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Users Guide for FRCS: Fuel Reduction Cost Simulator Software

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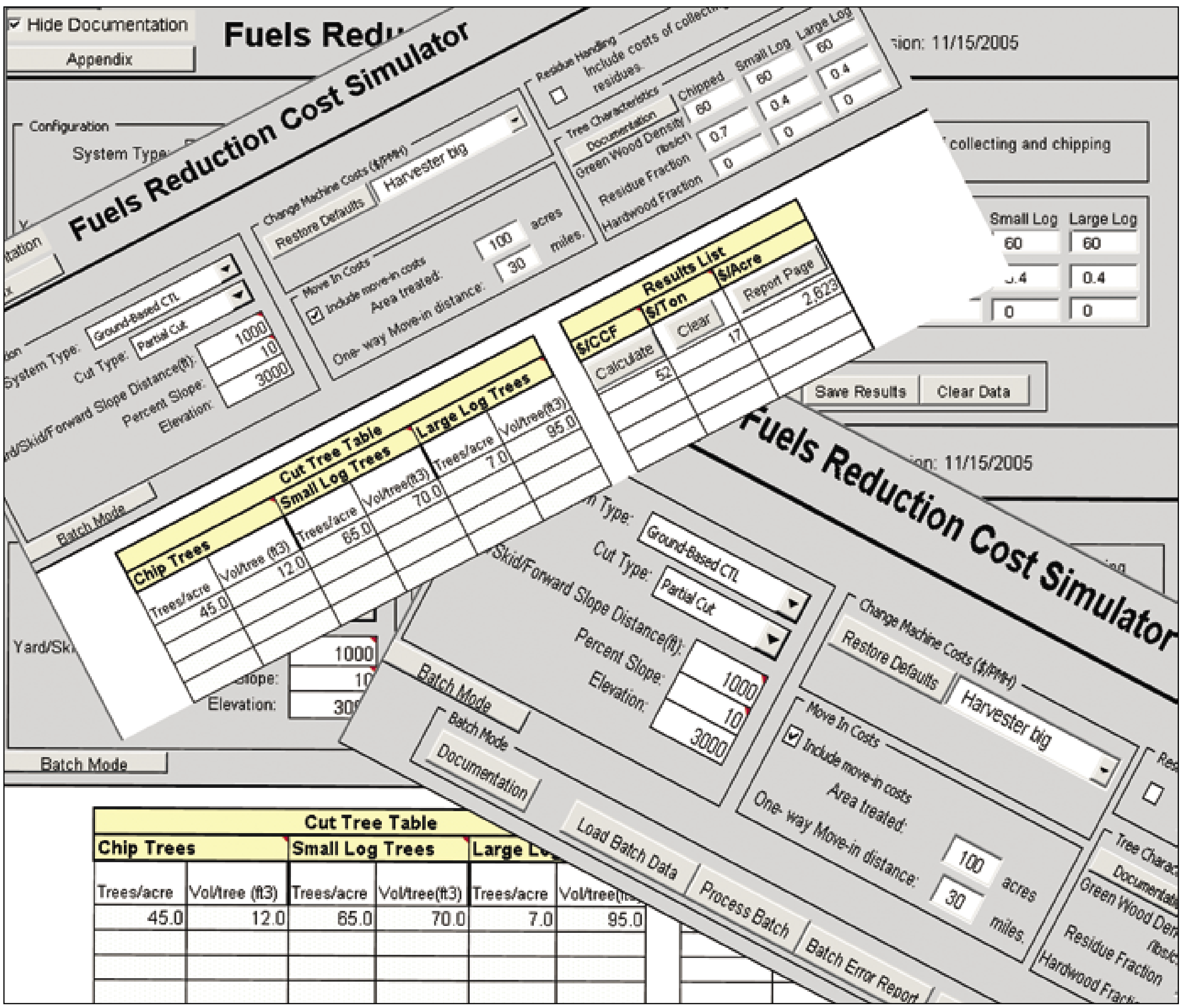

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Abstract

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The Fuel Reduction Cost Simulator (FRCS) spreadsheet application is public-domain software used to estimate costs for fuel reduction treatments involving removal of trees of mixed sizes in the form of whole trees, logs, or chips from a forest. Equipment production rates were developed from existing studies. Equipment operating cost rates are from December 2002 prices for new equipment and wage rates for the Pacific Northwest. These cost assumptions can be modified by the user. There are four ground-based systems, four cable systems, and two helicopter systems. Cost estimates are in U.S. dollars per 100 cubic feet, per green ton, and per acre.

Keywords: Cost (fuel treatment), harvesting economics, fuel treatment planning, software, simulation.

Contents

Introduction

The Fuel Reduction Cost Simulator (FRCS) can be used to estimate the cost of operations involved in cutting trees and delivering logs or trees to a landing for further processing or handling. It was designed to provide cost estimates for four ground-based systems, four cable systems, and two helicopter systems. It uses an engineering cost approach to estimate costs for individual machines (Miyata 1980) and combines machines into systems by using the approach described in Hartsough and others (2001). In that regard it is similar to the STHARVEST model (Fight and others 2003). The major additions beyond the STHARVEST model include the consideration of multiple products (logs and chips) and multi-product systems including chipping tops, limbs, and small trees. Four additional systems have been added: two additional cable systems and two helicopter systems. Production equations from additional studies are included, and equipment costs have been updated to December 2002. The FRCS model was designed to focus on the kinds of systems and thinnings that are designed to address the buildup of fuels in forests that contribute to risk of uncontrollable wildfire.

Information is included to provide an understanding of system configuration and the situations being simulated; however, it was not our intent to provide the information needed to determine whether a particular system is appropriate for a particular situation. It is the responsibility of the user to get the technical and policy information needed to make that decision. The FRCS software, this document, and related documents can be found at http://www.fs.fed.us/pnw/data/soft.htm.

The kinds of treatments that are contemplated and being implemented to reduce fire risk typically include thinning small trees from stands that are judged too dense. These small trees occur either in dense single-canopy stands or in a lower canopy level in multistoried stands. The prevailing attitude among public land managers is that some proportion of these stands needs to be thinned to create a desirable mix of future stand conditions to meet forest health and habitat objectives and to reduce fire hazard. This generally involves removing part or the entire small-tree component of a stand and may include trees across the full diameter range of the stand.

