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Preliminary Logging Analysis System (PLANS): Overview

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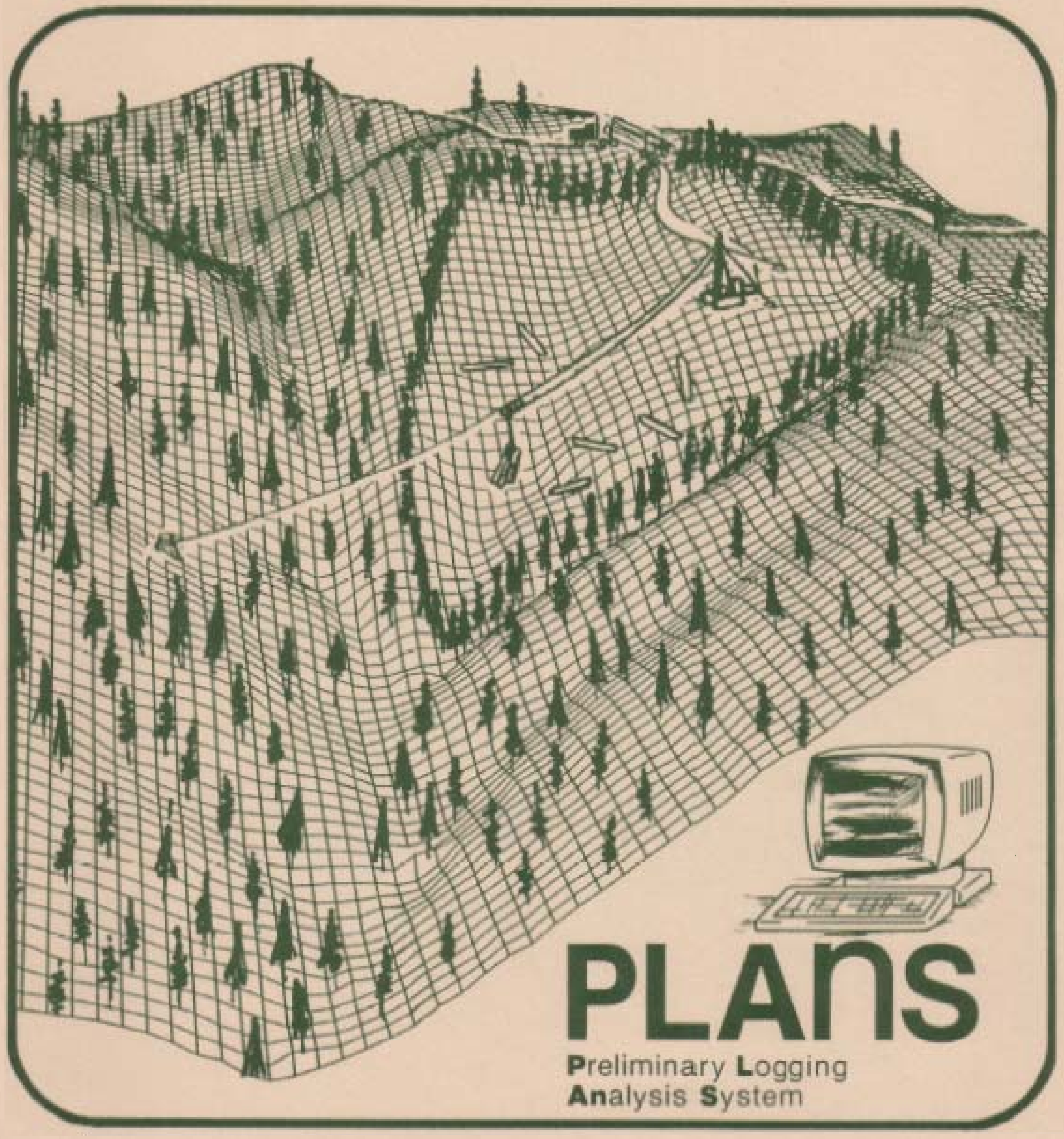

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Abstract

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The paper previews a computer-aided design system, PLANS, that is useful for developing timber harvest and road network plans on large-scale topographic maps. Earlier planning techniques are reviewed, and the advantages are explained of using advanced planning systems like PLANS. There is a brief summary of the input, output, and function of each program in the PLANS program set. The set presently includes programs for harvest unit design for a variety of cable logging systems, road locations, visual analyses, yarding costs, and slope attributes and a method for producing the elevation data files. Suggested ways to use PLANS to develop the harvest plans and to document and process harvesting alternatives are presented. Justifications are given for investments made in planning.

Keywords: Timber harvest planning, computer programs/programing, logging operations analysis/design, road building (forest/logging).

Contents

Introduction

This report introduces a planning tool for expediting development of timber harvest plans. This tool, called PLANS (preliminary logging analysis system), is a family of computer programs that focuses on timber harvest planning. A major feature of PLANS is that it uses a stored digital terrain model, the equivalent of the planning area map, to supply the topographic data needed to design the timber harvest plan.

Good planning is vital to cable-log timber from steep terrain. The economic and environmental success of timber harvesting is strongly influenced by the cable yarding system selected for the operation and by how well the system is positioned on the terrain. Good positioning of the cable span permits hauling an ample volume of logs in each yarding cycle, which results in higher production and lower costs. Poor positioning results in excessive soil disturbance, hangups, reduced production, equipment breakdown, unsafe operations, or unworkable harvest units. The quality of timber harvest plans depends on the planner's thoroughness, which is influenced by time constraints, management support, and the planning tools provided.

The need for and the benefit of good planning has long been acknowledged by timber managers; however, defining what good planning is and institutionalizing it in an organization can be difficult. Planning has been mandated for the National Forest System by the Forest and Rangeland Renewable Resources Planning Act (1974) and the National Forest Management Act of 1976 (U.S. Laws, Statutes, etc. 1976). Jones and others (1986) compared four analytical approaches that are used to make National Forest land management and transportation planning decisions. They focused on a scale of planning termed "area-level-analysis" (ALA), and defined this as management units that are geographically contiguous land areas of 5,000 to 50,000 acres. Their examples, which illustrated various processes used in these four analyses, began at the point where the timber harvest units and transportation networks had already been identified and delineated. As a precursor to ALA, PLANS enables users to rapidly design and delineate timber harvest units and road access to timber for extensive areas. Area-level-analysis that begins with well-designed harvest units and transportation systems can proceed on a solid foundation. The individual timber harvest units and road alternatives form the foundation of the final management plan, and PLANS helps to ensure the operability and soundness of this foundation.

The scenario described above for ALA pertains to a specific and evolving planning environment in the National Forest System. Some basic considerations of timber harvest planning transcend the details of planning jurisdiction. One basic consideration is the influence of topography on the cost of timber harvesting. Topography affects most timber harvesting activities, from felling and yarding to road and landing construction; timber harvest planners therefore need detailed topographic information. This need has traditionally been met by topographic maps. Accurate maps with a scale of 1 inch to 1,000 feet, or larger, and contour intervals of 50 feet, or less, provide an excellent foundation for planning if used correctly. Planners can visualize steepness, ridges, valleys, benches, and profiles of the terrain from topographic maps. With maps and a knowledge of the operating requirements of various harvesting systems, planners can make good estimates as to where roads can be built, how much timber can be accessed by a given yarding system from a selected landing, and how best to fit a road and landing network together to provide a workable and complete timber harvest plan.

