ASSESSMENT OF STREAM PROTECTION PRACTICES IN THE INTERIOR OF THE PRINCE RUPERT FOREST REGION

by
David Bustard and David Wilford

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June 1986

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ABSTRACT

Stream protection measures used in forestry operations in the interior of the Prince Rupert Forest Region were reviewed through interviews and field inspections. This report describes the development of stream protection measures in the region, identifies those that have been effective, and suggests where improvements can be made in research and training.

A review of streamside treatments suggests that the larger, well-known fish streams are recognized as important, and therefore usually receive careful treatment during logging. Measures such as leave strips or logging to the stream edge leaving leaners and deciduous vegetation are generally effective in ensuring that most streams are protected.

Observations of logging along small creeks suggest that protection of these systems varies much more than that of the larger systems. In many situations, these small creeks are identified, and measures for their protection are incorporated into the layout and harvesting operations, minimizing impacts from logging. In other cases, small fish creeks are yarded across and can be badly damaged.

Sediment, particularly from roads, was identified as a major influence of interior logging operations on streams. There was a wide difference of opinion as to the extent, duration, and implications of sediment on streams. At the same time, there is nearly a total absence of monitoring or evaluating of logging-induced sediment on streams in the interior districts. It is anticipated that soil erosion leading to increased stream sedimentation will become more prevalent as logging operations move to steeper mid- and high elevation sites.

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1 INTRODUCTION

During the past 30 years there has been an increased awareness of the potential impacts of forest harvesting on the stream environment. Poor forest management practices have been identified as one of the main causes of declining salmon and steelhead numbers in many of the rivers in British Columbia (Pearse 1982). Confrontations between the forest industry and the agencies responsible for the management of fisheries resources have developed in the past and continue today. However, an improved interagency referral process has been developed for planning stream protection measures and implementing them in forest harvesting practices. This positive interdisciplinary approach, as well as the improved understanding of stream processes and fish habitat needs, has helped reduce fishery and forestry interactions while still enabling forest operations to occur at most locations.

In British Columbia, background research and the resulting stream protection strategies have been developed mainly in coastal systems. For example, specialized techniques for streambank logging using timber jacks have been developed and site-specific guides for determining streambank treatments are used in some coastal areas (e.g., Moore 1980). However, different operational procedures have been developed in the interior areas in response to terrain, forest types, climate and other factors. Consequently, a different approach to stream protection has evolved in interior forestry operation. In many cases, measures undertaken in the immediate streamside zone and in upslope areas to minimize impacts on streams have been incorporated into the planning and implementation phases of forestry operations with relative ease and little additional costs. In other cases, substantial modifications resulting in increased costs are required.

There has not been any systematic evaluation of stream

protection practices in the interior sections of the Prince Rupert Forest Region. This analysis provides a preliminary review of the streamside and upslope measures presently incorporated into foresty operations for stream protection, and attempts to evaluate their effectiveness and identify their weaknesses. This project is an integral part of the forest hydrology research program for the region. Its results will help provide the necessary background for designing relevant research and training programs that will ultimately aim at developing sound interagency watershed protection measures.

The project has the following objectives:

1. To outline the existing process for stream protection in forestry operations in the interior areas of the Prince Rupert Forest Region.
2. To examine, through interviews and site inspections, the effectiveness of measures taken to date; and to outline those factors that have contributed to the success and failure of the measures.
3. To identify research and training needs that become apparent through the above evaluation.

2 METHODS

Interviews and field examinations were undertaken during the summer and fall of 1985. At the beginning of the study, the Lakes, Morice, Bulkley, Kispiox and Kalum Forest Districts and the major forest companies operating in these districts were advised by letter of the review and of the need for assistance from their staff. Interviews were conducted with personnel, ranging from the District Manager to resource officers. As well, biological and technical staff with the Ministry of Environment (MOE) and Department of Fisheries and Oceans (DFO) involved with forestry operations in the region

were contacted. Interviews with forest companies involved both management and field staff.

The management practices used in the districts for stream protection were discussed during the interviews. Site-specific examples of measures used and an evaluation of their effectiveness were encouraged. As well, research and training requirements were identified. Based on the interviews, key areas where stream protection has been a significant factor in forestry operations were identified and field examinations were conducted. The field work was undertaken with both industry and agency personnel, in an attempt to attain a balance of information.

This study was not intended to be an exhaustive review of all areas within the region. Rather, it focussed on key areas and relied on the information from representatives of the resource agencies and industry in each of the districts. The information gathered from the different districts was highly variable and depended on the experience of the people interviewed. Not unexpectedly, those districts with a history of interactions and concerns for stream protection became more involved in the project than did districts where stream protection was a minor concern.

Field examinations, although an important aspect of the study, were limited in that they were undertaken at one time, usually during dry weather. There were no field measurements made, and any comments by the author concerning the field examinations are subjective. The early arrival of snow cover in the fall of 1985 limited observations in some of the districts.

The suggestions and historical perspective provided by the interviews are the most important aspects of the review. It is recognized that different conclusions may be drawn from the same series, of events depending on the perspective of the person being interviewed; and this is sometimes difficult to

take into account in an analysis of this type. Nevertheless, many common strategies and concerns did arise and these are identified and discussed in this report.

3 HISTORICAL DEVELOPMENT OF STREAM PROTECTION MEASURES

Logging in the interior of the Prince Rupert Forest Region has changed from small scale selective and strip logging operations, common before the mid-1960's, to clearcut logging used today. Early logging operations, although small, were conducted with no formal consideration of other resource users. At times this caused extensive damage to stream systems. Streams were logged across and in some instances -- such as the Nadina and Stellako rivers -- they were used as transportation routes to mill sites (IPSC 1966).

Logging and milling operations have expanded rapidly since the mid-1960's. While earlier operations concentrated on high value timber in easily accessible sites, more recent operations have expanded roads and logging activities into much of the forest throughout the region. This period has also seen the development of a wide range of skidder types, including low ground pressure equipment for steep and wet ground areas, and the introduction of mechanized felling equipment. Harvesting moved from large progressive clearcuts before the "Planning Guidelines for Coast Logging Operations" issued in 1972 by the B.C. Forest Service, to patch cuts of 200 acres or less. Larger openings have become prevalent in recent years, as salvage of blowdown and insect-infested wood have had a major influence on logging patterns. In some cases this has resulted in removal of wood in a watershed more quickly than by the three-pass system usually sought. As well, there has been an increased use of herbicides and insecticides on forest sites as silvicultural programs have developed in the interior districts.

The increased logging activities and a growing awareness of interactions with the fisheries resources led to the development of government policies designed to address these issues. Although there has been some participation by DFO in cutting permit applications on the more important salmon creeks since the mid-1950's, a more formal referral process was instituted in 1970 (Pearse 1976). Since that time, the Fish and Wildlife Branch (now part of the MOE) and DFO have been consulted on applications for timber harvesting. However, because domestic water supplies are not a major concern, unlike in areas such as the Kootenays, the provincial Water Management Branch has little involvement in logging operations.