The costs of harvesting and utilizing small trees can be prohibitive because the unit costs of harvesting smaller diameter trees are generally higher than those for larger diameter trees, and the unit costs of harvesting low volumes per acre are generally higher than those for higher volumes per acre. The cost penalties for harvesting low volumes per acre and small trees differ depending on the type of logging system used. For example, harvesting with a cable system is typically more expensive than with a ground-based system and harvesting with a helicopter system is typically more expensive than with a cable system. In addition, the incremental cost increases are greater for cable systems than for ground-based systems when lower volumes per acre or smaller trees are harvested. It is therefore appropriate to consider at the time the silvicultural prescription is developed, the type of harvesting system likely to be used in a stand. With that system in mind, harvest costs can be estimated that will indicate the effect of different management strategies on harvesting costs and net return. If harvesting costs are not considered, prescriptions may be developed that result in costs of harvest that exceed the value of the timber or exceed the perceived fuel reduction benefits. To accomplish a thinning as a timber sale, there needs to be enough value in the trees to be removed to attract bidders. Harvesting costs are often the primary issue in whether or not a stand treatment will pay for itself. It is therefore important to have reasonable harvesting cost estimates for planning purposes in advance of preparing a timber sale or designing a treatment that must be paid for with the available budget. The FRCS software was developed for that specific purpose. It is intended to give reasonable cost estimates for a general type of harvesting equipment and conditions. Because it estimates an average cost for several alternative machines in a configuration, it is not intended to provide estimates for a specific harvest unit with a specific set of machines.

It is important to have reasonable harvesting cost estimates for planning purposes in advance of preparing a timber sale or designing a treatment.

The FRCS software uses more than 100 productivity equations drawn from the literature for machines doing various operations. Machines can be excluded from the model by setting their relevance to zero, a process described below. Capital and operating costs were developed with replacement purchase prices for new equivalent equipment for December 2002. The productivities and costs are used to develop stump-to-truck harvesting costs for the 10 system choices in FRCS. The resulting costs are an average of costs for each type of machine that might be included in a configuration weighted by the appropriateness of each machine for the conditions. These relevance weights vary from 1.0 (where the study is considered to be highly relevant) to zero in portions of the range where the relationships are not likely to be valid. Those interested in the detailed assumptions have access to them through the software and can override the hourly machine cost rates if they wish. When calculating costs for a harvest system, FRCS does not explicitly consider the differences in calculated production rates between individual activities such as felling and yarding. Harvesting contractors use a variety of methods to maintain a reasonable balance between the activities. The FRCS software does take average system imbalances into account because the assumed utilization rates include interactive delays caused by the imbalances. Therefore, the costs reported by FRCS are expected to be reasonable on average.

A glossary near the end of this document contains definitions of some terms and variables that are important in the proper use of the FRCS software.

Overview of FRCS Simulation

An FRCS simulation typically involves specifying a logging system, partial cut or clearcut, average yarding distance, slope, move-in distance, number of acres being harvested at that location, whether or not residues will be chipped, and, for helicopter systems, the elevation. Results can be made more relevant to local conditions by changing default values for machine costs, wood density, the volume of tops and limbs removed with the bole wood (residue fraction), and the proportion of hardwood volume. Logging cost in U.S. dollars per hundred cubic feet (US$/ccf), and dollars per green ton ($/gt), and dollars per acre ($/ac) are shown for user-specified combinations of average tree size in cubic feet and number of harvested trees per acre by categories of trees to be chipped (chip trees), trees to be made into logs that are small enough to fell and process into logs by machine (small log trees), and trees to be made into logs that require chainsaw felling (large log trees). The cost table provides an estimate of cost that might be applied to a single harvest, a series of harvests that might occur in a stand, or harvests applied to multiple stands with similar harvesting conditions.

Results can be made more relevant to local conditions by changing default values for machine costs, wood density, the volume of tops and limbs removed with the bole wood, and the proportion of hardwood volume.

Harvesting Systems and Conditions

Both whole-tree (WT) and log-length systems are included in FRCS. In a WT system, trees are felled either mechanically or by hand and delivered to the landing where the trees are processed into logs. (There are several terms for "delivered" to the landing: skidded for a skidder system, forwarded for a cut-to-length [CTL] harvester-forwarder system, and yarded for a cable or helicopter system. We use the generic term "delivered" where it may pertain to multiple systems to avoid long awkward sentences.) Tops and limbs left in the harvest unit may be left to decompose or may receive additional treatment not addressed by FRCS. Tops and limbs delivered to the landing may be chipped for fuel, left there to decompose, or may receive additional treatment not addressed by FRCS. In a log-length system, trees are felled, limbed, and bucked either mechanically (CTL) or by hand into logs at the stump. Logs are delivered to the landing by skidders, forwarders, cable yarders, or helicopters. Tops and limbs may remain in the woods to decompose or they may receive additional treatment not covered by FRCS. Those removed by a harvester on flat terrain may be bundled and delivered to the landing.

Ground-Based (Tractive) Systems

Ground-based systems are used where management conditions allow because they are typically less expensive and cause less damage to reserve trees than do cable-yarding systems. The potential to damage soils on steep or wet ground, however, limits tractive equipment to sites where the soil is relatively dry and where slopes are less than 30 to 40 percent. For slopes greater than about 10 percent, landings and road access for ground-based systems should normally be located on the downhill edge of the harvest unit. Skidding uphill on steeper slopes can cause excessive soil disturbance, and skidding or forwarding uphill is more costly.

With a ground-based manual-felling log-length system, trees are chainsaw-felled, limbed, and bucked into logs at the stump. Rubber-tired skidders (choker and grapple) collect the logs and transport them to the landing. Logs to be hauled in log form are loaded onto log trucks, and logs to be chipped for board products or fuel are processed through a disk chipper and blown into chip vans. A ground-based manual-felling log-length system is normally used where trees are large enough that they must be bucked into two or more pieces to remove them from the woods. It also may be used when managers wish to retain tops, limbs, and their associated nutrients on site.

With a ground-based manual-felling WT system, trees are felled with chainsaws but not limbed or bucked. Rubber-tired skidders (choker and grapple) collect and transport whole trees. Trees are chipped or processed mechanically with stroke or single-grip processors and loaded onto trucks. A ground-based manual-felling WT system would typically be used for smaller trees than would the manual-felling log-length method and where feller bunchers are unavailable or where managers wish to confine machine traffic to a sparse network of skid trails. It often will be the most economical system where few trees per acre are to be removed. It is appropriate where managers wish to remove residues from the site to reduce fuel loading.

With a ground-based mechanized-felling WT system, trees are felled and bunched; drive-to-tree machines are assumed for flat ground, whereas swing-boom and self-leveling versions are included for steeper terrain. Rubber-tired grapple skidders transport bunches to the landing. Trees are chipped or processed mechanically with stroke or single-grip processors and loaded onto trucks. A ground-based mechanized-felling WT system is normally used when most or all of the trees to be removed are small enough to be handled by a feller buncher. It is useful where fuel loading is high because it removes tops and limbs from the stand. Because all operators are in machines, this system is safer than either of the manual-felling systems, where fallers and choker setters are exposed to the dangers of falling trees and rolling logs.

