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IMPROVED FOREST HARVEST PLANNING
- INTEGRATION OF TRANSPORTATION ANALYSIS
WITH A MANAGEMENT UNIT CUT SCHEDULING MODEL

by

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ABSTRACT

Forest harvest planning involves determining, in time and place, the flow of timber to be generated from the forest resource. Existing planning models have addressed the temporal aspects of timber supply. However, the spatial aspects of timber supply planning, particularly at the management unit level, have principally been ignored.

This study presents an analytical framework for examining the transportation system of a management unit, its interrelationship with the timber base, and the impacts on strategic harvest planning.

The transportation system is evaluated through network analysis techniques. Routing strategies from the stand to the mill are examined. The costs of primary access development and log transport are integrated with the forest inventory, providing a more complete assessment of timber value.

Homogeneous stand aggregations and associated yield projections, pertinent to management unit planning, are formed using factor and cluster analysis. Dynamic programming allows optimal allocations of the stand groupings across stratifications which recognize transport and accessibility costs. The resulting timber classes are coupled with management prescriptions and evaluated through a cut scheduling model. Report generation capabilities then allow interpretation of the harvest scheduling results in terms of not only the timber

classes, but in the spatial context of the individual stands.

The methodology is applied to a British Columbia Public Sustained Yield Unit. The usefulness of the system is demcnstrated through analyses which:

1) identify road development and transport costs,
2) evaluate alternative wood flow patterns,
3) identify the volume flow potential of the unit,
4) identify the dollar flow potential of the unit, and
5) illustrate the contribution of integrating the transportation system in the scheduling of harvests.

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1. INTRODUCTION

The scheduling of timber harvests within a forest management unit has far reaching consequences. Environmentally, the rate of harvest affects the long term ability of the land to produce both timber and non-timber benfits. Economically, harvesting rates affect industrial operating strategies. More than ever, mill and market expansions are contingent on the continued availability of timber supplies.

Decisions affecting the flow of timber, despite their critical nature, cannot always be deferred until complete information is at hand. British Columbia has a valuable timber resource, and an industry developed for its utilization. Harvest scheduling can, however, be improved by planning.

Harvest planning involves not only the timber base, but also its interrelationship with the transportation network. Accessibility and log hauling requirements are key factors which must be considered in the scheduling of wood flows.

This thesis presents a quantitative, analytical methodology for harvest planning at the management unit level. The system developed integrates transportation considerations to improve cut scheduling decisions.

1.1 Forest Harvest Planning

Planning is any activity designed to provide efficient, controlled courses of action directed at achieving some identified end. It is a continuous activity, and as such must be flexible and dynamic. Planning allows assessment of change in economic, biological and social conditions. It facilitates consideration of alternatives and resolution of conflicts, thereby guiding decision making. Hence, planning is the foundation for efficient management.

Forest harvest planning encompasses those activities designed to provide efficient, controlled strategies for scheduling timber flows. The strategies are directed at achieving specified wood quantity and quality objectives, as well as allowing the integration of other resource uses. The main objective from a government standpoint is volume yield control. In contrast, the main objective of an industrial firm is the generation of cash flow and profit, i.e. value yield control. However, the need for an assured raw material supply provides for a consolidation of the two objectives.

Economics plays a fundamental role in the planning process. Scarcity, in turn, plays a fundamental role in the economic process. Economics is concerned with the efficient allocation of scarce resources so as to optimize a specified objective. If resources were not scarce, then there would be little need for efficient allocation. Without need for efficient allocations there would be little need for planning. Hence, the concepts of scarcity and economics are fundamental to planning.

Scarcity has also played a fundamental role in forest harvest planning. The early stages of the forest industry in British Columbia, and North America in general, were marked by an overabundance of forested lands. The most accessible, best quality stands were harvested. Timber of inferior species, size and quality was not cut. Such harvesting activities have been considered wasteful exploitations, resulting from a lack of planning. However in economic terms, such "explotations" were rational actions. In the face of excess timber supplies, there was little need for efficient allocation of timber resources, and thus no need for planning.

As excess inventories are depleted, the issue of scarcity develops. Reduced timber supplies force harvesting activities to the margins. Smaller diameter, lower quality stands are harvested at the intensive margins. More distant, less accessible stands are harvested at the extensive margins. At these margins the need for efficient allocation of resources becomes critical to viable operation.

The majority of the industry is currently facing operations at the margins. At the same time, there is ever increasing pressure for the production of a variety of goods and services from the forest land base. The forest industry is now aware of the necessity for proper planning to integrate timber supply needs with other forest land uses.

1.2 Levels Of Forest Planning

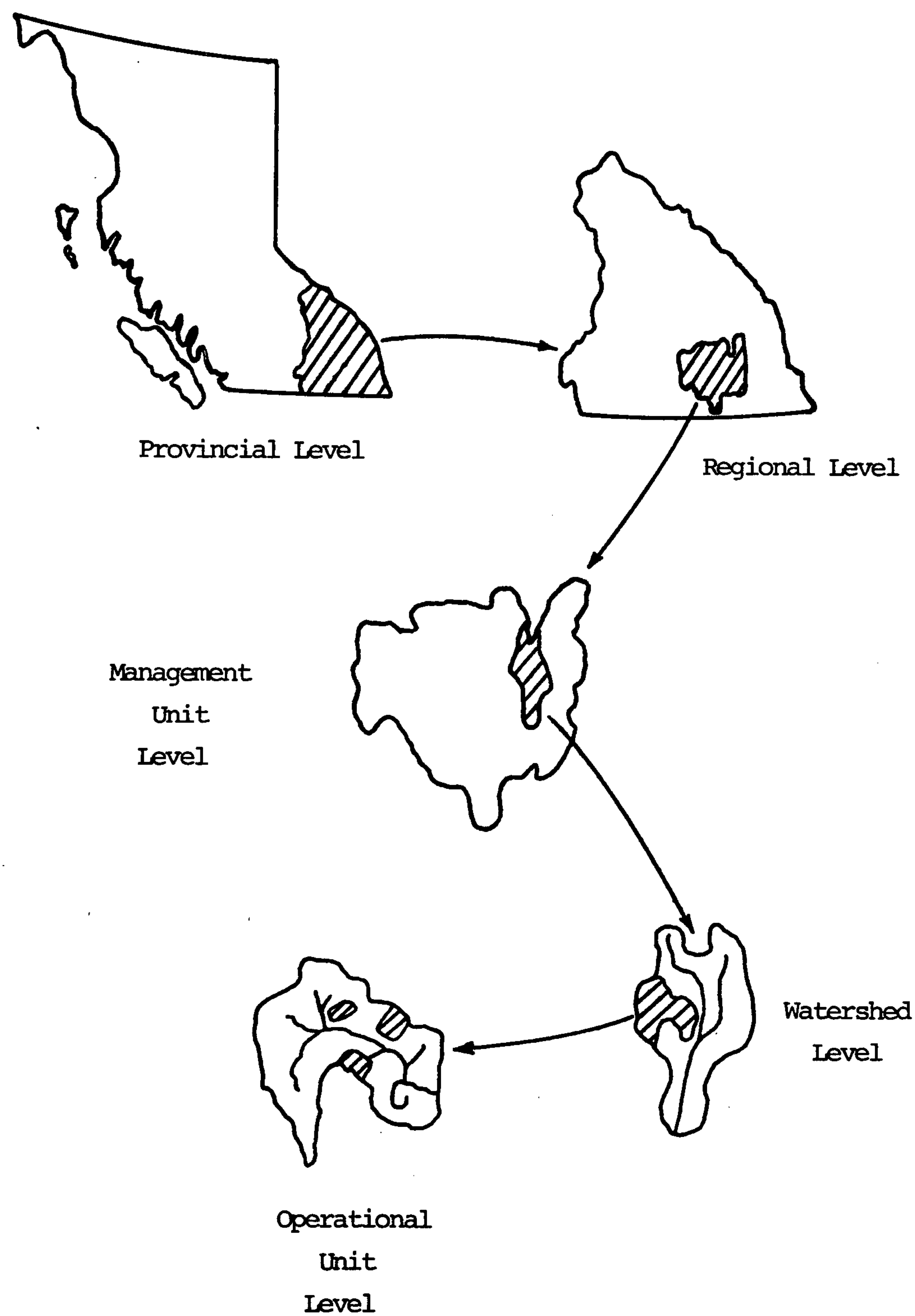
The British Columbia Forest Service (BCFS), the public agency responsible for management of some 95% of British Columbia's forest lands, recognizes five levels of forest land planning (Figure 1):

1) the provincial level,
2) the regional level,
3) the management unit level - Public Sustained Yield Units (PSYU) and Tree Farm Licences (TFL),
4) the watershed level, and
5) the operational unit/cut block level.

These planning levels provide a framework for linking philosophical policies to actual, on-site operations. At the higher levels, the planning horizon is longer and the objectives are more broadly stated. Conversely, at the lower planning levels the horizon is more immediate and the objectives more precisely defined. Williams (1976) noted the interrelationships that exist within the planning framework.

Decisions at any particular level constrain the activities of neighboring levels. For example, if the objective at the regional level is to develop the timber resource, then a corresponding industrial infrastructure must be established. A suitable harvesting schedule would have to be developed at the management unit level, subject to the industrial needs. Activities would involve evaluation of land use potentials, including assessment of the inventory and transportation system. The harvest scheduling strategy determined would then direct the

Figure 1. Levels of Forest Planning (BCFS, 1975)



development of watersheds. This example is a simplification of the actual process. Factors such as public values and political issues also enter into the planning picture. Nevertheless, the multi-level planning framework facilitates coordination of the planning effort within a temporal and spatial continuum.

The purpose of this thesis is to provide a methodology for explicitly integrating transportation considerations into management unit level harvest planning. A computer modelling system is presented which incorporates the effects of log transport and primary access development with the forest inventory, thereby providing a more complete assessment of timber value. This improved valuation, coupled with other management information is then assembled and evaluated through a cut scheduling model. The result is improved long term and short term forest harvest planning.

The following chapter reviews the development of pertinent harvest planning models. A problem analysis of harvest scheduling is then presented. Next, the methodology used in the study is described, followed by its application to an actual forest management unit in British Columbia.

2. FOREST PLANNING MODELS

2.1 Aspects Of Models

Models have been developed to facilitate effective, comprehensive forest land planning. They are an outgrowth of increasing management demands. More data, faster response time and the evaluation of alternatives, all under limited manpower, typify today's planning environment.

Models simplify the complex nature of problems to a manageable degree. The real problem is reduced to an abstraction. Only those factors identified as significant are represented, with less critical details ignored. The abstraction is then analyzed, typically with the aid of a computer. However, since the actual problem is not fully represented absolute answers do not result.

A major limitation of planning models is that the actual planning process is not a well defined activity. Consequently, validating a model against present practices is very difficult. Models and the modelling process, nevertheless, do offer numerous advantages. The model formulation stage can reveal significant factors which may otherwise be obscured by normal analysis. A model when properly formulated provides the capability for objective assessments on a reproducible basis. Further, a model provides a framework around which management knowledge and experience can be quantitatively expressed and explicitly incorporated in the planning process.

The computerization of models has provided the ability to evaluate many factors on a dynamic basis, with greater speed and efficiency than possible under manual procedures. Such improvements have enabled the evaluation of new alternatives. The end result is improved utilization of data and a reduction in the uncertainty around which decisions are made.

2.2 A Review Of Mangement Unit Planning Models

One of the first published efforts which introduced the use of computerized models for forest harvest scheduling was by Curtis (1962). He applied Linear Programming (LP) in the cut scheduling of southern pine stands to maximize both volume and revenue production. The application, however, considered a planning horizon of only one rotation and was specific to one forest company.

Loucks (1964) extended the application of LP to cut scheduling by developing a more general model directed at sustained yield management. His formulation included a capability to consider a variety of management and silvicultural alternatives. Leak (1964) used LP to examine the maximum allowable yields generated from a series of final cuts and thinnings over a single rotation. He considered harvest alternatives which yielded equal areas, as well as equal volumes. Kidd et al. (1966) incorporated biological factors of site and age with silvicultural alternatives over a five-period horizon in using LP for forest regulation. Littschwager and Tcheng (1967) introduced LP decomposition techniques for solving large scale versions of the earlier formulated harvest scheduling problems. The technique of solving a series of smaller subproblems was found to be useful for scheduling cuts over a large number of forest compartments.

Bare and Norman (1969) introduced the application of Integer Programming (IP) to harvest scheduling. Their formulation included the scheduling of both stands and entire compartments. Previous LP applications had resulted in non-integral solutions. Through IP, harvest schedules can be found which preserve the integrity of existing forest stands. However, the lack of an efficient algorithm greatly limits the application of IP to scheduling problems of realistic proportions.

Walker (1974) combined the economic concepts of supply and demand with the forest inventory to determine rates of harvest. His model, named the EConomic Harvest Optimizer (ECHO), maximizes present net value. The solution strategy employed equates the marginal net revenue derived from harvesting for each time period. ECHO incorporates downward sloping demand curve relationships where timber price varies inversely with the volume harvested. This relationship was not characteristic of previous models. Also unlike past approaches, sustained yield or volume flow constraints were not imposed. Instead, Walker criticized the criterion of sustained yield for determining optimal economic harvest levels.

Johnson (1976) pursued the significance of a downward sloping demand curve on harvest scheduling and value maximization using a quadratic programming formulation. He demonstrated, contrary to popular belief, that value optimization could be achieved by restricting volume harvested. Under a price responsive situation, the market mechanism will act to constrain volume flow. Hence, proper consideration of the price elasticity of demand allows achievement of optimal economic allocations, not possible under imposed sustained yield constraints. Hrubes and Navon (1976) demonstrated that a downward sloping demand curve could be incorporated into LP formulations by using separable programming in situations where volume harvested can affect stumpage prices.

Clutter (1968) presented a more complete computerized forest management planning system. The system included an appraisal simulator in conjunction with an LP harvest scheduler and report writer. The simulator calculated volume and value yields generated by alternative clearcutting policies for each cutting area. The cut scheduler then selected that set of alternatives which maximized present net worth subject to certain specified volume flow and area constraints. His system, Max-Million, has been adopted as an operational tool for management planning of southern pine forests by a number of companies (Ware and Clutter 1971).

The Timber Resource Allocation Method (RAM) is an LP timber planning system developed by Navon (1971) for the United States Forest Service (USFS). This system is similar in concept to

Max-Million. It takes a forest inventory and a set of alternate management prescriptions for each forest type and determines the optimal harvest schedule according to either a volume, revenue or cost objective. The long range planning horizon (up to 350 years) and current operational use on a number of United States National Forests distinguish Timber RAM from previous scheduling models. In fact, a USFS review (Mass, 1974) of computerized planning systems recommended that Timber RAM be used for allowable cut calculations and long range volume predictions[1].

The Resource Capability System (RCS, Mass 1974) is a multiple resource planning tool. Forage, sedimentation, recreational visitor days, as well as timber, are products considered from the total land base. LP is used to schedule the mix of resource activities for a given management unit. The primary benefit from RCS is a quantitative means of evaluating alternative land use combinations. However, RCS has limited applicability for timber planning. The model is not well structured for evaluating detailed timber management alternatives and is only capable of handling eight time periods.

Fowler (1978) discussed the need for estimating the impact of forest management decisions on broader socio-economic factors of a region. He presented a system of submodels to address this need. In addition to an LP cut scheduling model, he added:

1) a forest measurement simulator,

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[1]Further details of Timber RAM will be covered in subsequent chapters.

2) an economic input/output model,

3) an employment estimation model, and

4) a tax projection calculator.

This system enables one to trace a given schedule of timber flows through to its impact on levels of gross regional product, employment and taxes.

Extensions to harvest scheduling models appeared in the planning of forest roads. Odendahl (1975) reviewed several of the planning models used by the USFS for forest transportation analysis. The most pertinent of the models discussed, the Timber Transport model, was designed for analyzing modifications to an existing road network which links harvest areas to mills. This model is actually a system consisting of a route generator, matrix generator, an LP/IP optimizer and a report writer. Traffic allocations and assignments are produced based on the optimization of either a cost or revenue objective. The Timber Transport model is particularly useful for examining traffic volumes, for costing alternative route flows, and for assessing additions, improvements or deletions to the road network.

Navon (1975) presented two models for forest transportation planning. The first model addressed short run analyses of up to five years. It was assumed in the short run that both volume and location of harvest were known, with the planning problem reduced to determining the minimum cost strategy of hauling and road construction activities. The second model addressed long term planning. A detailed discussion is presented by Weintraub and Navon (1976). The long term model included timber management activities as well as hauling and road construction activities. The problem was to find that combination of activities which would optimize an economic objective, either minimum costs or maximum revenues. Both the short and long run models use a mixed integer linear programming formulation. Road construction activities were modelled as integer variables with silvicultural and hauling activities as continuous variables. As with most IP problems, the number of integer variables must be limited to keep the problem within solvable dimensions.

A progression in the development of forest harvest planning models has become apparent upon reviewing the literature. Initially, applications emphasized the biological aspects of growth and volume yield, particularly in the context of a sustained yield philosophy. Models then began to place more focus on the bio-economic aspects of harvest planning. From there the modelling effort has been characterized by the development of systems of models rather than a single model to address forest harvest planning. We are now at the stage where extensions to previous models are being developed (Williams, 1976). The focus is on improving and combining existing tools, rather than on developing entirely new techniques or models.

3. PROBLEM ANALYSIS

The problem analysis process basically involves the identification of; the decision maker, the objective, and the alternatives available to satisfy the objective. Among the alternatives there has to be doubt as to which is best. Constraints affecting the alternative-objective relationship must also be identified within the problem environment. The existence of a problem would not be clearly recognized if any of the above components were not identified.

The decision makers to which this thesis is directed are the forest managers who plan harvests at the management unit level. Included in this group are both government managers responsible for PSYU's, and industrial managers responsible for TFL's.

The basic objective of the forest manager, in regards to harvest planning at the management unit level, is to schedule the harvest of the supply of timber over time in an optimal manner. The desirability of possible cutting schedules is measured in terms of volume and value flow, giving due consideration to non-timber resources. Harvest scheduling encompasses the determination of:

1) the cut level,
2) the time period for harvest,
3) the species composition of the cut, and
4) the possible areas of harvest.

Several alternatives exist in addressing the four aspects of harvest planning. Planning time requirements and the ability to evaluate a variety of scenarios are measures by which alternative harvest regulation methods can be judged. Two particular alternatives are considered below; the present and historical method of determining harvest schedules, and a new approach which has gained considerable attention.

3.1 Harvest Scheduling - Background

The historical approach to harvest scheduling has been based on biological yield criteria. Cut regulation policies were non-existent in British Columbia prior to 1947. In the early 1950's sustained yield regulations were instituted to determine annual allowable cut levels as a result of the second Royal Commission of Inquiry related to British Columbia forest resources. The early attempts at determining harvest levels were based on the Hanzlik formula (Hanzlik, 1922). This formula was designed for the regulation of mature and over-mature forests. The basic form of Hanzlik's formula is shown below:

$$\text{Annual Allowable Cut} = \frac{\text{Volume of Mature}}{\text{Rotation Age}} + \begin{array}{c}\text{Mean Annual}\\ \text{Increment}\\ \text{of Immature}\end{array}$$

Subsequently, harvest levels were determined by a more detailed computational procedure designed to maximize mean annual increments of growth. In this process, localized estimates of growth and yield are obtained from the timber inventory of the management unit in question. Such estimates provide the basis for determining total yields and annual yields of mature and immature forest types. The annual yields represent a cut level which maximizes the rate of physical production from the forest base. A biologically optimal rotation age for each forest type is then determined by dividing the total yield by the annual yield. An iterative procedure called an "area/volume allotment check" is then carried out to verify the compatibility of the specified rotation age with the tabulated annual cut. If necessary the annual harvest level is adjusted so that the time period in which to harvest all age classes corresponds to the optimal rotation. Complete details of the BCFS annual allowable cut calculation can be found in a policy paper (Haley, 1975) from the most recent Royal Commission into forest resources[2].

A number of administrative adjustments are subsequently made to the indicated allowable cut level to reflect volume losses due to land alienations for non-timber uses, fires, roads, regeneration delays and other silvicultural and harvesting induced losses. The net result is an administratively approved cut level for a one year period for the management unit of concern. The above procedure has been used for determining annual harvest levels for both PSYU's and TFL's.

The determination of the remaining scheduling aspects of

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[2]Pearse, P.H., 1976. Timber Rights And Forest Policy, Report Of The Royal Commission On Forest Resources

what and where to harvest have also been based on volume criteria. From the government viewpoint, assignment of cutting priorities to stand types based on an increment gain philosophy has identified what species to harvest. High priority is given to those stands which, when replaced, result in greater growth. These prioritized stand types are then identified on the inventory type map showing potential harvest areas. From the industrial viewpoint, product marketing requirements are becoming increasingly prevalent in dictating species flow from the harvest. Potential harvest areas which will contribute to the desired species mix are again identified on the inventory type map.

3.2 Harvest Scheduling - Need For An Alternative

There are several disadvantages to the harvest planning approach described above. Foremost is the lack of economic considerations in the establishment of harvest regulation at the management unit level. The rate of timber harvesting has been determined so as to maximize biological productivity, and not necessarily economic or social returns. Economic as well as biological assessment of the management unit will provide an improved basis for cut scheduling. In particular, the need exists for the economic factors regarding species flow and harvest area accessibility to be explicitly integrated in the determination of the rate of harvest. Recently, the formal incorporation of economic analysis with biological analysis was evidenced on one of the National Forests in California (Craig, 1979). This study demonstrated that departures from a strict even flow sustained yield approach resulted in opportunities for increased levels of harvest, revenues and jobs without adversely affecting the long term biological capacity of the management unit.

A second disadvantage of present harvest scheduling methods is the limited opportunity for assessing alternatives. The need exists for assessing the impacts of possible current decisions over a long range horizon. Previous planning methods did not facilitate analysis of a spectrum of harvest schedules in a timely manner, a deficiency largely a result of the manual process of allowable cut determination.

A third major disadvantage is the absence of transportation considerations in determining timber flows for a management unit. The selection and timing of harvests are principally a function of the timber value, its location and its accessibility. Not only does the transportation network represent a major physical constraint in terms of access, but it represents a major expense. Roads represent approximately 20% of the capital investment of a harvesting operation in British Columbia, with the costs of construction not uncommonly exceeding $70,000 per mile ($43,497/kilometre). Substantial savings can be realized through thoughtful integration of cutting schedules with hauling and construction activities.

The integration of timber planning and transportation planning systems was endorsed in a review of USFS planning systems by Weisz and Carder (1975). In this regard, Weintraub and Navon (1976) state:

> "The sequential non-integrated approach leads to suboptimization on two counts:
>
> 1) the wrong set of harvest areas may be made accessible, and
> 2) the choice of period of access to each node (harvest area) may not be optimal"

In other words, transportation-related activities are major decision variables in harvest planning and should be given due consideration along with silvicultural activities.

Greater demand for other resources has forced alienations from the timber base. These supply-reducing pressures, coupled with the increasing demand for wood products have substantially increased raw material costs to the forest industry. Such changes in the physical and economic environment only accentuate the deficiencies of past harvest planning practices. The latest Royal Commission into British Columbia forest resources, the new Forest Act and the accompanying regulations are evidence that forest policy must be dynamic. Changes must be made to keep in step with economic and social needs. Change is now appropriate in the regulation of harvests. The traditional concepts and basis for harvest scheduling are no longer adequate or applicable to current planning needs.

The alternative method presented in this thesis to address the deficiencies identified above is the TRansportation Analysis-Cut Scheduling (TRACS) system. TRACS makes use of resource inventory compilations and management prescriptions to provide growth, yield, cost and revenue data for harvest schedule determination. Long range impacts of a variety of management strategies on both a volume and value basis can be evaluated. Furthermore, TRACS allows in its evaluations the explicit consideration of stand accessibility in terms of road construction and log transport. The result is a harvest planning system which integrates transportation in the biological and economic evaluation of cutting schedules for a management unit.

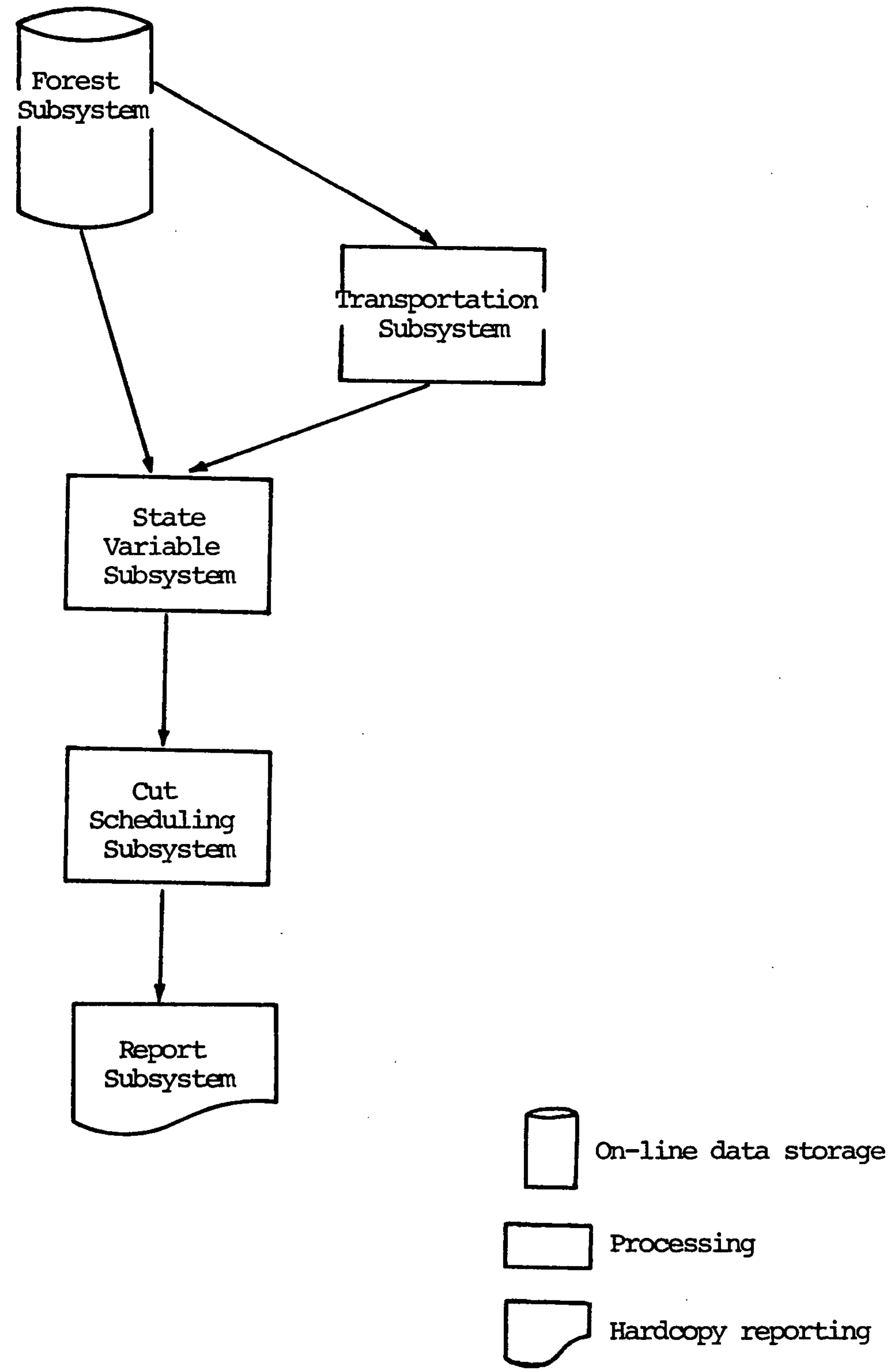
4. MODEL COMPONENTS

This thesis expands the effectiveness of existing management unit level harvest planning tools. In doing so, the TRACS system methodology draws largely from the components of the Computer Assisted Resource Planning (CARP) system (Williams et al., 1975). CARP was developed for the BCFS as a prototype harvest planning system. The original methodology has been extended by developing a transportation modelling subsystem. The results from this transportation subsystem are subsequently incorporated in cut schedule determination.

The flowchart in Figure 2 outlines the basic analytical structure of the TRACS system. The following five major subsystems are presented:

1) the Forest subsystem,
2) the Transportation subsystem,
3) the State Variable subsystem,
4) the Cut Scheduling subsystem, and
5) the Report subsystem.

Figure 2. Components of the TRACS System



4.1 Forest Subsystem

All methods of determining harvest levels first require an inventory of the physical resources of the management unit. Typically a map overlay system provides the foundation for compiling information on the supply of resources available. The overlays would include vegetation type and land classification as a minimum. The type map provides information on species, age, site and timber yield. The land classification map provides information on soils, landform, parent material and drainage characteristics.

The overlay process delineates distinct land units for which area and productive capability can be identified. All corresponding information is compiled as attributes of these physical geographic units. Land use plans and management prescriptions related to the identified land units accompany the physical resource information. Use suitability and prescribed treatments are derived as a function of local knowledge and soil-landform characteristics, and provide the basis for cost estimation.

Those areas having productive forest cover form the basic "stand" unit. Stands represent the finest level of resolution for unit planning. For each stand, the following attributes comprise the data base:

1) stand number
2) compartment number
3) geographic location
4) species type

5) land class

6) age class

7) site class

8) area

9) net volume per unit area

10) designated use(s)

11) harvesting method

12) season of harvest

13) earliest and latest harvest entries

14) expected site preparation

15) expected regeneration

All of the above information is assembled and maintained on a computerized data management and retrieval system. A computerized data base serves three basic functions. Firstly, it provides rapid answers to on-demand user queries. Secondly, it provides for generation of standardized management reports. Thirdly, it provides for the generation of basic data for further analysis.

As mentioned, the stand inventory provides an indication of productive capability of the land. The BCFS derives localized estimates of timber growth and yield through sampling. These estimates reflect average volume production per area to a given utilization standard, less deductions for decay. The yields are presented in graphical form in which volumes are plotted against age by species type, geographic location and site. These BCFS Volume/Age Curves (VAC) are a rudimentary form of a whole stand-distance independent growth model. The VAC's provide the basis for the standard annual allowable cut calculation procedure. The same basis for growth and yield projection is used in this thesis because of availability and also to demonstrate how the same data can be utilized to generate more information to aid management.

4.2 Transportation Subsystem

As previously discussed, the transportation system represents major decision variables in forest harvest planning. The importance of transportation considerations has been evidenced in a study by Herrick (1976). He found that hauling distance is one of the most critical determinants of successful logging operations.

Reliable estimates of the costs of moving logs from the landing to the manufacturing plant are required for proper stand valuation. However, models for evaluating such costs have not been long established in forestry. TRACS allows for the generation and evaluation of transportation-related costs. The transportation subsystem presents a procedure for deriving cost estimates for truck transport based on a minimum routing network analysis technique.

4.2.1 Derivation Of Transportation Costs

Two main factors affect the estimate of transportation costs for a given stand:

1) the transportation network, both existing and proposed, and
2) the location of the forest stand in relation to both the network and the manufacturing plant.

The typical forest road network can be characterized by two attributes; road class and, type of haul (i.e. on vs. off highway haul). These two characteristics determine the quality of the road network and the type of transport medium which utilizes the network. Road classes relate to the design and capability standards in terms of maximum allowable vehicle speeds and traffic concentrations for the road. They are significant as they directly affect "cycle" times for travel from landing to mill and back to landing. The type of hauling medium permissable, either on-highway or off-highway trucks, is also a significant factor. This characteristic directly affects allowable load limits and truck speeds.