Review of Analytical Harvest Planning Methods

To assume that the planner's good judgment in choosing yarding span patterns from topographic maps is enough to ensure consistently adequate cable system payloads[1] is a high-risk and totally unsatisfactory practice. Planners can judge whether a cable yarding system will operate with a sufficient payload by mentally visualizing terrain shape while viewing a topographic map. They should confirm their judgment by calculating the potential payload, however, and this requires that a profile of each yarding corridor be carefully plotted. Before computers were used for planning, handbook procedures were used to determine payload. Potential skyline corridors were marked on a topographic map, and the terrain breaks (intersections of the corridor and the contour lines) were measured. The resulting profile was plotted, and its skyline payload was calculated using a chain and board simulation method (Lysons and Mann 1967). It took about 30 minutes to construct the profile and complete the payload analysis for a single skyline corridor. Related analyses of topographic profile data extracted from maps also made it possible to establish the locations for highlead units and logging roads (Pearce 1960). Timber harvest plans can be developed in this manner, although the time and effort absorbed generally limit their application.

The process of obtaining terrain profiles from topographic maps and of analyzing skyline system payloads improved when computer-based methods were introduced (Carson and others 1971). Programs based on computers interfacing with digitizers and plotters can now provide machine plotted profiles of digitized corridors. Other programs can calculate the resulting skyline payload for each profile. Only 5 minutes is needed to construct the profile and complete the payload analysis for a single skyline corridor.

The use of computers has made it convenient to quantitatively evaluate timber harvest plans, but the level of convenience provided by the programs is still inadequate to encourage the planner to thoroughly analyze full-rotation, total-area alternatives. The programs require considerable digitizing for each corridor examined, and hundreds of corridors must be examined for each alternative plan. Because of this, planners usually cannot analyze the full range of alternatives when developing full-rotation, total-area plans.

Harvest Planning With Digital Terrain Models

Burke (1974) suggests using a digital terrain model (DTM) for harvest planning. A DTM is an organized and comprehensive data file containing elevations that represent ground -surface topography; the DTM is accessed directly by the computer. The advantage of the DTM concept is that it provides instant access to the numerous terrain profiles that should be analyzed when a total area harvest plan is developed.

[1] The maximum weight of logs that can be safely transported to the landing in a single yarding cycle.

Young and Lemkow (1976) present a prototype timber harvest planning system that uses a digital terrain model. Their planning programs were based on a computer system[2] that, by present standards, is obsolete and inadequate for computer-aided design of logging units, though it was a state-of-the-art, interactive, desk-top computer system in 1976. Improvements in computer equipment and an increased awareness of the economic benefits of computer-aided design methods have resulted in expanded and improved planning systems that use digital terrain data. Reimer (1979). reports that an operational harvest planning system using digital terrain models was successfully implemented by McMillan Bloedel, Ltd., in Canada. Twito and Mifflin (1982) distributed[3] a preliminary version of PLANS that, like Reimer's planning system, operated on a Hewlett-Packard 9845 computer system.[4] Reutebuch and Evison (1984) report that an operational package using digital terrain models for cable system layout is available in New Zealand.

Description of PLANS

PLANS is a set of computer programs designed to assist logging engineers and transportation planners in developing timber harvest plans. PLANS allows the planner, aided by an interactive graphics computer system, to examine a wide range of design and planning options-a range not possible with earlier planning methods. PLANS, although it does not fully automate the design process, enhances the planner's ability to develop alternative timber harvest plans.

An earlier version of PLANS, which ran on the Hewlett-Packard 9845 computer (Twito and Mifflin 1982), has been enhanced and implemented on the Hewlett-Packard 9020 computer, which has greater operational convenience and faster computing speeds. New programs have also been added to PLANS. By using the PLANS package, the planner can construct and analyze the profile of a skyline corridor in less than 30 seconds. Other related PLANS design routines determine the maximum reach of cable yarding systems for profiles of circular settings in 2 seconds; only the planimetric results are displayed. Such routines, which depend on digital terrain model data, could not be done in a continuous-flow process with earlier planning methods.

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[2] A Hewlett-Packard 9830 desk-top computer system with no graphics screen, 16K bytes of random access memory, and an 8-bit processor.

[3] PLANS was distributed for testing within the USDA Forest Service and to a number of interested industrial forestry corporations that had compatible computer hardware.

[4] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Required Computer Hardware

PLANS was developed for a microcomputer-based, interactive graphics system with the following components:

1. Hewlett-Packard 9020B microcomputer with 1 megabyte of core memory and BASIC operating system,
2. Hewlett-Packard 7908P with 16.5-megabyte disk drive,
3. Hewlett-Packard 2932A dot-matrix printer,
4. Hewlett-Packard 7580B eight-pen drum plotter, and
5. CalComp 9480 36- by 48-inch digitizer with 12-button cursor.

An operational version of PLANS has also been translated to the Hewlett-Packard 9836 computer by the State of Washington.[5] Most interactive graphics computer systems can support a package similar to PLANS; however, converting the package to another system or language may require considerable effort.

Program Descriptions

Each program in PLANS will be documented in a separate technical report. Each technical report will include an analytical description of the program and a users guide. The following are brief descriptions of the programs presently available in PLANS.

The MAP program—The MAP program is used to produce digital terrain models with a grid pattern. These models are the source of terrain data for the other PLANS programs. Digital terrain models are produced by manually tracing contour lines from a topographic map mounted on the digitizer. Digitized contour data are converted by the program to an elevation matrix in grid form and are stored for later use. Large planning areas can be divided into smaller units for purposes of inputting data. Through this technique, digital terrain models of map areas larger than the digitizer can be built. An experienced user should be able to digitize 170 acres per hour when using topographic maps at a scale of 1 inch to 400 feet with 20-foot contours. This rate will vary with the, map scale, the contour interval, and the complexity of the topography.

The SKYMOBILE and SKYTOWER programs—The SKYMOBILE and SKYTOWER programs analyze the load carrying capacity of skyline yarding systems. Terrain profiles of skyline corridors are obtained from a digital terrain model of the planning area. The SKYMOBILE program is used to analyze individual profiles and is best suited for planning harvest areas where the yarder is moved with each corridor change. The SKYTOWER program is used to analyze settings that will be yarded in a fan-shaped pattern to a central landing.

When the SKYMOBILE program is used, the planner designates a skyline profile for analysis by digitizing its beginning and ending points on the topographic map. The program extracts and displays the profile from the digital terrain model, and the planner chooses a yarder location from the profile. The program can then either determine the maximum span a specified payload can be yarded over, or it can determine the maximum payload that can be yarded over a specified span. SKYMOBILE simplifies the positioning of midslope roads by permitting analysis of several non-overlapping skyline spans on the same profile (fig. 1).

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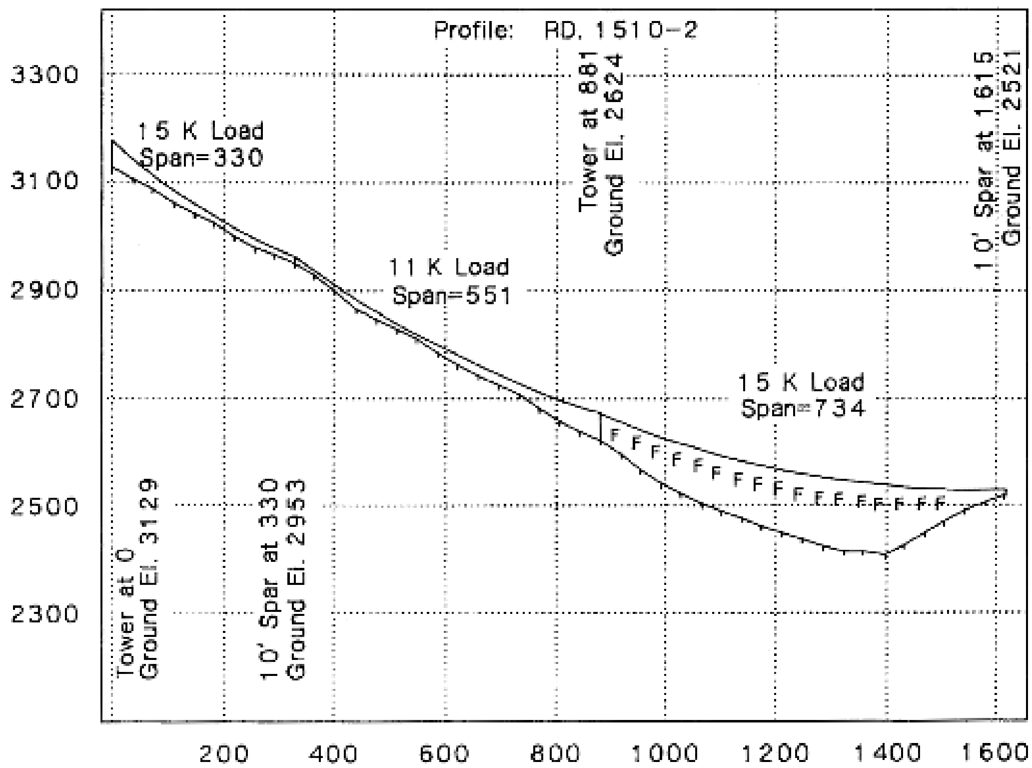
[5] Accomplished by the Department of Natural Resources, Olympia, in cooperation with the College of Forestry, University of Washington, Seattle.



