UTILIZING SCHEDULING AND NETWORK ANALYSIS PROGRAM (SNAP) AS A FOREST PLAN IMPLEMENTATION TOOL ON THE SIUSLAW NATIONAL FOREST

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

PROBLEM BACKGROUND

In the mid 1970's, two critical forest planning directives were legislated by Congress. The Forest and Rangelands Renewable Resoures Planning Act (RPA), mandating that the U.S. Forest Service undertake long-range planning initiatives, was passed in 1974. The National Forest Management Act of 1976 amended the RPA planning process. Together, these statutes ensure an adequate timber supply and the maintenance of environmental quality, while at the same time mandating greater public participation in the forest resource planning process. Today, an environmentally-conscious society has placed increased pressure upon the forest allocation process, so as to place an even greater emphasis upon the preservation of forest ecosystems-- even if that means reduced timber harvesting activities.

The Forest Service has responded to these concerns on all administrative levels-- from district personnel taking a thorough inventory of their forests, to forest and regional personnel compiling these data and analyzing them through complex computer programming systems. The program currently being used is FORPLAN, a forest planning program created by K. Norman Johnson. The function of this tool is not to provide decision-makers with an answer, but to guide them in a direction for meeting the demands placed on forest resources.

Despite the delays in the planning process, the Forest Plans will eventually be administratively approved. Once the course of each forest has been determined, these decisions will have to be implemented. Those analysts working at Supervisor's and Regional Offices will undoubtedly retain control of the allocation process and continue to advise in forest-wide decision-making. But what about the Forest Service staff on the district level? Those people are faced with making land allocation decisions daily in timber sale planning. They must also make their decisions comply with the Forest Plan standards and guidelines. The managers on the ground need tools to translate forestwide aggregate FORPLAN allocations to stand by stand decisions that meet multiple resource concerns.

Currently, on the Alsea Ranger District in the Siuslaw National Forest, timber sale planning is conducted by an interdisciplinary team (IDT). As the name suggests, this team is comprised of fish and wildlife biologists, soil scientists, timber sale officers, and recreation planners. Together, these specialists survey an area (subbasin) under consideration for timber sales. Because of the diversity of the group, decision-making ultimately reflects a balance of forest resource interests, in compliance with forest guidelines.

The current analysis procedure in timber sale planning is more or less an ad hoc process. Initially, queries are run through a computer to obtain inventory data on the subbasin. Based upon these data, spotted owl habitat areas (SOHA's), pileated woodpecker and marten habitat, riparian areas, soil and visual leave areas, and those stands too young to harvest are identified. Such areas will not be considered for harvest. The remaining area is comprised of harvestable units. In planning timber sales, adjacency requirements forbid the harvest of two units located next to each other in the same decade. Thus, meeting adjacency constraints has been a process of manually piecing together various harvest unit configurations.

At this point in the planning process, the IDT has narrowed its harvest configuration alternatives to two or three choices. Those configurations chosen must also meet volume goals set for that subbasin. Each individual harvest unit under consideration is then surveyed, to determine road construction (if necessary) and logging systems. Cost distinctly influences any final selection, but other factors (such as public response) play an equally important role in the selection process.

The amount of time taken to plan a timber sale in this fashion would not appear to be long. However, each IDT member on the district is not committed solely to timber sale planning. They have responsibilities in their own departments. Particularly during fire season, when many district personnel are on call, timber sales may take months to plan.

What is needed on the district level is an analysis tool which would enable timber sale planners to readily implement feasible forest plan standards and guidelines. Such a method should not be so complex that only a few skilled analysts can use it. Moreover, it must function as a tool in which efficient land allocation alternatives may be produced in a timely manner.

LITERATURE REVIEW

The following reviews summarize five case studies in which Forest Plans were implemented, representing several Forest Service Regions. The intent of this review is to familiarize the reader with analysis tools currently used in implementation.

Region 1 - The Payette National Forest

This study, by Ryberg and Gilbert (1987), tested Version II FORPLAN's usefulness as an analysis tool in the planning of timber sales. FORPLAN was chosen because of its optimization capability; maximizing discounted net revenue subject to appropriate constraints (i.e. standards and guidelines for the area). FORPLAN also has very limited ability to integrate road networks in identifying the best mix of resource projects (Jones et al., 1986). The test site used was an 11,425 acre roadless drainage. This site had been scheduled for harvest in the first decade, according to the Payette draft Forest Plan.

Because Version II of FORPLAN was used during planning, the data for this study came from the original model, except when site specific data were available. Disaggregating the model involved prorating forest-wide allocations and schedules to specific analysis areas, to properly reflect those in the subbasin. Standards and guidelines were taken into account when designing the subbasin's harvest unit configuration. In addition, adjacency constraints were added to assure that no openings larger than the 40 acre harvest unit maximum would be created.

The authors concluded that FORPLAN was in fact a useful tool in implementing Forest Plans. Site specific data could be directly entered into the disaggregated forest-wide model quite easily. FORPLAN was also capable of analyzing a range of alternatives. The information FORPLAN provided was useful in preparing and writing NEPA documents. Multi-period planning in FORPLAN also opened doors to resolving below-cost timber sale issues, through the efficient design of timber sales and roads. The authors noted, however, that disaggregating forest-wide solutions through prorating did not always lead to implementable results, because of the requirement of "packaging" timber activities.

Region 6 - Siskiyou National Forest

This 1987 case study, performed by the Systems Analysis Unit of the Washington D.C. Office and Siskiyou NF's analysis team, compared FORPLAN as an implementation technique with Jones' (1986) "simulation with minimization of road costs." The focus was to determine which of the two methods produced an economically more efficient solution, while meeting the same objectives. A set of criteria, qualitative in nature, was also used to evaluate the two techniques.

Overall, FORPLAN generated higher present net value to timber ratios, as well as lower unit costs. In terms of alternative formulation and summarizing data for reporting purposes, the simulation method required nine person-weeks versus FORPLAN's six person-weeks. FORPLAN's solutions, however, could not be used without some adjustments (i.e. site specific information that was not present in the original model). FORPLAN was a more complex model, which required more time to learn than the simulation method. While little expertise was required to enter site specific data into FORPLAN, the actual formulation of management objectives as constraints required linear programming experience. This type of expertise was also essential in understanding and correcting infeasible linear programming specifications within FORPLAN runs, which were inevitable due to the complex structure of the program.

Region 5

Region 5's experience using FORPLAN as an implementation tool, according to Klaus Barber (1989), revealed that standards and guidelines are more strictly interpreted by district personnel than by FORPLAN analysts. The FORPLAN model could not reflect the actual spatial constraints, and as a result, the allowable sale quantities (ASQ's) were higher than could be implemented on a long-term basis taking into account the area-based situation. In response to this problem, Region 5 developed a generic set of "implementation constraints" in their FORPLAN models that limited the rate of inventory liquidation by forest types.

Another problem encountered with FORPLAN was the prorating of solutions by strata. Prorating will only work when the compartment being prorated is average in terms of the distribution of strata. As a solution to this dilemma, Region 5 developed an inventory-based approach. This provides a self-correcting mechanism for disparities between the compartment being analyzed and the "forest average" as perceived by FORPLAN. It also accounted for differences between current inventory and the inventory as reflected in FORPLAN's database (observed as generally out of date or in error).

Region 3 - Kaibab National Forest

The Big Springs Case Study (Walker et al., 1987) tested three analysis procedures as implementation tools: the "mathematical formula approach," the "professional judgement approach," and the FORPLAN approach. Big Springs was selected as the 10,000 acre study area. Basically, the mathematical approach involved finding the fraction of the suitable acres in Big Springs that could be harvested in each 10 year entry. While this approach was time-saving, the assumptions that the study area was homogeneous (soil, slope, vegetation, wildlife, etc.), and that all harvesting units were shaped as squares was a gross over-simplification.

The professional judgement approach was based on the wisdom and intuition gained from years of "hands-on experience." The benefit of this approach was in how it accounted for constraints not explicitly modeled in the forest-wide FORPLAN model. The limitations of this method were found in the complexity of spatial problems. The human mind could not keep track of the spatial relationships effective over the life of one rotation (eighty years) as could a computer. As a result, there was no capability to examine effects of a project beyond one decade.

The forest-wide Version II FORPLAN model was disaggregated, as in the Region 1 case study (Ryberg and Gilbert, 1987), to more closely reflect the conditions present within the Big Springs area. Spatially restrictive standards and guidelines (adjacency constraints) were added to the FORPLAN model (Meneghin and Jones, 1988). This tested the feasibility of the Forest Plan's projected ASQ. FORPLAN proved to be successful in formulating and testing alternatives for subbasin level environmental assessments. Results indicated, after implementing standards and guidelines, that harvest levels in the draft plan were at least obtainable in the first decade.

Region 9 - Ottawa National Forest

With regards to utilizing FORPLAN on the Ottawa, Voytas (1986) observed that problems were encountered simply because district rangers and staff did not understand FORPLAN. Likewise, analysts were not familiarized with "on-the-ground" resource management. According to Voytas, these are key factors which must be remedied if FORPLAN is to be used as an implementation tool for the next generation of plans.

As an alternative, Region 9 developed a process called Integrated Resource Management (IRM) to guide them in the implementation of their Forest Plans. The process recognized that the Forest Plans generated by FORPLAN were only an approximation of reality and that more accurate, site specific information was needed for implementation. IRM is a manually-driven form of analysis. Guided by those desired future conditions outlined in the Forest Plan, interdisciplinary teams from the districts and the Supervisor's Office conceptually arrange analysis areas of up to 25,000 acres. According to Brenner and Meunier (1986), the team's knowledge of the area (its issues and its opportunities) is crucial in making realistic decisions, in addition to representing the intent of the Plan.

SCOPE OF THIS STUDY

Careful examination of the preceding reviews reveals that the complexity of plan implementation has encouraged many forest planners to utilize FORPLAN as an analysis tool. However, frustration with and limitations of FORPLAN in the planning process has forced a number to choose simpler tools, and in some cases, no tools at all. Alternately more complicated tools such as mixed integer programming have been suggested and demonstrated (Jones et al., 1986). It should be noted that the majority of those case studies where FORPLAN was partially successful in implementation were conducted by trained analysts. These are the same people who have been involved with FORPLAN since the beginning stages of planning. During plan implementation, however, the analysis will be done not by trained analysts, but by employees on the district level.

This is not to say that such employees should resort to no analysis tools whatsoever. Experience has shown that without integrated analysis, obtaining necessary outputs (within the standards and guidelines outlined by the Forest Plan) is highly unlikely in "the long run"(Gilbert, 1988). Consequently, there is a need for a tool that is not so complex as to overwhelm district personnel. Such users should be able to incorporate standards and guidelines into their analysis and be able to resolve errors without the aid of a trained analyst. However, this analysis tool must be sophisticated enough to solve spatial relation problems and integrate several disciplines into its problem-solving process.

This study will examine a process for implementing the Forest Plan's standards and guidelines at the subbasin level. This process is called Scheduling and Network Analysis Program (SNAP), developed by Sessions and Sessions (1988). SNAP was chosen as a candidate for this analysis for two reasons: first, because of its capabilities to schedule harvests, integrate the needs of various disciplines, satisfy spatial adjacency constraints, and maximize present net worth (or minimize discounted costs); secondly, as a menu-driven program, SNAP may well be the solution district personnel are seeking-- to simplify the complex implementation analysis that lies in store for them.

Green River subbasin on the Alsea Ranger District shall be used as a case study. This area contains mature conifer stands, and several Douglas-fir plantations, and serves as the home for two pine martens. It was chosen as a subbasin that is representative of conditions and planning concerns on the district.

This study will examine the complete planning process involved in using SNAP as an implementation tool. The process begins with data collection and the transfer of area attributes into a digitizing program called LIDES (Local Interactive Digitizing & Editing System). This information is then transferred into SNAP files and additional files are created that are necessary to run the program. Those Forest Plan standards and guidelines that directly affect timber sale planning will also be identified and incorporated into the model. The results of the SNAP analysis should provide a good indication of the feasibility of the harvest goal predicted in the Forest Plan. The analysis itself should demonstrate SNAP's usefulness as a Forest Plan implementation tool.

OBJECTIVES

There is a need to test whether smaller units of land, such as subbasins, can meet their harvest volume goal under the spatial constraints outlined in the Forest Plan's standards and guidelines. There is also a need to determine a method that will serve as a tool in implementing these standards and guidelines. The purpose of this study is to examine SNAP as a Forest Plan implementation tool and, in doing so, determine if the harvest goals for a specified subbasin can be met.

OBJECTIVE STATEMENT

Specifically, the objectives of the study are:

1. To provide a step-by-step procedure for using SNAP as an analysis tool in Forest Plan implementation. The first of these steps is collecting data for the subbasin, followed by digitizing and attributing the subbasin using LIDES. LIDES will be examined in significant detail because of its role in displaying spatial relationships, roading networks, and landing sites. SNAP files, their data requirements and function in the program, will also be examined. A description of the standards and guidelines and how

they are to be incorporated in the model will be covered as well.

2. To determine whether SNAP is useful as a Forest Plan implementation tool. A set criteria will be used as a form of evaluation. Each criterion aids in determining SNAP's usefulness on the Siuslaw N.F., not to forests in general. This is an important consideration due to the difference in staffing and technical resources from forest-to-forest.

3. To compare the Forest Plan's ASQ for the drainage, to the volume SNAP produced. The results will be analyzed in terms of their differences, similarities, and implications to the forest as a whole.

SITE SELECTION

Green River is a 6,238 acre subbasin. This area includes 5,265 acres of Forest Service lands and 973 acres of privately-owned lands. Land ownership distribution is shown in Figure 1. Green River was chosen as a study site because many of its physical features typify those of the district. This area is mountainous with very steep slopes. The timber resource is primarily Douglas-fir. Figure 2 illustrates the distribution of tree species. Rivers and creeks spread throughout the subbasin. There are also two identified marten habitat areas located within Green River's boundaries.

Another significant reason for choosing this subbasin as representative of the district is the age class distribution of its stands. Figure 3 illustrates the age class distribution of Douglas-fir stands. Most of the Alsea District was burned in a major fire occuring in the mid 19th century. The 80+ year age classes reflect stands originating from this fire, while the 40 year and younger age classes reflect accelerated harvest in the post World War II period. The older stands must be rationed out over the remaining decades until the current 40 year old and younger stands reach rotation. Thus, over the next 40 years, there will not be restocked stands available to harvest (80-year rotations). Consequently, of the 5,265 acres of Forest Service land, 1,813 acres will be harvestable during the time horizon (1990-2020) of this study. Figure 4 displays this relationship of harvestable acres to total acres.

