CAREFUL LOGGING, PARTIAL CUTTING AND THE PROTECTION OF TERRESTRIAL AND AQUATIC HABITATS[5]

Dan Dey[6]

INTRODUCTION

Stand management activities influence (1) tree growth and quality; (2) stand structure, stocking and composition; (3) wildlife and aquatic habitat quality; and (4) long-term site productivity. The cumulative impacts of stand-level treatments affect ecosystem structure and function at the landscape level.

The conduct of forest operations determines if management objectives will be met on the ground. Poorly managed operations can cause substantial environmental degradation, a reduction in merchantable volume and a decrease in timber quality, especially when the harvest involves partial cutting (Hesterberg 1957). In one harvest entry, one-third to half of the residual stems or stand basal area can be damaged during logging operations (Nyland and Gabriel 1971; Irwin 1972; Johnson 1978; Walsh 1980; Ostrofsky et al. 1986; Davis and Nyland 1991). With conventional logging, skid trails may cover from 20 to 40% of the ground surface after a single harvest (Dyrness 1965; Froehlich 1976; Froehlich et al. 1981; Turcotte et al. 1991). After repeated entries, skid trails may occupy as much as 80% of the ground surface (Froehlich et al. 1981).

Sediment delivery to streams and lakes as a result of erosion of logging roads, skid trails and landings reduces the quality and productivity of these aquatic ecosystems (OMNR 1988a). Removal of streamside and shoreline vegetation and inputs of logging debris to aquatic systems alter stream temperatures, water quality, dissolved oxygen levels, nutrient cycles, turbidity and habitat structure. Silvicultural manipulations of species composition, dead woody material, and stand structure all change habitat suitability and productivity for wildlife species. Proper resource management requires that *prescribed* silvicultural practices be developed and implemented based on sound ecological principals and a strong land ethic.

DAMAGE TO THE STAND

The significance of logging damage to stand growth, yield and quality depends on the type

---

[5] Paper presented at Central Region Timber/Wildlife Workshop, February 10&11, 1993, at the Frost Centre, Dorset.

[6] Research Scientist, Ontario Forest Research Institute, Sault Ste. Marie, Ontario.

and extent of damage, on the length of time damaged trees remain in the stand, and on tree vigor. Harvest operations damage or destroy advance reproduction, saplings, polewood and sawtimber. Although up to 40% of the advance reproduction may be damaged during logging, this loss is generally silviculturally insignificant (Jacobs 1974; Nyland et al. 1976; Davis and Nyland 1991). In northern hardwood forests, there is often an abundance of advance reproduction, especially of the shade-tolerant species. Many damaged stems will sprout from the root system, producing a new stem that is of higher quality than the original stem (Jacobs 1974). Height growth of the sprout is rapid and soon equals or exceeds the height of the original stem. Sprouts that originate from below the ground also often produce acceptable crop trees. Nyland et al. (1976) found that 10% of the advance reproduction located on skid trails survived logging. By reducing the amount of ground area covered by trails, the loss of advance reproduction will be minimized.

In partially cut northern hardwood stands, 50% or more of the trees injured during felling and skidding operations are saplings and pole-sized trees (Deitschman and Herrick 1957; Nyland and Gabriel 1971; Lamson et al. 1984; Davis and Nyland 1991). In the Central Region of Ontario, Johnson (1978) found that 74 % of the trees damaged in partial cut hardwood stands were 10 to 25 cm in dbh. Similar results were observed by Irwin (1972) in partially cut hardwood stands in Parry Sound District, Ontario. He found that removal of 43% of the basal area resulted in the destruction of one-third of the saplings, and that 60% of the damage to saplings and pole-sized trees was considered major. Furthermore, the amount of damage increased as the amount of overstory removed increased.

