University of Washington
Forest Engineering Class of 2000

A Thinning and Access Strategy for Accelerated Stand Habitat Creation

Burnt Mountain

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Executive Summary

Project Overview

During spring quarter 2000, the University of Washington Forest Engineering program developed *A Thinning and Access Strategy for Accelerated Stand Habitat Creation in the Burnt Mountain Block of the Olympic Experimental State Forest.* This project is a collaborative effort between the DNR and UW designed to provide real-world experience to the forest engineering class, while also supporting DNR management goals.

The project develops a harvest and transportation plan that provides habitat and economic outcomes. It also identifies alternative harvest strategies to aid in road density management, and also highlights new technologies and ideas for providing more intuitive representations of potential management outcomes in a visual format.

Another goal is to identify options for research and monitoring as specified in the HCP for the Olympic Experimental State Forest. In support of this need, the plan identifies harvest systems by setting, providing information needed to determine the type of silvicultural systems that can be implemented on a setting basis.

Habitat and Economic Outcomes

To provide opportunities for habitat creation during harvest operations, three silvicultural options are assessed: single-density thin, variable-density thin, and no-harvest. Outcomes of each option are assessed using growth models projected to the year 2040.

Economics of each option are also examined. This includes costs associated with harvest as well as road construction needed to reach these units.

From economic and habitat creation inputs, four scenarios are developed and details of habitat creation and economics are provided for each.

Based on management needs and desired outcomes, Scenario Three, a modified variable density thin, is recommended for the 1,679 harvestable acres in the planning area. Variable density thinning will create the desired habitat over 99% of the acreage by the year 2020. Of the operations analyzed the combined log length and whole tree yarding (modified variable density thin) shows the best return ($121/Mbf) over most of the planning area. The combined variable density thin with an 80 acre regeneration harvest would be the next best option. It has a net return of $77/Mbf to the trust and is able to access 1244 acres because regeneration harvest pays for the road construction. The last two options, variable density thinning and helicopter thinning would be the last choice due to the small amount of returned profit to the trust (helicopter $29/Mbf, and variable density thin $25/Mbf). But one advantage of the helicopter option is only 52 stations of road would have to be constructed.

Table 1 Stump-to-truck cost, revenues and road construction activities for three basic thinning regimes which also includes helicopter. The modified variable density thinning allows for best returns due to increased payloads made possible by tree-length yarding in settings where residual trees per acre drop below 100.

	Scenario I	Scenario II	Scenario III	Scenario IV
	/ariable Densit Thinning	Variable Density w/ 80 Acre Re-Gen Harvest	Modified Variable Density	Thinning w/ Helicopter
Area Harvested (Acres)	397	1244	1,679	2,557
Vol. Harvested (mbf)	2086	10,861	12,505	17,446
Haul Cost ($/mbf)	35	35	35	35
Harvest Cost ($) Harvest Cost ($/mbf)	590,720 283	2,494,124 230	1,877,191 150	6,280,560 360
Road Cost ($) Road Cost ($/mbf)	182,039 87	954,399 88	1,555,390 124	102,947 6
Road Length (sta)	91	477	777	52
Return To Trust($) Return To Trust ($/mbf)	51,593 25	836,297 77	1,513,105 121	505,934 29

Road Density

To support management goals of reducing road densities across the landscape, the plan also includes assessments of alternative harvest systems. The two systems examined are long-span cable yarding and helicopter yarding.

Long-span yarding was determined to be appropriate in areas where ridge-to-ridge corridors can be placed. Analysis of the planning area identified approximately 264 acres in the north section where use of long-span systems will enable the elimination of 41 stations of road.

The south section of the planning area did not provide opportunities for road density reduction using long-span systems. The reason for this is the dissected topography of the area. Dense networks of north-south ridges prevented development of long-span cable corridors. As a result, a denser road network is needed to support traditional length cable spans.

Thinning by helicopter is also assessed as a strategy for reducing road densities. Approximately 2,557 acres in the planning area are identified as appropriate for helicopter thinning, providing 17,446 mbf. This option produces the least return to the trust ($29/mbf) due to the high cost of operations, but provides the greatest road density reduction opportunities, requiring approximately 50 stations of road construction. Average stump-to-truck costs are estimated at $360.-/mbf, road construction and haul costs at $ 6.-/mbf and $ 35.-/mbf, respectively.

New Technology

A continuing focus of the UW's involvement in these projects is to highlight and showcase new technologies that give land managers increased options for communicating land management outcomes. The most recent addition to this toolbox is the visualization program EnVision, being developed at the UW by the Forest Systems Engineering Research Cooperative (FORSYS). The EnVision program provides landscape images for use in modeling management impacts on the landscape. Below is an example of a variable density thin modeled on the Burnt Mountain Planning Area.

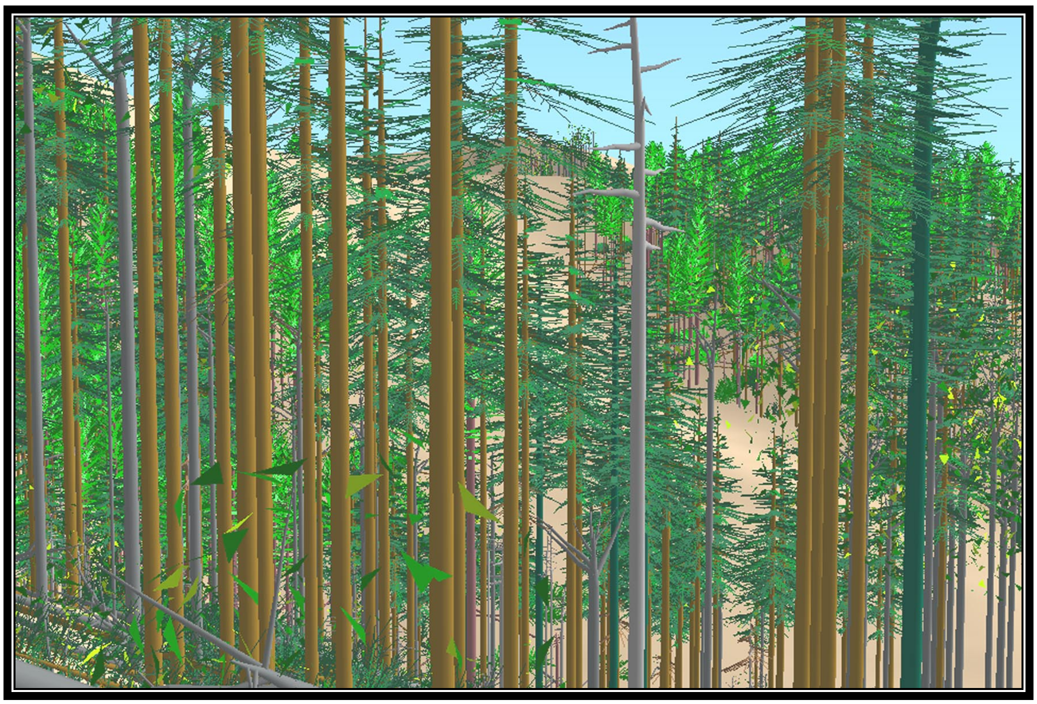


Figure 1 EnVision Landscape Visualization of the Burnt Mountain Area

The EnVision program is still in development at this time. The final version will use tree images derived from actual photographs to provide a "photo realistic" image of the landscape. The UW expects this tool to be useful for communicating management prescriptions in terms that a broader audience can grasp, even those without a natural resource background.

Other technology developed during this project consists of conversion programs to import FRIS data to FVS, and web-based project development.

The UW team developed a conversion program to take FRIS data and put it into a format that could be used in FVS. This allowed us to grow stands forward in time using data from each individual tree vs. a "stand average" tree. This provides more realistic representations of future conditions, something not possible with current approaches.

Web-based project development was used to allow interested parties access to project results in an on-going fashion. Using map management software (ER Mapper), we were able to post planning and results maps on the web in a format that preserves detail and resolution while allowing for extremely fast re-draw speeds.

Research Applications

A secondary goal of the planning project is to identify settings appropriate for research activities. The criteria used to identify these areas are:

- Average stand ages between 40 and 60 years.
- Accessible by either ground systems or cable systems.
- Returns a net profit to the trust.

By identifying the type of system that can be used on each setting, realistic silvicultural prescriptions can be identified and placed within the planning area. This supports design of a statistically valid research program by allowing for random placements of research settings.

Silviculture data has been developed for all of these stands using differing treatments. Also provided is information about habitat creation resulting from each option (see sliviculture section of report).

Opportunities are identified for long-span cable yarding (mostly in the NE area), and single and variable density prescriptions to be applied. This information can be found in the section on yarding costs and also the habitat and economics section.

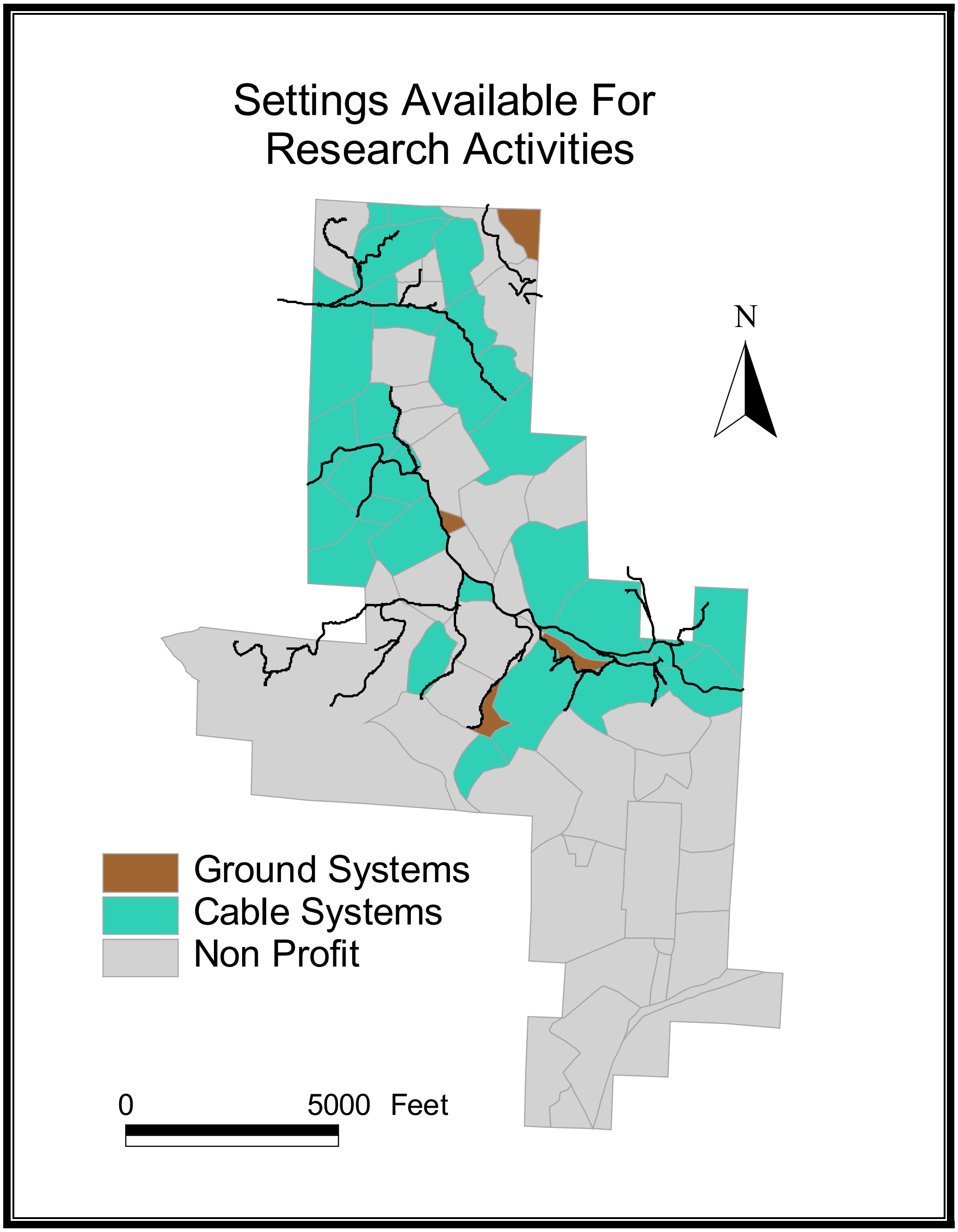


Figure 2 Potential research settings having a positive return to the Trust and the required road systems for cable thinning operations.

The above map, identifies areas where thinning operations can be carried out economically. The types of yarding system appropriate for each setting are identified.

Table of Contents

List of Figures

List of Tables

1 Design Team

1.1 Directors

1.1.1 Peter Schiess

The University of Washington Hoodsport Harvest Planning Project was under the direction of Professor Peter Schiess. Professor Schiess obtained his Ph.D. degree from the College of Forest Resources, University of Washington in 1975. After receiving his Ph.D. degree, Professor Schiess has played an important role in the development of the Forest Engineering curriculum at the University of Washington. He has research interests in mechanized harvest and cable thinning operations, and is currently researching timber harvest planning as a subset of landscape level analysis. Further information regarding Professor Schiess's educational background, professional experience, and publications can be found at http://faculty.washington.edu/schiess/.

1.1.2 Luke Rogers

Luke Rogers, the Assistant Director to Professor Schiess, obtained his Bachelor of Science degree in Forest Engineering from the College of Forest Resources, University of Washington in 1998. Luke is currently a graduate student at the University of Washington studying to obtain a masters degree in Forest Engineering. Luke has past engineering experience as a forest engineering intern with Weyerhaeuser Company, Cottage Grove, Oregon and Snoqualmie/White River in Washington. Special research interests are in Geographic Information Systems (GIS) applications in forested areas and in construction management. Further information regarding Luke Rogers educational background, professional experience, and related course work can be found at http://highlead.cfr.washington.edu/lwrogers/.

1.1.3 Weikko Jaross

Assisting in engineering design and acting as a liaison between the Forest Engineering Design Team and the Department of Natural Resources (DNR), Weikko Jaross received his Bachelor of Science degree from the College of Forest Resources, University of Washington in 1996. Weikko is currently a graduate student at the University of Washington studying to obtain a Masters Degree in Forest Engineering. Special interests are in DNR GIS and familiarizing University of Washington Forest Engineering students with aspects of harvest operations.

Further information regarding Weikko Jaross's educational background, professional experience, and related activities can be found at http://weber.u.washington.edu/~weikko/.

1.2 Forest Engineering Seniors

1.2.1 Barry Collins

Barry Collins is a senior in Forest Engineering and will be graduating in June of 2000 with a Bachelor of Science degree. He worked in forestry last summer for the DNR in the SE region. Following graduation, Barry plans to apply with the Seattle Fire Department.

1.2.2 Robert Stewart

Robbie Stewart is a senior in Forest Engineering and will be graduating in June of 2001 with a Bachelor of Science degree in Forest Engineering as well as a minor in Streamside Studies. He is interested in modeling issues dealing with hydrology and runoff using GIS. His area of emphasis is environmental analysis and design, including remote sensing. He worked in forestry last summer for the DNR in the Olympic region. Following graduation, Robbie plans to further his education and knowledge by obtaining his masters in either hydrology or Geographic Information Systems.

1.2.3 Bill Heymann

Bill Heymann is a senior in Forest Engineering and will be graduating in June of 2000 with a Bachelor of Science degree. He is interested in sediment issues and slope stability as they relate to forest transportation systems. His area of emphasis is environmental analysis and design with an interest in remote sensing and GIS. He has worked in the forestry field for the past ten summers as a forest fire fighter and a five-month internship with a private timber company. Following graduation, Bill plans to pursue a forestry-related carrier.

1.2.4 Tamra Zylstra

Tamra Zylstra is a senior in Forest Engineering and will be graduating in June of 2000 with a Bachelor of Science degree. She worked in forestry last summer for the DNR in the SE region. She will start work with the SE Region as a Natural Resource Engineer after graduation.

1.2.5 Aaron Roark

Aaron roark is a senior in Forest Engineering and will be graduating in December of 2000 with a Bachelor of Science degree in Forest Engineering. He is interested in Construction Engineering.

1.2.6 Justin Gardner

Justin Gardner is a senior in Forest Engineering and will be graduating in March of 2001 with a Bachelor of Science degree in Forest Engineering.

1.2.7 Aaron McDonald

Aaron McDonald is a senior graduating in June of 2000 with a Bachelor of Science degree in Forest Engineering from the University of Washington College of Forest Resources. He also holds Associate in Arts and Sciences and Associate in Science/Engineering degrees from Bellevue Community College. His emphasis area is Remote Sensing and Geographic Information Systems. He is also interested in Landscape Ecology and landscape level issues. Aaron spent the summer of 1999 working for the Oregon Department of Forestry as a forester intern where he gained experience in timber sale layout, timber cruising, contract administration, and road engineering. Aaron would like to get a few years of practical experience and acquire a Professional Engineer license, and possibly return to college for graduate work.

2 Introduction

2.1 Goals/Objectives, Opportunities, Project Expectations

2.1.1 Introduction

This year's planning project for the Burnt Mountain Planning Area is the most recent project undertaken by the University of Washington Senior Forest Engineering Class. Over the last twenty years, the Washington State Department of Natural Resources (DNR) has been involved in a partnership with the UW to undertake a real-world planning project that uses the skills learned in the classroom to develop answers to planning questions posed by the DNR. The results of these projects provide in-depth planning support to DNR's own field staff, providing a level of detail not normally possible due to time and budget constraints.

2.1.2 Goals/Objectives of the Project

DNR

The project location is in the Olympic Experimental State Forest on the Olympic Peninsula (T32N R12W sec.36, T30N R11W sec. 6, 7, 18, and T30N R12W sec. 1, 11, 12). Covering approximately 3,248 acres, this area has been designated by the state board of forestry and the legislature as a working forest where new management techniques can be applied and assessed for their impact and usefulness in other state managed lands.

Figure 3 below gives a sense of the location of the project area.

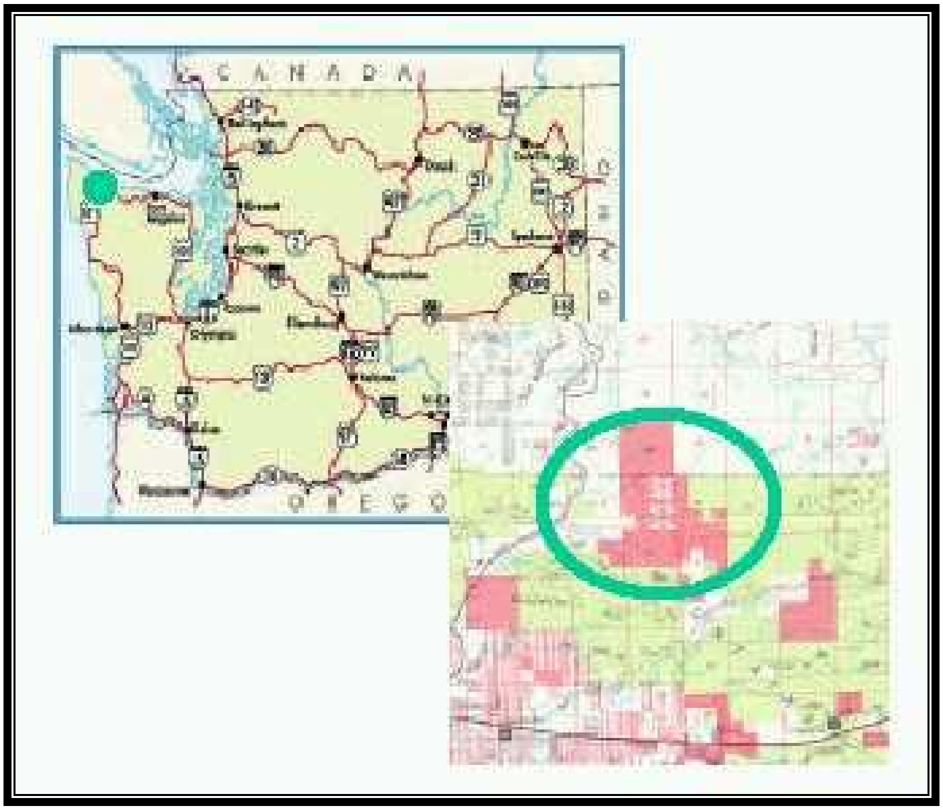


Figure 3 DNR/UW 2000 Planning Project Location on the Olympic Peninsula

The goals of this project were developed in consultation with the District Manager for the Crescent District, and the Research Planner for the DNR. The initial planning and development was undertaken during the UW winter 1999 school quarter as part of the FE444 engineering design class (http://courses.washington.edu/fe450/). The initial goals and objectives were developed during this project, with subsequent refinement during the planning project. In addition, the UW has also identified goals related to supporting the DNR and providing educational opportunity for its students.

In addition to the winter quarter project defining the goals and objectives, initial data acquisition was begun in January 2000. This allowed opportunity to assess the usefulness of the provided data, and identify additional data and support that would be needed during the spring quarter project.

The major goal of this planning project is to develop a timber harvest and transportation plan that identifies the types of silvicultural systems appropriate to meet thinning and habitat creation objectives in the planning area. This information can be used by the District Manager to identify and schedule timber harvest activities across the planning area.

A concurrent and important goal of this project is to support research and monitoring activities that assess the impacts of management activities on habitat and wildlife. As part of an agreement with the federal government under the Endangered Species Act, DNR has developed a Habitat Conservation Plan that specifies management actions to mitigate potential effects of forest management activities on habitat of endangered and threatened species. As part of this agreement, DNR will undertake implementation, effectiveness, and validation monitoring of the HCP. Results of this plan will provide research planners the information needed to design effective research and monitoring strategies in the planning area.

The planning team has also undertaken an extensive economic analysis of the harvest plan, developing silvicultural and yarding cost data to identify the economic feasibility of the various options examined. The planning team has developed economic assessments of both single density, and variable density thinning, using growth models developed during the course of the project. The planning team has identified the best economic opportunities available that are consistent with management and research goals.

A comprehensive road design plan has also been developed during the project. It identifies the location of roads, classes of the roads, harvest settings and landings, and also provides road costing data. In addition, a full road design was developed for the main access road with location, design, and cost of all components provided.

Creation of specific types of habitat in the planning area is also a major focus of the District Manager. The plan provides information on the potential to create habitat, using growth modeling to determine future silvicultural conditions and distributions. In addition, the planning team has also explored alternative ways of providing this information to managers and planners by using visualization tools currently under development at the UW.

The main goal of the University of Washington is to satisfy the needs of the client. The UW wishes to maintain its partnership with the DNR and strives to provide a relevant, and useful product to encourage continued participation.

The planning team's main goal is to provide a high quality product for the DNR that uses the best available knowledge and methods. The hallmark of a high quality product is that it meets the needs of the client, in this case, the DNR's District Manager. The plan supports the district manager's objectives, providing information needed to make management decisions. It is also responsive to the research designer's objectives, providing information for study design.

The UW also desires to provide the students a real-life educational experience. During the project, students gain an appreciation for the many problems faced in the planning environment. They learn how to adapt to changing operational needs while remaining focused on the overall goal. Experience is gained in a large-scale planning project that is not normally part of a Forest Engineering curriculum. This project provides an opportunity for students to meet with DNR employees and explore potential future employment options for post graduation.

There was also an expectation that new technologies and methods would be introduced during the course of the project. These approaches can provide new ways of presenting information that is intuitive, and easily grasped by people knowledgeable in natural resource issues, and laymen alike. These approaches may also provide opportunities for planning approaches that provide more detail, in less time, than was traditionally the case. This project provides an excellent forum to test these approaches and introduce them to potential users.

2.1.3 Opportunities

During the course of the project, opportunities were identified to take advantage of a number of aspects in the planning process. We identified regulatory, topographic, and economic aspects that allow the design to take advantage of these opportunities. By utilizing these opportunities during the planning phase, the design becomes more responsive to the needs of DNR managers.

2.1.4 Project expectations

During consultation with DNR, the expectations of the planning effort were discussed and formalized, creating a planning framework.

One expectation was that the plan would determine current and future harvest opportunities, laying out the most economically beneficial progression and timing for harvest operations. It also identifies timber growth timelines on a stand level over the planning area.

It was also desired that the plan provided functioning ecological links, both aquatic and terrestrial. This is done by making the plan responsive to regulatory guidelines, specifying how protective actions will be applied. We also designed harvest systems using the best placements and layouts to minimize or eliminate environmental degradation that commonly results from timber yarding operations.

Certain products will be produced for the client in the course of the planning process. The three main products expected are:

- The planning report, detailing the results and recommendations.
- Detailed planning maps used during plan creation, and the final map products.
- Data sets that were acquired or produced during the planning process.

All data and products will be provided on a "CD" to the DNR at the project conclusion. A written report will also be provided, along with example maps.

3 Data Collection

3.1 DNR Burnt Mountain

3.1.1 Introduction

In order for the project to get under way and be successful, vast amounts of information had to change hands. While much of the information was stored electronically (i.e., in a GIS) some was only available within the minds of the primary managers of the planning unit. Discussion of the electronic data is left to section 3.2. The latter is discussed here. One of the primary and easiest methods of information exchange is verbal communication. To facilitate the exchange of ideas, a meeting was held so UW forest engineers could utilize DNR staff to answer a variety of questions. A list of questions ranging from environmental, to roads, to harvest design was compiled for querying the staff. For the most part, these helped to define the objectives of the DNR beyond the HCP and to initiate a direction for the UW engineers.

3.1.2 Environmental

We covered environmental issues such as stream and wetland buffers, Marbled murrelet habitat, and Spotted Owl circles. The Marbled murrelet, a Pacific seabird, and the Northern spotted owl, a medium-sized dark brown owl, both require old growth structured stands. Structural features such as, large residual tress, large limbs, and nesting platforms are essential. The goal is to increase this habitat as quickly as possible while maintaining economic feasibility. Stream and wetland buffers were of small concern due to roads being located on ridge tops.

3.1.3 Road Design

Constraints in road construction and design were maximum adverse/favorable grades, balanced cut/fill and full bench parameters. Throughout the duration of the project, DNR employees from a wide range of fields were made available to the students. In particular, Sol Duc planning unit managers helped identify any access problems they knew about. They also helped to point out any sensitive areas we should be aware of and determine the priority given certain areas. DNR personnel also provided road-costing information (Clallam Bay road sale appraisal 1997). Goals pertaining to the products of the project were also defined here as well as in the contract.

3.1.4 Harvest Setting Design

In harvest setting design, we took a wide area approach as opposed to designing on a sale-by-sale basis. However, the DNR did have preliminary sale boundaries in place for current sales and upcoming sales, so we took those into consideration. Their goals pertaining to silvicultural strategies were clarified, as were their goals on structural diversity. Since the Burnt Mountain planning unit was an unmanaged natural regeneration, DNR wanted to accelerate the sub-mature and mature habitat. This included issues such as, a return to the Trust, maximizing yarding distances to reduce road density, and retention goals.

3.1.5 Aerial Photos

Aerial photos for years 1965 and 1997, as well as, 1980 ortho-photos were available for the Burnt Mountain planning area. These photos provide additional information that can not be seen from maps and GIS coverages. Some of the information that we collected from looking at the photos was useful in many areas of our harvest planning analysis. Previous landslides were identified and aided in the mass wasting/unstable module of the watershed analysis.

3.1.6 Road Costing Analysis

Burnt Mountain DNR staff supplied a copy of the Clallam Bay sale road appraisal they use for road construction cost estimating. We took this road appraisal and improved upon it for use in our road cost calculations.

3.2 GIS Coverages

3.2.1 Initial Data Collection/Database

Geographic information systems are powerful planning tools. As long as limitations of a GIS are understood, it is more than adequate for doing preliminary planning.

The DNR CONTOUR coverage provided us the elevation model necessary to do initial road design and identify areas of concern. The elevation contours served as guides for road pegging and initial landing location. Sensitive areas were defined using the wetlands coverage, soils coverage (i.e., rock outcrops and unstable areas), POCAL coverage (i.e., offbase areas), HYDRO (i.e., waterbodies and stream types) and more.

The FRIS coverage data was used to gather piece sizes, turn weights, expected tailhold sizes, and more for input into PLANS. This information was used in the initial design process and field maps were created for use during field reconnaissance. After field verification, information was put into ROADENG to create final designs. From this several coverages were created including the final landing/setting coverages, the harvest plan coverages, and the final road systems design.

The DNR creates and maintains its own GIS database. The Olympia office is the main source of data and normally a standard set of coverages is provided. However, regional offices will frequently have more current information and better overall coverage. We obtained the digital information in late February 2000 from the Olympia office and the Olympic Regional office in Forks. This gave us limited opportunity to become familiar with the data and check it for flaws, weaknesses, errors, etc. The coverages we acquired from the DNR included, but are not limited to:

DEM - a digital elevation model and contour coverage, derived from scanning original 1"=400' contour maps

HYDRO - a hydro coverage with arc and polygon features

TRANS - a transportation system arc coverage

POCAL - a coverage with public land survey boundary information

RIU -forest stand or resource inventory unit coverage including Forest Resource Inventory Survey (FRIS) data.

SOILS - a soil information coverage

SALES - a coverage with information on current and pending sales

BOUNDARY - a coverage showing the planning area

ONRC_DEM - dem obtained from the ONRC gis lab

ORTHO_S - digital ortho photo

PLS-PT - coverage of public land survey points

POCA - coverage of section lines

PRECIP - coverage of average rain fall per year

ROS - rain on snow coverage

SOILS - coverage of soil ground cover

STORM - coverage of precipitation during a storm

WAU - coverage of watershed units

Other coverages were provided, but not utilized in our analysis as extensively as above.

3.2.2 Creation of Layers

During this project, several coverages were created or modified to expedite and aid in our analysis. Modified coverages are discussed in section 3.2.3. This section discusses the coverages created, either to do analysis or as a product of it. All of the coverages that we created are listed and briefly described in the following table (Table 2).

Table 2: Coverages created during the analysis process, either to do further analysis or as a product of analysis done.

Coverage	Note
UW_TRANS	Road network for transportation plan. Includes planned and existing systems.
ROAD_COST	Coverage of construction costs for roads/see appendix
UW_RIDGEROADS	Coverage of all roads that are located on top of ridges
UW_RIDGE_25	Coverage of ridge roads that are less than 25% slope
SLPCLS_POLY	Polygon coverage of percent slope classes derived from the GRID module
SJ_BMTN_P	Coverage of Shaw Johnson for the burnt mountain planning area
UW_WSA	Coverages used to do stability analysis in the planning area
SKYC_REGEN	PLANS to ARC coverage with fan shaped profile yarder information used for regeneration setting boundaries.
SKYL_REGEN	PLANS to ARC coverage with landing information.
SKYP_REGEN	PLANS to ARC coverage with tower profile information.
SKYP_THIN	PLANS to ARC coverage with tower profile information.
UW_LANDING_SETTING	Coverage of UW landings and settings
REGEN_50FT_SET	Coverage of initial 50ft tower settings
REGEN_70FT_SET	Coverage of initial 70ft tower settings

THINNNING_ALT	Coverage with alternative thinning settings
LNGSPN70FT	Coverage of long span settings scenario
UW_FRIS	Cover of silvilcultural data made by UW
UW_SALES	Proposed and pending DNR sale information.
CLIPPER	Shape the size of the ortho photo to clip other objects to same size as ortho
HIMALAYA_GPS	GPS points of the Himalaya ridge road
MAPS	Different maps that can be plotted out by clicking instead of running amls
NWI	Coverage of wetlands inventory (USFW Service)
DNR_CONTOUR	Contour coverage made from the DNR dem
ROADENG	Map file
ROADENG_BOX	Coverage for box to set map extent
SHEET_800	Coverage of box to go around maps for printing purposes
SHEET_BOX	Coverage of box to go around maps for printing purposes
SLOPE_GRID	Coverage of %slopes in planning area broken up into three classes
TICCOV	UW Tic coverage to extent of whole planning area for map registration purposes.
WEST_BOUND	Coverage of only the west part of the planning area

3.2.3 Modification of Layers

It was necessary to modify some of the existing coverages so they could be easily utilized in analysis and map making. As part of the planning process coverages were modified to aid in analysis. A brief description, and what was done is listed in the following table (Table 3). Each item is discussed briefly with regard to its origin and its associated values.

Table 3: Table of coverages that have been modified.

Coverage	Modification	Item Name	Value	Note
DNR_CONTOUR	ADD ITEM	Flag_100	0 or 1	Identify contours divisible by 100.
SLPCLS_POLY	ADD ITEM	GRID-CODE	1 TO 4	Slope class the poly is in (e.g., 1 is 0-30%).
UW_TRANS	ADD ITEM	ROAD.ID	(e.g., Main Str)	Item containing UW ID of planned road.

UW_TRANS	ADD ITEM	GRADE	0 to 18	Percent grade of arc.
UW_TRANS	ADD ITEM	STATIONS	Integer	Length of arcs in stations.
UW_TRANS	ADD ITEM	UW_STATIS	Pegged, flagged, existing	Reconnaissance code
UW_TRANS	ADD ITEM	UW_FLAG	0 or 1	Identifies planned vs. existing roads.

Flag_100—Is an item added to the DNR contour coverage which, helped us to identify contours divisible by 100 (e.g., 100, 400, 500, etc.). A value of one was given to those arcs.

GRID-CODE—An item in the SLPCLS_POLY coverage, which identifies, which classes each polygon is in. Three values are associated with this item. A value of one is less than thirty- percent slope. A value of two identifies thirty to fifty-five percent slopes. A value of three specifies slope greater than fifty-five percent.

ROAD.ID—Is an item added to the UW_TRANS coverage that was used to input the names for the planned roads we did.

STATUS_UW—Is an item within the SALES coverage that helps define whether a sale is finalized or pending. Two values are associated with this item. The values of 'Proposed' and 'Sold' were used to distinguish between the two.

GRADE—This was an item added to UW_TRANS so we could input the percent grade of the road segments we designed. This attribute would then allow us to easily print out the designed percent grade onto the field maps.

STATIONS—This item was added to the UW_TRANS coverage and the value it was coded with was the length of each segment in stations. This value was calculated by dividing the LENGTH item by 100 and inputting it into an integer item.

UW_FLAG—This item helps distinguish proposed roads from existing roads in the transportation coverage. Two values were assigned to this item, zero and one. A value of zero indicates existing/reconstruction roads. A value of one indicates proposed or planned roads.

4 Slope Stability and Mass Wasting

4.1 Site Stability and Erosion Issues

4.1.1 Introduction

With the recent listing of certain salmonoid species under the Endangered Species Act, protection of aquatic resources has assumed a higher profile than in the past. In addition, the expense and disruption of road failures due to mass wasting or erosion has become a major management issue.

In design of a harvest and transportation plan that reduces or eliminates these hazards, an analysis was done to locate and classify these types of hazards so that designed structures can avoid, or minimize, exposure to these hazards and their contribution to sedimentation.

The approach taken was to assess these hazards using a number of the most common procedures and using readily available information, such as ground slope. The three methods used were Surface Erosion Potential, Mass Wasting Hazard (Shaw-Johnson), and the Infinite Hillslope Equation.

Products produced from this analysis are maps detailing the hazards by geographic location, and an assessment of their applicability or usefulness.

4.1.2 Methods

Surface Erosion Potential

The surface erosion potential method used is detailed in the Washington Forest Practice Board Watershed Analysis Procedures (WAC 222.22). This method is based on identifying the ability of erosive forces (rainfall, overland flow, etc) to mobilize soil particles, and also identifying slope classes in percent.

Using the DNR Soils GIS coverage, a layer was created using the soil_name to identify the geographic extent of each soil series within the planning area. With this information, descriptions of each soil series were collected from the USDA-NRCS Official Soil Series Descriptions (http://www.statlab.iastate.edu/soils/osd/). These soil series descriptions, while not providing any direct input for this method, provided information about soil composition and behavior.

After identifying the soil series present in the planning area, the State of Washington Soils Engineering Manual was used to determine k- values for each soil series. Soil k- values are a laboratory measure of the "erodability" of soil type based on soil properties, classifying soils by how easily particles are detached from the surface. These k- values were then combined with the soil_name layer by soil series and the layer was converted to an Arc/Grid coverage with a 30' by 30' cell size.

The other piece of information required is a slope layer. This was derived from a 1:400 contour coverage provided by the DNR. We used this coverage to create a digital elevation model using Arc/Info. The DEM created was modified using Arc/Grid to express slope as a percent on a cell by cell basis, with a cell size of 30' by 30'.

Using Arc/Grid the slope percent layer and the soil k- value were combined using the following erodability ratings in Table 4 to classify each cell.

Table 4 Erodability Ratings Based on K- Values and Slope

Slope Class (percent)	K < 0.25 (not easily detached)	0.25 < K < 0.40 (moderately detachable)	K > 0.40 (easily detachable)
< 30	Low	Low	Moderate
30 – 60	Low	High	High
> 65	Moderate	High	High

Shaw-Johnson Mass Wasting Potential

The Shaw-Johnson method uses slope percent classes along with slope form to identify high, medium, and low susceptibility to mass wasting. The method was developed in the Olympic region and uses regression analysis to identify the correlation between variables implicated in mass wasting events.

The method is based on the idea that steep, convergent landforms are most likely to be initiation points for mass wasting events, with less steep areas being somewhat less likely to initiate mass wasting. The classification scheme is presented in Table 5.

Table 5 Shaw-Johnson Mass Wasting Hazard Classification

Shaw-Johnson Mass Wasting Hazards					
Curvature	*Slope Percent*				
	0-15	**15-25**	**25-47**	**47-70**	**70+**
CONVEX	Green	Green	Green	Green	Yellow
PLANER	Green	Green	Green	Yellow	Red
CONCAVE	Green	Yellow	Red	Red	Red

The slope percent layer developed previously was also used in this analysis. The slope form layer was developed using Arc/Grid and the DEM for the area. Using the DEM, the curvature function was applied to create a planform curvature layer that can be used to identify which landform exists on a cell by cell basis. Using the matrix above, hazard ratings can be assigned to output maps using color-coding.

The Infinite Hillslope Equation

This method uses a free-body force analysis approach, with the forces acting on an individual soil unit being analyzed. It determines a "factor of safety" for the soil mantel, providing information about resistance to failure due to changes in forces within the soil mantel.

Figure 4 presents a schematic drawing of the forces being considered.

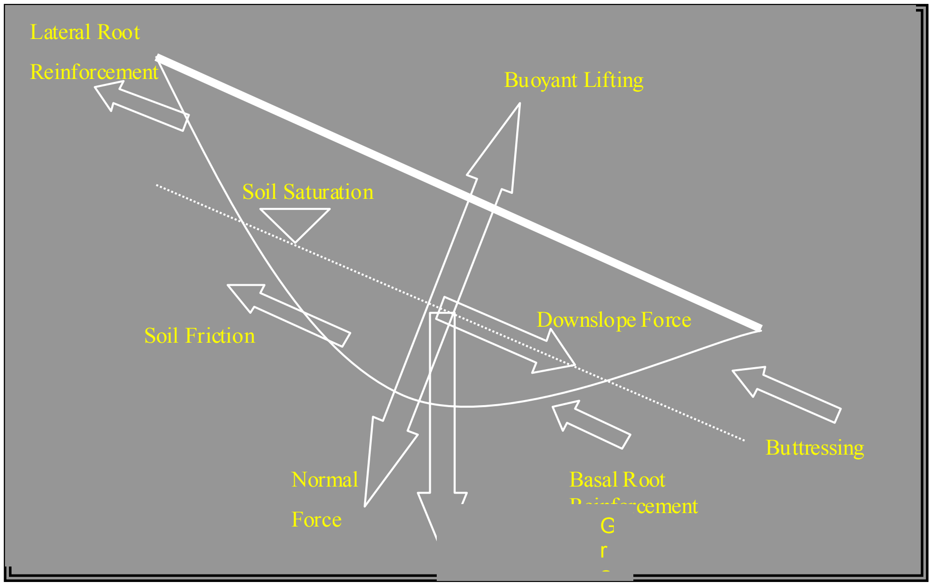


Figure 4 Infinite Hillslope Equation free-body diagram

These forces most commonly change with fluctuations in soil saturation levels, but can also change from vegetation modifications, such as fire or timber removal.

Using the equation found in appendix 12.1, a coverage was developed expressing the factor of safety over the planning area. The factor of safety has been characterized as very stable, moderately stable, and very unstable to reflect an F.S. > 2, 2 > F.S. > 1, and F.S. < 1 respectively. These numbers represent a ratio of soil strength relative to the predicted failure strength on a cell by cell basis, using Arc/Grid for the analysis.

A number of runs were made using the method with varying groundwater saturation levels, since this term has the greatest effect on stability. The OESF also lies in an area where extended winter storms with heavy precipitation accumulations occur, making this assessment the most relevant for this area.

4.2 Results

The results from each analysis are GIS layers depicting the spatial extent of erosion, mass wasting, and stability factors over the planning area. Two of the methods, the Erosion Potential and the Shaw-Johnson, return only qualitative results from the analysis. The third method, the Infinite Hillslope Equation, produces results that are quantitative in nature.

Shown below in Figure 5 is the GIS layer created from the surface erosion potential analysis. Figure 5 identifies areas where slope and soil erosion potential, as expressed by k- values, combine to create areas of differing suceptability to erosion. When combined with a topographic contour map, it can be seen how medium and high risk areas correlate with stream locations and the locations of steeper slopes. The usefulness of this information is in avoiding road placement and harvest activities in these areas when designing operational plans. This shows how major hazards can be avoided by staying on, or near, ridges.

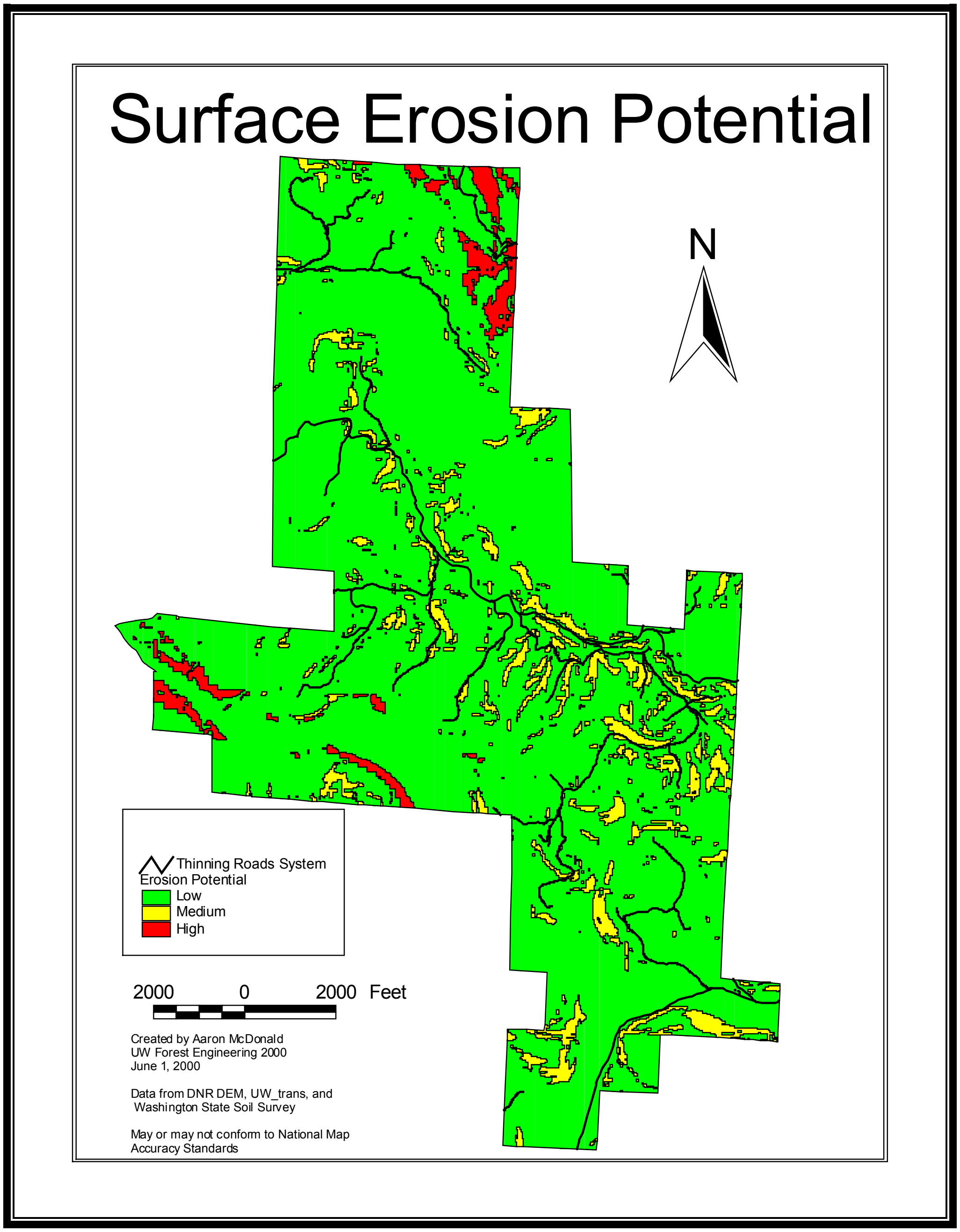


Figure 5 Surface Erosion Potential in the Burnt Mountain Planning Area

Figure 6 shows the results of the Shaw-Johnson Mass Wasting Hazards analysis.

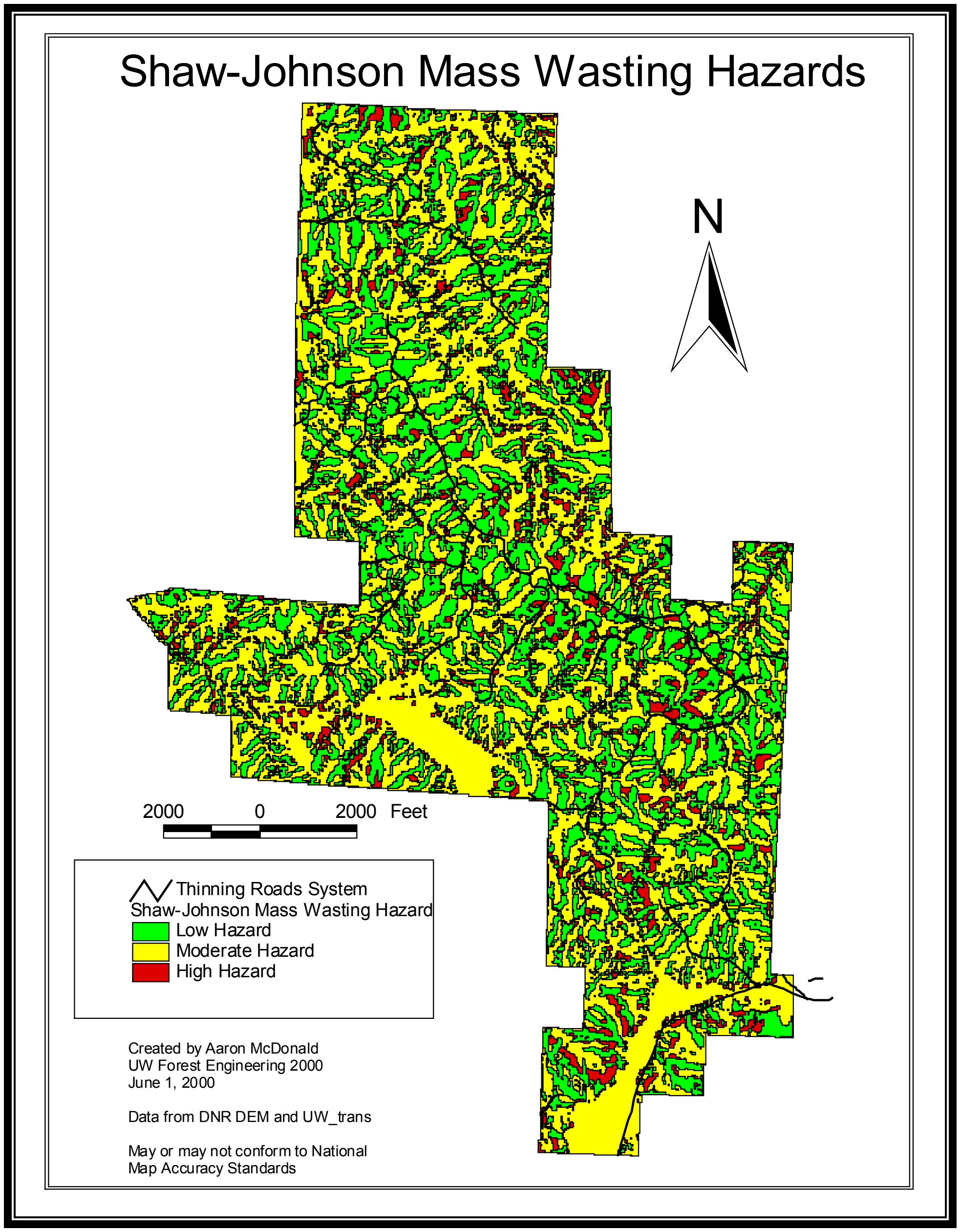


Figure 6 Shaw-Johnson Mass Wasting Hazards in the Burnt Mountain Planning Area

Information contained in this map was also used in road location and setting design. It provides information about potential for landsliding, based on slope form and steepness. It can be used to identify areas where further investigation of soil properties and underlying geology may need investigation before building roads or landings. This layer identifies potential for mass wasting events to occur, not certainty.

The final map, Figure 7 shows the results of the Infinite Hillslope Equation with the soil saturation level set at 50% of the soil depth.

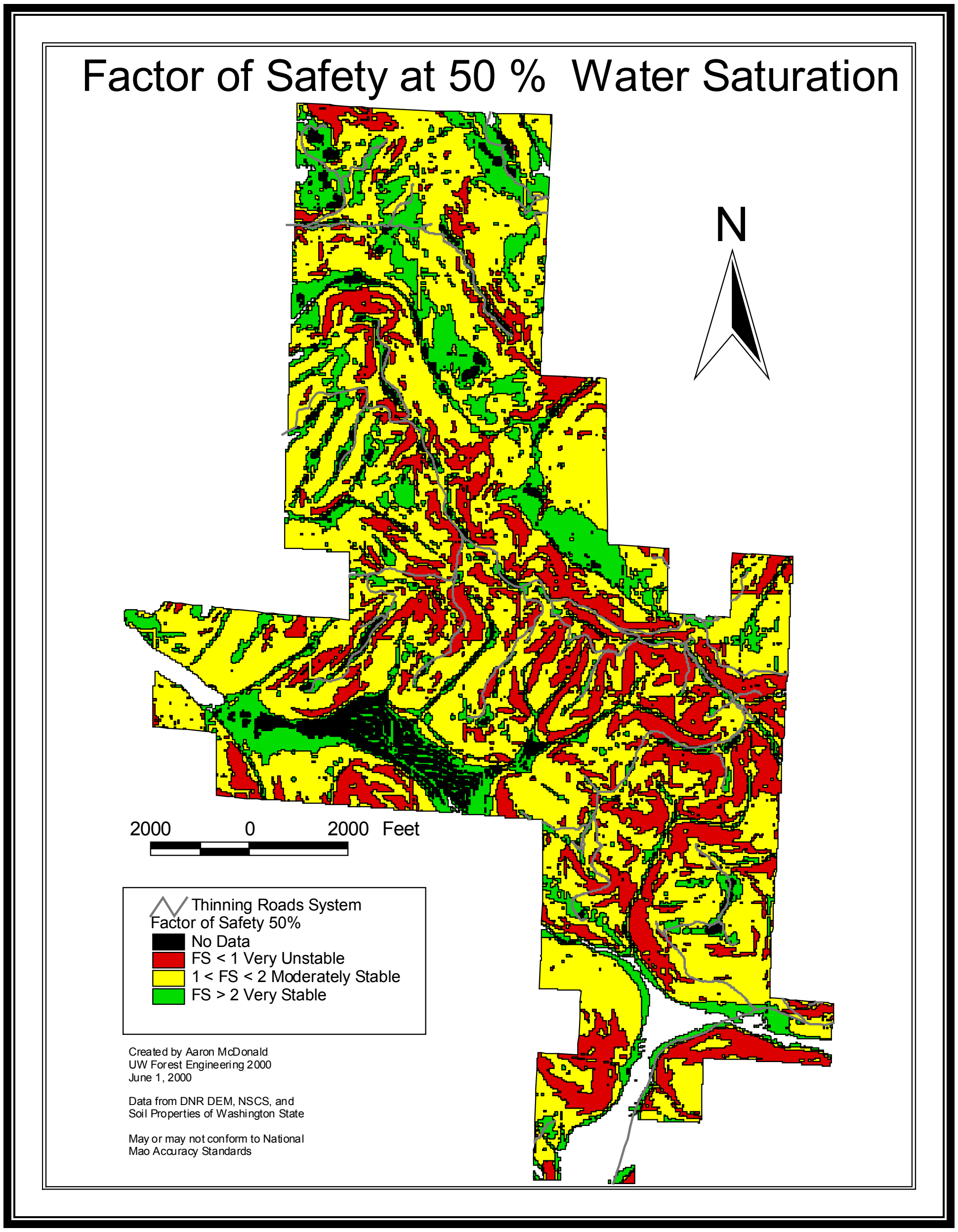


Figure 7 Factor of Safety with 50% Saturation Level in the Burnt Mountain Planning Area

The figure above indicates areas where soil strength could potentially be compromised during prolonged precipitation delivery (the planning area is below the rain-on-snow zone, so run-off should not be a factor).

The implications are that climatic conditions over time should be investigated as part of planning efforts to identify potential for run-off to contribute to stability problems.

4.3 Discussion

All the methods applied attempt to determine stability in a particular area for use in planning decisions. The differences between methods are in the type of information they use, and the type of stability assessment they imply. The usefulness of each method becomes important during the planning phase, particularly with regards to road location and silvicultural systems.

The main criticism of both the Erosion Potential and Shaw-Johnson methods is that they provide only qualitative information that is difficult to apply to a small area. The ratings "low", "medium", and "high" give only the relative potential within each methods rating scheme, and do not imply direct correlation with other methods.

The Infinite Hillslope Equation provides a more quantitative approach, producing a number that can be interpreted in relation to measurable factors such as soil shear strength or root strength. This results in wider acceptance of this method as a reliable indicator of stability. A number of runs were made with this method using different saturation levels to judge the effects on load carrying capacity and determine the extent of category. Designs using the "worst case scenario" of total saturation still show road and landing locations to be well placed.

To use any of these layers as a planning instrument, the accuracy and reliability of the output must be assessed to develop confidence in the planning decisions made using this information.

A natural process for assessing the accuracy of these methods is to examine their predictive capability in the field. During the fieldwork portion of the project, field maps were developed that contained this information. While not every high hazard area that was identified in the planning phase was found during field inspection, when a high hazard area was found in the field, it also appeared on the maps in the same location. This provides support for using these methods as a planning tool in determining such things as road locations in the office-planning phase.

Another method used to assess the accuracy of these methods was to compare the erosion predictions made with the UW erosion potential method, and the erodability ratings given in the DNR Soils GIS layer. Images were made of layers generated with each method and then compared. While the same general areas of low, medium, and high hazard were identified on each image, the detail found on the UW generated layers was much higher. It was felt that the general correlation between the two provided another way to support the applicability of these methods. Figure 8 below presents this comparison.

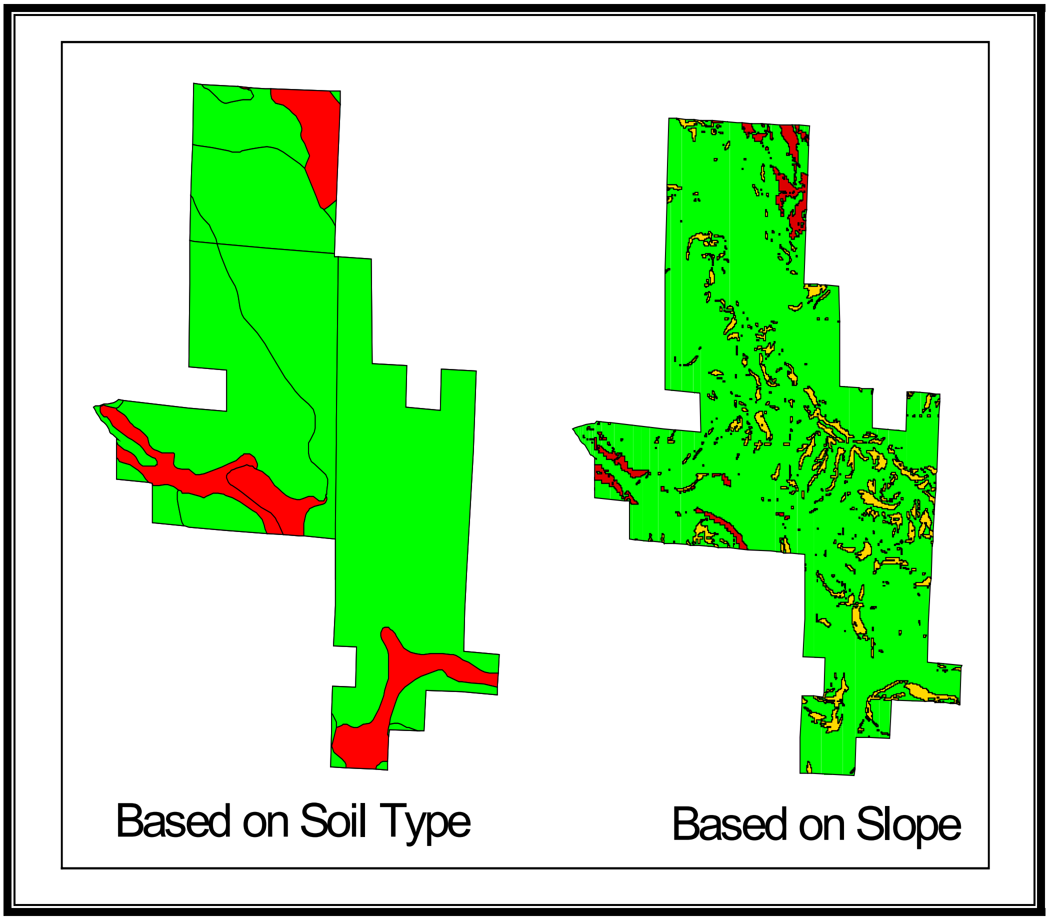


Figure 8 A Comparison of Soil Erosion Potential between DNR's Soils Layer Hazard Rating Index, and the UW Derived Soil Erosion Hazard layer.

The image on the left was created using the DNR Soils GIS coverage and extracting the Erosion Potential field for display. The image on the right shows the layer created using both slope and k- values.