There are 145 harvest units in Green River. The boundaries of these units are shown in Figure 5. All those which are harvestable are no larger than 60 acres in size. Harvestable units are mapped in Figure 6. Plantations vary in size, some being quite large. This variation in size is a reflection of past harvesting practices. Each harvest unit is characterized by one of thirteen possible analysis areas (AA). An analysis area is a timber stratum, the basic land unit used in FORPLAN. These areas are defined by five identifiers (1: ranger district, 2: land type association, 3: age class, 4: condition class, and 5: species). The relevance of these analysis areas to this study will be discussed in a subsequent section of this paper.

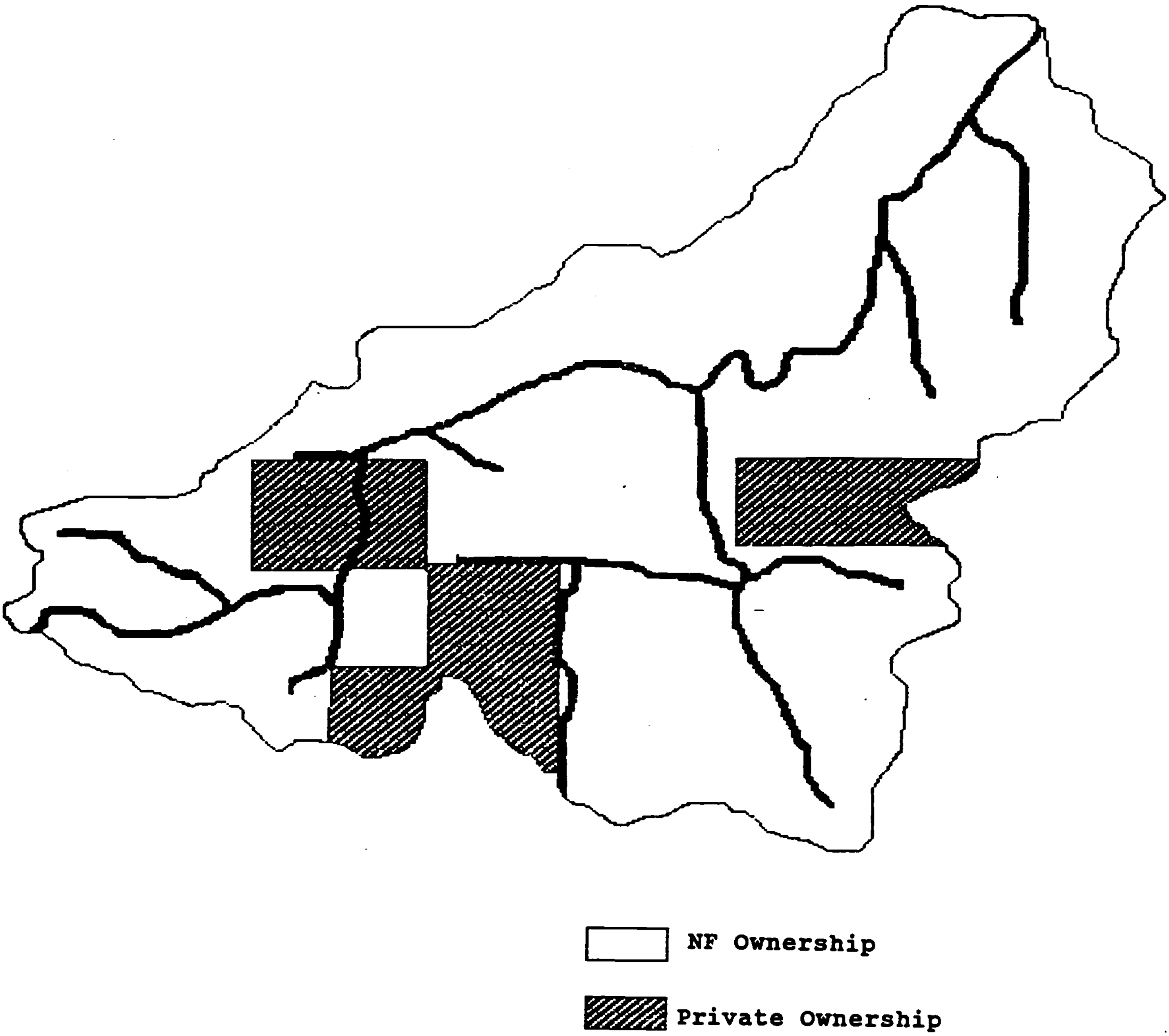

Figure 1. Map of NF ownership and private ownership.

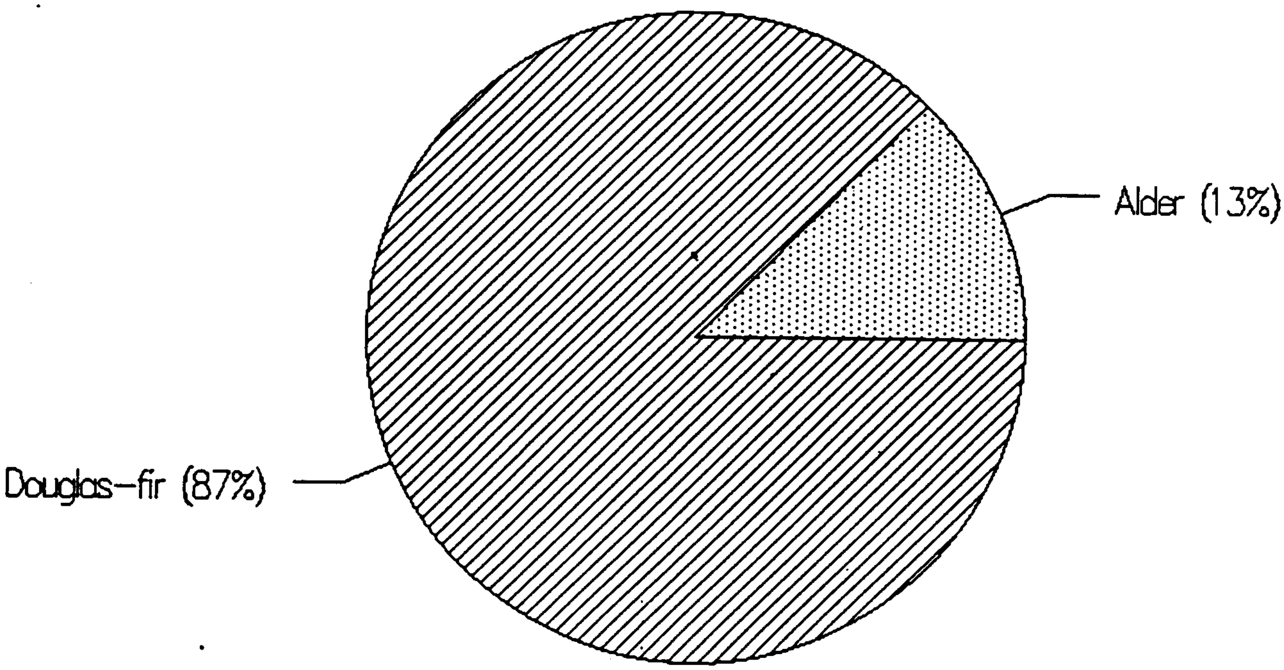

Figure 2. Distribution of total area by species.

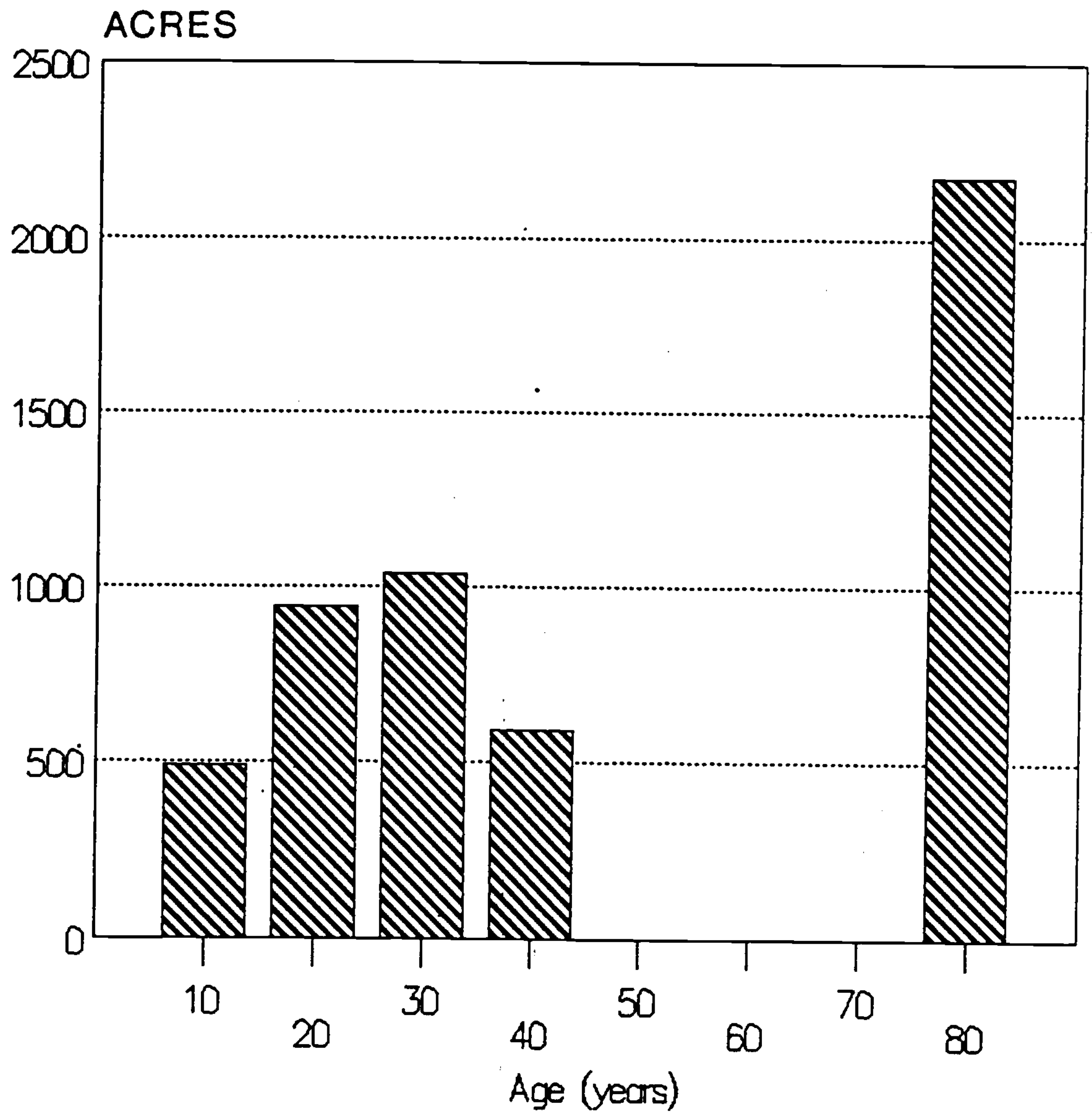

Figure 3. Age class distribution of Douglas-fir stands (NF).