Despite many changes in the organization of the resource agencies since the referral system began, the basic process has remained the same. The B.C. Forest Service is the lead agency, issuing cutting permits through the district offices. Any logging or road building constraints to be included in the cutting permit document are reached through a "bargaining process" between the agencies and the logging companies (Dorcey et al. 1980). This is normally carried out during joint field inspections.

Since the beginning, the two agencies responsible for fisheries input into the referral process have had difficulty handling the large numbers of applications. This has resulted in delays and sometimes costly interruptions of logging operations. Efforts have been made to streamline the process by priorizing watersheds and developing watershed plans (resource folios). In specific areas with high resource values, special multi-agency committees have been established in response to land-use activities. The earliest such group was the Babine Watershed Change Committee initiated in the early 1970's to review and collect baseline environmental data on Babine Lake, and to monitor possible impacts on the lake from logging and mining activity (Levy and Hall 1985). This

has been followed by resource committees for the Nadina River and Morrison Creek watersheds.

In addition, to aid in the development of cut allocations for timber supply areas, the B.C. Forest Service has identified environmental protection areas (EPA's). The EPA's include categories for the protection of fisheries and community water supplies, as well as categories for problem soil sites. The areas are delineated on forest cover maps and help identify sensitive sites.

Despite these efforts to improve planning and to priorize developments in watersheds, much of the recent logging in the interior of the region has been response-oriented to blowdown, insect, and fire damage. The referral system is still largely based on site-specific field inspections, sometimes with very short lead times before harvesting.

Special clauses for stream protection may be attached to cutting permits issued by the B.C. Forest Service. The most common is the P-1 clause, often the only stipulation requested by fisheries agencies on fish-bearing streams. Usually when resource values are sufficiently important, site-specific recommendations are included in the cutting permit letter to the forest company, in addition to the P-1 clause. B.C. Forest Service staff say the P-1 clause serves more as a management objective and legal recourse should stream clean-up be required, and that the site-specific measures outlined in the cutting permit letter are the important recommendations.

The DFO officers located in Smithers, Prince George, Hazelton, and New Aiyansh are responsible for advising on the referrals in the five districts comprising the interior of the Prince Rupert Forest Region. They are assisted by technical support from a biologist with the Habitat Management Section, based in Prince Rupert, and other specialists based in Vancouver. The MOE, through a habitat biologist and technician based in Smithers, makes recommendations to all districts

except the Kalum TSA. These individuals are responsible for both fisheries and wildlife advice on cutting plans. A technician in Terrace advises in the Kalum TSA. Occasionally, MOE specialists (e.g., in herbicides) are brought in from Victoria to assist. Until very recently, the International Pacific Salmon Commission (IPSC) has provided input into logging operations in the Nadina watershed. The commission has now been incorporated into the DFO. The B.C. Forest Service has specialists in the fields of hydrology, geomorphology, and soils who provide technical guidance into logging and silvicultural operations on request from the districts. None of the forest companies operating in the interior of the region have experts in stream management or forest hydrology.

Normally, stream protection considerations in logging plans are site-specific and depend highly on the past experience of the resource agency and logging company staff. Field staff do not have a strict set of guidelines to follow, and there tends to be flexibility in adjusting procedures for timber removal and stream protection. Although this flexibility often leads to considerable differences in logging plans because of the individuals providing the recommendations, fisheries staff advice is ultimately governed by the restrictions of the Fisheries Act. A handbook has been prepared by DFO to provide technical guidance to its field officers when they are making judgments and providing recommendations in the referral process (Toews and Brownlee 1981).

Although MOE's participation in the referral system is an important aspect of cutting plans in the Interior, the system is fragile because it depends on a single individual covering four forest districts. There has been essentially no MOE presence in the eastern portion of the forest region since a temporary position in Burns Lake was dropped over a year ago. Dorcey et al. (1980) and Pearse (1976 and 1982) provide a detailed description of the development of institutional and

administrative procedures governing stream protection measures in forestry operations in British Columbia.

4 FOREST HARVESTING EFFECTS ON BRITISH COLUMBIA INTERIOR STREAMS

In the interior of the Prince Rupert Forest Region, stream protection measures are primarily concerned with limiting the potential impacts of forest harvesting on fisheries resources and, in some instances, with protecting domestic water supplies. The three major drainages in the main areas of forest harvesting (Skeena, Nass and Nechako rivers) all possess large runs of salmon and, in some instances, steelhead. With present scientific knowledge there is considerable uncertainty about the effects of timber harvesting on streams and on their fish populations. The ecology of salmonids is complex and highly variable between species and within the same species for different locations. Although nearly a dozen detailed studies have assessed forest harvesting practices on streams in western North America, including three studies in British Columbia, care must be used in extrapolating the results of these studies to the interior of the Prince Rupert Forest Region. For example, results from studies conducted in coastal areas such as Carnation Creek (Hartman (editor) 1982) and on the Queen Charlotte Islands (Poulin 1984) have limited application to the interior watersheds.

4.1 The Slim-Tumuch Study

A study that does provide valuable insights into the effects of forest harvesting in interior areas was conducted in the Slim-Tumuch system of the upper Fraser River watershed, approximately 80 km east of Prince George. This short-term study was conducted between 1971 and 1975 with the objective of testing the effectiveness of

stream protection measures incorporated into cutting permits in a previously undisturbed interior watershed. It compared treated watersheds (those with road construction and logging) and control watersheds (those without roads or logging). The results are presented in a number of technical reports which documented changes in water quality,[1] physical alteration of stream channels (Slaney et al. 1977c), effects on spawning and rearing habitat (Slaney et al. 1977a and b), and effects on the limnology of a downstream lake (Parkinson et al. 1977). Most of the results are a comparative assessment of logging effects on fish habitat, as there was no detailed pre-harvest assessment of fish populations in the study area. Because many of the results of the study have direct implications for the interior districts of the Prince Rupert Forest Region, several key conclusions are discussed here.

Clearcut logging with whole tree skidding during the summer and winter was undertaken in the Slim-Tumuch study areas. Four different streamside treatments were tested as follows:

1. Reserve strips along the larger streams (20-200 m).
2. Selective cutting along the stream. Leaning commercial and immature trees were left within 20 m of the stream and equipment operation was minimized in this strip. This type of treatment is now referred to as a machine reserve.
3. Directional felling and skidding away from the stream wherever feasible (immature and deciduous trees were left standing).

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[1] Brownlee, M.J. and B.G. Shepherd. 1975 Effects of forest harvesting on the Slim-Tumuch watershed in the central interior of British Columbia: (b) stream water quality. Fisheries and Marine Service. Unpublished manuscript.

4. Nondirectional felling and skidding across streams. The skid trail layout was done by the contractors and did not avoid stream crossings and streambank encroachment.

