FOREST ENGINEERING DEPARTMENT

ABSTRACTS

OF

AVAILABLE THESES

AND

TECHNICAL PAPERS

June 2006
ACKER, T.A. 1996. Three strategies for tree bucking at the harvest site: consequences for the sawmill. (MS)
The timber shortage in the Pacific Northwest is forcing sawmill owners to improve the competitiveness of their harvesting and processing operations. A computer simulation and financial statement analysis were used to compare the processing efficiency and profitability of three bucking strategies: log cost minimization (traditional 40-foot preferred-length logs); hauling length maximization (55-foot preferred-length logs); and the Integrated Log Manufacturing system (ILM), a proposed computer-based strategy that acts as a harvest-site merchandiser and integrates harvest-site tree bucking and lumber manufacturing. Five days of sawmill operations were simulated for each strategy; the same second-growth Douglas-fir trees were processed each day to fill identical lumber orders. The sawmill produced 0.4 percent and 1.9 percent more cubic feet of targeted lumber with a 55-foot preferred-length strategy and ILM respectively, than with the 40-foot preferred-length strategy. Compared with the 40-foot preferred-length strategy, sawmill profits rose $2,262 (23%) per week in pas-as-scaled sales with the 55-foot preferred-length strategy, and $5,530 (57%) per week in lump sum sales with ILM.

ACUNA, M. A. 2006. Wood Properties and Use of Sensor Technology to Improve Optimal Bucking and Value Recovery of Douglas-fir. (PhD)
There are a number of wood properties which affect the quality of forest products such as lumber and pulp. Of these, wood density is considered by some to be the single most important physical characteristic because it is an excellent predictor of strength, stiffness, hardness, and paper-making capacities. Accurately assessing density in real-time can be a challenge for log supply managers wanting to segregate logs into different product classes based on density.

Mechanized harvesting machines are frequently fitted with computer technology and rudimentary sensor systems for measuring external stem dimensions. Research into technologies for measuring stem quality attributes is progressing on a number of fronts with varying levels of success. Some of these scanning technologies could be integrated into the design of mechanized harvesting systems.

In this dissertation:
• It is shown how Douglas-fir wood density can be predicted from near infrared (NIR) spectroscopy measurements of chain saw chips, ejected as a stem is cut into logs by a mechanized harvester,
• it is provided an analysis of the potential use of NIR technology for log segregation based on wood density,
• it is presented a general methodology to estimate log prices of Douglas-fir based on the net return obtained when logs of different wood density classes are processed and converted into end products (lumber and pulp),
• it is demonstrated how wood density could be included in optimal bucking procedures, and
• it is analyzed the effect of market requirements for density on log yields, total volume and revenue from a representative sample of Douglas-fir stems.

New sensor technologies are likely to lead to measurement, segregation and supply of a wider range of wood properties for forest product markets.
AEDO-ORTIZ, D.M. 1994. A mechanized harvesting system simulation: input, output, limitations and capabilities. (MS)

This study concerns the use of a discrete-event simulation model for analyzing the production of a mechanized forest harvest system. The simulation models a field collection data set of a harvester-forwarder system which was previously collected by the Forest Engineering Department of Oregon State University. The computer software consisted of the statistical package statgraphics and the simulation package Promodel PC.

Special emphasis is given to the use of statistical distributions and linear regressions as simulation input data. The simulation model was built in productive machine time. Input quality and output capabilities of the simulation language Promodel PC produced realistic output of weekly predicted production of the system. Also, linear regressions of average yarding distance and unloading time of the forwarder estimated the production of the harvest system. The unloading time regression was used to develop a cost evaluation of the possibility of adding a loader to the harvest system.

"Group" and "ungroup" functions of Promodel PC are powerful tools for generating a simulation model of a harvest system. These functions allow an easy programming transition despite the different system products. On the other hand, animation produced more model building difficulties than output benefits.

It is advisable for future field studies to be designed in a different manner. Variables should be collected according to the input needs of the simulation model.

AKAY, A.E. 1998. Estimating machine rates and production for selected forest harvesting machines operating in the western United States and determining the most economical machine combinations under representative conditions in Turkey. (MF)

During the last decades, there has been increasing interest in ground-based mechanized harvesting systems in the western United States as harvest of second growth increased. A major reason for that interest is that labor productivity using conventional methods decreases with smaller tree size. In Turkey, the application of mechanization is currently low due to low labor costs and high fuel costs. However, changing economic conditions might increase interest in mechanized harvesting systems in Turkey.

To select the most profitable harvesting equipment under given operating conditions, the harvesting manager must know how to determine logging costs to evaluate alternative systems effectively. Analytical methods were used in this project to estimate machine cost and productivity for different harvesting system combinations.

Animal logging was also considered because highly mechanized timber harvest systems are expensive, and energy consuming. Animals and farm tractors are the major energy sources for agricultural and forestry work and transportation in Turkey. A small amount of animal skidding also takes place in forestry operations in the western United States to reduce environmental impact.

Forty-two machines were selected from six categories of ground-based forest harvesting machines, including skidder, forwarder, harvester, feller-buncher, loader, and crawler tractor. Machine rates were estimated for selected forest harvesting machines under representative conditions in both western United States and in Turkey. Cable harvesting systems are described but not analyzed. A microcomputer spreadsheet program was developed to calculate machine rates.

Harvesting operations from stump to truck were investigated to have a clear picture of harvesting operations including felling and bucking, skidding, forwarding, yarding, and loading. Harvesting production and harvesting costs were determined depending on the types of equipment being operated. To estimate production rates for specific logging equipment, cycle time was obtained from the production equations as a dependent variable, and converted to production using log size, volume, or weight. Production equations are based on studies that have provided useful data to investigate productivity of the logging equipment under various harvesting conditions.

Finally, the most economical machine combination, which minimizes the unit cost of logging, was investigated for three different regions of Turkey. The data including topographic data, road data, tree and log data, soil data, and cost data was collected from selected sample plots of each region as representative conditions. In the sample plots selected from Black Sea and Aegean regions, the cut-to-length system using four sawyers and a forwarder produced wood on the truck at the lowest cost, $11.18/m³, and $13.88/m³, respectively. In the sample plots selected from Mediterranean region, the whole-tree system using four sawyers, a grapple skidder, and a loader produced wood at the lowest cost ($9.29/m³). This compared to an estimated logging cost of about
$7.00/m³ to $10.00/m³ in Turkey using chain saw felling, oxen skidding and manual loading.

The systems currently available for forest road design are not capable of making computer-aided design judgments such as: 1) automated generation of alternative grade lines, 2) optimizing vertical alignment, 3) minimizing total cost of construction, maintenance, and transportation costs, and 4) aiming for least environmental impacts.  In recent years, advances in the processing speed and realtime rendering and viewing of high-resolution three dimensional (3D) graphics on microcomputers, combined with improved resolution in mapping technologies have made it possible to locate a route interactively between two given points on a 3D display of a ground surface.  A 3D forest road alignment model, TRACER, aided by an interactive computer system, was developed to help a designer with rapid evaluation of alternatives.  The road design objective is to design a path with the lowest total construction, maintenance, and transportation costs, while conforming to design specifications, environmental requirements, and driver safety.

The model relies on a high-resolution digital elevation model (DEM) to provide terrain data for supporting the analysis of road design features such as ground slope, topographic aspect, and other landform characteristics.  Light Detection and Ranging (LIDAR) system is one of the systems that provide high-resolution and accurate DEM data.  The contributions of the TRACER program are (1) data input is enhanced through a 3D graphic interface, (2) user efficiency is enhanced through automated horizontal and vertical curve fitting routines, cross section generation, and cost routines for construction, maintenance, and vehicle use, (3) road feasibility is ensured by considering terrain conditions, geometric specifications, and driver safety, (4) design time is reduced in the early stage of the forest road design by allowing the designer to quickly examine alternative routes, (5) economic efficiency is enhanced by combining modern optimization techniques to minimize earthwork allocation cost using linear programming and to optimize vertical alignment using a heuristic technique (Simulated Annealing), and (6) environmental impacts are considered by estimating the average annual volume of sediment delivered to a stream from the road section.  It is anticipated that the computer-aided analysis of route alignment alternatives that are best suited to local conditions considering costs, environmental impacts, and driver safety.

ALARID, S.  1993.  Production and cost analysis of a skyline cable logging system operating in an uneven-age management prescription.  (MS)
Forest managers in recent years have begun to re-examine the possibilities of using uneven-age silvicultural systems in the Oregon Coast Range.  This increasing interest is being driven by a variety of forest resource management concerns, including wildlife habitat diversity, visual aesthetics, and long-term sustained yield.  In an effort to begin systematic exploration of coastal uneven-age silvicultural techniques, Oregon State University (OSU) researchers have established a demonstration site at Forest Peak on OSU's Dunn Forest.
This case study involving a single treatment at a single site reports on the design, performance, and cost of the skyline logging operation during September and October 1992 which was designed to achieve the goals of an uneven-age management prescription prepared by OSU silvicultural and wildlife specialists.  The operation harvested 13.9 MBF of 23-inch average dbh Douglas-fir and grand fir timber.

The study tracked the time spent in planning and laying out the logging system.  Field and office planning and layout procedures took 93.75 hours to complete at a cost of $6.47/MBF.

The project also involved detailed time studies and shift-level analyses of both the felling/bucking and the yarding phases of the logging operation.  A two-man felling crew produced 6.44 MBF/Hr at a cost of $10.44/MBF.  Cutting cycle time averaged 9.22 minutes per tree, with number of logs per tree, cutting method (wedges or no wedges), percent ground slope, and base diameter the most influential factors affecting cutting cycle time.

The six-man yarding crew using a Thunderbird TTY50 yarder and small Danebo MSP carriage yarded 4.7 MBF/Hr at a cost of $58.51/MBF.  Yarding cycle time averaged 5.73 minutes per turn, with corridor yarding distance, lateral yarding distance, choker setting method (pre-set or hot-set), and number of logs per turn the most influential factors affecting yarding cycle time.

The six-man crew plus the hook tender averaged 1.82 hours for each change of yarding corridors.  Corridor changes involved moving all rigging from one corridor to the next and repositioning the yarder if necessary.  The
hook tender alone spent an additional 1.31 hours per corridor pre-rigging tail trees, anchors, etc.

Total logging cost including planning and layout, felling and bucking, yarding, loading, and equipment move-in was $104.03/MBF.

AMMESON, J.E. 1984. A production study of the pendulum balloon logging system. (MF)

The purpose of this paper is to compare the estimated production of the pendulum swing logging system to the production of a conventional balloon logging system.

Cycle Time is established for the conventional system by time study techniques. A combination approach is used to model the pendulum system. A computer model simulates the mechanics of the inhaul and outhaul elements. The time study data from the conventional system is used to estimate the remainder of the cycle time for the pendulum system. Net payloads are calculated for both systems by a static analysis.

The calculations show the pendulum system to be more productive when yarding distances are less than 1200 feet. The production calculations show the conventional system to be more productive when yarding distances exceed 1200 feet.

ANDERSON, P.T. 1985. A survey of design, construction, and operation practices for steep roads in the Oregon Coast Range. (MF)

The selection of a road standard is a complex decision involving consideration of design, construction, maintenance, and vehicle operating costs. The first step in any analysis involves a definition of the physically feasible alternatives. In the Oregon Coast Range, a combination of steep topography and sensitive soils influence the type of physical options available to management. To reach the necessary landings for harvest operations with the minimum road lengths, requires steep roads. The conditions for successful operation of steep roads have not been documented.

This paper summarizes the effects of road gradient upon excavation, drainage, road surfacing, haul, and maintenance based upon information available from transportation planners, materials engineers, maintenance supervisors, logging contractors, and equipment operators. The physical aspects of soil-vehicle interactions and vehicle performance are investigated to a limited degree using laboratory and field tests. An economic framework for comparing the costs of steep roads is included. Subject areas where limited information is available are suggested for future research.

ARMLOVICH, D. 1995. Soil compaction study on a cut-to-length mechanized harvesting system. (MF)

This study looked at the soil compaction effects resulting from a cut-to-length harvest system on an area in the western Cascade Range of Oregon. The cut-to-length harvest system is a mechanized system in which trees are felled, delimbed, and bucked into short log lengths by a mechanical harvester. Logs are then picked up and carried to a landing area by a forwarder. The trails created by the harvester are typically also used by the forwarder.

On this area, the locations of the equipment trails were laid out in advance of logging operations by the logging contractor. Equipment use of the trails was monitored and mapped. Trails were then divided into strata based on the number of equipment passes. Stratum categories used were 1-4, 5-6, 7-8, 9-12, 13-20, 21-29, and 30+ equipment passes. Soil bulk density was determined by pass stratum using a single probe nuclear densiometer. Density measurements were taken at depths of 0-4, 0-8, and 0-12 inches. At each measurement point additional measurements made were: slope, 0 horizon depth, post harvest slash depth, slash quantity, and average slash size. Slash quantity and average slash size were ocular estimates categorized using index values.

To estimate the change in soil bulk density, background density was estimated from a grid of measurement points placed on undisturbed areas over the entire unit. Compaction was found to increase significantly in areas with four or fewer passes, then remain relatively constant in areas up to at least twenty passes. After thirty or more passes, an increase in compaction was again noted. Density increases over undisturbed were greatest in the upper 4 inches of the soil surface, increasing 20 percent after four or fewer passes and 28.6 percent after thirty or more passes. The values for slash parameters were greatest for the 1-4 stratum and least for the 30+ stratum. Mean values for the slash parameters for the 5-6, 7-8, and 9-20 pass strata are not statistically different but in general, there was a trend of decreasing mean values for slash parameters with increasing number of equipment passes. Regression analysis showed no association with slope, 0 horizon depth or any of the slash parameter values. Only a root value of number of equipment passes was significant though r-squared values were low. Total percentage of area covered by
equipment trails was 23.2 percent.

ARTLEY, R. 1980. A computer estimate of costs and engineering data for a proposed transportation network in New England. (MF)

This paper describes a computer program developed for the Hewlett Packard 9830, which analyzes and computes costs and engineering data for paper plan timber harvest road networks. The program will accept up to 110 road segments. Each segment is analyzed individually based on digitized data from a contour map and user defined road construction parameters. Three types of construction are analyzed for each segment: fullbench and sidecast, fullbench and endhaul and balanced construction.

Program results and operation are exemplified in an analysis of a proposed transportation plan in a cable logging study area in New England. The study area is on the Green Mountain National Forest in Central Vermont. The transportation plan contains 99 miles of proposed new road within the 25,000 acre study area. Cost and engineering data sensitivity to changes in road construction parameters is analyzed. Variations in the subgrade width and surfacing depth seem to affect cost the most.

Fuel consumption of alternative logging systems is also compared in this paper. The results indicate that cable logging initially consumes more fuel due to increased road construction. However, once the roads are established, cable logging systems consume less fuel than tractor logging. This study indicates that it takes approximately 40 to 60 years for cable logging systems to catch and surpass tractor systems in terms of total accumulated fuel consumption.

AUBUCHON, R. 1982. Compendium of cable yarding production equations. (MS)

This paper is a compilation of most of the recent cable yarding production equations generated by the Forest Engineering Department at Oregon State University. Additional production equations found in the literature review have also been included. Background information for each of the studies involved has been summarized.

Data is basically organized into a set of tables for small, medium, and large sized yarders. Each sheet in a set of tables contains a particular type of information, such as production data, equipment information, crew information, and physical characteristics of the sale area.

Guidelines on the potential use of the compendium and a discussion of equations as predictive tools is provided. A graphical summary was developed to assist the reader in locating an equation representing a particular set of conditions.

avery, R.B. 1984. Mathematical model for determining the position and line tension for a tethered logging balloon. (MS)

A program was developed on a desktop computer to determine the cable tensions and position of a balloon tethered by two or more guylines. The program was specifically applied to the analysis of the static load lifting capability of the Pendulum Swing Balloon System. This system uses a tethered balloon and a gravity assisted swing to provide lift and movement to a load of logs.

Due to fundamental differences between conventional cable yarding systems and the pendulum balloon system, a catenary analysis is used to determine cable tensions, balloon position and available lift at a specified load location. Available lift is determined by the tautness of the pendulum, or load carrying line. The length of this line is altered to induce tension into it. The balloon position changes in response to the length adjustment. A gradient search procedure is used in combination with the appropriate catenary equations to conduct the analysis.

Comparison of calculated line tensions with selected measurements obtained in a separate field study revealed an average difference of ±11.7 percent. Calculated balloon position coordinates were, on the average, within ±0.01 percent of the measured positions.

A hypothetical setting consisting of a uniform, 60 percent slope extending 2000 feet horizontally was used to evaluate available lift of the system. Guyline placement and corridor orientation were selected so as to facilitate the analysis. The effect of the pendulum swing was not considered. Results obtained are as follows:

1. Total cable weight has a dramatic impact on available lift. If the balloon is to be placed at a high elevation above the ground, guylines should be made of a material having a higher strength to weight ratio than wire rope.

2. Shortening the pendulum line causes a transfer of tension from adjacent guylines to the pendulum line. The relation of the load position to the balloon and the original amount of vertical tension in the guylines
determines the amount, and rate, of increase in available lift. In most circumstances, a shortening of 15 feet or less will provide a significant tension transfer without incurring significant balloon movement. Excessive balloon movement will alter the swing capability.

3. If lightweight guylines are used, the balloon should be placed between 1000 and 1500 feet above the 60 percent slope to obtain satisfactory lift at each end of the corridor.

The developed model can be used to study the effects of wind, live guylines and cable stretch on the system. Organization of the program is such that harvesting plans for a proposed setting can be developed quickly and easily.

BALCOM, J. 1983. Comparisons of skyline carriages for smallwood harvesting. (MS)

Three skyline carriage types are analyzed on the basis of their operating characteristics and limitations. Their effect on productivity is expressed as cubic feet per hour-yarded to the landing. These carriage types, tested as part of Oregon State University's School of Forestry Smallwood Harvesting Research Program represent those which are especially suited to thinning smallwood stands. The three types are distinguished by their clamping mechanisms: 1) skyline stop 2) self-clamping hydraulic and 3) self-clamping mechanical. The clamping mechanism is the means by which the carriage is secured to the skyline during the lateral inhaul element of the yarding cycle. Since data from the individual studies are not all comprehensive, five carriage studies are used for the analysis of the three carriage types. The Maki and Christy carriages represent the skyline stop carriages. The Koller 1.0 and 2.5 carriages represent the self-clamping hydraulic carriages and the Wyssen 2.5 represents the self-clamping - mechanical carriages.

The operating characteristics which proved to be most important are the ability to throw slack in the mainline, adaptability for use with sliding chokers, spotting ability and carriage delays. The skyline stop carriages tend to throw slack in the mainline when they hit the skyline stop at the end of outhaul (which aids in the lateral outhaul of the mainline). The Koller carriages, representing the self-clamping hydraulic carriages, cannot be used with sliding chokers without modification, since the load hook is part of the release mechanism. This effect, along with the effect of throwing slack, was not quantified. The Wyssen carriage was observed as having a greater capacity to be spotted at an exact location on the skyline for the lateral yarding sequence than any of the other carriages. This resulted in a lead angle standard deviation of only 17.7 degrees. A similar standard deviation of 16 degrees was observed for the Koller 1.0. The Christy carriage resulted in a larger standard deviation of 24 degrees. Lead angle data was not available for the Maki and Koller 2.5 carriages. The importance of spotting is that either the logs can be yarded laterally to lead or the best extraction path can be chosen for a turn. Both of these advantages serve to reduce resets and minimize stand damage.

Carriage delay analysis indicated very little difference between the time required to move the skyline stop calculated on a per turn basis and the time required for the self-clamping carriages to cycle every turn. With operational delays added in, the carriage delays for the skyline stop carriages is 0.2678 minutes per turn and for the self clamp mechanical is 0.2625 minutes per turn. This information was not available for the self-clamping hydraulic carriages, but is probably greater than the self-clamping mechanical type and may be greater than the skyline stop type.

The three carriage types were compared on a productivity basis. No conclusive differences were found since factors not accounted for in the individual studies tended to mask the affects of the different carriage types. The differences in productivity due to carriage types appear to be small in comparison to such factors as crew selection, stand conditions and site conditions.

BARBIERI, J.G. 1957. Forest road location and design in the Douglas-fir region. (MS)

The purpose of this thesis is to outline the principles involved in the reconnaissance, survey, and design of forest roads in the Douglas-fir region.

The reconnaissance survey is the most important element in road location. Poor reconnaissance often results in abandonment of the route at considerable expense.

The ground slope effects the type of reconnaissance employed. In level country alignment controls the location of the road and grade is adapted to the topography to balance excavation and embankment quantities. In sidehill country grade controls the location of the road and alignment is adapted to the topography to balance excavation and embankment quantities.

The reconnaissance survey may be separated into extensive and intensive reconnaissance. The extensive
survey is the study of an area or drainage to determine the general location of the route. The intensive
reconnaissance is a study of the ground adjacent to the general location of the route. The final selection of a
route often involves the comparison of one or more alternatives.

A preliminary survey is conducted along the final reconnaissance line to establish horizontal and vertical
control and the topography on either side of the line. The precisions desired determines the method of survey
employed. The staff compass-tape-abney survey is the most widely used method in the Douglas-fir region.

The road is designed from the data obtained from the reconnaissance and preliminary surveys. These data
are studied graphically using the plan, profile, and cross sections of the route or any combination of these graphic
aids. Center line of the road will closely follow the final reconnaissance line if the intensive reconnaissance is
thorough. Regardless of the method of design used, the final center line is a compromise between optimum
alignment and minimum excavation.

delimber-debarker systems. (MF)
The Pulp and Paper Industry in the Pacific Northwest is obtaining an increasing share of its fiber supply by
chipping small diameter trees from thinnings, insect damaged stands, and stand conversions. Since most of the
mills require pulp grade fiber to contain less than 0.5% bark, the timber must be debarked prior to chipping.
Traditional single-stem debarking operations have proven to be expensive compared with multiple-stem
alternatives.

Thus, three portable chain-flail delimber-debarker systems have recently been developed in the Pacific
Northwest. Two of the systems employ self-contained prototypes capable of simultaneously deliming and
debarking multiple whole-tree loads. The third is a two-machine system, with a mobile chain-flail delimber.
Chip samples obtained during short-term productivity studies averaged 0.5%, 0.7%, and 1.5% in bark content, for
the two self-contained units and the two-machine system, respectively. The most productive of the three
operations manufactured 170 Bone Dry Tons (BDT) of pulp grade chips per shift. Delimber-debarking-chipping
costs were $10.63 per BDT, with a 37% utilization rate. With minor machine modifications and better harvest
system balancing, production is expected to double.

The purpose of this paper is to determine the dynamic tensions that occur in the guylines and pendulum lines of a
tethered logging balloon. A scale model was used to represent the tethered logging balloon.

During the swinging of payloads, line tensions followed a very predictable sinusoidal curve. It was
determined that the maximum balloon displacement will occur when the payload is being lifted off the ground.
The maximum balloon displacement corresponds to a worst case position for the system as a whole. The
maximum dynamic tension that will occur in the pendulum line represented only a 5-10 percent increase over the
static tension to initially lift the payload off the ground.

BEAULIEU, M. 1989. Producing instructional video for the timber industry. (MF)
This paper was written to serve as an introduction to instructional video production for timber industry officials.
Discussed herein is the applicability of video to the timber industry and the development steps required to
produce a scripted, edited instructional video. The focus of the paper is on content development and the role of
the timber industry official as producer. The technical aspects of video equipment and their methods of usage are
not discussed except as necessary to improve understanding of the video production process. Additionally, the
development of a specific video project conducted by the Forest Engineering Department at Oregon State
University, "Slackline Productivity in Mechanized Logging Operations:, is discussed.

BEEMER, B. 1991. Tracking optimal bucking. (MF)
Recent development in handheld computers now make it possible to improve log value recovery by bucking
(cross cutting) a tree into log lengths that maximize its value. The use of a handheld computer allows these
decisions to be made at the stump for each individual tree. One program developed for this use is BUCK
(Sessions et al 1988), a single tree value optimizing program that specifies the length of logs to manufacture and
which mill the logs should be shipped to give the greatest return.

This study will determine if using BUCK has an impact on the time it takes to crosscut a tree. Previous
studies using BUCK have not investigated this, they focused on determining the increase in time required to measure the tree. This will be accomplished by regression analysis on data from a detailed time study of a falling operation using BUCK.

Additionally, this is the first time that trees were cut using the BUCK recommendation solution. Therefore, a quality "audit" on BUCK can be made in this study. A comparison will be made between values assigned to logs by BUCK and values assigned when scaled. From this a determination of the expected accuracy of BUCK can be estimated.

The final part of this study will be general observations from a implementation trials. BUCK will be used in a commercial operation by a commercial faller as if this was his normal method of operation. One goal is to discover how using the computer affects the faller. Another goal is to determine which areas of operation using BUCK need refinement.

BERGAN, E.E. 1986. Linking a growth model with logging production. (MS)

A model (called MERLIN) is presented that can allow the resource manager to consider the combined effects of silvicultural treatments and their effect on expected logging production and costs. This integrated analysis takes place within the framework of personal computer software readily available to most managers. This integration is accomplished by linking an individual-tree, distance independent growth simulator with a series of production equations within a spreadsheet environment. The modularized nature of the MERLIN model will also allow different growth models or production equations to be utilized without a major software revision. The MERLIN model requires an IBM compatible PC with at least 640 kilobytes of RAM. Two floppy disk drives and a printer are also required hardware. Software necessary includes a SYMPHONY software package (version 1.0 or later) and a specially revised version of the Stand Projection System (Arney 1985).

BETTINGER, P. 1996. Spatial analysis techniques for ensuring the compatibility of land management activities and aquatic habitat goals in eastern Oregon. (PhD)

A land management scheduling model is developed that uses a TABU search procedure to schedule timber harvests and road management activities, while simultaneously meeting (over time and space) two aquatic goals, and also providing for an even-flow of timber harvest volume. Decision variables include land units and roads, and they are considered to take on integer (0-1) solutions. Decision choices include those that involve land allocation issues (harvest and road obliteration), and those that involve changes in management practices (using lower tire pressures on certain roads to reduce the amount of sediment produced). The scheduling model included provisions for estimating stream sediment and temperature impacts as a result of the spatial location of management activities, and provisions for projecting the growth and yield of timber stands over time using growth rates derived from yield tables.

The model uses TABU search procedures to guide the selection of land management activities, and was applied to a 14,643 acre case study watershed in eastern Oregon. Twenty independent solutions were generated, of which 80 percent were within 10 percent of an estimated global optimum net present value, and all were within 15 percent. Although the limitation to using TABU search is that one is not assured of obtaining the global optimum solution to a particular problem, the model developed here is an important contribution to forest planning for problems which have 100,000+ integer variables and spatial goals.

An analysis of model results showed significant negative correlation between equivalent clearcut acres (ECA), a commonly used measure of cumulative watershed effects, and a stream temperature index. No correlation was observed between ECA, a stream sediment index, and timber harvest volume levels. These results suggest that sediment and temperature index levels may not be good proxies for ECA (or vice versa).

Finally, the sensitivity of model results was examined using three different representations of the landscape: (a) vegetation units, (b) soils units, and (c) a combination of vegetation and soil units. Results show significant differences exist in terms of net present value, length of road assigned to central tire inflation use per period, stream sediment and temperature indices, ECA, and timber harvest volume levels.


The three most expensive wildland fire suppression seasons have occurred since 2000, each exceeding $1 billion. Many problems and issues have been highlighted including the grounding of the federal air tanker fleet, training problems with private contractors, overspending, poor management strategies, negative public perceptions, and
the inability to utilize the safest and most efficient suppression resources available.

Technology used by today’s loggers has revolutionized many aspects of forest operations. The equipment available can safely and efficiently move earth, cut trees, remove dangerous fuels, and reduce the hazardous exposure to people. Because many of these tasks overlap those of wildland fire suppression, it is logical to incorporate these machines into firefighting.

Private landowners are already required by law to fight fires in the state of Oregon, and the suppression systems employed may be successfully applied on larger federal fires. The biggest factor for investigating the potentials of logging machinery is safety, especially the protection that machine cabs offer. In areas where vegetation and terrain are favorable to the use of equipment, there is no reason to endanger firefighters by assigning tasks that can be performed more safely and more efficiently by logging equipment.

This paper covers the use of forest technologies in wildland firefighting. Safety regulations, training concerns, and equipment issues—including an engineering stability analysis of equipment modified with water tanks. Also covered are attempts to improve wildland firefighting in the region through the founding of the Pacific Northwest Wildfire Equipment Group (PNWEG). Conclusions and recommendations based on the research are offered.

BOBBE, T.J. 1983. An analysis of forces and conditions which influence the successful passage of a carriage over an intermediate support jack during downhill multi-span logging. (MF)

In this paper, a catenary analysis of static skyline, mainline and haulback cable tensions just prior to carriage passage onto an intermediate support jack is presented. Field tests were conducted for a range of skyline deflections and span chord slopes. Data collected during the field tests included static and dynamic cable tensions and cable geometry. The relationship between upper span skyline deflection, the percent change in span chord slopes, and their influence on successful carriage passage was determined. During the field tests it was observed that maintaining a taut haulback as the carriage passed the support jack prevented the carriage from surging out of control and reduced dynamic tension fluctuations. It was also observed that yarding the loaded carriage uphill over the support jack was prohibited by skyline deflections which still allowed successful carriage passage for the downhill yarding configuration.

BODENHAUSEN, C.E. 1982. Skyline analysis programs for use with extended memory programmable calculators. (MF)

This paper describes a mathematical formulation and computer programs for use on hand-held programmable calculators to analyze the load carrying capacity of skyline systems, including the effects of log drag. The actual physical characteristics of the load and the ground geometry are used in the analysis of the payload capacities for standing, live, and running skylines. Included in this paper are instructions for the use of the programs and example problems illustrating their use.


Operational forest planning is characterized by a lack of formal planning often using only the intuition and experience of the forest planners. There are a number of sources of variability found in operational planning. Like most businesses there is significant variability in the demand forecasts obtained from customers. Forestry differs from many other businesses with significant variability in the supply due to the high sampling errors commonly used in forestry to in the statistical prediction of the volume, the non uniform distribution of the trees in the stand and finally the variability regarding the harvesting production. The aim of this project is to develop some the tools and processes to improve the forecasting of logging production at both the unit and daily levels. Data was collected from the Oregon State University logging crew operating on the McDonald-Dunn forests. For the unit forecasting model, and existing production model from the literature was used, since no unit model was developed in this study due to the small data set and the limited timeframe. This statistical model was selected because it uses a prediction variable that can be estimated prior the operation is executed. Fore the daily production forecasting level, the following data was collected: location maps, number of pieces, crew size, hours worked and weather conditions. This data was then analyzed using linear regression analysis. The statistically significant variables found in this study to predict daily production were skidding distance, average temperature and hours worked. The model was able to explain 76% of the variation in the daily production from the sampled area. One of the significant variables found from this study was skidding distance. A decision support system
was developed using GIS techniques that easily measure this variable. The GIS system found the path from the landing to the stump by applying a shortest path algorithm to minimize the total cost incurred in the operation. Both the unit and daily level forecasts were applied to two scenarios to demonstrate the system. The first scenario forecasts the production using the actual stream pattern, and the second scenario uses a high density stream pattern that in some cases affects the path distance. The decision support system was able to capture these differences on the forecasted productivity.

BOLDING, M. C. 2006. An Integrated Study of Mechanical Forest Fuel Reduction: Quantifying Multiple Factors at the Stand Level. (PhD)

Recent catastrophic wildfires have forced the forest management community to develop new strategies for reducing forest fuels. Tightly spaced understory trees often create a fire ladder allowing surface fires to encroach into the crowns of overstory trees. This situation can lead to intensive, catastrophic, stand-replacement forest fires. Mechanical removal or mastication of small understory trees is a common approach to promote fire resiliency in the Pacific Northwest. There are numerous limitations and knowledge gaps for managers to select, plan, and implement appropriate technologies to meet sustainable forest management goals involving fuel reduction. Understanding variables such as productivity, soil disturbance, and future fire behavior is essential for accurate and effective decision making. Decisions regarding equipment selection and silvicultural prescription design require forest managers to investigate alternatives from an integrated viewpoint. Therefore, the purpose of this study was to provide forest managers with comprehensive scientific information to aid silvicultural treatment design and machine configuration selection in mechanical fuel reduction treatments.

Results from the three overarching topic areas addressed in this dissertation provide significant insight into the relative capabilities and limitations of mechanical forest fuel reduction. Findings from an integrated commercial operation suggest that comprehensive and intensive silvicultural prescriptions may be necessary to favorably alter future fire behavior and to accomplish fuel reduction objectives economically. Additional stand travel necessary to harvest non-merchantable trees did not significantly affect soil physical properties. Non-commercial fuel reduction, employing masticating/mulching treatments proved costly with average costs per acre ranging from $246.62 to $414.07 when residual trees were spaced widely in an uneven-aged ponderosa pine stand. When individual tree selection was used, in dense initial stand conditions, costs per acre ranged from $479.31 to $1,559.79 highlighting the effect of treatment requirements on machine productivity and subsequent costs. The added surface fuel generated during treatment increased surface fire intensity immediately following treatment, based on simulations. This result suggests that follow-up treatments may be necessary for non-commercial approaches to reduce future fire intensity and severity. Discoveries made in this dissertation provide baseline information on approaches to mechanically altering forest fuel and will facilitate decision making by forest managers, landowners, and scientists.

BORN, R.G. 1995. Production and cost analysis of a helicopter thinning operation in the Oregon Coast Range and comparison to helipace production estimates. (MF)

With increasing environmental concerns, short harvesting seasons, salvage logging needs, and limited road access, helicopter yarding is becoming attractive to many land managers. Most helicopter yarding has occurred on clearcut or even-aged management areas containing large, valuable timber. Very little helicopter yarding has occurred in stands of smaller, less valuable timber which are often inaccessible or have other limiting factors which preclude logging by conventional methods. There has been little research on the use of small to medium-lift helicopters in harvesting of first thinnings of small diameter timber. The purpose of this study was to determine whether the use of small to medium-lift helicopters can be an economical alternative for commercial thinning of young timber stands in steep, mountainous terrain, and whether the HELIPACE software program accurately estimates production of a helicopter yarding system.

The study area consists of several stands of second-growth Douglas-fir requiring an initial thinning. The stands were thinned using a Sikorsky S-58T helicopter (with an external lift of 5000 pounds) to yard a total of 457 MBF over a period of four weeks. The average yarding distance was 775 feet and the average slope was about 30%. The diameter of the trees removed averaged 11.3 inches, and the average piece size was approximately 40 board feet (net).

A detailed time study was conducted and the results are used to estimate yarding production and costs for the Wildcat Thin sale for comparison to HELIPACE computer program estimates and cable estimates from a
Regression equations were developed and used to predict total turn time and evaluate the effects of yarding distance and weight per board foot on yarding cost. The detailed time study data was also used in comparing the actual turn times (and production) from 13 individual study areas to predicted turn times from the HELIPACE program.

The results of the study indicate that there was no significant difference between HELIPACE estimates of turn times and actual turn times observed. The average difference in turn time was approximately 6%. The results also indicate that using the Sikorsky S-58T can apparently be an economically feasible alternative for commercial thinning. An average yarding cost of $258.32 per thousand board feet was estimated for the helicopter operation, while HELIPACE estimated $242.85 per MBF for yarding. Average total logging costs for the helicopter operation were estimated to be $354.35 per MBF; total logging costs estimated by HELIPACE were $339.08 per MBF; and the total cable logging costs from the concurrent study on the same sale were $234.94 per MBF. The cable cost estimates were significantly lower than for the helicopter but at current timber values, helicopter yarding can be profitable. Helicopters should be considered where there are other concerns than strictly economics, such as environmental concerns, time constraints, limited access, and physical limitations of other systems.

BOSTON, K. 1991. The development of a rail transport model and its use for the prediction of rail shipping costs for forest products in Oregon. (MF)
Transportation costs compose fifty to sixty percent of the total operating cost in the forest products industry. This paper develops a framework for incorporating rail transportation into a statewide multi-model transportation planning model. It will allow for the analysis of various transportation scenarios that can possibly increase the efficiency of the forest products industry by reducing transportation costs.

This paper has two objectives. First, to develop a rail transport model (RTM) that is capable of predicting shipping cost for forest products within Oregon as a function of route alignment, grade, and volume shipped. Second, to construct a model of the Oregon rail network. The nodes in the network were created at rail intersections, major cities, and towns with wood processing facilities.

The Rail Transport Model was constructed by simulating train performance over the 47 rail routes in the state with varying quantities of lumber, plywood, and wood chips. The simulation results were then analyzed using simple linear regression to produce an equation for each route that predicts transportation cost for the quantity of wood products shipped. The coefficient of determination ($R^2$) for the individual products varies from 0.50 to 0.99. The average coefficient of determination for the regression equations over all links in the rail network for lumber, plywood, and chips is 0.736, 0.828, and 0.930 respectively. The average coefficient of determination for the combination of forest products is lower at 0.445.

An example of the use of transport cost equations is developed to find the breakeven volume between truck and rail transport for the route between Eugene and Coos Bay.

BOSTON, K.D. 1996. Using TABU search to solve tactical forest planning problems with spatial wildlife habitat goals and constraints. (PhD)
A method was developed to formulate and solve a fifty-year tactical harvest scheduling problem that included spatial wildlife habitat goals and constraints for a 4800-acre watershed in Northwestern Oregon under four scenarios.

Three goals and two habitat constraints were included in each scenario. The first goal was a volume goal. The second goal was a landscape aggregation goal measured with the contagion index. The third goal was a shape goal using the ratio of the existing perimeter of closed-canopy stands with that of a circle with equivalent area. The first constraint required a minimum cluster of connected closed-canopy stands that spanned opposite edges of a map. The second constraint limited the maximum opening created in any period. The algorithm included both fixed and variable cost components for the transportation network.

Tabu Search with both short-term memory restriction and a long-term diversification strategy was used to solve this ten-period problem. The performance of the heuristic was measured by comparing the results with an estimate of the optimal value obtained from extreme value theory using a three-parameter Weibull distribution.

In scenario one, the shape goal was reached in most periods and the average contagion index was 0.35. The volume goal was met or exceeded in all periods. The heuristic found one solution within 2 percent of the estimated optimal value, while 75 percent of the solutions were within 80 percent of the estimated optimal value.
In scenario two, the average contagion index was 0.40. The goal was met in order 50 percent of the periods. The volume and shape goals were met or exceeded in all periods. The heuristic found one solution within 6 percent of the estimated optimal value, while the remaining solutions were within 83 percent of the estimated optimal value.

Two additional scenarios were developed to create specific wildlife habitat. Scenario three developed high quality habitat for pine marten containing a connected landscape of closed-canopy stands with minimum edge habitat. Scenario four was developed for elk. This analysis produced habitat with a mixture of open and closed-canopy stands in a dispersed pattern.

BOYD, D.W. 1998. Predicting and quantifying recreation and harvesting interaction with a geographic information system. (MF)
This paper documents a study of the potential for using ARC View, a GIS software program, to evaluate possible interactions between timber harvesting impacts and recreational uses of adjacent forest roads and trails. Data on hiking, biking and horse riding was used to define recreational uses on specific trails. Harvesting was modeled using basic stand data: stand age, species and assumed rotation age. As a result of this study the author concludes that Arc View is a powerful, adaptable software program that is well suited to the evaluation of zones of influence upon recreation of management activities such as logging. In addition it was concluded by the author that for Arc View to be used to its full potential the input data should be descriptive of relatively small geographic units: in this case forest stands and trail segments.

This paper describes the results of a study conducted in the Sierra Nevadas located in California to determine the production rates, skidding costs and the extent of soil disturbance and compaction on two partial cut units harvested with a Caterpillar D-7F. A harvest unit with preplanned skid trails and winching was compared to a conventional harvest unit.

Production for the unit with preplanned skid trails and winching was 11 percent less than the unit with conventional tractor logging. Skidding costs per unit volume were increased by 29 percent. The unit was preplanned skid trails resulted in four percent of the area in skid trails whereas the other unit had 22 percent of the area covered by skid trails.

BRANTIGAN, R.T. 1978. Critical conditions for carriage passage at the support jack for uphill yarding. (MS)
Critical skyline and mainline tensions were identified as the conditions necessary for successful carriage passage uphill over an intermediate support jack. These critical tensions were measured during field tests and compared with predicted values from weightless line, rigid link, and catenary analyses. All three analyses predicted critical skyline tensions within the range of field measured values while critical mainline tensions were consistently overestimated.

An existing computer multispan skyline analysis program (MSAP) was modified using the rigid link analysis to check for critical tensions at the support jack. A comparison of MSAP results with measured field values showed good agreement for skyline tension and conservative estimates for mainline tension. As an alternative to the computer program, a graphical method for determining the critical midspan deflection was developed, patterned after the chain and board method.

The analysis and test results indicated that present multispan design criteria for uphill yarding were overly conservative in many instances. To evaluate the economic effects of designing below system potential, yarding costs/mbf were compared, on a typical setting, based on predicted payloads using present and new design methods. Results of this comparison, based on payload effects only, showed that a considerable economic advantage existed when the new design procedure was used.

This paper presents the results of a study performed to determine the optimal road spacing for forwarding equipment. The goal of the study is to provide transportation planners with the necessary tools to develop a transportation plan for a study area.

The study focuses on data collection for five time elements: 1) travel empty, 2) loading, 3) reposition during loading, 4) travel loaded, and 5) off-loading. The time to complete each element was measured on five
forwarders operating in four locations.

A productive hourly machine cost was calculated for use in completing an analysis of the economic breakeven points between the forwarder cost and road construction costs.

A computer model, FORWARDER PC, was written to model a six-wheel forwarder. This program has two internal programs. The first, the maximum gradeability program, calculates the maximum adverse and favorable slope on which the forwarder can operated loaded. Output from the gradeability program can be used in the second program, optimal road spacing, along with additional user defined input to calculate the optimal road spacing for use with the chosen forwarder. The optimal road spacing is calculated for a forwarder utilizing a continuous landing pattern for a single entry.

The results of this study increase the ability of the transportation planner to develop a road plan which will provide the land owner with the least cost alternative of road construction versus harvest cost where forwarders are required or considered.

An observational study was also conducted on elements for which data were not being directly obtained to provide additional information to harvest and transportation planners on other aspects of the forwarder. These observations and findings were made during the data collection phase and the literature review of forwarders.

BROWN, C.G. 1995. The Deerhorn case study: A production and cost analysis of a single-grip harvester and small cable yarder performing a thinning/salvage operation in eastern Oregon. Land managers in the Blue Mountains of eastern Oregon are currently faced with large areas of forest with health problems and extreme levels of fuel loading in the stand and on the forest floor. These conditions resulted from a combination of insect infestations, past management practices and the elimination of fire from the local ecosystems. These forests are now overstocked, diseased and contain vast amounts of dead woody debris on the forest floor posing a serious threat of large destructive fires. This paper presents an economic analysis of a harvesting system aimed at treating these stands while minimizing soil impacts.

A combined thinning of the dense stands and salvage logging of the larger fuels from the forest floor was completed using a single-grip harvester to process the stems into logs and a small cable yarder to transport the logs to landings. The terrain on the site was flat and therefore presented logistical challenges for yarding. This unique combination of equipment was chosen to minimize machine traffic on the site in an attempt to reduce ground impacts on areas with sensitive soils or critical habitat concerns.

The harvester was to fell and process all non-marked standing trees and process any solid stems on the forest floor into logs. A Koller K501 yarder (33 ft tower), using a standing skyline, slackline system rigged with a tail tree and occasionally an intermediate support, was used to transport the logs to the landing. Production estimates obtained for the harvester and yarder were 7.33 cunits/PMH (2074 m³/PMH (PMH=Productive machine hour)) and 5.41 cunits/PMH (15.31 m³/PMH) respectively. Actual system production was approximately three to four truck loads removed off the site on an average day, with some days as low as two loads and some as high as six loads. An average truck load contained 5 Mbf (28.3 m³) or 24 tons (21.7 tonnes) of wood.

Total logging cost for the system (stump to mill) was $78,809 which equated to $97/cunit ($34.24/m³) or $42.44/ton ($46.78/tonne) of material removed. On a per acre basis, the cost was $1,970/acre ($4869/ha). The presence of sawlogs in the unit allowed the landowner to make a profit from revenues of $103,258. Sawlogs made up 28% of the volume or 34% of the weight removed from the site but contributed 57% of the revenue generated. At the time of the study, pulpwood prices were approximately $36/ton and sawlog prices were approximately $515/Mbf. The logging cost of $42.44/ton was greater than the value of the pulpwood and thus logging was made profitable by the presence of sawlogs.

The thinning and salvage logging of a flat eastern Oregon stand with the combination of a single-grip harvester and small cable yarder proved to be reasonably cost efficient. The costs determined in this case study appear to be higher than traditional ground based methods of logging in similar terrain, but the cable system appears to have resulted in less soil impacts. Thus, in areas where soil protection is the most important consideration, this logging system may be a viable alternative to traditional ground based logging systems. Further research is recommended to evaluate potential improvements in the harvester - skyline system and to more fully compare this system with conventional skidding and forwarding systems, under the context of minimizing soil impacts.
BURDITT, A.L. 1981. Damage to the residual stand due to skyline yarding. (MF)

The use of partial cutting in the western conifers has become popular in the last decade. This has resulted in an increase in the amount of damage to the residual stand due to skyline logging. The purpose of this study is to provide models to predict the percent of a stand which can be expected to incur damage during skyline yarding.

Data was collected over a four year period on eight National Forests in Region 1, USDA Forest Service. Seventy-one corridors were partial cut and yarded uphill. Regression analysis was used to develop models based on the following classifications: silvicultural prescription, number of logs per thousand board feet, and type of yarding system.

The analysis of the data identified some of the variables which have an impact on the amount of damage. Those which had the most impact on the amount of damage are: landing size, tail tree height, number of cut trees per acre, number of leave trees per acre, and chordslope.

The paper provides an initial estimate of the amount of damage to the residual stand due to skyline logging. Further research is necessary to fully identify the manner in which variables affect damage and determine which other conditions influence damage to the residual stand.

BURROWS, J. 1983. Swinging and processing whole tree, tree length and log length pieces in a Douglas-fir thinning. (MF)

This paper describes a study done on swinging and processing whole tree, tree length and log length pieces in a smallwood Douglas-fir thinning. Two machines were evaluated, a 70 horsepower rubber tired skidder and a hydraulic loader mounted on a 6 x 4 live tandem truck.

The study took place in the foothills of the Coast Range in western Oregon. The stand averaged 217 trees/acre and 15 ft³/tree. Skidder and loader swinging occurred on rock surfaced truck roads.

Both the loader and skidder were analyzed using work sampling and detailed time study techniques. Regression analysis was used to develop an equation to predict delay free turn time for the skidder.

The whole tree/tree length skidder operation produced 2.74 cunits/scheduled hour at $16.45/cunit for a two man crew and $22.61/cunit for a three man crew. There was no difference in production rates. A comparable two man log length operation produced 3.41 cunits/scheduled hour at $23.51/cunit. This higher cost included limbing and bucking done at the stump. The whole tree/tree length loader operation produced 3.21 cunits/scheduled hour at $16.15/cunit.

Crew interaction was evaluated using work sampling. For the skidder operation, interference was nonexistent, the equivalent of almost one man was idle (93.8%) on the three man crew, and idle time ranged from 35-52% for the chaser and 12-18% for the skidder operator. For the loader operation, interference time was 7.1% for the loader and 9.7% for the chaser, and idle time was 30.1% for the loader and 37.5% for the chaser. All percents were based on total scheduled time.

For the skidder assisted operation, limbing and bucking production and cost rates were 1.82 cunits/scheduled hour for $13.19/cunit at the stump and 6.54 cunits/scheduled hour for $6.02/cunit on the landing.

Yarding and swinging knocked off the difference.

Slash, consisting of limbs and tops, averaged 4.95 ft³/tree. Slash handling accounted for 2% of total time for the skidder and 18% for the loader.

All breakage occurred on the skidder operation. Eleven pieces were broken resulting in 0.2% of the total gross volume being lost. All of these were on corridors where the angle with the truck road required the logs to be turned more than 90 degrees.


Small, independent logging contractors can benefit from cost control and cost planning. This report details the labor and equipment cost components of a logging crew. Records, both required and available for determining costs, are discussed. Recommended costing procedures are illustrated. Although the study took place in the Pacific Northwest, the principles apply to all logging companies.

Production records available to logging contractors are also described. These records determine the amount of volume removed from an area for a period of time. Cost and production for the same time period can be used to determine the unit cost of production.
An essential part of any logging operation is the maintenance of job quality and safety standards. This report describes the methods being used to insure that quality and safety standards are met.

BUSTOS-LETELIER, O. 1994. Wind direction and effect of tree lean on coarse woody debris production. (MS) The natural fall of trees in riparian areas is an important source of coarse woody debris for mountain streams, improving fish habitat and influencing stream morphology. Existing models consider the probability of coarse woody debris entering a stream channel based upon trees having a random direction of fall without consideration of tree lean or wind direction. This research presents (1) the results of a field study to document tree lean of conifers near streams in two stands in the Oregon's Coast Range and (2) a physical and probabilistic model to estimate the probability of a tree falling into the stream including the effects of tree lean and wind direction.

The measurement of 200 conifers along two creeks located in McDonald Forest found that tree lean varied from 1 to 34 percent uphill and 1 to 29 percent downhill on slopes of 1 to 88 percent. Approximately 75 percent of the trees leaned downhill and 25 percent of the trees leaned uphill. A significant linear relationship was found between lean and slope although there was considerable scatter around the regression line. In general, the steeper the slope, the greater the tree lean downhill. When tree lean data was stratified by aspect, the linear relationship was higher for the NE and SW aspects, slightly weaker for the NW aspect and not related with slope for the SE aspect.

A physical model was developed for calculating the critical wind speed required to overturn a tree. This critical wind speed is a function of maximum resisting moment of the tree root structure, crown cross sectional area, initial tree lean and the angle formed between wind direction and lean direction on the horizontal plane.

A probabilistic model was developed for determining the probability that a tree could fall and reach the stream. This probability is a function of exceedance probability for a particular period of time, wind direction probability, tree location and tree height.

The models were applied to two old-growth coniferous stands. Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] trees were selected to illustrate how the models can be used. Results of this study indicate that tree lean is not a major factor with respect to influencing tree blowdown for the range of tree lean data collected from coniferous trees along streams in the study area. Tree lean could be a major factor if it was greater than that observed in this study.

BUTRUILLE, F.R. 1993. Repeated loading behavior of a compacted cohesive soil consolidated under low confining stress. (MS) Considerable research has been done on the response of various soil types to dynamic loading conditions. However, the test procedures normally used do not accurately model the critical conditions assumed to exist under low volume aggregate surfaced forest roads. Typically, test samples have been consolidated under effective stresses of 5 psi and higher and the repeated loading testing has been conducted in an undrained mode. For this report, the conditions assumed to exist under a typical aggregate surfaced forest road include effective consolidation stresses on the order of 0.5 psi and a traffic frequency low enough that significant drainage can occur.

To characterize the response of a compacted cohesive soil (MH Unified Soil Classification) to repeated loading, a series of twelve repeated loading tests were conducted on saturated samples under various combinations of consolidation stresses and drainage conditions. The observed dilative and contractive behavior patterns were consistent with those normally associated with soils where identical samples will dilate if sheared at low consolidation stress, but contract if sheared at higher consolidation stresses.

The samples consolidated under effective stresses on the order of 0.5 psi exhibited dilative behavior. As a result, samples became progressively weaker during drained loading. The drained samples failed after fewer load pulses than the undrained samples tested under similar loading and consolidation conditions. The samples consolidated under effective stresses on the order of 3.0-5.0 psi, typical of values reported in the literature, exhibited contractive behavior. As a result, the contractive samples became progressively stronger during drained loading and did not strain to failure.

The results of the testing program highlight the importance of modeling the assumed field conditions as accurately as possible when using laboratory tests to predict field behavior.

CACCAVANO, M.P. 1982. Factors influencing residual stand damage levels due to cable thinning of
coniferous stands in western Oregon. (MF)
The purpose of this study was to determine the significant variables influencing the damage levels sustained by
the residual stand after skyline thinning of coniferous stands. Damage levels were measured in ten study areas in
western Oregon that had received their first commercial thinning.

For this post-logging study, 38 units consisting of one side of a corridor were chosen. Damage levels and
characteristics of stand damage were measured using a transect method designed to account for the high
variability in the distribution of damaged trees. Ten independent variables were measured in three categories:
harvesting system, stand conditions and topography. Total scar area per acre (ft²/acre) was used as the dependent
variable to indicate the damage level.

As a result of regression analysis, three variables were shown to be significant. These variables are the
percent of western hemlock in the stand, the volume removed per acre (ft³/acre) and whether the unit had been
logged conventionally or by prebunching and swinging. Damage levels ranged from 0.4 to 64.4 square feet of
scar area per acre. Individual scars ranged in size from 0.02 to 12 square feet.

This paper provides an indication of the important variables influencing stand damage levels including
several variables that could not be incorporated in the regression equation due to statistical limitations.
Information on some of the characteristics of stand damage such as location of damaged trees with respect to the
corridor and damage types is also included.

CAMPBELL, T.M. 1984. A HP-75C computer program for field recording logging equipment time study data.
(MF)
Time studies of logging equipment are important to determine production rates, calculate logging costs and
locate operating inefficiencies. However, using present time study techniques, they are also costly and time
consuming to complete. This project will develop a new data gathering and storage technique using the HP-75
portable computer to make time measurements and directly store field data.

Normally one or more analysts are assigned to observe an operating machine for two or more weeks.
During this time they divide the machine cycle into a series of easily definable operations called elements and
record the start and stop time for each of these elements. Various techniques are used, however, usually one
person will observe the machine and call out the start of each new element in the operating cycle. The second
person, using a stop watch, will note the times of these calls and record them on a data sheet. These jobs can be
both hectic, and tedious as element times are often numerous and fast paced while being repetitious and
uneventful.

These job characteristics can lead to data errors as calls are late or missed, stop watches are misread, data
sheet columns are confused and delays are omitted. Further expense, time and possible errors occur as the field
data is transcribed and processed.

The HP-75 is a small portable hand-held computer having a 24K bytes random access memory and an
internal clock. This project will program this computer to accept time study information keyed directly into
memory during field observations. By assigning time, delay and mensuration functions to different computer
keys one person can view an operation and punch the appropriate key to record necessary time study information.
Stop watch readings will be unnecessary as the computer program will automatically record the start and stop
times from the constantly running internal clock.

Once data is internally recorded in the HP-75 memory data transcription for processing will be
unnecessary. The HP-75 can be interfaced with the larger HP-80 series desk top computers, such as the HP-86,
for data processing. All recorded information is electronically transferred directly to the desk top unit saving
time and money while eliminating possible errors.

Using this approach this project will have three objectives:
1) Program the HP-75 to directly measure and store time study data. The program must: a) be fast enough
to record the type of elements that occur in typical harvesting operations, i.e. elements lasting less than one
minute; b) be designed to help the user from making observational or recording errors; c) have adequate memory
to record a full day's data; d) take less user training than traditional stop watch methods; be easier mentally and
physically to use as well as less stressful than stop watch studies.
2) Program the HP-75 to interface with and transmit data directly to the HP-86.
3) Program the HP-86 to accept, store, recall and print out data.
This project will also test the finished programs for compliance with the above objectives and will document
instructions on using the system.

CARLSON, S.H.  1994.  Analysis of the effects of snow and ice conditions on highway operations and capacity.  (MS)
This report evaluates and quantifies the effects of adverse weather and pavement conditions on highway operations and capacity.  The range of pavement conditions observed included dry, packed snow, and wet at temperatures above and below freezing.  In addition, a useful and adaptable procedure is outlined for determining individual vehicle speeds, headways, and traffic flows using a video camera an cassette recorder for data collection.

The location of this project is at milepost 52.85 on US Highway 26 near Government Camp.  This highway is a major route for commercial traffic between Portland and central Oregon.  It is also the primary route from Portland to ski resorts and other winter recreation facilities located on Mt. Hood. Significant volumes of winter traffic are generated by these facilities, and high levels of congestion typically occur during winter weekends and holidays.

Data collection began in February 1993 and has continued for over a year.  During this period a variety of pavement conditions and traffic flow regimes were documented on video tapes.  Information extracted from these tapes include individual vehicle speeds and corresponding headways during continuous 15 minute traffic flow periods.  A total of 4557 individual vehicle speed and headway estimates were obtained from this analysis.

For each pavement condition and lane direction, multiple linear, and nonlinear regression analysis were performed on the density and mean speed data.  Several models were applied to the data sets using the coefficient of determination, $r^2$, to evaluate the fit of data to the equation.  The relationships for flow-density and flow-speed, based on derivations of the exponential speed-density model, are used in defining the effects of various pavement conditions on highway operations and capacity.

Results of analysis indicate that the capacity of US 26, under ideal pavement conditions, is 1415 vehicles per hour per lane.  As weather conditions deteriorate, with precipitation above freezing or packed snow driving conditions, reductions in capacity of seven and forty-three percent, respectively, are likely.

CHUNG, JOOSANG  1987.  Development of a cable logging system analysis package for micro-computers.  (MS)
A computer program package to estimate cable yarding payload capability was made.  The package was intended to expand applicability of existing packages and to be user friendly.  It has six system options:  live skyline, standing skyline, running skyline, slackline, multispan and highlead.  In the standing skyline and multispan analyses, load path analysis, as well as payload analysis, is available as an optional basis.

Each program for the analysis of a system was built to include subroutines to consider its mechanical characteristics, which are usually ignored in existing packages.  The running skyline program has an option to consider the maximum torque on the haulback drum.  The highlead analysis program has an option to consider the effect of cable drag.  The multispan has a subroutine to check carriage passage over a support jack and an option to consider the effect of jack friction.  In addition, the effect of log drag and log shape as well as choking strategy can be considered as an optional basis.

The paper was written to present the mathematical formulations and modeling procedures used in building the package.  In addition, outputs of an example run for each system are presented with interpretations.

Designing timber harvesting units is a challenging task.  The task requires decision making on logging equipment, landing site, cable road profile, road location, and transportation system.  Traditionally forest planners have done the task manually.  However, the manual method makes it difficult to examine many alternatives and the harvest plans depend heavily on the experience of the individual planners.  Furthermore, increased environmental concerns require more sophisticated planning procedures.  Thus, it is challenging to find not only economically and environmentally “feasible” solutions but also “good” solutions by the manual method.  Tools for detailed analysis and systematic evaluation of alternatives become essential for better planning of harvesting operations.

This study develops a methodology with the purpose of assisting the planners in designing cable logging unit layout.  The methodology combines a cable logging operation planning problem with a road network
planning problem and optimizes them simultaneously. It incorporates modern computer software languages, Geographic Information System (GIS) technology, and optimization techniques that have become available during the last two decades. The methodology includes logging feasibility and cost analysis to evaluate alternative cable roads and yarding equipment. Once the feasible cable road alternatives are identified, the methodology formulates two cost minimization network problems. The networks represent variable and fixed costs associated with yarding and truck transportation activities to move logs from the stump to the mill. The methodology uses a heuristic network algorithm as an optimization technique to solve the network problems. One of the two cost minimization network problems is for cable logging operation planning and the other is for truck transportation planning. Each of the network problems is solved separately using the heuristic network algorithm while being connected to the other by a feedback mechanism.

The methodology is implemented in a computerized model that can be used as a decision support system. The model is applied to an actual harvest area of 93 ha. A total of 40 candidate landing locations with 2,880 cable roads from 2 yarding equipment alternatives were evaluated. The model found 1,719 feasible cable road alternatives by conducting the logging feasibility and cost analysis. Two cost minimization network problems were developed. A total of 141,139 links and 1,926 timber parcels were developed in the network problem for cable logging paths. In the network for solving road location problem, a total of 95,904 links were developed to connect 13,522 grid cells included in the planning area. After 47.2 hours for 10 repetitions on Pentium III 1GHz speed desktop computer, the heuristic network algorithm solved these network problems and selected a total of 19 landings and 155 cable roads to harvest 8,064 m³ of logs from 1,926 timber parcels over the planning area. A total of 2.85 kilometers of new access roads were proposed as a part of the solution for this application. Overall yarding and road costs for timber harvest in the planning area was $416,675 ($51.67/m³).