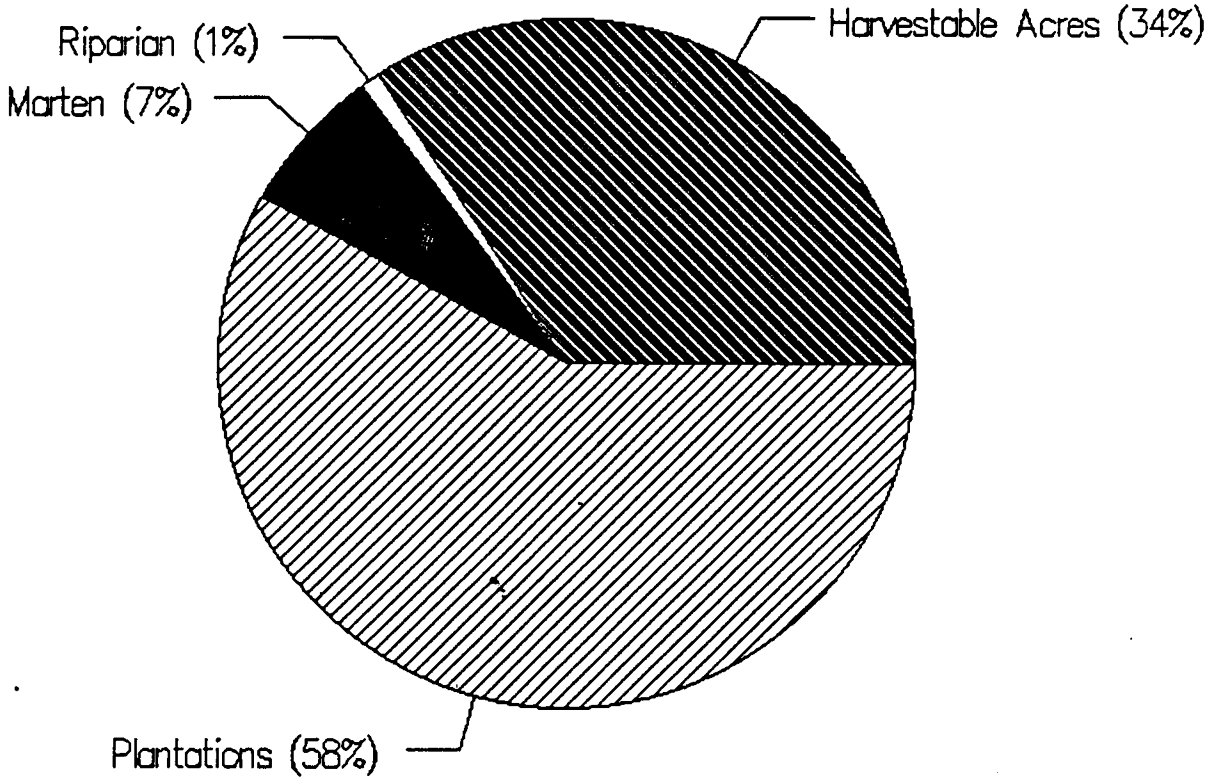

Figure 4. __Distribution of NF land by area status.__

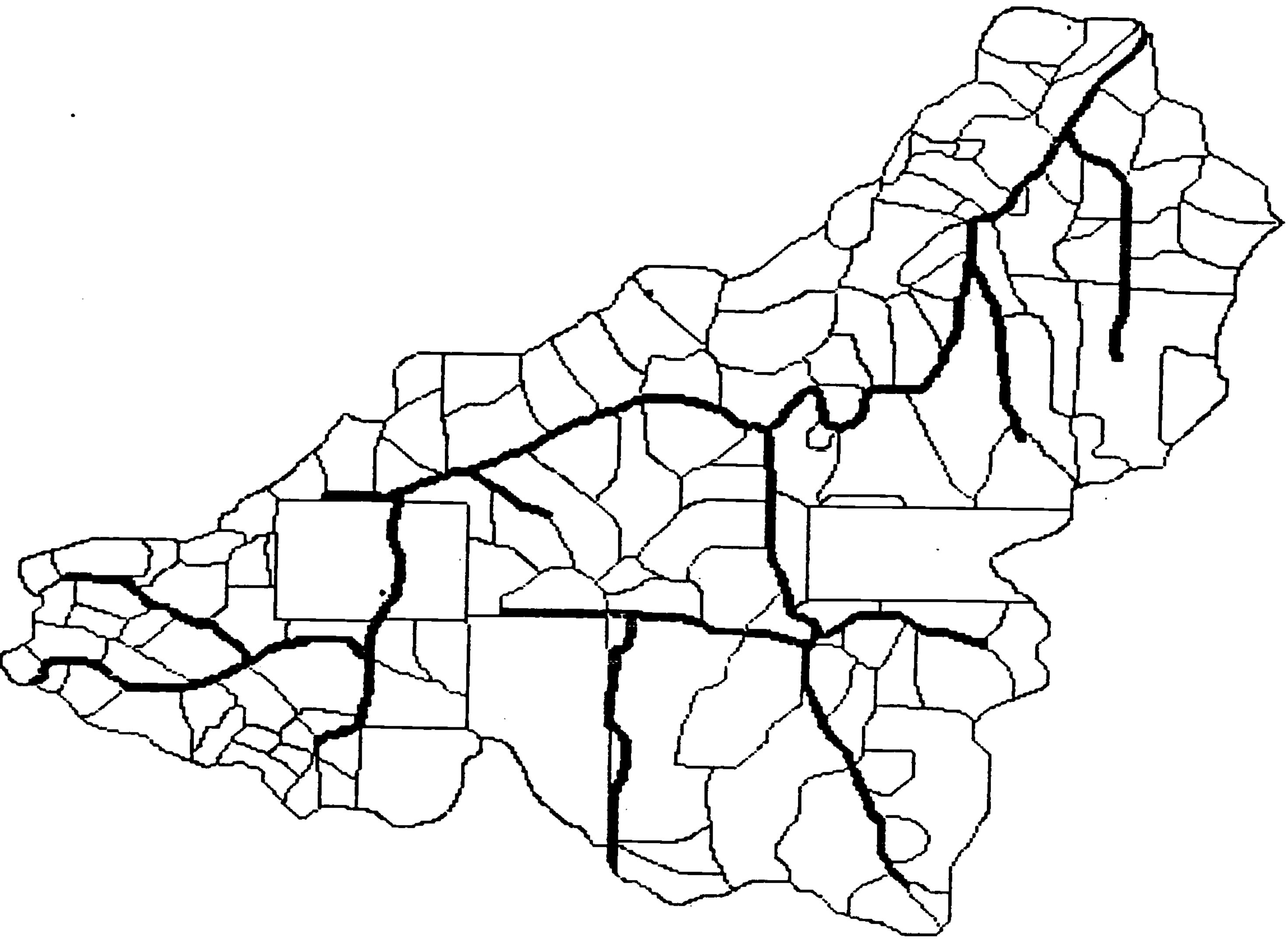

Figure 5. Map of harvest unit boundaries.

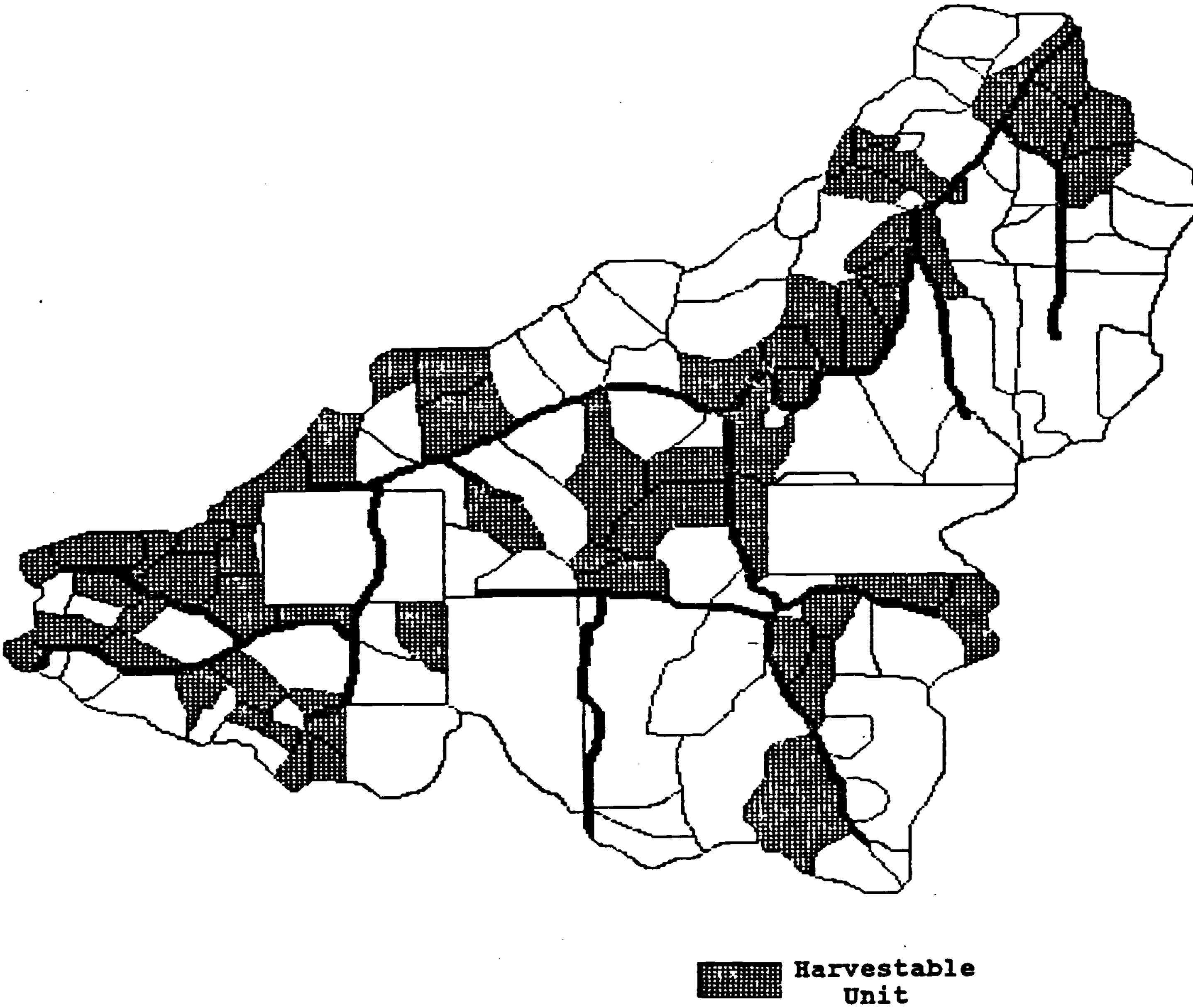

Figure 6. Map showing harvestable units.

STAND AND HARVEST UNIT VOLUMES

An inventory of Green River was completed in 1974. The stand information available from this inventory included the date of origin, species present in the stand, acres in the stand, and site index. In 1988, harvest and buy-back sales data contributed to an updating of acres in each age class.

As demonstrated earlier, the only stands available for harvest are Douglas-fir and mixed alder stands, 120 years and older. Volume yields for these stands are based upon the forest's empirical yield tables, developed using the Region 6 "empirical yield table regression program" (Teply 1976). Empirical yield tables estimate the existing immature and mature inventory of wood volume. Future volumes of these stands are based upon weighted average site conditions for the forest, and are calculated for 10-year age increments. This information has been updated since the original 1974 timber inventory, now reflecting the midpoint of the Forest Plan decade (1990). SNAP requires a yield-per-acre for each harvest unit, expressed as an attribute. The yields for this study were 78.535 mbf/acre for Douglas-fir stands, 120 years+, and 50.781 mbf/acre for mixed alder stands 120 years+. These yields were assumed to reflect net merchantable volumes.

Harvest unit volumes were arrived at by multiplying the total acres in the unit by volume/acre of the stand. However, these harvest unit volumes may actually be overestimated. Volume loss, due to headwalls and other vegetation "leave areas," was not reflected in these timber yields. Volume loss due to disease, defect, breakage, and minimum snag management requirements was taken into account. In most cases, these "leave areas" are not identified until a timber sale is actually laid out (i.e. profiles run, units flagged). In terms of spatial relationships, this had no implications for this analysis because the unit boundaries remained the same. It should be noted, in determining the forest-wide volume goal, that this loss in volume was not taken into consideration by the FORPLAN model. On the ground, this difference could be met by harvesting additional acres, but this then suggests that the original FORPLAN harvests may have a slight element of optimism imbedded in them.

VALUE OF TIMBER

Timber prices in this study reflected Forest Planning Timber Values based on diameter class assumptions. These values were based on forest receipts from the Timber Sale Statement of Accounts, covering the period April 1977 through September 1983. Stumpage values for Douglas-fir (120 years+), with a diameter at breast height (DBH) of 32.84" to 37.81", averaged $251/mbf. Stumpage values for mixed alder (120 years+), with DBH of 14.37" to 17.26", averaged $80/mbf. SNAP expresses its timber values in terms of pond values. The pond value is the amount the mill would pay for wood delivered to the mill gate. Pond values for the Douglas-fir and mixed-alder stands mentioned above were $363/mbf and $192/mbf respectively. Both stumpage and pond values are in 1982 dollars. Prices were assumed constant through the time horizon of this study (i.e. no real price increases).

STANDARDS AND GUIDELINES

Standards and guidelines state the limits within which forest-wide practices will be implemented, in order to achieve the Forest Plan's goals and objectives. Rather than outline management action in a "cookbook" format, standards and guidelines state a desired condition, and provide direction with regard to the types of management practices and activities intended by Plan prescriptions. This allows flexibility in adopting practices for meeting desired conditions, particularly if new information indicates a need for a different approach than specified in the Plan. Standards and guidelines also ensure consistency in interpreting Plan objectives over time, and across districts as personnel changes.

There are two major categories of standards and guidelines: forest-wide, and those related to specific management areas. Forest-wide standards and guidelines apply to all management areas throughout the forest. This study concentrated on implementing those standards and guidelines specific to Management Area (MA) 15 (Timber/Wildlife/Fish). MA 15 is the largest management area, and is one of two areas containing lands suitable for timber production, the other being MA 14 (Scenic Viewsheds). The primary goal of MA 15 is to provide habitats for wildlife species which are dependent on succession stages other than old growth. At the same time, MA 15 supplies high-value wood product outputs. Providing productive habitat for both anadromous and resident fish, while controlling soil associated disturbances (i.e. erosion), are additional goals for this area.

The desired condition for this management area will be visually a "patchwork" of age classes and species of trees. An extensive road network will be scattered throughout the landscape, providing access to harvest timber. Those lands suitable for timber production will be available for sale on a nondeclining flow basis. Those lands unsuitable for timber production will be managed so as to assure that the vegetation is left intact.

The following is a summary of the standards and guidelines for MA 15. Only those standards and guidelines representing spatial constraints will be included. Specifically, these are restrictions which would be implemented in area-based harvest scheduling. Those restrictions applied after planting has taken place are not applicable to this study.

1. <u>Stream Buffers</u>

   -Leave 100 feet on both sides of class I and II streams and 60 feet on both sides of class III streams unharvested

2. <u>Vegetation "Leave Areas"</u>

   -No harvest

3. Elk

-Maintain hiding or thermal cover adjacent to all clearcuts until clearcut attains over 60% tree crown closure (occurs naturally in 10 years)

-Shape harvest units such that the distance to vegetation cover does not exceed 800 feet from any point in the unit

4. Pileated Woodpecker

-Within each habitat area (1680 acres in a rectangular grid of 5 miles), provide a reproduction habitat equal to 500 acres of conifer, 80 years+, of which at least 300 acres are contiguous, the remainder of which 50 acres+ are within 1 mile of habitat area center

-In remaining habitat area, provide a feeding habitat (stands on rotation schedule) within 1 mile of habitat area center

5. Marten

-Within each habitat area (1250 acres in a rectangular grid of 2 1/2 miles), provide a reproduction habitat equal to 250 acres of conifer, 80 years+, of which 50 acres+ are within 1/4 mile of habitat area center.

-In remaining habitat area, provide a feeding habitat (stands on rotation schedule) within 1 mile of habitat area center

6. <u>Regeneration</u>

-Plant within one growing season of site preparation or slash treatment, or within one growing season of harvest if site preparation or slash treatment does not occur

7. <u>Harvesting Units</u>

-The area of a harvest unit equals 10 - 60 acres

-Harvest a unit only after adjacent units are no longer openings, unless opening created does not exceed a total of 60 acres. In general, a harvested area of commercial forest land will no longer be considered an opening when tree stocking is at least 4 1/2 feet high and free to grow (occurs naturally within 5-10 years)

-In any 10 year period, avoid harvesting more than 20% of the National Forest land in the subbasin

-Forest-wide nondeclining even-flow

LIDES PROCEDURE

BACKGROUND

SNAP requires its spatial data files to be created through the Local Interactive Digitizing and Editing System, otherwise known as LIDES. LIDES is a raster-based program for gathering, editing, and reformatting data. A map, in raster format, is a row and column defined system of miniscule rectangles (pixels). These pixels act like little lights in that they can be turned on and off. The "on" pixels form the points and lines on the map. LIDES can accept both manually digitized vector data or raster data in a digital scan file. The program will convert vector data to raster format for processing and then can transform the raster information to vector for output. Currently, its greatest use has been gathering data for Geographic Information Systems (GIS). LIDES was also used for the Silver Recovery Project on the Siskiyou NF, to prepare over 100 map separates comprising 18 GIS layers.

LIDES was developed in 1978 by Tom Bruce (Forest Service). It was originally a vector-based data collector, developed on Textronix hardware. This program was used to input and edit graphic data. In the early 1980's, Dick Liston and Vance Revennaugh, both Washington Office engineers, moved LIDES to the Hewlett Packard 9020 and developed a raster version of LIDES. This development enabled LIDES to accept digital data produced by the Line Scanner at the Geometronics Service Center (Salt Lake City). John Dabritz, a Forest Service programmer, combined the raster and vector versions of LIDES into an integrated package.