To determine the applicability of the method, we examined the relationships between the two images and how the information was derived. The DNR layer was developed based on soil types with broad soil type areas associated with particular hazard classes. The UW derived layer identifies the same geographic areas as having medium or high values, but the detail is much more refined as a result of the combination of k-values and slope classes. The general correlation of geographic areas between the two seems to support the method used.

It is recognized that prediction of erosion and mass wasting hazard is still underdeveloped. However, limited use of the types of information presented here seems useful if the limitations are understood. Utilization of multiple assessments along with field checks does offer some usefulness in the office-planning phase to identify potentially unstable areas. In this planning effort, it supported locating roads as close to ridges as possible to avoid suspected hazard areas. New techniques are being developed at the UW and elsewhere that may provide more useful and reliable information in the future.

5 Silviculture

5.1 Goals & Objectives

The goals in performing a silvicultural analysis were to create habitat and improve stand conditions using both ecological and economical methods, to determine the value of the planning area and to identify the suitability of thinning on a stand by stand basis. Another goal for the silvicultural analysis was to establish that the stands will respond to the thinning and to identify the removal rates under various thinning strategies.

The objectives for the silvicultural analysis are to describe and outline what will be done, develop specific design parameters to aid in the design of appropriate settings, and to determine turn weights and removal rates for each stand.

This section will define the thinning criteria for both single and variable density thinning, the criteria for regeneration harvest and the leave tree criteria.

5.1.1 Thinning Criteria

All thinning criteria used and the silvicultural analysis are based on the DNR Forestry Handbook (PR 14-005-030). An eligible stand for a commercial thinning must have enough timber available that the thinning harvest produces a positive income. The thinning must be able to produce the effect of allowing the leave trees a higher rate of growth resulting in a larger stand value at the time of final harvest. It should also improve the structural diversity and wildlife habitat in the stand.

Most commercial thinnings are performed on undifferentiated stands between 25 and 45 years old that are expected to grow at least 20 years before a regeneration harvest takes place. The stands must also have initial relative densities greater than or equal to 55 for Douglas Fir (*Pseudotsuga menziesii*), 60 for Western Hemlock (*Tsuga heterophylla)* or 65 for true firs (*spp Abies*). All stands are thinned from below. Relative Density is defined in the DNR Forestry Handbook as the total basal area divided by the square root of the quadratic mean diameter (ba/sqrt(qmd)).

Single Density Thinning

Single density thinning criteria are found in the DNR Forestry Handbook (PR 14-006-070). For a single density thinning, the criteria are based on relative density and the change in relative density. All stands will be thinned from below with the change in relative density less than or equal to 40% and the residual stand relative densities as follows:

35-45 Douglas Fir

45-55 Western Hemlock

40-50 True Firs

Variable Density Thinning

Variable density thinning criteria are found in the DNR Forestry Handbook (PR 14-006-070). The criteria for variable density thinning are also based on relative density. Variable density thinning should be conducted on a ½ to 1-acre scale using approximately rectangular plots where, for every 10 acres harvested, the relative densities of the leave trees should average:

3 acres thinned to relative densities between 23 and 33

5 acres thinned to relative densities between 34 and 45

1 acre unthinned

1 acre of open canopy

The unthinned area can be divided into two, ½ acre, plots to protect existing snags. If possible, the openings should be restricted to using natural openings and/or skid trails. However, if no natural openings or skid trails exist, small openings can be created that are no larger than ¼ acre and no wider than 200 feet with the longest side oriented in a north-south direction, with the exception of areas with wind issues, to take advantage of incident light.

All coarse and fine woody material should be left as cull on the ground by leaving branches and limbs where they fall and by cutting all tops less than 5 inches in diameter. For stands with a quadratic mean diameter of greater than 15 inches three snags or cavity trees should be retained per acre.

5.1.2 Regeneration Harvest

Stands eligible for regeneration harvest are coniferous stands with a primary age greater than 50 years or hardwood stands with a primary age over 40 years. Target stands are not likely to respond desirably to thinning and have height to diameter ratio greater than 90, a live crown ratio of less than 25 on dominant and co-dominant and a minimum relative density of 60 for Douglas Fir, 70 for Western Hemlock and mixed stands.

5.1.3 Leave Tree Criteria

Trees selected for their growth potential should have a post thinning height/diameter ratio less than: 85 for shade intolerant species, such as Douglas Fir, or 95 for shade intolerant species, such as Western Hemlock, and true firs. Live crown ratios on the residual trees should be at least 30%.

Other leave trees that should be considered are all habitat trees, snags and future snags.

5.2 Growth Model

The stand data that was used for our silvicultural analysis is based on the original Forest Resource Inventory Summary (FRIS) data. Due to these FRIS plots being of varying sizes, fixed or variable radius plots, all FRIS data had to be expanded out to trees per acre (TPA) before being entered into the Forest Vegetation Simulator (FVS) format.

In doing this, we were able to maintain the integrity of individual tree data because, instead of averaging the tree list data as it was entered into FVS, the stands were grown out using the original tree data. Every tree was grown out, therefore, individual tree data is available throughout the growth modeling process, from the FRIS data to the year 2040.

To grow the stands forward to the year 2040, we used the FVS program, Suppose, with the Pacific Northwest Coast variant of the FVS growth model. In order for the stands to be grown out in FVS we had to make sure the growth model grew the stands as close to actual conditions as possible. The most important step in achieving this is to use the "No Auto ES" FVS keyword. This keyword suppresses all natural regeneration and ingrowth features (for more information see Appendix 12.2).

5.3 Current Conditions

This section will discuss the current stand types, including stand age and primary species, and the current merchantable volume per stand.

5.3.1 Stand Types

There are 61 stands in the planning area with a range of timber ages and sizes (Figure 9). All stands in the planning area have a primary age of between 30 and 100 years old with the distribution as follows:

Green	60-100 yrs	5% of total acreage
Yellow	40-60 yrs	80% of total acreage
Red	30-40 yrs	15% of total acreage

The primary species in the area are Douglas fir and Western Hemlock as well as a few stands, in the south end of the planning area, with Red Alder (*Alnus rubra*) as the primary species. Other species present in the area include; Western Red Cedar (*Thuja plicata*) and Sitka Spruce.

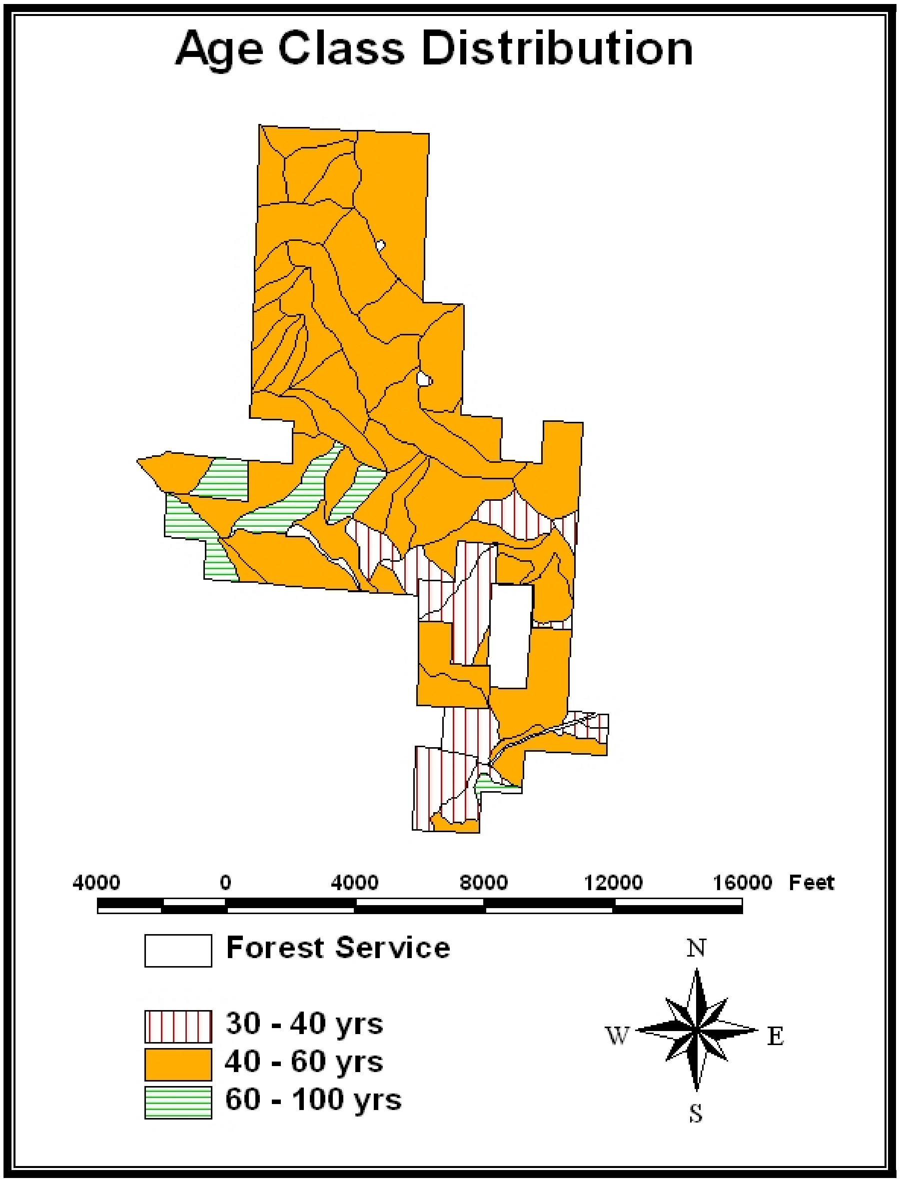


Figure 9 Age Class Distribution. Most stands are between 40-60 years of age.

5.3.2 Timber Volume

To calculate the current standing volumes in the existing stands, the Scribner volume equation was used on all trees with DBH greater than or equal to 5" from a 1-ft stump to a 4" small end diameter.

Current standing volumes range from 6-61 mbf per acre. The majority of the stands, Figure 10, range from 30-40 mbf per acre. These stands equal 55% of the total acreage in the planning area and can be considered for either thinning operations or regeneration harvest.

Stands with standing volume greater than 40 mbf per acre, Figure 10, equal 12% of the total acreage. These stands can be considered mature timber and are candidates for regeneration harvest.

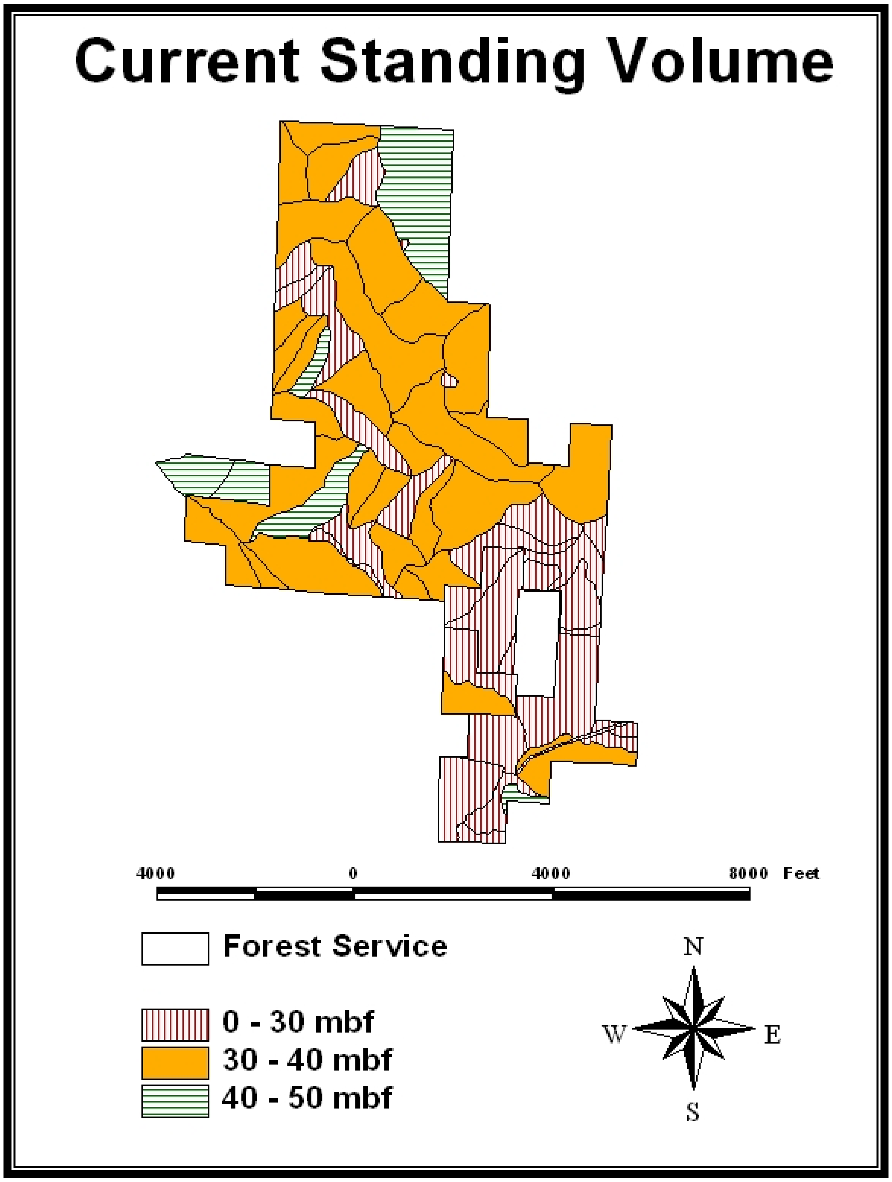


Figure 10 Current Standing Volume: Stands with standing volume less than 30 may be considered for thinning. Stands with standing volume between 30-40 may be considered for either thinning or regeneration harvest. Stands with standing volume greater than 40 may be considered for regeneration harvest.

The stands with timber volume less than 30 mbf per acre, Figure 10, currently equal 33% of the total acreage. The southern section of the planning area contains a higher concentration of stands with low standing volume (between 5-30 mbf per acre). These stands can only be considered for thinning operations.

Some stands, however, will not be available for harvest at this time due to the small size of standing timber in the area. An example of this is shown below in Figure 11.

Figure 11 Example of small timber that is not ready for thinning yet in the south end of planning area. A thinning in this area would not be cost effective.

5.4 Current Management Opportunities

This section will first discuss the available harvest volumes for single and variable density thinnings, which is an important design parameter for setting design. Then a comparison of the possible residual stands for each of the different thinning options will be discussed. Finally, there will be a discussion of the turn weight analysis, which includes analyses for single and variable density thinning turn weights for both bucked log yarding and whole tree yarding.

5.4.1 Available Harvest Volumes

Because of the wide range of thinning prescriptions and timber sizes, there is a wide range of removable timber volumes in the Burnt Mountain planning area.

Thinning operations with the potential to produce less than 5 mbf per acre of harvestable timber, according to the thinning procedures in the DNR Forestry Handbook, were considered unfeasible harvests due to high yarding0 cost.

All mature stands, Figure 12 & Figure 13, which equal 12% of the total acreage, are mature stands being considered for regeneration harvest only. There was no thinning analysis performed for these stands.

Single Density Thinning

The results of the analysis, based on the thinning procedures in the DNR Forestry Handbook, show that single density thinning is a largely unfeasible option for this planning area. These results show that 78% of the total acreage in the planning area is unthinnable due to a harvestable volume of less than 5 mbf per acre, Figure 12. This leaves only 10% of the acreage with harvestable timber volumes greater than 5 mbf per acre.

Using a weighted average, by area, of all stands being analyzed for single density thinning, the average harvested volume is 2.3 mbf per acre. This average was calculated with a maximum harvested volume of 7.2 mbf per acre and a minimum of 0 mbf per acre for the stands that do not yet meet the single density thinning requirements. There are currently 19 stands, which cover 22% of the total acreage mostly in the south end of the planning area, that do not meet the single density thinning requirements. Using an average of all stands in the planning area, the average bucked log size is 18 bf.

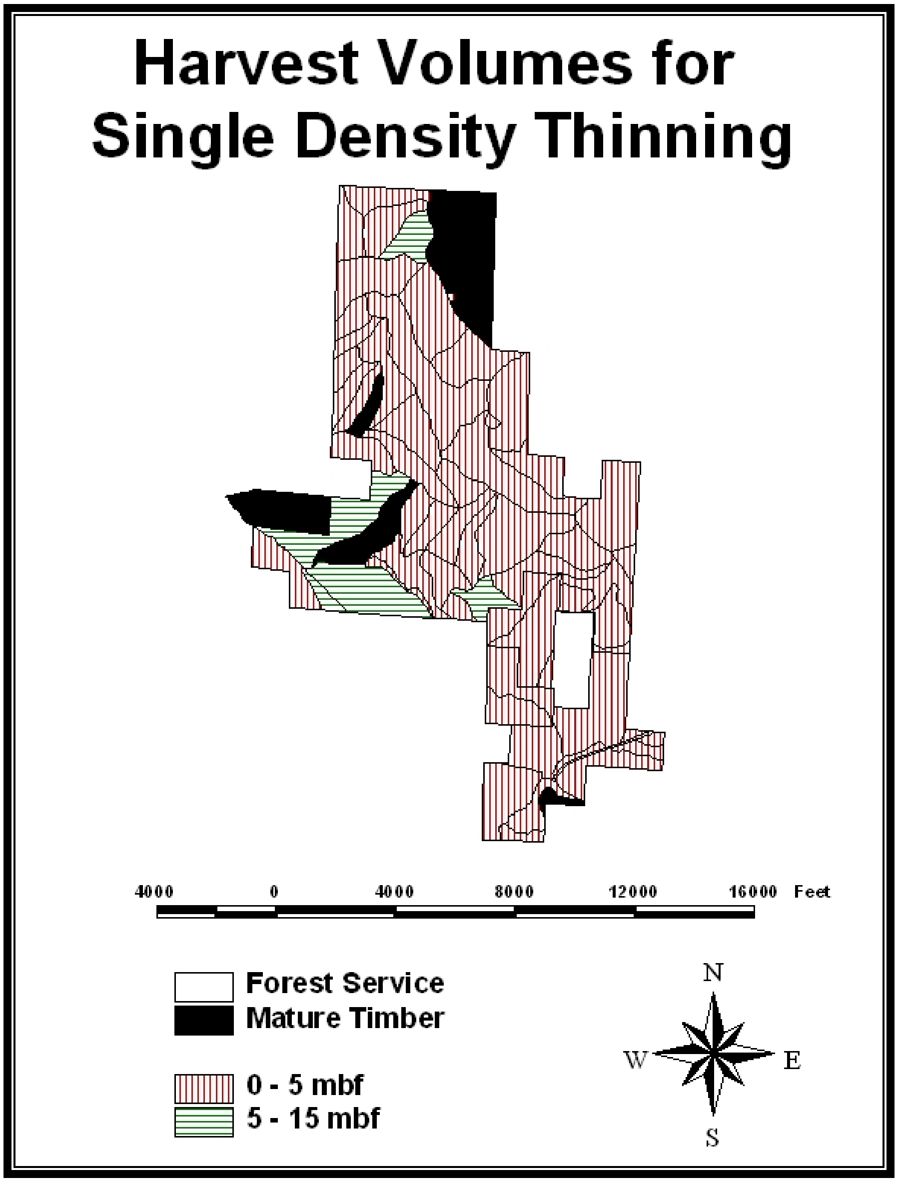


Figure 12 Harvestable volume for single density thinning using DNR Forestry Handbook. The majority of the stands, shown in red, do not have enough removable timber to make a harvest economically feasible. Mature timber was not considered for thinning operations.

Variable Density Thinning

When the criteria from the DNR Forestry Handbook was used, variable density thinning is currently a better option than single density thinning, Figure 13. The area that is more likely to be feasible for thinning has grown to 56% of the total acreage when variable density thinning is used. There are still large areas where thinning is an unfeasible option but these areas are down to 32% of the total acreage. The majority of these stands are contained within the southern end of the planning area.

Stands with cut volumes of 5-15 mbf/acre, over 56% of the area, using variable density thinning should respond well to a thinning operation.

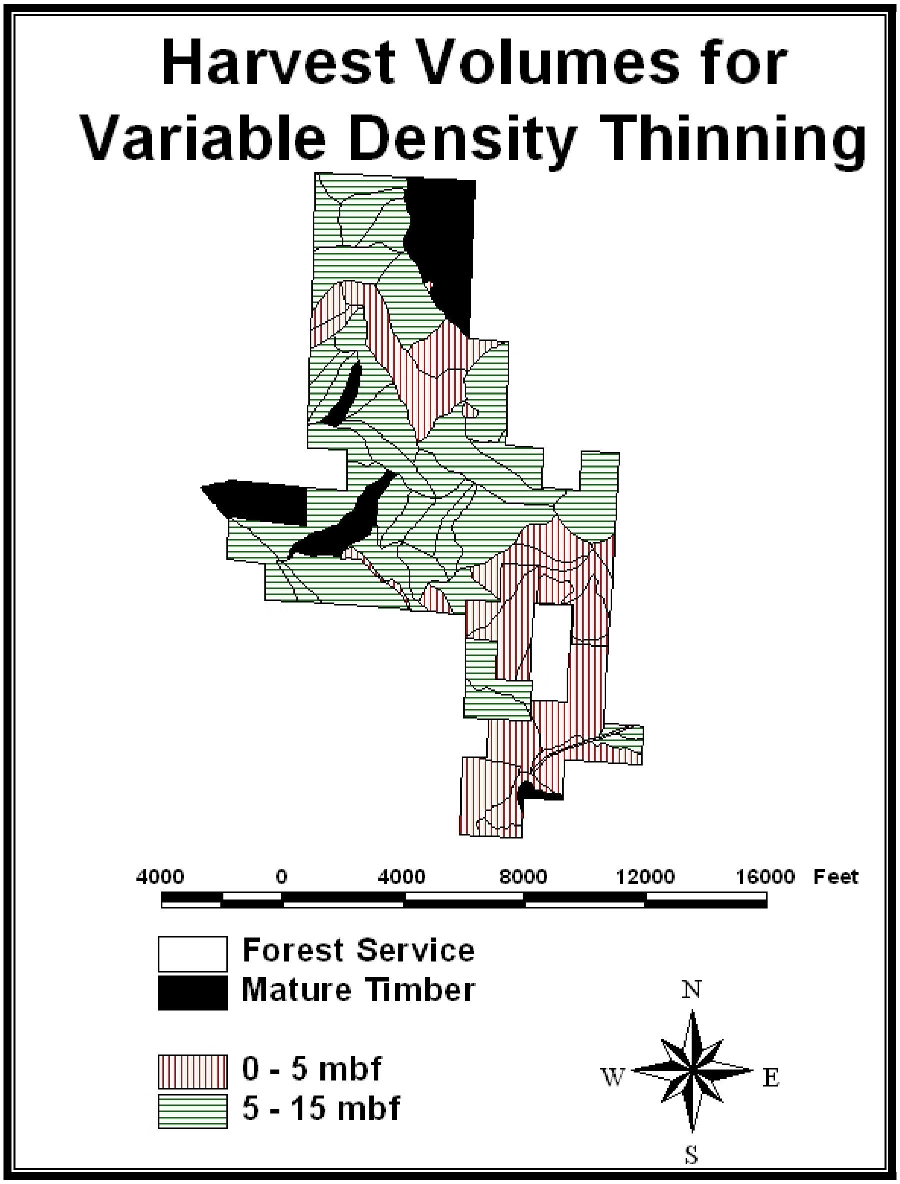


Figure 13 Harvestable volume for variable density thinning using DNR Forestry Handbook. This type of thinning allows for a larger number of stands to be available for economically feasible harvest operations. Mature timber was not considered for thinning operations.

Using a weighted average, by area, of all stands being analyzed for variable density thinning, the average harvested volume is 5.7 mbf per acre. This average was calculated with a maximum harvested volume of 14.8 mbf per acre and a minimum of 0 mbf per acre for the stands that do not yet meet the variable density thinning requirements. There are currently 12 stands, which cover 14% of the total acreage in the south end of the planning area, that do not meet the variable density thinning requirements. Using an average of all stands in the planning area, the average log size is 26.8 bf.

There is currently a popular thinning practice within the Department of Natural Resources of thinning stands to 140 trees per acre with a 10in DBH cut off. An analysis of this method was performed, but the results showed that variable density thinning is still a better option because, over all, more volume is removed from the stand. There are some cases, with variable density thinning, where the post-thinning stand is down to 80 trees per acre in the areas of heaviest thinning.

5.4.2 Thinning Comparison

In this section, a comparison is made of the three different types of thinning operations used in the thinning analysis, single density thinning, variable density thinning and 140 TPA. This comparison is based on the potential attributes of the residual stands after thinning.

When looking at the residual stand after a thinning, it becomes fairly obvious that the resultant stands are largely varied with the different types of thinnings. There are three major stand attributes that can be used as comparisons: relative density (RD), quadratic mean diameter (QMD) and TPA (Figure 14).

To make comparisons of the three types of thinnings, averages of RD, QMD and TPA were used. These averages include all stands, including stands that cannot be thinned at this time due to small timber.

Single density thinning, on average, leave the largest residual stand with an average relative density of 59, average QMD of 16.5" and average TPA of 172. It opens up only a minimal amount of growing space for the residual stand to expand into.

Variable density thinning, however, leaves the smallest residual stand, which opens up the most growing space for the leave trees, with an average relative density of 47, average QMD of 18.6 and average TPA of 122. Due to the low TPA for variable density thinning, the option of whole tree logging is a feasible option because the residual trees are spaced farther apart, close to shelterwood harvest conditions, and the probability of residual tree damage is very low.

The average results of the third thinning option, thinning to 140 TPA with a cut of DBH of 10", fall in between the results for single and variable density thinning. This type of thinning results in an average relative density of 53, average QMD of 17.3 and average TPA of 134. This thinning option may be a desirable option for stands where a single density thinning is desired, but stand conditions do not allow for single density thinning.

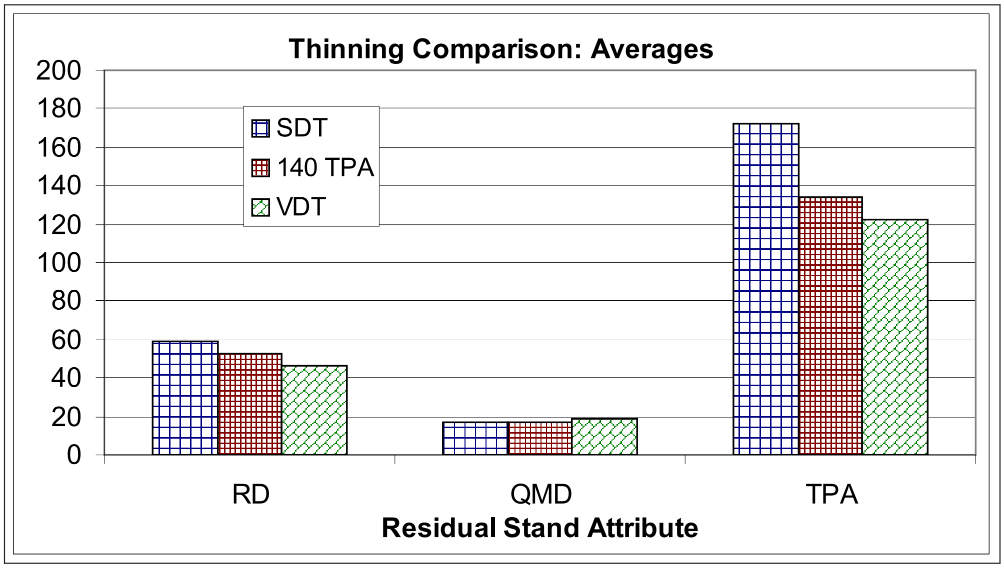


Figure 14 Comparison of 3 types of thinning operations using averages, of all stands, of RD, QMD and TPA. (SDT= single density thinning, VDT=variable density thinning, TPA=trees per acre)

There is a large range of values between stands in the data both within a certain type of thinning operation and between the different thinning operations (Table 6). However, variable density thinning averages consistently result in lower TPA and RD and higher QMD. This results in larger spacings between the residual trees, leaving the largest timber that is most likely to respond well to the thinning. This leaves the greatest amount of growing space for the residual stand, which will then be able to grow at a faster growth rate resulting in an increase in the value of the stand by the time the stand is ready for a regeneration harvest.

Single density thinning averages (Table 6), on the other hand, consistently result in higher TPA and RD and lower QMD. This results in smaller spacing between the residual trees, which means there is less growing space released by the thinning operation. This results in the trees not growing as fast as they could after a variable density thin which, in turn, means that the value of the stand will also not increase as much by the time the stand is ready for a regeneration harvest.

The 140 TPA thinning averages (Table 6) consistently reflect results that fall between the single and variable density thinning results. This type of thinning can be considered, therefore, when single density thinning results in low harvestable volumes in the hopes of increasing the harvestable volume enough to result in an economically feasible thinning operation.

Table 6 Residual Stand Statistics for All Thinning Options (min, max, mean of RD, QMD and TPA). The minimum and maximum values for each of the stand attributes shows the total range possible depending on the timber type within a stand. The mean value shows the average value for each attribute weighted by area.

	min RD	max RD	mean RD	min QMD	max QMD	mean QMD	min TPA	max TPA	mean TPA
SDT	35.27	110.95	57.39	10.4	22.75	16.35	91	486	164
VDT	18.08	106.69	44.94	10.77	25.98	18.43	25	442	115
140 TPA	33.61	66.08	50.93	12.75	21.46	16.7	117	136	130

Due to the sensitivity of costing to the yarding efficiency with respect to the residual TPA, whole tree yarding should only be considered for stands with a residual stand of less than or equal to 100 TPA (Figure 15). When a residual stand is within these parameters, there is a lower probability of residual tree damage while yarding whole trees. This is only possible, for the most part, using variable density thinning. The stands in which it would be possible to do whole tree yarding for variable density thinning comprise 41.5% of the total acreage of the planning area. The statistics for whole tree yarding turn weights are shown, in the Turn Weight section, in Figure 17 and Table 7.

Variable density thinning provides opportunities for tree-length or log-length harvesting. Usually long-log yarding in thinning is not a desirable option because of:

-increased residual tree damage

-increased delays in yarding.

However, variable density thinnng allows for larger residual tree spacing, and therefore provides for long-log or tree-length yarding opportunities. Yarding efficiencies are directly linked to turn weights. We assume that areas or stands with a residual tree count of <100 TPA allows for efficient tree-length yarding.

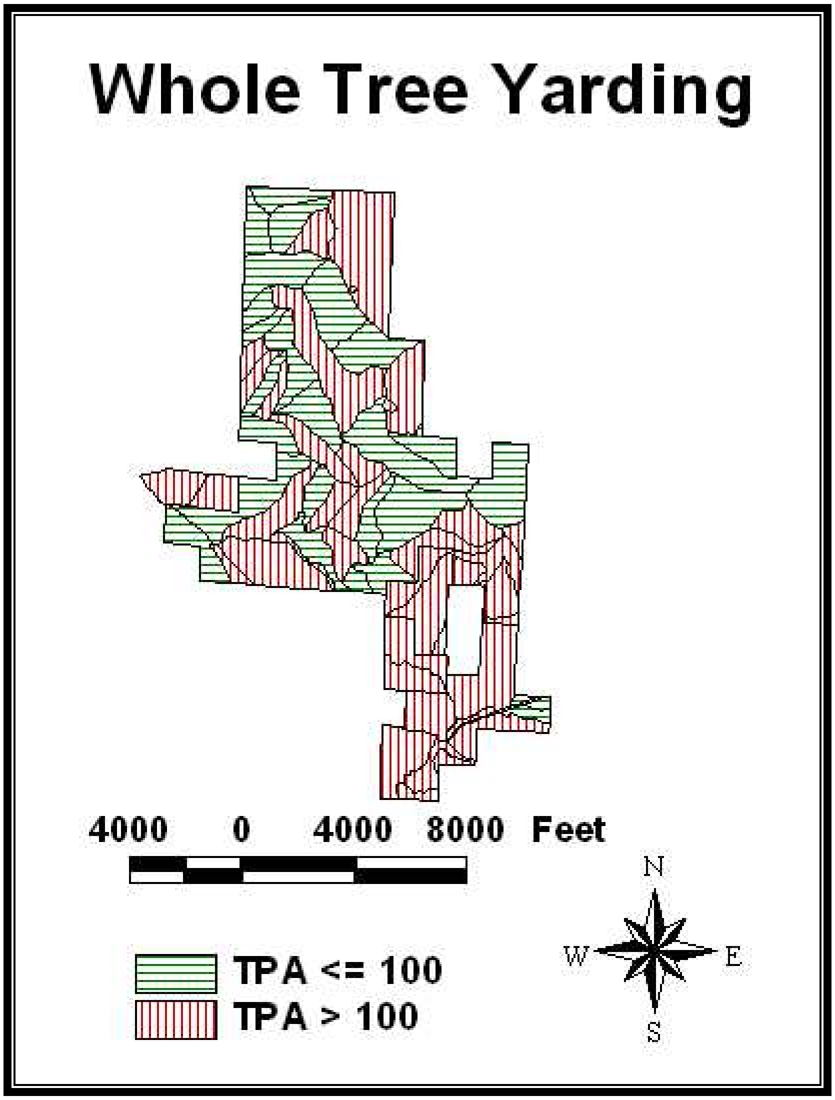


Figure 15 Whole Tree Yarding Possibilities. Stands with residual TPA <= 100 after a Variable Density Thin are shown in green.

5.4.3 Turn Weights

Turn weights were calculated using the average log size (32 ft log), an average density of 10.9 lbs/bf, calculated from field data, and 3.5 logs per turn. The density is an average calculated from the densities of sample cores, taken in the planning area. The densities of the sample cores were measured using a densiometer.

Mature timber stands were not further analyzed for turn weights. Turn weight analyses were performed for all stands except the mature stands. From these analyses stands in red have average turn weights are less than 1000 lbs, stands in yellow have average turn weights of 1000-2000 lbs and stands in green have average turn weights of greater than 2000 lbs (Figure 16 & Figure 17).

Single Density Thinning

The average turn weights for single density thinning are, for the most part, less than 1000 lbs as shown below in Figure 16. Low turn weights are a problem with single density thinning, making up 59% of the total acreage in the planning area, especially in the southern end of the planning area.

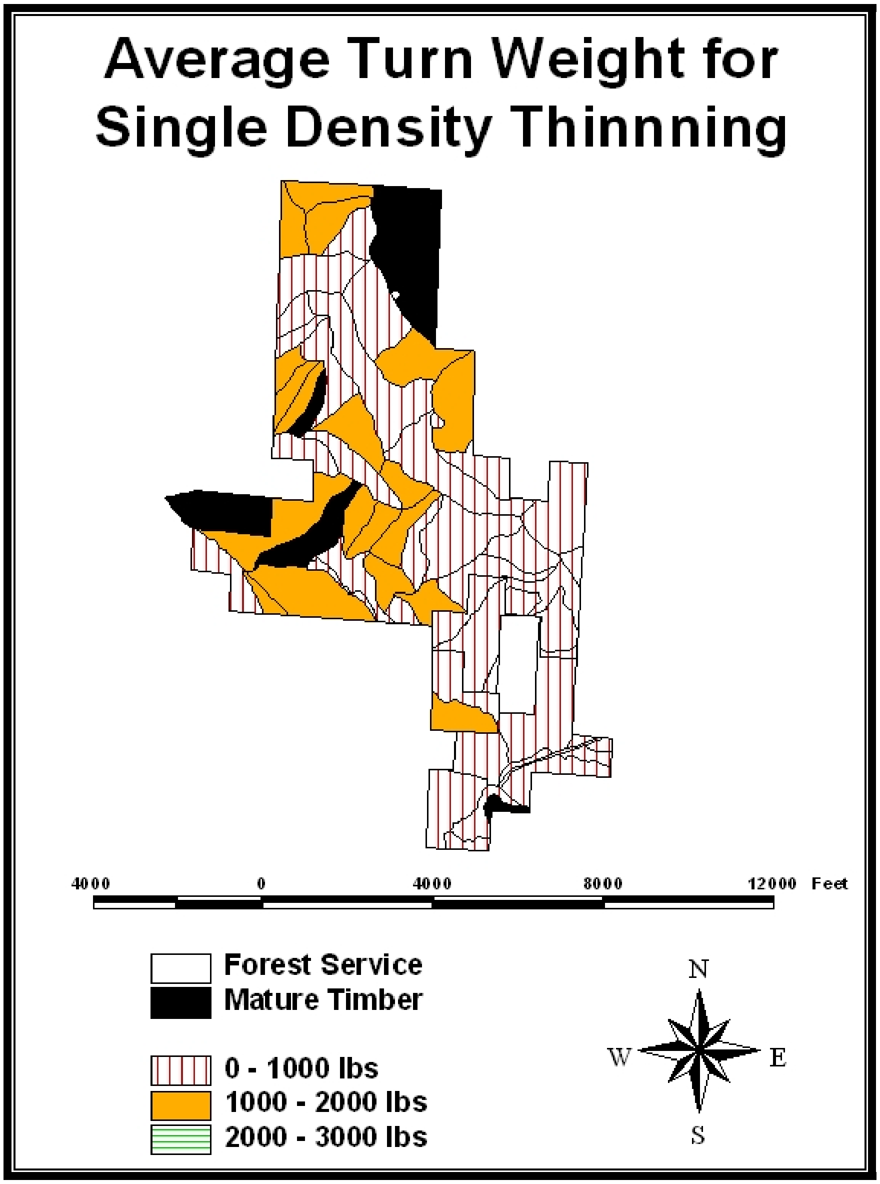


Figure 16 Average Turn Weight for Single Density Thinning. Most stands have average turn weights of less than 1000lbs.

Using a weighted average, by area, the average turn size for single density thinning is 743 lbs, the maximum turn size is 1592 lbs and the minimum turn size is 0 lbs.

Variable Density Thinning

Most stands, using variable density thinning, have average turn weights of 1000-2000 lbs and make up 69% of the total acreage in the planning area. The number of stands with average turn weights of less than 1000 lbs has dropped, compared to single density thinning, but nearly all of the stands in the southern end of the planning area still have a problem with low turn weights (Figure 17).

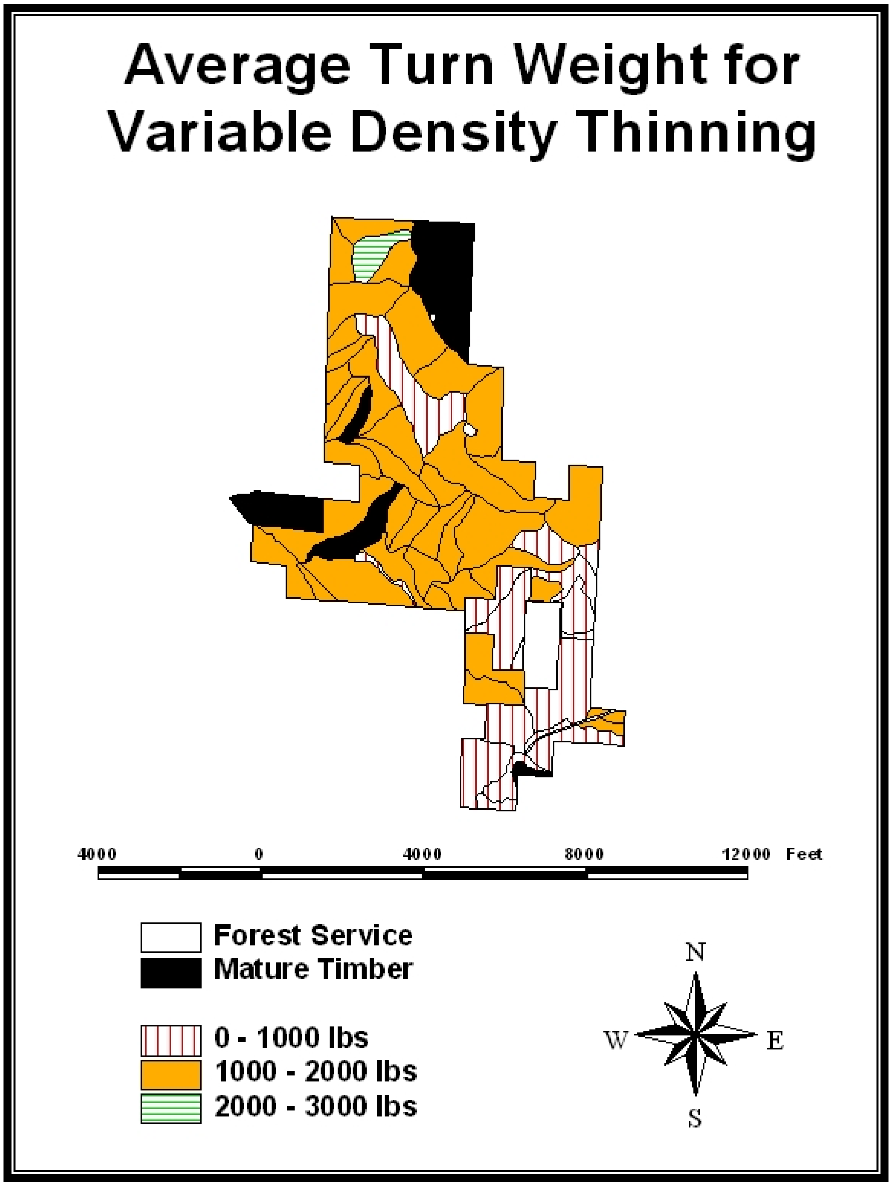


Figure 17 Average Turn Weight for Variable Density Thinning. The majority of the stands now have average turn weights of 1000-2000lbs, which is more economically feasible.

Using a weighted average, by area, the average turn size for variable density thinning is 1087 lbs, the maximum turn size is 2328 lbs and the minimum turn size is 0 lbs.

An example of turn weight distribution for the Burnt Mountain planning area for 2000 using single and variable density thinning and 3.5 logs per turn is shown in Figure 18. This figure shows the difference between the average turn weights for single vs. variable density thinning.

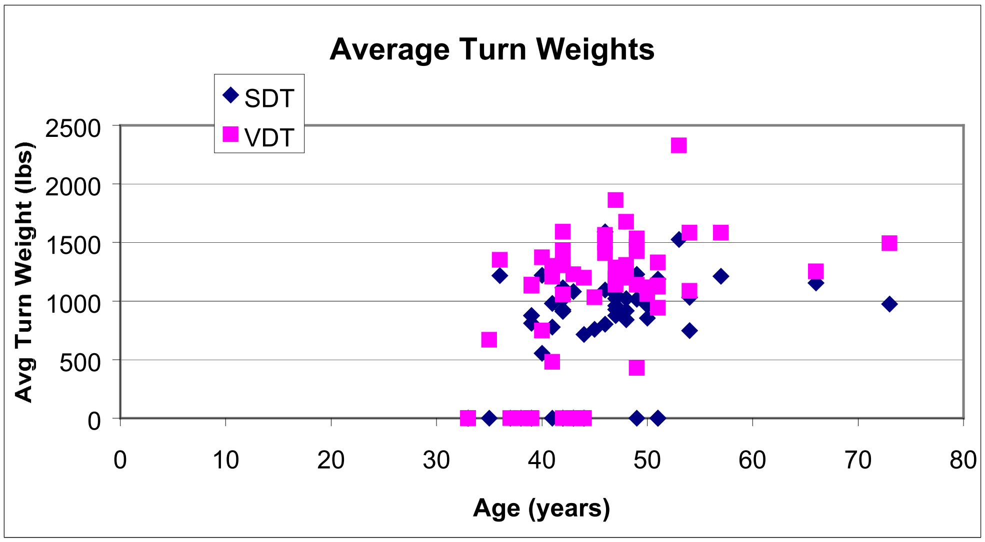


Figure 18 Average Turn Weights, by stand, for Single and Variable Density Thinning. Turn weights are calculated using average log (mbf), measured density of 10.9 lbs/bf for 3.5 logs per turn.

Whole Tree Yarding

With variable density thinning, there is a possibility of some parts of the planning area being thinned to less than 100 TPA (Figure 15). In these areas, due to the wide spacing, whole tree yarding will become feasible because residual tree damage and yarding efficiency will not be adversely affected. Whole tree yarding increases the turn weights, in many cases, such that the average turn weight is above 2000 lbs (Figure 17). There are still some stands with turn weights less than 2000 lbs, however, the turn weights for those stands are still larger than they are if the trees were bucked before being yarded. Shown below, in Table 7, are the statistics for whole tree yarding turn weights. These statistics include the minimum, maximum and mean turn weights and the percentage of the total acreage included in the weight distributions.

Table 7 Whole Tree Yarding Turn Weight Statistics. The minimum, maximum and mean payloads include all stands considered for thinning, this includes stands that do not meet the thinning criteria. The value ranges show the percentage of total acreage included in the turn weight range shown.

	min turn wt	mean turn wt	max turn wt	<1000 lbs	1000-2000lbs	2000-3000lbs	>3000 lbs
SDT	0	1773	3455	30.70%	19.70%	29.90%	14.40%
VDT	0	2469	4009	18.70%	12.40%	46.30%	17.30%

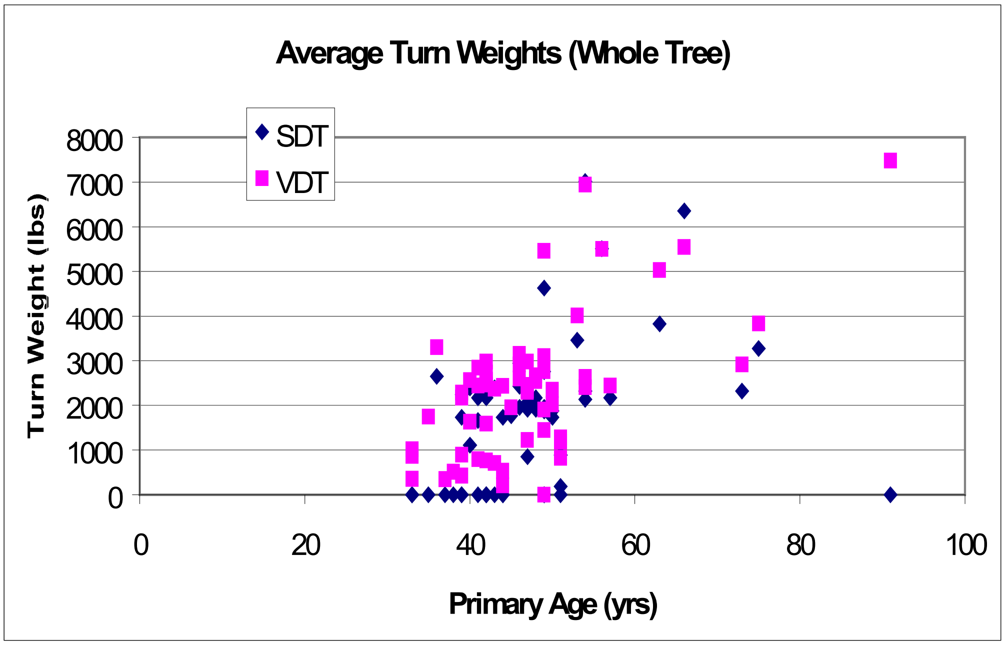


Figure 19 Average Whole Tree Yarding Turn Weights, by stand, for Single and Variable Density Thinning. Only stands with final relative densities less than or equal to 100 for variable density thinning are included in this graph. Turn weights are calculated using the average tree (mbf), measured density of 10.9 lbs/bf for 3.5 trees per turn.

5.5 Tail Tree Diameters and Rigging Heights

An analysis of available tail trees and their respective rigging heights was required for the analysis of the yarding corridor profiles. This allowed us to vary the rigging height of the tail tree according to the trees available in the correct stand. This section will highlight the distribution of tail tree diameters available, in the planning area as well as the distributions of rigging heights for the various stands. These distributions were analyzed for both 50 and 150 foot tree spacings.

Estimation of tail tree diameters was done by calculating the spacing and quadratic mean diameter in an Excel spreadsheet using the Landscape Management System (LMS) output tree list file (.trl). Tail tree spacings of 50 and 150 feet were chosen to determine the possible tail trees for carriages with and without lateral yarding capabilities. This equates to approximately 18 and 2 trees per acre, respectively. Due to problems with the FVS growth model working through LMS, we only have accurate tail tree data for the year 2000. In calculating tail tree QMD, only coniferous species were included in the analysis. This ensures that the data is representative to which trees will be used during actual logging operations. Distributions of tail tree QMDs for all stands with 50 and 150-foot spacings can be seen in Figure 20 and Figure 21 in 2 inch QMD classes.

One problem that came up in the Burnt Mountain planning area is that there is a large population of Western Hemlock, which have lower load capacities than Douglas Fir. To allow for this difference, 2 inches were subtracted from the DBHs of all trees except for Douglas Fir.

From tail tree QMDs, the potential rigging height can be determined from the Oregon Occupational Safety and Health Administration's guidelines for maximum tail tree height based on tree DBH (OR-OSHA, 1997). Given that tail trees will be rigged at 2' (stump), 30', 40' or 50' and that probably the largest diameter rope that will be used is 7/8" the rigging height can be determined based on the available tail tree QMDs at the different spacings. Figure 20 and Figure21 show the distributions of the number of stands that have tail trees available for these rigging heights.

These rigging height distributions were used in PLANS and LoggerPC during our profile and setting analyses in order to adjust accurately for inadequate deflection. This allowed us to more accurately predict the possible payload as well as to increase suspension to potentially fly logs over streams.

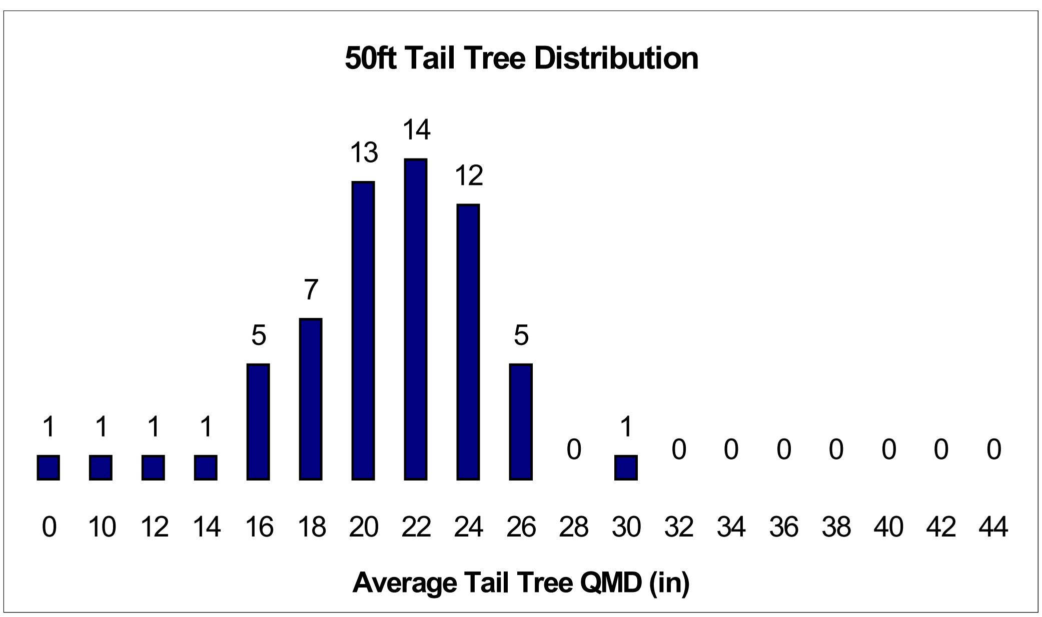


Figure 20 Distribution of number of RIU polygons in Burnt Mountain planning area with 18 potential tail trees per acre (50' spacing) in 2" QMD classes

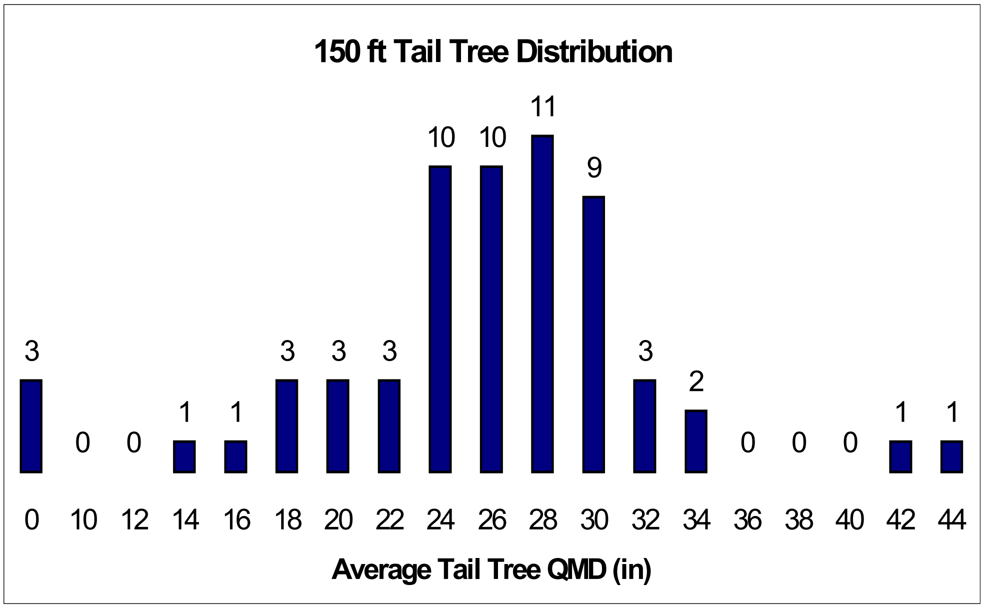


Figure 21 Distribution of number of RIU polygons in Burnt Mountain planning area with 2 potential trees per acre (150' spacing) in 2" QMD classes

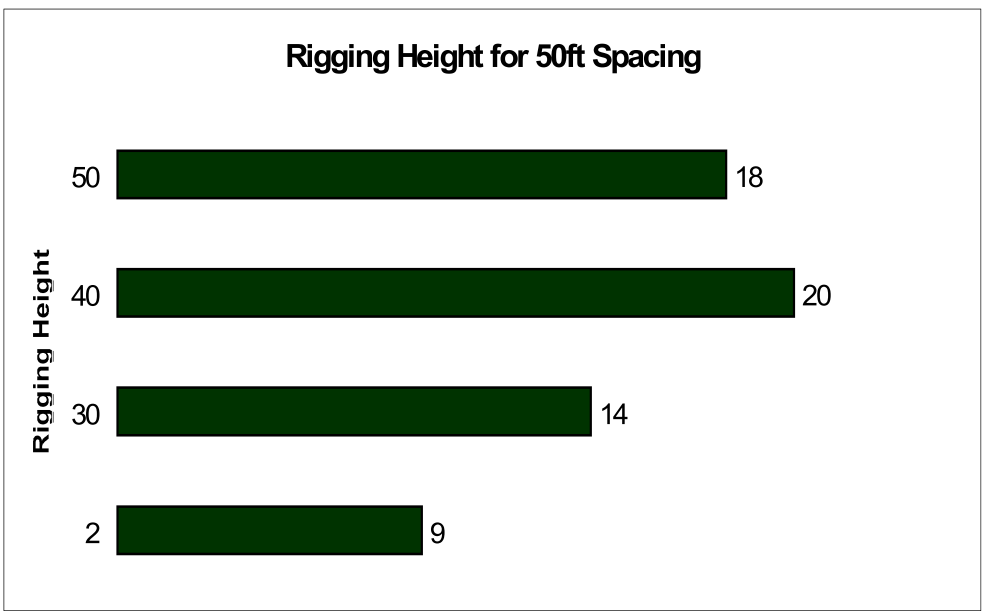


Figure 22 Number RIU polygons in Burnt Mountain planning area with average tail tree rigging height of 50, 40, 30, 2 feet (stump) based on 50 foot tail tree spacing and 7\8" skyline

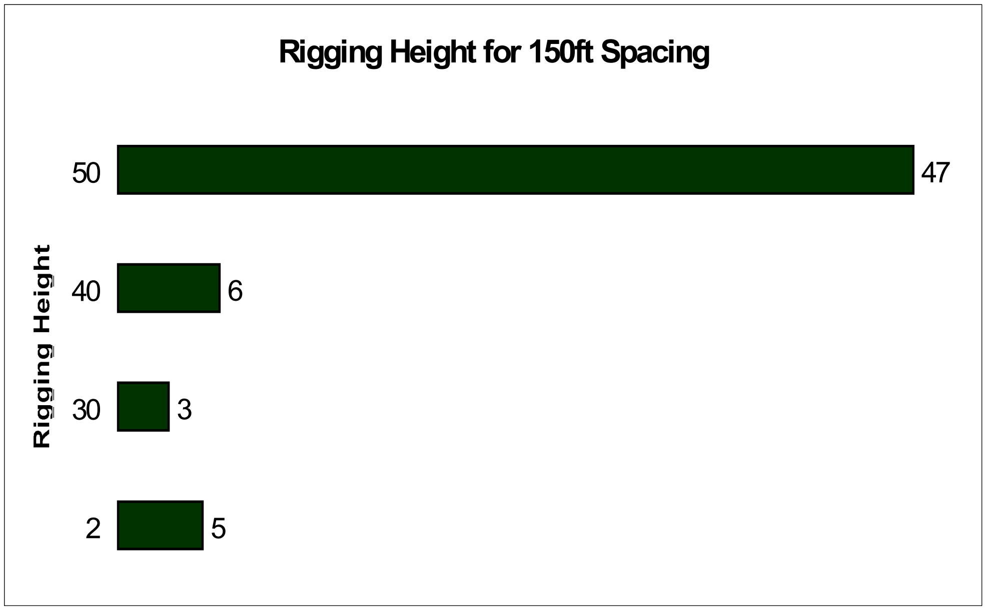


Figure 23 Number of stand polygons in Burnt Mountain planning area with average tail tree rigging height of 50, 40, 30 or 2 feet (stump) based on 150 foot tail tree spacing and 7\8" skyline

5.6 References

Oregon Occupational Safety and Health Administration (OR-OSHA). January, 1992.

DNR Forestry Handbook. August, 1999.

6 Roads

6.1 Design Inputs (paper plans)

The DNR digitally scanned their 1:400 contour map, creating a digital elevation model. The project team then converted the DEM into a contour coverage and used the coverage to print out as paper maps of the planning area. From these maps, potential landings were identified on flat areas on the ridges (Section 7.0). The next step in the design process was to design roads, on paper, to connect these landings to existing roads and to each other in a logical fashion. This process is called "pegging in" the roads. A divider was used to determine the desired grade and peg the road in between the control points, landings and existing roads. The guidelines used for this process are outlined below.