Logging damage to saplings and pole-sized trees has substantial affects on tree growth and quality. Because many of these trees will not be harvested for several more cutting cycles, wood-decaying fungi have enough time to infect logging wounds and cause substantial loss of volume and reductions in quality. These trees will also be subject to repeated injuries in future harvest entries, which compounds losses to decay. Felling and skidding operations can uproot or bend over trees, remove large portions of the cambium, or cause major damage to the crowns of saplings and polewood. Trees that receive these types of injuries are less vigorous and, therefore, less able to heal quickly. Wounds remain open longer, providing infection sites for wood-decaying fungi.

Sawtimber-sized trees are less numerous than trees in smaller diameter classes, especially in uneven-aged forests. Therefore, these trees are not damaged as often as saplings and poles. Large-diameter trees with major damage may be removed in the next harvest entry, thus providing less time for decay organisms to infect and invade the tree. Ohman (1970) observed little loss in value due to skidding wounds in sugar maple (*Acer saccharum* Marsh.) and yellow birch (*Betula alleghaniensis* Britt.) 10 years after injury. The development of decay in sugar maple was low 10 years after injury, especially for small wounds (Hesterberg

1957). However, the amount of decay increased substantially as time since wounding increased from 10 to 20 years for a given scar size (Hesterberg 1957).

Stands managed by single-tree selection are marked for harvest to achieve an optimum residual strand structure and basal area. Achievement of silvicultural objectives requires management of the logging operations. Excessive losses of specific size classes due to logging operations can lead to unbalanced diameter distributions, under utilization of growing space, and the creation of future cutting cycles with deficiencies of sawlog-sized material. Reductions in stand volume and quality will reduce the value realized from future harvests.

Some amount of logging damage to tree crowns, stems and roots is unavoidable. An understanding of decay development in relation to injury and time since wounding is a prerequisite to evaluating the severity of damage, and hence the need to control logging operations. Tree damage resulting from timber felling operations may include broken branches, broken tops, stem wounding, and leaning or partially uprooted trees. Tree felling is a major source of logging damage in northern hardwoods and causes 35 to 70% of the total stand damage (Nyland and Gabriel 1971; Irwin 1972; Walsh 1980). Of the trees damaged by falling operations, 60 to 80% of the damage has been classified as major (Nyland and Gabriel 1971; Irwin 1972; Walsh 1980). When overstory trees are felled, sapling and pole-sized trees are damaged, being completely destroyed or losing large portions of their crowns. Unacceptable damage occurs when the loss of saplings and poles results in unbalanced diameter distributions or an excessive loss of crop trees.

The extent of crown damage and subsequent decay development varies by species. Broken branches less than 10 cm in diameter on sugar maple are seldom infected by decay fungi, even after 20 years (Hesterberg 1957). However, larger broken branches (greater than 10 cm in diameter) are often associated with wood decay. Lavallée and Lortie (1968) reported that broken branches greater than 6 cm in diameter were important indicators of decay in yellow birch, and that branch stubs greater than 10 cm in diameter were almost always associated with decay. They found that 36% of yellow birch that showed broken branches due to past injuries contained cull. Berry (1969) observed that 11% of branch stubs greater than 10 cm in diameter were associated with decay in upland oaks (*Quercus* spp.). Fortunately, upper-stem logs represent a minor amount of total tree volume and are usually of lower quality even if undamaged. Loss of crown probably affects overall tree growth more than if affects the loss of volume to decay.

More than half of the damage to trees from logging occurs during skidding operations (Nyland and Gabriel 1971; Johnson 1978; Walsh 1980). Much of this damage is considered major, with up to 80% of stem wounds occurring on the butt log (Hesterberg 1957; Nyland and Gabriel 1971). The amount of decay development is related to the length of time since injury, the size of wound, the tree species, the location of wound on the tree and the tree's vigor. Stem decays are the major cause of low-quality wood. The amount of defect associated with stem wounds increases with the surface area of the wound and the length of time since wounding (Hesterberg 1957). Scars on sugar maple with surface areas greater than 1,000 cm^2 (major wounds) resulted in decay 50% of the time after 10 years. Twenty years after injury, trees with wounds of this size had more than an 80% chance of containing decay. Small scars (less than 15 cm wide) generally do not result in excessive decay of sugar maple in the first 10 years (Hesterberg 1957). Small scars on vigorously growing maple often callus over in 20 years. Scars less than 10 cm wide are at low risk of decay. Rot in sugar maple rarely becomes established in 10 years in scars less than 8 cm wide. However, scars greater than 18 cm wide have a 50% chance of causing decay after 10 years, and this increases to more than 80% after 20 years. The size of a stem wound is closely related to the loss in lumber value for sugar maple and yellow birch (Ohman 1970). Hesterberg (1957) observed that stem wounds decrease lumber and log grades by 10%. He found that stem wounds of greater than 1,000 cm^2 led to a 10% loss of volume 20 years after injury.