F--INDICATES FULL SUSPENSION OF THE LOAD

RUNNING SKYLINE SYSTEM SPECS:

HAULBACK CABLE UNIT WEIGHT	1.42 LB/FT
HAUL BACK CABLE WORKING TENSION	26500 LB
COMBINED UNIT WEIGHTS OF MAIN & SLACKPULLING CABLES	2.84 LB/FT
COMBINED WEIGHT OF CARRIAGE AND BUTT RIGGING	500 LB
TOWER HEIGHT	50 FT
TAILHOLD HEIGHT	10 FT
CARRIAGE GROUND CLEARANCE	10 FT
CARRIAGE HEIGHT FOR FULL SUSPENSION	50 FT
MAXIMUM SLOPE RIGGING DISTANCE	1500 FT
TARGET DRAGGING PAYLOAD	15000 LB

NOTE: PAYLOADS WERE NOT COMPUTED WITHIN 50 FEET OF THE TAILHOLD.

Figure 1—The skyline corridor profile plot and load path analysis as produced by the SKYMOBILE program.

When the SKYTOWER program is used, the planner designates a central landing by digitizing the yarder's location on the topographic map. The program automatically extracts 18 evenly spaced profiles radiating out from the landing. Each profile is analyzed to determine the maximum span a target load can be yarded over. A planimetric plot of the area that can be yarded to the landing is displayed. The planner can modify the boundary of this area by adding or deleting yarding corridors. Individual corridors can also be reanalyzed after the yarding system criteria have been altered. When a satisfactory unit design is complete, a planimetric overlay can be produced on the plotter (fig. 2) to simplify transfer of the harvest unit to the timber harvest plan.

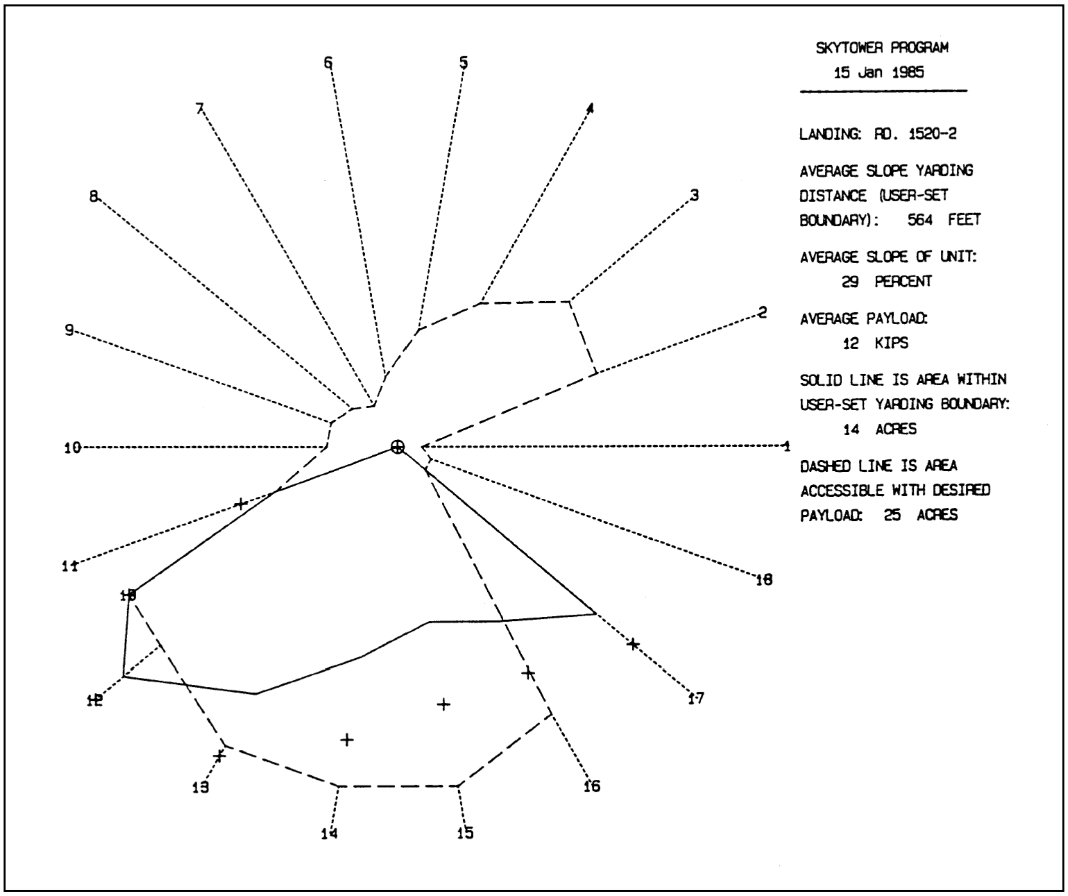


Figure 2—The planimetric plot of the setting boundary as produced by the SKYTOWER program.

The HIGHLEAD program**—**The HIGHLEAD program analyzes highlead settings yarded in a fan-shaped pattern to a central landing. Like SKYTOWER, the HIGHLEAD pro-
gram automatically analyzes 18 profiles radiating from a digitized yarder location. For each individual profile, the yarding limit is established either by the first instance of blind lead along the profile or by the maximum reach of the yarder. A plan of the area that can be yarded to the landing is displayed. The planner can attempt to increase the area of the setting by extending the yarding distance through tight-lining (tensioning the haulback line to increase lift and permit yarding beyond a point of blind lead). Figure 3 is an example of a corridor in which the yarding limit has been extended by tight-lining. The planner can also reduce the area of the setting by reducing yarding limits of individual corridors or by removing corridors from the setting. When a satisfactory setting design has been completed, a planimetric overlay can be produced on the plotter (similar to fig. 2) to simplify transfer of the harvest unit boundary to the timber harvest plan.

The ROUTES program**—**The ROUTES program allows the planner to rapidly identify road gradelines and to develop a road pattern within the harvest area. The program uses the DTM of the area as a source for terrain data. The planner can use the digitizer cursor to estimate the grade and distance between selected control points. The cursor can then project a gradeline between control points at the estimated grade. Operation of the program is similar in principle to manual map use and to field-based techniques that planners traditionally have used to plan forest road systems.

After a gradeline has been projected on the map, the profile view (fig. 4) and the planimetric view (fig. 5) of the route can be produced by the program as can a printed summary of the stations, elevations, grades, cuts and fills, and side slopes along the route.

The program can also be used to produce rough profile plots and summaries of side slopes along existing roads within the harvest planning area.