Although the exact solution could not be verified, the solution obtained with this methodology when coupled with sensitivity analysis can be considered as a feasible and good harvest operation plan for the management goals. By providing systematic and analytic tools, the computerized model presented in this study can be used as a decision support tool assisting the forest planners in designing timber harvest layout.


Intensive forest management requires efficient logging techniques to remain economical. Commercial thinnings and shorter rotations increase piece count inversely to piece size. Continued research aimed toward effective log handling processes is essential. The purpose of this study was to evaluate one case of a self-loading log truck (integral loader and truck) working in various decking configurations and piece sizes.

Data obtained by the multimoment time study method were analyzed by multiple regression techniques. Loading production rates were determined from regression equations with the remainder of the total loading time computed by averages from 90 observations. Decking configurations were compared on a productivity basis.

This study found excessive variation in loading times for large diameter logs. In small diameters, specific decking configurations reduced total loading times up to 20 percent. The results supported decking parallel to the road when visibility was good. Pre-sorting decks was found to be significant. Suggestions requiring additional research were made to better quantify the study method and economic limits.


The purpose of this project is to evaluate the feasibility of using GPS equipment and technology for resource transportation time study applications. The primary goal is to determine whether or not the GPS can be used to gather travel time and haul speed data for a planned update of the BNG Logging Road Handbook.

This study primarily focused on determining the accuracy and reliability of GPS derived speeds. This was done by measuring speeds of vehicles traveling in a variety of forest road situations, and then comparing the GPS derived speeds with those obtained using radar and stopwatch speed measuring techniques. A GPS receiver was mounted on a logging truck and used to collect time study data over the course of one day's log transportation operations.

The results of this study indicate that GPS speeds compare very closely to speeds obtained by other time study methods. No significant problems were found with the operation of GPS equipment on logging trucks. However, attenuation of satellite signals due to adverse topographic and vegetative canopy conditions may
significantly decrease the operability of the GPS equipment when used in a forested environment.

CONNER, G.F. 1989. Comparison of field-test and computer-model results for a 3-D guyed logging spar. (MS)

It is common for a logging operation to depend on a system of cable and blocks to move logs from mountainous terrain. A typical configuration for this system is shown in Fig. 1.1. In some locations the ground profile is such that the necessary elevation of the main load carrying cable, known as the skyline, can be achieved by simply attaching the end of the skyline to a stump, but in other locations, some added elevation is needed so that the skyline will have an acceptable ground clearance. When this added elevation is needed it is common practice to rig a block in a standing tree and pass the skyline through it (depending on the system there may be several sets of lines and blocks). The tree is also guyed to stumps to increase the load carrying capacity of the system.


A helicopter operations problem was studied for a private forest landowner testing an experimental application of minerals on Douglas-fir (*Pseudotsuga menziesii*) in the Coast Range of Oregon to offset growth reductions from Swiss needle cast disease. A planning approach was needed to minimize costs for transportation and aerial application of the minerals.

A transportation network model was developed for a heliport and service landing location facility problem which used mixed-integer linear programming techniques. Cost and production elements were identified along with interactions of significant variables for the operation. An empirical production model estimated application costs. For one type of mineral, five transportation and application options with two types of helicopters, two types of material delivery options and a shared road system were modeled for a simplified field application version (i.e. two application units in the case study). The solution minimized costs for a transportation and aerial application option for a total cost at $39,060, or $212 per ton of applied material, reducing costs on a per-ton basis by approximately 9% over estimates for current operations.

COULTER, E.D. 1999. Hungry Bob harvest production study: mechanical thinning for fuel reduction in the Blue Mountains of northeastern Oregon. (MS)

Fire exclusion in the western U.S.A. has caused fuel loads to build up and overall forest health to decline. Managers are now looking for ways to reduce these fuel loads while reintroducing some of the desired effects of natural wildfire. One method to do this is thinning using mechanical harvesting methods to reduce fuel loads. This study looks at mechanical thinning in ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) stands in the Blue Mountains of Northeastern Oregon.

A 409 acre (165.5 ha) unit of 7.1 inch (18 cm) average diameter at breast height was studied during the summer of 1998. Three feller-bunchers and three forwarders were observed in this cut-to-length (shortwood) operation. The three feller-bunchers were a Rottne SMV Rapid EGS, John Deere 653E, and a Caterpillar 320L Excavator, and three forwarders were a Timbco TF815-C, Rottne SMV Rapid, and a Rottne Rapid. These six machines operated on 409 acres (165.5 ha) removing a total of 15,786 tons (14,320 metric tons), 73.4% as sawlogs with the remaining 26.6% as pulp.

Felling and processing costs for the three feller-bunchers were $5.20/ton (5.35 euros1/ton) for the Rottne, $6.63/ton (6.83 euros/ton) for the John Deere, and $7.97/ton (8.21 euros/ton) for the Caterpillar Excavator. Forwarding costs were $7.12/ton (7.33 euros/ton) for the Timbco, $7.61 (7.83 euros/ton) for the Rottne SMV Rapid, and $7.58/ton (7.80 euros/ton) for the Rottne Rapid. Total stump-to-landing costs ranged from $12.27/ton to $15.81/ton (12.63 to 16.28 euros/ton).

1Euro to dollar exchange rate taken from the April 6, 1999 *Oregonian*.


The prioritization of road maintenance projects is an important forest engineering task subject to limited budgets and competing investment needs. Large investments are made each year to maintain and upgrade forest road networks to meet economic and environmental goals. Many models and guidelines are available for single-criterion analysis of forest roads, but guidelines for multi-criterion analysis are rare. Additionally, even single-criterion approaches often rely on expert judgment to inform models of user preferences and priorities. These
preferences are used to make tradeoffs between alternatives that contain data that are physical and biological, quantitative and qualitative, and measured on many different scales. The Analytic Hierarchy Process (AHP) has the potential to provide a consistent approach to the ranking of forest road investments based on multiple criteria. AHP provides a consistent, quantifiable approach to problems involving multi-criterion analysis, but it has not been applied to road management. The road investment problem differs from traditional AHP applications in that a large number of alternatives are compared at one time. AHP methodology is discussed, including the foundations, assumptions, and potential for use in prioritizing forest road investments to meet economic and environmental goals. Using AHP, the problem of scheduling maintenance and upgrade of forest roads is presented as a hierarchy and pairwise comparisons are elicited from decision makers to determine the relative importance of road characteristics to management goals. Issues regarding the use of the AHP to prioritize forest road investments are discussed. Three metrics are proposed to assist in evaluating the quality of a solution and to revise preferences when necessary. Various models using mathematical programming are used to incorporate the results of an AHP analysis into the scheduling of forest road maintenance and upgrade activities involving non-monetary benefits. Solutions to two non-linear integer programming formulations are found using a threshold accepting heuristic.

CRAIG, R.J. 1970. An introduction to the formulation of logging production forecasts by computer models. (MF) Potentially large savings can be realized within the forest industry by improved machine scheduling, labor scheduling, machine investment, inventory management, and the maximization of wood value. Forecasting must change within the forest industry from "guesstimates" to more efficient production forecasting models. Much work needs to be done with data collection and the establishment of production standards prior to any reasonable production planning. Once the standards are derived, production planning can be done by numerous operations research techniques. Linear programming, critical path scheduling, and PERT Simulation are suggested as methods of allocation, scheduling, and controlling resource inputs.

CURTIS, R.J. 1978. Production rates of skyline, balloon, and helicopter yarding systems from gross time study analysis. (MF) This paper describes the analysis of data from a three-year gross time study of skyline, balloon, and helicopter yarding systems operating in Western Oregon. Data collection activities were designed and supervised by the Pacific Northwest Forest and Range Experiment Station, U.S.D.A. Forest Service. The specific logging systems studied were running skyline, North Bend standing skyline, long-span standing skyline, balloon (inverted skyline, highlead, inverted skyline yo-yo, and highlead yo-yo), medium helicopter, and heavy helicopter. These systems were observed under a wide range of silvicultural and landscape design prescriptions, timber type, terrain, and weather conditions.

The objective of this study was to develop yarding producing equations, to summarize delays, road change times, and landing change times, and to compare yarding production estimates made from both gross and detailed time study data. This kind of information is useful for the comparison of alternative logging methods in environmentally sensitive, landscape-designed harvest units.

The data were segregated according to the individual logging systems and analyzed via multiple regression. Then individual system data were combined into the categories of short-span skyline, long-span skyline, balloon, and helicopter. These combined data were also analyzed via multiple regression. Chi-square tests were performed to determine whether the equations developed from the combined data were significantly different from the set of equations developed from the segregated data. The results of these tests support a conclusion, at the 95 percent level of fiducial probability, that the equations developed from the combined data are as adequate for predicting yarding production rates for these logging systems as the equations developed from the individual-system data.

The variables shown statistically to influence yarding production rates for all logging systems studied were yarding distance and number of logs per turn. In addition, helicopter yarding productivity was also found to be influenced by the type of cutting prescription, and short-span skyline yarding, by chordslope. A variable combining aspect and the season of work was found to be significant for both the running skyline and the heavy helicopter.

Yarding delays were found to be affected by yarder, landing size, season, and crews' experience. In order to compare similar systems' delays, it was found important to segregate out weather-related delays.
In a separate study, detailed time studies were made on four of the yarding systems analyzed in this paper. This allowed a comparison between the measurements of yarding production rates made during the detailed time study and those made during the gross time study. The gross time study rates were consistently lower than the detail time study rates. This suggests that the detailed method does not reflect the total downtime as accurately as the gross method. Thus the gross method appears better suited for developing information that is useful for appraisal purposes and the detailed method is better suited for evaluation of system efficiency.

DEAMER, P.J. 1987. Simulating cable yarding costs and production rates: a case study of first thinning operations within Pinus radiata plantations on steep slopes in south eastern Australia. (MF)

Cable yarding of first thinning size material from plantations of Pinus radiata in south Eastern Australia is simulated using a computer model. Production rates, expressed in cubic metres per hour and production cost, expressed in dollars per cubic metre were derived using the model to simulate cable yarding under set conditions.

Values for the production rate and cost were obtained from the simulation of three machines; a Koller K-300, a Timbermaster and a Madill 071, all rigged as standing skylines on uphill settings and using intermediate supports.

Results obtained by the simulation runs are presented showing the variation of total average costs per cubic metre, with slope distance of the setting and the variation of production per hour against slope distance. For each machine an optimal landing spacing and slope distance was identified for operations in forests of given average thinning piece size.

Management implications and alternative harvesting strategies are discussed concerning the introduction and use of such machines to cable log this forest type.

DOYAL, J.A. 1997. The LIMBER JIM case study: production and economics of line logging in a thinning/fuels reduction setting of mixed conifer stands in the Blue Mountains of Northeastern Oregon. (MF)

Forest managers in the Blue Mountains of northeastern Oregon are currently faced with vast areas of forests with health problems and high fuel loadings. These conditions resulted from a combination of insect infestations, past management practices and the elimination of fire from the local ecosystems. These forests are now overstocked, diseased and contain vast amounts of dead woody debris on the forest floor posing a serious threat of large destructive fires. This paper presents an analysis of the economics and production of using a cable system to reduce fuel loading, stand density, and minimize soil impacts.

A combined thinning and salvage logging of the larger fuels from the forest floor was completed using a single-grip harvester to process the stems into logs and a medium sized swing yarder to transport the logs to landings. This combination of equipment was not common to the area and was chosen to minimize soil impacts. There were four units designated for skyline logging. Each unit had different terrain and stocking characteristics. Two units were logged uphill, one unit was logged downhill, and one unit was relatively flat.

The harvester processed into logs all designated standing timber and any solid stems on the forest floor. A Diamond D210 swing yarder using a standing skyline, tailtrees, and intermediate supports was used to transport the logs to the landing. Production estimates for the harvester and yarder were 19.24 tons/pmh (9.33 cunits/hr) and 10.40 tons/pmh (6.48 cunits/pmh) respectively.

Total logging cost for the system (stump to mill) was $169,602. This equated to $73/ton ($115/cunit) of material removed. On a per acre basis, the cost was $2827 ($6985/hectare). Net revenue from sawlogs was $39,163.75 or $663.79 per acre. Net revenue from pulpwood was $97,785.79 or $1657.39 per acre. This resulted in a net loss of $32,653 or $544 per acre. Sawlogs represented 28.6% of the revenue, while pulpwood represented 71.4%. Gross weight from the project was 2332.69 tons with sawlogs representing 10.7% of the material removed, and pulpwood representing 89.3%. At the time of the study, pulpwood prices were $97.50/bdu² ($46.93/green ton) and sawlogs prices were $425/mbf. Figure 6.2 gives an indication of the range of logging costs and the percentage of sawlogs needed to break even at different chip prices.

The use of a skyline system in a thinning/fuels reduction setting proved not to be cost effective. Costs for a skyline system are generally higher than traditional ground based systems of logging in the area, but appears to have resulted in less soil impacts. Therefore, in areas where soil protection is the most important consideration, this logging system may be used, but careful consideration needs to be given to the percentage of sawlogs designated to be harvested, the type of equipment used, and the current market conditions or the system may operate at a loss. For this study, in order for the operation to break even, the percentage of sawlogs removed from 21
the project needed to be 21.5% or higher.

1 pmh = productive machine hours
2 bdu = bone dry unit. See Appendix H for conversion to $/green ton.

DURSTON, T.A. 1988. Improving the performance of multispan logging systems by suspending the mainline. (MS)
Multispan skyline logging systems are cable systems designed to yard logs over steep terrain having a constant or convex slope. An intermediate skyline support is used to raise the skyline high enough to achieve ground clearance without over-stressing the skyline. Certain improvements in performance can be realized by providing intermediate support for the mainline as well as the skyline.
A computer model has been developed to compare the performance of two possible suspended-mainline multispan logging systems. One of the systems is capable of suspending the mainline at the skyline intermediate support using a compound jack, and the other, the squirrel carriage, suspends the mainline from a pair of sheaves which are free to change location under the influence of cable forces.
The computer model is capable of predicting the effect of different parameters on the performance of the logging systems. Simulations on a typical logging setting, varying one parameter at a time, suggest that:
(1) Either system of suspending the mainline can potentially improve net payload, ground clearance of the mainline, and the likelihood of successful passage of the skyline carriage over the intermediate support jack.
(2) The compound jack system is capable of better performance than the squirrel carriage system under most conditions.
(3) The squirrel carriage system performance improves on steeper slopes and with optimum squirrel carriage weight. Squirrel carriage performance worsens as the ground profile becomes more convex.

EDWARDS, R.M. 1992. Logging planning, felling, and yarding costs in five alternative skyline group selection harvests. (MF)
Alternative silvicultural systems, such as group selections, have recently come into vogue in the U.S. Pacific Northwest in response to political and public pressure against traditional, even-aged silviculture. There is also interest in silvicultural systems for multiple resources. Little is known about planning logistics, operational requirements, and harvest costs for timber and site conditions of alternative silvicultural systems. Much of the terrain demands expensive cable logging systems requiring up-to-date production and cost information for harvest planning and administration.
This paper describes logging planning and harvest requirements, production, and cost results of an interdisciplinary experiment comparing alternative silvicultural systems for multiple resource management. The study was conducted in the Oregon Coast Range, second growth timber using five types of group selection harvest setting designs. Skyline group selections were compared to a clearcut. Group sizes ranged from 0.5 to 3 acres (0.20 to 1.21 hectares). Group shapes included rectangular to polygonal and wedge-shape, with parallel and fan shaped setting skyline road plans. Harvest units were assessed for their efficiencies and/or inadequacies for unit planning and layout, felling, and yarding production and cost.
In group selection units, total harvest costs increased from 7.3 to 31.5 percent over clearcutting. Patch size had the largest influence over total costs (i.e. larger size; lower cost). Total cost was also related to skyline setting road plan and shape. Harvest cost components were greater for group selection units than the clearcut.
Felling costs increased a minimal amount (0.4 to 2.6 percent) over clearcutting in most of the group selections because of the need for more directional tree wedging. However, standard yarding costs were estimated to be slightly lower than the clearcut (0.2 to 4.2 percent) in all group selections due to increased frequency of turn presetting. The wedge-shape group selection unit exhibited a 52 percent lower road change cost over the clearcut. Other group selection units were more costly (1.6 to 107.8 percent) than the clearcut road/landing change cost. The amount of timber volume removed was a key factor affecting the final yarding cost. Final yarding costs for all group selection units increased 3.4 to 26.0 percent over clearcutting.
Logging planning is the key to operationally efficient and cost effective group selection harvesting. Although such planning required 2.6 to 5.9 times more planning time and cost commitment as the clearcut, lack of such planning would cause other harvest costs to escalate as a result of increased operational difficulties.

Many of the analytical techniques that are currently available are not capable of analyzing the offtracking of truck and trailer combinations or the path of load overhangs through a set of curves that are commonly found on forest roads. Advances in the processing speed of microcomputers have made it possible to simulate how a truck and trailer combination negotiate a road. A microcomputer program, OFFTRACK, was developed to simulate the offtracking of six different vehicle configurations. The program will enable road designers to predict offtracking through a complex set of road geometrics, including compound and reverse curves. The program will also analyze the path of load overhangs on a vehicle such as a yarder tower on a lowboy or rubber tired undercarriage. Test results of the program compare favorably with several field studies and a scale model simulator. Outputs of the computer simulation are in the form of road widths required left and right of centerline, total width, and curve widening. A plot of the paths of the wheels and load overhang can be viewed on the screen or sent to a drum plotter.

FALK, G. 1980. A study of the lateral yarding forces in a cable thinning. (MF)
This paper describes the results of a project conducted to determine the magnitude of and the parameters affecting the magnitude of the cable tensions generated during lateral yarding operations in a cable thinning. Specific emphasis was placed on measuring mainline tensions as a function of turn weight, turn length, mainline vertical angle, mainline to log lead angle, ground slope, distance from carriage, number of logs per turn and thinning intensity.

The results show that the force resisting initial movement, exclusive of the gravitational component, is independent of the variables studied except number of logs per turn and thinning intensity. The average resistive force for two log turns was twice the magnitude of the resistive force for one log turns. The resistive forces encountered in heavier thinnings were higher than those encountered in lighter thinnings.

An upper limit of the magnitude of the mainline tensions necessary to cause initial log movement can be predicted by determining the resistive force such that an arbitrary percentage of the turns will result in a resistive force that will be less.

FEENEY, D.J. 1984. An economic evaluation of logging road maintenance. (MS)
This thesis describes the results of a project conducted to determine the economics of forest road maintenance alternatives between periods of timber harvesting. An open road and a closed road alternative will be compared to the economics of clearcutting an entire area and obliterating the road system until reentry at the end of the rotation. Road maintenance data was collected from the Siuslaw and Willamette National Forests in Oregon. An average present value cost per mile was determined for each location for U.S. Forest Service level on and level two maintenance. Level one is the maintenance performed on a road that is closed to vehicular traffic. Level two is the maintenance performed on roads open to high ground clearance vehicles. Reconstruction costs before each reentry were also included in the present value calculations.

Results show that for short-term reentry periods, it is economically better to leave road systems open and maintain at level two than it is to close the roads and maintain at level one. The third alternative of clearcutting and obliterating the system until the end of the rotation was by far the best economic alternative. Only costs for actual maintenance were included in the analysis. Administrative costs, and costs associated with other resource values were not considered.

To help demonstrate how maintenance costs compare to total timber revenues, road maintenance costs for different road densities were compared to associated timber value. Road densities per section (640 acres) for different logging systems were used to calculate a present value road maintenance cost per section. This was compared to timber values per section for three different volume per acre figures. These volumes represented site classes II, III and IV. It was found that road maintenance and reconstruction make up a small percentage of the total timber revenue. Although the percent of total revenue was low, road maintenance appears to be a significant investment.

FIELD, P.C. 1993. Scheduling road maintenance activities with project management software. (MS)
Project management software is a useful tool for the construction industry. Maintenance of a road system is similar to a construction project. Maintenance management systems assist road managers with the technical analysis to define the required maintenance activities, but do not provide a tool for road crew supervisors to
schedule those maintenance activities. Typically the maintenance management system gives the road crew supervisor a list of activities to complete during the year. Project management software, working with information in the maintenance management system, can provide a schedule to assist in completing the year's maintenance activities within available time and resources. As maintenance budgets decrease, the demand increases for road crews to perform the maximum amount of work with limited resources.

This paper evaluates use of project management software as a maintenance activity scheduling tool. During the evaluation, the parameters and logic for a future scheduling tool are developed. A low end (under $500) commercial project management software package is used for the evaluation. The study approach uses USDA Forest Service road crew supervisors as consultants for evaluation. Two forests in Region 6 (Oregon and Washington) serve as test sites. Evaluation requires development of task names, durations, standard crews, scheduled start dates, and task links.

Organization of the maintenance activities is important for providing a useful schedule. Developing separate schedules for each crew type and using historical dates for scheduled starts are two organizational techniques developed. Schedule organization assists linking the maintenance activities in a logical sequence.

The results suggest that maintenance activities are compatible with project management software after some development. The potential for improving maintenance activity scheduling is demonstrated utilizing project management software. Integration of road crew activities with the maintenance management system data, ability to track resources, creating long range schedules, and better tracking of activities are some of the improvements possible with a project management based scheduling tool.

FISCHER, G.S. 2002. The Influence of Multi-Stage Triaxial Testing on the Behavior of Oregon Coast Range Soil. (MS)

A series of single and multi-stage anisotropically consolidated undrained triaxial compression tests were conducted on undisturbed specimens obtained from the Oregon Coast Range. An anisotropic stress analysis was performed to estimate the in-situ effective stresses within a typical shallow homogeneous soil profile located on a moderately steep hillslope. These consolidation stresses were used for both the single and multi-stage tests in order to investigate the influence of multiple stages of consolidation and shear on the effective strength parameters, the undrained shear strength, and the volume-change behavior relative to behavior from single-stage tests.

Excessive axial strain and the formation of consolidation stress loops during the latter stages of the multi-stage tests were prevented, causing minimal soil remolding. As a result, the effective strength parameters from the multi-stage tests were only slightly lower than those from the single-stage tests. Preliminary data analysis showed a significant reduction in the undrained shear strength from the multi-stage tests at the highest consolidation stress used ($\sigma_{fc}' = 6.5$ psi). This implies that the latter stages of multi-stage tests will underestimate the undrained shear strength of soil, especially for conventional civil engineering stress ranges.

However, the volume-change behavior of this soil did not appear to be influenced by multiple stages. Due to a lack of specimens consolidated to $\sigma_{fc}' = 6.5$ psi (single-stage and the last stage of a multi-stage test), definite conclusions could not be made. The author suggests that by minimizing soil remolding during the latter stages, the volume-change behavior may not be influenced by the test method. Thus, the undrained shear strengths may not be significantly different.

FISHER, J.G. 1986. Logging with a hydraulic excavator: A case study. (MF)

This paper presents a production study of a modified hydraulic excavator used for yarding and loading logs. The machine utilized in this study is a Caterpillar 245. Approximately 3067 cunits (4053 pieces) of old growth Douglas fir were logged from a 29 acre setting in the Coast Range of southwestern Oregon.

The purpose of this study is to develop and present important information concerning the application of a logging technique that is generating increasing interest from the forest industry in the Pacific Northwest. This purpose is accomplished by, 1) identifying the conditions affecting production, 2) providing a description of operating techniques, and 3) providing a preliminary investigation of soil impacts.

Time study and regression techniques are used to develop equations for predicting yarding production. Significant independent variables include piece size, ground slope, and yarding distance. The relationships between production and piece size and yarding distance are nonlinear.
On relatively flat ground the machine travels in a serpentine pattern, methodically swinging logs closer to the road on each pass. On steeper ground slopes (>30%), the terrain may preclude adherence to this otherwise efficient pattern; here the operator uses several techniques to increase the effective reach of the machine.

A preliminary investigation of soil impacts indicated that off road soil compaction was not a significant problem; a 2 percent decrease in seedling height growth on 5 percent of the area. The high road density (7 percent of area) appeared to be the main impact on site quality. Mitigation measures could include tillage of the road surface and sidecast pull-back.

The actual yarding production rate on the setting was 54.47 cunits/scheduled yarding hour. The yarding cost was $2.02/cunit. Total cost including road construction within the setting and loading was $9.61/cunit. The regression equation over predicted actual cunit/hour production by 5 percent.

FLATTEN, L.B. 1991. The use of small helicopters for commercial thinning in steep, mountainous terrain. (MF)
A great deal of research has taken place in an effort to find more economically efficient yarding systems for commercial thinnings. Almost all of this research has centered on tractors or small yarders with limited capabilities in terms of long yarding distances. The purpose of this study is to determine whether using helicopters can be an economical alternative for commercial thinning in steep, mountainous terrain. The study area consists of a second-growth stand of Douglas-fir and mixed true fir species. The stand was thinned using a Lama SA-315B helicopter (external lifting capacity of 2500 lbs.) to yard a total of 383 mbf (800.5 cunits) over a period of 3 weeks. Average yarding distance was approximately 2500 feet and the average slope was 40%. The diameter of the trees removed averaged 15 inches and the average piece size was approximately 87 board feet (.182 cunits).

Gross production data were kept by the project manager for the logging company. This information is used to compare costs actually experienced during the operation with costs that might have occurred had the stand been cable yarded. The stand had originally been planned for uphill cable yarding using intermediate supports. A Thunderbird TMY 50 yarder is used as the hypothetical comparison operation.

A detailed time study was conducted and the results are used to evaluate the effects of turn weights and yarding distance on the helicopter operation. Regression equations were developed and used to predict hook time, haul time, and total turn time for specific conditions.

A damage survey was conducted after yarding to assess the condition of the residual stand. Results of this survey are compared with the amount of damage predicted for a cable system using a regression formula developed by Caccavano (1982).

The results of the study indicate that using the Lama helicopter can be an economically feasible alternative for commercial thinning. An average yarding cost per thousand board feet of $179.21 was estimated for the helicopter operation; the cable system would have cost an estimated $159.73 per mbf for yarding, with an additional $55.21 per mbf for necessary road and landing construction. The helicopter yarding resulted in no damage to the residual stand. An estimated 44.6 sq. ft. of scar area per acre would have resulted had the stand been cable yarded.

Shovel logging is a relatively new ground-based method of yarding timber. It involves moving logs from stump to landing by successive swinging with a hydraulic excavator modified into a log loader by replacing the shovel bucket with a grapple. Loaders used in shovel yarding can weigh in excess of 100,000 pounds so that the opportunity for soil compaction is great.

This study measured the amount of soil compaction that occurs with shovel yarding. The study was done on the Quinault District of the Olympic N.F. in Washington state. The results show that 20.5% of the total area logged consisted of shovel paths. Soil bulk densities in the shovel tracks when compared to undisturbed areas within the unit showed a statistically significant increase of about 7.5%. Soil compaction did not seem to increase after the initial pass up to seven passes.

Production rate for the shovel was 7.8 net mbf/hour. Logging with the shovel cost $18.57/mbf less than yarding the same unit with a Washington 208 slackline yader.

Three methods of economically analyzing the effects of soil compaction were reviewed and the idea that the value of soil compaction involves more than just the dollar value lost due to future decreased timber production was proposed. Values such as existence value, option value and quasi-option value need to also be
considered in any decision allowing soil compaction to occur.

FODGE, F. 1981. Engineering analysis of forces created in two tree intermediate supports during multi-span logging. (MF)
An analysis of forces on two tree intermediate supports is presented. The analysis is in two parts: 1) the maximum force that the support jack will experience; 2) the movement and forces created in the two tree support by the skyline and carriage. The maximum force on the support jack occurs when the carriage moves onto the jack. The support line tension varies with changes in skyline geometry and support tree geometry.

The equations developed to accomplish the above analysis require iteration to arrive at the solution. Computer programs developed for the Hewlett Packard 9830 desk top computer are presented. The computer programs solve for the maximum force on the jack, the support jack movement, and the support line tension.

Tensions in an experimental multi-span skyline were measured to test assumptions made during the analysis. The assumptions appear to cause the computer programs to overestimate the support line tension.

The two-tree analysis was used to analyze two current multi-span problems: 1) skyline spans that create a horizontal angle in the skyline at the support jack; 2) maximum support line tensions. The two problems were analyzed by using two hypothetical multi-span skylines and the two-tree support computer programs.

GABRIELLE, R.M. 1980. Cable thinning in young forests with average dbh of 5-8 inches: a case study. (MF)
This paper describes the results of a time-study conducted near Grand Ronde, Oregon, to determine the production rates and total harvesting costs of a cable thinning in a young stand. The stand had a species mix of 48 percent western hemlock (Tsuga heterophylla (Raf.) Sarg.), 45 percent Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), and 7 percent white fir (Abies concolor (Gord. & Flend.) Lindl.). The stand had an average age of 33 years, with a mean dbh of the total stand (over 1.5 inches (3.81 cm) dbh) of 5.7 inches (14.48 cm). The mean dbh of the merchantable stems (over 6 inches (15.84 cm) dbh) was 8.3 inches.

The yarder belonged to the small size class of yarders, and was rigged with a live skyline system using a self-clamping, manual slack-pulling carriage. Three hooking techniques consisting of three chokers with sliders, presetting three ring chokers and using a toggle hook, and flying six ring chokers per turn were compared on a production basis.

Training of woodworkers is described as important for the logging industry in Oregon. There has been little documentation of training gains or research that measures the effects of training from the perspective of the logging firm. Learning theories are evaluated and Towill's form of learning curves are selected for an experiment. A decision model is developed to assess the training gains in complex chokersetting tasks. Thirty subjects are matched and split into a control and experimental group based on initial task performance. Designed training is provided to the experimental group while the control group learns the way industry commonly performs training. Results are presented after six weeks of the experiment. Training gains are significant -- eighteen percent time savings in favor of the experimental group. Other statistical results were suggested by learning theory.

Results of the experiment are incorporated and translated into the decision model developed. A simplified approach is described for logging firms. Simulation and sensitivity analysis are used to examine parameters of interest which include training gains, training costs, job change characteristics of workers, and recovery points of training costs. Summary discussions identify implementation obstacles and future research needs.

This paper discusses the development of a computer simulation program for the operation of a log landing for the proposed Heli-stat airship. The first part of the paper describes the time study used to develop production rates for the chasers, buckers, front-end loaders, and skidders to be used on the landing. A time study was performed on a helicopter landing resulting in regression equations or production probability distributions for each of the five job functions on the landing. Because the Heli-stat is capable of delivering a much larger payload than the helicopter that was studied, extrapolations of the time study results were necessary. A mechanical analysis was
used to determine the production rate of a large rubber tired skidder used as a swing machine between the dropsite and the bucking chute.

The second part of the paper discusses the features of General Purpose Simulation System (GPSS V) program used to simulate the Heli-stat landing. Queue lengths and equipment utilization rates were used as evaluation criteria in determining the minimum turn times that could be handled by a number of different landing configurations. Different crewing patterns were evaluated for landings with one or two dropsites for old-growth log loads consisting of either bucked logs, tree length logs, or whole trees with tops and limbs. Production rates and production costs based on delay free times were used to compare the various alternatives. The results indicate that tree length logging may have some definite advantages over the other two types because the long, limbed logs can be handled more efficiently than either the bucked logs or the whole trees. The results also show that a standard helicopter landing configuration increased in both physical dimensions and crew sizes can accommodate Heli-stat turn times of 4.0 to 6.0 minutes.

A primary goal of this project was to develop production equations that could be used in a larger stump-to-cold-deck simulation of the entire Heli-stat yarding cycle. This larger simulation will be performed by the Aerospace Corporation of Los Angeles, California, and will incorporate the landing production rates developed here with yarding and load assembly production rates developed by John Miles and Bruce Hartsough at the University of California at Davis.

GIBBONS, D.J. 1982. Predicting skidder productivity: a mobility approach. (MS)
The principles of mobility are applied to the forest setting to simulate the movement of logs with a rubber tired-skidder. A computer program was written to perform the analysis. Vehicle-terrain and log-terrain interactions are the resistances which must be overcome by the available vehicle power. The rate at which these resistances can be overcome is potential vehicle speed. Vehicle speed and turn weight then define productivity.

The "mobility model" is then used to evaluate variable relationships and identify optimum vehicle horsepowers, turn weights, and skid trail slopes. A user oriented program is written with documentation for the Hewlett-Packard Model 9830 desktop computer.

GILES, R.S. 1986. LOGCOST a harvest cost model for southwestern Idaho. (MF)
LOGCOST is an interactive computer program that predicts stump to mill logging costs, stumpage and net present value of a harvest based on stand data, pond value and logging parameters, entered by the user. The program is intended for use by foresters to evaluate the economics of different stand management strategies. It is also useful in deciding whether commercial thinning of existing stands is profitable. The current version is designed for use in southwestern Idaho, but minor changes could be made which would extend the applicability to other parts of the USDA, Forest Service, Intermountain Region.

Approximately two minutes is required to enter data, and program execution takes approximately 15 seconds, using an IBM Personal Computer. LOGCOST is compiled in BASIC and will run on microcomputers that have at least 256K RAM and are IBM compatible. Documentation of the model and a Users' Guide are included in the Appendices.

Felling and bucking, as well as yarding production, computed by LOGCOST compared favorably with other studies.

A semi-empirical mobility model is presented which predicts tracked vehicle performance in timber harvesting applications. The interactions between the log load and the terrain, the log load and the vehicle, and the vehicle and the terrain cause resistances for the vehicle. The mobility model calculates these resistances, comparing them to both the power limitations of the vehicle and the tractive limitations of the soil, to determine if the vehicle is immobilized. If not, then the vehicle speed is calculated based on available drawbar pull. The timber harvesting productivity of the vehicle in the given terrain is calculated as a function of the vehicle velocity, non-travel time, and delays.

The mobility model can be used to analyze either flexible track or rigid track vehicles. Soil strength is measured by rating cone index.

R-A-F-T-S, a user-interactive computer program of the mobility model, is presented. R-A-F-T-S is an acronym for "rigid and flexible track skidding". The program is written in HP 97050A version of the BASIC
This thesis presents the idea for FORIN (Forest Roads Inventory), a computerized forest roads inventory system. FORIN is a tool to more efficiently inventory and manage information of forest roads. FORIN is intended for use by field personnel, who will use pen-based computers to improve productivity, accuracy of inventories, to lower the cost, and provide an efficient management tool for forest roads inventory.

FORIN is a relational database computer system designed for gathering data for forest roads. FORIN displays a menu, which controls the display of all other forms. The main purpose of the forms is for data collection, plus data updates for the roads and their elements. The data entry in the forms will be assisted by a pen-based computer, which will allow for fast, efficient, and accurate data gathering.

FORIN replaces the existing paper forms method of inventory with computerized forms, so that collected information can be transcribed into a summary report immediately after the data has been collected and input into the program.

Understanding the impact of thinning on residual stands helps forest managers achieve management objectives associated with sustainability and quality control. Stand damage control becomes more critical as thinning prescriptions in the Pacific Northwest are increasingly required for intensive management of second-growth young stands. The purpose of this study was to describe damage characteristics caused by various thinning systems, to recommend the best sampling strategy, and to estimate logging damage impact on future timber value.

For all logging systems, scarring was the most typical type of damage to crop trees, accounting for more than 90% of the total damage in most cases. Damage was concentrated along the skid trails or the skyline corridors. Harvesters caused more damage (70%) to crop trees in the cut-to-length thinning than did forwarders (30%). Damage levels dropped drastically when larger minimum scar sizes were applied. Damage levels were also greatly influenced by one or more compounding variables such as skid trail width, so that there was no specific relationship between damage level and logging systems.

Systematic plot sampling consistently provided estimates similar to the results of a 100% survey. This method also took the least amount of time and effort to lay out on the map and to locate plots in the field. An easy, quick survey method was proposed to monitor residual stand damage for in-progress and post-thinning operations. A quick assessment of damage allows forest managers to control stand damage in current thinning operations and also to determine whether detailed sampling is required for further investigation.

All scars that remained open in western hemlock and Sitka spruce sustained advanced decay during the 13 years after initial wounding. Scars less than 10 cm (4 in.) in width were closed in 8 years. Douglas-fir was more resistant to decay, and no rotting was observed in scars less than 21 years old. Advanced rotting and pitch ring defects, however, were observed in 29-year-old scars, both open and closed. Because of these defects, future value loss increased with time after wounding and with higher damage levels. Value loss can justify increased thinning costs incurred for minimizing stand damage.

Identification of variables influencing residual stand damage from skyline thinning a young western Hemlock-Sitka spruce stand. (MF)

Western hemlock and Sitka spruce are relatively thin-barked species and susceptible to damage during thinning operations. Damage to the wood allows decay-causing fungi to enter resulting in loss of merchantable volume at the time of final harvest. Cable yarding systems are needed for much of the thinning because most hemlock-spruce stands in the Pacific Northwest are located on steep slopes and fragile soils. It is during these thinning operations that much of the damage occurs. The purpose of this study was to determine the significant harvesting variables affecting residual stand damage due to cable thinning a 30-year-old hemlock-spruce stand.

Detailed stand damage measurements were made during logging on nine skyline units in two study areas in western Oregon. Less detailed damage was measured on 18 other units to determine difference in damage levels between three different thinning treatments: conventional low intensity thinning, conventional high intensity
thinning, and a herringbone (strip) thinning. Twenty-two variables were measured in two categories: harvesting variables and stand damage variables. Total scar area per turn (ft²/turn) was used as the dependent variable.

As a result of regression analysis, the following variables were found to most significantly influence residual stand damage: number of carriage repositions, log angle, carriage clearance, narrow treatment, rigging slinger, and cutter. An analysis of variance showed mean scar area per acre for the narrow and wide treatments were significantly different from the strip treatment.

Only 12 percent of the residual stand (trees/acre) in the strip treatment were damaged. The narrow and wide treatments experienced much higher levels of 47 and 61 percent, respectively. Conventional thinning treatments experienced extensive damage levels (84.78 ft²/acre in the narrow treatment and 91.64 ft²/acre in the wide treatment) compared to the strip treatment (17.57 ft²/acre). Individual scars ranged in size from 0.02 to 14.00 square feet. Of the total scar area in the detailed units, 66.6 percent was found within 20 feet of the skyline corridor centerline.


Steel wire rope is the accepted standard in logging. It is strong, durable, stiff, and dependable in the logger’s arsenal. However, steel wire rope has several disadvantages: its strength to weight ratio is low; it is difficult and time-consuming to splice; and used wire ropes contain jiggers. Ultra-high molecular weight polyethylene (UHMW-PE) braided rope has potential to replace steel wire rope. The offshore mooring and shipping industries have appreciated it for years. Characteristics such as a specific gravity less that one (it floats!), high flexibility, low stretch, and ease of splicing make the synthetic rope useful. At equivalent diameters, synthetic rope has an equal or greater breaking strength to that of steel wire rope, but at 1/7 the weight.

This thesis is an investigation of the end connectors for the unique physical, mechanical, and thermal properties of UHMW-PE 12-strand braided rope that make this technology of interest in logging applications. This study focused on three diameter classes of the synthetic rope that are common to logging operations: 3/8", 9/16", and 5/8". Within each diameter class there were five different spools representing separate production runs. A randomized complete block design was used with each diameter class and the corresponding five spools a separate population. Following the laboratory tests, the breaking strengths were compared to the buried eye splice.

Three types of end connectors were evaluated during this pilot study. They are identified as spliced, adhesives, and dry hardware. Spliced end connections provided consistent performance in breaking strengths. The end connections with adhesives had variable strength performance laboratory tests and are therefore not recommended. Within dry hardware end connections, the pinned nubbin and knuckle link provided the highest breaking strength relative to the buried eye splice.

This project has accomplished its objectives. It was the first extensive study on end connections specifically designed for synthetic rope. New end connections were developed and steel wire rope connections were modified to meet the strength and usability criteria for timber harvesting operations. Suitable end connections for forest operations were: buried eye splice, Whoopie Sling, long splice, rope clamps, knuckle link, pinned nubbin, and Y-splice. These end connections suitable for use with forest operations were identified and recommended user guidelines were given. Further research and development needs to be conducted on these seven concepts with larger sample sizes and in varied conditions.


Environmentally, the Wyssen skyline crane is a logging system with minimum impact. Steep terrain and difficult access to harvestable timber in remote areas make multi-span skyline logging environmentally and economically competitive with other systems.

The Wyssen skyline crane was studied in the summer of 1976 on an operation in northern Idaho and central Washington. This study was undertaken to determine a range of conditions under which the Wyssen skyline crane can operate efficiently, effectively, and economically.

Detailed timing and logging conditions during the harvesting operation provided specific information on factors expected to affect the skyline crane's productivity. The average turn time was 19.3 minutes on a 1,990 foot average yarding distance for uphill yarding and 11.8 minutes per turn on a 1,470 foot average yarding distance for downhill skidding.
Average productivity, as calculated from the average time per turn and average volume per log, was 16 MBF per productive machine day for uphill yarding and 19 MBF for downhill yarding.

The most important influences on total turn time were: (1) yarding distance; (2) men in crew and their expertise; (3) number of logs per turn; (4) volume per log; (5) lateral distance from the skyline; and (6) slope.

Yarding over long distances, with a reduction in constructed road mileage, is the main advantage of the Wyssen skyline logging system. Because logs are fully or partially suspended off the ground by the Wyssen skyline logging system, the need for skid roads is alleviated.

In the logging industry today there is an increasing need to fit the optimal yarding system to each logging operation due to increasing costs and environmental constraints. When the logging engineer is comparing cable systems for a specific show, he must be able to determine the load carrying capacity of each system under consideration. These calculations are often simplified by assuming that the load on a system such as a skyline is fully suspended (e.g. Carson and Mann, 1971). However, when dealing with situations that require or may require partial suspension of logs, the calculations are more difficult and require than the coefficient of drag resistance between the logs and the ground be known (Carson, 1975). It is possible to support larger loads on a cable logging system when the log load is partially suspended rather than fully suspended because part of the load's weight is supported by the ground. The amount of this increase may be calculated by knowing the load factor which is multiplied by the fully suspended net load capacity to determine the net load capacity under partial suspension. Figure 1 illustrates the sensitivity of the load factor to changes in the coefficient of drag resistance for a set of typical log geometry situations in cable yarding.

HOCHREIN, P.H. 1986. Prebunching versus full-cycle yarding in different thinning intensities. (MF)
This study compares the production rates and yarding costs of prebunching with a Koller K300 (small skyline yader) and swinging with a Madill 071 (medium-sized skyline yader) to full-cycle yarding with the Koller and Madill. These yarding techniques were studies in two different thinning intensities. The study took place in a stand of second-growth Douglas-fir on the Willamette National Forest in the Oregon Cascades. For the entire sale area, a 1975 stand exam showed an average volume of 49.8 cunits (21.5 mbf) and a average dbh of 11.3 inches. Average volume harvested was 25.2 cunits per acre (10.9 mbf per acre) in the high stocked stand and 11.7 cunits per acre (5.1 mbf per acre) in the low stocked stand. The average log size was 12.8 cubic feet (55.4 board feet) in the high stocked stand and 15.0 cubic feet (64.9 board feet) in the low stocked stand.

Regression analysis was used to develop production equations which can be used to predict how each system would function for a range of similar conditions. The results indicate that full-cycle Koller yarding was the least costly for slope yarding distances less than 1,000 feet. Full-cycle Madill yarding and prebunch and swing yarding had similar costs. The analysis indicates that a reduction in the Koller crew size would make a significant savings in yarding costs.

The analysis proposes that improvements are possible for prebunch and swing yarding with the use of different yarding techniques and careful evaluation of potential prebunch areas. With proper crew utilization, prebunch and swing delays could be reduced to those experienced during full-cycle yarding. By selecting areas where the difficulty of slackpulling is independent of slope yarding distance and minimal mainline sag develops during lateral outhaul, prebunch and swing production can be greatly improved. Swing crew size and yarding costs could also be reduced if tops were cut prior to yarding. It may be possible for prebunch and swing yarding to be more cost-effective than full-cycle Koller yarding at slope yarding distances greater than 325 feet.

A comparison between the time study and shift level study reveals that time studies may overestimate production. This study also points out the marginal economic nature of skyline yarding in small timber and the necessity of good planning. The results of this research are also applicable to other regions where commercial thinning is conducted.

HOSSAIN, M.M. 1998. Young stand thinning in Western Oregon: cost comparison of harvesting alternatives and comparison of time study techniques. (PhD)
Harvesting costs were determined for commercial thinning of young stands to achieve vegetation and wildlife objectives. This included replicated comparisons of thinning treatments. Treatments were defined based on residual tree stocking after thinning. Study procedures were developed and evaluated to improve statistical
Multiple linear regression models were used to compare cycle times of thinning treatments. Indicator variables were found to be effective in evaluating the treatment effects. Extraction costs of harvesting and 95% confidence intervals were determined for skyline yarding, tractor skidding and mechanized systems.

There is not a marked difference in costs between treatments except the heavy thinning treatment of the tractor site. Also the light with openings treatment was more expensive in the mechanized forwarding. Skyline yarding costs are approximately double tractor skidding costs. Skyline costs are more sensitive to yarding distance than tractor skidding. Mechanized harvester costs are higher than manual felling costs. When extraction distance increases the harvester-forwarder system becomes less expensive than the felling-skidding system.

Harvesting delay analysis for small and large delays shows that mean delay frequency and duration are not significantly different between treatments. Kolmogorov-Smirnov test results show that delay frequency and delay duration distribution of both small and large delays fit the Poisson and exponential curves respectively.

The length of study needed to achieve reasonable delay percentage estimates are roughly equivalent to those needed to achieve delay free cycle time estimates. Simulation of delay demonstrated the need for long study periods to correctly estimate the large delays, which are tracked in shift level studies. A study length of 334 cycles for small delays and 140 days for large delays were predicted with 90% confidence intervals of ±2% and ±3.68% respectively.

Comparison of detailed time study versus shift level study shows that although there is no significant difference in predicted means, the 95% confidence interval in shift level studies is much wider than the detailed. To attain an interval width of ±0.20 cycles per hour a detailed time study would be run for 4 days and a shift level could achieve this level only after 171 days.

HUTCHINSON, M.M. 1994. Suitability rating method of Forest Service roads as shared use facilities. (MS) Mountain biking is a growing sport. Many riders enjoy riding for the exercise and challenges that it offers. However, many other riders enjoy mountain biking for the fresh air, the forest setting and the opportunity for a relaxing family activity. These riders are not looking for steep challenging trails.

Many Forest Service roads would be ideal for these riders and could be shared use facilities. A shared use roadway is one where bicycles and motor vehicles share the same travel lanes, as opposed to bike lanes where a portion of the roadway is designated for use by bicyclists. The roads generally have grades less than 10 percent, and are usually 12 feet wide. This provides the maneuverability and comfort these riders desire. Many Forest Service roads, particularly the local roads, have very low traffic volume, less than 10 vehicles per day so the number of car-bike conflicts would also be very low.

However, not all roads are suitable as shared use facilities. A method is needed to determine which roads are suitable and to rate them according to their characteristics. This method is based on a method used in Florida to rate 2-lane paved urban and rural roads. The Delphi procedure was used to develop a method based on the Florida approach, that reflects a forest setting. The method considers many of the roadway characteristics, such as the average daily traffic, lane width, and alignment, as well as the setting of the road. A range of points is assigned to represent each factor depending on how that factor influences the suitability of the road.

The method was field tested on a portion of the Deschutes National Forest. Eighty-seven roads, including arterial, collector and local level roads, were rated. Approximately 50 percent of the roads were driven to check the ratings. In all cases the ratings properly represented the suitability of the road to function as a shared use facility.

It is recommended these ratings be shown on a map that is provided to the public. This would allow the bicyclist to choose the route they like rather than the agency selecting the "good" routes and providing them in the form of a guide book. If disclaimers are included on the maps, liability problems can be kept to a minimum.

IFF, R.H. 1977. An analysis of the slackpulling forces encountered in manually operated carriages. (MF) The popularity of gravity-return skyline logging systems is now increasing in the Western United States. Simplicity seems to be the basis for their success. While two drum yarders are most commonly used, some systems, such as the Wyssen, use only a single drum for yarding.

Carriages commonly used with these systems in partial cuts often depend on manpower to pull slack. The carriages either clamp to the skyline or latch to a stop on the skyline. The Koller and Wyssen carriages are
examples of the clamping type, while the Maki and Christy latch to a stop on the skyline.

The feasibility of logging with these systems may depend on whether or not the crew is able to pull line to
the side to reach the turn of logs. Another consideration for standing skylines, rigged above the reach of the
rigging crew, is the amount of weight that must be attached to the hook for it to drop from the carriage.

A quantification of the force required to pull the mainline through the carriage may be useful in the design
of carriages that provide some auxiliary means of pulling slack.

This paper treats the problem of pulling slack laterally as a function of ground slope under the skyline,
horizontal distance from the landing to the carriage, line weight, coefficient of friction and carriage clearance.

Because of the relatively low ratios of tension to line weight involved, it is necessary to use a catenary to
characterize the cable geometry. To find the magnitude of the slackpulling tension, we first find the tension at
the carriage which is required to overcome the friction force of the line on the ground between the yarder and the
carriage. This tension at the carriage, represented by the variable, \( T_f \), can be thought of as the weight that has to
be suspended on the end of the cable, including the hook, for the hook to reach the ground once the carriage has
clamped or latched.


This paper describes the results of a study of log truck travel speeds in three locations in Western Oregon on
favorable grades and curves. Independent variables of grade, curve radius, width, ditch depth, superelevation,
sight distance, time of day, and maximum engine braking horsepower were regressed against speed. Only grade
and curve radius were found to be important variables affecting speed. Regression equations are presented for
both the empty and loaded trucks.

Speeds were found to be independent of grade for favorable grades less than 11 percent and strongly
influenced by grades steeper than this. On sections of road not controlled by alignment, the method of Byrne et
al., 1960 (BNG) and the Vehicle Operating Cost Model (VOCM), Sullivan, 1977 were shown to predict downhill
speeds reasonable well for favorable grades between approximately 11 and 16 percent. On grades steeper than
16 percent, BNG and VOCM over predicted speeds. Due to the range of roads studied, nothing could be
concluded for favorable grades less than 11 percent.

Speeds in curves were found not to follow the widely accepted assumption that horizontal sight distance
controls speeds, nor the assumption used in VOCM that available friction controls speeds. Speeds predicted by
the BNG method were found to be slower than observed speeds. Both methods displayed a more rapid rate of
change of speed to change in curve radius. A proposed explanation for these differences, although not tested, is
that sight distance is less important due to the use of Citizens Band radios by drivers. These radios, in effect,
extended the sight of the drivers in curves. The reduced effects of sight distance on speeds and some
implications for road design are discussed.

An overall comparison of the predicted speeds of BNG against observed speeds over a 7.71 mile portion of
a logging road showed a 16.7 percent underestimation of round trip travel speeds. Assuming a truck operating
cost of $40.00 per hour, this error resulted in a hauling cost appraisal difference of $1.27/MBF ($1039.50 for
the entire sale volume) over this segment.

**KEIM, R. F. 2003. Attenuation of Rainfall Intensity by Forest Canopies. (PhD)**

Interception of precipitation by forest canopies has been found previously to reduce rainfall intensity, but this
effect is poorly understood. The goal of this research is to quantify the attenuation of rainfall intensity by forest
canopy interception, with the specific objective of estimating the contribution of this attenuation to hillslope
hydrology and slope stability during extreme rainfall.

Measurements of throughfall in two forest stands in the Pacific Northwest showed peak rainfall intensities
were lagged in time and damped in intensity compared to rainfall measured in nearby openings. Spatial patterns
of intensity smoothing and throughfall amounts persisted among storms. Modeling the responses of the soil
water pore pressure of a hypothetical hillslope to the most intense periods of rainfall resulted in estimates of
slope stability under the forest canopy that were greater than for the same hillslope without the forest canopy.

A black-box model to quantify lagging and damping of throughfall efficiently described timevarying rates of
throughfall using only data of rainfall and storm-total throughfall. However, the prediction capabilities of this
model were limited because variation of best-fit model parameters among storms was unpredictable. Modeled
mean hydraulic residence times for rainfall in canopies were approximately 15 min.
Coupling the black-box model of throughfall with stochastic models of rainfall and evaporation resulted in a stochastic model of throughfall. Modeled extreme rainfall events (> 20 yr return interval) in rainfall occurred 39 to 70% as often in throughfall, depending on return period.

Measurements of water detained on branches under simulated rainfall in the laboratory revealed higher storage at higher rainfall intensities. Conifers stored more water per leaf area than did broadleaved species at all intensities, but storage on broadleaved species showed greater increases at higher intensities. These storage increases, although short-lived at the branch scale (< 10 sec), indicate a mechanism for intensity attenuation at the canopy scale (~ 10 min), in which storage is temporarily increased during heavy rainfall and drains over time. Descriptions of canopy interactions with rainfall must include this “dynamic storage” to properly predict time-varying throughfall.

KELLER, R.R. 1980. Prebunching with a low investment skyline yarder in thinnings. (MF)

This study compares the production rates and yarding costs of prebunching with a low investment skyline yarder and swinging with a larger skyline yarder to full-cycle thinning with the larger yarder. The study analyzes two slackpulling techniques (manual and haulback assisted) and two carriages (a multi-span carriage and a clamping carriage) during the prebunching phase of the operation. The swing yarding employed a multi-span, clamping carriage requiring manual slackpulling. The full-cycle thinning employed a slackpulling carriage. All of the prebunch and swing units required multi-span skylines, while the full-cycle thinning units required single-span skylines. The study took place in a stand of young second-growth Douglas-fir and western hemlock with a mean volume of 6600 cubic feet per acre (30,300 board feet per acre). The mean log size was 12.3 cubic feet (55.4 board feet). Maximum skyline yarding distances ranged from about 500 feet to 1100 feet, with lateral yarding distances up to 140 feet perpendicular to the corridor.

The analysis indicates that the full-cycle thinning was significantly less costly than prebunching and swinging techniques. No significant differences were detected between the slackpulling techniques or carriage types used for prebunching.

The average cost of prebunching and swinging was $46.76 per cunit ($103.91 per MBF), while the average cost of full-cycle yarding was only $19.14 per cunit ($42.53 per MBF). The average yarding costs increased linearly at a rate of $1.70 per 100 feet of maximum yarding distance.

Full-cycle thinning produced 3744 cubic feet per eight-hour day (16,850 board feet per day) or 304 logs per day. Swinging produced 4305 cubic feet per eight-hour day (19,370 board feet per day) or 350 logs per day, and prebunching produced 1882 cubic feet per eight-hour day (8470 board feet per day) or 153 logs per day. The combined production rate of prebunching and swinging was 1413 cubic feet per day (6360 board feet per day) or 115 logs per day.

Prebunching production varied as a function of lateral distance and volume per acre removed in the thinning. Regression analysis was used to develop production equations which can be used to predict how each system would function over a similar range of conditions on other operations. The full-cycle thinning performed most consistently during the study. Both the prebunch and swing operations had a higher percentage of unexplained variation in the yarding cycles. The average delay-free yarding cycle for full-cycle thinning required 5.08 minutes, with an average turn volume of 47.4 cubic feet (213.3 board feet). The average delay-free yarding cycle for swing yarding required 5.01 minutes, with an average turn volume of 60.1 cubic feet (270.4 board feet). The average delay-free prebunching cycle was 2.45 minutes, with an average turn volume for prebunching of 19.1 cubic feet (86.0 board feet). The prebunching operation was affected most seriously by delays, with only about 52 percent of the total time spent in delay-free productive yarding. Both the swing operation and the full-cycle thinning operated at about 75 percent delay-free productive yarding time. A parcel model, developed to analyze prebunching production, shows promise as a tool for analyzing time study data.


Commercial thinning young growth forests in an increasingly important silvicultural technique for improving second growth management of Douglas-fir stands. Research aimed at advancing the efficiency of skyline logging operations in small wood timber stands is essential in order to make thinning these young stands economical. The purpose of this study was to evaluate one case of prebunching small logs to a skyline corridor with a portable winch and swinging the logs to a haul road with a conventional mobile yarder. Prebunching involves lateral yarding of logs from both sides of a skyline corridor and decking the logs along the corridor.
The multimoment time study method was used for obtaining data that was analyzed with multiple linear regression procedures. Predicted hourly and daily production rates were determined from the regression equations. The yarding system involving prebunching was compared to a similar system without prebunching on a cost basis.

This study showed that prebunching logs to a skyline corridor reduced the conventional mobile yarder's yarding time 65 percent and more than doubled log and volume production per day. The results favored the prebunching and swinging yarding technique. Several suggestions, that require additional research, were made for modification in the system that may improve the overall operation.

KELLOGG, L.D. 1986. A stand management strategy for young western Hemlock-Sitka spruce forests. (PhD) Western hemlock-Sitka spruce forests, where prior precommercial thinning has occurred, constitute one of the most productive young-growth management types along the Pacific Coast from Oregon to southeast Alaska. These stands are ready for a first commercial thinning entry, however, the costs and benefits of such entries and resulting impacts at final harvest are not well documented. The purpose of this study was to provide appropriate harvesting, silviculture and economic data in a comprehensive evaluation of four alternative stand management treatments (three different thinning prescriptions with a basal area per acre removal ranging from 49 percent to 67 percent and a no-thin, control prescription) conducted on a 32 year old managed western hemlock-Sitka spruce plantation.

A detailed logging production/cost study of skyline thinning showed high harvesting cost and resulting negative stumpage values. Thinning treatments influenced harvesting costs; herringbone strip thinning costs 31 percent less than a conventional selective thinning method with the same volume removal. Also, a residual tree damage study, conducted during logging, showed that damage was considerably lower for strip thinning compared with selective thinning. Various logging techniques and crew skill levels influenced stand damage.

An assessment of wind damage and tree growth rates was completed two years after skyline thinning. Annual windthrow losses totaled only 0.28 trees per acre for all treatments and was significantly lower in strip thinning than selective thinning. Windthrow also appeared to be related to specific site, tree or stand conditions.

Diameter growth increment rates declined in the unthinned units. However, in all thinned units, an immediate diameter growth response occurred. In the herringbone strip thinning method, trees exhibited a growth response regardless of distance from strip edge.

A stand table projection model and harvest simulation model were used for determining costs and revenues from clearcutting at rotation age. Final harvest costs and revenues per cunit were similar for all treatments. The unthinned stand had the highest present net worth per acre. A sensitivity analysis of real interest rate changes along with changing harvesting cost and pond values during thinning or final harvest did not alter the outcome.

Results of this study suggest that managed plantations of western hemlock-Sitka spruce can receive sufficient density control from precommercial thinning to maintain adequate stand development to a rotation age harvest without commercial thinning entries.

KENDRICK, D.E. 1992. Rigid link and catenary skyline analysis programs for microcomputers. (MF) Skyline logging is a commonly used method of harvesting logs, particularly on steep slopes. Logging systems planners frequently solve two kinds of skyline analysis problems. The first is the maximum payload problem and the second is the standing skyline load path problem. Computer assisted skyline analysis techniques have been available for over two decades. As microcomputers have become less expensive and more powerful, computer assisted skyline analysis has come within the reach of most logging systems planners.

The objective of this paper is to present two skyline analysis programs, one using a rigid link model and the other using a catenary model to solve maximum payload problems for live, running, and standing skyline programs and load path problems for standing skylines. The standing skyline analysis can include either single span or multispans systems.

A live skyline lift routine is included. Both programs can model a carriage that is clamped to the skyline or a carriage that is not clamped to the skyline. Both programs are written in Microsoft QuickBASIC Version 4.5.

KIMBALL, A.R. 1981. Tension relationships for steel cable on notched stumps. (MF) Tension relationships were determined in steel cable passed through a stump notch and anchored to another object. Tensions were measured in the cable coming into and leaving the notch with one full wrap on the stump.
Data was collected from two sites with two test stumps (15.7 to 37.5 inches inside notch diameter) per site and two cable sizes (3/4 and 7/16 inch diameter) per stump. Tensions measured in the cable coming into the notch ranged from 4063 to 18701 pounds.

Results show that the coefficient of static friction as determined assuming the V-belt tension equations increases with increased inside notch stump diameter and increased cable site. The coefficient of friction decreases with increased cable tension. A regression equation was developed incorporating these variables. The mean coefficient of friction was 0.1768. This represents a 9.22 to 1 ratio of cable tensions coming into and leaving the notch with full wrap (360°) on the stump.

KLIEWER, J.E. 1992. Test procedures for low-confining stress, multistage triaxial testing of compacted cohesive soils. (MS)

The use of the triaxial test to characterize the strength of soils for civil engineering applications is widespread. These tests are typically conducted with confining stresses in excess of 5 psi. To characterize the strength of a soil located in the upper layers of the subgrade of an aggregate surfaced road it is necessary to conduct triaxial tests with low confining stresses (5 psi or less).