6.1.1 Side Slope Considerations

A hill slope stability map was created to show which areas are prone to slumping. Whenever possible we tried to avoid pegging a road across a potentially unstable slope. The HCP states that all roads constructed on side slopes in excess of 40% must be designed with a full bench road prism. On roads with side slopes between 40%-55% a full bench road prism is required, but the excess material can be sidecast and compacted. Any road that is constructed on side slopes over 55% must have a full bench road prism and any excess material endhauled to a suitable disposal site.

On all roads constructed on side slopes of less than 40% a balanced cut/fill road prism may be used.

6.1.2 Road Grade Considerations

Favorable road grades are defined as the downhill travel of a loaded log truck. Truck performance, safety, and DNR road standards limit the favorable grade to 18%.

Adverse road grades are defined as the uphill travel of a loaded log truck. Truck performance and DNR road standards limit the adverse road grade to 18%. There were some grades run at 18% to catch ridges or to stay on ridges. By doing this most wet areas and streams were avoided. We felt it would be better to sacrifice grade for location.

The minimum curve radius used in the preliminary design of horizontal curves was 60 feet.

6.1.3 Stream Crossing

We avoided stream crossings by keeping the roads on the ridges.

6.2 Field Reconnaissance

Field reconnaissance took place during the scheduled three-week period, beginning April 24, 2000 to May 12, 2000. During this three-week period, the weather varied from sunny to pouring down rain.

The Burnt Mountain landscape which is located 5 mile north east of Sappho, is surrounded by Forest Service land to the East, Crown Pacific land to the South and West, and Merrill & Ring land to the North. The Forest Service owns a 91.7-acre block of land in the Southern portion of the planning area.

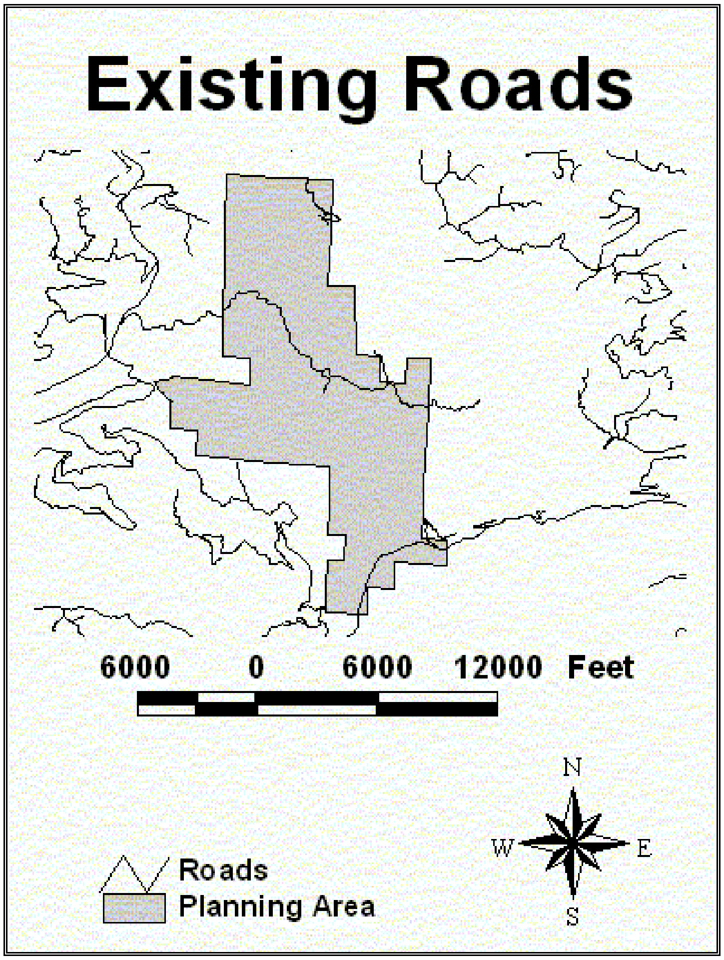


Figure 24 Currently existing roads in and around the planning area that provide access to the planning area. Most of the existing roads do not need any additional work to make them driveable, however, one road, that runs through the middle of the planning area, needs full reconstruction.

Currently three access roads run through the planning area. There are also various roads that, even though they do not enter the project area, it is possible to use these roads as take off roads into the planning area with the permission of the landowner (Figure 24).

There is one existing road that currently runs through the planning area that needs to be reconstructed, shown running through the center of the planning area (Figure 24). This road has subgrade problems in some areas that are causing slumps (Figure 25) the roadway. There are also drainage issues on the road that have caused large puddles of water to form on the roadway (Figure 26). This could be resolved by adding culverts to the roadway and putting a ditch on the uphill side of the roadway in order to keep the water off the roadway.

Figure 25 The suburban is stuck in a slump in the roadway caused by problems in the subgrade.

Figure 26 The suburban is driving through a puddle formed on the roadway caused by poor drainage and deep wheel ruts which channel water flow on the road bed. Substantial ballast may be required to provide a suitable traveling surface.

6.2.1 Processes

Office Design

The DNR supplied the contour coverage used by the design team. To make this contour coverage, the DNR made a hand drawn contour map based on stereo pairs of aerial photographs. This hand drawn contour map was then scanned into the electronic format used by the design team. This contour coverage was then used to determine possible landing sites and to design roads, on paper, to connect these proposed landing sites to existing roads as well as to each other (Figure 27).

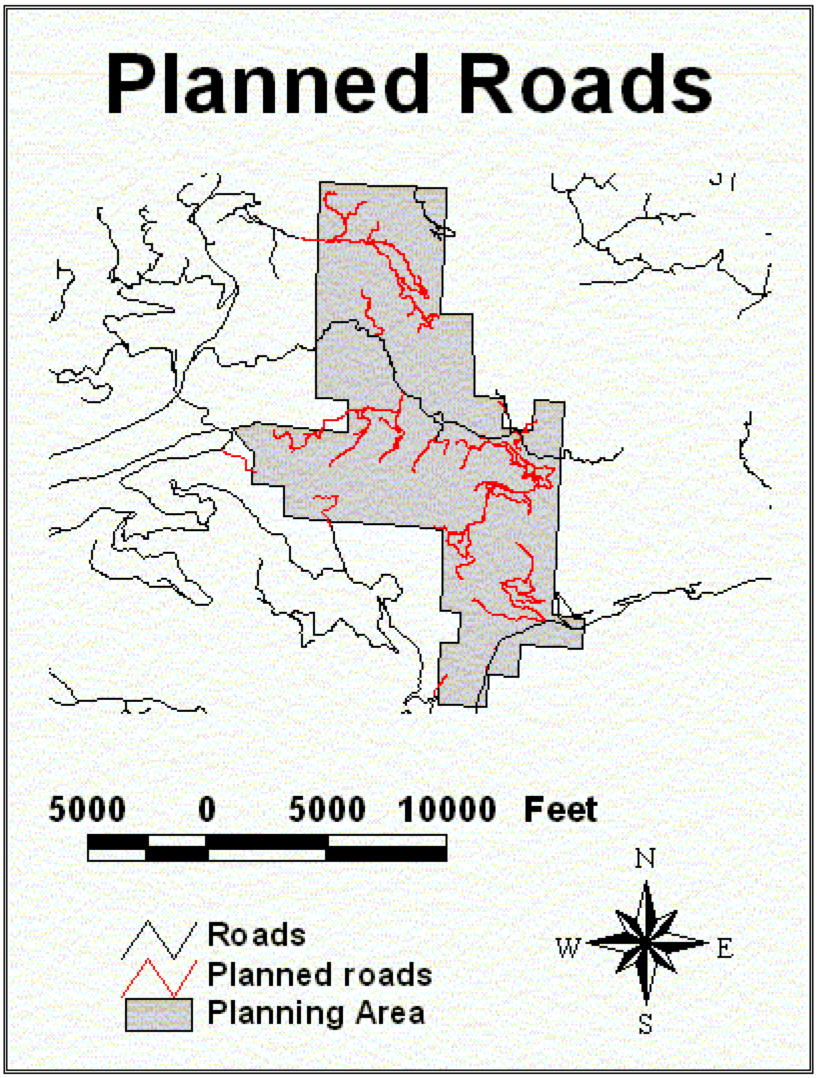


Figure 27 Original Paper Plan Roads. Not all of these roads were used in the final design. Many of the roads were discarded as unnecessary, while other roads were discarded or modified due to possible landing sites being discarded.

In this process, potential problem areas, such as sensitive areas and stream crossings were taken into account and avoided when possible. There were two analyses performed by the design team that assisted in the initial road design; ridge roads and watershed analysis.

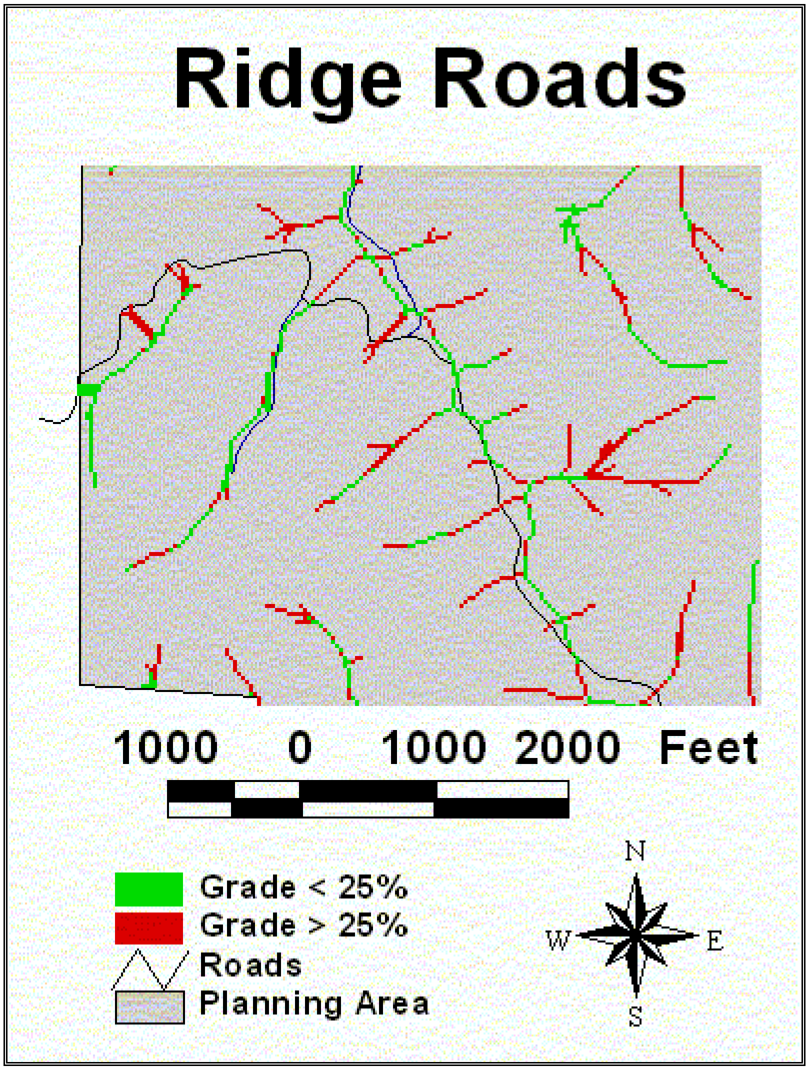


Figure 28 Ridge Roads Analysis. All roads shown in red and green are on top of ridges. The road segments shown in green represent grades less than 25%. Actual road locations are shown as black lines.

The ridge road analysis was performed using an aml (which can be found on the CD at atool \ grid \ ridgeroads.aml and ridgeroads2.aml). This aml finds the roads that are located on top of ridges by using a inverted dem along flow direction and flow accumulation. It then identifies the low points of the ridge, known as saddles, and creates path of travel up to the high point on the closest ridge. By analyzing ridge roads in this manner the tops of the ridges are not cut off, as they would be if the fill sinks method were used on the inverted dem. Instead the sinks are identified and the shortest path of travel is taken to get to the ridge. This analysis is helpful because ridge roads are generally more stable and deliver less sediment to the streams (Figure 28).

The watershed analysis assisted in identifying possible unstable areas, which should be avoided if possible in road design (Figure 29).

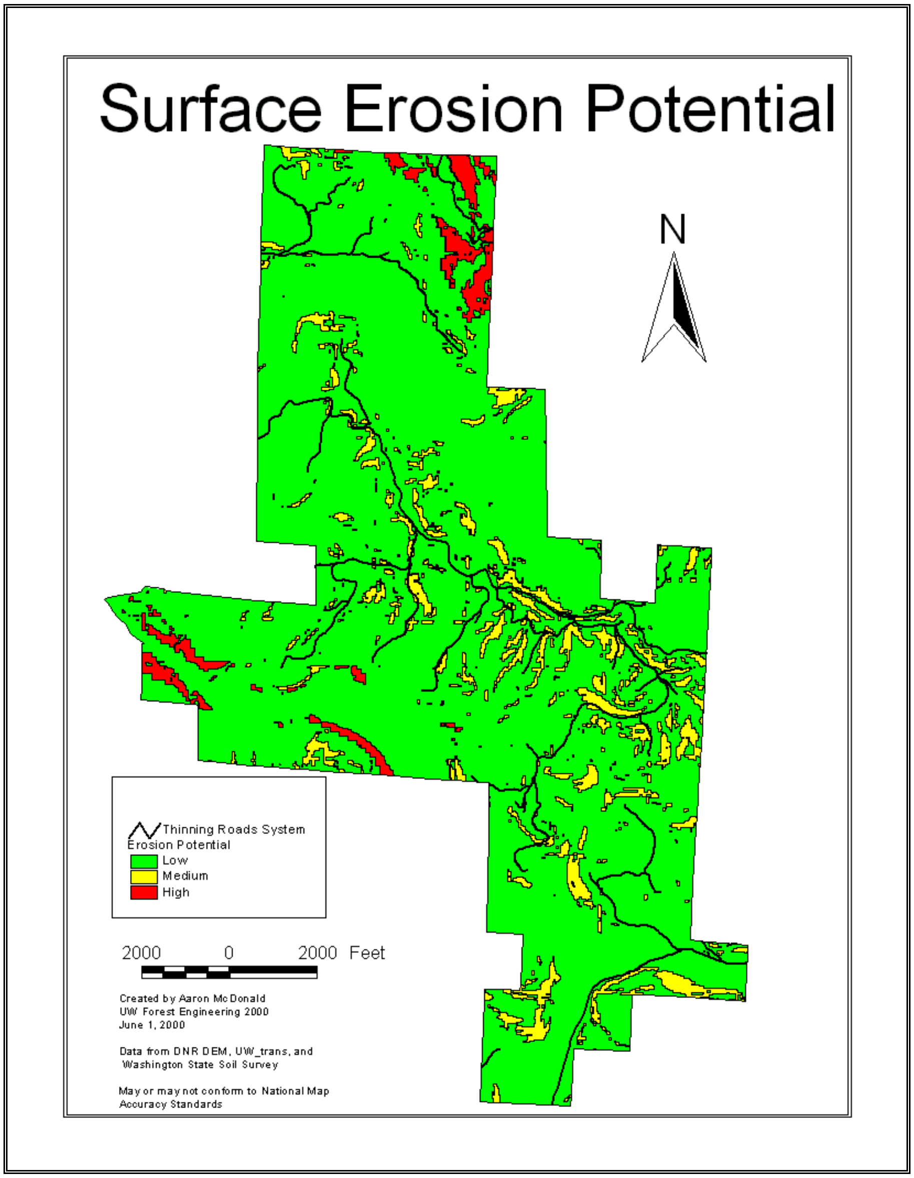


Figure 29 Watershed Analysis Map. Identifies possible unstable areas. The worst unstable areas are shown in red and unstable areas that aren't too bad are shown in yellow. These identified unstable areas were avoided when possible.

Field maps were created from the DEM coverage the DNR made, these maps showed the percent road grade and station at that grade (Figure 30). The maps also have section lines and property boundaries.

Field Reconnaissance

While performing field reconnaissance, when possible, the design team would follow the paper plans. The first step in locating the planned roads is to establish a grade line using orange flagging. Usually the grade line followed the paper plan very closely, however, there were areas where the paper plans needed to be modified in the field. These modifications were due to the need to avoid a problem area, due to changes in the desired ending point or due to the elimination of landing locations. For these areas, the design team would go ahead to the desired ending point, and then worked backward to miss the problem area until the flag lines met. The second step is to set a P-line with stakes. The last step is to perform an accurate road traverse of the P-line including distance, slope and side slopes.

6.2.2 Equipment

Along with the field reconnaissance process, is the equipment used. For running gradeline, a cloth tape and pacing were used to measure distances and a clinometer was used for setting grade. A compass was used for determining deflection angles and altimeters were used for establishing elevations at critical points (i.e. saddle, streams). A steel tape, staff compass, clinometer and Criterion were used for traversing. The Criterion bounces a projected laser off of reflectors placed at set turning points. GPS units were also used to create fixed points, or coordinated reference points, along critical road segments or terrain features.

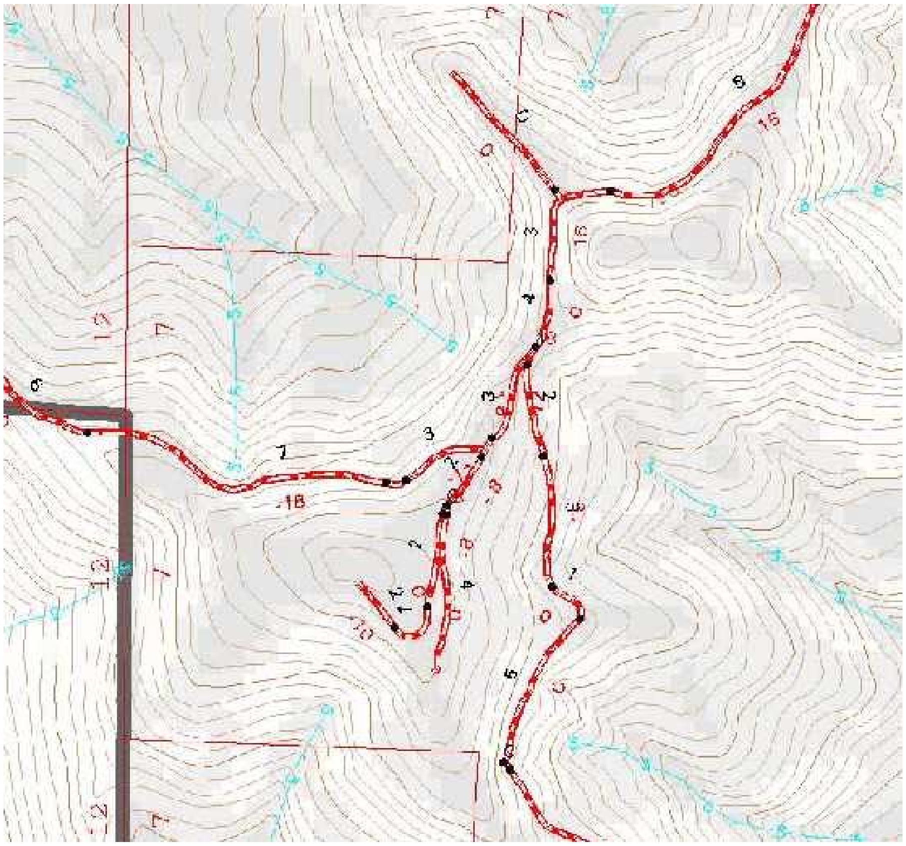


Figure 30 Example Field map. Numbers in black are the stationing numbers, numbers in red are the grade.

6.3 Field Reconnaissance Prioritization

Due to only a three week period in the field, time spent on road systems had to be allocated in such a way that areas of top priority were looked at first. We spent the majority of our time in the southern area checking profiles and running grade lines. Richard Bigley, in charge of DNR research and monitoring, identified this area for his research project. We prioritized the roads into 3 categories mainline roads, secondary roads, and spur roads.

6.3.1 Planned Mainline, Secondary and Spur Roads

During the four weeks of preliminary office work, mainline roads were designed to access large areas within the watershed. These roads were given top priority during the field reconnaissance since the road network was highly dependent upon the construction of these roads.

The secondary roads were designed to access timber settings. These roads were also given top priority since sale areas could not be accessed without them.

Spur roads were pegged in on the maps in the office but were omitted from the gradelining and traversing done while in the field. These roads were given a low priority due to time constraints.

6.4 Road Reconnaissance (Field Work)

During road reconnaissance, the routes initially laid out on the map were surveyed in the field using the equipment described previously in Section 11.1.2.

While in the field, we set our road gradelines according to what was previously pegged during the planning process and what was feasible.

6.5 Road System Overview

In the Burnt Mountain block, there are eleven road systems identified (Figure 32). These road systems are within the Burnt Mountain planning area, 3,248 acres, and were designed to connect to 3.6 miles of existing roads in the planning area. Of these existing roads, 2.7 miles require reconstruction. Throughout the planning area, there is a total of 16.6 miles of planned roads, which results in a road density of 3.8 miles per mile^2 and an average external yarding distance, AEYD, of 960ft for the planning area (Figure 31).

The following sections describe each road system and the critical issues that applied to each.

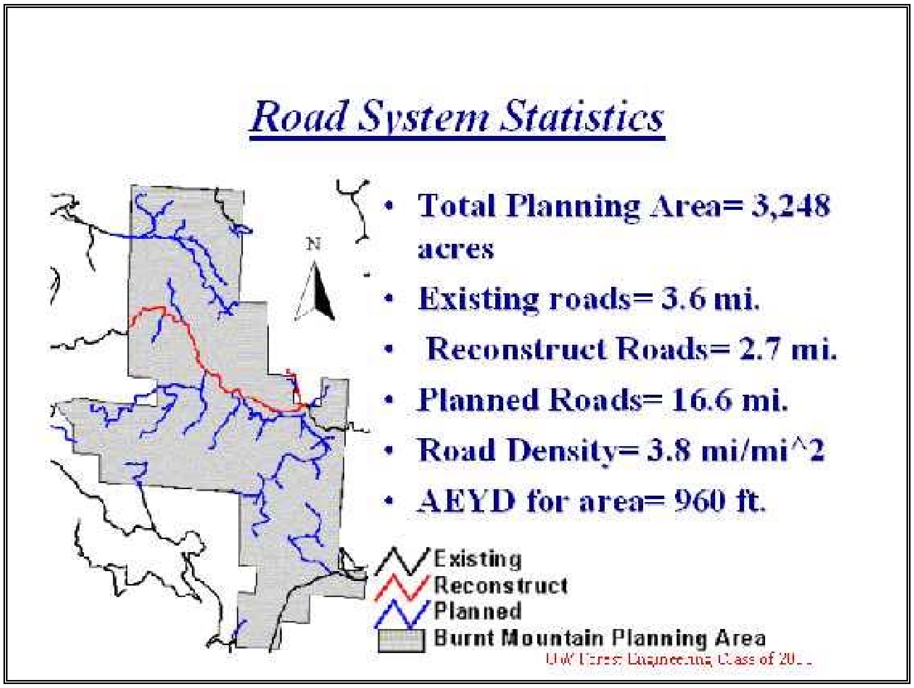


Figure 31 General statistics for all roads in the planning area. Existing roads that require reconstruction are shown in red, other existing road are shown in black. The roads shown in blue are the roads planned for this project (AEYD = average external yarding distance).

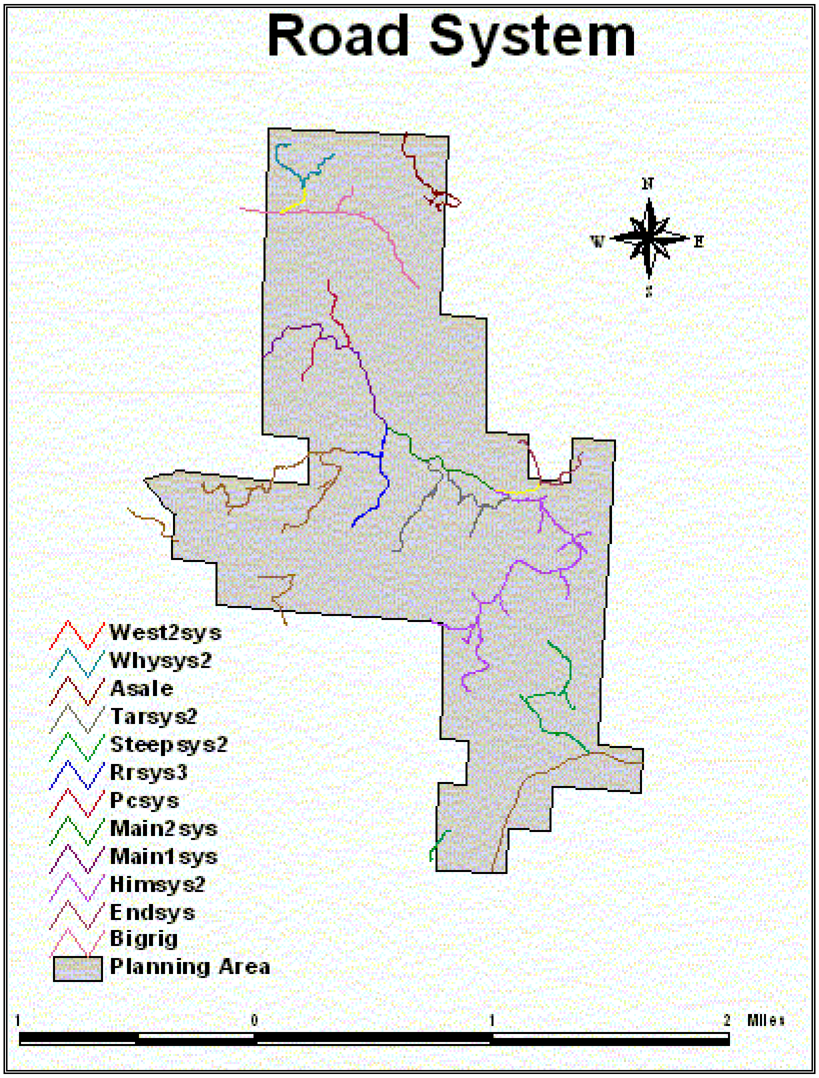


Figure 32 Road System Overview. Identifies each road system in the Burnt Mountain planning area.

The planned roads in the planning area were subdivided into 12 logical road systems based on topography and access.

Overall, the length of the road systems varied from 29 to 191 stations, the majority of the road systems have a maximum grade of 18% and a minimum grade of 0%. The road systems provided access to 55 to 580 acres of timber using 2 to 12 settings with average AYDs ranging from 507 to 1453 feet. This results in road cost, in dollars per station, ranging from $1264 to $3545.

Table 8 Road System Statistics

Road system	road length	Grade max/ min	acres	# settings	avg. EYD	$/ Station
Main 2	42	13/2	147	4	1453	1,383
Main1	64	12/0	232	8	1062	1,644
PC	39	18/0	298	9	1290	1,633
ASale	52	18/0	107	3	771	1,317
BigRig	81	18/0	366	12	1070	1,901
RRS	29	18/0	58	2	928	3,545
Tar	81	18/0	304	7	1009	3,513
Why	52	12/0	55	3	507	1,617
End	36	18/0	125	2	1094	1,303
Himalaya	191	18/0	580	9	940	2,000
Steep	69	18/0	214	6	1208	1264
West	109	18/0	462	MT	1350	1,327

6.5.1 Road Grade and Side Slope Statistics

During the road location planning process, maximum adverse and favorable grades were determined based on the DNR road design requirements. The adverse and favorable grades used for road design are shown in Table 8 Road System Statistics. The goal in designing all roads was keep a maximum of 18% grade for both adverse and favorable grade.

6.5.2 Main 1 & 2 Systems

The Main 1 System and the Main 2 Systems are an existing road, accessed from a Crown Pacific road on the west side of the planning area, that was divided into two smaller sections. These systems are a reconstruction of an existing, orphaned road that has 6 inches of organic material on top of a hard gravel base. This road was day lighted by a convict crew to allow us easier access to the planning area and can only be accessed by 4 wheel drive vehicles with high ground clearance.

The road needs major reconstruction before it can be used. The road is slumping in several locations (Figure 25), it also has several large puddles (Figure 26) on it from lack of drainage. The road is 106 + 44 stations long and accesses 379 acres of timber in 12 settings (Figure 33).

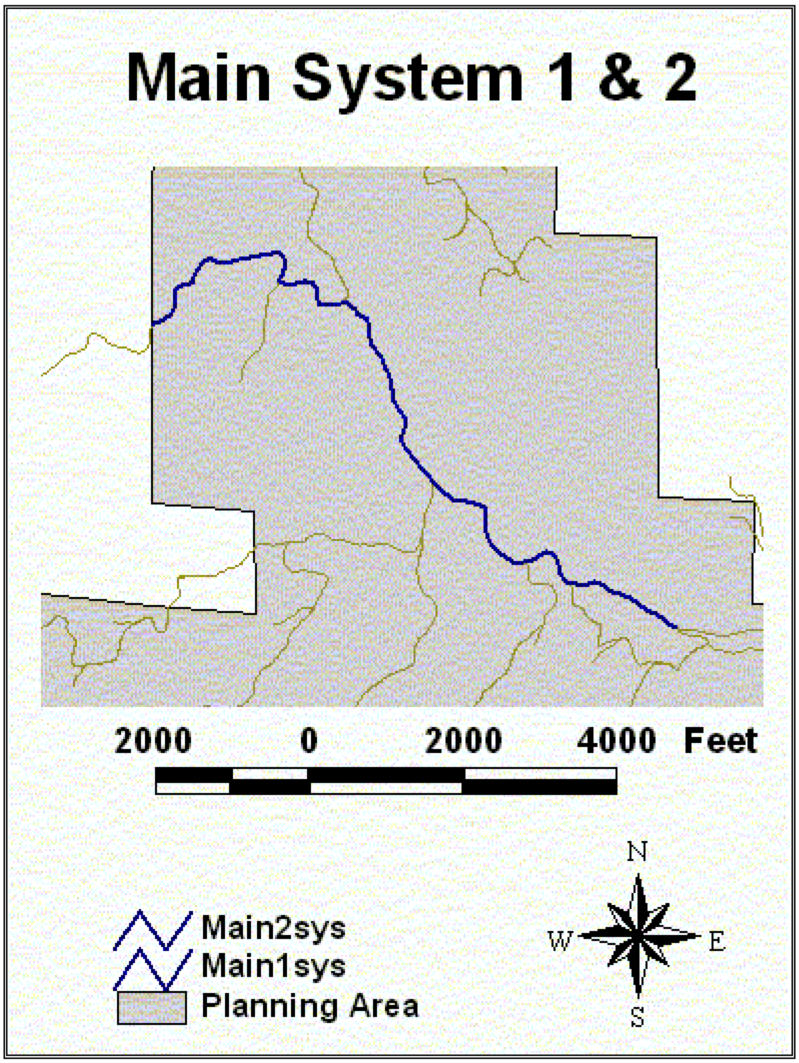


Figure 33 Map of Main 1 & 2 Systems. This is an existing road that requires reconstruction. Most road systems in the planning area take off from this road.

6.5.3 Himalaya System

The Himalaya Road System, which begins at station 106 + 22 on Main 2, consists of eleven roads, totaling 191.5 stations, accessing 580 acres in 9 settings (Figure 33). This system consists of the one mainline road, the Himalaya traversed road, one secondary road, BFE Road and nine spur roads: West Spur Road, SB-1 Road, Spiral Road, Boulder 1 Road, Boulder Road, Nose Lan Road, Cope Road, Spam Road and Himalaya N Spur Road.

Himalayan Mainline

The Himalayan traversed road is 92 stations long and a complete design was made for it (section 12.4). We used a GPS unit to locate fixed points at the beginning and end of the road that were accurate to plus or minus 2 feet. The survey precision was 1 / 1054. All the roads in the system originate from this road. The road climbs from Main 2 up to an old landing then runs along the ridge top where possible (Figure 34).

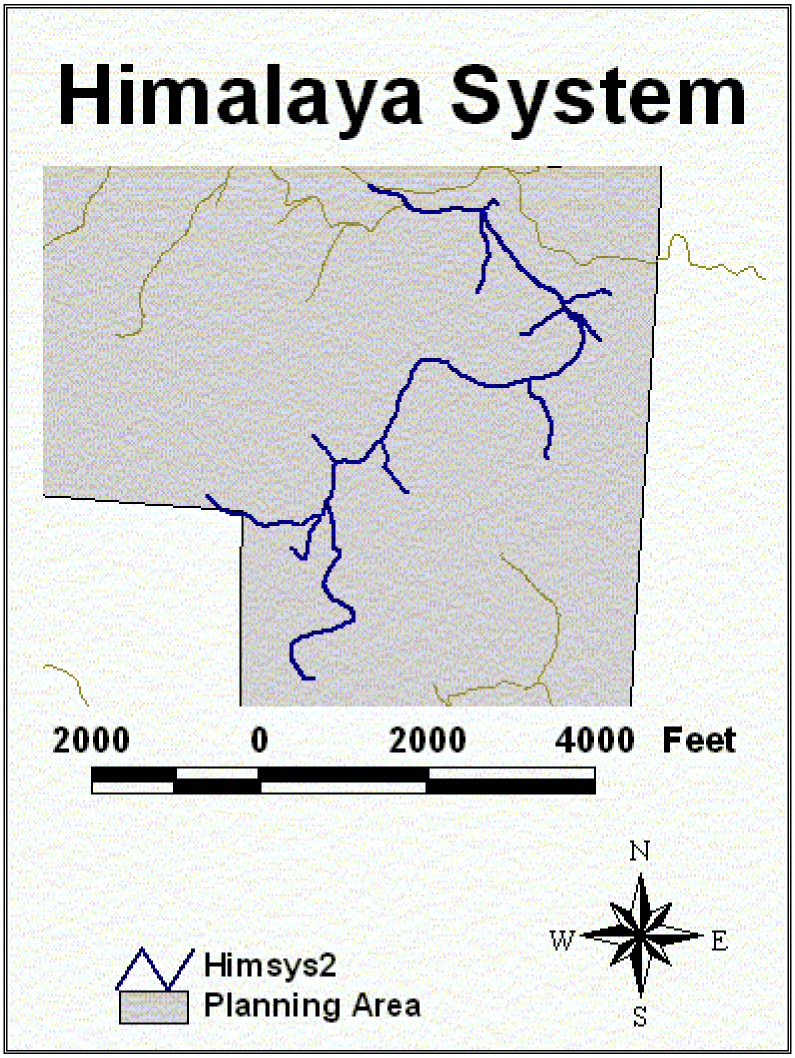


Figure 34 Map of Himalaya System within the Burnt Mountain Planning Area

Spam Road

Spam spur road begins at station 68 + 22 on the Himalaya traversed road and is 7 + 69 stations long, it accesses setting S14, which is 51.5 acres. Spam spur road is a paper plan only and has not been field verified.

Cope Road

Cope spur road begins at station 42 + 22 on the Himalaya traverse road and is 10 + 50 stations long. Cope accesses setting S16, which is 92 acres. Cope is a paper plan only and has not been field verified.

Nose Lan Road

Nose Lan is 5 + 20 stations long and begins at station 29 + 50 on the Himalaya Traverse road. This road accesses S16, which is 92 acres. Nose Lan is a paper plan only and has not been field verified.

Boulder 1 Road

Boulder 1 is 6 + 68 stations long, it takes off from station 29 + 50 on the Himalaya traverse road. It accesses setting S18, which is 57 acres. Boulder 1 is a paper plan only and has not been field verified.

Boulder Road

Boulder road is 6 + 16, it begins at station 29 + 50 on the Himalaya traversed road. It accesses setting S17, which is 47 acres. Boulder road is a paper plan only and has not been field verified.

SB1 Road

SB1 is 10 + 21 stations long and takes off at station 14 + 54 on the Himalaya traverse road. It accesses setting S31, which is 52 acres. SB1 is a paper plan only and has not been field verified.

Spiral Road

Spiral road is 2 + 15 stations long and starts at station 14 + 54 on the Himalaya traversed road. Spiral accesses setting S29, which is 15 acres. Spiral road is a paper plan only and has not been field verified.

BFE Road

BFE is 31 +46 stations long and starts at station 79 + 45 on the Himalaya traversed road. BFE accesses settings S10 and S12 for a total of 134 acres. A grade line was run for BFE road.

The flagged road was located higher than the paper location due to slumps and head wall below stations 4 and 10. The flagged road starts at traverse point 145, we started with a grade of zero for 4 stations and then dropped down to the ridge at 18% where Bill took a GPS reading (elev. 1300ft) at station 17. The side slope is about 50% from the Himalaya traverse to the ridge. From the ridge to the landing, side slopes are 60-80%. The road will probably have to drop at 18% to reach the landing, this will have to be explored further. Bill Heyman and Peter Schiess flagged a road from the landing back to the traverse that tied into the traverse at station 141. The flag line skirted the slumps and head walls and was unable to catch the flag line that started at station 145 it paralleled it about 80 feet below. The primary species present in the wet areas, on the lower slopes, consist of Alder and other hardwoods, while the dry upper slopes consisted of Western hemlock and Douglas fir.

West Spur

West Spur is the primary access road for setting S13, which is 80 acres. This spur road is 15 + 04 stations long and starts at station 81 + 82 on the Himalaya traversed road.

Grade was run initially at 0 % in order to stay above wet area that covers the entire basin. Examination of air photos revealed that the entire basin appears to be eroding towards the ridge. The spur will be a temporary construction and should experience no erosion problems unless significant long-term precipitation events occur.

Once the spur ridge was reached, the terrain was gentle enough to allow a road on top of the ridge. The ridge varied from 100 to 200 feet wide and has a 0 to 10 % grade both linearly and laterally. The nose of the ridge provides a wide, level landing area with access to all sides. The side slopes off the nose are 50+ % and the nose has an initial grade of 30 %.

No significant construction problems are expected to be encountered. At the roads closest approach to the unstable areas, there is an extensive bench area that will provide support for the roadbed. One area at the transition from the sidehill road approach to the ridge has a grade of 30 % for approximately 100 feet. We do not see this as a problem as it should be possible to fill in the area to lessen the grade at this transition

Himalaya N Spur

Himalaya N spur is an alternate access route for settings S13 & S14a, which is 131.5 acres. This spur is 4 + 41 stations long and takes of from the Himalaya traverse at station 75 + 65.

Himalaya N road starts from traverse point 73+00 (TP 130) on the Himalaya Traverse. It follows an existing old grade along a narrow ridge, varying between 20 and 40 feet wide. Initial grades are between 13% to 20% adverse for about 2 stations, then lowering for the remainder. It may be possible to reduce adverse grades by staying on the NW side of the hill ("side hill construction").

6.5.4 Steep System

The Steep system consists two secondary roads, the Steep Southern road and the Southern JR road and is located it the southern part of the planning area. The steep system contains 69 + 34 stations of road that access 6 settings, which cover 214 acres (Figure 35).

Steep Southern Road

The Steep Southern road is 30 + 06 stations long, it accesses settings S6, S7, S8, S9 which cover a total of 198 acres and takes off from an existing DNR road. The timber consists of mostly alder stands until the top of nose is reached. Timber size was marginal. The draws seemed very stable after walking through them and inspecting up and down slope. Road construction should not be a problem as long as full bench roads are laid out. Otherwise the road was flagged in as shown in the paper plan.

Southern JR Road

The Southern JR road is 52 + 41 stations long and starts at station 26 + 23 of the Southern Steep road. It accesses settings S11 and part of S9 for 16 acres.

The road starts at station 27 +00 off the Steep Southern Road. It starts out at an 18% favorable grade for nine and a half stations. Side slopes vary between –10% to –50% on the left and 5% to 60% on the right. The next ten stations stay on the top of the ridgeline with grades varying from –10% to 10%. The following eight stations run at –5% grade to the last landing. Timber throughout the top of the ridge are hemlock and Douglas fir measuring from 6 inch DBH to 24 DBH.

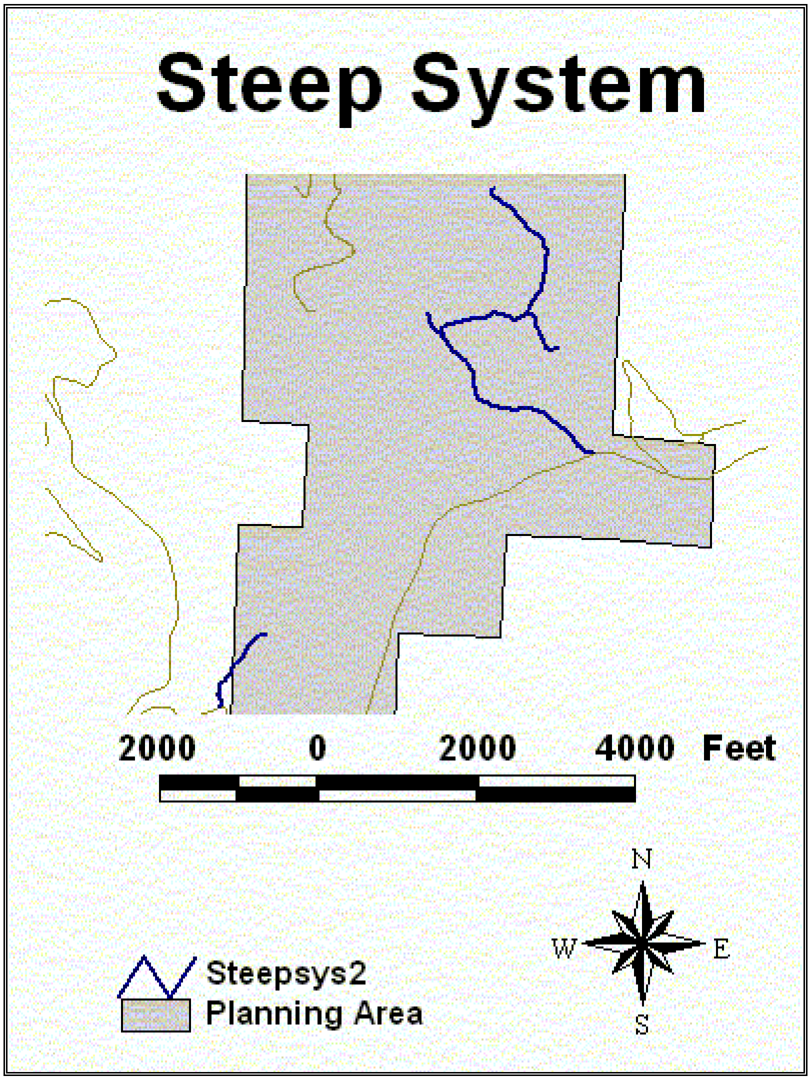


Figure 35 Map of Steep System within the Burnt Mountain Planning Area

6.5.5 PC System

The PC system consists of two secondary roads, Pidley Road and Central Road North. The system is 39 + 00 stations long and accesses 298 acres of timber in 9 settings (Figure 36). The maximum adverse grade in the system is 18%.

Pidley Road

The Pidley Road takes off from Main Road at station 25 + 90 and was flagged in at –15% at the beginning in order to stay on the ridge. After station 5+00 we continued the road following the paper plan until it reaches the final landing at station 14 + 96. The remainder of the road was at a grade of 0-5%. This road provides access to settings N7, N16, N19, N20, N21, N34 covering 215 acres. The side slopes varied from 0 to 65%.

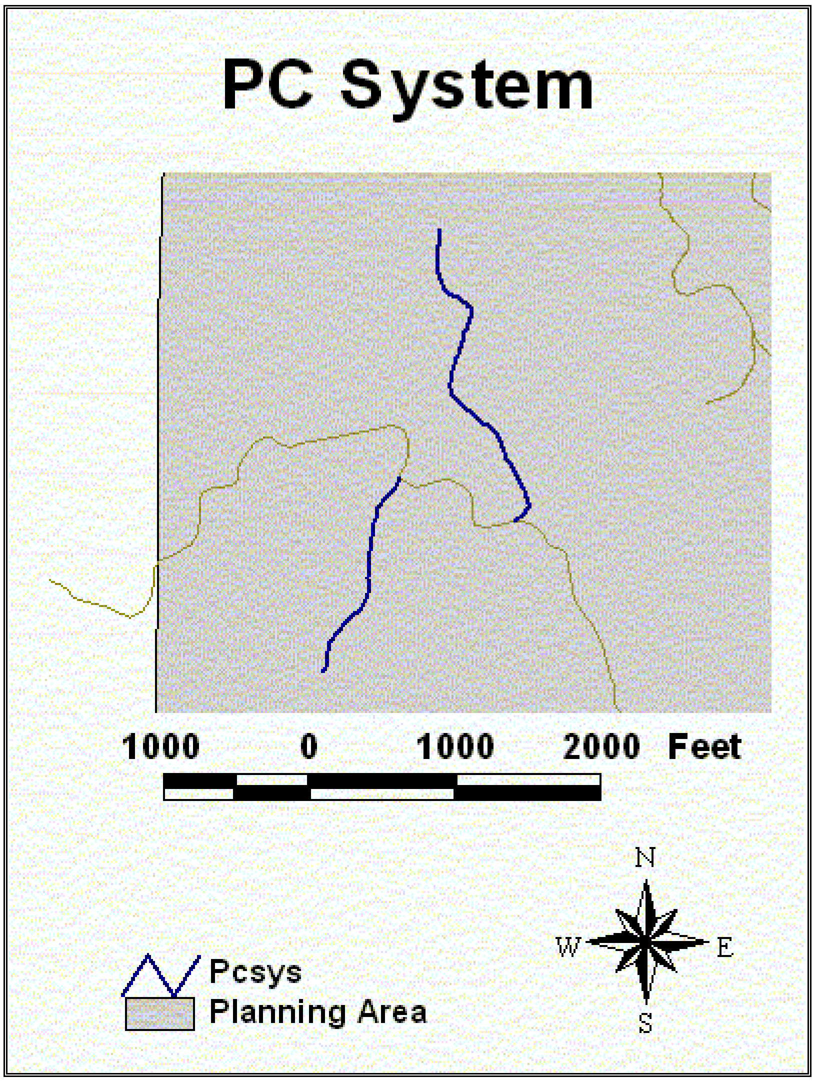


Figure 36 Map of PC System within the Burnt Mountain Planning Area

Central Road North

Central Road North accesses 83 acres of timber, which includes settings N31, N36 and N37. The Central Road North takes off from main road to the north at station 36 + 32 with an 80ft radius switchback, flagged in blue at a 10% grade, which ties into the flagged gradeline at approximately station 1 + 00. At the road take off, the road is grade-lined along an existing, orphaned road. The grade line was adjusted uphill from the old road grade at station 13+50 to avoid a wet area and to reach the desired landing site at station 23 + 90.

The grade line from station 19 + 50 to 20 + 00 was directly laid in as road location, which resulted in a 33% grade for 50ft. To adjust for the 33% grade, a cut and fill analysis was done from station 18+00 to 21+00. This resulted in a 12% grade from station 18+00 to 20+50 and a 15% grade from station 20+50 to 21+00. It continues on to the landing at grades of 16% and 5%. The side slope ranges from 0 to 85%.

6.5.6 Asale System

The Asale road is in the N.E. most corner of the planning unit and was not ground verified. The road is 52 + 12 stations long, 26 + 84 stations have already been built and 25 + 28 stations have been paper planned. The road is accessed from Merrill and Ring property. This road accesses settings N3, N6 and N42, which cover 107 acres (Figure 37).

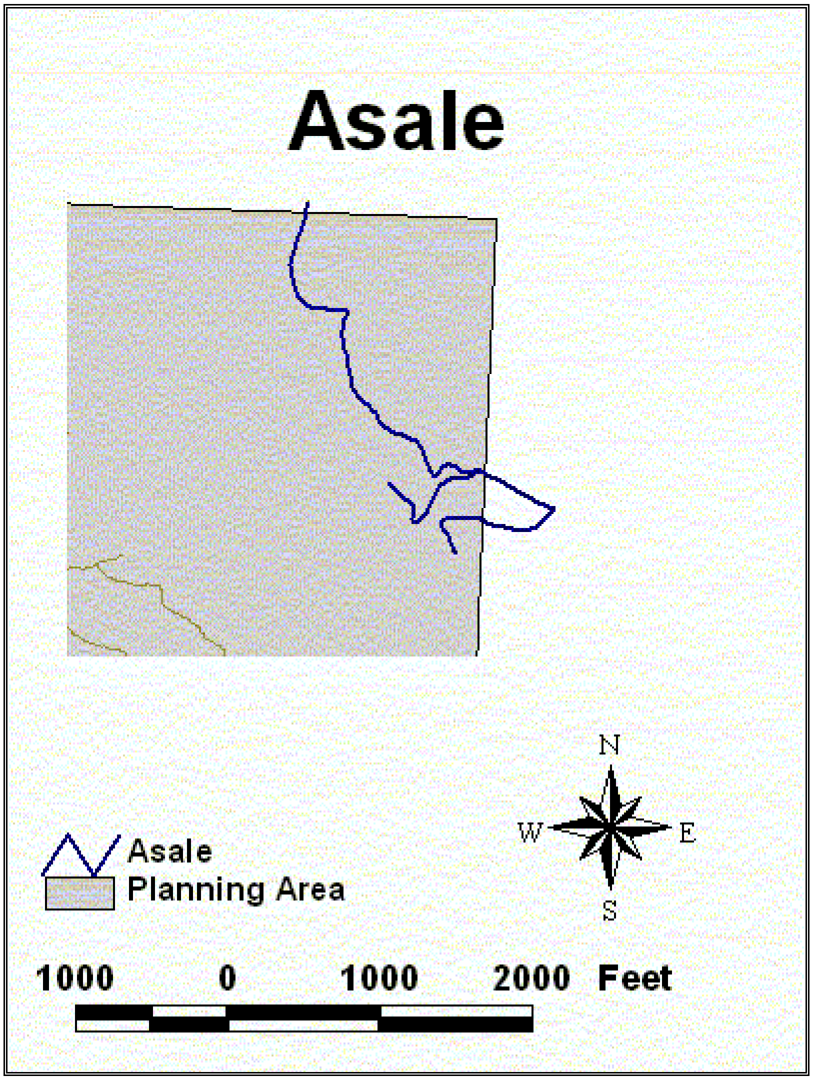


Figure 37 Map of Asale System within the Burnt Mountain Planning Area

6.5.7 Big Rig System

The Big Rig System is 81 + 09 stations long and consist of one mainline road, the Big Rig Road, and one spur road, the Big Spur. This system, accessed from Crown Pacific Land, provides access to 366 acres of timber in 12 settings (Figure 38).

Big Spur Road

The Big Spur Road is 10 + 97 stations long and takes off at 22 + 97 on the Big Rig Road. Big Spur Road accesses settings N4, N9 and N10 for a total of 60 acres. Big Spur Road is a paper plan only and has not been field verified

Big Rig Road

The Big Rig Road takes off from the end of an existing Crown Pacific Road at the edge of the project area at the quarter corner marker on the west edge of section 36 of T31N R12W. This road extends 68 + 73 stations and accesses 306 acres of timber, including settings N7, N8, N11, N12, N13, N14, N15, N17 and N23.

The first 11 stations of Big Rig road were already staked and traversed by DNR from a sale that was put on hold approximately three years ago. The road followed the ridge top until the gradeline drops down at 16% grade to meet the saddle at station 27+00. The trees in this area are good sized and ready for a final harvest. From here the road climbs at a constant 16% until we got back on the ridge at around station 39. This section of road is on a side hill of between 60 and 70 percent. The timber in this area was moderate in size. After this point the road follows the ridge until it reaches the nose of the ridge at station 68 + 73. The timber for this stretch of road was small to moderate.

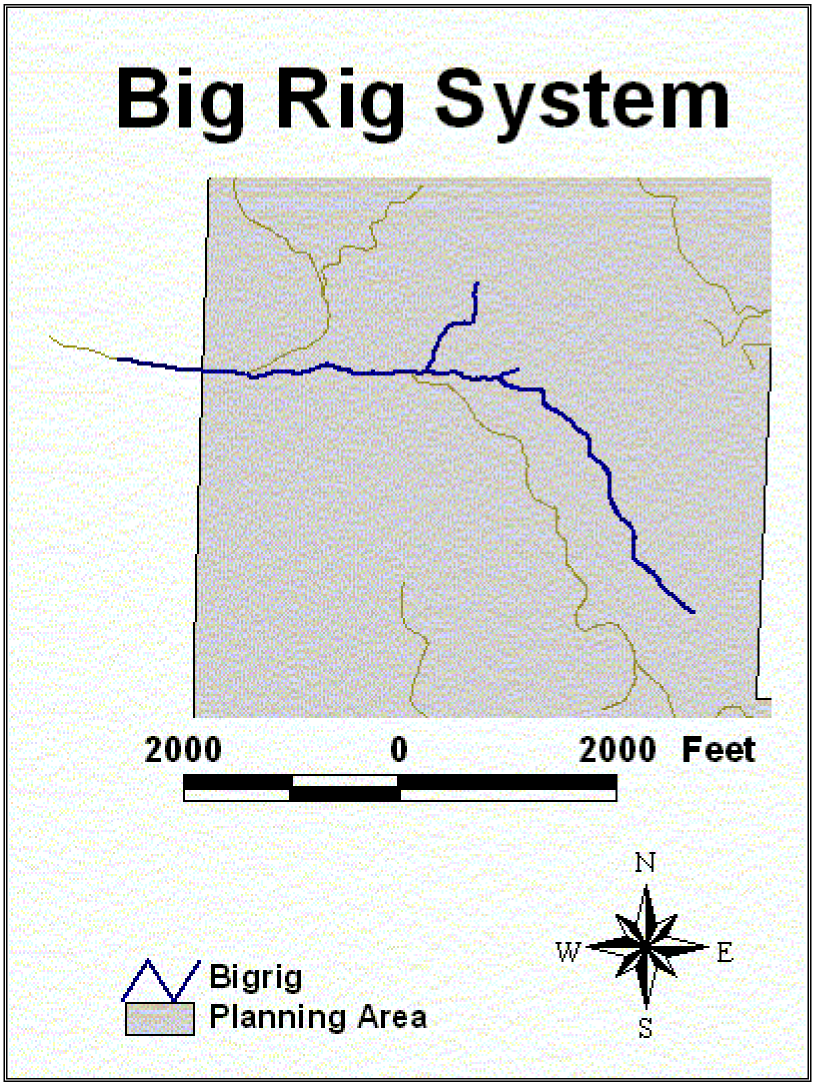


Figure 38 Map of Big Rig System within the Burnt Mountain Planning Area

6.5.8 RRS System

The RRS system consists of one secondary road, Lyle's Road. This road takes off from Rail Road North and extend a total of 28 + 89 stations and accesses a total of 58 acres of thinning timber in 2 settings and mature timber (Figure 39).

Lyle's Road starts at station 7 + 76 on Rail Road N Road. Lyle's Road is 28 + 89 stations long it accesses settings S22a and S24 for a total 58 acres. The side slope ranged from 0-75%.

The original road, on paper, went uphill from the saddle at 14% to create access to a possible landing that was taken out of consideration and will not be used. Since that part of the road was unnecessary, we followed the contour line at 0% until we reached the part of the road where we had to move downhill. We then continued the gradeline at 16%, following the paper plan, down towards the landing, however, this brought us below the saddle. To correct this, we started from the saddle and worked our way back to toward the beginning of the road at 12% grade until it intersected the 16% gradeline at station 12 + 50. To reach the landing, a grade of 10% was run from the saddle to the landing on the nose of the ridge.

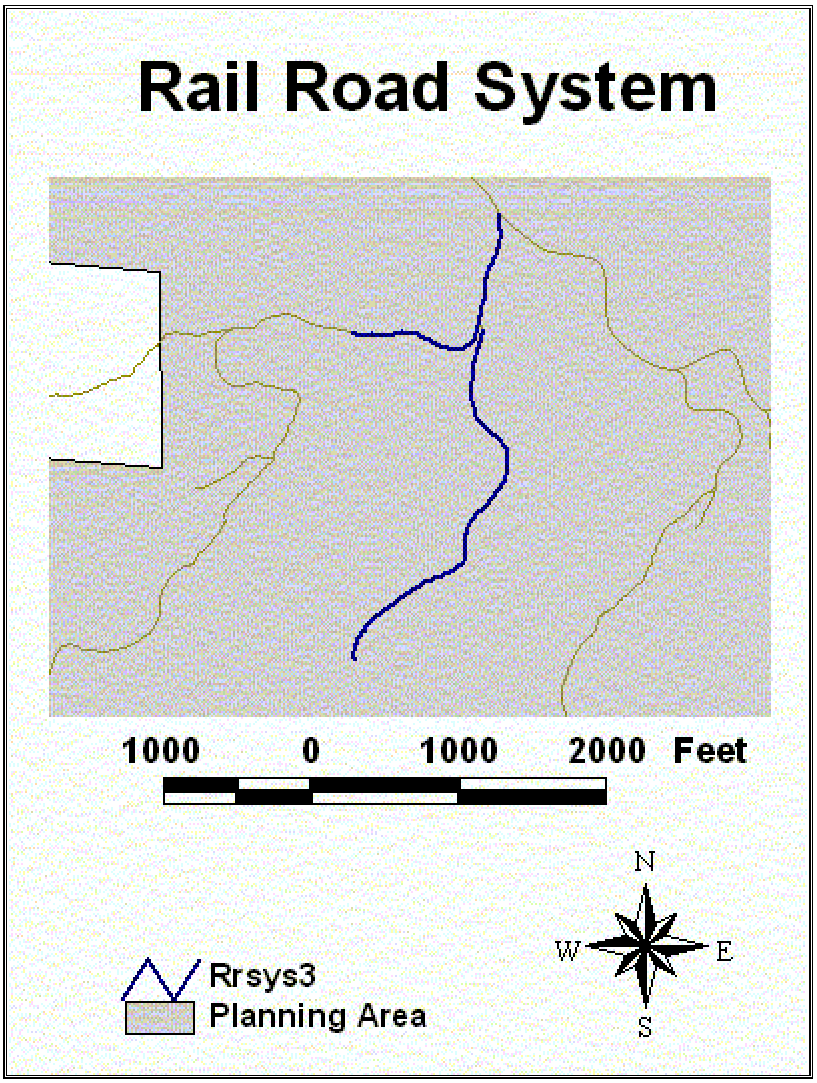


Figure 39 Map of RRS System within the Burnt Mountain Planning Area

6.5.9 Tar System

The Tar System consists of the Ridge Racer Road, Tar Road and the Himalaya West road. These roads, totaling 80 + 81 stations of roadway, provide access to 304.5 acres of timber in 7 settings (Figure 40).