With a ground-based CTL system, mechanized single-grip harvesters fell, limb, and buck the trees at the stump and pile the logs at trailside. Logs are transported to the landing by forwarders. Logs to be hauled in log form are loaded onto log trucks, and logs to be chipped are processed through a disk chipper and blown into chip vans. Because of the forwarder's high center of gravity, the ground-based CTL system is limited to gentler slopes than are the other tractive systems, and at the upper limits of slope, to terrain that is fairly uniform rather than dissected. In addition, forwarder trails must run close to the fall line and must be laid out on a parallel, uniformly spaced network so the harvester can access the whole area. The physical constraints of the harvester and forwarder limit this system to trees under about 20 inches diameter at breast height (d.b.h.). Mills that prefer logs longer than the forwarder can carry may pay less for short CTL logs. Forwarders carry rather than drag logs and can travel on mats of the tops and limbs left by harvesters. Managers may therefore prefer CTL systems when it is critical to leave residues onsite, minimize soil disturbance, begin operations earlier in the year and continue longer, and minimize aesthetic impact. Cut-to-length systems have safety advantages and can operate with small landings, but they are typically more expensive than mechanized-felling WT systems.

Cable-Yarding Systems

Cable-yarding systems are used where terrain is too steep or wet for ground-based systems or to reach across streams to areas not accessible by road. Yarding, however, requires deflection, that is, concave terrain profiles, in order to lift logs and avoid soil disturbance. Experience and careful planning are needed to ensure adequate deflection. In partial cutting, road access and landings usually should be located along the uphill edge of a harvest unit because yarding downhill can cause excessive damage to residual trees. Stand damage may be less of a problem when the trees being removed are smaller than the residual trees. The types of yarders include Idaho jammers (for clearcuts only), live skylines, and running skylines. All the cable-yarding studies included in FRCS were for uphill yarding, so the results should be applied to downhill yarding with caution.

With a manual-felling log-length cable-yarding system, trees are chainsaw-felled, limbed, and bucked at the stump. Cable yarders transport the logs to the landing. Logs to be hauled in log form are loaded onto trucks, and logs to be chipped are processed through a disk chipper and blown into chip vans. Manual felling is the most common means of preparing trees for yarding because it c an be used on essentially any type of terrain.

With a manual-felling WT cable-yarding system, trees are felled with chainsaws, but not limbed or bucked. (Trees too large to be yarded in one piece or too large to be mechanically processed at the landing are limbed and bucked in the woods.) Cable yarders transport the trees to the landing for chipping or mechanical processing and loading onto trucks. This system is appropriate where managers wish to remove residues from the site to reduce fuel loading.

Cable yarding typically is used on steeper terrain, and landings may not have enough space to accommodate a processor as well as a loader and chipper. In these situations a manual WT/log-length system may be appropriate for fuel reduction operations. Trees to be chipped can be felled and then yarded as whole trees, and those to be processed into sawlogs can be felled, limbed, and bucked prior to yarding. This combination reduces the amount of tops and limbs added to surface fuels as compared to using a log-length system exclusively, but removes less fuel than would the pure WT system.

With a CTL cable-yarding system, mechanized single-grip harvesters fell, limb, and buck the trees and bunch the logs along predesignated yarding corridors and along harvester trails between the corridors. A cable yarder (a standing skyline with motorized slackpulling carriage was the only machine for which data were available) transports the bunched logs to the landing. Logs to be hauled in log form are loaded onto trucks, and logs to be chipped are processed through a disk chipper and blown into chip vans. The CTL system is applicable where the terrain is gentle enough and trees are small enough to allow the use of a harvester. It is not very common but shows promise for reducing the costs and residual stand damage associated with manual-felling log-length cable yarding. Cable yarders do not have the log-length constraints that forwarders have.

Helicopter-Yarding Systems

Because helicopters are generally used on steeper terrain, the most common helicopter system (manual-felling log-length) uses chainsaws to fell, limb, and buck trees at the stump. The helicopters then transport the logs out of the stand. Large landings are required because of the high production rates of helicopters and to provide adequate space for safe operation of equipment outside the load drop zone. Because large landings are typically few and far between, yarding distances for helicopters are generally longer than they would be for ground-based or cable operations. Logs to be hauled in log form are loaded onto trucks, and those to be chipped are processed through a disk chipper and blown into chip vans.

With a CTL helicopter-yarding system a mechanical harvester fells, limbs, and bucks trees at the stump. Subsequent activities are the same as for the manual-felling log-length system. The CTL system is only applicable where terrain conditions allow access and operation of a mechanical harvester. If use of a harvester is possible, planners should consider carefully before using a helicopter for yarding rather than a much less costly forwarder.

How to Get Started with FRCS

The FRCS application is an Excel[1] spreadsheet program. It creates estimates of harvesting cost in dollars per hundred cubic feet, dollars per green ton, and dollars per acre for user-specified conditions and harvesting systems. Software that will run an Excel spreadsheet is required. The FRCS application was developed on Excel 2002. We have not tested the application with earlier versions or with spreadsheet programs other than Excel. A shortcut to the file can also be created and placed on the desktop or another convenient location.

Entering Data in FRCS

Figure 1 shows the screen where data are entered and results are displayed. A check-box in the upper left corner can be used to display or hide explanatory information on making cost simulations. There are two sections to the screen. The upper section provides for data entry for those variables that will be constant for all scenarios entered in the lower section of the screen. The upper portion deals with harvest systems and attributes of the site. The lower section deals with the size and volume of trees or logs being removed and presents the estimated costs in dollars per cubic foot, dollars per green ton, and dollars per acre.

The left side of the upper section requires that four or five items be addressed; elevation is required only for helicopter systems.

1. Select from a list of 10 types of harvesting systems in the combo box at the top: ground-based mech WT, ground-based CTL, ground-based manual WT, ground-based manual log, cable manual WT/log, cable manual WT, cable manual log, cable CTL, helicopter manual log, or helicopter CTL.
2. Select the type of harvest: clearcut or partial cut.
3. Enter the average distance that logs or trees are delivered to the landing. For ground-based and cable systems this is measured along the slope.
4. Enter the average slope for the harvest unit in percent.
5. For helicopter systems enter the elevation.