Yellow birch is more susceptible to decay following injury than is sugar maple. Lavallée and Lortie (1968) stated that the exposure of 600 cm^2 of sapwood in yellow birch almost always indicates internal decay. They considered stem wounds greater than 300 cm^2 to be important injuries in yellow birch. For sugar maple and yellow birch, Ohman (1970) found that 66% of stem wounds greater than 300 cm^2 resulted in value loss 10 years after injury.

Wounds that contact mineral soil lead to greater amounts of decay because the wound surface is more moist and therefore provides a better environment for infection. Basal scars that contact mineral soil and that have surface areas greater than 528 cm^2 will usually develop significant internal decay with time (Anderson and Rice 1993). Basal scars higher on the stem develop dry, case-hardened surfaces with some localized stain and limited decay.

Root wounds are a major cause of defect in the butt log, which represents the majority of a tree's volume. Root injuries occur when: (1) equipment or logs wound surface roots; (2) stems are jarred, wrenching roots from the root system; (3) the ground around a tree is compacted, wrenching roots; and (4) skidder-caused ruts sever root systems. Root injuries provide infection sites for root-rot fungi (eg., *Armillaria* complex) and sapstreak disease (*Ceratocystis coerulescens* (Muench) Bak.). Root injuries also reduce tree vigor, thus decreasing a tree's ability to heal wounds by forming callus and to restrict decay development by compartmentalization.

Rooting habits of tree species influence the amount of damage to roots from logging. Yellow birch has many major surface roots and is more prone to root wounding than other species such as sugar maple. Decay in damaged roots of yellow birch may develop within 4 years after wounding, with stain progressing into the butt log (Benzie et al. 1963). Size of root wounds and their distance from the main stem influence the amount of decay. Wounds more than 1 m from the main stem cause little decay in the first 10 years after injury (Ohman 1970). Root wounds greater than 300 cm^2 within 1 m of the stem may result in decay in the butt log of yellow birch 10 years after logging, especially if in contact with mineral soil.

Regardless of tree size, up to 70% of all trees along skid trails may be injured during skidding operations (Deitschman and Herrick 1957; Nyland and Gabriel 1971). As distance from the skid trail increases, the probability of damage from skidding decreases (Ostrofsky et al. 1986; Davis and Nyland 1991). Although trees along approved trails are still subject to injury, limiting the amount of area covered by skid trails reduces skidding damage to the residual stand.

DAMAGE TO THE SOIL RESOURCE

Logging operations damage the soil resource by causing soil displacement, soil compaction and soil erosion. Mineral soils are often relatively low in fertility. The upper organic layers: (1) contain major concentrations of soil nutrients; (2) increase infiltration rates; (3) increase water-holding capacity; and (4) improve soil structure. Displacement of the upper soil organic layers reduces site productivity and increases the erosion potential of the site.

Compaction of the soil increases bulk density, reduces soil porosity, decreases infiltration rates and lowers soil permeability (Froehlich et al. 1981). These changes in soil physical properties increase surface runoff and erosion, and create less-favorable soil environments for plant growth. When soil in the rooting zone is compacted, roots are injured. Root damage reduces tree vigor and provides infection sites for root-decaying fungi. High soil bulk density retards root growth and restricts the effective rooting area. Ultimately, soil compaction reduces tree growth, and vigor and long-term site productivity.