The SLOPE program**—**The SLOPE program produces overlays at map scale that delineate topographic attributes (that is, slope, aspect, or elevation or combinations) within ranges set by the planner. The program also provides a printed summary of acreage of the plotted attributes. Overlays can be produced at various resolutions based on the grid size of the digital terrain model. An example of a slope overlay, produced with a resolution of 16 digital terrain model grid cells per slope attribute cell, is shown in figure 6. These overlays are useful for several reasons. If the planner wants to prescribe yarding systems based on terrain steepness, a slope-attribute plot will delineate the appropriate boundaries. If the planner decides that the areas where winter logging is feasible are constrained to terrain on south, southwest, and west aspects below 3,500 feet elevation, and wants the acreage and location of that terrain, the SLOPE program can provide this information. Other topography-related information useful for land management (for example, to allocate planting stock, schedule slash burning, or locate wildlife winter range) can be obtained by using this program.

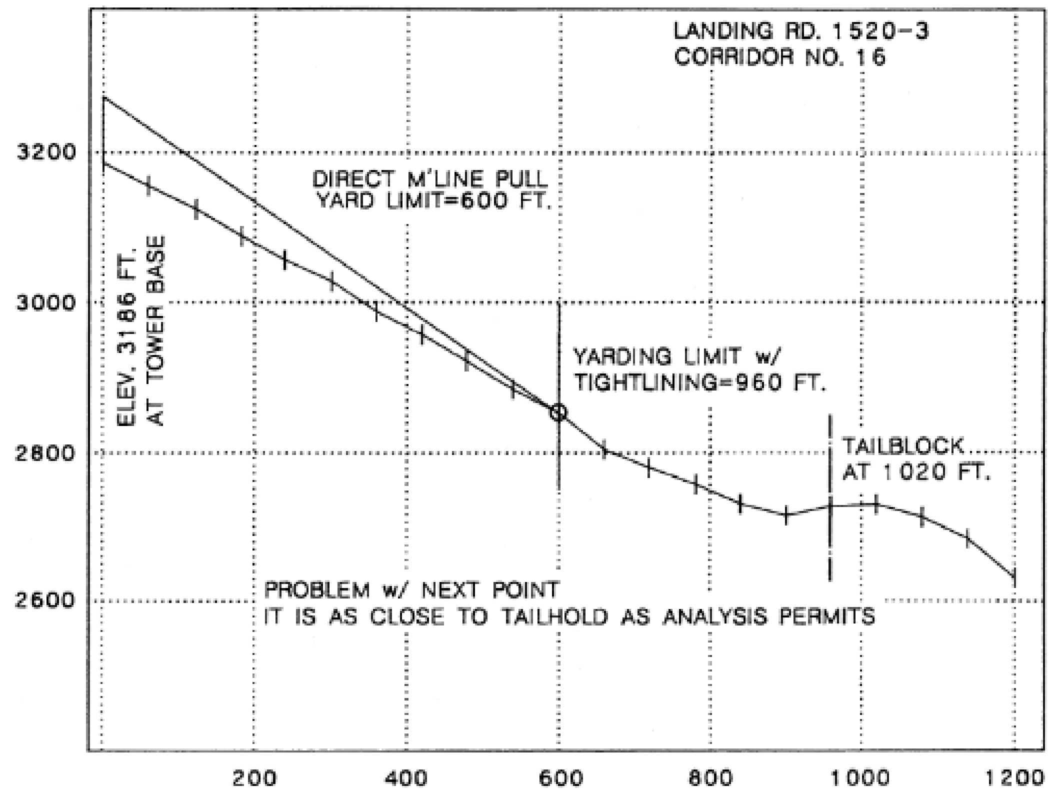


Figure 3—The highlead corridor profile plot as produced by the HIGHLEAD program.

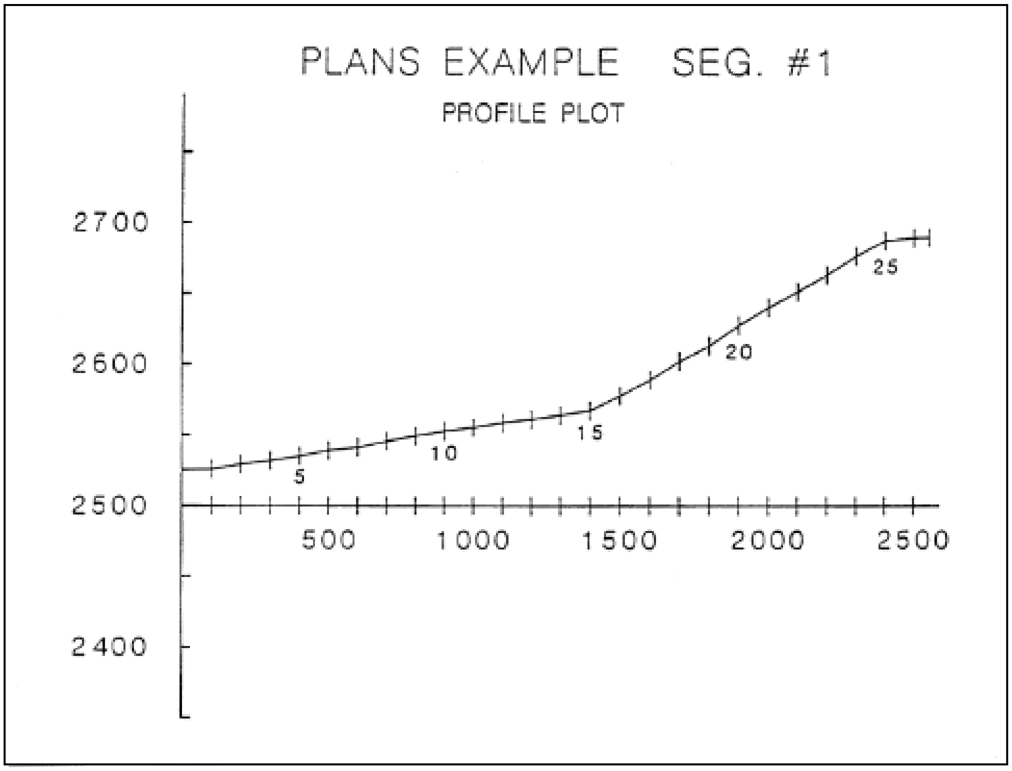


Figure 4—Profile plot of a road as produced by the ROUTES program.

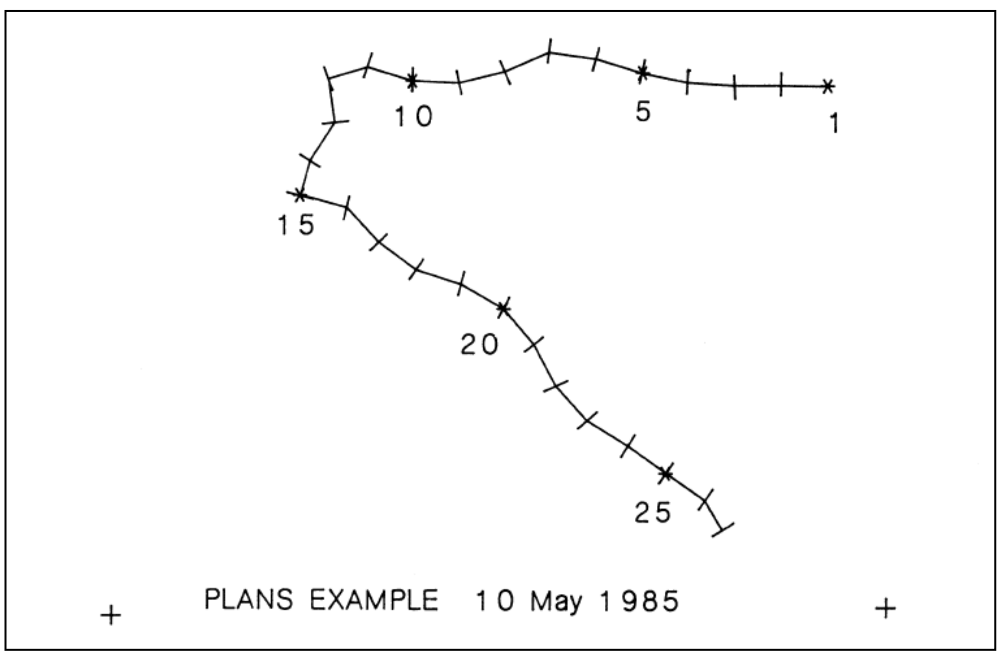


Figure 5—Planimetric plot of a road's location as produced by the ROUTES program.