The development of a method for conducting multistage, consolidated undrained (CU) tests at low confining stresses (0.5 to 5.0 psi), with back pressure saturation, is presented. Aspects of the test procedure that require special attention are described and recommendations are made including:

1. Compaction of the sample in an atmosphere of carbon dioxide reduces the time and pressure required to complete back pressure saturation.
2. Seepage force related pore pressures develop during sample flooding. Zeroing of the effective stress transducer should be completed prior to sample flooding so that it is certain that zero effective stress conditions are present.
3. Back pressure saturation is simplified by the use of a slave regulator (air loaded pressure regulator) that maintains a nearly constant pressure differential between the cell pressure and the back pressure.
4. The stress path method of interpretation is an essential part of multistage triaxial testing. This method simplifies the decision of when to stop each shear stage and the determination of shear strength parameters.
5. The use of a computer data acquisition system that processes data in real time and visually presents test progress simplifies the completion of multistage triaxial tests.


The analysis of two recent production studies indicates that the Igland-Jones Trailer Alp log yarder is capable of successfully yarding clearcut mixed stands of 35 to 40 year old red alder (Alnus rubra (Bong)) and bigleaf maple (Acer macrophyllum (Pursh)). Two basic carriage systems were employed yarding with a three-man yarding crew.

On the Spaulding Tract clearcut study, the production capabilities of the Trailer Alp rigged with a single span skyline and a small Christy gravity outhaul log carriage were evaluated. On the Blodgett Tract study, the production capabilities of the Trailer Alp were evaluated operating with single and multspan skyline systems using carriages requiring a haulback. A comparative production analysis of these two studies indicates that the Trailer Alp yarding with a gravity outhaul carriage is 35.3 percent more efficient than yarding with a carriage requiring a haulback.

In the Spaulding clearcut study, two clearcut units with a combined area of 4.64 acres (1.88 hectares) were yarded. The two units yielded a combined average of 142 pieces per acre (350 pieces per hectare). The average piece size was 16.48 cubic feet (0.47 cubic meters). The average skyline distance was between 100 and 175 feet (30 to 60 meters) and average lateral distance was 30 to 40 feet (9 to 12 meters). Operating on these two units, the Trailer Alp was capable of producing 3320 to 3080 cubic feet (94 to 87 cubic meters; 14,100 to 13,090 board feet) per eight hour yarding shift. The average daily yarding cost was estimated at $13.64 per cunit ($4.82 per cubic meter; $32.11 per M.b.f.). All derived production costs exclude overhead, risk, and profit costs. Operating delays and skyline road changes constituted 17.0 and 19.0 percent of total study time, respectively.

In the Blodgett Study, one small clearcut unit of 1.32 acres (0.53 hectares) with the study unit boundary
200 to 400 feet (60 to 120 meters) from the log landings had average skyline road ground slopes of 40 percent. The unit yielded 164 pieces per acre (405 pieces per hectare), with an average log volume of 2590 cubic feet per acre (191 cubic meters per hectare), yielding a mean piece size of 15.83 cubic feet (0.45 cubic meters).

At skyline distances of 200 to 350 feet (61 to 105 meters) the Trailer Alp was capable of producing 2180 to 2120 cubic feet (61.9 to 60.0 cubic meters; 9265 to 9010 board feet) per eight hour shift. With an average skyline slope distance of 350 feet (105 meters) and an average lateral distance of 41 feet (12.5 meters) the daily production rate was 2120 cubic feet (60.03 cubic meters; 9110 board feet). Daily operating cost yarding this material was $32.11 per cunit ($7.15 per cubic meter; $47.11 per M.b.f.). Operating delays accounted for 19.9 percent and skyline road changes for 44.0 percent of the total study time.

The results of a comparative analysis indicate that under the conditions studied, the Igland-Jones Trailer Alp yarder with a gravity outhaul yarding system is capable of an average production rate that is 35.3 percent higher than that obtained yarding with a system requiring a haulback. Assuming a $430.00 daily operating cost for each system, the difference in unit costs of logs on the landing is $5.29 per cunit ($1.87 per cubic meter; $12.46 per M.b.f.).

KRAMER, B.W. 1993. A road design process for low volume recreation and resource development roads. (MS-CE)

This study presents a rational process with supporting data to establish appropriate road design controls, criteria, and standards for low volume recreation and resource development. Much of the information presented can be used to supplement design data presented in a National road design policy published by the American Association of State Highway Transportation Officials, A Policy on Geometric Design of Highways and Streets, 1990.

A transportation development process requiring interdisciplinary analysis is developed with a detailed example. This process is necessary to assure that transportation facilities meet land management objectives with minimum environmental impact.

The location of recreation and resource development routes is addressed in detail. Proper route location is a key element in providing a safe road with minimum maintenance and operational costs while yielding minimal environmental impacts.


The Northwest timber industry is in a transition to a smallwood harvest environment. As the Northwest moves to smaller average diameter stands log values have decreased and harvest costs have increased. In an effort to increase profitability, Northwest loggers are beginning to "mechanize". The profitable operation of a mechanized harvest system is sensitive to changing market and stand variables. Because of this there is an increased need for strategic planning by land and business managers. Computers are an efficient tool for performing the repetitive and often tedious calculations involved in harvest system analysis. Computers also enable analysts to perform sensitivity analysis and answer "What if" questions.

This report identifies the existing personal computer-based software capable of performing as an analysis tool for Northwest timber harvest operations. It evaluates each by comparing them to a specific set of evaluation criteria after running each using four example harvest systems. The three harvest operation analysis programs evaluated by this paper are: LOGSIM (Wiese 1987), The Harvest System Analyzer, HSA (Hendricks et al. 1986), and the Auburn Harvesting Analyzer, AHA (Tufts et al. 1985).

The following conclusions were drawn upon completion of the analysis. All three programs can be used to model harvest operations in the Pacific Northwest, yet none will meet the needs of planners at all levels. HSA and AHA make assumptions that do not accurately reflect harvest methods used in the Pacific Northwest, therefore LOGSIM is the only program that can be recommended for modeling Pacific Northwest harvest systems.

LOGSIM's use is limited by its sophistication, long solution times, and limited sources for detailed input data, particularly production data for mechanized harvesting equipment. For this reason more production data needs to be collected and the currently available data centralized.

Finally after making the above observations it must be concluded that, the application of computer-based harvest system analysis in the Pacific Northwest, has not progressed to a point where it is available for use other
than by skilled analysts.

LEDOUX, C.B. 1975. Simulation of a helicopter yarding system in old growth forest stands. (MS)

Helicopter yarding systems have become a popular tool in removing timber from steep slopes, sensitive soils, limited access areas, and environmentally sensitive stands. Little is known about the system's dynamics. This study is part of a research project to explore "advanced" logging systems as to their economic efficiency and environmental applications.

The objectives of my study were: 1. to identify and isolate variables that significantly influence helicopter yarding efficiency, 2. to develop a simulation model that will simulate the response of the helicopter yarding operations to changes in these variables.

I observed a medium lift (Boeing-Vertol 107 Model II) helicopter operation yarding from old growth stands under varying conditions. The helicopter yarding cycle was broken down into four cycle elements and four delay elements. I used the method of continuous timing to observe these elements and obtain values for the variables that influence these elements.

Multiple linear regression analysis was used to analyze the effect of these variables on time required to complete each cycle element. Regression equations were developed for two cycle elements: outhaul and inhaul. Other cycle elements and delay elements were analyzed employing frequency distribution. A paired t-test was used to establish the reliability of the regression equations to predict element times.

A FORTRAN simulation model was used to simulate the yarding system. The model can be used to estimate efficiency, production rates, and delay times for a wide range of yarding situations.

I experimented with the finished model and, based on those results, made suggestions for system improvements.


Strip thinning is recognized as a way of commercial thinning young-growth stands. Strip thinning has been used worldwide. The purpose of this study was to explicitly evaluate the costs and benefits associated with skyline strip thinning in young Douglas-fir (Pseudotugo menziesii Franco) stands in the Pacific Northwest and to compare the results with the conventional method of cable thinning. A computer simulation model was developed to integrate logging technology, silvicultural treatments, and economic concerns. The computer model was validated using DFSIM. Simulation runs were conducted using data from previous O.S.U. field studies. The integrated results were expressed in present net worth yields over the rotation for specific treatments. The results suggest that in economic terms, strip thinning is always inferior to the conventional method of low thinning. This is due primarily to the reduced growth and yield experienced from strip thinning when compared to the conventional method. It is unlikely, under any foreseeable situation, that enough logging cost reductions can be realized for the first entry to make the strip thinning alternative competitive. Sensitivity analysis of d/D ratio suggests that strip thinning would be the best alternative only at d/D ratios of 1.15 and greater.


Steel wire rope is used for many logging applications. This material has served the logging industry well in terms of strength, durability, and longevity. Steel wire rope is difficult to use because of properties that make it stiff, heavy, and unyielding. These same properties cause fatigue, exhaustion, and may contribute to worker injuries.

Our research placed synthetic rope samples in the hands of selected loggers to try out alternatives to steel wire rope. Few studies have addressed the use of synthetic rope for logging applications. Initial trials with cooperating logging contractors showed positive ergonomics and logging productivity efficiencies. The logging industry is slow to change; so, not all of these initial trials were accepted. Designed research of synthetic rope is a suitable replacement for steel wire rope.

Synthetic rope has the potential to replace steel wire rope for many logging applications. In our trials, we assessed static line applications (guylines, intermediate support lines, tree straps, and snap guylines) and running line applications for yarding and ground-based logging systems. Our running line applications using synthetic rope included two skidder/crawler tractor winching trials, a Boman Mark IV carriage trial, and a Koller K300
mainline trial.

Static line applications such as guylines, intermediate support lines, tree straps, and snap guylines are acceptable replacements of steel wire rope with synthetic rope. Loggers were more likely to try additional applications once they used synthetic rope as tree straps and were confident of its strength. Cost was an initial drawback for most logging contractors. Additional research is needed to determine damage, replacement, and wear criteria for synthetic rope in logging applications.

Running line applications showed positive results in the skidder/crawler winching trials with faster cycle times and increased efficiencies for using synthetic rope. The Koller K300 mainline trials also produced positive results as a running line. The Boman Mark IV internal drum carriage trial showed no significant differences between steel wire rope and synthetic rope. We believe designed research is necessary to evaluate carriage applications with synthetic rope.

Future studies for static line applications should included guyline taglines, skyline taglines, haywire (rigging line) replacement, and various other applications. Putting synthetic rope into the hands of users will help identify valuable applications where synthetic rope has merit. Future studies for running lines should focus on designed trials to adequately observe the effects of synthetic rope in specific applications such as side-hill lateral yarding, uphill lateral pulling in winching trials, and other difficult logging conditions.

Preliminary results show synthetic rope is a good candidate for the replacement of steel wire rope in selected logging applications. More research is needed to determine damage, replacement, and wear criteria for all applications of synthetic rope in logging.

LEVESQUE, S.P. 1998. Evaluation of culvert condition and road closure methods in southern southeast Alaska. (MS)
Because of their potential for adversely affecting aquatic resources, increased rates of erosion and sedimentation associated with low-volume forest roads have recently gained the attention of land managers in the Pacific Northwest. For example, on the Tongass National Forest in southeast Alaska, there is an urgent need to explore the interaction of roads with existing hydrologic and geomorphic processes.

The design and maintenance of drainage structures are often of major importance for preventing environmental impacts from forest roads. The primary objective of this study was to evaluate the condition of culverts in order to address current maintenance and road closure strategies within the Ketchikan area of the Tongass National Forest.

A total of 671 drainage structures associated with 40 road segments were examined during the summer of 1997. The population of corrugated metal pipes consisted of 552 ditch-relief and 119 stream-crossing structures. Culvert condition was evaluated based on changes in the cross-sectional area of the culvert barrel reduced by damage or blockage. Overall, 47% of drainage structures were operating with at least a 10% reduction in culvert end area. Structural damage was the most frequent reduction mechanism observed (34%), closely followed by the accumulation of sediment (23%) and woody debris (21%) at the culvert inlet.

There was no significant difference in culvert condition for open and closed roads where culverts have been left in place and native vegetation has been allowed to become established on the road prism. The analysis suggests that landscape characteristics such as topographic location are commonly associated with the observed reductions in culvert end area. Loss of culvert end area appears to trigger a disturbance cascade, often resulting in the diversion of surface water past the culvert inlet and subsequent fluvial erosion.

LINJALA, E.T. 1979. The analysis of highlead yarding time study data from southeastern Alaska. (MF)
Production equations for appraisal cost allowances now in use by the United States Forest Service, Region 10, Alaska, were made at the time a large volume of timber was being yarded to wooden spars. Production equations for the portable tower yarding systems now in use have not been developed for Region 10. This portable tower yarding system requires much less time for rigup and moving, allowing for more and faster moves which results in shorter yarding distances and increased production.

Realizing the need for more accurate appraisal cost allowances, the Forest Service conducted a yarding time study on the mobile tower yarding systems from which they could obtain new production equations. This paper describes the analysis of data collected from the time study. Production data were gathered on eight models of yarders while harvesting clearcut areas under a wide range of terrain and weather conditions.

The objectives of this paper are to summarize the time study data, develop equations to predict yarding
production rates and to compare production rates in units where windthrow occurs to those in which no windthrow was present. This information can be used by an appraiser when estimating production costs during harvest planning.

Generalized production rates were developed for each yarder and for the yarders collectively. Detailed comparisons were made between uphill and downhill yarding and between highlead and Grabinski yarding systems. A analysis was also conducted to determine if yarding production in areas of high windthrow is statistically different from production in non-windthrow areas. The F-test using Neter and Wasserman's (1974) technique for comparing regressions was used to compare each set of individual equations with its respective combined equation.

Results indicate that production equations for individual yarders and yarding situations predict yarding production better than a single combined equation including all yarders and logging sites.

Yarding distance was the only variable which was statistically significant in all of the individual yarder and combined equations. Other variables which were found to be significant in some of the equations included: crew size, slope, number of chokers used and the number of choker setters.

In western Oregon and Washington, increased moisture levels in the subgrade and pavement structure of aggregate surfaced roads, which occurs during the rainy season, may be such that the bearing capacity of the soil, correspondingly, the structural capacity of the pavement are significantly reduced. Heavy traffic during this time of reduced strength may cause rapid deterioration and possibly complete failure of the road.

As part of this study, two aggregate surfaced roads on the Lowell Ranger District of the Willamette National Forest were monitored from November 1987 to April 1988. Soil moisture-temperature cells were used to monitor the temperature and moisture content of the subgrades. The moisture content of the aggregates was also measured periodically. Low cost portable testing devices, the Clegg impact tester and dynamic cone penetrometer, and distress surveys were used to monitor the condition of the roads. Samples of the surfacing, base and subgrades were taken and evaluated in the laboratory using standard methods. Results indicated that roads with freer draining aggregate materials seemed to perform better under wet weather conditions. These roads were less likely to develop slurry on the surface and to drain and heal more rapidly. Although not specifically noticed in this study, a disadvantage of these roads may be that their subgrades may become more easily saturated thereby causing loss of strength in the subgrade and contamination of the base.

Both the Clegg impact tester and the dynamic cone penetrometer proved to be fairly easy to use and appear to have some promising applications in management and design of low volume roads. Additional research is needed, however, before they can be routinely used. The Clegg impact tester proved to be easier to use than the dynamic cone penetrometer. The dynamic cone penetrometer, however, may be better suited for detecting problems occurring in the subgrade or below the surface.

LITTON, S. 2006. Physical Characteristics of Forest Soils After Timber Harvest and Tillage in Central Oregon: A Case Study. (MF)
This study examined the effects of timber harvest and subsoiling on soil physical properties considered important to forest productivity and hydrologic concerns. Ground based mechanical timber harvesting on some soil types can cause soil disturbance including compaction. These effects in turn can influence multiple important soil physical properties that affect forest productivity and watershed processes. On Federal forest lands in the Pacific Northwest, forest tillage, or subsoiling, is often used to ameliorate compacted soils. This case study examines multiple soil physical properties in a subsection of four harvest units that were clearcut harvested followed by subsoiling of skid trails, and in four adjacent control areas, in the Deschutes National Forest east of the Cascade crest in central Oregon. Subsections were biased towards areas of heavy machine traffic, generally next to a landing, and were tested for differences based on whether the sites were sloped versus flat, or “disturbed” versus “undisturbed.” Soil properties tested were: bulk density, total porosity, pore size distribution, available water capacity, soil strength, and infiltration. Significant differences were seen between harvested-subsoiled areas and undisturbed controls for bulk density, total porosity, soil strength in the 12.5-25.0 and 25.0-37.5 cm depths, and infiltration at very high rainfall rates. Significant differences between flat and sloped areas were observed in soil strength at the 12.5-25.0 and 25.0-37.5 cm depth classes. However, given the limited scale and variable nature of
the observed differences it appears that tillage of compacted areas mitigated most of the negative physical effects. Physical soil productivity and hydrologic behavior comparable to the undisturbed areas is expected.

LUCAS, A. 1983. Hot-yarding as an alternative approach to cable thinning in young forest stands: a comparative study. (MF)

Thinning is a silvicultural tool often used in the management of immature forest stands. The objectives of most thinnings are to improve residual stand conditions; increase the growth rate on selected remaining stems; shorten the rotational time for timber crops and increase the amount of useable wood fiber obtained from each rotation (Baker 1950). As an intermediate type cut, thinnings generally yield low volumes per acre as compacted to final harvest or regeneration cuts. In addition this volume is contained in numerous, small diameter stems that have a relative low market value. Because of this, the margin for profit in a thinning operation is usually narrow.

Thinning in areas requiring the use of cable yarding techniques such as in steep mountainous terrain, reduces this margin for profit even more. The high investment and operating costs associated with cable yarding equipment, lower production rates when compared with ground based logging and increasing labor costs combine to make cable thinning a risky venture as a commercial operation. This is especially true when market conditions for wood products are low, as is currently the case (1982). Yet thinning young stands using cable methods can make a profit (Gabrielli, 1980) but the magnitude of this profit, if any, is very sensitive to minimizing costs and efficiency in operating procedures.

Cable logging technology in the United States and especially in the Pacific Northwest, has evolved around the development of machines and techniques capable of handling large quantities of old growth timber. As a result there has been little expertise fostered in the area of equipment or procedures applicable to the efficient harvesting of smallwood. Yet, as the amount of old growth timber continues to decline (Tedder, 1979), being replaced by young stands under more intensive management regimes, the need for these types of systems will greatly increase. To date the primary contributors to this specialized field have been the Europeans whose managed forests are many rotations ahead of our own. Through necessity, they have developed equipment and procedures to economically handle the smaller sized timber generated through intensive management practices (Lisland, 1975).


Consider the bole of a tree to consist of a linear elastic material that is orthotropic with respect to the cylindrical coordinates. When the bole of a tree is subjected to resultant loads in the directions of the Cartesian base vectors, the $S_{11}$, $S_{22}$, $S_{33}$, and $S_{12}$ stresses in Cartesian coordinates are coupled. It is desirable to use beam elements to analyze the structural behavior of trees because of the ease with which these can be incorporated into Finite Element Models. However, elementary beam theory is not able to consider the problem where the $S_{11}$, $S_{22}$, $S_{33}$, and $S_{12}$ stresses are coupled. The objective of this study was to determine the magnitudes of the normal stresses in the radial and tangential directions ($S_{rr}$, $S_{\theta\theta}$) and the shear stress ($S_{r\theta}$), relative to the normal stress in the $x_1$ direction for an element of a tree bole.

In cylindrical coordinates the strains are not unique at $r = 0$. Therefore, a constitutive equation was adopted in cylindrical coordinates where the elastic coefficients are depended on $r$. An element of a tree bole was considered as a cantilever beam and posed as a Relaxed Saint-Venant’s Problem in Cartesian coordinates. It was found if the strains from the generalized plane strain part of the problem were considered linear functions of the $x_1$ and $x_2$ coordinates, then the strain compatibility conditions and equilibrium equations could be satisfied.

Given the assumption that the generalized plane strains are linear in $x_1$ and $x_2$, it was proven that the $S_{rr}$, $S_{\theta\theta}$, and $S_{r\theta}$ stresses are analytic functions of the complex variable $z$. It is also proven that the $S_{rr}$, $S_{\theta\theta}$, and $S_{r\theta}$ stresses are equal to zero on the lateral surface of the element of the tree bole. Therefore, using the analyticity of the stress functions and the fact that they are zero on the lateral surface it is possible to show that the $S_{rr}$, $S_{\theta\theta}$, and $S_{r\theta}$ stresses are zero throughout the element of a tree bole.

MAFERA, T.E. 1992. Tactical forest planning using the scheduling and network analysis program (SNAP II). (MF)

Approximately 750 million acres, or one-third, of the total area in the United States is in forest land. The United States Forest Service, a 34,000 person agency of the Department of Agriculture, is responsible for the
management of roughly 20 percent of the forest land in the United States. The cost to plan, prepare, and administer Forest Service resource management plans approaches $100-200 million annually.

Public land managers emphasize integrated resource management to maintain biological diversity and protect the health of the forest ecosystem. This approach helps to achieve a balance between wildlife, soils, water, timber, visual, and other resource considerations. These multiple resource objectives are addressed in the development of the strategic (long-range) and tactical (short-range) plans used to manage the national forests.

The challenge facing public land managers is to apply the general guidelines of strategic plans to the development of site-specific tactical plans which require a high degree of spatial and temporal resolution. The Scheduling and Network Analysis Program (SNAP II, Sessions and Sessions 1990) was developed to assist forest planners in the development of these detailed tactical plans.

This paper will briefly discuss strategic planning and some of the mathematical models that have been used in their development. Tactical planning will be emphasized. An overview of tactical planning will be followed by a discussion of mathematical models, spatial concerns that are addressed in the tactical plan, and inventory data that are required for plan development. An application of SNAP II will be presented in the form of a case study on a tactical planning area located on the Daniel Boone National Forest in Kentucky.

MANIKAM, D. 1982. Short distance transportation in the mixed peat swamp forests of Sarawak, Malaysia. (MF)

The peat swamp forests of Sarawak are an important resource in the context of the socio-economic development of the state. Logging is the main activity in these forests. In the absence of an economical mechanized system, the method of harvesting has evolved into a highly organized effective manual system. Though the method itself is well-known, there is still a dearth of quantitative data especially with respect to the mixed peat swamp forests of Sarawak.

A time study was conducted in two forest reserves near Simunjan in the First Division of Sarawak. The primary objective was to quantify the logging system with special emphasis on the skidding component. Other components that were studied include felling and bucking, skid track construction, debarking and loading. Both the one- and two-skid team crews were studied, with emphasis on the former. Both continuous timing and fixed interval activity sampling techniques were used.

The skidding component was the key element controlling the overall production of the logging operation. It is comprised of five basic work elements, namely outhaul, load, sling, inhaul and unload. Load and inhaul were the largest work elements accounting for 30 percent or more of the basic cycle time. The basic cycle time ranged from 63-88 percent of the total cycle time depending upon the skidding potential of a crew. The skidding potential is a measure of a crew's aggressiveness. Skid distance and log weight were found to be significant variables accounting for more than 60 percent of the variation in cycle time. Crew aggressiveness and variability in skidding potential could however counteract the effect of skid distance and log weight. The incidence of delays and their frequency may also be attributed to these factors. Hence, skid distance, log weight and skidding potential of crews control the skidding productivity of the system. On the whole the logging operation in the Mixed Peat Swamp Forest is a low-energy system of less than 13500 kilojoules per hour with an average productivity of 1.42 m³ per person day.

MANN, J.W. 1979. Skyline logging production in the southern Sierra Nevada Mountains: a case study. (MF)

This paper describes the results of a time study conducted on the Sierra National Forest to determine production capacity of the Madill 044 Skyline Yarding Crane operating in a partial cut situation for old-growth mixed conifer stands. The yarder was rigged in the running skyline configuration and used a Danebo mechanical slackpulling (MSP) carriage. Yarding distances ranged from 40 to 900 feet and lateral yarding distances ranged from 0 to 185 feet. An average of 35 thousand board feet of timber per acre was removed from the study area.

Regression equations were developed for the individual elements of the yarding cycle and for total cycle time. Results indicate that skyline yarding distance, lateral yarding distance and number of logs per turn are the most significant variables related to predicting total turn time, with cubic volume per turn and the number of workers on the rigger crew playing a less important role.

A comparison of the regression developed for the Madill 044 with another regression model for a Washington Iron Works 108 skyline yarding crane suggests that there is an approximate 33% difference in total turn times predicted for the same logging conditions.

Globally the forest harvesting industry is becoming increasingly mechanized. Driving this trend is the desire to increase productivity and reduce cost, as well as to improve labor-related issues. With mechanization comes an in-forest platform for the introduction of state-of-the-art communication and measurement technologies, and powerful on-board computers. These systems have the potential to increase efficiency and value gain from the whole forestry supply chain. However the performance to-date of mechanical harvesting systems has not lived up to their full potential, particularly with respect to value recovery.

One of the potential reasons for poor value recovery performance is the level of accuracy of stem diameter and length measurements on harvesters. Numerous studies have looked at the level of error in both the diameter and length measurements made by mechanical harvester/processors; however, few have looked at the economic impacts of these errors. The modeling work done in this dissertation showed that for the operations studied the value loss was between 3% and 23% due to measurement errors. Further analysis showed that increasing the precision of the length and diameter measurements would provide gains from reducing the measurement error rates.

One potential way of reducing the error rates is to introduce new scanning and forecasting procedures that would maintain or improve net value recovery. Five procedures were evaluated. It was shown that there was no economic advantage in partially scanning the stem. Breakeven capital investment costs were calculated for new scanning, forecasting, and optimization equipment. They ranged between zero and US $2,120,000 depending on tree species, markets, scanning speed, volume scaling rules, and scanning procedure.

Even with perfect information about the stem, the computer that controls the bucking solution still requires correct cutting instructions. These instructions are needed to obtain the optimal output log distribution that will maximize the return to the log suppliers while still meeting market and operational constraints. New algorithms were developed for efficiently planning and implementing these cutting instructions.

This dissertation demonstrated that the optimal output log distribution can be affected by measurement errors, work methods and bucking procedures.

MATZKA, P.J. 1997. Harvest system selection and design for damage reduction in noble fir stands (A case study on the Warm Springs Indian Reservation).

Many high-elevation stands of noble fir in the northern Oregon Cascades are being actively managed. Forest managers are investigating different activities that will control stand impacts and the subsequent spread of Heterobasidion annosum a rot pathogen on the Warm Springs Indian Reservation. The purpose of this study was to quantify the relationship of logging production and costs with associated residual stand damage during a commercial thinning operation. Investigated in the study were four ground-based harvesting systems and two different harvest unit layout methods.

The harvest systems encompassed a variety of equipment and mechanization levels ranging from mechanized felling and bunching with grapple skidders to manual felling, limbing, and bucking using a rubber-tired skidder equipped with a winch line. In addition, each harvest system was compared using two layout methods. The first method was conventional or logger’s choice and the second was a designated method incorporating proven methods for reducing stand damage. Log lengths varied from whole-tree to log-length depending on the harvest system employed. Logging production and costs were determined for the harvesting systems using a combination of detailed and shift level time studies. A stand damage survey conducted simultaneously with production studies determined percent residual stand damage, specific equipment causing damage, and individual scar characteristics.

Harvesting costs for the four different systems and layout methods ranged from $67.77/MBF-$92.68/MBF, with residual stand damage of 20.12-62.62%. Equipment size log lengths, and layout method were found to affect total residual stand damage. Reducing the use of larger, more mechanized pieces of equipment in the stand and keeping log length to a minimum resulted in a significant decrease in residual stand damage. Cost differences between designated and conventional layout methods for each harvest system were minimal. The main difference in harvesting cost was between the different systems and log lengths. Harvesting costs varied, being similar for the highest and lowest mechanized systems but increasing with the intermediate harvesting systems.

In the Blue Mountains of northeastern Oregon, prescribed fire and mechanical harvesting economics were investigated for fuels reduction and forest restoration. Using a cut-to-length harvesting system, three single-grip harvesters and three forwarders produced significantly different production rates. For the harvesters, significant variables that affected production rates were found to be: harvested material removed (live tree, standing dead tree, or downed wood), tree species, tree diameter, and distance traveled between processing. For the forwarder, significant variables that affected production rates were forwarding distance and the number of stops required to accumulate its rated payload. From the thinning, net revenues per acre ranged from $143 to $718 and averaged $315.

Prescribed fire costs ranged from $24 to $87 per acre and averaged $51. Prescribed fire intensity was found to be significantly higher in the mechanically thinned stands with tons of downed woody material being a significant predictor of fire intensity. Mean fire intensity was found to be 94.7° and 157.6° Celsius for the burn and thin and burn treatments, respectively. The addition of activity fuel from the mechanical thinning was the primary factor that increased fire intensity.

From the production data, net revenue was determined for stump-to-mill operations and predictive equations were used to develop a cost model that investigated stand conditions of significance. This information provided a framework for conducting sensitivity analysis on the effects of these significant variables to production and cost at differing levels. Equations were derived from the simulations and used to determine alternative scenarios for stand conditions in and around the study area.

The economics of fuels reduction and forest restoration needs to proceed with an increased level of cost analysis. While many areas in need of fuels reduction have produced positive net revenues, others have produced a loss. Land managers need to understand how equipment selection, material removed, stand conditions, market prices, and market locations affect harvesting costs and net revenue. Information provided in this paper can be used by land managers to aid in assessing the economic feasibility of a given operation and determine which treatment combinations are optimal.

MCINTIRE, J. 1981. The effect of swinging and sorting with a skidder on yarding and loading efficiency in small diameter Douglas-fir. (MF)

This study evaluated the impact of using a rubber-tired skidder to keep the landing clear by sorting and decking the logs along the road prior to loading by a self-loading truck. The evaluation was accomplished through detailed time studies conducted on a Koller K-300 yarder, a Crown Super 3000 self-loader, and a John Deere 440 choker skidder, in a selective thinning of a Coast Range Douglas-fir stand with an average diameter range of eight to twelve inches.

Production increases on the yarding cycle were observed when the skidder was used to keep the landing clear. A major factor for higher production rates was reduced landing delays. Comparisons of the loading operation from decks built by the yarder and by the skidder showed a significant time savings when loading from skidder decks. The portions of the loading cycle most affected were the sort and swing loaded elements. The analysis indicated that sorted decks oriented at small angles to the road and decked as high as possible required the shortest loading time. The skidding cycle was evaluated from a mechanical engineering approach and compared to regression analysis results. The results showed that the skidder was capable of production rates in excess of 10 cunits per hour. The hooking and decking elements consumed the largest portion of the skidding cycle. An alternate method of hooking or investigation of a grapple attachment is suggested.

Important factors influencing the harvesting of a unit were identified and a model was developed to aid in planning. The influence of landing geometry as related to log holding capabilities of a landing, log diameter, and stems removed per acre are explored.

Despite an improvement in overall production, the skidder did not prove cost effective for the study when its full cost was charged to yarding production. There were indications, however, that the skidder or a loader may be a necessity for longer yarding distances, flat decking slopes, high stem removals, or larger diameter trees. The skidder cost benefit ratio may also be improved if the skidder or operator remain active in the overall harvest operation when not needed for swinging and sorting.

Demand for outdoor recreation in the Pacific Northwest is growing each year. Recreation planners need to know where this demand is coming from if they are to properly plan recreation facilities. This paper discusses development of a model to estimate where overnight campers come from and how they get to camping areas in Oregon and Washington. This recreation traffic distribution model, RECDIS, is based on the gravity model used widely in urban transportation planning. A recreation travel network for the Pacific Northwest was developed and RECDIS predicts the route campers will take in going from their homes to campgrounds. The model only considers campers that live in Oregon or Washington. Data from the Pacific Northwest Outdoor Recreation Study is used to help predict campers' destinations.

The model results were compared to two surveys of campers in Oregon. The model and the actual survey results compared reasonably well for some of the places of origin, but there were several discrepancies, indicating that additional model calibration is needed.

McNEEL, R.E. 2000. Transportation production planning of an eastern Oregon hybrid poplar plantation. (MF)
The current production plan at the Potlatch Hybrid Poplar plantation in eastern Oregon is to haul 8,000 whole trees per day (170,000 bone dry tons of chips annually) to a centrally located processing facility (CPF) where the poplar will be processed. Harvests begin in 2001 and continue on a seven-year rotation. A transportation system for the Potlatch Corporation plantation is developed. The study provides a “stump to dump” transportation route model, a review of field tests, and a transportation schedule that predicts production based on loads, transportation times and costs from any harvest unit on the plantation to the CPF. Primary objectives are reduced costs through efficiency, workability and safety.

The transportation route system computes the shortest and “safest” transportation routes from harvest units to the CPF. Tree transportation speeds and times were obtained from field tests, and are included in the discussion of tested hauling equipment. For production management, spreadsheets are developed to modify and analyze different routes, and to monitor and maintain transportation efficiency. Data in the spreadsheets include harvest unit in acres, numbers of trees in each harvest unit, and hauling and return distances from corners and centroid of each harvest unit to the CPF. With this information harvest and transportation times, loads, and costs of harvesting any block on the plantation can be simulated.

An average 1.6-million trees will be harvested annually (11.3-million trees per 7 hear rotation) and hauled with an estimated 15,500 wagonloads in 46,000 harvester hours. When the constructed transportation route model was analyzed with field data, it was determined that four harvesters are sufficient to meet the 8,000-trees/day goal at Potlatch plantation. Eleven tractor/wagon combinations will be required to maintain continuous harvester production on the entire plantation at any time. Analysis indicates that harvest and transportation costs per rotation are approximately seven million dollars ($7,000,000) or an average of one million dollars ($1,000,000) annually. The estimated harvest and transportation cost is $0.625 per tree.

In field production/time studies must be performed to fine-tune routes and equipment. Several recommendations are presented that emphasize areas of greatest concern related to transportation speed, safety, productivity and overall profitability.

MCNUTT, J.A. 1976. A stochastic analysis of erosion and economic impacts associated with timber harvests and forest roads. (PhD)
A complex and sometimes serious problem facing modern day forest managers is that of estimating and analyzing potential on-site impacts which result from forest activities. A major type of adverse impact is man-initiated forest erosion. This consequence can be substantially magnified when forest harvest and road activities are implemented in steep, sometimes unstable terrain, characteristic of much of our Western forest land.

The objective of this study was to develop an analysis methodology and a decision model which will assist in evaluation of timber harvest and forest road alternatives and the potential scope of concomitant erosion consequences. The study effort consisted of four distinct parts: 1) development of probability functions for seven individual erosion events; 2) structuring a system model which simulates timber harvest and forest road alternatives in terms of several model products; 3) building an economic model which evaluates added capital costs associated with the erosion potential of each harvest and road for expected road and slope erosion events. The basic goal of this forest system study was to provide land managers with a tool for obtaining additional measurement parameters for proposed harvest and road alternatives. In order to illustrate how such a tool may be applied, the study concluded with an application of the complete methodology for ten well specified harvest and road alternatives. These alternatives ranged from highlead clearcutting to helicopter partial cutting to no harvesting at all. Output of system analysis for these alternatives demonstrated that harvest and road capital
components and erosion consequences can be integrated jointly into the decision making process.

MCCracken, M.J. 1994. Drained behavior of a silt soil under repeated load triaxial testing. (MS)
The study of the response of cohesive soils to traffic loading (repeated deviator stress) has been the subject of considerable study and research over the past 40 years. The purpose of the testing program presented here was to better characterize the behavior of a cohesive subgrade soil in response to repeated loading which modeled the conditions of a low volume aggregate surfaced forest road. There were three elements of the testing described herein which set these tests apart from the majority of the testing reported in the literature. These elements are the low confining stress which was used, continuous drainage throughout repeated load application, and the matching of the deviator stress to the confining stress.

Eight repeated loading tests were performed on a cohesive soil (MH, Unified Soil Classification) modeling three different levels of aggregate thickness within the range generally expected on forest roads. The permanent and recoverable strain, as well as volume change of the sample were measured as the pulse load application progressed. Several of the samples were also subjected to undrained monotonic shear phases performed both before and after the repeated load phase of the test in an effort to characterize the soil strength change due to repeated loading.

The results from these tests demonstrate the sensitivity of a fine grained soil to the stress conditions associated with a small change in aggregate thickness. They further give an indication of the variability in the rate of strain accumulation for those samples which were tested at the same stress levels. The sensitivity and variability which appears to be an inherent part of this problem was consistently shown in all of the results.

McRae, J.R. 1977. A force analysis of directional felling. (MF)
Environmental concerns have prompted the need for reviving an old art; controlled felling. The methods currently used, jacking and lining, present new and varied problems for the faller in today's environment. One of the major concerns of the faller is the purpose of this paper what kind of forces are being generated on a tree by using mechanical assistance and what are these forces doing to his falling procedures? This paper presents an analytical approach to these problems and presents the results in a form useable by the faller in the field.

Growing societal demand for forest products is pressuring managers to increase productivity from a finite land area, and it is expected that increased supply will come mostly from expansion of intensively managed stands. The USDA Forest Service and numerous collaborators created the Long-Term Soil Productivity (LTSP) network of research sites across North America to investigate the implications of intensive management. The purpose of the LTSP research program is to examine effects of management disturbances on soil productivity, evaluate standards for soil quality monitoring, understand fundamental relationships between soil, forest management practices, and long-term productivity, and to examine ways to mitigate adverse disturbance effects. Research in this thesis was conducted at the Matlock, WA and Molalla, OR LTSP affiliate sites, which were specifically designed to examine effects of contemporary management practices on growth and productivity of Douglas-fir (Pseudotsuga menziesii (Mirbel) Franco) as well as the driving soil factors associated with productivity. Three levels of logging-debris manipulations (bole-only, whole-tree, bole-only with debris piling) and two herbicide treatments (initial and sustained control) were replicated using a randomized complete block design at each study site. A stratified sampling scheme was used to characterize needle-litter decomposition (using a litterbag study) and associated nutrient dynamics as well as net nitrogen (N) mineralization (using in situ sequential coring) in the mineral soil. Rates of needle-litter decomposition were highest in conditions characterized by thick debris coverage. Needles acted as an N sink, immobilizing 14 to 40 kg N ha⁻¹ y⁻¹ initially. Needles were a source of potassium (K) and calcium (Ca), and a minimal source of phosphorus (P) and magnesium. Soil net N mineralization results were highly variable, likely reflecting extensive soil variability, although some patterns were observed. Nitrate-N was the dominant inorganic N form in soils, and accumulations between 25-45 mg N kg⁻¹ soil yr⁻¹ were found at sites. A faster Douglas-fir needle-litter decomposition rate was observed in bole-only logging-debris treatments at Matlock (lower productivity site), which also retained higher N, P, K, and Ca percentages than other treatment types. No treatment differences in needle-litter decomposition and nutrient-release dynamics were observed at Molalla (higher productivity site), possibly resulting from greater resource
availability. At both sites, a combination of soil net N mineralization in the range of 25-75 mg N kg\(^{-1}\) soil yr\(^{-1}\) and high rates of initial N immobilization in decomposing needle materials suggests that N is being retained in response to the three logging-debris and two vegetation control treatments. Early dynamics of these two soil processes suggest that soil N pools are initially conserved.

MICKELSON, J.S. 1990. An evaluation of project management software. (MS)
Project management programs are generic in design, allowing a wide variety of applications from various disciplines. Project management techniques have not been utilized extensively in the logging industry to schedule road construction. In March of 1989, Region 6 of the U.S. Forest Service asked for assistance in the evaluation of personal computer project management programs for scheduling forest road construction activities.

Road construction on National Forest lands is characterized by a number of problems, some of which are not encountered in other types of construction. These characteristics include a short construction season, limited labor and equipment, remote project locations, inclement weather delays, and coordination of construction with logging and recreational activities. Because of these problems, the ability to schedule road construction activities is an important component of the planning and construction phases of forest road construction.

MIKKONEN, E. 1981. The choice of the optimal sawtimber harvesting system. (MF)
An extension of the sensitivity analysis of linear programming, called parametric programming is used in determining optimal sawtimber logging system mix. The five logging systems under study are manual log-length system, log-length processor and harvester systems, manual tree-length system and tree-length harvester system. In conditions where it is not exactly known how much the monetary value of the final saw wood varies as a function of the logging system used, the parametric programming approach gives the ranges for those values.

If the market value of the saw wood is the same no matter what logging system is used, it is economical to use tree-length harvesting systems under the assumptions of the study. However, if the difference in value is more than 3.90 $/m^3 (14.85 Fmk/m^3) in favor of log-length systems, the tree-length systems are completely replaced by log-length systems in the conditions of Southern Finland. These results cannot be generalized, however, since each sawmill must be regarded as a special case. The approach developed for this study can be used to solve the problem in each particular case.

Land managers are increasingly turning to a new tool for visually depicting, analyzing, and communicating the technical aspects of forestry, specifically in the area of timber harvest and unit design. This tool is computer-based image editing software. In the 1980's, it was referred to as image capture technology, or ICT. In the 1980's, it is called digital photography, or video imaging. Regardless of which terminology is used, it all refers to editing images to display some particular effect. In this paper, I will use the term image editing.

The objective of this paper is to aid the natural resource manager in learning and applying image editing techniques to display the visual effects of timber harvesting. There are many articles that address the use of edited images, but few that actually provide step-by-step instruction on how the images were created. This paper is a basic introduction in how to use image editing technology. It is understood that software product upgrades will make this paper obsolete in just a short time, but the basic concepts will remain the same.

Chapter 2 provides some discussion of the software and hardware required to begin editing images. If you are knowledgeable about computer hardware, you may just want to read the section on input and output devices. There are many such devices available at a wide range of prices. The discussion is limited to the "affordable" choices. These are deemed "affordable" because it is assumed that the computer will be used in an office environment where the computer will not be used solely for image editing. Funds will probably be limited to those devices and applications that have use under a multi-tasked computer system.

Chapter 3 contains the step-by-step processes for editing an existing forest landscape. This chapter includes exercises on how to edit an image (regardless of the source of the image) using the tools available in Adobe Photoshop version 2.5 software program. The instructions include examples of overlaying one image onto another, editing an image to show timber harvest units on a landscape, and portraying changes in the harvest units over time due to timber growth.

Chapter 4 discusses the need for an image library. A small library is included in this section as an example. You will need to create your own image library depending on the type of terrain that you intend to stimulate.
The Appendix includes a glossary of terms that are commonly used in image editing.
This tutorial was tested by a group of natural resource managers. Their comments and suggestions have been incorporated in this document.

In Pakistan, forest land is either owned by government or at least managed by provincial forest service if it is private land. Timber is logged by contractors and delivered by small four wheel drive trucks over low standard roads to a transfer yard, where it is unloaded to await transport to an auction market by on-highway trucks. Six months to one year may pass between the time the timber is harvested and when it is delivered to the auction market, due to a variety of reasons related to the present transportation system. Not only is the transportation cost high, but deterioration of timber due to delays in delivery causes a significant reduction in value as well as a delayed revenue. This study analyzes an alternative transportation strategy; to construct higher standard roads, use on-highway trucks with trailers, and eliminate transfer yards.

The specifications of typical on-highway trucks are reviewed in order to determine the ability of the trucks to operate in adverse terrain and under necessary road standards. The study finds that gradeability and off-tracking of on-highway trucks is adequate.

A break-even equation is formulated to determine the volume of timber needed per entry to justify the higher standard roads. The study concludes that under some conditions found in Pakistan, the construction of permanent forest roads and elimination of transfer yards will yield both greater revenue to the government and increase the supply of higher value timber to the market.

The break-even volume is found to be sensitive to assumptions of the discount rate, road construction cost, and loss in timber value due to deterioration in transit.

The purpose of this project is to evaluate the fitness of the Laser Technology Inc., (LTI) tree laser device for use in low volume road surveying, and to develop a method for performing such surveys.

This study focused on determining the precision and reliability of the tree laser measurements of horizontal distance, azimuth, and vertical inclination. In addition, a standard traverse and cross section survey performed by a five person crew for a low volume road was duplicated by a two person tree laser crew for use in a time and cost comparison of survey methods. A software package was designed and prepared to manipulate and format the tree laser data as required for import to LUMBERJACK, an existing road design package.

Study results indicate that the distance and vertical angle measuring capabilities of the tree laser exceed the requirements for low volume road surveying. Tree laser azimuth measurements, however, do not meet requirements. LTI is upgrading the compass engine in the next generation device, thus further testing is required. Study results indicate possible survey time savings of 20%, and survey cost savings of about 63%. Savings in time and cost of keypunching survey data is potentially 82%. A Forest unit surveying 50 miles of road per year could expect to save 59% of its total survey and keypunching cost by using the tree laser rather than the standard surveying method.

MOORE, T.L. 1987. An empirical evaluation of three network analysis programs used in the USDA-Forest Service. (MS)
Network analysis is frequently used in forest applications to determine the most economical network of roads to construct and direction to haul timber. Computer programs have been developed to facilitate this task.

The accuracy of three of these programs used by the USDA-Forest Service is evaluated for the single time period analysis including fixed and variable costs. Input data for five planning areas was prepared and run through the MINCOST, TIMBER TRANSPORT, and NETWORK models. The errors in the models are compared to uncertainty in the input data. The sensitivity of each planning area to variability of the input data is estimated and compared to the errors generated by each network model.

The results show that the NETWORK model provided the best solutions for all five planning areas. The TIMBER TRANSPORT computer program developed the greatest variation from the best solution. TIMBER TRANSPORT generates optimal solutions only for smaller networks as a result of a program error in the model. The MINCOST program has difficulty solving simple three node loop problems in field situations as well as
experimental problems.

The errors provided by the models were more significant than reasonable errors expected in the input data.

The preparation of suitable sites for planting and growing of tree seedlings following logging is recognized by British Columbia Forest Service as a major silvicultural problem in the Central and Northern Interior regions of the province. Over the past few decades, scarification trials have been made with various types of drag and blade scarifiers. Substantial areas, particularly on the dry lodgepole pine (Pinus contorta latifolia) sites have also received mechanical scarification on an operational scale.

The wet white spruce--alpine fir (Picea glauca ssp. glauca--Abies lasiocarpa) sites, which often have a deep layer of decomposed organic material on the forest floor, have traditionally been winter logged. The resulting accumulation of undisturbed duff, and logging slash, has normally been either windrow or broadcast burned. Some recent escape fires, e.g. the Eden Fire on the Kamloops Forest District in September 1973, caused considerable personal property damage, and have heightened interest in mechanical scarification as an alternative to prescribed burning.

The author had occasion during the summer of 1974 to be employed by British Columbia Forest Service on a research project in the Prince George area entitled, Silvicultural Mechanical Site Preparation (S.M.S.P.). The purpose of this study was to measure and evaluate the performance of selected mechanical scarifiers, in producing an economically, and silviculturally acceptable level of planting site preparation.

This report examines the findings of the S.M.S.P. project, and where appropriate, compares them with earlier Canadian forest scarification studies. Recommendations for the use of specific mechanical site preparation equipment are viewed both singly, and in combination with other forest management practices.

MORDENO, A.G. 1963. Drainage structures for logging roads with special reference to Philippine conditions. (MF)
Drainage may be defined as the science of directing the removal of excess surface and ground water in such a manner as to safeguard the best interests of all concerned. Its ultimate objective in roads is the prevention of damage or failure of the road surface and subgrade by the action of storm water, seepage, underground flow, and capillary rise. The stability of roads is greatly affected by excess water due to the reduction of the soil bearing capacity.

The importance of drainage in any logging operation should be considered during the time of planning, design, construction, use and maintenance of roads. Sometimes a good road becomes impassable at a very vital time due to the absence or damage of a drainage structure. On the other hand, a poor road may be useable at such a time due to the presence of a good drainage structure.

In the Philippines, the industry is very exacting in its demand. Log exportation and the growing plywood industry demand fresh and good-quality logs. In the tropics it is not a good practice to leave logs in the woods or landings for a long period of time to wait for good weather. They have to be moved and dumped into the log pond within 24 hours after felling to prevent or minimize the attack of pin-hole and bark borers. Hot logging requires logging roads to be maintained always in good condition for truck hauling regardless of the weather condition. And maintenance in logging roads is almost always in reference to drainage.

This paper is a bibliography of drainage structures ranging from the cheapest and most primitive to the most modern and expensive ones. Much of the information and data presented comes from the review of available written material on road drainage and through observations and consultations by the author in the field in the Philippines, California, Nevada, Oregon, Washington, Montana, and Idaho.

MULLIS, C.F. 1994. The use of sawmill generated woodwaste as a construction material in low-volume forest roads in southeast Alaska. (MS)
Wood fibers have a long history of use in road construction across the United States and British Columbia. Wood fibers have been used in highway and low-volume road construction to reduce landslide potential and to cross settlement sensitive areas. The U.S. Forest Service has used wood fibers in many forms as an embankment material and as an alternative surfacing material. There are many forms of wood fibers that may be used in construction, these include: brush, construction slash, chunkwood, and sawmill residue such as bark, sawdust and planer shavings. This report discusses the history of wood fiber use and a recent U.S. Forest Service
Demonstration project which used sawmill residue to construct 4.5 kilometers (2.8 miles) of forest access road in Wrangell, Alaska. The project was implemented to study the suitability of these materials for use in Southeast Alaska. An evaluation of the engineering performance characteristics was conducted in an effort to determine some guidelines for future use. This evaluation focused on the rutting potential and road stiffness. A series of field and laboratory tests were conducted to address these issues. The main findings of the study are that the wood fibers perform adequately as both a driving surface or as a base layer for aggregate surfacing materials such as crushed or shot rock. When used as a driving surface, routine maintenance must be done to correct rutting and low frequency washboarding that occurs. Blading may be done easily with a standard motor grader or a bull dozer.


Over the next quarter century there will be about eight-fold increase in the volume of wood harvested annually from New Zealand's steep terrain radiata pine plantations. With the move to steeper terrain it is expected that there will be a trend towards considerably smaller landings. With smaller landings final log manufacture could have to take place at alternative locations to the large landings normally used. The locations examined in this thesis were: at the stump, at a landing, and at a central processing yard. Comparisons were made on the basis of value recovery, harvesting productivity and costs, and land taken out of production by landings.

A field trial indicated that value recovery at the landing was better than at the stump but the magnitude of difference was dependent on individual log manufacturers. Better value recovery on the landing was generally due to more logs meeting specifications and more accurate length measurements.

Radiata pine stems are too long to be hauled to a central processing yard without some initial cuts being made at the stump. Initial cuts preempts future log manufacturing decisions. An analysis of fixed long length patterns indicated that about 5% of possible value would be foregone by these preemptive cuts.

To analyze the effect of alternative log manufacturing locations on harvesting productivity and costs a stump-to-mill door simulation model was constructed. Tree-length logging to large landings was the most productive and least costly alternative, the stump was the second best alternative, and the central processing yard was the most expensive and least preferred alternative.

In an overall economic analysis it was concluded that where possible large landings and yarders should continue to be used. Where it is not possible to use large landings, final log manufacturing should be carried out at the stump, provided log manufacturers have handheld computers to assist them in decision making so that value recovery is kept as high as possible.


Results of a recent production study indicate that a four man crew thinning young growth Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] with an Igland-Jones Trailer Alp can produce 1360 to 1460 cubic feet (38 to 41 cubic metres; 8150 to 8750 bd. ft.) per eight hour day on slopes of 10 to 50 percent with average slope distances of 150 to 300 feet (46 to 91 metres) and average lateral yarding distances of 30 to 50 feet (10 to 15 metres). The stand studied was thinned from 226 stems per acre (558 stems per hectare) to 130 stems per acre (321 stems per hectare). The average tree size removed was 19.4 cubic feet (0.55 cubic metres) and the average log size yarded was 12.9 cubic feet (0.36 cubic metres). A standing skyline system was used with a haulback line attached to hold the carriage in position during lateral yarding.

The cost of a four man crew felling, bucking, and yarding this material with an average slope distance of 250 feet (76 metres) and an average lateral yarding distance of 35 feet (11 metres) is estimated at $36.63 per cunit ($12.93 per cubic metre; $61.04 per Mbf.). A three man crew operating under the same conditions would produce only 1160 cubic feet (33 cubic metres; 6950 bd. ft.) per day but the unit cost of production would be lower at $35.30 per cunit ($12.46 per cubic metre; $589.83 per Mbt.). During the study, operating delays accounted for 26 percent of total study time and skyline road changes accounted for 10 percent of total study time.

The use of intermediate supports can successfully extend yarding distance on unfavorable slopes and can facilitate efficient decking if placed within 100 feet (30 metres) of the landing.
NICKERSON, D.B. 1978. A model for the determination of optimum setting dimensions for tractor yard/swing operations. (MS)

A problem of interest to forest managers is the optimum arrangement of truck roads and landings for economical logging operations. This problem becomes more complex if a combined yarding and swinging operation is considered. It is possible to formulate a mathematical model to express the cost per unit volume for a particular configuration of truck roads, landings, and swing roads arranged to accommodate this type of harvest operation. Then, any of several numerical methods may be employed to assess the sought-for optimum configuration. The parameters of interest are the truck road spacing, landing spacing, and swing road length that produce the smallest logging cost. This paper critically examines several assumptions made in formulation of the problem, including yarding cost computation, tractor movement patterns, and average yarding distance.

This paper uses a numerical method not frequently employed with constrained objective functions: Newton Multivariate Gradient Iteration. A computer program was developed to implement the iteration procedures, using a Hewlett-Packard 9830A Desktop Computer. The solution procedure reduced iterations required for convergence from several thousand experienced with exhaustive enumeration techniques to less than thirteen. The use of this gradient method, observations on its behavior, and insights into the analytical approach to a complex problem are the subjects of this paper.


Factors that need to be taken into account in analysis of double-lane versus single-lane are identified. Methods are addressed for obtaining monetary values for as many of these factors as possible. Emphasis is placed on methods for obtaining accurate travel times and vehicle operating costs. A method is outlined by which data for traffic on the existing single-lane road can help predict travel times on a double-lane road. This method is compared with the results from the Logging Road Handbook method and the Vehicle Operating Cost Model.

A method for calculating accident costs on single-lane roads is adapted from a procedure for calculating double-lane road accident costs. A procedure is proposed for applying the level of service concept of describing the operational conditions within a traffic stream to a single-lane road.

An entire double-lane versus single-lane analysis is completed to show how an analysis can be done. For this example the monetary benefits of building a double-lane road will only pay for about 35 to 40 percent of the cost.


Evaluating different timber transport configurations for a large road network is a challenging task. Road curves are often too sharp to allow access to certain configurations. This paper evaluates the feasibility of using a geographical information system (GIS) road data set as a basis for determining the accessibility of plantation roads for several truck configurations and to determine the optimal road system for tree given vehicle configurations by minimizing total cost. The main constraint considered is the ability of a vehicle configuration to move through the curves found in the road network of the Elandshoogte plantation, Mpumalanga, South Africa. There are two objectives in this project: 1) to evaluate the feasibility of using geographical information system (GIS) road data as a basis for determining the accessibility of plantation roads to several truck configurations and 2) to determine the optimal road system for the three given vehicle configuration by minimizing the total cost. Constraints are generated by calculating the amount of offtracking for each vehicle configuration for all the roads and road connections found on the plantation by using the OFFTRACK program (Erkert, 1989). The minimum cost network is solved by using NETWORK 2000 (Chung and Sessions, 2001).

OHMSTEDDE, R.H. 1977. Production rates and skidding cost of the FMC model 210 CA high-speed skidder. (MF)

This paper describes the results of a time study conducted on the Malheur National Forest to determine production rates and skidding costs of the FMC model 210 CA high-speed skidder. Skidding distance ranged from 100 feet to 1550 feet, skid trail slopes varied from 10 percent to 50 percent, and 7,000 to 9,000 board feet per acre of ponderosa pine timber was removed.

Regression equations were developed for individual elements of the skidding cycle and also for total cycle time. Results suggest that skidding distance and number of logs per turn are the most significant variables in explaining cycle time, with slope and volume per turn playing a less important role. Skidding costs are comparable to those published for conventional skidders.

Uphill skidding capabilities of the FMC skidder have also been analyzed and a comparison with a crawler
type skidder suggests that the FMC has a definite advantage.

ORTMAN, T.L. 1977. Rock bolt anchors for cable logging systems. (MF)

All cable logging systems must be anchored at the end points and in some cases at intermediate points. Large stumps have historically been used for this purpose. However, in many areas such as second growth stands or areas of shallow soils, reliable stumps are scarce or non-existent.

A descriptive study was undertaken to examine current rock anchoring procedures in logging and other operations. This study included field observation as well as literature search.

Rock bolting was found to be widely used in the mining industry, primarily for rock stabilization and in civil construction for foundation stabilization. Logging applications were examined where rock bolts were worked with external loads applied in a variety of directions. Most of the installations in mining and civil construction were designed and tested while most of the logging applications were not.

It appears that rock bolt anchoring can be used on logging operations.

Reliable rock bolt anchors could be designed, installed, and tested to resist axial loads. For lateral loading, estimating loads is difficult because of the variables involved which include: 1) Identification of force reactions between the bolt, grout and rock; 2) the effects of non-axial loading on the behavior of the bolt, grout and rock.

It appears that even though laterally loaded bolts are indeterminate from a design standpoint, they can be used safely by adding safety factors. These factors include grouting and using two or more bolts in a picket configuration for every anchor.


Although previous research in central Oregon has shown soil compaction can lead to a decline in the site productivity, the subject is not understood well enough to predict the growth changes resulting from a given level of soil compaction. A student was initiated to relate the basal area, height and volume periodic annual increment (PAI) of residual, 70 to 80 year-old ponderosa pine (*Pinus ponderosa* Laws.) trees to compacted soil conditions, as measured by soil strength.

This study was superimposed on the USDA Forest Service Long Term Site Productivity Project research plots in Central Oregon and thus constrained by its design. Soil strength and tree growth were measured on six of these plots. Three plots had been thinned with a mechanical harvester and the stems removed with a grapple skidder from the plots (Complete Removal). Three other plots were thinned to similar stocking levels with the harvester, but the stems were left in place to minimize disturbance (No Removal). No true control existed for these installations as both the Complete Removal and No Removal plots were compacted by the harvester. A recording penetrometer was used to determine soil strength along systematically spaced grid points, to a depth of 24 inches. Each tree within each plot was mapped and measured for total height, diameter at breast height, and radial growth increment at diameter breast high (DBH).

The soil conditions around each residual tree were evaluated using 15-, 30-, and 45-foot radius plots. The penetrometer readings that fell within each of these plots were averaged to represent the overall soil conditions affecting each tree. The Complete Removal plots had significantly higher soil strength conditions than the No Removal plots (p<0.05). The percent increases in average soil strength of the Complete Removal plots over the No Removal plots were 39, 42, and 44 percent for the 15-, 30- and 45-foot radius plots, respectively.

Potential associations between basal area, height and cubic volume PAI growth rates and replication, treatment, soil strength and other covariates were explored with general linear models. Soil strength was not a significant factor for basal area PAI or for volume PAI at the 30- and 45-foot radius. Total height and cubic volume PAI at the 15-foot radius declined significantly (p<0.05) with increasing soil strength.

The volcanic ash soils did compact as a result of the low level of mechanical thinning activity conducted on the study sites. Tree growth was statistically associated with increased soil compaction. Lack of a tree control prevents full evaluation of the mechanical harvesting-related compaction; however, skidding resulted in a measurable increase in soil compaction in the Complete Removal plots. Forest management practices that lead to frequent entries appear likely to compact these volcanic ash soils. Depending on logging patterns, large areas could be impacted without careful planning. It appears that compaction effects are long-lasting and cumulative, thus the risk of reducing long-term site productivity is a concern.

PETAISTO, I.T. 1995. Critique of seven helicopter timber sales with recommendations for improved planning. (MF)
The U.S. Forest Service is one of the most publicly accessible agencies in the federal government. At present, virtually all projects, including timber sales, involve at least four levels of planning: forest, watershed, project, and activity. There is an extensive library of critiques, reviews, debates, and arguments regarding the effectiveness of planning in the Forest Service. It is beyond the author's disciplinary competence and beyond the scope of a Master's paper to evaluate all aspects (political, social, economic, and biological) of the agency's timber sale planning process. Therefore, this paper will focus primarily on the National Environmental Protection Act phase in the timber sale planning process and on two significant forest engineering questions.