More specifically, cost estimates for truck transport, in dollars per unit volume, are a function of four components:

1) distance
2) speed
3) machine rates
4) load size

Distance divided by allowable truck speed, loaded and unloaded, provide cycle times. Cycle times applied against machine rates for logging trucks yield costs for log transport in strict dollar terms. This cost when divided by load size generates log hauling cost in dollars per unit volume of wood. The derivation can be summarized as follows:

1) Distance/Average Speed = Cycle Time
(miles) (miles/hour) (hours)

2) Cycle Time X Machine Rates = Cost
(hours) ($/hour) ($)

3) Cost/Load Size = Transportation Cost
($) (cunits) ($/cunit)

Thus, hauling distance is the initial factor which contributes towards transportation cost derivation. Distances from the stand to the road network and through the network to the mill are required. Network analysis provides a means for determining the necessary hauling distances and facilitates the assessment of hauling strategies. The following section defines some basic terminology which will be introduced in the discussion of minimum routing and its application to stand valuation.

4.2.2 Network Analysis

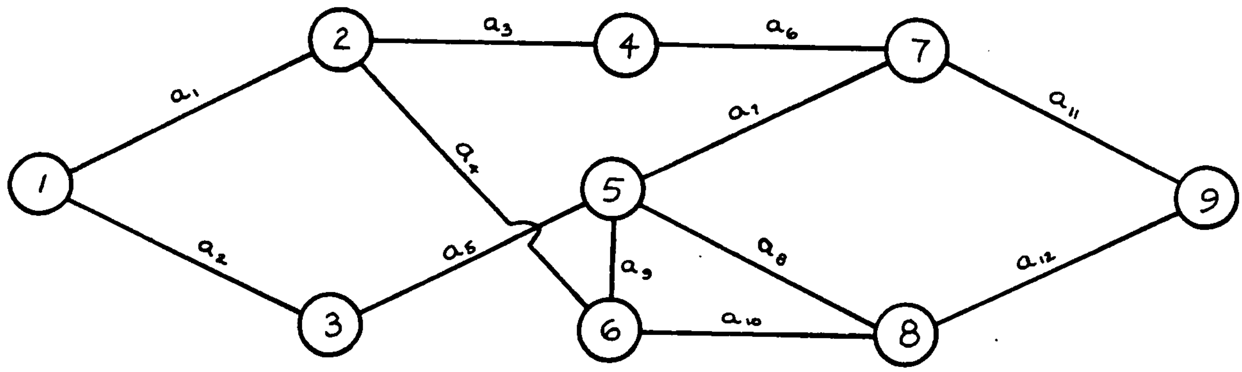
A basic characteristic of graphs and networks is their combinatorial nature. A graph is a collection of nodes joined by a collection of arcs. Graphs define purely structural relationships. A network is a graph containing in addition, flow, distance or some other measurable attribute associated with the member arcs and/or nodes. Thus, networks provide quantitative descriptions as well as defining structure.

In mathematical notation, the set of nodes can be represented by $N = \{i \mid i = 1,\ldots,n\}$, and the set of arcs represented by $A = \{(i,j) \text{ or } (j,i) \mid i \in N, j \in N\}$. Given the above two sets, a graph can be defined as the set $G = \{N,A'\}$ where $A' \subseteq A$. Extending the notation, node attributes can be represented by $B = \{b_i \mid i \in N\}$. Similarily, arc attributes can be represented by $C = \{c(i,j) \text{ and/or } c(j,i) \mid (i,j) \in A\}$. Given these additional sets, a network can be defined as the set $W = \{N,A',B,C'\}$ where $C' \subseteq C(A')$.

A number of other "graph-network" terms also require definition. A "branch" is an arc together with its corresponding end nodes. If all branches are unordered, where arc (i,j) = arc (j,i), then the graph, G, is "undirected". Conversely, if the branches are ordered yielding some sense of direction between the nodes (where arc $(i,j) \neq$ arc (j,i)), then the graph, G, is said to be "directed". A "source" node is oriented such that arcs lead away from it, whereas a "sink" node is one in which arcs are directed towards it. Figure 3 presents examples of both an undirected and a directed graph.

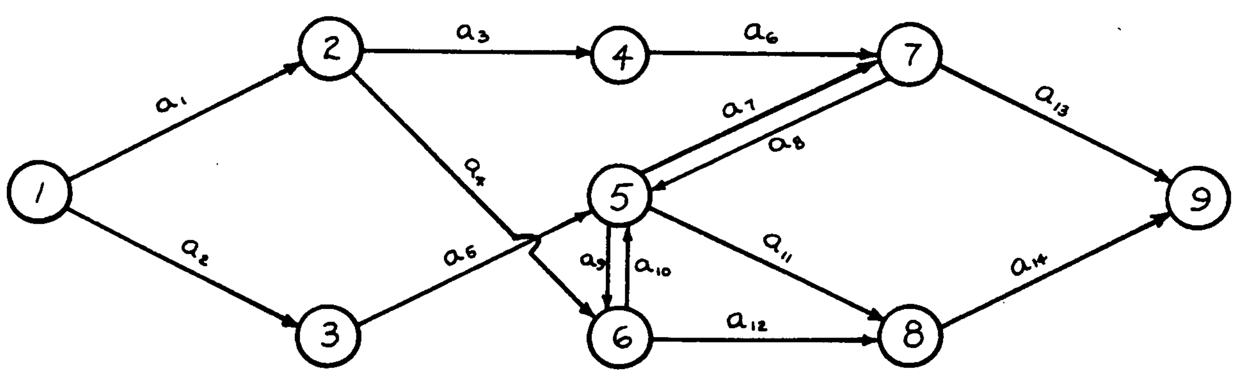
Figure 3. Examples of Graph Structures

Undirected Graph, $G_1 = \{N_1, A_1\}$:



Node Set : $N_1 = \{1,2,\ldots,9\}$
Arc Set : $A_1 = \{a_1,a_2,\ldots,a_{12}\}$
where $a_k = (i,j) = (j,i),\ i,j \varepsilon N_1$

Directed Graph, $G_2 = \{N_2, A_2\}$:



Node Set : $N_2 = \{1,2,\ldots,9\}$
Arc Set : $A_2 = \{a_1,a_2,\ldots,a_{14}\}$
where $a_k = (i,j) \neq (j,i),\ i,j\ \varepsilon\ N_2$
Source Node = {1}
Sink Node = {9}

Corresponding set definitions accompany the diagrammatic representations. Note also, intersections occur only at nodes, not where arcs are shown to cross each other.

The "degree" or "order" of a node is the number of arcs incident upon it. A node of degree 1 is an extreme point[3], and its corresponding arc is a terminal arc. Further, arcs are defined to be adjacent if they are incident on a common node. Completing the terminology, a "path" is a series of ordered, adjacent branches leading from a given node i to another node j such that each intervening node is encountered just once. A path initiating and terminating at the same node is called a "cycle" or "loop". Conversely, an acyclic path is referred to as a "simple path". A graph, G, is "connected" if there exists at least one path connecting any two nodes i and j, where $i \in N$ and $j \in N$ and $i \neq j$. As a final term, a "subgraph" of G is that subset of nodes, $N' \subseteq N$ together with the appropriate subset of incident arcs, $A' \subseteq A$.

The Shortest Route problem involves finding the feasible path of minimum distance from a particular source node to a particular sink node. The problem is characterized by a directed graph, $G = (N,A)$. The node set, $N = (i \mid i=1,\ldots,n)$, can be partitioned into three subsets:

1) N_1 = source nodes,

2) N_2 = intermediate nodes, and

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[3]However the converse is not true. It is not necessary for an extreme point to be a node of degree 1.

3) N_3 = sink nodes

The arc set, $A = \{(i,j) \mid i \varepsilon N, j \varepsilon N\}$ where $A \geq n-1$, connects every pair of nodes. There exists a set of attributes, $C = \{C(i,j) \mid (i,j) \varepsilon A\}$, associated with each arc between nodes i and j. The feasible path between nodes i and j can be represented by x_{ij}. The following additional conditions also hold:

1) the arc attributes c_{ij} need not be symmetric, i.e. $c_{ij} \neq c_{ji}$,
2) the attributes c_{ij} are non-negative, i.e. $c_{ij} \geq 0$,
3) the value of an attribute from a node to itself is zero, i.e. $c_{ii} = 0$, and
4) where no arc exists between any particular pair of nodes, the attribute c_{ij} is assumed to be infinite.

Given the above specifications, the Shortest Route problem can formulated as follows:

$$\text{MIN } Z = \sum_i \sum_j c_{ij} x_{ij}$$

subject to :

$$\text{i) } \sum_h x_{hi} - \sum_j x_{ij} = \begin{cases} -1 & \text{for } i \varepsilon N_1, \text{ where } N_1 = \{1\} \\ 0 & \text{for } i \varepsilon N_2, \text{ where } N_2 = \{2,\ldots,n-1\} \\ 1 & \text{for } i \varepsilon N_3, \text{ where } N_3 = \{n\} \end{cases}$$

$$\text{ii) } \quad x_{ij} \geq 0 \text{ for all i}$$

The objective is to find the route which minimizes the total distance travelled from a specified source to a specified sink. The first set of constraints specify that only a single unit flows out of the source (N_1) and into the sink (N_3), while flow is conserved at the intermediate nodes (N_2). The second constraint states all flows are to be positive. In the usual case, the arc attributes, c_{ij}, represent distances between respective nodes. However, the arc attributes need not be restricted to distance. They may be times, for determination of the minimum duration route, or probabilities of delays, for determination of the most reliable route, or the attributes may be costs, for determination of the minimum cost route. Note that as with most problems the optimal value (i.e. the minimum distance) is not of key concern, but it is rather the decision strategy yielding optimality (i.e. the minimum route) which is of primary importance.

Closely associated with the basic Shortest Route problem is the determination of the shortest path between a selected sink and all other nodes. As Elmaghraby (1970) points out, almost all algorithms that solve the basic one source to one sink problem, also solve the all sources to one sink problem. The all sources-one sink Shortest Route problem is the one of particular interest.

The algorithm considered to be most efficient in determining the shortest path between a specified pair of nodes is a tree method developed by Dijkstra (1959). The method is a permanent labelling, iterative process in which the distance from a particular source node, 1, to every other node, i, (i=2,...,k,...,n) is determined in ascending order until the specified sink node, k, has been processed, or until all other nodes have processed. The algorithm is capable of handling non-symmetric arc lengths and both positive or negative arc attributes. A detailed description of Dijkstra's algorithm is presented in Appendix I.

4.2.3 Log Transportation Based On Minimum Routing

The forest road system of a management unit can be represented in digital form. Two-dimensional spatial relationships of the road network can be captured from a map through a process of digitization[4]. Road segments can be delineated on the basis of road class, road status and haul type. In other words, road segments represent sections of road of uniform characteristics. Lengths of the individual road segments can be computed directly from the digitized data.

Empirically observed cycle times from centres of active operation can be supplied along with the road system. These cycle times, combined with current machine rental rates and average load volumes, provide transportation costs per volume of log. Distances from the active operations to milling sites allow generation of haul costs in dollars per cunit per mile

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[4]Digitization is the process of recording x and y coordinate values relative to a predefined base origin. The recording of a series of coordinate pairs enables the geographic location of such features as roads to be numerically represented.

($/cubic metre/kilometre). These costings from observed operations can then be used as the basis for establishing hauling cost zones. Within a particular zone, the transportation cost for a given stand can be derived by multiplying the distance from stand to the mill by the respective dollars per cunit per mile ($/cubic metre/kilometre) figure. Alternatively, distance to a pre-determined location for cost appraisal purposes could take the place of the mill site.

The distance from a stand to the mill or point of appraisal involves two components. The first component is the distance from the stand to the access road. The coordinate location of each stand is captured through digitization of a visual centroid. The selection of an access road for a particular stand is based solely on linear distance. In other words, the closest road will be accessed. Pythagorus' Theorem is used to determine this linear distance. This approach is a simplification in at least two respects. First, the distance will be underestimated, since in most cases the path of access from a stand to the road will not be linear. Second, no regard is given to topography which may hinder access of the closest road. Nevertheless, to facilitate an estimate of the first distance component it is assumed that the nearest road will be accessed.

The second component is the distance from the point on the access road through the road system to the point of appraisal. The criterion employed in selection of the route is one of minimum distance. Dijkstra's algorithm, discussed in Section

4.2.2, is used in determining this second distance component.

The forest road system can be represented as an undirected, symmetric network[5]. The node set, N = {i|i=1,2,...,n}, becomes the points of the road class transitions (and road segment end points). The corresponding arc set, A = {(i,j) | i∈N, j∈N} is the road segments themselves with distance as the quantitative attributes c_{ij}, of interest. The source nodes i, $i \in N_1$, are the geo-coordinate centroids of the forest stands. The sink node j, $j \in N_3$ is the point of appraisal, usually a specified mill site. Thus, the situation is formulated as a minimum routing problem involving multiple sources and one sink. The objective is to minimize the distance travelled in proceeding from a source node i, through the network to sink node j. The decision is to determine the routing strategy, x_{ij}, which yields minimum total distance travelled.

The approach of using Dijkstra's algorithm in conjunction with digitized data is unique relative to applications reviewed in the literature. The distinguishing feature of this approach is that as part of the process of determining minimum distances and routings, the precedence relationships of the network are constructed. Node and arc relationships of the road system are assembled and maintained from the initial digital representations, and are not expressly identified.

Cost estimates for primary road development can also be

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[5]Although distances are symmetric, travel times may not be. However, the simplifying assumption is that cycle times are directly related to distance.

generated by the transportation subsystem. Lengths of proposed main roads, by road class, within the network are determined by the subsystem. These distances, when combined with construction costs for given conditions of terrain, parent material and road standard, yield a cost estimate for the proposed road development. The construction costs are then proportioned among the timber volume of the stands which will use the proposed road for access. The result is an additional per unit volume cost estimate reflecting access development. A further use of the subsystem is for evaluating road class selections for proposed construction or upgrading. Tradeoffs between the extra costs for developing better class roads versus the estimated savings in transportation costs can be examined.

The transportation subsystem can also be employed on a stand alone basis for evaluating alternative wood flow patterns from stand holdings to mill complexes. Routing strategies both within and between management units can be examined. Impacts of fluctuations in unit costs for transportation and road construction can be assessed. For example, forecasted fuel price increases, suggested practices of end hauling and other such considerations could be evaluated.

To summarize, the transportation subsystem provides the capability for generating both transportation and primary road construction cost estimates for stand access. The estimates provide a more comprehensive assessment of stand value. This improved appraisal can be used as the basis for independent analysis or can contribute to the overall scheduling of timber harvests at the management unit level.

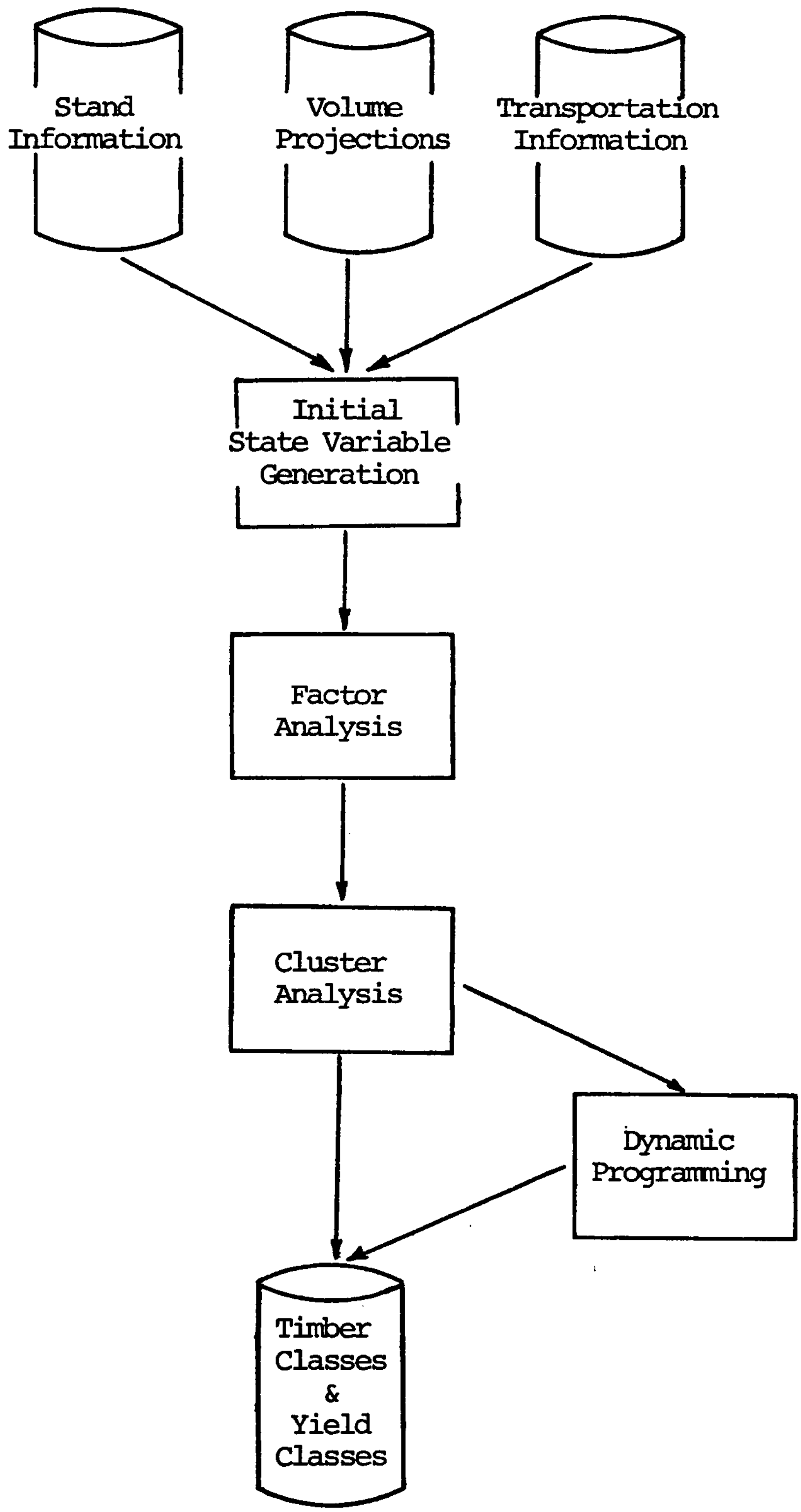
4.3 State Variable Subsystem

Resource managers are being forced to deal with a diverse and ever increasing data base. Under such conditions, the efficient utilization of data becomes a significant concern. The degree and extent to which data should contribute to planning must be identified for rational analysis to take place. The issue is one of data resolution.

The required level of resolution is very much connected with the concepts of planning levels. For regional planning only broad, incisive parameters need be considered. Conversely, for cut block planning very detailed data are necessary. Between these two limits is a wide range in levels of data resolution. The user should be able to select a level appropriate to the planning needs.

This section describes a methodology which allows base data, in the form of variables which describe the state of the resource, to be synthesized to varying levels of resolution. In this study, data are transformed into information pertinent to management unit level harvest planning. The components of the state variable subsystem of TRACS are outlined in Figure 4.

Figure 4. Components of the State Variable Subsystem



4.3.1 Initial State Variables

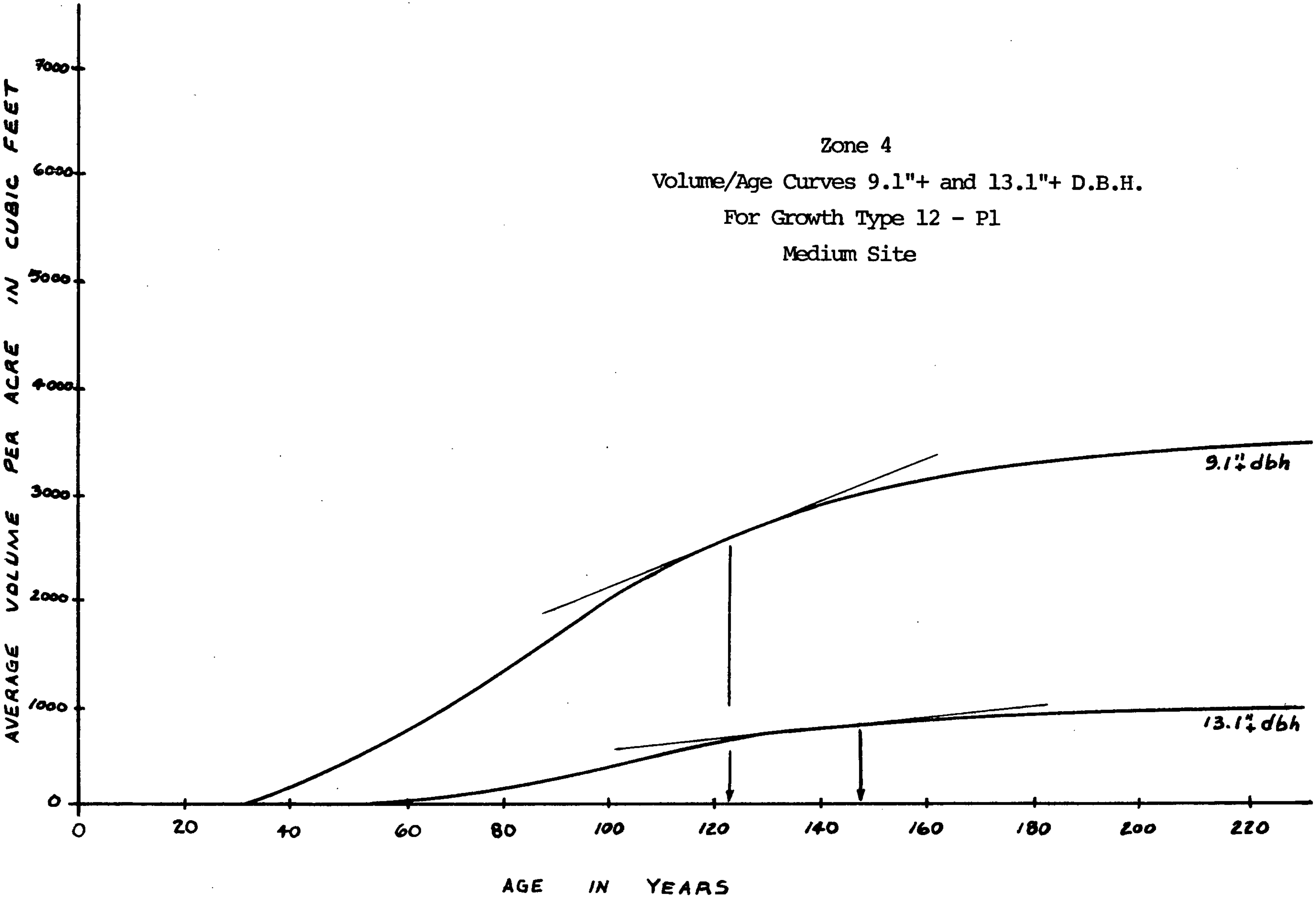
The finest level of data thus far has been the stand, characterized by species type, productive capacity and management prescriptions. However, for policy decisions concerning harvest scheduling at the management unit level a broader level of resolution is appropriate.

Groupings of stands or "timber classes" can be derived which are homogeneous with respect to their response to management treatments. Since cut scheduling decisions are based on yield attributes, the condition or state of each stand can be reflected by volume and value yields. Any consolidation of stands should be based on similarities in these yield characteristics. This necessitates determining the volume and value yields for individual stands, for both the present and the future. Such yields represent the set of initial state variables.

Current volume per area estimates for mature and over-mature stands are derived from the type map, with current stand stocking used to adjust future volume yields projected by the BCFS VAC's. An example of a VAC is presented in Figure 5. The curve identifies volume yields which can be expected over time from logdepole pine (Pinus contorta Dougl.) stands of medium site quality. Yields from immature stands are derived directly from the VAC's, assuming stand management will result in necessary stocking conditions for the corresponding volume flow.

Estimates of stand value are obtained from a simulation of

Figure 5. BCFS Volume Over Age Curve



the BCFS Interior End Product Appraisal System. Inventory cruises to industrial standards provide compilations of stand volume by log grade. Recoveries in terms of lumber and chips for a representative mill are used to generate end product outturns. Corresponding market prices for the products provide gross revenue for the stand. Such revenue estimates are derived for each stand as a function of age, site and species type. Harvesting costs, including felling, bucking, skidding and loading, for each stand are derived as a function of age, volume, species type, soil-landform class and management prescription. Area costs for landing construction, skid road construction and site preparation are also included in the stand appraisal. These costs together with the costs derived from the transportation subsystem are then subtracted from the gross revenue figures, resulting in net value estimates for timber delivered to the mill. Projections of stand value over time are generated on the basis of the volume yields projected from the VAC's.

4.3.2 Data Analysis

The initial state variables of each stand provide the basis for generating timber classes. Data analysis techniques[6] provide the capability for reducing data sets to manageable dimensions while minimizing the loss in information.

Factor analysis is performed on the original stand yield characteristics which transforms the variables to an orthogonal, normalized state space. Basically, the procedure involves first an extraction of the principal components of the input variables. These components are then rotated to delineate underlying dimensions of the input variables. An orthogonal rotation reduces the amount of inter-correlation that may exist. In simple terms, independent factors which contain the essence of the original state variables are extracted to yield a smaller set of stand attributes. This step eliminates redundant information which may bias the generation of timber classes.

Next, stands are aggregated into timber classes based on the factors extracted above. Cluster analysis is employed to perform the aggregations. It is a descriptive, statistical technique whose successful application relies on the existence of inherent natural groupings. Groups are formed sequentially so as to minimize the total variation in the factor values among each stand member. The process begins with each stand as an

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[6]Others have better covered the computational details of the techniques to be discussed (Ward, 1963; Gower, 1967; Veldman, 1967).

individual group. Groupings are made, one at a time, until eventually all stands are members of one group. At each step the decision to combine particular stands or groups of stands is based on the minimization of the increase in total intra-group variation. Examination of the variances associated with each successive grouping level may indicate a particular number of groups worthy of consideration. Reduction to the next lower level may result in a substantially large increase in error. Typically there are a number of significant error increases. The determination of significance is mainly subjective and dependent on the user's objective. If minimizing loss in information is of prime concern, then the grouping level that exists prior to the first substantial increase in error should be selected. If however, a particular range of grouping levels is of interest, then the error increases only within that range should be examined.

An extension to the clustering process has been developed where special qualitative attributes can be used to segregate stands in determining timber groupings. A dynamic programming formulation is used to allocate grouping levels among the stratifications in an optimal manner. A paper by Williams and Yamada (1975) describes the procedure in detail with an application which preserves species type within the timber class groupings.

The net result of the data analysis subsystem is the formation of timber classes which have similar silvicultural and economic yield characteristics. The same process is applied to the yields over time to form concise classes for volume and value projections. The resulting timber classes and yield classes are the state variables which are used as input for harvest schedule determination.

4.4 Cut Scheduling Subsystem

The TRACS system schedules timber harvests based on the LP model, Timber RAM. Other papers have described the Timber RAM model in detail (Hennes et al., 1971; Navon, 1971). The major aspects of the model will be reviewed here.

Timber RAM was developed by the USFS for formulating long range timber management plans. The model has the capability for considering planning horizons of up to 35 decades. Such long range horizons allow assessment of the future implications of short term decisions. Given an inventory of timber classes and a set of management prescriptions and responses, RAM will determine a cutting schedule that optimizes a specified objective subject to specified constraints. The objectives may be to maximize volume production, maximize discounted value production or minimize discounted costs over any number of decades[7]. Various constraints on periodic levels of volume, revenue, costs and forest accessibility can be specified. The resulting schedules indicate the area of each timber class cut,

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[7]The first planning period can be split into two 5 year periods.

and the corresponding flow of volume, costs and revenues generated for each decade of the planning horizon.

The activities to be scheduled represent a sequence of management treatments for each timber class over the span of the planning period. The timber classes and the volume and value yield classes generated from the state variable subsystem are used to formulate RAM activities. An example of a sequence of management treatments may be to clearcut employing an 80-year rotation with precommercial thinning at 20 years. One corresponding timber class activity would be to clearcut and regenerate in decade two, precommercial thin in decade four and clearcut and regenerate again in decade ten, repeating the sequence over the planning horizon. Hence, activities can differ not only in the type of treatment but also in the timing of treatments. In this way a multitude of timber class activities can be generated and evaluated with Timber RAM.

There are three major types of constraints which can be imposed on timber class activities:

1) area and accessibility constraints,
2) period constraints, and
3) harvest control and regulation constraints.

Area constraints restrict the maximum area available for management of any timber class. Alternatively the total area to be managed of each timber class can be controlled. Accessibility constraints restrict the area of each timber class accessible during the first five planning periods. Constraints on minimum acceptable levels of volume or revenue, or maximum acceptable levels of costs can also be specified for any period in the planning horizon.

Harvest control constraints can be used to control volume flow[8] during the conversion period. Harvest regulation constraints can be used to regulate volume flow during the post conversion period. The conversion period is that span in which old growth is liquidated, with the post conversion being that period in which second growth management is in effect. During the conversion period three types of harvest control can be implemented:

1) arbitrary control, where harvest levels are restricted to absolute upper and lower limits[9]
2) sequential control, where upper and lower limits on harvests are restricted to a percentage of the harvest specified in the preceding period. This allows smooth transitions in decade harvests.
3) conventional control, where harvest levels are restricted to a percentage range around the average harvest level of the conversion period.

During the post conversion period conventional control is used to regulate harvest levels.

The optimal scheduling of timber class harvests which

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[8]The option also exists to regulate the area harvested rather than volume.

[9]Arbitrary control is the same as instituting periodic volume constraints.

satisfy the imposed constraints is found using LP. Generally, allocation decisions are based on a series of evaluations under a variety of constraints and objectives, not solely on a specific optimal situation. The underlying benefit of Timber RAM rests in its ability to examine alternative policies. Such alternatives are formulated by varying objectives, activities and/or constraint combinations. Different objectives can be specified by changing the planning horizon, discount rate or output criteria (i.e. volume versus revenue). Activities can be altered by manipulating rotation ages or silvicultural treatments. Similarily constraints can be changed, for example, by varying volume flow requirements or land accessibility allowances. Evaluation of such changes provides not only an indication of desirable strategies, but also an indication of the stability of various management policies.

To summarize, Timber RAM provides:

1) a schedule of timber classes to be cut with the corresponding volume and value flows per decade,
2) an estimate of the productive capability of a management unit in terms of both volume and value,
3) a means of evaluating impacts of alternative management policies,
4) a framework in which to assemble and utilize a comprehensive forest data base, and
5) an assessment of the opportunity costs of non-timber land uses and alienations

There are also several disadvantages of Timber RAM, and LP in general. First, the model is deterministic with no allowance for risk. All specified activities must be implemented for the indicated results to hold. Second, all variables are continuous. Hence, any even age structure that exists within timber classes or stands may be violated. Third, all relationships are linear. Changes in responses that may occur at varying rates cannot be reflected[10]. This is a particular disadvantage where economies (or diseconomies) of scale, or downward sloping demand hold. Further disadvantages inherent in the Timber RAM model itself have been presented by Chappelle et al. (1976).

Timber RAM nevertheless provides a means of addressing the harvest scheduling problem. It has proven to be a very useful tool for providing guidelines in the planning of management unit timber harvests.

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[10]Separable programming techniques can be employed to reflect non-linearities.

4.5 Report Subsystem

Each subsystem of TRACS has report generation features. The forest subsystem allows for the generation of standard management reports. The transportation subsystem reports road network and stand access descriptions. Economic valuations of each stand are reported by the state variable subsystem. Examples of such reports will be cited in the discussion of results. However, the reporting facilities directly concerning the harvest scheduling plans deserve brief discussion here.

The Timber RAM model itself generates a variety of reports which describe the optimal cut schedule. A detailed harvest schedule can be generated, listing for each timber class the area to be managed by the selected activity and the resulting volume yields (in total and per unit area) for each decade in the planning horizon. A corresponding report of the resulting economics can be generated on the same basis. Summary reports of the periodic levels of volume and value flow across all timber classes can also be generated. A graph of harvest volumes over time is a particularly useful output feature. The value of the objective, the average long run sustainable yield and other plan statistics are also reported.

