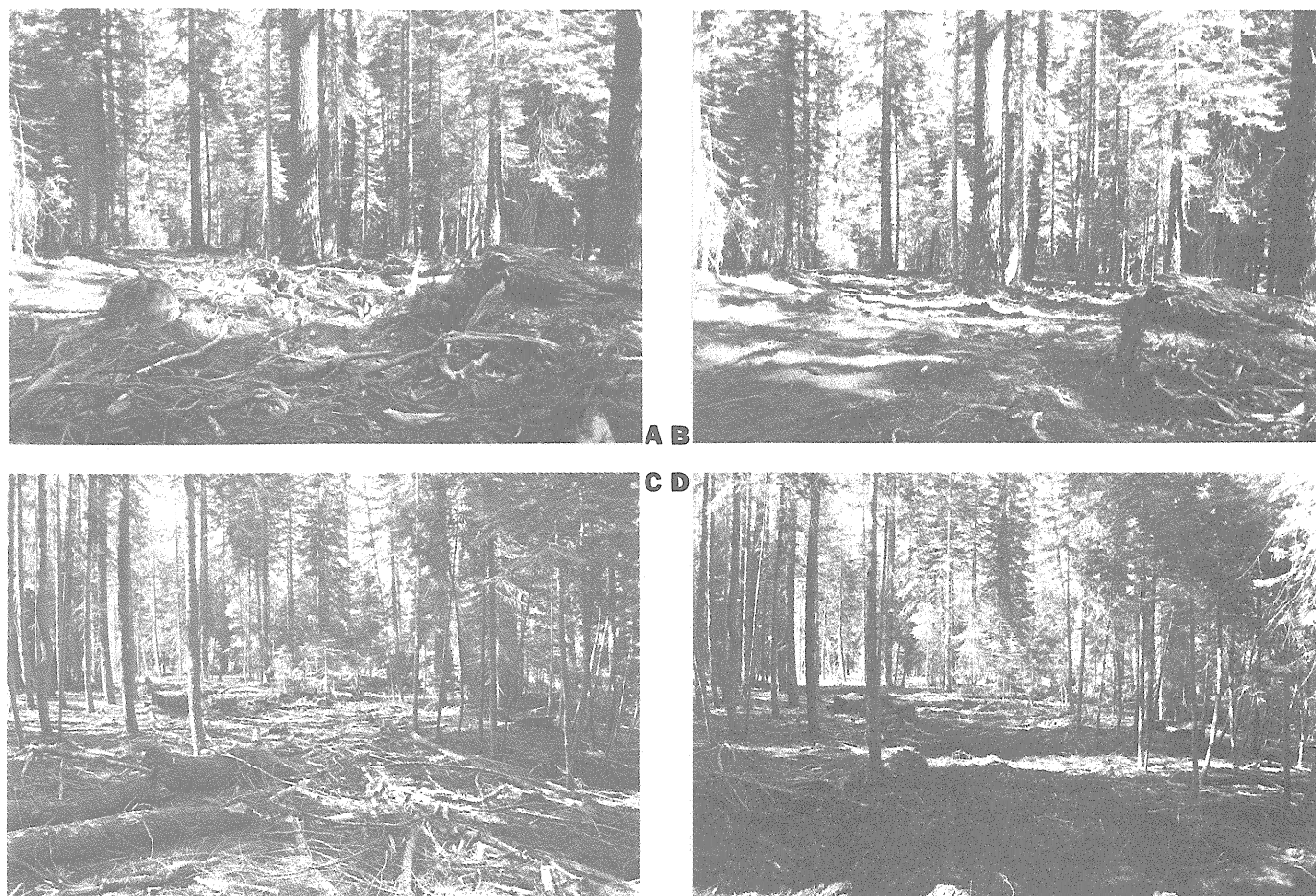


Figure 1—Typical conditions on the study blocks before (A and C) and after (B and D) residue retrieval. Much of the smaller material was re-

moved incidentally during retrieval of specified residue.

duction rates were 0.53 ton (0.48 t) per man-hour and 0.67 ton (0.61 t) per equipment-hour. Times for transporting residue to the point of utilization (or disposal) and for transporting equipment to and from the job site were not included.