PUUGH, E.V. 1985. Load bearing capacity of alder, spruce and hemlock tail trees. (MF)

This paper presents an evaluation of the cable loading support capacity of red alder, *Alnus rubra* Bong., Sitka spruce, *Picea sitchensis* (Bong.) Carr, and western hemlock, *Tsuga heterophylla* (Raf.) Sarg., tail trees. Capacity is measured in terms of combined stress resulting from compression and bending, rather than the traditional methods of buckling or compressive stress alone.

Results from field tests to determine moduli of elasticity, base stiffness values, and functions for moment of inertia are presented to provide strength properties for capacity analysis.

A two dimensional model with one guyline is used to calculate the combined stress at points along the trees. In addition to strength properties of each species, model inputs include front and rear skyline angles, rigging height, and the following guyline parameters: angle, metallic area, unit weight, modulus of elasticity, and lower end pretension.

The control calculations for each species are made with the guyline angle equal to a rear skyline angle of 45 degrees. A 3/4" guyline with 100 pounds of pretension is used, and the skyline and guyline are placed at a height of 30 feet. Given these conditions, it was found that a skyline angle of about 15 degrees below horizontal maximized combined stress per pound of skyline tension in alder and spruce. An angle of about 10 degrees below horizontal was found to maximize stress in hemlock per pound of skyline tension.

Figures are presented which show that skyline tension to be a given level of stress may be a function of tree diameter, if other variables are held constant.

Values for maximum allowable combined stress for each species are set by adjusting published average values downward. Calculations for 16 inch (diameter inside bark) trees indicate that hemlock is able to withstand the greatest skyline tension of the three species before reaching its allowable stress, with alder and spruce following in descending order.

A comparison is made between a 14 inch DIB Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, and a 16 inch DIB alder, spruce and hemlock. Calculations indicate the hemlock can withstand about 9% more skyline tension to its allowable stress than the Douglas-fir. An alder slightly over 17 inches DIB would be needed to support the same tension, and a spruce with a DIB over 18 inches, which is outside the range of field data, would be needed.


Whole tree and tree length thinning are two alternatives which are likely to be more productive and may prove to be more cost effective than conventional log length thinning. The purpose of this study was to evaluate and compare log length, tree length, and whole tree thinning techniques in terms of productivity and harvesting costs. The thinning operation took place in a second-growth Douglas-fir stand [*Pseudotsuga menziesii* (Mirb.) Franco] (average dbh = 12.8") using a small skyline yarder (28' tower, 120 HP) in a gravity return configuration.

The treatments were defined by the amount of work done by the faller prior to yarding. Log length implies that felling, limbing, bucking and topping occurred at the stump. Tree length indicates that trees were felled, limbed and topped only, and finally, whole trees were felled only prior to yarding.

A rubber-tired cable skidder was used to swing material from the landing chute to a processing area. Here the skidder operator completed any limbing and bucking which was necessary. He then sorted and decked the logs prior to loading. During log length thinning, logs were either cold decked in front of the yarder or swung with the skidder to a loading deck.

Detailed time studies were used to evaluate the felling and yarding operations for each of the three thinning techniques. Multiple linear regression was then used to develop predictive models for felling and yarding work cycles. An analysis of the delays on this study made it possible to separate out delays which were affected by a
particular thinning technique, rather than having a single prorated delay time as is usually done. By combining results from the regression and delay analyses, estimates of productivity for each thinning technique were obtained. Finally, harvesting costs in dollars per cunit at the loading deck were generated and used to compare log length, tree length, and whole tree thinning.

Results indicated that where cold decking is feasible and will not overly hamper the operation it will probably still be the cheapest alternative since a skidder is not required. The cost per cunit for this method was $8.24 or 11% cheaper than its closest competitor, the whole tree system. However, where cold decking is not feasible, as is often the case on steep slopes with narrow roads, the whole tree technique will be the most cost effective alternative. It has a per cunit cost which is $10.06 or 12% less expensive than conventional log length thinning with a skidder swing. The advantage to the whole tree system results primarily from transferring limbing and bucking from the stump to the landing where it is not only done more efficiently but also reduces operator idle time on the skidder swing.


Traditional rationale for design factors is briefly reviewed. Methodologies for determining these traditional design factors are lacking and are usually based upon subjective reasons which result in applying a design factor of 3.0 in all cases (western United States).

Factors which affect wire rope life are discussed. These factors include steel properties (i.e. elastic limit), rope construction, types of loading (static and impact), bending stress, fatigue, wire rope maintenance, line length, line use, and expected life.

Historically, the logging industry has not explicitly considered the economics of harvesting in selecting a design factor for harvest planning. Maximizing the service life of the wire rope may not maximize profit or minimize yarding costs. When cable yarding is considered, log production is a very important factor. The net payload which can be transported to the landing and the speed of the transport determine, to a large extent, the hourly production rate. In order to maximize production it is often necessary to operate at high line tensions. Although wire rope used in such a manner must be replaced more often (shorter life), work is accomplished which cannot be performed by any other means for the same cost. This paper presents a procedure for applying a design factor based on yarding costs.

Since the planning of most skyline harvest systems starts with some design factor for the determining maximum tensions which can be used on a particular profile, the economic approach for determining a design factor seems like a reasonable strategy. To the operator of a cable system, this strategy may be more appropriate than applying a design factor of 3.0 in all cases. Finding the optimum payload (or range of payloads) which minimizes overall yarding costs is a sound strategy for planning skyline harvest systems.

The procedure in this report uses a yarding simulation model to determine yarding production, wire rope tensions, wire rope lives, and yarding cost per unit volume. The simulation was done on a hypothetical timber stand with a running skyline system. Line lives were determined by accumulating the proportion of line life used as each turn was yarded. The number of bends until failure was used as a yardstick for determining line life. Yarding cost per unit volume was then compared as logloads were increased until a minimum cost was identified. Design factors for both the mainline and skyline for each average logload were calculated and compared.

The results of the simulation indicated that applying a design factor of 3.0 may not be appropriate when considering the effects of the design factor on yarding costs.

Crew safety was not considered implicitly in the procedure. However, modifications of the procedure to include crew safety are discussed.

RICHARDS, D.P. 1971. The efficiency of resource use in the logging industry. (MF)

Oregon's forest industry provides about sixty cents of each dollar earned in the state. The industry employees approximately 90,000 workers or about 65 percent of the state's industrial working force. In 1959 it contributed in excess of one billion dollars worth of production to the state's economy.

The raw material for this gigantic industry is grown on Oregon's 26 million acres of commercial forest land. Western Oregon, comprised of those counties west of the summit of the Cascade mountains contributes the major portion of this wealth. Seventy-five percent of Western Oregon or 14.5 million acres is considered to be commercial forest land.
Forest land through its multiple-use characteristics provides many intangible benefits to society such as watershed protection, wildlife habitats, and recreational playgrounds. However, these uses do not provide revenue for owners to offset annual carrying charges for land and timber or to undertake certain desirable forest management practices.

As indicated above, 46% of the forest land is owned by private tax payers. Many of these private owners are well informed timber producers supplying raw material for their own conversion plants or for the open market and conversion plants of others. In each case, these owners derive revenue from their lands.

Other private owners are less well informed, especially those holding areas of 5,000 acres or less. These are classified by the U.S. Forest Service as "small private owners" (4, p. 75). In Western Oregon there are more than 31,000 small private owners controlling 3,637,000 acres or 55 percent of the privately owned forest land (3, p. 11). About one-half of this acreage is owned jointly with farming enterprises while the other half is owned by persons in various field of endeavor.

Characteristically, revenue from sales of forest products from small ownerships is small and intermittent. Owners frequently do not realize the product potential of their forest crop, nor do they comprehend the market structure they face when making sales. These small owners sell directly or indirectly to primary wood converters, mostly sawmills, operating within a complex market structure. Many factors determining the market structure for these primary wood converters are transferred to the small owner when his products are purchased. The demand schedule faced by the primary converter becomes the derived demand schedule faced by the owner of small forest holdings.

To properly assess their market position, the small owners should be well informed on the market structure of the sawmilling industry. This information when judiciously used could substantially increase and stabilize the returns from forest products grown on their land. This should provide some incentive to undertake certain forest management practices to increase the productivity of their lands.

SALM, F.D. 1987. Central tire inflation study: the Idaho demonstration project. (MS)
The effects of operating log trucks with lower than recommended tire inflation pressures was investigated. The methodology consisted of two phases. First a literature review of the effects of tire inflation pressure on the pavement, the tires, and the vehicle and it's occupants was undertaken. Second, a demonstration project on the Cascade Ranger District of the Boise National Forest provided an opportunity to view qualitatively the effects of operating log trucks with lower tire inflation pressures. Measurements were taken in the field to establish base data on tire contact area, radius of contact, and truck dimensions. Additional measurements were taken to determine the displacement and the vertical strain in the pavement (earth) that was caused by the log trucks. Comparisons were made between the measured displacements and strains and computed displacements and vertical strains from the linear elastic pavement design model ELSYM5. Attempts were also made using the non-linear elastic program PSAD-PC.

This study has found that operating a vehicle with reduced tire inflation pressure at low operating speeds on low volume roads, will allow for a reduction in the design standard of the road, a reduction in the maintenance of the road, or an increase in the season of use of the road. Additional benefits may accrue to the users of lower tire inflation pressures.

The measured displacements and vertical strains were found to vary from the predicted displacement and strain by a factor of 10. It is believed that the measured displacement and strain are inaccurate. The program PSAD-PC is inoperable for analysis of aggregate roads. Modifications to the program to allow additional iterations would permit a determination of appropriateness for aggregate roads.

Pending the results of the analysis performed by the Tire and Rim Manufacturers Association, operating log trucks at low tire inflation pressures appears warranted. Additionally, this technology may be transportable to other segments of the trucking industry, such as oil, gas, mining, and agriculture.

SAUNDERS, G.P. 1987. Laboratory investigation of the mechanics of raveling soils. (MS)
Oregon's forestry industry has and will continue to be a vital component of Oregon's economy, with twenty-two percent of Oregon's 1986 gross state product and thirty-nine percent of Oregon's 1986 gross manufacturing product related the forestry goods. An integral component to proper management of Oregon's forestry lands is sustaining the timber yield from the commercial forest land base. The Oregon Forest Practice Rules and Statue (1985) mandates that commercial forest lands are subject to reforestation requirements. Forest lands which do
not meet these requirements are candidate for deletion from the commercial forest land base.

Reforestation of steep skeletal slopes has proven difficult; high seedling mortality has occurred due, in part, to dry raveling of the surface soil. Dry raveling is a form of slope failure on steep slopes generally characterized by surface movement of individual particles, and/or a shallow veneer of material. The extent of seedling mortality due to dry raveling is believed to be substantial in mountainous forest lands in Southwest Oregon. The present study represents a research effort to define the raveling process and the potential for seedling mortality due to dry raveling.

Laboratory testing of the raveling process was conducted using a tilting bed constructed to infinite slope criteria. Sixty-one raveling tests were performed on material taken from ravel-prone sites in Southwest Oregon. Tests involved variations in water content, grain size distribution, and profile thickness. Raveling angles, profile mantle failure angles, and the angle of repose were examined, along with the kinematics of the granular flow during mantle failure.

The raveling events were found to progress from individual particle movement, to particle assemblage movement, to mantle failure. A dry ravel model was proposed based on the analysis of the literature and test results. The ravel model reflected the dependence to the raveling system on the free surface boundary and momentum transfer to the surface material by the raveling particles.

The angle of repose was identified as a fundamental soil property which can be related to a dry raveling potential and therefore used by forest management personal as a slope limit above which progressively greater dry ravel-induced seedling mortality will occur.

SCHERER, T.E. 1979. Release-conversion of hardwood stands with a small skyline yarder. (MF)
The release-conversion treatment consisted of felling and yarding merchantable bigleaf maple (Acer macrophyllum Pursh), Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), and grand fir (Abies grandis (Dougl.) Lindl.) and windrowing the brush, tops, and limbs, in the skyline corridor by yarding. The treatment was conducted and studied with the objectives of (1) analyzing the cost of the treatment, (2) evaluating the damage, to the residual fir, due to the treatment, and (3) identifying operational problems and formulating guidelines for conducting the treatment.

An Igland-Jones Trailer Alp yarder was used in yarding the logs and brush on 7.3 acres (2.9 hectares). The Alp is a small skyline yarder that is powered and moved by a farm tractor. A singlespan shotgun system and a multispan system with a haulback were rigged for the yarding. A two-man crew was used in yarding the logs and a three-man crew was used in yarding the brush.

The brush was yarded by encircling and hooking it with the mainline, cinching it by tightening the mainline, and cutting it off with chain saws. This stage of the treatment was conducted after the logs were yarded.

The gross cost of the treatment (felling, yarding-logs, yarding-brush, and road change operation) was $1,462.08/acre ($3,612.78/hectare) (based on the total time, including delays). The net cost was $1,126.52/acre ($2,783.62/hectare). The net cost was determined by calculating a net return on the bigleaf maple and fir logs on the firewood and sawlog markets. The treatment could be conducted at the break-even point if the market price for the logs were three times the current level.

Stand composition and density were highly significant variables (at the 0.01 probability level) in predicting the productive time per unit area. Regression equations were generated which could be used to predict productive time required to conduct the treatment, and thus cost, for stands which vary in composition and density from the stand studied in this paper.

Damage to the residual firs was assessed by developing a bark damage index and a top damage index, and by determining whether or not a tree was a fatality or was bent from its original position. Based on these criteria, the fir reproduction density was determined to be reduced from 296 trees/acre (731/hectare) to 200 trees/acre (494/hectare). The stocking, on the other hand, was reduced from 22 percent to 19 percent (based on the stock quadrant method).

SCHNARE, J.K. 1978. Factors that affect USDA timber sale layout time in the Pacific Northwest. (MS)
The change in emphasis from tractor and highlead logging systems to the advanced logging systems of skyline, balloon and helicopter has stirred researchers to study the operations of the advanced systems. The extra work involved in preparing an area for contract timber removal using advanced logging systems, however, has not
been studied. The impacts of the extra time and extra manpower required for this process are large and they are important impacts which need to be taken into consideration during crew work planning. This is difficult to do since the factors which affect crew manhours have not been defined.

The objectives of this paper are to determine which factors affect the manhours spent on the presale fieldwork portion of preparing a U.S.D.A. Forest Service timber sale for contract; to compare presale field work time on conventional and special-design sales; and to develop a methodology for predicting presale fieldwork time.


In order to appraise timber, it is necessary to estimate logging costs with reasonable accuracy. The purpose of this study is to provide a method for estimating log loading costs in the Intermountain Region.

Nine different log loader were studied loading from cold decks on six USDA Forest Service timber sales in the Intermountain Region. Regression analysis indicated that loading time per truck was a linear function of pieces per truck. It also indicated a significant difference in loading times between hydraulic loaders and cable loaders. Regression analysis of sample truck scale data for each sale indicated that both the number of pieces loaded per truck and the volume per truck were functions of average piece size. The results also suggested that timber species affected volume per truck.

The time study regression equations and the sample truck scale regression equations were combined to obtain production equations for both cable and hydraulic loaders as a function of average piece size. Then estimated owning and operating costs for a typical hydraulic loader were combined with the production equation to obtain a relationship for loading costs per unit volume as a function of average piece size and hours of annual use. These costs were compared with costs obtained using the USDA Forest Service Handbook (Forest Service, 1977). Results of this comparison indicated that the USDA Forest Service appraised loading costs did not vary nearly as much with average piece size as did the cost estimated in this paper.

SEARS, J.Z. 1975. Yarding system and carriage development: a case study. (MF)

In recent years considerable work has been done in the development of improved logging machinery. The word improvement may bring to mind entirely new or improved systems which offer the logger greater mobility and efficient use of manpower. Logging has generally been labor intensive, however, "The need to achieve greater output to offset ever increasing labor costs prompted continued mechanization of the yarding process." (Hilton Lyson and Roger H. Twito, 1973)

Capital investment as well as labor has been a problem to the logging industry. Large and complex machines represent investments which necessitate continued use on high volume logging areas. The future may see size oriented development of logging machinery. By size oriented, I mean machinery developed so that the machine's size is as small as possible to handle the volumes of logs met on the logging units. To achieve the objective of lower costs through small machinery, the emphasis is on efficient use of gearing and cable alignment to achieve mechanical advantage (increase in power without increases in the forces applied) throughout the machinery system.

The reason for many improvements in machinery or methods is that an industry or individual is confronted with a problem that is not adequately solved by existing methods or machinery. This principle also holds true for logging improvements. Most of the machinery or even the logging methodology improvements require considerable ability in engineering and a knowledge of the problems confronted.

The whole system approach is needed in any machinery development. The system is made up of a number of components with each component relying on or affecting another component's performance. The whole system cannot be any better than the weakest component.

SEDLAK, J.P. 1978. The loading of second-growth Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) to simulate the forces acting on an immediate support tree. (MF)

The commercial thinning of second-growth stands in the Pacific Northwest is become increasingly important for satisfying the demand for timber. Cable logging will require the rigging of smaller intermediate support trees rather than those utilized on old-growth timber sales. This paper reports on the results of a study designed to evaluate the ability of second-growth trees to sustain the compressive forces similar to those generated by a cable logging system.
The movements of nine trees subjected to increasing amounts of force were measured with two theodolites. The conditions of loading were similar to those imposed on intermediate support trees. The study demonstrates that a tree will continue to move in the direction of its initial lateral movement. Once a tree is bent, the downward compressive force governs the movement of the tree. The results from the study are compared to Euler's design formula. It is suggested that a factor of safety be applied when designing an intermediate support. Additional research is proposed by the author to determine the forces acting on support trees during the actual yarding cycle.

SEIFERT, J.C.W. 1982. Production rates and residual stand impacts for four skidding machines during overstory removal. (MS)
This study compares production rates and costs for four ground skidding machines and for four harvesting treatments. The four machine types studied were a Caterpillar D6D crawler (D6D), Caterpillar 518 rubber tired skidder (RTS), FMC 200 CA (FMC), and International TD-8E crawler (TD-8E). Two treatments, conventional/whole tree and designated/tree length, were studied, and two, conventional/tree length and designated/whole tree, were determined through the regression analysis and statistical inference. Conventional versus designated refers to skid road location and restriction to, while whole tree versus tree length refers to whether the skidded trees contained limbs and tops or not.

The study took place in northern Idaho. The stand was two-storied and the overstory was removed to release the advanced understory. The overstory averaged 59 trees per acre and contained 23.0 cunits (gross) per acre.

Two operators were time studied for each of the four machine types to help eliminate operator influence and produce more meaningful comparisons. Eight operators, 483 hours of detailed time study, and 2,270 cunits skidded allowed for many delays and all significant variables to be averaged over machine types and treatments.

Regression analysis was used to develop equations to predict delay free elemental times. Indicator variables were employed to determine significant differences between conventional and designated skid roads and between whole tree and tree length skidding. In addition, significance was determined between independent variables. Delay free turn time was calculated by summing the predicted elemental times.

At an average residual distance of 350 feet, the study average, dollars per cunit for conventional/whole tree were calculated to be: D6D, $27.60; RTS, $19.00; FMC, $36.30; TD-8E, $27.70 and for designated/tree length: D6D, $27.10; RTS, $21.50; FMC, $31.40; TD-8E, $29.30. For all skidding distances and both studied treatments, the RTS was the most economical machine type. The FMC was the most expensive, and this is attributed to the low observed mechanical availability and high operating costs. The D6D and TD-8E were midway in costs. Lower initial and operating costs made the TD-8E more economical than the D6D for distances less than 500 feet for conventional/whole tree and for distances less than 275 feet for designated/tree length. Designated/tree length was more economical than conventional/whole tree for the D6D and FMC but not for the RTS and TD-8E. The main reason was that a significant increase in pieces per turn for the D6D and FMC offset the additional sawyer costs required to produce the tree length pieces. The RTS and TD-8E showed no increase in pieces per turn.

Just the restriction to skid roads (designated/whole tree versus conventional/whole tree) is expected to influence costs per cunit by: D6D, +$0.40; RTS, +$0.40; FMC, -$0.50; TD-8E, +$0.20.

Mortality and damage to the advanced regeneration was shown to be related to machine impact (visual signs of machine activity within an 1/200th acre plot). Plots not impacted by the machine (timber impacted) averaged 37 percent mortality and damage. The conventional/whole tree units averaged 34 percent machine impacted plots, and designated/tree length averaged 21 percent. Overall impact, mortality and damage, averaged 54 percent for the conventional units and 46 percent for the designated units. The eight percent difference was primarily mortality rather than damage.

Percent of area in skid roads was calculated using parameters collected during the damage study and assuming an average skid road width of 10 feet. For all machine types, 17 percent of the conventional units and nine percent of the designated units were calculated to be roaded.

SESSIONS, J. 1978. Effects of harvesting technology upon optimal stocking regimes of forest stands in mountainous terrain. (PhD)
Although one of the most common problems facing the forest manager is the determination of management
regime, there has been little effort to explicitly recognize the effect of harvesting technology and topography in the analysis. This study introduces a unified theory of harvesting in mountainous terrain which brings together silvicultural method, harvesting technology, product yield, and product price to identify the optimal path through time for a forest stand managed for the objective of maximization of net present worth.

Techniques for predicting harvesting costs as a function of the specific diameter distribution to be removed from the stand have not been available. The first part of the research fills this gap by the development of a harvesting simulator for mountainous terrain. Considerable detail is devoted to discussing the validity of model assumptions include log distributions, heuristic rules for log gathering and cost sensitivity with respect to the shape of the diameter distribution. The harvesting simulator is tested against two detailed time studies of Douglas-fir thinning in mountainous terrain and is found to compare favorably with field observations.

To develop the relative harvesting costs for illustration in the stocking level analysis, two skyline yoders typical of the range expected to be operating in second growth Douglas-fir are evaluated using the simulator. Analysis of the harvesting cost results indicates that over the range of values analyzed, the elasticity of harvest cost with respect to volume removed is constant for a given mean diameter of material removed.

Costs from the harvest simulator are combined with a Douglas-fir growth model in a three descriptor dynamic programming structure. The potential effects of diameter growth acceleration are modeled through biometric relationships between the three descriptors; stand age, trees per acre, and basal area per acre.

The optimal thinning regime and optimal rotation age are determined simultaneously for a medium site Douglas-fir example under a predetermined set of average conditions. The sensitivity of optimal stocking level to harvest technology variables of yarding direction, yarding distance, truck transport cost, and log gathering strategies is examined. Under assumed cost differentials between uphill and downhill yarding, bare land values for downhill yarding are lower than for uphill yarding and the optimal management intensity is lower with less frequent, heavier entries. Increase in yarding cost with distance indicate that optimal stocking levels not only depend on traditional concepts of prices and costs, but that management intensity is also spatially oriented. It is demonstrated that under certain conditions substantial increases in net present worth can be made by treating portions of the stand in the same skyline road and with the same rotation age with different thinning regimes. Haul costs are exogenous to the harvesting cost simulation. However, reductions in haul cost increase bare land values by at least the magnitude of the present value of the haul cost decrease and may increase the optimal level of management intensity. The sensitivity of management regime to log gathering technique is examined by formulating a prebunching model which stratifies the log handling activity into two components. Logs are first gathered into bunches along the skyline corridor, and then the bunches are forwarded up the corridor to roadside. Prebunching and forwarding under the model assumptions is found not only to increase bare land values but in some circumstances to reduce the cost of handling early thinnings sufficiently to justify noncommercial entries to accelerate diameter growth. Constraints eliminating noncommercial thinning opportunities are shown to reduce present value.

SHEMWETTA, D.T.K. 1997. Comprehensive timber harvest planning for plantation forests on difficult terrain: Sokoine University of Agriculture Training Forest, Tanzania. (PhD)

Plantation forests on mountainous areas in Tanzania, East Africa, were successfully established in the 1950's. Harvesting started in the 1970's to meet increased national timber demand. Current problems of unharvested areas and potential environmental degradation are associated with uncontrolled harvests, mismatch of harvest systems to site needs, and post-harvest practices. Comprehensive harvest planning is offered as the needed solution. Effective timber harvest planning is proposed for successful harvesting using a suggested process and protocol. Planning for difficult terrain in the United States Pacific Northwest (PNW) provides valuable lessons for objective refinement, systems selection, monitoring and planning tools of the protocol.

An area on the Sokoine University of Agriculture Training Forest (SUATF), Tanzania, with difficult terrain, valuable timber, and environmentally sensitive conditions is used to develop a planning protocol and monitoring guidelines for harvesting. A reference area on the Warm Springs Indian Reservation (WSIR) of Oregon provides comparative data for the project. Plan objectives, planning tools, harvesting systems options, implementation requirements and monitoring criteria were explored through observation, interviews and analytical procedures.

A planning procedure incorporating the technical, economical and institutional timber harvesting factors of Tanzania and other similar circumstances is demonstrated. Guidelines for monitoring plan execution and
harvesting impacts are shown, with a new emphasis on monitoring. The student recommendations and summary will help Tanzania national forestry policy to avoid crisis management in harvesting operations.

SHEN, Z. 1988. Log truck scheduling by network programming. (MF) In northeast China, logging has three stages; timber harvest, transportation and the operations inside a timber yard. The timber yard is an intermediate transhipment point between truck transport and rail transport to manufacturing centers. The transhipment capacity of the timber yard is often the limiting activity in the logging chain.

Since the transportation is the middle part, its management affects both the technology and the economics of the other two. At the same time, the other two stages provide constraints to the transportation operations.

The objective of this paper is to find an optimal economic plan for assigning trucks to timber yards in such a way as to minimize the number of trucks while satisfying the delivery schedule for the timber yard. This is done by controlling the log truck arrival distribution over time. As a result, the fewest number of trucks are used and the timber yard is efficiently used.

A computer program was developed to provide the transportation manager with detailed information about truck allocations and to permit rapid updating of the transportation plan.

The truck allocation problem is formulated as a capacitated network problem and the out-of-kilter algorithm is used to solve it. After the network problem is solved, the number of trucks needed to carry out the schedule can be determined through an hour-by-hour truck inventory analysis.

SHERAR, J.R. 1978. Production rates and a comparative analysis of fuel consumption for a live, standing skyline, and highlead cable yarding system. (MF) This paper describes the results of three time studies conducted in the Cascade and Coast Ranges to determine the production rate and fuel consumption of flyer, standing skyline, and highlead systems. Skagit BU-94 yarder was observed on the standing skyline system.

Regression equations were developed for individual elements of the yarding cycle and also for total cycle time. Results indicate that yarding distance and volume per turn were the most significant variables in explaining the variation in the time study data.

Actual fuel consumption data were recorded for each of the three systems by measuring the change in the depth of the fuel in the fuel tank at intervals during the time study. Total gallons of fuel consumed were calculated and used with the total volume yarded and the average yarding distance to determine the actual fuel consumption of each system in gallons per cunit - station (gal/cunit-sta). Results obtained from the actual fuel consumption analysis show that the flyer system used the least amount of fuel, 0.030 gal/cunit-sta; the highlead system used the greatest amount, 0.069 gal/cunit-sta; and the standing skyline system used more than the flyer, but less that the highlead, 0.043 gal/cunit-sta.

A model was developed for each of the three systems estimating the fuel consumption given the volume per turn, average yarding distance, number of pieces per turn (flyer only), and the horsepower of the yarder engine.

The model uses the regression equations to estimate the time spent in each element of the yarding cycle. The estimated time per element is then used with the fuel consumption rate (gallons per hour) as determined from the manufacturer's curves for the given yderer horsepower to estimate the fuel consumption in gal/cunit-sta. The procedure followed to build the predictive models is outlined in detail in succeeding sections.

SIDDIQUI, A.K. 1990. Evaluation of productivity and cost of chain saw vs. manual tools in the Chir Pine forests of Pakistan. (MF) To improve the present state of forestry and the condition of forest workers is an important goal to be achieved in developing countries. With the growth of population, demand for wood products is increasing tremendously. Prices have gone up manyfold. One way to meet this demand is to increase productivity by reducing the wastage of wood and by saving time on various operations. The present tools and equipment are no longer adequate to achieve this goal so we should introduce new machines in timber harvesting. Chain saws, the first step toward mechanization, was introduced successfully, about 40 years ago in Europe and Northern America. This study indicates that chain saws can be used effectively in the hilly forests of Pakistan. Productivity is increased 92% and 29% compared to manual tools, based on its effective time and total time respectively. The cost of the output of one cubic meter of wood with a chain saw is decreased 35% considering its effective time but for its total time,
cost is increased 6% over the manual tools. This increase in cost may be reduced considerably by reducing the high delay times through better planning and crew vocational training.

SIMONSON, R. 1990. Effects of tire deflection on rear axle torque. (MF)  
This paper presents data obtained in the study of an 18-wheel western type log truck outfitted with CTI and carrying a highway load. Operating on grades of 20 and 25 percent, drive shaft torque was monitored to quantify stress levels on the drive while varying tire deflection.  
This paper provides information on the limits of additional traction to be gained through the use of tire deflection when operating on steep terrain--without excessive tire slip or vehicle maintenance. Torque levels for each grade/deflection combination are presented.  
A combination of steep topography and escalating road construction costs have led to the use of shorter, steeper roads. To reach landings of harvesting operations with a minimum road length, spur roads are often constructed in the 20 to 25 percent slope range. Haul roads exist with grades of 15 to 20 percent. An assist vehicle is often appraised for when grades exceed 16 percent.  
Utilizing the proper tire deflection for the application (based on speed and load) appears feasible through the use of central tire inflation (CTI) systems. Benefits have been seen in reduced vehicular damage to forest roads and increased tire life. An additional benefit realized with the use of CTI is improved traction on some road surface types; because of the increased tire tread length.

SINNER, H. 1974. Simulating skyline yarding in thinning young forests. (MS)  
Cable logging systems are being applied frequently in thinning young-growth forests, but the dynamics of these systems are relatively unknown. This study is part of a research project to develop aerial logging systems for thinning and to analyze them for economic, silvicultural, and environmental implications. The objectives of my study were: 1) to measure the influence of thinning intensity, slope steepness, load size, skyline distance, lateral rigging distance, and number of workers on yarding times; 2) to develop a model to simulate these relationships under varying working conditions of the skyline system and to identify proposals for improved logging methods.  
I observed a cable-thinning operation on a 35-40 year old Douglas-fir stand on gentle and medium steep slopes. Three thinning intensities of 70, 50 and 20 percent, respectively, were applied. The skyline yarding work cycle was separated into six regular and three irregular elements. I used the multimoment time study method to observe these elements and obtained values for the variables that influenced these elements.  
Stepwise multiple linear regression analysis was used to analyze the effect of these variables on time required to finish an element. I developed regressions for four regular elements, carriage out, lateral out, lateral in, carriage in, and for total regular yarding time. Regressions with the observed variables did not produce adequate results for other elements. I analyzed only their frequency distribution. I tested the results of the analysis against a sample from the same yarding system in a different operation. Close correspondence in a chi-square and t-test, respectively, suggests the reliability of the regressions. Several suggestions were made for modifications that may improve the skyline system. They concern hooking and unhooking, the cable configuration, and lateral yarding.  
I developed a simulation model in the GPSS-computer language to simulate skyline thinning. The elements of the model can be modified to adjust to distinctive situations. I tested the influence of lateral yarding distance on total yarding time and simulated a regular approach with limited lateral yarding distance and a "line thinning" method.

SMITH, R.S. 2001. An Investigation of the Influence of Root Reinforcements on Soil Strength and the Initiation of Static Liquefaction in Forest Soils. (MS)  
A study was conducted to investigate the influence of root reinforcements on soil strength and the initiation of static liquefaction in forest soils. The design and operation was developed of an apparatus capable of modeling rainfall-induced shallow hill-slope failures that also permitted observation of the soil volume change tendencies at failure and at large strains. Fiber reinforced and non-reinforced soil samples were tested in field stress path mode until failure and in undrained constant rate of strain mode after failure. The reinforcements were oriented longitudinally in the soil samples and the samples were failed in extension to mobilize tension in the reinforcements. The pore pressure was gradually increased during field stress path testing by raising the water level in a water column connected in series with the backpressure line in order to simulate a rising water table.
during rainfall. The test results indicated that the reinforcements significantly increased the pore pressures necessary to initiate soil failure. An analysis of the data suggested that the water table would likely have to be at the soil surface of a hill-slope on a 50% gradient for the reinforced soil to fail; whereas, the non-reinforced soil could fail with the water table at much lower levels. The soil strength data, along with the fundamental assumptions of the Mohr-Coulomb failure criterion, suggested that a Mohr circle analysis of the reinforced soil data was inappropriate. The preliminary development is presented of a soil strength model that could account for reinforcement potential in terms of specific soil and reinforcement properties and the stress conditions required to cause slippage or breakage of the reinforcements.

Static liquefaction was not observed during the soil tests and the soil samples dilated upon failure suggesting a low potential for the initiation of static liquefaction; however, soil volume change tendencies following failure indicated that liquefaction on remolding may be possible at large strains. Moreover, the reinforcements seemed to be capable of preventing the initiation of liquefaction on remolding.


Over the past 15 years, changes in forest-management values have led to an increase in the amount of planning requirements necessary to complete harvesting activities. The measurement of forested land areas is typically a large part of operational plans. In the two studies presented here, new measurement technologies were examined for their effectiveness in meeting those requirements. Both investigations involved area measurements and corridor layout in the Oregon Coastal mountain range.

The first study compared four survey techniques for traversing 16 1-ac patches: 1) string box, hand-held compass, and clinometer; 2) laser, digital compass, and digital data collector; 3) global positioning system (GPS); and 4) the benchmark method, as set with a total station. Defining the effectiveness of each system was based on predetermined management objectives, including the precision and accuracy of data, time to complete the survey, and cost. Precision was highest with the total station, while the laser and digital compass method required the most time. The least expensive technique was the string-box method. GPS proved ineffective under canopy conditions. Potential differences in the orientation of harvest units were revealed because of variations in the horizontal angles used for measurements.

In the second study, two surveying techniques were compared against a benchmark (i.e., total station) for profiling skyline corridors for commercial thinning. The first method employed a string box, clinometer, and hand-held compass; the second, a laser, digital compass, and a digital data collector. Analysis of the profile information (slope distance and slope percent) by LoggerPC4 showed no significant differences (p<0.57) in lbs-per-payload results between the two surveying methods, based on t-tests. The string-box technique was most effective in terms of time (10.8 hr vs. 13.5 hr from the laser/digital method) and cost ($0.35/mbf vs. $1.00/mbf). These contrasts might be attributed to differences in: 1) the position of the critical point due to elevational changes within the mid third of the profile; 2) the elevation of the intermediate support; and 3) elevation of the tail hold.

The results of both studies demonstrate that many tools are available for completing operational planning and layout. Each has benefits and drawbacks that should be matched to the operational plan objectives.


SkidPC 2000, written in Visual Basic Version 6.0, is an updated version of the 1987 DOS program that calculates the mobility and productivity of ground-based logging vehicles over a ground profile. As in the original program, the user enters the vehicle and operational conditions and the program will calculate the vehicle speed, productivity, and other aspects of the vehicle, log, and soil interaction.

New features have been added to the program and there has been a complete revision of the program’s user interface. Additions to the program include the ability to model six-wheeled forwarders and clamshell skidders, and the ability to simulate wheel and track rutting. Throughout the updating of the program, small errors in the original version were corrected and the user interface was restructured and streamlined to utilize the features of the Microsoft Windows environment.

SkidPC 2000 is an updated tool for operations planners, loggers, foresters, students, equipment salespeople, and others to estimate productivity, ground pressure, velocity, and wheel or track slip. This program can be used to examine relative changes in operational performance to vehicle configuration, vehicle loading, and terrain
STARNES, L.W. 1984. Skyline thinning production rate equations obtained by transforming delay free turn time regression equations using the thin simulation model. (MF)
This paper shows how ten easy-to-use linear skyline thinning production rate equations were obtained by transforming existing but more cumbersome turn time equations using the THIN simulation model [11]. The equations provide reasonable approximations of delay-free hourly production for several cable yarders operating skyline thinnings under a variety of conditions. The equations have been limited to three independent variables which can be influenced by management decisions. The independent variables are relatively easy to obtain and include: cut volume per acre, average slope yarding distance, and average log volume. The production equations which were linearly regressed for user simplicity have an inherent source of error since some of the data is nonlinear. A log bucking model is presented which aids in the determination of average log volume. Suggestions for future transformations are offered.

STEFFAN, D. 1982. Mechanical brush control on steep slopes in southwest Oregon. (MF)
Undesirable brush species presently occupy a substantial portion of land available for commercial timber production in the Pacific Northwest. In the Oregon Coast range alone, 15% or 568,400 acres of forest land are occupied by noncommercial vegetation. If converted to full conifer production this land has the potential of producing 31.5 billion board feet of timber over a 60-year rotation.
Such lands exist today due to a variety of reasons including natural succession, natural catastrophic events, i.e., fire, and man's activities. Indians used fire on lands in southwest Oregon to enhance big game habitat. This practice was used by early settlers to convert lands for livestock management. More recently clearcuts left to natural regeneration have resulted in brush-fields and hardwood stands. More specific and detailed information concerning the geography, history, and description of brushfields in southwest Oregon is available.
The problem of combating competing vegetation for site preparation or release has confronted foresters since the advent of modern forestry. Many tools have been developed to aid the forester in this problem. They can be ground into three broad categories: fire, chemical methods and mechanical methods.

When considering a mechanized harvesting operation, the harvest planner or researcher is faced with a multitude of modern equipment choices. A decision support system (DSS) is presented to assist in selecting the appropriate level of mechanization. The DSS examines individual machines and formulates mechanized harvesting systems from them that adequately match the site and stand work environment, achieve user defined goals of a final product at a specific location, and operate within user defined constraints.
Individual machines are identified by assigned "attributes" describing the physical limits of operability and the equipment's interaction with other machines. Mechanized systems are constructed using the "output" of a machine (the product's state, location and accumulation arrangement) as an "input" for a successor machine. The "output-input" is also used as an eligibility requirement for potential successor machines in the system.
The DSS is implemented in a computer program called TIMBER HARVESTER for use on personal computers. The program makes use of a support data bases including mechanized equipment lists and common mechanized systems.

A model is presented which predicts the net present value of a stand level multi-entry harvest plan. The model accounts for potential volume losses due to harvest-related soil compaction. The goal of this project was to answer five economic questions about the issue of soil compaction in forestry. The five questions tested the sensitivity of net present value to changes in skid trail spacing, to avoiding compaction altogether by the use of aerial yarding systems, to different assumptions about growth losses adjacent to the skid trails, to initial site quality (high vs. low), and to different discount rates used in the net present value calculations.
Given the assumptions used in the applications of the model which are presented here, wider trail spacings were warranted while the use of aerial yarding systems to avoid compaction was not warranted. Net present value in this case was very sensitive to growth losses occurring in the area adjacent to the skid trails. Similar compaction ameliorization techniques were called for when high or low sites were considered and greater
ameliorization costs were justified when low discount rates were used in the net present value calculations vs. when high discount rates were used. Forest managers can use this model to gain insight into similar issues about harvest-related soil compaction.

The model was formulated as an electronic spreadsheet template that runs on IBM PC microcomputers or IBM-PC compatible microcomputers.


There is much interest in the State of Vermont in cable harvesting. Since there are not time studies available for cable harvesting with various machines in Vermont, it is necessary to arrive at production and cost levels by a different method.

The method chosen for this paper is made up of four parts. In the first part a decision table is used to decide which machine or machines best meet the requirements of the Green Mountain National Forest in Vermont. Second, using the (SAP) program for the HP 9830 desktop calculator, the payloads are found for each machine for a representative profile. Third, using this payload in combination with individual machine characteristics, a theoretical production per day is calculated for each machine. Fourth, yarding costs are constructed for a given set of conditions and this is combined with the production per day to arrive at a cost per MBF for each machine.

In this paper the method for arriving at theoretical production and thus cost per MBF, is compared against an actual study done with a Smith Timbermaster in Newfoundland. The cost from the model is $27.82 as compared to $28.35 per MBF from the study.

Using this method the machines found most suitable for conditions in Vermont that were specified were: 1) Ecologger II, 2) Rosedale Timbermaster, 3) Thunderbird, 4) Smith Timbermaster, and 5) Igland-Jones Trailer Alp. Payloads for a given profile were calculated for each machine. Using these payloads and individual characteristics, a theoretical daily production was calculated for each machine. Each machine was then costed out for situations when a skidder: 1) is required, 2) is not required to clear the landing. Both situations were then calculated twice: using 16% (taxes, interest and insurance) and using 20% (taxes, interest and insurance). The results show the inter-relationships between payload, production, initial costs, other costs, and the final cost per MBF.

Since under present conditions the initial cost may be as important to a purchaser as cost per MBF at the landing, this study allows the people on the Green Mountain National Forest a chance to estimate what they will be loosing or gaining by buying a particular machine.


Stumps are often used as anchorages for guylines support sparpoles and spar trees in cable logging systems. A single guyline failure may cause a logging system to become unstable and collapse, so the stabilizing forces that these stump anchors provide is of important concern.

Historically, the selection of adequate stump anchors has been based on past precedence or "rule of thumb" procedures. Large diameter stumps, in excess of three feet, are commonly available as anchorages in old growth timber stands. However, with the advent of second growth timber harvesting, smaller diameter stumps are often a logger's only recourse when selecting guyline anchors short of a more complicated man-made system. The ability to estimate the load carrying capacity of these stump anchors is therefore of great concern from the standpoint of safety.

The primary objective of this study was to develop a model to aid in the prediction of the response and load carrying capabilities of stump anchors. To achieve this objective, the following tasks were undertaken:

1) A review of the literature related to tree and stump stability.
2) A field testing program to determine the response of stump anchors under loading conditions. Lateral loads were applied to twenty Douglas-fir stumps while monitoring both horizontal and vertical stump movements.
3) Evaluation of the field testing results and development of the data into a rational, systematic approach for assessing the load carrying capacity of stump anchors.
4) The incorporation into the stump capacity model of a probabilistic approach of assessing safety in place of the conventional factor of safety method.
STRINGER, T.N. 1965. An economic comparison of construction of coastal logging roads by power shovel and tractor. (MS)
Logging road construction in the coastal regions of British Columbia has always been a difficult and expensive undertaking. The soils are generally ill-suited to road construction, rock outcrops are numerous, and climatic conditions unfavorable. In addition, the mineral soils are overlaid by a heavy layer of partly decomposed organic material. This "overburden" renders conventional tractor and scraper construction methods impractical.

For the Port Hardy Forest Development Road it was decided to experiment with three basic methods of construction; the power shovel method, the tractor method and a combination of the two. These methods were tried for nearly two years while accurate cost and production records were kept. A comparison was then made considering only the phases of construction that were affected by the construction method used. Soil types, climatic conditions and the resulting roadway were also considered in the determination of the best method of construction.

For the climatic and soil conditions considered, for the machinery used and for the results desired, the most advantageous method of construction was the combination method.

Gradeability of log trucks is limited by either vehicle rimpull or ground-tire adhesion. The analysis presented shows that log trucks in current use in the Pacific Northwest are limited by tire-slip gradeability rather than by rimpull. Analytic techniques were used to determine that gradeability is greatest for piggyback and least for empty truck configurations. Effects of horizontal curvature and superelevation rates on truck "seen" grade were analyzed as well as road design gradient limitations. Road design criteria graphs are presented in the appendices by log truck configuration for varying curve radii, superelevation rates, and centerline gradients.

TOBEY, A.C. 1980. Skyline analysis with log drag. (MF)
This paper describes a mathematical formulation and a computer program in basic language for analyzing the load carrying capacity of skyline systems using the effects of log drag. The actual log and ground geometry are used in the analysis of the payload capacities for standing, live and running skylines. The paper uses an example problem to show the effects of the various parameters used in computing payload capacity using the effects of log drag (choker length, log length, log to ground clearance, point of choker attachment, center of gravity of the log, coefficient of friction, and type of carriage).

The method described in this paper was compared with an existing method which calculated skyline payloads for a fully suspended load. It was found that when logs have one end suspension, there can be considerable difference in the payloads calculated by the two methods.

TOUPIN, R.C. 1985. Load deformation characteristics of multiple stump anchor systems. (MF)
This paper documents the development of a model which determines multiple stump anchor system displacement as a response to skyline load for four anchor rigging configurations: 1. Series multiple, 2. Tieback, 3. Elevated tieback, and 4. Equalizer block. It is also documents the field testing of four two stump anchors rigged in the four rigging configurations. A comparison of the model and field results is presented, as well as a discussion of load transfer from the skyline to the second stump.

Diagrams are presented which illustrate the model load-deformation curves for a variety of stump sizes and pretensions between the two stumps prior to skyline loading. Also presented on these diagrams are the loads at which system failure occurs.

Load-deformation curves for all four rigging configurations are similar when the two stumps are the same strength. When one stump is weaker than the other, the equalizer block system load-deformation curve is different from the curves for the other three systems, and the system fails at a lower total load.

Four sets of two stumps were field tested in the four rigging configurations. Within a load range common to all rigging configurations, the load-deformation curves for the four rigging configurations are similar.

Load-deformation curves for the model and field test data were compared. Curves were most similar for the series multiple and high pretension tieback configurations.

Since the load-deformation characteristics for the series multiple and the two tieback systems are similar, the preferable system is the one that is easiest to rig. The series multiple system requires less hardware to rig because the skyline is used as the link between the two stumps, rather than a twister. Consequently, the series
multiple system appears to be the preferred system.

The equalizer block system appears to be the least preferred system because it is likely to fail at a lower system load than the other systems.

The results presented are of limited scope. The field data was collected during August 1984 when soil moisture conditions were relatively dry, and the model computations are restricted because the linkage between the stumps was assumed to be rigid.

It is recognized that the capacity of a stump to resist applied loads might be influenced by varying soil moisture contents, particularly at a saturated level. However, the tests documented in this report were conducted when soil moisture was at a low level. The resulting load-deformation curves can be expected to change in magnitude as soil moisture content varies.

The model load-deformation curves were developed with the assumption that the linkage between the two stumps was rigid. The linkage is not rigid in a real anchor system. The positions of the system load-deformation curves may change if the linkage length is affected by line stretch, line travel, or wood crushing. The ranking of the four systems from preferred to least preferred could change if these three factors were included in the multiple stump model.

This dissertation re-examines the now standard perceptual model of hillslope hydrological response to rainfall, which includes the growth of a saturated wedge at the soil-bedrock interface or impeding layer. It also challenges the notion of bedrock impermeability and the assumption that the pattern of subsurface stormflow is determined by the soil moisture pattern. The results presented in this dissertation challenge the status quo model and show that at the Panola Mountain research hillslope, subsurface storm flow is a threshold-function of precipitation. This threshold is a result of a disconnection between transient saturated areas and the slope base during small to medium size storms (< 55 mm). Water must fill bedrock depressions before it can flow further downslope. Once filled, connectivity between subsurface saturated areas and the slope base is established and subsurface flow initiates. Transient saturation does not have the form of a saturated wedge but starts first in the shallow soil areas. The pattern of transient saturation does not resemble the pre-event soil moisture pattern but is a function of soil depth and bedrock micro-topography. Flow through bedrock is a major component of the hillslope water balance. Soil moisture distribution across the slope shows two distinct states: wet and dry. Soil moisture in the shallow soil areas of the hillslope limits transpiration during the late growing season but transpiration is not soil moisture limited on deeper soil sections. Overall, these findings represent a new perceptual model of hillslope hydrological response during and between rainfall events.

TUOR, B.L. 1984. Field testing the statics and dynamics of a scale model, tethered balloon logging system. (MF)
This paper represents preliminary engineering analysis on the pendulum swing balloon system. It also describes an analysis of measurements taken in the summer of 1982, during a field test of a 37,000-foot³ balloon used as a prototype model under static conditions. This work established the influence of important variables on the load lifting capabilities, the line tensions, and the balloon movement.

Balloon movement does not appear to be a major problem, for practical operating conditions it may be considered to be fixed in position. Line tensions were shown to conform with mathematical model predictions. The payload that the system can support at any given load position is a function of four variables: lift at the base of the balloon, the haulback line angle, the pendulum line angle, and the opposing guyline(s). Figures are used to quantitatively show the relationships. Although the paper is based on simplified mathematical models, static conditions, and a field test that wasn't an exact scale model, the results established an important understanding of the engineering fundamentals of this system.

UTTERBACK, P. 1992. Testing an urban pavement management system on a forest service road network. (MS)
The Pacific Northwest Region of the USDA Forest Service manages some 3,600 miles of low volume asphalt paved roads. The Region has been faced with a need to improve the effectiveness by which funds are allocated to pavement rehabilitation and maintenance projects. The need for a Pavement Management System (PMS) was identified by the Forest Service in 1987. As a result a Construction Technology Improvement Program study was initiated to determine an appropriate PMS for use on low-volume federal lands roads. The above study recommended that the Forest Service adopt the Metropolitan Transportation Commission's PMS (MTC-PMS).
The MTC-PMS is a personal computer program designed to develop cost effective maintenance strategies for roads paved with asphalt. The MTC-PMS was developed for the cities in the San Francisco Bay Area. Though recommended to the Forest Service, the MTC-PMS had not been tested on an actual Forest Service road network. The project in this report provides a test run of the urban MTC-PMS on a Forest Service paved road network. This was accomplished by implementing the MTC-PMS on 225 miles of asphalt paved roads on the Siuslaw National Forest located in the coastal mountain range in the state of Oregon. The paved roads on the forest were analyzed in detail by all of the MTC-PMS procedures. Maintenance, pavement rehabilitation, and funding strategies were developed for the forest.

The Forest Service identified that a Pavement Management System should have the following capabilities:
1. A means to rate pavement condition
2. Identify pavement treatment needs
3. Prioritize treatment needs
4. Make cost effective use of limited funds
5. Predict future funding needs
The Forest Service also placed high importance on simplicity in concept, software maintenance and field procedures. This project study tested the ability of the MTC-PMS to perform the above tasks. It was found that the system could perform the above tasks and be used as an effective pavement management tool on the Siuslaw National Forest.

The MTC-PMS consists of two pavement management modules: The Network Level module and the Project Level module. This study evaluates only the Network Level pavement management module.

VAN WINKLE, D.J. 1977. An analysis of road changes on several cable logging operations. (MF)
Road changing is the activity of moving operating lines on a cable yarding operation to permit access to logs in an unyarded portion of a logging unit. The time required to perform this activity varies widely and may consume a significant portion of the total yarding time.

With rising costs in the logging industry, the efficiency of cable logging systems is constantly under critical review. Additional research in the area of road changing has been suggested in several studies (Dykstra, 1974 and Peters, 1973).

Road changing information was gathered on several yarding operations in conjunction with detailed production studies of cable logging systems. On six of the operations the total time consumed by road changing was noted and recorded as a delay in the yarding process. On four operations, road changing was segmented into various activities, and factors hypothesized to influence road changing time were identified and measured.

On the four operations studied in detail, two crewmen timed the road changing operation as the activities involved occurred at widely separated locations on the logging unit. The continuous time study method used on the overall production study (Dykstra, 1975a) was also used during road changing.

The analysis of road changing involves a descriptive analysis of all the operations studied and a quantitative analysis of road changing on the four operations studied in detail. The descriptive analysis consists primarily of a comparative investigation of road changing time between the operations. The quantitative analysis consists of a regression analysis of the four operations examined in detail.

In the comparison of road changing times for the ten operations observed, road changing time varied widely. Even among similar systems a wide range was observed. This variability was most likely due to the differences in the road changing methods themselves, varying characteristics of the logging units and lengthy delays encountered during road changing. This could not be confirmed for six of the operations as road changing was not recorded in detail. However, among those operations observed in detail, this influence could be seen.

Following a breakdown of road changing into machine intensive activities and delays, a large percentage of road changing is occupied by delays. Also, the greatest proportion of delay-free time involved labor intensive activities. This was expected on the operations where pre-layout of roads was not done. On the operation where roads were pre-layed, other activities requiring labor intensive action occurred. Some of the delays encountered may have been due to characteristics of the particular yarder being used.

A quantitative analysis was made of four operations. Road changing time, excluding delays and the time required to relocate the yarder was used as the dependent variable. Delay-free road changing time was found to be a function of the distance from the landing to the tailhold (SPAN) and groundslope. For two of the operations, identical machines and methods were used. A combined regression equation was formed based on the
independent variable SPAN. Also, based on the scatter of observations for these systems, an equation using $SPAN^2$ as the independent variable was found to be a better predictor of delay-free road changing time than SPAN.

WILBANKS, S.J. 1985. Predicting running skyline performance based on the mechanical capability of the yarder. (MF)

During the timber sale planning process, the forest engineer must determine the type of yarding system which can most efficiently harvest the area. In the case of steep, environmentally sensitive terrain, the running skyline system is often an alternative. The first step in the analysis is to determine physical feasibility. Once this is known, yarding costs are estimated in order to help determine the most efficient system.

Currently, skyline analysis programs, available for desktop computers and hand-held calculators, are used to determine the maximum payload which can be supported at various points along the skyline corridor.

The programs are based on the following information: 1) diameter and length of wire rope recommended for the yarder; 2) yarder tower height; 3) profile geometry; 4) minimum skyline or log clearance; and 5) allowable working tensions.

The rope dimensions and tower height are available from manufacturer's specifications. Profile geometry is obtained from field or map surveys. Minimum skyline clearance is determined as necessary to meet sale objectives. Finally, the tensions are assumed to be the safe working load of the time and the tensioning capability of the yarder is not considered.

After determining that payloads are adequate, production is estimated using available regression equations for cycle time, or "rules of thumb" based on past local experience. Yarding costs can then be calculated as a basis for comparison between systems.

WOMACK, K.C. 1989. The dynamic behavior of a cable logging skyline and its effect on the tailspur. (PhD)

Initially, a small experimental study was undertaken to examine the influence of incline on the frequency of taut cables. The experiments consisted of exciting a short cable at angles of incline from zero to 90 degrees and at various tensions. The results from these experiments shows a small effect due to the incline as the cable approaches the vertical. However, this influence is small enough that the theoretical equation for the frequencies of a horizontal cable could be used to determine the frequencies of a taut, inclined cable.

A computer model intended to simulate the dynamic behavior of a cable logging system skyline is the main thrust of this paper.

In developing the computer model both finite element and finite difference methods were considered. The finite difference method was selected based on its efficiency in achieving the desired solution. A nine point implicit finite difference scheme, which guarantees stability of the solution, was employed.

Computer model output for skyline frequencies and tensions were compared with a number of field tests. The results were encouraging and indicated the model to be reliable in simulating the dynamic behavior of a skyline with a log load. This information can be used to determine the influence of dynamic skyline behavior on loads experienced by the tailspur.

WOODRUFF, W.C. 1984. Payload analysis for the North Bend, South Bend and modified North Bend skyline logging systems. (MS)

The North Bend skyline system was first introduced into the Pacific Northwest in 1912 by the North Bend Lumber Company, North Bend, Washington. The system was able to raise the front end of logs over obstacles while yarding large payload uphill. Yarding efficiency was improved since hangups were minimized. The Modified North Bend System was developed at the same time, and was used to yard timber downhill. The South Bend System was introduced as a second variation of the North Bend System.

The three systems are currently used throughout the world to yard or swing timber over broken terrain where access is limited. The minimum system uses a two drum yarder, for the main and haulback lines, and a standing skyline. The systems are best utilized on clearcuts where tail holds are limited. Greatest production is realized when turns are dragged. However, logs can be fully suspended over streams and other sensitive areas.

The payload capacity of a yarding system is one component of its productivity. Payload analysis techniques have been developed for a variety of skyline systems. Modern computers and programmable calculators have increased the speed and accuracy of these techniques. No program has yet been reported which
analyzes the payload capability of the North Bend System and its variations.

This paper presents a mathematical algorithm for determining payload capabilities of the North Bend, the South Bend, and the Modified North Bend skyline systems. The formulations utilize catenary and log drag geometry to represent static loadings of the systems. Full and partial log suspension are considered.

The algorithms were implemented on an IBM Personal Computer. The computer code, written in BASIC, for an interactive payload analysis routine is included. Operating instructions are provided. Sample analyses are presented. Field verification was outside the scope of this study.

XU, SHENGLIN. 1996. Preliminary planning of forest roads using ARC GRIS. (MF)
Forest road planning is important in logging operations because it can affect feasibility and cost of forest operations. Due to rapid advances in computer hardware, GIS software, and remote sensing techniques, computer forest road planning models using GIS are becoming practical. DEM data at 30 meter resolution are common and 10 meter resolution exists. Eventually 10 meter resolution will be common and perhaps 5 meter or better resolution will be available.

The objective of this paper is to explore the usefulness of existing “off-the-shelf” GIS software in preliminary forest road planning. I choose ARC/INFO a widely used GIS in the United States by public and private forest managers. I tried two approaches to forest road location. In the first approach I used the available PATHDISTANCE and COSTPATH functions within ARC GRID. In the second approach I developed a supplementary “C” program to calculate earthwork costs for each cell to improve the cost estimates in the shortest path calculation. The earthwork costs included considerations of excavation quantities and type of soil. I compared the results for the two approaches on a 1657 acre section of the H.J. Andrews Experimental Forest. I found the second approach that included calculation of the earthwork costs to give superior results.

The test results suggest that preliminary planning of roads using GIS coupled with supplementary programs may be useful for preliminary road planning, particularly as higher resolution data becomes available. Additional research needs to be done on refining horizontal and vertical geometry considerations within the GRID GIS structure in order to evaluate vehicle performance and to improve estimates of construction quantities.

The calculation of optimum setting dimensions and road standards simultaneously on a timber sale is a common problem in uniform terrain. Analysis usually begins by evaluating certain road standards under various road spacings and profile geometries. Linear costs, single period entry and simplified skidding patterns are often assumed to permit simpler calculations and closed form solutions. Various skidding patterns, nonlinear costs, multiple periods, and variable road standards are not considered. In this paper, the simultaneous solution of spur road spacing, collector road spacing, and choice of collector road standards for linear and nonlinear skidding functions are considered. For the linear skidding function, a multiple period formulation is made. The road and landing spacing problem is solved by (1) complete enumeration, (2) a combination of complete enumeration and the Hooke and Jeeves pattern search method, and (3) by the Hooke and Jeeves pattern search method. The Hooke and Jeeves pattern search method provided the fastest solution times with solutions almost as good as the complete enumeration. The improvements in road spacings, and cost evaluation using the more complex assumptions are compared with simpler analyses.

The use of mechanized harvest equipment has been increasing as an economical method to harvest small diameter timber. While the use of this equipment is increasing, little is known about associated soil compaction. In particular, little information exists on soil compaction caused by feller-bunchers.

This study measured soil compaction caused by a mechanized harvest operation using 2 swing-boom, tracked feller-bunchers and 2 rubber-tired grapple skidders. The study took place on the LaGrande Ranger District of the Wallowa-Whitman National Forest, located in eastern Oregon on volcanic ash soils. USDA Forest Service definitions of detrimental compaction (20% or greater increase in soil density over pre-activity levels) were used as a guideline to determine if detrimental compaction had occurred. Results show that 54% of the total area was impacted by either the feller-bunchers, skidders or both. Feller-bunchers impacted 19% of the total area and caused a statistically significant increase in soil bulk density of 8.8% when compared to before logging densities. Main skid trails covered 12% of the total area and had a statistically significant increase in soil density.
of 36.3%, when compared to before logging densities and was considered detrimentally compacted. These main skid trails were also feller-buncher trails. Thus, 12% of the total area was impacted by both feller-bunchers and skidders while 7% of the total area was impacted only by feller-bunchers. Twenty three percent of the total area received 1 to 4 skidder passes and was not in identifiable skid trails. Even these non-skid trail areas showed a statistically significant increase in soil density of 9.6% when compared to before logging densities. An additional 12% of the total area received 5 to 8 skidder passes and was also not in identifiable skid trails. This area showed a statistically significant increase in soil density of 19.8% and was considered detrimentally compacted. Regression analysis showed that slash significantly reduced compaction caused by feller-bunchers and skidders.

ZIELINSKY, C.R. 1980. Operational prebunching: a logger’s application to reduce skyline thinning costs. (MF) In the Pacific Northwest, loggers are faced with the problem of changing from logging old growth to second growth. This is due to the shrinking old growth timber supply and increased entry into the second growth stands. Beuter (1980) indicated that in western Oregon 70.2 percent by volume of the softwood timber presently being less than 12.9 inches (53.09 centimeters) dbh, with 37 percent being less than 12.9 inches (32.77 centimeters) dbh. Tedder (1979) states that by the year 2075 the average diameter for all western Oregon owner groups will fall from 23 inches (58.42 centimeters) to 14 inches (35.56 centimeters). The trend to harvesting smaller timber will require development of harvesting techniques that can handle small wood more efficiently. Small wood is defined (Aulerich 1975) as a tree under 20 inches (50.08 centimeters) dbh or logs averaging less than 100 board feet (0.71 cubic meters) in volume.