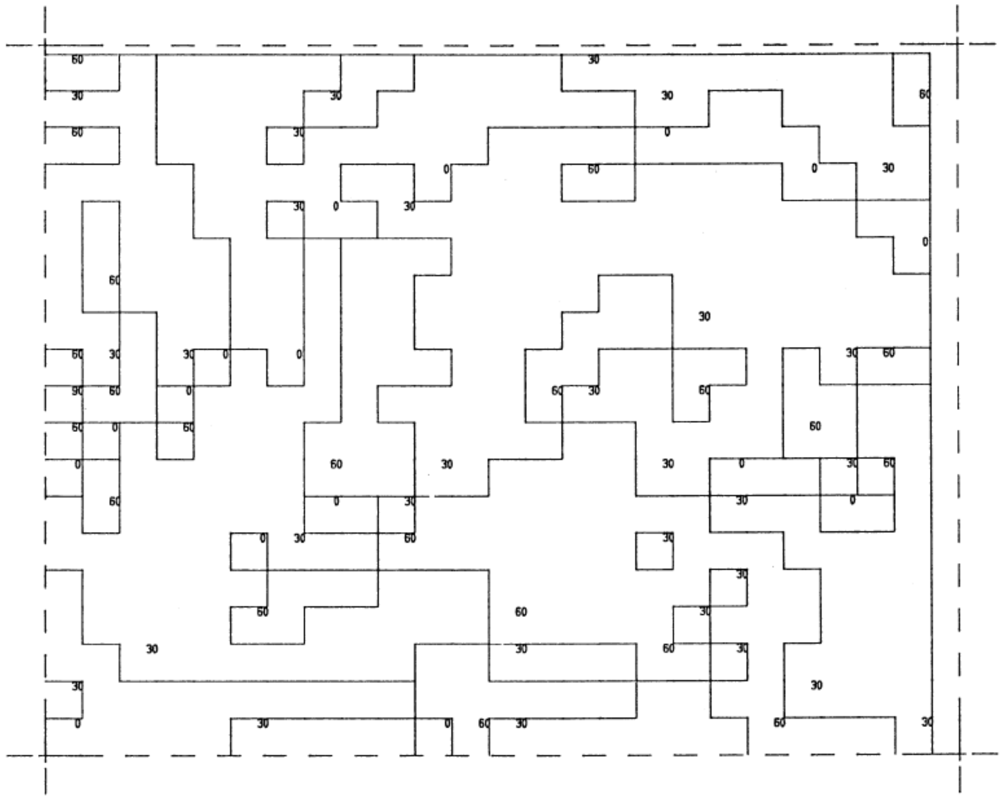


Figure 6—Slope overlay as produced by the SLOPE program.

The VISUAL program—The VISUAL program produces perspective views of terrain, roads, and harvest boundaries from user-selected viewpoints. These perspective views provide a preview of the visual impact of proposed harvest activities. Perspective views, such as the one shown in figure 7, show only the areas of terrain and harvest activity visible from the selected viewpoint. VISUAL also provides the planner with the opportunity to view a three-dimensional projection of the topographic map (represented by the digital terrain model). Such projections help the planner to get a better sense of the general lay of the land in early stages of planning.

The SIMYAR program—The SIMYAR program is a cable logging simulation model that uses a harvest unit's geometry, timber stand characteristics, and yarding equipment specifications to estimate cost and productivity of yarding. The planner can use the estimates to compare alternative timber harvest plans. Both parallel settings yarded with mobile yarders and fan-shaped settings yarded to a central landing can be modeled by the SIMYAR program. Output from SIMYAR includes a summary of costs and productivity for various yarding systems (see fig. 8) and information that details yarding production and volume statistics for the unit.

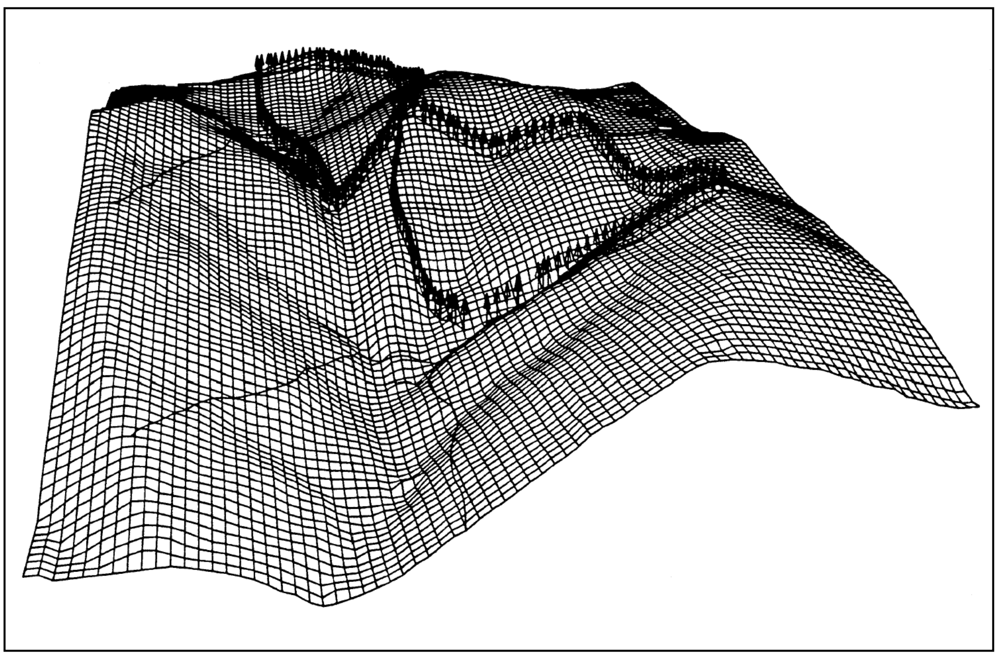


Figure 7—The perspective plot as produced by the VISUAL program.

SPEARFISH SALE: UNIT #3 5 Jun 1985

Type of system: SKAGIT BU-90: LIVE SKYLINE
Operating cost per hour is 203.86 dollars.
The set up cost for the logging system is 1000.00 dollars.
The maximum slope yarding distance is 798.88 feet.
The maximum lateral yarding distance is 24.15 feet.
The average system payload is 15000.00 pounds.
The preferred log length is 40.00 feet.
The minimum log length is 12.00 feet.
The small end merchantable diameter limit is 6.00 inches.
33.00 skyroads are required on the harvest unit.
The average road services .42 acres.
Road change time: 1.15 hours.
The stand contains 34230 board feet per acre (Scribner).

TURN STATISTICS

	Mean	Std dev	Minimum	Maximum
Weight (Pounds)	6383.40	3164.67	232.01	14225.03
Volume (Cu. Ft.)	127.67	63.29	4.64	284.50
Volume (Bd. Ft.)	631.95	368.74	8	1548
Number of logs	3.24	1.00	1.00	4.00
Cycle time (Min.)	6.32	.45	5.25	7.23

Cycle times determined using user selected regression equations.