The results of the study suggested that the main impact of the logging operations in the area came from a substantial (5-to-10 fold) increase in sediment levels in the logged watersheds, which persisted for the duration of the study. The main sediment source area was a pocket of silty loam soil located on a road cut near the stream. Skid trails were secondary sediment sources. The reserve strip helped to reduce sediment from overland flow but did not reduce sediment transported through small drainages transecting the strip. Sediment levels in the smaller, steeper gradient (4-5%) tributary streams recovered rapidly to pre-logging levels. Experiment results suggested that the sediment loadings and subsequent deposition in the larger, lower gradient systems downstream would result in poorer survival of the eggs to fry stage. Observations showed that intragravel silt formed a barrier that would restrict emerging fry. As well, it was estimated that there was some loss of overwintering habitat for juvenile fish because of sediment filling spaces in the substrate.

Summer maximum water temperatures increased up to 9 C in the study streams. These higher water temperatures resulted in increased growth rates for rearing fish because pre-harvest stream temperatures were low. Sediment and nutrient loading in the lake downstream of the logged watershed were increased. However, light penetration and primary production was reduced, and some reduction in fish growth in the lake was suggested, although the evidence was inconclusive.

Considerable attention was devoted to assessing physical changes in the stream channels along the different

streamside treatments. The greatest channel disturbance occurred in those streams where nondirectional felling and skidding occurred (summer and winter logged). Directional felling and skidding away from the streams resulted in fewer instream channel changes except when they were undertaken on steeper terrain adjacent to the stream. Logging debris causing stream blockages and channel diversions, as well as bank damage leading to increased sedimentation, were identified as the main channel disturbances. The "selective" strip resulted in few channel alterations where blowdown was limited. In locations with blowdown, disturbance was similar to the directionally felled sites. The reserve strips were effective in preventing any instream channel changes but did not prevent sediment transport through the strip to the stream.

Study results included several recommendations for streamside treatments: streams to be winter logged should be marked; skidder crossings of creeks should be avoided, regardless of the season of logging; 20-m machine-free zones should be used, with directional felling away from the streams; and forest companies should lay out landings and skidder trails in the vicinity of streams. The need for a more detailed synoptic survey of reserve strips in the interior, and for guidelines to assess blowdown potential in them, was also identified. Other recommendations emphasized the need to use soil information for road location at the early planning stage of logging developments; and called for erosion control measures such as contouring skid trails, installing water bars and cross-ditches on skid trails, and revegetating landings and roads.

The extent of erosion and stream sedimentation that occurred in the study may have been more severe than normally encountered in interior logging operations, representing a "worst case". However, other aspects of the

study, such as the results of different streamside treatments, are particularly relevant to other locations in the central interior of British Columbia.

It should be noted that there has not been any follow-up evaluation of the effectiveness of the streamside treatments since the study ended in 1975. According to several individuals there has been considerable blowdown in the selectively logged strips and a number of the original reserve strips have been damaged by beetles and subsequently logged.

4.2 Prince Rupert Forest Region Studies

There have not been any detailed research studies conducted in the interior of the Prince Rupert Forest Region examining forest harvesting effects on streams. Nearly all stream-related research of the B.C. Forest Service Forest Sciences Section has occurred in coastal areas in the region, primarily in the Queen Charlotte Islands. A number of analyses of interior watersheds have been undertaken, based on specific requests from district staff. These include rate-of-cut, sediment, and water temperature analyses of logging in the Nadina watershed;[2] an assessment of logging effects on streamflow regimes in the Harold Price[3] and Kispiox rivers;[4] and hydrological

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[2] Wilford, D. and D. Toews. 1978. Forest hydrology considerations for forest management of the Nadina watershed. B.C. Forest Service, Smithers, B.C. Unpublished report. 23 p.

[3] Wilford, D. 1982. Harold Price Creek watershed - forest hydrology input into planning management. B.C. Forest Service, Smithers, B.C. Unpublished report.

[4] Wilford, D. 1985. A forest hydrology overview of the Kispiox River watershed. B.C. Forest Service, Smithers, B.C. Unpublished report.

evaluation of a number of smaller watershed referrals. As well, some surface erosion rehabilitation work on roadsides and burned areas has been undertaken.

The fisheries agencies that participate in the referral process have not been able to undertake any detailed monitoring or evaluation of the effectiveness of the measures recommended. The one exception is the monitoring of water temperature and sediment in the Nadina River by the IPSC.

It is of note that few of the individuals interviewed, including staff of the fisheries agencies, were aware of the results -- or even the existence -- of the Slim-Tumuch study. Industry foresters were generally more aware of the work than were Forest Service staff.

4.3 Stream Protection Concerns of the Resource Managers

4.3.1 Fisheries agencies

Interviews were conducted with more than a dozen biological and technical field staff from the fisheries agencies that provide input to interior logging operations. Although response varied as to what the critical stream protection issues were, certain concerns were consistently raised.

Stream sedimentation was considered by most fisheries personnel to be the main potential impact from interior logging operations. Road construction and maintenance, particularly in the vicinity of stream crossings, and sediment from machine damage to streambanks and channel diversions were identified as the main sources of sediment.

The maintenance of an intact channel, especially in small streams , was a key objective of fisheries

personnel, who were concerned that the stability of the streambed and banks not be altered.

Logging debris in streams was not a major concern of staff interviewed in the eastern portion of the region. Most indicated that debris was usually not entering fish creeks except in some situations where small creeks were overlooked or where contractors were poorly supervised. However, debris in small creeks and side channels was a concern in the Kispiox and Kalum TSA's, possibly reflecting the greater number of important small streams in these districts. Debris entering non-fish creeks is common, and some individuals indicated that this caused washouts and subsequent sedimentation to downstream fish habitat.

Opinions were mixed about whether blowdown of streamside timber was undesirable, causing streambank damage and increased sedimentation, or desirable, providing debris for structure and habitat diversity. Staff of MOE thought it was important to have large organic material in streams more than staff from other agencies did; and felt that a limited amount of windthrow along the stream edge over time was beneficial to the stream. On the other hand, the IPSC was opposed to any debris entering spawning streams such as the Nadina River due to concern for scouring of spawning beds.

Nearly all fisheries staff interviewed identified the positive aspect of increased water temperatures to many of the colder streams in the interior following logging. Lake-headed streams are the exception, and systems such as the Nadina River and Morrison Creek already experience high summer water temperatures. Only one individual was concerned about depressed

winter water temperatures in clearcut areas and about the effect this might have on ice conditions and egg incubation. This concern was based on results in the Slim-Tumuch study that indicated that winter temperatures can be depressed up to 2 C following logging. Increased nutrient levels in streams after logging was cited as a benefit to most interior watersheds. However, in the Fulton River there has been some concern that increased nutrient loading due to logging may be accelerating periphyton growth in the spawning channels and having a detrimental effect on egg-to-fry survival. It was stated that nutrient and water temperature considerations are generally not a part of the overall fisheries habitat management strategy, since other objectives usually prevail.