In small wood harvesting, commercial thinnings pose special problems. Thinning are used as silvicultural treatment to enhance the growth of the residual stand. In skyline thinnings, yarding logs laterally into the corridors is a time consuming activity, especially pulling slack during lateral outhaul and finding enough logs within reach of the chokers to build an optimum turn (near maximum payload). Aulerich (1974) found lateral yarding accounted for 46 percent of the total yarding time. Sparse log density and small log size make building an optimum turn difficult.

Yarding logs laterally through standing timber is also a problem. There are frequent, time-consuming hangups requiring resetting the chokers or dropping off part of the turn. Reset time can be expensive, because the yarder stands idle and its hourly operating costs are high.

In previous research at Oregon State University, prebunching and swinging has been suggested as a means for reducing yarding costs in skyline thinning operations. Prebunching and swinging differs from full-cycle (conventional) yarding in prebunching and swinging, logs are moved from the unit to the landing in two yarding cycles. The first cycle is the prebunching cycle, where the logs are laterally yarded to decks along the skyline corridor. The second yarding cycle is the swinging cycle, where the logs are yarded from the prebunched decks to the landing. In full-cycle yarding logs are yarded in one cycle which includes the lateral yarding and swinging. By prebunching with a low investment yarder, it may be possible to increase the utilization of an expensive yarder and thereby reduce total yarding costs.
An energy balance analysis was performed on each of four transplanted Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedlings growing on two cutover sites in southwestern Oregon. The two sites were a clearcut and a partial-cut (shelterwood) side by side, with a pair of seedlings used on each site. One seedling of each pair had a shadecard to the southwest of that seedling. This way, the shelterwood harvest system and the use of shadecards were compared in relation to their success in ameliorating the microclimate of the seedlings.
A model of seedling radiation geometry was used along with measurements of site radiation and environmental temperatures to calculate the net radiation "loading" upon each seedling. This heat load was then partitioned into the two major heat dissipation modes, latent heat (transpiration) and sensible heat convection.
ADAMS, J.N. 1979. Variations in Gravel Bed Composition of Small Streams in the Oregon Coast Range. (MS)
A study of the temporal and spatial variability of stream gravel bed composition and the factors affecting the amount of fine sediment within the bed was conducted in the streams of the Oregon Coast Range. Streambed samples were obtained by frozen core techniques and the amount of sediment smaller than 1.0 mm in diameter was expressed as a percentage by weight of the total sample.

The amount of fine sediment in stream gravel beds was found to be highly variable in time and space. Temporal variability in percent fines was caused by flushing of fines from the gravel beds during high streamflow events. This flushing of fine sediment seemed to occur randomly during winter freshets. Seven of 13 total streambed sample locations on five small streams showed trends of decreasing amounts of fine sediment during the winter high streamflow season.

The percent fines within the streambed was also found to display large variation (a) between streams, (b) between locations in the same stream, and (c) between locations in the same riffle. Bed samples were collected on 21 watersheds in the coast Range during the summer of 1978. The amount of fine sediment averaged 19.4% and ranged from 10.6% to 29.4%. Comparisons between locations on the same stream showed bed composition to be highly variable. Approximately 75% of the bed composition comparisons were significantly different at the 95% confidence level. One gravel bed was sampled on a 1.2 by 1.2 m grid design and significant (95% confidence level) changes in percent fines were found to exist both perpendicular and parallel to the streamflow in this small area of the stream.

Regression analysis on the samples collected on the 21 streams indicated that the amount of fine sediment in the bed is influenced by the slope, area, relief, and land use characteristics of the watershed. Within a single stream, however, regression analysis indicated that gravel bed composition was dependent on sinuosity and bankfull stage. These two variables suggest that the intrusion of fines into the stream bed is influenced locally by hydraulic conditions within the channel.

Regression analysis and field observations suggest that the amount of fine sediment in stream gravel beds might be increased by road construction and logging operations. However, increases in levels of bed fines after disturbance should be temporary due to the flushing of fines with high flows. Key words: Bed sediments, forest harvesting, Oregon Coast Range, sedimentation, stream channels, water quality.

ALLEN, M.M. 1997. Soil compaction and disturbance following a thinning of second-growth Douglas-fir with a cut-to-length and a skyline system in the Oregon Cascades. (MF)
Soil bulk density and disturbance were measured before and after a commercial thinning of 30-50 year-old Douglas-fir using a cut-to-length (CTL) and a skyline system on the Willamette National Forest in the Oregon Cascades. A dual-probe nuclear densimeter was used to measure bulk density at four and eight inches. Slash depth after thinning and disturbance category were determined at bulk density measurement points in all units. Data were analyzed using paired t-tests, Tukey-Kramer multiple comparison tests, and multiple linear regression.

Data were collected in two CTL units pre-thinning but one unit post-harvester and post-thinning (after both harvester and forwarder). During the sampling period thinning was completed only in the northeast corner of one unit (approximately 25 acres) before operations were ended due to concerns about soil moisture conditions and damage to hauling roads. Thus post-harvester and post-thinning data and conclusions apply only to that portion of the CTL units. In this harvested portion, slopes ranged from 0-10 percent and equipment traffic levels were estimated to range from three passes at the end of skid trails, to 30 passes on secondary trails and well over 40
passes on primary trails. These values are considered characteristic of most of Unit 82 except for areas near streams with steeper slopes.

Plot centers were located using an incomplete, offset grid system. A sub-sample of bulk densities in old skid trails was also taken. The effects of harvester-only and the combined effect of harvester-forwarder traffic on the bulk density of old skid trails and previously undisturbed soils was assessed. In the three skyline units, bulk density was measured in the center, edge and halfway between skyline roads both before and after thinning. In addition, detailed maps of soil disturbance were created from transects located both directly on top of and halfway between a sub-sample of skyline roads within each unit.

From the randomly located plots in the CTL units, it was determined that old skid trails covered approximately 27 and 13% of the two units, respectively. In the portion of the one unit where thinning was completed, it is estimated that an additional 27% of the area was disturbed, for a total of 40% disturbance post-harvester. Further, the harvester was estimated to have left exposed soil on 4% of the area and mixed the mineral and organic horizons on 9%. Post-thinning (both harvester and forwarder), new disturbance was estimated at 25%, for a total combined disturbance of 38%. Exposed or mixed soil was not observed at this time. The discrepancy between post-harvester and post-thinning disturbance estimates is thought to be due to different surveyors, slightly different data sets, redistribution of slash during forwarding or sampling error.

In the skyline units, the maximum unit-wide disturbance was 1.8%, though greater than 10% of some units were in skyline roads. Mixing accounted for most of the disturbance, with exposure and rutting never reaching 0.5% on a unit-wide basis. The areas of exposure and rutting were small, discontinuous and usually occurred within 150 feet of the landing.

In comparison to undisturbed soil, bulk density was still significantly elevated on the fifty-year-old skid trails sampled in the CTL units. The old skid trail center was 10-16% more dense than undisturbed soil at the four inch depth in both units, but only ruts in Unit 81 were also greater in density (+8%) at the same depth. At eight inches, old skid trail ruts in both units were consistently more dense (13-15%), as well as the center of trails in Unit 82 (+15%). In neither unit was the bulk density of old skid trail berms statistically different from undisturbed soil. Overall, it is estimated that 4 and 10% of Unit 81 (4 and 8 inch depth) and 6 and 4% of Unit 82 was already in a compacted state prior to this thinning entry. It is important to note, however, that elevated bulk densities on old skid trails may also be explained by measurements being made on naturally more dense subsoils exposed after scalping of the surface soils during the initial harvest entry.

The harvester alone was not found to significantly compact either undisturbed soil or old skid trails (p>0.10). Harvester-forwarder traffic significantly increased the bulk density of previously undisturbed soil by an average of 12 (4 inch depth) and 11% (8 inch depth, p=0.04 and 0.05), but did not change the bulk density of old skid trails. Compaction levels as a result of this entry were comparable with those of old skid trails. Overall, it is estimated that this new entry contributed an additional 25% (4 and 8 inches) to the compacted area, for an estimated total compacted area of 29-31%. The estimate of total compaction due to this thinning is based on the estimated area in new skid trails and an average of all observed compaction values across the width (both ruts and center) of the skid trail.

The bulk densities of the center, edge and zone between skyline roads after thinning were compared to pre-thinning values, but revealed no evidence that a significant difference existing between the four categories (90% level). There was some evidence that mixed soil with ruts greater than six inches deep were approximately 40 and 45% (4 and 8 inch depth) more dense than undisturbed soil (p=0.0006 and 0.0002). Also, points along the skyline roads where over 16000 ft³ were yared were found to be significantly associated with a reduction in bulk density of approximately 16 and 18% at four and eight inches in depth (p=0.022 and 0.008).

AMANN, J.R. 2004. Sediment Production from Forest Roads in the Upper Oak Creek Watershed of the Oregon Coast Range.
Unpaved roads area sources of chronic sediment in forested watersheds. Bare soil on roads is exposed to erosion from rainfall and runoff. Published research on sediment production from forest roads focuses primarily on road characteristics. Since water drives the mechanics of sediment transport, hydrologic variables should correlate with sediment production. This project investigated the relationship between sediment production and runoff-producing storms.

Road and hydrologic variables were correlated with total sediment production for nine road segments in the upper Oak Creek Watershed from November 2002 through June 2003. One of the road segments
was monitored intensively during four runoff-producing storms. Field data were compared with total sediment production predicted by SEDMODL2 and WEPP:Road.

Total coarse and settleable sediment produced from the nine road segments ranged from 0.025 kg (2.77 x 10^-6 kg/m²/mo) to 15.0 kg (1.04 x 10^-2 kg/m²/mo) while total runoff volume ranged from 100 m³ (1.11 x 10^-2 m³/m²/mo) to 52,000 m³ (36.1 m³/m²/mo). Correlation between total coarse and settleable sediment and total runoff volume for all road segments was significant (R² = 0.51, p-value = 0.004). No other variables correlated as strongly with total coarse and settleable sediment. However, while hillslope gradient and cutslope height did not yield significant correlations with total coarse and settleable sediment as individual variables, when added to total runoff volume in a multiple linear regression model, the relationship was improved.

Suspended sediment data was collected for four storms at one culvert. Results showed that suspended sediment concentration had time derivatives similar to those of culvert discharge, 1-hr rainfall intensity lagged one hour, and 2-hr rainfall intensity lagged two hours. Summed instantaneous suspended sediment concentration was correlated with cumulative rainfall.

SEDMODL2 results of predicted sediment produced from the nine road segments ranged from 0.0 to 6.7 kg (4.4 x 10^-4 kg/m²/mo). WEPP:Road results ranged from 160 kg (7.4 x 10^-2 kg/m²/mo) to 3020 kg (19.5 x 10^-2 kg/m²/mo). When compared with actual sediment data (0.025 kg to 15.0 kg), SEDMODL2 had much closer agreement. Further research is needed to quantify the total amount of suspended mineral sediment transported in runoff from unpaved forest roads in the upper Oak Creek Watershed.

ANDRUS, C.W. 1982. Tilling compacted forest soils in Oregon following ground-based logging. (MS)

Implements for tilling compacted forest soils were tested on sites logged with ground-based machines in Oregon. The sites covered a variety of soil conditions ranging from a clay loam to a rocky loam. Implements tested included disk harrows (four sites), brush blades (three sites), standard subsoiler tines (two sites), winged subsoiler tines (two sites), and rock ripper tines (five sites).

Soil density and strength measurements made prior to the tillage operations indicated that the depth of compacted soil within primary skid trails exceeded 12 inches and was often detectable to a depth of 18 inches. Logging debris typically was incorporated into the skid trail surface.

The disk harrow proved ineffective for loosening compacted forest soils at depth when: 1) the soil had a high rock content, 2) disk weighing was insufficient, or 3) the trail cross-section was concave and the harrow wide.

The brush blade failed to loosen the deeper layers of compaction and resulted in transfer of some of the loosened soil to the trail edges. The short closely-spaced tines did not allow loosened soil and logging debris to pass between the tines.

The performance of subsoiler and rock ripper tines was favorable in the rocky coarse-grained soils and some of the cohesive soils. However, plastic flow rather than shattering occurred when tines operated below their critical depth. The critical depth was controlled by soil conditions and tine geometry. The winged subsoiler tines resulted in 30 to 64 percent greater shattering than did standard subsoiler tines at a ripping depth of 1.5 feet. Close tine spacing caused logging debris to accumulate in front of the tines. The tines produced large angular clods when working in a cohesive soil. These clods did not break down after heavy rains. Clods from coarse-grain soils broke down readily when moistened.

A trapezoid-shaped representation of the soil shattering pattern produced by tines was shown to compare adequately with actual shattering patterns. A computer program was developed to analyze ripping depth and tine spacing combinations resulting in maximum shattering across the skid trail width.

The cost of the tillage operations ranged from $89 to $228 per mile of skid trail (1980-1981 dollars).


A landslide inventory, statistical analyses and a Geographic Information System (GIS) are used to analyze landslide sites and potentially unstable terrain in the Oregon Coast Range. The objectives are to evaluate the efficacy of locating landslide sites with topographic variables and discriminate the difference between sites where landslides have and have not occurred. The population of known landslides are characterized as up-slope, non-road related, and associated with 1996 storm events. Topographic variables are derived from a Digital Elevation Model (DEM) for index construction forming six groups; i) slopes, ii) contributing areas, iii) ratios of
slope and contributing area, iv) curvature v) infinite slope models, and vi) functions of slope and contributing area based on statistical models. Index groups employ different algorithms. Index performance is measured with landslide and aerial densities. Cumulative landslide occurrence is plotted against cumulative area on a continuous domain of the index to locate a maximum landslide density on equal sized areas. Indices are used to generate model definitions of potentially unstable terrain based on similarity to the landslide population. Aerial densities of potentially unstable terrain based on index definitions are determined but no common metric is achieved. Statistical analyses on spatially stratified data suggest a significant ($\alpha < 0.05$) difference between landslides sites and adjoined terrain. The minimum resolution at which a significant difference is achieved based on spatial stratification is a three cell radius surrounding the slide population. Curvature and area discriminate better than simple slope and topographic ratios. The relative performance is mostly a function of DEM error and resolution, and spatial correlation. Hydrologic geomorphic models perform about as well as the topographic ratios, and much less than the simple area index. There is no statistical evidence to suggest that the hydrologic geomorphic models accurately describe a threshold in the Mapleton slide population. The lack of significance is likely due to limitations on the available parameter sets. Logistic regression produced an index with the highest discrimination performance due to a maximum likelihood algorithm. Regression models have a physical basis in and parallel the behavior of linked hydrologic geomorphic and slope stability models. The measured differences in performances are a useful assessment of the DEM – index combination.

ATKINSON, B. 1992. The effects of channel modification on characteristics of streams during low flow. (MS) Fluorescent dye was used to assess summer low flow hydraulic retention and transient storage (dead zone) associated with fish habitat structures at Camp Creek, Drift Creek, and the East Fork of Lobster Creek within the central Coast Range of Oregon. Utilizing channel units to stratify stream reaches, the effect of instream structures upon the hydraulic retention of pools was evaluated. The cycling time of water into and out of storage was also estimated by calculating an exchange coefficient.

Camp Creek had a pre- and post-treatment design that included unaltered, low, medium, and high levels of coarse woody debris loading. Except for one Camp Creek channel unit (CC21), major alterations to low flow channel unit dimensions did not occur after treatment and the volume of water in transient storage in the other treated channel units was probably not altered. Intensive debris loading increased the length of channel unit CC21 by 6 meters and the average cross-sectional depth by 0.04 meters.

An "additional sums of squares" test was used to evaluate whether there was a statistically significant difference existing between Camp Creek pre- and post-treatment simple linear regressions of transit time versus debris loading and the average cross-sectional area, depth, width, and velocity. The additional sums of squares comparison did show that an increase in post-treatment transit time was statistically significant ($p < 0.10$) when compared against debris additional that were located within the low flow wetted perimeter of the stream (wood influence Zone I).

Statistically significant ($p < 0.10$) results for dye plume and geomorphic variables for Drift Creek and Lobster Creek are not presented as major conclusions because of a lack of pretreatment control data. Qualitatively, however, one-tailed t-test indicate that during summer discharges, flow velocities and peak concentrations may significantly decrease in treated channel units, compared to the channel units that were assumed to be controls.

Intensive debris loading may enhance low flow channel complexity by increasing turbulent mixing and increasing the transit time of water. However, in this study the largest amount of debris volume was located in the cross-section of channel existing between low flow and bankfull flow (wood influence Zone II). Thus, hydraulic interaction with debris primarily occurs during winter flows and storm flows when streampower is at its highest.

BAKKE, P.D. 1993. The spatial and temporal variability of nitrate in streams of the Bull Run Watershed, Oregon. (MS) An 18-year record of nitrate ($\text{NO}_3$), orthophosphate, total nitrogen and total phosphorus in four streams of the Bull Run watershed, Oregon, was examined to determine its precision and time resolution. Of these four species, only $\text{NO}_3$ was found to be known to a sufficient level of detail for modeling and inference purposes. The precision of precipitation $\text{NO}_3$ and total nitrogen measurements at the Bull Run was found to be inadequately determined and much poorer than the precision of corresponding stream chemistry data.
An autoregressive time-series multiple-regression model was developed to predict stream NO3 load (kg/ha/day) based on 14-day cumulative stream discharge, the current day's, previous day's and cumulative 7-day precipitation, the 14-day average maximum air temperature and a storm hysteresis factor. Coefficients of determination ranged from 0.66 to 0.75. The model was found to be of limited use in inference about watershed processes due to the coarse time resolution of the data (1 to 3 week sampling intervals). Although the 47 independent variables considered were known at much finer time scales (30 minutes to 1 day), this was insufficient to offset the problem of long sampling intervals and strengthen the inference capability. Complete description of the nutrient record would require sampling intervals of less than one day during periods of rapid change.

Peak NO3 concentration and load events were found to be unrelated to suspended sediment concentration or the magnitude of snow melt. Stream NO3 showed a weak inverse relationship with precipitation NO3 or total nitrogen content. Where light and other non-nutrient factors are present in abundance, streams of the Bull Run watershed were found to be predominantly phosphorus limited, although nitrogen-limited conditions occur in 1 to 37 percent of the days sampled, depending on sub-basin.

BEEDLE, D. 1992. Physical dimensions and hydrologic effects of beaver ponds on Kuiu Island in southeast Alaska. (MS)

Dimensional characteristics of 44 beaver dams and ponds on Kuiu Island in southeast Alaska were determined to evaluate the hydrologic effects of these structures on peak flows. The study area consisted of low gradient, incised streams in broad U-shaped valleys. Pond routing simulations were conducted using four return intervals (2-, 10-, 25-, and 50-year) and seven watershed sizes through medium- (752 m² of surface area) and large-sized (6002 m²) beaver ponds. The annual precipitation during field data collection was below normal resulting in a need to estimate winter pond conditions from summertime measurements.

The average dam length and height was 32 m and 0.7 m, respectively. The average winter pond surface area and volume was 2,140 m² and 1,250 m³, respectively. Pond volume was significantly related (p = 0.05) to surface area (r² = 0.91). Dam and pond dimensions were influenced by local stream and landscape characteristics.

Simulated peak flow routing through a beaver pond was accomplished using the Modified Plus method to calculate the theoretical percentage reduction in storm peak flows due to beaver dams and ponds. A triangular inflow hydrograph with the time to peak at 1/2 the total hydrograph duration was used. Thirty inflow hydrographs of various durations and peak discharges were routed through each pond to determine their effect on peak flows.

Beaver dam surface profiles are very flat. This resulted in large outflow rates over a dam with little increase in pond head. Single, full beaver ponds were found to theoretical reduce peak flows by no more than 5.3%, regardless of the return interval or watershed size. The shape of the outflow hydrographs were the same as the inflow hydrographs, with only a 10 or 15 minute delay in the time to peak and slightly increased duration. Reductions in peak flows became increasingly large as the number of ponds in a series increased. Five large-sized beaver ponds in series reduced the storm peak flow by 14% for a 2-year event, but only 4% for a 50-year event.

Detention storage effects of stormwater discharging over a beaver dam and onto the floodplain was not addressed in this research.

BENNER, D.A. 1999. Evaporative heat loss of the Upper Middle Fork of the John Day River, Northeastern Oregon. (MS)

Evaporation was studied along the Middle Fork of the John Day River in northeastern Oregon. Evaporation pans and various meteorological sensors recorded data at nine sites during the summer of 1998; measurements were made at each site over a 3-4 day period. A Dalton-type evaporation model was produced using water loss measurements in conjunction with the following meteorological information: pan water temperature, air temperature, relative humidity, and windspeed. This model was highly significant (r² = 0.88, F2,360 = 5572, p > F = 0.0001, n = 363). Regression coefficients composing the evaporation relationship were found to vary as a result of unstable atmospheric conditions (overcast periods and/or variable daytime wind direction) and windspeed measurement height.

At each of the nine sites, stream channel characteristics were analyzed to determine potential effects on the
streams’ capacity to cool by evaporation. The alignment of the stream channel with respect to wind direction, the
degree of incision of the stream channel, and the gradient of stream bank side slopes in the direction of wind
were found to potentially affect wind movement at the stream surface, thereby, restricting evaporative cooling.

Water movement was found to increase rates of evaporation relative to non-moving water during periods of
low vapor pressure deficit and no air movement. At higher vapor pressure deficits with no wind and during
periods of light wind movement with a low vapor pressure deficit, differences in evaporation rates between
moving water and non-moving water were less important. Much of the field data used to produce the
evaporation relationship presented in this study were recorded during periods of atmospheric conditions similar
to those that demonstrated minimal differences in evaporation rates between moving water and non-moving
water. Nonetheless, because water loss was measured in stagnant water evaporation pans, it can only be safely
assumed that the evaporation relationship presented in this document will tend to underestimate rates of
evaporation from streams with moving water.

The evaporation relationship provided in this document is applicable to aridland environments.
Application to other climatic regimes is probable but has not yet been validated by additional scientific research.

BERRIS, S.N. 1984. Comparative snow accumulation and melt during rainfall in forest and clearcut plots in
western Oregon. (MS)  
A study was conducted to compare snow accumulation and melt during rainfall in adjacent forest and clearcut
plots in the transient and snow zone of the western Cascade Range in Oregon. Snow accumulation differences
were determined by comparing the water equivalents of forest and clearcut snowpacks. During rain-on-snow
periods, energy balances were analyzed to evaluate the differences in energy transfers acting to melt snow in the
two plots. In this way, snowmelt differences can be linked to the microclimatic alterations related to clearcut
logging. Snowmelt estimated by energy balance analyses was compared with snowmelt determined by snowmelt
lysimeter data and snow survey information.

The forest canopy played a strong role in controlling snow accumulation. Snow trapped in the forest
canopy melted faster than snow that accumulated on the ground in the clearcut plot. Snow survey information
indicated that the water equivalents of clearcut snowpacks averaged 29 mm, but were up to 74 mm greater than
forest snowpacks.

For five rain-on-snow events during the winter of 1983-1984, four of which rainfall amounts were smaller
than the called for in the study design, a comparison of snowmelt estimated by the three methods had variable
results. Only during the last two rain-on-snow events, of which one was the annual rainfall event, did results
from the three methods all show greater snowmelt in the clearcut plot. Snowmelt determined by lysimeter
information was more reliable during these events than the previous three events because of improved rainfall
sampling.

Snowmelt estimated by energy balance analyses was consistently greater in the clearcut plot. Longwave
radiation was the greatest source of snowmelt for all events, contributing 38-88 percent of the total computed
snowmelt of each event. Snowmelt attributed to net longwave radiation was 22-56 percent greater in the clearcut
plot. However, the combined fluxes of latent and sensible heats accounted for a large portion of the snowmelt
differential between the plots. Although the combined fluxes ranked second in importance as a source of heat for
snowmelt (6-36 percent of the total snowmelt for each event), in the clearcut plot they were 226-300 percent of
the combined fluxes in the forest plot.

During the largest rain-on-snow event (February 11-13, 1984), total snowmelt was 55-111 percent greater
in the clearcut plot depending on the method of measurement. The increased snowmelt of the clearcut plot is
attributed to (1) greater snow accumulation prior to the event and (2) greater energy inputs during the event.

BERRY, J.D. 1975. Modeling the impact of logging debris on the dissolved oxygen balance of small mountain
streams. (MS)  
Previous research has indicated that considerable amounts of finely divided slash accumulate in small mountain
streams following timber harvesting. The subsequent biological decomposition of this organic matter can result
in the reduction of dissolved oxygen (DO) concentration to levels as low as 0.6 ppm. These DO levels are lethal
to the salmon and trout fry which habitat these waters during the summer months.

The purpose of this study was to verify the results of previous research on the biochemical oxygen demand
(BOD) characteristics of Douglas-fir needles, western hemlock needles, and red alder leaves, and to develop an
oxygen balance model to describe the effect of logging debris BOD on the dissolved oxygen of small mountain streams.

The concept of the leaching process was examined and refined. As a result, the leaching rate constant, K₄, was introduced to describe the addition of leachate to the stream. This necessitated redefining K₁, the first order decay rate constant, as it had been reported in previous studies. Slash may be described by its ultimate oxygen demand, or potential BOD, and two rate constants, K₁ and K₄. Manometric BOD tests were run for 20-day periods to estimate the potential BOD and the rate constants K₁ and K₄. The 20-day ultimate BOD, K₁ and K₄ estimates at 20°C were: 139 mg O₂/gm (dry weight), 0.266 and 0.189 per day for Douglas-fir needles, 183 mg O₂/gm (dry weight), 0.202 and 0.189 per day for western hemlock needles, and 226 mg O₂/gm (dry weight), 0.121 and 0.141 per day for red alder leaves.

Laboratory experiments designed to examine the possibilities of occurrence and impact of nitrification on the oxygen demand curve concluded that even though it is possible to observe nitrification under special conditions, coastal streams are generally too nitrogen and carbon poor for nitrification to exert a significant oxygen demand. Even with the addition form of nitrogen must be added to produce detectable amount of nitrogenous oxygen demand. It was found that the presence of nitrification cannot be detected in small mountain streams by nitrate analysis because of rapid fixation of nitrogen. Thus, the nitrification process appears to be of more concern for evaluating nutrient pathways and fixation than oxygen demand.

The leachate of the Douglas-fir, western hemlock, and red alder vegetation was analyzed for sugar and phenol concentration and rate of leaching. The vegetation was gas sterilized using ethylene oxide. The sterile vegetation was placed in autoclaved aliquots of water and sealed. The leachate of each vegetation type was analyzed at periodic intervals over 90 days, and the leachate expressed in glucose and gallic acid equivalents. Of the 120 samples treated, only one showed signs of contamination. The sugar and phenolic release rate constants for Douglas-fir and western hemlock were very similar; 0.049 and 0.062 for Douglas-fir sugars and phenols respectively and 0.060 and 0.046 for western hemlock sugars and phenols. All of these rates are less than the leaching rates derived by BOD experimentation. These differences may be due to biological interaction in the leaching process. The leaching rate constants for red alder leaves were much higher than the experimental rates, 0.88 and 0.187 for sugars and phenols respectively.

The mean maximum sugar concentration was: 117 mg glucose equivalent / gm (dry weight) for Douglas-fir needles, 86 mg glucose equivalents / gm (dry weight) for western hemlock needles, 121 mg glucose equivalents / gm (dry weight) for red alder leaves, and 50 mg glucose equivalent / gm (dry weight) for dissected Douglas-fir twigs. No rate constant was computed for Douglas-fir twigs because of the lack of fit to an exponential function.

Experimentation of the effects of temperature showed a significant response of potential BOD, K₁ and K₄ to variations in water temperature from 15 to 27°C. In general, ultimate BOD, K₁ and K₄ values increased with increasing water temperature.

The effect of mass concentration on ultimate BOX, K₁ and K₄ were negligible for vegetative loadings of 4 to 16 gm, fresh weight per liter.

The second phase of this study involved constructing a finite difference model of the dissolved oxygen balance in small mountain streams. A fixed cell approach was used to demonstrate the negligible effects of dispersion on pollutant and oxygen concentration. This then allowed the use of the much more efficient Lagrange variation of the finite difference modeling technique, utilizing a moving cell. By using available data and estimates of the distribution of slash in a simulated stream following clearcutting along 991 feet of the stream, DO levels as low as 5.72 ppm were computed for the simulated stream 5890 ft below the top of the clearcut. At these DO concentrations, salmon and trout fry experience "critical" stress conditions. Further model runs indicated that by reducing the length of the clearcut or by removing a portion of slash this condition could be avoided.

BOHLE, T.S. 1994. Stream temperatures, riparian vegetation and channel morphology in the Upper Grande Ronde River Watershed, Oregon. (MS)
The Upper Grande Ronde River Watershed in northeastern Oregon is considered important habitat for threatened stocks of chinook salmon (Oncorhynchus tshawytscha). Documented reductions in channel complexity and riparian vegetation within the watershed have increased concern over loss of viable habitat. An important component of salmonid habitat is stream temperature during critical summer periods. In general, annual
maximum stream temperatures and diurnal fluctuations in the Upper Grande Ronde River were found to reflect local reach characteristics, position in the drainage, and large-scale changes in valley shape. Stream temperatures on the Grande Ronde River at a distance of 71 km from the watershed divide exceeded 14°C, the "upper preferred temperature" for chinook salmon, more than 90% of time in July of 1991 and in July and August of 1992. While the occurrence of temperatures above 14°C were less common in the headwaters of the Grande Ronde River, downstream of a large meadow (i.e., Vey Meadow) (29 km from the divide) 14°C was exceeded at least 60% of the time during the same three month period. Seven-day maximum stream temperatures on the Upper Grande Ronde River ranged between 17.9°C and 26.6°C in 1991 and between 19.1°C and 26.7°C in 1992. Diel fluctuations on the mainstem were greatest immediately below Vey Meadow (about 12°C) but tended to stabilize at approximately 8°C at distances of over 49 km from the divide.

Maximum stream temperatures in tributaries of the Upper Grande Ronde River varied by as much as 11°C (during 1992), reflecting large differences in stream cover, aspect and flow. The timing of annual maximums seemed to be strongly linked to aspect during 1992. In addition, the high-elevation, forested tributaries had annual maximum stream temperatures and diel fluctuations which were 3°C lower than those associated with more open, low-elevation sites.

Relationships between stream temperatures, riparian vegetation, and channel morphology characteristics were evaluated for 11 tributary reaches. Difference in stream cover, average flow velocity, bankfull depth and percent undercut bank were found to be significantly (p <0.1) related to maximum stream temperatures and/or average August diel fluctuations based on linear regression models.

A stream temperature prediction model (i.e., TEMP-86) was found to be an accurate predictor of average hourly stream temperatures through short 250-m long reaches. An average WSTAT (a measure of model accuracy) of -0.18°C was calculated based on 11 reaches through two reaches led to consistent over- and under-predictions of downstream temperatures. A series of temperature simulations using TEMP-86 and combinations of wetted width and percent stream cover suggest that lower maximum daily stream temperatures would be observed through altered reaches if concurrent changes in both parameters occurred.

BRANSOM, M. 1991. Soil engineering properties and vegetative characteristics for headwall slope stability analysis in the Oregon Coast Range. (MS)

Six headwalls in the central Oregon coast range were selected for study of soil engineering properties and vegetative characteristics important for analysis of slope stability. The headwalls were considered representative of those which would be candidates for timber leave areas due to geomorphic and topographic features, including steepness of slope and presence of a well defined constriction point on the downslope end. Of the six, only one headwall had evidence of recent debris-avalanche activity.

No standing overstory species were found on any of the headwall blocks, the area of the headwall thought most susceptible to failure. Douglas-fir (Pseudotsuga menziesii), maple (Acer sp.), and red alder (Alnus rubra) were common on the headwall perimeters. Salmonberry (Rubus spectabilis) and swordfern (Polystichum munitum) dominate the understory plant community on the headwalls.

Subsoils from two profiles on each headwall were sampled for index and classification properties. The soils are typically shallow, averaging under one meter in depth. They are silt-sand-gravel mixtures, with non-plastic fines. The soils all have exceptionally low density, and correspondingly high void ratio.

Consolidated-undrained triaxial tests with pore pressure measurements were conducted using relatively undisturbed samples to determine the effective soil strength parameters, angle of internal friction, f', and cohesion, c'. Low consolidation pressures were chosen to model field overburden conditions. The arithmetic mean f' was 31.1°. All the soils are considered to be slightly- to non-cohesive. There are no apparent correlations between index or classification properties and strength parameters. Variability of index properties and strength parameters appears to be as great within a particular headwall as between the six study sites.

Variability in the results of the strength tests are thought to reflect natural variability resulting from colluvial soil formation soil formation processes, as well as difficulties inherent in collecting and testing relatively undisturbed soil samples. Further investigations of strength parameters designed to include root contribution to strength are needed in order to more fully define stability characteristics of headwalls.

BRANSOM, M. 1997. Geohydrologic conditions on a steep forested slope: modeling transient piezometric response to precipitation. (PhD)
Two hillslope sites in the central Oregon Coast Range were instrumented and monitored for winter precipitation and saturated and unsaturated subsurface conditions. The study sites were near-ridge depressions typically known as headwalls. Based on results of the monitoring, two existing mathematical models were adapted to predict piezometric levels in headwalls during storms. The first is a statistically based model, using an Antecedent Precipitation Index (API) as an independent variable in a regression model. The second is a mass balance model based on the kinematic assumption that the hydraulic gradient is equal to the slope of the impermeable base of the control volume. Several extreme storm events recorded during the monitoring period were used to calibrate the models. Precipitation data from a subsequent extreme event was then used in verification runs of both the API and the kinematic storage models.

Soil from one site was sampled for index properties, strength parameters, and hydraulic properties. The soil is a non-plastic, sand-silt mixture derived from sandstone. A relatively undisturbed sample tested in a consolidated-undrained triaxial test had a $N_r$ value of 32.5E and a $c_N$ value of 5.2 kPa. Laboratory testing suggests that the soil is hydraulically similar to other soils in similar geographic and topographic locations. An estimate of the “effective” saturated hydraulic conductivity, considering both macropore and matrix flow, is approximately $10^{-2}$ cm/s.

In general, the API models for individual storms were capable of reproducing observed piezometric hydrographs. However, the use of API was limited by the high degree of variability in API values and antecedent hydraulic head conditions from storm to storm. A multi-storm API model was developed to overcome these limitations, and produced reasonably good results. The kinematic storage model also performed well for this site, for two of three methods of determining drainable porosity of the soil.

Hillslope discharge measurements made on one occasion suggested that approximately 70% of flow at the outlet was occurring in pores larger than 2.5 centimeters in diameter. Macropore flow would seem to be an important feature of the subsurface flow regime under certain precipitation and antecedent soil moisture conditions.

BRAZIER, J.R. 1972. Controlling water temperatures with buffer strips. (MS) Buffer strips have been proposed as a method for controlling temperature changes in streams adjacent to clearcutting. Nine small mountain streams in Oregon's Coast Range and Cascade Mountains were studied to determine the influence of buffer strips on water temperature. Timber volume in the strip, strip width, and canopy density perpendicular to the sun's rays were compared to the effectiveness of the strip in controlling temperature change. This effectiveness was not well correlated with timber volume or strip width. The density of the canopy in the path of the sun is the most important buffer strip characteristic for water temperature control. A method for measuring the density of the canopy in the path of the sun is described. The use of this method in the design of buffer strips will provide protection for the stream and maximum harvesting of the timber resource.

BROWN, G.W. 1966. Temperature prediction using energy budget techniques on small mountain streams. (PhD) This study is part of the Alsea Basin Logging-Aquatic Resources Study research program. It was initiated to determine the applicability of energy budget theory to stream temperature prediction on small forested streams. The study was also designed to evaluate the energy budget technique as a tool in the management of mountain streams for the production of high quality water.

Temperature predictions were made on four stretches of three streams in the Coast and Cascade Ranges in Oregon during the summers of 1965 and 1966. Three of these stretches were forested. The fourth was completely exposed to direct radiation.

Stream temperature change occurring within a stretch of stream was determined by evaluating the radiative, evaporative, and conductive fluxes incident at the surface of the water as it moved downstream. Net radiation was measured directly. Evaporation was computed using a Dalton type equation. Conduction was determined with the Bowen ratio. These fluxes were then added to determine the net flux. Stream temperature change was computed as:

$$ \Delta T = \frac{\text{surface ~ area} \times \text{of ~ stretch} \times X \times \text{Qt} \times X \times \text{time}}{\text{streamflow} \times X \times \text{time}} \times 0.000267 $$

where $\Delta T = $
the change in stream temperature through the stretch in °F.

\[
Qt = \text{the net energy flux at the stream surface in BTU/ft}^2/\text{min.}
\]

\[\text{time} = \text{travel time through the stretch in minutes.}\]

Stream temperature was predicted with varying degree of accuracy on the four stretches. Tests suggested that the prediction could be improved slightly on long stretches by subdivision of the stretch and by separating data into daytime or nighttime units. Additional tests indicated that under a broken canopy, net radiation estimates, and thus stream temperature predictions, may be improved by measuring, or utilizing in the predictive equation, only the diffuse radiation penetrating the canopy. Integration of the net radiation recorded to include occasional spots of sunlight results in an over-estimation of temperature change during sunny periods.

A stream bottom may act as a heat sink during the day and as a heat source at night. This phenomenon was measured on one stretch. This helped explain predictive errors of about 10°F.

The study on the open stretch showed that during the day, conducive and evaporative fluxes were small compared to the radiative flux. This lead to modification of the original formula for predicting temperature maxima. This formula is:

\[
\Delta T = \frac{\text{Stretch} \times \text{surface area}}{\text{Streamflow}} \times 0.0001
\]

This permits field personnel to make estimates of maximum temperature changes attainable by opening a stretch of stream.

CAFFERATA, P. 1981. The effects of compaction on hydrologic properties of forest soils of the Sierra Nevada. (MS)

This study evaluated the effects of a crawler tractor, a rubber-tired skidder, and a torsion suspension vehicle on several soil and hydrologic properties in the western Sierra Nevada Mountains of California. Four sites, with soil textural classes ranging from a loam to a loamy sand and elevations between 680 and 2180 m, were studied at three moisture contents. Compaction was monitored with a double prove nuclear densiometer and an air permeameter after 1, 3, 6, 10, 15, and 20 round trips. Density measurements were made at five different depths. Infiltration capacities were determined with a small, portable rainfall simulator. Soil core samples were taken to observe porosity and conductivity levels before and after disturbance.

Compaction, or the change in bulk density, was significantly greater on the crawler tractor trails at all depths. When only the plots established in the outer positions of the trails were included, this distinction between vehicles could not be made. The crawler tractor generated more uniform compaction across its trails than either the torsion suspension vehicle or the rubber-tired skidder. The greatest change in bulk density for all the vehicles took place in the surface five centimeters.

Infiltration capacities on the undisturbed sites were found to exceed predicted maximum precipitation rates. Mineral soil at the three higher elevation sites was very hydrophobic. This was thought to be due to the coating of soil particles with the metabolic products of fungal mycelia. The crawler tractor reduced infiltration capacities by 78 percent, while the torsion suspension vehicle and the rubber-tired skidder caused 67 percent decreases. Suspended sediment concentrations determined from runoff collected on the infiltration plots served as an erosion index for the skid trails. The crawler tractor trails had runoff with 40 percent higher sediment loads than that found on the trails of the other two skidders. Organic matter content was inversely correlated with the sediment levels.

Air permeability readings showed that the three vehicles produced very similar reductions in macroporosity in the surface 2.5 cm layer as the number of trips increased. Approximately 75 percent of the decrease in macropore space occurred by six trips. The air permeameter provided a relatively good index of compaction.

Porosity and conductivity levels determined from the soil core samples showed that machine differences did not exist in the track position. Macropore space was reduced 43 percent and the conductivity decreased 80 percent. Site differences were much more evident than vehicle differences.

Observations made after one over-wintering period showed that measurable recovery had not occurred.

Keywords: soil compaction, ground based skidding, infiltration capacity, hydrophobicity, surface erodibility.

CAMACHO, P. 1984. The effect of major environmental factors on growth rates of five important tree species in
The growth of Alnus acuminata (HBK). Kitze, Cupressus lusitanica Mill., Gmelina arborea Roxb, Pinus caribaea var. hondurensis Barr. & Golf, and Tectona grandis L. in Costa Rica and twenty seven soil and climatic factors were analyzed to determine the relationship between major environmental factors and growth rates of these five species. The growth of the species was compared within specific climatic zones of Costa Rica, and in the country as a whole. A reduced set of environmental factors was selected that best explains the species growth in the country and in specific geographic zones.

The forestry plots used in this study were installed by the Forest Service of Costa Rica, complemented with a few private farmer plantations. Diameter at breast height (dbh), the height, and volume growth of the trees were used as dependent variables. Data for twelve climatic variables were obtained from the national meteorological stations. Fifteen soil characteristics were evaluated for each study site.

The growth of Alnus was found to be related to relative humidity, the distribution of precipitation and the percentage soil base saturation. Within the range evaluated (78-80%) an increase in the mean annual relative humidity will depress growth of this species.

For Cupressus it was found that soil texture (% silt content), altitude of the plots, soil base saturation, as well as cation exchange capacity and nitrogen in the Central Valley of Costa Rica, were the environmental factors most closely related to the growth of this species. For the latitudinal range evaluated (1100-2620 m) a decrease in growth can be expected as altitude increases.

Growth of Gmelina was found to be closely related to soil characteristics: available phosphorus, exchangeable sodium and potassium, cation exchange capacity and organic matter. The general observation from this regression analysis and experience in other countries is that Gmelina requires fertile soils and favorable physical properties for optimum growth. However, this species is growing satisfactorily in all areas below 500 meters of elevation in Costa Rica; no data is available above this elevation.

Amount and distribution of precipitation, exchangeable potassium, magnesium, and sodium, soil texture, and an energy factor (number of hours of light and radiation, or interaction of these two variables) were the factors most closely related to the growth of P. caribaea in the country.

For Tectona it was found that soil texture, temperature, and exchangeable potassium, calcium, and sodium were the factors most closely related to the growth of this tree in Costa Rica.

The information developed in this study provides a better basis for understanding the growth requirements of these five species. However, planting guidelines must await the inclusion of additional data into the analysis.

Keywords: soil fertility, tropical climate, tropical forestry, growth rates, introduction of species, Alnus acuminata (HBK). Kitze, Cupressus lusitanica Mill., Gmelina arborea Roxb, Pinus caribaea var. hondurensis Barr. & Golf., Tectona grandis L.

CAMPBELL, A. 1981. Flood frequency analysis of small forested watersheds for culvert design. (MS)

Forest engineers must frequently make flood frequency estimates for very small watersheds when designing culvert installations. Empirical formulae and simplified rainfall runoff models, the most commonly used techniques to predict floods from very small watersheds, require considerable engineering judgement to give reasonable results. As an alternative to such methods, this study presents equations to predict peak flows on small watersheds in Oregon. The equations were developed from 80 watersheds ranging in size from 0.21 to 10.60 square miles.

Oregon was divided into six physiographic regions based on previous flood frequency studies. In each region, annual peak flow data from gaging stations with more than 20 years of record were analyzed using four flood frequency distributions (Gumbel, two-parameter log-normal, three-parameter log-normal, log Pearson type III). The log Pearson type III distribution was found to be suitable for use in all regions of the state, based on the chi-square goodness of fit test. Flood magnitudes having recurrence intervals of 10, 25, 50, and 100 years were related to physical and climatic indices of drainage basins by multiple regression analysis. Drainage basin area (A) was the most important variable in explaining the variation of flood peaks (Q) in all regions. Mean basin elevation (E) and mean annual precipitation (P) were also significantly related to flood peaks in two regions in western Oregon. The following equations to predict the 25-year flood were developed for each physiographic region in Oregon:

1. Willamette region Q_{25} = 156A^{0.80}
2. Coast region Q_{25} = 6.31A^{1.01}E^{0.51}
3. Cascade Region Q_{25} = 0.32A^{0.43}P^{0.97}
4. Rogue-Umpqua region Q_{25} = 163A^{0.77}
Average percent error for all developed regression equations ranged from 16.1 to 64.1 percent, the smaller errors being associated with the more humid regions. Confidence limits developed for the regression equations provide the engineer with estimates of prediction uncertainties over the range of design flows. These prediction equations provide a better basis for culvert design on small forested watersheds than rules of thumb or empirical methods.

CARLSON, J.Y. 1989. Effects of forest management on fish habitat and macroinvertebrates in northeast Oregon streams. (MS)
This study describes streams in the Blue Mountains and Wallowa Mountains of Northeastern Oregon in order to characterize the interactions between the terrestrial and aquatic ecosystems and to determine how logging affects those relationships. Five stream reach pairs, each consisting of an undisturbed reach and a similar reach flowing through an area where the riparian zone had been logged, along with six additional undisturbed reaches were studied. The riparian stand, large woody debris, stream channel morphology and the benthic macroinvertebrate community were measured at each reach.

Large woody debris volume ranged from 91.1 to 284.0 m3/ha and was greater in the logged reaches than undisturbed reaches. Stream channel morphology, as indicated by the pool-riffle ratio, in the logged reaches was not significantly different than undisturbed reaches and percent pool area was less than 50 percent in all reaches.

Macroinvertebrate density ranged from 146.6 to 963.2 individuals/sample and was greater in the logged reach of each stream pair. Community diversity, as expressed by the Shannon-Wiener Diversity Index, at logged reaches was not significantly different from that at undisturbed reaches.

Although some differences were found between logged stream reaches and undisturbed reaches, there was no indication that overall fish habitat was greatly diminished or improved as a result of logging.

Stem form development of trees in response to wind has been established in the literature to be a response to stem away induced by the wind. The response is manifested in modifications to height and diameter growth which strengthen the stem against wind stresses. Experiments in the literature show that significant responses result from short durations of sway daily. An experiment exploring the growth responses resulting from a wide range of daily durations of sway was conducted. Also, the influence of timing of periods of sway during the growth season and during different seasons was examined.

The pooled mean leader length for seedlings swayed different durations daily at a rate of 0.8 Hz was 86 percent of that for unswayed controls. Leader length for seedlings swayed only 10 seconds daily were not significantly different from unswayed controls. Growth during certain stages of apical bud burst seems to have been retarded by the longer durations of sway. Growth ring increment on the compression side of the stem increased due to swaying, with the greatest response due to a 10 second daily duration and the least due to a 10 hour duration. Growth ring increment on the tension side responded in like manner, the longer durations of sway were not significantly different from the unswayed controls, but the short durations resulted in significant increases.

In a separate experiment, seedlings were swayed 2.5 hours daily. Treatments were begun with the initiation of bud burst, and terminated after periods of 6, 12, and 18 weeks. Leader length growth was not found to differ between controls and the 6-week swaying treatment, but was reduced due to longer treatment periods. The stem diameter in the direction of sway increased as the period of swaying increased. These results suggest that the response system directing height and diameter growth loses its effect, in time, if swaying is terminated before the completion of bud burst.

A field experiment was conducted measuring growth responses of 17-year-old trees which were prevented from natural wind sway during certain seasons of the year. No differences between treatments were found. Wind strength at the study site may have been inadequate to provide measurable differences.

CHESNEY, C. 1982. Mass erosion occurrence and debris torrent impacts on some streams in the Willamette National Forest. (MS)
This study focused on extensive soil mass movement occurrence in the Willamette National Forest of western
Oregon and on intensive measurements of some physical and biological changes in streams following debris torrents. Debris torrents are a rapid movement of water-charged debris confined to steep headwater channels. The frequency (events/ha/yr) of mass failures identified from aerial photos increased in the presence of clearcuts and roads relative to forest conditions. Approximately 71% of hillslope mass failures entered the stream channel, and an estimated 43% of hillslope mass failures resulted in debris torrents.

Standing crop of large organic debris and annual input to streams affected by debris torrents were highly variable. Silvicultural conditions of upslope vegetation and morphological features of debris torrent tracks influenced woody loading and input. Old-growth streams and depositional stream sites contained higher amounts of large organic debris and received higher inputs of larger organic debris than streams in clearcuts and erosional stream sites.

Depositional sites along debris torrent tracks have higher pool area and depth relative to erosional stream sites. Stream channel gradient and channel cross-sectional form influence the character of erosional or depositional sites sluiced by a debris torrent. Higher total pool ratings in depositional stream sites indicate spatial complexity of channel form that is related to the availability, transport, and stability of particulate bed materials.

Herbs produced the majority of foliar biomass (> 50% of total) in one-fifth of all stream sites. Successional changes in clearcut riparian zones included a shift to intolerant deciduous overstory species and more numerous shrub species than in old-growth riparian zones. The diameter growth of tolerant late successional overstory species in these riparian zones was inconsistent, whereas diameter growth of early successional species was rapid.

Case studies of two streams permitted analysis of riparian recovery relative to that of an undisturbed stream site upstream of the debris torrent track. Warfield Creek is a stream where a high energy debris torrent remarkably altered stream conditions. Simmonds Creek is a stream where a low energy debris torrent imperceptibly changed stream conditions.

Riparian recovery remains difficult to quantify because of physical and biological structures of stream ecosystems that vary in space and time.

CLARK, M.E. 2004. The Relationship between Landslide Density and Precipitation Intensity in the Central Oregon Coast Range During the February 1996 Storm. (MF). The storm event of February 3-9, 1996, caused widespread landsliding and flooding across the Pacific Northwest. Following this storm, a thorough landslide inventory was conducted in the central Oregon Coast Range by the Siuslaw National Forest. In the same region, rainfall intensity data were collected by eight tipping bucket gages in landslide-prone terrain. This combination of rainfall intensity and landslide distribution data for a major storm event provided a rare opportunity to investigate the spatial correlation between landslide and rainfall parameters on a landscape scale.

The study area was divided into subregions for which both rainfall and landslide parameters could be estimated for the February 1996 storm. Seven rainfall parameters for each subregion were calculated: maximum short-duration intensity (1/2-hr, 1-hr, 2-hr, 6-hr, 12-hr, and 24-hr), and Antecedent Precipitation Index (API), an indicator of antecedent moisture conditions. Landslide density, represented by discrete landslide events per area of clearcut, was chosen as the primary landslide parameter. Areas clearcut within five windows of time were analyzed—1972-95, 1977-95, 1984-95, 1988-95, and 1991-95—leading to five landslide parameters per subregion.

For each of the 35 pairs of rainfall and landslide parameters, a straight line regression model was fitted to the eight data points. The adequacy of each regression model was tested with a lack-of-fit F-test, resulting in a p-value to express the statistical significance of the model fit. Two of the 35 linear regression models were found to be statistically significant at the 90% confidence level. These suggest a weak spatial correlation between 1-hr rainfall intensity and landslide density. No significant correlation was found between other rainfall parameters (1/2-hr, 2-hr, 6-hr, 12-hr, and 24-hr maximum intensity, or API) and landslide density in clearcut areas.

Importantly, there was a consistent outlier in the regressions involving longer-duration rainfall intensities (6-hr, 12-hr, and 24-hr) and API. For example, with the outlier subregion removed from the analysis, each of
the five linear regression models correlating landslide density and API was statistically significant at the 95% confidence level. Additional research could shed light on the validity of the outlying data point.

Finally, the data were compared with four published thresholds for landslide initiation. Three of these were generally corroborated, while the fourth was not.

**COMMANDEUR, P.J. 1987.** Shear stress transfer between roots and soil. (MS)
Mass wasting events are a principal form of erosion that occurs on steep forest land throughout the Pacific Northwest. Numerous studies have reported that tree roots help stabilize steep forest land. A complete understanding of the mechanism by which roots strengthen soil would enable modeling to more closely approximate field conditions, and would provide an improved basis for formulating forest management guidelines directed at minimizing slope failure incidents.

Laboratory investigations were conducted to determine the material properties of green Douglas-fir roots which include the modulus of elasticity and the shear stress transfer at the soil/root interface. Two distinct types of moduli of elasticity were observed for the roots sampled in the study: form modulus (average = 2.7 x 10^4 psi) which occurs as a root straightens out, and material modulus (average = 7.3 x 10^4 psi) which occurs once the wood fibers fully resist elongation. For the cohesionless, dry sand (uniform 30 grade) used in the pull-out tests, the average ultimate shear stress transfer between roots and soil was observed to increase from 0.73 psi to 1.79 psi as a function of increasing soil density and confining pressure.

Apparent friction coefficient (f*) values were calculated and f* was shown to decrease with increasing confining pressure and to increase with increasing density. These findings are in agreement with those reported in the literature. Two mechanisms that may account for the high f* values are discussed. Reduce f* values (based on these two mechanisms) are demonstrated to approach the tangent of the angle of internal friction (N'), which is the upper bound of the actual friction coefficient as reported in the literature.

Preliminary results indicate an increase (from 13 to 34%) in shear stress transfer for roots with rootlets left attached over that obtained for the same roots with rootlets removed. This is considered to be a conservative estimate of the shear stress at the soil/root interface for in situ conditions.

A comparison of the findings in this study with values assumed in soil/root (fiber) system models, suggests that the coefficient of friction between roots and soil may be significantly greater than values used in the models.

**DENT, E.F. 1993.** Influence of hillslope and instream processes on channel morphology of Esmond Creek in the Oregon Coast Range. (MS)
Esmond Creek is a tributary to the Siuslaw River located in the Oregon Coast Range. It is 18 km in length and drains a watershed area is 48.9 km². Average channel gradient of the study reach is 0.9%. In 1988 a landslide occurred in the Esmond Creek watershed involving approximately 250,000 cubic yards of material, of which a small portion was delivered to Esmond Creek.

In 1984 and 1991 8% and 17.5%, respectively, of the study reach was influenced by beaver ponds. The effects of the landslide, log jams and beaver dams on channel morphology were assessed by comparing width and depth data collected in 1984 (pre-slide) to width and depth data collected in 1991 (post-slide). In addition, sediment samples were analyzed to investigate landslide, beaver-pond and log-jam influences on particle size distributions.

Field observations in 1991 indicate the longitudinal influence of observed sediment deposition from the landslide extended approximately 2.5 km downstream from the slide input. These field observations concurred with analysis of 1990 aerial photograph. Statistical analysis revealed no changes in channel width and depth associated with the landslide. However, reaches in which major changes in channel width and depth had occurred were associated with the occurrence of beaver dams and ponds. In general, the presence of beaver ponds tends to increase channel width and depth.

Particle size analysis of sediment from floodplain, point-bar and channel-bed locations revealed localized decreases in the geometric mean diameter of particles due to the interaction between sediment input from the landslide and instream structures (e.g., beaver dams and log jams). The channel bed, typically a zone of sediment transportation, was altered by these structures to function as a zone of fine sediment deposition upstream from the structures.

**DUAN, J. 1996.** A coupled hydrologic-geomorphic model for evaluating effects of vegetation change on
watersheds. (PhD)

This work describes the modeling framework and initial results for CLAWS (Coupled Landscape and Water System), a physically-based, spatially-distributed hydrologic-geomorphic model that has been coupled with a vegetation dynamics simulation. Spatial variability of topography, soil, vegetation, and climate drive a hydrology module that calculates the water budget at given time steps and with a spatial resolution defined by digital elevation data. Important hydrologic processes, including snow accumulation and melt, interception, evapotranspiration, infiltration, subsurface flow, overland flow and channel flow routing are incorporated in CLAWS. The hydrology drives hillslope and channel geomorphic processes, including probability of mass movements (landslides, debris flows). Both the hydrologic and geomorphic modules are linked to forest growth simulation so that effects of changing forest stand structure in response to cutting or other disturbances through time can be examined. Dynamic integration of CLAWS with geographic information systems enhances model parameterization and result analyses. Calibration and testing of CLAWS from three small watersheds at HJ Andrews Experimental Forest in western Oregon shows that watershed hydrologic behavior and hillslope stability can be simulated accurately. The module for snow accumulation and melt has been tested using four years of point measurements of snow water equivalent and showed that this simple energy and mass balance model accurately simulated snow accumulation and melt processes. Application of CLAWS to land use management permits long-term simulations of effects of alternative forestry practices on hydrologic and geomorphic responses of watersheds. Results from Monte Carlo simulations in small watersheds in western Oregon, show long-term effects of forest harvesting over 100 years, which are in agreement with long-term observations. Simulations show that 40 years is needed for watershed recovery to pre-clearcutting status with respect to old growth through an exponential trend and changes in watershed responses show strong seasonal and storm variations. Models such as CLAWS, that successfully incorporate hydrologic, geomorphic and forest dynamic processes into a single model, are an effective complement to traditional paired-watershed studies of hydrologic and geomorphic responses.

EDWARDS, R.E. 1980. Sediment transport and channel morphology in a small mountain stream in western Oregon. (MS)

Sediment transport measurements on Flynn Creek, a headwater stream in the Oregon Coast Range, have illustrated the magnitude of fluvial transfer processes, primarily on the bedload component, during a moderate storm runoff season (1979 water year). The total dissolved solids concentration of storm runoff averaged 40 mg/L, and was independent of water discharge. Most particulate export from the 202 ha forested watershed occurred during the annual peak flow of 0.75 m³/sec-km² (2-year return interval). Suspended load was the most important transport mode, with a total yield of 5.7 x 10⁴ kg during the 24 h peak flow period. The export of coarse particulate organic matter during the same period was 1.5 x 10³ kg.

Bedload discharge, as measured with vortex tube and Helley-Smith samplers, occurred in pulses of short duration that did not necessarily coincide with peak streamflow. For the same 24 h storm runoff period, the total bedload yield at the mouth of the watershed was only 2.6 x 10³ kg (particles > 0.25 mm), and considered primarily of sand-size material. Bedload discharge at an upstream site (1.3 x 10⁴ kg) was dominated by gravel-size particles. Channel morphology and instream obstructions (organic debris, fish trap) appear to cause significant spatial temporal variations in sediment transport and streambed composition.

Although streamflow was the principal variable controlling sediment transport, results suggest that supply limitations exist. The supply of transportable materials is dependent on the retention characteristics of the stream channel and on local hydraulic conditions. The discharge of both suspended solids and coarse particulate organic matter peaked early in the storm; however, pulses of the latter component on the recession limb appeared to be related to streambed disturbances. Bedload movement is an important process regulating both bed composition and particulate yields in this Coast Range stream.

The Helley-Smith sampler was the preferable method for use in streams having a large fraction of bedload in the sand-size range. The vortex tube trapped from 60-70% of the bedload sediment measured by an upstream Helley-Smith sampler, with trapping efficiency of the former increasing as transport increased. The variability in bedload movement suggests that monitoring designs must address: (1) rapid temporal fluctuations in bedload discharge, (2) variations in bedload transport along a stream, (3) lateral variations in bedload discharge at a cross section, and (4) the type of sampler used.

Keywords: bedload transport, vortex tube sampler, Helley-Smith sampler, suspended load, bed material load,
coarse particulate organic matter, mountain streams, channel morphology, sedimentation.

Understanding how forest roads interact with hillslope hydrology by intercepting and/or rerouting storm runoff will better enable land managers to reduce erosion related to forest roads. Watershed scale knowledge of how culvert runoff response varies across the landscape would provide valuable information to those individuals designing and maintaining forest road systems. In order to better understand the hydrologic interactions of the hillslope and the road, this study focused on all cross drain culverts in a 3rd order watershed of Oak Creek located in the McDonald/Dunn Research Forest 3 miles west of Corvallis Oregon. Stage recorders measured runoff response for winter months from October to March 2001 to 2002 and data for the January 25, 2002 storm event were analyzed in detail. Instantaneous peak discharge was measured at all culverts with either a crest gauge or a capacitance rod. Those culverts with a capacitance rod measured water height data every 10 minutes and provided a runoff response hydrograph. Fifty-eight of 74 gauged road segments were used in the analysis. Measurable instantaneous peak discharge was received from all 58 cross drain culverts and total runoff volumes were measured at 40 of the road segments. Frequency distributions of the runoff response for both instantaneous peak discharge and total runoff volume follow a right skew distribution. This indicates that a majority of the culverts measured had lower amounts of runoff than the mean and that only a small fraction of the culverts had a large runoff response.

Geographic Information System (GIS) coverage for McDonald/Dunn Forest was used to calculate road and hillslope characteristics. The correlation of instantaneous peak discharge for the cross drain culverts to road and hillslope characteristics indicates significant relationship at the 99% confidence level (p = 0.0030). Road length (p= 0.0029) and elevation (p = 0.0239) are statistically significant at greater than a 90% confidence level. However, the multiple linear regression model only explains 34% of the variability of instantaneous peak discharge. This result indicates it will be difficult to predict variations in runoff. Total runoff volume correlated with road and hillslope characteristics provided a similar result. None of the independent watershed/road variables were found to be significant predictors.