DISTRIBUTION OF TURN WEIGHTS

Weight per turn (Pounds)		Relative frequency
1 - 1500	**	.0476
1501 - 3000	**	.0476
3001 - 4500	************	.2381
4501 - 6000	*****	.0952
6001 - 7500	************	.2381
7501 - 9000	*******	.1429
9001 - 10500	*****	.0952
10501 - 12000	**	.0476
12001 - 13500		.0000
13501 - 15000	**	.0476

Figure 8—The analysis summary produced by the SIMYAR program.

SPEARFISH SALE: UNIT #3 5 Jun 1985

DISTRIBUTION OF LOGS PER TURN

Number of logs per turn		Relative frequency
1	**	.0476
2	************	.2381
3	*******	.1429
4	*****************************	.5714

DISTRIBUTION OF CYCLE TIMES

Time per turn (min.)		Relative frequency
0.00 - .72		.0000
.73 - 1.45		.0000
1.46 - 2.17		.0000
2.18 - 2.89		.0000
2.90 - 3.62		.0000
3.63 - 4.34		.0000
4.35 - 5.06		.0000
5.07 - 5.78	*******	.1429
5.79 - 6.51	**************************	.5238
6.52 - 7.23	**************	.2857

UNIT SUMMARY

Unit area:	13.86 acres
Number of pieces yarded:	2244.00
Number of turns:	693.00
Total yarding time:	72 hours 57 minutes
Total yarded volume:	884.74 cunits
	437.94 M board feet

YARDING COST

Total yarding cost:	$ 23374.85
Yarding cost:	$ 26.42 /cunit
	$ 53.37 /MBF

Figure 8—The analysis summary produced by the SIMYAR program (continued).

Developing a Harvest Plan With PLANS

The topographic map is the foundation of a timber harvest plan developed using PLANS. The first question from a prospective PLANS user might well be, "Is the topographic map of my harvest area adequate (in scale, detail, and accuracy) to be used for planning?" The answer is yes, if the resulting map-based harvest plan fits closely enough to what can actually be achieved on the ground to provide:

1. Information that a land manager can confidently use to evaluate the economic and environmental consequences of a specific timber harvest.
2. A harvest plan that can be sustained as a pattern for layout. The size and impact of the necessary layout adjustments (that is, fitting the harvest plan to the terrain) can be accommodated without a major overhaul of the harvest plan.

Users of PLANS need topographic maps sufficient in accuracy and scale for map-based planning. Maps with a scale of 1 inch to 400 feet and 20-foot contours are recommended, although scales up to 1 inch to 1 ,000 feet with contours up to 50 feet can be used.

Practical Sequences of Use for PLANS Programs

The MAP program must always be used first with PLANS. After the general area to be planned has been marked on the topographic map, the planner uses the MAP program to build the DTMs of the planning area by tracing the contour lines.[6]

After the DTM of the planning area has been constructed, any of the design programs can be used. The basic functions performed by the PLANS programs are built around analytical routines commonly used for planning cable logging operations. Special situations may require that these basic functions be performed in a different sequence or that more emphasis be placed on one function. For instance, in one area the required road pattern may dictate the type and placement of the yarding system. In such a case, the planner may want to develop the road system first using the ROUTES program and then develop yarding coverage using the SKYMOBILE, SKYTOWER, and HIGHLEAD programs. In another area, the required yarding system may dictate where the roads are to be constructed. In this case, the yarding analysis programs may be used prior to the route-location program. Whatever the case, the PLANS programs allow the planner to quickly verify that a harvest plan is workable. With the exception of the MAP program, the PLANS programs can be used in any order. Each program operates independently and requires only that a digital terrain model has been produced and loaded prior to running the program. The PLANS package does not force the planner to use all the programs contained in the package. The planner may choose to use only those PLANS programs that are suited to the particular planning task.

The PLANS package does not force the user into a structured planning process. This may appeal to those planners who do not want their creativity and intuition constrained by required procedures. Other planners, who want a more detailed explanation of how to use the PLANS package, should review the following planning procedure. (Suggestions for managing and organizing documents while developing a harvest plan are given in the appendix.)

[6] Even when existing DTM tapes are converted to the correct structure for use in PLANS, they are loaded by using the MAP program.

An Example Approach to Harvest Planning With PLANS

We were asked to make a timber harvest plan for a 3,200-acre unit in the Cascade Range at the Wind River Experimental Forest, Gifford Pinchot National Forest, Washington. This provided an opportunity to put PLANS to a practical test and to develop a methodology for its use. Efficient and thorough planning requires a logical and structured methodology. Although PLANS does not force users into a structured planning process, it does not prevent them from using one. The approach taken in developing the Wind River plan is shown in figure 9. Even though this schematic can fit a range of planning situations, the variability of harvesting situations makes it unlikely that this generalized harvest planning approach will fit all situations.

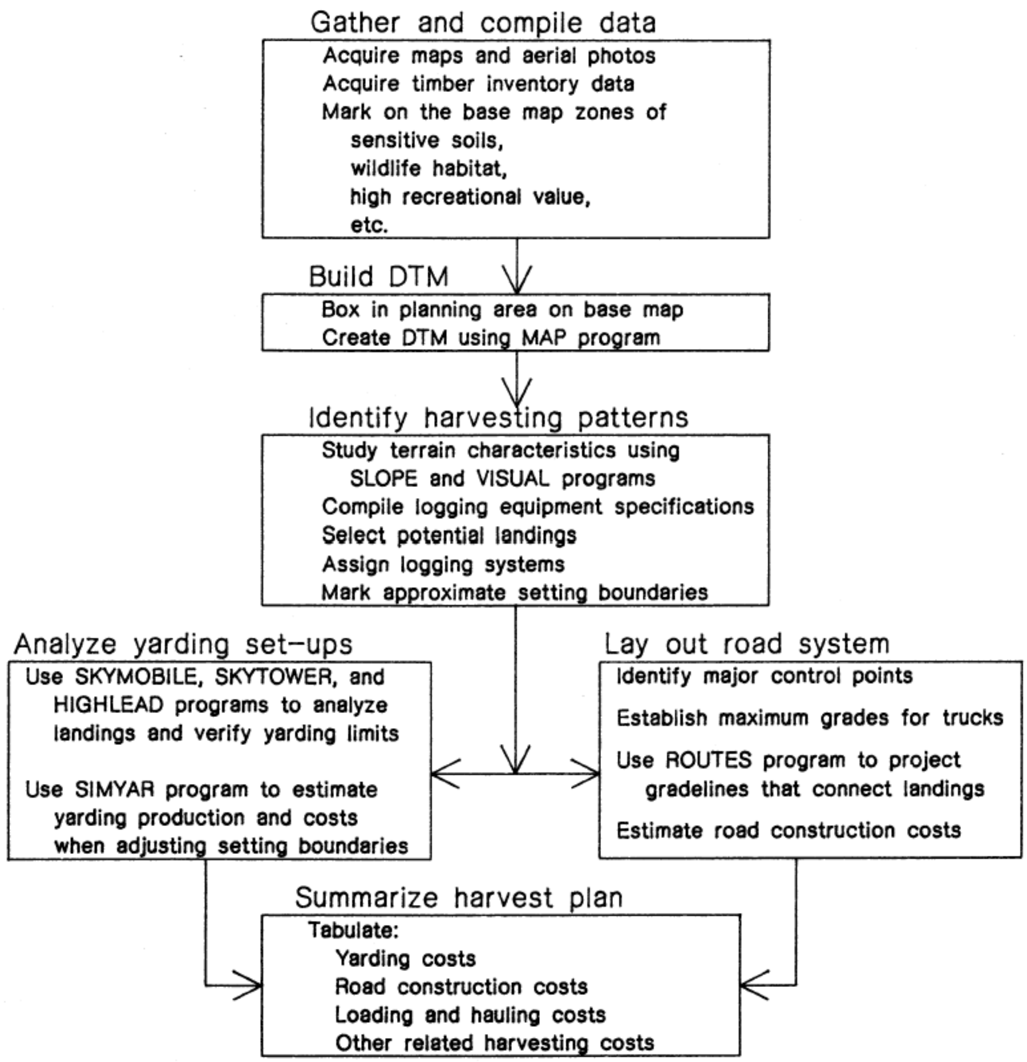


Figure 9—A preliminary harvest planning approach that incorporates the PLANS package.