Rate-of-cut concerns in several larger watersheds have been alleviated by recent B.C. Forest Service and DFO analyses that show that the rate-of-cut is probably not excessive enough to affect streamflow regimes significantly. Some individuals said they are still concerned about forest harvesting effects on streamflows in certain smaller watersheds that have been heavily logged during beetle programs.

The use of herbicides and insecticides by the forest industry in interior watersheds was identified as a major issue by some DFO staff. The accelerated use of chemicals, including aerial applications and back-pack spraying in the streamside zone, is causing increased concern.

4.3.2 B.C. Forest Service and forest industry

Foresters identified stream sedimentation and debris in small creeks as the two most common impacts of logging on streams in the interior districts. Most

indicated that stream sedimentation associated with road construction and maintenance was the most prevalent stream protection concern. However, many of those interviewed suggested that there was an overreaction by the fisheries agencies to "muddy water". They said that any impacts were probably of short duration and localized. Some noted that sediment problems were more persistent in certain areas, often the result of poor drainage control on roads and skid trails (especially at approaches to stream crossings) and of poor road maintenance programs. A number of foresters suggested that erosion from upslope areas would probably increase in the future as harvesting progresses to steeper areas.

Logging debris in small winter-logged streams was identified as a second area of concern to foresters. This was area-specific, and was most prevalent in the Bulkley and Kispiox districts. Some foresters questioned whether debris in these small creeks really was a problem. In most districts, if the problem of debris was considered at all, it was felt that the bank damage from blowdown along streams outweighs any instream benefits of debris. Foresters again suggested that the fisheries agencies were too conservative in their streamside protection measures, largely because of the inadequate inventory they had of many of the small creeks in areas that are logged. Only one forester identified blockage to fish passage (mainly at road crossings) as a significant effect of logging on streams.

The main locations where concern for water temperature changes due to logging have modified harvesting plans are in the Nadina River and Morrison Creek. The level of protection undertaken in the

Nadina River was questioned based on monitoring results that suggest there have not been any changes to date. Foresters in some districts suggest that stream productivity is improved with higher water temperatures and with a shifting of streamside vegetation towards a more open, deciduous cover type. The need for more specific water temperature information on small logged streams was identified.

Most foresters indicated that they were not concerned with the rate-of-cut affecting streamflows in the interior watersheds. It was suggested that there was enough of a mosaic of timber types and age classes, in addition to the three passes made in watersheds, to keep changes in the streamflow regime of most watersheds to a minimum. Concern for possible changes in peak flows from accelerated snow melt and road development was raised. As well, possible summer minimum flow increases and subsequent potential decreases due to a shift in stand thriftiness were identified.

A number of foresters in the Lakes and Morice districts indicated the need for a rational approach, based on sound management objectives, to determine where and how much logging could be carried out along lakes. There is a need to know whether there are any biological reasons for not logging to the lakeside, or whether the issue is primarily one of recreation and aesthetics?

5 MEASURES UNDERTAKEN FOR STREAM PROTECTION IN THE INTERIOR

This section summarizes in two parts the results of the interviews and field inspections. The first discusses those measures taken in the immediate streamside zone, in particular,

techniques for timber removal at the forest and stream interface. The second part discusses upslope measures such as road construction and maintenance, silvicultural prescriptions, and rate-of-cut considerations that influence stream systems.

5.1 Streamside Treatments

The interior of the Prince Rupert Forest Region includes a wide range of treatments in the streamside zone, from the 1 km reserve along the Nadina River to logging to the edge of, and sometimes across, smaller creeks. Streamside treatments can be separated into three categories:

1. Leave strips, where all vegetation is left for a distance from the stream. Strip width depends upon terrain and stream values.
2. Machine reserves, where leaners and immature, and deciduous vegetation are left standing and equipment operation is restricted to within 10-30 m of the stream.
3. Logging to the stream edge and sometimes across small streams. Often the leaners and deciduous vegetation are left, but there are no restrictions on equipment operation to the streambank.

Leave strips and machine reserves are typically used along more valuable fish streams where there is reason to suspect damage from equipment operation to the stream edge. Smaller streams, particularly non-fish streams, are often logged to the edge and sometimes across. In recent years there has been a shift away from leave strips to machine reserves or logging to the stream edge in those areas where the terrain and stand type is suitable.

5.1.1 Leave strips

The use of leave strips along fish streams in the interior districts used to be widespread and was a generally accepted practice for stream protection. Widths, although sometimes fixed and inflexible, usually varied depending upon the terrain features. Windthrow in leave strips is the key concern, for it can block fish movement and cause bank damage. Leave strips that were left in many of the interior areas during the 1970's have suffered extensive windthrow. Probably the most severe examples of this are in the Babine Lake and Fulton River areas where forest companies have gone back into many areas to remove the blowdown. Leave strips are now left in some districts where windthrow is not prevalent or where the terrain prevents logging to the streamside as in deep gullies. As well, they are sometimes incorporated into areas (such as Morrison Creek), where other resource values, wildlife and recreation for example, are also a consideration.

According to most fisheries managers, some windthrow along streams is acceptable, especially in smaller creek gullies where it often hangs above the creeks, but a lot during a short time period presents problems. As well as not achieving the intended stream protection objectives, leave strips in these situations result in lost timber values and provide breeding areas for beetle populations. For these reasons, foresters had strong reservations about using leave strips along any streams where the trees could be harvested.

At present, timber reserves are commonly left in deep gullies from the topographic break to the stream edge. Often timber in these draws is too difficult to

reach with existing types of interior logging equipment. Logging them would require cutting deep skid trails into the gullies and skidding down the creeks. There are many examples of steep draws where timber has been left, especially in the western portion of the interior in areas like the Telkwa, Kispiox, and Morice watersheds.

A 1 km leave strip along the Nadina River deserves special mention as it is the most stringent constraint placed on any logging operation in the interior of the region. This reserve was requested by the IPSC to provide a buffer between logging operations and a sockeye spawning stream. Monitoring of water temperatures and sediment levels in the river indicate that the water quality of the system has not changed significantly since logging began in the watershed. In the past 2 years, some logging of windthrow within the reserve has occurred and more is planned.

Effectiveness of leave strips

Observations during the field trips indicated that leave strips are usually effective in providing stream protection if they are not exposed to storm winds or if they are wide enough that fringe blowdown does not become excessive. Most of the reserves examined are located in gullies, where they provide an effective means of stream protection. Usually the immediate streambank environment remains intact, while the leave strip ensures that logging debris and equipment stay out of the stream, provides a partial buffer for sediment, and maintains continued recruitment of large organic debris. One disadvantage is that leave strips do limit the opportunity for some

manipulation of streamside vegetation on systems with naturally low water temperatures.