The current version of LIDES is comprised of 200 subprograms, including 29 menus with help screens and approximately 280 screen prompts. Each LIDES map is composed of 12 interlink files containing information pertaining to: job status, map registration, raster data, five arc/node data files, two files holding numeric and string attributes, an attribute dictionary, and a file used for editing. All files are user-accessible.

CREATING A POLYGON MAP

LIDES accepts graphic data in two forms, scanned and manually digitized. In this study, both the polygon map and the road network map were manually digitized. Before digitizing began, it was necessary to divide the entire subbasin into individual harvest units. Those areas that were not plantations, and were not considered for harvest (i.e. marten habitats, riparian zones), were identified as separate polygons. Forest Service and private land boundaries were also identified in the mapping process. Once completed, the map was attached to the 48x54-inch digitizing tablet (CalComp 9000 Series). It should be noted that the standardized quadrangle maps (3.75 min by 7.5 min) used for digitizing usually do not include an entire subbasin. Green River itself lies on three adjacent quadrangle maps. Each map must be digitized separately.

To begin digitizing, LIDES first requires the user to enter information about the map. Registering the geodetics allows entry of the size of the map (in minutes), the latitude and longitude (in degrees), and the scale. The state plane zone must also be entered, which in this study was Oregon South. Registering the raster allows the user to choose how many pixels wide and long the map will be. The map itself is then registered by digitizing the corners of the map. The outline of the polygons were traced with the digitizer until the entire map was copied. The map was displayed on the computer screen throughout the digitizing process.

After the digitizing was completed, errors were edited. A macro was built so that several errors could be edited automatically. The macro included commands that removed isolated points, removed spurs, thinned lines, erased the map margin, and filled all one-pixel holes. Further editing was manually done by using an on/off pixel command. This command was helpful in opening narrow riparian zone corridors, where the pixels were often so close they touched.

Once all errors had been edited, the map was processed/assembled. In processing the map, LIDES confirms all polygons, their segments and vertices, and records this data in its files. Only after the map has been processed can polygon attributes be assigned. LIDES allows string and coded pair attributes to be entered, both of which were used in this study. The program that transfers LIDES files to SNAP files requires that at least one coded pair attribute be associated with each polygon. String attributes, if used, must be unique for each polygon. The string attribute used here consisted of 8 characters identifying each polygon by species, year of origin, and a unique number (more than one polygon usually shared the first two characteristics). The coded pair, defined in the user's code pair dictionary, described the polygon in terms of the logging system appropriate in harvesting the unit.

This entire process was repeated for all three maps. When all three were completed, the edges of the maps were matched. Overlaying the maps required that a new map be created, one that was four times the size of each (7.5 min by 15 min.). Both raster and geodetics were registered accordingly to accommodate the maps. A macro was created so that each map would be automatically laid onto the newly created map. This new map was checked for errors (using the edit macro created earlier), and those polygons that had not been attributed (because they existed on more than one map) were defined.

CREATING A ROAD NETWORK MAP

As with the polygon map, the roads in Green River had to be laid out before digitizing began. A few new roads will need to be constructed to reach harvest units-- these were included. In addition, landing locations had to be identified. These locations will later be used in creating the SALE file in SNAP.

The actual process of digitizing the network map was the same as that of the polygon map. The only difference arose in attributing the segments. No string attributes were assigned. Two coded pairs were used for each segment. The first defined whether or not the segment was part of an existing road, or one that needed construction. The second defined whether the segment was part of an arterial, collector, or local road. Again, the network map laid on three quad maps, all of which were digitized and overlaid onto one map.

LIDES to SNAP INTERFACE

SNAP is unable to read LIDES map files directly. LIDES6.4_SNAP is a program used for "interrogating" LIDES map files and creating input files for SNAP. As previously mentioned, SNAP only requires that one coded pair be attributed to each polygon and segment for this transition. The string attributes assigned to the polygons were used as polygon labels. During execution of LIDES6.4_SNAP, all raster data was transformed into state plane coordinates.

Two output files were created for each LIDES map identified. For the polygon data, these files were the .RPLOT file and the .RPTS file. The .RPLOT file contained polygon labels, polygon area, vertices, and other polygon identifiers. The .RPTS file contained all coordinates of polygons. For the network data, these files were the .LPLOT file and the .LPTS file. The .LPLOT file contained segment length, node coordinates, road class, and so on. The .LPTS file contained all coordinates of segments. These files were later used in creating the additional files SNAP required for operation.

It is not unlikely that some distortion in both the polygon and the network maps may result during the transfer. The distortion in this study did not appear to be significant enough to affect the results. However, some road segments were disconnected in the transfer. As a result, they were isolated and would not reach any mill node if the units were to be harvested. An editing program, Edit Link Data (ELD), was used to connect these unattached road segments. Two additional polygon attributes, volume (mbf/acre) and pond values ($/mbf), were added through the use of another editing program, Edit Sale Units (ESU).

SNAP PROCEDURE

OVERVIEW

SNAP was developed from those network analysis techniques used in creating an earlier program called NETWORK. NETWORK was designed to assist in transportation planning for harvest areas. SNAP differs from NETWORK in that it (1) schedules harvests, (2) satisfies spatial constraints, and (3) satisfies traffic capacity constraints on road links. SNAP can schedule the harvest of an area for up to three time periods. Harvesting costs, revenues, alternative destinations, adjacency requirements, and transportation systems are factors taken into consideration throughout this analysis. SNAP will try to either maximize present net worth or minimize discounted costs.

Before the analysis began, SNAP required the creation of several files, four of which were constructed earlier with the LIDES to SNAP interface. Figure 7 displays an outline of the file requirements. The SALE file, LINK file, MILL file, and ECON file are SNAP's primary files. These files, their data requirements and mathematical formulations, will be discussed in greater detail.

Creating the files was rather simple, due to the program's hierarchical structure of menus. The main menu offers the primary file choice options. Each choice has a corresponding submenu. These submenus list the files needed to create the primary file. The menus for intermediate

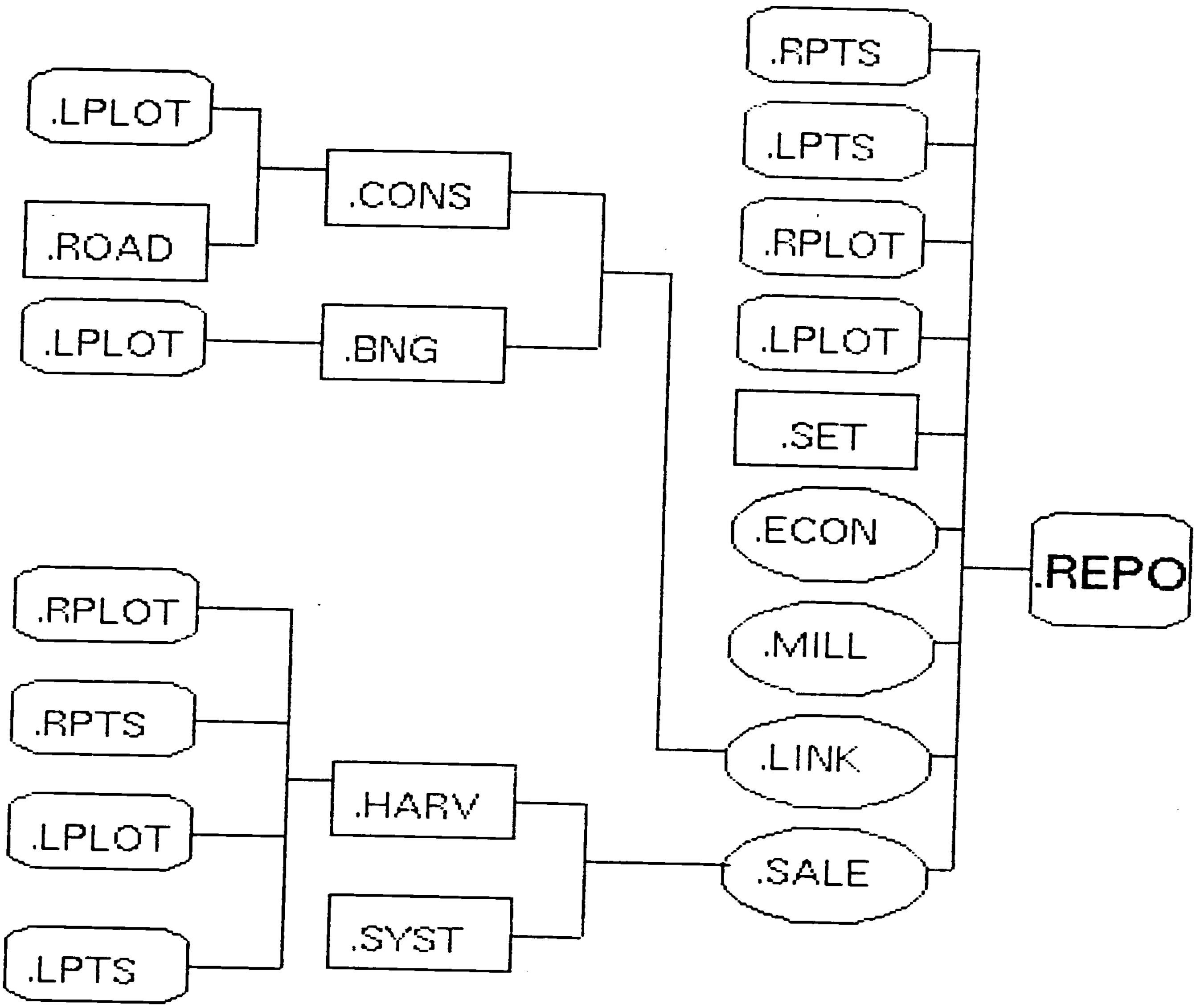

Figure 7. Required SNAP files outline.

files list options which include creating new files, loading old files, and editing files. Entering data into the editor files is self-explanatory, because the user is prompted for the information needed. In other words, SNAP does not require the user to decode complex strings of variables and to enter data in the same manner. SNAP is current state of the art "user friendly."

SALE FILE

The first file created was the SALE file. In general, the SALE file describes the eligible harvest units, their volumes, and their costs. In creating the SALE file, landing locations needed to be identified and two intermediate files had to be prepared, the HARVEST file and the SYSTEMS file. To identify the landing locations, both the .LPLOT and the .RPLOT files were loaded. A sweep radius of 2000 feet was set. This is the approximate distance, from the center of each unit, to be examined for landing locations. On command, SNAP displayed each unit with all possible landing nodes within the prescribed radius. For each unit, up to three landing nodes were identified. These nodes represented where the logs would enter the road system. Upon selecting a node, a logging system was specified. This information was retrieved from the unit attributes previously specified in the .RPLOT file. No landings were identified for those units not eligible for harvest over the course of the study. Once completed, this information was stored for later use in calculating harvesting costs.

The SYSTEM file defines the characteristics and cost for the candidate logging systems. Because Alsea R.D. has a steep sloped, mountainous terrain, it is no wonder that the two logging systems used in Green River were helicopter logging and skyline logging. For each, the following data was entered: skyline logging with a cost of approximately $600/hr, and helicopter logging at $2000/hr. This estimate, obtained from Jerry Holdgrafer, logging specialist at Siuslaw NF, included both equipment and labor. The delay-free time either machine works each clock hour (EF-HR) was estimated at 45 minutes for both systems. The average number of logs per turn (LG/TN) was quoted at 2.5. The in-haul speed for the loaded trip (IN) and the out-haul speed for the unloaded trip (OUT) were respectively 400 ft/min and 1000 ft/min for skyline, and 800 ft/min and 2000 ft/min for helicopter. The combined hook plus unhook time (HOOK) was quoted as 5 minutes for both systems. Rigging time per corridor (RIG) was estimated at 1 hour for both systems. The measure of the distance along the back of each unit (LATT) was averaged at 100 feet. Average yarding distance (AYD) varied from unit to unit. This distance was determined by those landing locations identified earlier. Both LATT and AYD are used in determining volume per corridor. Volume per corridor is ultimately used in calculating rigging cost.

The HARVEST file combines the SYSTEMS file and the landing location data to calculate harvest costs in mbf/$.

The formula which SNAP used for calculating yarding costs was:

cost= ($/hr)/(mbf/hr)

where mbf/hr= (EF-HR/cycle time)(LG/TN)(BF/LG)
cycle time= HOOK + AYD/OUT + AYD/IN

The formula used for calculating rigging cost was:

rigging cost= $/hr * RIG/volume per corridor
where volume per corridor= vol/acre * 1.5 * AYD * LAT/2

Once the intermediate files were completed, the SALE file was assembled. This file contains, for each unit, the harvesting costs calculated in the HARVEST file, and volume and pond values retrieved from corresponding polygon attributes.

LINK FILE

The LINK file was the next file created. This file described both existing and potential road network, in terms of variable and fixed costs from node to node. To create the LINK file, three intermediate files were built: the haul cost file, the ROAD file, and the CONSTRUCTION file. The haul cost file calculated the variable costs for each link. There are two options in SNAP for generating haul costs: the BNG method and the R-6 method. The R-6 method uses the time-speed matrix found in the Timber Transport Model. The

BNG method follows the method used in the Logging Road Handbook, USDA Handbook 183, by Byrnes, Nelson and Googins (1956). While BNG does not calculate or track link maintenance costs, as does R-6, its database is easier to assemble and was quite conducive to the purpose of this study. BNG required the following data to be entered: percent grade in the direction of loaded haul, surface width, alignment class, and surface type. Distances for each link were retrieved from the .LPLOT file. With this data, $/mbf/round trip mile (travel one mile loaded and return one mile empty) was calculated as follows:

$/mbf=($0.667/min*travel time per round trip mile)/load(mbf)

The equations for calculating truck travel times were:

<u>Grade-Limited Travel Time</u>
For uphill travel,

$$\text{time(min/mile)} = W \sin(G) + R*W \cos(G)/6.25*HP*E$$

W= weight of truck,unloaded or loaded, in lbs.
R= rolling resistance, in lb/lb
HP= gross engine power at max torque, in hp
E= efficiency of power transmission
G= grade, in degrees

For downhill travel,

$$\text{time(min/mile)} = 3 + ABS(G)/4 \quad , \quad G \text{ in percent}$$

<u>Alignment-Limited Travel Time</u>
(single lane roads used in this study)

$$\text{time(min/mile)} = 60/-26.4 + 3(77.44 + .67*SD)$$
where SD=(8*R*M)

SD= sight distance, in ft
R= equivalent radius, in ft
M= 0.5*running surface + ditch + 6

Fixed costs are determined by calculating construction costs. There are a total of 43.06 miles of projected roads in Green River. Figure 8 shows the location of these roads. Of the total miles, 15% will require road construction to access harvest units. The ROAD file offers two options in specifying road construction costs. In the first option, road costs are developed based upon average link characteristics. These characteristics include cut slope, fill slope, and other specifications. From these data, $/link and $/mile are calculated. In the second option, road costs, at an estimated $1000 per mile, are specified directly. Using empirical road costs was sufficient for the purposes of this study. A forest-wide average construction cost of $169,000 per mile was the estimate used for the 6.33 miles of road that were required in harvesting some of the units.