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

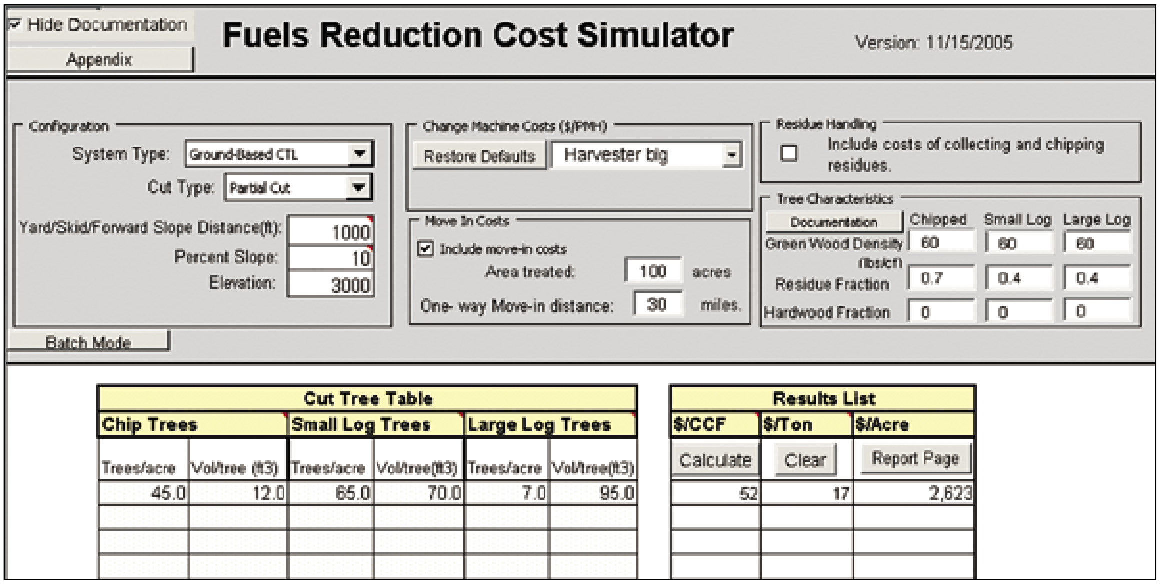

Figure 1—User interface for Fuel Reduction Cost Simulator where data are entered and results viewed.

In the middle of the upper section two areas are addressed: changing machine costs, which will be discussed later, and move-in costs.

To include the costs of moving equipment to the harvesting unit, check the box labeled "Include move-in costs." If this is the only unit in a treatment contract or timber sale, these costs should be based on how far equipment would likely be brought in and the area of this unit. If there are multiple units that would likely be harvested together that are close enough to drive equipment between them, the area of the combined units would be the more appropriate value to use. Area is entered in acres, one-way move-in distance in miles.

On the right side of the upper section, check the box to include the cost of collecting and chipping residues. This option is not available for some systems. For the three WT systems, the tops and limbs are transported to the landing as part of the tree. If this option is selected, a chipper will be included in the equipment configuration and the tops, limbs, and small trees will be converted to dirty chips at the landing. This is accomplished at a small addition to overall cost because the tops and limbs are at the landing and only incur the added cost of chipping. The only other system for which this option is available is the ground-based CTL system. In this case, a bundler is used to gather up and bundle the tops and limbs that have been left in windrows by the CTL operation. These bundles will be transported to the landing on a forwarder for subsequent chipping. The cost of recovering and chipping CTL residues is considerably more than for residues from a WT system.

The section labeled "Tree Characteristics" requires some explanation. Three types of trees are mentioned: chipped, small log, and large log. The chipped category includes the trees that will be WT chipped at the landing. The small log trees are those that will be converted to logs and that are small enough to be handled with mechanical equipment. The large log trees are those that must be felled, limbed, and bucked with chainsaws.

Because the weight of different species of trees differs widely and weight is an important determinant of machine capacity and therefore productivity, we gain precision in cost estimates by adjusting the default values for wood density to reflect the situation. If the cell is left blank, a default value of 60 pounds per green cubic foot will be used. The densities provided are green weights of bole wood and bark per cubic foot of bole wood (gross scale). Appendix table 2 presents some estimates of weights per cubic foot by species provided by regional offices of the Forest Service. In general, they are from loads of logs that have been weighed and scaled in cubic feet. In some cases where the weights for two species are the same in a Forest Service region, it is because the data were for the two species combined and the weight was assigned to both species.

The residue fraction is the ratio of the weight of tops and limbs to the weight of the bole. The log weights are based on converting the volumes that will be entered in the lower section of the screen to weight. For all classes of trees, if the cell is blank a default value of zero will be used. Appendix table 3 presents estimates of residue ratios for commercially important species for a range of average tree size. These values are based on a 4-inch minimum top and only include trees that are large enough to have at least a full 16-foot log. Comparable values for a 6-inch minimum top are very close to these and are therefore omitted.

The hardwood fraction is the volume of hardwood removed as a proportion of the total. The FRCS includes no information from production studies on hardwoods, so for the hardwood fraction, estimated costs for conifers are increased by 20 percent to adjust for the generally lower productivity associated with hardwoods owing to their lean, tree form, and branchiness.

In the lower section of the screen, enter the number of trees per acre and the average volume for each category of trees. It is acceptable to leave blanks for categories that do not have any cut trees. The screen will accommodate a large number of alternative combinations. These values can be copied and pasted from a spreadsheet. After entering any number of rows, click the calculate button to calculate results for all rows. The results are presented in the three columns on the right. All calculations are based on the values entered in the top section of the screen. Appendix table 4 presents volumes to a 4-inch top for commercially important species for a range of average tree diameters and heights. These volumes are calculated with the Inland Northwest Growth and Yield Cooperative profile equations (Flewelling and Ernst 1996). Volumes are only reported for trees that are large enough to have at least a full 16-foot log.

To recalculate all of the combinations entered in the lower part of the screen with a different system or other variables in the upper part of the screen, just change the system selection or other variable and click the calculation button again. It is especially important when using the model to make comparisons of systems to make sure that the combination of variables is appropriate for both systems. For example, it would seldom be appropriate to make a comparison between a helicopter system and another system with the same delivery distance from stump to landing. The requirements for landings for ground or cable systems are such that they are usually at the edge or within the unit. The requirements for landings for a helicopter system are such that they are usually some distance beyond the unit boundary. So a direct comparison of a helicopter system with another system would ordinarily involve changing the average delivery distance.