Several examples of gullies that were logged during the winter were examined. In cases where skidders operated within the gullies, there was generally significant instream disturbance including extensive logging debris accumulations causing blockages, stream diversions and bank damage. These observations suggest that operating skidders in most gullies would be unacceptable if conducted in or a short distance upstream of fish streams without suitable buffer areas such as marshes. In the Prince George Forest Region, skidding down creek gullies has been permitted in some situations when there is deep snow (greater than 1 m) and if debris is cleaned up before snow-melt. There were mixed opinions as to the effectiveness of this technique.

In some gullies it was shown that most of the timber within 20-30 m of the topographic break could be removed during the winter by directional felling and skidding, with little bank or channel damage. Since fringe blowdown often occurs from the topographic break into the gullies for a short distance, timber should be removed from as far down into the gully as can be reached from the topographic break so that trees are not fully exposed to windthrow and breakage. Feller-bunchers have been used to reach into gullies for short distances to remove these edge trees. Once blowdown has occurred within the gully, it is difficult to remove this wood from above.

There is a need to adopt logging systems that are suitable for removing timber in gullies without causing extensive soil disturbance. Logging in many of these areas is presently being deferred, although

many of the areas in gullies may be too small to be economically logged in the future. A number of those people interviewed indicated that small cable systems may be required to log the more difficult sites.

5.1.2 Machine reserves

Machine reserves usually range from 10 to 30 m in width. Within this zone, all leaners and immature and deciduous vegetation are left standing, and equipment operation within the reserve is restricted. Merchantable wood is felled away from the stream, and skidded to the landing. Since many of the trees have to be top-skidded, machine reserves cannot be used in heavy blowdown sites. They do work particularly well on gentle ground where feller-bunchers can reach in and remove timber along the stream. In some areas, however, such as along the Nadina, operators have found that the trees are too large to be handled by a feller-buncher.

Machine reserves result in a minimum of ground disturbance in the immediate streambank area and are most effective in sensitive sites such as wet ground where equipment operation would cause site damage. Their effectiveness depends upon adequate snow cover and stream marking so that they are visible during winter operations. They work well in mixed stands where there are some immature or deciduous trees remaining. In some stand types, they can result in the total removal of vegetation along streams unless a minimum diameter limit is specified. For example, minimum diameter limits up to 35 cm were specified for a reserve along the Cranberry River. Another reserve along the Kispiox allowed for the removal of the larger spruce, but left the balsam.

As an alternative to minimum diameter limits, wider machine reserves have been used in the Prince George Forest Region (up to 40 m wide). Resource agency personnel indicated that directional felling and top-skidding in a reserve of this width usually assured that some timber remained along the streamside, and that the amount left increased nearer to the stream edge.

Since machine reserves usually only involve a small proportion of the overall setting (typically less than 5%), it has been estimated that additional logging costs of a machine reserve amount to less than 1% of the total logging cost for the setting. One company forester indicated that a small cost allowance is made to the logging contractor for the additional effort to remove timber from within a reserve. However, there are no allowances made in B.C. Forest Service appraisals for extra costs associated with logging machine reserves.

Effectiveness of machine reserves

Most of the forestry and fisheries personnel interviewed indicated that they were satisfied with the machine reserves approach to streamside logging on appropriate sites. Generally, logging debris was not getting into fish creeks and streambank areas were not being damaged.

Opinions of how wide machine reserves should be and how effective they are varies considerably among operators and forest companies. Resource agency personnel indicated that on the more important streams, they preferred to keep the logging contractors away from the creeks because of poor past performances. Without adequate supervision, it was

claimed, operators sometimes avoid the extra work required to pull cable from the skidder into the reserve. The other main reason cited for the failure of machine reserves at some locations was streams being poorly marked for winter logging. In one example, cutting permit specifications for a machine reserve on Ironside Creek and a tributary in the Kispiox TSA were not passed on to the logging contractor. The site was not adequately supervised during the logging operation and the creeks were logged across. Similarly, a machine reserve at McDonell Lake was not effective because objectives were not clearly explained nor the logging contractor adequately supervised.

Machine reserves are normally not used in the Bulkley TSA. While deciduous trees and leaners are left along fish creeks, equipment is allowed to operate to the stream edge so that trees do not have to be top-skidded. Minimal ground disturbance, breakage, and extra efforts to top-skid were cited as reasons for this difference.

The machine reserves examined in the field in the Morice and Kispiox districts appeared to provide adequate stream protection. Although no field measurements were made, there was an apparent difference in ground disturbance between sites within and outside of equipment-free areas at sites in the Kispiox. In some situations, the reserves represent a compromise. Although there may be some long-term loss to bank stability and stream structure because of less large organic debris, there are potential benefits to stream productivity and less risk of severe windthrow. At the same time, most of the merchantable wood along the stream can be harvested.

5.1.3 Logging to the stream edge

There are a number of examples where larger streams, such as the Morice River, have been logged to the streambank. Usually only leaning trees or immature and deciduous vegetation that occur on the streambank are left, although in one situation (Nadina River) the leaners were felled onto the ice and yarded. Typically this type of logging along important streams occurs on flat or gentle terrain with well-drained soils, where equipment can be operated to the stream edge with minimal ground disturbance.

Many of the smaller creeks (less than 3 m wide) throughout the interior of the Prince Rupert Forest Region are logged to the edge. If fish are suspected or known to occur in them, usually the P-1 clause is requested. This clause specifies that landings, logging debris, and equipment must be kept out of the creeks. Creeks that are not fish habitat and where water quality is not a concern can have timber felled across them and can be skidded across.

On a linear basis, small streams may be just as productive as larger systems, but they are influenced more by the forest canopy. Removal of streamside vegetation may have greater impacts on the smaller creeks, and possibly more benefits, depending on the streamflow characteristics.

It is often difficult to determine appropriate streamside treatments for small creeks. Deciding whether or not trees should be directionally felled away from the creeks or whether skid bridges are needed may be hampered by lack of information. Setting boundaries, the location and number of landings required, and the skidding distances to the

landings can all be influenced by the creeks transecting the blocks and whether or not they require protection. Because these all influence logging costs, recommended stream protection measures have important consequences.

Usually these small creeks have the poorest fisheries inventory, and agency recommendations are often based on suspected presence rather than definitive information. As a result, foresters feel that the fisheries resource agencies are too cautious with their recommendations and overprotective of low-value streams. Fisheries personnel, however, recognize that some small (including ephemeral) streams can provide important spawning and rearing habitat, particularly for coho and steelhead. When specific information is not available, fisheries personnel tend to make cautious recommendations based on potential.

Observations of logging along small creeks in the interior districts indicate there is wide variability in treatments. In some locations, such as in the Morice, companies are taking considerable care in logging along small creeks where water quality is a concern. In creeks upstream of fish habitat, directional felling and skidding away from the streams is standard practice. These measures appear to work well in minimizing erosion and channel damage. At the same time, observations in the Fulton River area indicate that some small fish creeks have been logged across and in some instances are receiving no stream protection at all. Examples were observed in some districts where skidding across streams immediately upstream of fish habitat could have been avoided with small changes to the setting boundary.