As indicated in figure 9, many tasks must be completed before design of the harvest unit can begin. The tasks include collecting and studying information that describes the planning area, compiling a list of yarding equipment needed to accomplish the harvesting objectives, and developing a first-try or best-hunch projection of an overall harvesting pattern. These tasks have always been important prerequisites to using computer programs for harvest planning (Burke 1984), and they continue to be with PLANS.

A large-scale topographic map and aerial photos of the area must be obtained before planning can begin. Additional information to be collected may include maps of soil type, geologic hazards, timber type, land ownership, silvicultural stand treatment priority, stream classification, and recreation area; visual resource management objectives; and the primary transportation plan. The boundary of the planning area must be delineated on the topographic base map; areas requiring special consideration, such as unstable slopes, specialized wildlife habitat, and special streamside buffer zones, also have to be shown.

The planner should compile a generic list of ground-based and cable yarding systems that may be needed to accomplish the harvest objectives. This list should include yarder types, general rigging configurations, line sizes, line lengths (that is, maximum yarding reach), potential yarding payloads, skidder types, and maximum uphill and downhill hauling grades for ground-based equipment. Yarding equipment will be selected from this list later in the planning process.

Before identifying an overall harvesting pattern for the planning area, the planner should study the general form of the terrain. It is often helpful to separate the more gently sloped areas where the timber can be yarded with ground-based equipment from the steeper areas that require the use of cable yarding systems. The SLOPE program can be used to create map overlays that break the planning area down into whatever ground-slope categories the planner specifies. For instance, the planner may want to identify all areas that have a ground slope of 0 to 20 percent, where a feller-forwarder can operate. Other overlays can be produced that identify areas with a ground slope of 20 to 40 percent, where a crawler-tractor can operate. The remaining areas may require cable yarding systems.

The planner must recognize on the topographic map terrain patterns that look promising for long- and short-span skyline, highlead, or ground-based yarding systems. These patterns should be shown by a different color for each yarding system on a topographic map overlay of the planning area (see appendix). The approximate locations of landings, key yarding corridors, skid trails, roads, and setting boundaries for each harvesting system should be included on this overlay. Extreme accuracy is not needed when sketching in these locations, which will be refined in the yarding analysis stage. Numerous attempts may be needed to develop this overall harvesting pattern, depending on the judgment of the planner and the complexity of the terrain.

This harvesting pattern overlay serves as a general guide for subsequent analysis of individual yarding setups (fig. 9). The yarding analysis programs, SKYMOBILE, SKYTOWER, and HIGHLEAD, can be used to evaluate and refine the general setting boundaries that were sketched on the overlay. The SKYTOWER and HIGHLEAD programs allow the planner to quickly identify the area that can be yarded to a central landing. If a landing shows promise, the planner can examine individual profiles and adjust the setting boundary. The SKYMOBILE program, which analyzes payload and span combinations on individual profiles, provides an effective tool for planning use of mobile yarders operated from parallel settings. Landing locations, rigging configurations, turn volumes, and yarding limits can be modified until satisfactory yarding coverage is obtained.

As the analysis of landings proceeds, a mosaic of setting boundaries is developed and plotted on another overlay. Inevitably some gaps in the harvesting pattern will be identified and alternative landings will need to be selected. After enough landings have been added to ensure that all timber within the harvest area can be harvested, the planner can use the SIMYAR program to make estimates of the yarding production rates and costs. When a parcel of timber can be yarded to two or more landings, the production and cost estimates can be used to select one option over another.

The planner can use the ROUTES program to develop a road network that connects all the landings necessary to harvest the area. During this process, the planner may find it impossible to access some of the landings. If so, alternative landings may need to be selected and analyzed with the SKYTOWER, SKYMOBILE, or HIGHLEAD program before the road system can be completed. Designing the roads before the harvest units may sometimes be more efficient for the planner.

After the setting boundaries and road locations have been identified, the planner can use the VISUAL program to examine the visual impact of the harvest plan from selected viewpoints. If the visual impact of some feature of the plan is too great, the PLANS programs can be used to modify the feature.

After developing an initial harvest plan for the planning area, the planner may wish to develop and compare alternative plans that focus on competing resource management objectives. Alterations to the initial plan may range from minor revisions, such as changes in the size-class of equipment to be used or the location of selected landings and roads, to a complete revamping. When the PLANS package is used to develop alternatives, much of the data needed to compare alternatives on an economic basis are already generated by the various design programs. The summaries of grade, sideslope, and road length produced by the ROUTES program are useful in estimating costs of road construction. The yarding production and cost estimates, along with the areas and harvest volumes of settings, are available from the SIMYAR program output. The planner can use these data in any economic comparison that is appropriate.

Cost and Benefits of Preliminary Harvest Planning

A timber harvesting operation is a materials handling activity that can be made more efficient through the application of rigorous planning methods (Dykstra 1976). Sauder and Nagy (1977) projected, for one specific coastal British Columbia harvest area, logging and hauling costs that ranged from $3,582 to $3,120 per acre, depending on the choice of harvesting system. This $462-per-acre range in costs, which is 14 percent of the average total harvesting and hauling cost, represents the potential savings that can result when an area is intensively planned. Included in this $462 are estimated differences in costs for roads, hauling, loading, felling, and yarding that result when different yarding systems are selected to harvest the same area. All these cost components are related through complex interactions between the logging and transportation systems. Rigorous analysis of each component of the harvesting and transportation systems is required if the highest possible return from timber harvest operations is to be achieved.

Savings in the harvesting and hauling cost for an area can result from two processes carried out during the preliminary planning. First, identify the harvesting and transportation system that is best suited to local topography and timber conditions. Second, layout the harvest area to provide optimum operating conditions for the selected harvesting system. Even in areas where only a limited range of logging equipment is available, considerable savings can be achieved by laying out the area so that available equipment can operate efficiently.

The PLANS package enables the planner to evaluate possible harvesting and roading alternatives so that the appropriate harvesting system for a particular location can be identified. The cost for developing a preliminary harvest and transportation plan using the PLANS package is estimated to be about $1 per acre.[7] With harvesting and hauling costs of several thousand dollars per acre, a planning cost of $1 per acre represents only a fraction of a percent of the total cost incurred to deliver timber to the market. With the potential for saving 10 percent or more of harvesting and transport costs through proper selection and application of harvesting systems, this cost for planning should be easily justifiable.

The benefactors of improved harvest plans often are not part of the management unit that must pay for the planning; hence, the economic profits accrued from planning cannot be internally recycled to sustain planning. Additional planning costs, necessary to maximize (or at least increase) net revenues from harvesting operations must be justified, but the planning unit is not credited for the increase in net revenues. In such situations, additional expenditures for harvest planning must be justified through net profit to the overall organization, rather than as just an extra cost. Convincing upper management to take such a view can- often be a daunting task; however, the planner now has, in PLANS, a tool that greatly reduces the magnitude of preliminary planning costs and that should make justification somewhat easier.

[7] Twito and McGaughey (1984) experienced planning costs using PLANS of $0.43 per acre; however, this estimate did not include costs of owning and operating the computing facility.

In addition to the financial benefits associated with intensive preliminary harvest planning, environmental benefits also usually occur. By selecting the right type of logging system for local terrain and timber conditions, soil disturbance (Megahan 1980, Rice and others 1972) and residual stand damage (Aho and others 1983, Fieber and others 1982) can be minimized. Construction of roads and landings, which has been shown to be the major contributor to erosion and water quality problems, can be minimized (Amaranthus and others 1985). The impact of a range of proposed environment restrictions on harvesting operations can be evaluated (Reutebuch and Murphy 1986), and the restrictions that best meet all management objectives can be applied to the harvest operation.