All results reported by Timber RAM are in terms of timber classes. The inability to relate the harvest plan to stands has been identified as a serious drawback (Chappelle et al., 1976). Reports relating harvest schedules to identifiable stand units have been developed to augment the timber class reports. These reports allow interpretation of the cut schedule in a spatial context for the management unit. Recognition of the spatial implications of scheduling results is necessary for realistic management assessments.

Specifically, the reports identify the individual stand members of the timber classes which are to be harvested in a particular decade. The species type, soil-landform class, age class, area and volumes of the candidate stands are reported. A species composition report for the decade harvest is also generated. An option exists which allows the plotting of candidate stand locations. This feature is facilitated only where geographic coordinates have been recorded as a part of the basic stand data. In this manner, potential stands which could comprise the specified decade cut are identified. This is the first step towards linking management unit harvest plans to watershed level planning.

5. AN APPLICATION TO MANAGEMENT UNIT HARVEST PLANNING

The TRACS system was applied to an actual forest management unit, the Westlake PSYU. The Westlake PSYU, a part of the Prince George Forest District, is situated in the central interior of British Columbia. The unit is approximately 600,000 acres (242,803 hectares) in size. It is in the Montane forest region with the principal commercial species being lodgepole pine and white spruce (*Picea glauca* (Moench) Voss).

Individual stand units were delineated on the basis of three map overlays. A forest cover map containing 42 inventory types provided the first overlay. A soil-landform map provided the second overlay. Nineteen different land classes were identified for the Westlake PSYU. Descriptions of each land class can be found in Appendix II. The third overlay identified designated use in terms of timber production, grazing, wildlife, fisheries, recreation, agriculture and deferred use. A total of 2,441 stand units resulted. Prescribed stand treatments also accompanied the overlay information. The treatment sequences which are based on land class and growth type are detailed in Appendix III. From the above information the fifteen attributes listed in Section 4.1 were compiled for each stand. This stand information together with BCFS VAC's provided the initial data base.

A computerized data management system called ASAP[11] was

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[11]ASAP, an acronym for As Soon As Possible, is a product of Compuvisor Inc., Ithaca, New York.

used for storage and retrieval of the Westlake data base. An example of the query capability from a computerized data base is shown in Table 1.

Table 1. Age Class Distribution Of The Westlake PSYU Via ASAP

Run 2 12/13/79 page 1
Output 1
Summary agedist
Reqt 1
Task 1
Line 19
2441 records selected
****

Age class distribution by volume and area
****

Age Class	Total Volume (cf)	Total Acreage
0-20 Yrs	25	26729
21-40 Yrs	64510	97004
41-60 Yrs	263672	51504
61-80 Yrs	830337	117307
81-100 Yrs	1553442	152105
101-120 Yrs	929724	49893
121-140 Yrs	764107	22513
141-250 Yrs	692530	31200
250+ Yrs	4000	466
Other	14480	51351
Subtotal	5116827	600072

The table shows the results from a request for the age class distribution in terms of both area and present volume across all 2,441 stands of the unit. The Westlake PSYU does not have a balanced distribution of age classes. The greatest portion of the volume and area are from stands between 60 and 100 years of age. Hence, harvest scheduling for continuous volume flow is not directly apparent. In addition to query capability, management reports as those shown in Appendix IV can be generated, giving detailed descriptions of each stand.

The forest road network of the Westlake PSYU was obtained in map form. Empirical costings from areas of active operation were also supplied. The data gave rise to three sets of hauling cost zones and six sets of road development costs. Table 2 shows the basic access-related costs for the unit.

The primary access roads were digitized with the attribute information and precedence relationships established through the transportation subsystem. The forest road network of the Westlake PSYU consists of 46 primary access roads. There are in fact three separate networks within the management unit. Two of the networks lead to Prince George mills, while the third leads to an Isle Pierre mill. The node network constructed and the precedence relationships are shown in Figure 6. The large, underscored numerals represent the individual road segments. The smaller numerals correspond to the nodes generated during network construction. A summary of the road segments within the network is shown in Table 3. For each road there is a description of its length, node precedence relationships, status, road class, haul cost zone assignment and cost for development, if any.

Table 2. Basic Access Cost Data

COST DATA SUMMARY

TRANSPORTATION COSTS

ZONE	$/CUNIT/MILE
1	0.22
2	0.18
3	0.15
4	0.0
5	0.0
6	0.0
7	0.0
8	0.0
9	0.0
10	0.0

ROAD DEVELOPMENT COSTS

ROAD CLASS	$/MILE
1	65000.00
2	50000.00
3	40000.00
4	33000.00
5	12000.00
6	8000.00

Figure 6. Road Network of the Westlake PSYU

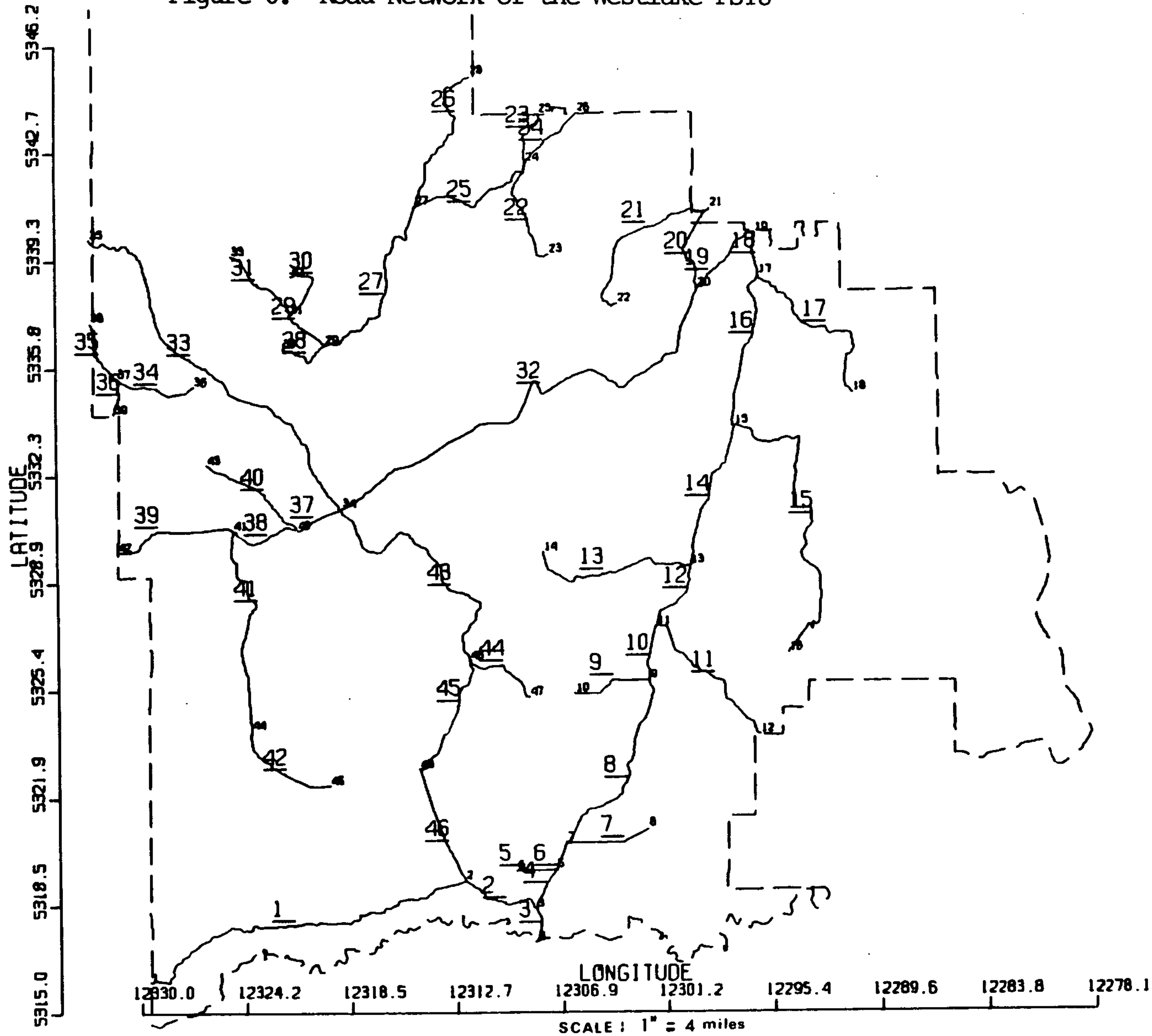

Table 3. ROAD SEGMENT REPORT

RD. #	RD. LENGTH (MILES)	1ST NODE	2ND NODE	ROAD STATUS	ROAD CLASS	HAUL COST ZONE	DEVELOPMENT COST ($)
1	13.94	1	2	ON-HWY,EXISTING	6	1	
2	3.22	3	2	ON-HWY,EXISTING	6	1	
3	1.36	4	3	ON-HWY,EXISTING	6	1	
4	1.65	3	5	ON-HWY,EXISTING	6	1	
5	1.49	6	5	ON-HWY,EXISTING	6	1	
6	1.10	5	7	ON-HWY,EXISTING	6	1	
7	3.22	7	8	ON-HWY,EXISTING	6	1	
8	7.61	7	9	ON-HWY,EXISTING	6	1	
9	3.03	10	9	ON-HWY,EXISTING	6	1	
10	2.16	9	11	ON-HWY,EXISTING	6	1	
11	6.08	12	11	ON-HWY,EXISTING	5	1	
12	2.87	11	13	ON-HWY,EXISTING	5	1	
13	6.63	14	13	ON-HWY,EXISTING	6	1	
14	5.66	13	15	ON-HWY,EXISTING	5	1	
15	12.73	16	15	ON-HWY,EXISTING	5	1	
16	6.09	15	17	ON-HWY,EXISTING	5	1	
17	7.09	18	17	ON-HWY,EXISTING	5	1	
18	1.61	17	19	ON-HWY,EXISTING	3	1	
19	3.14	20	19	OFF-HWY,EXISTING	4	1	
20	3.61	20	21	OFF-HWY,EXISTING	4	1	
21	6.80	22	21	OFF-HWY,EXISTING	4	1	
22	4.33	23	24	ON-HWY,EXISTING	6	1	
23	2.13	24	25	ON-HWY,EXISTING	6	1	
24	2.70	24	26	ON-HWY,EXISTING	6	1	
25	5.21	27	24	ON-HWY,EXISTING	6	2	
26	6.26	27	28	ON-HWY,EXISTING	5	2	
27	7.41	29	27	ON-HWY,EXISTING	5	2	
28	2.12	30	29	ON-HWY,EXISTING	5	2	
29	1.79	31	29	ON-HWY,EXISTING	5	2	
30	2.49	32	31	ON-HWY,EXISTING	5	2	
31	3.28	33	31	ON-HWY,EXISTING	5	2	
32	18.22	34	20	OFF-HWY,EXISTING	3	1	
33	15.32	34	35	ON-HWY,EXISTING	6	3	
34	3.20	36	37	OFF-HWY,EXISTING	3	3	
35	2.39	37	38	OFF-HWY,EXISTING	3	3	
36	1.37	37	39	OFF-HWY,EXISTING	3	3	
37	1.92	40	34	OFF-HWY,EXISTING	3	1	
38	2.76	41	40	OFF-HWY,EXISTING	3	1	
39	4.77	42	41	OFF-HWY,EXISTING	3	1	
40	4.26	43	40	OFF-HWY,PROPOSED	4	1	140625.00
41	8.05	44	41	OFF-HWY,EXISTING	4	1	
42	4.04	45	44	OFF-HWY,PROPOSED	4	1	133204.75
43	10.33	46	34	ON-HWY,EXISTING	6	1	
44	2.96	47	46	ON-HWY,EXISTING	6	1	
45	4.94	46	48	ON-HWY,EXISTING	6	1	
46	4.48	48	2	ON-HWY,EXISTING	6	1	

For each stand there is a transportation cost representative of its location relative to the point of appraisal. Since each stand is accessed by the closest road from among one of the possible road networks, processing across all networks will assure a transportation cost estimate for each stand. Not only will an estimate be generated, but that estimate will be based on the minimum route distance to the respective appraisal point. If stand access requires a proposed road to be developed, then the costs of road construction are distributed over the total volume accessed by that road. Such costs reflect primary road development, and are assigned to the stands directly involved.

The initial base of stands was reduced prior to state variable analysis. Stands which would not significantly contribute to the productive capacity of the unit were eliminated. Such stands included those less than ten acres (4 hectares) in size (213), those classified as "non-productive" (231), and those classified as "not sufficiently restocked" (12). This left 1985 stands comprising 573,840 acres (232,217 hectares) as the basis for harvest planning within the Westlake PSYU.

For each of the 1985 stands, twenty initial state variables were generated. The state variables represented present and future volume and economic yields to be derived from each stand. Current volume per unit area and current net value per unit volume were two of the state variables of each stand. Future volumes and values describing each stand at twenty year intervals, from 40 to 200 years of age provided the remaining eighteen state variables.

Volumes were derived from the BCFS VAC's. Values were derived from a stand appraisal simulation. The appraisal involved estimation of the end product market values minus the related costs of making the wood available to the mill. Appendix V displays the appraisal report for the mature stands of the Westlake PSYU. The contribution of each component to the derivation of stand value is itemized in the report.

Factor analysis was then performed on the initial 20 state variables. Five orthogonal factors resulted which accounted for approximately 99% of the information represented by the original variables. In other words, a four-fold reduction in the state variable space only resulted in a 1% loss of information. Appendix VI presents the factor analysis results. Two factors correlated with volume yield over time, while another two correlated with value over time. Each pair of factors could be interpreted to represent the rate of change in yields, and the absolute range in yields over the time span. The remaining factor correlated with current volume and value yield.

This reduced set of state variables was then used to derive stand groupings or timber classes. Prior to the aggregation process, stands were pre-stratified into accessibility classes based on transportation and road development costs. The rationale behind such a stratification was to demonstrate the impact of explicity accounting for stand access in cut schedule determination. Stands with similar access costs were deemed to have similar access characteristics. Accessibilty costs ranged from \$0.10/cunit (\$0.04/cubic metre) to \$14.00/cunit (\$4.94/cubic metre). Fourteen accessibility classes were established for the 1985 stands. Table 4 presents the distribution of the stands across the 14 classes. Thus, stand accessibility provided the initial basis for timber class formation.

The cluster-dynamic programming approach was employed in reducing the original 1985 stands to 100 timber classes[12]. Cluster analysis was performed on the five state factors to determine stand aggregations within each accessibility strata. The optimal number of timber classes within each strata considering all accessibility classes was found using dynamic programming. The determination of the number of timber classes within each strata was weighted by the area representation of each strata. The distribution of the ultimate number of timber classes across the accessibility classes is shown in Table 5. This data reduction process from 1985 stands to 100 timber classes resulted in a 23% error in aggregation.

Cluster analysis was further employed to reduce the volume and value yield projections for the 100 timber classes to a smaller, more manageable subset. Fifteen volume yield classes were generated with only a 2% loss in information. Thirty economic yield classes were generated with a corresponding information loss of less than 1%. Tables of the resulting yield

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[12]A level of 100 classes reflects a Timber RAM restriction on the maximum number of timber classes allowed.

Table 4. Stand Distribution Across Accessibility Classes

Accessibility Class	Access Cost ($/CCF)	Stand Frequency	% of Total Stands
1	0 - 1.00	145	7
2	1.01 - 2.00	181	9
3	2.01 - 2.50	114	6
4	2.51 - 3.00	153	8
5	3.01 - 3.50	142	7
6	3.51 - 4.00	130	7
7	4.01 - 4.50	92	5
8	4.51 - 5.00	165	8
9	5.01 - 6.00	180	9
10	6.01 - 6.60	138	7
11	6.61 - 7.00	184	9
12	7.01 - 8.00	169	9
13	8.01 -11.00	167	8
14	11.01 -14.00	25	1
TOTAL		1985	100

Table 5. Timber Class Distribution Across Accessibility Classes

Accessibility Class	% Area Representation	Stand Frequency	# of Timber Classes Formed	Intra-class Clustering Error (%)	Total Inter-class Error (Area-weighted %)
1	4	145	6	31.1	1.2
2	9	181	10	19.1	1.7
3	9	114	6	26.5	2.4
4	8	153	6	22.7	1.8
5	7	142	6	31.5	2.2
6	7	130	8	18.8	1.3
7	5	92	6	30.2	1.5
8	11	165	11	14.5	1.6
9	10	180	10	18.9	1.9
10	7	138	7	26.7	1.9
11	5	184	7	25.9	1.3
12	7	169	8	21.4	1.5
13	10	167	8	19.9	2.0
14	1	25	1	100.0	1.0
TOTAL	100	1,985	100		23.3

classes are shown in Appendix VII.

The timber classes and yield classes thus formed were then used in cut schedule determination for the Westlake PSYU.

6. ANALYSIS AND DISCUSSION

6.1 Transportation Planning

Fundamental road network information for the Westlake PSYU was generated from the transportation subsystem. Basic statistics on length of given road class, length of proposed road and other road network characteristics were identified. This data was used in the transportation subsystem to determine optimal routing strategies, i.e. given a selected appraisal point, routings based on minimum distance were identified for the entire unit.

An example of the optimal routings and distances pertaining to the 46 primary access road segments of the Westlake PSYU is outlined in Table 6. Node 35 is specified as the appraisal node (sink) in the table. This appraisal location leads to an Isle Pierre mill. So for example, in travelling from node 1 to the appraisal node the minimum distance is 49.00 miles (78.9 kilometres). The corresponding optimal routing strategy is sequentially decoded. The bracketed value specifies the next node in the minimum route. Thus, from node 1 the optimal route is to travel to node 2, then to node 48, to node 46, to node 34, and finally to node 35, the appraisal point. In this manner the optimal routings and distance are identified for the road network of the management unit.

The nodes possessing large values (99999.00 and 9999)

Table 6. Minimum Routing Distances and Policies

ROAD NETWORK REPORT

NODE OF APPRAISAL : 35

MINIMUM DISTANCE IN MILES, (AND ROUTING) TO NAP

NODES:	1	2	3	4	5	6	7	8	9	10
0:	49.00	35.06	38.28	39.63	39.93	41.42	41.03	44.25	48.65	51.68
:	(2)	(48)	(2)	(3)	(3)	(5)	(5)	(7)	(7)	(9)
10:	50.81	56.89	50.04	56.67	44.38	57.11	38.29	45.38	36.68	33.54
:	(9)	(11)	(15)	(13)	(17)	(15)	(19)	(17)	(20)	(34)
20:	37.15	43.95	99999.00	99999.00	99999.00	99999.00	99999.00	99999.00	99999.00	99999.00
:	(20)	(21)	(9999)	(9999)	(9999)	(9999)	(9999)	(9999)	(9999)	(9999)
30:	99999.00	99999.00	99999.00	15.32	0.0	99999.00	99999.00	99999.00	99999.00	17.23
:	(9999)	(9999)	(9999)	(35)	(0)	(9999)	(9999)	(9999)	(9999)	(34)
40:	19.99	24.76	21.49	28.04	32.08	25.64	28.60	30.58		
:	(40)	(41)	(40)	(41)	(44)	(34)	(46)	(46)		

indicate the unit consists of one or more separate sub-networks. Travel between nodes of separate networks is impossible. Hence, the large values indicate infeasible routings.

Minimum routings, distances and associated transportation costs were determined for each of the 1985 Westlake stands. A sample of the results can be found in Table 7. For each stand there is a description of its qualitative characteristics, its geographic location (based on its visual centroid), the distance to the nearest access road (with a corresponding pointer), the minimum distance to the specified node of appraisal and the corresponding transportation cost. An additional feature of the analysis is the generation of road development costs for those proposed roads in the network, together with a proportioning of such costs over the volume from the stands involved.

To examine the results in detail, focus is placed on one particular stand, 20057160. This stand is the 57th stand (057) located in Compartment 20, Region 60 of the Westlake PSYU. The stand is a white spruce type, age class 8 (141-160 yrs.) and of good site. It has a volume yield of 4700 cubic feet per acre (329 cubic metres/hectare). The nearest access road is road 46, being a distance of 1.39 miles (2.24 kilometres) from the centroid of the stand. The distance from the stand to the specified Prince George appraisal point is 37.85 miles (60.91 kilometres), which in turn results in a transportation cost of \$8.33/cunit (\$2.94/cubic metre) for the stand. In perspective, the transportation costs for the stands in Compartment 20 as a whole ranged from a low of \$5.70/cunit (\$2.01/cubic metre) to a high of \$9.10/cunit (\$3.21/ cubic metre) with the average being

Table 7. STAND ACCESS REPORT

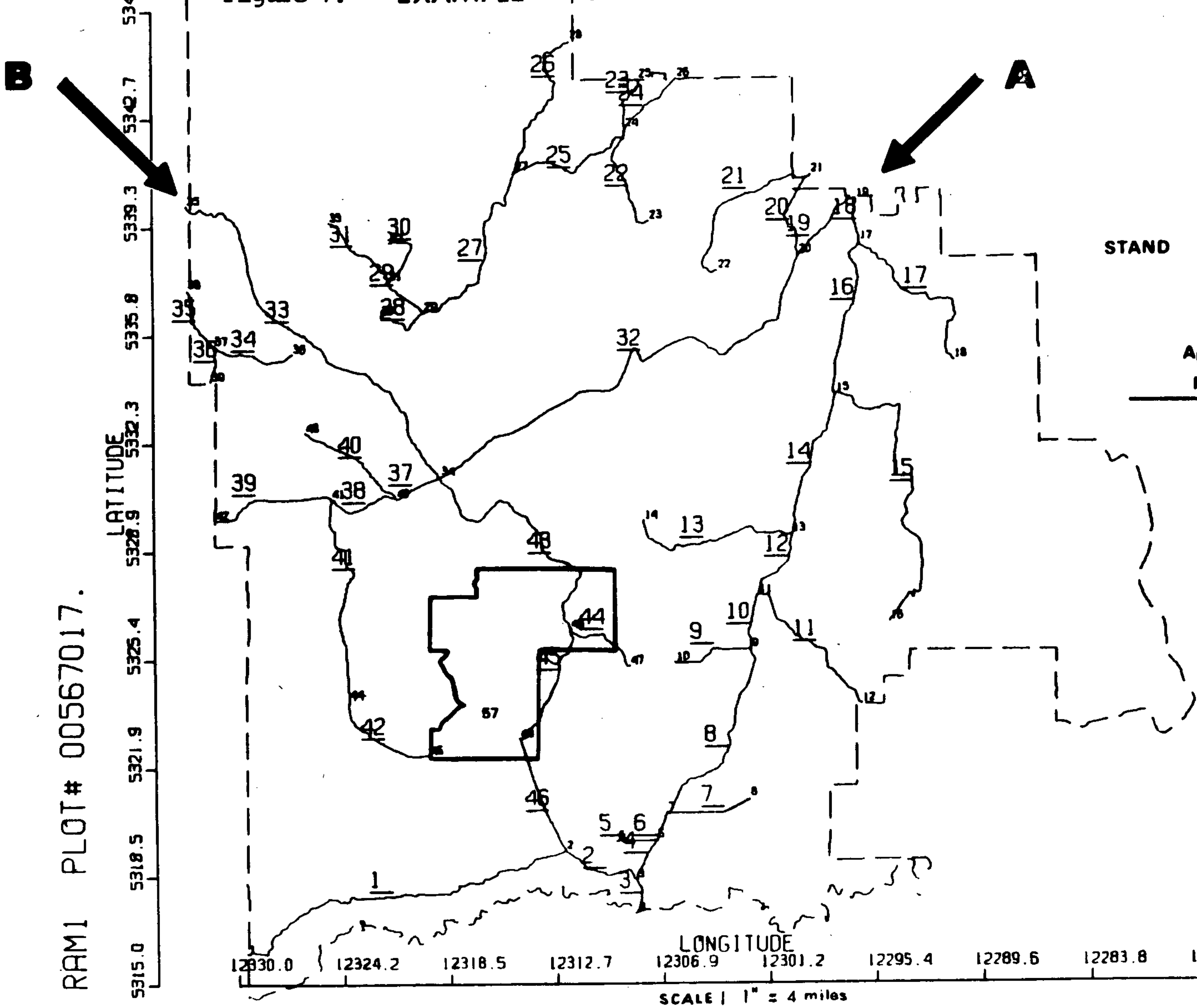
STAND NO.	TYPE	AGE	SITE	SLC	USE	CENTROID LOCATION IN LAT-LONG.		DIST. TO NEAREST RD. (MILES)	RD. NO.	DIST. TO NAP (MILES)	HAUL COST ($/CUNIT)	ROAD DEVELOPMENT COST ($/CUNIT)
8002160	PL	8	1	4	1	5331.17	12252.33	0.69	15	14.50	3.19	0.0
8003160	S	8	1	4	1	5335.43	12252.20	0.51	17	8.62	1.90	0.0
8034160	S	8	2	5	1	5327.89	12242.27	7.36	15	24.74	5.44	0.0
8065160	COTD	8	2	13	1	5331.43	12242.60	7.10	17	15.81	3.48	0.0
8033160	F	8	2	5	1	5328.63	12242.80	6.97	15	24.34	5.36	0.0
8001160	F	8	2	4	1	5332.93	12250.23	2.33	17	11.04	2.43	0.0
8064160	F	8	2	13	1	5331.77	12243.33	6.47	17	15.17	3.34	0.0
10001160	F	8	1	4	1	5339.98	12301.75	0.32	21	9.45	2.08	0.0
10029160	F	8	1	4	3	5339.41	12306.08	0.96	22	7.43	1.63	0.0
10058160	S	8	2	5	3	5341.48	12305.48	2.30	24	6.19	1.36	0.0
11034160	F	8	1	4	4	5346.46	12314.71	2.31	26	14.87	2.68	0.0
11013160	F	8	2	4	1	5339.77	12313.30	1.32	27	9.93	1.79	0.0
11043160	SF	8	2	5	1	5340.59	12312.62	0.66	25	6.37	1.15	0.0
12001160	S	8	1	1	1	5341.33	12325.59	2.34	31	22.16	3.99	0.0
12056160	S	8	1	10	1	5342.27	12325.41	3.39	31	23.21	4.18	0.0
14068160	SF	8	1	5	1	5333.75	12313.80	0.69	32	17.37	3.82	0.0
14038160	FS	8	1	4	1	5338.45	12312.73	2.40	27	11.09	2.00	0.0
14128160	S	8	1	9	2	5336.33	12315.60	1.50	27	13.76	2.48	0.0
14062160	SF	8	1	4	2	5300.00	12300.00	20.77	3	50.90	2.86	0.0
14122160	S	8	1	9	1	5336.41	12316.70	1.00	27	14.17	2.55	0.0
15110160	F	8	1	12	1	5336.56	12304.73	1.11	32	10.72	2.36	0.0
15034160	F	8	1	7	1	5330.80	12309.36	1.53	13	21.53	4.74	0.0
15127160	F	8	1	4	1	5336.43	12304.53	1.02	32	10.57	2.33	0.0
16013160	F	8	1	12	1	5337.38	12304.32	0.40	21	13.71	3.02	0.0
16073160	S	8	1	4	2	5339.35	12253.93	1.51	17	4.03	0.89	0.0
16045160	S	8	1	4	1	5339.46	12254.77	1.09	18	2.09	0.46	0.0
16046160	F	8	1	4	1	5337.41	12304.02	0.32	21	13.53	3.00	0.0
17053160	PL	8	1	6	1	5330.68	12256.46	1.71	15	14.89	3.28	0.0
17033160	PLS	8	1	12	1	5329.23	12254.38	0.57	15	16.47	3.62	0.0
17020160	PL	8	1	4	2	5331.66	12254.50	0.21	15	12.72	2.80	0.0
17001160	S	8	1	4	1	5332.46	12256.13	1.04	15	9.89	2.18	0.0
17002160	PL	8	1	4	1	5330.66	12254.89	0.82	15	14.00	3.08	0.0
17040160	S	8	2	12	2	5329.80	12257.23	1.69	14	14.55	3.20	0.0
17019160	S	8	2	4	2	5330.00	12257.23	1.69	14	13.66	3.00	0.0
17031160	S	8	2	12	1	5329.77	12257.46	1.53	14	14.39	3.17	0.0
17032160	F	8	2	12	1	5329.63	12254.63	0.51	15	16.15	3.55	0.0
18055160	F	8	1	7	3	5327.06	12308.20	1.68	44	34.75	7.65	0.0
18101160	S	8	1	4	6	5324.73	12304.39	0.72	9	21.22	4.67	0.0
18001160	S	8	1	5	3	5330.30	12305.33	1.42	13	18.81	4.14	0.0
18089160	F	8	1	4	2	5324.80	12306.60	0.63	9	22.00	4.84	0.0
18022160	S	8	1	7	1	5324.39	12304.63	1.05	9	21.55	4.74	0.0
18073160	F	8	1	4	1	5325.89	12306.80	0.82	9	22.25	4.90	0.0
18074160	S	8	1	4	1	5325.03	12303.80	0.73	9	20.81	4.58	0.0
18040160	S	8	2	7	6	5325.50	12305.46	0.49	9	20.98	4.62	0.0
19033160	F	8	1	18	1	5321.05	12305.27	0.51	8	25.18	5.54	0.0
19014160	F	8	1	7	1	5321.05	12306.39	0.25	8	25.70	5.65	0.0
19001160	F	8	1	4	1	5325.25	12307.96	0.50	44	35.15	7.73	0.0
19045160	PLF	8	1	15	2	5300.00	12300.00	20.77	3	50.90	6.85	0.0
20057160	S	8	1	15	1	5323.35	12316.46	1.39	46	37.85	8.33	0.0
20056160	F	8	2	15	1	5322.05	12317.27	1.63	42	39.75	8.75	1.73

$7.67/cunit ($2.71/cubic metre). Detailed compartmental results can be found in Appendix VIII.

A comparison of harvesting cost with transportation cost exemplifies the significance of transportation in the economic evaluation of a stand. The harvesting cost for stand 057 was $7.80/cunit ($2.75/cubic metre). With due consideration given to transportation cost, total cost more than doubles to $16.13/cunit ($5.70/cubic metre). Hence, it can be seen that analysis devoid of transportation cost could have serious management consequences.

Another area of interest in the planning of harvests is the possible effects of wood flows to alternative appraisal locations. To examine the effects on transportation costs of directing logs to another mill site an additional analysis was performed. A new node of appraisal to an alternative milling site (Isle Pierre) was selected with new routings, distances and transportation costs computed. Again turning attention to stand 057, the transport distance to the new appraisal point was 31.97 miles (51.45 kilometres) yielding a cost of $7.03/cunit ($2.48/cubic metre). A comparison of the log transport results from stand 057 to the two alternative points of appraisal is shown in Figure 7. Appraisal point A represents the Prince George location, while appraisal point B represents the Isle Pierre location. The results show that by hauling to the Isle Pierre location there would be a savings of $1.30/cunit ($0.46/cubic metre) for stand 057. On examining the results for the stands in Compartment 20 as a whole transportation costs ranged from $4.37/cunit ($1.54/cubic metre) to $7.77/cunit

Figure 7. **EXAMPLE OF WOOD FLOW ANALYSIS**



STAND 20057160: 1.39 miles from ROAD 46

Appraisal Point	Distance (miles)	Cost ($/CCF)
A	37.85	8.33
B	31.97	7.03

($2.74/cubic metre) with the average being $6.35/cunit ($2.24/cubic metre). Detailed results for stand 057 can be found in Appendix IX. With all other things being equal, a manager contemplating log transport to several alternative mills can now assess the effects of transportation costs. In the above example it would appear to be much more economical to transport wood from stands in Compartment 20 to the alternative appraisal location B.