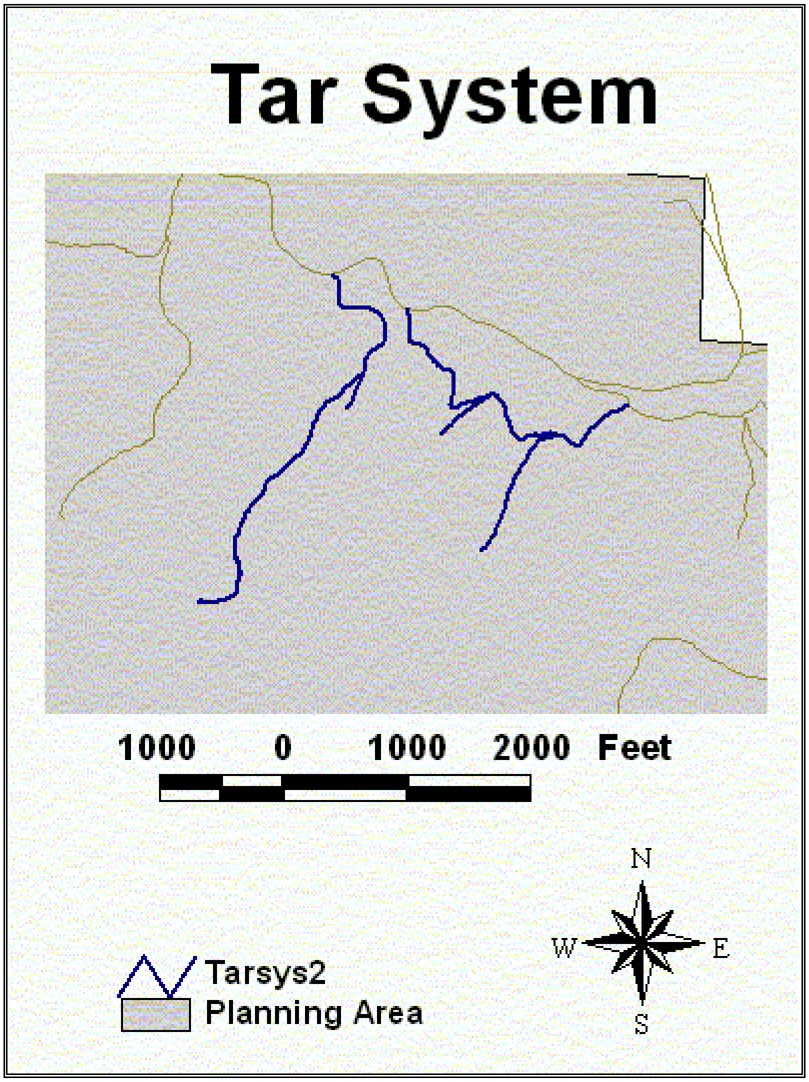


Figure 40 Map of Tar System within the Burnt Mountain Planning Area

Ridge Racer

Ridge Racer Road takes off of Main Road at station 81 + 99, extends 40 + 10 stations long and accesses settings S19, 20, 21, 22 and 23 for a total of 243 acres. The side slopes range from 0 to 90%.

The Ridge Racer road takes off to the south approximately 1.5 miles into Main Road. The grade runs three stations at -5% to –7% where the direction changes from SE to NE. A potential landing location exists here. The grade continues into a draw for approximately 200 feet where an area of partial roadbed erosion is encountered. The topography is highly convergent, located in an area predicted to be moderately stable to unstable. A more thorough assessment of this area is advisable prior to road construction.

A wet area is located between 7+00 and 8+00 with Devil's Club being the indicator. The area is rocky with no water visible near the surface in the vicinity of the grade. Drainage problems may be avoided here by use of coarse fill to smooth the grade in this section.

From station 10+00 to 12+00, the grade was continued until reaching a large former landing that appears to be built partially on rotting logs. The stability of this is questionable when loaded. From this point, we determined that we could not reach the saddle below from this position

We descended to the saddle, which was broad, measuring 200 feet by 50 feet. From this point, we ran a grade line of 18% back towards the original grade on the NW side of the hill. This grade passed through a number of areas with unstable, loose soil with a slope of 60% or more. This line connected with the original grade near 10+00. This point is on a corner and appears to have enough room for grade separation if the uphill side slope is cut back. We also considered abandoning the original grade at this point and using the lower grade. This option will be explored further during the next session of grade reconnaissance.

We took off from the old road grade at station 10+00, and marked the stations back down to the saddle at 18%. Too ease vertical alignment we ran the first 25ft at 12% and the next 25ft at 14%. At station 14+25 there was an apparent slump to the east on a +70% slope. Between stations 14+25 and 14+75 a bench exists, which is approximately 25ft wide, and continues to station 15+25. At station 15+25 an old tractor road is encountered. The tractor road climbs to the east headed toward the landing with the rotting logs. The tractor road also parallels the road from station 15+75 to just past 16+75, at which point the trail fades. The grade continues down at 18% to station 19+25 at, which point the grade reaches the saddle, which is approximately 100ft wide. The grade at this point reduces to 3% and then 9% ending at this point at station 20+25.

A reconnaissance was done at this point and an old road grade was found and followed out. The old road went to the necessary area, however there were indications of current/active slumping and wet areas. We continued to the location of the landing and decided to run a road back around the west side of the ridge and then climb back over a small saddle and continue back toward the old road attempting to avoid slumps. A saddle was reached at station 35+00. At this point we climbed at 15% to station 33+00 in order to avoid a slump in a wet area. The grade was then run at 0% from station 32+75 to 32+25 and then down slope at 10% to station 28+25. From 32+25 to 30+25 the ground up-slope (east) was hummacky, however the trees did not have pistol buts. The grade was changed to 12% at station 28+25 in order to meet the existing road grade. The existing grade was met at station 25+25, there is a slump which is located between stations 26+50 and 25+25. We then continued the old road grade to the saddle, tying in with the previous grade at station 18+00.

The Tar Road

The Tar Road is 21 + 49 stations long it take off from Main Road at station 90 + 84. It accesses setting S27 which is 10 acres.

The Tar Road follows an abandoned grade towards two large landing locations. The old grade is in good shape and will need only minor excavation. One wet area was found between stations 2+00 and 4+00. This area contains Devil's Club, an indicator of excessive soil moisture. There is also slumping apparent, but this area is small and should present no reconstruction problems or excessive costs. The majority of the roadbed is sound and of moderate grade between 0 and 17%. This road will allow access to two major landings that are suited for fan shaped settings. There is also opportunity for parallel settings along the length of the road. This road joins the Himalaya West road at the "Mona Lisa" landing.

Himalaya West Road

The Himalaya West road is 19 + 22 stations long and starts at station 106 + 44 on Main Road. It accesses landing S14a which is 51.5 acres. The side slope ranges from 0 to 80%.

The road begins at large landing area at station 5+00 from Himalayan Traverse. The road curves around the end of the ridge towards the SW. The initial three stations are on an existing grade that is in good condition, stable and relatively flat.

At station 3+00 there is a large landing area, 100' x 50' The road then comes off the landing and transitions from 0% to 10% to 18% grade. Then the 18% grade continues down to the landing at station 17 + 00. At station 8+50 there is a flat area on the ridge, not far off the grade line, where a spur can be placed to access a possible landing. The side hill is solid and stable. Two of the survey crew ran an 18% flag line approximately 400 feet downhill from the landing on the SE side of the ridge to reach another potential landing site.

There will be a take off from this road at approximately station 7 + 00 to access the "Mona Lisa" landing. The section of this road between the take off and the ridge is planned on paper for an easy grade and, therefore, was not flagged in. The grade line for this road begins on the uppermost flat area, potential landing site, on the ridge and progresses west to connect with the "Mona Lisa" landing. The grade line cuts across a hill slope with an average side slope of –70%. A 0% grade was run for the first 3+50 stations and crosses a class 5 stream here. The stream gully is somewhat steep and narrow and may require filling, but the accumulation area above is small, so there should be little problem with water accumulation. The grade, then, continues at 10% for 3+00 more stations to reach the "Mona Lisa" landing. The "Mona Lisa" landing is a broad landing that appears to offer enough room to create a landing and switchback. Another landing was located about 150 vertical feet below the ending point of this road.

6.5.10 Why System

The Why system consist of one secondary road, the Already Road and one spur road, Test 1 Road. These roads provide access to 55 acres in three settings (Figure 41).

Test 1 Road

The Test 1 road is a paper plan only it has not been field verified. It is 22 + 20 stations long and takes off from Already Road at station 8 + 50. Test 1 accesses setting N1 which is 46 acres. Test 1 Road is a paper plan only and has not been field verified

Already Road

The Already Road is 30 + 00 stations long and begins at station 11 + 94 on the Big Rig Road. It accesses settings N2 and N40, which total 9 acres. The side slope varies from 0 to 30%.

The Already Road is flagged in at 12% grade approx. 5 stations from the saddle until it ties in with the Big Ridge Road (station 11+50). The road from the saddle was walked, but not flagged for about another 10 stations. This brought us to a stream that will require a stream crossing. A suitable crossing sight was noted where the ground was dryer than the soil upstream and it was determined that from the stream, the road should proceed at a +5% grade back towards to saddle until the saddle elevation is reached, then change to a 0% grade.

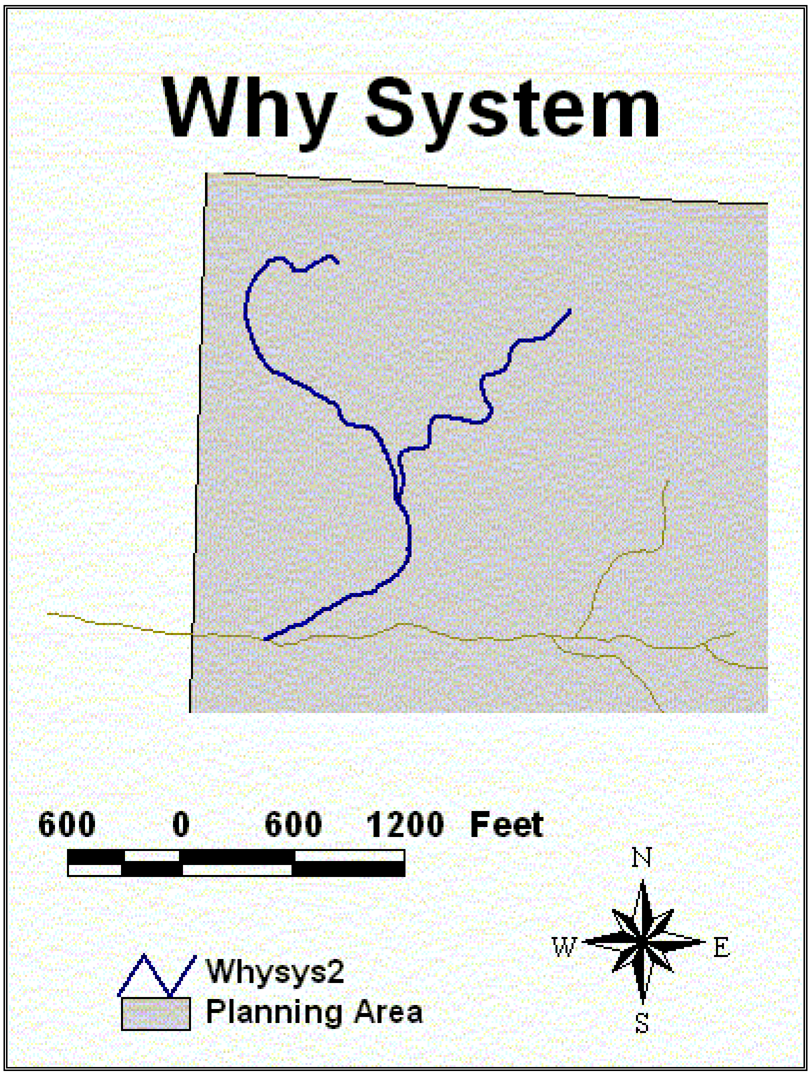


Figure 41 Map of the Why System within the Burnt Mountain Planning Area

6.5.11 End System

The End System consists of the end road. The End Road is 36 + 18 stations long and takes off from the Main Road at station 106 + 44. It accesses settings S28 and S30, which is 125 acres. The road is just a paper plan, it has not been field verified (Figure 42).

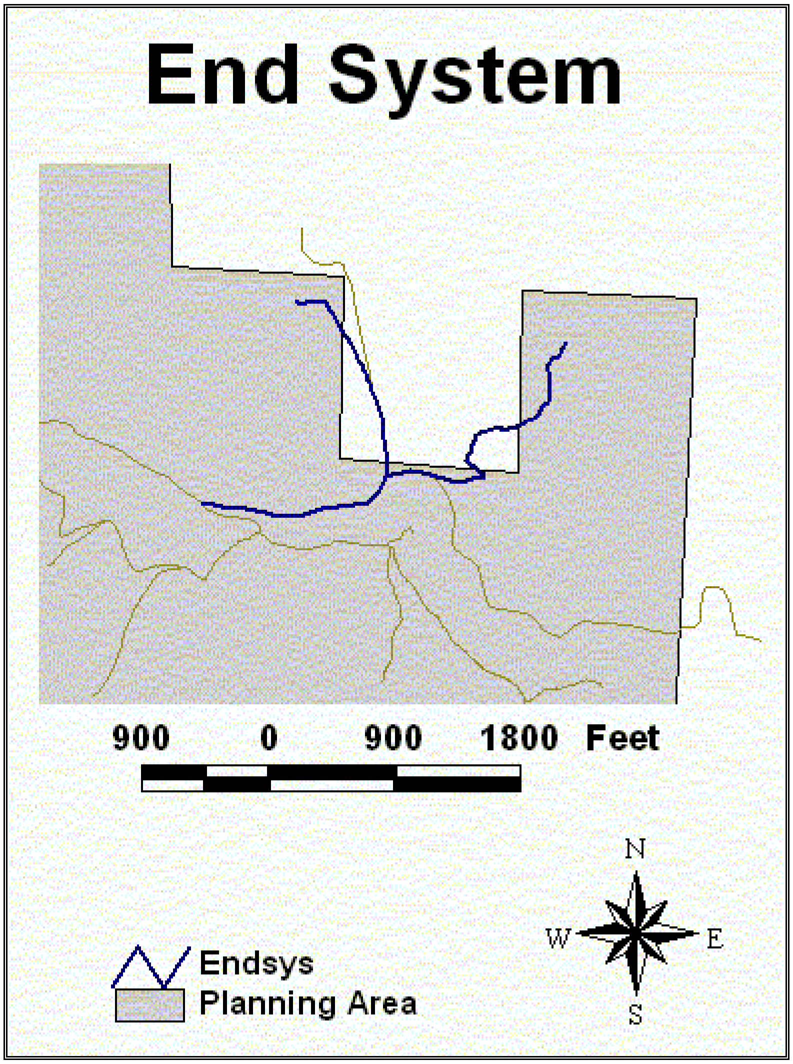


Figure 42 Map of the End System within the Burnt Mountain Planning Area

6.5.12 West System

The West System consists of 109 + 31 stations of road, which includes three secondary roads, Rail Road N, Cool Hand and Rail Road South, and one spur road, Don't Know (Figure 43). These roads access mature timber stands.

Rail Road N

We flagged this road following an existing railroad grade to the first saddle at station eight. The side slope along this section varied from 40-80%. Lyle's road takes off from this saddle to the south. The road leaves the railroad grade and is flagged at 0% for seven stations along the north side of the slope. The side slope averages 50-80%. At station 23 Rail Road South splits off. At station 31 the road reaches a second saddle. The flag line crosses on to private property at station 32 and back onto state land at station 46. The flagged road is 20-30 feet higher than the paper road at stations 43-50 because the ground is unstable, wet and slumping. The side slope of this area is 25-50%. There is a spur take off to a landing at station 58. The timber looked pretty good overall but, at station 49, the trees had quite a bit of mistletoe. We crossed the section line at station 50. We reached a saddle at station 64, this is where we stopped flagging the road at station 65 + 92. A spur goes out to the end of the ridge to a landing.

Cool Hand

Cool Hand is a secondary road, 31 + 85 stations long, that takes off from an existing Crown Pacific road in the SW ¼ of the NW ¼ of T30N R12W Section 12. Cool Hand is a paper plan only and has not been field verified

Rail Road South

Rail Road South starts at station 26 + 36 on Rail Road N Road. Rail Road South is 38 + 86 stations long and accesses mature timber. Most of the stations flagged in are on top of the ridge. We ran into no problems. It is flagged in with the grade staying between 0% and 15%, just as shown on the map. The timber in the area is very large and is one of the older stands of trees that were seen out there. We came across one draw with a type five stream. There should be no problems with the construction of this road. The side slope ranged from 0 to 50%.

Don't Know

Don't Know is a spur road, 11 + 54 stations long, that takes off from an existing Crown Pacific road in the NE ¼ of the NW ¼ of T30N R12W Section 11. Don't Know is a paper plan only and has not been field verified.

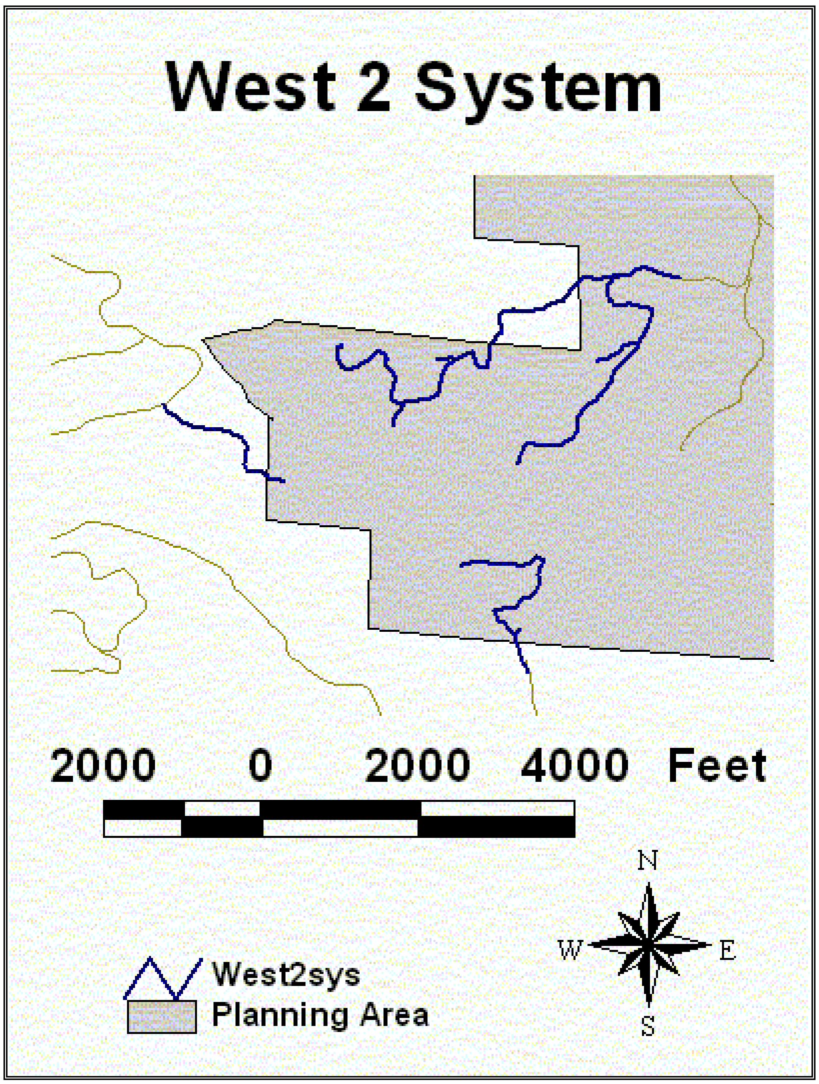


Figure 43 Map of West System within the Burnt Mountain Planning Area

6.6 Cost Analysis

6.6.1 General Cost Analysis

A preliminary cost analysis was performed to determine the total road cost and road cost per station ($/sta). A costing coverage, using the Clallam Bay sale road appraisal information from 1997, was created to determine the total road cost.

This cost analysis can be run in ArcView using the uw_arc and the uw_fris polygon coverages. The "select" feature was used to highlight the road of interest, which highlighted the selected segments in the attribute table of the selected theme. In the table, select the total road cost field and use the field statistics operation, which will give the sum, high, low and other statistics of that field. The sum value is the total cost for the selected sections of road. For a more detailed description of this process, see Appendix 12.4.

An average cost of $100 per station for culverts was used to assist in determining road costs.

6.6.2 Traverse Cost Analysis

For the traversed road, we used the road costing spreadsheet from the 1999 Hoodsport project.

6.6.3 Clearing and Grubbing

This section is based entirely on the average volume per acre along the proposed road. By inserting the appropriate road length and width, the spreadsheet will sub-total the cost for clearing and grubbing. The production factor compares each volume class to the cost of 36-50 Mbf/Acre.

6.6.4 Excavation

By inserting the estimated volume of excavation and specification of the excavation machinery, along with round trip mileage and average speed, this section will cost out the excavation and haul costs associated with the proposed road. The defaults were for a CAT 235 with a two cubic yard bucket and an operator with 95% efficiency and a 10 cubic yard dump truck. The values attained for cycle times were obtained from the Caterpillar Performance Handbook. Again inserting the best information available for your particular region will best estimate true cost of the road.

6.6.5 Ballast and Surfacing

This is the section where local costs most affect the section sub-total. Again, the round trip mileage and average speed were factors along with volume of each grade of surfacing material needed. Sub-grade finishing was taken as a flat rate from recent contractor information.

6.6.6 Culverts

By inputting the number of culverts needed by diameter, this section will compute the cost to purchase and install the needed culverts. The prices were obtained from the Clallam Bay sale, just north of our planning area. The important thing to note here is that the break-even point, based on purchase price alone, between plastic and metal pipes is at 24 inches diameter. Plastic culverts should be purchased below a 24" diameter, and metal culverts should be purchased above a 24" diameter.

6.6.7 General Expenses

This section includes overhead costs associated with road building. This was assumed to be 10% of the above costs. This section DOES NOT include profit and risk. Profit and risk are assumed to be distributed throughout in the hourly costs.

6.6.8 Move in Costs

This section was added to estimate the cost associated with moving a piece of equipment to the construction site. Important here is whether you can distribute the move in cost of this machinery between two or more construction sites. An example would be the crusher and rock drill.

7 Harvest Systems

In order to economically remove timber from the forest, the correct harvest system must be chosen for the terrain. In choosing a system to do this, the capabilities must be adequate for the given situation. This section deals with the harvest systems chosen, why they were chosen, the setting design and analysis process, and the costs associated with each harvest system.

7.1 Systems Selected

Terrain is the leading factor in deciding which systems can be used throughout the Burnt Mountain planning area. Because the planning area terrain is mostly broken and has very little area (less than 10%) that ground based equipment can be used on, we will not be discussing these types of systems in great detail.

The choice of what system to use is dictated by site conditions. On level ground with slopes 0-30 percent, ground based systems can be used when the soil conditions are suitable. If the soil is too sensitive or the slope is greater than 30 percent, cable systems are employed. When the terrain is severely broken or there is no way to get a road to the site, helicopters are used. Ground operations are generally least expensive followed by cable systems, with helicopter logging being the most expensive.

7.1.1 Ground Systems

The terrain in the planning area limits the use of ground equipment. All the ground units in the planning area were analyzed by using two tracked skidders, and a loader. The costs of other ground systems are shown for comparison reasons.

7.1.2 Cable Systems

Cable systems are limited less by the steep topography and more by shape of the ground. Cable systems are best suited for areas where the slopes were between 30% and 100+%. The major limiting factor is shape. A ground profile can be classified as concave, planar, or convex. The ideal ground profile is highly concave. This allows the cable system the greatest deflection, and therefore the highest payloads. The worst case profile is highly convex. This ground shape affords little or no deflection and therefore payloads tend to be uneconomical. In the planar case, deflection can usually be found, but most times this requires rigging a tailhold tree 30-50 feet high and/or through the use of intermediate supports.

For the Burnt Mountain project, five yarders were selected that reflect both what is available on the Peninsula and that represented a good range of size and machine capabilities. Weikko Jaross (DNR project liaison) supplied the planning team with a list of contractors and equipment that operated from across the state. From this list a good idea of what was available in the area for use on possible sales was gained. A total of 13 yarders were found in the area ranging in size from the Koller 501 to Thunderbird TY-90 (See Table 9). From this list we selected yarders that had similar characteristics of those found on the Peninsula, but that we had more information on. The yarders selected can be used for any given situation from small timber thinnings to mature final cuts.

Table 9 Yarder availability. Yarders in operation near planning area

YARDERS IN USE ON THE PENINSULA	
Yarder	Count
Christy	1
Diamond 210	1
Koller 501	1
Madill 071	1
Madill 171	1
T-Bird 225	2
T-Bird TY-70	2
T-Bird TY-90	3
Urus	1

The Koller 501 is the smallest of the discussed yarders both in tower height and horsepower. The Christy is a smaller yarder that is used in thinning mostly. This yarder was used to define the stump to truck costs. Then a conversion factor was applied to these numbers to convert the costs to the yarders used in the analysis. The 6150 is a fairly versatile yarder that can be applied in late thinnings and final cuts efficiently. Its swing capabilities allow its use on road landings. The larger Madill 172 was first looked at for final cut analysis. Partially through the analysis the emphasis changed to focus more on thinnings than final cuts. When this happened the capabilities of the Madill were inappropriate for a thinning operation.

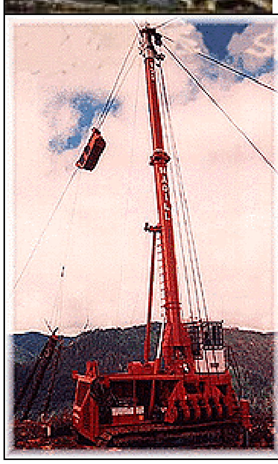
	**Koller 501, Truck mounted** • **Tower Height: 33 foot** • **Yarding Distance: 1600 feet** • **Hourly Operating Cost: $102** • **Purchase Price: $133,500**
	**Christy Yarder** • **Tower Height: 50 foot** • **Yarding Distance: 2000 feet** • **Hourly Operating Cost: $162** • **Purchase Price: $215,000**
	**Thunderbird 6150.** • **Tower Height: 50 foot** • **Yarding Distance: 2000 feet** • **Hourly Operating Cost: $188** • **Purchase Price: $395,000**
	**Madill 172** • **Tower Height: 72 feet** • **Yarding Distance: 2600 feet** • **Hourly Operating Cost: $ 247** • **Purchase Price: $585,000**

Figure 44 Yarders used in analysis.

7.1.3 Helicopter Systems

The major benefit of a helicopter system is that it doesn't need road access into the unit. This can be a huge benefit in steep, remote areas where road building is too costly or physically unfeasible. The first limiting factor of this harvest system is its landing size requirement. A good helicopter landing must be at least four acres in size. This is to accommodate both the landing/decking of logs as well as the refueling of helicopters. The second limiting factor for this system is external yarding distance. For helicopter yarding the maximum, economical external yarding distance is approximately one mile.

7.2 Setting Design and Analysis Process

Designing settings follows a well-defined pattern. First, possible sites for landings were found. Then roads were designed to link the landings. The first settings were chosen with regeneration harvest in mind that could be reached with a 50 foot or 70 foot tower. Profiles were analyzed and verified in PLANS and LoggerPC, both of which are profile verification programs. The existing road and landing system were broken into settings that would work for thinning operations that would utilize a 50-foot tower only. Of these thinning setting, the ones that could successfully be reached with a 33-foot tower were identified. With this known, it allows for more bidders to vie for a timber sale.

7.2.1 Setting Boundary Methodology

The boundaries for the settings were designed keeping many things in mind. Four logical guidelines to the setting design boundaries were used to best divide the harvest area into units. These guidelines were met whenever possible and sometimes compromised on when impossibilities arose.

1. Try to make anchor points and landings on the ridges. This will utilize spans from ridge to ridge.

2. Streams were often used as unit boundaries

3. Roads were made boundaries to facilitate the use as continuos landings.

4. Timber type and class were made as boundaries in some cases.

The specifications that were used in PLANs concerning the individual yarders can be seen in Table 9. These yarder files can also be found in the \settings\lpc_yarder_carrige directory. In general, the minimum ground clearance was 2 feet, the carriage height was 42 feet (this was determined by saying that the log was 32 feet long, with 8 foot chokers and 2 feet of ground clearance) and the tailhold was set at a height of 2 feet. The desired payload was dictated by the silviculture information. This is discussed in further detail in the silviculture section.

PLANs asked for the following information:

- Max slope rigging distance (ft)
- Desired payload (lbs)
- Min. required ground clearance (ft)
- Carriage height when logs fly clear (ft)
- Carriage weight (lbs)
- Tower height (ft)
- Tailhold height (ft)
- Allowable skyline tension (lbs)
- Skyline weight (lbs/ft)
- Mainline weight (lbs/ft)

Table 10 Yarder Specifications

	MADILL 172	T-BIRD 6150	CHRISTY	KOLLER 501
Tower Ht.	72 ft	50 ft	50 ft	33 ft
Mainline Length	2900 ft	2300 ft	2100 ft	1800 ft
Mainline Dia.	7/8 in	5/8 in	5/8 in	1/2 in
Mainline Wt.	1.42 lbs/ft	0.72 lbs/ft	0.72 lbs/ft	0.46 lbs/ft
Haulback Tension	19600 lbs/ft	8900 lbs/ft	6800 lbs/ft	6800 lbs/ft
Haulback Line Wt.	1.04 lbs/ft	0.46 lbs/ft	0.35 lbs/ft	0.35 lbs/ft
Haulback Dia.	3/4 in	1/2 in	7/16 in	7/16 in
Skyline Length	2600 ft	2000 ft	2000 ft	1600 ft
Skyline Dia.	9/8 in	7/8 in	3/4 in	3/4 in
Skyline Wt.	2.34 lbs/ft	1.42 lbs/ft	1.04 lbs/ft	1.04 lbs/ft
Skyline Max. Load	26500 lbs	13700 lbs	13700 lbs	8900 lbs

7.2.2 Final Harvest Settings

With these guidelines in mind, the task of setting boundaries was started. First a contour map of the planning area was printed. Prospective landings were scattered throughout the planning area wherever the ground permitted their placement. Then roads were drawn to access these landings. Those landings that couldn't physically be accessed by roads were eliminated. Now the landings were digitized into PLANS with central landing being selected for analyses. These profiles were looked at to see the acreage that could be reached from each landing. By manipulating these profiles regeneration-setting boundaries were set to cover the entire planning area. Two sets of settings were created. (These settings can be found on the CD in the \settings\regen_50_set or regen_70_set directory). One that was comprised of 70 foot towers (Figure 46), and one that was made up of 50 foot tower settings (**Figure 45**). These settings formed the basis for a detailed thinning setting boundaries analysis. The approach is based on the assumption that final harvest will utilize the same road system as the thinning operation.

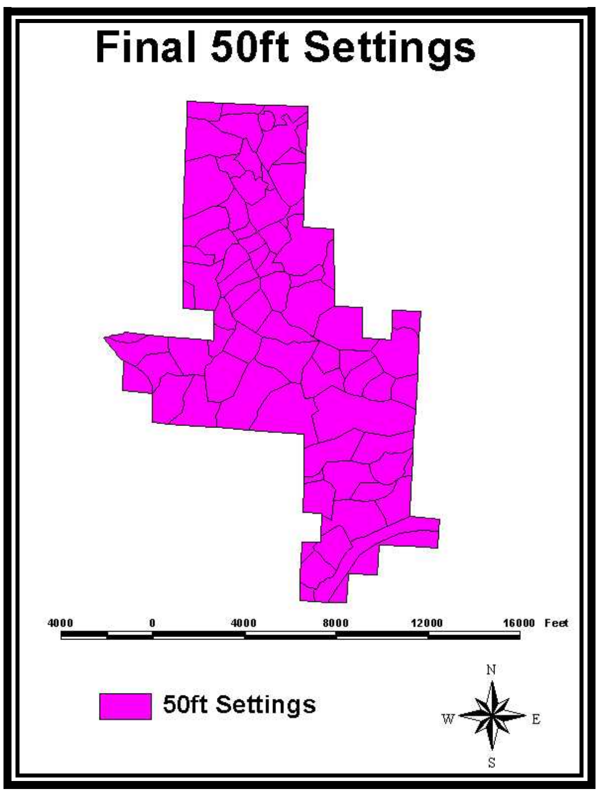


Figure 45: Final Cut Settings based on 50 ft tower heights

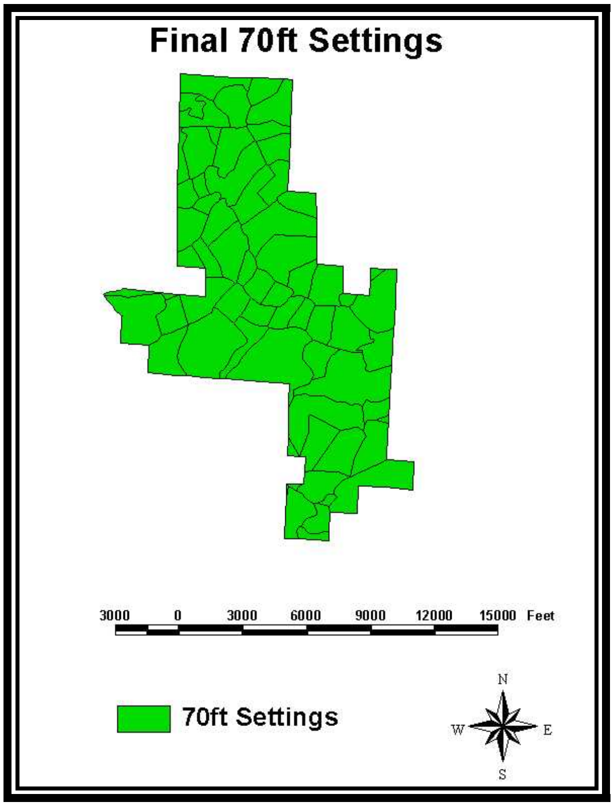


Figure 46: Final cut units based on70 Foot Tower Settings

7.2.3 Thinning Settings

The thinning design had some specific requirements that had to be met. The landings that were to be used had to be on roads with less than ten-percent grade. Another limiting factor to the location of the landings was that no roads could be created solely for thinning because of cost. This means that the roads that must be used are the roads plotted out for the final cut design. The DNR provided an outline of which areas could be thinned. The boundaries for thinnings were made slightly different than the final cut settings. A map was printed with the contours, existing roads and landings on it. Then single profiles were drawn throughout the planning area to cover all the ground. These profiles were digitized into PLANS to see if the requirements were met. From this the boundaries were established. (These settings can be found on the CD in the \settings\thinning_set). Further information on number of settings, yarding distances, size of units, and other related information can be seen in the appendix titled Variable Density Thinning For Whole Tree Logging. The settings are shown in **Figure 47**.

External Yarding Distance (EYD) affects production and production costs. For this reason special attention must be paid to the profile corridor lengths. The length of the profiles ranged from 500 feet to 3000 feet long. There were about 30 profiles that were 500 feet long, 90 that were 1,000 feet long, 85 that were 1,500 feet, 25 that were 2,000 feet, 5 that were 2,500 feet long and 1 that was 3000 feet in length. About half the profiles run were less than or equal to 1000 feet long. The other half were 1,500 feet or greater in length. These profile lengths are summarized in figure 46.

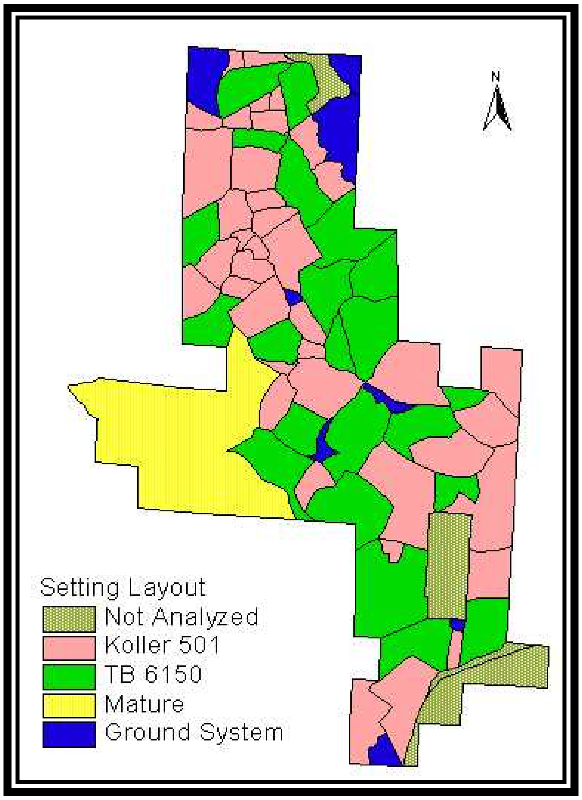


Figure 47 Thinning Setting based on Koller 501 and TB-6150 yarders

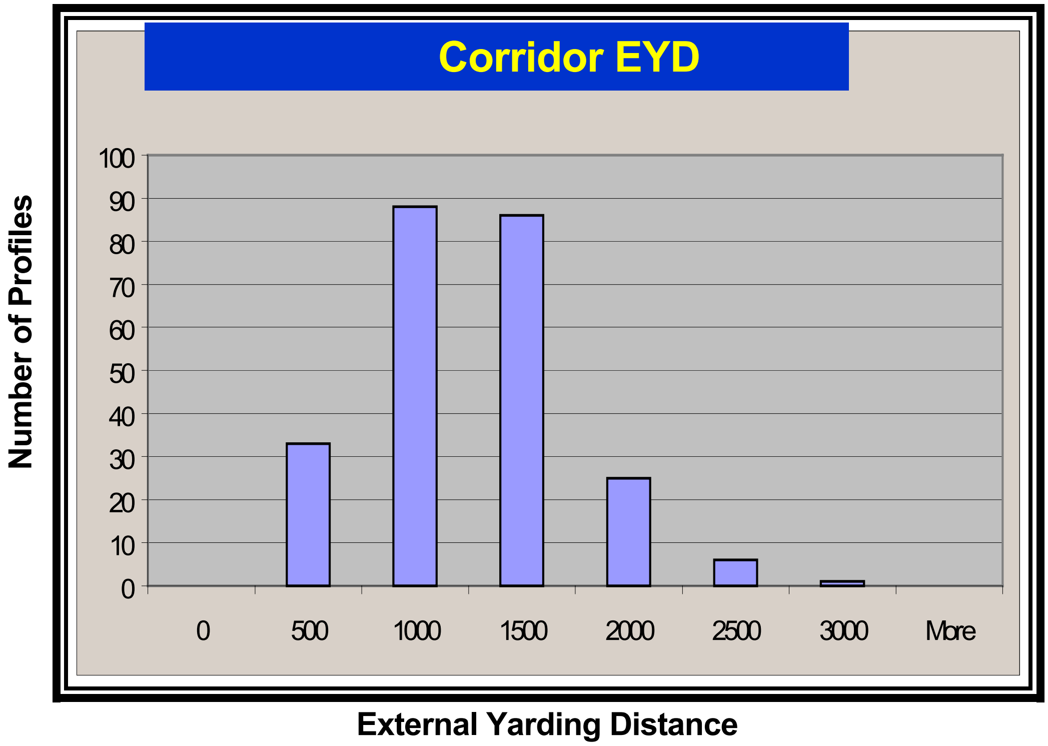


Figure 48 Profile lengths distribution for the thinning settings

7.3 Profile Verification

Each profile had to meet specific requirement for this project. They had to have sufficient reach and adequate deflection with a set payload. The profiles for each setting design were checked to make sure there was adequate clearance over streams and that desired payloads were achieved. If these goals weren't met, the profile was changed.

Once the initial boundaries for the settings were chosen, verification whether they would meet the required goals were performed. The settings were broken into several profiles and then these profiles were analyzed in PLANS (Preliminary Logging Analysis System). These profile verifications can be found on the CD in the \settings\verified_profiles directory) and can be seen in Figure 49. PLANs takes the DEM's (Digital Elevation Model) and the specifications of a given yarder and analyses how the yarder will perform on the given terrain. Each yarder used in the analysis had its own specifications.

To find out if the chosen cable sides where feasible, several profiles were run in PLANS. Once it was established that the majority of timber could be yarded with these systems the owning and operating costs were found by using the World Forest Institute (WFI), and the UW Logging Equipment Costing Program models.

The desired payload was set at 5,000 lbs to ensure that any plausible payload was achievable for the chosen system. The silviculture data indicated that this was twice as much as could be expected for any thinning in the planning area. Along with having an added measure of confidence that the system would perform as expected this also allowed some leniency of when the areas could be harvested. If it is decided that a setting is not to be harvested for several years the analysis will still be feasible.

To further analyze profiles that initially didn't meet the requirements previously stated, LoggerPC was used. This program enabled the user to analyze multispan systems, which wasn't possible in PLANS. Using PLANS we were able to plot the landings and tailholds directly in the computer without using the digitizer. This was done in PLANS by bringing up a contour map of the planning area and by placing points for both the yarder and tailhold on the map. Once these points were entered, PLANS could be run in a conventional manner to analyze each profile. After the locations of the landings and tailholds were done, they could be pulled up in LoggerPC if they need to be analyzed with intermediate supports by using a conversion aml (this aml can be found on the CD in \settings\arc2lpc_conversion_amls). 240 profiles were checked one by one for stream clearance and payload. If the spans were not possible they were eliminated. Most spans could be manipulated to fit the profile with decent payloads. Determining the thinning unit involved analyzing the possible profiles and mapping out the area.

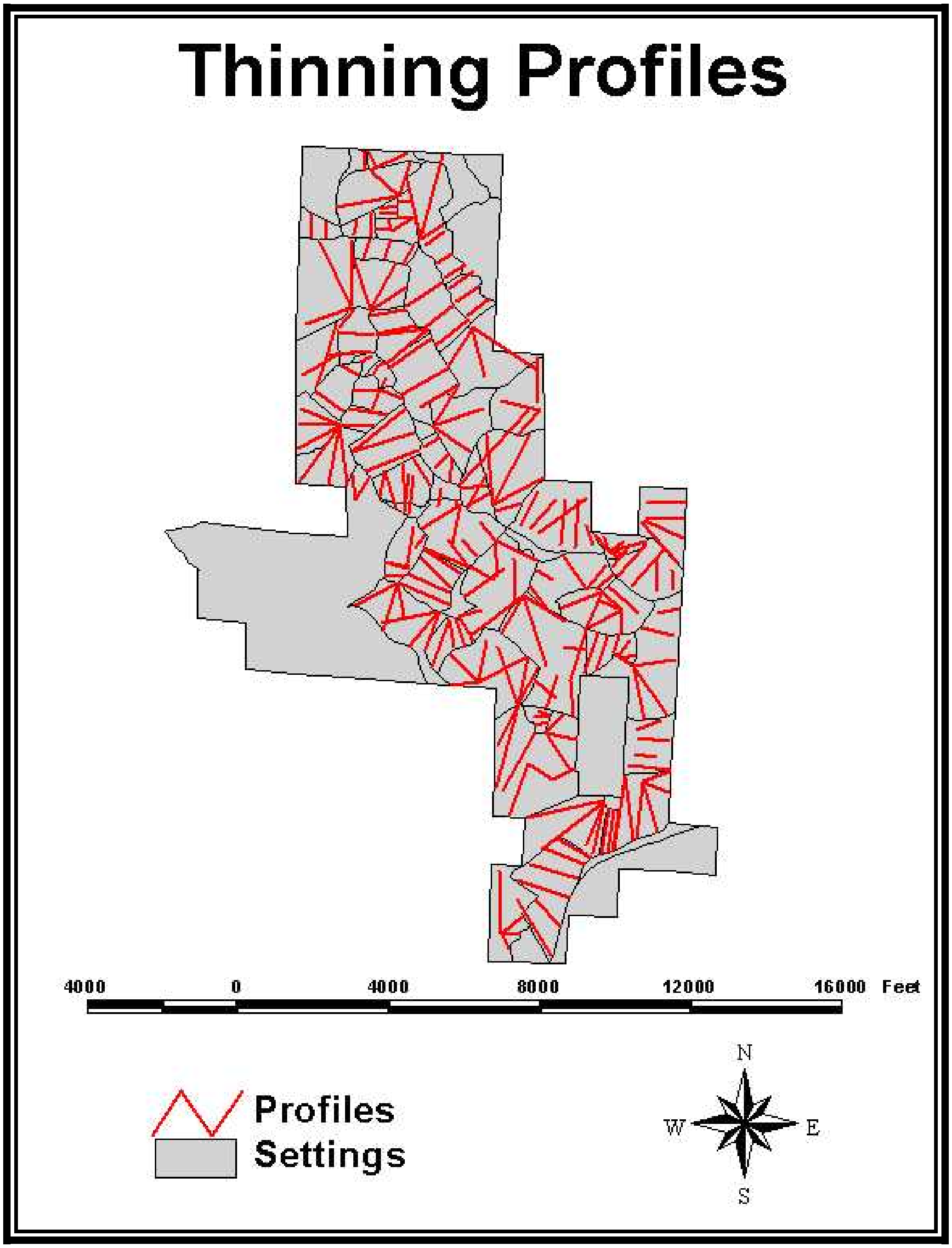


Figure 49 :Thinning Profiles Locations. They were manually placed and later analyzed in LoggerPC.

7.3.1 Confidence in Analysis

The DEM accuracy needed to be verified to ensure that the work being performed in the office was a viable alternative to walking every profile. Single profiles were randomly selected for verification in the filed. The field profiles were then compared to the DEM profiles. The DEM seemed to smooth out the more critical points of the profile, making them less noticeable. To ensure that the planned profiles would work in the field a payload of 5000 lbs was used. The use of 5000 lbs payloads gave a reasonable factor of safety that our planned profiles would work since the calculated payloads ranged from a low of 800 lbs to a maximum of 3000 lbs.

7.3.2 Helicopter Settings

Helicopter settings were created by logically grouping the individual thinning settings into seven larger settings. If possible the landing location was kept at a lower elevations because helicopter yarding is more efficient down hill. Ridges became natural boundaries. These settings can be found on the CD in the \settings\heli_set directory, or seen in **Figure 50**. Setting size varied from 210 acres to 606. The average flight distances of each unit ranged from 1750 to 2550 feet. This information can be seen in Table 11.

Table 11 Helicopter Unit Statistics

	UNIT 1	UNIT 2	UNIT 3	UNIT 4	UNIT 6	UNIT 7	UNIT 8
Acres	284	210	434	301	306	436	606
Avg. Flight Dist.	2050	1750	1950	2200	2400	1950	2550
Elev.	1187	1070	5470	5813	1179	1379	1123
Landing Elev.	1100	800	1400	1150	1500	1500	720

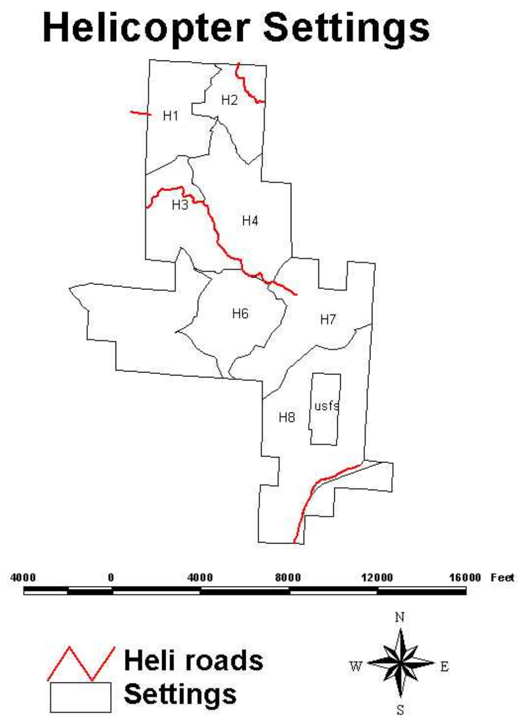


Figure 50 Helicopter thinning settings

7.4 Harvest System Owning and Operating Costs

7.4.1 Costing Models Used

The WFI model requires some broad categories to be chosen from. You must choose a logging system, and a delimbing method. The only thing that needs to be verified is that the purchase price of the machine in question is correct. This can be done by looking at the SkyAp89 spread sheet that is found on the Forest Services web page. The only default that needs to be changed is the fuel cost and the days of operation. We used $1.30 and 220 for each respective field.

To determine the costs of these systems, the UW Logging Equipment Costing Program, in conjunction with the WFI model were used. For the helicopter costs, a past DNR helicopter sale was looked at. In these programs all the side information can be entered into an easy to use interface and an hourly operation cost can be derived. Most of the equipment picked was made by CATERPILER because of the vast information that is available from that company's performance handbook. If a specific piece of machinery not made by Cat that was in significant use in the area was indicated by the contractor list, a comparable machine that was made by CAT was selected so that performance information could easily be obtained.

7.4.2 Purpose

By combining the equipment costing information with the production information we can obtain the contractor's cost per unit volume and/or cost per day. This is particularly useful when reviewing timber sale bids. If the low bid is significantly lower than expected, it may be cause for further review.

7.4.3 Method

To better estimate costs, we included all equipment, owning and operating, and overhead cost associated with a sale. To do this we determined all the equipment that is required for a "typical" timber sale. The equipment was combined in several different systems in order to capture any given situation that presented itself. The cable systems were divided into systems that could yard large, medium, and small wood. Then each one of these was divided into whether it was traditional or semi mechanized. The Ground systems were divided into thinning and final cuts. The skidder operation was then split into traditional and semi-mechanized. You have a traditional and mechanized shovel side, and a cut to length side. The helicopter was divided into thinning and final cut categories. Then each of these categories was cut into short, medium, and long yarding distances. A break down of what each one of these is comprised of is seen below. Table 12 shows the basic components of each side.

- *Traditional Cable, Long Distance*: Madill 071, 1 Cat 330 loader, Eagle Eaglet carriage, hand fellers/buckers.

- *Traditional Cable, Medium Distance*: Thunderbird 6150, 1 Cat 330 loader, Eagle Eaglet carriage, hand fellers/buckers.

- *Traditional Cable, Short Distance*: Koller 501, 1 Cat 330 loader, Eagle Eaglet carriage, hand fellers/buckers.

- *Semi-mechanized Cable, Long Distance*: Madill 071, 1 Cat 330 loader, Eagle Eaglet carriage, hand feller, delimber.

- *Semi-mechanized Cable, Medium Distance*: Thunderbird 6150, 1 Cat 330 loader, Eagle Eaglet carriage, hand feller, Cat 320 stroke delimber.

- *Semi-mechanized Cable, Short Distance*: Koller 501, 1 Cat 330 loader, Eagle Eaglet carriage, hand fellers, stroke delimber.

- *Skidder Traditional*: 2 Cat 517, 1 Cat 330 loader, hand feller.

- *Skidder Semi-mechanized*: 2 Cat 517, 1 Cat 330 loader, 1 Cat 320 Feller/Buncher.

- *Shovel:* 2 Cat 325, 1 Cat 330 loader, 1 Cat 320 Feller/Buncher.

- *Mechanized:* 1 Timberjack 1270, 1 Timberjack 1110, Cat 330.

- *Helicopter*: 1 Bell 204 helicopter, 1 Cat 330 loader, hand fallers.

Table 12 Harvest System Components Equipment that is used for each respective system

SYSTEM	YARDER	HELICOPTER	SHOVEL	SKIDDER	FELLING/BUCKING
Cable	1	0	1	0	Manual/Manual
Shovel	0	0	2	0	Feller Buncher/ Stroke Delimber
Tracked Skidder	0	0	1	2	Feller Buncher/ Stroke Delimber
Helicopter	0	1	1	0	Manual/Manual

.

The owning and operating costs for each system can be seen in

Table 13. These numbers were generated by using theWFI costing model. The Large Wood designation refers to the Madill 172 used in a final cut situation. Medium wood would be removed with the TB 6150 under large thinnings or partial cut situations. The small wood term refers to a situation where a smaller yarder such as Koller is yarding smaller timber in a thinning only operation.

Table 13 Owning and Operating Costs The hourly cost of owning and operating for each system

HARVEST STYSTEMS COST PER HOUR			
CABLE SYSTEMS			
	Traditional	Large wood	$314/hr
		Medium wood	$288/hr
		Small wood	$210/hr
	Semi-Mechanized	Large wood	$360/hr
		Medium wood	$334/hr
		Small wood	$248/hr
GROUND SYSTEMS			
	Traditional	Thinning	$172/hr
		Final Cut	$181/hr
	Semi-Mechanized	Thinning	$218/hr
		Final Cut	$227/hr
	Shovel	Traditional	$160/hr
		Mechanized	$280/hr
	Mechanized	Thinning	$226/hr
		Final Cut	$226/hr
HELICOPTER			
		Thinning	$2580/hr

7.4.4 Helicopters

Helicopters are unique in that they require different aspects to be taken into account when analyzing cost. In order to determine what it would cost to harvest with helicopters, a similar sale in Capital forest was analyzed. The Larch Canyon sale was similar in flight distance, crew size, timber conditions and landing selection. The cost per MBF came out to $360. In the Capital Forest sale a Bell 204 helicopter was used with a crew that consisted of 2 cutters, 4 choker setters, one loader and one processor, and 2 chasers. The sale was 569 acres in size and produced 6.2 MBF per acre of cut wood. Whole tree logging was performed with an average piece size of 38 feet long with a small end diameter of 5 inches. On average, a turn was made up of three pieces with an average turn weight of 1300 pounds. A section of road 1.5 miles in length was used as a continuous landing.

PRODUCTION COSTS $/TON (actual contracted costs)

- Felling $03.25
- Loading $05.50
- Flying $37.50
- Hauling $06.00

The Stand was about 33 years old with 420 trees per acre and a stand index of 118. The elevation of the sale was about 2500 feet. There were Douglas Fir, Noble Fir, Grand Fir, and Hemlock present. They thinned down to about 100 to 130 trees per acre, ending with a final relative density of 36% to 40%. The $360/MBF is based on this sale. According to WFI the cost of this type of sale is anywhere between $400 to $500 per MBF. Helipace was used to generate numbers that reflected the conditions found on Burnt Mountain. The results that Helipace produced where $220-$240 per MBF. After talking to Jim Neal (formerly a member of the Helicopter Association and co-author of Helipace) he indicated that for the conditions of the planning area a range of between $300 and $400 per MBF would be appropriate. However without a site visit, he could not provide a better estimate. Rick Toupin (Region 6 helicopter expert) indicated that the load factor is a sensitive parameter and needs special attention. Other important inputs into figuring costs in Helipace are the average flight distance, elevation, turn size and amount of wood harvested. Information for each unit can be seen in Table 13. An accurate number for this parameter was not derived, so the results of Helipace are in question. Because of this, more analysis is needed to determine the feasibility of helicopter logging in the Burnt Mountain planning area.

Table 14 Helicopter Units Pertinent information needed to find the cost of operation helicopter systems. Cost to harvest is based on a stump to truck cost of $360/MBF.

	UNIT 1	UNIT 2	UNIT 3	UNIT 4	UNIT 6	UNIT 7	UNIT 8
Acres	284	210	434	301	306	436	606
Avg. Flight Dist.	2050	1750	1950	2200	2400	1950	2550
Elev.	1187	1070	5470	5813	1179	1379	1123
Landing Elev.	1100	800	1400	1150	1500	1500	720
Helicopter	Bell 204	Bell 204	Bell 204	Bell 204	Bell 204	Bell 204	Bell 204
Crown Closure	50%	50%	50%	50%	50%	50%	50%
Scaling Defect %	5	5	5	5	5	5	5
Log Avg.gross scale BF	74	94	48	73	55	57	28
lbs/gross BF	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Logs per turn	3.5	3.5	3.5	3.5	3.5	3.5	3.5
residual tree ht	100	100	100	100	100	100	100
Cutters	4	4	4	4	4	4	4
woods and landing crew	5	5	5	5	5	5	5
loaders with operators	2	2	2	2	2	2	2
MBF harvested	2556	2520	2170	1806	2142	2616	3636
Cost to harvest ($360/MBF)	920,160	907,200	781,200	650,160	771,120	941,760	1,308,960

7.5 Conclusion

The systems chosen are representative of what is available in the vicinity of the Burnt Mountain planning area. Each system was selected because it demonstrated the capabilities of a wide variety of systems. Each system has been thoroughly analyzed with several different costing models in several different ways. Confidence is high that the correct costs are associated with these systems and that with these costs the correct owning and operating costs have been generated.

8 Stump to Truck Yarding Costs

This chapter includes four sections summarizing the stump to truck costs for each silvicultural option explored. It is followed by a detailed comparison of alternative yarding systems including helicopter logging and a long-span cable yarding. The four silvicultural options explored are as follows:

1. Single density thinning
2. Variable density thinning
3. Variable density thinning utilizing whole tree yarding
4. Regeneration Harvest

Each setting is analyzed separately in each of the four cases. The cost results for the individual settings can be found in appendices 12.8-12.10. Figure 51 shows the settings used in the analysis and their identifying labels. The white areas are not considered for harvest because of either power line obstruction or Forest Service land. The large area in the southern west region marked with a zero is older aged uneven aged stands. This does not meet the requirements for research and monitoring.

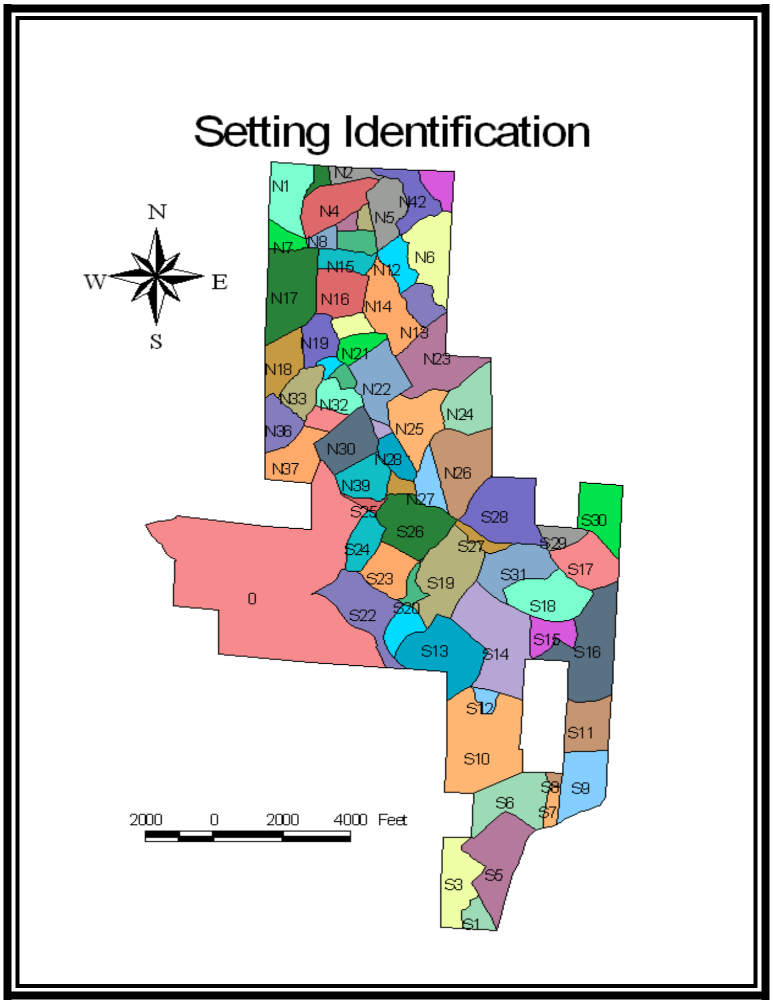


Figure 51 Setting Identification: Shows the setting number for all settings analyzed. A '0' indicates that this setting is not analyzed. It represents older uneven aged stands. The settings considered for thinnings are 40-60 year-old even aged stands. The white section in the southern area is forest service land. The area shown in white in the bottom right corner is under power lines or young aged stands. This is why it is not considered for harvesting.

