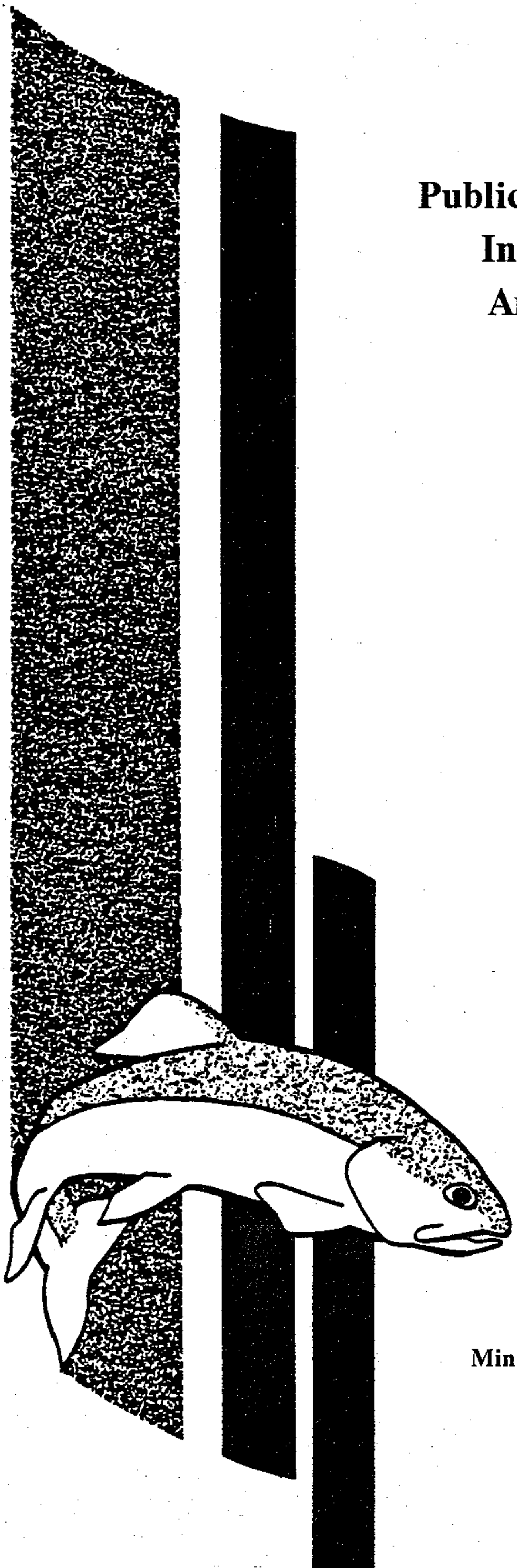

Public And Industrial Involvement In Watershed Management And Stream Enhancement

by

P. A. Slaney

Fisheries Project Report No. RD0
1980

Province of British Columbia
Ministry of Environment, Lands and Parks

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[1] Prepared for the Public Involvement Conference of the Ministry of Forests

INTRODUCTION

Forested watersheds in British Columbia yield a wealth of educational, recreational and soci-economic benefits. Forestry and fisheries agencies manage forests and fish resources, respectively, to provide most of these benefits. The management of land for the quality and quantity of water production is, therefore, an integral part of these disciplines (e.g., W. Jeffrey; Forest Club 1971) and it is an accepted truism in the 1980's that integration of fisheries and forestry planning and operations is advisable to maximize total watershed benefits. This concept has been difficult to enact because of several factors which are beyond the scope of this discussion, but suffice it to say, progress has not been rapid, with gradual shifting to more integrated approaches being evident only in the past decade.

Both these renewable resources of fish and forests have reached a level of harvest where there is pressure to shift to more intensive management practices. Vigorous fishery and forest enhancement programs, either planned or operational, are being phased in to meet an immediate (fisheries) or forecasted (forest) 'short fall' or supply problem. The purpose of this paper is to identify and summarize several methods for watershed protection, rehabilitation and improvement, including stream enhancement techniques that can be applied economically by use of public assistance. Although these procedures are directed mainly at maintenance or enhancement of salmonids, there are associated benefits to forest production resulting from stable slopes and water courses. Involvement of public or non-agency assistance from recreational societies, angling clubs, members of commercial fishing associations and unions, forest industry workers, unions and companies, schools, other interested public and youth groups as well as various public institutions can make significant contributions which may be reflected in benefits to their life styles.