Thus for a specified point of appraisal, transportation costs based on the minimum route can be generated for any given stand within the management unit. Such transportation costings can then be incorporated with stand revenues and harvest cost estimates to provide a more complete economic assessment of stand harvest value.

6.2 Cut Scheduling

Harvests were scheduled for the Westlake PSYU using the Timber RAM model. The 100 timber classes formed from the state variable subsystem were the forest units to be scheduled. Silvicultural treatments for each timber class consisted of simple clear-cutting strategies, with either natural regeneration or planting within five years of harvest. Site preparation activities such as slash burning or drag scarification, as prescribed by management, were also included. The 30 economic yield projections and 15 volume yield projections shown in Appendix VII were used to generate returns from the various harvesting alternatives. The timing of the first harvest for each timber class was the primary decision.

All evaluations for the Westlake PSYU were based on a 100-year conversion period, with a total planning horizon of 350 years. Volume flow was constrained during the conversion period using sequential harvest control. The harvest in the first decade was allowed to vary from -50% to +250% of the current harvest level of the unit. Subsequent harvests were constrained to within 10% of the cut of the preceding decade.

The above basic harvest management parameters were used in the following three sets of evaluations:

1) Volume Optimization - long term vs. short term
2) Economic Optimization - volume vs. value
3) Economic Optimization - with transportation vs. without

6.2.1 Case 1: Volume Optimization - Long Term vs. Short Term

Case 1 evaluated the implications of scheduling harvests for the maximization of long term (200 years) vs. short term (30 years) volume production. Harvesting alternatives for mature stands allowed for clear-cutting anytime within the first six decades up to 200 years of age, at which time the stand had to be cut. For immature stands, clear-cutting was allowed during a sixty-year span from a first entry of either 20 years prior to culmination of mean annual increment or 60 years of age. The previously described sequential volume control constraints were employed.

Two RAM runs were made. The objective of the first run was to maximize volume over a 200-year planning period. The cut scheduled in the first decade yielded 2.58 million cunits (7.31 million cubic metres). The corresponding net revenue generated during the first decade totalled 156.2 million dollars. The resulting long run sustained yield average was 1.83 million cunits (5.18 million cubic metres) per decade for the Westlake PSYU. This level can be viewed as representing the silvicultural potential for the Westlake under clear-cutting management sequences.

The objective of the second run was to maximize volume production over a 30-year planning period. The volume scheduled for harvest in the first decade totalled 2.88 million cunits (8.16 million cubic metres), with the corresponding net revenue being 171.2 million dollars. The long run sustained yield average was again approximately 1.83 million cunits (5.18 million cubic metres) per decade. A summary of the results can be found in Appendix X.

In comparison, maximizing volume over a 30-year period (short term) vs. a 200-year period (long term) generates an additional 300,000 cunits (849,510 cubic metres) during the first decade. In other words, an additional 30,000 cunits (84,951 cubic metres) can be harvested annually without appreciably sacrificing the long range productive capability of the management unit. This is equivalent to an additional 1.5

million dollars per year in net revenue which could be generated.

A comparison of the volume flows per decade is shown in Figure 8. The graph shows that during the first 40 years the scheduled harvest under short term volume maximization is approximately 12% higher than the level for the long term run. However, from 50 to 100 years the harvest for the long term schedule more than compensates for the earlier deficiencies. Total harvest under long term volume maximization for the 200-year period is approximately 39.266 million cunits (111.19 million cubic metres). The total harvest under the short term run for the same period is approximately 38.422 million cunits (108.80 million cubic metres). Thus, the overall harvest is increased by approximately 844,000 cunits (2.39 million cubic metres) under long term volume maximization. Nevertheless, in both cases the perpetual sustained yield average stabilizes about a common harvest level as is shown for the post conversion period.

Figure 9 shows the effect on the species flow resulting from the stands available for harvest in the first decade for the two runs. The incremental volume for the short term maximization is primarily lodgepole pine. The species distribution is approximately 20% Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), 11% white spruce, 65% lodgepole pine with the balance primarily hardwood species. The distribution under long term volume maximization is approximately 21% Douglas-fir, 18% white spruce, 57% lodgepole pine with the balance primarily hardwoods species. A complete summary by

Figure 8. Comparison of Volume Flow - Case 1

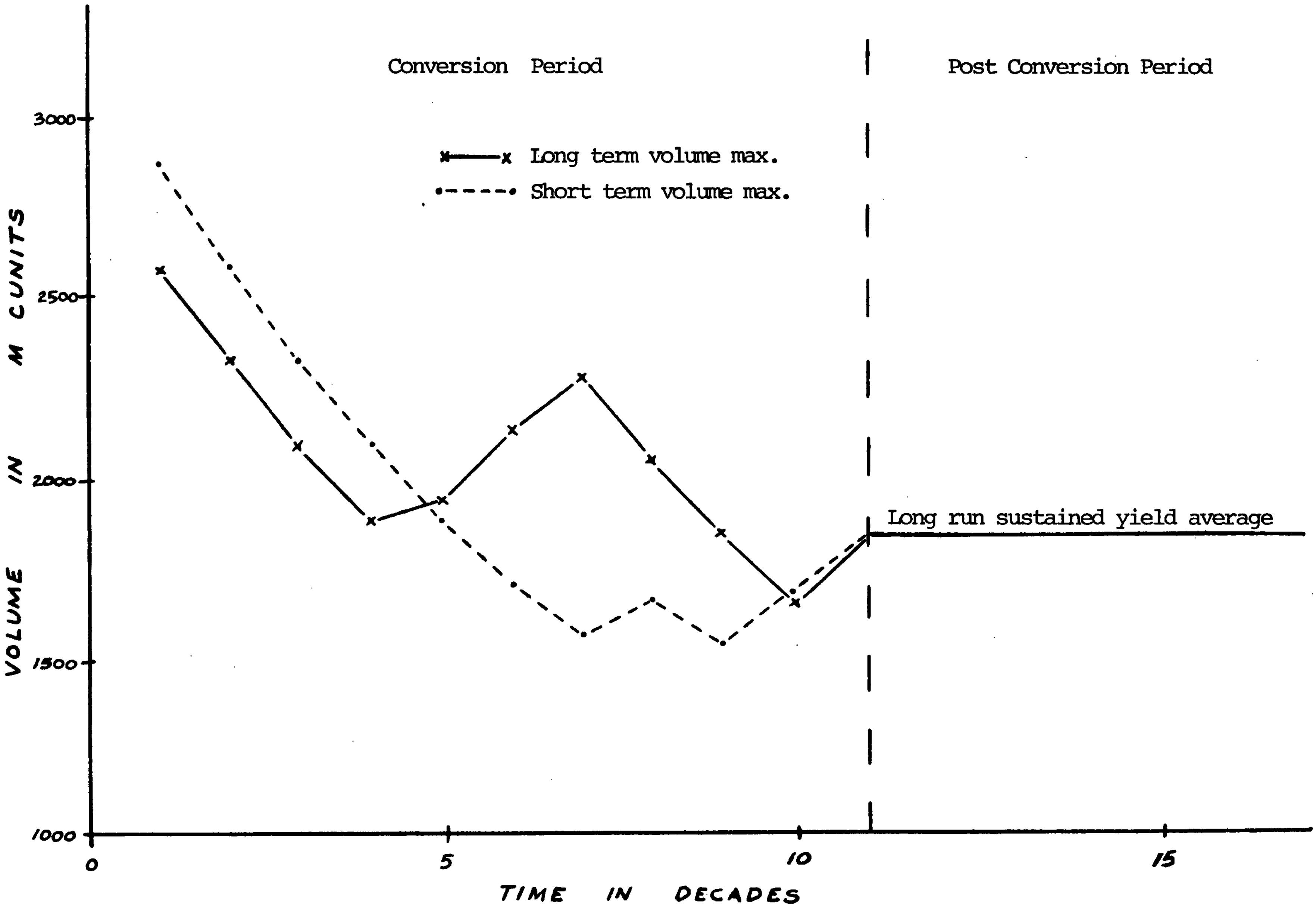
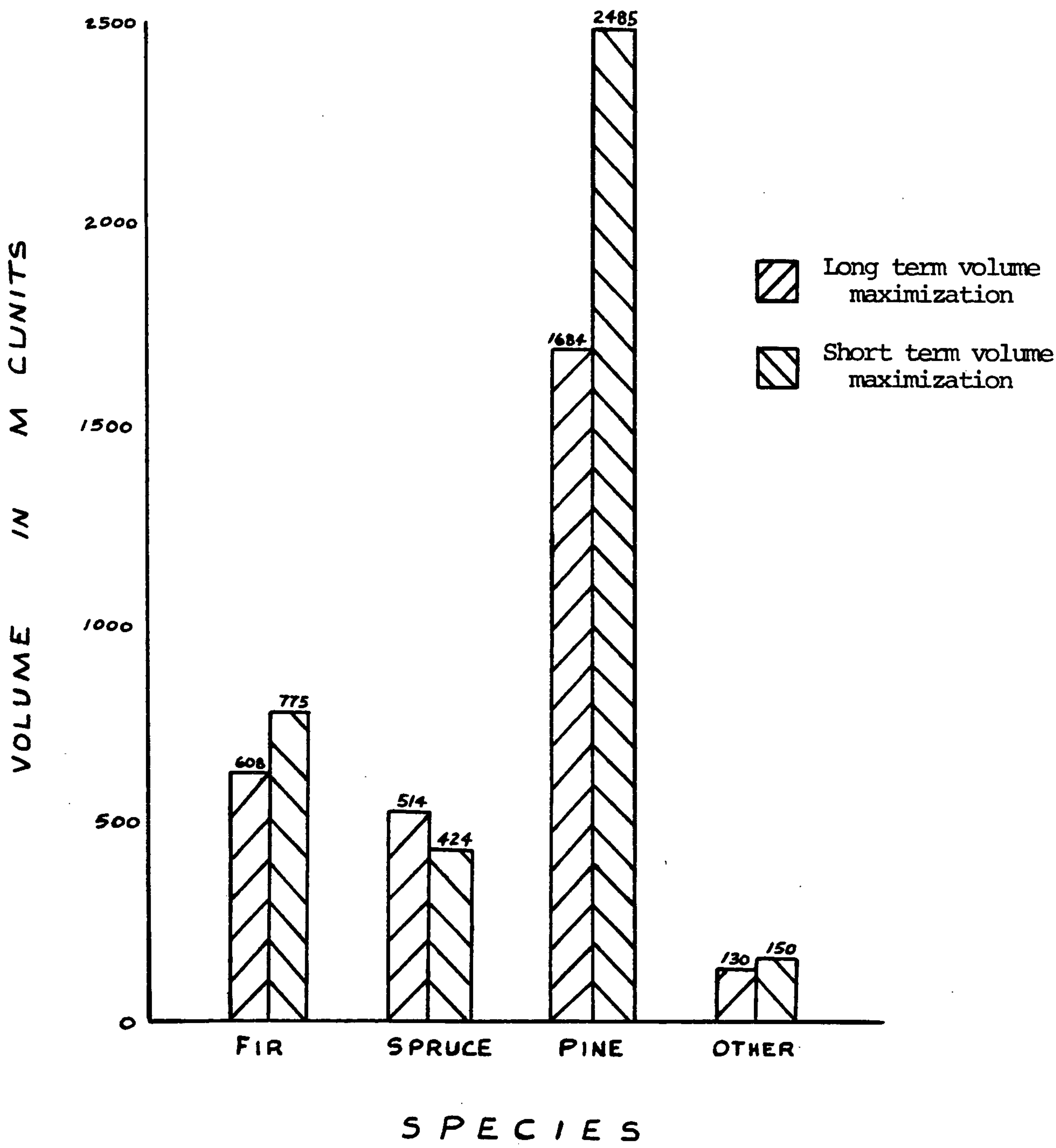


Figure 9. Comparison of Species Flow in Decade 1 - Case 1
(Ref. Appendix XI)



timber class of the species harvest for the two runs can be found in Appendix XI.

In summary, these runs indicate that the overall timber productivity for the Westlake PSYU should average approximately 183,000 cunits (518,201 cubic metres) per year. Of this yearly production the approximate species distribution will be 60% lodgepone pine, 20% Douglas-fir, 15% spruce and 5% other species. Further, maximizing the volume harvested over the next 30 years rather than a longer period will not adversely affect the long term productivity of the management unit. Without the analytical capability of a system like TRACS, the insight provided above would be difficult to obtain.

6.2.2 Case 2: Economic Optimization - Volume vs. Value

Case 2 evaluated the implications of scheduling harvests for the maximization of net revenue as opposed to maximization of long term volume production.

The RAM run with the volume objective over 200 years, as described in Section 6.2.1, was used to represent the optimization of long term volume production. Another run, under the same conditions, was made with the objective of maximizing net revenue over 200 years. This run represented the optimization of value production. A discount rate of 8% was used to reflect the present value of future revenue streams. Consequently, only revenues generated during the first 30 or so years were of any significance.

The net revenue generated during the first decade totalled 175.5 million dollars, in comparison with 156.2 million dollars for the long term volume production run. The net revenue generated over the 200-year period was 200.4 million dollars. The corresponding net revenue under volume maximization was 179.3 million dollars. The volume scheduled for harvest in the first decade was 2.86 million cunits (8.10 million cubic metres), in comparison with 2.58 million cunits (7.31 million cubic metres). Once again the long run sustained yield average was approximately 1.83 million cunits (5.18 million cubic metres) per decade. A summary of the results can be found in Appendix XII.

Figure 10 displays a comparison of volume flows per decade for the two runs. A similar pattern of volume harvests to that of Figure 9 is exhibited. During the first five decades, harvest levels are higher under value maximization. For the next five decades harvest levels are much lower than the levels shown for volume run. The excess inventory is liquidated much earlier under value maximization to capture increased revenue. In contrast, the volume maximization strategy rations out the excess inventory to generate increased volume flow during the conversion period. Volume production stabilizes during the post conversion period around a common harvest level for both runs.

A comparison of the species distribution of the harvest in the first decade is shown in Figure 11. The results are similar to those shown for short term volume maximization.

Differences in the timber classes scheduled for harvest

Figure 10. Comparison of Volume Flow - Case 2

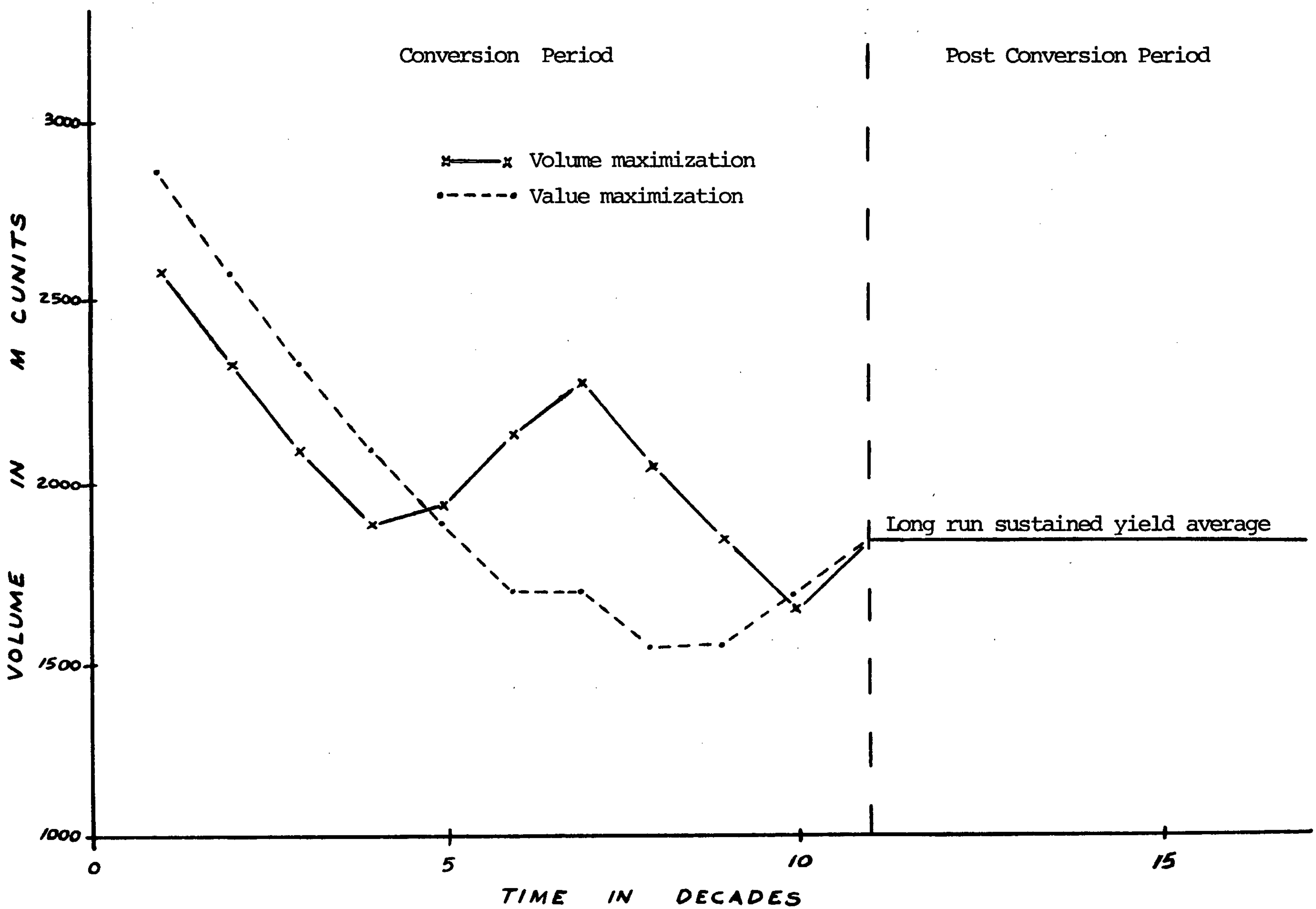
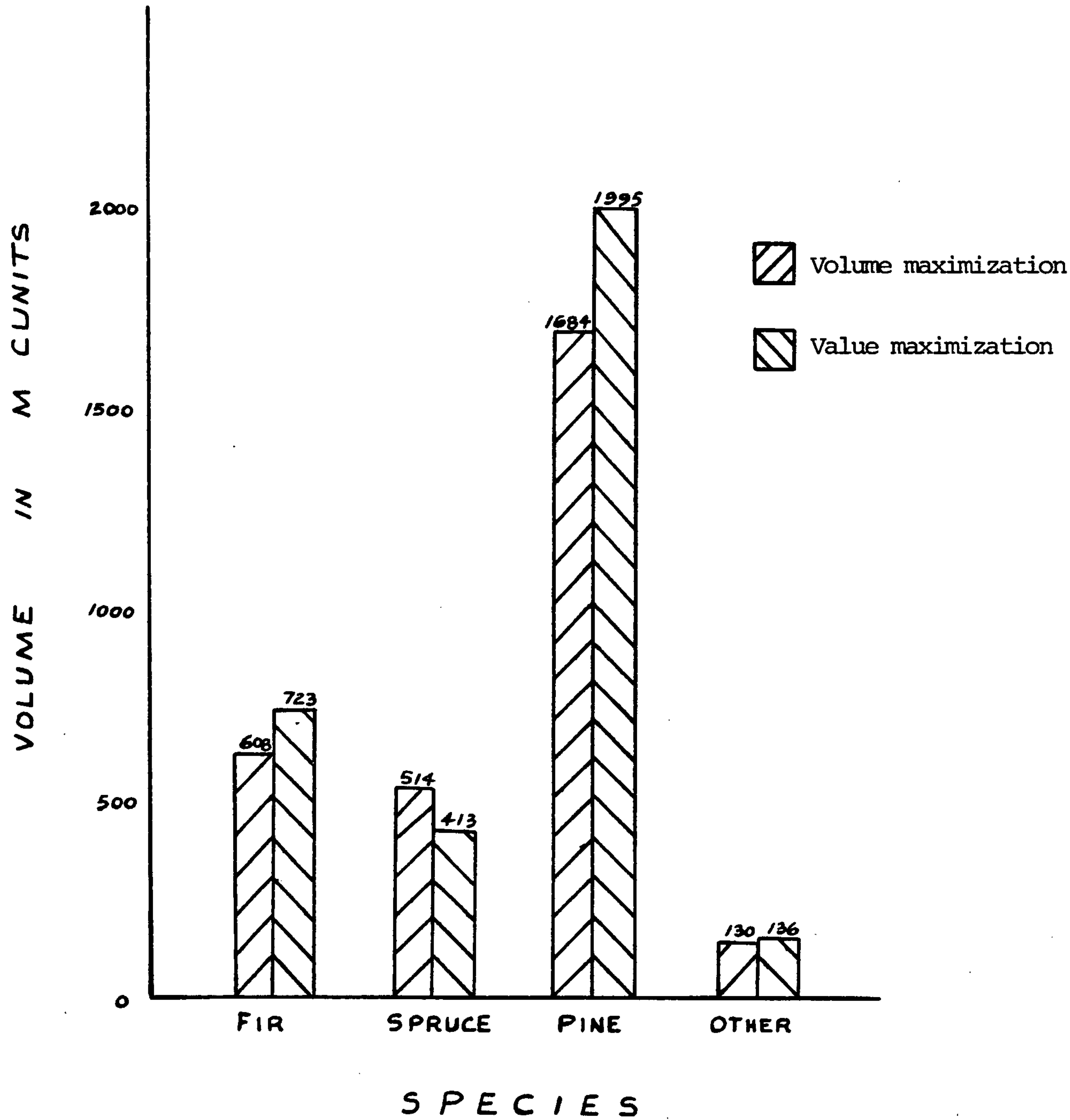


Figure 11. Comparison of Species Flow in Decade 1 - Case 2



during the first decade are shown in Table 8. The results generally support the early harvest of the higher valued stands under an economic objective. There is an average of $11/acre ($27.18/hectare) incremental return in favor of the stands harvested under value optimization. Conversely, stands with greater volume yields per unit area are given priority under volume maximization. Here the incremental return averages almost 12 cunits/acre (84 cubic metres/hectare) over those stands harvested under value optimization.

Hence, these results indicate that the economic potential of the Westlake PSYU, based on the harvest from the first decade, is approximately 17.55 million dollars per year. Further, value-based harvest planning generates an additional 1.93 million dollars annually (during the first decade) over a volume-based strategy, without any significant difference in the long range productivity of the unit.

6.2.3 Case 3: Economic Optimization - With Transportation vs. Without

Case 3 evaluated the consquences of recognizing accessibility and transportation in the scheduling of management unit harvests.

The Timber RAM run which maximized value production in Section 6.2.2 was compared with a previous run on the Westlake PSYU performed under the BCFS CARP system. The generation of a

Table 8. Differences in Timber Classes Scheduled for Harvest in Decade 1 - Case 2

Timber Class	Major Species	Age at Harvest	Volume CCF/acre	Value $/acre	Volume Max. Run MCCF	Volume Max. Run Acres	Value Max. Run MCCF	Value Max. Run Acres
009	Spruce	120	46.12	65.80	6	135		
021	Spruce	120	46.12	65.80	72	1,570		
036	Pine/ Pine-Spruce	90	32.11	57.02	248	7,731		
063	Spruce	120	46.12	65.80	155	3,355		
069	Cottonwood	150	70.19	18.65	4	50		
081	Pine	100	45.62	57.08	140	3,073		
083	Pine-Spruce	110	11.30	48.69	2	144		
096	Pine/ Pine-Spruce	120	58.62	53.65	78	1,337		
Total					705	17,395		
Average		116	44.53	54.06				
002	Pine	90	28.40	62.65			270	9,495
006	Fir	90	14.11	76.60			4	252
010	Pine/ Pine-Spruce	90	28.40	58.43			350	12,321
034	Fir	150	22.38	73.71			3	133
056	Spruce-Fir	130	47.10	66.17			105	2,225
076	Pine	110	55.44	55.54			21	379
Total							753	24,805
Average		110	32.63	65.52				

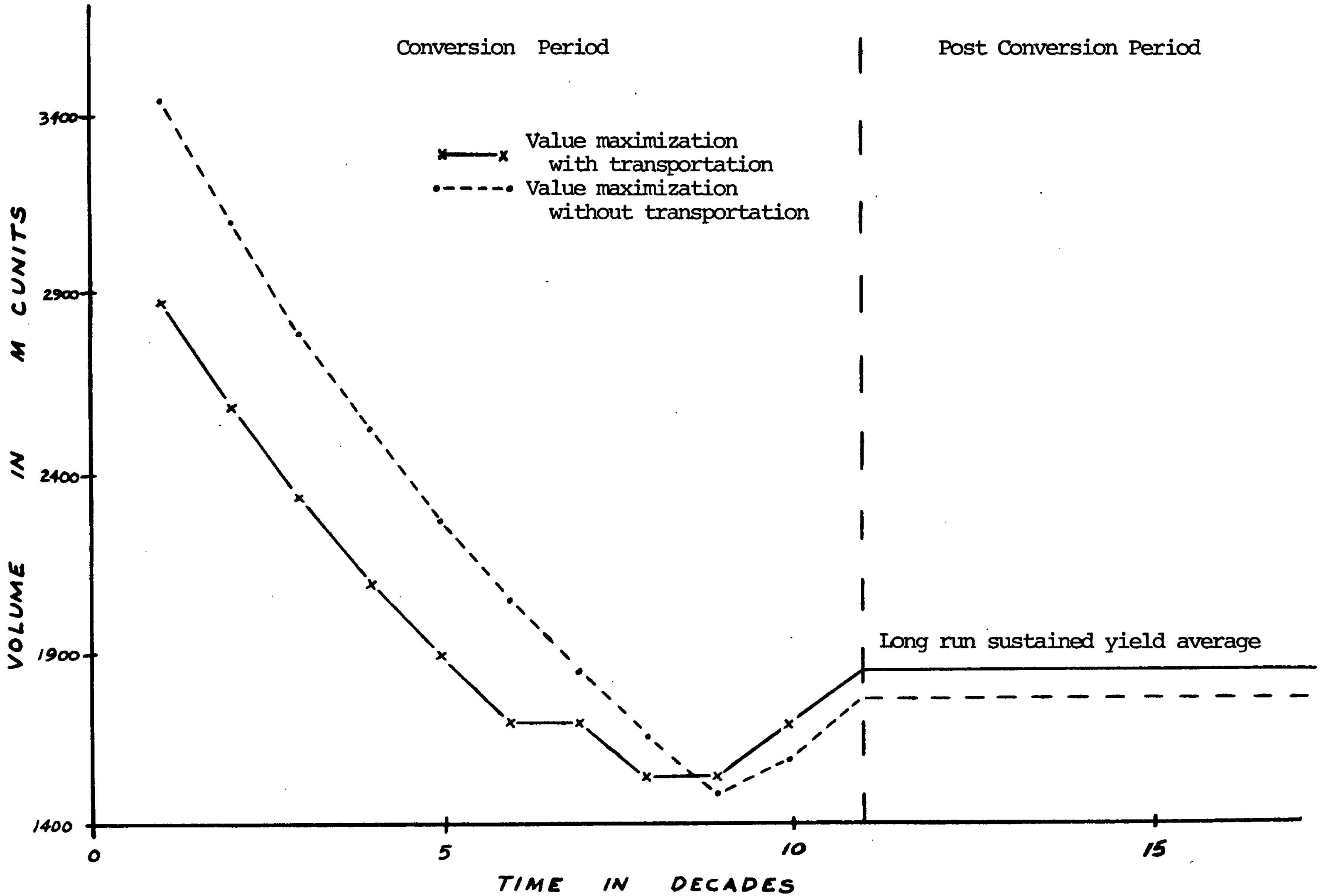
harvest schedule for this CARP run was devoid of any consideration of stand location. Stand valuation encompassed only those harvesting activities which resulted in the logs being loaded at the landing. No consideration was given to road development requirements, proximity to the existing road network or mill sites, hauling costs or stratification of the resulting timber classes into accessibility classes, as was incorporated in the TRACS system. These differences not only affected the present and projected value of each stand, but also affected timber class formation. In other words, stands for CARP were grouped together based on similarities in volume yields and value yields which included harvesting costs up to the landing. This differed from stand groupings for TRACS which were based on volume yields and value yields which included delivered cost to the mill. The CARP run resulted in 89 timber classes and 24 economic yield classes, whereas the TRACS system resulted in 100 timber classes and 30 economic yield classes.

Other than the above differences resulting from recognition of accessibility and transportation, the parameters for both RAM runs were identical. The objective of each run was to maximize net revenue (with an 8% discount rate) over a 200-year planning period. The conversion period for the old growth stands was specified to be 100 years, with a total scheduling horizon of 250 years. Sequential volume control and regulation constraints were imposed. The cut for the first decade was loosely constrained to be within -50% and +250% of the current cut level for both runs. Each subsequent decade's cut had to be within 10% of the previous 10-year cut level. The harvesting alternatives for each timber class consisted of the timing of a simple clearcutting-regeneration sequence. For mature classes, clearcutting was allowed to take place within a sixty-year span starting from the first decade. For immature classes, clearcutting was allowed within a sixty-year span starting from age 60 or 20 years prior to culmination of mean annual increment. Harvests became mandatory at an age of 200 years.

The objective function value for the CARP-based run was approximately 267.2 million dollars, whereas the value for the TRACS-based run was approximately 200.4 million dollars. Summary of the results can be found in Appendix XIII. Hence, ignoring transportation costs resulted in a 33% overstatement of the economic potential of the management unit over the planning horizon.

A comparison of the volume flow resulting from each run is shown in Figure 12. The CARP run, lacking transportation considerations, resulted in an 18% greater harvest level during the first 80 years. This harvest volume increment was realized to the detriment of the post conversion harvest level as shown in the figure. The long run sustained yield average for the CARP run was 1.76 million cunits (4.98 million cubic metres) as compared with 1.83 million cunits (5.18 million cubic metres) for the TRACS run. Examination of the results for the first decade reveals that the net revenue from the CARP run is 162.6 million dollars, as compared with 119.4 million dollars from the TRACS run. The corresponding volume harvested in the first decade is 3.4 million cunits (9.6 million cubic metres) for the CARP run versus 2.9 million cunits (8.2 million cubic metres)

Figure 12. Comparison of Volume Flow - Case 3



for the TRACS run. Hence, by not reflecting transportation considerations the scheduling not only generates more net revenue than actually exists but also harvests more volume than is currently accessible.

Figure 13 presents a comparison of the species flow resulting from the stands available for harvest in the first decade. The CARP run reveals that there is more Douglas-fir and spruce, and less lodgepole pine available than shown for the TRACS run. Specifically, the distribution for the CARP run is 32% Douglas-fir, 27% spruce, 36% lodgepole pine with the remainder other species. The distribution for the TRACS run is 22% Douglas-fir, 13% spruce, 61% lodgepole pine with the remainder other species.

The effect of reflecting accessibility and transportation considerations can be further evidenced by examining the results within one particular sub-unit, Compartment 20, Region 60 of the Westlake PSYU. Table 9 lists the stands available for harvest in the first decade. A description of the major species, age, soil-landform class, area and volume yield are given for each stand. In addition, two positional attributes are identified. The first attribute is the distance from the stand centroid to the road network. This attribute serves as an indicator of accessibility. The second attribute, distance from the stand to the appraisal location, serves as an indicator of transportation requirements.