This study was conducted at portions of Trap Bay Creek, a medium sized third-order stream on Chichagof Island, Southeast Alaska, to 1) quantify short-term sediment transport and channel morphology changes, 2) relate measured sediment transport rates to the major hydrologic parameters that appeared to determine the mechanisms of sediment transport, and 3) evaluate how bedload transport can influence channel morphology. Morphologic characteristics were evaluated by means of plani-metric surveys and cross-sectional measurements made in July and August of 1980 and August of 1981. Bedload and suspended sediment data were collected during the Fall of 1980 along with data on streamflow and precipitation.

Morphologic evaluations indicated that the stream is a dynamic system and that it appeared to be widening and aggrading during 1980-81. Large organic debris, especially fallen trees, are important in stream morphology, especially above the zone of tidal influence. The tides, as well as human activity, probably contributed to recent morphological changes in lower reaches of the channel.

Problems involved in processing suspended sediment samples resulted in a limited amount of suspended sediment data. However, data that were collected from one point on the stream indicated that suspended sediment concentrations were low, usually less than 5 mg 1⁻¹, and did not exceed 90 mg 1⁻¹ during an approximate 2 to 5-year return interval storm event. Under average storm conditions, therefore, suspended sediment transport appears to be supply limited and constitutes a small portion of total sediment transport.

Bedload sediment samples were collected from a short pool-riffle study reach during a total of ten storms with streamflow ranging from 0.01 to 1.26 m³ s⁻¹ km⁻². Bedload sediment transport ranged from 3.0 to 4400 kg hr⁻¹, with peak transport rates occurring during peak streamflow.

Regression relationships were developed between bedload transport, gravel-sized inorganic bedload transport, coarse particulate organic matter transport, two particle size diameter classes (D₅₀ and D₉₀), and stream discharge during the ten storms. This analysis revealed that total inorganic bedload transport was more strongly related to discharge than was transport of the large size category, coarse particulate organic matter transport tended to be more strongly related to streamflow than bedload discharge, and that neither of the particle size
diameters had any consistent relationship to streamflow.

Bedload transport during the ten storms was further evaluated in terms of the sampling sites that were used, i.e. riffles above and below a depositional area approximately 20 m in length. Transport tended to be greater, in terms of amount transported, at the upper riffle for most of the storm events. The opposite was true during the largest storm of the season and a storm which occurred a week later. It may be that bedload sediment is transported past the upper riffle by lesser magnitude events and is temporarily stored in the pool. Transport out of the pool requires events of greater magnitude. Supply limitations also appear to determine bedload transport in Trap Bay Creek.

Keywords: Helley-Smith sampler, pool-riffle sequence, armor layer, coarse particulate organic matter, suspended sediment, Southeast Alaska.

FEDORA, M.A. 1987. Simulation of storm runoff in the Oregon coast range. (MS) Simulation of storm hydrographs in the Oregon Coast Range was explored using the Soil Conservation Service (SCS) curve number methodology, and be developing and testing an antecedent precipitation index (API) method. Standard SCS procedures over-estimated peak discharge by about a factor of two (i.e., average over-prediction of 118 percent). When an average curve number was derived for Deer Creek (an Oregon Coast Range stream), errors in predicted peak flows averaged 26.8 percent. Even with adjustment of SCS parameters (watershed lag, shape of the unit hydrograph, and curve number), the simulated hydrograph shape and timing of predicted peak flows did not match with observed hydrographs. The assumed rainfall-runoff relationships of the SCS method are unable to account for changing runoff responses related to the time distribution of precipitation, and therefore provides an unrealistic approach to storm runoff simulation. The SCS runoff curve number method is not recommended for estimation of peak discharge nor simulation of storm hydrographs in Oregon's Coast Range.

A simple rainfall-runoff model was developed, which requires only precipitation and watershed area as inputs. An antecedent precipitation index (API) was developed by decaying the residual effects of precipitation observations through time. Coefficients used to decay API values were derived from recession analyses of storm hydrographs during periods of no rainfall. Linear regression was used to correlate API and discharge values for five Coast Range watersheds. Model coefficients for the five watersheds were used to predict the API-discharge relation for a sixth coastal watershed. Errors in peak flow estimates for Deer Creek and the independent test watershed averaged 10.7 and 17.8 percent, respectively. Storm runoff volume errors for all watersheds averaged 15.9 percent, and storm hydrograph shape was accurately simulated. Errors in peak discharge and volume estimates may be attributed to differences in timing between observed and simulated hydrographs, seasonal variation in antecedent moisture, and effects of snowmelt during rainfall. Temporal and spatial variability in precipitation observations were also evaluated. API methods may be useful in frequency analyses (in areas where rainfall records are longer than runoff records), estimation of missing data, slope stability research, and suspended sediment modeling.

FLEURET, J. M. 2006. Examining Effectiveness of Oregon’s Forest Practice Rules for Maintaining Warm-Season Maximum Stream Temperature Patterns in the Oregon Coast Range. (MS) Stream temperature, as an important component of stream ecosystems, can be affected by forest harvesting through removal of riparian shade and changes in hydrology. Riparian Management Areas (RMAs), as implemented through the current Oregon Forest Practice Rules, are designed, in part, to maintain stream temperature following forest harvesting. However, effectiveness of RMAs in achieving this outcome is uncertain. The objective of this research was to examine effectiveness of RMAs, as outlined by the current Oregon Forest Practices Act and the Northwest State Forests Management Plan, in maintaining warm-season temperature patterns of streamwater. Twenty-two headwater streams, on either private- or state-owned forestlands in the Oregon Coast Range that encompassed a range of RMA widths and harvest prescriptions, were evaluated for effectiveness of RMAs on stream temperature. A Before-After-Control-Impact/Intervention design was used, and each stream had an upstream control and a downstream treatment reach. Temperature probes were placed 1) at the top of the control reach, 2) at the boundary between the control and treatment reaches, and 3) at the bottom of the treatment reach from June to September for four years starting in 2002. All but one stream has at least two years of pre-harvest temperature data, and one year of post-harvest temperature data. Selected stream and riparian characteristics were collected every 60 m within the control and treatment reaches once prior to and once
following harvest. I hypothesized that RMAs would be effective if pre-harvest warm-season maximum
temperature patterns were maintained following harvest treatments. Comparisons of temperature patterns
between control and treatment reaches both pre- and post-harvest indicate that my hypothesis should be rejected
because warm-season maximum temperature patterns were not maintained when mean values in treatment
reaches across all study streams were considered. Difference in temperature gradients between control and
treatment reaches averaged 0.6°C, based on two years of pre-harvest and one year of post-harvest data. This
indicates that more warming or less cooling occurred in treatment reaches than occurred in control reaches when
pre-harvest and post-harvest periods were compared, suggesting that current RMAs for small- and medium fish-
bearing streams of the Oregon Coast Range are not effective for maintenance of warm-season maximum
temperature patterns.

FLOYD, W.C. 2005. Seasonal Relationships Between Dissolved Nitrogen and Landuse/Landcover and Soil
Drainage at Multiple Spatial Scales in the Calapooia Watershed, Oregon. (MS).
The Calapooia River, a major tributary of the Willamette River in western Oregon, is a watershed typical of
many found in the Willamette Basin. Public and private forested lands occur in the steep Upper Zone of the
watershed, mixed forest and agriculture lands are found in the Middle Zone, and the Lower Zone of the
watershed is comprised primarily of grass seed agriculture on relatively flat topography with poorly drained soils.
High levels of dissolved nitrogen (DN) have been identified as a water-quality concern within the Calapooia
River. To gain a better understanding of the relationship between landuse/landcover (LULC), soil drainage, and
DN dynamics within the watershed on a seasonal basis, we selected 44 sub-basins ranging in size between 3 and
33 km² for monthly synoptic surface water-quality sampling from October 2003 through September 2004. We
selected an additional 31 sample locations along the length of the Calapooia River to determine relative influence
of the 44 sub-basins on DN concentrations in the river.

T-tests were used to analyze differences between zones (Upper, Middle and Lower) and regression analysis
was used to determine relationships between DN and LULC or soil drainage class. The agriculture-dominated
sub-basins had significantly higher (p-value < 0.05) DN concentrations than the predominantly forested sub-
basins. Winter concentrations of nitrate-N were 43 times higher in agriculturally dominated sub-basins than in
forested sub-basins, whereas in the spring, the difference was only 7-fold. High DN concentrations associated
with the predominantly agriculture sub-basins were substantially reduced once they mixed with water in the
Calapooia River, highlighting the likelihood that water draining the relatively nutrient-poor, forested sub-basins
from the Upper Zone of the watershed, was diluting DN-rich water from the agriculture sub-basins.

Relationships between DN and agriculture, woody vegetation or poorly drained soils were moderate to strong
(0.50 < R² > 0.85) during the winter, spring and summer seasons. Results indicated an exponential decrease in
DN concentration. The high variability in DN concentration in the agriculture-dominated sub-basins suggests
factors in addition to LULC and poorly drained soils influence DN in surface water.

Seasonal relationships were developed between DN and proportion of poorly drained soils, agriculture, and
woody vegetation at differing scales (10 m, 20 m, 30 m, 60 m, 90 m, 150 m, 300 m, and entire sub-basin), which
we defined as Influences Zones (IZs), surrounding the stream network. Correlations between DN and proportion
LULC or poorly drained soil at each IZ were analyzed for significant differences (p-value< 0.05) using the
Hotelling-Williams test. Our results show strong seasonal correlations (r > 0.80) between DN and proportion of
woody vegetation or agriculture, and moderate-to-strong seasonal correlations (r > 0.60) between DN and
proportion of sub-basins with poorly drained soils. Altering scale of analysis significantly changed correlations
between LULC and DN, with IZs < 150 m generally having higher correlations than the sub-basin level. In
Contrast, DN correlations with poorly drained soil were generally higher at the sub-basin scale than the 60-
through 10-m IZs during winter and spring. These results indicated that scale of analysis is an important factor
when determining relationships between DN concentration and proportion LULC or poorly drained soils.
Furthermore, seasonal shifts in significant differences among IZs for correlations between LULC and DN suggest
land management proximity and its influence on DN concentration changes temporally. DN relationships with
poorly drained soil suggest that during winter and spring, when rainfall is highest, sub-basin scale soil drainage
properties have a greater influence on DN than soil properties within IZs in close proximity to the stream
network.

FRIEDRICHSEN, P.T. 1997. Summertime stream temperatures in the north and south forks of the Sprague River,
South Central Oregon. (MS)
The Upper Sprague River Watershed (North and South Forks of the Sprague River) in south central Oregon provides important habitat for salmonid species, including native bull trout (*Salvelinus confluentus*) and redband trout (*Oncorhynchus mykiss* ssp.). Concern over the loss of viable habitat for these species has increased due to reductions in channel and habitat complexity, and modification of riparian vegetation. Many of the factors affecting habitat quality also influence water temperature, which is an important habitat component of salmonids during the summer months. Maximum stream temperatures and diel fluctuations in the Upper Sprague River System generally reflected local reach characteristics, position in the drainage, and large scale changes in valley shape.

Stream temperatures in the North Fork Sprague River (NFSR), at a distance of 35 km from the drainage divide, equalled or exceeded 15°C, the ‘upper preferred temperature’ for salmonids, 16% and 36% of the time during the seven-consecutive warmest days of 1993 and 1994, respectively. Upstream of Lee Thomas Meadow (LTM), 6.5 km from the drainage divide, 15°C was equalled or exceeded only 1% and 13% of the time during the same period, while below LTM (18.3 km from the drainage divide), 15°C was exceeded 66% and 85% of the time during this same period. Diel fluctuations in the NFSR were greatest immediately below LTM (>11.8°C), decreasing to <6.0°C below the canyon section at the mouth of the watershed during both 1993 and 1994.

In the South Fork Sprague River (SFSR), 15°C was equalled or exceeded 79% and 99% of the time during the seven-consecutive warmest days of 1993 and 1994, respectively, 28.4 km from the divide. At this same distance, the upper lethal limit of 25°C was equalled or exceeded 16% of the time in 1994, representing very stressful or potentially life-threatening conditions for salmonids. Diel fluctuations for the SFSR were >6.5°C both years, the highest values being 9.5°C or greater at 28.4 km from the divide.

Seven-day maximum stream temperatures and diel fluctuations in tributaries of the Upper Sprague River System varied widely during the study period. Maximum stream temperatures varied from 13.8°C to 23.1°C while diel fluctuations varied from 4.8°C to 11.0°C; the highest values corresponding with relatively open, unshaded reaches and the lower values corresponding with shaded, forested reaches.

Relationships between stream temperatures, stream cover and channel morphology characteristics were evaluated for eight reaches within the study area. Only stream cover was found to be significantly (p <0.05) related to seven-day maximum stream temperatures, change in stream temperatures, and diurnal fluctuations in stream temperatures based on simple linear regression. When multiple linear regression analysis was used, several combinations of independent variables were found to be significantly (p <0.05) related to seven-day maximum stream temperatures, and/or change in stream temperatures, and/or diurnal fluctuations in stream temperatures. The variables that were consistently part of significant (p <0.05) regressions included: stream cover, wetted width, thalweg depth, width/depth ratio, and reach length.

A stream temperature model, SHADOW, was found to be a relatively good predictor of maximum stream temperatures for short (#1130 m) reaches and generally a poor predictor for longer (1340-4130 m) reaches. For the three short reaches (#1130 m), the average difference between observed and modeled temperatures was 0°C (+0.3EC); for the five longer reaches (1340-4130 m), the average difference was 2.9EC (+0.6EC) indicating that the SHADOW Model over-predicted stream temperatures for these longer reaches. The shortest forested reach was under-predicted by 0.4EC. Temperature simulations for five meadow reaches using SHADOW and multiple regression models suggest that lower maximum stream temperatures would be observed if stream cover were increased.

GARVIN, W.F. 1974. The intrusion of logging material into artificial gravel streambeds. (MS)
The objective of this study was to quantitatively describe the intrusion of logging debris into artificial gravel streambeds during conditions of low stream flow with a stable streambed, and begin an analysis of the effect of high flow and unstable streambeds. This study was initiated because prior studies indicated that logging debris was responsible for dissolved oxygen reduction within the gravel bed of spawning streams.

Low flow--stable streambed studies were run for eighteen to twenty days in a flume. Two control samples of the gravel were taken. Logging slash was then placed on the gravel in volumes approximating those of logged streams. A sample was taken every other day for eighteen to twenty days using a device which froze a core of the streamed gravel. Since there were many problems with vandalism and weather, only two low flow replications were completed.

No variables in the high flow study were found to be good predictors of intrusion. Natural random error
and the extreme variability of this dynamic system were too great to draw even general conclusions. The range of concentrations of high flow studies one and two were .14 gm/l and .04 gm/l respectively. The average concentration values for high flow studies one and two were .01 gm/l and .02 gm/l respectively. Beneath the armor layer, the streambed exhibits less variability, but the large random error is sufficient to make prediction of intrusion difficult. During high flow periods where the streambed is moving, no predictive equation could be developed to estimate organic material release or incorporation owing to the large variability existing in the system.

GAWEDA, F.M. 1983. First year effects of broadcast burning on soil infiltration and wettability in southwest Oregon. (MS)

Soil infiltration and wettability measurements during the first year following a broadcast burn in the Siskiyou Mountains of southwest Oregon, have illustrated the magnitude of the effects of light-to-moderate intensity burning on hydrological soil properties. A prescribed fire near White Creek in late spring significantly reduced soil infiltration for 4 months following the burn, but infiltration rates below the maximum 100 year precipitation event for the area were not observed. The lowest infiltration rate recorded on logged and burned soil was 5.3 cm/hr (2.1 in/hr), but 94% of all the observations ranged between 9.0 and 11.4 cm/hr (3.5 and 4.5 in/hr).

Infiltration rates recorded on logged and unburned soil were greater than 11.2 cm/hr.

Broadcast burning caused hydrophobic substances in the litter and duff layers to become volatilized, subsequent condensation of these substances on soil particles located in the 0-5 cm depth of soil. A total of 25% of the exposed mineral soil surface in the burned section was water repellent 9 days after burning, but this was reduced to 6% within five months. Some naturally-occurring water repellency existed in the unburned condition, yet the greatest percentage recorded was only 1% in August, when soils were at their driest.

In assessing the wetting difficulties of a soil sample, the measurement of an apparent liquid-solid contact angle was more consistent than obtaining water drop penetration times. The penetration time of a water drop is dependent on the wetting difficulties and pore geometry of the soil directly beneath it, therefore measurements were highly variable for any one soil sample.

Regression models correlated infiltration rates with soil contact angles in the burned section. Association was strongest ($r^2 = .93$) for infiltration rates obtained an unsaturated soils in which attraction forces between the soil particles and water molecules predominate. Since this attraction is inversely related to the liquid-solid contact angle, infiltration rates decreased with increases in the liquid-solid contact angle.

During the summer, residual vegetation in the unburned section significantly reduced percent soil moisture below levels recorded in the burned condition. Increased precipitation and lower evapotranspiration demands, combined with rapid growth of resprouting and invading vegetation in the burned section during early fall, probably let to soil moisture becoming nearly equal in both conditions by mid-fall.

Supplemental hydrological soil measurements, collected 33 days after a moderate intensity broadcast burn at Shan Creek, did not markedly differ from those obtained 44 days after the light-to-moderate intensity burn at White Creek. Although Shan Creek did have a greater percentage of water repellent soil (52% vs. 12%), there was not a significant difference between infiltration rates obtained at both sites.


Forest roads alter hillslope hydrologic processes by intercepting, concentrating, and rerouting storm runoff. Current road drainage guidelines are based on minimizing erosion and do not take into account the impact of forest roads on hillslope hydrology. This work monitors ditch flow and rainfall for 10 road segments over the course of one winter in the central Oregon Coast Range. The objective was to determine rainfall/runoff relationships and quantify metrics of runoff for the flow of water in roadside ditches. Road and hillslope characteristics were also recorded and related to the metrics of runoff of ditch flow.

Five large discrete storms were selected from the record for analysis. Two distinct ditch flow behaviors were identified from field observations and hydrograph inspection and were termed intermittent and ephemeral flow. Road segments that had intermittent flow had higher peak flows and greater storm runoff volumes than road segments with ephemeral flow. Rainfall/runoff relationships such as the lag time from the maximum rainfall intensity to the peak flow and the percent of rainfall seen as ditch flow were also significantly different between the two flow behaviors. Road and hillslope characteristics were not related to runoff peak flows or storm volumes. The best predictors of runoff were rainfall intensities and amounts. Evidence suggested that
road segments with intermittent flow were being driven by the interception of upslope subsurface flow and that road segments with ephemeral flow were being driven by road surface runoff.

GILL, R.E. 1994. Sediment delivery to headwater stream channels following road construction and timber harvest in the Blue Mountains, Oregon. (MS)

Many studies have focused on improving our understanding of the effects of timber harvesting activities on soil, water, and fisheries resources. Much of this work has led to the development and widespread use of soil erosion prediction models by land managers. This widespread use has often resulted in model applications that are outside the bounds in which the models were developed. There is currently no adequate method for predicting the quantity of sediment delivered to first and second order channels following road construction and harvesting in areas of ash-influenced soils in the Blue Mountains of eastern Oregon. The objectives of this study were: (1) to determine the amount and rate of sediment delivery to ephemeral (first and second order) stream channels following road construction and logging, and (2) to evaluate the WWSED sediment yield predictions.

A variety of methods were employed to accomplish these objectives, including: in-channel and on-slope sediment trapping for quantity and rate determination, physical characterization of the area contributing flow and sediment, physical characterization of the soil samples themselves, and statistical analysis for extrapolation of results.

No statistically significant relationships between the quantity of sediment yielded versus either inherent or management disturbance factors could be concluded from this data set. While there appears to be no significant relationship between inherent or management induced disturbance factors and sediment yield, there has been a two-fold increase in sediment yield when comparing 1993 to 1991 sediment yields, and a ten-fold increase in sediment yield when comparing 1993 to 1992 sediment yields. The R-Squared values for 1993 sediment yield versus inherent values were considerably higher than 1991 or 1992 values.

It can be concluded that while there was an increase in annual sediment yield in the Syrup Creek Study Area, there is no statistically significant relationship between this increase and inherent or management factors. This may be due, in part, to the limited data set with only three years of observations. It is likely that there are other inherent and management factors which would help explain the variation in sediment yields.

Results indicate that the WWSED Model was drastically overestimated the sediment yield from this area. From this, we can conclude that the variability of natural systems is far more complex than can be simplified into a prediction model.

Several additional years of measurement are necessary. The WWSED model predicts sediment yield for a seven year period. At a minimum, measurements should continue for an additional four years and preferably longer. In addition, it is recommended that a pumping sampler be installed at the mouth of the study area to quantify total suspended load yielding the watershed. This may assist additional years of sampling and provide a more robust data set in which to evaluate the WWSED model.

GILLILAN, S.E. 1989. Storage dynamics of fine woody debris for two low-order coastal streams in Southeast Alaska. (MS)

The characteristics and associated storage dynamics of approximately 2000 pieces of fine woody debris (FWD; 2.5 cm < diameter < 10 cm and 0.3 m < length < 10 m) was evaluated over a three-year period in two undisturbed salmonid nursery streams in southeast Alaska. To index a given reach propensity to capture and store FWD over time, 100 survey stakes (diameter = 2.9 cm, length = 44 cm) were introduced at one-year intervals to the head of four reaches with distinct coarse woody debris (CWD; diameter > 10 cm, length > 1 m) loadings, and their downstream dispersal monitored.

Between 1987 and 1989, storage of FWD was temporally and spatially variable and not suggestive of steady-state conditions. In the 1987-1988 stormflow period, the total resident FWD volume (cm$^3$ per meter of reach) declined 43%. This was followed by a resident volume increase of 9% in the 1988-1989 period. These changes in FWD storage occurred despite maximum peak flows which differed between periods by only 10%. These annual changes in FWD storage indicate that factors and processes in addition to magnitude of peak flow were important in FWD storage dynamics. Factors important in describing the observed storage fluctuations might include the effects of an unusually low peak flow regime (20% of nine-year average) in the year prior to the study's commencement, as well as variable rates of FWD recruitment from the riparian environment.

The majority of FWD was shorter (66-102 cm) than bankfull width (3.8-5.6 m), approximately 4.7 cm in
diameter, geometrically simple in form, and in moderate to advanced states of decay. Shorter pieces were
generally entrained more frequently than longer pieces, resulting in selective retention of longer pieces through
time. The data strongly suggest FWD loadings are positively correlated with the amount of CWD in the reach.

Retention of stakes was generally highest in a reach with high CWD loading (0.47 m³/m), intermediate in
two reaches with moderate CWD loading (0.13 m³/m and 0.11 m³/m), and lowest in a reach with low CWD
loading (0.0082 m³/m). Distinct spatial and temporal stake dispersal patterns were noted between reaches. The
retention of stakes declined most dramatically during the first stormflow (1.31 m³/s) following their introduction,
while succeeding storms of equal or greater magnitude had less of an effect.

GOARD, D.L.  2003.   Characterizing the Spatial Distribution of Short Duration, High Intensity Rainfall in the
Central Oregon Coast Range.   (MS).
Shallow, translational landslides occur naturally and are the dominant form of erosion in the Pacific Northwest
and the Oregon Coast Range. These landslides are triggered during large, infrequent storms. Forest
management activities, such as timber harvesting, can exacerbate the occurrence of shallow, translational
landslides and the temporal and spatial variability of short duration, high intensity rainfall is an important step to
understanding how to manage landslide-prone forested terrain. Rainfall intensity data collected during the last
14 years form a network of 13 tipping bucket rain gauges were analyzed to characterize the rainfall regime of the
central Oregon Coast Range. Partial duration analysis was carried out to determine the 2-, 5-, 10-, 25-, 50-, and
100-year return period antecedent precipitation index (API) and rainfall intensities for the 30-minute, 1-, 2-, 6-,
12-, and 24-hour rainfall durations. The Spearman Rank Correlation method was used to determine if patterns
existed in the relative rank of rainfall intensities across the study area. Isohyetal maps of rainfall intensity for
each unique combination of rainfall duration and return period were also developed. Analysis of the rainfall
intensity data showed that rainfall intensity was highly variable across the study area, although the variability
across the study area was fairly constant. The coefficient of variation in average rainfall intensity across the
study area was approximately 20 percent. The Spearman Rank Correlation method showed that patterns in
rainfall occurred across the study area and that these patterns were consistent for all rainfall durations and return
periods. In other words, the rain gauge locations that got the most rainfall were the wettest regardless of rainfall
duration or return period and the same is true for the rain gauge locations that received the least amount of
rainfall. Examination of the isohyetal maps showed that all of the variability in rainfall intensity occurred within
the minimum distances between rain gauge locations, which is 10 to 15 km. Analysis of the API data showed
similar trends.

GRIZZEL, J.D.  1993.  Municipal water source turbidities following timber harvest and road construction in western
Oregon.   (MS)
Many municipalities throughout western Oregon rely upon forested watersheds as a source for domestic water
supply. These watersheds are commonly managed by state or federal agencies or private corporations for timber
production. Activities related to forest management within municipal watersheds have the potential to adversely
affect water quality. Timber harvesting and/or road construction operations may accelerate rates of surface
and/or mass soil erosion and subsequent stream sedimentation.

This study investigated the effects which timber harvesting and road construction operations had on source
water turbidity levels within 13 municipal watershed throughout western Oregon. Turbidity records were
obtained from municipal water treatment facilities and ranged from 5.1 to 16.9 years in length. Information
regarding forest land use activities which occurred during 1980-91 was obtained from Oregon Department of
Forestry records.

An analysis of turbidity residuals before, during and after known timber harvesting and/or road
construction operations indicates that forest land use alone did not result in sustained increases in turbidity levels.
In some cases, forest operations apparently exacerbated the effects of a severe storm which occurred along the
northern Oregon Coast during January of 1990. Mass soil movements occurring in two watersheds as a result of
the storm led to large, but short-term increases in turbidity levels. The source of increased turbidities not
associated with the 1990 storm could not be identified due to a lack of information regarding sediment sources
and transport processes.

A second analysis was performed which quantified the level of disturbance resulting from forest operations
occurring during each year of record. Mean water year turbidity and the mean of the 10 highest water year turbidities were regressed against the disturbance level for all watersheds. Disturbance levels were based on the type and areal extent of forest operations. Simple linear regression analyses indicate that the relationship between turbidity and disturbance level over the range of data encountered was insignificant (α = 0.05).

Impoundments located within the surface water system of many of the study watersheds affected turbidity levels. By acting as a settling basin for sediment particles, impoundments reduced turbidity levels when municipal intakes were located within the structures. Mean turbidity, the standard deviation in turbidity, and the mean of the 10 highest turbidities were all inversely related to impoundment volume.

Although the results of this study indicate that forest operations were not a direct causal factor leading to increased source water turbidity levels, any forest management activity has the potential to negatively affect stream water quality. Monitoring efforts designed to investigate the effects of forest land use on water quality should be implemented with a set of predetermined objectives and methods to ensure reliable results.

This study assessed implementation of the 1994 Water Protection Rules in the Oregon Forest Practices Act from the perspective Rule users and post-harvest riparian conditions. A 1993 evaluation found that under the previous rules over half of riparian conifers were removed during harvest, prompting concerns about future sources of desirable instream woody debris. Twenty-four harvest sites throughout Oregon were assessed for riparian conditions after harvest, focusing on potential contribution of future large woody debris to streams relative to conditions at similar sites under prior rules. Industry foresters, logging operators, and nonindustrial private forest owners who had filed harvest notifications in Fall 1994 were sent questionnaires to determine the level of support for the Rules and related concerns. Return rate was 67 percent of 848 sent, yielding 403 usable surveys from people who had harvested. Personal interviews during visits to harvested sites supplemented the survey results.

Most (61%) generally or strongly supported the Water Protection Rules, while 26 percent generally or strongly opposed the Rules. Of choices listed in the survey, those factors that most affected support, or lack of it, were: 1) flexibility of rules, 2) whether rules were backed by good science, and 3) lack of compensation or incentives. For nonindustrial owners, whether the rules take better care of the land (stewardship) was also an important factor. The policy options considered most effective for influencing private forest management were more favorable tax policies and compensation.

Riparian condition measurements were compared to results from the 1993 Oregon Department of Forestry Rule Effectiveness study. Significantly more conifers were left under the 1994 Rules than previously: 75% of preharvest conifers/1000 feet of stream was left in 1995 versus 35% in 1993 (p<0.01), and 68% of initial conifer basal acre (ft²/acre) was left in 1995 versus 27% in 1993 (p<0.01). For the 1995 data, an average of 50 percent of trees could fall directly into the stream, contributing debris over 8 inches diameter and 5 feet long. The number of snags left in the riparian areas in Western Oregon was higher in 1995 (p<0.01), but not east of the Cascade Mountains.

HARPER, W.C. 1969. Changes in storm hydrographs due to clearcut logging of coastal watersheds. (MS)
The purpose of this study was to determine the effect of clearcut logging on stormflow by analysis of characteristic parameters of individual storm hydrographs. Parameters considered included height-of-rise, peak discharge, volume and time-to-peak. The hydrologic data were derived from experimental watersheds of the Alsea Study located in the Oregon Coast Range.

Three clearcut watersheds were selected for study; Deer Creek IV (39 acres) was clearcut, and Needle Branch (175 acres) was clearcut and burned. Both watersheds were compared to Flynn Creek (502 acres), an untreated control, before and after treatment.

Change in hydrologic parameters was determined from differences between pre- and post-logging linear regressions. Statistical techniques were utilized to test for difference in slope or vertical position.

Significant increases were found in peak discharge from both Needle Branch and Deer Creek IV following clearcut logging. Larger increases were noted during the fall period than during the winter period. Volume parameters of quick flow, delayed flow, and total flow were increased for Needle Branch. Volume of flow was not shown to increase from Deer Creek IV. This may have been due to a lack of unstable storm events for analysis from this watershed. Time-to-peak was not altered in Needle Branch but was decreased for low flows
and increased for high flows on Deer Creek IV. The height-to-rise parameter did not prove to be of value for detecting change in this study. Comparison of the burned watershed (Needle Branch) to the unburned watershed (Deer Creek IV) did not produce a noticeable difference in any of the parameters.

The observed changes in stormflow were related to clearcut logging and the effect of vegetative removal on watershed response.

HEIMANN, D.C. 1988. Recruitment trends and physical characteristics of coarse woody debris in Oregon Coast Range streams.

This study investigated the long-term consequences of timber stand removal on the recruitment, physical characteristics, and spatial distribution of coarse woody debris in small (second- and third-order) streams of the Oregon Coast Range. A chronosequence of stream-stand systems, ranging from 21- to 140-years since disturbance (YSD), were sampled to determine temporal trends in coarse woody debris characteristics along with successional changes in riparian forests.

Total debris volumes ranged from 135 to 864 cubic meters per hectare. No distinct trends was found in the total volume of debris over time because of the variable effects of the disturbance event on pre-disturbance debris volumes (debris delivered prior to or during the disturbance event). Post-disturbance deliveries (debris delivered after disturbance by second-growth stand) of deciduous debris increased through 65-YSD then decreased. Post-disturbance coniferous debris volumes, which were first detected at the 28-YSD site, increased from 28- to 140-YDS. Pre-disturbance coniferous debris comprised the large proportion of the total volume in the stream system until approximately 122-YSD at which time post-disturbance coniferous debris made up the largest proportion of total debris volume.

At all sites the largest volume of pre-disturbance debris volumes were in the large (greater than 0.30 meters) diameter size class while the largest proportion of post-disturbance debris volumes were in the large diameter class only at 65- through 140-YSD sites. The largest proportion of pre-disturbance debris volumes were in the large (greater than 4.0 meters) length size class at the 28- through 140-YSD sites and the largest proportion of post-disturbance debris was in the large size class at the 28- through 140-YSD sites.

Morisita's index of dispersion, I_F, was used to test the type of spatial distribution pattern followed by the debris pieces. Results indicate that debris pieces in the pre- and post-disturbance delivery classes along with total pieces tended to follow a contagious (clumped) spatial distribution pattern at all sites.

Results from this study will provide an improved perspective of the long-term forest stand and coarse woody debris dynamics associated with riparian areas.


This study has analyzed factors which affect the accumulation of terrestrial organic debris within natural gravel streambeds. In addition, the amounts, sizes, and physical conditions of intruded material were measured, along with the effect of the detritus on intragavel dissolved oxygen levels.

Measurements indicate that aged intragavel detritus had no significant impact on subsurface dissolved oxygen levels. The organic material extracted from the streambeds was composed primarily of highly conditioned woody material, which is characterized by a very low B.O.D. These measurements support the hypothesis that decomposing organic material produces only a temporary demand on intragavel dissolved oxygen supplies. Previous work has indicated that this demand has generally been met after only 60 days.

One hundred and forty-four frozen core samples of ten streambeds were taken as a means of analyzing subsurface organic debris concentrations. These cores provided the data needed to calculate streambed porosity, median cobble size, and average detritus size. In addition, stream gradient and surface debris loading were measured.

Subsurface organic debris concentrations were found to be extremely variable. The range of values observed, in grams of detritus per liter of pore volume, was 1.4 to 439.9. The mean value was 29.3 grams per liter of pore volume, with a standard deviation of 52.9. These values indicate that organic material may provide a severe threat to subsurface dissolved oxygen levels, especially if high concentrations of fresh, finely divided material, such as leaves or needles, are present. Although the impacts exerted by organic material are only temporary, there may be a detrimental impact on the fisheries resource if a large B.O.D. is produced at the time alevins are depending on intragavel dissolved oxygen.
Regression equations for predicting subsurface debris concentrations were developed. It was observed that subsurface debris accumulations can generally be expected to increase with increases in streambed porosity, surface debris loading, and median cobble size. Concentrations can be expected to decrease with increases in stream gradient.

Estimates developed with these models cannot be expected to yield accurate values under all conditions, and the possibility of high variability must be anticipated. However, the models developed in this study do provide a means of predicting subsurface debris accumulations in natural gravel streambeds under a variety of conditions. In addition, the measurement and analysis techniques described will encourage future research which will further develop an understanding of the small stream ecosystem.


Although soil tillage has been used successfully to alleviate compaction of forest soil after logging in a number of management contexts, little is known about the feasibility of tilling in residual stands. In an attempt to weigh the benefits of tillage against possible damage done to residual trees during tillage, a study was set up to look at both immediate and long-term effects of various treatments in a second-growth Douglas-fir thinning.

Designated skid trails were laid out 46 m apart prior to ground-based logging with a rubber-tired skidder and a small crawler tractor. Pre-logging analysis consisted of penetrometer transects used to obtain a general indication of soil strength; during logging, machine movements along trails and turn characteristics were recorded. After logging, four of seven trails were tilled and approximately 40 trees were selected as study trees in each of three populations: (1) trees near untilled trails, (2) trees near untilled trails, (2) trees near tilled trails, and (3) trees away from any trails (control). Bulk density changes were measured in soil near trees in each population using a dual probe nuclear densimeter. In addition, tree and site characteristics, root and stem damage from logging and adjacent competition were recorded for each tree.

Untilled trails showed average increases in soil bulk density over control of 17.8 and 11.2 percent for 10.2- and 20.3-cm depths, respectively, but a decrease of 2.7 percent at the 30.5-cm depth. Tilled trail average bulk density showed a difference of 6.1 percent greater than control at 10.2 cm and 2.2 and 3.6 percent less than control for 20.3 cm and 30.5 cm, respectively.

Stepwise multiple regression used to explore associations between slope, number of vehicle turns, cumulative ground pressure, slash characteristics on trails, and interactions of all these variables showed no significant associations with bulk density changes due to logging. Analysis of Variance did reveal greater mean bulk densities at the 10.2- and 20.3-cm depths near trees on untilled trails where slash did not exist as compared to where slash did exist.

Root damage due to tillage was assigned to low, moderate or high damage classes based on length and diameter of roots exposed above ground after tillage. Analysis by regression showed that these root damage classes had significantly different tree diameters, revealing a possible trend of higher root damage for larger trees along trails being tilled.

A rough economic analysis estimated tillage for this project cost the Bureau of Land Management approximately $600/mile or $400/acre of tilled trail area. These figures are unusually high due to several factors including the small amount of work done for high move-in costs, complications brought on by research demands, and operator inexperience.


The energy budget of a pumice desert surface was analyzed under clear skies during early, mid- and late summer periods. The pumice site is in the semi-arid plateau region of Central Oregon at an elevation of about 1500 meters. The flat pumice surface is approximately 250 hectares in extent, and is bordered by a sparse lodgepole pine forest. Energy budget components of net radiation, soil heat flux, sensible heat flux, and latent heat flux were evaluated for one clear day in each of the three measurement periods.

The daily energy budget totals were (cal/cm² day):

<table>
<thead>
<tr>
<th></th>
<th>17 July 1969</th>
<th>13 August 1969</th>
<th>4 September 1969</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net radiation</td>
<td>258</td>
<td>228</td>
<td>194</td>
</tr>
<tr>
<td>Soil heat flux</td>
<td>-7</td>
<td>-14</td>
<td>-2</td>
</tr>
<tr>
<td>Sensible heat flux</td>
<td>-197</td>
<td>-197</td>
<td>-180</td>
</tr>
<tr>
<td>Latent heat flux</td>
<td>-54</td>
<td>-17</td>
<td>-11</td>
</tr>
</tbody>
</table>

The most significant features of the pumice desert energy budget were: 1) Radiant energy transformed by
the pumice surface (net radiation) was approximately 60 percent of the amount measured over a nearby forested surface; 2) Energy transfer into the soil amounted to less than 3 percent of the energy supplied to the surface by net radiation, while surface temperatures varied through a 50°C range each day; 3) Sensible heat flux dissipated 85 percent of the net radiation supplied to the surface; and, 4) Evaporation at the pumice site averaged less than 0.05 cm per day, although the pumice beneath the dry surface layer remained moist.

A unique stability correction, \( N \), for the aerodynamic flux analysis of sensible or latent heat was developed to extend over the wide stability range found at the pumice site. The form of this correction during unstable conditions is:

\[
N = (1 - 34R_i)^{0.55},
\]

where \( R_i \) is Richardson's stability parameter.

A method for estimating the uncertainty of the measurement system and of the resultant flux analyses was developed and applied to the results of this study. The average relative uncertainties of the net radiation and soil heat flux analyses were estimated to be less than 1 percent and 5 percent, respectively. The average uncertainty of the sensible heat flux analyses was estimated to be 3 percent when using an aerodynamic model, and 9 percent when using the Bowen ratio model. The corresponding figures for latent heat flux are 25 percent with the aerodynamic model and 30 percent with the Bowen ratio model. The larger percentage uncertainties associated with latent heat are due in part to the small vapor pressure gradients near the pumice surface, relative to the measurement capabilities, and in part to the small values of the latent heat flux.

This study demonstrates the applicability of micrometerological theory in characterizing complex microclimatological relationships by presenting them in a concise, comparable form through use of the energy budget.


The Steamboat Creek basin drains 227 mi² (588 km²) of steep forested terrain into the North Umpqua River of Southwest Oregon, 39 mi (63 km) northeast of Roseburg. Summer base flows for Steamboat Creek average 83 cfs (2.35 m³/sec). Steamboat Creek and its tributaries are considered important to the production of summer-run steelhead; the basin has been closed to angling since 1932.

Harvesting has occurred in every subdrainage of the Steamboat Creek basin. Trees were routinely removed from riparian areas when harvesting in the basin began in 1955. Since the mid-1970s to early-1980s, however, buffer strips were left adjacent to streams. In addition, the floods of 1964-65 caused significant damage to riparian vegetation in the basin. This study was undertaken to: (1) determine long-term trends over the period 1969-90 of summertime water temperatures in the mainstem of Steamboat Creek, selected tributaries, and in Boulder Creek, an unharvested control stream in adjacent watershed and (2) evaluate spacial patterns of maximum water temperatures in the Steamboat Creek basin during the summer of 1990.

Significant \((P<0.10)\) trends of decreasing maximum daily summertime stream temperatures on Steamboat Creek and tributaries occurred from 1969-90. In contrast, an unharvested control stream showed a small, but nonsignificant, increasing trend in stream temperatures. The largest decrease in maximum stream temperatures (7 to 11°F, 3.9 to 6.1°C) occurred on small streams with summer base flows less than 6 cfs (0.17 m³/sec). These streams also had the highest proportion of stream length adjacent to harvesting activities before 1974. The smallest decrease in maximum stream temperatures (0 to 3°F, 0 to 1.7°C) occurred on streams with little or no history of timber harvest activity along riparian areas, or at locations where summer base flows were greater than 15 cfs (0.42 m³/sec).

Since no trends in either air temperature or streamflow were apparent over the 1969-90 period, regrowth of riparian vegetation that was previously removed by flooding, debris torrents, or streamside harvesting, appears to be the major cause of trends in decreasing maximum summer stream temperature. Regrowth of riparian vegetation provides shade over small streams, decreasing energy input to the stream from solar radiation.

Maximum daily stream temperatures in lower Steamboat Creek did not change significantly during the 1969-90 study period and stream temperature data in 1960 indicates that maximum stream temperatures in lower Steamboat Creek have historically been high. Any cooling effects by groundwater or tributaries are largely negated by the large volume of water in the main channel. Also, the large stream width renders riparian vegetation relatively ineffective in protecting the stream from solar radiation.

Minimum stream temperatures decreased during the 1969-90 study period for all of the long-term stations.
in the Steamboat Creek basin while the control stream showed a slight increasing trend. Similarly, diurnal stream temperature fluctuations decreased for several tributaries.


Fishery biologists and watershed management specialists have recently begun to investigate the pollutional threat posed by organic debris left in or near the forest watercourses. Oxygen content in some streams has fallen below the limits required for fish survival. The biochemical oxygen demand exerted by the debris and the reaeration potential of the stream must be determined to predict the effects of debris accumulation on dissolved oxygen.

The purpose of this study is to specify equations suitable for predicting reaeration in small, turbulent streams and identify the factors affecting reaeration under these circumstances. Reaeration rates in a mountain stream were determined by depleting the oxygen content at one point with sodium sulfite and then measuring the changes in dissolved oxygen as the deaerated water moved downstream. These reaeration rates were then correlated with the hydraulic characteristics of the stream. Thus, the difference in reaeration between small streams and larger rivers is related to the degree to which turbulence extends through the bulk of the fluid.

HOPSON, R.G. 1997. Shallow aquifer characteristics adjacent to the Upper Middle Fork John Day River, eastern Oregon. (MS)

Subsurface inputs into lotic systems are a primary mechanism for cooling streams with high ambient water temperatures. Objectives of this study include: 1) to determine the effectiveness of Forward Looking Infrared (FLIR) thermal imagery to detect shallow aquifers, 2) to characterize certain physical, spatial, and temporal characteristics of the fluvial, floodplain, and subsurface environments, and 3) to determine if hyporheic water can be distinguished from true groundwater using water quality characteristics. Primary variables include free water surface elevation, temperature, and specific conductivity. Study sites were located within three effluent reaches of the unconstrained, fourth order upper Middle Fork John Day River in eastern Oregon.

A significant association was observed between relative ground surface temperature and depth-to-groundwater at the three well fields. In addition, the ability of FLIR to predict shallow aquifers decreased as depth-to-groundwater increased. However, a high degree of variability was observed.

Spatial aquifer water surface patterns varied between sites and appear to be influenced by hydrologic origin, including various groundwater, hyporheic water, and irrigation water sources. The net hydrologic flux into the river per meter depth at Well Field 3 was estimated at 4.2E-03 m³/s-m. Diurnal water surface elevation varied among wells and between wells and staff gages. Annual mean aquifer recharge was greatest during fall months while mean discharge occurred only during spring months. Mean annual aquifer temperature varied according to degree of connectivity between surface/subsurface environments.

Subsurface aquifer temperature and specific conductivity patterns were not always correlated to water surface gradients. However, these variables may represent subsurface fluxes not apparent using water surface contours. An irrigation effect on aquifer temperature and specific conductivity may have influenced these variables.

Mean percent saturation of dissolved oxygen was low in the wells and saturated in the Middle Fork. pH values were generally neutral in the aquifer and slightly alkaline in the Middle Fork.

Water surface gradient provided the most reliable indicator of hyporheic water, followed by subsurface temperature and specific conductivity. Boundaries between groundwater, hyporheic water, and irrigation water appeared to exist as a gradient rather than an abrupt edge. However, environmental factors may also have influenced this relationship.


Twenty-one countersunk culverts in Oregon were inventoried to establish baseline information for the stream crossings so that subsequent resurveys can assess the long-term stability and functionality of the culvert design. A subset of the inventoried culverts was selected for detailed hydraulic measurements. The detailed velocity measurements were used to help derive and empirical model, which will calculate the proportion of a cross-section that is less than or equal to a particular velocity. The model could be used in the design stages of countersunk culvert installations to determine what proportion of the culvert cross-section will be within a swimming velocity of a fish species and age class of interest at a specific fish passage design discharge. Natural channel roughness equations were examined for applications to countersunk culverts, which is a stream
simulation design. A weighting factor to account for corrugation roughness along the sides of the culvert is proposed. The roughness equations corresponded well with back-calculated roughness values.

As the demands for forest products increase, additional timber harvesting operations can be expected on steep mountainous terrain. The resulting disruption of natural slope stability by man's disturbances (roadbuilding, logging and vegetative manipulation, etc.) may also accelerate mass movement processes in this terrain.

Swanson (1969) defines mass movement as "...the slow to rapid downslope movement of large masses of earth material (soil, rock and forest debris) of varying water content, primarily under the force of gravity". Earlier, Popov (1963) quoted Pogrebov's definition of mass wasting as "...movement of a rock mass downward under the pressure of gravity, commonly associated with the activity of surface and ground water."

As a dominant form of erosion on mountainous lands in the Pacific Northwest, mass movement may reduce site productivity by removing soil material and lowering the nutrient capital; cause damage to roads, other improvements and scenic values; lead to serious channel degradation and scoured channel banks; contaminate water quality with increased sediment loads, turbidities and dissolved chemical content; shorten the life span of reservoirs due to excessive siltation, and impair fish habitat through increased sediment in spawning gravels and blockage of fish passage by landslides (Brown, 1973; Swanston and Dyrness, 1973). Accelerated mass movement is probably the most serious problem facing land managers in areas characterized by steep slopes and heavy rainfall.

The objective of this paper is to review and summarize the present knowledge about mass movement processes on mountainous forest lands. This review will emphasize problems associated with man's activities and may provide professional hydrologists and land managers with information that can be applied in making effective management decisions. In addition, several types of studies will be identified from which an improved understanding of mass movement processes may be obtained.

ICE, G. 1978. Reaeration in a turbulent stream system. (Ph.D.)
The oxygen concentration in a stream is an important parameter of water quality. Changes in oxygen concentrations can affect various stream organisms including fish. Foresters have become concerned with predicting the impacts of forest activities on oxygen levels in streams. Slash, which accumulates in streams as a result of harvesting activities, is a food source for stream organisms. During aerobic respiration, oxygen is utilized. Under some conditions the oxygen concentration can be depleted below acceptable levels. Large, fish bearing streams are generally well protected by forest practice regulations. For smaller streams without fish populations, the issue is one of downstream impairment of water quality as deoxygenated water enters fish-bearing reaches.

A natural process counteracting oxygen depletion is reaeration. Reaeration is the exchange of gases between the atmosphere and water. This process operates to maintain oxygen near the saturation concentration. The change in the oxygen deficit in a stream is a function of the existing deficit and the reaeration rate coefficient.

The objective of this study was to develop a predictive equation for the reaeration rate coefficient based on the hydraulic characteristics of stream channels. This is a first step in developing guidelines to regulate harvesting residues in streams. Seven natural stream sites were selected in Oregon. These sites represented a wide range of hydraulic conditions. The stream reaches were segregated into segments of uniform hydraulic characteristics. Sodium sulfite was injected into the stream to artificially deplete the oxygen concentration. The recovery of the oxygen concentration was used to determine the reaeration rate coefficient.

Several models for the reaeration process were tested using regression techniques. Some were models proposed by other investigators and some were developed independently. The predictive equation which fit the data best is a function of the maximum unit energy dissipation rate (E_d) and a depth parameter (H_d):

\[ K_2 \sim 37 \left( E_d^{1/2} \right) \over \left( H_d^{2/3} \right) \]

This equation is consistent with theoretical descriptions of gas exchange phenomena. As the rate
of energy dissipation increases in a segment, the turbulence in the segment also increases. Turbulence promotes an increase in the liquid-atmosphere interface area and in the exchange rate of volume elements in the interface. Reaeration is stimulated when deaerated water from the bulk flow of the stream replaces the oxygen saturated water in the surface film. As the area of liquid-atmosphere contact increases, the total flux of oxygen molecules into the depleted fluid volume increases. As the fluid volume increases, the change in concentration for a specific flux of molecules decreases. The depth term (H_D) can be used to describe the ratio of the surface area to the volume of fluid in the segment. In this study, the depth term used was the discharge divided by the mean width and maximum velocity. This approach adjusts for dead zones that do not actively mix with the bulk flow.

For field applications, predicting the reaeration coefficient for any temperature (T) requires that the slope (s), active width (W_D), maximum velocity (U_D), and discharge (Q), be measured for uniform stream segments. These variables are combined in the following equation:

\[ K_{2T} \approx 1.016 \sqrt{(T-20)} \sim 37 \left\{ \frac{W_D}{D} \right\}^{2/3} \left\{ \frac{s}{2} \right\}^{1/2} \left\{ \frac{g}{2} \right\}^{1/2} \left\{ \frac{U_D}{D} \right\}^{7/6} \left\{ \frac{Q}{2} \right\}^{1/2} \]

Using the predicted reaeration rates, estimates of mean segment velocities, biochemical oxygen demand loading, and rates of oxygen demand decay, it is possible to predict the oxygen concentration of a stream moving through and downstream from a harvesting site. The reaeration rate influences the maximum deficit and time required for recovery and can be used to evaluate the risks that debris accumulations pose to water quality.


A descriptive model of bed material routing was developed for alluvial streams exhibiting sequences of pools and armored riffles. The model assumes that channel geometry, sediment transport competence and the availability of sediments for transport are all non-uniform in the downstream direction. Bedload transport is described as occurring in two relatively distinct phases. Phase I involves the transport of predominantly sand-sized bed materials over stable riffles. Phase II occurs at flows which are greater than those required to entrain riffle armor and involves the transport of riffle sediments in addition to Phase I sediments.

Phase I bedload transport was sampled during three high flow events at Flynn Creek, a 2 km², third order drainage in the Oregon Coast Range and at Huntington Creek in the Wasatch Plateau of central Utah during a controlled release of water from Electric Lake reservoir. A power relationship existed between Phase I bedload transport and discharge at Flynn Creek. The relationship was consistent between storms and between years. At Huntington Creek, Phase I bedload transport correlated with discharge on the rising limb of the hydrograph, but transport rates decreased over time at constant discharge, indicating a sediment supply control over Phase I transport.

Phase II bedload transport was sampled at Flynn Creek during a 1.8 year return period streamflow event in February, 1979. Bedload transport rates were closely correlated with the storage and release of bed material from the riffle at the bedload sampling cross section; transport peaks corresponded to periods of scour and large decreases in transport occurred during periods of deposition. Particle size analysis of the bed material in transport showed as much as a 12-fold increase in the transport of large (> 12.5 mm diameter) bed material during periods of riffle scour. Phase II transport, which involves rapid scour and redeposition of riffles, can be described as highly non-uniform in a downstream direction and highly unsteady at any point over time. At Flynn Creek, significant scour and redeposition of riffles can be expected to occur on an average of once every one to two years.

Corresponding to the two phases of bedload transport are two processes which result in changes in the particle size composition of riffle sediments. First, the intrusion of fine sediments into the pore spaces of stable riffles dominates during Phase I transport. Second, the deposition of entirely new riffle features occurs during Phase II transport. Deposition is often associated with one or more streambed scour and fill sequences and is the direct result of instantaneous differences in sediment transport rates between different channel locations.

The particle size gradation of riffles is determined primarily by bed material deposition. Sampling at Flynn Creek indicated that a riffle contains the range of sediment sizes found in transport at the time of deposition but, over all, is more coarse than the particle size distribution of sediment in transport. In flume studies of the deposition process, riffle composition was shown to be sensitive to the rate of sediment transport at the time of deposition--becoming more coarse at lower transport rates. Small but significant (p = 0.95) decreases in the
median particle diameter of riffle sediments resulted as the sediment mixture in transport increased from a 1:1 to a 5:1 sand-to-gravel ratio.

Flume studies showed the intrusion process to be selective towards finer sediments which cannot be filtered by the riffle sediment matrix. Intrusion may decrease or even cease if filterable sediments block surface pores in riffle substrate. Intrusion, if it occurs, is a function of two factors: (1) the pore size distribution of the stable riffle feature, and (2) the particle size distribution and concentration of suspended and Phase I bedload sediments in transport immediately above the streambed.

JOHNSON, M.G. 1978. Infiltration capacities and surface erodibility associated with forest harvesting activities in the Oregon Cascades. (MS)

An infiltration capacity and surface erodibility study was conducted six years after forest harvesting in the Oregon Cascades. A portable rainfall simulator was utilized to obtain field measurements on the Coyote Creek and Hi-15 Watersheds during summer and fall 1977.

Seasonal variations were found to occur in infiltration capacities and surface erodibility. Infiltration capacities increased by 1.4 times from summer to fall, while surface erodibility characteristics, suspended sediment concentration and sediment yield, decreased from summer to fall. Surface limiting conditions during the summer and soil profile controlled conditions in the fall were hypothesized to explain this season variation.

Nearly all timber harvesting treatments for each study area had statistically equal summer infiltration capacities in comparison with adjacent unlogged areas. In addition, summer surface erodibility characteristics on located areas were typically less than those found on undisturbed areas. Only certain skid trails, cable log paths and severely disturbed sites such as tractor windrowed and burned areas had substantially reduced infiltration capacities and increased surface erodibility. However, all areas, including the most severely distributed, had fall infiltration capacities that exceeded usual and maximum fall precipitation intensities.

Many skid trails and other highly disturbed and compacted areas at Coyote Creek appeared to have greatly recovered since logging six years ago. Freezing/thawing, biological activity, and shrinking and swelling of soils may account for this recovery in infiltration capacities, surface erodibility and soil properties. Skid trails and severely disturbed areas may partially account for peak flow increases and minor sedimentation the first few years after logging. However, data from this study collected six years following timber harvesting do not support the premise that continued increases in peak flows are caused by changes in infiltration capacities, except perhaps for a tractor windrowed and burned area.

Predictive models for infiltration capacity (normally distributed) and surface erodibility characteristics (requiring normalizing transformations) were not found using regression techniques because of large amounts of variance. Variation in estimates of infiltration capacities and surface erodibility for individual plots and between study areas was identified.

Keywords: infiltration, surface erosion, western Oregon, forest harvesting, rainfall simulator, forest soils.

KAHKLEN, K.F. 1993. Surface erosion from a forest road, Polk Inlet, Prince of Wales Island, Alaska. (MS)

Rainfall, discharge, traffic, and suspended sediment were monitored for a period of 4.5 months at three locations on a secondary haul road at Polk Inlet, Alaska to determine the important processes and variables involved in surface road erosion for this area. Three sites all less than 500 m² and within 5 kilometers of each other on the same road were chosen to be instrumented for monitoring. The proximity of the sites to each other resulted in the sections all being nearly identical in age, topographical location, aspect, elevation, and construction materials. Also, the sites were subjected to the same traffic amounts of approximately 3 to 4 loaded logging trucks per day plus other light vehicles.

Maps were developed of the sites which helped determine the source areas for each one. The gradients of sites 2 and 3 were approximately 7%, and the gradient of site 1 was 10%. Each study site was equipped with a flume, pressure transducer, datalogger, and pumping sampler to collect data on discharge and suspended sediment. Sites 1 and 3, had rain gages connected to the dataloggers which recorded 5 minute rainfall intensities. Hourly suspended sediment samples were collected at each site. An infrared traffic counter was used to count the daily traffic amount. An infiltration rate for the road was determined to be 0.9mm/hr using a simple water balance method and also by determining the minimum amount of rainfall to initiate runoff. The infiltration rate was used in development of representative hydrographs for the three sites.

The runoff response of the sites were very similar when normalized to an area of 280 m². The precipitation
catches for the two gages were very similar with precipitation amounts of 893 mm for site 1 and 975 mm for site 3 during 89 days of record. Several regression analyses were completed for both hourly and storm data to determine which variables and technique would be best for estimating total sediment production. The method that proved to be the best for determining hourly production was to multiply the hourly sediment concentration by the average hourly discharge to obtain a total estimated sediment weight produced for that hour.

During multiple regression analysis, all three sites and the combined model had rainfall as the most important variable. The variable that averaged the number of axles per day since the last runoff event was also found to be significant in the combined model. Qualitative variables were used to determine that timing of the events may have an influence on the sediment production. The total storm sediment production was determined by summing the total hourly sediment weights for a given storm. The regression analyses found rainfall to be the most significant of ten variables for the total storm sediment production.

A comparison of all the different models coefficients was developed. The multiple regression model with total storm rainfall, a qualitative variable for gradient, and axles per day was found to have the best coefficient of determination of 0.66 for the combined data of all the sites. The model for site 3 of axles per day and total storm rainfall was found to have the highest coefficient of determination, $R^2 = 0.85$. The simple linear regression model of log of total sediment yield/km of road to total storm precipitation was used to estimate the annual sediment production from a kilometer of road at Polk Inlet. The annual precipitation data was from a gage located about 16 kilometers northeast of Polk Inlet. The annual road surface sediment erosion estimate is 8.1 tonnes/km of road.

A comparison of other studies shows this to be similar to other locations in the United States and areas of New Zealand. Several assumptions were made and the resulting limitations are described for this estimate. Any use of this estimate or equation for sites without very similar characteristics would not be advised. Future studies are in progress to expand the understanding of some of the other variables not accounted for in this study.

KAUFMANN, P.R. 1987. Channel morphology and hydraulic characteristics of torrent-impacted forest streams in the Oregon Coast Range, USA. (PhD)

Tracer-derived estimates of hydraulic resistance and transient hydraulic storage were related to measures of pool volume and channel morphometric variability in small streams of the Oregon coast, U.S.A. Fourteen 100 m study reaches in 3 streams were selected to compare channel and hydraulic characteristics in streams representing a time series of recovery since major torrent scour or deposition (2, 12 and 120 years). Transient storage ("dead zone") volume fractions, ranging from 0.3 to 0.6 in the study reaches, were significantly ($p < 0.01$) correlated with aggregate residual pool volume ($r = +0.94$) and the standard deviation of thalweg depth ($r = +0.95$). Darcy-Weisbach friction factors ($f$) ranging from 2 to 90 were correlated ($r$ values from $+0.95$ to $+0.98$) with the standard deviation of thalweg depth (SDD) within restricted ranges of summer low flow and elevated springtime discharge. Regressions of $f$ versus SDD for combined data collected over a range of discharges (0.019 to 0.11 m$^3$/s) showed increased scatter. A semi-logarithmic relationship ($r^2 = 0.60$, $n = 40$) between dimensionless velocity ($U/f$) and a dimensionless measure indexing relative submergence of large scale bed features (mean thalweg depth/SDD) was significant at $p <0.1$.

Measures and indices of pool volume and transient storage were positively correlated ($r = +0.78$ to $+0.89$) with volumetric loadings of woody debris. High total pool and dead zone volumes in reaches were largely due to plunge pools formed by scouring downstream of woody debris accumulations. Among the study streams, the greatest reach pool volume and channel complexity occurred in torrent deposit reaches of the intermediate (12 yr.) recovery stage stream. Reaches scoured recently (2 yr.) by a debris torrent had the lowest pool volume and channel complexity. The stream experiencing the longest period of "recovery" (120 yr) had characteristics between those of the 2- and 12-year recovery streams. Torrent scouring reduced pool volume, dead zone fraction and channel morphometric variability. Torrent deposition and subsequent local reworking of sediments by the stream increased values of these variables, especially when torrent deposits contained woody debris and boulders.