Stream enhancement techniques have recently been summarized in a Stream Enhancement Guide[1] organized and prepared under the auspices of the joint federal-provincial Salmonid Enhancement Program (SEP). Public use of most of these methods within streams must be approved by the appropriate regulatory authority: SEP Community Advisors and the regional office of the Fish and Wildlife Branch. Financial support for some of the techniques described here can be made available through this program.

SALMONIDS AND THE HARVESTABLE SURPLUS

Fisheries management is concerned with the maintenance of each fish population or stock to provide a continued annual harvest. This harvestable segment or harvestable surplus, is in excess of that needed to fully or optimally utilize the available spawning areas (e.g. pink or chum salmon) or rearing habitat (e.g. coho salmon and steelhead trout). Ensuring a fish population or 'run' is not harvested beyond this surplus (i.e. 'overfished') is attained by application of fishery regulations, stream protection measures and enhancement techniques.

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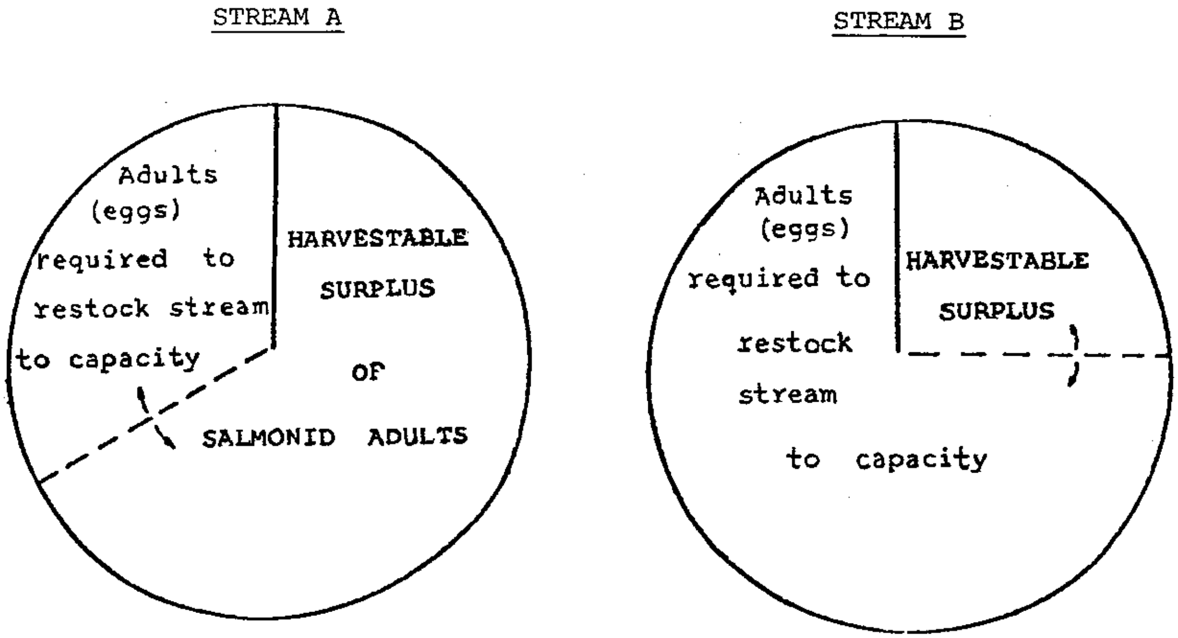
[1] Prepared under contract by Kerr Wood Leidal and D.B. Lister and Associates; available in limited supply from SEP Community Advisors located in regional offices of the federal Department of Fisheries and Oceans.

Table 1. Stream utilization by salmonids during life history phases (from Northcote 1974).