In accordance with a prior agreement with the contractor, production rates are presented rather than actual costs. This in-

formation, however, should be as useful as costs to most forest managers or contractors contemplating similar work, because production rates are key to developing site-specific cost estimates.

As with case studies elsewhere, results of this study should be viewed within the context of its particular conditions, including stand, residue, terrain, and oper-

ator characteristics. Reported costs and production rates for residue retrieval vary widely, in part because of wide variability in these characteristics.¹ In comparison with a number of other studies of residue utilization,¹⁻⁸ the production rates reported here are relatively low (costs high). They seem reasonable, however, when we consider the following factors:

- Relogging—a separate followup operation to retrieve residue—was more expensive than it would have been if combined with the timber harvest.²

- Large unmerchantable material (at least 10 inches in diameter and 10 ft in length) generated by the logging was removed as part of the timber harvest. Although some non-harvest-related large residue was still present, that prior removal substantially reduced the loading and average piece size of residue available for retrieval under the contract. Both loading and size of residue are strongly related to production rates for collecting residue.^{1,8} Assuming that residue retrieval is

Table 2—Original residue loadings after overstory removal harvest and amounts removed under retrieval contract

Residue size class	Block 1 (3.2 acres)		Block 2 (7.1 acres)		Block 3 (5.0 acres)	
	Original	Removed ¹	Original	Removed ¹	Original	Removed ¹
	<i>Tons/acre</i>					
>6 inches ²	³ 13.1 ± 7.4	13.1	24.0 ± 14.4	24.0	11.6 ± 9.6	10.7
>3 inches ⁴	11.2 ± 4.3	9.1	10.1 ± 5.9	8.8	12.7 ± 5.4	11.0
¼-3 inches ⁴	30.5 ± 10.4	23.3	13.0 ± 3.5	5.9	12.1 ± 2.2	5.7
Total	54.8 ± 15.9	45.5	47.1 ± 12.7	38.7	36.4 ± 14.7	27.3

¹ Difference between loadings inventoried before and after residue retrieval. Confidence limits are not given because variance was almost totally attributable to variance for original loadings.

² Removal required by contract (at least 6 inches and 6 feet).

³ Confidence limits are for 95 percent probability level.

⁴ Removal not required by contract.

planned as a separate operation from timber harvest, removing large unmerchantable material during residue retrieval generally would be preferable.

- The contract required removal of small material attached to pieces of residue specified for removal. Separate piling and removal of this small material required significant additional man and machine time. These specifications perhaps should be changed in subsequent residue retrieval contracts because they added—probably unnecessarily—to costs, and resulted in a more thorough cleanup than might be desirable from the standpoint of nutrient and organic matter management.

- The method of cutting preceding residue retrieval can be expected to affect production rates. Timber volume removed and amount of residue produced are normally less per unit area for overstory removal cuttings than for, say, clearcuts. And lower amounts of residue lead to lower production rates for retrieval.

- The overstory removal cutting method, along with restrictions designed to reduce damage to the residual stand, affected production rates. The contractor was required to restrict equipment to existing skid trails and prepared felling beds and to avoid stand damage adjacent to these areas. Compared with unrestricted movement of equipment, as on a clearcut, such requirements undoubtedly slowed production rates. Furthermore, average yarding distance, which was strongly related to production rates,⁸ was thus increased substantially for a given unit of accessible area. On the other hand, residues were more concentrated within that accessible area than they would have been without the special logging restrictions.

- Specified and unspecified bucking reduced production rates. Long pieces of residue had to be bucked to less than 115 inches before they could be yarded. In addition, voluntary partial processing of product—i.e., bucking of fuelwood into stove lengths—on the site added to the time expended.

Residue retrieval in this study was subsidized through a service contract. The value of the product (fuelwood) would not have paid for the full costs of removal, transportation, and processing under conditions of the study. Fuelwood could be produced and transported profitably because costs of removal were covered by the contract. By means of this contract, however, it was possible to determine production rates for a rather intensive degree of utilization, thereby defining a point toward the high cost end of the curve for utilization alternatives.

Additionally, by documenting the resulting residue amounts, the study provides managers with information that could be used in assessing fire hazard reduction and other benefits associated with residue retrieval. The extent to which residue utilization could be subsidized in lieu of treatment and resource costs can be evaluated accordingly.

END NOTES AND REFERENCES

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