Simulated Harvest Cost Results

Cost comparisons for a system over a range of conditions should be quite robust and in most cases have smoothly changing cost curves. The method of averaging and weighting described in the "Introduction" and "Glossary" strongly promotes that outcome. In some cases, there can be an abrupt shift when the relevance for a machine goes to zero. Abrupt shifts are more likely if this machine has a cost that is considerably above or below the average and if there are a small number of machines in that average.

Cost comparison anomalies can be avoided by artificially constraining the model.

Cost comparisons between systems may sometimes appear to give anomalous results, especially near the boundaries of the conditions where they are considered relevant. For example, some cable systems may have lower costs than some ground-based systems on slopes in the range of 35 to 40 percent owing to extrapolation of study results that showed increasing costs with slope for ground-based systems. These kinds of anomalies can only be avoided by artificially constraining the model to ensure that they do not occur. Doing this, however, would distort in unpredictable ways the comparisons for a system over a range of conditions. The primary purposes for which we see FRCS being used (evaluating prescriptions and getting broad average costs for a set of prescriptions applied to a set of conditions) make smooth cost curves for systems more important than artificially constrained comparisons between systems, so we have not added these constraints.

There can be anomalies between the cost of partial cutting and clearcutting for cable-yarding systems. On average the clearcutting studies are older than the partial-cutting studies. Many of the clearcutting studies include equipment that is older, less efficient, and less commonly used now. We do not see FRCS being used to make decisions about whether to clearcut or partial cut so we do not see this as a serious problem. Again artificial constraints could be added to ensure that clearcutting is always less expensive than partial cutting under the same conditions, but to do so would distort the costs of some systems relative to other systems so we have not added these constraints.

Constraints and Error Messages

There are constraints on the values that are permitted to be entered in FRCS. There are two general reasons for these constraints. Firstly, we try to prevent circumstances that are outside what is reasonable, given equipment limitations or safety considerations. We also try to prevent unreasonable extrapolation beyond the range of conditions that were represented in the studies on which the model was based. The latter constraints are internal to the application and are dealt with by use of the relevance factors that were discussed in an earlier section.

Table 1 shows the upper limits on average tree volume and slope; values greater than these will produce error messages. Cut-to-length harvesters cannot handle large log trees, but CTL systems can accommodate a small number of such trees by using chainsaws to fell and buck as needed to reduce piece size to that which can be subsequently handled by the harvester or forwarder. For CTL systems, we limit the number of large log trees removed to 10 per acre and the number of large log trees to 10 percent of the total number of log trees removed. Systems that involve mechanical felling or processing are limited to slopes less than 40 percent for safety or environmental damage considerations. Cable systems are limited to average yarding distances of no more than 1,300 feet owing to the typical drum capacities on cable yarders.

Error messages will appear in the results cells for trees that violate the constraints listed above. The messages will include an indication of the error type and the tree group that is in violation. Error messages that appear when limits are exceeded are provided here: “Small Tree” for small tree average volume limits, “Chip Tree” appears if chip trees exceed limits, and “Large Log Tree” appears if large log trees exceed average volume limits. The word “Slope”

Table 1—Constraints on values that average volume and slope can take under different harvest systems

System	Maximum average volume for chip trees	Maximum average volume for small log trees	Maximum average volume for large trees	Maximum slope
	Cubic feet			*Percent*
Ground-based:				
Mechanical whole tree	80	80	250	40
Cut-to-length	80	80	100	40
Manual whole tree	80	80	250	40
Manual log length	80	None	None	40
Cable:				
Manual whole tree/log	80	None	None	100
Manual whole tree	80	80	250	100
Manual log length	80	None	None	100
Cut-to-length	80	80	100	40
Helicopter:				
Manual log length	80	None	None	100
Cut-to-length	80	80	100	40

appears if slope limits are exceeded for the equipment selected, and "Yard Dist" will appear if yarding distance is too great. There are also limits on the average d.b.h. of all trees and all log trees that may be constraining in some cases. These will be reported as "Avg Vol" or "All Log." If there are multiple constraints that are violated, only one will be reported. In those cases, it may require more than one adjustment of the numbers to clear all of the constraint violations.

Changing Default Machine Cost Values

The machine operating costs should include the full cost of ownership, labor, and fuel.

The machine costs used by FRCS can be changed in order to make the per-hour costs of equipment operation more closely match the costs in your area. To change the default machine costs, select the machine that needs to be changed from the drop-down list in the "Change Machine Costs" area on the user interface. Once a piece of equipment has been selected, a text box will appear prompting the user to enter the new per-hour machine costs. The text box will provide the current per-hour value and an entry field for the user to set the new costs. Once a new value has been entered, that value will be stored by FRCS until the user either resets default costs by selecting the "reset defaults" button, or changes the cost again.

For Advanced Users

Description of Calculation Sheets

The following descriptions of the calculation sheets within FRCS are provided for those who want to understand in more detail how the model works and where the calculations are to be found.

The FRCS workbook includes 25 sheets. Twenty-one are calculation sheets; of the others, one is a user interface sheet, one is a treatment report, one is a data input sheet for batch processing, and the last is an error report sheet for batch processing. Tables of simulated harvesting costs can be run from the user interface sheet without ever accessing other sheets. The additional sheets are accessible for those who want to understand the derivation of results or change some of the model assumptions. Equations can be viewed on the formula bar by checking “Show Formula Bar” under the Options menu. If the user selects “no” in the message box asking if the user would like to format tool bars, the user will be able to use the sheet tabs for the sheets described in this section. Or the user can select the “Sheet tabs” box in the Options menu of Excel Tools.

User interface—

The name of the main user interface sheet is **Interface_page**. This sheet contains the results of one or more cost simulations. It also contains the values that have been used in making the simulations so that simulation assumptions can be verified and retained when the spreadsheet is saved. This sheet also contains the input features to allow the user to describe the harvest that they wish to simulate. The sheet will retain these values if the spreadsheet is saved.

Batch Error Report—

The **Batch_Error_Report** sheet displays cell errors for users who have run a batch file, but have made errors in system selection or have received error warnings in the outputs of some cut profiles processed.

Bundle & Forward Residue—

The **Bundle&ForwardResidue** sheet calculates costs per green ton for CTL residues by using three productivity equations drawn from the literature and displays the relevances assigned for the last cost calculation shown on the **Interface_page, i.e., the one at the bottom of the list**.

Cable yarding—

The cable yarding sheet calculates cost per ccf based on 18 cable yarder productivity equations drawn from the literature and displays the relevances assigned for the harvest cost calculation shown on the **Interface_page**.