		TYPE AND TIME OF STREAM UTILIZATION						
Degree of Utilization	Salmonid Form	Indirect	Adult Migration	Spawning	Egg Incubation Alevin Development	Juvenile Migration	Juvenile Rearing & Feeding	Adult Feeding
None (directly)	Kokanee (lake spawners)	year round						
	Lake trout	year round						
	Stocked trout & char	year round						
Very Low	Sockeye salmon (lake spawners)	year round	summer-autumn			spring		
Low	Pink salmon		summer-autumn	late summer-autumn	winter	early spring		
	Chum salmon		autumn-winter	autumn-winter	winter early spring	spring		
	Sockeye salmon	year round	summer-autumn	autumn	winter	spring		
	Kokanee	year round	summer-autumn	autumn	winter	spring		
	Lake dwelling trout	year round	early spring early summer	spring-early summer	spring-summer	summer		
	Lake dwelling char	year round	summer-autumn	autumn	winter	spring		
Moderate to High	Chinook salmon	summer-year round	spring-summer	summer-autumn	winter	spring	spring-autumn or year round	
	Coho salmon		late summer winter	autumn-winter	winter-spring	spring	usually year round (1-2 years)	
	Steelhead		autumn-summer	early spring	spring-early summer	spring	year round (2-4 years)	
	Sea-run Cutthroat		winter-spring	late winter-spring	late winter-spring	spring	year round (2-4 years)	
	Sea-run Dolly Varden		autumn	autumn	winter	spring	year round (2-5 years)	
	Lake-dwelling trout	year round	early spring-early summer	spring-early summer	spring-summer	spring-summer	year round	
	Lake-dwelling char	year round	summer-autumn	autumn	winter	spring-summer	year round	
Highest	Stream-dwelling trout		spring	spring-summer	spring-summer	summer	year round	year round
	Stream-dwelling char		autumn	autumn	winter	spring	year round	year round

Salmonids (salmon, trout and char) are the group of fish that are the main basis of the commercial and sport fish resource in British Columbia. The duration each species utilizes a stream varies, but with few exceptions salmonids rely greatly on stream gravels for spawning and the incubation of eggs to the emergent fry stage (Table 1). Because of the importance of streams to salmonids, survival and thereby abundance of these fish is highly affected by the quality and quantity of stream flow. In some streams, conditions are severe and production of the various species is low or fluctuates widely from year to year. Accordingly, the *harvestable surplus* available to commercial and sport fishermen is either low or nonexistent (Fig. 1). This contrasts with stable, undisturbed streams where a large harvestable surplus is available annually (Fig. 1).

Fig. 1. The salmonid harvestable surplus available under two natural stream conditions in which the incidence of sands, silts and clays is low in stream A and high in stream B.