SNAP will calculate both a cost-per-mile and a cost-per-link in the CONSTRUCTION file. The following data is required in calculating cost-per-link: average % ground slope for the link, % rock in the cross-section along the link, and depth of surface. Because an empirical cost-per-mile was used in estimating construction costs, this data was not required.

All costs, both variable and fixed, are assumed to remain constant throughout all planning periods.

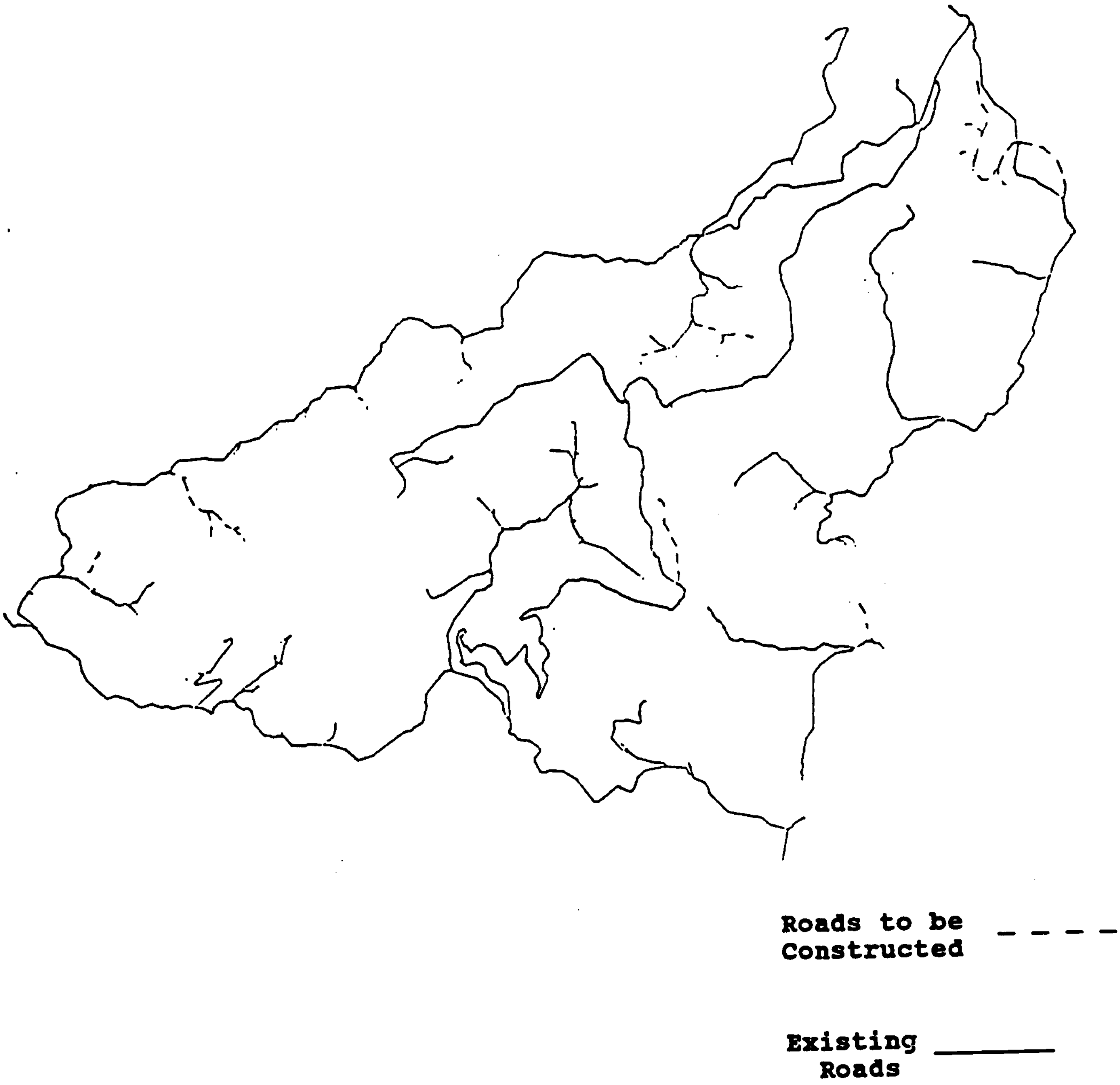

Figure 8. Map showing road network.

MILL FILE

The third required SNAP file is the MILL file. This file specifies the acceptable destinations for the timber. These destinations must be nodes on the network map. Two mill nodes were chosen for Green River-- North Mill and South Mill. Both were chosen on the basis of their proximity to the state highway and their accessibility to the greatest proportion of landing sites. The price the mill will pay for each unit of a specified species is also required, if a pond value was not reflected in the SALE file. In this study, only two pond values were necessary to reflect all harvestable timber: Douglas-fir, 120 years+, at $363/mbf, and mixed alder, 60 years+, at $192/mbf.

ECONOMICS FILE

SNAP's fourth file is the ECONOMICS file. This file specifies period length, discount rate, adjacency constraints, and the limits on volume flow. The period length chosen was 10 years. This time period was appropriate because harvest scheduling, at the district level, is usually planned out in 10-year increments. While harvesting may occur more than once in this time frame, timber sale planners can choose which units to harvest in each entry based on the pattern generated by SNAP for that period. This time increment is also significant in terms of spatial constraints, to be discussed later.

The real discount rate used was 4%. This rate approximates the return on investments for AAA corporate bonds (1960 - 1978) above the rate of inflation (Row et al 1981). The 4% rate was used by FORPLAN in formulating and evaluating all benchmarks and alternatives in the Forest Plan. Today, the Forest Service continues to use it in converting all benefits and costs to a common point in time. In this study, all costs and revenues were discounted from the midpoint of each decade.

There are several adjacency options from which to choose in SNAP. A three-period problem was chosen, which guaranteed that adjacency constraints would apply to the first period and the second period, but not the third period. There is no option which included this third period. Adjacency can be determined by sides or points. In this study, sides were chosen. A minimum length side to be considered in the analysis is also an option. Zero was chosen for this study, so that all sides, regardless of length, would be considered for adjacency. This is a conservative assumption, but it adequately represents adjacency, as interpreted by district level planners.

Volume limits for each period were determined by prorating the forest-wide volume goals, generated by FORPLAN, to the subbasin level. These forest-wide volume goals are expressed in terms of analysis areas. Using FORPLAN's eight level identifiers (ranger district, special areas, land type, age class, accessibility to commercial thinnings, species, management emphasis, and management intensity), portions of 13 analysis areas were identified in Green River. The acres in each analysis area were totaled and divided by the total acres for each analysis area forest-wide. Using these percentages and the forest-wide volume goals for each analysis area (over three 10-year periods), volume goals for the subbasin were established. Volume goals (upper bounds) for periods 1 - 3 were 68,770 mbf, 33,830 mbf, and 17,600 mbf respectively. Lower bounds were set at 68,500 mbf, 33,500 mbf, and 17,300 mbf respectively.

The ECONOMICS file also gives the user the option to control percentage increases in link variable costs, link fixed costs, harvest volumes, and harvest costs. Discount rates, too, can be changed from period to period. These options were not utilized in this study.

The SET file was the final file required before the SNAP analysis began. This file is a setup file consisting of the SALE, LINK, MILL, and ECONOMICS files. The aforementioned adjacency requirements were also specified here, along with an output report filename.

INCORPORATING STANDARDS AND GUIDELINES INTO SNAP

Before proceeding with the analysis, the following describes how the standards and guidelines, identified earlier in this paper, were incorporated into this analysis.

1. Stream Buffers

Riparian zones were identified in mapping-out harvest unit boundaries. The dimensions of these areas represent those specified in the standards and guidelines. Riparian zones were then digitized as polygons and given a "non-timbered unit" status in SNAP. As a result, riparian zones were not considered for harvest.

2. Vegetation "Leave Areas"

There were no identified vegetation "leave areas" in Green River. As with the stream buffers, vegetation "leave areas" would be treated as a polygon with a "non-timbered unit" status. This area would not be considered for harvest.

3. Elk

The 10 year requirement for maintaining hiding or thermal cover adjacent to all clearcuts was met by assigning an increment of 10 years for each period. Adjacency constraints effective during each period decrease the possibility of a clearcut occurring next to a unit less than 10 years old. This allows for entries to be made within each period, without violating elk cover requirements. In mapping-out unit boundaries, units were shaped such that the distance to vegetation cover did not exceed 800 feet from any point in the unit.

4. Marten

Two marten habitat areas were identified in this subbasin. One reproduction habitat consists of 210 acres. The remaining reproduction habitat acres are located in an adjacent subbasin. The area around this habitat is comprised of Douglas-fir stands on a rotation schedule, providing the required feeding habitat. The other marten habitat area in this subbasin shares 250 contiguous acres of reproduction habitat with an adjacent subbasin. Green River contains 150 of these acres. The area around this habitat is comprised of Douglas-fir stands on a rotation schedule, providing the required feeding habitat. Those polygons designated as reproduction habitat were given a "non-timbered unit" status in SNAP. As with stream buffers and vegetation "leave areas," these polygons were not considered for harvest. The polygons surrounding this area are comprised of plantations and Douglas-fir stands with a SNAP status "to be harvested."

5. Pileated Woodpecker

There were no pileated woodpecker sites identified in this subbasin. Had there been, such areas would have been represented in the same manner as the martens in SNAP.

6. Regeneration

In this study, it was assumed that planting will begin within one year of harvest. Because this analysis extends over only three periods, regeneration assumptions had no significant influence on the problem.

7. Harvesting Units

The area of each harvest unit was established when laying out the polygon map. Each harvestable unit (plantations exempt), was made no larger than 60 acres. There were a few exceptions-- however, these polygons did not have areas exceeding 80 acres. These deviations were most likely attributable to digitizing errors, but it was assumed that these larger openings were shaped as such to meet visual quality objectives.

Adjacency requirements were met by setting period length equal to 10 years. Within each period (1 and 2 only) SNAP will not create a harvest pattern containing adjacent harvest units.

To avoid harvesting more than 20% of the National Forest land in Green River each period, the volume goal per decade was converted into acres. These acre totals were then each divided by the total amount of Forest Service acres in Green River. Assuming the volume goal is met (high estimate), 16.8% of the subbasin will be harvested in Period 1, 8.2% in Period 2, and 4.2% in Period 3. Forest-wide nondeclining even-flow was assumed to be met by attempting to meet the subbasin volume goals. These goals were generated by FORPLAN and, combined with those volume goals of all subbasins on the forest, should support forest-wide nondeclining even-flow.

RESULTS

In this section, SNAP's analysis procedure is outlined, along with a summary of SNAP's reporting options. Results of this study are also presented and interpreted. Tables and figures are used to summarize these findings. The SNAP input and output files are available upon request from the Siuslaw National Forest, Supervisor's Office, 4077 Research Way, Corvallis, Oregon 97333.

SNAP ANALYSIS

SNAP follows a step-by-step procedure in its analysis. These steps are outlined on the computer screen, so that the user may follow SNAP's progress. This flowchart is useful in pin-pointing the location of errors should the analysis abnormally terminate. A diagnostic message is also printed at the bottom of the screen to aid in locating errors.

SNAP begins its analysis by processing link data and renaming node labels. The sale data is then processed, followed by classifying polygons according to the adjacency specifications given earlier. Next, feasible polygon patterns are generated. Recall that in this study, the upper and lower volume boundaries were initially set at 68,770 mbf and 68,500 mbf, 33,830 mbf and 33,500 mbf, and 17,658 mbf and 17,300 mbf for Periods 1, 2, and 3 respectively. Keeping in mind that the solution procedure is volume-driven, SNAP then tries to reach, but not exceed, the upper bounds in each period given that the volume is available in patterns meeting the adjacency constraints. A total of 18 feasible patterns were generated for Green River. None of these patterns exceeded the upper boundaries, yet all were below a lower boundary for at least one period. In such a case, SNAP utilizes what is available, because there is not a sufficient amount of volume to meet upper bounds.

To see if these initial boundaries could be met under a more tightly constrained problem, lower boundaries were set at 68,700 mbf, 33,800 mbf, and 17,600 mbf for Periods 1, 2, and 3 respectively. Upper boundaries remained unchanged. 17 patterns were generated this time, all of which matched the initial patterns, save one. This pattern was apparently omitted due to its degree of deviation from the lower bound set in Period 2. The pattern numbers, associated present net values (PNV's), and volume produced by SNAP are shown in Table 1. By modifying the setup file, each pattern can individually be analyzed. In doing so, SNAP will attempt to improve the pattern's transportation plan and obtain a higher PNV.

PAT NUMBER	SOLUTION	TOTAL VOL (mbf)	PR1 VOL (mbf)	PR2 VOL (mbf)	PR3 VOL (mbf)
2	$ 19,895,419	118,650	68,023	33,344	17,283
3	$ 19,851,121	118,710	68,247	33,036	17,427
5	$ 19,845,086	116,046	67,341	33,206	15,499
1	$ 19,731,277	117,362	66,264	33,662	17,436
9	$ 19,697,018	118,094	67,892	33,253	16,949
6	$ 19,610,729	117,202	68,330	33,143	15,729
4	$ 19,143,976	116,695	66,602	33,093	17,000
7	$ 19,141,123	117,599	67,309	33,132	17,158
14	$ 18,938,927	116,197	66,955	33,120	16,122
15	$ 18,861,099	116,410	66,466	33,118	16,826
11	$ 18,854,798	118,385	68,205	33,528	16,652
8	$ 18,834,716	117,298	66,579	33,508	17,211
10	$ 18,650,220	117,122	66,640	33,624	16,858
13	$ 18,546,973	118,200	67,347	33,319	17,534
12	$ 18,389,900	118,941	68,720	33,688	16,533
16	$ 18,281,207	117,253	66,732	33,709	16,812
17	$ 18,273,049	117,469	66,761	33,638	17,070

Table 1. **Patterns generated by SNAP.**

SNAP REPORTS

During the individual pattern's analysis phase, files are written for the Report Writer. Reports reflect only the best solution for each harvest pattern. SNAP offers a choice of 9 tabular reports and 5 graphic displays. Each report is summarized below:

Tabular Reports

Traffic Maintenance Summary -
Provides a summary of volume hauled over each link and associated maintenance, haul, and construction costs.