Soil compaction occurs most frequently on skid trails and landings. The majority of soil compaction results after the first few passes of the skidding equipment (Froehlich et al. 1981; Shetron et al. 1988). The severity of compaction depends on: (1) the equipment type and its use; (2) soil texture; (3) soil strength; (4) soil moisture; and (5) soil organic matter content. Coarse-textured soils (eg., sands) and very clayey soils do not compact as easily as medium-textured soils. Maximum compaction of soils occurs at moisture levels near field capacity (Howard et al. 1981). Soils with high organic matter contents compact less than mineral soils. The amount of compaction increases as the ground pressure of skidding equipment increases, and is greater with increasing equipment vibration (eg., crawler tractor versus rubber-tired skidders).

Recovery of soils that have been compacted depends on the frequency of freeze/thaw and wet/dry cycles, the action of roots and soil organisms, soil type, soil depth, and the degree of compaction. In northern hardwood stands in Vermont, Donnelly et al. (1991) observed small increases in bulk density in the upper 10 cm of very stony loam soils after clearcutting. Two years after harvest, bulk densities had returned to "normal" levels. In Indiana, Reisinger et al. (1992) found that the mean bulk density of silt loams on secondary skid trails required 2 to 4 years to recover to pre-harvest levels. They also reported that recovery rates on primary skid trails and landings were significant, but that the trails would require longer than 4 years to return to pre-harvest bulk densities. Logging had been conducted in the late summer/early fall, when soil moisture was low and soil strength near its maximum. In Minnesota, Thorud and Frissell (1976) found that 5 to 9 years were required for the 0- to 8-cm zone of compacted sandy loam and loamy sand soils to recover, but compaction effects persisted unchanged in the 15- to 25-cm soil layer. In another Minnesota study, Mace (1971) reported that the bulk density of relatively dry, coarse-textured soils recovered to pre-harvest levels in one year on skid trails that received moderate use. However, major skid trails showed only minimal improvement after one year. Others have found that increased bulk density and soil strength resulting from ground-based operations on skid trails may last more than 40 years (Froehlich et al. 1985; Vora 1988).

Skidding can cause deep ruts in trails, especially when the soil is wet (Turcotte et al. 1991). Without proper erosion-control measures, these ruts channel water and cause severe erosion, especially as slope steepness and slope length increase. In addition, soil compaction on skid trails, landings and roads increases surface runoff and therefore promotes erosion (Nyland et al. 1976). Loss of topsoil from the site not only reduces long-term site productivity but also adversely impacts aquatic ecosystems when sediment enters watercourses. Minimizing the amount of ground area in trails, landings and roads, in concert with proper erosion-control practices, reduces the loss of soil from the site. Preventing soil movement from the source is the most practical means of maintaining site productivity and keeping it out of aquatic systems.

DAMAGE TO AQUATIC ECOSYSTEMS

All aspects of timber harvest, from felling and skidding to road construction, have major impacts on the quality and productivity of aquatic ecosystems. Timber removal affects water yield, water quality, water temperature, habitat structure, and bank and shoreline stability. Any activity that results in the delivery of sediment to aquatic systems adversely affects the quality of fish habitat. Roads are the most significant source of sediment (Freedman 1982; Martin and Hornbeck 1994). Poor road location, inadequate drainage, unstable cuts and fills, and improper stream crossings contribute to erosion (Rothwell 1978). Guidelines are available for designing access roads and water crossings (OMNR 1988b). Road design standards should adequately meet the fishery management objectives. The location and construction of road systems must be specified, monitored and controlled to ensure resource protection of aquatic resources. Road locations near and in areas of concern are most critical. Stream crossings should be planned and designed properly. The location of roads by logging operators from the seat of a crawler tractor is no longer an acceptable method of conduct.

Proper road maintenance must be provided during the life of the road. Road maintenance is required to minimize sedimentation of waterways. Erosion control throughout road construction, use and abandonment is an ongoing process. Restrict the use of roads during rainy periods and during spring break-up to minimize damage to road surfaces, drainage structures and road profiles.