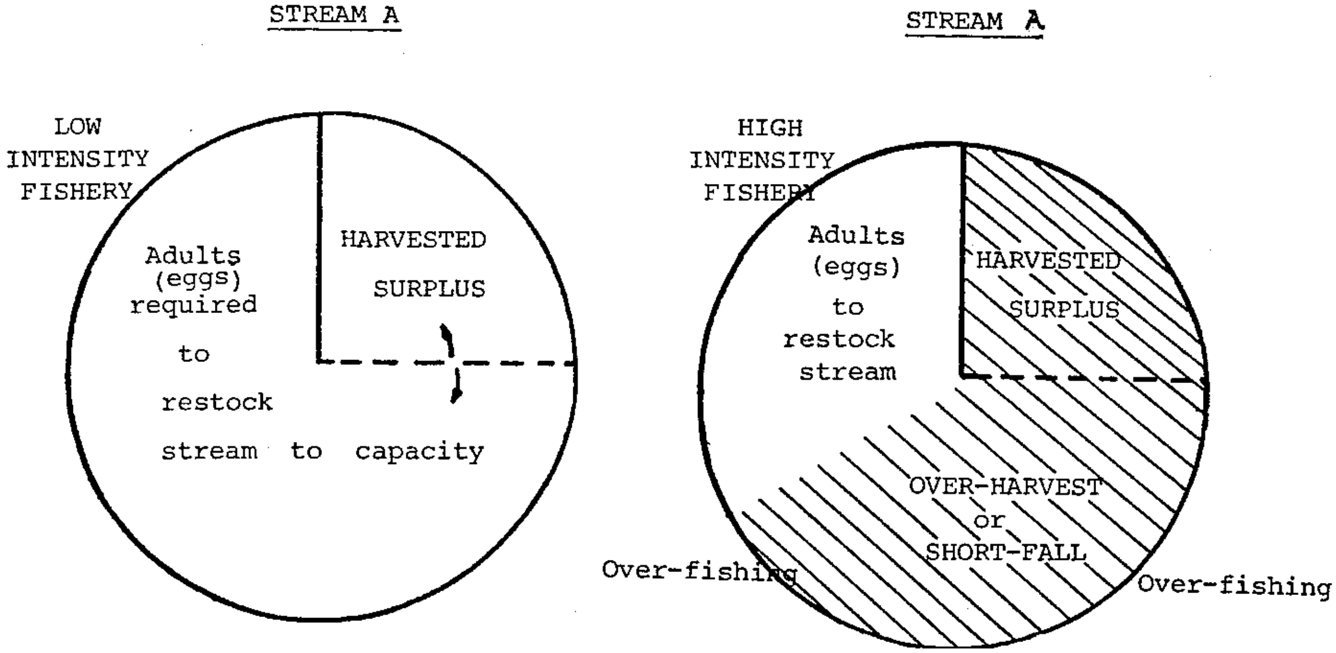
As intensive industrial or urban use of a watershed occurs, substantial changes in water quality and quantity of a stream can take place, although the magnitude is frequently site specific, varying with conditions of weather, elevation, soils, land forms, slope, and particularly forestry and engineering practices (Burns 1972; Moring 1975; Slaney *et al.* 1977a,b,c; Koski and Walter 1978). Several studies in western Northern America have documented various changes in sediment, stream flow, debris, channel shape, streamside vegetation, and in some cases (e.g. urban land-use) water chemistry.

Intensive land-use practices such as clearcutting and road building can thereby reduce survival rates of salmonids, particularly during their early stage of life; egg-to-fry and juvenile overwintering. The result is a reduction in the *harvestable surplus* and if that harvest rate is maintained at a previously high level, then a major decline in the stock occurs, essentially a *double impact* (Fig. 2).

Unfortunately, most of the salmon fisheries in British Columbia are operated as *multi-stock harvests* conducted on the continental shelf (troll) and within straits as gauntlet net fisheries (e.g. Johnstone and Juan de Fuca). The result is that effects of even short-term habitat impacts cannot be easily ameliorated by reduced fishery effort, and overfishing of weakened stocks is either risked or accelerated.

Studies of winter steelhead, which are essentially harvested only in a terminal sport fishery, have demonstrated how varying habitat conditions result in a highly fluctuating and a sometimes nonexistent *harvestable surplus* to steelheaders. Five years of intensive study of the Keogh River on northern Vancouver Island has indicated such wide fluctuations. The Salmon River on Vancouver Island is considered an example where the harvestable surplus in a low intensity fishery for winter steelhead was largely eliminated as a result of past clearcutting and roadbuilding practices that have greatly accelerated sediment and debris transport in the mainstem and its main tributaries (R.S. Hooton, pers. comm.).

Fig. 2. Interaction of two intensities of fisheries with habitat impacts from poorly integrated land use: increased sediment and debris and greater peak freshets in Stream A from Fig. 1.



This scenario for stream A remains controversial to some because it is difficult to demonstrate owing to site specific conditions and complex interactions of various fisheries and habitat impacts. Assuming it does occur what *integrated practices* can be employed to minimize and/or compensate for this impact? There are several, but these can be grouped into three techniques: (1) watershed protection, (2) watershed stabilization, and (3) stream restoration and enhancement.