Chipping—

The chipping sheet calculates costs per ccf for chip trees and costs per green ton of residues by using eight chipping productivity equations drawn from the literature and displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Data—

The data sheet is provided for analysts who want to use the FRCS spreadsheet with large batches of data. Procedures have been developed to allow the spreadsheet to be called by other programs to simulate harvesting costs for specific conditions as part of a broad analysis of fuels treatment. That use is not documented here, but the ability to process batch data is facilitated with the "Batch Mode" tool bar that appears when the batch mode button is clicked in the **Interface_page**. This is included so that one spreadsheet will serve both purposes. Values entered on this sheet will not affect the results shown in the table on the **Interface_page**, as the data are only entered when the "Process Batch" button is selected.

Data_management—

The **Data_management** sheet serves to facilitate updates of the calculation sheets without affecting the user input sheet. Its format is a combination of the **Inputs** and **Outputs** sheets. The **Data_management** sheet shows intermediate results calculated for the last harvest cost calculation executed. Values entered for the treatments on the interface sheet are recorded on the **Data_management** sheet. The values on the **Data_management** sheet are sent to the **Inputs** sheet. Results from the **Outputs** sheet are collected with errors interpreted into the error codes for display on the **Interface_page**. The "Stand variables" table collects the data from each row of the input table on the **Interface_page**. The "Unit variables" table collects the variable inputs (yarding distance, slope, treatment area, move-in distance, and elevation) that are common to all stands in the simulation. The following table collects the inputs from each of the binary inputs (clearcut or thinning, collecting residues or not, and including move-in costs or not) and translates them to be read into the calculation for each stand. To the right of the binary values is a small table that presents the values for the harvest system selected by the user, to be read into the results display on the **Interface_page**. The **Data_management** sheet also includes the table of machine cost values that allow the user to customize the machine cost values through the **Interface_page**. The next table down, "System cost summaries," reads the system outputs from the **Outputs** sheet for display on the **Interface_page**. Below that is a table that checks for possible errors in the system summaries and interprets the errors for output to the user. The final section of the sheet contains a table of system components and the default average cost-per-hour values along with any user modifications. Modifications to machine costs should only be made through the **Interface_page**.

Fell & Bunch—
The **Fell&Bunch** sheet calculates the costs per ccf for 11 feller-buncher productivity equations drawn from the literature and displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Felling—
The felling sheets calculate the costs per ccf for four felling productivity equations drawn from the literature for chainsaw felling and three equations for chainsaw felling, limbing, and bucking. The sheet also displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**. This and the other three felling sheets share common productivity equations, but receive different inputs from the Interface_page as indicated below.

(a) Felling (all trees)—
This sheet applies to the systems where all trees are cut with chainsaws.

(b) Felling (large log trees)—
This sheet applies to the systems where only the large log trees are cut with chainsaws.

(c) Felling (WT chip, log other)—
This sheet applies to the systems where chainsaws are used to fell the trees to be chipped, and to fell, limb, and buck all the other trees.

(d) Felling (WT small, log other)—
This sheet applies to the systems where chainsaws are used to fell the trees to be chipped or processed at the landing, and to fell, limb, and buck all the large log trees.

Forwarding—
The forwarding sheet calculates costs per ccf for six forwarder productivity equations drawn from the literature and displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Harvesting—
The harvesting sheet calculates costs per ccf for 17 harvester productivity equations drawn from the literature and displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Helicopter yarding—

The **HelicopterYarding** sheet calculates the daily costs, capacities, productivities, and costs per ccf for three helicopters. It also displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Inputs—

The **Inputs** sheet displays user inputs, model assumptions, and some intermediate calculations to facilitate validating the model and to provide a convenient place to pass variables between sheets within the model.

Loading—

The **Loading** sheet calculates costs per ccf for six loading productivity equations drawn from the literature and displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Machine costs—

The **MachineCosts** sheet calculates the cost per hour for each type of machine. This is where the default machine costs are calculated. These costs can be overridden by use of the "Change Machine Cost" pull-down menu found on the **Interface_page** user interface.

Move-in costs—

The **MoveInCosts** sheet calculates the move-in costs for each of the harvesting systems.

Outputs—

The **Outputs** sheet collects the outputs for all the system combinations. The products recovered per acre are presented in the top section. The costs of the elements of each system are displayed. These are added together and presented in the "system cost summaries" section of the sheet in three forms: $/acre, $/bole ccf and $/gt. Below, in the "Limits" section, the cut profile variables are checked against the constraints of each system, and any errors are reported. The **Data_management** sheet collects the system cost outputs, and the limit error outputs for presentation on the **Interface_page** user interface sheet.

Processing—

The **Processing** sheet calculates costs per ccf for seven processor productivity equations drawn from the literature and displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Relevance Weight Inputs—

The **RelevanceWeightInputs** sheet calculates the relevance weights for each machine or study included in a system. The cost for a system is an average of the costs of all machines weighted by their relevance weights. A machine can be excluded from the average cost by putting in a weight of zero in column B by the machines to be excluded. User-supplied weights that are within the valid range of zero to 1 will be used except when the calculated weight is zero. If the calculated weight is zero, the user-supplied weight will be ignored to prevent extrapolation beyond what is deemed a reasonable use of the machine. Note that the current model weight shown in column C is for the last calculation made by the model, that is, the one reported at the bottom of the list, and depends on the circumstances input to FRCS. Column K shows the weights used in calculations. They will be identical to the model-calculated weights unless user-supplied weights are used.

Report—

The **Report** sheet displays the inputs and results for a group of harvests that differ only in the size and volume of cut trees. The first section displays the stand profile variables, and the second section provides the cut tree list and the estimated cost for the stand described in each row, and the third section displays the costs per hour used for all machines. The report sheet allows the user to select the "Print" button to have the report formatted and printed.

Skidding—

The **Skidding** sheet calculates costs per ccf for seven productivity equations for skidding unbunched logs and seven productivity equations for skidding bunched logs drawn from the literature. It also displays the relevance assigned for the harvest cost calculation shown on the **Interface_page**.

Variable list—

The **VariableList(just for info)** sheet is used by the spreadsheet developers to keep a complete list of the named ranges used in the spreadsheet and identify their source locations. Model users should not need to use the information on this sheet.

Use of FRCS in Batch Mode

The **Interface_page** also contains a hidden bar of menu buttons titled "Batch Mode" that facilitate the process of importing and processing large amounts of data. Detailed documentation of batch mode formats and operations are available in the program. To activate the batch mode, the user must click the batch mode button. A group of buttons will appear that allow the user to access batch mode functions (fig. 2).