These observations suggest that there is still a need in some areas for logging operators to recognize the value of small streams and to provide suitable protection strategies. It also highlights the need for fish inventory data on small streams.

5.1.4 Off-channel rearing areas

The recently proposed logging in the Stephens Creek area in the Kispiox TSA illustrates a situation that poses special difficulties for harvesting in the streamside zone. Side channels, small drainages, and ponds located along the base of hillsides but within the floodplain often provide very important rearing areas for juvenile salmonids. Although they do not look productive, fish may use these areas year-round, depending on access and whether they remain wetted. Measures such as machine reserves do not always provide adequate protection for some of these sites, particularly those located well back from the main system. In some situations, detailed mapping and inventory of seasonally inundated areas may be required. As well, special procedures may be needed to minimize logging debris accumulations in the channels and to ensure that the wetlands remain accessible at skid road and mainline crossings.

5.1.5 Stream clean-up

There have been a number of situations in the interior of the Prince Rupert Forest Region where stream clean-ups have been conducted after logging. For example, Byron Creek and an unnamed tributary to Nadina Lake (Morice TSA) were incorrectly ribboned and subsequently yarded across. Crews had to go back into these creeks after logging to remove the debris and

small limbs. In fact, there are examples in every district of the interior where operators have returned to creeks to clean up. Costs have ranged from a few hundred dollars for small sections of streams to approximately $10000 on Haystack Creek and nearly $25000 on Ironside Creek, where a crew of 20 worked for 10 days.

Stream clearance is a rehabilitation measure that attempts to remedy a mistake. Usually clean-ups are conducted on small creeks that were inadequately marked and not recognizable under snow; or where the equipment operator was unaware that protection was required, or just did not care. Although subsequent clean-up of the logging debris can benefit the stream, it must be done properly and under the supervision of fisheries personnel who understand the role of large debris in streams.

Studies thoughout the Pacific Northwest have shown that poorly managed stream clean-up can cause more damage than good (e.g., Swanson and Lienkaemper 1975). The clean-up of a tributary of Ironside Creek is a good example. Virtually all of the debris (logging and natural) was removed from this creek in a costly undertaking that may have left the stream in worse condition than before the clean-up.

5.2 Upslope Treatments

Stream protection measures usually focus on the streamside zone. There is a tendency for resource managers to assume that if this area is protected, then the stream system will remain viable. This section discusses activities such as road construction and maintenance, skid trail layout, rate-of-cut considerations, and post-logging treatments. Although

these activities are conducted in upslope areas, they can have a significant influence on stream systems.

5.2.1 Roads and skid trails

Nearly all the fisheries and forestry personnel interviewed suggested that stream sedimentation was the major effect logging activities had on streams in the interior of the Prince Rupert Forest Region; and most indicated that forest roads and skid trails were the major source of sediment to streams. However, there was a wide divergence of opinion concerning how long-lasting and significant the effects of sediment might be. Several questions arose: Is there an overreaction of fisheries staff to muddy water? Are streams being overprotected with tight restrictions on the timing of construction at stream crossings? How capable are the interior stream systems, particularly lake-headed streams, in coping with stream sedimentation from logging operations? The questions are complex and there is little data to turn to for answers.

It is not possible to describe all the considerations and measures that are undertaken in determining where a road is located, how it is built, and why it did or did not result in erosion and potential damage to a stream system. There are too many variables that enter into each aspect of the operation. However, several considerations were identified and recommendations made during discussions in this project. These are separated into planning, construction, and maintenance of roads and skid trails.

5.2.1.1 Planning considerations

1. Roads that are built with a short lead time in response to insect or fire control measures or salvage of blowdown tend to be the most damaging. Sufficient lead time before construction is needed to ensure that road locations can be checked during high flow periods for proper sizing and location of drainage structures. Road construction during wet periods or during the winter usually results in more sedimentation and stream crossing problems than does construction during dry periods. Erosion problems associated with road construction in the Footsore Creek area in the Kispiox TSA during a wet period in the late fall of 1985 illustrate the problems with construction during the wrong time of year.

2. Overall watershed development plans, focussing on long-term location of roads to optimize development while minimizing impact, are being replaced with short-term response-oriented developments. The location of the crossing site of Pierre Creek was cited as an example of short-term planning that has resulted in a crossing at the most important salmon spawning area on this creek, despite other options that could provide better overall access to the watershed.

3. Forest road development planning in the interior usually does not involve the use of soil or terrain mapping to help recognize and avoid

difficult construction areas. Although this is not necessary in many operating areas, there are situations where it could reduce road construction and maintenance costs and reduce erosion from roads. Identifying and avoiding problem sites at the planning stage benefits all aspects of the operation.

4. There are no standard procedures for the layout of skid trails and landings on areas identified as critical sites, or for the subsequent rehabilitation of areas where disturbance has occurred. Field studies conducted in the Nelson Forest Region indicate that soil disturbance in ground skidding operations can be reduced by as much as 50% with the use of appropriate planning and layout procedures. At present, provisions for the use of certain equipment types -- such as FMC skidders or small cats -- on critical ground are left to the discretion of the individual forest officer who may or may not recognize the concerns. Although techniques for minimizing erosion have been identified and many of them are applicable to the interior of this region (e.g., Hammond 1982), they are not a priority in many of the interior operations. Careful planning of skid roads and landings may become more essential as logging moves into more of the mid- and upper slopes such as the McKendrick Creek area in the Bulkley TSA. A committee to study steep slopes was established in the Bulkley TSA, and is presently waiting for guidelines from the B.C. Forest Service in Victoria.

5. The lack of specific inventory information on small stream systems to be crossed by roads creates difficulties for designing crossing structures and identifying critical sites. Fisheries personnel indicate that there has been an improvement of structures to accommodate fish passage in recent years.
   According to some foresters, fisheries agencies in the past have sometimes recommended bridges rather than culverts on an ad hoc basis. Because companies are on minimum stumpage, these types of requests cost them more directly; and unless the resource agencies provide good technical justification for their decisions, the companies will likely be increasingly reluctant to accept them. For example, several bridge crossings were required in the Nadina watershed on small non-fish streams where culverts would have been adequate. As well, the lack of hydrological data on small creeks, particularly in new development areas such as the Nilkitkwa, has resulted in problems in developing estimates for the sizing of bridge and culvert structures adequate to handle floods.

6. Timing restrictions placed on culvert and bridge installations in trout and salmon streams (usually late July and early August) were felt to be too tight. The narrow timing window, in conjunction with little flexibility for equipment crossings, causes difficulties for planning road construction.

5.2.1.2 Construction considerations

Often erosion from roads is greatest during and shortly after road construction. Although some erosion during this period of active soil disturbance is unavoidable, certain measures have been developed to reduce erosion from road construction. There are several considerations:

1. Both type of equipment used for construction in critical sites (backhoes versus cats) and timing of construction are important. On sensitive sites, particularly wet ground, backhoes allow for much better control of ground disturbance, material placement, and ditch construction. The need for close supervision of construction activities was stressed so that during wet conditions at important sites, operations can either be stopped or moved to other locations until conditions improve.