WATERSHED PROTECTION: PREVENTATIVE TECHNIQUES

There is some opportunity for public input into forest harvest planning within watersheds because the regulatory authority has been delegated to a public resource agency who works cooperatively with the forest industry, and fisheries and water agencies. Some primary sources of impacts on salmonid production can thereby be identified during the planning process and measures incorporated to minimize or offset them. It is considered by fisheries researchers that the closely interrelated effects of freshets, debris movement and stream sedimentation are the major causes of reduced survival rates of the various life stages of salmonids that inhabit streams in the Pacific northwest. Secondary impacts can occur by disturbance of the streambanks, although some manipulations of streamside vegetation are considered beneficial.

MINIMIZING INCREASES IN AUTUMN-WINTER FRESHETS

Increased mean monthly flows have been demonstrated by studies of intensive clearcutting of coastal watersheds in Oregon. Such treatment may provide some benefits to salmonids by increasing summer low flows, although in some cases low flows can be reduced by accumulations of gravel in the streambed as occurred at Robertson River on southern Vancouver Island (T.G. Northcote, pers. comm. 1979). Peaking or storm flows are also increased by intensive clearcutting and is caused primarily by increasing the rate at which water moves to watercourses (Moring 1975). A similar effect on peak spring flow can occur by increasing snow melt in interior watersheds if the proportion clearcut approaches 100% (Goodell 1959).

More recently, some studies have estimated that clearcutting in elevations of snow accumulation in the coastal regions can theoretically increase water input to the soil by up to 22% (Harr and Fredricksen 1979) and 60% (Toews and Wilford 1978). This second type of run-off is caused by warm winds and heavy rains on snow and occurs in both disturbed and undisturbed watersheds during the autumn to winter seasons. For example, the notorious floods of 1974 and 1964 to 1965 in Oregon caused 70 and 120 million dollars in flood damages. Similar flood events have occurred in British Columbia in late 1975 and early 1976 on Vancouver Island and the Fraser Valley, respectively. Clearcutting accelerates this process because more snow accumulates and melts more rapidly in clearcuts than in forested areas.

These two processes that affect freshets can be additive in coastal streams, causing widening of stream channels; extensive movement of debris, gravel and sediments, requiring about 25 years to stabilize. As a guideline forest hydrologists have, therefore, recommended a maximum 33% harvest rate per 25 years in upland watersheds, although a more rapid harvest rate may be acceptable in lowland watersheds (e.g. Toews and Wilford 1978). Accordingly, public groups can become involved in the planning process to minimize these impacts. Recommendations to the appropriate public agencies in advance of cutting plan approval could alter the rate of timber harvest, particularly where extreme upland clearcutting is proposed for important salmonid watersheds.

PREVENTION OF DEBRIS-AVALANCHES AND LANDSLIDES

Road planning should minimize the potential for both avalanches and torrents or what is referred to as 'mass wasting'. Studies have demonstrated that most of these events are caused by incorrect road engineering involving culverts, road location and excessive fill slopes (Swanston 1971; pers. comm. 1979). Debris torrents, which are common in coastal B.C., are caused on steeper slopes by the practice of diverting one or more small watercourses along road ditches into a single watercourse to reduce culverting costs (B. Willington pers. comm. 1979). The channel becomes severely overloaded at peak run-off and sluices into the mainstem stream depositing large quantities of debris, gravel and sediment. In addition, significant productive forest land is lost for several years. Another protection measure that can be planned into road engineering is the use of a greater frequency of culverts to minimize erosion of ditches and road surfaces, especially on steep grades (e.g. Packer and Christensen 1964). Roads can also be outsloped as a practice to divert water into natural vegetation and slash, thereby reducing culverts (Forest Club 1971). Splash aprons (rock, debris) at culvert outfalls or culvert extensions can be used to eliminate erosion of large fill slopes.