The use of an intensive preliminary harvest planning procedure ensures that land managers have based harvesting decisions on a thorough analysis of all available data and are seen to be doing so by concerned public groups. The use of computer-aided harvest planning techniques assists the planner in this analysis and provides ample documentation of the thoroughness and completeness of the planning effort.

Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 30.5 centimeters
1 cubic foot = 0.03 cubic meter
6,000 board feet = 28.3 cubic meters
1 acre = 0.40 hectare
1 cubic foot per acre = 0.069 cubic meter per hectare
1 pound = 453.6 grams

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Appendix

Suggestions for Managing Documents When Developing a Harvest Plan

Putting together a harvest plan involves the use of a large number of documents regardless of whether a totally manual or a computer-assisted procedure is used. The documents include large maps, aerial photographs, inventory data, and often a large number of worksheets and computer output sheets. Organization of these documents into a manageable and coherent form is essential to maintain the credibility of the harvest plan and to communicate the plan to others. The document management techniques that follow help to minimize the amount of drafting and nonproductive paper shuffling that seems to occur.

Use of transparent overlays—Timber harvest plans are usually drafted on a base, usually a large-scale topographic map. Often several smaller map sheets must be combined to make a base map that covers the entire area being planned. Map sheets must be carefully aligned and securely joined, mismatched contour lines along the joins must be adjusted, and the boundary of the planning area must be carefully marked. The contour lines on the base map can then be traced to produce a DTM of the planning area for use with the PLANS package.

The original base map used for building the DTM should be used to develop the harvest plan. This ensures that the elevation data in the DTM correspond properly with the contour lines on the base map used for planning. Because of slight differences in the alignment of adjacent map sheets and differential shrinkage of individual map sheets, a replacement base map, pieced together at a later date, probably will not exactly match the original base map and therefore should not be used when developing the harvest plan.

The orginal base map can be used throughout the entire planning process if it is protected with transparent overlays. The use of overlays saves time and expense by eliminating the need to assemble multiple copies of the base map and by preventing the introduction of differences between the DTM and the actual copy of the base map used for planning. In addition, use of overlays encourages the planner to sketch more alternatives and makes modifying or redrawing of portions of the harvest plan much quicker and easier.

Wide rolls of clear acetate film suitable for preliminary planning can be purchased from drafting supply firms. This material, although not as dimensionally stable as Mylar, can be purchased for a fraction of the cost of Mylar. Sheets of acetate film can be cut to any size needed for developing the harvest plan. With an overlay sheet taped to the base map, the planner can freely sketch details and write comments anywhere in the planning area without defacing the base map. Errors can be quickly corrected. If an overlay sheet becomes cluttered, it can be replaced with a new one. Several sheets, each containing a portion of the overall harvest plan, can be registered on the base map and viewed simultaneously. One overlay sheet may contain the road network, another may contain the landing locations, and another may show unit boundaries.

Water-permanent, felt-tipped pens, sometimes referred to as "overhead projector" pens, are recommended for drafting the harvest plan onto the acetate film. These pens are available in a variety of line weights and colors and can be purchased from office supply firms. The pens with the finest tips should be selected for harvest planning work. Water-permanent ink dries quickly (usually in a matter of seconds) when applied to the acetate film. This eliminates the smudging problem that occurs when water-soluble pens are used on acetate film. In addition, acetate overlays drafted with these pens can be taken to the field in wet weather without fear of smearing.

Erasures and corrections of features drawn with water-permanent ink on acetate film can be made in two ways. First, lines can be selectively erased by vigorously rubbing with a soft eraser. (Slightly moistening the eraser speeds up the process and reduces the amount of rubbing needed to remove a line.) Second, large areas or entire overlays can be wiped clean with a tissue or cloth dampened with ethyl (rubbing) alcohol.

The alignment of each overlay sheet with the base map should be recorded so that if the overlay is removed, it can be properly realigned with the map at a later time. This is most easily accomplished by marking two or three reference points on the overlay. The corners of the DTM boundary can be used as convenient reference points.

It is advisable to cover the base topographic map with a clear overlay sheet immediately after the boundaries of the DTM units have been drawn on the base map and before starting to build the DTM with the MAP program. This ensures that the planner does not inadvertently draw on or mar the base map while tracing the contour lines with the digitizer cursor. The overlay sheet also provides a smooth surface to slide the cursor on while tracing contour lines. As each successive contour line is traced, the planner can keep track of progress by drawing a tick mark through the contour line on the overlay sheet. It is sometimes helpful to trace the streams on the overlay sheet with a blue pen to better define the general form of the terrain before starting to digitize the contour lines. The overlay sheet used while tracing the contour lines is simply a work sheet and can be cleaned or discarded after the DTM has been built.

The planner may wish to use several overlay sheets when sketching an initial estimate of the overall harvest and road patterns needed for the area. A different overlay sheet and pen color for each harvesting system can be used to sketch the approximate locations of landings and setting boundaries. The approximate locations of roads can also be sketched in a different color on a separate overlay sheet.

Overlay sheets of the overall harvesting pattern can be left in place on the base map and can be used as general guides when the PLANS analysis programs are used to verify and adjust setting boundaries and road locations. Additional overlay sheets, on which the final harvest unit boundaries and road locations are drawn, can be taped over them. The PLANS yarding analysis programs produce plots of setting boundaries that can be slipped between the base map and the overlay sheet and then traced onto the overlay sheet. The route location program produces plots of road locations that can be transferred to an overlay in the same fashion.

After all analyses have been completed and the locations of landings, setting boundaries, and road locations have been finalized and drawn ,on various overlay sheets, the entire harvest plan can be traced from the acetate film to a more dimensionally stable Mylar base for storage or for subsequent reproduction.

Organization of the PLANS computer output—In addition to drafted harvest plan overlays, a considerable volume of computer output (printed tables and paper plots) is generated by the PLANS analysis programs. This output must be keyed to the harvest plan overlays and organized in a form that enables the planner to quickly review the assumptions that were used in the analysis of each detail of the plan. Some of these assumptions are subsequently modified, and details of the plan must be reanalyzed as the preliminary harvest plan is reviewed and adapted into an operational field layout.

A simple, straightforward method of organizing the computer output associated with a harvest plan is by landing and road number. As the output is produced, it should be assembled in a ring binder. If landings are assigned numbers that are prefixed by the number of their access road, the ring binder can be subdivided into major sections by road number. Each section can be further divided into the following catagories: yarding analysis output, yarding production and cost estimates, and road location and design.

The ring binder should include separate sections for output associated with visual and terrain attribute analyses that are carried out using the VISUAL and SLOPE programs of PLANS.

This loose-leaf format, coupled with the use of transparent overlays of the harvest plan, enables the planner to quickly modify and update the plan as it progresses toward implementation.

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Twito, Roger H.; Reutebuch, Stephen E.; McGaughey, Robert J.; Mann, Charles N. Preliminary logging analysis system (PLANS): overview. Gen. Tech. Rep. PNW-GTR-199. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; 1987. 24 p.

The paper previews a computer-aided design system, PLANS, that is useful for developing timber harvest and road network plans on large-scale topographic maps. Earlier planning techniques are reviewed, and the advantages are explained of using advanced planning systems like PLANS. There is a brief summary of the input, output, and function of each program in the PLANS program set. The set presently includes programs for harvest unit design for a variety of cable logging systems, road locations, visual analyses, yarding costs, and slope attributes and a method for producing the elevation data files. Suggested ways to use PLANS to develop the harvest plans and to document and process harvesting alternatives are presented. Justifications are given for investments made in planning.

Keywords: Timber harvest planning, computer programs/programing, logging operations analysis/design, road building (forest/logging).

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