The inputs for determining the stump to truck yarding cost are categorized into three types:

1. Setting inputs – varying from setting to setting

- Uphill/downhill yarding
- Average EYD

- Area
- Parallel/Centralized Landings
- Number of intermediate supports
- Number of skyline anchors

2. Yarder inputs – varying from yarder to yarder

- Owning and operating cost
- Line speeds
- Crew size

3. Silvicultural inputs – varying from prescription to prescription

- Turn Volume
- Harvest Volume

The specific setting input values are found in appendix 12.8 and on that setting's particular spreadsheet which may be found on the Burnt Mt. Harvest Planning CD under /production/cost/. The input variables are calculated in the following ways. Sample profiles are digitized using PLANS or LoggerPC and are analyzed for payload and terrain feasibility. From these profiles, uphill/downhill determination is made by visual inspection on contour maps. These same profiles are made into ARC coverages where the arithmetic mean is taken for the average length of the profiles within a setting resulting in the average external yarding distance (EYD). The average EYD throughout the whole planning area is 960 ft. The area of a particular setting is taken from shapefiles made in ARC also. The determination of a parallel versus fan-shaped setting is made by visual inspection of the landings and profiles within the setting. The number of intermediate supports is determined based on analysis in LoggerPC. Where the terrain or payload does not meet requirements, intermediate supports are added to suffice these requirements. The number of skyline anchors is two in all cases analyzed.

Determining the yarder to be used depends on terrain and availability. All possible yarders and their specifications can be found in the Harvest Systems chapter. For the initial stump to truck cost analysis, all yarder input specifications are based on the Christy yarder. In the case that a different yarder needed to be used as a result of terrain clearance or availability, the costs were converted using the yarder cost conversion ratios shown below. Reference appendix 12.6 for explanation of these conversions.

When converting from a cost associated with the Christy yarder to a cost associated with the:

Thunderbird 6150	multiply by	0.853
Koller 501	multiply by	1.147

The crew size is 4.5 in all cases analyzed. This accounts for a yarding engineer, loader operator, two choker setters, a chaser, and cutters.

Many of the output costs in this chapter are compared with the going mill price. This is considered to be $430/mbf. This number was reached in the following way. Hemlock has a current price of $425/mbf, spruce $410/mbf, and Douglas Fir $475/mbf. The silviculture data determined the percentage of harvestable volume of each of these species. A weighted average was then taken to determine the mean pond price.

Inputs varying between each silvicultural prescription are summarized under that prescription heading in the sections to follow. The specific data for each setting can be found in appendix 12.8. The averages for the turn volumes and harvest volumes in this chapter are taken for only the settings analyzed in Figure 51. This is why values differ from those stated in the silviculture chapter. The first silvicultural option explored is single density thinning.

8.1 Single Density Thinning

8.1.1 Inputs

The silvicultural inputs are received from the silvicultural data collected. These values changed from setting to setting, but the averages and ranges are found in Table 15.

Table 15 Silvicultural Input Summary for Single Density Thinning. The average harvest volume throughout the thinning area is 3.7 mbf/acre. Values range anywhere from N/F (non-feasible), which means that this setting is not even considered because of the lack of timber, to 7.4 mbf/acre. The turn volumes average 102 bf/turn throughout the area. These values range anywhere from N/F to 138 bf/turn.

Input	Average	Maximum	Minimum
Harvest Volume (mbf/acre)	3.7	7.4	N/F
Turn Volume (bf/turn)	102	138	N/F

Harvest volumes for the single density thinning prescription range from 0 to 7.4 mbf/acre with an average of 3.7 mbf/acre. This volume is very low and accounts for the high cost associated with this thinning regime. The turn volume is also low with an average of 102 bf/turn. This equates to low turn weights. In this case the payload is only 1100 lbs. This is another reason for the high cost of harvesting with these thinning prescriptions. These high costs are shown in the following paragraph.

8.1.2 Cost Results

Figure 51 illustrates the stump to truck yarding cost for each setting. They are categorized into high, medium, and low associated cost. The hatched region is not analyzed. They are either already cut, other land property, or standing mature timber that is not considered for thinning.

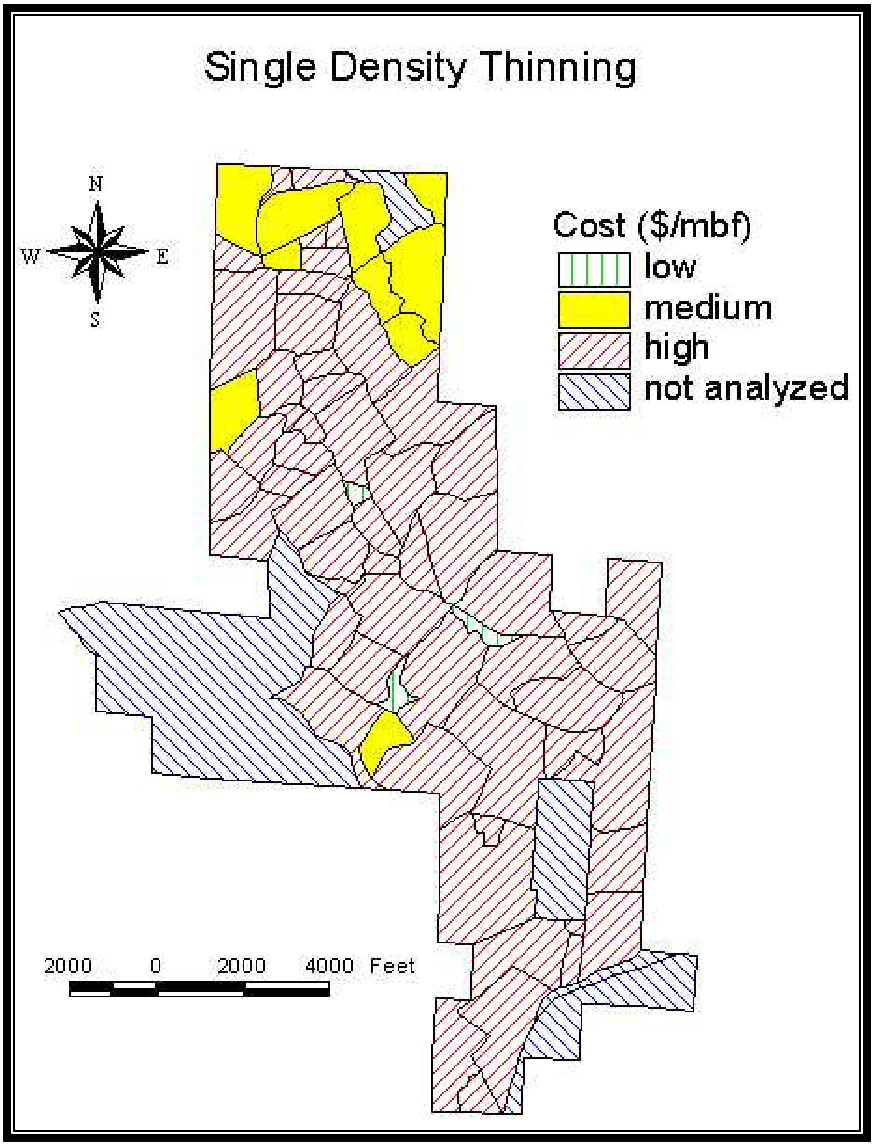


Figure 52 Cost by Setting for Single Density Thinning: The hatched red zones imply that most of the area has a high cost to harvest stump to truck. This value represents at or above mill price ($430/mbf) not including road costs. There is little area that is in the $200-$400/mbf range that is shown in solid yellow. The only low cost settings are represented in green vertical stripes.

The high cost is equal to stump to truck cost of over $400/mbf. Yellow represents costs from $200-$400/mbf. Green represents the setting that cost less than $200/mbf. After adding a haul cost to the "high" settings, their cost will already be over the going mill price of $430. After adding road cost in these settings will well exceed any cost feasible situation. These settings in red are exceeding helicopter system costs.

8.2 Variable Density Thinning

8.2.1 Variable Density Thinning Inputs

The silvicultural inputs for the variable density thinnings are shown in Table 2.

Table 16 Silvicultural Input Summary for Variable Density Thinning: The average harvest volume throughout the thinning area is 8.4 mbf/acre. This is twice as much as with single density thinning. Values range anywhere from N/F (non-feasible), which means that this setting is not even considered because of the lack of timber, to 15.0 mbf/acre. The turn volumes average 128 bf/turn throughout the area. These values range anywhere from N/F to 200 bf/turn. This is not considerably higher than that of the single density thinning.

Input	Average	Maximum	Minimum
Harvest Volume	8.4	15.0	N/f
Turn Volume	128	200	N/f

Average harvest volume for variable density thinning is 8.4 mbf/acre. That is about twice as much than the single density thinning but the turn volumes are not that much more at only 128 bf/turn. This does not improve the production significantly and is reflective in the cost results shown in Figure 53.

8.2.2 Cost Results

Stump to truck cost results for the variable density thinning analysis are shown in Figure 53. The same classifications were used here as in the single density thinning settings in Figure 51.

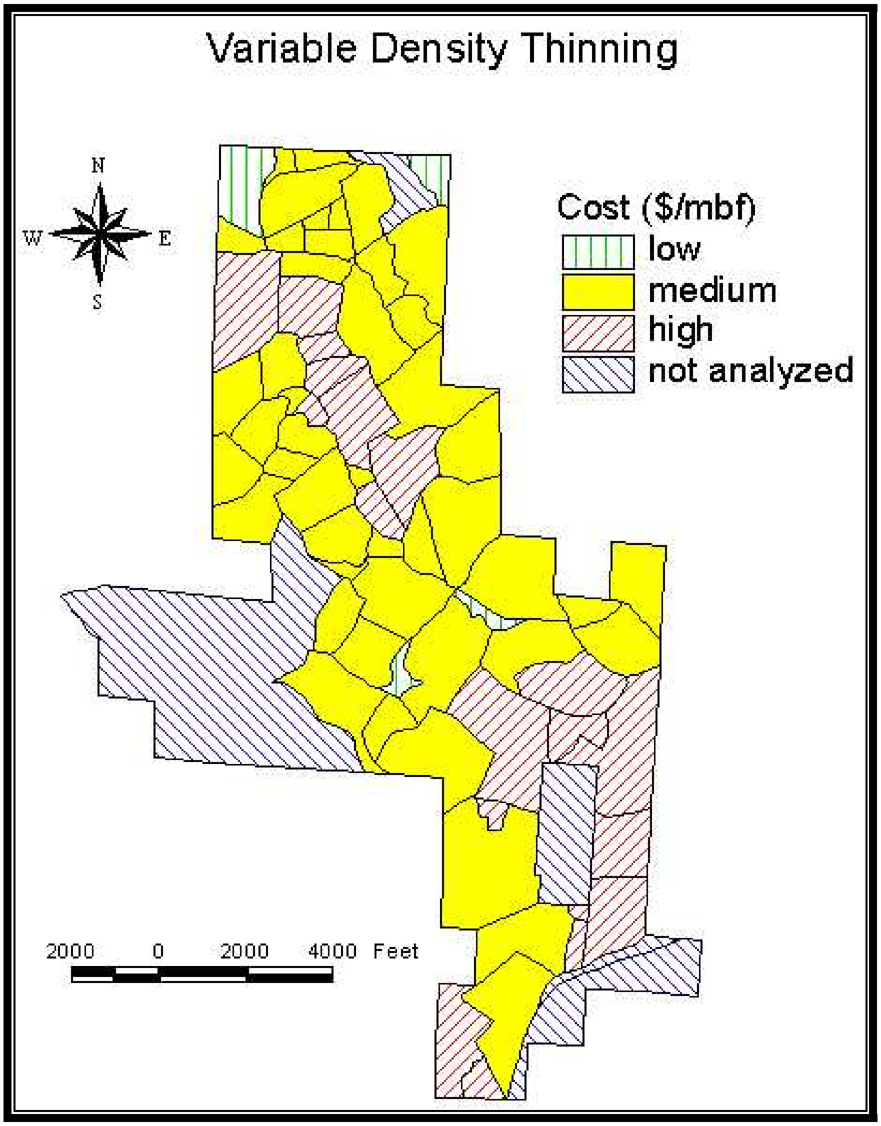


Figure 53 Cost by Setting for Variable Density Thinning: The greatest amount of area is represented by the solid yellow color with the stump to truck costs ranging from $200-$400 /mbf. There are still very few settings that have a low stump to truck cost; represented by the vertical green shaded area. There are nineteen settings that are near or above a going mill price o $430/mbf.

The majority of the settings cost between $200/mbf and $400/mbf. With expensive road costs, most of these settings will be cost prohibitive. The going mill price is $430. After only adding haul cost many of these settings in yellow exceed this price. Reference Figure 53 for more details.

For comparison of typical model outputs, different costing programs are used for comparison. One of which is the Logging Cost Estimates made by WFI. Value outputs are not as precise as the model used in the planning team's program. The WFI model gives the same results for different external yarding distances. The output is also in truckloads per day. A typical output for a medium tower at a reasonable stump to truck cost of $300 gives about three truckloads per day. This equates to about 11,000 board feet. These values are slightly lower than that of model used by the planning team.

Table 17 Samples from the Logging Cost Estimates program made by WFI. This program does not distinguish between external yarding distances.

Tower size	EYD (ft)	2 truck loads	3 truck loads	4 truck loads	5 truck loads
Medium tower	400	448 ($/mbf)	299 ($/mbf)	224 ($/mbf)	179 ($/mbf)
Medium tower	800	448	299	224	179
Medium tower	1500	448	299	224	179
Small tower	400	348	232	174	139
Small tower	800	348	232	174	139
Small tower	1500	348	232	174	139

Typical values for the Christy yarder at 1000 EYD that equated to about $200 $/mbf is slightly above 4 truckloads per day. Reference

Table 17 to see that for four truckloads per day costs about $224/mbf when using this other costing program. This states that the model used in the analysis is close to the values that would be obtained with other costing programs such as WFI.

Different methods must now be taken to reduce the cost of the variable density thinning operations. One way of doing this is to increase the poor turn volumes while keeping the cut volume the same. This will reduce yarding time and increase production rates. The next section explains this process and the output costs that result.

8.3 Variable Density Thinning (Whole Tree Yarding)

It has been determined to improve turn weights that whole tree logging can be used where the residual stand has less than 100 trees per acre. This section shows how stump to truck costs are drastically improved as a result of this scenario. Below in Figure 54 are the settings that were able to be whole tree logged.

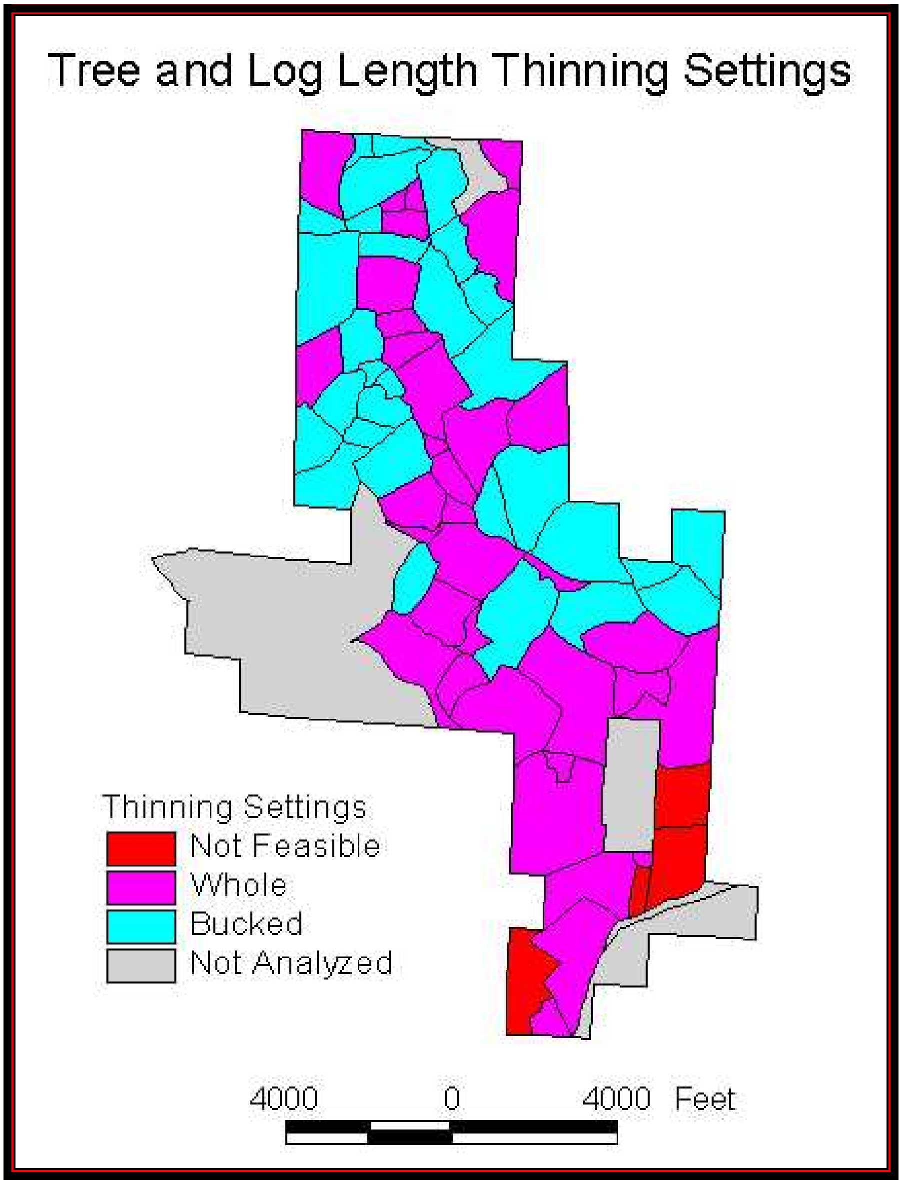


Figure 54 Whole tree feasibility Yarding: This depicts the settings that are able to be whole tree logged.

8.3.1 Inputs

The silvicultural inputs are shown in Table 18.

Table 18 Silvicultural Input Summary for Whole Tree Variable Density Thinning: The average harvest volume throughout the thinning area is 8.4 mbf/acre. This is twice as much as with single density thinning. Values range anywhere from N/F (non-feasible), which means that this setting is not even considered because of the lack of timber, to 15.0 mbf/acre. The turn volumes average bf/turn throughout the area. These values range anywhere from N/F to bf/turn. This is considerably higher than that of the bucked log variable density thinning.

Input	Average	Maximum	Minimum
Harvest Volume (mbf/acre)	8.4	15.0	N/F
Turn Volume (bf/turn)	165	490	N/F

All that has changed in this analysis from the last one is the turn volume. Notice that the harvest volumes at 8.4 mbf/acre are the same as the other variable density thinning analysis. The turn volumes are much greater at 165 bf/turn. This improves the production substantially and is reflective on the cost results shown below.

8.3.2 Cost Results

Figure 55 shows cost results for the variable density thinning analysis for whole tree logging. The same classifications were used here as in the previous analysis.

The results of this change in turn volumes are evident in the number of economically feasible settings that are now possible. The number of settings costing below $200 went from 4 to 28 settings when whole tree yarding whenever possible while variable density thinning instead of bucked log yarding. This is an improvement of seven fold. The number of settings over the pond price also reduced, but not near as dramatically. There are 19 settings over $400/mbf with the bucked yarding method. With the new turn volumes there are 17 settings over $400/mbf. This shows that while increasing the turn volumes on settings that have very low harvest volumes does not change the cost enough to make any substantial difference.

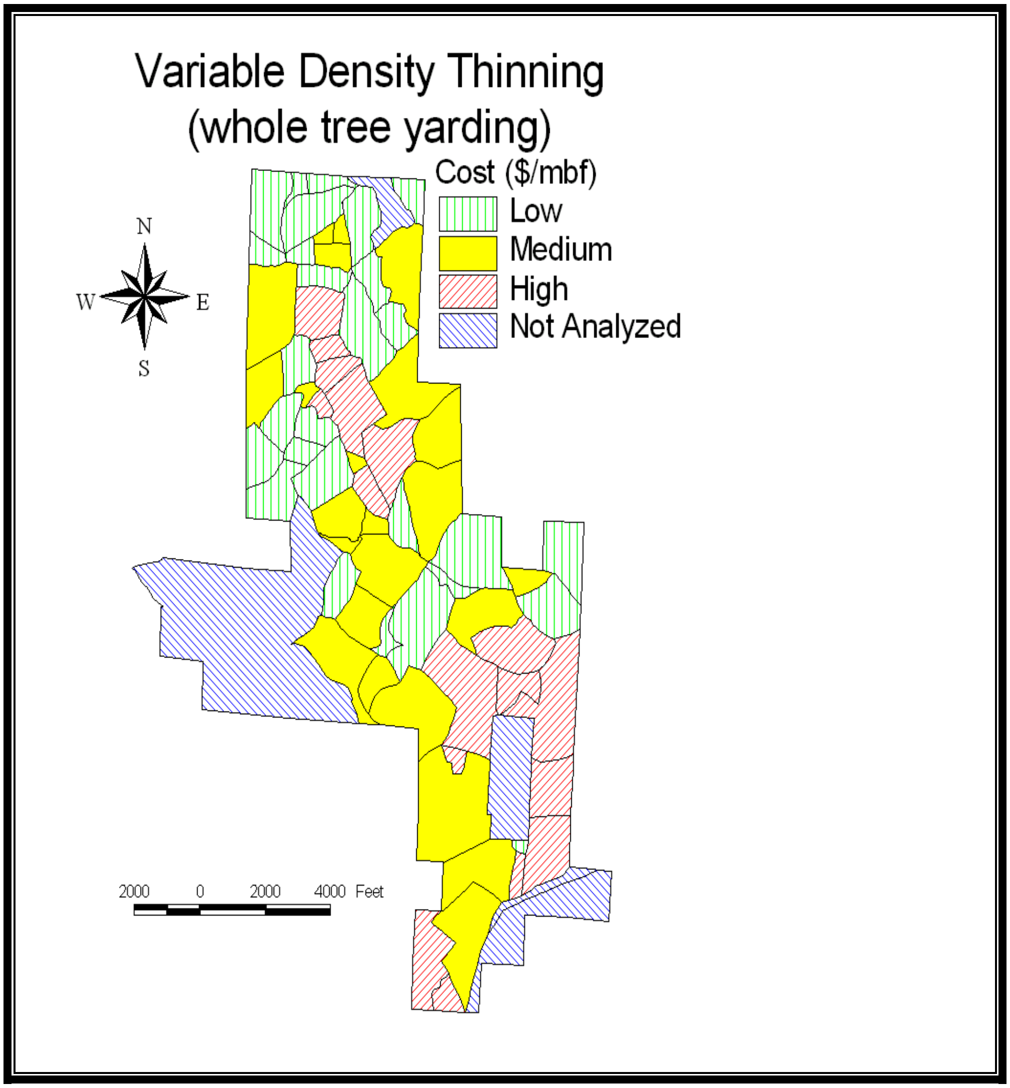


Figure 55 Stump to truck cost by Setting for Whole tree Variable density thinning: The green striped represents stump to truck cost of less than $200. The yellow represents stump to truck cost of $200-$400. The red is above $400. Refer back to Figure 51 to see the difference in the number of green settings. There are several more settings that cost less than $200/mbf. These settings are economically feasible.

8.4 Regeneration Harvest

8.4.1 Inputs

A summary for the silvicultural inputs in the regeneration harvest is in Table 19.

Table 19 Regeneration Harvest: silvicultural input summary: The average harvest volume throughout the harvest area is 30.7 mbf/acre. This is substantially higher than both thinning prescriptions. Values range anywhere from 12.5 to 43.2 mbf/acre. The turn volumes average 596 bf/turn throughout the area. These values range anywhere from 322-to1167 bf/turn. This is considerably higher than that of the thinning prescriptions.

Input	Average	Maximum	Minimum
Harvest Volume (mbf/acre)	30.7	43.2	12.5
Turn Volume (bf/turn)	596	1167	322

The Harvest volumes and turn volumes are substantially greater than those of the single or variable density thinning prescriptions. At 30.7 bf/acre, this regeneration harvest is over 3.5 times greater than the variable density thinning. Likewise, the turn volume is nearly five times greater than the variable density thinning. Refer to Table 19 above for the ranges of those variables.

8.4.2 Cost Results

The individual settings, shown in Figure 56, are categorized in the same way as the settings in Figure 51 and the other two silvicultural prescriptions.

As indicated by the green in Figure 56, most settings will likely produce a profit when applying a regeneration harvest to each unit. There are only five settings where profit is questionable after adding road and haul costs.

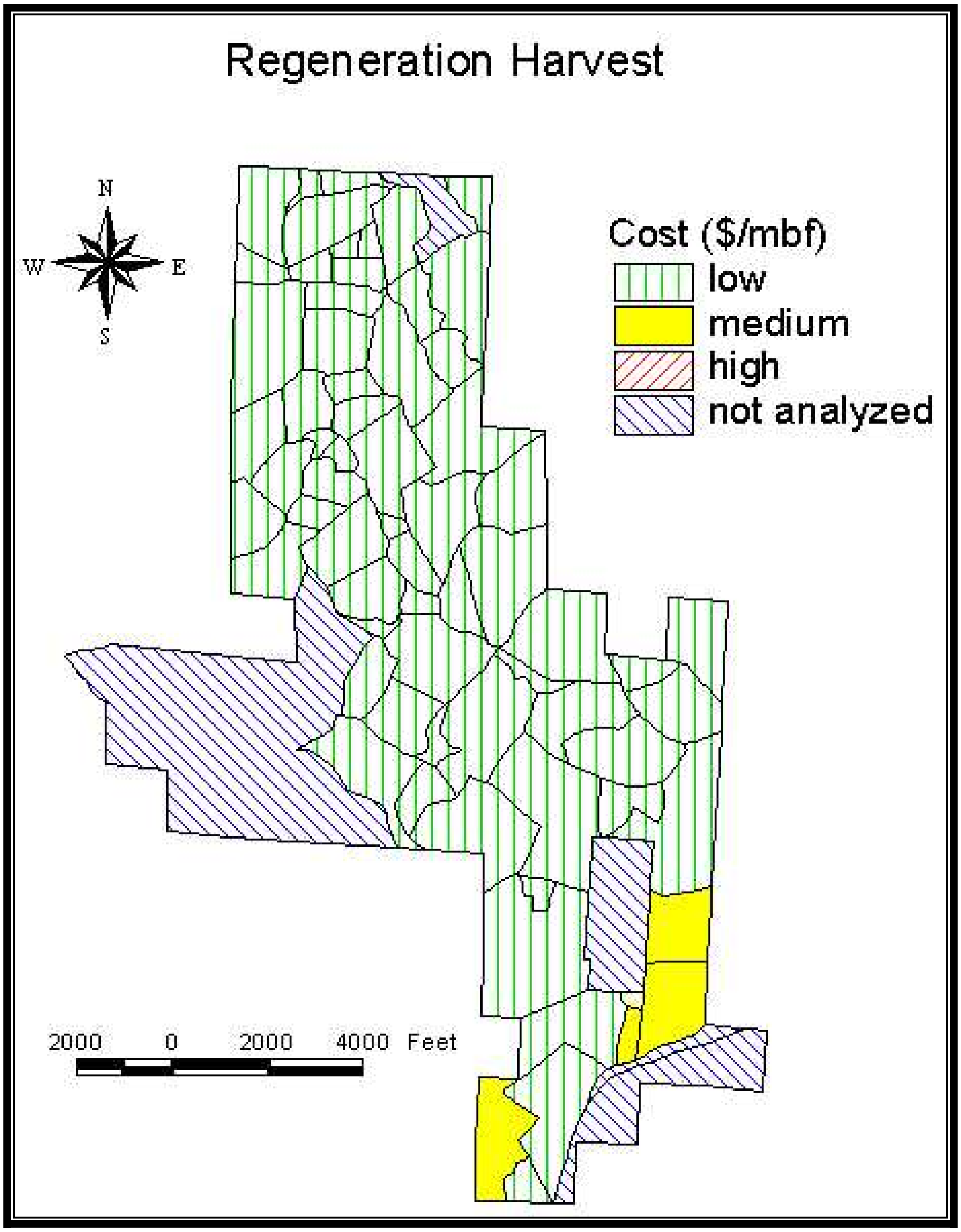


Figure 56 Cost by Setting for Regeneration Harvest: All but five settings have low stump to truck cost. Those are shown in vertical green stripes. There are no settings that exceed the going mill price of $430/mbf.

8.4.3 Conclusions

The following table demonstrates a cost comparison between the four silvicultural prescriptions applied to the planning area.

Table 20 Stump to truck cost comparison by silvicultural prescription

Silvicultural Prescription	Average Harvest Volume (mbf/acre)	Average Turn Volume (bf/turn)	Average cost ($/mbf)	Total Cost (million $) all settings
Single Density Thinning	3.7	102	553	4.0
Variable Density Thinning	8.4	128	347	5.8
Variable Density Thinning (limited whole tree logging)	8.4	165	265	4.3
Regeneration Harvest	30.7	596	72	5.4

Most single density thinning options are out of the question because of the low harvest volumes averaging 3.7 mbf/acre. Still the majority of the variable density thinnings will not pay for road costs either; however, when whole tree yarding is applied a drastic improvement in the number of settings that are economically feasible occurs. This is because of the increased turn volumes from 128 bf/turn to 165 bf/turn. Still to harvest enough of the research and monitoring area the analysis suggests a solution involving different prescriptions to different settings to make harvesting affordable while still meeting the habitat goals. For an explanation of habitat goals, reference chapter 10.

8.5 Alternative System Analysis Comparison

This section compares a long-span analysis and a short-span analysis. Only one area in the Burnt Mountain Planning area has the suitable requirements necessary for this comparison. The main requirement included feasible ridge to ridge cable systems that would allow for the elimination of a road. The specific area chose to model this comparison is shown in Figure 57 and Figure 58. This section in the northern planning area utilizes two ridge roads using short EYD's, yarding from both roads. This comparison will determine if it is more economical to use yarding from both roads or eliminate one road but sacrifice higher yarding costs from longer EYD's. This analysis can be used as a generalization in other similar situations to determine whether it is beneficial to have fewer roads with longer EYDs, or more roads with shorter EYDs.

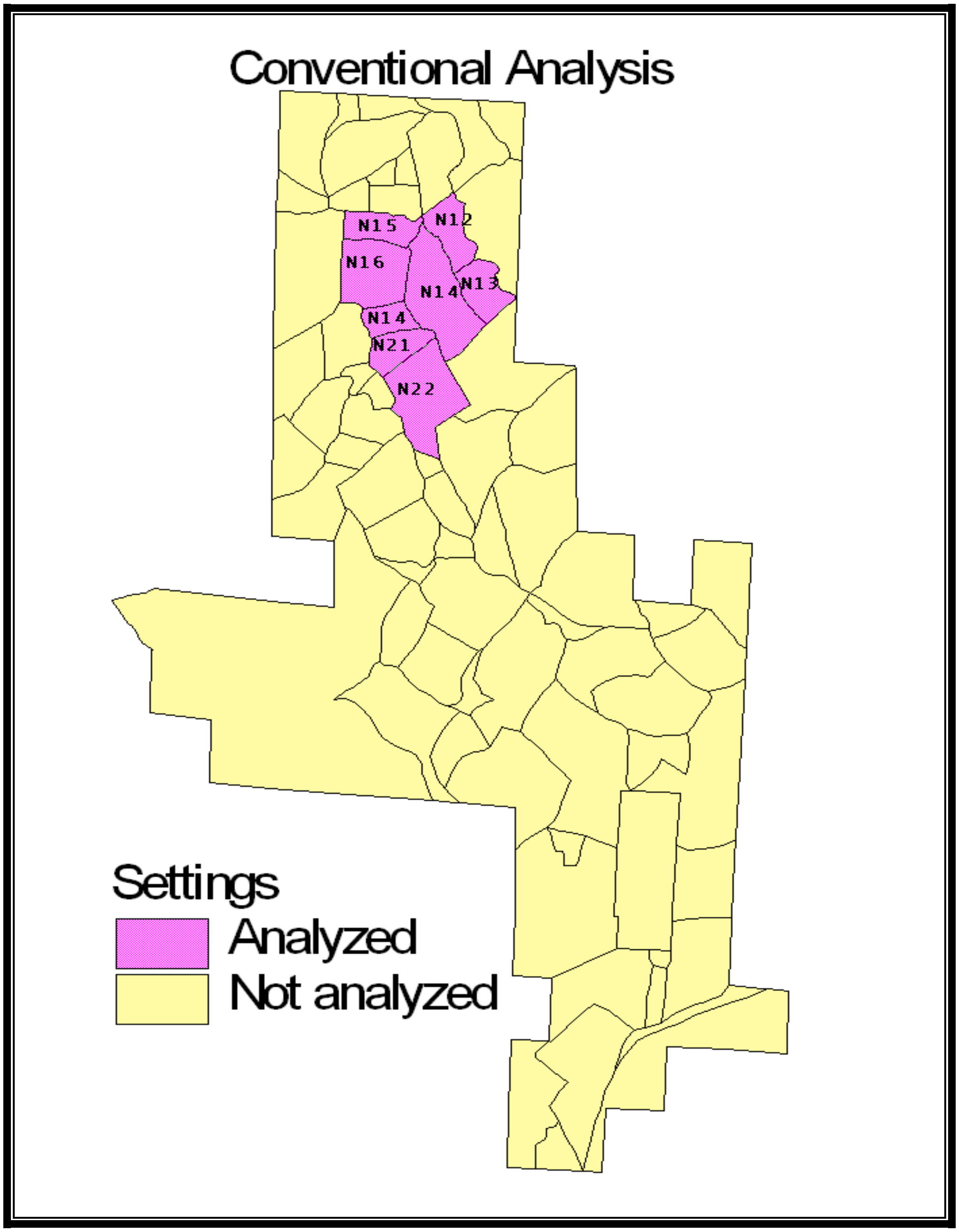


Figure 57 The conventional settings which have the required terrain and road criteria for a cost comparison against an alternative system for the same area.

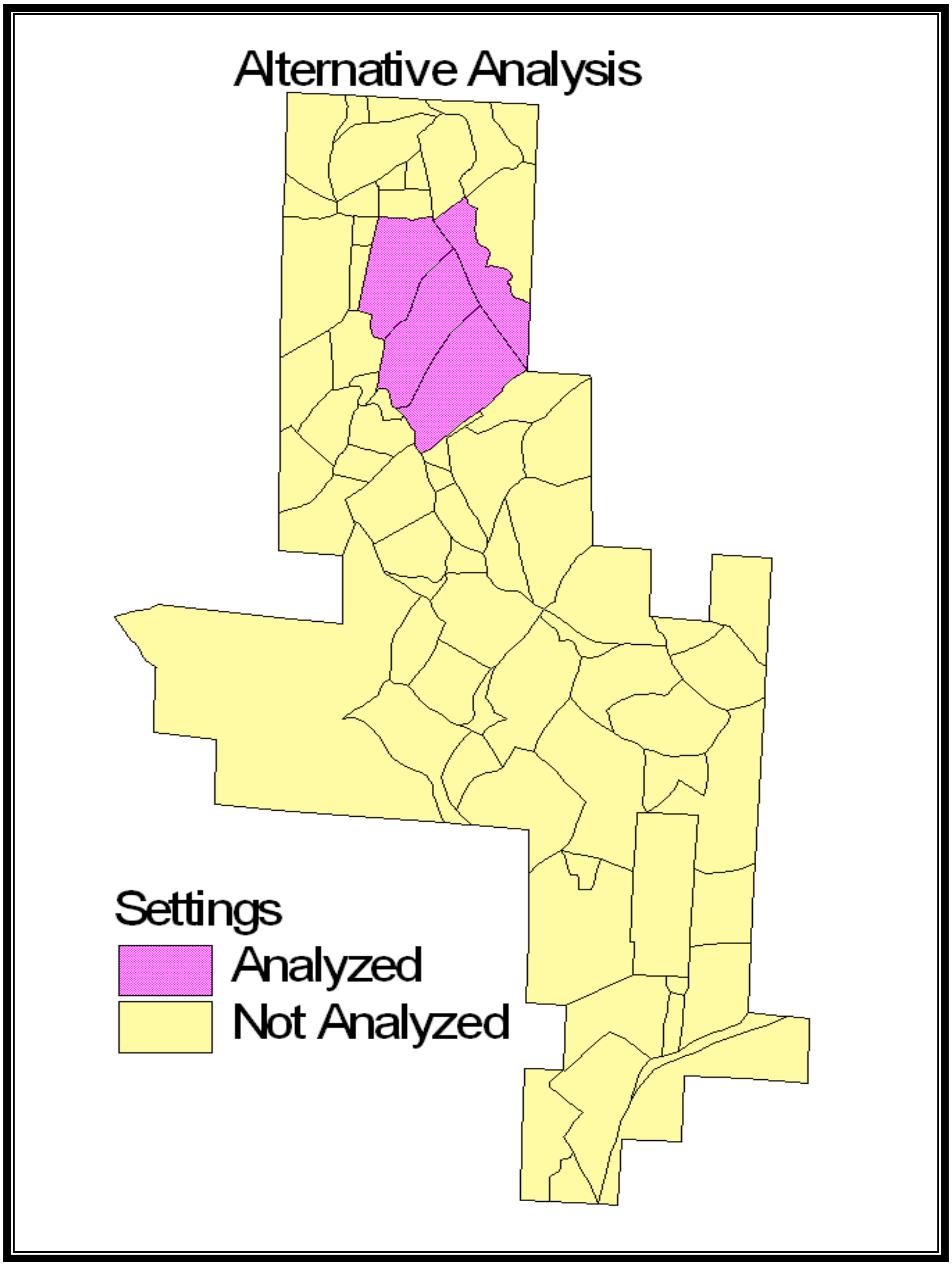


Figure 58 The alternative settings which have the required terrain and road criteria for a cost comparison against a conventional system for the same area.

Shown in Figure 58 are the long-span alternative settings. Big Ridge Road will be eliminated from this part of the analysis because with the long-span system the settings are hung from ridge to ridge. All setting to the southwest of Big Ridge Road will be reached from the Central Road North. The settings to the north east of Big Ridge Road will be helicopter logged. Figure 56 shows the short-span conventional settings. This analysis utilizes both roads.

This comparison was done using the variable density thinning data. Both whole tree and bucked log yarding were analyzed in the process. The same criteria for distinguishing between the whole tree and bucked log yarding was used as before. As seen in previous analysis the whole tree yarding costs were substantially lower. This comparison uses the whole tree yarding analysis because of its economical advantages.

The setting boundaries chosen for the short-span analysis are the same as in the previous variable density thinning settings. There are eight settings in the comparison area for the short-span analysis. The long-span alternative includes four settings (A1, A2, A3, and A4). Setting #A4 is a helicopter setting. As explained above this is necessary because the settings on the northeast side of the Big Ridge Road cannot be reached from the Central Road North landings. Because of setting constraints and boundaries the two areas in the comparison are approximately 2 acres different. This will account for an error in the comparison of less than 1%.

Table 21 shows the total cost to harvest the area using the short-span conventional method would cost $528,190. This figure includes all costs from stump to mill. This equates to $282/mbf throughout the area.

Table 21 Conventional Cost Analysis: This table shows the unit cost (stump to mill) of each setting and the volume that is harvested in that setting. The total cost, including yarding, haul, and road costs, of each setting harvest is shown on the right column. The total cost of the harvest is noted in the bottom right cell.

Setting #	Unit Cost ($/mbf)	Total Volume (mbf)	Total Cost ($)
N12	343	154	52,822
N13	246	277	68,142
N14	256	527	65,792
N15	344	163	56,072
N16	272	229	62,288
N20	346	129	44,634
N21	592	69	40,848
N22	364	378	137,592
Total	282	1,876	528,190

One of the alternatives to the conventional cable logging system is long-span cable logging. The total stump to mill cost to harvest the area using the long-span alternative method is $661,970 or $321/mbf. This again includes all yarding, haul, and road costs. Reference Table 22 for the breakdown of the settings.

Table 22 Alternative Cost Analysis-This table shows the unit cost (stump to mill) of each alternative setting and the volume that is harvested in that setting. The total cost, including yarding, haul, and road costs, for each setting in shown in the right column. The total cost for the harvest is shown in the right bottom cell.

Setting #	Unit Cost ($/mbf)	Total Volume (mbf)	Total Cost ($)
A1	332	401	133,132
A2	346	443	153,278
A3	380	400	152,000
A4	360	621	223,560
Total	354	1,865	661,970

In this case it is more economical to harvest using the short-span conventional method than using the long-span method. In total harvest cost there is a difference of $133,780 even with the extra cost of the road.

Another possible alternative is helicopter logging. The table below shows the cost to helicopter log the whole area.

Table 23 Helicopter Cost Analysis: Depicts the total cost to harvest the compared area. This includes all road and haul costs involved with helicopter logging. The total cost is found in the bottom right cell.

Setting #	Unit Cost ($/mbf)	Total Volume (mbf)	Total Cost ($)
H1	360	401	144,360
H2	360	443	159,480
H3	360	400	144,000
H4	360	621	223,560
Total	360	1865	671,400

The helicopter option is only 2% greater than that of the long-span alternative. Considering some environmental benefits, this may be a better alternative than long-span cable systems. It still; however, is more costly than the short-span cable logging option.

8.5.1 Alternative Analysis Conclusions

There are not very many settings in which terrain permits a well rounded long-span versus short-span cable logging analysis in the Burnt Mountain Planning Area. The few settings that are suitable for analysis show that the short-span cable logging option is more economical. This analysis is only applied to variable density thinnings with certain parameter values. This can be used as an example for other similar situations. With different thinning prescriptions, results will be different than those obtained in this particular analysis. The helicopter analysis must be treated in the same way. The terrain does not matter as much as with the cable logging but the silvicultural prescription does. In this particular case helicopter logging is not significantly more expensive than the long-span cable logging alternative. Further analysis into road use and environmental factors may prove this a more environmentally beneficial method of logging in the future.

9 Habitat and Economics

9.1 Introduction

Five silvicultural prescriptions are analyzed; single density thinning (SDT), variable density thinning (VDT), modified variable density thinning (MVDT), no harvest (or no touch), and regeneration harvest (Re-gen). Each silvicultural prescription is analyzed for economic feasibility, and the amount of sub-mature and old forest habitat that will be created in the future. Recommendations identifying the option most likely to achieve management goals are provided.

9.2 Habitat Creation

9.2.1 Habitat Defined

To classify the different habitat categories, the Washington administrative code (WAC 222-16-085) was used. Table 24 below describes the characteristics and structural characteristics of each type of forest habitat. The three different habitats that are identified are young forest marginal, sub mature, and old forest.

The information in Table 24, along with the Forest Vegetation Simulator program from the U.S. Forest Service (http://www.fs.fed.us/fmsc/fvs/index.htm) is used to project habitat modifications due to differing silvicultural prescriptions. The different habitats are characterized by, forest community, canopy closure, tree height, tree density, vertical diversity, and snags/cavity trees.

Table 24 Western Washington Spotted Owl Sub-Mature, Young Forest Marginal Habitat, and Old Forest Characteristics (from WAC 222-16-085)

		Habitat Type	
Characteristic	**Young Forest Marginal**	**Sub-Mature**	**Old-Forest**
Forest Community	Conifer-dominated *or* conifer-hardwood (greater than or equal to 30% conifer)	Conifer dominated *or* conifer-hardwood (greater than or equal to 30% conifer)	Conifer dominated *or* conifer-hardwood (greater than or equal to 30% conifer)
Canopy Closure	Greater than or equal to 70% canopy closure with 115 – 280 trees/acre (greater than or equal to 4 " dbh) *with*	Greater than or equal to 70% canopy closure with 115 – 280 trees/acre (greater than or equal to 4" dbh) *with*	Greater than or equal to 60% canopy closure with 75 trees/acre (greater than or equal to 20" dbh) *with*
Tree Density and Height	Dominants/co-dominants greater than or equal to 85 feet high *or*	Dominants/co-dominants greater than or equal to 85 feet high *or*	Dominants/co-dominants greater than or equal to 85 feet high *or*
Vertical Diversity	Dominants/co-dominants greater than or equal to 85 feet high with 2 or more layers and 25 – 50 intermediate trees	Dominants/co-dominants greater than or equal to 85 feet high with 2 or more layers and 25 – 50% intermediate trees	Dominants/co-dominants greater than or equal to 85 feet high with 2 or more layers and 25 – 50% intermediate trees
Snags / Cavity Trees	Greater than or equal to 3 per acre (greater than or equal to 20 dbh, and 16 feet in height	Greater than or equal to 3 per acre (greater than or equal to 20 dbh, and 16 feet in height	Greater than or equal to 3 per acre (greater than or equal to 20 dbh, and 16 feet in height

9.2.2 Single Density Thinning Habitat Creation

Habitat creation was projected out to the year 2040 as shown in Figure 59**.** The different silvicultural prescriptions that were used are single density, variable density, and also the no touch. Presently 52% of the total acreage is considered sub mature habitat. If the single density thinning were to be prescribed to the entire area today then by the year 2020, 61 of the 62 settings would be sub mature habitat. By the year 2020 the no habitat classification has gone down to 1 setting. Notice that old forest habitat is increasing in the far future just as sub-mature habitat starts to decrease.

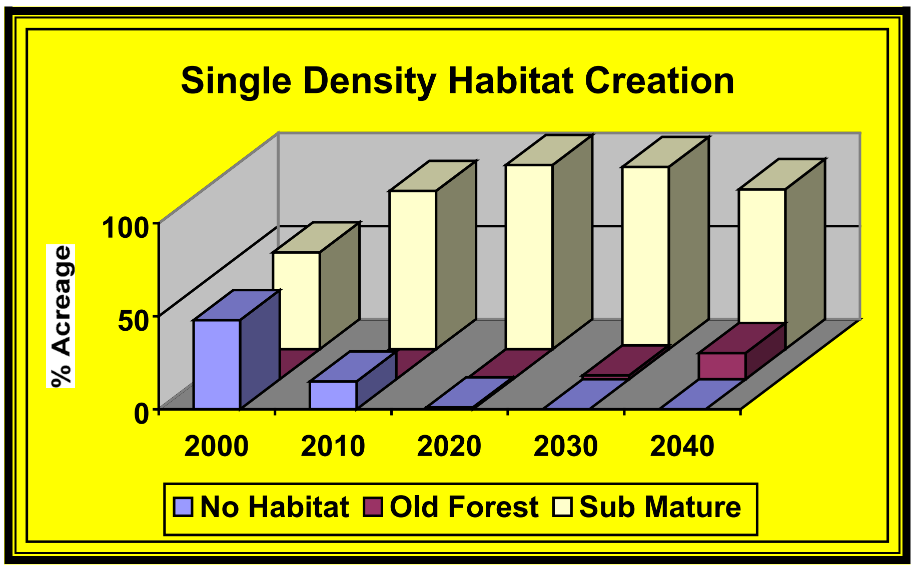


Figure 59 Single Density Habitat Creation: How sub-mature, no habitat, and old forest habitat is effected over time by applying single density thinning.

9.2.3 Variable Density Thinning Habitat Creation

Variable density thin is similar to the single density thin option in terms of habitat creation as shown in Figure 60. If the variable density thin were prescribed to the entire area today then by the year 2020, 99% of the total acreage would be sub mature habitat, displayed with the yellow color. By the year 2020 the no habitat classification has decreased to 1% of total acreage, shown with the blue color. Old forest habitat is increasing in the future just as sub-mature habitat starts to decrease.

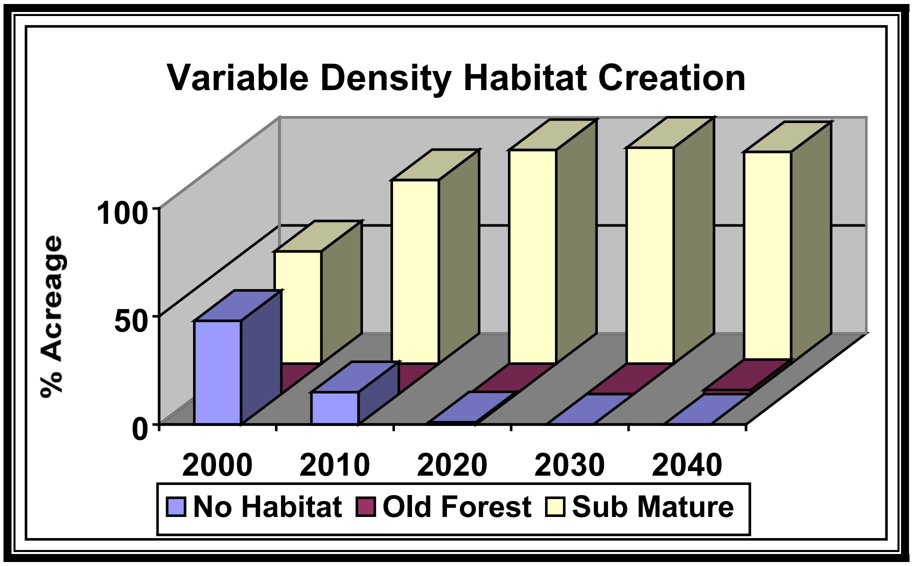


Figure 60- Variable Density Habitat Creation: How sub-mature, no habitat, and old forest habitat is effected over time by applying variable density thinning.

9.2.4 No Touch Habitat Creation

In the year 2020 the no touch option has 99% of the total acreage as sub mature habitat, shown with yellow color. However, Figure 61, No Touch Habitat Creation shows it takes longer before the habitat really starts to take off and flourish, also shown with the yellow. If nothing was to be prescribed to the area today then by the year 2020 the no habitat classification has decreased to 1% as can be seen in blue. Old forest habitat is increasing in the far future just as sub-mature habitat starts to decrease. There is not as much old forest habitat in the future as can be seen in Figure 59 and Figure 60 above.

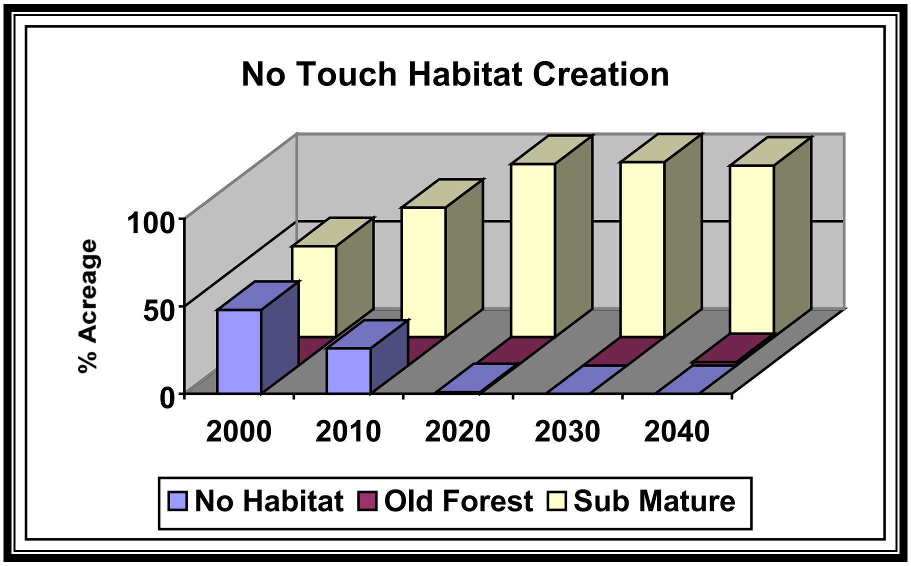


Figure 61 No Touch Habitat Creation How sub-mature, no habitat, and old forest habitat is effected over time by applying a no touch harvest.

9.2.5 Conclusion

Presently 52% of the total acreage with in our planning area is considered to be sub mature habitat. By the year 2020, 99% of the total acreage will be considered sub-mature habitat no matter which silvicultural prescription is chosen. Twenty years later (2040) 14% of the total acreage is considered old forest if the single density thinning option is chosen. Both the variable density thin and no touch option have 2% of the total acreage considered old forest by the year 2040.

9.3 Economics of Silvicultural Options

9.3.1 Introduction

The different silvicultural prescriptions that were analyzed for economic return were variable density thinning, single density thinning, and regeneration harvest.

The economics of habitat creation is expressed as total cost in $/Mbf. Total cost is derived from adding harvest cost, road construction cost, falling and bucking cost, hauling cost, and adding in 15% for contractors margin and profits. If all those variables are known in terms of $/mbf then a total cost can be assigned to each setting. Once the total cost (also know as stump-to-mill costs) are known we then subtracted that total cost from the going pond price ($430/mbf), and then the gain or loss in each setting is known in terms of $/mbf.

The pond price came from the going rate on March 30, 2000 from a local mill. This is discussed in detail in Chapter 8, Stump to Truck Yarding Cost.

9.3.2 Economics of Regeneration Harvest

Profit and loss potential for each setting are shown in Figure 62 for the case of the re-gen harvest. If a particular setting is not profitable then the stump to mill price is greater than the going pond price. In this case, there is only one of these settings. Most of the settings have over a $200/Mbf profit. Only four settings have a profit between $20/Mbf and $200/Mbf.

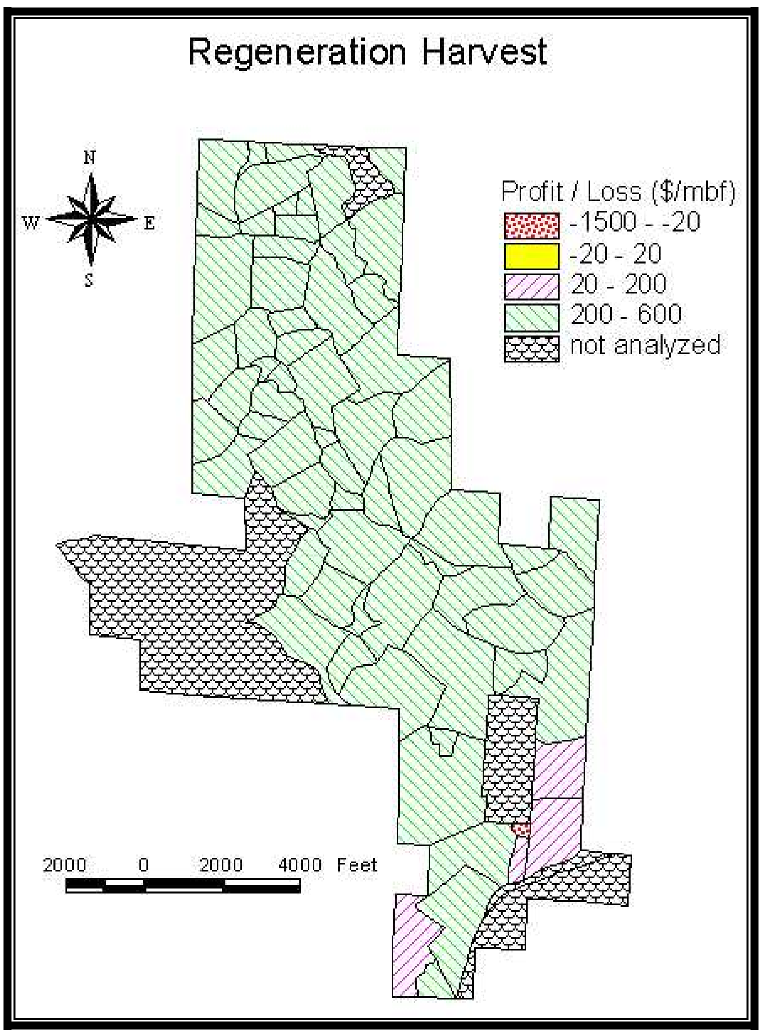


Figure 62 Profits for Regeneration Settings: 97% of the total acreage, shown in green, will return a profit of better than $200/Mbf.

9.3.3 Economics of Variable Density Thinning

Due to the small volume of timber being harvested in variable density thinning, profit margins are less than that of the regeneration harvest (Figure 63). There is only one setting which will have a loss, meaning that the stump to mill price is greater than the pond price. The areas that have very little loss or very little return are considered marginal areas in that they can be either profitable or un-profitable.

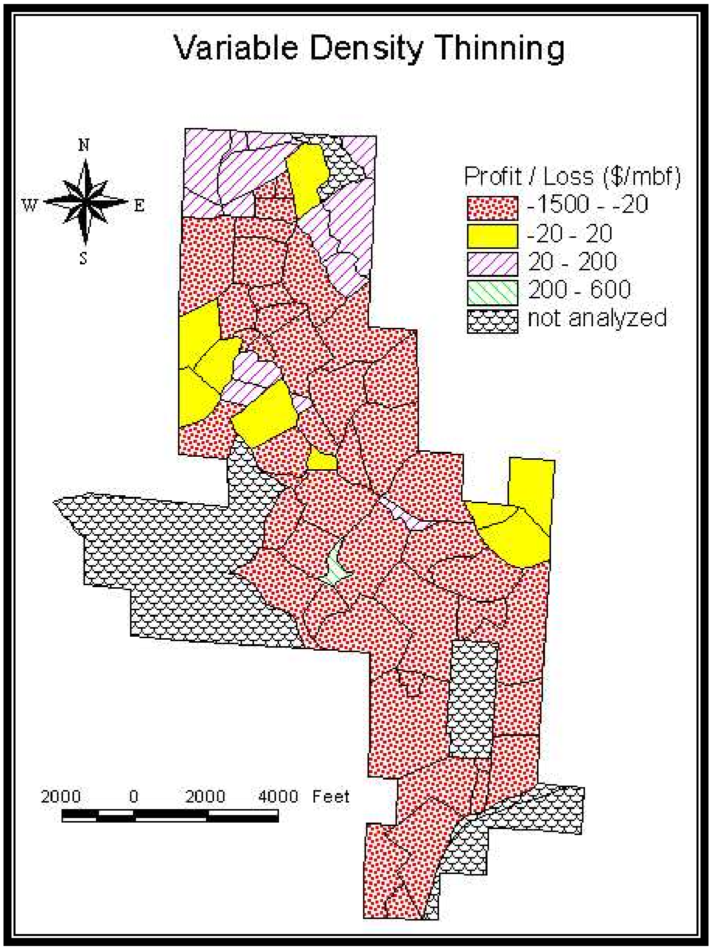


Figure 63 Profits for Variable Density Settings: Due to small timber diameters and lack of volume, most of the settings shown will barely break even under the variable density thin.