Volume vs. Miles Summary -
Summarizes volume and acres harvested by period, and roads by class and type.

Link Usage Summary -
Displays which links are used and in what period they are used.

Sale Paths -
Provides the path from the harvest unit to the mill for each species. A summary of the acres and volume harvested, by species, for each unit is also given.

Unit Cost Summary -
Provides the unit cost of harvesting and hauling each species to its destination. For each unit, volume, variable costs, shared fix costs, pond value, and net value are given by species.

Mill Summary -
Summarizes mill deliveries by period and species. Net value of the timber delivered is also given.

Summary by Period -
Provides volume and acres harvested, road miles used, logging costs, haul costs, and road construction costs by period.

Available Volume For Pattern -
Summarizes the amount of volume available each period and the amount actually taken.

Query Unit Attributes -
Displays all the units in the solution that meet a user-specified criteria.

Graphic Reports

Percent Miles vs. Area vs. Volume (CRT) -
Plots two lines. The % miles vs. volume line is the ratio of the miles used during each period, divided by the total miles used in all periods (vertical axis), against the ratio of volume harvested during each period, divided by the total volume harvested in all periods (horizontal axis). The % miles vs. acres line is the same, except that acres replace volume on the horizontal axis.

Bar Chart of Miles By Period (CRT) -
Displays the existing, reconstruction, and construction miles by period.

Display Options for Road Network (CRT or PLOTTER) -
Offers options for plotting road network. Some of these options include: plot node boxes, plot links per period with a pause after each period, and plot links only in selected periods. There is a toggle switch for choosing between stick data or point data.

Display Options for Units Harvested (CRT or PLOTTER) -
Offers options for plotting units selected for harvest. Some of these options include: plot polygons per period with a pause after each period, plot frame and legend, and plot only selected periods. There is a toggle switch for choosing between stick data or point data. It should be noted that only the display on the CRT appears to "shade in" selected polygons.

Percentage Miles vs. Area vs. Volume (Plotter) -
Displays the same graph as the first graphic report, except this one is sent to the plotter.

INTERPRETING SNAP RESULTS

Judging by Table 1, SNAP was unable to meet the volume goals generated by the forest-wide FORPLAN model. It is interesting to note that pattern number 12, which came closest to reaching the volume goal, was third-to-last in total PNV. To understand how this discrepancy occurred, both patterns were analyzed further.

Pattern number 2 generated the highest PNV. This pattern was run through SNAP's analysis phase to determine if a higher PNV could be produced. The pattern of harvest units in each period will not be reconsidered. Only landings and associated routes from the unit to the mills will be reanalyzed, so as to find those that are lowest in cost. The resulting solution was an increase in PNV from \$19,895,419 to \$20,124,669. A map of the three-period harvest pattern is shown in Figure 9. A table of the corresponding harvest units cut in each period is shown in Table 2.

Pattern number 12 came closest to meeting the harvest volume goals. As with pattern number 2, this pattern was run through the analysis again in an attempt to achieve a higher PNV. The resulting solution was an increase in PNV from \$18,389,900 to \$18,724,526. The difference in PNV between pattern numbers 2 and 12 remained relatively unchanged. A map of the three-period harvest pattern is shown in Figure 10. Note the two adjacent units, harvested in Period 3, located in the lower right-hand side of the subbasin. SNAP does not take adjacency into account during Period 3. Fortunately, the opening created between the two units is under the 60-acre harvest area limit as outlined in the standards and guidelines. A summary of the corresponding harvest units cut in each period is shown in Table 3.

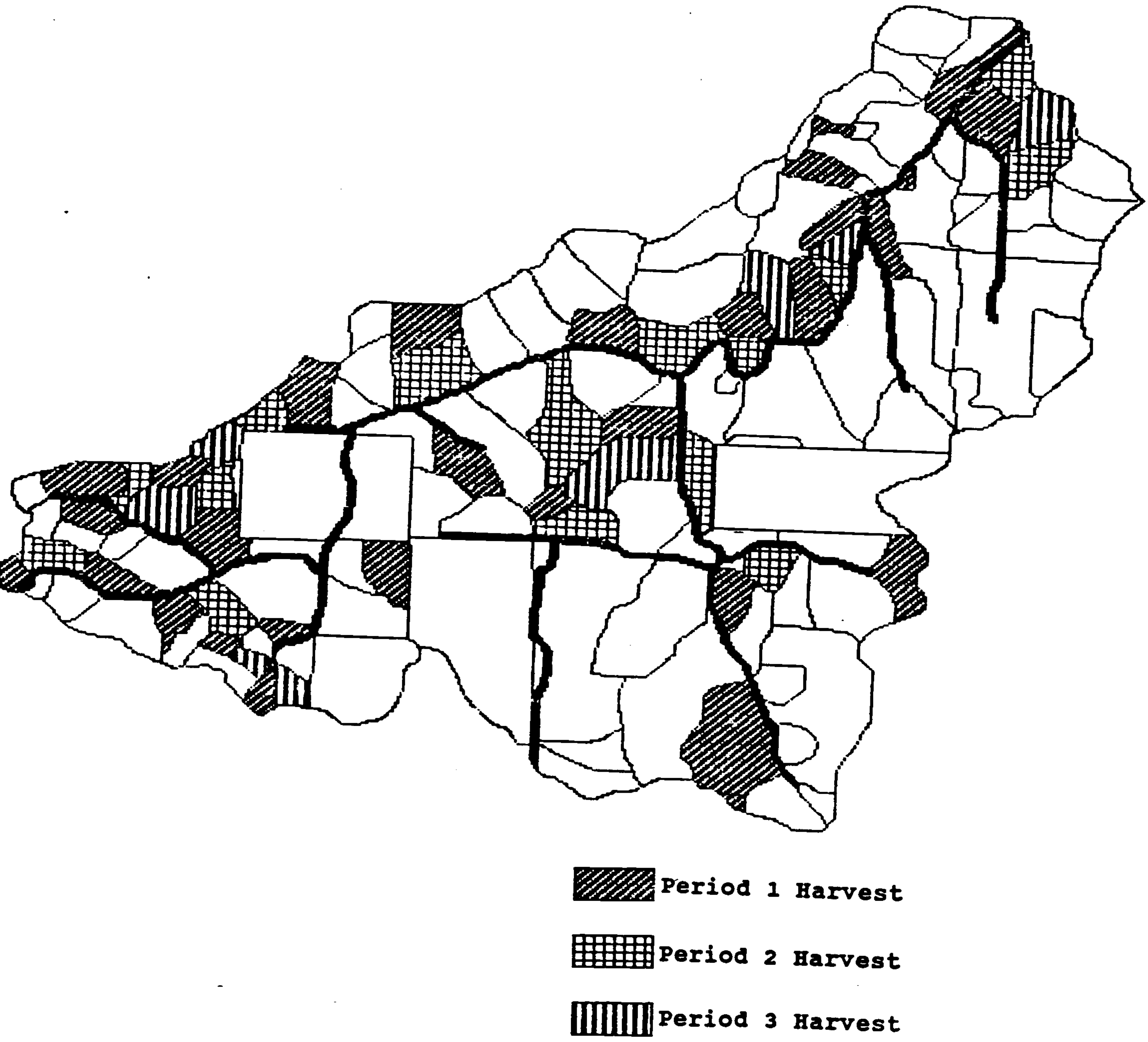

Figure 9. Map of three period harvest for pattern number 2.

Period 1

UNIT	MILL	SYS	SP	VOLUME	VAR CST	SHARED FIX	VALUE	NET VAL
M-1865-01	N.MILL	1	1	192	545.27	0.00	192.00	-353.27
M-1930-10	N.MILL	1	1	852	528.92	11.37	192.00	-348.29
C-1865-05	S.MILL	1	1	1,210	90.30	0.00	363.00	272.70
C-1865-23	S.MILL	1	1	2,615	88.01	13.02	363.00	261.97
C-1865-56	N.MILL	1	1	2,098	87.72	39.21	363.00	236.07
C-1865-43	S.MILL	1	1	2,144	90.33	0.00	363.00	272.67
C-1865-62	N.MILL	1	1	1,320	90.39	0.00	363.00	272.61
C-1865-36	S.MILL	1	1	2,389	94.57	0.00	363.00	268.43
C-1865-12	N.MILL	1	1	1,706	91.98	16.74	363.00	254.28
C-1865-34	N.MILL	1	1	3,319	93.68	6.84	363.00	262.49
C-1865-57	N.MILL	1	1	3,001	90.75	0.00	363.00	257.72
C-1865-17	S.MILL	1	1	1,893	93.72	0.00	363.00	269.28
C-1865-10	N.MILL	1	1	1,642	93.91	11.37	363.00	257.72
C-1865-25	N.MILL	1	1	3,422	95.23	0.00	363.00	267.77
C-1865-39	S.MILL	1	1	1,663	97.96	18.76	363.00	246.27
C-1865-26	S.MILL	1	1	3,369	97.92	0.00	363.00	265.08
C-1865-46	S.MILL	1	1	1,079	99.37	0.00	363.00	263.63
C-1865-29	N.MILL	1	1	2,799	101.83	13.01	363.00	248.16
C-1865-31	N.MILL	1	1	1,635	102.30	2.88	363.00	257.82
C-1865-03	S.MILL	1	1	3,178	100.61	0.00	363.00	262.39
C-1865-40	S.MILL	1	1	3,174	103.76	0.00	363.00	259.24
C-1990-01	S.MILL	1	1	849	105.38	0.00	363.00	257.62
C-1865-38	S.MILL	1	1	2,477	110.56	0.00	363.00	252.44
C-1865-47	S.MILL	1	1	4,112	110.83	0.00	363.00	252.17
C-1865-35	N.MILL	1	1	2,771	117.17	0.00	363.00	245.83
C-1865-08	S.MILL	1	1	6,023	112.82	0.00	363.00	250.18
C-1993-02	N.MILL	1	1	1,670	117.06	14.06	363.00	231.88
C-1993-03	N.MILL	1	1	3,776	128.14	0.00	363.00	234.86
C-1865-53	N.MILL	2	1	1,645	334.46	14.06	363.00	14.48
~	~	~	~	~	~	~	~	~
PER AVE	~	~	~	~	114.22	4.63	360.38	241.53

Table 2. Summary of harvest units chosen for pattern number 2.

Period 2

UNIT	MILL	SYS	SP	VOLUME	VAR CST	SHARED FIX	VALUE	NET VALUE
C-1865-09	S.MILL	1	1	1,380	93.13	0.00	363.00	269.87
C-1865-21	S.MILL	1	1	3,043	90.51	0.00	363.00	272.49
C-1865-55	N.MILL	1	1	2,130	88.05	29.30	363.00	245.65
C-1865-28	N.MILL	1	1	1,327	92.80	0.00	363.00	270.20
C-1865-06	S.MILL	1	1	1,879	92.94	0.00	363.00	270.06
C-1865-13	N.MILL	1	1	1,373	92.34	0.00	363.00	270.66
C-1865-18	S.MILL	1	1	2,120	93.63	0.00	363.00	269.37
C-1865-30	N.MILL	1	1	1,352	97.49	0.00	363.00	265.51
C-1865-02	S.MILL	1	1	1,716	97.55	43.81	363.00	221.64
C-1865-33	N.MILL	1	1	3,719	97.61	0.00	363.00	265.39
C-1865-24	N.MILL	1	1	3,365	96.87	13.91	363.00	252.22
C-1865-37	S.MILL	1	1	2,070	98.70	0.00	363.00	264.30
C-1865-14	N.MILL	1	1	1,649	96.48	0.00	363.00	266.52
C-1865-52	N.MILL	1	1	3,135	96.45	4.52	363.00	262.03
C-1865-41	S.MILL	1	1	3,086	112.67	0.00	363.00	250.33
~	~	~	~	~	~	~	~	~
PER AVE	~	~	~	~	96.46	5.96	363.00	260.59

Period 3

UNIT	MILL	SYS	SP	VOLUME	VAR CST	SHARED FIX	VALUE	NET VAL
C-1865-32	N.MILL	1	1	1,472	92.18	0.00	363.00	270.82
C-1865-27	N.MILL	1	1	3,015	93.28	7.06	363.00	262.66
C-1865-44	S.MILL	1	1	2,183	92.83	0.00	363.00	270.17
C-1865-54	N.MILL	1	1	3,047	90.76	0.00	363.00	272.24
C-1865-42	S.MILL	1	1	803	97.30	0.00	363.00	265.70
C-1865-11	N.MILL	1	1	2,739	96.40	0.00	363.00	266.60
C-1865-04	S.MILL	1	1	2,718	98.35	0.00	363.00	264.65
C-1865-99	N.MILL	1	1	1,306	97.64	0.00	363.00	265.36
~	~	~	~	~	~	~	~	~
PER AVE	~	~	~	~	94.49	1.23	363.00	267.28