The results from the TRACS run showed that from the list of candidate stands, both the distance to a primary access road and distance to the appraisal point are more favorable than for the

Figure 13. Comparison of Species Flow in Decade 1 - Case 3

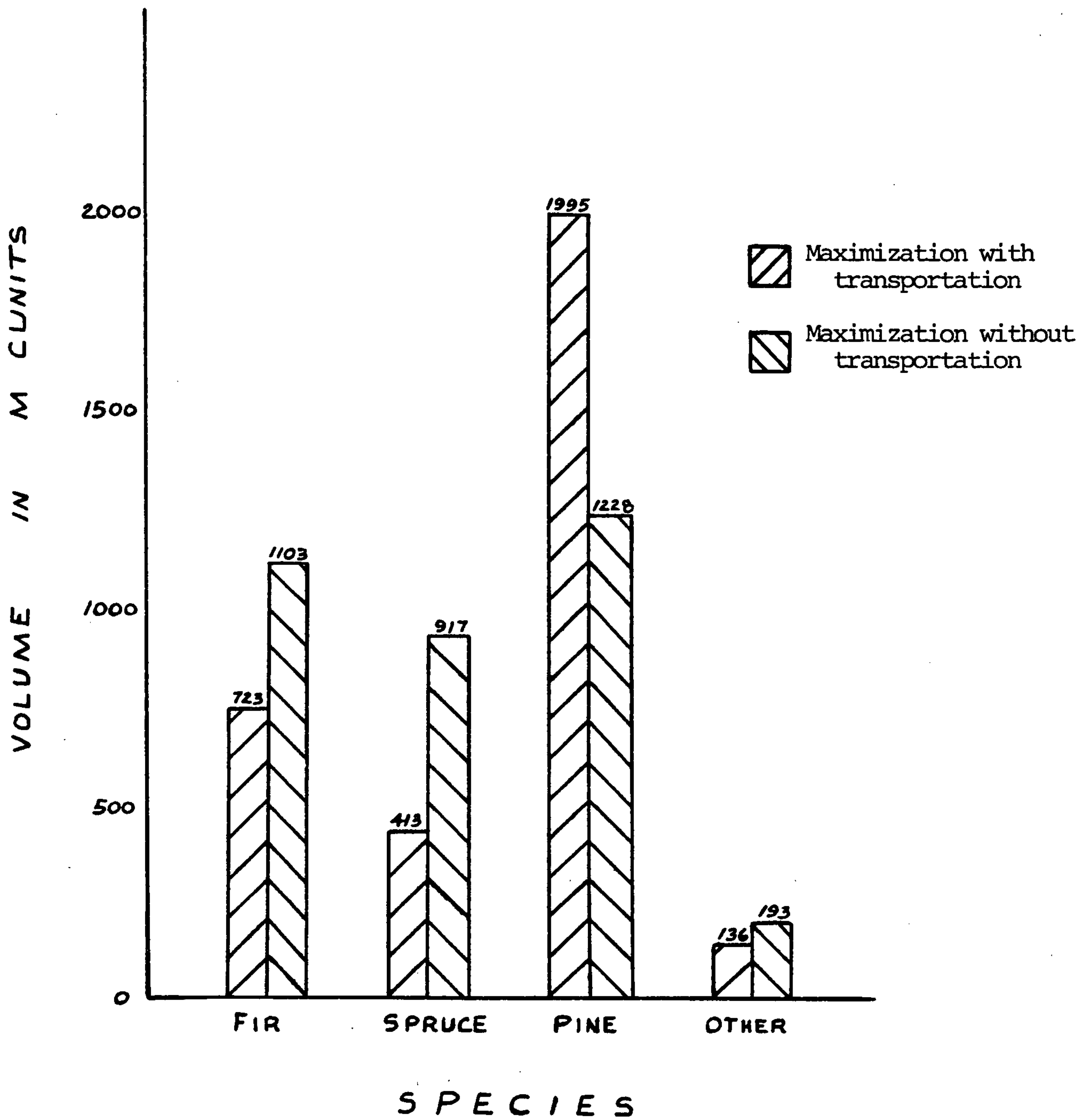


Table 9. Comparison of Stands Harvestable in Decade 1 within Compartment 20

Stand No.	Species	Age (Years)	Soil-Land Class	Transportation				Without Transportation			
				Acres	Volume (M cunits)	Dist. to road (miles)	Dist. to Appraisal (miles)	Acres	Volume (M cunits)	Dist. to road (miles)	Dist. to Appraisal (miles)
20007	Pl	90	17	215	7.2	0.5	24.6				
20013	Pl	90	17	43	1.5	0.2	24.9				
20018	Pl	70	18	498	15.9	0.4	30.5				
20025	Pl	70	18	140	4.5	0.5	31.1				
20029	Pl	90	8	39	1.4	0.2	24.3				
20033	S	90	8	23	1.2	0.2	24.7				
20050	Pl	70	8	68	2.2	0.1	25.5				
20056	F	150	15					19	1.1	1.6	33.7
20057	S	150	15					17	0.8	1.4	32.0
20058	F	130	15					632	28.1	0.2	30.8
20059	PlS	130	15					346	17.0	3.5	32.5
20061	PlS	110	15					37	1.3	2.0	28.9
20064	F	110	15					320	13.9	3.0	27.7
20066	S	90	15					330	17.1	1.6	28.7
20075	PlS	130	15					272	13.3	3.6	30.7
20076	S	130	15					26	1.7	3.7	29.9
20077	F	130	15					52	2.3	0.9	28.7
20078	Pl	110	15	45	3.0	0.8	32.9	45	3.0	0.8	32.9
20080	F	110	15	40	1.9	0.4	27.6	40	1.9	0.4	27.6
20081	S	90	15					17	0.9	2.5	29.6
20086	S	130	7					42	0.9	2.0	28.9
20090	F	110	7					104	4.5	3.4	28.5
20092	F	90	7					14	0.6	3.9	31.0
20099	S	130	7					10	0.2	0.2	5.7
20103	Pl	70	7	220	7.0	0.2	25.4				
20116	F	110	7					44	2.6	2.5	27.2
20117	S	110	7					21	1.3	0.1	27.6
20128	S	130	7					216	4.8	0.3	27.0
20129	PlS	130	7					109	5.3	3.5	6.7
20130	Pl	110	7	89	5.9	0.6	25.7				
20137	Pl	70	7	175	5.6	0.6	25.8				
TOTAL				1595	57.3			2713	122.6		
AVERAGE - weighted by volume						0.4	27.6			2.0	28.9

CARP run. Under the TRACS run, each stand is within a mile (1.6 kilometres) of the main road network. The average across all stands, weighted by volume, is 0.4 miles (0.6 kilometres). In comparison, stands up to 4 miles (6.4 kilometres) away from the road network are selected for harvest in the CARP run, the average distance being 2 miles (3.2 kilometres).

The stands scheduled for harvest in the first decade across the entire unit were on the average approximately 40% closer to the road network under the TRACS system. The table also shows that scheduling harvests without considering transportation, results in a greater average distance from the stands to the appraisal location. The stands selected from the CARP run averaged 1.3 miles (2.1 kilometres) more than for the TRACS run, with the average haul distance being 28.9 miles (46.5 kilometres) and 27.6 miles (44.4 kilometres) respectively.

Hence, accessibility and transportation considerations have significant impact on the scheduling of stands for harvest. The volume accessible and the value yield are both overstated for the Westlake PSYU in the absence of proper accounting of stand location. Stand location in relation to both the road network and the appraisal point or mill site must be integrated in management unit harvest planning.

7. CONCLUSIONS

Planning models never provide the total answer. They do, however, allow evaluation of alternatives. They provide management with a quantitative framework for exploring the consequences of proposed actions. The improved analytical capability provided by models reduces uncertainty in the planning environment. The result is better decision-making.

A continued supply of timber is critical to the well-being of both the industrial firm and the province as a whole. Harvest planning concerns the control of timber flows over time to meet supply needs. This control encompasses the quantitative aspects of when, what and where, relative to the volume and value yields to be derived from forest stands.

This thesis has presented TRACS, a Transportation Analysis-Cut Scheduling system designed for harvest planning at the management unit level. TRACS is an extension to existing harvest planning tools. The system integrates accessibility and transportation into the silvicultural and economic aspects of scheduling timber harvests for a management unit.

TRACS begins with a physical resource inventory, from which timber yields and silvicultural potential can be determined. Next, a transportation modelling subsystem relates the road network to primary stand access and log hauling requirements. Alternative stand-to-mill flows can be evaluated, with optimal routing strategies identified. An economic valuation is then performed for each stand based on delivered wood costs to the mill and end-product pricing of lumber and chips. At this point, the management unit inventory contains both volume and value information yielding an improved reflection of the timber resource.

Data analysis techniques of factor and cluster analysis were incorporated with dynamic programming to generate stand aggregations or timber classes. These timber classes, homogeneous in respect to volume and value responses, were a more appropriate delineation for management unit planning. Projections of volume and value yields corresponding to the timber class components were also formed. The Timber RAM model was then used to schedule the timber classes for harvest. The reporting features of TRACS finally transformed the results into understandable graphs and tables which related the havests back to the original stands.

The utility of the TRACS system has been demonstrated on a actual British Columbia forest management unit. The analyses presented have evaluated alternative volume flow and value flow strategies. The silvicultural and economic potential of the management unit has been identified. In addition, the consequences of excluding transportation considerations in harvest planning have been shown to be significant.

Relevant harvest planning results can only be achieved through explicit recognition of accessibility and transportation requirements. The TRACS system has been developed to facilitate such needs. The net result is a means for improved management unit harvest planning.

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APPENDIX I

Dijkstra's Shortest Route Algorithm

The algorithm considers the nodes and arcs of a network to be a member of one of three possible sets at any given instance:

1) SET I = $S_{N1} + S_{A1}$

   This is the set of permanently labelled nodes and arcs. The set includes all those nodes, S_{N1}, and arcs, S_{A1}, which are a part of a known minimum path. Nodes and their corresponding arcs will be added to this set in ascending order of path length from the source.

2) SET II = $S_{N2} + S_{A2}$

   This is the set of temporarily labelled nodes and arcs. The set includes all those nodes, S_{N2}, and arcs, S_{A2}, which are candidates for inclusion in Set I. All nodes in S_{N2} are connected to at least one node in S_{N1}. Further, each node in S_{N2} has one and only one arc in S_{A2} leading to it.

3) SET III = $S_{N3} + S_{A3}$

   This is the set of unlabelled nodes and arcs. The set includes all those nodes, S_{N3}, and arcs S_{A3} which have not been rejected.

Initially, all nodes and arcs are unlabelled and members of Set III, i.e. $S_{N3} = \{i \mid i=1,2,\ldots,n\}$ and $S_{A3} = \{a(i,j) \mid i \in S_{N3}$ and $j \in S_{N3}\}$. The algorithm then proceeds through the following steps:

Step 1) The source node, 1, is put in node set I, (i.e. $S_{N1} = \{1\}$) and given a permanent label value of zero.

Step 2) Consider all arcs connecting the node just transferred to S_{N1}, with any of the other nodes in S_{N2} or S_{N3}. Two possibilities arise in this temporary labelling process:

Case 1: $i \in S_{N1}$, $j \in S_{N2}$, $a(i,j) \in S_{A3}$
If any of the new nodes, j, to be considered are in S_{N2}, then check to see if the corresponding new arc, a(i,j) yields a shorter path distance from the source to node j than the previous arc. If arc a(i,j) yields a shorter distance, then place a(i,j) in S_{A2} and reject the previous arc in S_{A2}. If however, a(i,j) yields an equal or longer path, then reject a(i,j).

Case 2: $i \in S_{N1}$, $j \in S_{N3}$, $a(i,j) \in S_{A3}$
If any of the new nodes, j, is in S_{N3} place node j in S_{N2}, and place the corresponding arc, a(i,j) in S_{A2}.

Step 3) Restricting consideration of arcs to S_{A1} and to S_{A2}, every node j in S_{N2} has one and only one path connecting to the source node, 1. Associated with each path is a distance. The node j ($j \in S_{N2}$) having the shortest distance from the source is transferred from S_{N2} to S_{N1}, with the corresponding arc a(i,j) ($i \in S_{N1}, j \in S_{N2}$) transferred to S_{A1}. This step is the permanent labelling process.

Step 4) If all nodes (or the specified sink) have been transferred to S_{N1}, then stop. Otherwise, go to step 2 and continue processing.

If the shortest path from the source to all other nodes of an N node network is desired, then the iterative minimization must be executed exactly N-1 times. During the procedure N(N-1) elementary operations are needed to assign temporary labels, with an additional N(N-1)/2 comparisons necessary to assign permanent labels. A further $(N-1)^2$ comparisons are needed for updating and indexing the node list. Hence, a total of approximately $3N^2$ elementary operations are required. On this basis Dreyfus (1969) states that Dijkstra's algorithm is the most efficient around. Elsner, *et al.* (1975) offers further support in assessing Dijkstra's algorithm as superior to two other algorithms investigated.

APPENDIX II

Land Classes Of The Westlake PSYU
(Source: BCFS - Prince George, 1974)

Land Class I

Parent Material: Sandy loam and loam textured colluvium and/or till deposits overlying basic bedrock. Loam and clay loam textured glacial till.

Soil Series: A mixture of Cluculz and Twain.

Topography: Very steeply sloping and strongly rolling or very hilly.

Drainage: Ranges from imperfectly to rapidly drained.

Comments: Liable to damage by skidding and erosion. Susceptible to frost heaving. Soils often shallow and rocky with moisture limitations to regeneration.

Land Class II

Parent Material: Sandy loam and loam textured colluvium and/or till deposits overlying basic bedrock. Loam and clay loam textured glacial till.

Soil Series: A mixture of 60% Oona and 40% Twain.

Topography: Very steeply sloping and strongly rolling.

Drainage: Moderately well to rapidly drained.

Comments: Liable to damage by skidding and erosion.

Land Class III

Parent Material: Ablation till deposits or gravelly outwash and valley train deposits overlain with loamy sand, sand and sandy loam textured capping.

Soil Series: A mixture of 60% Cobb and 40% Ramsey.

Topography: Gently to moderately rolling.

Drainage: Ranges from imperfect to rapid.

Comments: Soil moisture limitations to regeneration. Fertility sometimes low.

Land Class IV

Parent Material: Loam and clay loam textured glacial till deposits; intermittent surface modification with sandy loam textures. Rolling and hilly drumlinized till plain land forms. These may be combined with gravelly outwash and valley train deposits overlain with loamy sand and sandy loam textured capping.

Soil Series: Deserter or mainly Deserter.

Topography: Sometimes steeply sloping and hilly, usually rolling and hilly.

Drainage: Mostly imperfectly to well drained with rapid drainage on the gravelly outwash deposits.

Comments: Susceptible to some frost heaving.

Land Class V

Parent Material: Heavy clay textured glacio-lacustrine deposits. Some silt loam to silty loam textured glacio-lacustrine deposits.

Soil Series: Pineview or 80% Pineview and 20% Berman.

Topography: Undulating to strongly rolling.

Drainage: Ranges from imperfect to moderately well.

Comments: Susceptible to frost heaving. Logging may increase compaction and erosion and cause stream siltation.

Land Class VI

Parent Material: Sphagnic moss, sedge and associated hydrophytic vegetation.

Soil Series: A mixture of Chief and Moxley.

Topography: Depressional to nearly level or gently undulating.

Drainage: Very poor.

Comments: Filled in areas of lakes and ponds often supporting black spruce.

Land Class VII

Parent Material: Mainly clay textured glacio-lacustrine deposits. Some variable textured fluvial deposits and silt loam to silty clay loam textured glacio-lacustrine deposits.

Soil Series: Mainly Vanderhoof, with some Stellako, Berman and Bednesti.

Topography: Ranges from nearly level to strongly rolling.

Drainage: Ranges from imperfectly to rapid, with the majority moderately well to well drained.

Comments: Susceptible to frost heaving. Logging results in loss of soil structure, increased compaction and erosion yielding stream sedimentation.

Land Class VIII

Parent Material: Variable textured fluvial deposits. Small inclusions of sphagnic moss, sedge and associated hydrophytic vegetation.

Soil Series: Mainly Stellako, with some Moxley and Chief.

Topography: Nearly level to undulating.

Drainage: Ranges from very poor to rapid.

Comments: Logging may cause stream sedimentation.

Land Class IX

Parent Material: Loam and clay loam textured glacial till deposits. Rolling, hilly, strongly to very steeply sloping till plain land forms between approximately 3500 to 4500 feet elevation. Also sandy loam textured colluvium and/or till deposits overlying basic bedrock.

Soil Series: A mixture of 70% Twain and 30% Oona.

Topography: Very steeply sloping.

Drainage: Moderately well.

Comments: Frost heaving and generally poor climatic conditions for growth.

<u>Land Class X</u>

Parent Material: Sandy loam and loamy sand textured ablation till deposits; clay textured glacio-lacustrine deposits; some loam and clay loam textured glacial till deposits; some inclusion of sphagnic moss, sedge and associated hydrophytic vegetation.

Soil Series: A mixture of Crystal, Cobb, Deserter; Crystal, Moxley and Chief; Crystal and deserter; Beaverly.

Topography: Ranges from gently undulating to strongly rolling.

Drainage: Ranges from very poor to well drained.

Comments: The areas of non-organic origin are stable and robust.

<u>Land Class XI</u>

Parent Material: Gravelly outwash and valley train overlain with loamy sand, sand and sandy loam textured capping. Silt loam to silty clay loam textured glacio-lacustrine deposits. Gravelly and sandy esker deposits with variable interstratified loamy sand, sand and sandy loam. Sandy outwash and deltaic deposits.

Soil Series: A mixture of Alix, Berman, Roaring, Giscombe, Mapes, Saxton and Deserter.

Topography: Gently undulating to gently rolling.

Drainage: Ranges from moderately well to rapidly drained.

Comments: Generally stable, logging on the fine textured glacio-lacustrine deposits results in some erosion and stream siltation.

Land Class XII

Parent Material: Sandy loam and loam textured colluvium and/or till deposits overlying acidic bedrock.

Soil Series: A mixture of Decker, Deserters and Ormond.

Topography: Hilly to very hilly.

Drainage: Ranges from well to rapidly drained.

Comments: Shallow and rocky soils. Significant soil loss can occur as a result of skidding and erosion.

Land Class XIII

Parent Material: Silt loam to silty clay loam textured glacio-lacustrine deposits. Heavy clay textured glacio-lacustrine deposits.

Soil Series: A mixture of Berman, Pineview, Giscome and Fraser.

Topography: Gently undulating to moderately rolling.

Drainage: Ranges from poorly to well drained.

Comments: Susceptible to frost heaving. Stream siltation may occur after logging on the steeper slopes.

Land Class XIV

Parent Material: Gravelly and sandy esker deposits with variable inter-stratified loamy sand, sand and sandy loam. Some inclusion of sedge and associated hydrophytic vegetation.

Soil Series: A mixture of Roaring and Chief.

Topography: Ranges from nearly level to strongly rolling.

Drainage: Rapid on mineral soils, very poor on organic.

Comments: Mineral soils droughty and of low fertility.

Land Class XV

Parent Material: Loam and clay loam textured glacial till deposits; intermittent surface modification with sandy loam textures. Rolling and hilly drumlinized till plain land form. Some beach deposits of loamy sand and sandy textures.

Soil Series: Mainly Barrett with some Kluck and Crystal.

Topography: Ranges from undulating to hilly.

Drainage: Ranges from imperfectly to rapidly drained.

Comments: Generally stable and robust.

Land Class XVI

Parent Material: Loam to clay loam textured glacial till deposits; intermittent surface modification with sandy loam textures. Steep land till land forms. Sandy loam and loam textured colluvium and/or till deposits overlying basic bedrock.

Soil Series: A mixture of Telegraph and Ormond.

Topography: Strongly rolling and hilly.

Drainage: Ranges from moderately well to rapidly drained.

Comments: Climatic conditions for growth are poor.

Land Class XVII

Parent Material: Gravel and sand esker and kame deposits; hummocky.

Soil Series: A mixture of Morice, Guniza and Ramsey.

Topography: Gently undulating to moderately rolling.

Drainage: Ranges from rapid to well drained.

Comments: High probability of damage from slash burning.

Land Class XVIII

Parent Material: Sandy outwash and valley terrace deposits overlain with finer sands and loamy sands. Some depositional clay strata.

Soil Series: Mainly Cottonwood, with some Blackwater.

Topography: Ranges from gently undulating to strongly rolling.

Drainage: Rapid to well drained, but moderately well to imperfectly drained where clay strata occur.

Comments: High probability of damage from slash burning.

Land Class XIX

Parent Material: Sandy outwash and valley terrace deposits overlain with finer sands and loamy sands. Some depositional clay strata. Silt loam to silty clay loam textured glacio-lacustrine deposits.

Soil Series: A mixture of Blackwater, Beaverly, Bednesti and Cottonwood.

Topography: Ranges from gently undulating to strongly rolling.

Drainage: Ranges from imperfectly to rapidly drained.

Comments: Broadcast burning acceptable on the lacustrine deposits. Otherwise a high probability of damage from slash burning.

APPENDIX III

Prescribed Stand Treatments For The Westlake PSYU

TREATMENT SEQUENCES

LC/GT	Method of Falling	Tree Extracted As	Extracted By	Season	Site Prep.	Regen. Method	Next Crop
Number	H = hand	T = tree length	S = Skidder	W = Winter	D = Drag Scarify	N = Natural Regen.	Species
Species	M = Mech	F = Full tree	C = Cat	S = Summer	B = Broadcast burn	P = Plant	
Either	= Snip, saw or feller-buncher	L = Log length			W = Windrow		
					N = No treatment		
S = Spruce + F		C = Clean log			(N*)		
P = Pine + F							
D = Decid.							
All							

Note: When there are optional operations, the frequency of occurrence is given as a percent.

Link operations are obligatory sequences.

N* - If not cleanly logged, knock down slash with chain.

Land Class and Growth Type		Method of Felling	Tree Extracted As	Extracted By	Season	Site Preparation	Regeneration Method	Subsequent Crop
I	All (Twain)	H	T C	C 6 S 4	W	N	N	Pl (F)
II	All	= I						
III	All	M	F (fert. problem)	S	S 7	N*	N	Pl
					W 3	D		
IV	All	M 7 H 3	F	S 8 C 2	W 5	D	N	Pl
					S 5	N		
V	S	H	T	C 5 S 5	W	B	P	S (F)
V	P+D	M	F	S 6	W 8	B+W	P	S (F)
			T	C 4	S 2	D	N	Pl (S)
VI		No logging						
VII	S	H	T	S 6 C 4	W 7	B	P	S (F)
					S 3	W+B		

Land Class and Growth Type		Method of Felling	Tree Extracted As	Extracted By	Season	Site Preparation	Regeneration Method	Subsequent Crop
VII	P	M	T F	S 7 C 3	W 7 -------- S 3 --------	B+W 6 --------- D 4 -----------	P ----------- N -----------	S (F) Pl (S)
VIII	D (Cottonw.)	H (20 ac)	L	C 7 S 3	W	N	Residual	Cot.
VIII	S (+P)	H	T	C 5 S 5	W	B (Brush prob.)	P	S
IX	All	= I & II	(Twain)	Topography	Important			
X	All	= III	Wide fluctuations in X. X may need more cat and more winter than III					
XI	All	= X = III						
XII	All	H	T	S 5 C 5	W	N D if slope % < 20%	N	Pl
XIII		= V	(2 sections)					
XIV	All	H 7 M 3	T	S	S	D 7 N 3	N	Pl

Land Class and Growth Type	Method of Felling	Tree Extracted As	Extracted By	Season	Site Preparation	Regeneration Method	Subsequent Crop
XV All	M	F	S	S 6 -------- W 4 --------	N D	N	Pl
XVI	= I						
XVII	= XIV						
XVIII All	M	F	S	S 7 -------- W 3 --------	N D	N	Pl
XIV	= VII	(2 way)					

APPENDIX IV

Management Reports On Stands Of The Westlake PSYU

REGION	COMPT.	STAND NO.	SOIL-LAND	USE CLASS	POT. USE	TIMBER SPP.	AGE CLASS	EXP. REGEN.	STOCKING	SITE	ACREAGE	VOL.(MCF)
60	14	14065160	4	DEFERRED	NONE	PL	4	PL(SF)		G	16	2154
60	14	14066160	4	DEFERRED	NONE	S	5	SFB		M	14	616
60	14	14067160	4	DEFERRED	NONE	PLS	5	PL(SF)		M	14	2228
60	14	14068160	5	FORESTRY	NONE	SF	8	SF		G	151	4700
60	14	14069160	5	FORESTRY	NONE	FS	7	FSPL		M	132	3700
60	14	14070160	5	FORESTRY	NONE	PLS	6	PLS		M	140	4000
60	14	14071160	5	FORESTRY	NONE	PL	1	PLF(S)		M	132	0
60	14	14072160	5	FORESTRY	NONE	PL	2	PL(AF)		P	1876	140
60	14	14073160	5	FORESTRY	NONE	S	2	S		P	11	60
60	14	14074160	5	FORESTRY	NONE	PL	3			P	186	300
60	14	14075160	5	FORESTRY	NONE	PL	4	PL(SF)		G	1428	1828
60	14	14076160	5	FORESTRY	NONE	S	4	SPL		P	37	285
60	14	14077160	5	FORESTRY	NONE	DECID	4			M	65	1150
60	14	14078160	5	FORESTRY	NONE	PLS	5	PL(SF)		G	75	3019
60	14	14079160	5	FORESTRY	NONE	FS	5	F(S)		M	47	2681
60	14	14080160	5	FORESTRY	NONE	S	6	S		M	42	731
60	14	14081160	5	FORESTRY	NONE	NP					163	0
60	14	14082160	5	UNGULATE	NONE	F	7	F(PLS)		M	86	2750
60	14	14083160	5	UNGULATE	NONE	PL	2	PL(AF)		P	80	140
60	14	14084160	5	UNGULATE	NONE	PL	3	PL(AS)		P	6	300
60	14	14085160	5	UNGULATE	NONE	DECID	3			P	6	616
60	14	14086160	5	UNGULATE	NONE	PL	4	PL(SF)		P	86	850
60	14	14087160	5	UNGULATE	NONE	PLS	5	PL(SF)		G	37	3019
60	14	14088160	5	UNGULATE	NONE	LOGGED				P	10	0
60	14	14089160	6	FORESTRY	NONE	S	7	S		G	131	5200
60	14	14090160	6	FORESTRY	NONE	PL	2	PL		M	113	550
60	14	14091160	6	FORESTRY	NONE	S	2			M	13	875

REGION	COMPT.	STAND NO.	E. HARV. YR.	L. HARV. YR.	SEASON OF HARVEST	OPERATION TYPE	SITE PREPARATION	REGENERATION
60	14	14065160	601	60	SUMMER	FULL TREE SKID	NONE	NAT
60	14	14066160	601	80	SUM. OR WIN.	FULL TREE SKID	NONE	NAT
60	14	14067160	601	60	SUMMER	FULL TREE SKID	NONE	NAT
60	14	14068160	600	20	WINTER	FULL TREE CLEAN LOG	NONE	NAT
60	14	14069160	600	20	WINTER	LOP AND SCATTER	NONE	NAT
60	14	14070160	600	20	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14071160	601	100	SUM. OR WIN.	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14072160	601	80	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14073160	601	100	WINTER	FULL TREE SKID	COMPLETE SLASHBURN	PLT
60	14	14074160	601	60	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14075160	601	60	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14076160	601	100	WINTER	SELECTION CLEAN LOG	NONE	NAT
60	14	14077160	60		NONE	PROTECTION FOREST	NONE	
60	14	14078160	601	40	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14079160	601	60	SUM. OR WIN.	FULL TREE SKID	NONE	NAT
60	14	14080160	601	80	WINTER	SELECTION CLEAN LOG	NONE	NAT
60	14	14081160			NONE	NONE	NONE	
60	14	14082160	601	40	WINTER	FULL TREE CLEAN LOG	NONE	NAT
60	14	14083160	601	80	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14084160	601	60	WINTER	FULL TREE CLEAN LOG	NONE	NAT
60	14	14085160	60		NONE	PROTECTION FOREST	NONE	
60	14	14086160	601	60	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14087160	601	40	WINTER	FULL TREE SKID	DRAG SCARIFY	NAT
60	14	14088160	60		NONE	PROTECTION FOREST	NONE	
60	14	14089160	600	40	WINTER	SELECTION FULL TREE	NONE	NAT
60	14	14090160	601	80	WINTER	FULL TREE SKID	NONE	NAT
60	14	14091160	60		NONE	PROTECTION FOREST	NONE	

STAND#	G-TYPE	SL	AGE	USE	SITE	VOL	AREA	SEAS	OP	SITE PREP	REG	SPECIES	LOGPRICE /MCF	HARVEST COST/MCF	FORESTRY COST/MCF	ROADING COST/MCF	COORDINATES
14058160	B	4	6	F	M	325	6	W	LAS		NAT	SF					
14059160	F	4	6	F	M	249	20	S	FTS	DS	NAT	FS					
14060160	LOGGED	4		F	G		1047	*	FTS		NAT	PLFS					
14061160	NP	4		F			212										
14062160	SF	4	8	D	G	520	21	W	LAS		NAT	SF					
14063160	PLS	4	6	D	G	400	284	S	FTS		NAT	PL(S)					
14064160	PL	4	5	D	G	355	449	S	FTS		NAT	PL(SF)					
14065160	PL	4	4	D	G	215	16	S	FTS		NAT	PL(SF)					
14066160	S	4	5	D	M	61	14	*	FTS		NAT	SFB					
14067160	PLS	4	5	D	M	222	14	S	FTS		NAT	PL(SF)					
14068160	SF	5	8	F	G	470	151	W	FCL		NAT	SF					
14069160	FS	5	7	F	M	370	132	W	LAS		NAT	FSPL					
14070160	PLS	5	6	F	M	400	140	W	FTS	DS	NAT	PLS					
14071160	PL	5	1	F	M		132	*	FTS	DS	NAT	PLF(S)					
14072160	PL	5	2	F	P	14	1876	W	FTS	DS	NAT	PL(AF)					
14073160	S	5	2	F	P	6	11	W	FTS	CSB	PLT	S					
14074160	PL	5	3	F	P	30	186	W	FTS	DS	NAT						
14075160	PL	5	4	F	G	182	1428	W	FTS	DS	NAT	PL(SF)					
14076160	S	5	4	F	P	28	37	W	SCL		NAT	SPL					
14077160	DECID	5	4	F	M	115	65		PRT								
14078160	PLS	5	5	F	G	301	75	W	FTS	DS	NAT	PL(SF)					
14079160	FS	5	5	F	M	268	47	*	FTS		NAT	F(S)					
14080160	S	5	6	F	M	73	42	W	SCL		NAT	S					
14081160	NP	5		F			163										
14082160	F	5	7	U	M	275	86	W	FCL		NAT	F(PLS)					
14083160	PL	5	2	U	P	14	80	W	FTS	DS	NAT	PL(AF)					
14084160	PL	5	3	U	P	30	6	W	FCL		NAT	PL(AS)					
14085160	DECID	5	3	U	P	61	6		PRT								
14086160	PL	5	4	U	P	85	86	W	FTS	DS	NAT	PL(SF)					
14087160	PLS	5	5	U	G	301	37	W	FTS	DS	NAT	PL(SF)					
14088160	LOGGED	5		U	P		10		PRT								
14089160	S	6	7	F	G	520	131	W	SFT		NAT	S					
14090160	PL	6	2	F	M	55	113	W	FTS		NAT	PL					
14091160	S	6	2	F	M	87	13		PRT								
14092160	PL	6	3	F	M	135	7	S	FTS		NAT	PL					
14093160	S	6	5	F	M	347	10	W	FTS		NAT	S(PL)					
14094160	B	6	6	F	M	344	5	W	LAS		NAT	BS					
14095160	NP	6		F			356										
14096160	PL	7	1	F	M		8	W	FTS		NAT	PL					
14097160	PL	7	2	F	P	14	21	W	FTS		NAT	PL					
14098160	DECID	7	3	F	P	80	15	W	FTS		NAT	APL					
14099160	LOGGED	7		F	G		112	W	FTS		NAT	PL(SF)					
14100160	NP	7		F			10										
14101160	F	7	7	U	M	275	19	W	LAS		NAT	FS					
14102160	PL	7	5	U	G	290	86	W	FTS		NAT	PL(AS)					
14103160	PL	7	1	U	M		67	W	FTS		NAT	PL					
14104160	PL	7	2	U	P	14	248	W	FTS		NAT	PL					
14105160	DECID	7	3	U	P	80	26	W	FTS		NAT	APL					
14106160	PL	7	4	U	G	215	15	W	FTS	DS	NAT	PL(F)					
14107160	LOGGED	7		U	G		81	W	FTS		NAT	PL(SF)					
14108160	NP	7		U			45										
14109160	PL	7	5	G	G	290	8	W	FTS		NAT	PL(AS)					
14110160	PL	7	2	G	P	14	27	W	FTS		NAT	PL					
14111160	DECID	7	3	G	M	40	13		PRT								
14112160	PL	7	3	G	G	121	9	W	FTS	DS	NAT	PL					
14113160	DECID	7	3	G	P	80	18		PRT								