2. Special measures for erosion control have been used in a few locations, but they are generally not standard practice in the interior region and are often instituted after a problem has developed. For example, settling ponds have been used in ditches at approaches to stream crossings and some grass seeding has been undertaken at several sites where surface erosion is prevalent (e.g., Footsore Lake and Problem Creek Hill in the Nadina). The section of road on Problem Creek Hill in the Nadina had the most elaborate erosion control measures of any forest road observed in the interior. These included the installation of frequent cross drains, upslope

ditching, inverted culverts, grass seeding, and settling ponds in the ditches. The effectiveness of measures such as settling ponds depends on maintenance after installation.

3. Drainage control during construction was one area identified as needing improvement throughout the region. Adequate drainage structures should be installed at the time of initial road construction, yet culverts on small creeks that have been logged upstream of the road are often too small to handle increased debris and streamflows at the crossing sites. In particular, winter roads often lack adequate drainage. There is also much variability in the types and impacts of crossings used, ranging from logs covered by snow and dirt to prefabricated skid bridges. For example, there was no damage to the streambank at a site in the Morrison Creek area where a portable skid bridge was used. At other sites, however, streambanks were damaged where logs and dirt were used as temporary crossing structures. Skid bridges have an additional positive feature in that they can be removed and reused at other locations.

5.2.1.3 Maintenance considerations

1. Inadequate road maintenance, particularly on nonactive roads, was identified as an area of concern in most districts. Some of those interviewed suggested that the lack of road maintenance resulted in more damage to streams than did the construction phase. However, the

lack of an adequate maintenance program can sometimes be costly in the long term, since some roads have to be virtually rebuilt if logging operations or silvicultural projects are to go back into these areas after 5-10 years. Most road maintenance programs are concentrated on the active roads. Programs such as culvert and bridge replacements, debris removal at culverts, ditch maintenance, thawing of frozen culverts, and the proper maintenance of road surfacing are critical for stream protection as well as for long-term road stability.

2. Field observations suggest that water bars and other measures for putting roads to bed were rarely incorporated into operations. Collapsed culverts and fill washouts due to blocked culverts were encountered on secondary roads in all of the districts. Culverts blocked with debris or by beaver dams are particular fisheries problems on flood plain locations such as in the Cranberry and Morice rivers. In addition to erosion considerations at these sites, they can also block the upstream movement of fish, especially to wetland locations used by coho salmon. Culverts blocked by debris or ice may redirect water along the road ditches, causing low water in fish rearing and spawning areas. Small sidehill drainages may be the main water sources to critical stream reaches during low flow periods such as the late winter.

3. An example of how poor road maintenance can offset special erosion control measures is found

at the creek crossing at the base of Problem Creek Hill. The extensive measures undertaken to reduce erosion on this hillside were reduced in effectiveness by careless grader operations that pushed road surfacing material into the stream channel.

5.2.2 Rate-of-cut

The rate and spatial distribution of logging within interior watersheds, and their influence upon streams, were minor problems for most resource managers. In the past, concern for the rate-of-cut and resultant changes in water quality and quantity and channel stability resulted in modifications to the logging developments in the Nadina River watershed. There have also been concerns that logging in the Kispiox, Fulton, and Harold Price watersheds might affect runoff patterns, possibly causing increases in peak flows. However, several factors -- the low percentage of area in clearcuts, their spatial distribution within the watershed, and the fact that the source areas for peak flows during the early summer are high elevation areas -- suggest that logging probably has little influence on peak streamflows in these systems.

The rate-of-cut in the Cranberry River watershed was identified as the major forestry-fisheries concern in the interior portion of the Kalum District. The cumulative effects on gravel quality and channel stability of highway construction, in conjunction with extensive logging in this watershed, have not had any technical evaluation.

To date, hydrological considerations have focussed on large systems that have at least a portion of their watershed in mountainous terrain and

permanent snowfields that maintain late summer flows in the systems. There have not been any assessments of small watersheds (e.g., 5-25 km^2) that have a significant proportion of commercially accessible timber and no permanent snowfields. Accelerated snowmelt due to logging in these watersheds may increase peak flows and decrease late summer low flows. Some of these small creeks are used by steelhead and coho, and under natural conditions may become intermittent during the late summer. The timing of fry emergence and their movement out of the stream before low water can be in fine balance and may be altered by logging.

5.2.3 Post-logging treatments

Two post-harvesting activities have important implications for stream systems in some areas: 1) the construction of fire guards; and 2) the use of chemicals for insect and brush control.

5.2.3.1 Fire guards

Fire guards can be more of a potential erosion source on logged settings than roads, skid trails, and landings. Those that are deeply bladed with a cat along the perimeter of the setting can concentrate water on long slopes if drainage is not dispersed with water bars. Examples were observed during field trips where the benefits of careful streamside treatments were offset by adjacent, badly eroded fire guards. At other sites, ground disturbance was minimal where debris had been pushed back and the duff layer had been carefully bladed, exposing a minimum of mineral soil needed to stop a creeping fire.

5.2.3.2 Chemical treatments

Normally, a pesticide-free zone restricts the routine application of pesticides within 10 m of any waters frequented by fish or leading into such waters. These areas include water-filled ditches and marshes. Most resource managers interviewed felt that this approach to stream protection was satisfactory. However, several concerns were raised regarding the increasing use of pesticides in the region.

Fisheries personnel are concerned about how well buffer zones can be maintained during aerial applications over extensive brush areas. In addition to the 10 m pesticide-free zone, the pesticide applicator establishes a buffer zone to ensure that the 10-m zone does, in fact, stay pesticide-free. These buffer zones are set by the applicator according to his personal experience. Fisheries personnel expressed concern over this, calling for buffer zone widths to be set more consistently, based on site factors such as slope, aspect, runoff conditions, and soil textures. It is anticipated that as the use of chemicals increases in the future, there will be a need to monitor adjacent streams to determine whether there are any off-site effects in the aquatic systems.

6 CONCLUSIONS

A review of streamside treatments suggests that the larger, well-known fish streams are recognized as being important and usually receive careful treatment during logging. Measures such as leave strips, or logging to the stream edge leaving leaners and deciduous vegetation, are usually effective in ensuring that most streams are protected. An effective alternative to leave strips on most sites are machine reserves

which restrict equipment operation along the streambank but allow for the removal of much of the merchantable wood in areas subject to windthrow. At some sites, however, machine reserves may reduce streambank stability over the long term.

Close supervision of operations at sensitive sites is critical. When it is properly undertaken, high value sites -- such as along the Nadina River -- can be logged with little impact. On the other hand, if communication and close surveillance do not occur, streamside protection measures can fail, as at Ironside Creek in the Kispiox TSA. This review identified the need for site-specific logging treatments based on better fisheries inventories and habitat mapping for logging undertaken near side channels and wetlands along important fish-producing streams.