When a road is physically abandoned, appropriate measures should be taken to prevent erosion and sedimentation of water bodies. This may include removal of culverts and bridges, grading slopes to stable angles, installing water bars, and revegetating exposed mineral soil. Active and abandoned roads should be inspected annually and necessary repairs planned. Good road management practices apply to all road types. Low-standard tertiary roads have the potential for causing significant adverse impacts on aquatic resources.

In general, roads and landings are not permitted in areas of concern involving critical fish habitat, especially those that include cold-water fisheries. Here, harvesting is restricted entirely or is limited to selection methods. Timber production is not the driving factor in these areas. All efforts should be made to avoid damaging banks and shorelines, to keep debris out of waterways, and to minimize sedimentation. Harvest restrictions are less demanding for cool-water and warm-water streams and lakes. Trees should be directionally felled away from streams and lake shorelines. Winches should be used to remove timber and keep equipment away from banks and shorelines. For fish habitat protection, buffer strips of undisturbed vegetation should be 30 m wide (from each bank) where sideslopes are less than 15% and up to 90 m wide for sideslopes greater than 40%. These widths may need to be larger to ensure the windfirmness of the stand.

Engineers, fisheries biologists and foresters should work together in developing area transportation plans. In this planning process, the transportation system is developed to service the entire forest for the long-term. Designing road systems to serve only the immediate timber harvest is short-sighted and leads to excessive amounts of road building. The best approach to reducing road impacts on fishery resources is to minimize the total amount of roads constructed. Roads take land out of production for long periods and represent the single largest financial investment in the development of forest resources. Area transportation planning just makes good sense.

Foresters and fisheries biologists need to coordinate the collection of resource inventory information during the forest planning process. This data is necessary in evaluating the impacts of management alternatives. Timber management guidelines are provided for protecting fish habitat and can be used in planning harvest activities in or near riparian areas (OMNR 1988a). These guidelines should be used in developing timber management plans and stand prescriptions. Operations in these "areas of concern" should be evaluated by an interdisciplinary team of resource managers. Mitigative measures and the conduct of logging should be specified in management plans, stand prescriptions, timber sales contracts, harvest approval documents and license agreements.

DAMAGE TO WILDLIFE HABITAT

Timber harvest affects stand structure (horizontal and vertical); mast, browse, berry and forage production; cavity trees; dead woody material; and hiding and thermal cover; it therefore affects the quality of wildlife habitat. In the Great Lakes/St. Lawrence forests, 15% of known wildlife species use cavity trees and snags for a variety of purposes (Tubbs et al. 1987). Guidelines for management of cavity trees are incorporated in *A Tree-Marking Guide to the Tolerant Hardwoods Working Group in Ontario* (Anderson and Rice 1993). Each wildlife species has its own requirements for cavity trees and snags. Coordination with wildlife biologists in developing stand prescriptions is necessary to properly manage this valuable resource. We cannot assume that adequate numbers of suitable cavity trees will occur as a byproduct of timber management. In fact, proper timber management will result in the improvement of tree quality and a reduction in the number of large, standing, defective trees. It takes a long time for trees to grow to a usable size for many wildlife species. For many cavity users, a prerequisite is that the trees have some degree of internal decay to facilitate their excavation. It takes an even longer period of time for this decay to develop in large trees. To maintain cavity trees and snags, they must be managed. By providing for cavity trees, we are creating habitat for more than 30% of all terrestrial vertebrates in the Great Lakes/St. Lawrence forests (Anderson and Rice 1993).

Another major structural component of hardwood forests that provides critical wildlife habitat is large woody debris such as logs, branches and stumps. Approximately 15% of the wildlife in central Ontario uses this debris (Anderson and Rice 1993). Timber harvest operations have major impacts on the amount, spatial distribution and size distribution of large woody debris. Large snags should be left standing, if safety permits, to provide a regular supply of woody debris to the forest floor. Girdling culls after a harvest may be prescribed to replace large debris destroyed in logging operations. Also, stem injection of herbicides may be used to kill cull trees.