APPENDIX V

Stand Economics Report On Mature Stands

STAND ECONOMICS REPORT

STAND NO.	AGE	SITE	G-TYPE	VOLUME CCF/AC	STOCK. PCT.	SELL PR. $/CCF	F-B COST $/CCF	SKID COST $/CCF	AREA COST $/CCF	HARV.COST $/CCF	HAUL COST $/CCF	RD DEV. $/CCF	NET VALUE $/CCF	NET VALUE $/ACRE
24139160	12	2	PL	36.00	0.95	70.03	2.55	4.05	0.38	6.98	0.50	0.0	62.54	2251.58
24035160	12	2	S	37.50	0.95	75.52	3.48	5.73	0.63	9.84	5.09	0.0	60.59	2272.16
24069155	12	2	F	38.60	1.05	87.45	2.86	3.22	0.43	6.51	7.98	0.0	72.96	2816.26
24131160	12	2	PLS	44.00	1.14	59.17	2.59	4.78	0.24	7.61	0.84	0.0	50.72	2231.50
24155160	12	2	PLS	36.00	0.93	59.17	2.59	4.19	0.38	7.16	0.54	0.0	51.47	1852.92
24095160	12	2	PLS	36.00	0.93	59.17	2.59	4.19	0.55	7.33	0.63	0.0	51.22	1843.76
24074160	12	2	PL	36.00	0.95	70.03	2.55	4.05	0.55	7.15	0.56	0.0	62.32	2243.51
24078160	12	2	SPL	44.00	1.08	73.76	2.94	4.47	0.45	7.86	5.33	0.0	60.57	2665.21
24015155	12	2	PL	44.00	1.16	70.03	2.55	4.05	0.45	7.05	6.89	0.0	56.09	2467.82
25006160	12	1	PL	43.00	0.75	69.59	2.55	5.45	0.70	8.70	6.05	0.0	54.84	2358.05
25041160	12	1	PLF	44.00	0.77	74.55	2.64	3.66	0.31	6.61	6.12	0.0	61.82	2720.02
25007160	12	2	PLF	43.00	1.11	74.55	2.64	5.00	0.70	8.34	6.76	0.0	59.45	2556.23
25057160	12	2	S	31.90	0.81	75.52	3.03	4.66	0.43	8.12	7.85	0.0	59.56	1899.84
25056160	12	2	PLS	36.00	0.93	59.17	2.59	4.19	0.38	7.16	7.81	0.0	44.20	1591.30
25064160	12	2	PL	36.00	0.95	70.03	3.49	4.90	1.13	9.53	7.90	0.0	52.61	1893.79
25043160	12	2	S	37.50	0.95	75.52	3.03	4.66	0.36	8.05	6.99	0.0	60.47	2267.80
25065160	12	3	PLS	11.00	0.51	71.55	4.83	5.03	3.69	13.55	7.90	0.0	50.11	551.16
25075160	12	3	SF	21.50	0.90	77.61	4.66	4.91	1.89	11.46	7.67	0.0	58.48	1257.27
25074160	12	3	PLS	11.00	0.51	71.55	4.83	5.03	3.69	13.55	8.41	0.0	49.59	545.52
25067160	12	3	SF	21.50	0.90	77.61	4.66	4.91	1.89	11.46	7.91	0.0	58.24	1252.12
39003160	12	1	PLS	40.00	0.70	70.03	2.87	5.13	0.59	8.58	2.71	0.0	58.73	2349.29
43009160	12	1	PL	32.00	0.56	69.59	2.55	4.05	0.62	7.22	6.75	0.0	55.61	1779.63
43004160	12	2	PLS	36.00	0.93	59.17	3.56	6.24	0.75	10.55	6.59	0.0	42.03	1513.20
43010160	12	2	PLS	36.00	0.93	59.17	2.59	4.19	0.55	7.33	6.77	0.0	45.07	1622.53
43001160	12	2	PLS	36.00	0.93	59.17	3.18	8.59	0.47	12.23	6.78	0.0	40.16	1445.90
53002155	12	1	PL	36.00	0.63	69.59	2.55	4.05	0.38	6.98	8.58	1.73	52.29	1882.35
53013155	12	3	PLS	13.00	0.60	71.55	4.55	5.03	3.13	12.70	8.32	1.73	48.80	634.34
53007155	12	3	PLS	13.00	0.60	71.55	4.55	5.03	3.13	12.70	8.61	1.73	48.51	630.64
76008155	12	1	PL	35.60	0.62	69.59	2.55	4.05	0.38	6.99	10.32	0.0	52.28	1861.12
76003155	12	1	PL	35.60	0.62	69.59	3.50	4.90	1.14	9.55	10.31	0.0	49.73	1770.54
77006155	12	1	PLS	40.00	0.70	70.03	2.59	4.19	0.34	7.12	9.73	0.0	53.17	2126.98
77044155	12	1	PL	35.60	0.62	69.59	3.50	4.90	1.14	9.55	8.54	1.73	49.77	1771.73
77045155	12	1	PLS	40.00	0.70	70.03	3.51	5.03	1.02	9.55	9.99	0.0	50.49	2019.46
77038155	12	1	PLS	40.00	0.70	70.03	3.51	5.03	1.02	9.55	9.95	0.0	50.53	2021.31
77037155	12	1	PL	35.60	0.62	69.59	3.50	4.90	1.14	9.55	8.57	1.73	49.74	1770.57
77005155	12	2	PL	35.60	0.94	70.03	2.55	4.05	0.38	6.99	9.51	0.0	53.53	1905.59
9043160	14	1	S	50.50	0.92	75.52	3.39	5.40	0.47	9.26	2.63	0.0	63.63	3213.48
9007160	14	2	S	8.00	0.19	75.52	6.42	6.69	3.58	16.69	1.63	0.0	57.20	457.62
9023160	14	2	S	8.00	0.19	75.52	6.42	6.69	3.58	16.69	1.57	0.0	57.27	458.12
9038160	14	2	F	44.00	1.12	87.45	2.86	4.17	0.65	7.68	1.26	0.0	78.51	3454.49
9029160	14	3	F	44.00	1.62	87.45	2.86	4.17	0.65	7.68	1.26	0.0	78.51	3454.36
6001160	14	1	S	52.00	0.95	75.52	4.30	6.69	0.55	11.54	2.13	0.0	61.84	3215.89
6011160	14	1	S	29.00	0.53	75.52	3.48	5.40	0.82	9.69	2.10	0.0	63.72	1847.90
8004160	14	1	PL	64.10	1.03	65.20	2.74	4.67	0.37	7.78	4.02	0.0	53.40	3422.76
8035160	14	2	PL	53.40	1.30	67.12	2.55	5.28	0.54	8.37	5.74	0.0	53.01	2830.87
8066160	14	2	DECI	24.60	0.81	32.36	2.56	5.43	1.17	9.15	5.52	0.0	17.68	435.03
8021160	14	2	PL	26.20	0.64	67.12	2.87	4.67	0.90	8.45	4.16	0.0	54.51	1428.03
10069160	14	2	S	47.00	1.11	75.52	4.34	6.16	0.64	11.15	0.92	0.0	63.45	2982.25
10130160	14	2	F	44.00	1.12	87.45	2.86	3.48	0.24	6.58	0.39	0.0	80.48	3541.04
10067160	14	2	S	47.00	1.11	75.52	4.34	6.69	0.61	11.64	1.43	0.0	62.45	2935.26

STAND ECONOMICS REPORT

STAND NO.	AGE	SITE	G-TYPE	VOLUME CCF/AC	STOCK. PCT.	SELL PR. $/CCF	F-B COST $/CCF	SKID COST $/CCF	AREA COST $/CCF	HARV.COST $/CCF	HAUL COST $/CCF	RD DEV. $/CCF	NET VALUE $/CCF	NET VALUE $/ACRE
10030160	14	2	F	68.00	1.73	87.45	3.28	3.73	0.35	7.36	1.70	0.0	78.39	5330.70
10059160	14	2	S	47.00	1.11	75.52	4.34	6.69	0.61	11.64	1.39	0.0	62.49	2936.87
10109160	14	2	F	44.00	1.12	87.45	2.86	4.17	0.65	7.68	0.26	0.0	79.51	3498.45
10042160	14	2	S	47.00	1.11	75.52	4.34	6.69	0.61	11.64	1.16	0.0	62.72	2947.75
10002160	14	2	PLS	24.00	0.58	71.55	2.94	4.81	0.98	8.74	2.92	0.0	59.90	1437.53
10140160	14	2	F	44.00	1.12	87.45	2.86	3.48	0.24	6.58	0.31	0.0	80.56	3544.58
10003160	14	2	SF	50.00	1.30	77.61	3.26	4.66	0.47	8.40	2.71	0.0	66.50	3325.12
10018160	14	2	PLS	24.00	0.58	71.55	2.94	4.81	0.98	8.74	3.01	0.0	59.80	1435.30
11062160	14	1	S	56.00	1.02	75.52	4.28	6.69	0.48	11.45	2.53	0.0	61.54	3446.29
11015160	14	1	FS	56.00	0.95	86.34	3.34	3.93	0.42	7.69	2.38	0.0	76.28	4271.54
11014160	14	2	PLS	49.00	1.18	71.55	2.81	4.81	0.48	8.11	1.23	0.0	62.22	3048.58
11044160	14	2	PLS	49.00	1.18	71.55	2.58	5.43	0.58	8.60	1.04	0.0	61.91	3033.74
12057160	14	1	PLS	49.00	0.81	71.74	2.58	3.89	0.40	6.88	3.96	0.0	60.90	2983.94
12002160	14	2	S	45.00	1.06	75.52	4.36	5.40	0.90	10.67	3.91	0.0	60.95	2742.72
12058160	14	2	S	35.00	0.83	75.52	2.99	4.35	0.56	7.90	4.37	0.0	63.24	2213.51
14032160	14	1	FS	44.50	0.75	86.34	2.88	3.65	0.24	6.77	1.92	0.0	77.65	3455.55
14089160	14	1	S	52.00	0.95	75.52	3.78	9.33	0.32	13.43	2.22	0.0	59.87	3113.13
14001160	14	2	S	8.00	0.19	75.52	6.42	5.40	5.08	16.90	3.66	0.0	54.96	439.70
14040160	14	2	SF	40.00	1.04	77.61	3.29	4.66	0.59	8.55	2.12	0.0	66.95	2677.89
14101160	14	2	F	27.50	0.70	87.45	2.86	4.10	1.10	8.06	2.86	0.0	76.53	2104.64
14022160	14	2	SF	42.00	1.09	77.61	2.93	4.33	0.25	7.51	1.88	0.0	68.22	2865.23
14039160	14	2	PLS	49.00	1.18	71.55	2.81	4.81	0.48	8.11	1.20	0.0	62.24	3049.93
14069160	14	2	FS	37.00	0.81	81.29	2.88	4.41	0.77	8.07	2.37	0.0	70.85	2621.48
14123160	14	2	F	27.20	0.69	87.45	4.69	3.77	1.49	9.95	2.83	0.0	74.67	2030.97
14082160	14	2	F	27.50	0.70	87.45	2.86	4.17	1.04	8.07	3.44	0.0	75.93	2088.20
15128160	14	1	PLS	57.60	0.95	71.74	2.79	4.81	0.41	8.02	3.33	0.0	60.40	3478.78
15013160	14	1	S	15.00	0.27	75.52	5.25	6.69	1.91	13.85	3.95	0.0	57.72	865.84
15129160	14	2	S	35.00	0.83	75.52	3.44	5.40	0.68	9.52	2.99	0.0	63.01	2205.36
15035160	14	2	S	39.00	0.92	75.52	4.43	6.16	0.78	11.37	3.01	0.0	61.14	2384.59
15058160	14	2	S	47.40	1.12	75.52	4.34	6.16	0.64	11.14	4.90	0.0	59.49	2819.61
16075160	14	1	S	52.00	0.95	75.52	3.38	5.40	0.45	9.24	0.89	0.0	65.38	3400.00
16027160	14	1	PLS	48.70	0.80	71.74	3.04	8.19	0.35	11.57	0.94	0.0	59.22	2884.21
16074160	14	1	PLS	49.00	0.81	71.74	2.81	4.81	0.48	8.11	0.79	0.0	62.84	3079.25
16047160	14	1	PLS	49.00	0.81	71.74	2.81	4.81	0.48	8.11	1.00	0.0	62.63	3069.00
16048160	14	2	F	44.00	1.12	87.45	3.33	3.73	0.54	7.59	1.26	0.0	78.60	3458.32
17003160	14	1	PL	64.10	1.03	65.20	2.74	4.67	0.37	7.78	2.51	0.0	54.91	3519.76
18057160	14	1	F	68.00	1.34	87.45	2.86	4.10	0.44	7.41	4.06	0.0	75.99	5167.03
18056160	14	2	S	45.00	1.06	75.52	4.36	6.16	0.67	11.19	4.47	0.0	59.85	2693.44
18090160	14	2	F	27.00	0.69	87.45	3.41	3.73	0.88	8.02	4.93	0.0	74.50	2011.62
19047160	14	1	PLS	32.00	0.53	71.74	2.58	3.89	0.43	6.91	6.85	0.0	57.98	1855.37
19034160	14	1	F	44.40	0.87	87.45	2.86	2.99	0.37	6.23	5.75	0.0	75.48	3351.11
19046160	14	1	S	36.00	0.65	75.52	2.99	4.35	0.38	7.72	6.85	0.0	60.95	2194.21
19015160	14	2	F	32.90	0.84	87.45	2.86	4.10	0.92	7.88	7.47	0.0	72.10	2372.18
19066160	14	2	PLS	28.00	0.67	71.55	3.65	4.76	1.45	9.86	6.85	0.0	54.84	1535.45
20111160	14	1	PLF	57.60	0.95	74.55	2.64	4.68	0.52	7.84	6.54	0.0	60.17	3465.97
20076160	14	1	S	65.50	1.19	75.52	2.99	4.35	0.21	7.55	7.90	0.0	60.07	3934.78
20045160	14	2	S	22.00	0.52	75.52	4.83	6.69	1.23	12.75	7.67	0.07	55.04	1210.81
20058160	14	2	F	44.50	1.13	87.45	2.86	2.99	0.31	6.16	8.08	0.0	73.21	3257.98
20128160	14	2	S	22.20	0.52	75.52	4.82	6.16	1.36	12.34	7.28	0.0	55.90	1241.00
20059160	14	2	PLS	49.00	1.18	71.55	2.58	3.89	0.28	6.76	8.47	0.0	56.32	2759.84

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20086160	14	2	S	22.20	0.52	75.52	4.82	6.16	1.36	12.34	7.67	0.07	55.44	1230.81
20075160	14	2	PLS	49.00	1.18	71.55	2.58	3.89	0.28	6.76	8.08	0.0	56.71	2778.84
20099160	14	2	S	22.20	0.52	75.52	4.82	6.16	1.36	12.34	7.00	0.0	56.18	1247.23
20077160	14	2	F	44.50	1.13	87.45	2.86	2.99	0.31	6.16	7.64	0.0	73.65	3277.34
20129160	14	2	PLS	49.00	1.18	71.55	2.58	5.27	0.62	8.47	8.07	0.0	55.01	2695.52
21005155	14	1	F	61.90	1.22	87.45	3.29	3.73	0.38	7.40	7.66	0.0	72.39	4480.80
21055155	14	1	F	61.90	1.22	87.45	2.86	4.10	0.46	7.42	7.18	0.0	72.84	4508.88
21001155	14	1	F	61.90	1.22	87.45	3.29	3.73	0.38	7.40	7.69	0.0	72.36	4479.28
21024160	14	1	PL	26.00	0.42	65.20	2.55	3.77	0.53	6.84	7.28	0.0	51.08	1328.11
21044155	14	1	F	61.90	1.22	87.45	2.86	2.99	0.27	6.12	6.98	0.0	74.35	4602.07
21026160	14	1	FS	52.00	0.88	86.34	2.88	3.14	0.26	6.28	7.97	1.73	70.36	3658.77
21038160	14	1	SPL	52.00	0.91	73.76	4.12	5.00	0.78	9.91	8.61	1.73	53.51	2782.48
21025160	14	1	PLS	60.00	0.99	71.74	2.58	3.89	0.23	6.71	8.53	1.73	54.77	3286.27
21029155	14	1	SPL	65.40	1.15	73.76	3.71	3.86	0.35	7.91	6.98	0.0	58.86	3849.71
21012160	14	1	PLS	60.00	0.99	71.74	2.58	3.89	0.23	6.71	7.78	1.73	55.52	3331.09
21049160	14	1	S	65.00	1.18	75.52	4.23	5.40	0.63	10.25	8.38	1.73	55.16	3585.11
21058160	14	2	SF	65.00	1.69	77.61	3.64	3.46	0.35	7.45	8.09	1.73	60.34	3921.88
21055160	14	2	S	65.00	1.53	75.52	3.85	4.05	0.35	8.25	7.78	1.73	57.75	3753.95
21053160	14	3	PLS	19.00	0.81	71.55	3.99	4.76	2.14	10.89	8.29	1.73	50.64	962.16
22086160	14	1	SPL	32.00	0.56	73.76	4.36	6.20	0.85	11.42	3.94	0.0	58.41	1869.11
22032155	14	1	PL	53.40	0.86	65.20	2.76	4.67	0.44	7.87	4.17	0.0	53.16	2838.49
22094160	14	1	SPL	32.00	0.56	73.76	4.36	6.20	0.85	11.42	5.98	0.0	56.36	1803.65
22011155	14	1	F	44.60	0.87	87.45	3.32	3.73	0.53	7.59	5.03	0.0	74.83	3322.58
22018160	14	1	S	52.00	0.95	75.52	3.38	5.40	0.45	9.24	2.74	0.0	63.54	3303.97
22005160	14	1	FS	43.00	0.73	86.34	3.37	3.93	0.55	7.85	2.05	0.0	76.44	3287.06
22012155	14	1	S	32.00	0.58	75.52	3.46	5.40	0.74	9.60	6.65	0.0	59.27	1896.74
22006160	14	1	PLS	49.00	0.81	71.74	2.81	4.81	0.48	8.11	2.50	0.0	61.13	2995.44
22008155	14	1	PLF	53.40	0.88	74.55	2.82	4.25	0.44	7.51	3.24	0.0	63.80	3406.95
22004155	14	1	PL	53.40	0.86	65.20	2.76	4.67	0.44	7.87	4.32	0.0	53.01	2830.78
22024160	14	2	SF	47.00	1.22	77.61	4.07	5.72	0.61	10.40	3.61	0.0	63.60	2989.23
22119160	14	2	FPL	48.00	1.04	82.29	2.85	3.18	0.28	6.32	5.62	0.0	70.36	3377.10
22053160	14	2	S	47.00	1.11	75.52	4.34	6.16	0.64	11.15	4.67	0.0	59.70	2806.06
22038160	14	2	F	27.00	0.69	87.45	2.86	4.17	1.06	8.09	3.26	0.0	76.10	2054.66
22114160	14	2	FPL	37.00	0.80	82.29	4.59	4.01	1.10	9.70	6.61	0.0	65.98	2441.44
22067160	14	2	F	62.00	1.58	87.45	2.86	4.10	0.49	7.45	5.55	0.0	74.45	4615.77
22102160	14	2	SPL	32.00	0.74	70.09	4.36	6.20	0.85	11.42	5.45	0.0	53.23	1703.30
22005155	14	3	PL	10.80	0.50	70.28	3.20	4.67	2.19	10.06	4.72	0.0	55.50	599.42
22034155	14	3	S	10.80	0.41	75.52	3.82	5.40	2.19	11.42	4.35	0.0	59.75	645.31
22009155	14	3	PLS	10.80	0.46	71.55	3.25	4.81	2.19	10.25	3.56	0.0	57.74	623.63
23039155	14	1	PL	64.10	1.03	65.20	2.93	7.99	0.26	11.18	4.29	0.0	49.73	3187.82
23012160	14	1	PLS	63.00	1.04	71.74	3.25	4.76	0.65	8.66	4.60	0.0	58.48	3684.23
23055160	14	1	F	44.00	0.87	87.45	2.86	4.10	0.69	7.65	6.34	0.0	73.46	3232.45
23017160	14	1	S	55.00	1.00	75.52	3.38	5.40	0.43	9.21	3.24	0.0	63.07	3468.79
23043160	14	1	F	44.00	0.87	87.45	3.79	6.38	0.38	10.56	6.64	0.0	70.25	3090.99
23049155	14	1	S	52.10	0.95	75.52	2.99	4.35	0.38	7.72	6.02	0.0	61.78	3218.97
23070160	14	1	S	65.00	1.18	75.52	4.23	6.16	0.47	10.85	6.85	0.0	57.82	3758.49
23004155	14	1	PL	64.10	1.03	65.20	2.74	4.67	0.37	7.78	4.56	0.0	52.86	3388.11
23030155	14	1	PL	64.10	1.03	65.20	2.93	7.99	0.26	11.18	4.26	0.0	49.76	3189.81
23168160	14	1	F	44.00	0.87	87.45	2.86	2.99	0.31	6.16	6.81	0.0	74.48	3277.15
23030160	14	1	S	15.00	0.27	75.52	4.35	9.33	1.12	14.80	6.69	0.0	54.03	810.49

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23152160	14	1	S	25.00	0.45	75.52	2.99	4.35	0.55	7.88	5.66	0.0	61.98	1549.47
23020155	14	2	PL	26.20	0.64	67.12	2.87	4.67	0.90	8.45	4.26	0.0	54.41	1425.62
23003160	14	2	S	45.00	1.06	75.52	4.36	5.40	0.90	10.67	3.24	0.0	61.61	2772.64
23045155	14	2	ACON	18.50	0.56	64.72	2.58	3.48	1.07	7.13	6.01	0.0	51.58	954.32
23149160	14	2	SF	44.00	1.14	77.61	2.93	3.76	0.31	7.00	5.59	0.0	65.02	2861.02
23150160	14	2	PL	26.00	0.63	67.12	2.55	3.77	0.53	6.84	6.89	0.0	53.39	1388.06
24038155	14	1	PL	64.00	1.03	65.20	2.55	3.77	0.26	6.58	6.46	0.0	52.16	3338.26
24106160	14	1	SPL	50.00	0.88	73.76	2.93	4.75	0.21	7.89	6.30	7.54	52.03	2601.31
24003160	14	1	S	45.00	0.82	75.52	4.36	5.40	0.90	10.67	3.89	0.0	60.96	2743.24
24075155	14	1	F	61.90	1.22	87.45	2.86	2.99	0.27	6.12	6.49	0.0	74.84	4632.42
24088160	14	1	PLF	58.00	0.95	74.55	2.64	3.40	0.34	6.38	5.23	0.0	62.94	3650.42
24002160	14	1	PLF	61.00	1.00	74.55	3.19	4.26	0.67	8.12	4.92	0.0	61.51	3751.93
24137160	14	1	SPL	52.00	0.91	73.76	2.93	4.16	0.26	7.35	4.82	0.0	61.59	3202.56
24112160	14	1	FS	44.50	0.75	86.34	2.88	3.65	0.24	6.77	0.84	0.0	78.73	3503.70
24138160	14	1	PLF	58.00	0.95	74.55	2.64	3.40	0.24	6.27	1.05	0.0	67.23	3899.19
24073160	14	1	PLF	58.00	0.95	74.55	2.64	3.40	0.34	6.38	5.38	0.0	62.79	3641.69
24013160	14	2	FS	44.50	0.98	81.29	3.37	3.93	0.53	7.83	0.81	0.0	72.65	3232.84
24037155	14	2	F	40.00	1.02	87.45	2.86	2.99	0.41	6.27	7.57	0.0	73.61	2944.28
24032160	14	2	FS	35.00	0.77	81.29	3.41	3.93	0.68	8.01	0.91	0.0	72.37	2533.08
24130160	14	2	FS	45.00	0.99	81.29	2.88	3.65	0.24	6.77	4.45	0.0	70.07	3153.12
24072160	14	2	SPL	45.00	1.05	70.09	2.93	4.16	0.44	7.53	3.91	0.0	58.65	2639.47
25040160	14	1	FS	44.00	0.75	86.34	2.88	3.14	0.31	6.33	7.29	0.0	72.72	3199.77
25004160	14	1	PLF	58.00	0.95	74.55	2.64	4.68	0.52	7.84	6.40	0.0	60.32	3498.32
25005160	14	1	SPL	56.00	0.98	73.76	4.10	5.74	0.54	10.37	6.83	0.0	56.56	3167.43
25059160	14	1	PL	22.60	0.36	65.20	2.55	3.77	0.60	6.92	7.60	0.0	50.68	1145.42
25022160	14	1	S	56.00	1.02	75.52	4.28	6.16	0.54	10.98	6.76	0.0	57.78	3235.77
25054160	14	1	PLS	32.00	0.53	71.74	2.58	3.89	0.43	6.91	8.04	0.0	56.79	1817.23
25053160	14	1	S	36.00	0.65	75.52	2.99	4.35	0.38	7.72	6.35	0.0	61.45	2212.24
25073160	14	2	PLS	28.00	0.67	71.55	3.65	4.76	1.45	9.86	8.03	0.0	53.66	1502.47
39002160	14	1	SF	47.00	0.91	77.61	3.27	4.66	0.50	8.44	2.69	0.0	66.49	3124.85
43008160	14	1	PLS	49.00	0.81	71.74	2.58	3.89	0.40	6.88	3.95	0.0	60.90	2984.21
53001155	14	1	SPL	65.00	1.14	73.76	2.93	4.16	0.21	7.30	8.64	1.73	56.09	3645.92
53006155	14	3	PLS	11.00	0.47	71.55	4.75	4.76	3.69	13.21	8.63	1.73	47.97	527.71
53012155	14	3	PLS	11.00	0.47	71.55	4.75	4.76	3.69	13.21	8.33	1.73	48.28	531.08
76007155	14	1	S	65.00	1.18	75.52	2.99	4.35	0.21	7.55	10.34	0.0	57.63	3745.76
76002155	14	1	S	22.00	0.40	75.52	4.83	5.40	1.85	12.07	10.31	0.0	53.13	1168.95
76006155	14	1	PLS	64.00	1.05	71.74	2.58	3.89	0.21	6.69	10.01	0.0	55.04	3522.58
77019155	14	1	PLS	64.10	1.06	71.74	2.58	3.89	0.21	6.69	9.74	0.0	55.31	3545.24
77002155	14	1	PL	32.00	0.52	65.20	2.55	3.77	0.43	6.75	9.29	0.0	49.17	1573.35
77043155	14	1	PLS	64.00	1.05	71.74	3.25	4.76	0.63	8.64	9.89	0.0	53.21	3405.13
77004155	14	1	SPL	50.60	0.89	73.76	2.93	4.16	0.27	7.36	9.75	0.0	56.65	2866.66
77036155	14	1	SPL	65.40	1.15	73.76	4.04	5.00	0.62	9.67	9.88	0.0	54.21	3545.57
77003155	14	1	PLS	64.00	1.05	71.74	2.58	3.89	0.21	6.69	8.67	0.0	56.37	3607.96
77034155	14	2	PL	30.00	0.73	67.12	3.53	4.64	1.35	9.53	9.56	0.0	48.03	1440.83
77035155	14	2	PLS	64.00	1.54	71.55	3.25	4.76	0.63	8.64	9.45	0.0	53.46	3421.31
9037160	16	3	F	19.50	0.65	87.45	2.86	4.09	1.47	8.42	1.19	0.0	77.84	1517.98
8054160	16	1	PL	58.00	0.89	70.79	2.91	7.64	0.29	10.84	3.51	0.0	56.44	3273.45
8020160	16	1	PL	58.00	0.89	70.79	2.73	4.43	0.41	7.57	3.24	0.0	59.98	3478.92
8063160	16	1	S	49.00	0.87	75.52	4.25	6.64	0.58	11.48	3.57	0.0	60.47	2962.90
8019160	16	1	S	49.00	0.87	75.52	3.35	5.51	0.48	9.34	1.83	0.0	64.35	3153.12