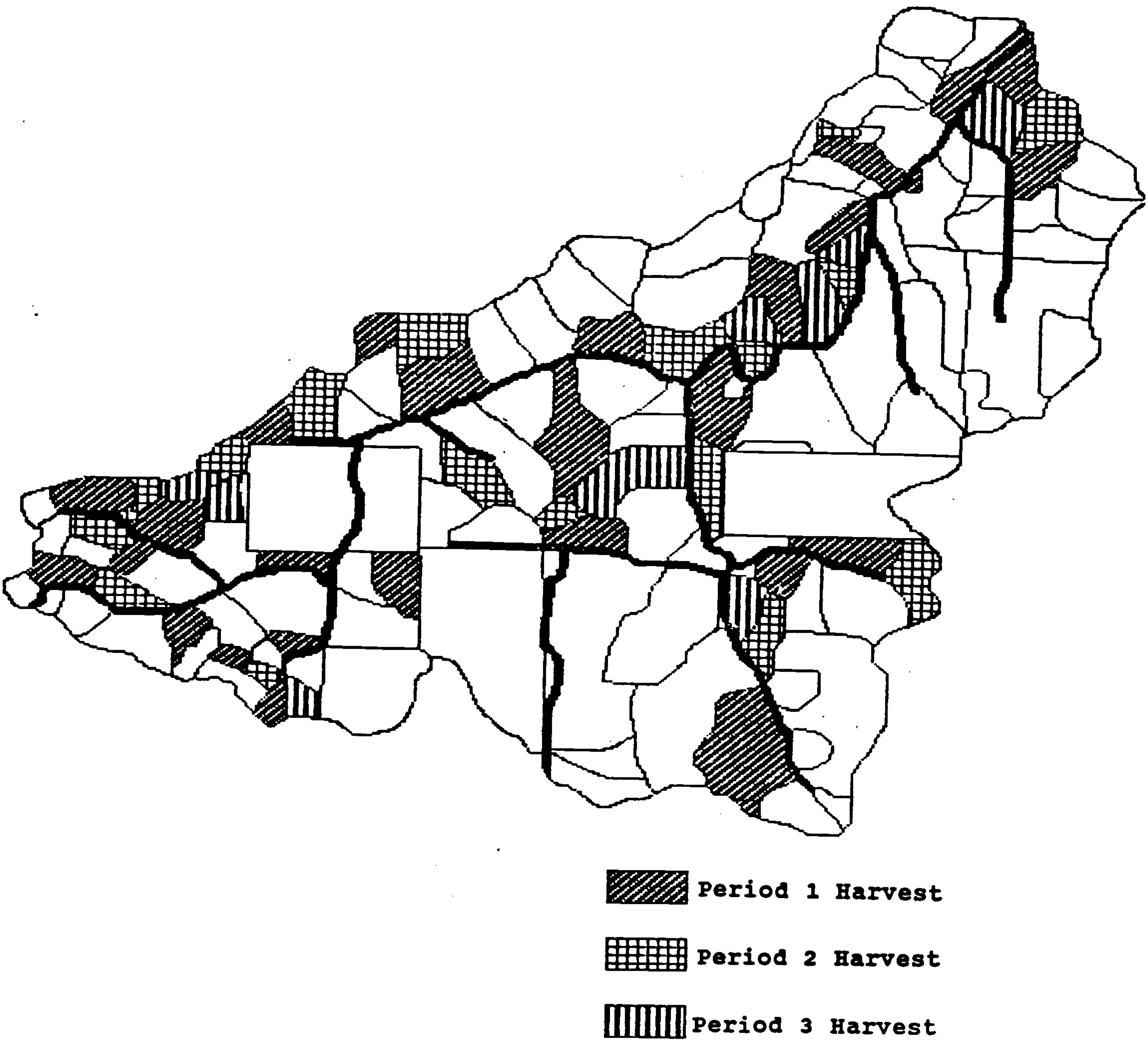

Figure 10. Map of three period harvest for pattern number 12.

Period 1

UNIT	MILL	SYS	SP	VOLUME	VAR CST	SHARED FIX	VALUE	NET VAL
M-1865-01	N.MILL	1	1	192	545.27	0.00	192.00	-353.27
M-1930-10	N.MILL	1	1	852	528.92	33.29	192.00	-370.22
C-1865-21	S.MILL	1	1	3,043	90.51	0.00	363.00	272.49
C-1865-55	N.MILL	1	1	2,130	88.05	53.33	363.00	221.62
C-1865-43	S.MILL	1	1	2,144	90.33	0.00	363.00	272.67
C-1865-27	N.MILL	1	1	3,015	93.28	9.44	363.00	260.28
C-1865-06	S.MILL	1	1	1,879	92.94	0.00	363.00	270.06
C-1865-57	N.MILL	1	1	3,001	90.75	0.00	363.00	272.25
C-1865-18	S.MILL	1	1	2,120	93.63	0.00	363.00	269.37
C-1865-33	N.MILL	1	1	3,719	97.61	0.00	363.00	265.39
C-1865-24	N.MILL	1	1	3,365	96.87	13.91	363.00	252.22
C-1865-37	S.MILL	1	1	2,070	98.70	0.00	363.00	264.30
C-1865-11	N.MILL	1	1	2,739	96.40	13.49	363.00	253.11
C-1865-46	S.MILL	1	1	1,079	99.37	0.00	363.00	263.63
C-1865-52	N.MILL	1	1	3,135	96.45	9.91	363.00	256.64
C-1865-40	S.MILL	1	1	3,174	103.76	0.00	363.00	259.24
C-1990-01	S.MILL	1	1	849	105.38	0.00	363.00	257.62
C-1865-47	S.MILL	1	1	4,112	110.83	0.00	363.00	252.17
C-1865-63	N.MILL	1	1	2,580	112.34	0.00	363.00	250.66
C-1865-35	N.MILL	1	1	2,771	117.17	0.00	363.00	245.83
C-1865-08	S.MILL	1	1	6,023	112.82	0.00	363.00	250.18
C-1993-02	N.MILL	1	1	1,670	117.06	22.89	363.00	223.05
C-1992-02	S.MILL	1	1	2,396	135.03	0.00	363.00	227.97
C-1993-01	N.MILL	1	1	2,392	134.62	0.00	363.00	228.38
C-1865-22	N.MILL	2	1	3,132	308.88	0.00	363.00	54.12
C-1865-01	S.MILL	2	1	2,806	372.91	26.79	363.00	-36.70
C-1992-01	N.MILL	2	1	2,332	401.62	20.03	363.00	-58.64
~	~	~	~	~	~	~	~	~
PER AVE	~	~	~	~	140.65	6.48	360.40	213.27

Table 3. **Summary of harvest units chosen for pattern number 12.**

Period 2

UNIT	MILL	SYS	SP	VOLUME	VAR CST	SHARED FIX	VALUE	NET VAL
C-1865-05	S.MILL	1	1	1,210	90.30	0.00	363.00	272.70
C-1865-09	S.MILL	1	1	1,380	93.13	0.00	363.00	269.87
C-1865-23	S.MILL	1	1	2,615	88.01	13.02	363.00	261.97
C-1865-32	N.MILL	1	1	1,472	92.18	0.00	363.00	270.82
C-1865-28	N.MILL	1	1	1,327	92.80	0.00	363.00	270.20
C-1865-62	N.MILL	1	1	1,320	90.39	0.00	363.00	272.61
C-1865-36	S.MILL	1	1	2,389	94.57	0.00	363.00	268.43
C-1865-34	N.MILL	1	1	3,319	93.68	6.84	363.00	262.49
C-1865-13	N.MILL	1	1	1,373	92.34	0.00	363.00	270.66
C-1865-54	N.MILL	1	1	3,047	90.76	0.00	363.00	272.24
C-1865-25	N.MILL	1	1	3,422	95.23	0.00	363.00	267.77
C-1865-02	S.MILL	1	1	1,716	97.55	0.00	363.00	265.45
C-1865-39	S.MILL	1	1	1,663	97.96	18.76	363.00	246.27
C-1865-42	S.MILL	1	1	803	97.30	0.00	363.00	265.70
C-1865-14	N.MILL	1	1	1,649	96.48	0.00	363.00	266.52
C-1865-26	S.MILL	1	1	3,369	97.92	0.00	363.00	265.08
C-1865-19	S.MILL	1	1	1,614	115.54	0.00	363.00	247.46
~	~	~	~	~	~	~	~	~
PER AVE	~	~	~	~	94.87	2.61	363.00	265.52

Period 3

UNIT	MILL	SYS	SP	VOLUME	VAR CST	SHARED FIX	VALUE	NET VAL
C-1865-56	N.MILL	1	1	2,098	87.72	6.76	363.00	268.52
C-1865-12	N.MILL	1	1	1,706	91.98	0.00	363.00	271.02
C-1865-44	S.MILL	1	1	2,183	92.83	0.00	363.00	270.17
C-1865-10	N.MILL	1	1	1,642	93.91	0.00	363.00	269.09
C-1865-30	N.MILL	1	1	1,352	97.49	0.00	363.00	265.51
C-1865-17	S.MILL	1	1	1,893	93.72	0.00	363.00	269.28
C-1865-04	S.MILL	1	1	2,718	98.35	0.00	363.00	264.65
C-1865-99	N.MILL	1	1	1,306	97.64	0.00	363.00	265.36
C-1865-31	N.MILL	1	1	1,635	102.30	0.00	363.00	260.70
~	~	~	~	~	~	~	~	~
PER AVE	~	~	~	~	94.91	0.86	363.00	267.24

By comparing the harvest patterns in Figure 9 and Figure 10, it is apparent that every unit harvested in one pattern was not harvested in the other. Also, those units that were harvested in both patterns were not always harvested in the same periods. Graphically, the differences in volume harvested in each period are demonstrated in Figure 11. The total volume was greater in pattern number 12, by 291 mbf. Average pond values are equal for each pattern, thus total revenues do not explain the discrepancy in PNV.

A closer look at both variable and fixed costs revealed why pattern number 2 generated $1,734,769 more than pattern number 12. Variable costs consist of logging costs and haul costs. The differences in variable costs in each period are graphed in Figure 12. Fixed costs consist of construction costs for roads (local, arterial, and collector). The differences in fixed costs in each period are shown in Figure 13.

There were three primary reasons why pattern number 12 incurred significantly greater costs. First, helicopter logging was used to log three units in pattern number 12, and only used to log one unit in pattern number 2. Second, more road miles were used in harvesting units in pattern number 12. Third, more new roads were necessary to access those harvest units in pattern number 12.

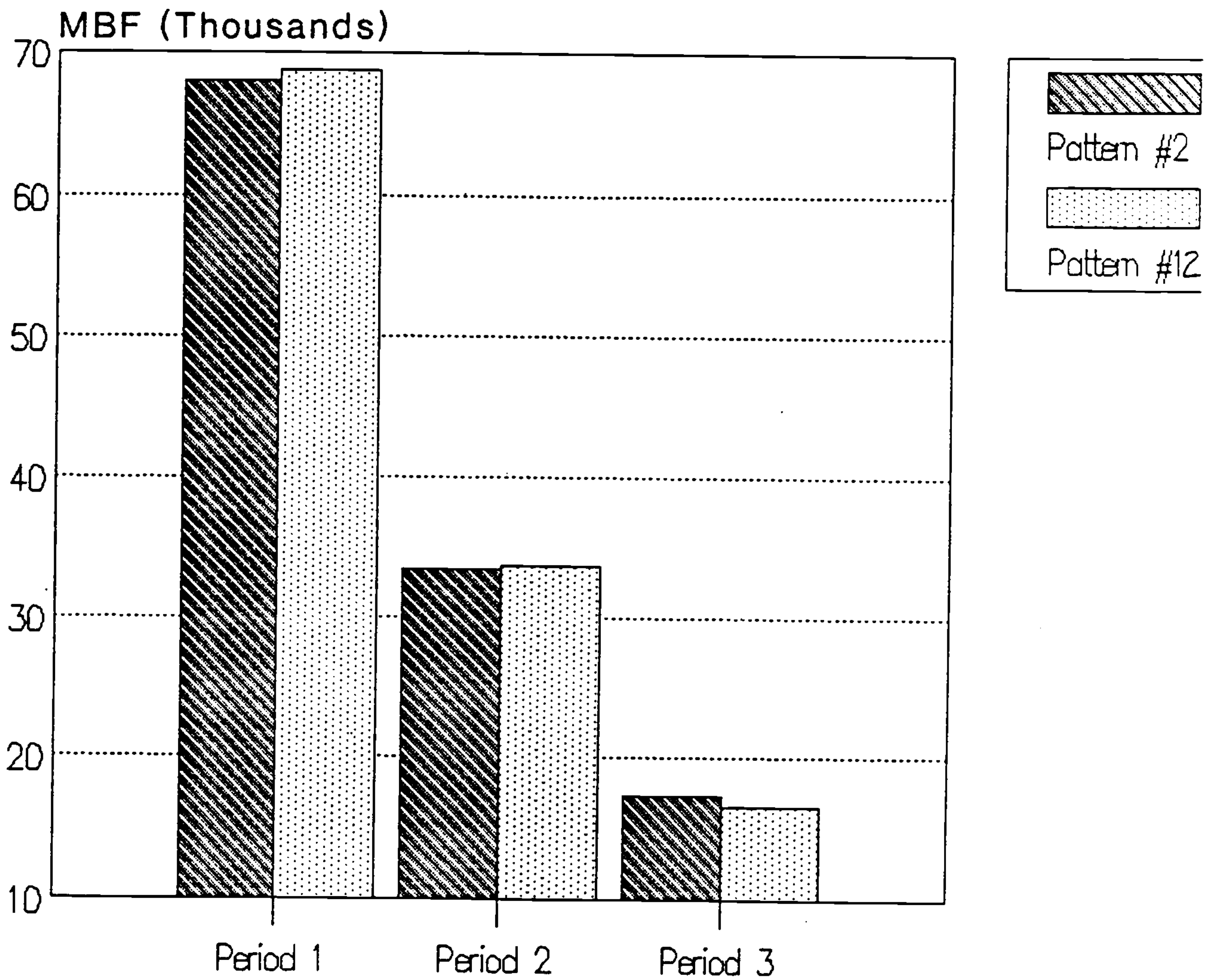

Figure 11. Volume distribution.