9.3.4 Economics of Single Density Thinning

The final option analyzed was the single density thinning. This option was not analyzed in great detail because 93% of the settings had stump to mill prices greater than the pond price. This option was ruled out because no positive return would be made to the trust.

9.3.5 Conclusion

The variable density thinning is the best silvicultural prescription for habitat creation and return to trust. The variable density thinning creates sub-mature habitat quickly, and starts to create old forest habitat in the future. The economical return to the trust is not high, but there is no net loss. This is shown in Table 25.

Table 25 Economic and Habitat Summarization

	Economic Return to Trust	2020 Habitat (% total acreage)	2040 Habitat (% total acreage)
Single Density	Loss of Profit	99% - sub mature	14% - old forest
Variable Density	Slight profit	99% - sub mature	2% - old forest
Regen	Large Profit	Not analyzed	Not analyzed
No Touch	No Profit	99% - sub mature	2% - old forest

9.4 Blue Print For Action Using Identified Scenarios

9.4.1 Introduction

The variable density silvicultural regime was used for more detailed economic analysis to determine feasible harvest scenarios. The most single important parameter which affects cost is turn weight. Turn weights so far were based on log length. It was assumed that in thinning the short length would result in better turn weights and therefore higher profits. However, variable density thinning, as the name implies resulted in residual tree densities as low as 45 tree per acre. In such cases it was reasoned, whole tree yarding could be feasible. The wide spacing should have no detrimental effect on turn sizes or residual tree damage. Based on the above consideration we used less than 100 trees per acre as the number to identify settings where whole tree yarding could be used. As 100 trees per acre the tree spacing is greater then 20 feet. This is feasible for habitat considerations, but economic considerations are borderline.

Other options considered were helicopter use. For this case, road considerations would be minimal. A third option looked at was an 80 acre regeneration harvest to help finance road system development for further thinning access.

9.4.2 Scenario I – Variable Density Thinning

Scenario I involves using the first ten profitable settings to build additional roads. The proceeds from these settings (including road cost) allow additional road construction (Figure 64). However, the additional length of road will not provide sufficient access to the remaining profitable settings on the east end of the planning area.

Using the $25,000 profit from the first ten settings allows the construction of only 12 stations at a cost of $2,000/sta (Figure 65). Most of the settings accessed by this additional road length are not yet profitable, even with out carrying the road construction cost.

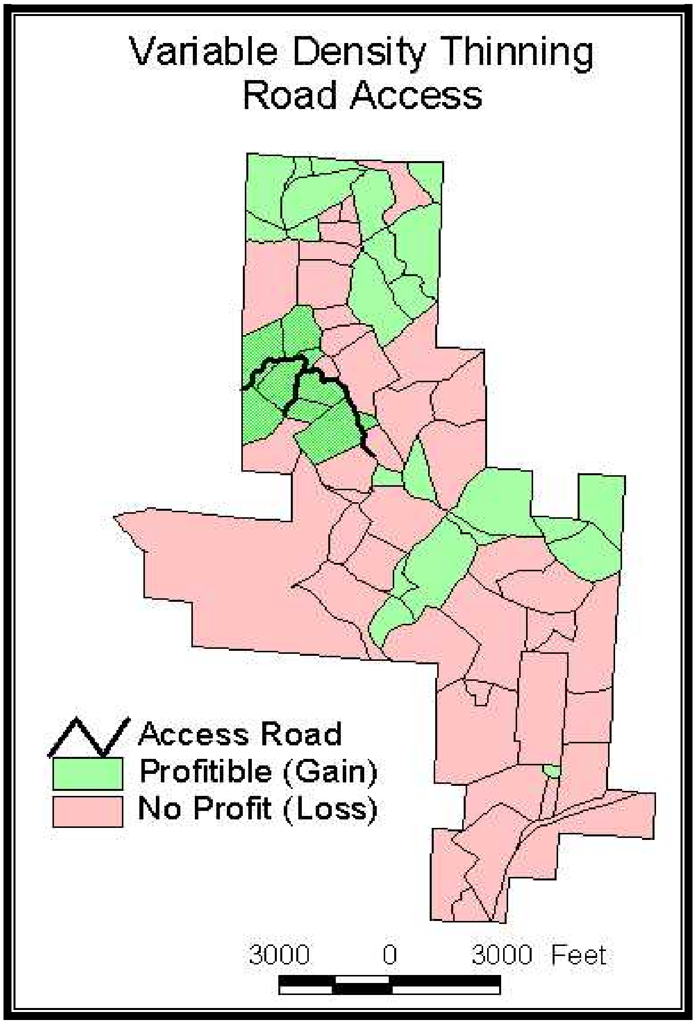


Figure 64 Variable Density Thinning: The first ten settings result in a net profit of $25,000 (including road cost). Twelve additional stations can be built based on an average road cost of $2,000/sta.

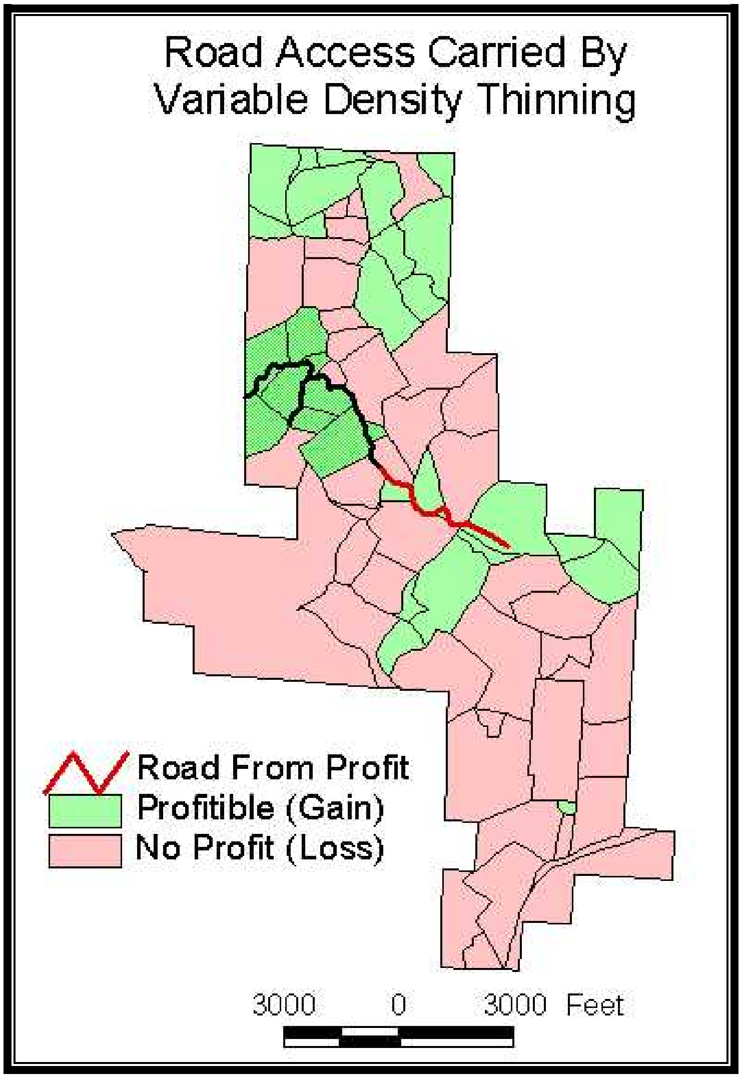


Figure 65 VDT Profit Road: The Variable density thinning road can only be built out to where the red portion of the road stops. Once the road is constructed to this spot we are now $45,000 in the red, or negative.

9.4.3 Scenario II – Variable Density with an 80 Acre Regeneration Harvest

Scenario II involves the regeneration harvest of mature timber in the west portion of the planning area to support additional road access to thinning.

We propose an 80 acre regeneration unit along the railroad south road system. Current stand data suggests a harvest volume of 39 Mbf/acre with an average log size of 63bf/log. The returns from this harvest can be used to access additional thinning units for the purpose of accelerated stand habitat creation.

Based on timber data if the 80 acre regeneration harvest were to be done along with the ten variable density thinning settings will generate a $800,000 return. The profit allows the construction of an additional 444 stations of roads (Figure 66). These additional stations now access another 650 acres for additional thinning and potential habitat creation (Figure 67).

If the 444 additional stations were constructed using the regeneration profits, the total road cost for the area would be $77/Mbf (Table 26)

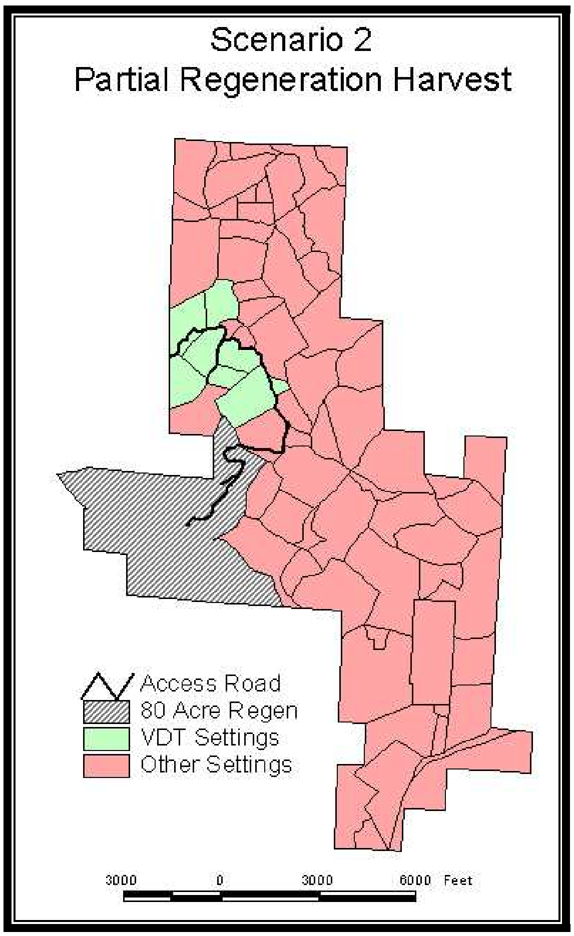


Figure 66 Scenario 2 Partial Regeneration Harvest: A regeneration harvest on 80 acres of mature timber and a variable density thin on the ten westerly settings (shown in green) will return a profit of $800,000. This allows for additional road construction.

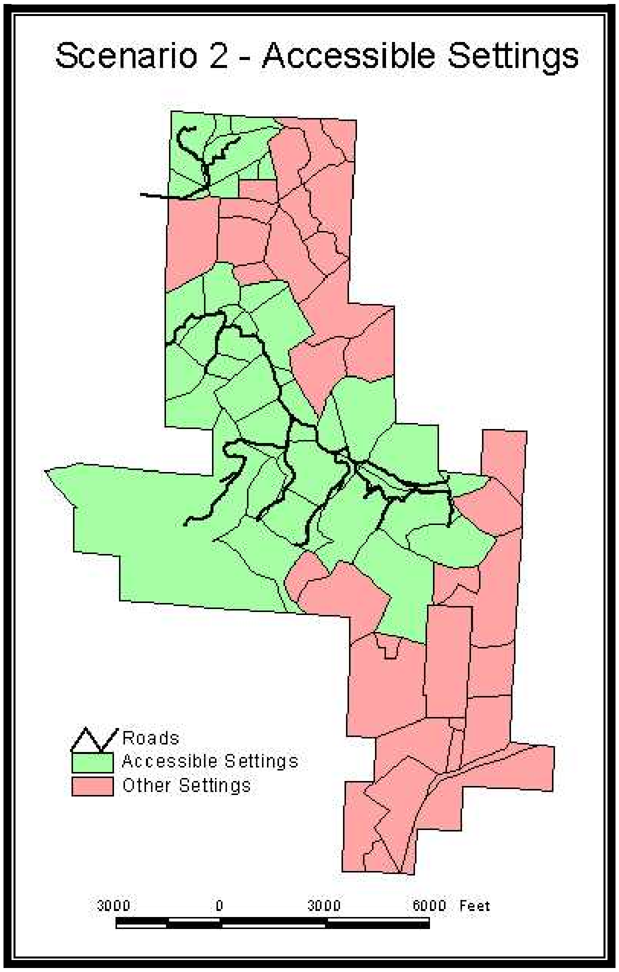


Figure 67 Scenario 2 Accessible Settings: The profit from the regeneration harvest will allow us to build a total of 400 station of additional road (shown in black). These additional roads will now give us access to a total of 650 acres for habitat creation.

9.4.4 Scenario III Modified Variable Density Thinning

After reviewing the silvicultural data and finding in some places the tree spacing was high, whole tree harvesting became a possibility in some cases. Variable density thinning tree-length was analyzed for settings where the residual stand is less than 100 trees per acre. In such stands whole tree yarding appears feasible due to the low residual tree density and corresponding wide spacing. In such situations it is reasonable to assume that the greater tree log length will not delay the yarding cycle or result in higher residual tree damage (Figure 68).

The modified variable density results in a total profit of $1,500,000. The profit allows the construction of 777 total stations and will provide access to an additional 1,650 acres (Figure 69). The total road cost for using this scenario would be $124/Mbf.

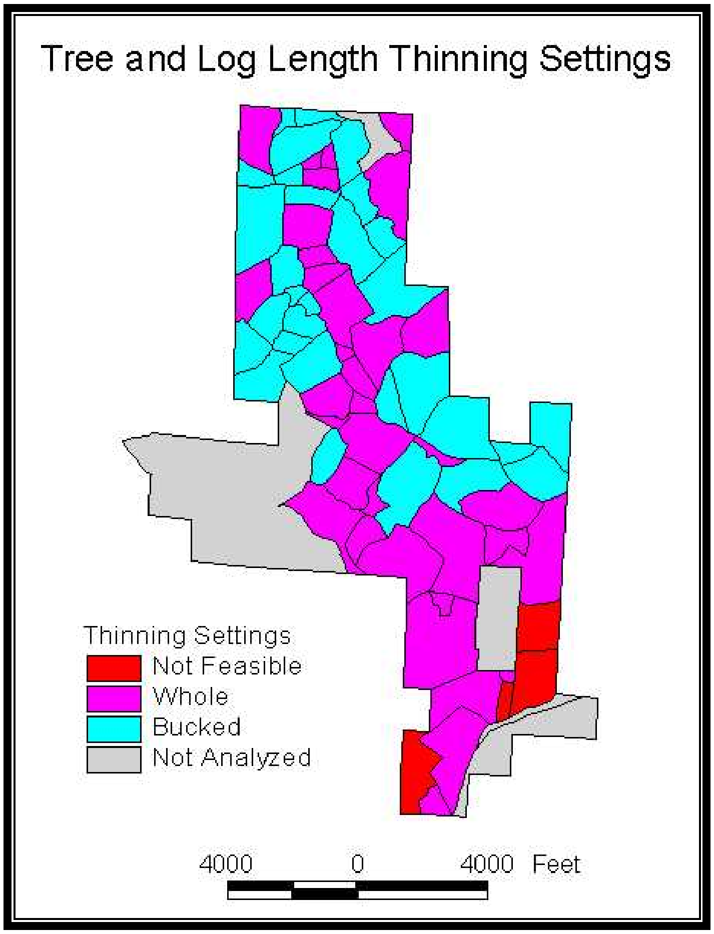


Figure 68 Tree and Log Length Thinning Settings: Settings which can be harvested whole tree and shown in purple and the settings which must be harvested using bucked logs are shown in red.

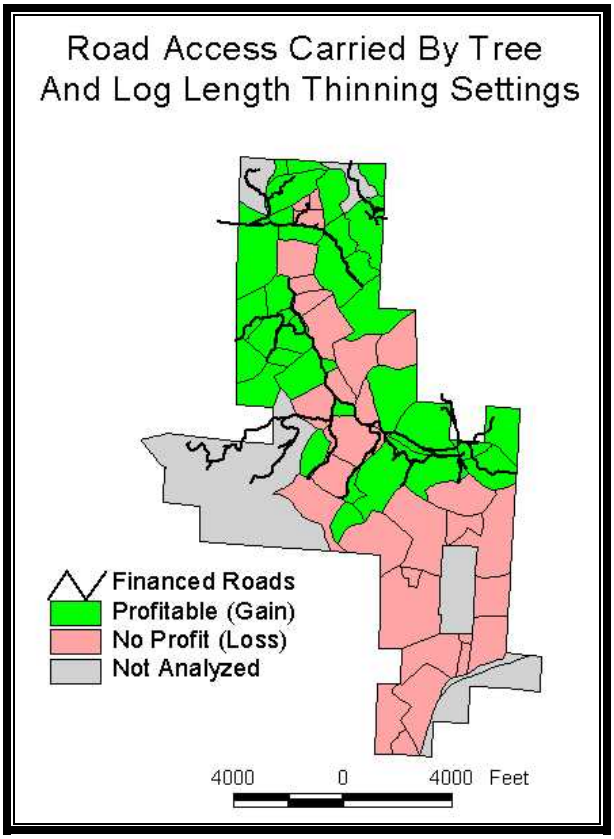


Figure 69 Road Access Carried By Tree And Log Length Thinning Settings: Thinning using whole tree method allows for 700 stations of total road to be built in the area (shown in black). These additional roads give access to 1,650 total acres (shown in green)

9.4.5 Scenario IV Helicopter Variable Density Thinning

The last scenario looks at helicopter thinning as one of the options. This option was analyzed to evaluate the cost effect of reduced road density. We assumed the helicopter option was able to access the entire area while only building $103,000 worth of road. This equates to 5,912 feet of new road in the entire planning area. The overall road length is a mere 59 stations long and costs $6/MBF. The harvest cost for the entire area is estimated at $360/mbf, returning a net profit to the trust of $121/Mbf (Table 26).

9.4.6 Conclusion

Although the profit in $/Mbf are similar between the variable density thinning ($25/Mbf) and the thinning with the helicopters ($29/Mbf). The length of road constructed is quiet different. The helicopter scenario only needs 59 stations of road while the variable density needs approximately 91 stations of road constructed. The helicopter would prove to be a better option if one had to choose between the helicopter or the variable density thinning. However, after identifying and analyzing all of the potential options, the modified variable density thinning proved to be most feasible. This scenario provides the most harvested area which will provide the most habitat creation, and by adopting scenario III, it will return the greatest profit to the trust (Table 26).

Table 26 Scenario Summarization Table

	Scenario I	Scenario II	Scenario III	Scenario IV
	Single Density Thinning	Variable Density w/ 80 Acre Re-Gen Harvest	Modified Variable Density	Thinning w/ Helicopter
Area Harvested (Acres)	397	1244	1,679	2,557
Vol. Harvested (mbf)	2086	10,861	12,505	17,446
Haul Cost ($/mbf)	35	35	35	35
Harvest Cost ($) Harvest Cost ($/mbf)	590,720 283	2,494,124 230	1,877,191 150	6,280,560 360
Road Cost ($) Road Cost ($/mbf)	182,039 87	954,399 88	1,555,390 124	102,947 6
Road Length (sta)	91	477	777	52
Return To Trust($) Return To Trust ($/mbf)	51,593 25	836,297 77	1,513,105 121	505,934 29

10 Research Applications

10.1 Goals

A secondary goal of the planning project is to identify settings appropriate for research activities. The criteria used to identify these areas are:

- Average stand ages between 40 and 60 years.
- Accessible by either ground systems or cable systems.
- Returns a net profit to the trust.

By identifying the type of system that can be used on each setting, realistic silvicultural prescriptions can be identified and placed within the planning area. This supports design of a statistically valid research program by allowing for random placements of research settings.

Silviculture data has been developed for all of these stands using differing treatments. Also provided is information about habitat creation resulting from each option (see sliviculture section of report).

Opportunities are identified for long-span cable yarding (mostly in the NE area), and single and variable density prescriptions to be applied. This information can be found in the section on yarding costs and also the habitat and economics section.

To provide the type of information needed, we developed two maps identifying these areas and the timber age classes contained within each area. Figure 70 below displays the settings appropriate for this application.

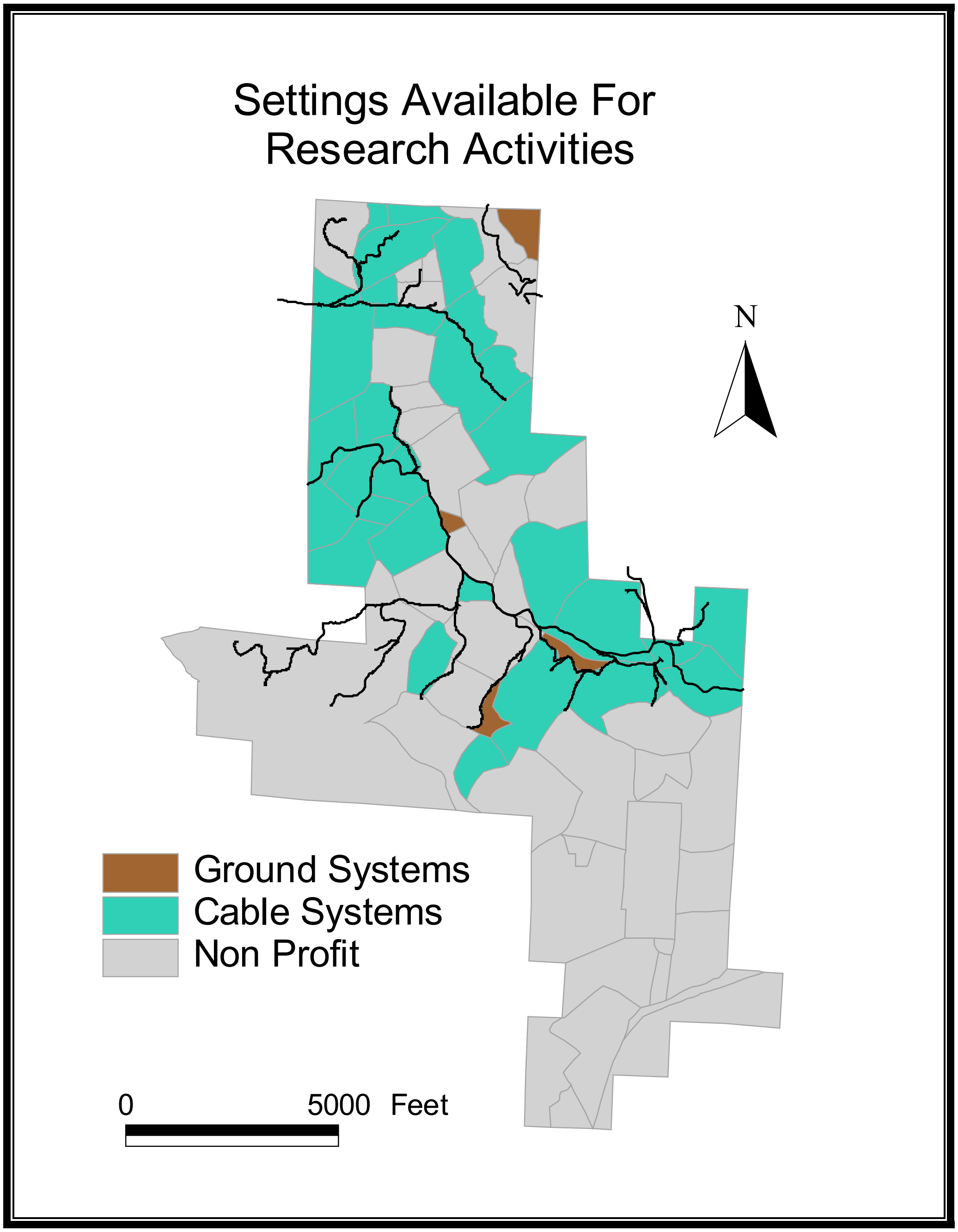


Figure 70 Potential Research Settings Having Positive Return to the Trust

The above map, identifies areas where both ground and cable thinning operations can be carried out economically. The types of yarding system appropriate for each setting are identified.

We also wanted to provide information concerning which age classes are contained within these potential research settings (Figure 71). The bold areas represent settings that return a net profit under the most restrictive thinning regime , making them suitable for research projects

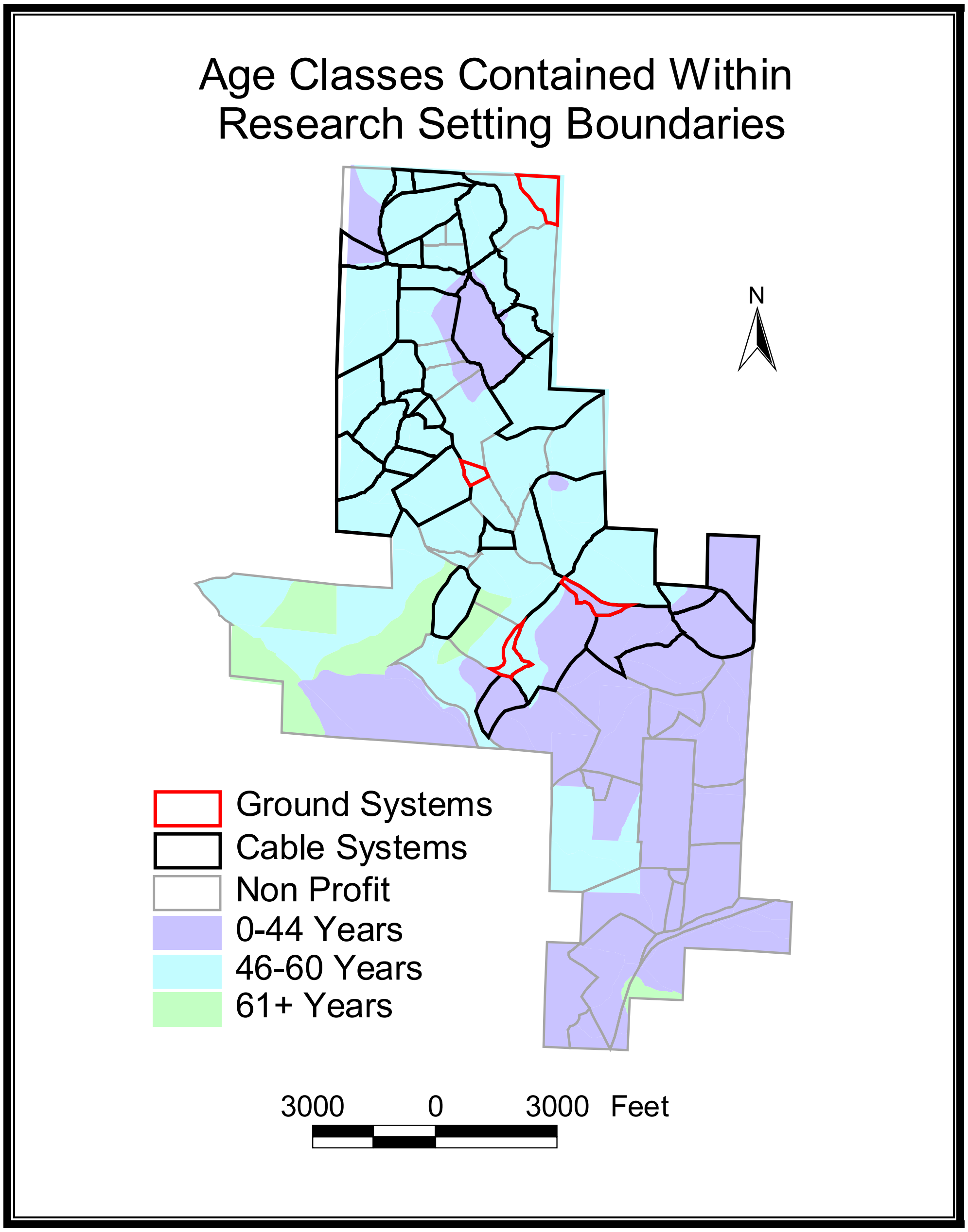


Figure 71 Potential Research Settings with age Classes

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11 Conclusions / Recommendation

Variable density thinning will create the desired habitat over 99% of the acreage by the year 2020. Of the operations analyzed the combined log length and whole tree yarding (modified variable density thin) shows the best return ($121/Mbf) over most of the planning area. The combined variable density thin with an 80 acre regeneration harvest would be the next best option. It has a net return of $77/Mbf to the trust and is able to access 1244 acres because regeneration harvest pays for the road construction. The last two options, variable density thinning and helicopter thinning would be the last choice due to the small amount of returned profit to the trust (helicopter $29/Mbf, and variable, $25/Mbf). But one advantage of the helicopter option is only 52 stations of road would have to be constructed.

12 Appendices

12.1 Derivation of the Infinite Hillslope Equation

The Infinite Hillslope Equation:

$$FS = \frac{C_r + C_s^{'} + \cos^2 \alpha[q_0 + \gamma(D - D_w) + (\gamma_{sat} - \gamma_w)D_w]\tan\phi'}{\sin\alpha\cos\alpha[q_0 + \gamma(D - D_w) + \gamma_{sat}D_w]}$$

where $FS =$ **factor of safety**

$\alpha =$ **slope of the ground surface in degrees**

$D =$ **total soil thickness**

$D_w =$ **saturated soil thickness, ft**

$C_r =$ **tree root strength expressed as cohesion, psf**

$q_0 =$ **tree surcharge , psf**

$C_s^{'} =$ **soil cohesion, psf**

$\phi' =$ **effective internal angle of friction degrees**

$\gamma_d =$ **dry soil unit weight, pcf**

$\gamma =$ **moist soil unit weight, pcf**

$\gamma_{sat} =$ **saturated soil unit weight, pcf**

$\gamma_w =$ **water unit weight, pcf**

Uplift Force on Base

Pore-Water pressure

$$u = \gamma_w h_p = \gamma_w D_w \cos^2 \alpha$$

Uplift Force

$$U = \frac{ub}{\cos\alpha} = \gamma_w D_w b \cos\alpha$$

Other Forces

Total Weight

$$W_T = b(q_0 + \gamma_m D_m + \gamma_{sat} D_w)$$

Normal Force

$$N = W_T \cos\alpha + b\cos\alpha(q_0 + \gamma_m D_m + \gamma_{sat} D_w)$$

Effective Normal Force

$$N' = N - U$$

$$= b\cos\alpha(q_0 + \gamma_m D_m + \gamma_{sat} D_w) - \gamma_w D_w b \cos\alpha$$

$$= b\cos\alpha[q_0 + \gamma_m D_m + (\gamma_{sat} - \gamma_w) D_w]$$

Shear Force

$$T = W_T \sin\alpha = b\sin\alpha(q_0 + \gamma_m D_m + \gamma_{sat} D_w)$$

(side forces are assumed to be equal and opposite and to cancel)

Stresses

Effective Normal Stress

$$\sigma' = \frac{N'}{b/\cos\alpha} = \cos^2\alpha[q_0 + \gamma_m D_m + (\gamma_{sat} - \gamma_w) D_w]$$

Shear Stress

$$\tau = \frac{T}{b/\cos\alpha} = \cos\alpha\sin\alpha(q_0 + \gamma_m D_m + \gamma_{sat} D_w)$$

Shear Strength

$$S = C_r + C'_s + \sigma' \tan\phi'$$

$$= C_r + C'_s + \cos^2\alpha[q_0 + \gamma_m D_m + (\gamma_{sat} - \gamma_w) D_w]\tan\phi'$$

Factor of Safety

$$FS = \frac{S}{\tau} = \frac{C_r + C_s^{'} + \cos^2 \alpha [q_0 + \gamma_m D_m + (\gamma_{sat} - \gamma_w) D_w] \tan \phi'}{\cos \alpha \sin \alpha (q_0 + \gamma_m D_m + \gamma_{sat} D_w)}$$

Substituting $D - D_w$ for D_m and rearranging gives:

$$FS = \frac{C_r + C_s^{'} + [q_0 + \gamma_m D + (\gamma_{sat} - \gamma_w - \gamma_m) D_w] \cos^2 \alpha \tan \phi'}{[q_0 + \gamma_m D + (\gamma_{sat} - \gamma_m) D_w] \cos \alpha \sin \alpha}$$

12.2 Growth Modeling Tools

Introduction

In the early stages of project planning DNR research staff was to provide silvicultural data and related silvicultural prescriptions, growth data and harvest volumes for the Burnt Mountain Planning Area. However, after close inspection of the initial silviculture data the UW Forest Engineers decided to tackle the growth modeling and silvicultural modeling in-house due to the intensive modeling effort required and high priority needs for these data. Most of our engineering design had to be based on such silvicultural models and prescriptions necessitating detailed accurate data.

FRIS Data Conversion

Chosen for its simplicity and excellent support, the planning team utilized the Forest Services Suppose/Forest Vegetation Simulator growth-modeling program. The initial challenge in developing our growth-modeling routines was converting the data into the FVS format. In order to minimize errors introduced by data entry into spreadsheet programs, a conversion program (which can be found on the CD at /silviculture / silviculture_amls / arc2fvstpa.aml) was written in ArcInfo's macro language; AML.

Due to the complex nature of the DNR's FRIS data, typical data entry routines for FVS could not be used. Typically, .fvs stand data tables are created with corresponding .slf files containing expansion factors. However, the FRIS data has fixed radius plots of varying diameter, variable radius plots with different basal area factors, live and dead trees. The conversion amls written to bring the data into FVS expands both the live and dead plots before writing them to the .fvs input files. Bringing the standing dead trees into FVS is critical when modeling the stands. Standing dead trees not only allow determination of habitat requirements but also take up valuable growing space, which limits tree growth and models the stands more accurately. The aml needs 4 inputs to run in Arcplot, at the prompt type arc2fvstpa (Figure 72).

```
Arcplot: Usage: ARC2FVSTPA <FIU.MAIN> <PLT.TREE>
<FIU.EXPAN> <SLF_FILE>
```

Figure 72: Arc2fvstpa.aml command usage in Arcplot. This aml coverts FRIS INFO files into the FVS input format.

Three of the inputs are FRIS data, the info files fiu.main, plt.tree and fiu.expan, the third input is the name of the output .slf file. It is absolutely necessary that you have all three files with complete data for all stands of interest. The aml will generate an .fvs file for each stand as well as the .slf file for all the stands.

There is one more file that is needed before you can run Suppose, the Suppose Locations file, .loc. The location file points to the .slf files for the project area (Figure 73). For Burnt Mountain we had two separate inventories; Deadmans and Olyup were created using a text editor like Notepad.

```
A "Deadmans" @ deadmans.slf @ @
A "Olyup" @ olyup.slf @ @
```

Figure 73: The Locations (.loc) file for the Burnt Mountain FVS growth modeling.

Suppose

Suppose is vary straightforward. Open the Location file, select the groups of interest and select the stands you want to model. In our analysis, we used a few keywords to control the output of Suppose. The most important keyword is "NoAutoES" with turns off the regeneration and in-growth features of the model. FVS was not designed to thin stands based on the prescriptions in the DNR's Forestry Handbook, therefore stands had to be thinned outside of FVS. To get the data out of Suppose use the TreeList Keyword. Also of interest to the Planning Team was the ability to visualize treatments in SVS and EnVision. Using the SVS keyword in Suppose generates the necessary files for SVS and EnVision.

Silvicultural data for the Burnt Mountain area consisted of two FRIS cruises, Deadmans from 1996-97 and Olyup from 1999. To bring the stand data up to date we projected all the stands up to the common year 2000. Using the Suppose output TreeList .trl files for the year 2000 we were able to simulate single and variable density thins using the DNR's 1999 Forestry Handbook Westside Small-wood Thinning Procedures. Since Suppose and FVS were not designed to thin stands with such measurements the Project Team wrote an aml (fvs_id_thinnings.aml) to identify the break-point DBH for each stand.

```
Arcplot: Usage: FVS ID THINNINGS <TRE FILE>
<OUT_INFO_FILE>
```

Figure 74: Fvs_id_thinnings.aml command usage in Arcplot. This aml identifies DBH break points for Single Density and Variable Density thins. This data can then be used to thin the stands from below.

Using initial stand relative density, residual relative density and change in relative density the stands are thinned from below until the minimum RD is reached. The break-point diameter is written to an INFO file which can be used to thin the stands using another aml (fvs_trl2tre.aml) or by using the Suppose program and thinning from below.

```
Arcplot: Usage: FVS_TRL2TRE <TRL_FILE> <TRE_FILE>
<SAMP_YEAR> {<ABOVE|BELOW>
<BREAK_POINT_DBH|INFO_FILE> {STAND_ID} {DBH}}
```

Figure 75: Fvs_trl2tre.aml command usage in Arcplot.

The thinning aml and Suppose generate identical numbers for cut and residual volumes for each stand.

Harvest and Residual Volumes

If the stands are thinned in Suppose the .trl TreeList files need to be converted to a format that the DOS program Bucktree can use to buck the harvested trees into logs. If the stands are thinned using fvs_trl2tre.aml then the .tre files are created for you already. However, for the Burnt Mountain area habitat creation is a major consideration. Therefore, stands need to be thinned in Suppose so that the thinned stands response can be monitored. To get the cut volume, residual trees and dead standing wood data out of the TreeList files an ArcView script (fvs_trl2tre.ave, Figure 76) was written to extract data for particular years.

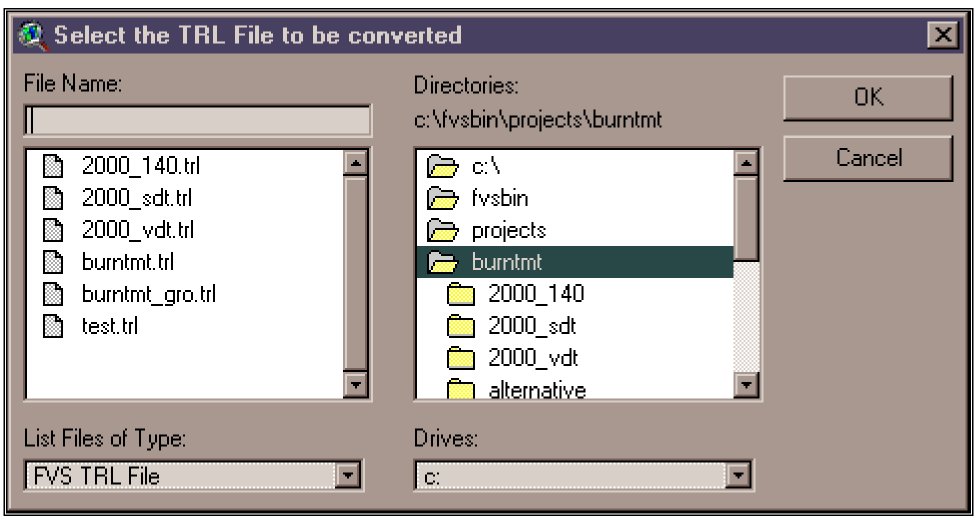


Figure 76: Fvs_trl2tre.ave ArcView script for .trl file conversion and data extraction.

Using either the ArcInfo aml or the ArcView script gives the same results. Once the .tre files are created they can be brought directly into ArcView, converted to INFO files and joined to the original stand coverage. If the stands are bucked into logs using the Bucktree program, the .lgl files output from bucktree can be brought into ArcView and converted to INFO files. Converting the .tre and .lgl files into INFO format has significant performance advantages over native .dbf and .txt formats. In time, all these silvicultural conversion amls will be moved into the ArcView environment for runtime efficiency and convenience.

To calculate statistics about cut volumes, the .lgl file must be converted into INFO format. An ArcInfo aml (fvs_lgl_stat.aml, Figure 77) calculates the cut volume statistics from the .lgl INFO files and another aml (fvs_tre_stat.aml, Figure 78) calculates statistics for the residual stand.

```
Arc: Usage: FVS_LGL_STAT <LGL_FILE> <OUT_FILE>
```

Figure 77: Fvs_lgl_stat.aml command usage in Arc. Calculates statistics about the harvested trees.

```
Arc: Usage: FVS_TRE_STAT <TRE_FILE> <OUT_FILE>
```

Figure 78: Fvs_tre_stat.aml command usage in Arc. Calculates statistics about the residual stand.

Habitat

Habitat creation was a major consideration in the Burnt Mountain Planning area. To calculate habitat statistics another aml (tree_habitat.aml, Figure 79) was created. This aml uses the current procedures in the Washington Administrative Code 222-16-085 to identify suitable Northern Spotted Owl habitat.

```
Arcplot: Usage: TRE_HABITAT <ALIVE_TRE> <DEAD_TRE>
<INFO_OUT> <OUT_ITEM>
```

Figure 79: Tre_habitat.aml commands usage in Arcplot. This aml identifies young, sub-mature and old-forest habitat using TreeList stand tables.

In order to properly identify habitat it is necessary to have both the residual standing trees as well as the standing dead wood.

Getting Stand data into Settings

There are two different approaches to consider when summarizing stand data into settings. The first method involves regenerating stand boundaries that are the same as the setting boundaries and re-sampling the spt cruise points into the new setting boundaries. While this is the best method for modeling conditions in individual settings it is also the most labor intensive. Given the delay in receiving quality silvicultural data from the DNR we chose to use another method of placing stand data into settings.

The planning team chose to weight the stand data by area (avg_by_area.aml, Figure 80) and place it into the settings coverage. Therefore, if a setting had multiple stands in it, then each stands data was averaged by area and placed into the setting.

```
Arcplot: Usage: AVG_BY_AREA <IN_COVER>
<IDENTITY COVER> <IDENTITY ITEM> <OUT COVER>
<OUT_ITEM>
```

Figure 80: Avg_by_area.aml command usage in Arcplot. This aml takes two polygon coverages and weights the data in the identity_cover by area and places it into the in_cover.

EnVision Landscape Visualization

To better understand the effects of single and variable density thinning on the landscape the planning team used Bob McGaughey's EnVision program. EnVisions native data source is SVS stand files and a Shapefile for location information. The Shapefile can be generated in ArcView and the SVS files are created when you use the SVS keyword in Suppose. In addition to the SVS files and the Shapefile, a look-up table needs to be created that maps specific SVS (Figure 81) files to specific stands in the Shapefile. The planning team constructed an aml (envision_shp_lut.aml, Figure 82) to do this task.

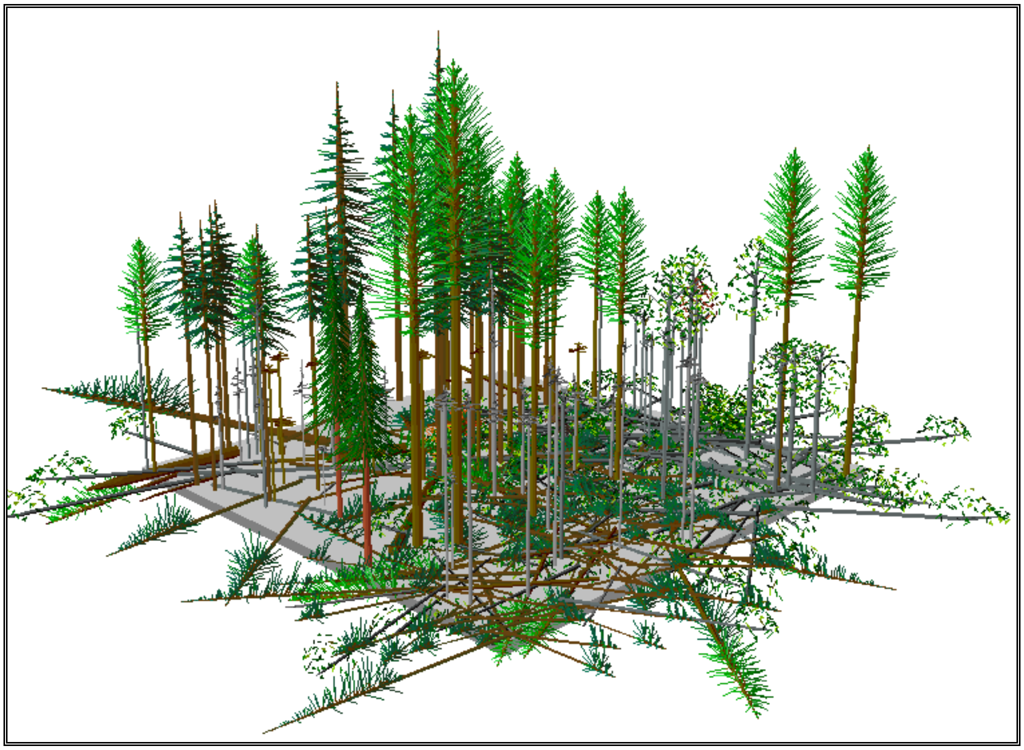


Figure 81: SVS visualization of a variable density thin in one stand in the Burnt Mountain Planning Area. The same SVS files can be used in EnVision

```
Arcplot: Usage: ENVISION_SHP_LUT <DIRECTORY> <YEAR>
<OUTPUT_FILE>
```

Figure 82: Envision_shp_lut.aml command usage in Arcplot. This aml creates a look-up table for EnVision Shapefiles and SVS files. Given a directory path from the EnVision working directory and the year of interest the aml creates a look-up table.

In EnVision you must bring in a digital terrain model, which can be done using the latticedem command in ArcInfo and then the import USGS dem function in EnVision and the appropriate Tree Form File (.trf) for the FVS variant you are using for the Analysis. For the Burnt Mountain area we used the Pacific Northwest Coast variant and its corresponding tree form file, PN.trf. Be sure and have this .trf file in your current working directory!

In EnVision on the *Project Components - Vegetation* page (Figure 83) select the setting ***Shapefile*** as your *Vegetation set* with ***Direct*** *Vegetation set characteristics*. Under the *Primary file Format* select ***ARC-INFO Shapefile*** and select the attribute in the Shapefile that is your unique stand number. For FRIS data, the unique stand number attribute name is Riu.id. Under the *Secondary File* select ***SVS stand look-up table*** and select the ***.lut file*** that was created with the Envision_shp_lut aml.

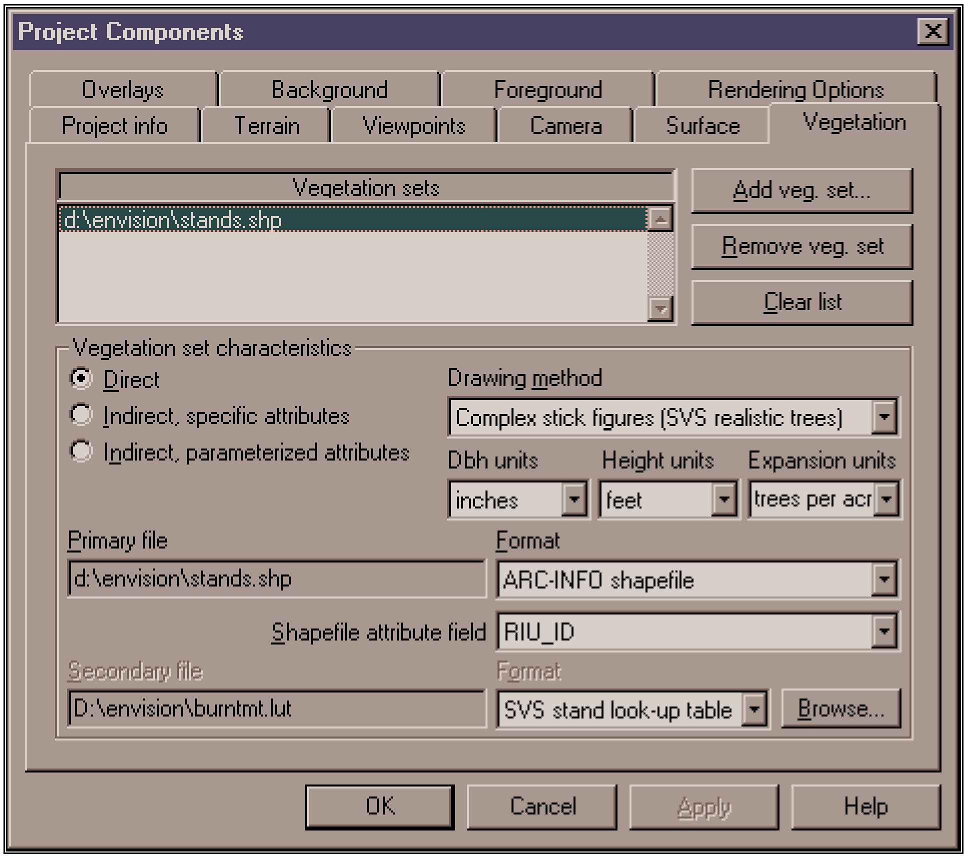


Figure 83: EnVision Project Components vegetation page. Here is where you define your vegetation datasets including the ArcInfo Shapefile and look-up table pointing to the SVS files.

Once the vegetation data, and DTM have been brought in the program should be ready to render the landscape (Figure 84). If the trees on the landscape come up orange, check to make sure you have the right Tree Form Definition file in your current directory. To check the contents of the .trf file use the SVS Tree Form Designer. In the Tree Form Designer you can add new species, change existing species or make entirely new definition files.

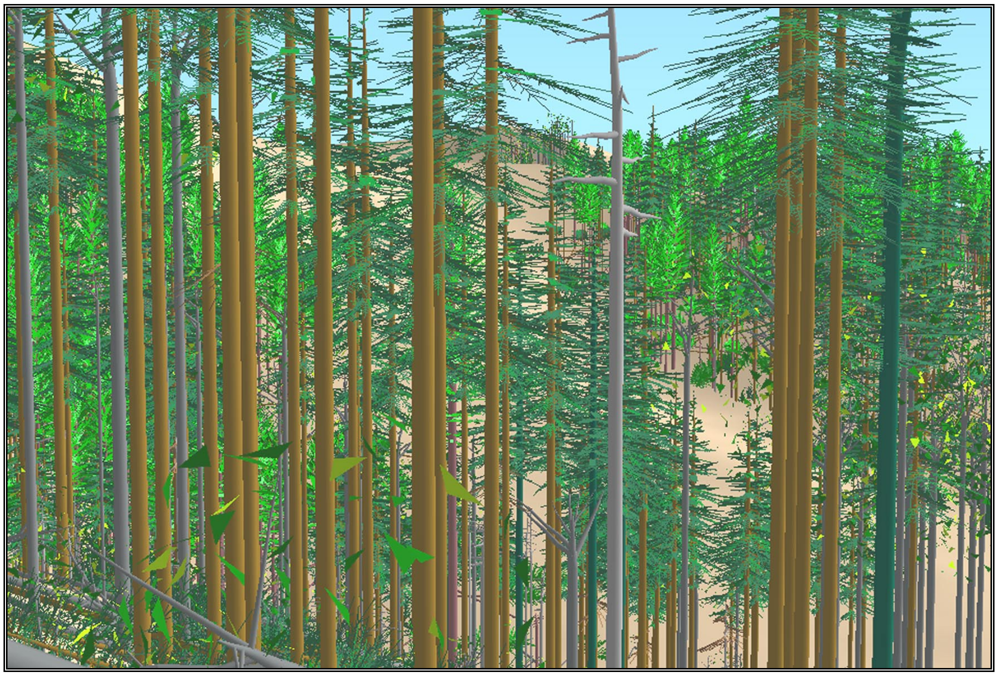


Figure 84: EnVision Landscape Visualization of a variable density thin treatment in the Burnt Mountain Project Area

Conclusions

While we initially planned on using DNR provided silvicultural prescriptions, models and data, the UW Senior Forest Engineers discovered serious flaws in the data provided by the DNR's silvicultural liaison and decided to use their own growth modeling techniques. Over the course of the quarter, many tools were developed to assist in growth modeling and landscape visualization. These tools should prove useful to any Forest Engineer interested in growth modeling.

12.3 Tailtree Analysis

Objectives

A tailtree analysis was performed in order to find the size of trees present in each stand at 50 and 150ft intervals. This provides information regarding how high a skyline can be rigged in order to increase deflection.

Procedure

To obtain the required information to predict tailtree spacing, we used the view table/stand tables/stand sort summary in LMS, which needs to be run separately for each stand in the project area. The stand sort summary table is not actually used. Only the .tre file, which LMS creates and stores in the cache, is used. These files were copied into separate excel spreadsheets, within the excel workbook named "'stand#'calc."

Tailtree spacing

To calculate tailtree spacing, we copied the deadmans.tre, which is a temporary file created by LMS using the stand sort summary table, into an excel worksheet. The deadmans.tre can be found in the deadman66/Cache and the file contains individual tree information, including: year, stand, tree number, species, dbh, height, crown ratio, trees per acre (exp), and volume (mbf). From this information, we calculated the following data found on the sheet named "'stand#' single dens. thinning":

Tail Tree TPA

The tail tree TPA was created to eliminate Red Alder (RA) from the tail tree selection process.

IF(spp="RA",0,exp)

Tail tree DBH

All RA DBH was set to 0, and all other species, except DF, DBH were reduced by 2" because of lower strength properties.

IF(spp="DF",DBH,IF(spp="RA",0,DBH-2))

Sum TPA

This sums all trees per acre greater than or equal to the current diameter class.

TBA

The total basal area per diameter class is calculated using an equation from the Forestry Handbook (August 1999). The equation used is

$$TBA = 0.005454\ (DBH)^2\ (TPA).$$

Sum TBA

This sums all total basal areas greater than or equal to the current diameter class.

Spacing

The spacing between tail trees of the current diameter class was calculated by the following equation from the Forestry Handbook:

$$Spacing = 43560^{0.5} / sum\_tpa^{0.5}$$

Rig QMD

The tail tree quadratic mean diameter (tree of average basal area) estimates the average tailtree DBH for the representative spacing using the following equation from the Forestry Handbook:

$$QMD = (sum\_TBA/(.005454*TPA))^{0.5}$$

This information can be used to predict the possible rigging heights on tail trees according to the Oregon Administrative Code (OR-OSHA, 1997).

12.4 Road Reconnaissance Reports

Road Name:	
UW Common Name:	Already Road
Road Class:	Secondary
Initial Designers:	Robbie Stewart, Justin Gardner, Tamra Zylstra, Peter Schiess
Total Length (stations):	5+00 (Gradeline) 20+00 (Paper only)
Road Access Description:	The road takes off from the Big Ridge Road at station 11+50
Take Off Location:	T31N R12W--- SW ¼ of NW ¼ of Section 36
Termination Location:	T31N R12W--- NE ¼ of NW ¼ of Section 36
Quantity of Settings Accessed:	4
Area of Sales Accessed (acres):	79
Road Status:	Flagged with notes
Stream Crossing Information:	Approximately at station 14 there is a stream with some wetlands areas around it. This section of road was not flagged in, but a possible crossing sight was noted.
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	The road was flagged in at 12% grade approx. 5 stations from the saddle until it tied in with the Big Ridge Road (station 11+50). The road from the saddle was walked, but not flagged for about another 10 stations. This brought us to a stream that will require a stream crossing. A suitable crossing sight was noted where the ground was dryer than the soil upstream and it was determined that from the stream, the road should proceed at a +5% grade back towards to saddle until the saddle elevation is reached, then change to a 0% grade.

Road Grade Information:	Maximum: 16 Minimum: 0 Max sideslope: 55

Road Name:			Already Road	
Station	**Slope %** left	**Slope %** right	**Grade %**	**Comments**
0+00	0	0		saddle
			0	
0+50	0	0		
			14	
1+00	10	-10		
			14	
1+50	20	-20		
			12	
2+00	10	-20		
			12	
2+50	15	-10		
			12	
3+00	30	-35		
			12	
3+50	20	-35		
			12	
4+00	25	-35		
			12	
4+50				
			12	
4+90				Big Ridge Road station 11+50

Road Name:	
UW Common Name:	Big Ridge Road
Road Class:	Secondary
Initial Designers:	Justin Gardner, Tamra Zylstra
Total Length (stations):	54
Road Access Description:	Road started where Rayonier road stopped.
Take Off Location:	¼ corner of T31N R12W Section 36
Termination Location:	T31N R12 W --SE ¼ of SE ¼ of Section 36
Quantity of Settings Accessed:	9
Area of Sales Accessed (acres):	306
Road Status:	Previously traversed and staked: Sta 1-11 Flagged, Notes: Sta 11-20, 24-27, 39-54 Flagged: 20-24, 27-39
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	The first 11 stations were already staked and traversed by the DNR for a sale that fell through. This section of road rides along the spine of the ridge. These trees were good sized and are ready for harvest. The road followed the ridge top until a saddle was reached at station 27. From here the road climbs at a constant 16% until we got back on the ridge at around station 39. This section of road is on a side hill of between 60 and 70 percent. The timber in this area was moderate in size. After this point the road follows the ridge until the end. The timber for this stretch of road was small to moderate, but not much was seen of what was on the side slopes. There are notes for stations 11-20, 20-27, and 39-54 that can be seen in the accompanying table. This road was very straightforward

Road Grade Information:	Maximum Grade 16% Minimum grade 0% Maximum side slope 60%

Figure 85Timber on big ridge road in the saddle.

Figure 86 Timber on the ridge.