STAND ECONOMICS REPORT

STAND NO.	AGE	SITE	G-TYPE	VOLUME CCF/AC	STOCK. PCT.	SELL PR. $/CCF	F-B COST $/CCF	SKID COST $/CCF	AREA COST $/CCF	HARV.COST $/CCF	HAUL COST $/CCF	RD DEV. $/CCF	NET VALUE $/CCF	NET VALUE $/ACRE
8002160	16	1	PL	64.90	1.00	70.79	2.72	4.43	0.36	7.52	3.19	0.0	60.09	3899.75
8003160	16	1	S	49.00	0.87	75.52	3.35	5.51	0.48	9.34	1.90	0.0	64.29	3150.04
8034160	16	2	S	44.80	1.02	75.52	4.29	6.64	0.64	11.57	5.44	0.0	58.51	2621.10
8065160	16	2	COTD	51.50	1.61	32.36	2.65	6.27	0.56	9.47	3.48	0.0	19.41	999.52
8033160	16	2	F	38.40	0.93	85.37	2.86	4.09	0.75	7.70	5.36	0.0	72.32	2777.19
8001160	16	2	F	38.40	0.93	85.37	3.33	3.80	0.62	7.75	2.43	0.0	75.20	2887.63
8064160	16	2	F	38.40	0.93	85.37	2.86	4.09	0.75	7.70	3.34	0.0	74.34	2854.65
10001160	16	1	F	38.00	0.73	87.17	3.34	3.80	0.62	7.76	2.08	0.0	77.34	2938.77
10029160	16	1	F	38.00	0.73	87.17	3.34	3.80	0.62	7.76	1.63	0.0	77.78	2955.67
10058160	16	2	S	47.00	1.07	75.52	4.27	6.64	0.61	11.52	1.36	0.0	62.64	2944.01
11034160	16	1	F	57.00	1.10	87.17	3.28	3.80	0.41	7.50	2.68	0.0	77.00	4388.93
11013160	16	2	F	40.00	0.96	85.37	3.33	3.80	0.59	7.72	1.79	0.0	75.87	3034.81
11043160	16	2	SF	55.00	1.39	77.61	3.95	5.42	0.52	9.89	1.15	0.0	66.57	3661.39
12001160	16	1	S	47.00	0.83	75.52	4.27	5.34	0.86	10.47	3.99	0.0	61.06	2869.64
12056160	16	1	S	47.00	0.83	75.52	2.96	4.55	0.42	7.93	4.18	0.0	63.41	2980.28
14068160	16	1	SF	47.00	0.89	75.33	4.01	5.42	0.51	10.04	3.82	0.0	61.46	2888.73
14038160	16	1	FS	52.00	0.83	88.03	3.34	3.69	0.45	7.48	2.00	0.0	78.55	4084.81
14128160	16	1	S	49.00	0.87	75.52	4.25	5.34	0.83	10.42	2.48	0.0	62.62	3068.42
14062160	16	1	SF	52.00	0.98	75.33	3.23	4.41	0.45	8.10	2.86	0.0	64.38	3347.56
14122160	16	1	S	49.00	0.87	75.52	4.25	5.34	0.83	10.42	2.55	0.0	62.55	3064.81
15110160	16	1	F	38.40	0.74	87.17	4.45	3.47	1.45	9.36	2.36	0.0	75.45	2897.18
15034160	16	1	F	44.00	0.85	87.17	2.86	4.09	0.69	7.64	4.74	0.0	74.79	3290.94
15127160	16	1	F	38.40	0.74	87.17	3.33	3.80	0.62	7.75	2.33	0.0	77.10	2960.53
16013160	16	1	F	38.40	0.74	87.17	4.45	3.47	1.45	9.36	3.02	0.0	74.79	2871.95
16073160	16	1	S	30.00	0.53	75.52	3.42	5.51	0.79	9.72	0.89	0.0	64.91	1947.40
16045160	16	1	S	30.00	0.53	75.52	3.42	5.51	0.79	9.72	0.46	0.0	65.34	1960.16
16046160	16	1	F	38.00	0.73	87.17	3.34	3.80	0.62	7.76	3.00	0.0	76.42	2903.77
17053160	16	1	PL	44.50	0.68	70.79	2.97	7.64	0.38	10.99	3.28	0.0	56.53	2515.45
17033160	16	1	PLS	49.20	0.79	72.82	3.28	4.27	1.13	8.68	3.62	0.0	60.52	2977.43
17020160	16	1	PL	44.50	0.68	70.79	2.76	4.43	0.53	7.72	2.80	0.0	60.27	2682.05
17001160	16	1	S	70.30	1.24	75.52	3.31	5.51	0.34	9.15	2.18	0.0	64.19	4512.54
17002160	16	1	PL	64.90	1.00	70.79	2.72	4.43	0.36	7.52	3.08	0.0	60.20	3906.90
17040160	16	2	S	49.20	1.12	75.52	4.25	5.06	1.13	10.44	3.20	0.0	61.88	3044.45
17019160	16	2	S	55.00	1.26	75.52	3.33	5.51	0.43	9.27	3.00	0.0	63.24	3478.44
17031160	16	2	S	49.20	1.12	75.52	4.25	5.06	1.13	10.44	3.17	0.0	61.91	3046.21
17032160	16	2	F	38.40	0.93	85.37	4.45	3.47	1.45	9.36	3.55	0.0	72.46	2782.39
18055160	16	1	F	38.40	0.74	87.17	2.86	4.09	0.79	7.74	7.65	0.0	71.78	2756.51
18101160	16	1	S	49.00	0.87	75.52	3.35	5.51	0.48	9.34	4.67	0.0	61.51	3014.19
18001160	16	1	S	47.00	0.83	75.52	4.27	6.64	0.61	11.52	4.14	0.0	59.86	2813.44
18089160	16	1	F	38.00	0.73	87.17	3.34	3.80	0.52	7.76	4.84	0.0	74.57	2833.85
18022160	16	1	S	29.00	0.51	75.52	4.53	6.16	1.04	11.74	4.74	0.0	59.04	1712.13
18073160	16	1	F	50.00	0.97	87.17	3.30	3.80	0.47	7.57	4.90	0.0	74.71	3735.32
18074160	16	1	S	57.00	1.01	75.52	3.33	5.51	0.41	9.25	4.58	0.0	61.69	3516.24
18040160	16	2	S	20.00	0.45	75.52	4.84	6.16	1.51	12.52	4.62	0.0	58.38	1167.68
19033160	16	1	F	46.50	0.90	87.17	2.86	3.20	0.36	6.42	5.54	0.0	75.21	3497.31
19014160	16	1	F	38.00	0.73	87.17	2.86	4.09	0.80	7.75	5.65	0.0	73.77	2803.14
19001160	16	1	F	38.00	0.73	87.17	3.34	3.80	0.62	7.76	7.73	0.0	71.68	2723.93
19045160	16	1	PLF	57.00	0.91	74.55	2.64	3.21	0.24	6.09	6.85	0.0	61.61	3511.94
20057160	16	1	S	47.00	0.83	75.52	2.96	4.55	0.29	7.80	8.33	0.0	59.39	2791.35
20056160	16	2	F	59.00	1.42	85.37	2.86	3.20	0.23	6.29	8.75	1.73	68.60	4047.40

STAND ECONOMICS REPORT

STAND NO.	AGE	SITE	G-TYPE	VOLUME CCF/AC	STOCK. PCT.	SELL PR. $/CCF	F-B COST $/CCF	SKID COST $/CCF	AREA COST $/CCF	HARV.COST $/CCF	HAUL COST $/CCF	RD DEV. $/CCF	NET VALUE $/CCF	NET VALUE $/ACRE
21011155	16	1	F	46.20	0.89	87.17	2.86	3.20	0.43	6.49	7.09	0.0	73.59	3399.79
21053155	16	1	F	46.20	0.89	87.17	2.86	4.09	0.62	7.57	6.99	0.0	72.61	3354.65
21024155	16	1	S	70.30	1.24	75.52	3.78	4.25	0.34	8.37	6.98	0.0	60.16	4229.55
21037160	16	1	S	42.00	0.74	75.52	4.32	5.34	0.97	10.63	8.14	1.73	55.02	2310.80
21023155	16	1	F	46.20	0.89	87.17	3.91	2.90	0.52	7.33	7.15	0.0	72.68	3358.04
21054155	16	1	S	70.30	1.24	75.52	4.13	6.64	0.43	11.20	6.98	0.0	57.34	4030.88
21028155	16	1	F	46.20	0.89	87.17	3.91	2.90	0.49	7.30	6.99	0.0	72.88	3367.19
21006160	16	2	S	47.00	1.07	75.52	3.75	9.03	0.36	13.13	7.95	0.0	54.44	2558.69
21011160	16	2	S	49.00	1.12	75.52	2.96	4.55	0.28	7.79	7.99	1.73	58.00	2842.08
21001160	16	2	S	47.00	1.07	75.52	3.75	9.03	0.36	13.13	7.75	0.0	54.64	2568.11
21048160	16	2	S	42.00	0.96	75.52	4.32	5.34	0.97	10.63	8.31	1.73	54.85	2303.70
21023160	16	2	S	49.00	1.12	75.52	2.96	4.55	0.28	7.79	8.41	1.73	57.59	2821.86
22052160	16	1	F	49.00	0.95	87.17	2.86	4.09	0.62	7.57	6.03	0.0	73.57	3604.92
22003155	16	1	PL	58.00	0.89	70.79	2.73	4.43	0.41	7.57	4.59	0.0	58.64	3400.97
22023160	16	1	SF	47.00	0.89	75.33	4.01	5.42	0.61	10.04	3.63	0.0	61.65	2897.62
22001155	16	1	S	48.00	0.85	75.52	3.35	5.51	0.49	9.35	4.63	0.0	61.54	2953.79
22002155	16	1	F	66.20	1.28	87.17	3.27	3.80	0.36	7.42	5.23	0.0	74.52	4933.33
22029155	16	1	F	66.20	1.28	87.17	3.27	3.80	0.36	7.42	5.39	0.0	74.36	4922.36
22030155	16	1	S	49.00	0.87	75.52	3.35	5.51	0.48	9.34	5.19	0.0	60.99	2988.74
22031155	16	1	PL	53.00	0.82	70.79	2.74	4.43	0.45	7.62	5.28	0.0	57.90	3068.66
22118160	16	2	SF	47.00	1.19	77.61	2.91	3.54	0.29	6.74	4.92	0.0	65.95	3099.50
22004160	16	2	FS	64.00	1.33	82.41	3.31	3.69	0.37	7.38	4.49	0.0	70.55	4514.97
22062155	16	3	S	7.70	0.28	75.52	5.05	9.03	2.18	16.26	5.03	0.0	54.23	417.58
22006155	16	3	S	7.70	0.28	75.52	4.00	5.51	3.07	12.58	4.72	0.0	58.22	448.31
23139160	16	1	F	38.00	0.73	87.17	2.86	3.20	0.52	6.58	3.83	0.0	76.76	2916.97
23029155	16	1	PL	58.00	0.89	70.79	2.91	7.64	0.29	10.84	4.49	0.0	55.47	3217.07
23019155	16	1	PL	64.90	1.00	70.79	2.72	4.43	0.36	7.52	4.42	0.0	58.86	3819.71
23069160	16	1	S	47.00	0.83	75.52	4.27	6.16	0.64	11.08	6.91	0.0	57.53	2704.05
23167160	16	1	F	38.00	0.73	87.17	2.86	3.20	0.36	6.42	3.76	0.0	76.99	2925.44
23054160	16	1	F	66.00	1.28	87.17	2.86	4.09	0.46	7.41	6.18	0.0	73.58	4856.35
23001155	16	1	S	49.00	0.87	75.52	3.35	5.51	0.48	9.34	5.44	0.0	60.74	2976.33
23092160	16	1	F	60.00	1.16	87.17	2.86	4.09	0.50	7.46	5.76	0.0	73.95	4437.17
23046155	16	1	COTD	68.70	2.83	32.36	2.65	4.65	0.29	7.59	5.77	0.0	19.00	1305.55
23002155	16	1	F	38.40	0.74	87.17	3.33	3.80	0.62	7.75	5.18	0.0	74.25	2851.04
23065155	16	1	F	68.70	1.33	87.17	2.86	3.20	0.29	6.35	5.75	0.0	75.07	5157.47
23003155	16	1	PL	64.90	1.00	70.79	2.72	4.43	0.36	7.52	4.47	0.0	58.80	3816.42
23044155	16	1	S	49.00	0.87	75.52	2.96	4.55	0.40	7.91	5.55	0.0	62.05	3040.53
23066155	16	1	S	44.80	0.79	75.52	2.96	4.55	0.44	7.95	5.78	0.0	61.79	2768.09
23043155	16	1	F	66.20	1.28	87.17	2.86	3.20	0.30	6.36	5.68	0.0	75.13	4973.61
23038155	16	2	F	38.40	0.93	85.37	3.81	5.87	0.44	10.12	5.58	0.0	69.67	2675.24
23016160	16	2	S	47.00	1.07	75.52	3.35	5.51	0.50	9.36	3.01	0.0	63.15	2968.06
23002160	16	2	F	23.00	0.55	85.37	4.79	3.66	1.77	10.22	4.53	0.0	70.62	1624.21
23018155	16	2	F	38.40	0.93	85.37	3.33	3.80	0.62	7.75	5.53	0.0	72.10	2768.69
23148160	16	2	SF	38.00	0.96	77.61	2.91	3.54	0.36	6.81	5.37	0.0	65.44	2486.58
23001160	16	3	S	32.00	1.15	75.52	4.47	5.34	1.27	11.08	3.57	0.0	60.87	1947.89
23011160	16	3	F	23.00	0.78	87.45	4.79	3.66	1.77	10.22	3.33	0.0	73.90	1699.73
24001155	16	1	F	46.50	0.90	87.17	4.35	4.39	0.58	9.32	6.81	0.0	71.04	3303.30
24025160	16	1	SPL	49.00	0.85	76.18	3.26	4.84	0.48	8.59	5.30	0.0	62.29	3052.18
24005155	16	1	F	54.60	1.05	87.17	4.29	4.39	0.50	9.17	6.81	0.0	71.18	3886.63
24014155	16	1	F	39.70	0.77	87.17	2.86	3.20	0.50	6.56	6.73	0.0	73.88	2932.97

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24031160	16	1	FS	62.00	0.99	88.03	3.32	3.69	0.38	7.39	5.41	0.0	75.23	4664.48
24081155	16	1	F	46.50	0.90	87.17	2.86	3.20	0.36	6.42	6.52	0.0	74.23	3451.68
24012160	16	1	SF	49.00	0.92	75.33	3.24	4.41	0.48	8.13	5.46	0.0	61.74	3025.28
24136160	16	1	PLF	46.50	0.74	74.55	2.64	3.21	0.29	6.14	0.91	0.0	67.50	3138.65
24089155	16	1	F	43.60	0.84	87.17	2.86	4.09	0.66	7.61	6.97	0.0	72.59	3164.87
24023155	16	1	F	46.50	0.93	87.17	2.86	3.20	0.42	6.49	7.07	0.0	73.61	3423.03
24087155	16	1	F	52.00	1.00	87.17	2.86	3.20	0.32	6.38	6.72	0.0	74.07	3851.41
24098155	16	1	F	38.00	0.73	87.17	2.86	4.09	0.75	7.71	7.13	0.0	72.34	2748.79
24036155	16	1	F	52.00	1.00	87.17	2.86	3.20	0.32	6.38	6.40	0.0	74.39	3868.07
24057155	16	1	F	49.00	0.95	87.17	2.86	3.20	0.34	6.40	7.04	0.0	73.73	3612.90
24062160	16	2	FS	46.50	0.97	82.41	4.45	4.49	0.58	9.52	0.84	0.0	72.06	3350.65
24026155	16	2	F	59.00	1.42	85.37	2.86	3.20	0.23	6.29	8.78	1.73	68.57	4045.65
24068155	16	2	F	52.00	1.25	85.37	2.86	3.20	0.32	6.38	7.70	0.0	71.30	3707.43
24105160	16	2	FS	46.50	0.97	82.41	2.88	3.45	0.23	6.55	0.91	0.0	74.95	3485.36
24154160	16	2	FS	46.50	0.97	82.41	2.88	2.97	0.29	6.14	0.85	0.0	75.43	3507.56
24071160	16	2	SPL	54.00	1.21	73.50	2.91	3.92	0.37	7.20	3.95	0.0	62.34	3366.49
24111160	16	2	FS	46.50	0.97	82.41	2.88	3.45	0.23	6.55	0.87	0.0	74.99	3487.03
24094160	16	2	SPL	47.00	1.05	73.50	2.91	3.92	0.42	7.26	3.85	0.0	62.39	2932.21
24001160	16	3	FS	25.00	0.75	84.60	4.82	3.73	1.53	10.18	4.46	0.0	69.96	1748.96
25039160	16	1	FS	49.00	0.78	88.03	2.88	2.97	0.28	6.12	6.32	0.0	75.59	3704.04
25052160	16	1	PLF	57.00	0.91	74.55	2.64	3.21	0.24	6.09	6.78	0.0	61.69	3516.27
25003160	16	2	FPL	52.00	1.07	83.29	2.85	4.11	0.58	7.55	6.65	0.0	69.10	3593.07
25016160	16	2	FS	38.00	0.79	82.41	2.88	4.06	0.80	7.73	6.90	0.0	67.78	2575.78
39001160	16	1	F	57.00	1.10	87.17	3.28	3.80	0.41	7.50	2.78	0.0	76.89	4382.73
46012160	16	1	SPL	49.00	0.85	76.18	3.26	4.84	0.48	8.59	5.61	0.0	61.98	3036.87
53010155	16	2	S	42.50	0.97	75.52	4.32	5.34	0.96	10.61	8.33	1.73	54.85	2331.09
76005155	16	1	F	38.00	0.73	87.17	2.86	3.20	0.36	6.42	10.10	0.0	70.65	2684.64
77001155	16	1	PLS	61.00	0.98	72.82	2.58	3.67	0.22	6.48	8.99	0.0	57.35	3498.49
77047155	16	2	F	46.50	1.12	85.37	2.86	3.20	0.36	6.42	8.43	0.0	70.52	3279.38
77033155	16	2	SF	49.00	1.24	77.61	4.00	4.41	0.83	9.23	9.32	0.0	59.05	2893.60
77055155	16	2	F	46.50	1.12	85.37	2.86	3.20	0.36	6.42	8.63	0.0	70.32	3270.06
77066155	16	2	F	46.50	1.12	85.37	2.86	3.20	0.36	6.42	8.41	0.0	70.55	3280.45
10005160	18	1	SPL	10.00	0.17	73.76	3.72	4.64	2.36	10.72	1.91	0.0	61.13	611.30
10072160	18	2	PL	10.00	0.23	70.28	2.55	4.66	3.02	10.24	1.47	0.0	58.57	585.73
10032160	18	2	SPL	10.00	0.22	73.76	3.72	4.64	2.36	10.72	1.61	0.0	61.43	614.34

EXECUTION TERMINATED 12:04:01 T=23.706 RC=0 $13.47

$SIG

APPENDIX VI

Factor Analysis Results

- FACTOR ANALYSIS - REVISED JAN. 8, 1975

THE PROGRAM WILL ATTEMPT TO ACQUIRE 2 PAGE(S) OF MEMORY TO RUN THIS PROBLEM

*****FACTOR ANALYSIS ON 20 TYPE ISLAND STATE VARIABLES OF THE WESTLAKE PSYU *****

INPUT FORMAT (A4,10X,F5.2,10X,F8.2,18X,9(1X,F5.2),7X,9(1X,F6.2))

OUTPUT FORMAT (A4,10X,8F8.3)

NUMBER OF VARIABLES 20

MAX. ITERATIONS FOR COMMUNALITIES 1

MAX. ITERATIONS FOR ROTATION 50

MAXIMUM NUMBER OF FACTORS TO BE EXTRACTED 8

LOWER LIMIT ON EIGENVALUES 0.10000

UPPER LIMIT ON REFERENCE AXIS CORRELATIONS 0.95000

THE CORRELATION MATRIX IS FORMED

DIAGONAL ELEMENTS ARE UNALTERED

VARIMAX ROTATION IS PERFORMED

VARIABLE NAMES ARE READ IN

CASE IDENTIFICATION IS READ WITH EACH CASE

NUMBER OF CASES 1985

VARIABLE	MEAN	ST.DEV.	VARIANCE	ST.DEV. OF THE MEAN	MINIMUM	MAXIMUM	# OBSERVATIONS	SUM
1 VOL NOW	23.637	18.129	328.670	0.40691	0.0	70.300	1985.0	46919.
2 VAL NOW	1347.7	1184.5	0.140299E+07	26.586	-51.850	5330.7	1985.0	0.26752E+07
3 VOL@40	7.4104	4.7313	22.3854	0.10619	0.33000	30.150	1985.0	14710.
4 VOL@60	16.041	7.6736	58.8847	0.17223	1.4000	46.730	1985.0	31841.
5 VOL@80	24.055	9.6387	92.9038	0.21634	2.8000	64.000	1985.0	47749.
6 VOL@100	30.481	11.011	121.241	0.24714	4.2000	71.220	1985.0	60504.
7 VOL@120	34.584	11.915	141.966	0.26743	5.1700	72.500	1985.0	68648.
8 VOL@140	37.194	12.535	157.135	0.28136	5.7100	71.790	1985.0	73830.
9 VOL@160	38.591	12.915	166.806	0.28988	5.9800	75.260	1985.0	76604.
10 VOL@180	39.341	13.138	172.602	0.29488	6.0800	77.000	1985.0	78091.
11 VOL@200	39.476	13.211	174.520	0.29651	6.0800	77.580	1985.0	78360.
12 VAL@40	46.340	17.453	304.594	0.39172	0.0	76.950	1985.0	91985.
13 VAL@60	48.406	15.428	238.038	0.34629	2.4700	78.370	1985.0	96085.
14 VAL@80	51.737	14.658	214.853	0.32900	8.3900	79.170	1985.0	0.10270E+06
15 VAL@100	52.611	14.702	216.151	0.32999	9.8100	79.850	1985.0	0.10443E+06
16 VAL@120	53.756	14.627	213.940	0.32830	9.9400	80.270	1985.0	0.10670E+06
17 VAL@140	53.582	14.501	210.286	0.32548	10.030	80.560	1985.0	0.10636E+06
18 VAL@160	55.575	14.372	206.557	0.32258	10.060	80.650	1985.0	0.11032E+06
19 VAL@180	55.686	14.417	207.850	0.32359	10.090	80.510	1985.0	0.11054E+06

CORRELATION MATRIX WITH INITIAL COMMUNALITY ESTIMATES ON THE DIAGONAL

	1 VOL NOW	2 VAL NOW	3 VOL@40	4 VOL@60	5 VOL@80	6 VOL@100	7 VOL@120	8 VOL@140
1 VOL NOW	1.0000							
2 VAL NOW	0.96134	1.0000						
3 VOL@40	0.70019	0.74511	1.0000					
4 VOL@60	0.73942	0.75220	0.95301	1.0000				
5 VOL@80	0.72223	0.72201	0.88170	0.97927	1.0000			
6 VOL@100	0.68139	0.67404	0.80335	0.93124	0.98476	1.0000		
7 VOL@120	0.66034	0.64806	0.75660	0.89694	0.96556	0.99552	1.0000	
8 VOL@140	0.64777	0.63122	0.72504	0.87242	0.94923	0.98732	0.99770	1.0000
9 VOL@160	0.64366	0.62845	0.70922	0.85792	0.93843	0.98041	0.99405	0.99896
10 VOL@180	0.63948	0.62789	0.70005	0.84641	0.92860	0.97332	0.98935	0.99623
11 VOL@200	0.63734	0.62760	0.69240	0.83617	0.91853	0.96451	0.98257	0.99155
12 VAL@40	0.44926	0.58170	0.56655	0.58483	0.59311	0.58782	0.56947	0.55045
13 VAL@60	0.42065	0.57957	0.52952	0.53121	0.52012	0.49671	0.46932	0.44514
14 VAL@80	0.37204	0.53754	0.45870	0.44026	0.43428	0.41928	0.39801	0.37787
15 VAL@100	0.37204	0.53580	0.45436	0.44593	0.45192	0.45160	0.43458	0.41536
16 VAL@120	0.34585	0.51455	0.42496	0.40240	0.40320	0.39913	0.38181	0.36248
17 VAL@140	0.33935	0.51140	0.43832	0.42710	0.42050	0.40390	0.37908	0.35592
18 VAL@160	0.33768	0.50107	0.41503	0.41352	0.42176	0.41996	0.40247	0.38313
19 VAL@180	0.32992	0.49630	0.41145	0.40489	0.41115	0.40830	0.39058	0.37123
20 VAL@200	0.33015	0.49683	0.41095	0.40424	0.41046	0.40769	0.39011	0.37091

	9 VOL@160	10 VOL@180	11 VOL@200	12 VAL@40	13 VAL@60	14 VAL@80	15 VAL@100	16 VAL@120
9 VOL@160	1.0000							
10 VOL@180	0.99905	1.0000						
11 VOL@200	0.99616	0.99894	1.0000					
12 VAL@40	0.54723	0.54775	0.54247	1.0000				
13 VAL@60	0.44028	0.44066	0.43595	0.93441	1.0000			
14 VAL@80	0.37755	0.38143	0.37925	0.91010	0.96855	1.0000		
15 VAL@100	0.41521	0.41963	0.41687	0.90450	0.94086	0.96298	1.0000	
16 VAL@120	0.36243	0.36743	0.36488	0.88951	0.94109	0.98298	0.97629	1.0000
17 VAL@140	0.35297	0.35531	0.35147	0.88700	0.97792	0.98599	0.94903	0.96819
18 VAL@160	0.38243	0.38546	0.38155	0.90604	0.96193	0.98982	0.96850	0.98087
19 VAL@180	0.37084	0.37464	0.37137	0.90436	0.96358	0.99219	0.96874	0.98252
20 VAL@200	0.37063	0.37456	0.37143	0.90405	0.96361	0.99221	0.96855	0.98260

	17 VAL@140	18 VAL@160	19 VAL@180	20 VAL@200
17 VAL@140	1.0000			
18 VAL@160	0.98591	1.0000		
19 VAL@180	0.98859	0.99871	1.0000	
20 VAL@200	0.98857	0.99860	0.99992	1.0000

SUM OF SQUARES OF OFF DIAGONAL ELEMENTS= 91.689
MEAN OF SQUARES OF OFF DIAGONAL ELEMENTS= 0.24129
SQUARE ROOT OF MEAN OF SQUARES OF OFF DIAGONAL ELEMENTS= 0.49121

EIGENVALUES

13.353	4.8831	0.99859	0.44807	0.11590	0.81387E-01	0.42399E-01	0.32316E-01	0.15498E-01	0.13468E-01
0.76567E-02	0.36242E-02	0.29308E-02	0.11856E-02	0.36499E-03	0.10261E-03	0.61443E-04	0.23207E-04	0.11182E-04	0.32787E-05

CUMULATIVE PROPORTION OF TOTAL VARIANCE

0.66767	0.91182	0.96175	0.98415	0.98995	0.99402	0.99614	0.99775	0.99853	0.99920
0.99959	0.99977	0.99991	0.99997	0.99999	1.0000	1.0000	1.0000	1.0000	1.0000

PER CENT OF TOTAL VARIANCE ACCOUNTED FOR BY EACH FACTOR

66.76684	24.41530	4.99293	2.24034	0.57949	0.40693	0.21200	0.16158	0.07749	0.06734
0.03828	0.01812	0.01465	0.00593	0.00182	0.00051	0.00031	0.00012	0.00006	0.00002

TIME FOR INITIAL FACTOR-LOADINGS-MATRIX IS 0.9036E-01 SECONDS

TIME FOR ACCURACY CHECK IS 0.14E-01 SECONDS.

ERROR BOUNDS FOR EIGENVALUES
0.37567E-04 0.18819E-04 0.14133E-05 0.65505E-06 0.41168E-06

ERROR BOUNDS FOR EIGENVECTORS
0.88703E-05 0.96892E-05 0.51346E-05 0.39441E-05 0.24787E-05

VARIABLE	ORIGINAL COMMUNALITY	ESTIMATED COMMUNALITY	FINAL COMMUNALITY
1 VOL NOW	1.0000	1.0000	0.99128
2 VAL NOW	1.C000	1.0000	0.99027
3 VOL@40	1.0000	1.0000	0.98504
4 VOL@60	1.0C00	1.0000	0.99583
5 VOL@80	1.CC00	1.0000	0.99173
6 VOL@100	1.0000	1.0000	0.99373
7 VOL@120	1.CC00	1.0000	0.99746
8 VOL@140	1.0000	1.0000	0.99950
9 VOL@160	1.C000	1.0000	0.99938
10 VOL@180	1.0000	1.0000	0.99665
11 VOL@200	1.0000	1.0000	0.99032
12 VAL@40	1.CC00	1.0000	0.99574
13 VAL@60	1.0000	1.0000	0.97270
14 VAL@80	1.0000	1.0000	0.99097
15 VAL@100	1.0000	1.0000	0.95786
16 VAL@120	1.0000	1.0000	0.97938
17 VAL@140	1.0000	1.0000	0.98372
18 VAL@160	1.0000	1.0000	0.99409
19 VAL@180	1.0000	1.0000	0.99666
20 VAL@200	1.0000	1.0000	0.99668
SUM OF COMMUNALITIES	20.000	20.000	19.799
MEAN COMMUNALITY	1.0000	1.0000	0.98995

MATRIX OF RESIDUALS WITH UNIQUENESSES ON THE DIAGONAL

	1 VOL NOW	2 VAL NOW	3 VOL@40	4 VOL@60	5 VOL@80	6 VOL@100	7 VOL@120	8 VOL@140
1 VOL NOW	0.67174E-02							
2 VAL NOW	-0.91295E-02	0.97333E-02						
3 VOL@40	-0.35534E-02	0.27814E-02	0.14964E-01					
4 VOL@60	0.21908E-02	-0.20159E-02	-0.70986E-02	0.41677E-02				
5 VOL@80	0.33746E-02	-0.28839E-02	-0.10628E-01	0.51995E-02	0.82735E-02			
6 VOL@100	0.28821E-02	-0.23704E-02	-0.73530E-02	0.27575E-02	0.59740E-02	0.62680E-02		
7 VOL@120	0.16088E-02	-0.12977E-02	-0.34454E-02	0.89682E-03	0.28231E-02	0.37083E-02	0.25378E-02	
8 VOL@140	0.57583E-03	-0.49829E-03	-0.44167E-03	-0.96217E-04	0.23999E-03	0.76830E-03	0.75542E-03	0.49507E-03
9 VOL@160	-0.86503E-03	0.76016E-03	0.22815E-02	-0.10083E-02	-0.18933E-02	-0.17807E-02	-0.90764E-03	-0.31695E-04
10 VOL@180	-0.26606E-02	0.23713E-02	0.56818E-02	-0.24798E-02	-0.46165E-02	-0.44308E-02	-0.25737E-02	-0.59011E-03
11 VOL@200	-0.42044E-02	0.36806E-02	0.88062E-02	-0.35335E-02	-0.72878E-02	-0.74902E-02	-0.46286E-02	-0.12340E-02
12 VAL@40	-0.11718E-02	0.84226E-03	0.58352E-02	-0.25060E-02	-0.31741E-02	-0.17698E-02	-0.75978E-03	-0.21454E-03
13 VAL@60	-0.32913E-03	0.10206E-02	-0.10528E-01	0.39277E-02	0.40560E-02	0.12831E-02	0.33243E-03	0.36636E-03
14 VAL@80	0.98578E-03	-0.13457E-02	0.16386E-02	-0.18351E-03	-0.95029E-03	-0.29491E-02	-0.19564E-02	-0.30764E-03
15 VAL@100	-0.26389E-02	0.13569E-02	0.64685E-02	-0.18035E-02	-0.30800E-02	-0.23340E-03	-0.13928E-03	-0.79373E-03
16 VAL@120	-0.99319E-03	-0.66988E-04	0.71187E-02	-0.30779E-02	-0.38106E-02	-0.14455E-02	-0.92232E-04	0.13000E-03
17 VAL@140	0.27643E-03	0.79160E-03	-0.86748E-02	0.27637E-02	0.43482E-02	0.24230E-02	0.91475E-03	0.28867E-03
18 VAL@160	0.23719E-02	-0.19416E-02	-0.16765E-02	0.10502E-02	0.18554E-02	0.17578E-02	0.10693E-02	0.36952E-03
19 VAL@180	0.16393E-02	-0.12883E-02	-0.44208E-03	0.14951E-03	0.73969E-03	0.77025E-03	0.46679E-03	0.13560E-03
20 VAL@200	0.14593E-02	-0.11126E-02	-0.27316E-03	0.96285E-04	0.54278E-03	0.56578E-03	0.33557E-03	0.11035E-03

	9 VOL@160	10 VOL@180	11 VOL@200	12 VAL@40	13 VAL@60	14 VAL@80	15 VAL@100	16 VAL@120
9 VOL@160	0.62019E-03							
10 VOL@180	0.12511E-02	0.33483E-02						
11 VOL@200	0.19608E-02	0.55886E-02	0.96840E-02					
12 VAL@40	0.50547E-03	0.13548E-02	0.18987E-02	0.42621E-02				
13 VAL@60	-0.31036E-03	-0.78137E-03	-0.54873E-03	-0.10082E-01	0.27299E-01			
14 VAL@80	0.10221E-02	0.17191E-02	0.28835E-02	0.79175E-03	-0.19754E-02	0.90317E-02		
15 VAL@100	-0.59869E-03	0.31433E-04	0.16374E-03	0.42493E-02	-0.11358E-01	-0.90035E-02	0.42141E-01	
16 VAL@120	0.31492E-03	0.10607E-02	0.10644E-02	0.63927E-02	-0.12980E-01	-0.12903E-03	0.10535E-01	0.20625E-01
17 VAL@140	-0.60348E-03	-0.13096E-02	-0.16332E-02	-0.59421E-02	0.15300E-01	-0.29686E-03	-0.17065E-01	-0.11327E-01
18 VAL@160	-0.31338E-03	-0.15534E-02	-0.26963E-02	0.27157E-04	-0.28075E-02	-0.12059E-03	-0.58688E-02	-0.43844E-02
19 VAL@180	-0.10749E-03	-0.55921E-03	-0.10381E-02	0.18968E-04	-0.17267E-02	0.80526E-03	-0.62411E-02	-0.42151E-02
20 VAL@200	-0.56243E-04	-0.40027E-03	-0.76087E-03	0.11253E-04	-0.15377E-02	0.84897E-03	-0.64333E-02	-0.41818E-02

	17 VAL@140	18 VAL@160	19 VAL@180	20 VAL@200
17 VAL@140	0.16284E-01			
18 VAL@160	0.33255E-03	0.59091E-02		
19 VAL@180	0.11659E-02	0.34282E-02	0.33350E-02	
20 VAL@200	0.11843E-02	0.33186E-02	0.32544E-02	0.33249E-02