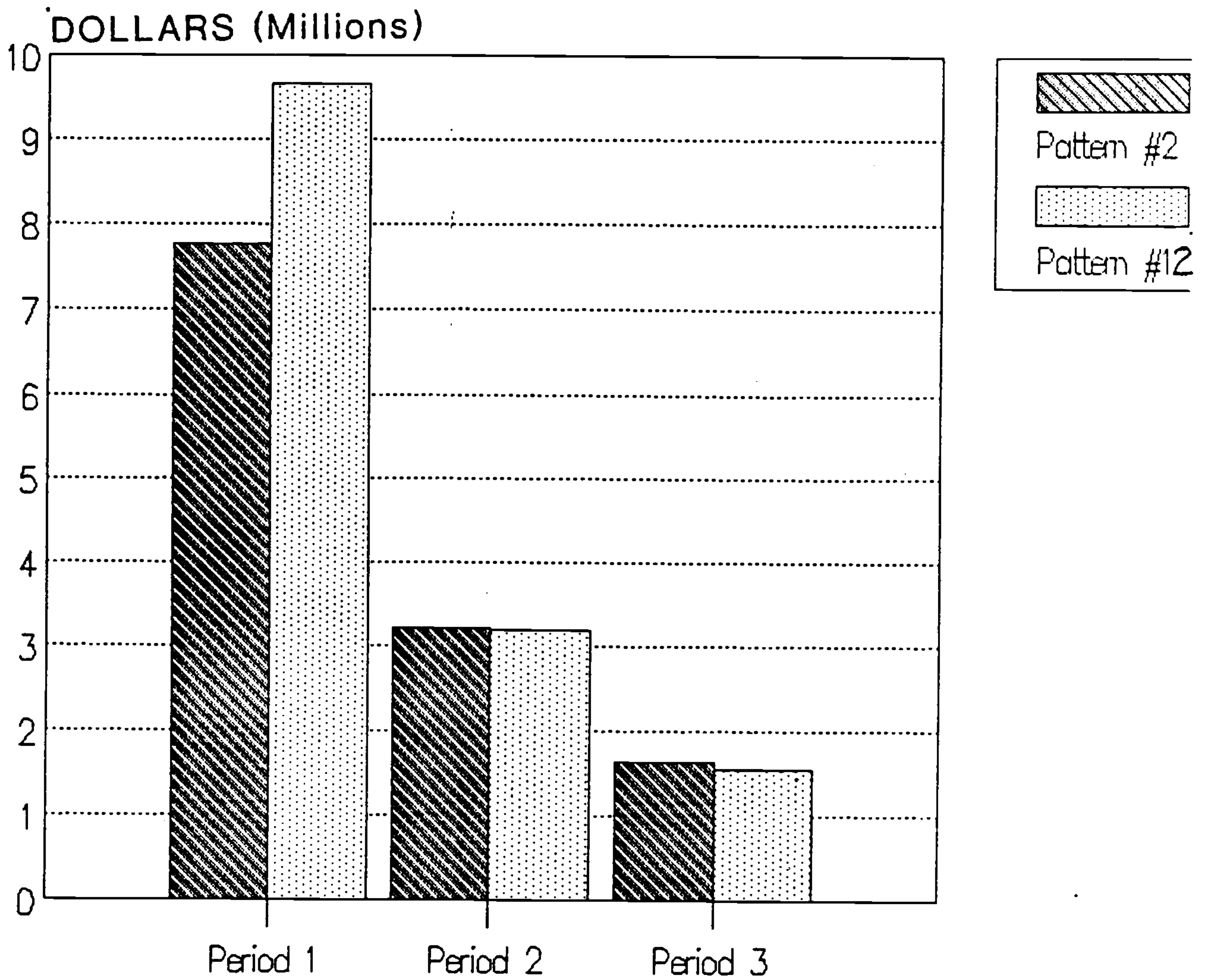

Figure 12. **Distribution of total variable costs.**

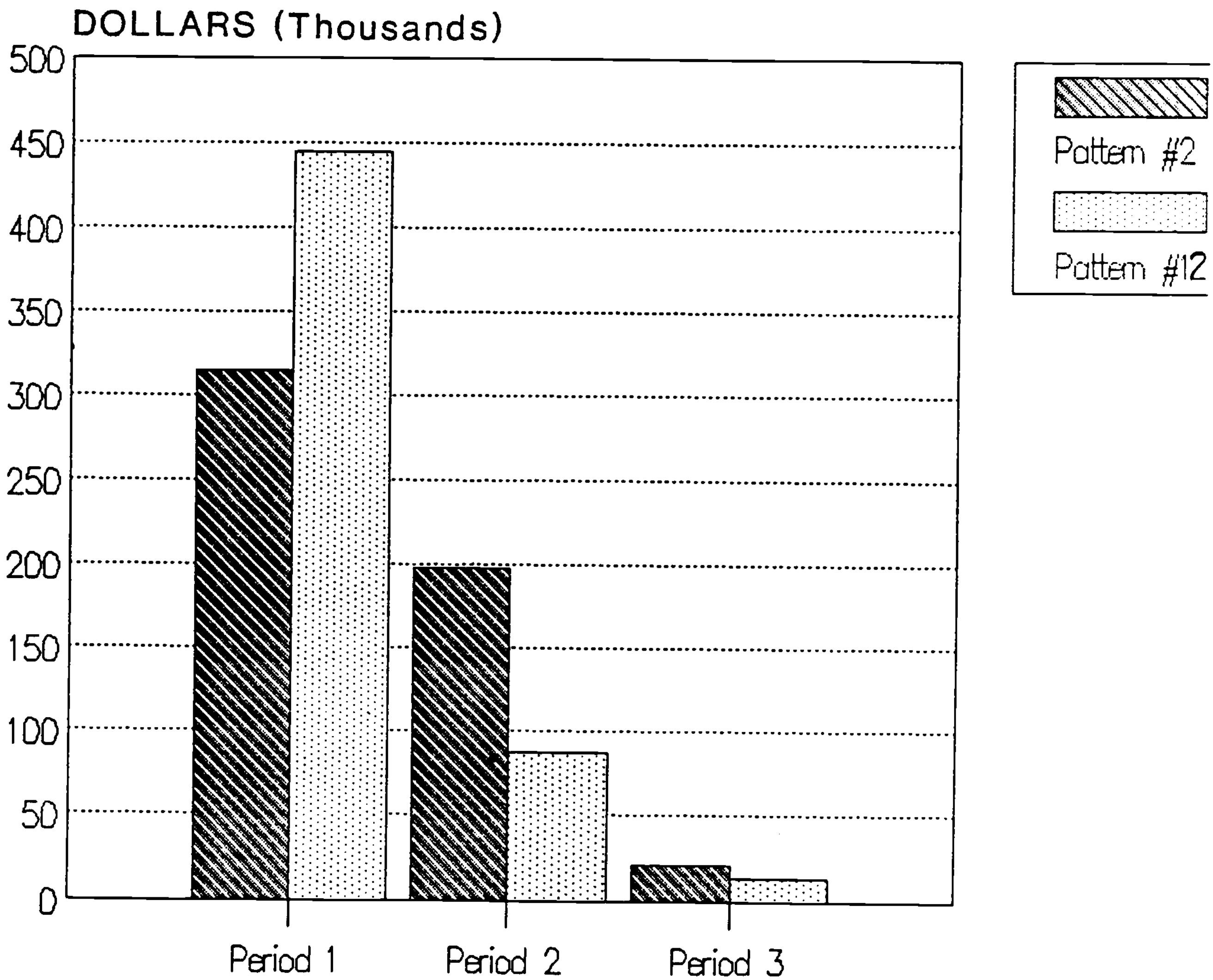

Figure 13. <u>Distribution of total fixed costs.</u>

As demonstrated, pattern number 12 did come closer to meeting Green River's volume goals; however, it was not as economically efficient as pattern number 2. At a yield of 78.5 mbf/acre, 3.7 acres were left uncut at a savings of $1,734,769. Assuming both patterns were equal (in terms of meeting wildlife requirements, etc.), pattern number 2 would undoubtedly be chosen as a foundation for scheduling timber sales.

SNAP was unable to create a harvest pattern which met the volume goals assigned to Green River. To reach the volume goal, it was necessary to cut 1,538 acres of Green River. Using pattern number 2 to represent Green River's harvest configuration, a total of 1,519 acres were scheduled to be harvested. A total of 1,813 acres were available for harvest in Green River over the three periods. Thus, it was highly unlikely that timber supply was a factor in failing to meet volume goals.

Spatially, the subbasin was quite restricted. Adjacency constraints precluded harvesting two adjacent units. Alone, this requirement would not have such a large influence on meeting volume goals, because units could be made quite large. However, limiting openings to 60 acres or less created a patchwork of evenly-distributed areas, split between those acres that could and could not be harvested. As a result, of those acres available for harvest before the spatial constraints were applied, beginning in Period 1, only half could be considered.

Another significant reason why SNAP was unable to reach its harvest goals is due to the upper bounds set for volume in each period. A strict interpretation of the volume goals generated by FORPLAN was used in the Green River analysis. Recall the upper bounds in the ECONOMICS file were set equal to the volume goals. In the analysis, SNAP searches the subbasin for harvest patterns that satisfy adjacency constraints. Patterns generating volumes greater than the upper bounds are considered infeasible and are not reported. As an integer program, SNAP will only assign units to be harvested in integer quantities. In other words, SNAP will not split harvest units. The probability of a harvest pattern containing units in which volumes total the exact volume goal is slight. Unless the subbasin is environmentally sensitive, in practice, these volume goals can be exceeded within a reasonable amount, inventory permitting.

Within the 36 subbasins in Alsea R.D., it is highly probable that sufficient inventory does exist to make up deficiencies in meeting volume goals (as experienced in this analysis). This assumption is based upon the way in which the volume goal was determined in Green River. Recall 13 analysis areas exist in this subbasin. Each analysis area represents only a percentage of those existing on the forest as a whole. Of these 13 analysis areas, only three have volume goals over the next 30 years. These volume goals are less than the volume available in each analysis area.

Prorated to the subbasin level, the volume goals are in fact less than what is available, regardless of how rich or poor an area is in timber resources. This then would permit another subbasin's harvesting of more than its goal, picking up the slack of those unharvested acres.

CONCLUSIONS

In this study, standards and guidelines, as defined in the Forest Plan, were implemented on a subbasin in the Alsea Ranger District. The purpose of the analysis was (1), to determine if harvest volume goals, on a subbasin level, were attainable after implementing spatial constraints as outlined in the standards and guidelines and (2), to examine SNAP as an analysis tool in Forest Plan implementation.

Green River did not meet its volume goal; however, it came within 99% of its objective. This 1% difference was attributed to the spatial requirements implemented in the analysis, assuming strict volume goal bounds. The implications, forest-wide, depend upon how closely Green River typifies the other 35 subbasins in the forest. While one subbasin is not enough to justify an average, if Green River did represent an average in reaching volume goals, approximately 99% of the harvest volume predicted on the forest could be reached. An investigation of two or three more drainages, using the same procedures as outlined in this study, would provide a better approximation of a forest-wide average.

Despite an effort to completely replicate Forest Plan implementation on the district level, some factors were beyond the scope of this study. As a result, it is highly probable that the difference in volume goal and volume actually attained might be slightly greater than 1%.

Only two such factors could be identified as having this effect: unidentified soil "leave areas," and interpretations of adjacency. As discussed earlier, many units have areas that will be left unharvested, due to soil disturbances. These soil "leave areas" are unlikely to be noticed before actually flagging the unit for a timber sale. Per unit, the areas left uncut will not be significantly large. Yet, in terms of the entire forest, these unharvested acres will undoubtedly add up.

Another factor to take into consideration is the district's interpretation of adjacency. Both a conservative and a liberal definition of adjacency were taken into account in this study. Considering units to be adjacent regardless of the overlap was a conservative interpretation of adjacency. In other words, if two units touched at all, they were treated as adjacent units. Treating riparian zones as units was a liberal interpretation of adjacency. This implied that units lying on either side of a riparian area could both be harvested at the same time. Whether these units should be considered adjacent or not is usually evaluated on a case-by-case basis, taking other factors into account. In the past, districts have tended to favor a conservative approach in both instances.

SNAP's usefulness as an analysis tool, in implementing the Forest Plan on Green River, was evaluated by the following criteria:

1. How difficult was it to prepare the data required for the SNAP analysis?

   SNAP requires its data be entered into files. These files are easy to assemble, because menus guide the user step-by-step throughout the input process. SNAP's User's Guide is also very useful, and easy to follow. Spatial information must be digitized using LIDES and transformed into SNAP files. LIDES, if never used before, takes longer to master than SNAP itself. Currently, the Forest Service is transferring most of its resource maps to Geographic Information Systems (Weisz, 1988). The required digitized information from GIS can be transferred to LIDES, thus saving the necessary time involved in learning LIDES.

2. How accurately does SNAP incorporate standards and guidelines into its analysis?

   SNAP was able to implement all the standards and guidelines outlined in this study. To do this, data input must be manipulated in such a way as to reflect these requirements. For example, unlike FORPLAN, SNAP does not assure that only 20% of a subbasin will be harvested, unless the user specifies a volume goal reflecting this percentage. Likewise, SNAP will harvest in any unit-- regardless whether or not it is a plantation or marten area-- unless the user specifies a status of "non-timbered unit" for the polygon. Except for determining which harvestable unit should be harvested, SNAP is not a tool for deciding upon an area's future condition (unless one were to play "what if" games by changing each unit's status).

3. How accurately does SNAP represent the forest?

   Each unit in SNAP has its own file, in which a series of attributes can be used to describe the unit in detail. Some of these attributes include species (specify up to three), volume, silvicultural prescription, and pond value. Volume yield in SNAP is perhaps the least-accurately represented characteristic for each unit. SNAP does not access a yield table, so as to reflect increases in volume each period.

4. How difficult is it to change data in SNAP?

   Because of the menu system, it is very easy to access files that require changes in data. For example, if a fire destroys an area scheduled to be harvested, the status of the units can be changed by entering the SALE Editor file. A new harvest schedule may then be created by re-running the old LINK, MILL, and ECONOMICS files with the revised SALE file. Physical changes to the polygon map must be re-digitized using LIDES. Road segments can be added in the ELD program if the nodes connecting the segments already exist.

5. How long does SNAP take to run an analysis?

   Once all the data was entered, SNAP took approximately four minutes to run the Green River analysis. An additional two minutes was required to reanalyze both pattern 2 and pattern 12.

6. How much does it cost to run SNAP?

   Running SNAP does not require "logging-on" to a centralized computer system. Assuming the user has access to an HP 9000 and the SNAP program, there is no cost incurred per analysis. Currently, USFS Region 6 has over 60 HP 9000 systems at its 19 National Forests. Thus, SNAP is a cost-efficient tool for plan implementation, accessible to district personnel.

7. How difficult is it to interpret results (SNAP output)?

   SNAP displays its results in both tabular and graphic form. All reports (their columns, rows, x-axes, and y-axes) are clearly labeled and defined in the SNAP User's Guide.

8. How useful are these results to forest planners?

   SNAP has the potential to illustrate both the spatial and the financial ramifications of implementing standards and guidelines at the subbasin level. However, the usefulness of SNAP's results are based on the planner's interpretation of the standards and guidelines and the accuracy of the forest's database. SNAP's results should be integrated with "a human system of resource management" (J.Garland, 1988). This accounts for site-specific information possibly not represented in the model.

Judging from this evaluation and the Green River analysis itself, SNAP is undoubtedly an effective tool in Forest Plan implementation. SNAP's ability to incorporate the Forest Plan's standards and guidelines gives timber sale planners a realistic outline for scheduling harvests. The ease of manipulating data in SNAP offers opportunities to play "what if" games for scheduling harvests as well. Again, SNAP is not a complex program to use. District personnel can easily input data, change data, and interpret SNAP results without having a technical background in analysis. In light of the complexity of developing the Forest Plans, SNAP offers a welcome alternative for their implementation.

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