One-quarter of Ontario's wildlife species feed on fruits, seeds and nuts. Manipulation of overstory cover influences the diversity, abundance and productivity of many understory seed- and fruit-bearing species. In general, heavier partial cuts favor the development of understory plants, thus increasing the production of seeds and fruits. Leaving oaks, beech (*Fagus grandifolia* Ehrh.) and black cherry (*Prunus serotina* Ehrh.) in the residual stand will maintain mast production and provide room for crown expansion of these species.

These examples illustrate the need for integrated resource management to meet the objectives of foresters and wildlife biologists. Timber management is wildlife habitat management. A managed logging operation is the key to the successful achievement of management goals defined in the stand prescription.

In forest planning, timber management alternatives must be integrated with wildlife management objectives. Coordinated resource inventories are needed to evaluate management impacts on critical wildlife areas such as calving and nursery areas, travel corridors, and winter yarding areas. Timber management guidelines are available for selected wildlife species. Specific guidelines should be outlined in timber management plans and stand prescriptions. Areas of concern should be identified in the forest planning process, which guides the selection of harvest operations. Specific mitigative measures and the conduct of logging should be addressed in stand prescriptions.

CONDUCT OF LOGGING

Planning landing locations and skid trail systems before logging commences may reduce the damage to the site and the stand. Most of the damage to soil and trees occurs at or near skid trails. By minimizing the extent of the trail system, damage to stand and site will be reduced. A trail system that covers 10 to 15% or less of the area is a reasonable objective (Froehlich et al. 1981). This can be achieved by spacing trails at least 30 m apart (Froehlich et al. 1981; Ostrofsky et al. 1986). Comparisons of designated skid trails (using directional felling and winch extraction) with conventional logging have shown little difference in logging productivity (Froehlich et al. 1981).

Locate the landing first. This should be done during the location of main haul roads. Road locations that are not coordinated with unit layout often lead to problems in locating good landings and in access to the unit. They should be large enough to accommodate equipment and operations safely. Slope of landings should not exceed 8%. The spacing of landings depends on topography, stand conditions, other resource constraints and skidding distances. Garland (1983) recommends that landings should be located so that the longest skid distance is less than 370 to 460 m. Average skid distances of 250 m are appropriate.

Once landings are located, walk through the unit. Nothing can substitute for knowing the lay of the land. Locate critical areas to avoid, such as rock outcrops, wet areas and property corners. Identify areas the trail must pass through such as landings, topographic benches, ridge-points and stream crossings. Flag the initial location to see if it is feasible. Layout skid trails to access the entire stand for the long-term. Maximize the use of existing trails in future entries. Consider the trail system as an extension of the transportation system. Trails are a permanent facility, especially in selection management. When trails are laid out before felling, it is easier to walk the unit than when trails are laid out after felling. This facilitates finding the best location for trails. Trails should not be laid out from the seat of the skidder. Work with logging operators in trail layout. They are experienced and have much to offer. Consider the possibility of laying out trail systems, at least roughly, before marking timber. Markers can better anticipate damage and mark accordingly.

Vary trail grades to provide natural grade breaks. This facilitates the control of surface water on trails. Long, steady grades permit the buildup of water and increase the erosion potential. Avoid long level sections of trail that are difficult to drain properly (grades of 3 to 5% are desirable). Side-hill locations permit good cross drainage, but as side slopes increase, skidders and logs will cause more damage as they fight to stay in the skidding corridor. Trails on less than 20% sideslopes probably do not need to be excavated. On steeper slopes, excavation will be necessary to keep the skidding corridor level and narrow (the width of the machine). On steeper terrain, locate skid trails along the topographic contours.

Approach streams at right angles to minimize the impact on stream banks and to keep the water from flowing down the skid trail. Minimize the number of stream crossings. Use culverts at major stream crossings. Keep skid trails as straight as possible. This reduces stem wounding and increases skidder travel time. Curves in skid trails are the site of frequent major stem wounding. Make trail intersections at 45° angles or less with respect to travel toward the landing. Avoid branching from the main trail directly opposite from another trail branch. Avoid sharp curves at the bottom of steep downhill trail segments.