FACTOR-LOADINGS MATRIX BEFORE ROTATION

VARIABLE	FACTOR 1	2	3	4	5
1 VOL NOW	0.68814	-0.34108	-0.57664	0.26138	-0.23780E-01
2 VAL NOW	0.77691	-0.17475	-0.56269	0.19868	0.67334E-02
3 VOL@40	0.78140	-0.32948	-0.28778	-0.42557	0.44416E-01
4 VOL@60	0.84009	-0.43995	-0.14138	-0.27654	0.74704E-02
5 VOL@80	0.86155	-0.47837	-0.76976E-03	-0.14351	0.46521E-02
6 VOL@100	0.85693	-0.49319	0.12286	-0.32329E-01	0.45682E-02

7 VOL@120	0.84072	-0.50841	0.17626	0.32675E-01	0.50882E-02
8 VOL@140	0.82412	-0.52245	0.20413	-0.75384E-01	0.46892E-02
9 VOL@160	0.82018	-0.51961	0.21464	0.10273	0.77856E-02
10 VOL@180	0.81895	-0.51231	0.22091	0.12063	0.12450E-01
11 VOL@200	0.81366	-0.51070	0.22115	0.13521	0.16219E-01
12 VAL@40	0.88098	0.34944	0.57415E-01	-0.41089E-01	-0.30417
13 VAL@60	0.85565	0.48086	-0.19613E-01	-0.64189E-01	-0.69493E-01
14 VAL@80	0.81855	0.56565	-0.39091E-02	-0.30987E-02	0.30875E-01
15 VAL@100	0.82445	0.52393	0.38006E-01	0.33432E-01	0.32755E-01
16 VAL@120	0.75845	0.57880	0.19805E-01	0.30497E-01	0.73902E-01
17 VAL@140	0.80074	0.58165	0.77114E-02	-0.29647E-01	0.57235E-01
18 VAL@160	0.81124	0.57462	0.58669E-01	0.29616E-01	0.38203E-01
19 VAL@180	0.80539	0.58553	0.54986E-01	0.24539E-01	0.39298E-01
20 VAL@200	0.80519	0.58578	0.54487E-01	0.25908E-01	0.39708E-01

SUM OF SQUARED FACTOR-LOADINGS DIVIDED BY SUM OF COMMUNALITIES

0.67445	0.24663	0.50436E-01	0.22631E-01	0.58537E-02

ORTHOGONAL ROTATION

ITERATION	SIMPLICITY CRITERION
0	-0.45574
1	-7.7960
2	-7.8022
3	-7.8022

TIME FOR ROTATION IS 0.2832E-01 SECONDS

ROTATED FACTOR-LOADINGS MATRIX

VARIABLE	FACTOR 1	2	3	4	5
1 VOL NOW	-0.16961	0.50079	-0.83842	0.91678E-01	-0.19123E-01
2 VAL NOW	-0.35260	0.45265	-0.80010	0.14449	0.40995E-02
3 VOL@40	-0.26161	0.62007	-0.34573	0.64230	-0.49246E-02
4 VOL@60	-0.23314	0.78903	-0.30849	0.47179	-0.33852E-01
5 VOL@80	-0.23223	0.88344	-0.24841	0.30788	-0.28889E-01
6 VOL@100	-0.22939	0.93800	-0.18417	0.16391	-0.21920E-01
7 VOL@120	-0.21224	0.95875	-0.16042	0.84817E-01	-0.16746E-01
8 VOL@140	-0.19338	0.96859	-0.15015	0.34750E-01	-0.13857E-01
9 VOL@160	-0.19392	0.96913	-0.14987	0.53295E-02	-0.88033E-02
10 VOL@180	-0.19917	0.96663	-0.14968	-0.13834E-01	-0.29037E-02
11 VOL@200	-0.19698	0.96293	-0.15328	-0.28031E-01	0.20333E-02
12 VAL@40	-0.85019	0.37109	-0.12528	0.98471E-01	-0.33138
13 VAL@60	-0.92716	0.24412	-0.15058	0.14569	-0.97857E-01
14 VAL@80	-0.96779	0.17367	-0.13478	0.77270E-01	0.73705E-02
15 VAL@100	-0.94508	0.22129	-0.12004	0.34225E-01	0.11385E-01
16 VAL@120	-0.96690	0.16214	-0.11843	0.36848E-01	0.53010E-01
17 VAL@140	-0.96873	0.15427	-0.10662	0.95281E-01	0.32146E-01
18 VAL@160	-0.97501	0.18604	-0.89319E-01	0.24090E-01	0.16705E-01
19 VAL@180	-0.97870	0.17344	-0.87268E-01	0.28373E-01	0.17601E-01
20 VAL@200	-0.97872	0.17304	-0.88123E-01	0.27257E-01	0.18117E-01

SUM OF SQUARED FACTOR-LOADINGS DIVIDED BY SUM OF COMMUNALITIES

0.44108	0.41428	0.95448E-01	0.42735E-01	0.64530E-02

MATRIX OF CORRELATIONS OF FACTORS WITH VARIABLES.
VARIABLES ARE REORDERED ACCORDING TO HIGHEST CORRELATION WITH A FACTOR.

VARIABLE	FACTOR 1	2	3	4	5
12 VAL@40	-0.85019	0.37109	-0.12528	0.98471E-01	-0.33138
13 VAL@60	-0.92716	0.24412	-0.15058	0.14569	-0.97857E-01
15 VAL@100	-0.94508	0.22129	-0.12004	0.34225E-01	0.11385E-01
16 VAL@120	-0.96690	0.16214	-0.11843	0.36848E-01	0.53010E-01
14 VAL@80	-0.96779	0.17367	-0.13478	0.77270E-01	0.73705E-02
17 VAL@140	-0.96873	0.15427	-0.10662	0.95281E-01	0.32146E-01
18 VAL@160	-0.97501	0.18604	-0.89319E-01	0.24090E-01	0.16705E-01
19 VAL@180	-0.97870	0.17344	-0.87268E-01	0.28373E-01	0.17601E-01
20 VAL@200	-0.97872	0.17304	-0.88123E-01	0.27257E-01	0.18117E-01
	********	********	--------	--------	--------
9 VOL@160	-0.19392	0.96913	-0.14987	0.53295E-02	-0.88033E-02
8 VOL@140	-0.19338	0.96859	-0.15015	0.34750E-01	-0.13857E-01
10 VOL@180	-0.19917	0.96663	-0.14968	-0.13834E-01	-0.29037E-02
11 VOL@200	-0.19698	0.96293	-0.15328	-0.28031E-01	0.20333E-02
7 VOL@120	-0.21224	0.95875	-0.16042	0.84817E-01	-0.16746E-01
6 VOL@100	-0.22939	0.93800	-0.18417	0.16391	-0.21920E-01
5 VOL@80	-0.23223	0.88344	-0.24841	0.30788	-0.28889E-01
4 VOL@60	-0.22314	0.78903	-0.30849	0.47179	-0.33852E-01
	--------	********	********	--------	--------
2 VAL NOW	-0.35260	0.45265	-0.80010	0.14449	0.40995E-02
1 VOL NOW	-0.16961	0.50079	-0.83842	0.91678E-01	-0.19123E-01
	--------	--------	********	********	--------
3 VOL@40	-0.26161	0.62007	-0.34573	0.64230	-0.49246E-02
	--------	--------	--------	********	********
	--------	--------	--------	--------	********

SUM OF SQUARED FACTOR-LOADINGS DIVIDED BY SUM OF COMMUNALITIES

0.44108	0.41428	0.95448E-01	0.42735E-01	0.64530E-02

REGRESSION COEFFICIENTS FOR FACTOR SCORES

VARIABLE	FACTOR 1	2	3	4	5
1 VOL NOW	0.65893E-01	-0.83960E-01	-0.75377	-0.34574	-0.15961
2 VAL NOW	0.27321E-01	-0.11401	-0.68219	-0.18956	0.92376E-01
3 VOL@40	0.36172E-01	-0.97135E-01	0.80654E-01	1.0657	0.28871
4 VOL@60	0.22988E-01	0.17539	0.14050	0.43151	0.13599
5 VOL@80	0.58785E-01	-0.73450E-01	0.29777E-01	0.55866	-0.15694
6 VOL@100	-0.13566E-01	0.12190	0.85045E-01	0.59506E-03	0.18325
7 VOL@120	0.52214E-01	0.38319	0.19740	-0.24686	-0.50041E-01
8 VOL@140	0.0	0.0	0.0	0.0	0.0
9 VOL@160	0.0	0.0	0.0	0.0	0.0
10 VOL@180	0.39076E-01	0.66511	0.19681	-0.98837	0.43771
11 VOL@200	0.0	0.0	0.0	0.0	0.0
12 VAL@40	-0.48789E-01	-0.30885E-01	0.77869E-02	-0.10910	-2.6273
13 VAL@60	-0.10215	-0.60369E-01	0.14283E-01	0.11488	-0.61065
14 VAL@80	-0.13259	-0.11205E-01	0.15862E-01	-0.39411E-02	0.27798
15 VAL@100	-0.12774	-0.58356E-02	0.12177E-01	-0.64786E-01	0.28056
16 VAL@120	-0.14376	-0.26654E-01	0.72592E-02	-0.17418E-01	0.63829
17 VAL@140	-0.13589	-0.17210E-01	0.51064E-01	0.73321E-01	0.48543
18 VAL@160	-0.14030	0.56296E-02	0.41283E-01	-0.77385E-01	0.33670
19 VAL@180	-0.27825	-0.51287E-01	0.64936E-01	-0.63346E-01	0.66941

APPENDIX VII

Volume And Value Yield Classes From Cluster Analysis

AGE IN YRS.	WEIGHTED VOLUME YIELD CLASSES IN CCF/ACRE									
	1	2	3	4	5	6	7	8	9	10
20:	0.92	0.00	0.11	0.0	0.18	0.02	2.27	0.36	0.00	0.00
40:	12.69	6.59	4.34	1.51	2.10	5.16	17.78	2.70	8.06	10.88
60:	22.63	15.54	9.98	5.63	5.01	12.05	29.56	6.49	18.47	27.40
80:	29.55	24.57	15.44	11.58	7.96	19.13	37.66	10.55	28.22	41.65
100:	34.20	32.24	19.78	16.65	10.37	25.20	42.89	13.97	35.99	52.26
120:	37.02	37.02	22.75	19.74	12.22	29.05	46.12	16.68	41.10	58.62
140:	38.74	40.02	24.76	21.76	13.43	31.49	48.07	18.43	44.43	62.59
160:	39.63	41.65	25.79	22.99	14.03	32.82	49.24	19.33	46.35	64.68
180:	40.09	42.52	26.34	23.73	14.31	33.55	50.01	19.89	47.32	65.45
200:	40.23	42.64	26.53	23.97	14.43	33.70	50.20	20.13	47.55	65.19

AGE IN YRS.	WEIGHTED VOLUME YIELD CLASSES IN CCF/ACRE				
	11	12	13	14	15
20:	0.0	0.28	1.10	5.75	2.43
40:	9.30	21.23	8.63	28.74	20.29
60:	23.11	46.70	16.70	43.75	35.73
80:	35.71	63.96	23.12	53.65	46.43
100:	45.62	71.18	27.73	59.40	53.61
120:	51.60	72.46	30.71	62.91	58.02
140:	55.32	71.61	32.71	64.83	60.73
160:	57.28	68.77	34.03	66.11	62.12
180:	58.13	65.09	34.90	67.07	62.87
200:	58.01	60.01	35.33	66.74	63.16

EXECUTION TERMINATED
T=11.37 DR=17 $3.36, $3.45T

$SIG

AGE IN YRS.	WEIGHTED ECONOMIC YIELD CLASSES IN $/CCF									
	1	2	3	4	5	6	7	8	9	10
20:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40:	58.77	55.07	8.09	37.63	6.65	34.52	53.54	62.06	71.93	56.94
60:	59.82	55.51	15.06	46.94	71.80	48.63	53.98	63.70	73.79	59.36
80:	62.08	57.07	18.20	57.28	75.81	54.26	55.87	64.88	74.89	59.38
100:	63.23	55.79	19.79	54.75	77.39	51.88	56.93	65.43	75.70	61.43
120:	63.96	59.34	20.50	58.83	78.19	56.28	57.69	65.80	76.18	61.68
140:	63.65	59.62	21.15	60.26	78.70	58.05	58.68	66.54	76.73	62.59
160:	64.86	62.44	21.57	60.90	78.75	58.88	60.85	66.40	75.81	63.03
180:	65.27	61.96	21.90	61.19	79.01	59.03	60.97	66.77	76.66	62.73
200:	65.47	62.14	22.15	61.41	79.21	59.25	61.15	67.00	76.80	63.10

AGE IN YRS.	WEIGHTED ECONOMIC YIELD CLASSES IN $/CCF									
	11	12	13	14	15	16	17	18	19	20
20:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40:	23.85	52.44	13.78	38.88	6.76	51.77	0.0	50.64	17.82	11.70
60:	71.99	51.57	38.53	43.31	12.78	50.10	60.78	48.41	18.42	34.82
80:	75.46	55.76	54.53	56.30	15.70	55.18	68.77	53.52	18.57	51.53
100:	76.88	58.28	50.23	50.34	17.19	57.08	71.47	55.18	18.62	47.26
120:	77.64	58.75	57.71	58.11	17.82	57.75	72.74	55.90	18.64	54.82
140:	78.15	56.66	58.57	58.45	18.44	55.20	73.53	53.46	18.65	55.82
160:	78.31	60.38	58.98	58.86	18.84	59.42	73.90	57.62	18.65	56.26
180:	78.63	60.33	59.30	59.08	19.14	59.26	74.27	57.50	18.64	56.58
200:	78.88	60.51	59.53	59.26	19.38	59.44	74.55	57.67	18.62	56.80

AGE
IN YRS.

WEIGHTED ECONOMIC YIELD CLASSES
IN $/CCF

	21	22	23	24	25	26	27	28	29	30
20:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40:	16.74	50.01	70.15	25.02	4.10	66.26	6.06	45.91	5.78	52.35
60:	66.92	47.87	71.40	37.16	10.31	67.71	36.82	44.84	45.14	54.23
80:	70.54	52.22	72.26	49.04	13.18	68.60	45.76	49.29	52.00	54.84
100:	72.01	53.14	72.91	45.21	14.65	69.14	47.56	51.27	54.59	54.63
120:	72.52	53.65	73.29	51.38	15.27	69.88	49.82	52.17	55.98	56.35
140:	73.23	52.45	73.58	52.11	15.88	70.31	50.55	50.63	56.72	56.91
160:	73.26	56.06	73.16	52.50	16.27	70.25	51.00	53.62	57.17	57.93
180:	73.50	55.83	73.57	52.79	16.57	70.48	51.25	53.71	57.45	57.33
200:	73.68	55.57	73.67	53.00	16.80	70.64	51.40	53.86	57.64	57.52

EXECUTION TERMINATED
T=11.83 DR=130 $3.80, $3.86T

$SIG

APPENDIX VIII

Transportation Economics By Compartment For The Westlake PSYU

COMPARTMENT REPORT

COMPARTMENT	REGION	# OF STANDS	# OF UNLOCATABLE STANDS	AVERAGE HAUL COST ($/CCF)	MIN. HAUL COST ($/CCF)	MAX. HAUL COST ($/CCF)	AVERAGE ROAD DEV. COST ($/CCF)
9	60	38	0	1.63	0.83	2.63	0.0
6	60	17	1	2.03	1.83	2.38	0.0
8	60	65	5	3.04	0.86	5.88	0.0
10	60	133	0	1.69	0.10	4.22	0.0
11	60	64	0	2.09	0.77	2.75	0.0
14	60	100	17	2.86	1.20	4.40	0.0
15	60	126	1	2.80	1.57	5.00	0.0
16	60	62	4	1.06	0.30	3.25	0.0
18	60	92	0	4.82	3.38	7.91	0.0
19	60	59	24	6.85	4.88	8.06	0.0
20	60	113	17	7.67	5.70	9.10	0.07
21	55	58	28	6.98	6.25	7.69	0.0
22	60	123	1	4.48	2.05	6.71	0.0
23	60	151	8	4.47	2.85	6.93	0.21
23	55	64	5	5.25	4.26	6.42	0.0
24	60	140	1	4.22	0.03	6.45	1.21
24	55	84	2	7.05	6.20	8.90	0.25
12	60	95	0	4.10	2.13	6.73	0.0
17	60	54	3	2.51	1.36	3.62	0.0
22	55	70	15	4.72	2.88	6.84	0.0
25	60	68	3	6.76	6.05	8.41	0.0
39	60	15	0	2.91	2.69	3.06	0.0
44	60	12	0	6.59	6.43	6.77	0.0
76	55	11	0	10.13	9.96	10.34	0.0
77	55	64	0	9.35	8.21	10.31	0.01
21	60	65	0	7.99	6.99	8.97	1.04
40	60	4	0	3.34	3.29	3.35	0.0
43	60	12	0	6.42	3.95	6.89	0.0
46	60	10	0	5.94	5.61	6.17	0.0
53	55	12	0	8.49	8.32	8.64	1.73
27	55	4	0	10.45	10.31	10.56	0.0

APPENDIX IX

Transportation Analysis Results For An Isle Pierre Appraisal Point - Stand 057

TYPE ISLAND REPORT

STAND NO.	TYPE	AGE	SITE	SLC	USE	CENTROID LOCATION IN LAT-LONG.	DIST. TO NEAREST RD. (MILES)	RD. NO.	DIST. TO NAP (MILES)	HAUL COST ($/CUNIT)	ROAD DEVELOPMENT COST ($/CUNIT)
8002160	PL	8	1	4	1	5331.17 12252.33	0.69	15	51.18	11.26	0.0
8003160	S	8	1	4	1	5335.43 12252.20	0.51	17	45.30	9.96	0.0
8034160	S	8	2	5	1	5327.89 12242.27	7.36	15	61.41	13.51	0.0
8065160	COTD	8	2	13	1	5331.43 12242.60	7.10	17	52.48	11.55	0.0
8033160	F	8	2	5	1	5328.63 12242.80	6.97	15	61.02	13.42	0.0
8001160	F	8	2	4	1	5332.93 12250.23	2.33	17	47.71	10.50	0.0
8064160	F	8	2	13	1	5331.77 12243.33	6.47	17	51.85	11.41	0.0
10001160	F	8	1	4	1	5339.98 12301.75	0.32	21	39.85	8.77	0.0
10029160	F	8	1	4	3	5339.41 12306.08	0.96	22	7.43	1.63	0.0
10058160	S	8	2	5	3	5341.48 12305.48	2.30	24	6.19	1.36	0.0
11034160	F	8	1	4	4	5346.46 12314.71	2.31	26	14.87	2.68	0.0
11013160	F	8	2	4	1	5339.77 12313.30	1.32	27	9.93	1.79	0.0
11043160	SF	8	2	5	1	5340.59 12312.62	0.66	25	6.37	1.15	0.0
12001160	S	8	1	1	1	5341.33 12325.59	2.34	31	22.16	3.99	0.0
12056160	S	8	1	10	1	5342.27 12325.41	3.39	31	23.21	4.18	0.0
14068160	SF	8	1	5	1	5333.75 12313.80	0.69	32	20.69	4.55	0.0
14038160	FS	8	1	4	1	5338.45 12312.73	2.40	27	11.09	2.00	0.0
14128160	S	8	1	9	2	5336.33 12315.60	1.50	27	13.76	2.48	0.0
14062160	SF	8	1	4	2	5300.00 12300.00	20.77	3	60.41	13.29	0.0
14122160	S	8	1	9	1	5336.41 12316.70	1.00	27	14.17	2.55	0.0
15110160	F	8	1	12	1	5336.56 12304.73	1.11	32	28.18	6.20	0.0
15034160	F	8	1	7	1	5330.80 12309.36	1.53	13	58.20	12.80	0.0
15127160	F	8	1	4	1	5336.43 12304.53	1.02	32	28.15	6.19	0.0
16013160	F	8	1	12	1	5337.38 12304.32	0.40	21	44.11	9.70	0.0
16073160	S	8	1	4	2	5339.35 12253.93	1.51	17	40.70	8.96	0.0
16045160	S	8	1	4	1	5339.46 12254.77	1.09	18	38.77	8.53	0.0
16046160	F	8	1	4	1	5337.41 12304.02	0.32	21	44.03	9.69	0.0
17053160	PL	8	1	6	1	5330.68 12256.46	1.71	15	51.57	11.34	0.0
17033160	PLS	8	1	12	1	5329.23 12254.38	0.57	15	53.15	11.69	0.0
17020160	PL	8	1	4	2	5331.66 12254.50	0.21	15	49.40	10.87	0.0
17001160	S	8	1	4	1	5332.46 12256.13	1.04	15	46.57	10.24	0.0
17002160	PL	8	1	4	1	5330.66 12254.89	0.82	15	50.67	11.15	0.0
17040160	S	8	2	12	2	5329.80 12257.23	1.69	14	51.23	11.27	0.0
17019160	S	8	2	4	2	5330.00 12257.23	1.69	14	50.33	11.07	0.0
17031160	S	8	2	12	1	5329.77 12257.46	1.53	14	51.07	11.23	0.0
17032160	F	8	2	12	1	5329.63 12254.63	0.51	15	52.82	11.62	0.0
18055160	F	8	1	7	3	5327.06 12308.20	1.68	44	28.71	6.32	0.0
18101160	S	8	1	4	6	5324.73 12304.39	0.72	9	51.47	11.32	0.0
18001160	S	8	1	5	3	5330.30 12305.33	1.42	13	55.49	12.21	0.0
18089160	F	8	1	4	2	5324.80 12306.60	0.63	9	52.25	11.49	0.0
18022160	S	8	1	7	1	5324.39 12304.63	1.05	9	51.80	11.40	0.0
18073160	F	8	1	4	1	5325.89 12306.80	0.82	9	52.50	11.55	0.0
18074160	S	8	1	4	1	5325.03 12303.80	0.73	9	51.06	11.23	0.0
18040160	S	8	2	7	6	5325.50 12305.46	0.49	9	51.23	11.27	0.0
19033160	F	8	1	18	1	5321.05 12305.27	0.51	8	42.89	9.43	0.0
19014160	F	8	1	7	1	5321.05 12306.39	0.25	8	41.85	9.21	0.0
19001160	F	8	1	4	1	5325.25 12307.96	0.50	44	29.10	6.40	0.0
19045160	PLF	8	1	15	2	5300.00 12300.00	20.77	3	60.41	13.29	0.0
20057160	S	8	1	15	1	5323.35 12316.46	1.39	46	31.97	7.03	0.0
20056160	F	8	2	15	1	5322.05 12317.27	1.63	42	33.71	7.42	1.73

APPENDIX X

Summary Of Cut Scheduling Results - Case 1

	Long Term	Short Term
Objective:	maximize volume over 200 yrs.	maximize volume over 30 yrs.
Objective value at 30 years:	6,978.3 MCCF	7,802.3 MCCF
Objective value at 200 years:	39,265.6 MCCF	38,422.1 MCCF
Long run sustained yield average:	1,831.9 MCCF/decade	1,831.9 MCCF/decade
Volume harvested in decade 1:	2,575.0 MCCF	2,879.1 MCCF
Net revenue in decade 1:	$106.3 MM	$116.5 MM

APPENDIX XI

Species Harvest By Timber Class - Case 1

SPECIES BREAKDOWN OF HARVEST IN DECADE 1 - CASE 1: LONG TERM

VOLUME IN M C C F

TIMBER CLASS	F	C	H	B	S	CY	PW	PL	PY	L	CT	D	NB	BI	A	PA
7	0.33	0.0	0.0	0.27	7.87	0.0	0.0	3.94	0.0	0.0	0.03	0.0	0.0	0.13	0.30	0.0
9	18.28	0.0	0.0	2.50	154.43	0.0	0.0	32.13	0.0	0.0	0.70	0.0	0.0	1.57	6.01	0.0
14	77.69	0.0	0.0	0.84	5.74	0.0	0.0	5.27	0.0	0.0	0.09	0.0	0.0	1.84	1.60	0.0
16	7.15	0.0	0.0	0.05	0.37	0.0	0.0	0.35	0.0	0.0	0.0	0.0	0.0	0.15	0.13	0.0
21	30.98	0.0	0.0	1.61	83.61	0.0	0.0	18.73	0.0	0.0	0.43	0.0	0.0	1.32	3.67	0.0
30	22.06	0.0	0.0	3.51	40.39	0.0	0.0	370.15	0.0	0.0	2.43	0.0	0.0	1.95	7.03	0.0
36	20.12	0.0	0.0	4.18	38.52	0.0	0.0	282.43	0.0	0.0	2.66	0.0	0.0	2.24	5.81	0.0
45	10.52	0.0	0.0	0.52	6.04	0.0	0.0	126.38	0.0	0.0	0.26	0.0	0.0	0.48	1.29	0.0
54	27.99	0.0	0.0	1.70	18.51	0.0	0.0	185.97	0.0	0.0	1.15	0.0	0.0	2.79	3.25	0.0
63	56.54	0.0	0.0	3.41	60.44	0.0	0.0	26.79	0.0	0.0	1.10	0.0	0.0	2.40	4.11	0.0
67	13.24	0.0	0.0	0.28	3.91	0.0	0.0	81.92	0.0	0.0	0.10	0.0	0.0	0.89	0.87	0.0
68	84.32	0.0	0.0	0.58	4.35	0.0	0.0	4.16	0.0	0.0	0.0	0.0	0.0	1.74	1.55	0.0
69	0.0	0.0	0.0	0.0	0.14	0.0	0.0	0.0	0.0	0.0	3.37	0.0	0.0	0.0	0.0	0.0
73	95.68	0.0	0.0	0.74	12.43	0.0	0.0	6.08	0.0	0.0	0.02	0.0	0.0	2.02	2.30	0.0
81	19.25	0.0	0.0	0.45	6.17	0.0	0.0	112.19	0.0	0.0	0.24	0.0	0.0	1.64	1.39	0.0
83	0.14	0.0	0.0	0.04	0.28	0.0	0.0	1.06	0.0	0.0	0.03	0.0	0.0	0.02	0.05	0.0
88	91.05	0.0	0.0	0.63	4.70	0.0	0.0	4.49	0.0	0.0	0.0	0.0	0.0	1.88	1.67	0.0
96	32.76	0.0	0.0	9.01	65.69	0.0	0.0	421.97	0.0	0.0	6.95	0.0	0.0	4.11	11.95	0.0
TOTALS:	608.09	0.0	0.0	30.32	513.59	0.0	0.0	1684.01	0.0	0.0	19.55	0.0	0.0	27.16	52.79	0.0
% :	20.7	0.0	0.0	1.0	17.5	0.0	0.0	57.4	0.0	0.0	0.7	0.0	0.0	0.9	1.8	0.0

SPECIES BREAKDOWN OF HARVEST IN DECADE 1 - CASE 1: SHORT TERM

VOLUME IN M C C F

TIMBER CLASS	F	C	H	B	S	CY	PW	PL	PY	L	CT	D	MB	BI	A	PA
7	0.33	0.0	0.0	0.27	7.87	0.0	0.0	3.94	0.0	0.0	0.03	0.0	0.0	0.13	0.30	0.0
14	77.69	0.0	0.0	0.84	5.74	0.0	0.0	5.27	0.0	0.0	0.09	0.0	0.0	1.84	1.40	0.0
16	7.15	0.0	0.0	0.05	0.37	0.0	0.0	0.35	0.0	0.0	0.0	0.0	0.0	0.15	0.13	0.0
30	22.06	0.0	0.0	3.51	40.39	0.0	0.0	370.15	0.0	0.0	2.43	0.0	0.0	1.95	7.03	0.0
34	2.60	0.0	0.0	0.02	0.13	0.0	0.0	0.13	0.0	0.0	0.0	0.0	0.0	0.05	0.05	0.0
36	20.12	0.0	0.0	4.18	38.52	0.0	0.0	282.43	0.0	0.0	2.66	0.0	0.0	2.24	5.81	0.0
45	10.92	0.0	0.0	0.52	6.04	0.0	0.0	126.38	0.0	0.0	0.26	0.0	0.0	0.48	1.29	0.0
54	27.99	0.0	0.0	1.70	18.51	0.0	0.0	185.97	0.0	0.0	1.15	0.0	0.0	2.79	3.25	0.0
56	45.81	0.0	0.0	1.41	40.64	0.0	0.0	12.65	0.0	0.0	0.39	0.0	0.0	1.43	2.49	0.0
63	56.54	0.0	0.0	3.41	60.44	0.0	0.0	26.79	0.0	0.0	1.10	0.0	0.0	2.40	4.11	0.0
67	13.24	0.0	0.0	0.28	3.91	0.0	0.0	81.92	0.0	0.0	0.10	0.0	0.0	0.89	0.87	0.0
68	84.32	0.0	0.0	0.58	4.35	0.0	0.0	4.16	0.0	0.0	0.0	0.0	0.0	1.74	1.55	0.0
69	0.0	0.0	0.0	0.0	0.14	0.0	0.0	0.0	0.0	0.0	3.37	0.0	0.0	0.0	0.0	0.0
73	95.68	0.0	0.0	0.74	12.43	0.0	0.0	6.08	0.0	0.0	0.02	0.0	0.0	2.02	2.30	0.0
80	72.09	0.0	0.0	0.92	16.56	0.0	0.0	9.49	0.0	0.0	0.05	0.0	0.0	1.68	1.80	0.0
81	19.25	0.0	0.0	0.45	6.17	0.0	0.0	112.19	0.0	0.0	0.24	0.0	0.0	1.64	1.39	0.0
83	0.14	0.0	0.0	0.04	0.28	0.0	0.0	1.06	0.0	0.0	0.03	0.0	0.0	0.02	0.05	0.0
88	91.05	0.0	0.0	0.63	4.70	0.0	0.0	4.49	0.0	0.0	0.0	0.0	0.0	1.88	1.67	0.0
92	95.82	0.0	0.0	6.18	91.59	0.0	0.0	829.23	0.0	0.0	3.82	0.0	0.0	4.85	12.95	0.0
96	32.76	0.0	0.0	9.01	65.69	0.0	0.0	421.97	0.0	0.0	6.95	0.0	0.0	4.11	11.95	0.0
TOTALS:	775.15	0.0	0.0	34.74	424.47	0.0	0.0	2484.65	0.0	0.0	22.68	0.0	0.0	32.28	60.39	0.0
% :	20.2	0.0	0.0	0.9	11.1	0.0	0.0	64.8	0.0	0.0	0.6	0.0	0.0	0.8	1.6	0.0

APPENDIX XII

Summary Of Cut Scheduling Results - Case 2

	Volume	Value
Objective:	maximize volume over 200 yrs.	maximize value over 200 yrs.
Objective value at 200 years:	$179.3 MM	$200.4 MM
Volume production at 200 years:	39,265.6 MCCF	38,385.3 MCCF
Long run sustained yield average:	1,831.9 MCCF/decade	1,831.9 MCCF/decade
Volume harvested in decade 1:	2,575.0 MCCF	2,864.3 MCCF
Net revenue in decade 1:	$106.3 MM	$119.4 MM

APPENDIX XIII

Summary Of Cut Scheduling Results - Case 3

	TRACS	CARP
Objective:	maximize value over 200 yrs.	maximize value over 200 yrs.
Objective value at 200 years:	$200.4 MM	$267.2 MM
Volume production at 200 years:	38,385.3 MCCF	40,471.2 MCCF
Long run sustained yield average:	1,831.9 MCCF/decade	1,755.7 MCCF/decade
Volume harvested in decade 1:	2,864.3 MCCF	3,442.4 MCCF
Net revenue in decade 1:	$119.4 MM	$162.6 MM