The relative importance of pool-forming agents varied with recovery time and amount of torrent deposits. Bedrock, cobbles, log clusters, and single logs contributed about equally to the small residual pool volume in reaches recently scoured by a torrent. Log clusters and boulders dominated in two reaches of the intermediate recovery class stream where logs and sediment were deposited by a torrent, and in two reaches where boulders were left as lag deposits. Bedrock and log clusters contributed about equally to pool formation in the relatively
Mass soil movements of four types; debris avalanche, debris torrent, debris slide and bank slough, were field inventoried in the Oregon Coast Range. A total of 104 mass movements were located in 21 undisturbed watersheds and 13 clearcuts harvested in the last six years. Failures associated with roads and landings were not included in this inventory. Failure volume ranged from 2 yd$^3$ to 196 yd$^3$. The average volume of all failure types ten cubic yards or more in volume is 41 yd$^3$ in undisturbed watersheds and 47 yd$^3$ in clearcuts. Failures less than ten cubic yards are of little significance in terms of initial volume moved, but in undisturbed watersheds they account for over one-fourth of the channel impact by mechanical scour and deposition. The frequency of all failures is similar in clearcuts and undisturbed watersheds, one in 19 acres and one in 17 acres, respectively.

Mass failures travel 1.7 times farther in clearcuts than in undisturbed watersheds. Debris jams from failures in clearcuts contain 3.2 times more inorganic and 2.5 times more organic debris than debris fans from undisturbed watersheds. Eight percent of the Class III and IV stream length (U.S. Forest Service Classification) in forested drainages and ten percent of that within clearcuts is impacted by channel scour and deposition.

The erosion rate of all soil land types encountered in undisturbed watersheds is 0.11 yd$^3$/ac/yr. This rate increases by 3.5 times in clearcuts. Land types with very steep, highly dissected slopes show the largest increase in erosion rate from uncut to clearcut watersheds (10 times). Less than one percent of the forested or clearcut land area is affected by the mass soil movements.

Half of the failures in undisturbed drainages and nine-tenths of the failures in clearcuts occurred on slopes of 80 percent or greater. The average volume of failures is greatest on slopes of 80 to 100 percent. No apparent relation exists between failure frequency and aspect in this study.

The results are compared with other studies in the Pacific Northwest and the differences are discussed. Natural variation accounts for much of the differences. Guidelines are given for assessing the risk of damage by debris avalanche and torrent type failures in proposed timber harvest areas.

Keywords: mass soil movements, debris avalanche, slope stability, debris jams, channel scour.
accurate estimate of the peakflow frequency distributions. The individual curves provide a better idea of the distributions, especially when the curves are extrapolated to low, rarer, exceedence probabilities. Damage to structures may be reduced if causative mechanisms are considered when designing structures using peakflow analysis. Constructing a composite curve to incorporate the probability of each type of seasonal mechanism, in any given year, is an appropriate tool to consider where mixed mechanisms are evident in the streamflow record.

KNIGHT, S.M. 1990. Forest harvesting impacts on coarse woody debris and channel form in central Oregon streams. (MS)
Several streams in the mixed conifer cover type of the Ochoco and Blue Mountains of central Oregon were studied to determine what effects selective harvesting of the riparian timber stand had on the amounts and distribution of coarse woody debris (CWD) in the stream. Pristine streams were measured to develop a data base for the streams of the region. Watersheds that had experienced harvests from 12 to 60 years ago which had from 22 to 93 percent of the basal area removed were then measured to determine the effects of selective harvesting.

CWD volumes were computed for all pieces greater than 10 centimeters in diameter at the small end, and at least 1 meter in length. Each piece was classified according to source, association with other debris, age, species, and overall characteristics. No statistical difference could be found in the total volume of CWD when comparing the managed to the pristine streams. Debris volume was found to be directly related to riparian stand basal area, with species composition of the stand being a strong indicator of stand basal area and stream debris volumes. With the exception of large multi-tier jams, which were not present in the six managed streams, the number and distribution of debris associations were found not to be affected by harvesting.

Channel morphology measurements were taken along the same 300 meter reaches and included average active channel width and depth, bank slopes, gradient, spherical canopy density, and angular canopy density. Individual channel parameters measured included pool surface area and depth, riffle surface area and depth, depth and length of bank undercutting, and surface area and depth of multiple channel sections. All measurements were based on active channel flow conditions.

No significant differences were found between the harvested and pristine streams with regard to active channel width, depth, or streambank slope. Individual pools were larger in volume in the managed streams. Since the number of pools and their average depth was the same as in the pristine streams, the managed streams had a larger volume of pool habitat. Multiple channel units were seven times more prevalent in harvested reaches than in pristine reaches. There were no differences found in the role of CWD in the formation of stream channel units between the types of stream.

LAMMELL, R.F. 1973. Natural debris and logging residue within the stream environment. (MS)
Amounts of natural debris in small headwater streams under old-growth Douglas-fir vary from 6 1/2 tons per 100 ft. of stream to 26 tons per 100 ft. of stream, depending on terrain and timber characteristics and sequence in the natural accumulation-flushing cycle. Approximately 10% of the weight of the total debris is in the size-class smaller than 10 cm in diameter.

After falling, there was an increase of debris depending on stream protection measures, falling methods and environmental factors.

After yarding, the amount of total debris was reduced on the average to almost 50% from what it was originally. At the same time, the amount of branch-type debris increased although the amount of finer debris (<1cm) decreased.

A wide buffer-strip provided an almost complete physical barrier against debris movements, while a very small buffer-strip provided much less stream protection in terms of logging residue. Cable-assist falling methods minimized breakage and provided for cleaner yarding as compared to conventional timber falling.

LARSON, K.R. 1981. An evaluation of a procedure for predicting sediment yield increases from silvicultural activities. (MS)
Sediment yield increases following timber harvest and road construction were predicted for four Pacific Northwest experimental watersheds. Sediment yields were predicted using a handbook developed by the U.S. Forest Service entitled, "An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources" (WRENS). Predicted sediment yield increases varied from 40 to 180 percent of measured increases.

Several conceptual problems and difficulties in the application of the procedure responsible for observed
differences between predicted and measured sediment yield increases were identified. Major problems included (1) sediment budgeting inaccuracies, and (2) no consideration of delays in the export of predicted sediment inputs to stream channels due to in-channel sediment storage.

The accuracy and applicability of the WRENS procedure estimating actual sediment yield changes in forest management planning is limited by (1) the unknown and complex nature of several erosion and sediment transport processes, and (2) temporal variability and the probabilistic nature of rainstorms of extreme magnitude and their effect on erosion and sediment transport processes.

In an effort to improve prediction accuracy and applicability of the procedural handbook, several recommendations are made including; (1) discontinue use of the channel sediment source prediction procedure in rain-dominated areas of the Pacific Northwest, and (2) area-wide inventories to assess the effects of silvicultural activities on landslide rates.

LOMBARD, P.J. 1997. The effect of the size and orientation of large wood on pool volume in two Oregon Coast Range streams. (MS)

This study was conducted to determine how the size and orientation of large wood placed in streams in combination with peak flows, substrate and channel gradient affect pool volume, surface area and maximum depth in to coastal Oregon streams. Eighteen Douglas-fir (*Pseudotsuga menziesii*) logs were placed in each of two streams, J-Line Creek and Preacher Creek, in the summer of 1989. Surveys were conducted annually from 1989-1996 at summer low flow using a total station electronic theodolite. The orientation of the introduced wood and the parameters of residual pools associated with the wood were determined from high resolution topographic maps made from the surveys.

Residual pool volume associated with the introduced wood increased 2,500 percent over the seven years for J-Line Creek and 30 percent for Preacher Creek. Large spanners, logs placed perpendicular to the stream flow and flush with the stream bottom, had the greatest pool volume associated with them, however, horizontal orientations shifted downstream over time. Large ramps, logs placed at a downstream orientation and angled up onto the bank, were the most stable treatment.

Differences between the two watersheds and an interaction variable between the diameter of the introduced wood and the horizontal orientation of the introduced wood were the significant variables which entered the multiple linear regression model for residual pool volume. These variables, as well as the vertical orientation of the introduced wood, were significantly correlated to both residual pool area and maximum depth. The recurrence interval of the annual maximum instantaneous peak flow was not significantly associated with residual pool volume, surface area nor maximum depth. Multiple regression models explained, at most, twenty-eight percent of the variability in residual pool volume. Multiple regression models explained from the topographic maps. Pool volume in a reach determined by aquatic habitat inventories explained 96 percent of the variability of residual pool volume in a reach, however, estimates of individual pool volume explained only 40 percent of the variability in residual pool volume.

LONG, B.A. 1987. Recruitment and abundance of large woody debris in an Oregon coastal stream system. (MS)

Research was conducted in the Oregon Coast Range to address the concern that conversion of large diameter old-growth forests to small diameter second-growth forests would lead to reduction of large woody debris in adjacent stream channels. The objective of the study was to quantify spatial trends in large woody debris recruitment and abundance in a stream system bordered by a second-growth forest. Big Creek in Lincoln County was selected for the study. The watershed was clearcut between 1922 and 1935, and subsequently burned by wildfire in 1936. A large woody debris inventory was conducted in first- through fourth-order stream channels. Comparisons were made between pre-disturbance (wood in place during logging and fire) and post-disturbance (contributions from new forest) woody debris types within each stream order.

Approximately 5200 pieces of large woody debris (greater than 0.1 m diameter and 1 m length) were measured in 11.5 kilometers of channel. Total volume per square meter and number of pieces varied considerably among stream orders. Second-order channels had the heaviest debris loading (0.0422 m$^3$/m$^2$), followed by first- (0.03008 m$^3$/m$^2$), third- (0.0242 m$^3$/m$^2$), and fourth-order (0.0201 m$^3$/m$^2$) channels. Piece numbers ranged from 54.8 to 35.6 per 100 meters of channel, with a basin average of 45.1 pieces per 100 meters. Pre-disturbance debris pieces constituted 63 to 70 percent of the total number of pieces and 86 to 89 percent of
the total volume within all stream orders. Species composition within the post-disturbance group varied significantly among stream orders. Third- and fourth-order channels contained mostly hardwood post-disturbance debris, whereas first- and second-order channels contained a greater proportion of conifer post-disturbance debris. Riparian stand density and basal area per hectare were positively correlated with the recruitment of post-disturbance woody debris in small channel segments.

Flotation, windthrow, and logging were the most common delivery mechanisms for pre-disturbance debris. Fifty-two percent of pre-disturbance debris pieces were located in channels or on channel banks, and 17 percent influenced pool habitat formation. Bank cutting was the predominant delivery mechanism for post-disturbance debris. Thirty-two percent of post-disturbance pieces were in channels or on channel banks, and seven percent formed pools. Most post-disturbance pieces were suspended above channels or on side terraces. Fifty-two percent of the total debris pieces were found in debris accumulations. The largest debris accumulations commonly were located at tributary junctions.

LOWRY, M.M. 1993. Groundwater elevations and temperature adjacent to a beaver pond in central Oregon. (MS) This study was designed and implemented to observe the spatial and temporal dynamics of groundwater levels and temperatures adjacent to a beaver pond in semi-arid central Oregon. The study site was located on the eastern boundary of Painted Hills National Monument along Bridge Creek, a tributary to the John Day River. Groundwater levels and groundwater temperature were monitored in 64 wells from July 3, 1991 to June 11, 1992.

Groundwater elevations varied seasonally and were generally positively correlated with increased streamflow. In addition, beaver dam-building activity appeared to increase aquifer recharge near the beaver pond in comparison to downstream areas. The groundwater elevation of a well located near the pond rose 0.35 m between August and November 1991, while the beaver pond stage increased by 0.22 m. Groundwater elevation at another well located downstream of the dam increased by only 0.17 m during this period with a corresponding increase in stream stage of 0.05 m. Groundwater levels throughout the study site averaged a 0.31 m gain from August to November 1991. All wells at the study site responded to changes in streamflow, and thus appear to be hydraulically connected to the stream.

Hydraulic gradients adjacent to the pond were relatively low (i.e., 0.005 m/m). However, a zone about 50 m from the pond of relatively high hydraulic gradient (0.05 m/m) persisted over time, and groundwater flow directions in this area were both normal and parallel to the stream. Based on hydraulic gradients and observed groundwater elevations, the movement of water from the stream to subsurface recharge of riparian areas appeared to be greater near the pond than the streamside locations.

Approximately 90 m$^3$ of water could be drained from the aquifer if the dam were breached. Results of this study support the conclusion commonly expressed in the literature, but seldom quantified, that elevated water tables occur adjacent to beaver ponds.

Groundwater temperatures for each successive month closely followed stream temperatures in wells next to the stream, indicating that stream temperatures readily influence groundwater temperatures adjacent to the stream.

Wells located relatively far out on the floodplain (i.e. 50 meters) from the beaver pond had about a two month temperature response lag behind stream temperature. These results further indicate that stream temperature can influence groundwater temperature, and that groundwater recharge is highest near the pond.

LUECKER, T. 2004. Aquatic Invertebrate-Habitat Relationships and Stream Channel Cross Section Area Change in Response to Streamside Management Zones in North Central Mississippi. (MS). The southern states lead the country in timber production and are subject to Best Management Practices (BMPs) designed to mediate the effects of forest harvesting on water quality. Small headwater streams on timberland in North Central Mississippi have received little attention with respect to effectiveness of the BMPs designed to protect them. With stand rotations of 25-30 years and with some counties held in nearly 30% private industrial forestry ownership, impacts of intensive forest management on water resources have the potential to be large. In North Central Mississippi, I evaluated the effectiveness of Streamside Management Zones (SMZs), corridors of the riparian zone along the stream left unharvested, as a component of BMPs. The streams sampled were low-order perennial headwaters either within a clearcut with no SMZ, a clearcut with an SMZ, or a site that had not been harvested. Aquatic invertebrate community composition, habitat and substrate composition, and stream
channel cross-section areas were evaluated in 2002 and again in 2003. My objectives were 1) to describe the invertebrates and habitat conditions at each site, 2) to determine if there are relationships between invertebrates and water quality, cover metrics, or relative amounts of substrate size fractions, and 3) to determine whether or not there were detectable treatment effects on either substrate composition or stream channel cross-section areas. Water quality, cover, and substrate size classes were highly variable within each harvest treatment. No significant differences were found downstream of harvest treatments for relative distribution of substrate within each harvest treatment group. Even though the habitat and substrate were highly variable, the invertebrate composition at many sites was dominated by a single family, Chironomidae. Ordinations of the Presence of invertebrate taxa using non-metric multidimensional scaling showed a separation of the Reference and No-SMZ treatment groups for 2003, indicating that treatment effects may only be expressed in the biota and not in physical stream habitat characteristics measured by this study three to five years after harvesting. Changes in stream channel cross-section area occurred for all treatments, with Reference treatments degrading and SMZ and No-SMZ treatments aggrading between 24 and 29 months after harvesting treatments were established. Overall, No-SMZ treatments did not have significant changes in stream channel cross-section between sampling intervals, while Reference and SMZ treated streams changed significantly throughout the study. High natural variability of the streams made it difficult to discern differences in stream habitat parameters for each harvest treatment. Differences between Reference and No-SMZ sites in the 2003 ordinations and between No-SMZ and the other treatments for stream channel cross-sections indicated that SMZs are functioning in these low-order streams.

LYONS, J.K. 1981. Influence of landslides, floods, and land use on channel changes of the Upper Middle Fork Willamette River, Oregon. (MS)
Time trends in flow and channel characteristics were evaluated for the Middle Fork Willamette (MFW) River, which drains a 668 km2 forested watershed in the Cascade Mountains of western Oregon. Timber production is the primary land use in the watershed.

Analysis of precipitation and peak flow data from 1959 to 1980 suggests that peak flow (greater than 0.15 m3 s-1 km-2) increased 2% per year as timber harvesting and road building expanded in the basin. Landslides associated with roads and clearcuts, based on an inventory of aerial photographs dating from 1959 to 1972, were 27 and 23 times more frequent (respectively) than in forested situations. The majority of landslides appear to have been initiated during the relatively large flood of December 22, 1964.

Changes in channel plantform morphology from 1936 to 1980 were documented from aerial photographs. Based on the photographic record, channel width increased prior to 1967 followed by a decreasing trend from 1967 to 1980. Sixty-five channel cross-sectional profiles were surveys during summer low flows in 1979 and 1980 to provide detailed measurements of existing channel conditions. The presence or absence of aggradational features was noted at each cross section. Regression analysis revealed that significantly greater (" = 0.05) channel widths were recorded for 62% of the aggraded reaches compared to the dimensions of nonaggraded reaches.

The results of the cross-section surveys, combined with the channel morphology and landslide measurements, suggest three conclusions: (1) major aggradation along the MFW River occurred during the 1964 flood, (2) landslides associated with the 1964 flood contributed to the development of aggraded locations along the river, and (3) the majority of landslides during this period occurred within one geologic zone and were associated with land use activities, thus suggesting management activities, particularly roads, influenced changes in channel morphology.

Some results of a study conducted in the Sierra Nevada Mountains west of Lake Tahoe are reported. The study measured soil impacts resulting from the use of a Caterpillar Tractor model D6D, a John Deere wheeled skidder model JD-640, and an FMC Corporation model FMC 210CA logging vehicle. The three vehicles were operated under carefully controlled conditions on straight 30.48 meter (100 feet) by 3.66 meter (12 feet) test strips. Three test strips were established for each machine on four sites to permit an analysis of the impacts of the machines through a range of soil moisture contents and soil types. Measurements of soil compaction were made after 1, 3, 6, 10, 15, and 20 passes with a load of logs through the test strip followed by a return through the test strip
unloaded. Only the impacts resulting from 20 complete trips are presented in this paper.

Two tools were tested to determine suitability for use as instruments to predict soil compaction. The Gus probe, a new tool designed for the study utilizing the energy derived from a weight falling through a constant distance to drive a 3.8 cm (1.5 in.) diameter foot into the ground, failed to generate useful predictive models. A cone penetrometer, the second tool tested, did generate a significant predictive model.

\[ CD_{0.08} = 0.2631 - 0.0001022 \times CI_6 \quad R^2 = .7339 \]

where:

- \( CD_{0.08} \) = the change in soil density, in g/cc, resulting from 20 trips of the logging vehicles, averaged to the 20.3 cm (8 in.) layer.
- \( CI_6 \) = the cone index, in kPa, required to push the cone tip to the 15.2 cm (6 in.) depth.

Graphs of soil densities attained after 20 trips by each machine for the four sites are presented along the curves depicting the change in densities. Greatest compaction resulted from the tractor on the slightly cohesive sites at depths greater than five cm (2 in.) with little differences between machines being observed at the five cm depth. Little differences in compaction were observed between machines at depths greater than five cm on the cohesionless sites. The FMC compacted the loose cohesionless five cm depth the least. The skidder compacted the dense cohesionless site the least.

Soil disturbance, defined as a combination of soil displacement and soil compaction, is quantified. The tractor displaced 1.9 times more soil than the FMC and the skidder displaced 1.2 times more soil than the FMC.

Appropriate equilibrium equations of motion are derived to quantify the pressures along the bottom of the tracks of the tractor and FMC and on the bottom of the tires on the skidder. The pressure distributions encountered in the study are presented.


Four wetland sites were identified and delineated in Silver Falls State Park, Oregon using procedures outlined in the 1989 Federal Manual for the Identification and Delineation of Jurisdictional Wetlands and subsequently monitored for a ten month period. A network of 225 shallow (32") wells was installed throughout the sites to track the subsurface hydrology over a full wet season. In order to scrutinize the growing season, plant phenologies and soil temperatures were observed from senescence in the late fall to full vigor in the spring.

The study concurs with the concept and intent of the 1989 Manual, but presents the view that a number of improvements are necessary. The major areas requiring improvement include techniques used to assess the prevalence index of plant communities, the definition of the growing season and the recognition of the interactive involvement with and dependence upon the wetland environment of faunal organisms. Further, the protection of an influence zone may be important to the maintenance of the intact hydrologic system upon which the wetland depends.


Understanding the impact of low volume road networks on forested watersheds is important for future forest management and watershed restoration. This study characterized the hydrology of five segments of forest road in the Oregon Coast Range. Rainfall, infiltration, road surface runoff, and intercepted subsurface flow were measured at each road segment. Results indicate that these individual segments of forest road differ hydrologically, depending on how much subsurface flow they intercept from the hillslope.

The first objective of this study was to compare and contrast hydrologic behavior of ditch flow resulting from infiltration-excess overland flow on the road surface with ditch flow that was intercepted subsurface flow from the hillslope. Overland flow and intercepted subsurface flow were physically separated in the ditch by a divider and routed through two trapezoidal flumes at the bottom of each road study segment. Runoff derived from infiltration-excess overland flow on the road surface was ephemeral, responding to high intensity rainfall, and it ceased within minutes to hours after rainfall. This was the only type of flow observed in road ditches at four of the five study sites. Subsurface flow intercepted form the hillslope was intermittent, occurring continuously during the rainy season with a more gradual, muted response to storms. This type of flow occurred, along with ephemeral ditch flow, at one of the five study sites. Ephemeral flow in the ditch of this site produced minimal runoff volume, no more than 4.5 m³ (16 mm / m² of road), for storms up to 140 mm in depth. In contrast, intermittent ditch flow intercepted from the hillslope produced up to 801 m³ (2800 mm / m² of road) for similar storms, 20 times more flow than all of the rainfall that had occurred on the road surface. Any ephemeral
The second objective of this thesis was to quantify the relationship between rainfall intensity, infiltration capacity and road surface runoff at the study road segments. A rainfall simulator was used to measure road infiltration capacities. Estimates of infiltration capacity from the rainfall simulation averaged 4 mm/hr and ranged from 0 to 11 mm/hr. Despite the low infiltration capacities, runoff volumes from the road surface were on average only 5 percent of natural rainfall, because rainfall intensity remained lower than infiltration capacity during most of the duration of storms. Infrequent pulses of high intensity rainfall overwhelmed the infiltration capacity of the road and produced surface runoff. Median lag time from peak rainfall intensity to peak discharge of road-derived ditch flow was 10 minutes on road segments with up to 250 m² of surface area. Two other estimates of the infiltration capacity of a given road were 1) the maximum rainfall intensity that did not produce runoff, and 2) the minimum rainfall intensity that did produce runoff. These intensities ranged from 0.5 to 11 mm/hr, similar to the infiltration capacity estimates from rainfall simulation.

Infiltration capacity and ephemeral road surface runoff were similar for all road segments in this study. Intermittent flow, intercepted from the hillslope, differed between roads and was two orders of magnitude greater than ephemeral runoff from the road surface. Intercepted subsurface flow has greater potential to cause erosive damage than ephemeral runoff from the road surface, because of its large peak discharges and flow volumes.

MARTIN, K.S. 1997. Forest management on landslide prone sites: the effectiveness of headwall leave areas and evaluation of two headwall risk rating methods. (MS)

For about the last two decades forest management practices have become a very volatile topic. The effects of timber harvesting and road building on natural resources such as water, fisheries and wildlife, aesthetics, and on public safety have raised concern. Mass erosion from landslides, either natural or management induced, can have serious consequences. Understanding the cause and effect relationships of forest management activities and landslides is important in their prediction and mitigation, and protecting life, property, and other resources.

Landslides are caused by a critical combination of steep slope, shallow soils, and abundant rainfall and are the dominant source of erosional shaping of the landscape in the central Oregon Coast Range. Early studies indicate that a significant percentage of landslides occur at the heads of steep draws commonly referred to as headwalls (Ketcheson and Froehlich, 1978). Headwalls are zero-order drainages that occur near ridge tops and are characterized by loose soils, steep slopes, and are bowl-shaped in appearance. Timber harvesting and road building have been shown to increase erosion by landslides (Swanson and Dryness, 1975; Amaranthus et al., 1985). Modern forest road location, design, and construction techniques appear to reduce the incidence and size of road related landslides per mile of road (Sessions et al., 1987). Recently, more attention has been given to timber harvesting related landslides. Since the mid 1970’s, federal timber sales in the Oregon Coast Range have been evaluated for slope stability. The most inherently unstable headwalls were identified and timber removal activities were not permitted within the headwall. These retained patches of timber are called “headwall leave areas” (Skaugset et al., 1993). A statistical analysis of failure rates from an inventory of headwalls in the central Oregon Coast Range produced results that were not definitive, and left uncertainty and concerns about the effectiveness of the headwall leave areas on reducing in-unit landslides (Skaugset et al., 1993).

Two “formal” methods have been used, or considered for use, in rating headwall stability on Federal lands in the Central Oregon Coast Range during the mid- to late 1980’s. The first is the Mapleton Headwall Risk Rating System and was developed by the Mapleton District of the Siuslaw National Forest. This semi-quantitative method gives numerical ratings to descriptive characteristics of a headwall, which when summed, yield a final rating. The rating indicates the relative stability of a headwall. The higher the rating the more unstable the headwall and vice versa. A second method developed to rate slope stability is a computer model called the Level I Stability Analysis, or LISA, and the three-dimensional version, 3DLISA. The model was developed by Forest Service and University researchers at the Intermountain Research Station and University of Idaho in Moscow, Idaho. The LISA model uses the infinite slope equation in original form for a continuous slope. The 3DLISA model uses rigid body mechanics for a three-dimensional sliding block case. Both LISA and 3DLISA use a Monte Carlo simulation along with probability density functions describing slope characteristics to calculate a probability of failure. Probabilistic analysis and the mechanics of the 3DLISA slope stability model are discussed in Chapter 2. Evaluation of risk rating methods on a headwall inventory in the central Oregon Coast Range revealed that the Mapleton Risk Rating method predicted risk reasonably well but the 3DLISA slope stability model did not (Skaugset et al., 1993).
In this report, the Mapleton Headwall Risk Rating System and 3DLISA slope stability model are considered risk assessments. Risk is defined as the probability of an event occurring, in this case a headwall failure. Downslope impacts of headwall failures were not addressed and are beyond the scope of this project. It is important to note that there may be other “formal” methods that have been used to rate headwalls in the central Oregon Coast Range as well as in other locations. These two risk rating methods where chosen for analysis because they were being developed during the headwall inventory period and were specifically designed to rate headwall stability. In addition to these two risk rating methods, professional judgement of the forester or engineer is also used to rate headwall stability.

A set of 119 study trees was identified in a 65 year-old Douglas-fir stand after a thinning operation conducted seven years ago using pre-planned skid trails and ground-based machinery. Some of the trails were tilled using a winged subsoiler after this operation in order to alleviate the effect of compaction caused by the heavy machinery used during logging.

The primary objective of this study was to determine whether tilling compacted forest soils after a harvesting operation serves to alleviate the compaction over time, and if tillage has any discernable positive or negative effect on the growth of the residual trees adjacent to tilled skid trails. To clarify growth relationships, soil bulk density measurements were taken around study trees adjacent to undisturbed areas, tilled trails, and untilled trails. In addition, different tree growth parameters and competition indexes were evaluated to help distinguish thinning and other effects.

The results showed that although mean soil bulk densities were generally higher around trees adjacent to untilled skid trails, there was no statistical difference between the densities in untilled and tilled zones (95% confidence level). This may help explain the observation that seven years after the thinning and tillage, there was no apparent benefit or damage to the growth response of trees adjacent to tilled trails.

Regression analysis of several important stand and site variables showed that just two were meaningful in predicting growth, diameter at the time of thinning and Competition Stress Index after thinning (95% confidence level).

This suggests that limiting the area of compacted or tilled soil by the use of planned skid trails may have effectively restricted the treatment growth response to the influence of basic tree and stand characteristics after thinning.

MAT ISA, A.Z. 1990. The application of linear programming for forest land use and timber management planning with watershed considerations in Terengganu, Peninsular Malaysia. (MF)
The purpose of this paper is to illustrate the use of linear programming (LP) and other mathematical procedures to evaluate watershed and perpetuity constraints on forest land use for a selected scenario in Terengganu, Peninsular Malaysia. The paper describes the system of modelling and forecasting estimates of potential timber growth, forest harvest and inventory for use in planning with environmental considerations. The LP model provided a range of feasible solutions for decision making. Equations were derived for the model to show interaction of sedimentation due to road construction, timber harvesting and other related forest management activities.

Sensitivity analysis was used to test model behavior. A literature review provided information to supplement the findings gathered from simulation of the linear programming problem. The model further gathered from simulation of the linear programming problem. The model further evaluated using theoretical, mathematical and observational procedures. Results indicate the constraining effects of sedimentation upon forest revenues when sedimentation is allowed to vary within the feasible region of the model (i.e., from 600,000 m³/decade up to 1,140,000 m³/decade).

MAY, C.L. 1998. Debris flow characteristics associated with Forest Practices in the Central Oregon Coast Range. (MS)
Debris flows in the Pacific Northwest play a major role in routing wood and sediment stored on hillslopes and in first- through third-order channels to higher order channels and valley floors. Forest practices on steep, unstable slopes and removal of riparian trees along low-order streams can affect the frequency, magnitude, and
composition of debris flows. The quantity and quality of debris flow deposits provides sediment and wood fundamental to the development of the receiving channel. Field surveys document characteristics of the initiation site, runout zone, and deposit of 53 debris flows in the Siuslaw Basin of the central Oregon Coast Range, during the winter of 1996. Landslides that initiated debris flows in clearcuts had a higher frequency, larger average volume, and runout zones that affected a greater length of stream channel than landslides from forested slopes. This difference resulted in an increase in the total volume of sediment mobilized by the debris flow, and a greater proportion of this sediment came from hillslope sources. Debris flows initiated at roads had an order of magnitude greater volume of sediment compared to non-road-related failures. Debris flows of equivalent size that traveled through a forested channel delivered only a slightly greater volume of large wood, than those through clearcuts. Size-class distributions of wood in the deposit and trees on the hillslope were not well correlated. The average diameter of wood in the deposit was greater than the diameter of trees currently present on the surrounding hillslopes. This difference reflects the legacy of large woody debris stored in low-order channels and valley floors. Large trees along the edge of the runout zone is also an important component in the recovery of these low-order channels, which were transformed into a bedrock state. Large trees along the edges of forested slopes are already supplying wood to these channels, and were the only mechanism observed for trapping large volumes of sediment. This mechanism for retaining sediment in high gradient, low-roughness channels is not available in clearcuts, which now contain the greatest proportion of bedrock channels. Forest practices, by altering the frequency, magnitude, and composition of the debris flow, may alter the long-term potential for developing complex channel morphology and high-quality aquatic habitat.

McGEE, K.K. 2000. The effects of forest roads on surface and subsurface flow in southeast Alaska. (MS)

Well water levels and ditch flow were used to evaluate road-induced changes in surface and subsurface flow for two sites (Trocadero and Polk) in southeast Alaska. At the Trocadero Site, low water levels before and peak water levels during a storm were used to test for differences in subsurface water levels above and below an existing road. Low water levels at the Trocadero Site were significantly different in the wells above versus below the road (p = 0.02). However, peak water levels above and below the road showed no significant difference (p = 0.25).

Low water levels before and peak water levels during a storm were used to test for changes in subsurface water levels pre- and post-road construction at the Polk Site. Four storms were measured prior to road construction. Thirty-one storms were measured following road construction. Using an Antecedent Precipitation Index, fifteen storms from the post-road construction dataset were selected that were within similar moisture conditions as the pre-road storms. After road construction there was no significant change in low water levels. There was a small (0.08 m and 0.05 m), but significant (p = 0.01 and 0.03), decrease in the peak water levels following road construction.

Ditch flow measured on two forested hillslopes showed that road cutbanks intercepted roughly 100% of the area precipitation from upslope contributing areas. Due to shallow soils, and excessive amounts of precipitation during the late summer and fall, much of the precipitation falling on the forest floor becomes shallow subsurface flow between the organic and mineral soil interface. The amounts of road-intercepted flow do not translate into equivalent changes in subsurface water levels, rather the changes in subsurface water levels are typically minimal. Where changes do occur, they tend to be concentrated immediately above the cutbank and below the road fillslope.

McGREER, D.J. 1975. Stream protection and three timber falling techniques: a comparison of costs and benefits. (MS)

The objective of this study was to quantify the amounts of logging residues that are added to mountain stream channels as a result of timber falling - logging procedures, and to evaluate these procedures with respect to both ecologic and economic considerations. Tree falling - logging treatments were observed: Conventional falling, Cable-assist falling, and Conventional fall with streamside buffer strips. Streamside environmental impact was evaluated in terms of the potential for damage due to the addition of organic logging residues to stream channels. Economic considerations included stream debris removal, timber volume left unharvested in buffer strips, timber falling labor and equipment, and timber breakage.

Stream debris was quantified for ten headwater streams in western Oregon prior to logging, after falling,
and after yarding. To determine timber falling breakage and direct falling costs for both conventional and cable-assist methods, over 1.6 million board feet of timber was observed during falling operations.

Results show that buffer strips were most effective in preventing logging debris from reaching stream channels. A 160 foot wide buffer strip allowed no debris penetration. During falling operations, 1.8 and 2.0 tons of debris per 100 feet of stream penetrated buffers with widths of 36 and 15 feet respectively. Conventional falling added an average of 47 tons of debris per 100 feet of stream. Cable-assist falling added only 14 tons per station, thus demonstrating its applicability as a stream protection technique.

Stream debris removal costs were found to be quite low for the observed buffer strip units. Estimated clean-up costs for the conventional falling treatment averaged $400 per station compared to only $154 per station for cable-assist falling.

Timber falling production rates averaged 9.3 MBF per hour for conventional falling, and 6.3 MBF per hour for cable-assist falling. Due to lower production rates, larger falling crews, and additional machinery costs, direct falling costs for cable-assist falling averaged $8.02 per MBF (gross scale) compared to $3.33 per MBF for conventional falling. Timber breakage averaged 7.35 percent of gross scale for conventional falling compared to 5.92 percent for cable-assist falling, a difference of 1.43 percent. For both methods, breakage increased as trees became larger and more defective.

The total cost of the economic factors evaluated was applied to a hypothetical 40 acres setting of 2,800 MBF. The analysis showed that all treatments, the narrow 15 foot wide buffer strip treatment was most economical, total cost being only $6.12 per MBF. Due to the high cost of leaving 285 MBF of timber the 160 foot wide buffer strip treatment was most expensive at $13.18 per MBF. For the conventional falling - logging treatment, the total cost per MBF was $7.93. This compares with $10.96 per MBF for cable-assist falling; savings of breakage and stream debris removal costs were offset by much higher direct falling costs.

Although not included as a cost consideration in this analysis, cable-assist falling produced a greater average log length than did conventional falling. Consideration of log length relationships, and use of higher stumpage values would have altered the outcome of this analysis. The cable-assist treatment would have become more economically desirable compared to the conventional and buffer strip treatments.

McGUIRE, K.J. Water Residence Time and Runoff Generation in the Western Cascades of Oregon. (Ph.D.). The age, or residence time of water is a fundamental descriptor of catchment hydrology, revealing information about the storage, flow pathways and source of water in a single integrated measure. While there has been tremendous recent interest in residence time to characterize catchments, there are few studies that quantify residence time at the catchment scale or explore the process controls on the distribution of residence times. The objective of this study is to determine the controls on catchment-scale residence time using hydrometric, tracer, and modeling approaches at hillslope to multiple catchment scales. Topographic controls on residence time are examined for seven catchments at the H.J. Andrews Experimental Forest that range in basin area from 0.085 to 62.4 km² representing diverse geologic and geomorphic conditions. Residence times are estimated using stable isotope tracers and convolution integral models. Baseflow mean residence time results range from 0.8 to 3.3 years. There is no correlation between residence time and basin area; however, mean residence time is correlated to the catchment-scale median flowpath distance and flowpath gradient to the stream network, suggesting that topography is a first-order control on catchment-scale transport. The examination of detailed hydrological processes at the hillslope scale through a wet-up period, provide the basis for a dynamic conceptual model of runoff generation and residence time, which are controlled by moisture thresholds and expanding subsurface saturated areas. The residence time of runoff during storms is a dynamic amalgamation of various components, each with their own characteristic shape, mixing behavior, and timescale, which range from 6 to 27 hours for event water and 10 to 30 days for soil water. A coupled hydrologic-tracer model at the hillslope scale indicates that the combination of storm event and between-event processes is necessary for the representations of realistic residence time distributions at hillslope and catchment scales. This study demonstrates that water residence time provides insight to hydrological processes from hillslope to large catchment scales.

McSWAIN, M.D. 1987. Summer stream temperatures and channel characteristics of a southwestern Oregon coastal stream. (MS) The Elk River Basin drains 93 sq mi of steep forested terrain on the west side of the Klamath Mountains in
Southwest Oregon. This river and its tributaries support a diverse and abundant population of anadromous fish; a hatchery located at river mile 13 (km 21) supplements these native populations. Clear weather in combination with dry summers and low streamflow produce warm water temperatures. Historical data indicate that summer stream temperatures as high as 76 degrees F (24.4 degrees C) have occurred in the mainstream of the Elk River.

This study was undertaken to evaluate summer stream temperatures and to what extent they were affected by natural factors and land use. In selected tributaries and along the mainstream of the Elk River, measurements were made on canopy cover, stream surface width, and thalweg depth during the summers of 1984 and 1985. Recording thermographs and maximum/minimum thermometers were used to determine the overall temperature pattern of the basin.

In general, maximum stream temperatures appear to be declining since 1970, following a period of increased landslide activity in the basin. The trend of decreasing maximum temperatures was not associated with changes in summer streamflow or summer precipitation patterns, suggesting that a recovery of streamside vegetation and/or change in channel morphology is proceeding within the basin.

Tributaries with relatively large width/depth ratios (exceeding 14 or more), generally exhibited large diurnal fluctuations in temperature indicating solar heating was occurring. For drainages of similar size, large diurnal temperature fluctuations were associated with large surface area to volume ratios. Tributaries found to be especially low in maximum temperatures generally flow subsurface as a result of channel aggradation. In the 1984 and 1985 field seasons, maximum stream temperatures in the tributaries never exceeded the maximum temperature of 69 degrees F (20.6 degrees C) found in the mainstem. The upper reaches of the mainstem, which is wide and aggraded, was the portion of the basin found to have the highest maximum stream temperatures.

Five pools were sampled to determine vertical profiles of temperature and dissolved oxygen. Temperatures and dissolved oxygen concentrations did not vary with depth.


The Lookout Creek Earthflow is located in the Cascade Mountain Range in Western Oregon. The Cascade Mountains are mainly volcanic in origin, and deposits in and around the slide have a complex geomorphic history, affected by glacial, mass movement, and fluvial processes. The currently moving land mass is about 1600 ft long and 300 to 800 ft wide. The average depth to the failure surface is around 20 to 25 ft, and the average surface inclination is 9 degrees. Movement takes place mainly in the wet winter months, from late fall to early spring. Average surficial movement is about 4 in. (10 cm) per year, with a maximum recorded velocity of 0.16 in/day (0.4 cm/day). There is some variation in movement rates measured up and down the slope.

Movement is best described by a shear failure of soil at residual shearing strength. Rheological models cannot explain the variations in movement rates with very slight changes in stress levels. Limit equilibrium methods with infinite slope and two-dimensional non-circular procedures are used in backanalysis for strength parameters. For both methods, back calculated N' is about 15 degrees, much lower than that N' determined from laboratory testing.

Phreatic level observed in three continuously recording piezometers does not correlate well with the annual start of slide movement, or movement rates. The annual start of movement is better explained by the pore pressure-volume change relationship in a 10 in. thick relatively impermeable shear zone.

The Lookout Creek Earthflow is covered by coniferous forest vegetation which is equivalent to a surcharge load of 10 psf or less. There is not effect of root strength along the slip surface of this slide. Removal of vegetation should have very little affect on stability of the Lookout Creek Earthflow.

MINOR, K.P. 1997. Estimating large woody debris recruitment from adjacent riparian areas. (MF)

Large woody debris recruitment to streams from adjacent riparian forests influences stream channel morphology, sediment routing, and fish habitat. A mathematical model was developed to 1) determine whether the trees in a stand adjacent to a stream, upon falling, would provide large woody debris of a specified size to the stream and 2) determine the volume of trees, upon falling, that reach a stream over a specific time period. The model considered stand and topographic parameters such as tree size, tree form, distance from the stream, hill slope gradient, stream gradient, stream width, riparian buffer width, and basal area of the stand. The likelihood that a tree of a specified size will reach the channel is the probability the tree will fall in a given direction evaluated at 1 degree azimuth from 0 to 360 degrees multiplied by the probability it is tall enough to reach the stream. Volume estimates were calculated by multiplying estimated tree volumes by the joint probabilities.
A test riparian polygon comprised of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) was selected to illustrate how the model predicts large woody debris recruitment of both key pieces and volume to an adjacent stream. Estimating large woody debris recruitment to streams from adjacent riparian stands over several decades may be useful in determining effectiveness of various configurations of riparian buffers and provide assistance in the prediction of the future quality of aquatic and terrestrial habitats in riparian zones. This model provides one way to estimate where large wood is coming from within a riparian leave area and could be useful in determining necessary widths for riparian areas that are intended to provide large woody debris recruitment over time.

MORRISSETTE, B.A. 2002. FishXing: Evaluation of Fish Passage Culvert Model And Comparison with Oregon Department of Forestry’s Compliance With Fish Passage and Peak Flow Requirements at Stream Crossings. (MF).

FishXing (fish crossing), a computer aided stream crossing culvert model designed to analyze fish passage through culverts was compared with results of an Oregon Department of Forestry fish passage monitoring report. FishXing was created at Humboldt State University through sponsorship from the US Forest Service, USDA, Stream Team, Six Rivers National Forest, San Dimas Technology and Development Center, The Watershed Stewards Project, and the Federal Highway Administration. A comparison was made between results generated using FishXing with results found by ODF in the Oregon Department of Forestry (ODF): Compliance With Fish Passage and Peak Flow Requirements at Stream Crossings monitoring project. Stream crossing culvert data from the ODF fish passage study was used to run FishXing. The ODF monitoring project investigated 74 fish passage culvert installations that were constructed following approval of Written Plans filed with ODF in 1998. (An approved Written Plan is equivalent to a permit with ODF). Information about culvert installations was analyzed using FishXing. Four different trials were run for each culvert using both adult and juvenile Coho Salmon and Cutthroat using the FishXing software. Three trials used the default values for swimming abilities of adult and juvenile Coho salmon and adult Cutthroat trout. Juvenile Cutthroat trout were also included in the comparison; however, FishXing did not contain a default setting for them. Therefore, a velocity of 2 feet per second (fps), the current target velocity for stream crossings on fish bearing streams in the state of Oregon, was used for juvenile Cutthroat trout (ODFW 2).

After making comparisons with the preliminary ODF results, further study was done to assess the accuracy of the calculations carried out within FishXing. This was based on Manning’s equation \( V=1.49/n*R^{2/3}*S^{1/2} \) and other formulas given in the “Help” section of FishXing. Flow calculations were also compared with the Haestad Culvert Master program. The results produced using Manning’s equation show no statistical difference from those generated using FishXing. Furthermore, there was an insignificant statistical difference found between FishXing-generated output and that of Culvert Master. Positive and negative attributes concerning FishXing are addressed at the end of the report.

O’LEARY, S. 1980. Bedload transport in an Oregon Coast Range Stream. (MS)

Utilizing both vortex and Helley-Smith samplers, bedload measurements were obtained for three storms during the 1977-78 winter at Flynn Creek. Flynn Creek drains a 2 km² undisturbed watershed in the Coast Range of Western Oregon. The highest peak flow observed for the two-year study, including both 1977 and 1978 water years, was 0.79 m³s⁻¹km⁻², and represented approximately an average annual peak flow based on fifteen previous years of streamflow data.

Results of measurements obtained with the vortex sampler indicated that as streamflow increased bedload transport rate increased. Temporal variations in bedload transport rate also indicated that as the storm season progressed, bedload transport rates increased even though streamflow did not necessarily increase above the streamflow of the previous storm. This may be a result of some critical discharge being necessary to initiate bedload transport. The calculated critical discharge for Flynn Creek was 0.72 m³s⁻¹km⁻² and was exceeded several times during the storm season. The peak bedload transport rate of 325 kg/hr occurred at a discharge of 0.77 m³s⁻¹km⁻². Significant (p<0.01) differences in bedload transport versus water discharge relationships occurred between storms.

Helley-Smith bedload transport rates were consistently larger than vortex rates observed during all storms except on December 13, 1977, when the rates were approximately equal. The higher transport rates measured with the Helley-Smith sampler are attributed to sampler design and indicate that the sampler is more efficient for sand-sized material. Sand-sized particles represent the predominant particle size transported as bedload in Flynn
Creek.  

Bedload transport did not occur uniformly with time, but rather occurred in "pulses" that did not appear to follow any pattern. Variations in stream cross sections and scour and fill measurements indicated that the release of bedload material occurred nonuniformly at many locations along the length of the stream channel. Information collected with cross-sectional measurements during 1977 indicated that the bed slope upstream of the fish trap may have been adjusting to the change in height of the streambed in the fish trap. Consequently, sediment data from different years should be compared with caution until it can be determined that the stream has come to equilibrium. On a seasonal basis, as the amount of organic matter in transport decreased, bedload transport rates generally increased.

Keywords: bedload transport, vortex sampler, Helley-Smith sampler, critical discharge, sedimentation, scour and fill, Oregon.

PAUSTIAN, J.S. 1977. The suspended sediment regimes of two small streams in Oregon's Coast Range. (MS) The protection of water quality and the maintenance of productive anadromous fisheries is a primary concern in the Pacific Northwest. Excessive suspended sediment loads is a principle water quality problem on small wildland watersheds in this region (Anderson, 1971; Brown, 1972). Man's activities have been shown to increase sedimentation rates in some cases (Burns, 1970; Megahan, 1972). However, more research is needed to define the basic sedimentation processes and factors before adequate assessments of man's impacts can be determined on a broad basis.

This paper presents the results of a study of the suspended sediment regimes for two small mountain watersheds located in Oregon's Coast Range. Suspended sediment concentrations in these kinds of watersheds are typically variable over short time spans. In-channel sources of fine sediment, particularly sediment stored in the bed gravels of armored stream segments, may be a major factor influencing the sediment regimes of these watersheds.

The primary objective of the study was to characterize the temporal variability in suspended sediment concentration on the two watersheds. In addition, nephelometric and gravimetric sampling procedures and the potential contributions of in-channel sources of suspended sediment were evaluated on the Oak Creek watershed.

The temporal variability in suspended sediment concentration during storm events and on a seasonal basis was determined using intensive automatic and manual sampling procedures. Sieve analysis of bed material composition and channel profile measurements were utilized to define the potential and channel profile measurements were utilized to define the potential availability of suspendable material within the channel system. It was found that: (1) stream bed gravels are a significant potential source area of suspendable material, (2) a decline in the suspended sediment concentration in the stream channel at a given flow occurs during the falling stage of individual runoff events and with successive events over the winter runoff season. This phenomenon can best be described as a flushing process, where the depletion of suspendable sediments may be associated with the successive release and capture of fine material by the bed armor layer, (3) sampling of sediment concentration did not appear to be significantly influenced by horizontal concentration gradients. However, vertical concentration gradients, particularly in the transition zone between suspended load and bedload, did prove to be significant, and (4) basic soils and geomorphic parameters provided useful indexes for comparing the sediment regimes of these watersheds.

PEACOCK, K.A. 1994. Valley fill and channel incision in Meyer's Canyon Northcentral Oregon. (MS) Meyer's Canyon, a tributary of Bridge Creek in the John Day Basin, is a deeply incised valley fill in northcentral Oregon. The current channel is incised to the Cretaceous and Tertiary bedrock. To determine the precedence of the current incision and the variation and timing of depositional sequences, the sediments exposed by incision were examined for clues. The incision evaluated in this study occurs along the length of the lower valley fill, approximately 2300 meters, with a maximum depth of about 22 meters near the medial section of the valley. The incision occurred near the beginning of the 20th century and widened from 1951 to 1979, after which tributary headward cutting only is occurring at one location. Colluvial aprons and aggradation within and at the margins of alluvial fans indicate depositional processes again dominate.

Fill sediments dates from the early Holocene. Volume of the fill prior to incision was estimated to be about 10.8 mcm (million cubic meters), of which 1.2 mcm (11%) was removed by the incision. Fill sediments are contributed by coalescing alluvial fans and alluvial plain sedimentation. The Upper Drainage and Permian
Tributary could potentially donate 67% of the Lower Valley fill sediments though these portions of the drainage were not studied. Early sedimentation is dominated by coarse-grained fluvial transport, followed by numerous thick fine-grained sequences, topped by debris flow/mud drape couplets where proximal fan processes dominate. Sediment size decreases and sorting increases toward the fan margins. Valley plain deposition is currently and was, within the Holocene, enhanced and influenced by thick vegetation due to perennial groundwater saturation. Aggradation throughout the Lower Valley fill has dominated over the course of the Holocene, with only one previous episode of incision coincident with the Mt. Mazama eruption, about 6900 yrs BP.

Rates of accumulation have changed over the course of the Holocene. Volume rate of accumulation was 140 m$^3$/yr prior to the Mazama eruption and 210 m$^3$/yr following the eruption at a proximal fan location. Within the alluvial fans and plains, sediment characteristics change with distance from source of sediment. At more distal fan and alluvial plain locations, an average volume accumulation rate of 260 m$^3$/yr was estimated prior to the Mazama eruption, and 130 m$^3$/yr following the eruption. These rates indicate that input at the proximal locations has been increasing in the late Holocene and that aggradation may again be dominating Meyer's Canyon sedimentation.

Recurrence intervals of debris flows (proximal locations) or events capable of transporting matrix-supported gravels (distal and alluvial plain locations) show an average recurrence interval of 600 yrs pre-Mazama and 1500 yrs post-Mazama. At proximal locations, the shortest interval is after about 1200 yrs before present (BP) when debris flows occurred about every 500 years. Shorter intervals also generally occurred in all pre-Mazama locations when coarse-sediment input was rapid, probably from the Pleistocene-Holocene climate shift from cool/wet to warmer/drier. Following the Mazama eruption, the medial section of the Lower Valley fill had rapid input of coarse debris, while proximal fan locations had massive fine-grained input. This is interpreted as a complex response, i.e., rapid runoff reworked previously deposited sediments at proximal locations and sediments were deposited at more distal locations. Fine-grained sediment accumulation followed this period until about 1200 yrs BP.

The strongest evidence for a causal mechanism for incision is a complex response at the previously saturated wet-meadow, medial portion of the Lower Valley fill due to loss of riparian vegetation which maintained an oversteepened alluvial slope. The previously saturated portion of the Lower Valley fill shows an increasing transportation slope over time. This slope was probably maintained by the hydrophytic vegetation, but loss of that vegetation due to Euroamerican influence could have led to a geomorphic threshold being crossed on the oversteepened slope and channel incision ensued. The incision is widest at this point and, if width is used as a surrogate for length of time of exposure, it is likely that incision began here.

PIEHL, B.T. 1986. An evaluation of culverts on small volume forest roads in the Oregon Coast Range. (MS)
A total of 515 ditch relief culverts and 140 stream crossing culverts were randomly selected for evaluation, in the central Oregon Coast Range. The purpose of this evaluation was to compare existing design guidelines to these road drainage installations and also rate their capability of functioning effectively during high flow events. The study area consists primarily of steep slopes, sandstone bedrock and has an extensive road network.

The inlets of 74% of all ditch relief culverts (DRCs) were reduced from original; the average inlet cross-sectional area was 80% of original. Almost half of all DRCs have inlet reductions associated with sediment and/or denting. Outlet erosion occurred at 38% of all DRCs and had an average volume of 2.5 cubic yards. Outlet erosion increased substantially with fill slopes greater than 40% and for spacings which exceeded USFS (R-6) guidelines. Significant differences in erosion volumes and spacing were related to land ownership.

In order to evaluate the design capacity of stream crossing culverts (SCCs), 25-year peak flows were calculated using the latest regional analysis for the Oregon Coast Range. The ability of SCCs to pass a 25-year peak flow was then evaluated with two different methods. For almost one-quarter of all stream crossing culverts the estimated 25-year peak flows would be expected to overtop the road. About 80% of all SCCs were unable to pass a 25-year peak flow at a headwater to diameter ratio of 0.75. Significant differences in SCC design were related to ownership. The capacity of most Coast Range SCCs seems to have been seriously underdesigned.

PONCE, S.L., II. 1974. The biochemical oxygen demand of Douglas-fir needles and twigs, western hemlock needles and red alder leaves in stream water. (MS)
Field studies indicate that accumulation of finely divided organic debris in the channels of mountain streams after clearcutting may be responsible for subsequent reduction in the dissolved oxygen concentration. The purpose of
this study was to quantify the biochemical oxygen demand (BOD) of Douglas-fir needles and twigs, western hemlock needles and red alder leaves, ascertain the chemical characteristics of the leachate from these materials, and determine if such materials are toxic to fish.

Long- and short-term BOD and BOD rate constants were determined for the different types of vegetation. A standard temperature BOD test was run 90 days for the leaf material and 45 days for the Douglas-fir twigs. Four replications were run for the leaves and three run for the twigs. Half the leaf samples were fixed with a nutrification inhibitor. However, later analyses proved nutrification did not occur. As a result, all the replications within a species were combined and one curve was fitted through each group of data. A BOD curve was constructed by least squares fit through the 90 days of leaf data and through 45 days of the twig data and extended to 90 days. The 90 day K1 and the BOD90 were calculated from this curve and were: 0.125 and 110 mg O2/gm (dry weight) for Douglas-fir needles, 0.056 and 110 mg O2/gm (dry weight) for Douglas-fir twigs, 0.064 and 286 mg O2/gm (dry weight) for red alder leaves. Further tests showed that these 90 day values could be accurately estimated by tests of shorter duration; 20 days for Douglas-fir and western hemlock, and 60 days for red alder. The 20-day western hemlock values may, in fact, yield a more precise estimate of the actual 90-day values than the composite fit. The 20-day western hemlock projections were 0.049 for K1 and 200 mg O2/gm (dry weight) for the BOD90.

Leachates of the test materials were analyzed with respect to composition, concentration, and rate of nutrient release. This information was to be used in the explanation of the 90 day BOD values obtained. Half the samples were poisoned with 2.7 mg/1 mercuric chloride to inhibit microorganism growth while the rest of the samples remained untreated to show the effect of the microorganisms. These data were of limited use due to fungal growths appearing after 20 days and failure of half the twig samples to be adequately poisoned. The test was terminated after 20 days.

Simple sugars and phenolic compounds were found in all the samples. Simple sugars were arabinose, xylose, galactose, mannose, and glucose. Mean maximum sugar concentrations released in poisoned leaf samples varied from 2.15 mg glucose equivalent/gm (fresh weight) to 15.0 mg/gm (fresh weight) for Douglas-fir and red alder. The mean maximum sugar concentrations in the non-poisoned samples were much less: 6.0, 5.0, and 8.0 mg glucose equivalent/gm (fresh weight) respectively for Douglas-fir, western hemlock and red alder. The rate of sugar release was rapid for Douglas-fir needles, show for red alder, and intermediate for western hemlock.

The different types of phenolic compounds were not identified. The mean maximum concentration of phenolics in the poisoned samples were 0.72, 0.46, and 0.55 mg gallic acid/gm (fresh weight) respectively for Douglas-fir, western hemlock, and red alder leaves. There was little difference between mean concentrations of the poisoned and non-poisoned samples until day 10, at which time mean phenolic concentrations of the non-poisoned samples began to drop. The Douglas-fir twigs had a slow initial sugar release, followed by an increase in the rate; the maximum concentration reached was 10.0 mg glucose equivalent/gm (fresh weight). The pattern of phenolic release was the same with a maximum concentration of about 1.0 mg gallic acid/gm (fresh weight).

The five-day BOD of leaf material was determined under conditions of fluctuating temperature (12.8 to 35.0°C) similar to that observed in streams exposed by clearcutting. The BOD5 values were: 202 mg O2/gm (dry weight) for Douglas-fir, 109 mg O2/gm (dry weight) for western hemlock, and 249 mg O2/gm (dry weight) for red alder leaves.

The BOD5 of samples incubated at standard temperature was much lower than those exposed to conditions of fluctuating temperature: it was 25, 42, and 24 percent of the temperature fluctuated BOD5 for Douglas-fir, western hemlock, and red alder leaves respectively.

The toxicity of leachate extracted from 50 grams (fresh weight) per liter of water of each species were determined on guppies and steelhead fry. The 96-hr LC50 to guppies from leachate of Douglas-fir, western hemlock, and red alder was 35, 65, and 18 percent of the original concentration for the steelhead fry. These are extremely low levels of toxicity to such a concentrated sample and pose no threat to the fish.
Logging roads and the associated cut and fill slopes on steep terrain represent a major discontinuity in the natural state of stress in the soil mantle. Therefore, a greater incidence of slope failures is likely to be associated with roads than with natural field conditions. This observation has been verified by field studies (Swanson et al., 1981).

A landslide evaluation system has been proposed for U.S. Forest Service use (Prellwitz et al., 1983) to address the instability of hillslopes associated with timber harvest activities. This evaluation system has been separated into three levels of analysis based on the degree of complexity and required input data. These three levels are:

1. Resource Allocation - Level I
2. Project Planning - Level II
3. Critical Site Study - Level III

The purpose of the Level I analysis is to delineate areas susceptible to landslides on a broad scale. The Level II analysis is performed to identify unstable sites along proposed road alignments. The Level III analysis provides site specific road stabilization measures for unstable sites.

An important tool suitable for use in a Level II analysis is the PLANS (Preliminary Logging Analysis System) group of computer programs which presently operates on the Hewlett-Packard HP 9845B microcomputer (Twito and Mifflin, 1982). The PLANS group provides a convenient, thorough and rapid method of analyzing timber harvest alternatives based on digitized terrain data. The PLANS group includes the ROAD computer program. The ROAD program provides a rapid method of designing and evaluating alternative logging road alignments. This evaluation is based on road length, grades, and alignment. Presently, the slope stability of road alignments is not addressed in the evaluation of alternate routes.

The approach to slope stability analysis for a Level II analysis differs significantly from a detailed, site specific analyses in several ways. The available soil property data generally consist of average values for soil types on a regional basis for a Level II analysis. Topographic data used are typically at a scale where small features, which can be important to the stability of road cut and fill slopes, are not discernable. Ground water data may be non-existent, therefore requiring reliance on engineering judgment in an analysis. Due to this lack of precision of the data base, rigorous stability analyses are unwarranted and simplified approaches are generally used for Level II analyses. This level of stability analyses can be performed with the assistance of a computer program developed for this project which is operated in conjunction with the ROAD computer program.

A key factor to the value of a simplified stability analysis is the accurate prediction of design ground water conditions. Site specific ground water models have been developed by researchers but, presently, no generalized predictive ground water model exists. A simple ground water model was developed for this project.


The purpose of this study was to examine certain hydrologic properties of the soil and subsoil on a steep forested slope and relate these properties to the movement of water via subsurface routes. The hydrologic properties examined were bulk density, soil texture, total porosity, pore size distribution, saturated hydraulic conductivity, and soil moisture-tension relationships.

Soil samples were taken from a 2.5 ha study slope on watershed 10 of the H.J. Andrews Experimental Forest near Blue River, Oregon. Eleven soil pits were excavated and six soil core samples were taken at depths of 10, 30, 70, 110, 130, 150, and 200 cm where soil conditions permitted. Laboratory analyses were conducted to determine the hydrologic properties of each sample. The extreme permeability and high porosities of the samples necessitated the use of specially designed apparatus to measure the saturated weights and hydraulic conductivities.

Particle size distribution changed only slightly with depth. The A and B horizons were predominantly clay loams and the C horizons were classified as clays. Total porosities also varied little with depth. The porosity of the soil (A and B horizons) averaged nearly 65% while the porosity of the subsoil (C horizons) averaged nearly 55%. Bulk density also varied little with depth. Soil bulk densities averaged .825 gm/cm$^3$ and subsoil bulk densities averaged 1.180 gm/cm$^3$.

The hydraulic conductivity and pore size distribution of the soil and subsoil were well correlated and changed considerably with depth. Significant decreases in the hydraulic conductivities occurred between the 30 cm and 70 cm depths as well as between the 110 cm and 130 cm depths in some of the soil pits. At most soil pits the surface soil had conductivities greater than 400 cm/hr while the soil at the 70 cm and 110 cm depths had...
conductivities near 200 cm/hr. Subsoils had much lower conductivities, less than 60 cm/hr in most soil pits and less than 10 cm/hr in some pits. A power curve regression analysis was used to relate the hydraulic conductivity (Y) and the mean percentage of pores greater than .294 mm in diameter (X) according to the equation: $Y = 10,040X^{2.997}$. The resulting $r^2$ was .945. The percentage of pores greater than .294 mm in diameter was also found to change abruptly between the 30 cm and 70 cm depths in most soil pits and between the 110 cm and 130 cm depths in some soil pits.