Road Name: Big Ridge Road

SECTION 1				
STA	SSL	SSR	GRA	Comments
				0+00 is in saddle approximately 17 stations from start point of road
				Then progresses toward the start point of the road
0	0	0		on saddle
			14	
1	0	20		
			16	
2	-20	20		
			16	
3	-25	25		
			16	
4	-40	30		
			16	
5	-65	65		
			16	
6	-35	55		
			16	
7	-40	25		
			16	
8	-25	10		
			12	
8+50	0			on ridge
			16	
9	-15	0		
			9	
9+50	0	0		
			15	
10	0	-10		
			5	
10+50	10	-10		
			3	
11	0	0		
			10	
11+50	0	0		
			0	
16+55				tied into stake from previous incomplete DNR survey

SECTION 2				
STA	SSL	SSR	GRA	Comments
12				
			16	
13	-65	65		off ridge
			12	

14	-65	65		
			8	
15	-10	0		
			-3	
16	-10	-5		
			-4	
17	0	-10		
			-4	
18	-50	25		
			5	
19				skipped sta
			5	
20	-30	10		on ridge
			10	
21	-16	0		leave ridge
			-4	
22	-15	5		
			-6	
23	0	0		
			-8	
24	-10	0		
			8	
25	0	0		on ridge
			2	
26	-10	-10		between 26 & 27 extra half sta
			-2	
27	0	-10		
			-3	
28	-60	20		
			-6	
29	-70	20		
			-6	
30	-60	5		
SECTION 3				
STA			GRA	
0+00				
			10	
0+50				
			-10	
1+00				
			-10	
2+00				
			0	
3+00				
			0	
3+50				

			0	
4+00				

Road Name:	
UW Common Name:	Pidley Road
Road Class:	Secondary
Initial Designers:	Bill Heymann, Robby Stewart, Tamra Zylstra
Total Length (stations):	16
Road Access Description:	Station 26 on main street
Take Off Location:	T 30N R11W NE ¼ of NW ¼ of Section 1
Termination Location:	T30N R11W SW ¼ of NW ¼ of Section 1
Quantity of Settings Accessed:	103
Area of Sales Accessed (acres):	Flagged/Blazed
Road Status:	None
Stream Crossing Information:	None
Switchback/Curve Information:	None
Rock Outcrop Information:	none
Comments:	The road was flagged in at –15% at the beginning in order to stay on the ridge. After station 5+00 we continued the road following the paper plan. The remainder of the road was at a grade of 0-5%. The landing location allows for access to stands with a dbh of 18+.
Road Grade Information:	Max adverse grade 17% Minimum grade 0% Maximum side slope 65%

Road Name: Pidley

Station	Slope % left	Slope % right	Grade %	Comments
0+00	30	-10		edge of Main Street
			-15	
0+50	30	-25		
			-15	
1+00	50	-50		
			-15	
1+50	45	-45		
			-15	
2+00	-20	-5		
			-15	
2+50	-15	-10		
			-15	
3+00	-20	-5		
3+50				
			-15	
4+00	-10	-20		
4+50	20	-30		
			-15	
5+00	20	-40		
			-17	
5+50	-15	-35		
			0	
6+00	-20	15		
			0	
6+50	-40	25		
			0	
7+00	-50	50		
			0	
7+50	-55	45		
8+00	-50	50		
			0	
8+50	-50	50		
			0	
9+00	-60	65		
			0	
9+50	-60	60		
			0	
10+00	-65	60		
			0	
10+50	-60	65		

			0
11+00	-50	50	
			0
11+50	-55	55	
			0
12+00	-60	50	
			0
12+50	-55	50	
			0
13+00	-55	45	
			0
13+50	-50	50	
			0
14+00	-55	45	
			0
14+50	-50	25	
			0
15+00	-30	20	
			-15
15+50	-15	0	

Road Name:	
UW Common Name:	Rail Road North
Road Class:	Secondary
Initial Designers:	Barry Collins, Aaron Roark, Bill Heyman, Aaron McDonald, Luke Rogers
Total Length (stations):	66
Road Access Description:	When entering property line on Main Street go approximately 65 stations to start of Rail Road North
Take Off Location:	T30N R11W—SE ¼ of SW ¼ of Section 1
Termination Location:	T30N R11W—NE ¼ of NE ¼ of Section 11
Quantity of Settings Accessed:	2 clearcut designs
Area of Sales Accessed (acres):	Unknown
Road Status:	Flagged and blazed
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	We flagged this road following an existing railroad grade to the first saddle at station eight. The side slope along this section varied from 40-80%. Lyles road takes of from this saddle to the south. The road leaves the rail road grade and is flagged at 0% for seven stations along the north side of the slope. The side slope averages 50-80%. At station 23 rail road south splits off. At station 31 the road reaches a second saddle. The flag line crosses on to private property at station 32 and back onto state land at station 46. The flagged road is 20-30 feet higher than the paper road at stations 43-50 because the ground is unstable, wet and slumping. The side slope of this area is 25-50%. A spur take off to a landing at station 58. The timber looked pretty good overall but station 49 the trees had quite a bit of mistle toe. We crossed the section line at station 50. We reached a saddle at station 64, this is were we stopped flagging the road. A spur goes out to the end of the ridge to a landing
Road Grade Information:	Maximum = 18%

Figure 87 Wet area on Railroad N. road

Road Name: Railroad North

Station	Slope % left	Slope % right	Grade %	Comments
0+00	-70	-55		
			0	
0+50	-60	-40		
			-4	
1+00	55	-40		
			5	
1+50				
2+00	90	-70		
			0	
2+50				
3+00	80	-70		
			0	
3+50				
4+00	80	-55		
			0	
4+50				
5+00	80			Ridge drops down to near road
5+50	70	-65		
6+00	70	-70		

6+50	70	-70		grade change
			-10	
7+00	65	-60		
			-13	
7+50	-15	-43		saddle 100 ft to the left
			-17	
8+00	0	-35		
			-5	
8+50	5	-20		
			0	
9+00	-5	-15		old grade 80 ft. to the left paralleling this grade
			0	
9+50	20	-25		
			0	
10+00	30	-45		
			0	
10+50				
			0	
11+00	30	-60		
11+50	90			
12+00	90	-60		
12+50	85	-60		Rocks, cobbles for soil
13+00	80	-75		
13+50	75	-65		
14+00	75	-50		
14+50	65	-60		
15+00	65	-60		
15+50	75	-60		
16+00	60	-70		
16+50	60	-60		
17+00	60	-55		
17+50				
			0	
18+00	75	-55		
			-5	
18+50				

19+00	70	-57	
			-10
19+50	70	-65	
			-10
20+00	70	-60	
20+50	50	-60	
21+00	-35	-55	
21+50			
			-10
22+00	70	-70	
			0
22+50			
			0
23+00	50	-50	
23+50	-50	50	
			-12
24+00	0	30	
			16
24+30	0	30	
25+00	0	0	
			15
25+50			
26+00	0	0	
			14
26+50	0	0	
27+00			
27+50			
28+00	-50	20	
			-15
28+50			
29+00	-15	50	
			-10
29+50			
30+00	-25	5	
30+50			

31+00	60	10		saddle
31+50				
32+00	-40	10		
32+50				6ft dbh cedar
			-5	
33+00	-70	70		
33+50				
34+00	-65	65		
34+50				
35+00	-50	50		
35+50				
36+00	-65	65		
36+50				
37+00	-40	60		
37+50				
38+00	-50	60		
38+50				cruise plot #13
39+00	-50	50		
39+50				
40+00	-50	50		
			1	
40+50				
41+00	-20	40		
41+50				
42+00	-45	40		
42+50				
43+00	-50	50		

			1	
43+50				
44+00	-60	50		
44+50	-60	40		
			0	
45+00	-45	30		
			1	
45+50				
46+00	-30	30		200ft above old grade
			-5	
46+50				
47+00	-50	50		
47+50				
48+00	-45	45		
48+50				
49+00	30	50		
49+50				
50+00	30	30		80ft from section line
			-12	
50+50				
51+00	-60	30		
51+50				
52+00	-45	40		
52+50				
53+00	-50	60		
53+50				
54+00	-65	65		
54+50				
55+00	-65	65		

55+50				
56+00	-55	45		
56+50				
57+00	-30	25		
57+50				
58+00	-60	40		spur takes off
58+50				
59+00	-50	40		
			-12	
59+50				
60+00	-50	50		
60+50				
61+00	-60	30		
61+50				
62+00	-60	60		
62+50				
63+00	-40	40		
			-12	
63+50				
64+00	-30	25		
			-12	
64+50	0	10		
			10	
65+00	0	5		corner
65+50				
66+00	0	0		elev. 1290 ft

Road Name:	
UW Common Name:	Rail Road S.
Road Class:	Secondary
Initial Designers:	Rob Stewart, Bill Heyman, Aaron Roark
Total Length (stations):	Starts at 0+00 ends at 35+00 (starts at approx. station 27+00 of railroad north)
Road Access Description:	Take US 101, then head west on Burnt Mountain Road, Take a left ……., Go ……miles, take a left on railroad north, once traveled 27 stations then you are at the railroad south cut-off which will be on your left side.
Take Off Location:	T30N R12W SE ¼ of SW ¼ of Section 1
Termination Location:	T30N R12W SW ¼ of NW ¼ of sec 12
Quantity of Settings Accessed:	Flagged, Notes, Bearings of flag line
Area of Sales Accessed (acres):	
Road Status:	
Stream Crossing Information:	One stream crossing (type five) between stations 8+50 – 9+00
Switchback/Curve Information:	One curve flagged in. Starts at station 23+50 of Railroad north, and curves into the railroad south road, stopping at station 1+00 of railroad south and continuing with grade of –10% on RR south.
Rock Outcrop Information:	None found
Comments:	Most of the stations flagged in are on top of the ridge. We ran into no problems. It is flagged in just as shown on the map. The timber out there is the very large and is one of the older stands of trees that were seen out there. We came across one draw with a type five stream. There should be no problems with the construction of this road.
Road Grade Information:	0+00 – 0+50 = -10% 0+50 – 1+00 = -5% 1+00 – 2+00 = 0% 2+00 – 9+00 = 2% 9+00 – 12+50 = -10% 12+50 – 13+50 = 10% 13+50 – 14+00 = 5% 14+50 – 20+50 = 0% 20+50 – 27+50 = 5% 27+50 – 28+00 = -5% 28+00 – 28+50 = -10% 28+50 – 29+50 = -15% 29+50 – 31+00 = -10% 31+00 – 32+00 = -15% 32+00 – 33+00 = 0% 33+00 – 34+00 = 10% 34+00 – 34+50 = 14% 34+50 – 35+00 = 0%

Road Name: Railroad South

Station	Slope % left	Slope % right	Grade %	Bearing	Comments
23+00					
			0		Curve Starting on exsiting Rail Road North Road
23+50					Beginning of Curve with radius 70ft
			-12	262	
24+00					
			-16	272	
24+50					
			-16	300	
25+00					
			-15	300	
25+50	-6	6			
			-6	280	
26+00	-20	20			
			-20	240	
26+50					Railroad South starts here 0+00
			-10	240	
0+00	20	10			Start of Railroad South (also station 26+50 RR North)
			-10	200	
0+50	18	-30			
			-5	160	
1+00	30	-43			
			0	122	
1+50	43	-37			
			0	138	
2+00	44	-37			
			2	153	
2+50					
			2	178	
3+00	25	-50			
			2	174	
3+50					
			2	164	
4+00	15	-50			
			2	102	
4+50					
			2	40	
5+00	30	-55			
			2	81	
5+50					

			2	99	
6+00	45	-40			
			2	99	
6+50					
			2	90	
7+00	50	-40			
			2	101	
7+50					
			2	101	
8+00	50	-40			
			2	107	
8+50					
			2	164	Crossing Type Five Stream / Draw (No water at this location) But water can be seen 100 - 200ft below this location
9+00	55	-55			
			-10	195	
9+50					
			-10	189	
10+00	50	-35			
			-10	200	
10+50					
			-18	216	
11+00	-2	1			
			-10	226	
11+50					
			-10	230	
12+00	-30	15			
			-10	169	
12+50					
			10	220	
13+00	-40	15			
			10	39	
13+50					
			5	242	
14+00	-30	0			
			0	237	
14+50					
			0	248	
15+00	0	-25			
			0	214	
15+50					
			0	196	
16+00	-35	5			
			0	213	
16+50					
			0	214	
17+00	-45	40			
			0	198	

17+50				
			0	219
18+00	40	35		
			0	215
18+50				
			0	202
19+00	-30	5		
			0	178
19+50				
			0	218
20+00	-40	5		
			0	245
20+50				
			-10	201
21+00	-20	-25		
			-10	227
21+50				
			-10	223
22+00	-5	-30		
			-10	223
22+50				
			-10	240
23+00	-10	-25		
			-10	210
23+50				
			-10	246
24+00	-30	-20		
			5	214
24+30				
			5	183
25+00	-40	20		
			5	183
25+50				
			5	221
26+00	-30	30		
			5	234
26+50				
			5	237
27+00	-35	10		
			5	260
27+50				
			-5	210
28+00	-30	5		
			-10	190
28+50				
			-15	224
29+00	-50	40		
			-15	258
29+50				

			-10	271	
30+00	-60	40			
			-10	278	
30+50					
			-10	299	
31+00	-50	25			
			-15	324	
31+50					
			-15	299	
32+00	-15	-25			
			0	192	
32+50					
			0	210	
33+00	-50	5			
			10	256	
33+50					
			10	198	
34+00	-45	30			
			14	218	
34+50					
			0	243	
35+00	-35	35			Landing location

Road Name:	
UW Common Name:	Lyle's Road
Road Class:	Secondary
Initial Designers:	Tamra Zylstra, Bill Heymann
Total Length (stations):	Approx. 25+00 (Gradeline)
Road Access Description:	Road takes off to the South from a saddle at station 8+50 on Railroad North Road.
Take Off Location:	T30N R12W SW ¼ of SE ¼ Section 1
Termination Location:	T30N R12W NW ¼ of NE ¼ of Section 12
Quantity of Settings Accessed:	2
Area of Sales Accessed (acres):	100
Road Status:	Flagged, Blazed, Notes
Stream Crossing Information:	None
Switchback/Curve Information:	None
Rock Outcrop Information:	None
Comments:	The original road on paper went uphill from the saddle at 14% to create access to a possible landing that was taken out of consideration and will not be used. Since that part of the road was unnecessary, we followed the contour line at 0% until we reached the part of the road where we had to move downhill. We then continued the gradeline at 16%, following the paper plan, down towards the landing, however, this brought us below the saddle. To correct this, we started from the saddle and worked our way back to toward the beginning of the road at 12% grade until it intersected the 16% gradeline at station 12 + 50. To reach the landing, a grade of 10% was run from the saddle to the landing on the nose of the ridge.
Road Grade Information:	Maximum: 16 Minimum: 0 Max Sideslope: 75

Road Name: Lyle's Road

Station	SSL	SSR	Grade %	Comments
0+00				
			-10	
1+00	-50	50		
			-10	
2+00	-60	65		
			0	missed 1/2 sta
3+50	-50	60		
			0	
4+50	-55	60		
			0	
5+50	-57	65		
			0	
6+50	-60	75		
			0	
7+50	-60	55		
			-16	
8+50	-60	60		
			-16	
9+50	-50	50		
			-16	
10+50	-68	68		
			-16	
11+50	-58	67		
			-16	
12+50	-50	60		
			-10	
13+50	-50	60		
			-12	
14+00	-45	65		3ft-d stump
			-12	
15+00	-60	60		5ft-d stump
			-12	
16+00	-55	55		4-5ft-d stump
			-12	
17+00	-45	45		
			-12	
18+00	-40	40		
			-12	
19+00	-45	45		
			-12	
20+00	35	-45		saddle
			0	
21+00	35	-45		
			-10	
22+00	35	-45		

			-10	
23+00	35	-45		
			-10	
24+00	35	-45		
			-10	
25+00				landing

Road Name:	
UW Common Name:	Himalaya
Road Class:	Mainline
Initial Designers:	Whole Team
Total Length (stations):	92 + 95 stations
Road Access Description:	Station 106 on Main Street 2
Take Off Location:	T30N R11W—SE ¼ of SW ¼ of Section 6
Termination Location:	T30N R12W---SE ¼ of SW ¼ of section 7
Quantity of Settings Accessed:	9
Area of Sales Accessed (acres):	529 acres
Road Status:	Full Blown design
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	The project team did a full road design on the Himalaya using Roadeng, with the numbers from Roadeng the cost of the road was calculated. The road was designed with a 60 foot wide clearing limit and a 12 foot running surface.The road is 92 + 95 stations long. The road will produce 43,955 cubic yards of excavated material at a cost of $107,966, 22,006 cubic yards of material will be needed for fill. Clearing and grubbing will cost $12,040 for the length of the road. The cost for the ballast and surface material is from the Mary Clark pit. The road was designed using 14 inches of ballast which equals 5752 cubic yards of material at a cost of $20,821,The running surface will be 4 inches thick using 1582 cubic yards of material for a cost of $28,739. Plastic culverts will be used instead of galvanized culverts, 21 18 inch X 30 foot culverts will cost $6,716. The total cost of the road is $196,754 or $2,139 per station.
Road Grade Information:	

Sale Name:	Himalaya				**Side Slope:**	20-70%		
Contract # :					**# of Stations:**	92.00		
File Name:					**Contract Date:**			
Road Standard:	Mainline				**Compiled by:**	BEAR		
Road Name/s:	Himalaya							
Project Cost Summary		**Total**	**Per Station**					
Clearing and Grubing		$12,040	$131					
Excavation		$107,966	$1,174					
Ballast and Surfacing		$50,727	$551					
Culvert		$6,716	$73					
Overhead		$17,745	$193					
Move In		$1,560	$17					
Total Road Costs		**$196,754**	**$2,139**					
*Profit and Risk is distributed throughout								
CLEARING, GRUBBING, DISPOSAL COSTS								
	MBF/	Prod.	Cost/	Road	R/W			
Section	Acre	Factor	Acre	Length	Width	Subtotal		
	0-15	0.210	$525		50	$0		
	16-25	0.342	$855			$0		
0+00-92+00	26-35	0.615	$1,538	9244	60	$12,040		
	36-50	1.000	$2,500			$0		
					Clear and Grub Total =		$12,040	
EXCAVATION COSTS								
Volume	Bucket Capacity	Cycle Time	Operating	Load Time	Total Trucks	Total Excav.		
(CUYD)	(CUYD)	(MIN)	Efficiency	(MIN/TRUCK)	Loaded	(HRS)		
43995	2.00	0.30	0.95	2.00	4,400	109.9875		
Volume	RT to Waste	Truck Capcty	Avg Speed	Load/Unload	RT Travel	Total Haul Time		
(CUYD)	(Mi)	(CUYD)	(MPH)	(MIN)	(MIN)	(HRS)		
43995	1.0	10	10	1.56	6.00	554.34		
Equipment		Time(hrs)	$/Hour	Quantity		Subtotal		
Cat 235		398	$97.00	1		$38,606		
Dumptruck		554.3	$60.00	1		$33,260		
Vib. Roller		175.0	$50.00	1		$400		
Grader		700.0	$51.00	1		$35,700		
D6 Dozer		0.0	$74.00	0		$0		

D8 Dozer		0.0	$114.00	0		$0	
					Excavation Total =		$107,966
BALLAST AND SURFACING COSTS							
Surface Source		UNIT COSTS		Surface	Ballast	Riprap	
Ballast Source		Drill & Shoot		$0.00	$0.12	$0.00	
Riprap Source		Dig and load		$0.70	$0.70	$0.70	
		New Pit develope		$0.00	$0.00	$0.00	
		Haul *		$16.50	$2.00	$5.90	
		Spread		$0.40	$0.40	$0.00	
		Compact		$0.25	$0.25	$0.00	
		Strip		$0.27	$0.10	$0.00	
		Reclamation		$0.05	$0.05	$0.00	
		TOTALS		$18.17	$3.62	$6.60	
		*Haul Cost		Surface	Ballast	Riprap	
		R.T. Miles		5.0	5.0	5.0	
		Ave. Speed		10	10	10	
		Delay (hrs)		0.2	0.2	0.2	
		Cost/Hour		$60.00	$60.00	$60.00	
		CY/Load		10	10	10	
		Haul Formula:(R.T.Miles/MPH+Delay)($/hr / Cy/load)					
Type	Volume		Cost per CUYD			Total Cost	
Surface	1582	Cu. yds @	$18.17	/cu. yd =		$28,739.49	
Ballast	5752	Cu. yds @	$3.62	/cu. yd =		$20,821.52	
Riprap	0	Cu. yds @	$6.60	/cu. yd =		$0.00	
Subgrade Finishing				No of Stations	Cost/Station	Total	
				106.00	$11.00	$1,166.00	
					Ballast and Surfacing Total =		$50,727
CULVERT COSTS				Purchased	Labor		
Description	Number	Length/pipe	Diameter	Cost/ft	Cost/ft	Subtotal	
galvanized steel	0	50	48	$28.00	$13.85	$0	
galvanized steel	0	50	42	$25.00	$10.35	$0	
galvanized steel	0	50	36	$21.00	$9.25	$0	
galvanized steel	0	50	30	$19.00	$8.25	$0	
plastic	0	30	24	$13.00	$3.00	$0	
plastic	21	30	18	$8.00	$2.66	$6,716	
plastic	0	30	15	$7.00	$2.33	$0	
plastic	0	30	12	$4.00	$2.00	$0	
					Culvert total =		$6,716

					Subtotal =		$177,449
GENERAL EXPENSES					Overhead and General Exp. Add	10%	$17,745
MOVE IN COSTS							
Description			$/Move	Moves	Subtotal		
Dozer			$450	1.00	$450		
Excavator			$450	1.00	$450		
Front End Loader			$250	0.00	$0		
Vib. Roller			$300	1.00	$300		
Rock Truck			$100	2.00	$200		
Grader			$160	1.00	$160		
Crusher & Drill			$4,100	0.00	$0		
					Move In total =		$1,560
					TOTAL ROAD COST =		$196,754

Traverse Notes for Himalaya Road

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
0	0		0	0	0.1			0	-0.1	10.2	23.5
		-1				24.9	0				
49.5	49.5		0	0	0.1			1.2	-0.1	13.4	15.7
		2				0.6	0				
50.5	51.9		0	0	0.1			-1	-0.1	10.8	8.1
		2				1.2	25.4				
102.2	103.7		0	0	-1.5			-0.8	1.5	8.3	7.5
		2				0	0.6				
102.7	104.2		0	0	-1.5			-0.5	1.5	8.3	7.5
		3.6				0	104.7				
153.5	155.1		0	80	-4.4			-2.6	4.4	12.6	7.8
		6.7				0	2.6				
154.1	155.9		0	80	-4.4			-3.1	4.4	12.8	8
		6.7				15.7	166.7				
227.6	229.4		0	0	-2.7			2.5	2.7	10.1	20.2
		11.7				18.6	498				
301	303.1		0	0	-2.7			-1.9	2.7	44.4	8.4
		10.7				117.2	343.3				
352	355		0	25	-1.2			8.6	3.7	11.8	58.9
		4.8				192.6	26.9				
397.5	400.9		0	0	0			3.1	0	6	54.5
		13				73.8	0.5				
412	416.7		0	0	-0.2			4.9	0.2	6.3	59.8
		18.3				533.5	107.6				
530	535.1		0	0	0.4			12.3	6.4	16.9	37
		18.3				4.1	3				
530.7	536.6		0	0	-0.8			11	6.5	16.8	29
		10.5				222.9	217.5				
645.9	652.5		0	0	-2.8			8.3	3	10.5	37.4
		10.5				29.9	32.4				
666.9	673.6		0	0	-3.1			7.3	3.1	10.7	30.1
		7.9				26.4	7.5				
673.1	679.9		-1	10	0.9			6.5	3	11.3	59.9
		7.9				302	20.3				
707.1	714.9		-1	10	2.3			7.4	2.4	10.6	59.8
		4				350.5	12.8				
749.5	758.6		-1	10	0.2			2.9	0.7	7.2	62.9
		9.1				775.6	6				
811.5	821.8		-3	106	8.2			9.1	1.5	11.3	42.8
		7.5				169.2	0				
820	831.2		-3	106	7.8			9.2	2	10.7	42.3
		7.5				261	38.8				
849.5	861		0	0	-3.6			13.5	3.6	11.4	7.7

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
		3.8				0	97.9				
885.1	893.5		0	0	-4.2			11.3	4.2	12.2	9.5
		4.1				0	663.1				
1101	1106.7		5	0	-3.5			0.6	3.5	9	12.5
		12.8				70.6	113.2				
1188	1193.7		29	0	2			2.3	-2	13.4	8.6
		12.8				0.2	0				
1188.2	1193.8		29	0	2			2.3	-2	13.4	8.6
		13				0.6	0				
1188.5	1194.2		29	0	2			2.4	-2	13.5	8.7
		13				111.1	0				
1224.5	1230.4		29	0	4.2			-1.6	-3.8	17.9	15.6
		5.7				2.9	0				
1225.5	1231.4		-40	-55	3.2			-1.7	-3.9	9.2	8.8
		5.7				99.1	0				
1261.1	1266.2		-40	-55	6.2			-5.3	-8.3	11.5	12.6
		3.2				75.4	0				
1287.5	1291.6		-40	-55	2.8			-3.7	-4.3	9.1	9.4
		3.2				1.4	0				
1288.5	1292.6		-40	-55	2.7			-3.6	-4.2	8.4	9.3
		4.6				18.7	483.6				
1410.3	1414.9		-11	4	-6.6			5	6.8	18.5	12.1
		9				253.9	205.3				
1468	1475		-61.5	25	7.7			12.8	-4.5	21.8	20.5
		17.1				136.8	173.4				
1510.3	1519.9		-30	10	-9.5			21.7	11.6	24.9	14.1
		15.3				0	727.7				
1588.5	1588.9		19	-30	-8.5			27.3	0.3	13.5	22.1
		16.7				1.1	159				
1622.8	1616.9		10	33	-1.7			13.1	6	15.6	9.3
		17.7				173.7	50.6				
1685.9	1684.9		39	-52	10.9			-18.7	-4.7	19.4	15.1
		19.4				234.4	7.1				
1740.2	1735.7		-7	-65	-0.4			-17.7	-0.8	7.4	6
		16.1				0	178.2				
1779.8	1776.2		-24	-24	-6.8			-6.1	5.3	25.4	12.8
		17.1				0	300.5				
1831.7	1828.6		-33	6	-3.5			8.1	3.9	15.7	8.9
		16.9				86	98.3				
1899.1	1894.5		-70	27	3.1			7.5	-1.1	9.6	15.2
		19.1				112.5	0				
1932.5	1927.6		-79	32.9	4.8			7.2	-2.5	11.4	15.6
		16.1				75.6	0				

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
1950	1944.9		-79	32.9	5.2			7	-2.9	11.8	15.9
		16.1				153.1	0				
1987.7	1982.6		-73	37	6			6.6	-3.6	13	12.8
		18.3				242.9	0				
2059.5	2051.3		-5	15	4.2			11.5	-2.5	12.3	14.5
		16.5				235.2	0				
2104.3	2094.1		-35	38	7.7			0.6	-7.5	13.9	19.6
		17				625.2	0				
2204	2194		-60	40	6.5			5	-4.5	14	14.4
		17				2	0				
2204.4	2194.4		-60	40	6.5			5	-4.5	14	14.4
		18.5				180.1	0				
2247.5	2236.4		-77	40	5.1			7	-2.3	11.2	13.3
		2.1				106.3	0				
2300.5	2289.2		0	-10	0.6			-3.9	-0.6	9.6	10.3
		8.3				5.9	29.2				
2331.6	2320.3		0	-10	-2.2			-0.6	2.2	9.4	11
		21.2				0	108.9				
2388.4	2377		-4	-7	-2.4			-2.7	2.3	10.3	10.3
		5.9				57.4	35.6				
2424.5	2413.3		-4	-7	4.3			-6.6	-4.5	15.4	12.2
		17.6				41.1	0				
2434.8	2423.6		0	3	5.3			-6.3	-5.3	18.3	13.5
		13.6				219.6	0				
2468.3	2457.5		0	3	9.1			-5.1	-9.1	14.6	17.4
		5.6				182.2	0				
2501.9	2491.4		0	3	3.2			-6	-3.2	14.6	11.3
		1.6				102.3	583.2				
2582.9	2572.4		0	-5	-9.1			-8.4	7.9	35.4	14.2
		8.7				0	58.8				
2586.9	2576.5		0	-5	-9.1			-8.5	7.8	35.4	14.2
		8.7				0	1020				
2692.8	2683.3		0	0	-5.5			12.7	7.6	13.7	8.7
		5				88.5	128.7				
2762.9	2752.6		-65	43	4.3			6.3	-1.6	9.7	23.4
		10.4				342	0				
2873.6	2863.6		-30	18	3.3			-3.7	-4.4	11.5	15
		6.3				152.6	0				
2915.2	2905.1		-17	8.2	5.6			-4.4	-6.4	13.7	15.3
		11.1				116.1	62				
2966.2	2954.1		-7	-4	-3.2			-14.9	2.1	12.1	8.6
		6.4				0	371.8				
3031.6	3016.7		-16	0	-7.8			-10.5	6.2	27	12.3

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
		12.8				57.7	208.1				
3099	3083.6		33	2	2.5			-9.3	0.6	15.8	8.1
		6.1				288.1	0				
3163.5	3147.8		-63	27	5.5			-4.7	-8.4	10.2	13.8
		14.7				238.2	0				
3221	3205.3		-66	65	5.3			-4.2	-8	9.5	17.9
		19.5				94.8	0				
3242.5	3226.9		-66	65	5.3			-1.6	-6.4	9.8	17.9
		11.6				0.5	0				
3242.6	3227		-66	65	5.4			-1.6	-6.4	9.8	17.9
		9.4				135.7	0				
3268.9	3253.4		-82	42	8			2.1	-7.1	13.4	15.7
		5				148.9	0				
3295.3	3279.6		-82	42	7.5			2.9	-6.3	13	15.5
		2.8				221.9	0				
3329.7	3314		-73	62	8.5			4	-6	14.9	20
		-1.5				77.2	0				
3340.6	3324.5		-73	62	8.5			3.4	-6.4	14.9	20.1
		6.8				231.4	0				
3382.2	3365.7		-70	54	5.1			3.5	-3.2	9.6	15.6
		-5				140	0				
3416	3399.5		-70	54	5.8			2.3	-4.5	10.5	16.2
		-5				118	0				
3442.6	3426.1		-70	54	5.8			3.4	-4	10.8	16.2
		1.1				86.5	0				
3475.5	3459.1		-9	-5	1.2			2.6	-1.3	17.6	7.3
		-1.9				0.1	0				
3475.6	3459.2		-9	-5	1.2			2.6	-1.3	17.6	7.3
		-2.2				14.7	11.2				
3515	3498.4		-9	-5	-0.9			6.7	0.5	6.8	7.9
		-2.9				16.7	9.8				
3554.5	3537.6		-9	-5	1.2			2.9	-1.4	18.3	9.6
		-1.3				156.6	0				
3599.4	3583.1		66	-39	3.2			-1.6	-2.1	38	7.9
		-4.1				184	0				
3623	3607.5		66	-39	5.4			-6.7	-1	39.9	10.8
		-14.4				368.3	0				
3672.7	3657.6		55	-57	4.2			-0.9	-3.8	30.4	8.6
		-7.6				586.9	0				
3727.9	3716.6		28.6	-50	6.3			-22.3	0.1	34	24.3
		-14.1				299.8	31.1				
3811.2	3767.2		26.6	-47	-0.9			-51.1	8.7	14.8	14
		-32.9				112	11.6				

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
3861.5	3785.1		47	-40	5			-28.5	8.4	38.5	17.5
		-12.8				535.4	33.7				
3897.6	3829		47	-40	3.1			-20.9	6.7	41.9	28.7
		-12.8				90.5	9.2				
3898	3836.3		47	-40	3.6			-20	5.8	43.3	26.7
		-18.1				2186	44.8				
3973.5	3920.7		59	-46	17.2			-24.5	-2.7	52.1	28.2
		-18.1				384.8	0				
3974.1	3930.3		59	-46	16.4			-20.4	-4.4	55.1	27.8
		-13.6				954.3	0				
4041.3	4000.5		47	-35	3.4			-0.5	-3.2	23.6	10.2
		-7.3				436.6	0				
4124.4	4083.9		59	-60	4.6			-4.7	-1.8	34.7	9
		-23.9				83.9	0				
4137.1	4097.7		59	-60	4.2			0.6	-4.6	31.6	8.6
		-14.2				60.3	3.1				
4149.5	4110.5		42	-69	3			4.2	-5.9	23	17.7
		-11.1				125.2	5.6				
4172.1	4132.6		42	-69	4.3			4.6	-7.5	41.8	7.5
		-13.1				141.4	5.8				
4200.5	4161.4		42	-69	2.8			-2.3	-1.9	19.8	25
		-17.7				59.1	46				
4241.1	4203.1		19	-25	-2			-11.5	4.2	7.6	13
		-14.6				0	78.4				
4300	4262.9		6.4	-6	-1.3			-1.3	1.3	6.8	8.7
		-20.5				0	1.7				
4302.1	4265		6.4	-6	-1			-1	1.1	6.6	8.3
		-20.5				3.6	40.3				
4351.7	4315.1		-1	-28	-0.8			5.5	-0.7	8.8	12.9
		-20.5				0.9	7.5				
4359.1	4322.5		-1	-28	-1.1			5.2	-0.4	8.5	13.6
		-15				1.9	112.8				
4402.2	4365.6		-19	-9	-4.5			6.9	3.9	10.6	14.8
		-5				0.7	70.9				
4433.2	4396.8		-24	-11	-0.6			9.7	-0.4	11.6	8.4
		-3.3				11.2	4				
4452.4	4414.9		-24	-11	1.6			10.5	-2.8	10.8	12.5
		-4.6				119.6	0				
4498.8	4460.3		-24	-11	4.5			11.3	-5.8	13.3	17.7
		-7.7				2.8	0				
4499.5	4461		-24	-11	4.6			11.3	-5.9	13.4	18
		-7.7				135.6	0				
4542.8	4505.7		-11	0	3.1			22.6	-10.2	16.4	10

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
		-4.6				0.3	0				
4542.9	4505.8		-11	0	3.1			22.6	-10.2	13.3	11.1
		-5.5				18.5	0				
4549.5	4513.1		-11	0	3.2			22.9	-10.4	15.5	10.3
		-2.3				23.9	0				
4556.1	4519.8		-11	0	3.4			22.2	-10.2	22.4	8.2
		-2.8				226.3	0				
4605.9	4569.9		31.2	4	6.4			17	-8.6	20.9	13.3
		-6.4				43	0				
4613.6	4577.6		31.2	4	6.9			16.1	-8.7	21.7	14.3
		-13.6				47.7	0				
4621.4	4585.4		31.2	4	7.7			15.8	-9.3	23.8	15.9
		-17.3				0.8	0				
4621.5	4585.5		31.2	4	7.7			15.8	-9.3	23.9	16
		-6.3				235.9	1.2				
4653	4617.1		47	-60	1.6			14.5	-10.3	24.8	19.6
		-4.7				0.3	0.1				
4653.1	4617.2		47	-60	1.6			14.5	-10.3	24.8	19.6
		-7.7				88.4	18.7				
4680.7	4643.2		47	-60	2.4			15.3	-11.5	26.4	17.9
		-13.7				127.6	6.1				
4708.2	4670.5		47	-60	4.6			7.3	-9	27.5	9.3
		-7.7				335.4	0				
4764	4728.7		57	-44.2	4.3			-9.3	1	30.8	8.9
		-7.7				-2.4	0				
4764.3	4728.3		57	-44.2	4.2			-9.3	1.1	32.2	8.6
		-27.1				266.3	0				
4802	4765.3		49	-58	6.5			-8.2	-2.5	26.7	14.1
		-17.1				106.2	0				
4816.2	4779.5		49	-58	6			-7.1	-2.5	27	13
		-17.1				415.3	0				
4859.6	4823.4		52	-67	8.9			-0.4	-8.7	37.9	16.5
		-22.4				474.4	0				
4902.2	4869.8		64	-64	5.4			17.4	-16.5	42.8	10.1
		-14.3				383.2	0				
4951.9	4920.1		68	-57	4.5			15.5	-13.3	36.3	9.1
		-23.3				87.5	0				
4963.5	4932.4		68	-57	5.2			12.6	-12.4	34.6	10.6
		-18				167.1	0				
4992.8	4962.4		18	-48	3.8			9	-8.1	18	9.8
		11.1				43.3	0				
4999.5	4974.2		18	-48	5.1			-0.5	-5	16	12.6
		-6.2				46.1	3.4				

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
5024.5	5000.1		-5	-4	-0.4			6.2	0.2	6.3	7.1
		2.4				0	85.5				
5047.4	5022.7		-5	-4	-7.1			5.6	6.9	13.3	18.2
		2.4				0	44.6				
5054	5029.6		-5	-4	-5.9			3	5.7	12.2	15.7
		2.1				167.2	218.8				
5130.1	5106.1		13	-4	5.8			11.6	-7.8	16.7	10.8
		4.1				93.2	0				
5145.6	5121.7		13	-4	9.1			10.3	-10.3	19.7	17
		4.1				195.5	0				
5172	5148.1		13	-4	9.1			9.5	-9.8	19.1	17
		1.2				184	0				
5207.4	5178.7		4	0	4.9			18.3	-10.1	18.8	11.1
		0.8				309.7	0				
5271.8	5237.4		23	-8	7.2			14.3	-9	18	15.1
		-4.3				88.5	0				
5285.1	5250.9		23	-8	8.5			11.6	-9.5	19.3	18.9
		-4.3				169.1	0				
5324.5	5290.5		-10	-15	1.7			8.3	-2.9	10.7	11.3
		-15.7				3.1	0				
5327.6	5293.6		-10	-15	1.5			8	-2.7	9.9	10.4
		-15.7				29.2	9.2				
5383.7	5349.9		-10	-15	-0.7			3.4	0.2	6.8	9.2
		-11.2				0	65.9				
5417	5383.4		-9	-7	-3.5			0.7	3.4	12.8	12.5
		-2.5				35.5	54.6				
5449.5	5416		0	-15	2.8			0.5	-2.9	16.1	11.1
		1.9				2	0				
5450.4	5416.9		0	-15	3			0.5	-3	16.3	11.3
		2.1				0.2	0				
5450.5	5417		0	-15	3			0.5	-3.1	16.3	11.4
		-1.3				55.1	0				
5464.8	5431.3		0	-15	5.7			-0.2	-5.7	20.9	16.1
		-2.6				198.6	2.5				
5539.7	5505.4		-2	-4	-0.1			4.5	-0.1	9.4	6.5
		-6				19.9	1.9				
5596.7	5561.5		-7	-16	0.9			8.9	-2.3	10.3	6.1
		-12.9				29.7	0				
5615.6	5580.5		-7	-16	3			8.6	-4.4	12.2	14.2
		-8				73.5	0				
5649.5	5615.3		-11	-57	3.5			0.5	-3.8	11	8.8
		-14.1				4.8	0				
5650.5	5617.7		-11	-57	3.9			-1.7	-4.1	10.9	11.1

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
		-14.1				80.9	0				
5682.6	5649.8		-11	-57	5.3			-0.7	-5.4	12.1	11.4
		-17.2				158.3	0				
5714.8	5682.4		3	-64	7.9			3.8	-10.3	19	14.8
		-10.2				203.6	0				
5741.2	5708.7		3	-64	8.8			5.8	-12.5	21.4	16.3
		-10.2				208.4	0				
5774.5	5742.1		3	-64	5.3			3	-7.2	15.8	9.8
		-8.6				95.3	1.4				
5816.2	5784		-3	0	-0.1			-1.9	0	6.4	6
		-10				0	33.3				
5872.7	5840.4		-15	-8	-1.3			1.4	1.2	9.7	8
		-11.2				0	30.7				
5898.5	5866.3		-15	-8	-1.6			2.9	1.4	9.6	8.3
		-13.7				5.9	16.3				
5924.4	5892.2		-15	-8	0.9			3.3	-1.1	10.9	11
		-15				0.1	0				
5924.5	5892.3		-15	-8	0.9			3.3	-1.2	11	11.1
		-12.1				46.5	0.3				
5965.2	5933		-10	-39	3.3			3	-4.5	11.6	9.1
		-7.8				157.7	0				
6004	5971.9		55	-60	5.7			-0.2	-5.6	22	11
		-7.8				2.9	0				
6004.5	5972.4		55	-60	5.7			-0.2	-5.6	22	11.1
		-15.7				403.7	0				
6050.2	6018.1		75	-72	5.9			-1.2	-5	42.3	10.1
		-17.5				721.8	0				
6100.5	6068.6		73	-81	8.9			-4.9	-5.3	46.7	14.5
		-17.2				564.1	0				
6140	6107.5		68	-80	6.7			-5.1	-3.2	38.6	11.4
		-20.9				108.1	0				
6150.5	6117.6		68	-80	6.1			-2.4	-4.5	40.9	10.4
		-15.3				192.3	13.9				
6171.8	6139.7		70	-76	3.6			3.4	-6.2	44.3	30
		-17.6				93	23.4				
6185.5	6153.8		70	-76	2.4			6.8	-7.6	43.5	26.8
		-15.3				85.8	38.2				
6201.3	6169.2		70	-76	1.7			5.9	-6.3	39.5	28.7
		-13.2				121	30.8				
6221.8	6190.7		59	-61	4.6			-0.8	-4.2	33.2	9.2
		-17.3				308.7	0				
6250	6220		69	-58	8.1			-9	-1.9	49.6	14.8
		-10.9				8.1	0				

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
6250.5	6220.5		69	-58	7.9			-8.8	-1.9	49.6	14.4
		-10.9				270.9	0				
6268.7	6239.1		69	-58	8.1			-13	0.8	45.9	14.8
		-10.9				325.5	0				
6285	6257.3		69	-58	12.6			-20.9	1.8	41.7	22.1
		-16.2				264.4	0				
6299.5	6273.1		67	-63	7.9			-14.6	1.9	33.8	14.7
		-16.2				131.8	0				
6311.8	6285.7		67	-63	5.7			-11.6	2	34.8	10.5
		-18.1				271.1	182.6				
6357.5	6332.6		49	-80	2			-1.1	-1.4	21.6	52.3
		-18.1				654.4	382.3				
6403.2	6378.2		44	-49	0.1			-15.2	6.6	97.5	42.2
		-18.2				384.6	415.9				
6447.5	6425.5		43	-30	-6.3			4.2	5.1	14.2	39.8
		-18.2				198.5	305.3				
6484.9	6466.3		49	-38	1.7			-16.2	6.2	43.5	27.6
		-21.5				299.9	3.7				
6524.5	6503.3		67	-59	7.6			-20	5.8	55.4	13.7
		-12.4				13.9	0				
6525.5	6504.3		67	-59	7.6			-20.1	5.9	55.5	13.7
		-12.4				327.9	0				
6550	6528.9		67	-59	7.5			-22.3	7.5	51.5	13.7
		-12.4				26.4	0				
6552	6531.3		67	-59	6.4			-20.9	7.6	35.9	13.4
		-12.4				5.1	0				
6552.5	6532		67	-59	6.2			-20.5	7.6	33.3	13.3
		-18.1				64.1	0				
6553.5	6541.3		67	-59	4.3			-15.6	6.1	43.3	7.9
		-18.1				379.8	0.2				
6630.9	6618.7		39	-63	2.1			-12.9	2.9	17.7	7.2
		-16.5				80.4	0.1				
6650.2	6639.5		39	-63	5.3			-19.3	2.2	23.3	14.8
		-16.5				106.2	0				
6674.5	6664.3		39	-63	3			-17.8	3.9	19.4	8.3
		-15.3				243.6	0				
6723.1	6713.4		55	-51	5.4			-24.5	8.1	29.3	11.3
		-15				178.9	0				
6758.8	6743.9		51	-58	3.7			-27.4	10.3	29.1	8.2
		-21.6				160.3	0				
6800	6781.2		40	-61	3.3			-16.7	3.4	29	8.8
		-15.7				95.6	0				
6816.5	6798		40	-61	5.9			-17.9	1.3	38.2	16.2

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
		-15.5				266.9	0				
6850	6834.3		35	-57	7.3			-31.3	3.7	19.8	22
		-15.5				56.6	0				
6859	6843.6		35	-57	5.8			-29.3	4.4	18.8	17.8
		-17.5				103.3	0				
6891.9	6876.5		28	-41	2.2			-26.6	5.3	9.2	8.3
		-17.9				9.5	0.2				
6902.6	6888.5		28	-41	1.1			-22.8	5.3	9.4	7.5
		-17.9				15.4	262.9				
6948.8	6936.7		8	25	-9.1			-11.1	10	17.7	18.4
		-18.6				0	380.3				
6977.4	6965.3		0	-21	-10.7			-9	10.7	22	28.3
		-19.6				0	340.9				
6997.6	6986.8		0	-21	-10.7			-8.2	10.7	22.1	28.8
		-17.5				0	398.5				
7024.3	7014.9		-3	-17	-9.6			-8.7	9.3	21.3	23.9
		-15.5				0	313.2				
7049.7	7040.4		-3	-17	-8.9			-7	8.6	20.2	23.1
		-6.9				0	1136				
7121.8	7113.2		-7	-4	-12.4			3.7	12.3	26.8	26.2
		-1.7				0	265.2				
7135.8	7128.5		-7	-4	-10.5			-2.7	10.3	24.2	22.6
		-0.1				0	365.8				
7169.7	7160.4		-8	-10	-7			-10.1	6.2	18.9	16.3
		4.1				0	198.5				
7199.5	7188.5		-30	2	-4.9			-2.6	4.1	24.6	11.9
		7.9				0	6.4				
7200.5	7189.5		-30	2	-4.8			-2.4	4.1	24.5	11.9
		7.9				0	109.3				
7221.5	7211.2		-30	2	-3.4			1.6	3.5	19.1	10.8
		9.6				0	45.8				
7236.2	7227.2		-30	2	-2.4			7.3	2.5	11.1	9.3
		11.3				0	0.2				
7236.3	7227.3		-30	2	-2.4			7.4	2.5	10.9	9.3
		11.9				26.1	29.1				
7269.7	7259.7		-39	15	2.5			21.3	0.7	17.2	9.7
		13.2				23.8	4.7				
7303	7289.2		-23	-4	-0.5			21.6	-0.4	6.4	7.2
		16				0	2.4				
7318	7300.4		-23	-4	-0.2			22.2	-0.7	6.1	6.6
		18.6				0	0.3				
7319.1	7303.2		-23	-4	-0.1			22	-0.7	6.1	6.6
		-21.1				0	-0.2				

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
7322.2	7300.8		-23	-4	-0.1			21.7	-0.8	6.2	6.5
		-21.1				0	0.1				
7323.5	7302.1		-23	-4	-0.1			21.5	-0.8	6.3	6.5
		15.3				4.1	1.2				
7367.5	7342.7		-23	-5	0.4			19.8	-1.4	7.1	7.7
		16.6				116.4	0				
7416	7387.7		17	-14	6.2			16.7	-8.5	19.6	11.9
		19.5				-8	0				
7416.1	7385.9		17	-14	5.1			16.7	-7.4	17.4	10.7
		17.7				191.2	0				
7468.4	7436.9		16	-71	3.3			10	-10.4	21.8	12.5
		17.6				466.4	0				
7558	7527		44	-54	5			-1.3	-4.4	25.2	10.6
		17.1				209	0				
7616.8	7587.4		44	-15	2.6			14.2	-4.7	12.5	17.5
		12.4				173.8	0				
7674.5	7645.1		49	-14	5.2			15.4	-7.9	16.8	10.2
		28.1				59.4	0				
7691.5	7657.1		49	-14	4.7			15.7	-7.6	33.6	9.2
		10				179	0				
7737.2	7695.1		62	-4	4.4			14.9	-6.6	49.3	9.2
		3.8				1213	0				
7787.3	7749.4		70	-20	8			-11.4	0	92.1	14.2
		9.4				551.7	0				
7801.8	7764.3		70	-20	5.9			-8.8	0.2	93.2	10.5
		-1				813.5	0				
7826.1	7789		68.5	-58.4	4.4			-3.5	-2	101	8.2
		3.9				716.4	0				
7849.5	7812.3		68.5	-58.4	4.8			-5.5	-1.1	99.8	9
		-17.3				19.9	0				
7850.5	7813.4		68.5	-58.4	5.4			-6	-1.3	18.3	10.1
		1.8				131.1	0				
7881.4	7844.4		67	-72.8	4.7			-5.9	-0.7	17.8	8.4
		4.7				413	0				
7961.4	7924.8		75	-42.4	7.1			-14.6	3.9	21.6	12
		11				33.2	0				
7963.8	7929.8		75	-42.4	7.8			-16.4	4.5	22.5	13.1
		-0.4				411.5	0				
7999.5	7967.7		82.8	-48	13.6			-16.5	0	28.1	22.9
		1.6				52.5	0				
8000.5	7969.4		82.8	-48	12.5			-15	-0.1	69.4	22.5
		1.6				546.5	0				
8011.1	7981.4		82.8	-48	10.7			-11.6	-1.1	70.8	18

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
		2.4				1150	1.9				
8044.3	8015.9		75.8	-33	4.4			-3.6	-1.6	52.3	15.3
		-0.2				434.9	0.4				
8065.1	8036.6		58.4	-14	4.8			-0.1	-4.8	47.4	21.5
		-1.4				398.4	0				
8082.9	8052.3		58.4	-14	12.5			-8.3	-7.7	50	27.3
		-4.8				946.2	0				
8110.4	8076.4		51	-70	18			-1.3	-17.4	60.7	27.5
		-5.3				1766	0				
8157.5	8123.5		95.6	-38	4.6			3.1	-5.8	62.4	13
		-5.3				106.1	0				
8160	8127.2		95.6	-38	5			0.5	-5.2	61.1	14.9
		-9				1009	0				
8199.5	8167.2		72.5	-49	5.9			6.6	-9.2	51.5	14.3
		-17.5				15.6	0				
8200.5	8168.4		72.5	-49	5.7			7.3	-9.2	16.8	13.3
		-17.5				264.1	0				
8255.7	8223.5		110	-57	5.2			6.5	-8.9	25.3	10.6
		-19				209.7	0				
8312	8279.7		69	-22	3.4			7	-5	12.5	9.2
		-19				0.4	0				
8312.2	8279.8		69	-22	3.4			7	-5	12.5	9.2
		-7.4				102.6	10.6				
8378.6	8346.8		54.2	-11	-0.1			-1.1	0.7	11.6	8.3
		-9.2				24.3	169.9				
8439.5	8411.1		-14	-7.5	-5.4			19.7	3.9	8.4	19.6
		-8				0	-27.3				
8440.3	8406.1		-14	-7.5	-5.9			19.9	4.4	8.7	23.4
		-8				0	302				
8466.7	8427.8		-7	-12	-10.4			11.8	9	26	35.4
		-4.4				0	1522				
8512.6	8473.7		-7	-12	-17.7			9.9	16.5	43.7	54.7
		-1.5				0	143.6				
8515.5	8476.8		-7	-12	-18.1			9.1	17	44.8	55.3
		-0.9				0	2356				
8552	8514.4		-13	-2	-18.3			-0.2	18.3	57.4	73.6
		0.4				0	1640				
8588.4	8552.4		-25	-8	-13.2			-10.9	10.4	57.8	29.7
		1				0	3.6				
8588.5	8552.5		-25	-8	-13.2			-11	10.4	57.8	29.7
		9.7				0	67.5				
8590.5	8554.5		-25	-8	-13.1			-11.6	10.2	57.4	28.8
		9.7				0	67.3				

P-Stn ft.	L-Stn ft.	Grade %	Ssl %	Ssr %	Cut Dp. ft.	Cut V. cu.yd.	Fill V. cu.yd.	H.Offset ft.	V.Offset ft.	Stk L ft.	Stk R ft.
8591.5	8556.6		-25	-8	-13.1			-11.6	10.2	57.2	29.1
		10.8				0	343.7				
8611	8569.1		-25	-8	-10.3			-9.9	7.8	53	23.9
		11.6				110.9	940.6				
8743.8	8703.5		-32	25	4.5			10.5	-1.9	17.2	21.9
		15.4				233.9	0				
8792.8	8749.4		-36	8	5.5			17	-4.1	9.9	16.1
		15.4				39.6	0				
8805.2	8758.4		-36	8	5.2			15	-4	9.7	16.4
		10.7				142.2	0				
8850.2	8804.2		-5	-14	2.6			6.6	-3.5	9.2	19.2
		10.1				58.3	25				
8910.9	8865.9		-8	-10	-1.2			-3.7	0.9	13.4	30.4
		4.8				0	196.7				
8950.5	8905.9		-19	-5	-3.4			-9.3	1.6	21.5	28.9
		2.7				0	123.7				
8971	8926.8		-19	-5	-2.6			-5.5	1.6	19.7	29.1
		2.7				0	70.2				
8982.4	8938.3		-19	-5	-3.1			-4	2.3	15.1	10
		2.7				0	92.8				
9005.2	8961.3		-26	-8	-4			-0.4	3.9	20.1	13.4
		5.9				56.2	85				
9038	8994.5		-53	40	3.1			5.1	-1	7.9	27.7
		19				67.5	0				
9052.5	9009.4		-53	40	4.6			8.4	-1.3	11.8	34.7
		17.7				392.6	0				
9104.5	9063.5		63	25	7			7.1	-5.2	11.5	31.2
		16.7				315.8	0				
9158	9117		47	25	4.2			14.5	-0.5	9.2	17.3
		14.9				2.3	0				
9158.7	9117.6		47	25	4			14.1	-0.5	9.1	17.5
		14.9				62.4	0				
9179.4	9137.9		47	25	2.7			19.2	2.1	11.5	20.3
		10				41.3	0				
9205.3	9158.8		-36.3	19.9	1.2			24.7	3.7	6.3	15
		6.7				23.2	4.7				
9249.5	9198.3		-26	14.4	-0.4			16.5	2.8	6.4	6.1
		4.1				0.1	0.4				
9250.3	9200.3		-26	14.4	-0.2			17.8	2.8	6.3	9
		4.1				5	8.8				
9295.1	9244.1		-26	14.4	-0.3			6.4	0.6	6.3	8.7

Road Name:	
UW Common Name:	Ridge Racer Road
Road Class:	Secondary
Initial Designers:	Bill Heyman, Luke Rogers, Aaron Roark, Aaron McDonald
Total Length (stations):	38
Road Access Description:	Access is from the Main Street road at 82 stations from the boundary to the right (south).
Take Off Location:	T30N R12W SE ¼ of SE ¼ of Section 1
Termination Location:	T30N R12W SW ¼ of NE ¼ of Section 12
Quantity of Settings Accessed:	6
Area of Sales Accessed (acres):	242
Road Status:	Flagged, Blazed, Notes
Stream Crossing Information:	None
Switchback/Curve Information:	None
Rock Outcrop Information:	None
Comments:	See on next page
Road Grade Information:	Max adverse grade 18% Min grade 0% Max Side Slope 110%

Comments:

The section begins from the Main Street road at approximately 1.5 miles, leaving the main road to the south. The grade runs three stations at -5% to –7% where the direction changes from SE to NE. A potential landing location exists here. The grade continues into a draw for approximately 200 feet where an area of partial roadbed erosion is encountered. The topography is highly convergent, located in an area predicted to be moderately stable to unstable. A more thorough assessment of this area is advisable prior to road construction.

A wet area is located between 7+00 and 8+00 with Devil's Club being the indicator. The area is rocky with no water visible near the surface in the vicinity of the grade. Drainage problems may be avoided here by use of coarse fill to smooth the grade in this section.

From station 10+00 to 12+00, the grade was continued until reaching a large former landing that appears to be built partially on rotting logs. The stability of this is questionable when loaded. From this point, we determined that we could not reach the saddle below from this position

We descended to the saddle, which was broad, measuring 200 feet by 50 feet. From this point, we ran a grade line of 18% back towards the original grade on the NW side of the hill. This grade passed through a number of areas with unstable, loose soil with a slope of 60% or more. This line connected with the original grade near 10+00. This point is on a corner and appears to have enough room for grade separation if the uphill side slope is cut back. We also considered abandoning the original grade at this point and using the lower grade. This option will be explored further during the next session of grade reconnaissance.

We took off from the original road at 10+00, and marked the stations back down to the saddle at 18%. Too ease vertical alignment we ran the first 25ft at 12% and the next 25ft at 14%. At station 14+25 there was an apparent slump to the east on a +70% slope. Between stations 14+25 and 14+75 a bench exists, which is approximately 25ft wide, and continues to station 15+25. At station 15+25 an old tractor road is encountered. The tractor road climbs to the east headed toward the landing with the rotting logs. The tractor road also parallels the road from station 15+75 to just past 16+75, at which point the trail fades. The grade continues down at 18% to station 19+25 at, which point the grade reaches the saddle, which is approximately 100ft wide. The grade at this point reduces to 3% and then 9% ending at this point at station 20+25.

A reconnaissance was done at this point and an old road grade was found and followed out. The old road went to the necessary area, however there were indications of current/active slumping and wet
areas. We continued to the location of the landing and decided to run a road back around the westside of the ridge and then climb back over a small saddle and continue back toward the old road attempting to avoid slumps. A saddle was reached at station 35+00. At this point we climbed at 15% to station 33+00 in order to avoid a slump in a wet area. The grade was then run at 0% from station 32+75 to 32+25 and then down slope at 10% to station 28+25. From 32+25 to 30+25 the ground up-slope (east) was hummacky, however the trees did not have pistol buts. The grade was changed to 12% at station 28+25 in order to meet the existing road grade. The existing grade was met at station 25+25, there is a slump which is located between stations 26+50 and 25+25. We then continued the old road grade to the saddle, tying in with the previous grade at station 18+00.