Recommended grades for main skid trails are 10% for adverse (uphill) skidding and up to 20% for favorable (downhill) skidding. This varies according to the type of equipment used. Adverse skids for rubber-tired skidders should not exceed 10%, or 20% for crawler tractors. Favorable skids for rubber-tired skidders should not exceed 30%, or 40% for crawler tractors. Grades may be higher on short pitches of adverse terrain (30 to 60 m) provided the trail is straight, or if the machine is on level to favorable grades before the short segment. Try to minimize adverse grades. More damage to the soil occurs in skidding uphill and this decreases logging productivity.

Fell timber in the skid trails first and construct trails before felling the rest of the stand.

Sawyers know where the trails are and can fell to lead more effectively. Directional felling of trees minimizes turning of logs onto trails. Trees that are felled no more than 45° from the direction of skidding can be winched onto the trail with a minimum of damage to residual trees. This also reduces breakage of logs. Lop the tops in the woods, and remove forks and large branches before skidding. Log-length or tree-length (no top) skidding are acceptable when done properly (Deitschman and Herrick 1957; Nyland and Gabriel 1971; Johnson 1978).

Where logs are likely to leave the skidding corridor, such as along curves, use rub trees or cut high stumps along the trail to keep logs tracking in the corridor. Leave small pole trees near valuable residual sawlog trees to protect them. Machines should stay on approved skid trails and use a winch line to reach trees off the trails. Pulling a winch line 10 to 23 m is common and permits trail spacings of up to 46 m. Use the smallest equipment possible without unduly sacrificing productivity or compromising safety. Damage to trees along trails increases with increasing equipment size (Deitschman and Herrick 1957; Benzie 1959; Meyer et al. 1966). Avoid working two vehicles on the same trail. Inevitably, they will get in each other's way and cause unnecessary damage as they side-step off the trails during passing.

Avoid skidding in the spring, when tree bark is easily damaged. From April to July, tree bark slips easily from trees. Bark is tight in late summer, fall and winter, and requires greater impacts to dislodge it from the tree. Avoid skidding when soils are too wet, which increases soil displacement by increasing rutting and soil compaction (Froehlich 1978; Turcotte et al. 1991). Machine operation in rutted areas increases stem wounding on residuals because of poor machine maneuverability. Often, additional skid trails are established as the operator tries to avoid the rutted areas. Suspend operations or log the area in winter when soils are frozen or snow covered. Walsh (1980) found that winter logging in central Ontario reduced site damage by half compared with spring/summer logging. Save well-drained sites for possible logging during wet periods.

These are a few recommendations that have been proven to reduce stand and site damage without adversely affecting logging efficiency. In fact, many of these practices lead to more productive operations. Work closely with logging operators, sawyers and other woods workers. Implementation of these recommendations can reduce damage to residual stands to less than 10% of the residual basal area (Deitschman and Herrick 1957; Froehlich et al. 1981; Lamson et al. 1984, 1985), with only 10 to 15% of the ground area occupied by skid trails and landings (Froehlich et al. 1981).

EROSION CONTROL

Once the last load of logs goes down the road, the logging job is not over. Proper precautions must be taken to minimize soil erosion. This is necessary for maintenance of long-term site productivity. Skid trails and landings should be outsloped, water-barred, seeded and fertilized.

A water bar is a soil berm constructed on roads, trails and landings to help minimize the volume and velocity of water flowing over exposed areas. It is used to divert water onto places where it will not cause erosion. Water bars help in the revegetation of bare ground, for eroding surfaces are slow to revegetate. Install water bars to control water as soon as logging is completed or when operations are suspended during wet periods.