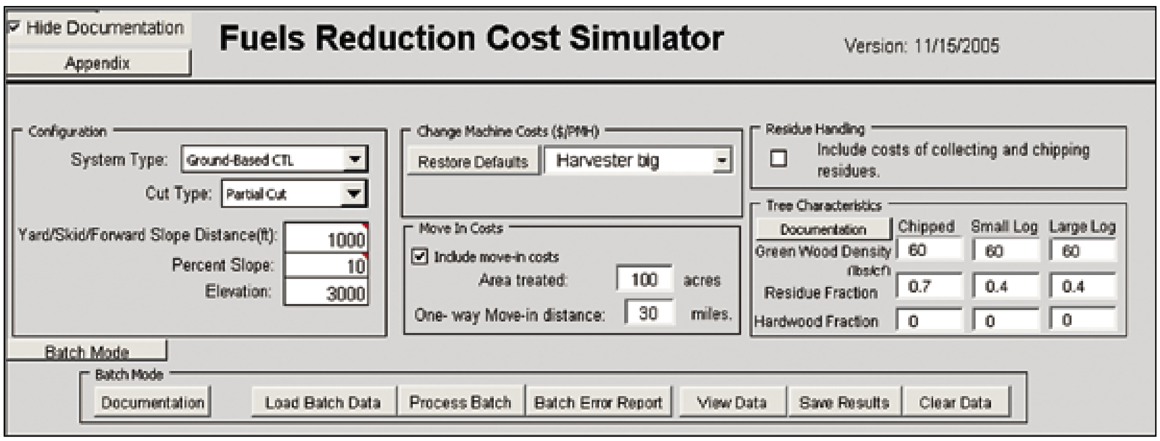

Figure 2—User interface for Fuel Reduction Cost Simulator with batch mode button bar displayed.

The most important button for the new user is the "Documentation" button, as it will walk the user through the batch mode process.

The most important button for the new user is the "Documentation" button, as it will walk the user through the batch mode process. Briefly, to operate batch mode, the user must load a data file by using the "Load Batch Data" button. To process the data the user must select the "Process Batch" button, which will scan the data for input errors, then process the file. The user can then examine the error report to fix problems with the data. The results can be saved as a separate file by using the "Save Results" button. The data page can be cleared with the "Clear Data" button. The batch mode settings will process files with up to 60,000 rows.

Glossary

area harvested—The total area in acres to be harvested by one harvesting system during one entry.

dirty chips—Chipping of whole trees or boles that have not been debarked resulting in chips that are generally used for hog fuel.

green density—The weight of green wood and bark per cubic foot of bole wood measured in pounds per cubic foot of bole wood.

one-way move-in distance—Distance in miles that equipment is transported to reach the harvest unit.

skidding/forwarding/yarding distance—This is the skidding distance for the ground-based skidder systems or the forwarding distance for the CTL system or the yarding distance for the cable and helicopter yarding systems. It refers to the average (not external) one-way distance. For ground-based and cable systems, distance is measured along the slope rather than horizontally.

slope—The average fall-line slope for the harvest unit, measured as a percentage.

tree volume—Average gross volume in cubic feet to the merchantable top diameter of trees being harvested.

trees per acre—Number of harvested trees per acre.

utilization rate—Productive hours divided by scheduled hours.

Acknowledgments

Our thanks to Professor Glen Murphy of Oregon State University for identifying and evaluating the results of a number of recent field studies for inclusion in the model and for updating the equipment costs.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	.3048	Meters
Yards (yd)	.914	Meters
Miles (mi)	1.609	Kilometers
Acres (ac)	.405	Hectares
Cubic feet (ft^3)	.0283	Cubic meters
Dollars per hundred cubic feet ($/ccf)	.353	Dollars per cubic meter
Dollars per green ton ($/gt)	1.102	Dollars per green metric ton
Dollars per acre ($/ac)	2.471	Dollars per hectare
Pounds per cubic foot (lb/ft^3)	16.0185	Kilograms per cubic meter

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Appendix

Table 2—Green weight of logs to a merchantable top by species

Species	Scientific name	Northern Region (1)	Rocky Mountain Region (2)	Southwestern Region (3)	Intermountain Region (4)	Pacific Southwest Region (5)	Pacific Northwest Region (6) (east side)
		Pounds per cubic foot of log volume (gross scale)					
Aspen	*Populus tremuloides* Michx.	58	58		54		
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco	60	50		52	64	61
Engelmann spruce	*Picea engelmannii* Parry ex Engelm.	56	50		51		
Grand fir/white fir	*Abies grandis* (Dougl. ex D. Don) Lindl./*concolor* (Gord. & Glend.) Lindl. ex Hildebr.	65	62		57		
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.	56	50		51	55	63
Mountain hemlock	*Tsuga mertensiana* (Bong.) Carr.	68					
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.	66	68	68	60	69	69
Subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.	53	46		51		
Western larch	*Larix occidentalis* Nutt.	63			52		55
Western redcedar	*Thuja plicata* Donn ex D. Don	43					
Western white pine	*Pinus monticola* ex D. Don	52					

Table 3—Ratio of the weight of tops above a 4-inch minimum and limbs, to the weight of logs, by species and tree diameter

	Diameter at breast height (inches)							
Species	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13+**
Alpine fir		1.05	0.89	0.80	0.76	0.73	0.72	0.70
Douglas-fir		.95	.73	.61	.54	.49	.46	.41
Engelmann spruce		1.08	.77	.61	.51	.45	.41	.32
Grand fir	1.26	.81	.61	.51	.44	.40	.38	.33
Lodgepole pine	1.00	.64	.47	.39	.33	.30	.28	.24
Mountain hemlock	1.05	.73	.58	.50	.46	.43	.41	.38
Ponderosa pine			.90	.78	.70	.64	.60	.46
Western larch	1.22	.76	.55	.44	.37	.33	.30	.25
Western redcedar	.53	.32	.23	.19	.16	.14	.13	.12
Western white pine		.76	.56	.46	.39	.36	.34	.31

See table 2 for species scientific name.