Observations of logging along small creeks suggests that protection of these systems varies much more than protection of larger systems. In some cases, these small creeks are identified early, and measures for their protection are incorporated into layout and harvesting operations, minimizing the impacts from logging. In other cases, small fish creeks are still yarded across and can be badly damaged. Small creeks that are to be winter-logged, especially if they are not adequately marked, are the most vulnerable systems. Part of the difficulty arises from an inadequate fisheries inventory to enable managers to identify important smaller creeks. As well, logging operators do not fully appreciate the role that these small creeks may play in overall fish production, including their influence on more valuable fisheries habitat downstream.

Bridge and culvert installations that allow for fish passage have improved considerably in recent years. Fish passage problems can arise at stream crossings where there is inadequate pre-logging inventory or where culverts are not maintained.

Sediment from roads, and to a lesser extent from skid trails, landings, and fire guards, was identified as a major effect of interior logging operations on streams. There was a wide difference of opinion as to the extent, duration, and implications of sedimentation on streams and on their fish populations. However, there is nearly a total absence of monitoring or evaluation of logging-induced sediment on streams in the interior districts.

The incorporation of measures to minimize erosion from road building and logging activities is highly variable and tends to reflect individual initiative and priorities. Timing logging operations to periods when there is adequate snow cover and restricting equipment types on critical sites are measures presently used in districts to minimize soil erosion. There is no consistency in the procedures used, however, either between districts or -- within the same district -- between logging operators. Special measures for erosion control, such as the use of water bars and revegetating disturbed sites, are typically not used except after problems have developed. Road maintenance tends to focus primarily on active forest roads while the others fall into disrepair and become major source areas for stream sedimentation. It is anticipated that soil erosion leading to increased stream sedimentation will become more prevalent as logging operations move to mid- and high elevation sites.

Analyses of the rate and spatial distribution of logging in the interior districts suggest that harvesting operations to date do not have a major influence on the streamflow patterns of the larger systems. These analyses have not addressed small watersheds, especially those without permanent snowfields. The run-off patterns of these systems may be altered by an earlier snowmelt or by the transition from old-growth forests to extensive clearcuts and thrifty regeneration.

Finally, this review found that the use of chemicals for

insect and brush control is increasing in the interior, and that there is a need to ensure through research and monitoring programs that these activities are not affecting stream productivity.

7 RECOMMENDATIONS

Much of the forest hydrology program in the interior has been response-oriented to specific problem areas identified by district staff. While these requests should be given a high priority, there is a need to establish research projects to test stream protection measures and to improve upon them. Some of the research needs are relatively straightforward and require only short-term evaluations; others are more complex and long term. The establishment of study areas that are accessible can serve both research and subsequent training needs as the study progresses.

Based on site inspections and discussions with resource personnel, the following areas were identified as having the greatest need for research.

7.1 Research Needs in the Streamside Zone

1. There is a need for basic pre- and post-harvesting assessment of small creeks that are winter logged to determine whether there are significant fish habitat impacts resulting from increased debris, physical channel alteration, and stream productivity changes (e.g. alteration of summer and winter water temperatures). This research would be best oriented towards areas in the Morice and Kispiox TSA's where anadromous fish species such as coho and steelhead are prevalent throughout many of the small streams. As

well, there are a large number of resident trout streams in the Fulton River area which have received different intensities of treatment and might serve as potential study streams.

2. Ground and streambank disturbance should be compared between sites that have been logged using machine reserves and sites where equipment has been allowed to work to the streambank. Sites should be established to monitor the long-term streambank stability under these different treatments. There are a number of settings that may be suitable for this type of evaluation scheduled for logging in the Lamprey Creek area in the Morice District. Other areas that might be included in this comparison include the Mitten Lake area in the Kispiox and sites in the Fulton River.

3. There is a need to test techniques that might enable logging in some of the gully areas presently avoided. Special equipment or methods should be sought which would allow some of these areas to be logged without damaging the stream systems. Initially, it is recommended that the results of experimental work conducted in other regions be reviewed, including ongoing operations in the Bowron River area.

4. Technical information is needed to help develop a sound management strategy for dealing with logging to the lakeshore on some systems, particularly in the eastern portion of the region.

5. There is a need to develop a process for incorporating better fisheries inventory information in the early stage of forest development plans, particularly for

small creeks. In many instances the fisheries agencies are not able to provide the site-specific information required.

6. Consideration should be given to returning to the Slim-Tumuch study areas to re-evaluate the streamside treatments that were incorporated during the early 1970's. Are the conclusions that were developed from this study 10 years ago still valid?

7.2 Research Needs in Upslope Areas

1. The most important research need in the region is to evaluate how significantly streams are affected by sediment from roads. How long-lasting are its effects? What are the long-term implications of sediment to low energy productive fish streams in the interior districts? Are there special problem areas in the interior? How can these be recognized? How effective are existing measures such as settling ponds at bridge approaches in reducing sediment from road construction?

2. Evaluating erosion from skid trails on steep slope areas and identifying ways of minimizing it should high priorities for research. This type of study would require the expertise of several disciplines, including hydrology, and should include a review of the work that has been done on steep slope logging in other areas such as Nelson and McBride.

3. With the expanding use of chemicals for brush and insect control in the interior districts, there is a need to become familiar with any research that has

examined the use of these chemicals and their implications for streams. As well, an approach for determining buffer zone widths based on site factors should be developed.

4. There is a need to assess the hydrological implications of logging a large proportion of a small watershed that does not have permanent snowfields supplementing late summer flows. What are the implications of an accelerated snowmelt for peak flows and late summer low flows in such a system? Study watersheds should be monitored over a number of years before and after logging.

5. There is a need to examine means of expanding the timing window and reducing restrictions on machine movements in streams to aid bridge construction. Several techniques should be examined, including the use of portable pads for machine crossings and the use of construction cloth to allow work on footings at other times of the year than the late summer.

6. There is a need to evaluate the cumulative effects of logging and highway development in the Cranberry watershed.

7. Better hydrological data in new development areas are needed to aid in the design of adequate crossing structures (e.g., Nilkitkwa area).

7.3 Training Needs

Most of the personnel interviewed in this study said that there is a need for a permanent process of training, particularly at the field level. In most instances,

training would probably be best undertaken in conjunction with research developments.

Several topics were identified as useful areas for training: A workshop focussing on logging techniques in interior steep slope areas was suggested. This would include, for example, instruction in methods of yarding timber from gullies and in equipment operation on steep slopes. Other workshops might address such topics as how to minimize erosion from roads and how to put roads to bed. Some foresters were skeptical about the value of more training programs, saying that many practices are still not operational, despite several training programs over the past decade.

Clearly, any training programs that are to be undertaken should address local needs and would be more effective if combined with ongoing research studies.

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