Water bar effectiveness depends on: water bar angle (30 to 60°), height of soil berm (at least 30 cm), and whether the water bar outlet is clear (Yee and Thomas 1984). Water bars built with less than 30° angles have a greater chance of failing. Water bars built without an outlet are also more likely to fail. If water bars survive the first year, they have a good chance of lasting long periods (10 years or more) with only 1 to 5% of them failing (Yee and Thomas 1984).

Divert water into vegetation, rocks, slash or sod to disperse the force. This reduces the erosion potential of the water, and causes it to drop its sediment load. Surface runoff should not be diverted directly into waterways. The spacing of water bars along trails and roads depends largely on the steepness of the slope and its length. The erosive energy of surface water increases with increasing slope and slope length. On slopes of 5%, water bars should be spaced about 40 m apart. For slopes over 40%, spacing should be reduced to about 9 m. Finally, seed and fertilize exposed mineral soil. This can substantially reduce soil erosion on trails, landings and roads. Garland (1983), Haussman and Pruett (1978), Hartung and Kress (1977) and OMNR (1988b) provide guidelines for road, landing and skid trail location, construction and maintenance.

CONCLUSIONS

Partial cutting alters wildlife habitat, affects aquatic habitats, affects timber quality and yield, and influences long-term site productivity. Forest operations must be planned, well-defined and monitored to the maximize achievement of management objectives while minimizing adverse impacts on forest resources. Forest management plans are used: (1) to define resource objectives for specific management units, (2) to develop a range of management alternatives, (3) to evaluate the immediate and long-term impacts of the alternatives, and (4) to guide the conduct of operations in areas of concern. This planning process sets objectives and identifies management practices that will be implemented during the planning period at a larger landscape level.

Implementation of forest plans involves the selection of individual stands for harvest. Stand prescriptions are developed to evaluate alternative treatments in relation to management objectives. From there, preferred stand treatment is chosen. Specific areas of concern are identified. The conduct of the logging and required mitigative measures are well defined in the prescription. Silvicultural goals are given to guide stand management and operations.

Implementation of the silvicultural prescription is embodied in the timber sale contract, the harvest approval document or the timber license agreement. It is imperative that logging operators understand the terms of timber contracts and agreements before operations begin. A close working relationship with operators during road construction and timber harvest will facilitate successful implementation of forest management plans, stand prescriptions and harvest agreements. All forest operations must be monitored regularly, especially during critical periods such as road construction, rainy seasons, layout of skid trails, and as harvest operations near completion.

Careful logging is not solely the responsibility of the harvest inspector. It begins with the development of interdisciplinary forest management plans. Specific careful logging practices are identified in stand prescriptions and timber harvest contracts/agreements. Rigorous administration of road construction and timber harvest activities is necessary for the successful implementation of forest management plans.

Forest Research Information Paper No. 117

Logging Damage : The Problems and Practical Solutions

Edited by
J.A. Rice

Ontario Forest Research Institute
1235 Queen Street E
P.O. Box 969
Sault Ste. Marie, Ontario
P6A 5N5

Papers reprinted with permission of the authors and the Central Region Science and Technology Section.

Ministry of Natural Resources
Ontario

Ontario Forest Research Institute
OFRI • IRFO

Canadian Cataloguing in Publication Data

Anderson, H. W.
Logging damage: the problems and practical solutions

(Forest research information paper, ISSN 0319-9118 ; 117)
ISBN 0-7778-3365-4

1. Logging-Environmental aspects.
I. Nyland, R. D. (Ralph D.)
II. Dey, D. (Dan C.)
III. Rice, J. A. (James A.)
IV. Ontario Forest Research Institute.
V. Title.
VI. Series.

SD538.A52 1994 634.9'8 C94-964057-3

Printed in Ontario, Canada

Single copies of this publication are available at no charge from the address noted below. Bulk orders may involve charges.

Ministry of Natural Resources
Ontario Forest Research Institute
P.O. Box 969
1235 Queen St. East
Sault Ste. Marie, Ontario
P6A 5N5

Telephone: (705) 946-2981
Fax: (705) 946-2030

Cette publication scientifique n'est disponible qu'en anglais.

TABLE OF CONTENTS