Road Name: RidgeRacer

Station	Slope % left	Slope % right	Grade %	Comments
0+00	-40	-40		
			5	
0+50				
1+00	-50	-40		Takeoff from Main Street
			7	
1+50				
			-7	
2+00	65	-60		
2+50				
			-4	
3+00	60	-60		
			-5	
3+50	80	-50		possible landing location
			0	
4+00	85	-70		
4+50				
			-3	
5+00	65	-65		
5+75	70	-60		draw-partial roadbed erosion
			-2	convergent topography
6+00	70	-60		
			-4	
6+50				
7+00	65	-55		
			-6	
7+50	65	-70		
			-7	
8+00	70	-65		
			-8	
8+50				
9+00	90	-65		
			-5	
9+50				
10+00	70	-70		takeoff from existing grade
			-12	
10+50	80	-76		
			-17	

11+00	85	-78		
			-18	
11+75	85	-75		
			-18	
12+00	80	-80		
			-18	
12+50	80	-80		
			-18	
12+75	90	-70		
			-18	
13+25	80	-65		
			-18	
13+75	70	-70		
			-18	
14+25	75	-65		slump
			-18	
14+75	100	-65		small bench
			-18	
15+25	60	-65		
			-18	
15+75	75	-65		
			-18	
16+50	20	-80		
			-18	
16+75	65	-55		
			-18	
17+25	70	-60		
			-18	
17+75	80	-60		
			-18	
18+25	30	-75		
			-18	
18+75	12	-40		
			-18	
19+25	15	-15		saddle
			-3	
20+25	5	-15		
			-9	
20+50	7	-25		
			-7	
21+00	7	-25		run existing grade
			-8	
21+50	30	-35		
			-11	
22+00	45	-50		
			-11	
22+50	50	-55		
			0	
23+00	70	-55		

			-1	
23+50	60	-55		
			4	
24+00	70	-60		
			-2	
24+50	80	-50		
			-4	
25+25	80	-60		takeoff uphill from existing grade to avoid slumps
			12	and wet areas
26+00	55	-70		
			13	
26+75	65	-65		
			12	
27+25	65	-60		
			12	
27+75	70	-60		
			12	
28+25	75	-80		
			10	
28+75	80	-90		
			10	
29+25	80	-70		
			10	
29+75	70	-60		
			10	
30+25	80	-60		
			10	
31+00	80	-65		
			10	
31+50	65	-50		
			10	
32+25	45	-45		
			0	
32+75	70	-50		
			-15	
33+00	30	-50		small slump
			-15	
33+50	20	-30		
			-16	
34+00	10	-33		
			-15	
34+50	15	-27		
			-2	
35+00	-15	10		saddle
			-2	
35+50	-55	50		
			-12	
36+00	-65	35		

			-12
36+50	-50	70	
			-14
36+75	-60	45	
			-14
37+25	-60	55	
			-14
38+00	-55	40	
			-14
38+50	-60	50	
			0
39+00	-20	25	

Road Name:	
UW Common Name:	TAR
Road Class:	Secondary
Initial Designers:	Aaron McDonald, Tamra Zylstra
Total Length (stations):	10 Stations
Road Access Description:	TAR road begins at 1.7 miles from western boundary of DNR land on the Main Street road.
Take Off Location:	SW ¼ SW ¼ sec. 6 T30N R11W, NW corner.
Termination Location:	SW ¼ SW ¼ sec. 6 T30N R11W, SE corner.
Quantity of Settings Accessed:	S-19
Area of Sales Accessed (acres):	78 acres
Road Status:	Flagged, Notes.
Stream Crossing Information:	No stream crossings.
Switchback/Curve Information:	
Rock Outcrop Information:	
Comments:	Road follows an abandoned grade towards two large landing locations. Old grade is in good shape and will need only minor excavation. One wet area is found between stations 2+00 and 4+00. This area supports Devil's Club, an indicator of excessive soil moisture. There is also slumping apparent, but this area is small and should present no construction problems or excessive costs. The majority of the roadbed is sound and of moderate slope. This road will allow access to two major landings that are suited for fan shaped settings. There is also opportunity for parallel settings along the length of the road. This road joins the Himalaya West road at the "Mona Lisa" landing.
Road Grade Information:	

Road Name:
TAR

Station	Slope % left	Slope % right	Grade %	Comments
0+00	-45	-45		leaves Main road at approximately 1 3/4 miles
			12	from DNR boundary to the west. Follows old grade.
0+50	-45	-45		
			12	
1+00	-50	-50		wet area, slumping
			15	
1+50	-50	-50		
			15	
2+00	40	-65		
			16	
2+50	40	-65		
			16	
3+00	55	-60		
			17	
3+50	55	-60		
			17	
4+00	0	0		
			7	
4+50	0	0		
			7	
5+00	60	-75		
			0	
5+50	60	-75		
			0	
6+00	60	-60		landing area. Appr. 150' x 100'
			0	
6+50	60	-60		
			0	
7+00	70	-75		
			4	
7+50	70	-75		
			4	
8+00	75	-80		
			0	
8+50	75	-80		
			0	
9+00	70	-75		
			0	
9+50	70	-75		
			0	
10+00	20	0		"Mona Lisa" landing 200' x 200'.
				Spur can be built out ridge 200'.

Road Name:	
UW Common Name:	Himalaya West
Road Class:	Secondary
Initial Designers:	Aaron McDonald, Tamra Zylstra
Total Length (stations):	17 stations
Road Access Description:	Station 5 of Himalaya Traverse.
Take Off Location:	T30N R11W—SE ¼ of SW ¼ of Section 6
Termination Location:	T30N R11W—NW ¼ of NW ¼ of Section 7
Quantity of Settings Accessed:	S-19, S-31
Area of Sales Accessed (acres):	Approximately 180 acres
Road Status:	Flagged, Notes
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	See on next page
Road Grade Information:	Max. adverse grade18%, Max. favorable grade 5%, Max. sideslope 80%

Road begins at large landing area at station 5+00 from Himalayan Traverse. Road curves around ridge end towards the SW. The initial three stations are on an existing grade that is in good condition and stable. At station 3+00 is a large landing area 100' x 50'. The road then comes off the landing and transitions from 0% to 10% to 18% grade. Then the 18% grade continues down to the landing.

At station 8+50 is a flat area/ridge saddle where a spur can be placed to access a landing. This area also provides a connection north to the "Mona Lisa" landing.

The grade continues down the ridge staying on the SE side at a constant –18% to reach a landing location at station 17+00. This is a broad saddle that appears to offer enough room to create a landing.

Another landing was located about 150' in elevation below the ending point. Two of the survey crew ran a 18% flag line uphill from this point on the SE side of the ridge and reached the saddle at station 17+00. Some quick curve layout was done and it is felt that enough space exists at the saddle to connect the two grades.

Another gradeline was run from the saddle at 8+50 to the North towards the "Mona Lisa" landing. This grade cuts across a hill slope with an average side slope of –70%. A 0% grade was run for the first 3+50 stations and crosses a class 5 stream here. The stream gully is somewhat steep and narrow and may require filling, but the accumulation area above is small, so there should be little problem with water accumulation.

The grade continues at 10% for 3+00 more stations to reach the "Mona Lisa" landing.

Road Name:

Station	Slope % left	Slope % right	Grade %	Comments
0+00	-6	5		Big flat area ~ 150'x150'
			5	Saddle
0+50	-7	10		
			0	
1+00	-80	20		
			0	
1+50	-55	80		Existing road ~ 6' wide
			0	
2+00	-70	80		
			0	
2+50	-80	70		
			0	
3+00	-70	75		Grade change
			5	
3+50	-70	80		Wide flat area w/ Alders ~ 50'x100'
			5	Landing
4+00	-70	80		
			0	
4+50	0	0		
			0	Leave Landing
5+00	-75	65		
			-10	
5+50	-80	85		
			-18	
6+00	-65	70		
			-18	
6+50	-65	75		
			-18	
7+00	-70	70		
			-18	
7+50	-70	75		
			-18	
8+00	-60	60		
			-18	
8+50	-70	65		
			-18	
9+00	-70	65		
			-18	
9+50	-65	30		
			-18	
10+00	-60	45		
			-18	
10+50	-65	50		
			-18	

11+00	-55	10	
			-5 Tying in between two gradelines
11+50	-70	55	
			-18
12+00	-75	60	
			-18
12+50	-70	75	
			-18
13+00	-70	60	
			-18
13+50	-80	70	
			-18
14+00	-70	65	
			-18
14+50	-60	70	
			-18
15+00	-65	75	
			-18
15+50	-55	65	
			-18
16+00	-60	50	
			-18
16+50	-70	40	
			-18
17+00	-45	50	
			-18
17+50	0	0	Landing

Road Name:	
UW Common Name:	Cope Road
Road Class:	Secondary
Initial Designers:	Bill Heymann, Luke Rogers
Total Length (stations):	11 stations
Road Access Description:	
Take Off Location:	T30N R11W NW ¼ of Section 7
Termination Location:	T30N R11W SW ¼ of Section 7
Quantity of Settings Accessed:	1, S16
Area of Sales Accessed (acres):	92 acres
Road Status:	Paper plan, Flagged, No Notes
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	The road was flagged in according to the paper plan at –18%. The road ends on a good ridge location. Trees in this area had a dbh of less than 15.
Road Grade Information:	

Road Name:	
UW Common Name:	. Himalaya N. Spur
Road Class:	Secondary
Initial Designers:	Aaron McDonald
Total Length (stations):	4+50 stations
Road Access Description:	Himalaya Traverse, station 73+00, TP 130
Take Off Location:	SW ¼ of NW ¼ of Sec. 7, T30N R11W
Termination Location:	SW ¼ of NW ¼ of Sec. 7, T30N R11W
Quantity of Settings Accessed:	S-14
Area of Sales Accessed (acres):	Approximately 30 acres each in S13 and S14
Road Status:	Walked, Flagged
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	Road starts from traverse point 73+00 (TP 130) on the Himalaya Traverse. It follows an existing old grade along a narrow ridge, varying between 20 and 40 feet wide. Initial grades are between 13% to 20% adverse for about 2 stations, then lowering for the remainder. Possibility to reduce adverse grades by staying on the NW side of the hill ("side hill construction").
Road Grade Information:	Max. adverse grade 20 % Minimum grade 1 % Max. sideslope 70 %

Road Name: Himalaya
N. Spur

Station	Slope % left	Slope % right	Grade %	Comments
0+00	-60	-65		
			-13	
0+25	-70	-60		
			-20	
0+50	-50	-60		
			-20	
0+75	-65	-45		
			-12	
1+00	-65	-50		
			-18	
1+50	-70	-35		
			-15	
2+00	-65	-70		
			-11	
2+50	-55	-65		
			-10	
3+00	-70	-50		
			-1	
3+25	-60	-60		
			4	
3+50	-55	-65		
			-14	
4+00	-60	-45		
			-25	
4+50	-50	-40		

Road Name:	
UW Common Name:	BFE
Road Class:	Secondary Road
Initial Designers:	Barry Collins, Justin Gardner
Total Length (stations):	33 Stations
Road Access Description:	Take off from Himalaya ridge road at station 145
Take Off Location:	T30N R12W---SE ¼ of NW ¼ of Section 7
Termination Location:	T30N R12W---SE ¼ of SW ¼ of section 7
Quantity of Settings Accessed:	0 thinning settings
Area of Sales Accessed (acres):	100 acres +
Road Status:	Grade line Flagged, no notes
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	The flagged road was located higher than the paper location due to slumps and head wall below stations 4 and 10. The flagged road starts at traverse point 145, we started with a grade of zero for 4 stations and then dropped down to the ridge at 18% where Bill took a GPS point (elev. 1300ft) this was station 17. The side slope was about 50% to the ridge and after the ridge it was 60-80%. The road will probably have to drop at 18% to reach the landing, this will have to be explored further. Bill Heyman and Peter Schiess flagged a road from the landing back, it tied into the traverse at station 141. The flag line skirted the slumps and head walls and was unable to catch the flag line that started at station 145 it paralleled it about 80 feet below. The wet areas consisted of alder and other hard woods and the dry upper slopes consisted of hemlock and doug fir.
Road Grade Information:	Maximum grade 18% Minimum Grade 0% Maximum side slope 80%

Figure 88 Lowest landing, GPS point

Figure 89 GPS point on nose of ridge

Figure 90 Wet area

Figure 91 Wet area 2 stations past nose of ridge

Figure 92 GPS point on nose of ridge

Figure 93 Wet area

Road Name:	
UW Common Name:	West spur
Road Class:	Secondary
Initial Designers:	Aaron McDonald, Barry Collins
Total Length (stations):	4 + 39
Road Access Description:	station 83 + 49 of the traversed road
Take Off Location:	T30N R11W NW ¼ of SW ¼ of Section 7
Termination Location:	T30N R12W SE ¼ SE ¼ of Section 12
Quantity of Settings Accessed:	S-13
Area of Sales Accessed (acres):	77
Road Status:	Flagged, Painted , Notes
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	Grade was run initially at 0 % in order to stay above wet area that covers the entire basin to the north. Examination of air photos revealed that the entire basin appears to be eroding ridgeward. The spur will be a temporary construction and should experience no erosion problems unless significant long-term precipitation events occur. Once the spur ridge was reached, the terrain was gentle enough to allow a road on top of the ridge. The ridge varied from 100 to 200 feet wide and has a 0 to 10 % grade both linearly and laterally. The ridge end provides a wide, level landing area with access to all sides. The slope on the sides of the nose are 50+ % and the nose has an initial grade of 30 %. No significant construction problems are expected to be encountered. At the roads closest approach to the unstable areas, there is an extensive bench area that will provide support for the road bed. One area at the transition from the sidehill road approach to the ridge has a grade of 30 % for approximately 100 feet. We do not see this as a problem as it should be able to be filled in to lessen the grade through the transition
Road Grade Information:	

Road Name:	
UW Common Name:	Southern Steep Road
Road Class:	Secondary
Initial Designers:	Rob Stewart, Aaron Roark
Total Length (stations):	28.5
Road Access Description:	Three miles north of the hwy 101 and hwy 112 interchange, head west on west twin road, after entering the stream valley, cross stream twice and note road access just before powerlines.
Take Off Location:	T30N R11W SE ¼ of NE ¼ of Section 18
Termination Location:	T30N R11W SW ¼ of SE ¼ of Section 7
Quantity of Settings Accessed:	5
Area of Sales Accessed (acres):	218
Road Status:	Flagged
Stream Crossing Information:	Several class five stream crossings, noted on excel document. Crossings at approximately stations 6+00, 11+50, and 22+50.
Switchback/Curve Information:	None
Rock Outcrop Information:	None found
Comments:	The road started on an exsiting paved road. It was flagged in all the way to the top of the nose at 18% for 28 stations. Some spots where draws were crossed the grade was shot at 0%. There was no merchantable timber until the top of the nose was reached. Otherwise the timber was young alder stands. No

rock sources were found on or near the flag line.

Road Grade Information:

Max. 18% favorable. This grade is flagged in all the way up to the ridge except across the draws and type five streams the grade that was flagged in there was 0%.

Road Name: Steep Southern Road

Station	Slope % left	Slope % right	Grade %	Comments
0+00	0	0		
			18	
0+50	-15	30		
			18	
1+00	-15	15		
			18	
1+50	-40	65		
			18	
2+00	-40	65		
			18	
2+50	-40	65		
			18	
3+00	-40	65		
			18	
3+50	-50	65		
			18	
4+00	-65	65		
			18	
4+50	-65	10		
			18	
5+00	-10	10		
			18	
5+50	-30	75		
			18	
6+00	-60	50		
			0	type 5 stream crossing
6+50	-40	65		
			18	
7+00	-70	60		
			18	
7+50	-65	65		
			18	
8+00	-65	40		
			18	
8+50	-60	50		
			18	
9+00	-60	40		
			18	
9+50	-80	80		
			18	
10+00	-80	80		
			18	
10+50	-70	70		

			18	
11+00	-70	60		
			18	
11+50	-60	65		
			0	type 5 stream crossing
12+00	-80	65		
			18	
12+50	-60	45		
			18	
13+00	-50	40		
			18	
13+50	-60	30		
			18	
14+00	-50	20		
			18	
14+50	-30	20		
			18	
15+00	-45	60		
			18	
15+50	-50	60		
			18	
16+00	-55	50		
			18	
16+50	-70	55		
			18	
17+00	-60	40		
			18	
17+50	-10	30		
			18	
18+00	-20	20		
			18	
18+50	-20	15		
			18	
19+00	-20	30		
			18	
19+50	-30	15		
			18	
20+00	-30	10		
			18	
20+50	-10	10		
			18	
21+00	-10	30		
			18	
21+50	-25	25		
			18	
22+00	-20	30		
			18	
22+50	-70	70		
			0	type 5 stream crossing

23+00	-70	65		
			18	
23+50	-50	55		
			18	
24+00	-60	50		
			18	
24+50	-60	60		
			18	
25+00	-60	10		
			18	
25+50	-60	60		
			18	
26+00	-60	60		
			18	
26+50	-60	30		
			18	
27+00	-10	0		
			-7	Southern jr. road starts here
27+50	0	10		
			0	
28+00	0	0		
			0	
28+50	0	0		Landing Location

Road Name:	
UW Common Name:	Southern JR road
Road Class:	Secondary
Initial Designers:	Robbie Stewart, Aaron Roark
Total Length (stations):	26.5
Road Access Description:	Road starts off of station 27 +50 on the Steep Southern Road
Take Off Location:	T30N R11W SW ¼ of SE ¼ of Section 7
Termination Location:	T30N R11W NW ¼ of SE ¼ of Section 7
Quantity of Settings Accessed:	2 thinning designs; S9, S11
Area of Sales Accessed (acres):	94
Road Status:	Flagged
Stream Crossing Information:	0
Switchback/Curve Information:	0
Rock Outcrop Information:	0
Comments:	This road starts at station 27 +00 off the Steep Southern Road. This is two stations from the landing at the end of that road. It starts out at an 18% favorable grade for nine and a half stations. Side slopes vary between –10% to –50% on the left and 5% to 60% on the right. The next ten stations try to stay on the top of the ridgeline with grades varying from –10% to 10%. The following eight stations run at –5% grade to the last landing. Timber throughout the top of the ridge are hemlock and Douglas fir measuring from 6 inch DBH to 24 DBH.
Road Grade Information:	Max. 18% favorable

Road Name: Southern Jr. Road

Station	Slope % left	Slope % right	Grade %	Comments
0+00	0	0		
			18	
0+50	-10	20		
			18	
1+00	-20	15		
			18	
1+50	-15	15		
			18	
2+00	-30	30		
			18	
2+50	-35	30		
			18	
3+00	-20	25		
			18	
3+50	-20	20		
			18	
4+00	-40	35		
			18	
4+50	-35	35		
			18	
5+00	-50	30		
			18	
5+50	-20	20		
			18	
6+00	-30	40		
			18	
6+50	-50	45		
			18	
7+00	-30	40		
			18	
7+50	-10	5		
			18	
8+00	-20	25		
			18	
8+50	-60	55		
			18	
9+00	-35	10		
			18	
9+50	-50	60		
			5	
10+00	0	0		
			0	
10+50	20	-40		

			10	
11+00	25	-50		
			10	
11+50	0	-50		
			18	
12+00	0	-30		
			12	
12+50	0	-20		
			58	
13+00	0	0		
			12	
13+50	0	-20		
			10	
14+00	0	-20		
			0	
14+50	-5	0		Landing Location
			-18	
15+00	0	0		
			6	
15+50	-2	-3		
			8	
16+00				
			-10	
16+50	-4	0		
			0	
17+00				
			-7	
17+50	-5	0		
			-10	
18+00				
			-2	
18+50	-30	40		
			-5	
19+00				
			-5	
19+50	-40			
			-5	
20+00				
			-5	
20+50	-45	45		
			-5	
21+00				
			-5	
21+50	-55	60		
			-5	
22+00	-60	65		
			-5	
22+50	-70	75		
			-5	

23+00				
			-5	
23+50	-80	75		
			-5	
24+00				
			-5	
24+50	-60	10		
			-5	
25+00	-60	15		
			-5	
25+50	-80	80		
			-5	
26+00	-5			
			-5	
26+50				end of road

12.4 Road_cost coverage

This coverage was created from the uw_trans arc coverage and the uw_fris polygon coverage.

UW_FRIS MODIFICATIONS

This coverage was modified in Arc/Info by deleting all items in the .pat, accept for fiu.tot.tim.sv6n. This field indicates the live timber tree species net Scribner board foot volume per acre (to a six-inch top). This information will then be used to calculate the clearing and grubbing costs.

UW_TRANS MODIFICATIONS

The uw_trans coverage was created from the original DNR trans coverage. The roads for the planning area were first pegged on a map of the area with contours. After all roads were pegged in connecting all landings, the roads were then digitized so that the coverage could be made. From this coverage edits were made until the final road plan was developed for the planning area. Other coverages were developed from this by selecting road segments and converting them to shape files in Arc View.

road_grade.aml – added two fields, Snap_grade and Snap_slope. Only the Snap_slope was used for further calculations. The numbers produced were used for the side slopes.

road_fac.aml - added a field named clear.grub.fact, which calculated the production factor, based on side slope from Snap_grade, and volume from fiu.tot.tim.sv6n.

exc_pro_fac.aml - this aml created a production factor field for excavation and asigned values based on side slopes. The factor was interpolated from the Clallam Bay sale road appraisal.

the_excv_fac – the field added was the actual excavation factor, which was interpolated from the Clallam Bay sale road appraisal.

Fields added manually using Arc/Info

Stations - dividing the Length field by 100 created this field. The Stations field is used to calculate the cost per station.

Clear.$.per.sta - This is a field added for cost per station, which was taken from the Clallam Bay sale road appraisal ($40/sta).

Tot.clear.cost - This field calculates the cost per segment of road by multiplying the Clear.grub.fact, Clear.$.per.sta, and Stations.

The.exc.cost – this field calculated the excavation costs for the road segment by multiplying the excavation factor, excavation production factor, excavation cost per station and the number of stations.

Culvert$.per.sta – this was created by simply calculating the field to equal 100.

Tot.culv.cost – this field gives the costs for each road segment in stations and was calculated by multipying the cost per station ($100) with stations.

The.tot.rd$ – This field summed the results from the clearing and grubbing, culvert, surface and ballast, excavation costs, which is the total road cost used for construction.

Road costs may be calculated in Arc/View by using select feature to highlight the road of interest. Once the road has been selected the segments should be highlighted in the associated table. From this table a field statistic may be performed, which will give the sum, high, low and other statistics of the chosen field. For example, once the desired road system is selected a field statistic of the total road cost will produce the sum or total cost for that section of road. If you desire the cost per station of this road simply perform a field statistic on the stations field and use that sum to divide the previous road cost. Other combinations include $/mbf, and total volume harvested.

12.5 Road Abandonment

This analysis is used to find the most cost beneficial solution in determining whether to abandon, inactivate, or maintain a road until the next harvest date. This is only for a cost aspect analysis. Other considerations must be taken into account for a well-analyzed outcome. Some of these other considerations include stream adjacencies and crossings, recreational considerations for road use, and the stand development. This appendix explains the development of this spreadsheet and the theory behind it. This spreadsheet can be found on cd/transportation.

A road cost estimates guide for Western Washington was obtained from the DNR and these values were used in the determination of the road cost per station. These costs are put into three categories. They are High, Medium, and Low. These values are explained in the table below and can be found on the 'road cost guidelines spreadsheet.' These values are loaded into the spreadsheet on a page called 'Road cost estimates' and can be changed and adjusted to accommodate changes in costs that might occur. The page marked "AA" is the only page needed for inputs. The year the road was constructed, the last harvest date before abandonment consideration and the future harvest date are the only inputs that are necessary. These inputted values are then processed on the 'data processing' worksheet. From the inputted values it calculates the cost for every year individually in the period considered. These values are then summed up to determine the total cost. A discount factor was used to estimate the interest rate and the inflation rate also. This was multiplied for each year before the sum was taken.

Discount factor = $[\{1+c\}/\{1+I\}]^n$

Where c = Real annual cost increase expressed in decimal format

i = Real interest rate expressed in decimal format

n = year

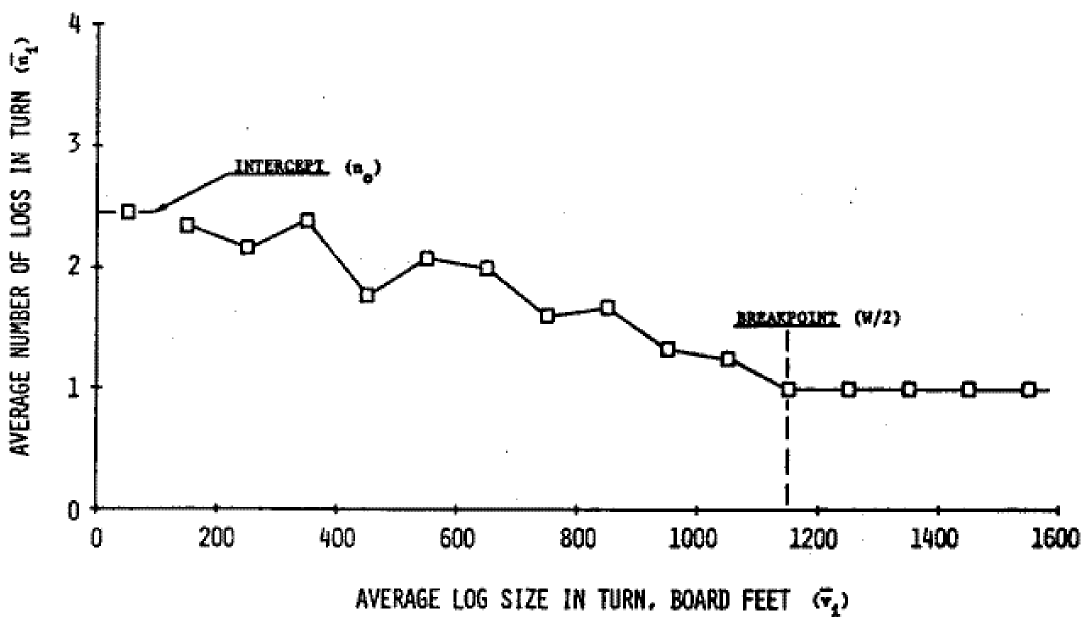
After entering the input values you can look on the graph next to the input section and see the different cost at different times for inactivation, abandonment, and maintenance. For the most cost efficient method choose the lowest cost at the time of the future harvest date. Notice that the abandonment cost goes up at this time because of the new road construction as well as the inactivation costs. It seems as an estimate that it is more cost effective to maintain until twenty years and then inactivating the road is more cost efficient. Note that this value is site specific. Abandonment becomes more cost effective after about 40 to 45 years after the road construction. These are just generalizations from inputs that were taken.

12.6 Stump to Truck Model Construction

Average volume per turn

The volume of wood is an integral part in determining the total cost of a logging operation. With more volume and larger trees come more turns. The average volume per turn can be determined by combining a log size distribution with a load curve. The Penn Peters approach to estimating the yarding cost was followed in the proceeding way. An example of a load curve is shown below.

FIGURE 1.--LOAD CURVE FOR A YARDING SYSTEM, EXAMPLE.



The following equations were used in the calculation of the average volume per turn.

Average volume per turn = $\bar{v} * n$

Where:

$\bar{v}$ = the average volume per log

n = # of logs per turn

The total area in acres (A), the volume per acre harvesting (B), the maximum payload per turn, the average payload ratio, the average dbh, the log length and the wood density are all the inputs required. The average payload ratio is an estimate of the actual payload.

Where the average payload = the average payload ratio(r) * maximum payload

The average cycle time must also be calculated. The inputs needed in the spreadsheet are

The external yarding distance (EYD), the lateral yarding distance (LYD), the lateral inhaul speed, the outhaul (e_{OH}), inhaul (e_{IH}), hook (e_{HK}), and unhook efficiencies (e_{UH}). From these values you can obtain the outhaul, inhaul, hook, and unhook times with the following equations.

Where:

Outhaul (OH) = 0.0388 + 0.0006475*AYD

Inhaul (HI)= 0.06258 + 0.000781*AYD

$$\bar{c} = (\overline{OH} / e_{OH}) + (\overline{HI} / e_{HK}) + (\overline{IH} / e_{IH}) + (\overline{UH} / e_{UH})$$

Hook time (UH) = LYD/lateral inhaul speed

The total yarding cost is then calculated by using the following inputs.

# of intermediate supports (I)

# of skyline anchors (A)

Ownership costs

Operating costs

Machine rate (R)

Crew size

From these you can calculate the # of corridors (M), the directional variable (P), the rigging time (T_R), and the yarding time (T_Y) from the equations found in “A New Approach To Yarding Cost Analysis.”

$$T_Y = V*c/n*vD$$

Where:

V = the total volume of the harvest unit

$$T_R = (EYD*0.01454349 + 6*\text{crew size} + 19.5*I + 10.5*(A))*M - 5*(M-1) + P$$

$$M = 43560*A/(EYD*LYD)$$

Where:

A = total acreage

The other equations came from “Comparing Long-span vs. Conventional Skyline Design” by Weikko Jaross and Peter Schiess. Notice that different equations were used for uphill and downhill yarding, and rectangular, fan-shaped common anchor, or fan-shaped common landing. Notice that this does change the values of the AYD also.

$P = 0.0063*EYD+3.5231$ (uphill)

$P = 0.0089*EYD+5.4176$ (downhill)

$AYD = .5*EYD$ (rectangular)

$AYD = (1/3)*EYD$ (common anchor)

$AYD = (2/3)*EYD$ (common landing)

The number of corridors was calculated from the EYD and LYD values.

$M = A*43560/(EYD*2*LYD)$ (rectangular setting)

$M = A*43560/(EYD*LYD)$ (fan-shaped setting)

The total yarding cost can then be calculated easily by the following equation.

$C_y = R*(T_Y/60 + T_R/\text{crew size})/V$

The road spacing was determined by simply multiplying the EYD by two. This will allow for optimum road spacing when the yarding cost is optimized. This configuration will allow for the use of the same tailholds. The landing spacing is twice the LYD in a rectangular situation. In a centralized landing the spacing is twice the EYD again. During a common tailhold setting the landing spacing is twice the LYD.

Estimating the optimum spacing for the yarding cost was difficult because of the terrain limitations. The LYD is optimized by viewing the output graph and noting at which LYD the lowest cost occurs.

12.7 Stump to Truck Cost Model Trends

The following are examples of different manipulations and inputs into the yarding cost program. This example compares the use and relationships of different values for different variables. This helps better understand the output variables and their significance. The variable that are manipulated are divided into three catagories.

1. Setting Inputs
2. Yarder Inputs
3. Silvicultural Inputs

Setting Inputs

These values change from setting to setting in the analysis. This section will give details on how these changes affect the output cost result. The inputs that are considered setting inputs in this analysis are as follows.

1. Uphill/downhill yarding
2. Average EYD, LYD
3. Area
4. Parallel/Fan-shaped landings
5. Number of intermediate supports
6. Number of skyline anchors

Uphill/downhill yarding

Downhill yarding increases the cost. This happens because of the P factor as explained earlier in the chapter. An example of a setting analyzed with all the same variables except for the uphill versus downhill aspect results in a cost of

$309 $/bf for the downhill setting and $249 for the uphill setting. This is quite a significant difference. All settings in the Burnt Mountain Planning area except one had uphill yarding characteristics.

Average EYD

The external yarding distance is one of the most important and active inputs in the yarding cost analysis. Too short of an EYD will result in high cost and too long of an EYD will also result in high cost. Generally external yarding distances shorter than the optimum EYD increase more dramatically than external yarding distances longer than the optimum EYD. To see this relationship more clearly refer to **Figure 94**. **Figure 96** shows how greater harvest volumes affects long EYDs more than low turn volumes affect long EYDs. This illustrates how with low turn volumes it is good to use longer EYDs to make for less rigging. With high volumes it is necessary to use the optimum EYD because your cost will be effected more dramatically for using longer EYDs.

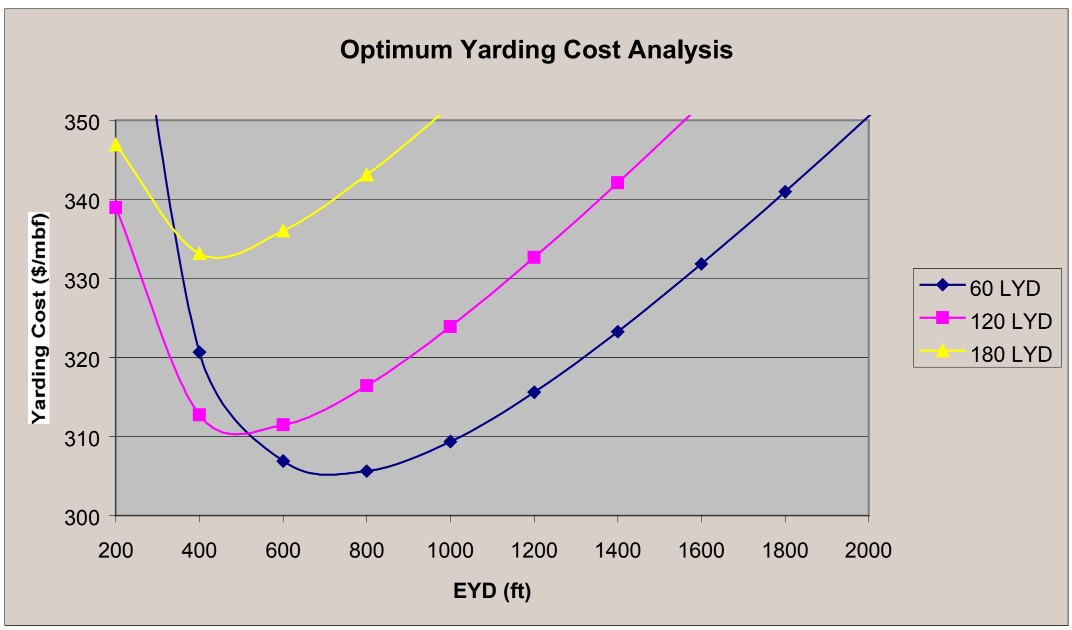


Figure 94 Optimizing Production costs: For this particular setting ideal dimensions is to have an external yarding distance of 750 ft. with a lateral yarding distance of 60 ft. These are the dimensions to have the lowest possible cost.

Lateral Yarding Distance

The lateral yarding distance determines the landing spacing on parallel settings and the affects the cycle times. On fan-shaped settings the LYD determines the road spacing and also effects the cycle times. The lateral yarding distance must be optimized along with the EYD. Generally, for short yarding distances utilization of wide corridors (long LYDs) is crucial. Refer to **Figure 94** to see this relationship more clearly. With longer EYDs it is more economical to use narrower LYDs. This phenomenon occurs on account of the number of corridors that must be constructed. The number of corridors has direct effect on the rigging time which effects the cost directly. With different harvest volumes the shape and values of the LYDs and EYDs that account for the best production will change from the graph above but the same general trend will occur.

Area

The area of the settings does affect the unit cost in a small way. The greater the area of the setting, the less effect it has on the cost/mbf. For settings greater than 10 acres, which is very small, the cost effects are minimal. Reference Figure 95.

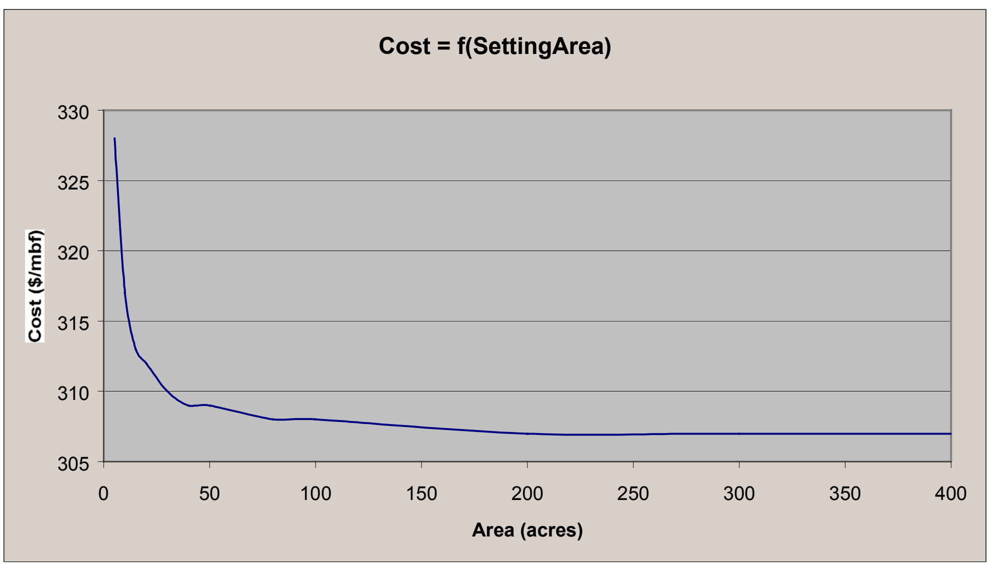


Figure 95 Cost as a function of Area: Area has little effect on the unit stump to truck yarding cost. A setting of 5 acres is only $21 more per mbf than a setting of 500 acres.

Parallel versus fan-shaped Landings

Parallel landing are cheaper than the fan-shaped when analyzing stump to truck costs. Throughout the variable density thinning analysis the parallel landing configurations are on average about 12% cheaper than the fan-shaped landings when the input parameters are equal. This does not include the required road construction costs, which in some situations the opposite may be true

Number of intermediate supports

In most settings the number of intermediate supports needed for the corridor configurations was zero. In some cases; however, there was the need for intermediate supports. Intermediate supports increase the rigging time, which increases the total yarding time, which equates to higher costs. The increase is linear. In typical harvest systems an additional intermediate support will increase the cost $8-$18/mbf.

Number of skyline anchors

The number of skyline anchors increases rigging time, which increases the total yarding time, which increases costs. In all the settings analyzed the number of skyline anchors was two. A detailed analysis was not done on the effects of increasing the number of skyline anchors.

Yarder Inputs

The yarder used has direct effect on the machine rate, which includes all owning and operating cost for a harvesting system. Different yarders also have different horsepower which results in different line speeds; this affects the cycle times in an inverse relationship. Generally the larger yarder that is used has better line speeds associated with it. This will give better production rates overall than the smaller yarder in question. Using the larger yarder has drawbacks. It costs more to operate the larger yarder. Different setting designs need to be analyzed with the available yarders to determine which will be the most economically beneficial. In most cases in the Burnt Mountain Planning area the Thunderbird 6150 was more cost effective than the smaller Koller 501. In other situations this could prove otherwise. In the case of the Burnt Mountain Planning area the Thunderbird yarders benefits of faster cycle times outweighed the downfalls of higher operating costs.

Silvicultural Inputs

The silvicultural inputs that change the production in a harvest unit are harvest volume and turn volume.

Harvest volume

The greater the unit harvest volume (mbf/acre) is, the less the unit cost is going to be and the greater the production will be. This relationship is always true. As the harvest volume gets greater the less rigging time there is for the amount of timber yarded. In a regeneration harvest there is even a more drastic improvement in unit cost because the turn times will not increase. In a thinning setting the turn times are affected more to avoid the scarring of standing timber. This relationship is illustrated in **Figure 96**.

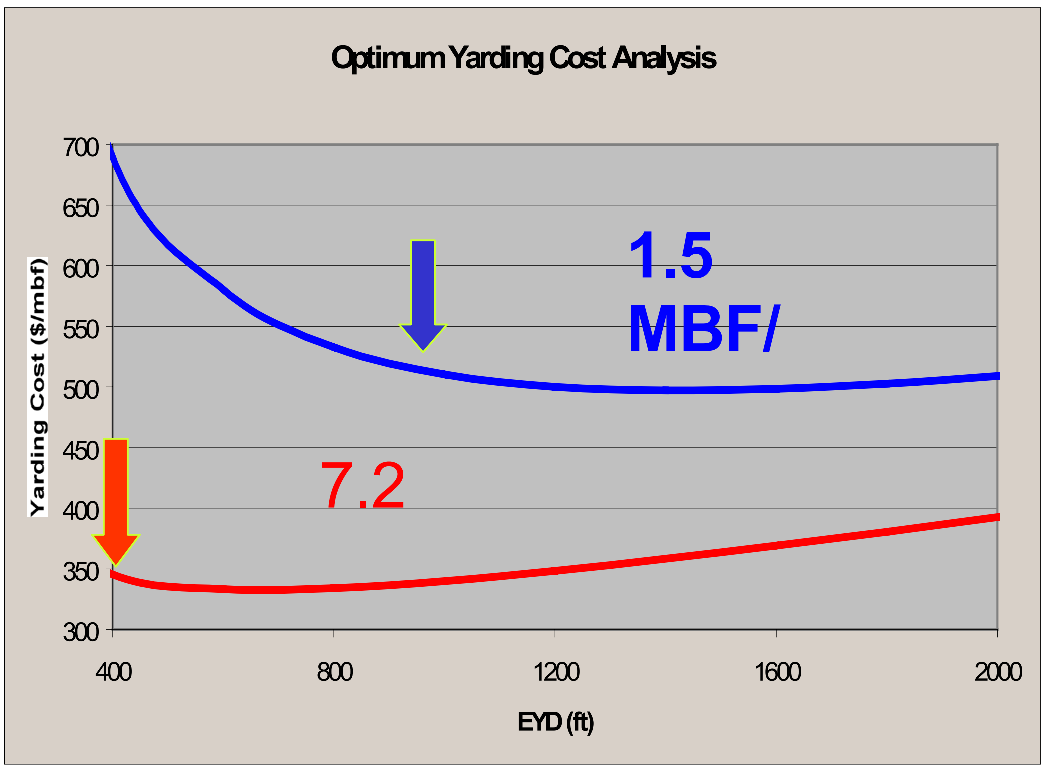


Figure 96 Cost as a function of Harvest Volume: The blue (upper) curve represents stump to truck cost throughout different EYDs with a harvest volume of 1.5 mbf/acre. The red (lower) curve represents the stump to truck cost with a harvest volume of 7.2 mbf/acre. Harvest volume has dramatic effects on the harvest cost of a setting. The greater the unit harvest volume, the less the cost will be.

Another relationship that closely resembles this relationship is cost and turn volume.

Turn volume

The turn volume affects the number of turns that must be made to harvest all of the volume. This effects the cycle time and where the optimum lateral yarding distance will occur. Even though both of these items are affected by the turn volume, larger turn volumes always increases production and decreases the unit cost. This relationship is illustrated in figure 4.

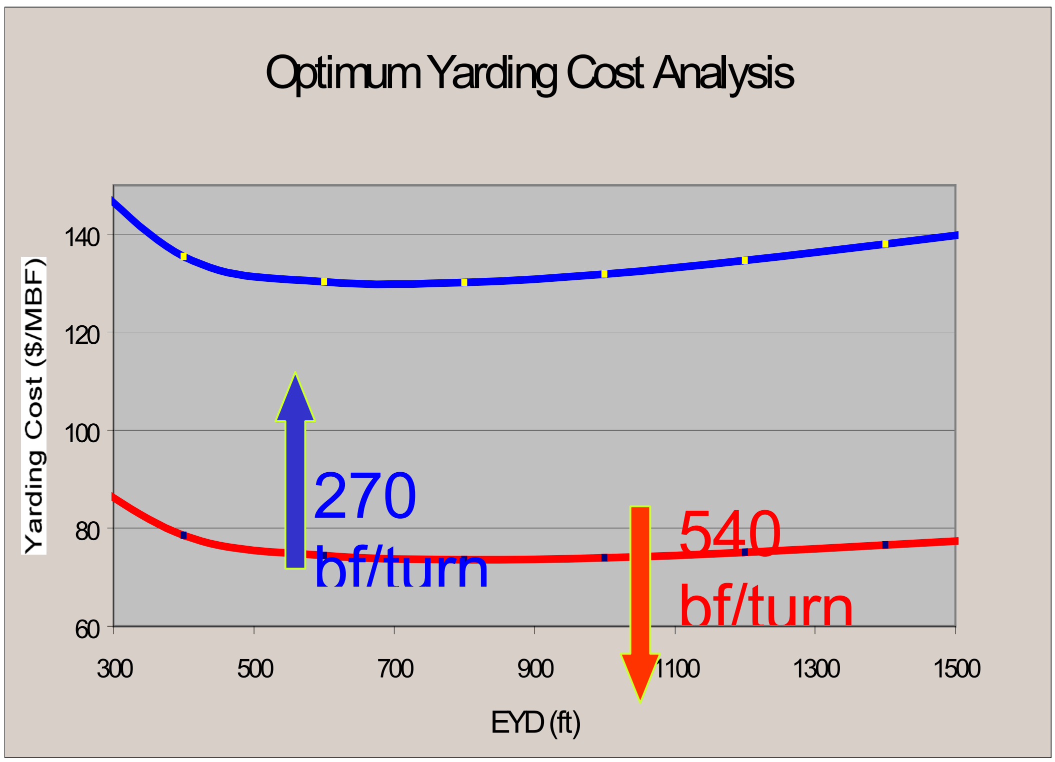


Figure 97 Yarding Cost as a Function of Turn volume: The blue (upper) curve represents a turn volume of 270 bf/turn. The red (lower) curve represents a turn volume of 540 bf/turn. This shows that a higher turn volume decreases cost dramatically.

12.8 Single Density Thinning Summary

Setting_number	Area (acres)	Cut Volume (mbf/acre)	Turn Volume (bf/turn)	Average EYD (ft)	Yarding Cost ($/mbf)	Total Volume (mbf)	Total Cost ($)
N01	7	4.6	95	800	287	32	9294
N02	12	4.6	95	645	423	56	23597
N03	32	7.3	121	600	239	233	55637
N04	17	7.4	121	1204	380	125	47483
N05	37	6.9	113	1510	419	254	106349
N06	48	4.8	134	600	275	232	63710
N07	6	5.6	88	509	582	34	19568
N08	5	5.6	90	528	377	28	10526
N09	57	7.4	121	455	457	419	191467
N10	14	1.8	92	441	460	26	11839
N11	10	4.9	115	440	481	49	23505
N12	15	5.1	88	588	336	77	25826
N13	22	7.1	118	759	328	156	51127
N14	78	3.7	85	1104	406	290	117795
N15	20	3.9	86	562	493	78	38643
N16	57	4.9	90	1323	482	277	133529
N17	41	4.3	87	1645	524	175	91743
N18	21	7.2	119	714	352	151	53070
N19	67	2.6	100	798	859	173	148571
N20	13	4.9	90	1030	445	63	28152
N21	27	0.6	74	1415	516	17	8830
N22	36	3.6	138	1296	427	128	54629
N23	18	4.9	90	1552	554	88	48530
N24	54	3.0	94	1036	428	160	68487
N25	5	0.6	75	1271	644	3	2089
N26	49	3.8	109	1843	589	188	110715
N27	7	0.6	74	1361	504	4	2221
N28	27	1.9	105	542	505	50	25280
N29	21	0.9	98	200	183	20	3616
N30	53	3.2	77	1673	392	167	65610
N31	29	2.0	110	949	494	57	28149
N32	47	3.0	108	658	706	141	99801
N33	13	1.3	122	761	491	17	8127
N34	4	3.2	113	234	1500	13	19448
N35	41	2.4	102	360	1173	100	117594
N36	73	3.2	91	1134	500	230	115095
N37	19	3.2	89	1684	561	61	33946
N39	22	3.2	77	871	465	70	32610
N40	34	2.6	99	515	447	88	39130
N41	461	9.1	120	333	562	4184	2351480
S01	78	2.2	79	700	1500	170	254935
S03	45	0.5	84	806	1500	23	33911

Total Cost ($)	6434274
avg. Cost ($/mbf)	552.2893

S05	6	2.1	89	1299	486	12	6039
S06	63	3.6	94	1720	489	229	111771
S07	27	3.4	107	1149	1500	92	138577
S08	9	1.6	85	100	1500	14	21186
S09	78	1.8	85	1350	1500	143	214403
S10	15	1.4	81	1197	549	22	11807
S11	47	0.5	83	798	1500	24	35507
S12	36	3.4	100	365	820	124	101725
S13	51	1.4	77	1192	391	71	27722
S14	9	3.0	90	1141	695	27	18660
S15	57	1.1	56	672	850	60	51187
S16	62	2.9	83	1058	838	178	148748
S17	92	1.0	59	891	698	93	64714
S18	102	1.1	72	791	924	116	107067
S19	21	4.5	111	948	563	94	53121
S20	77	4.3	97	200	172	334	57519
S21	24	0.9	66	970	378	22	8482
S22	91	1.4	70	1230	528	131	69220
S23	126	2.8	79	1237	397	355	140750
S24	7	1.4	70	639	422	10	4256
S25	42	0.0	0	1023	547	0	0
S26	52	0.0	0	959	449	0	0
S27	60	4.5	91	200	194	271	52552
S28	3	0.0	0	1054	516	0	0
S29	9	0.0	0	527	700	0	0
S30	15	1.8	80	1165	683	27	18702
S31	98	3.0	76	767	659	296	194897

12.9 Variable Density Thinning Summary

Setting_number	Area (acres)	Cut Volume (mbf/acre)	Turn Volume (bf/turn)	Average EYD (ft)	Yarding Cost ($/mbf)	Total Volume (mbf)	Total Cost ($)
N01	46	10.0	146	800	118	461	54438
N02	12	13.1	146	645	249	158	39249
N03	17	12.8	158	600	185	218	40351
N04	48	14.1	200	1204	224	675	151090
N05	37	11.9	143	1510	315	442	139163
N06	57	12.8	158	600	212	731	155040
N07	14	8.3	140	509	288	116	33379
N08	10	11.9	161	528	238	119	28355
N09	5	9.4	100	455	374	47	17536
N10	6	9.2	97	441	383	55	21244
N11	15	8.8	100	440	387	132	51037
N12	22	12.4	153	588	275	274	75314
N13	21	12.6	155	759	238	264	62895
N14	57	9.2	111	1104	312	527	164386
N15	20	7.8	110	562	351	156	54594
N16	41	5.4	100	1323	414	223	92440
N17	78	5.8	106	1645	410	452	185195
N18	36	6.1	128	714	332	221	73337
N19	27	4.7	127	798	339	126	42722
N20	13	3.7	93	1030	389	48	18540
N21	18	3.9	94	1415	528	69	36631
N22	54	3.1	97	1296	370	168	62034
N23	67	5.1	122	1552	416	339	140911
N24	49	5.6	120	1036	368	275	101219
N25	53	2.4	89	1271	610	125	76461
N26	73	7.3	124	1843	390	536	209065
N27	22	8.5	110	1361	327	188	61499
N28	19	3.9	100	542	440	74	32445
N29	4	2.5	101	200	204	10	2064
N30	47	5.5	134	1673	298	261	77658
N31	13	5.8	177	949	252	75	18873
N32	21	5.6	157	658	292	118	34461
N33	27	6.8	135	761	299	183	54621
N34	7	3.7	115	234	579	26	15025
N35	5	4.9	130	360	369	24	8959
N36	29	6.8	138	1134	321	198	63595
N37	41	5.4	133	1684	388	223	86594
N39	34	5.6	123	871	333	190	63345
N40	7	13.2	146	515	224	92	20620
N41	8	9.2	112	333	284	74	20960
S01	14	0.6	44	700	603	9	5208

Total Cost ($)	5396429
avg. Cost ($/mbf)	331

S03	50	0.6	44	806	1500	31	46268
S05	73	15.0	122	1299	355	1093	387872
S06	60	8.7	117	1720	365	524	191231
S07	9	0.0	0	1149	1500	0	0
S08	3	0.0	0	100	1500	0	0
S09	52	0.0	0	1350	1500	0	0
S10	126	6.8	99	1197	399	855	341304
S11	42	0.0	0	798	1500	0	0
S12	7	6.3	95	365	448	44	19610
S13	77	6.8	107	1192	339	521	176724
S14	102	4.2	95	1141	440	433	190561
S15	24	1.5	97	672	559	37	20500
S16	92	1.6	97	1058	516	145	74644
S17	47	6.5	131	891	280	306	85687
S18	57	3.1	83	791	543	176	95666
S19	78	7.1	133	948	298	554	165162
S20	9	6.3	124	200	125	57	7066
S21	21	5.4	124	970	334	113	37626
S22	62	6.6	108	1230	372	410	152492
S23	36	5.5	110	1237	341	199	67943
S24	27	6.5	131	639	312	174	54342
S25	6	5.7	109	1023	361	34	12364
S26	63	7.8	107	959	351	492	172527
S27	9	6.7	121	200	137	60	8285
S28	78	8.4	138	1054	260	656	170677
S29	15	7.2	124	527	335	108	36260
S30	45	6.5	131	1165	284	293	83306
S31	51	5.7	109	767	367	288	105759

12.10 Variable Density Thinning Summary for Whole-Tree

Setting_number	Area (acres)	Cut Volume (mbf/acre)	Turn Volume (bf/turn)	Average EYD (ft)	Yarding Cost ($/mbf)	Total Volume (mbf)	Yarding Cost ($)	Total turns
N01	46	10.0	253	800	118	461	54438	1825.377
N02	12	13.1	302	645	136	158	21437	521.6075
N03	17	12.8	371	600	185	218	40351	587.9072
N04	48	14.1	413	1204	125	675	84314	1635.132
N05	37	11.9	322	1510	162	442	71570	1372.611
N06	57	12.8	371	600	212	731	155040	1971.218
N07	14	8.3	230	509	197	116	22832	503.2523
N08	10	11.9	329	528	138	119	16441	362.4373
N09	5	9.4	100	455	374	47	17536	468.8939
N10	6	9.2	97	441	383	55	21244	570.8843
N11	15	8.8	100	440	387	132	51037	1315.18
N12	22	12.4	355	588	147	274	40259	772.3698
N13	21	12.6	360	759	121	264	31976	733.1944
N14	57	9.2	217	1104	175	527	92203	2428.786
N15	20	7.8	234	562	194	156	30174	663.6721
N16	41	5.4	100	1323	414	223	92440	2228.272
N17	78	5.8	227	1645	211	452	95308	1986.087
N18	36	6.1	128	714	332	221	73337	1724.86
N19	27	4.7	263	798	194	126	24449	478.6251
N20	13	3.7	93	1030	389	48	18540	510.3955
N21	18	3.9	94	1415	528	69	36631	738.2461
N22	54	3.1	97	1296	370	168	62034	1723.127
N23	67	5.1	212	1552	266	339	90101	1598.599
N24	49	5.6	120	1036	368	275	101219	2290.479
N25	53	2.4	89	1271	610	125	76461	1400.599
N26	73	7.3	263	1843	210	536	112573	2035.631
N27	22	8.5	252	1361	159	188	29903	747.6659
N28	19	3.9	100	542	440	74	32445	738.9712
N29	4	2.5	101	200	204	10	2064	100.0402
N30	47	5.5	229	1673	189	261	49253	1138.304
N31	13	5.8	490	949	118	75	8837	152.8943
N32	21	5.6	383	658	152	118	17939	308.1654

Total Cost ($)	4312954
Avg Cost ($/mbf)	265
avg. turn volume (bf/turn)	164.8884

N33	27	6.8	313	761	156	183	28498	583.2333
N34	7	3.7	217	234	446	26	11574	119.7967
N35	5	4.9	258	360	243	24	5900	94.12154
N36	29	6.8	329	1134	161	198	31896	602.9393
N37	41	5.4	324	1684	191	223	42628	688.6922
N39	34	5.6	123	871	333	190	63345	1549.309
N40	7	13.2	303	515	145	92	13348	304.093
N41	8	9.2	112	333	284	74	20960	659.3728
S01	14	0.6	44	700	603	9	5208	196.6215
S03	50	0.6	44	806	1500	31	46268	702.2197
S05	73	15.0	122	1299	355	1093	387872	8978.151
S06	60	8.7	117	1720	365	524	191231	4488.514
S07	9	0.0	0	1149	1500	0	0	
S08	3	0.0	0	100	1500	0	0	
S09	52	0.0	0	1350	1500	0	0	
S10	126	6.8	99	1197	399	855	341304	8623.829
S11	42	0.0	0	798	1500	0	0	
S12	7	6.3	95	365	448	44	19610	462.8645
S13	77	6.8	107	1192	339	521	176724	4894.693
S14	102	4.2	95	1141	440	433	190561	4566.084
S15	24	1.5	97	672	559	37	20500	378.8162
S16	92	1.6	97	1058	516	145	74644	1498.057
S17	47	6.5	231	891	175	306	53554	1325.987
S18	57	3.1	83	791	543	176	95666	2132.946
S19	78	7.1	283	948	163	554	90340	1956.907
S20	9	6.3	124	200	125	57	7066	456.3592
S21	21	5.4	124	970	334	113	37626	908.1992
S22	62	6.6	108	1230	372	410	152492	3807.581
S23	36	5.5	110	1237	341	199	67943	1817.042
S24	27	6.5	325	639	157	174	27345	536.4755
S25	6	5.7	109	1023	361	34	12364	314.4535
S26	63	7.8	107	959	351	492	172527	4592.449
S27	9	6.7	222	200	137	60	8285	272.7062
S28	78	8.4	260	1054	153	656	100437	2523.99
S29	15	7.2	238	527	204	108	22081	453.9818
S30	45	6.5	231	1165	176	293	51626	1269.824
S31	51	5.7	194	767	233	288	67144	1487.265
								98881.06

12.11 Regeneration Harvest Summary

Setting_number	Area (acres)	Cut Volume (mbf/acre)	Turn Volume (bf/turn)	Average EYD (ft)	Yarding Cost ($/mbf)	Total Volume (mbf)	Total Cost ($)
N01	46	32.9	592	800	51	1514	77189
N02	12	38.4	715	645	55	460	25325
N03	17	43.2	777	600	44	735	32328
N04	48	36.2	715	1204	66	1735	114529
N05	37	39.6	670	1510	71	1464	103912
N06	57	43.2	777	600	52	2464	128103
N07	14	30.6	538	509	76	429	32571
N08	10	34.0	608	528	67	340	22793
N09	5	29.5	373	455	104	148	15355
N10	6	29.3	363	441	106	176	18662
N11	15	30.3	419	440	96	454	43592
N12	22	41.9	742	588	54	921	49740
N13	21	42.4	755	759	52	889	46248
N14	57	30.6	456	1104	78	1742	135893
N15	20	32.6	560	562	71	651	46251
N16	41	32.2	638	1323	66	1321	87204
N17	78	30.6	663	1645	67	2391	160175
N18	36	35.1	797	714	54	1263	68197
N19	27	29.4	776	798	55	793	43620
N20	13	32.2	701	1030	59	418	24661
N21	18	32.1	693	1415	69	578	39867
N22	54	32.7	746	1296	52	1768	91957
N23	67	35.0	767	1552	65	2347	152582
N24	49	34.1	711	1036	62	1671	103593
N25	53	32.7	771	1271	64	1735	111014
N26	73	31.9	639	1843	79	2326	183736
N27	22	32.3	580	1361	65	710	46142
N28	19	33.0	721	542	59	626	36955
N29	4	33.4	759	200	31	134	4147
N30	47	34.1	640	1673	61	1604	97867
N31	13	35.1	1167	949	39	457	17819
N32	21	32.1	953	658	49	675	33061
N33	27	32.0	766	761	55	863	47461
N34	7	30.7	761	234	79	215	16983
N35	5	29.9	755	360	62	149	9259
N36	29	32.7	795	1134	58	947	54939
N37	41	37.2	910	1684	57	1524	86886
N39	34	32.2	626	871	64	1094	70000
N40	7	38.3	715	515	58	268	15558
N41	8	32.1	516	333	90	257	23112
S01	14	9.2	237	700	116	128	14884
S03	50	16.3	348	806	134	813	108890

Total Cost ($)	5202024
avg Cost ($/mbf)	70

S05	73	16.3	328	1299	141	1192	168055
S06	60	22.3	393	1720	111	1338	148500
S07	9	18.1	324	1149	114	163	18545
S08	3	17.9	323	100	49	54	2628
S09	52	18.0	324	1350	128	936	119764
S10	126	26.4	434	1197	93	3326	309358
S11	42	17.2	322	798	123	721	88684
S12	7	20.4	370	365	116	143	16549
S13	77	31.5	701	1192	55	2422	133235
S14	102	24.1	485	1141	85	2455	208690
S15	24	14.5	360	672	118	348	41033
S16	92	12.5	406	1058	108	1146	123771
S17	47	30.1	654	891	57	1416	80689
S18	57	26.5	505	791	84	1511	126940
S19	78	32.9	731	948	56	2567	143735
S20	9	31.8	680	200	24	286	6859
S21	21	35.0	731	970	56	736	41216
S22	62	29.6	512	1230	79	1833	144843
S23	36	31.3	606	1237	63	1125	70901
S24	27	37.8	884	639	48	1021	48989
S25	6	29.9	615	1023	67	179	12011
S26	63	30.6	528	959	74	1928	142656
S27	9	31.4	646	200	27	283	7635
S28	78	31.6	653	1054	57	2467	140634
S29	15	30.9	630	527	69	464	32006
S30	45	30.2	655	1165	58	1358	78776
S31	51	29.9	598	767	67	1526	102259