The hydrologic properties were used to discuss the possible nature of water movement through the soil and subsoil of the study slope. The soil hydrologic properties and antecedent moisture conditions were predicted to be conducive to vertical unsaturated translatory flow. A zone of saturation was predicted to occur during winter rainfall events above the subsoil horizon having extremely low conductivity rates (above the 130 cm depth near soil pit 1). This zone of saturation was predicted to be the most probable zone of lateral water movement in the form of saturated translatory flow during the winter rainy season.


Three culverts, judged to be fish barriers, were replaced with “stream simulation” culverts on the Fremont National Forest of south central Oregon. The culvert sites are located in the Fort Rock Basin in streams that are home to resident Great Basin redband trout (*Oncorhynchus mykiss*). Great Basin redband trout is the common name for the native trout in the great basin and is informally recognized as *O.m. newberrii*.

The design process is discussed and documented for the three culvert replacements. The fish passage conditions in the new culverts were compared to the old culverts both quantitatively and qualitatively. One assumption with stream simulation culverts is that fish will be able to move through a culvert if the flow conditions are similar to that of the natural channel. Velocity measurements were taken during one discharge condition of spring snowmelt, the migration period for spawning redband trout. The comparisons were further examined to determine which would be appropriate metrics in the determination of success or...(next page not found in file).

REITER, M. 1990. Subsurface flow of a forested riparian area in the Oregon Coast Range. (MS)

This study was undertaken to gain further understanding of the subsurface hydrology for a stream-adjacent riparian area in western Oregon's coast range. Spatial and temporal fluctuations of the free water surface of a toeslope, adjacent riparian area, and stream channel in a forested terrace reach were monitored over a period of one year. A total of 27 piezometers were installed (nine in each of three transects established perpendicular to the stream) in a stream-adjacent terrace and hillslope. These piezometers were monitored from September 27, 1989 to July 25, 1990.

Results indicate that the direction of flow within a forested terrace can vary throughout the year. During the drier months of September and October, flow direction was generally towards the stream. However, by November the direction of flow for those areas closest to the stream had begun to change. In some cases the direction of flow changed up to 180° from the September direction.

The location of influent/effluent zones along the stream (i.e., zones along the stream where the terrace has a lower or higher hydraulic head than the stream, respectively) also varied throughout the year. During October, 1989 the furthest upvalley stream-adjacent piezometer had hydraulic heads greater than the stream for the entire month, while two other stream adjacent piezometers did not. During normal precipitation in January, 1990 both furthest upvalley and the middle stream-adjacent piezometers had hydraulic heads greater than the stream for the entire month. By July, 1990 only the middle stream-adjacent piezometer had a hydraulic head greater than the stream for the entire month, while the furthest upvalley piezometer had a higher head for 33% of the month and the hydraulic head of furthest downvalley piezometer never exceeded that of the stream.

For the Deer Creek study site, subsurface velocities were estimated to be in the range of $10^{-8}$ to $10^{-11}$ m/s resulting in a 3.8 year minimum travel time for storm water to reach the stream. Thus, soil matrix velocities using the Darcy equation were not sufficient to generate stormflow. However, no overland flow was observed during storm events, indicating that alternative subsurface flow pathways, such as macrochannels, are being utilized.

Previous research has suggested that the release of water from terrace storage in small headwater streams is not sufficient to maintain baseflow. The results of the Deer Creek study support this conclusion.
Furthermore, the results of this study indicate that forested riparian areas are hydrologically complex with respect to both space and time and that oversimplification of these systems may lead to misinterpretation of other processes associated with subsurface water dynamics.


Through the trapping of sediment behind dams, the presence of beaver in a watershed may cause substantial changes to fluvial and geomorphic processes. In an effort to investigate sedimentation patterns in beaver ponds in the Oregon Coast Range, a case study was made of the annual accumulation of sediment in a series of ponds on Flynn Creek, a small watershed in the Alsea River drainage. Depth, texture, and organic content of sediment deposited during the 1992-93 highflow season were measured. However, three out of four of the ponds studied drained between January and March 1993 because of dam failures. Sediment retained in these ponds varied between -0.9 and 3.5 m$^3$. Cumulatively, these breached ponds retained 4.3 m$^3$ or 3% of their potential storage. The volume of sediment retained behind the intact dam was 10.3 m$^3$, or 29% of potential. The net quantity of sediment retained in the four ponds was estimated to be 22 t (i.e., 11 tons per square kilometer of watershed area) and represents about 11% of the average annual sediment yield from the watershed. Depth, sediment particle size and organic matter content patterns were highly variable within the drained ponds, but were relatively orderly within the intact pond. Particle size of the deposited sediment tended to decrease in the downstream direction. Organic content was significantly inversely related to the logarithm of the mean particle size ($p<0.01$).

Sediment trapping efficiency of the intact pond was estimated for a range of streamflows and particle sizes. For the highflow event of the 1992-93 water year, the pond was estimated to be 100% efficient in trapping particles 0.4 mm and larger in diameter.

The variations in the depth, texture and organic content of the sediment captured in the beaver ponds indicate a complex depositional environment occurs within the ponds. The intact pond captured substantial quantities of suspended sediment-sized material that might have otherwise been transported to low-gradient reaches further downstream. These results indicate that beaver ponds not only alter local rates and quality (i.e., particle size distribution) of sediment accumulations in the valleys of small coastal watersheds, but that they also affect the downstream routing of these materials. Over long periods of time they may thus have a significant influence on the morphology and occurrence of floodplain features in the Oregon Coast Range.


This study evaluated the effect of soil compaction on the growth of natural regeneration on volcanic ash-influenced soils in the southern Washington Cascades. Growth of 9 to 18 year-old sapling-sized Ponderosa pine (Pinus ponderosa Laws.) was studied on sites ranging from 915 to 1006 m elevation in an area selectively logged in 1959, and for 10 to 13 year-old lodgepole pine (Pinus contorta Dougl.) established following a group selection harvest on a 1342 m elevation site logged in 1967. Soils ranged from loam to sandy loam texture. Height, diameter, and volume growth were measured for trees growing under an array of disturbance conditions to determine the influence of soil compaction on their size and growth rates.

A number of soil, vegetation, and site variables were studied to determine possible cause and effect relationships with growth parameters. Bulk density of the surface 30.5 cm was measured within the lateral rooting zone to provide an index of compaction. Trees were destructively sampled to obtain a detailed record of their development, and to adjust for differences in age as a result of variable establishment delays.

Average bulk density increases of 15.4 and 27.5 percent relative to adjacent undisturbed soil were found for skid trails in the ponderosa pine and lodgepole pine study areas, respectively. The effect of soil displacement overshadowed any possible relationship between bulk density and growth for lodgepole pine. The strong correlation of growth with organic matter content indicates that removal of nutrient-rich surface soil during logging and slash disposal operations may significantly affect site productivity, particularly for poorly developed skeletal soils.

Regression analysis showed that several growth parameters for ponderosa pine were strongly associated with the increase in bulk density despite additional significant relationships with tree age, site index, and overstory cover. Reductions in total growth of 4.8, 7.7 and 20.4 percent were predicted for height, diameter, and stem volume of 14 year-old skid trail regeneration based on the mean bulk density increase. Evaluation of
current growth increment was effective in adjusting for differences in tree age. Predicted average reductions in height, diameter, and volume growth of 7.1, 11.8, and 18.9 percent were estimated for young ponderosa pine based on the last five year period. Projected impacts from regression analysis represent conservative estimates, since the mean density increase used is the prediction model included measurements for sample trees growing in soil with bulk densities comparable to undisturbed levels.

When the ponderosa pine sample was stratified into low and high impact groups based on bulk density increases, differences in the shape of height-age and diameter-age curves were apparent. A significant decrease in the rate of growth was noted for trees growing under high disturbed conditions. Projected effects of compaction on site productivity throughout the rotation are difficult to assess, but measurable reductions in young tree growth coupled with frequent stand entries and the slow rate of natural soil recovery provide a basis for concern for long-term impacts.

Keywords: soil compaction, skid trails, southern Washington Cascades, site productivity, natural regeneration.

ROBISON, E.G. 1987. Large woody debris and channel morphology of undisturbed streams in southeast Alaska. (MS)
The characteristics and interactions of the riparian stand, large woody debris (LWD), and channel morphology were examined on five undisturbed, low gradient streams in southeast Alaska. One first-, two second-, one third-, and one fourth-order streams were studied. Stream morphology variables were measured systematically at fixed intervals of three to ten feet depending on stream size: 50-foot intervals were used for riparian forest measurements.

The percentage of alder comprising the riparian forest increased with stream size. The first- and second-order streams had alder comprising approximately 8% of the total basal area whereas, the fourth-order stream had 25%. Likewise, the percentage of LWD pieces consisting of alder increased from 12% in the two smallest first and second-order streams to 31% in the fourth-order stream. These findings, along with inspection of air photos indicate an alternating "one sided" alder corridor exists along the largest stream.

The proportion of large woody debris pieces with rootwads in the channel increased from 2 and 6% in the two smallest first- and second-order streams to 32% in the fourth-order stream indicating the largest stream has recruited LWD from bank cutting and/or lateral channel migration. LWD oriented perpendicular (90°) to general stream flow was relatively frequent for all streams. No significant (alpha=0.05) linear relationship was found (r²<0.05) between piece length and orientation to flow.

Channel morphology changed with stream size. For example, the length of stream with side channels and/or braided reaches increased from 1% in the first-order stream to 41% of stream length in the fourth-order stream. The overall percentage of pools averaged 57% and showed no changes with changes in stream size. However, the relative proportions of individual pool "morphological types" and "causal elements" did change with stream size. "Underflow pools" comprised less than 10% of the morphological types in the first-, second-, and third-order streams but increased to 17% in the fourth-order stream. Autocorrelations of the spatial distributions of stream morphological variables (i.e., depth and width) indicated that the streams are influenced by a wide variety of interacting factors and processes. Thus channel dimensions are characterized by high variability and an absence of "memory" or "repeatable" components.

A positive linear relationship (alpha<0.01, r²=0.23) was found between LWD volume and the standard deviation of bankfull width. No such relationships were found for other stream morphological variables including thalweg depth, low-flow width, cross-sectional area, and width depth ratio, indicating other variables besides wood volume present are influencing variability in stream morphology, or that the effects of large woody debris upon channel morphology is not easily expressed by linear regression techniques.

Autocorrelations and frequency histograms of an upstream forested section, with instream LWD, and a downstream meadow section with no LWD, noncohesive soils and tidal effects, show that the meadow section had greater "memory" and less diversity in "morphological types" and "pool causal elements".

These results provide a quantitative assessment of several stream morphology variables for first- through fourth-order streams in southeast Alaska. Further research is needed to compare these results for undisturbed streams with streams influenced by management activities.

ROBISON, E.G. 1997. Reach scale sampling metrics and longitudinal pattern adjustments of small streams. (PhD)
Several types of channel morphology measurement parameters used to characterize fish habitat of small streams
are refined, developed and evaluated in terms of their accuracy, precision, and sensitivity to disturbance. Data for 74 stream reaches in Oregon and Alaska are used in analysis. Over half the reaches are from a pre-pilot study funded by EPA’s Environmental Monitoring and Assessment Program (EMAP).

A new methodology for determining residual pools is developed (termed the Longitudinal Streambed Simulation Method). This new method and an older method are compared with a more rigorous time consuming method for determining residual pools. Results indicate a generally close correspondence. For instance, the absolute percent departure of longitudinal residual pool area was typically within 10% and always less than 25% for streams with wetted widths greater than 3.5 meters.

Precision is evaluated for three data sets containing replicated stream reach measurements. Directly measured parameters like standard deviation depth are demonstrated as precise and repeatable. In contrast, visual scoring systems and visual determination of riffles versus pools have low precision.

Adequate reach length for determining various channel characteristics is evaluated by using classic sample size statistics, time series, and short versus long reach comparisons. Results suggest that reach lengths of 30-40 channel widths with 2-3 measurements per wetted channel width seem to provide adequate coverage to determine residual pools. However, simple determinations of mean depth or width can be spaced as wide as two channel widths apart without significant accuracy loss.

While many relationships regarding pool formation versus riparian and watershed characteristics are evaluated, probably the most intriguing result is the influence roughness (large woody debris) has on the formation of residual pools and in increasing variation in systematically placed depth measurements along the stream. The results also suggest a range of channel slope in which variability in these depth measurements is maximized (0.5-6.0% slope).

These results provide valuable information for anyone attempting to develop, implement, or analyze data from a monitoring protocol that evaluates channel morphology or morphological fish habitat. Information on the residual pool concept and how to use it in monitoring is also provided.

ROYER, T. A. 2006. Scaling Hydrologic Impacts from Road Segments to a Small Watershed. (MS)

The impact of forest roads on the hydrology of forested watersheds has long been studied. While forest roads have been reported to alter storm runoff at the road segment scale, the potential for changes to be detectable at the small watershed scale has been debated. The purpose of this study was to quantify the road affect at the road segment scale and estimate how those effects are expressed at the mouth of a watershed. This study took place in the McDonald-Dunn Research Forest located in the Oregon Coast Range near Corvallis, Oregon. Claire Creek, a small watershed within the Oak Creek Watershed, and two road segments with the associated inboard ditches and upslope contributing areas were selected to represent the roaded watershed. Runoff from both road segments enters small headwater streams at stream crossing culverts. Discharge was measured from the headwater streams and from the road segments at the stream crossing culvert for five storms during the winter of 2004 – 2005. Discharge was also measured at the mouth of Claire Creek, an adjacent roadless watershed, Finley Creek, and at a gauging station on Oak Creek near the boundary of the McDonald-Dunn Forest. The difference in time of occurrence of peakflows and the length of the stream between the culverts and the mouth of Claire Creek was used to estimate a ‘real’ travel time of the peakflows for all five storms. Kinematic wave equations were used to model travel times of peakflows from the culverts to the mouth of Claire Creek, with and without the influence of the road.

At the road segment scale the road affect was detectable for changes in peakflow magnitude, quickflow, and total stormflow, but the affect of the road on changes in the timing of occurrence of the peakflow was inconsistent. At the watershed scale the road affect could not be calculated for changes in peakflow magnitude, quickflow, or total stormflow because of the unavailability of pre-road runoff data. The modeled travel time of peakflows that included discharge from the road were shorter than the modeled travel time of peakflows of stream discharge alone by less than 10 minutes for all five storms. The road affect on real travel times of peakflows was inconsistent and did not correlate to the magnitude of the increase at the road segment or at the mouth of the watershed. These findings agree with earlier studies that have reported a road affect on storm runoff at the road scale, and suggest that the road affect at the mouth of a watershed may not be detectable. The findings also suggest that other factors are influencing runoff at the mouth of a watershed more than the addition of ditch runoff at stream crossing culverts.
SALMINEN, E.M. 1990. Undercut streambanks in forested headwater streams of the Oregon Coast Range. (MS)
This study was undertaken to evaluate the occurrence and characteristics of undercut streambanks in forested headwater streams of the Oregon Coast range. Undercut streambanks and associated reach characteristics were surveyed along 46 sample reaches (each 152 m in length) in 8 streams; all sample reaches occurred in unmanaged forested riparian areas. Drainage areas ranged from 0.3 to 16.6 km².

At each undercut location length, surface area, volume, low-flow (summertime) volume, and maximum horizontal depth were measured. Individual undercuts had surface areas ranging from 0.3 to 27.7 m² with a mean value of 2.6 m², and lengths ranging from 1.2 to 15.2 m with a mean value of 5.0 m.

The area of undercut streambanks ranged from 0.0 to 27.4 m² / 100 m of stream, with an average value of 6.5 m² / 100 m. The proportion of bankfull channel area undercut ranged from 0.0 to 4.5%, with an average value of 1.1%. Reach length undercut ranged from 0.0 to 23.6%, within an average value of 6.2%. The values reported in this study are approximately mid-range in comparison to characteristics of undercut banks reported in studies from Alaska, Montana and Wisconsin. The % of reach area covered by undercut streambanks in this study is approximately half of that provided by large woody debris.

Outside channel bends had approximately 6 times more undercut streambanks than inside bends or straight sections. Streams having a sinuosity index greater than 1.15 averaged approximately twice as much % streamlength undercut and 3 times as much % surface area undercut than streams having a sinuosity index less than 1.15.

Number of undercuts and undercut characteristics were inversely correlated with channel gradient; significant differences occurring among 1%, 2-4%, and 5+% channel gradient classes.

Streambanks ranging in height from 1-2 m had a higher occurrence of undercut streambanks than either lower or higher streambanks. Undercut streambanks were 4 times more common in "composite" than "non-composite" streambanks. Undercut characteristics appear to be correlated with valley segment type.

Channel widths were, on average, significantly narrower at undercut sites when compared to reach average channel widths. However, it does not appear that width characteristics are a cause of undercutting. Based on field observations it appears that flow obstructions (gravel bars, boulders, large woody debris) have little impact on undercut characteristics.

Both at-a-site and reach-level comparisons of undercut bank characteristics showed relatively strong correlations with streamside tree densities. Red alder (Alnus rubra) is the most prevalent species found in Coast Range riparian areas, and the most significant species in explaining reach-level differences in undercut characteristics. Sitka spruce (Picea sitchensis) is less common in riparian zones, but appears to be positively correlated with the proportion of reach area undercut.

SCHERER, R.A. 1995. The short term temporal and spatial variability of nitrogen and phosphorus in two Oregon Coast Range streams. (MS)
High intensity sampling was undertaken to characterize the temporal and spatial variability of oxidized nitrogen (NO₃-N + NO₂-N), ammonia-nitrogen (NH₄-N), total dissolved phosphorus, total unfiltered phosphorus and orthophosphorus (PO₄-P) from two adjacent small streams in Western Oregon's Coast Range, Deer Creek (303 ha) and Flynn Creek (203 ha). Deer Creek has been 39% clearcut from 1966 to 1987 while, Flynn Creek has never been logged and remains a "control" watershed for various research projects. A sequential wet-deposition precipitation sampler was also used to determine the temporal variability of oxidized-nitrogen, ammonia-nitrogen, total dissolved phosphorus and orthophosphorus entering a watershed during two storm events.

Samples collected every one hour over a 25 to 26-h period during summer low flows indicated that oxidized nitrogen, ammonia-nitrogen, total unfiltered phosphorus, and orthophosphorus remained relatively constant. Total dissolved phosphorus concentrations were the most variable but did not have a discernible diel pattern.

On a spatial scale, total unfiltered phosphorus and total dissolved phosphorus remained relatively constant or showed no discernible patterns when samples over five 250-m intervals on each reach during summer low flow. Oxidized nitrogen and orthophosphorus concentrations increased on Deer Creek and decreased on Flynn Creek in a downstream direction. Ammonia-nitrogen concentrations decreased in a downstream direction on Deer Creek and remained constant on Flynn Creek.

Nutrient constituent concentrations observed during high intensity sampling of three storm events had a variable response with stream discharge. Oxidized nitrogen concentration levels collected during the first fall
storm appeared to be consistent with other research that has shown a flush of oxidized nitrogen out of the forest soil profile during the first fall storm. Sample concentrations from the first sampled storm had a 35% decrease in concentration with the falling limb of the first sampled storm on both Deer Creek and Flynn Creek. Whereas, oxidized nitrogen concentrations had a 9 to 25% decrease with an increase in discharge on the two studied creeks and returned to pre-storm levels with a decrease in discharge during two winter storms. Total unfiltered phosphorus concentrations had a 90 to 1150% (0 to 10 fold) increase with a rise in storm discharge and decreased with the fall in storm discharge depending on the storm event and creek sampled. Ammonia-nitrogen, total dissolved phosphorus and orthophosphorus concentrations were not related to changes in discharge.

Precipitation concentrations of oxidized nitrogen and ammonia-nitrogen either had a variable response or became diluted with an increase in rainfall amounts. The different responses appear to be related to storm intensity, with greater dilution in higher intensity storms.

Results from this study indicate that the input and output of nitrogen and phosphorus into forested streams can be quite variable on both small temporal and spatial scales depending on the particular nutrient sampled, the particular creek sampled, stream flow conditions and season. It appears that sampling schemes designed for monitoring water chemistry or nutrient flux should initially presume significant short interval (2 to 20-h) variation until intensive sampling is able to prove otherwise.

SHERWOOD, K. 1993. Buffer strip dynamics in the western Oregon Cascades. (MS)

Although buffer strips have long been used as a protection tool when logging near streams, long-term studies investigating buffer strip dynamics are rare. Steinblums et al. (1984) inventoried 40 buffer strips 1 to 15 years old in the western Oregon Cascades beginning in the summer of 1975. Numerous site and stand characteristics were evaluated and regional regression equations were developed to predict survival of the buffer strips (Steinblums et al. 1984).

During the summer of 1990, 20 of the original buffer strips (Steinblums et al. 1984) were selected for reinventory to assess overstory conifer changes and density of conifer regeneration. Three sites had experienced severe windthrow followed by salvage logging, and a fourth could not be matched with original field notes. The 1990 comparison utilized the 16 remaining sites.

Four diameter classes (10-14 inches DBH, 16-29 inches DBH, 30-44 inches DBH, and ≥45 inches DBH) were used to evaluate change in overstory conifers since the original study. Density and basal area of each class were evaluated for each of the three common coniferous species (western hemlock, western red cedar, and Douglas-fir), and combined conifers. Average combined conifer densities of these late successional buffer strips increased from 54 to 59 trees per acre since the earlier study (Steinblums et al. 1984); average combined conifer basal area decreased from 299 to 263 ft² per acre since the original study.

Ingrowth was most common in the two smallest diameter classes, with the majority of buffer strips showing increases in density and basal area. Average combined conifer density increased from 32 to 41 trees per acre; average combined conifer basal area increased from 64 to 76 ft² per acre. Western hemlock was the major contributor to the increases. Western red cedar and Douglas-fir represented relatively minor components of the two smallest diameter classes in both samplings. While combined conifer basal area increases were small, density increased as much as 900%.

Decreases in density and basal area were common for conifers 30-44 inches DBH, with the majority of losses evident among western hemlock. However, Douglas-fir also exhibited some declines in this class. Western red cedar was relatively unchanged since the original study. Density losses ranged from 0 to 50% of the original buffer; basal area losses ranged from 0 to 72%.

Density and basal area losses typically occurred among conifers ≥45 inches DBH. Though trees of this size were not prevalent, basal area losses from this class ranged from 0 to 84% of the original sample value. Conifer regeneration data indicate these buffer strips are sufficiently stocked to maintain conifers over time. Average densities of saplings (<8 inches DBH and >3 feet tall) ranged from nearly 200 to 3600 trees per acre.

SKAUGSET, A.E., III. 1980. Fine organic debris and dissolved oxygen in streambed gravels in the Oregon Coast Range. (MS)

Intragravel organic loading and intragravel dissolved oxygen were studied to determine the relationship between timber harvesting adjacent to first-, second- and third-order streams and intragravel water quality. Twenty watersheds in the central Coast Range of western Oregon were studied of which five were undisturbed, nine were partially harvested, and six were completely harvested. Intragravel dissolved oxygen was sampled by accessing intragravel water with a small, steel probe and dissolved oxygen was determined with a membrane electrode and
dissolved oxygen meter. Streambed gravels were sampled with a liquid nitrogen freeze-core technique and the organics were separated from the inorganics by elutriation.

Intragravel organic loading averaged 6.6 gms/1 core volume and ranged from 0.2 to 79.5. Intragravel dissolved oxygen averaged 6.5 mg/l and ranged from 2.2 to 10.8 while intragravel dissolved oxygen depression averaged 34% and ranged from 0% to 74%.

Partially harvested watersheds had significantly (" = .01) lower intragravel organic loading than the undisturbed or completely harvested watersheds which were not significantly different. A reduction of large organic debris was observed in the partially harvested watersheds. This could have modified the stream's retention capacity for fine organic debris and in turn reduced intragravel organic loading. The most significant variables associated with intragravel organic loading in the multiple linear regression equations were: sample depth, streambed porosity, percent inorganic fines, and large organic debris loading. An increase in any of these variables indicated increased intragravel organic loading. When percent area harvested and length of streambank with harvesting adjacent were included in a regression equation, they explained a small, but significant amount of variation in intragravel organic loading. Increased harvesting activities as indicated by these variables were associated with decreased intragravel organic loading.

There was no significant difference in intragravel dissolved oxygen depression between the undisturbed, partially harvested, and completely harvested watersheds. Percent inorganic fines was the single most significant variable correlated with intragravel dissolved oxygen depression in the multiple linear regression equations. An increase in inorganic fines was associated with decreased intragravel dissolved oxygen. Another group of variables which were indicators of watershed size was correlated with intragravel dissolved oxygen depression. The relationship indicated that larger watersheds were associated with higher intragravel dissolved oxygen.

The general conclusion drawn from this study is that timber harvesting in the Oregon Coast Range has not had an adverse impact upon intragravel dissolved oxygen by increasing intragravel organic loading.

A hypothesis used to explain the relationship between timber harvesting and landslides is that tree roots add mechanical support to soil, thus increasing soil strength. Upon harvest, the tree roots decay which reduces soil strength and increases the risk of management-induced landslides. The technical literature does not adequately support this hypothesis. Soil strength values attributed to root reinforcement that are in the technical literature are such that forested sites can’t fail and all high risk, harvested sites must fail. Both unstable forested sites and stable harvested sites exist, in abundance, in the real world thus, the literature does not adequately describe the real world.

An analytical model was developed to calculate soil strength increase due to root reinforcement. Conceptually, the model is composed of a reinforcing element with high tensile strength, i.e. a conifer root, embedded in a material with little tensile strength, i.e. a soil. As the soil fails and deforms, the reinforcing element also deforms and stretches. The lateral deformation of the reinforcing element is treated analytically as a laterally loaded pile in a flexible foundation and the axial deformation is treated as an axially loaded pile. The governing differential equations are solved using finite-difference approximation techniques.

The root reinforcement model was tested by comparing the final shape of steel and aluminum rods, parachute cord, wooden dowels, and pine roots in direct shear with predicted shapes from the output of the root reinforcement model. The comparisons were generally satisfactory, were best for parachute cord and wooden dowels, and were poorest for steel and aluminum rods.

A parameter study was performed on the root reinforcement model which showed reinforced soil strength increased with increasing root diameter and soil depth. Output from the root reinforcement model showed a strain incompatibility between large and small diameter roots. The peak increase in soil strength attributed to roots was controlled by the small (<4mm) diameter root fraction.

These results were used to calculate the effect of timber harvesting on a small, approximately 7.6 m³ (10 yd³), hypothetical landslide in a shallow, cohesionless, forest soil. The root reinforcement model predicted a post-harvest reduction in soil strength of 14 and 19 percent for a soil with and without 5 kPa (105 lbs/ft²) of cohesion, respectively.

The role of riparian forests in maintaining temperatures of headwater streams is well established and is a foundation of forest practice rules designed to protect streamwater quality. However, detailed investigation is
still needed quantifying specific characteristics of stream systems that affect streamwater temperature including riparian features, stream morphology, and subsurface interactions. The objectives of this research were to investigate summertime streamwater temperature patterns and identify characteristics within headwater streams and riparian zones that influence stream temperature. This study was designed to evaluate these relationships prior to logging in 38 perennial headwater catchments of the Oregon Coast Range. Stream reaches of greater than 1000 m were instrumented with temperature probes and selected stream and riparian characteristics were measured at 60-m intervals within each study reach in 2002 and 2003. A subset of the streams was examined in 2003 to determine the potential influence of streamwater residence time on temperature patterns. Findings suggest that canopy cover is the driving factor controlling summer stream temperature in these small headwater streams, but other stream and riparian characteristics should not be discarded. Longitudinal stream temperature patterns were quite variable for these forested streams and results suggest a high degree of complexity in small headwater streams. Maximum 7-day moving average temperatures ranged from 11.4 °C to 16.8 °C, with three streams above the standard 16 °C threshold. Effects of stream and riparian characteristics on stream temperature were strongest when average of the weekly high temperature was assessed, suggesting this may be a more sensitive index of stream temperature than the commonly used maximum 7-day moving average. Results of tracer dilution tests were inconclusive in that temperature was not consistently correlated to residence time in streams.

Pool morphology was surveyed in 19 stream sections within the central Oregon Coast Range. Pool locations, sizes, spacings, numbers, and factors affecting pool formation were determined for each stream section. All sections were underlain by sedimentary rocks, had drainage areas ranging from 1.3 to 17.3 km², and had average water surface slopes from 0.5 to 5.6%. Stream sections were divided into two categories: (1) low timber harvest (<20% of watershed area harvested) and (2) high timber harvest (>45% of watershed area harvested).

A "Rapid Bed Profile" (RBP) technique was developed to measure residual pool characteristics in each stream section. The RBP technique is a survey method that requires only thalweg depths and the average reach gradient. The technique was effective for classifying pools since it is objective, independent of flow, accurate, and time-efficient.

Residual pool size characteristics (e.g., volume) for the low timber harvest stream sections were positively correlated to a power function of drainage area. Stream sections with beaver dams, especially those with at least 10% of their reach length in beaver-caused pools, typically had larger residual pools. Pool size characteristics for high timber harvest stream sections were not different from low timber harvest stream sections.

The average spacing between residual pools was positively correlated to a power function of drainage area for the low timber harvest stream sections (a negative correlation was found between the number of pools and drainage area). High timber harvest stream sections may be associated with an increased spacing and a decreased number of pools for larger watersheds (i.e., greater than 8 km²). However, the potential effects of previous large storms, changes in timber management practices, and/or the small number of streams surveyed precluded a definitive conclusion.

The frequency of occurrence of pool forming processes (e.g., plunge, deflection) was correlated with average water surface slope for the low timber harvest stream sections. The percentage of plunge and impoundment processes increased as water surface slope increased while the percentage of deflection and underflow processes decreased. Two high timber harvest streams had a higher percentage of plunge pools than expected based on the relationships established for the low timber harvest streams.

The frequency of occurrence of wood and boulder pool forming elements was correlated with an index of stream power (drainage area times average water slope) for the low timber harvest stream sections. As the stream power index increased, the relative frequency of wood-formed pools decreased while boulder-formed pools increased. Wood and boulder combined, generally, made up 80% of pool forming elements was not different between low and high timber harvest stream sections.

STEINBLUMS, I. 1977. Streamside buffer strips: survival, effectiveness, and design. (MS)
Stream buffer strips are an important tool for protecting the stream environment. This research documents the losses from 40 stream buffer strips, in the Western Cascades of Oregon, established 1 to 15 years before the study. Predictive equations are developed which identify the major reasons for buffer strip losses. Losses from wind, sunscald, logging damage, and other factors were estimated. The effectiveness of buffer strips for stream shading was quantified.
Wind is the major cause of stream buffer strip mortality. Damage from wind is often sudden, and catastrophic, while damage due to logging or disease and insects occurs at a slower rate. The average percent of standing timber remaining in the stream buffer strips sampled was 84 percent, ranging from 22 to 100 percent. Additional losses occurred over the winter of 1975-1976, amounting to 5 percent of an initial sample of 34 buffer strips. A second set of 6 buffer strips suffered a 52 percent loss. The combined array of buffer strips lost 13 percent additional volume in this relatively mild winter.

Topography and uncut timber stand protection are the most important factors modifying the amount of windthrow in a buffer strip. The distance to the cutting line in the direction of damaging winds was the most important single variable influencing buffer strip survival, with increasing distances leading to significantly poorer survival. Two other significant protection factors were the distance and change in elevation from the buffer strip to the nearest major ridge in the direction of damaging winds. Nearby ridges and steeper slopes give better protection.

Timber factors also influence stream buffer strip survival. Increasing values for the following timber factors are associated with significantly poorer survival: average stand height, average height of trees taller than 100 feet, number of trees per acre taller than 160 feet, original timber volume per acre, original basal area per acre, and average volume per tree. Western red cedar (Thuja plicata), was the most windfirm tree species, followed by western hemlock (Tsuga heterophylla), Douglas-fir (Pseudotsuga menziesii), and true fir (Abies spp.), in decreasing order of windfirmness. Species tolerance to wet sites, plus the timber factors described above, may help explain the windfirmness ranking.

Wet sites increase a tree's susceptibility to windthrow. Water table measurements in two buffer strips with windthrow indicated that the water table rose high enough to reach a tree's rooting zone, while the water table in a buffer strip without windthrow did not enter the root zone. Water tables within a tree's rooting zone may result in poorer rooting and tree anchorage.

The above factors, combined in multiple regression equations developed in this study, account for approximately 68 to 95 percent of the variation in predicting buffer strip survival.

Measured buffer strip shading shows that a buffer strip 85 feet wide shades a stream as well as an average undisturbed canopy, while 75 percent of the undisturbed canopy shading can be achieved with a buffer strip 52 feet wide. Width alone is not adequate for buffer strip design as topographic, timber stand, and understory factors greatly influence stream shading.

Windthrow in stream buffer strips poses a difficult salvage problem, and may also damage the stream environment. Therefore, on sites very susceptible to windthrow, the best stream protection alternative may be to carefully remove the streamside trees with directional falling methods.


This study investigated the development of riparian zone vegetation at varying stand ages from one to 29 years following clearcut timber harvesting in western Oregon. Vegetation was classified into three layers for observation including the ground (less than 13 cm), the understory (less than 2.5 m), and the overstory (greater than 2.5 m) layers. Variables observed included cover by vegetation types, vegetation directly overhanging the stream channel, canopy density and angular canopy density (an effective estimate of stream shade).

Five vegetational zones as presented by Franklin and Dyrness (1973) were selected for study. The primary sampling unit for this study was the transect with ten transects at each site located along the stream reach. A site in an unmanaged old growth stand in each zone was measured in the same manner to provide a comparison with the several harvested sites. A total of 40 sites were sampled during the course of the study.

Equations relating the development of angular canopy density (ACD) with the period since harvesting are presented for each of the five vegetation zones. These equations may be used to predict the percent ACD within a given zone for a proposed time period which may be useful to the resource manager in harvest planning. In three of the vegetational zones, seventy five percent ACD can be expected in eight to 20 years following harvesting. The maximum ACD value observed in two of the zones averaged approximately 60 percent in the 20 year period since harvesting.

Depending upon the vegetation zone, deciduous cover provided approximately 40 percent cover in the understory layer after a period of three to 14 years. Litter cover (organic material greater than 1 mm in diameter) generally dominated the ground layer at all the harvested sites with approximately 45 percent of the ground
surface in that cover type. Coniferous vegetation was generally less than 20 percent in both the understory and overstory layers during the two and one-half decade period since timber harvesting.

The tendency for the riparian zone to develop dense corridors of deciduous vegetation at some sites was noted. In terms of the number of stems per acre, some Alnus rubra corridors in the Coast Range zones were ninety times more dense than the unmanaged forested sites in that area. In contrast, the high elevation Cascade range zone only had 40 percent of the unmanaged forested site stand density after a period of 19 to 24 years following harvesting.

The large organic debris loading in the harvested streams was generally lower than in the unmanaged forested sites. The LOD load averaged 13.4 pieces per 100 feet (30.5 m) for the five harvested sites. The harvested sites had an average of only 10.4 pieces. A few harvested streams had unusually high loadings while 77 percent of the streams contained less than the forested streams.

SURFLEET, C.G. 1997. Precipitation characteristics for landslide hazard assessment for the central Oregon Coast Range. (MS)
Precipitation data from 1988-1995 for 13 rain gauges of the Department of Forest Engineering rain gauge network, and a longer precipitation record, 1976-1995, at Mapleton were analyzed. The objectives were to assess the spatial and temporal distribution of precipitation intensity and antecedent precipitation, and understand the role of these characteristics for triggering debris slides from headwalls in the central Oregon Coast Range.

Frequency distribution curves and recurrence intervals using a partial-duration series were calculated for the maximum 5-minute, 30 minute, 1 hour, 2 hour, 6 hour precipitation durations and antecedent precipitation index (API) for the rain gauge network and the maximum 1 hour and 2 hour precipitation durations for Mapleton. Isohyet lines showing selected 2-year precipitation intensities and API were used to characterize the spatial distribution of precipitation intensity and API across the central Oregon Coast Range. The effect of elevation on this spatial distribution was investigated.

An attempt to quantify the occurrence of high intensity precipitation occurring with high antecedent precipitation, which is hypothesized to trigger debris slides, was done by testing if the highest precipitation intensities (greater than a 1-year recurrence interval) occurred during the storms with the highest API. API and precipitation intensity were tested for correlation to discern if a particular precipitation duration could be used to predict API, thus make it possible to use a precipitation intensity based threshold to assess the general hazard of landslides.

Precipitation intensities associated with selected recurrence intervals vary considerably over the study area. Precipitation values for selected durations and recurrence intervals could vary as much as 50% or larger for selected rain gauge locations. Precipitation intensities are higher in the central portion of the study area, centered around the ridges of the Siuslaw River watershed, with decreasing intensity toward the northern and southern boundaries possibly due to topographic influences. Higher API values are found more frequent where the high precipitation intensity spatial trends exists. Relationships between short duration precipitation intensities with elevation, and API with elevation, within the rain gauge network could not be determined.

No single precipitation intensity, including total storm precipitation, showed a strong positive correlation with high API for the entire rain gauge network. It appears that any attempts to predict the precipitation characteristics which trigger headwall failure by a precipitation intensity threshold in the central Oregon Coast Range is not possible. Attempts to assess the risk of headwall failure by high API may be possible. High precipitation intensities occurred with high antecedent precipitation conditions and they occur at the highest antecedent precipitation conditions.

Evaluations were performed on three stream temperature prediction models: Heat Source 5.6, SSTEMP 3.9, and Brown’s equation. Each model was evaluated using data collected from three Coastal Oregon and two western Cascade streams. Stream temperature simulations were performed on two forested reaches, one clearcut reach, and one buffered reach, for each site. One hot day, within five to seven consecutive hot days, was simulated. Each model was evaluated on sensitivity, accuracy, precision, and practicality.

Sensitivity evaluations were performed to determine the input parameters that had the greatest effect on modeled temperatures and that helped determine the precision needed for input parameters. Sensitivity was
quantified as the number of sensitive parameters compared to the total number of input parameters. The percentage of sensitive parameters for Heat Source, SSTEMP, and Brown’s equation were 12, 30, and 100 percent, respectively.

Model accuracy was evaluated to determine how well the predicted stream temperatures matched the observed stream temperatures. Precision was evaluated to determine consistency, bias, and the overall average error for all study sites combined. Heat Source demonstrated the highest model accuracy and precision. However, a double-peaked pattern in hourly stream temperature predictions showed deviations from the observed temperatures by as much as 3.5°C in buffered and some forested areas. This pattern was never observed in the stream temperature data and could indicate a potential flaw in the model. Heat Source also consistently predicted maximum daily stream temperatures prior to the observed maximum daily temperatures. Brown’s equation demonstrated relatively poor model accuracy and precision, especially in clearcut treatments. However, the model’s strongest predictive ability is in daily mean stream temperature. SSTEMP under-predicted 95 percent of the observed minimum temperatures and over-predicted 90 percent of the observed maximum temperatures.

Evaluations of practicality considered the cost and user-friendliness of each model. All models are in the public domain and may be obtained for free by internet or mail. Collection of input data for Heat Source and SSTEMP require the most time and resources because of the large number of input parameters. Brown’s equation does not require a field visit, however, one will increase prediction accuracy. The input of data and the simulation run times were generally less than two minutes for all models.

Heat Source is very user-friendly primarily because of graphic output and user-screens. Brown’s equation is also user-friendly primarily because it is simple and requires no computer. SSTEMP was user-friendly in some aspects, yet outdated in others like the MS-DOS interface and absence of graphic output.

Results in this document are applicable only to hot summer days. Use of the models for other climatic conditions will, most likely, work but were not validated by this project.

TAYLOR, R.L. 1983. The effects of red alder leaf fall on the water color and other water quality characteristics of a small watershed in northwest Oregon. (MS)

Streamside red alder (Alnus rubra Bong.) stands are common in western Oregon, and they have been suspected of causing water quality problems in domestic supplies during autumn leaf fall. Studies in the Seaside municipal watershed showed potential water quality effects (particularly increased color) from alder leaves, but stream sampling during 1981-82 revealed no chronic problems. The few observed short-term increases in water color occurred near the onset of storm flows, which suggested a flushing of organic matter storage sites. An extended period of unusually low flows and high leaf fall are probably necessary to produce significant water quality problems in this stream system. Laboratory leaching of alder leaves in filtered stream water indicated a fairly constant release of colored organic matter over time, and running water leached this matter more efficiently than still water. Water color increased linearly with increasing leaf mass added to still water, and for a given leaf mass there appeared to be a limit to the amount of colored matter that could be removed in the first 48 hours of leaching. Other laboratory tests showed that ultraviolet absorbance (254 nm) may provide a reasonable estimate of dissolved organic carbon concentrations in systems dominated by alder leaf inputs.

Keywords: riparian vegetation, forests, municipal watersheds, water quality, water color, red alder (Alnus rubra Bong.).


The management of existing forest road systems is an issue of growing importance and public debate. Roads can alter the hydrologic processes in a watershed especially at stream crossing culverts where road ditches channel runoff directly into the stream. The objective of this study was to determine how surface runoff from roads augments natural stream flow at stream crossing culverts. This study took place within an 824 ha watershed in the foothills of the Oregon Coast Range approximately three miles west of Corvallis, Oregon. Sixteen stream crossing culverts were selected for study. Discharge was measured from October 2002 through May 2003 at each stream and at the adjoining ditch(es). Hydrographs for both stream flow and ditch flow were analyzed for five storms that occurred during the winter 2002-2003. The interaction of the road with subsurface flow from the hillslope caused the hydrology of the road segment to be classified as either “intermittent” or “ephemeral.” Peak flow and total runoff at the stream crossing culverts was compared with the magnitude and timing of peak flow
and total runoff in the adjoining ditch(es). Forest roads were found to alter the flow paths of water through the Oak Creek watershed. The road altered storm runoff and peak flow at the stream crossing culverts seventy-four times out of seventy-eight opportunities during five storms. The amount of the change depended primarily on whether or not the road cutslope intercepted subsurface flow. Contributions of intercepted subsurface runoff to the stream were greater than contributions of surface runoff by an order of magnitude. In the Oak Creek watershed, 56 percent of the road cutslopes adjacent to streams intercepted subsurface flow. Intercepted subsurface flow was more connected in time to stream flow than surface runoff. Ditch flow, on average, contributed the most volume on the rising limb of the stream hydrograph at the culvert. Flow responses at individual culvert locations were highly variable and could not be predicted using traditional topographic variables.

VANDERHEYDEN, J. 1980. Chronological variation in soil density and vegetative cover of compacted skid trails in clearcuts of the western Oregon Cascades. (MS)
This study evaluated the recovery of compacted soils on logging skid trails in clearcuts of the western Cascade Mountains of Oregon. Soil types included clay, clay loam, silt loam, loam, sandy loam and loamy sands. Sites ranged in age from five to 38 years since harvest and 370 to 1100 m in elevation. Soil bulk density, measured with a nuclear density probe, was used to characterize compacted soil conditions. A number of soil, vegetation and site variables were studied to determine possible cause and effect relationships with compaction recovery.

Study design consisted of nine sites with nine plots at each site. Plots were classed by level of use with three plots in each of the low, medium and high use level classes. At each plot, measurements of bulk density were taken at the skid trail center, skid trail track and the less-disturbed area adjacent to the skid trail. Determination of vegetative cover was also made at these locations. Depths of measurements for bulk density were 5.1 cm, 15.2 cm and 30.5 cm.

No statistical difference of bulk density values was detected between skid trail use-level classes. A similar result was found for the vegetative cover variables. Bulk density values on the skid trail center and skid trail track were statistically similar. However, density on the skid trail track (and center) were greater than those of the less-disturbed area (" = 0.05). When the data were stratified by site age, the skid trail track still retained greater bulk densities than the less-disturbed area on the 38 year old site. No trends in bulk density changes were observed over time.

Interaction between herbaceous cover and overstory cover decreased the usefulness of these variables for correlation with recovery. However, shrubs indicated a reduction of percent cover on skid trails up to 21 years since harvest, but not after than time. This was the only variable measured which indicated possible skid trail recovery.

Regression analysis was performed using the bulk density difference between the skid trail track and less-disturbed area as the dependent variable and several soil, site and vegetative variables as independents. Multicolinearity among the independent variables was high and when coupled with the variable nature of the bulk density data, produced inconsistent results.

It was concluded that soil compaction can occur and persist on all soil types and that the recovery process is extremely complex. The large degree of variability inherent to the compaction process and recovery requires large sample sizes to detect statistically meaningful recovery trends.

Keywords: soil compaction, recovery, forest harvesting, western Cascades, soil productivity, skid trails.

VELDHUISEN, C.N. 1990. Coarse woody debris in streams of the Drift Creek Basin, Oregon. (MS)
This study examined the occurrence of coarse woody debris (i.e., pieces greater than 0.15 m in diameter and 2.0 m in length) in first- through fifth-order streams located within the Drift Creek Basin of the Oregon Coast Range. Nine "tributary reaches" were surveyed to determine how three land management treatments (undisturbed, patch clearcut with buffer strip, and entirely clearcut) and/or geomorphology were associated with CWD loadings or piece characteristics. An additional 45 km of third- to fifth-order channels were surveyed to identify CWD distribution patterns over changing stream size. All surveys recorded channel characteristics and the dimensions and attributes of each CWD piece.

Coarse woody debris loadings varied greatly (11 to 62 pieces/100 m, 0.3 to 4.3 m³/100m² of inchannel volume) between the tributary reaches, but were not significantly (p > 0.10) related to harvest treatment. However, reaches associated with clearcut treatment contained less hardwood CWD and pieces were...
significantly shorter, and more decayed than in the other treatments. This suggested that little CWD recruitment had occurred in the 15 to 20 years since harvest. The undisturbed and buffer strip tributaries contained CWD that reflected continued recruitment of both hardwood and conifer trees.

Inchannel CWD loadings averaged 0.44 m$^3$/100m$^2$ and decreased significantly ($p < 0.01, r^2 = 0.68$) with drainage area. Coarse woody debris frequency and total loading averaged 10 pieces/100m and 14 m$^3$/100m, respectively, and were not significantly related to stream size. The percentage of total CWD volume within the channel increased with stream order and decreased with increasing channel gradient. "Large" debris pieces (i.e., pieces greater than 0.5 m in diameter and 10 m in length) were particularly frequent in the gorge-like reaches of the Drift Creek Wilderness. Over one third of the CWD pieces in larger channels occurred within debris jams.

Coarse woody debris loadings in the Drift Creek Basin appear to be lower than other forested streams in the Pacific Northwest. It is concluded that past stream cleaning, harvesting, and basin geomorphology have influenced CWD loadings within the Basin. However, the effects of nineteenth century forest fires on stand characteristics and debris recruitment trends appear to be a major cause of the observed CWD loadings.


The design of stream crossings for roads in forest situations is an important part of road design. Surveys of 50 stream crossing culvert locations in the Western Cascades of Oregon show that a majority of them meet legal and reasonable design standards. However, no common design standard was apparent for a 25 year peak flow, and 24% of the culvert locations appeared unable to satisfy Oregon Forest Practice Regulations. Additionally, 50 low water stream crossings were also surveyed on Forest Service land in the Western Cascades of Oregon. It was found that low water stream crossings can, in many instances, be an effective alternative to culverts.

WASNIEWSKI, L.W. 1995. Hillslope sediment routing below new forest roads in Central Idaho. (MF)

Several road and hillslope characteristics were evaluated in association with sediment travel distance and volume of eroded material at 40 different insloping ditch relief culverts on forest roads less than two years in age. The newly constructed roads were located in five different project areas in the Nez Perce National forest in Central Idaho. Approximately half of the culverts were on roads constructed on soils derived from a granitic geology and the other half were on soils derived from a gneiss/schist geology. The general road design consisted of a 3.7 m (12 ft) wide graveled travelway with a road gradient ranging from 1-12 percent. The surface was insloped 2-4 percent to a standard v-shaped ditch. The cutslope had a gradient of 1:1 and was dry seeded without mulch.

The average travel distances of sediment below the culverts were longer on the granitic roads with a distance of 22.4 m than on the gneiss/schist roads which had a distance of 20.0 m. Average total volumes for the eroded deposits on the granitic and gneiss/schist sites were 3.45 m$^3$ and 1.73 m$^3$, respectively. However, the maximum travel distances were 81.0 m and 64.2 m on the granitic and gneiss/schist sites, respectively. These maximum travel distances and the associated volumes were 5 to 6 times greater than any of the other sites when distances and volumes were normalized by the number of hydrologically active months (May 1 to Sept. 30) between the start of road construction and the time of site evaluation. This was most likely attributable to precipitation events during road construction. Sediment travel distances and volumes on the forest slopes decreased rapidly downslope. Of all the deposits measured, 80 percent did not exceed a length of 23.7 m and a volume of 3.5 m$^3$.

The use of slash windrows at the toe of the fillslope seems to be a very effective erosion mitigation measure. Out of the 40 sites approximately 33 percent of the deposits did not pass the windrow, consistently for both geologies. In addition, an average of 77 percent of the total deposit volume did not pass the windrow. An accurate assessment of trapping efficiency by the windrows was not possible because in this study all road segments had windrows. The comparison of road segments with and without windrows to determine trapping efficiency could not be made in this study. The effectiveness of windrows for erosion mitigation has potential for improvement, but more detailed evaluation of construction specifications is needed.

A preliminary look at possible downslope particle sorting of the eroded material below the culvert was done on the granitic and gneiss/schist deposits. The granitic deposits seemed to show a sorting trend whereby coarser material is located higher on the hillslope and finer material is located farther down the hillslope. This was evident when comparing cumulative percent passing at four different sieve size fractions (16mm, 2mm, 0.5mm, and 0.075mm) at two extreme sampling locations (upper and lower portion of the deposit). The four size
fractions were significantly different at the 84 percent level at the two sampling locations. The gneiss/schist deposits did not show as strong of a downslope sorting trend. The three smaller size fractions were significantly different at the 30 percent level, and this was thought to be a result of the finer range of particle sizes and the shorter sediment traveling distances. Future studies are needed to further clarify downslope sorting trends.

Finally, the evaluated road and hillslope characteristics were used to develop regression models to predict sediment travel distance below culvert outlets on the different geologies and the geologies combined. The number of observations used in developing the models were reduced because deposits that did not pass the windrow were not included. Longitudinal deviation, which is the vertical deviation in meters above or below the average hillslope gradient for a length of 10 meters, was the only variable in the granitic prediction model which explained a moderate amount (55 percent) of the variation in travel distance. Elevation was the only variable in the gneiss/schist prediction model which explained even a small amount (35 percent) of the variation in travel distance. Longitudinal deviation and elevation combined explained 46 percent of the variation in travel distance in the model for both geologies combined. The low coefficients of determination can be explained in part by the high amount of variability within each of the road and hillslope characteristics as well as the limited number of observations.

WHITAKER, C.A. 1983. Restoring productivity of compacted forest soils with tillage. (MS)
Tillage of forest soils compacted by ground-based logging systems is a practice that is becoming widely accepted in the Pacific Northwest. However, past research has failed to adequately define the conditions and specifications that particular tillage operations should meet in order to produce the maximum growth response from planted seedlings. The objective of this study is to quantify the early growth response of conifer seedlings to altered soil conditions produced by conventional ripping practices.

To achieve the stated objective, a field study and a growth chamber study were implemented. A small tractor equipped with two 58-cm long ripper teeth spaced 140 cm apart performed the tillage on compacted gravelly loam soils in the Cascade Mountains of southwestern Oregon. Conditions for both studies included undisturbed soil, compacted soil in skid trails, and ripped soil in skid trails. Fifty-nine soil cores (15 cm in diameter by 32 cm long) were extracted from each treatment as growth media for the growth chamber study.

Preliminary results from the field study showed no significant differences in height growth or diameter growth of planted 2-0 bare root Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedlings after two years, even though soil bulk density and strength were significantly different and depth of compaction extended to 40 cm. It is possible that improper handling of seedlings either in the nursery or during planting has retarded development to the point that planting stock is overriding any effects due to soil treatment. This phase of the study will be continued for another four years, so treatment effects may yet appear.

The growth chamber study included observations on Douglas-fir and white fir (Abies concolor) seedlings grown from seed for 226 days. At 148 days, the Douglas-fir seedlings growing in tilled soil showed a 44 percent improvement in height growth compared to seedlings growing in compacted soil. Differences between names were statistically significant at p = 0.051 level. Differences between means for white fir were statistically significant at p = 0.074 level. Significant differences in root development were evident for both species at the end of 226 days. Dry root weight found in the top 20 cm of tilled soil for white fir was 61 percent greater than for trees growing in compacted soil. For Douglas-fir, a 42 percent increase was noted. These differences reflect the influence of aggregate strength rather than bulk density since the latter values for soil in the cores were not significantly different as a result of disturbance from sampling and handling. It was postulated that seedlings growing in tilled soil with their more extensive root systems would fare better under stressed conditions than seedlings growing in compacted soil.

WHITE, D. 1996. Hydraulic performance of countersunk culverts in Oregon. (MS)
Twenty eight countersunk culverts in Oregon were evaluated to assess current conditions and hydraulic performance. The culverts were also assessed with respect to their stability, particularly when subjected to high flows. In general, the culverts were found to be resistant to erosion and effective at conveying large discharges. Based on study results and reviewed literature, recommendations are given for design of countersunk culverts. Recommendations include countersinking culverts at least 20% of their height and using boulder weirs or bed riprap to stabilize channel bed elevation downstream from culvert outlets.

Water veolocity within the barrels of selected culverts was examined. Detailed measurement of water
velocity distributions in several culverts during fall and winter discharges documented the presence of zones of velocity of a magnitude currently accepted in the literature as passable by juvenile salmonids. A method for predicting the extent of low velocity zones within the flow cross-section, based on commonly used hydraulic parameters such as normal depth, channel slope, and average cross-sectional velocity, was explored. The extent of low velocity zones was under-predicted in most cases. In all cases the relationship between predicted and measured areas of low velocity appeared linear, suggesting that the development of such a method for use in culvert design may be possible.

WIDNER, G.L. 1991. Summer low flow characteristics of forest streams in northeast Oregon. (MS) Summer low flow characteristics of six forest streams in Northeast Oregon were examined using long term streamflow records. Time series and trend analysis revealed highly significant (alpha=0.01) increasing trends in summer low flow over the period of record on four of the selected streams, and significant (alpha=0.05) year-to-year dependence on three of the selected streams. Low flow frequency curves, flow duration curves, and flow-date curves were constructed for each stream from the long term flow records. A simple method of forecasting streamflow recessions using flow records is developed resulting in improvement over the average in forecasting recession volume, but little improvement in forecasting end-of-water year flow levels.

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YEE, C.S. 1975. Soil and hydrologic factors affecting stability of natural slopes in the Oregon Coast Range. (Ph.D.) This study was conducted to examine certain soil and hydrologic properties of two major cohesionless soils occupying 55% of the central portion of the Oregon Coast Range. Knowledge of these properties was desired to determine the role each played in the stability of slopes in this region. Bohannon and Klickitat soils often occupy the steep mid-slopes where the greatest potential for stability problems exists. The Bohannon series is derived from Tyee sandstone and the Klickitat series is derived from intrusive, igneous parent material.

Soil samples were obtained from four widely separated sites, two for each of the soil series and were examined for particle-size distribution, bulk density, porosity, pore-size distribution, aggregate stability, saturated and unsaturated hydraulic conductivity, and shear strength. A 1.15 ha study site was instrumented with a recording rain gage, 78 piezometers, and four tensiometers placed at varying depths in the soil profile. Field measurements were made to the subsurface water movement in the Klickitat soil during the 1973-74 water year, one of the wettest on record for this area. An intensive subsurface geologic survey of this study site was also made.

Both soils, although derived from very different parent materials, exhibited nearly identical ranges of values for soil and hydrologic properties. Both were found to be extremely porous, highly permeable, very well aggregated and graded, sandy to gravelly cohesionless soils. From engineering and hydrology standpoints, the two soil series can be considered as one.

In spite of low bulk densities and high porosities, the dry effective angle of internal friction, N, was found to be unusually large in both soils. For the Bohannon and Klickitat soils, N was 40° and 41°, respectively. Such large N values for such loosely packed soils were attributed to the high aggregation in both soils. Pseudomorphs were stable enough to function as primary particles and possessed increased surface roughness, angularity, and effective size over what they would have had as discrete particles.

The effect of water on N was found to be atypical for both soils. Reductions in N of 9.5° and 11° were noted when the two soils were rested in a drained, saturated state. The severe reductions in N were attributed to aggregate disintegration under direct wetting conditions. A decrease in aggregate content of 29% in the Bohannon soils was accompanied by a 28% decrease in N. For the Klickitat soils, the 26% decrease in aggregate content was accompanied by a 23% decrease in N. Aggregate destruction by direct wetting is a possible mechanism for some slope failures near roads.

Movement of subsurface water was predominantly by unsaturated flow. While saturated flow was observed in fractured bedrock near the sedimentary-igneous contact, only one instance of saturated flow in the soil profile was noted. Tensiometry indicated that minimum capillary pressures of 5-10 cm of water existed during storm events. Analysis of pore-size data and moisture-tension relationships substantiated the effectiveness and adequacy of unsaturated flow as the prime mechanism of water transmission in these soils. Both soils were able to transmit water rapidly and at large fluxes even under unsaturated conditions. Large scale saturated subsurface flow is unnecessary for dispersing the low intensity, long duration rainfall found in this
ZEB, A. 1992. Characteristics of stream low flows in eastern Oregon: their relationship with precipitation and watershed parameters. (MS) Characteristics of low flows of nine streams in eastern Oregon were explored using long-term streamflow records. Year-to-year dependence of low flows is highly significant for streams in the Blue Mountain and the southeastern Oregon regions. Low streamflows increased over the period of record for several of the selected streams. Flow duration curves, flow-date curves and low flow frequency curves were constructed for each stream. Flow per unit area is higher for streams in northeastern Oregon than streams in southeastern Oregon. Forecast equations for streamflow recession were made for each stream. Forecasts are highly accurate for recession volume and August average flow except for Mill Creek and Bridge Creek. Forecasts are poor for the later part of the water year. Even for the later part of the water year, highly accurate results are obtained when forecasts are made for shorter periods (about 40 days). Annual precipitation is fairly well-distributed over the whole year in eastern Oregon with July and August as the driest months. Streams in the Wallowa Mountain and southeastern Oregon regions showed higher trend similarities between summer low flows and precipitation than streams in the Blue Mountain region. Correlations between summer low flows and precipitation were highly significant for the Wallowa Mountain and the southeastern Oregon regions. Correlations between low flows and watershed parameters, as well as average annual precipitation, were found insignificant for all streams.

ZEB, A. 1994. Long-term effects of changes in vegetation condition, precipitation and watershed parameters on summer low-flows in the semi-arid Pacific Northwest. (PhD) Summer low-flow behavior in the semi-arid areas of the Pacific Northwest was studied. Long-term data from thirty-eight streams/rivers and thirty-six precipitation stations was exploited. The study area was divided into five zones based on annual average precipitation. Trends and patterns in summer low-flows and precipitation were identified. Different zones showed different trends and patterns in precipitation over the period of record but significant similarities within each zone. Most of the summer low-flow and precipitation records showed that the 1930's and the late 1980's to early 1990's experienced major droughts. A possible return interval of 50-60 years appeared reasonable for similar major droughts in the study area.

Spring, summer and fall precipitation, on average, were found insignificantly related to the summer low-flows, except for northern Idaho and southeastern Oregon where summer precipitation was significant in explaining the summer low-flow trends. Winter and annual precipitation were found significantly related to summer low-flows. But the zonal equations constructed to predict summer low-flows using precipitation alone were considered unsuitable for practical use.

Zonal and regional recession models to forecast summer stream flows with significant accuracies were constructed successfully. Extreme summer low-flows were not significantly related to different watershed cover types in eastern Oregon. However, percentage of rangelands appeared to be more related to the extreme summer low-flow than other cover types.

An extreme summer low-flow prediction model was constructed using several watershed and precipitation variables. Many of these variables were found to be significantly related to extreme summer low-flow. Watershed average width and annual minimum precipitation explained 71% of the variations in the extreme summer low-flow. The model finally selected, with the inclusion of watershed end point elevation, was able to explain 79% of the variability in the extreme summer low-flow. Stream and precipitation gauges need to be carefully maintained during dry periods. Also, generalization of climatic trends based on a few observations in a large region can be misleading.