Table 4—Volume of logs to a 4-inch minimum top by species, tree diameter, and height

Diameter at breast height	Alpine fir Height	Alpine fir Log volume	Douglas-fir Height	Douglas-fir Log volume	Engelmann spruce Height	Engelmann spruce Log volume	Grand fir Height	Grand fir Log volume	Lodgepole pine Height	Lodgepole pine Log volume
Inches	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*
6.0										
6.0							41	3	43	3
6.0	46	3	48	3	45	3	53	4	54	4
7.0							35	3	36	4
7.0	42	4	42	4	41	4	48	5	48	5
7.0	52	5	54	5	51	5	60	6	60	7
8.0	36	4	34	4	35	5	41	5	41	6
8.0	47	6	47	6	46	6	54	7	53	8
8.0	57	8	60	7	57	8	67	10	65	10
9.0	40	6	38	5	39	6	45	7	44	8
9.0	51	9	52	8	50	9	59	10	56	11
9.0	62	11	66	10	62	11	73	14	69	13
10.0	44	9	41	7	42	9	49	10	47	10
10.0	56	12	56	11	55	11	64	14	60	14
10.0	67	15	71	14	67	15	80	19	73	18
11.0	47	11	45	9	45	11	53	13	49	13
11.0	59	15	61	14	58	15	69	18	62	18
11.0	71	19	76	18	71	19	84	24	75	22
12.0	50	14	48	12	48	14	57	17	51	16
12.0	63	19	65	18	62	19	73	23	65	22
12.0	75	24	82	23	75	24	89	30	78	27
13.0	52	17	51	15	51	18	61	21	52	20
13.0	66	23	69	22	65	23	77	29	67	26
13.0	79	29	87	29	79	29	93	37	81	33
14.0	55	21	53	18	54	22	65	26	54	24
14.0	68	27	73	27	69	28	81	35	69	31
14.0	82	35	92	35	83	35	97	45	83	39
15.0	57	25	56	22	57	26	68	30	54	27
15.0	71	32	76	32	72	33	84	42	70	36
15.0	85	41	96	42	87	42	101	53	85	45
16.0	60	30	59	26	59	31	70	36	55	31
16.0	74	38	80	38	75	40	87	49	70	41
16.0	88	48	100	49	91	49	104	63	86	51
17.0	61	34	61	30	62	36	72	41	56	36
17.0	76	43	83	44	78	46	90	56	72	47
17.0	91	55	104	57	94	57	107	72	87	58
18.0	62	38	63	34	64	42	74	46	57	41
18.0	78	49	86	51	81	53	92	63	73	53
18.0	94	62	108	66	97	66	110	82	89	66
19.0	63	43	66	39	66	47	77	53	58	46
19.0	79	55	89	58	83	61	95	72	74	60
19.0	96	70	112	76	101	76	112	92	90	74
20.0	64	48	68	44	68	54	80	60	58	51
20.0	81	62	92	66	86	69	97	81	74	66
20.0	98	78	116	87	104	86	114	103	90	82
21.0	67	55	70	50	70	61	83	68	58	56
21.0	83	69	95	75	89	78	100	91	74	72
21.0	100	87	120	98	107	97	117	116	89	88
22.0	69	62	72	56	73	68	85	76	58	61
22.0	85	77	98	84	91	88	103	102	73	77
22.0	102	96	123	111	110	109	120	129	88	95
23.0	70	68	73	62	75	76	87	83	58	67
23.0	87	85	100	94	94	98	104	112	74	86
23.0	104	105	127	124	113	121	122	142	90	105
24.0	72	75	75	68	77	85	88	91	59	74
24.0	89	94	103	104	96	109	106	122	75	94
24.0	105	115	131	138	116	135	124	155	91	116

Table 4—Volume of logs to a 4-inch minimum top by species, tree diameter, and height (continued)

Diameter at breast height	Mountain hemlock		Ponderosa pine		Western redcedar		Western larch		Western white pine	
	Height	Log volume	Height	Log volume	Height	Log volume	Height	Log volume	Height	Log volume
Inches	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*	*Feet*	*Cubic feet*
6.0							41	2		
6.0	46	3			39	3	53	3		
6.0	59	3			49	3	65	4	48	3
7.0	38	3			33	3	48	4		
7.0	52	5			44	4	60	5	44	4
7.0	66	6	43	3	55	6	72	7	58	6
8.0	43	5			38	5	55	7	34	4
8.0	58	7	35	4	50	7	67	8	51	7
8.0	73	9	48	5	61	8	80	10	69	9
9.0	48	8			42	7	60	9	44	7
9.0	63	10	38	5	54	9	73	12	61	10
9.0	79	13	52	8	67	12	85	14	77	14
10.0	53	11			46	9	65	13	54	11
10.0	69	14	41	7	59	12	78	15	70	15
10.0	85	18	56	10	72	15	91	18	86	19
11.0	57	14	27	6	49	12	68	16	56	14
11.0	73	19	44	9	62	15	82	20	74	19
11.0	90	24	60	13	76	19	95	23	91	24
12.0	61	18	28	7	51	15	72	20	59	17
12.0	78	24	46	12	66	19	85	24	78	24
12.0	95	31	64	17	80	24	99	28	96	30
13.0	65	23	29	9	55	18	75	24	63	21
13.0	82	30	49	15	69	23	89	29	83	29
13.0	100	38	68	22	84	29	103	34	102	37
14.0	69	28	31	10	58	22	79	29	68	26
14.0	87	37	52	18	73	28	93	35	88	36
14.0	105	47	72	27	88	35	106	41	107	45
15.0	72	34	33	12	60	26	82	35	71	31
15.0	91	44	55	22	75	33	96	42	91	43
15.0	109	56	76	33	91	41	110	48	111	53
16.0	75	40	35	15	63	30	85	41	73	37
16.0	94	53	58	26	78	38	99	49	94	49
16.0	114	67	80	39	94	48	113	56	115	63
17.0	79	48	37	18	65	34	88	47	69	38
17.0	98	62	61	32	81	44	102	56	91	53
17.0	117	77	84	47	96	55	117	65	114	70
18.0	83	56	39	21	68	39	91	54	65	40
18.0	101	72	64	37	83	50	106	65	89	56
18.0	120	88	89	55	99	62	121	74	112	76
19.0	85	64	44	26	70	44	92	60	66	45
19.0	104	82	68	45	86	56	107	72	93	64
19.0	123	101	92	64	102	71	122	83	120	91
20.0	87	72	48	33	71	50	93	67	67	50
20.0	107	92	72	53	89	63	109	81	97	74
20.0	126	115	96	75	106	81	124	93	127	107
21.0	89	82	53	40	73	55	96	76	75	62
21.0	109	104	76	62	90	70	112	92	101	86
21.0	128	128	99	86	107	89	129	106	127	117
22.0	92	93	58	48	74	61	99	85	84	74
22.0	111	116	80	73	92	77	116	103	105	99
22.0	130	142	102	98	109	98	134	120	127	127
23.0	95	104	62	57	76	67	102	96	73	72
23.0	114	130	84	83	93	84	118	114	102	101
23.0	134	159	106	111	110	106	135	131	130	142
24.0	98	117	65	66	78	74	105	107	63	67
24.0	117	145	87	95	95	91	120	126	98	102
24.0	137	177	109	126	111	114	136	143	134	158

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