Hydrologic planning of road and landing locations, and the seasonal timing of construction are important means of minimizing erosion. Unstable slopes or land forms can often be avoided or worked in the dry season, thus avoiding earth flows or slumping into water courses and loss of productive forest lands. Swanston (1971; pers. comm. 1979) estimates that at least 50% of these are predictable in coastal areas and result from water accumulation in overloaded fill slopes. Filter strips of vegetation and slash can be maintained between roads and watercourses and are one of the most common practices for reducing overland flow of sediment into streams (e.g. Packer and Christensen 1964, Slaney *et al.* 1977). Use of land form inventory for selecting the locations of primary roads, secondary roads, skid trails (interior), and landings can also reduce sediment transport. Roads can occupy 15 to 17% in high lead logging (Toews and Wilford 1978) and 25% in tractor logging areas and neither type of operation is conducted without some sediment production (For. Club 1971). Circumventing unstable land forms, comprised of highly sloping deposits of sand and silt, and use of filter strips can greatly reduce sediment loads in streams.

Unfortunately, the general public can obtain only limited involvement in the planning of these measures to minimize debris avalanches, landslides and mass erosion. However, greater formal recommendations from forest company staff or union groups, who are often comprised of enthusiastic members of the angling public, would be a major advancement for improving engineering layouts of road systems.

STREAMBANK VEGETATION

Streambank vegetation affects streams and salmonids in several ways. Shade reduces water temperature at very low summer flows and may moderate extreme winter temperatures. Roots of trees and shrubs maintain the integrity of the stream banks, reducing erosion and favoring formation of cutbanks and slower pockets of flow ideal for salmonid rearing. Leaf litter contributes to the food web in the stream and terrestrial environments supply much of the food energy to small coho streams (e.g. Narver 1974). Deciduous trees are preferred to conifers owing to leaf breakdown by bacteria and fish food insects, although some mixture of conifers may be beneficial for insulation during winter low flow periods. Alder, in particular, is valued because of its ability to fix atmospheric nitrogen which becomes available to the stream from decomposing leaf litter, thus promoting algal growth and litter decomposition at the base of the salmonid food web (e.g. Kaushik and Hynes 1971).

Directional logging can be planned in the streamside zone both to reduce the input of debris and sediment, and to maintain or promote streambank vegetation. In specific sites (generally small streams where the water is too cold) selective thinning of a closed canopy of streamside trees should maximize production of the fish food web and improve growth of salmonids by moderately increasing water temperatures. Carried further in the future this concept could involve nutrient additions because streams rich in phosphorous and nitrogen have up to five times the rearing capacity of infertile streams, a subject of current research activity. Future integrated management of forest and fish resources could involve coordinated planning of forest fertilization with stream and lake fertilization.

Public groups, working in cooperation with a fishery agency, the B.C. Forest Service and forest companies, can greatly influence what type of vegetation is maintained or enhanced in the stream edge zone. Where most commercial conifers have been logged and few deciduous trees occur along the streambank, planting of rapid growing trees would be a wise, long-term investment, analogous to the restocking of cutting blocks with preferred conifers. Native species of alder seedlings and willow cuttings should be planted within a narrow zone at the edge of the bank. Although willow, and in some areas cottonwood, will readily sprout from cuttings, there is a risk on small, low gradient streams of willow roots encroaching on the streambed (H.J. Mundie pers. comm. 1979). Integrated management of the streambank zone is in an early stage of development. Although the benefits to salmonids are not obvious, and in addition are complex to demonstrate, public involvement would greatly stimulate more intensive management of streambanks in British Columbia.

WATERSHED STABILIZATION

Stabilization techniques can be applied to both undisturbed and land-use watersheds. Water quality can be improved thus improving salmonid survival rates and the available *harvestable surplus* of salmon and trout. Two types of erosion are evident within watersheds: upland and stream channel.

UPLAND EROSION

Vegetative stabilization of eroding slopes can be highly successful in reducing both stream sedimentation and the loss of productive forest lands to continuous erosion and mass wasting (slides). Cut and fill slopes of eroding materials (e.g. sandy-silty loams) can readily be stabilized by seeding with selected grasses and fertilizing. In coastal regions,[1] species include: Alaska clover (poor soils), white Dutch clover (sandy soils), perennial rye (rapid growth when applied in spring and autumn), Timothy (suited to wet areas), reed canary crass (periodically flooded areas), creeping red fescue (ideal soil binder) and fall rye. Steeper slopes require more intensive treatment including mulching with organic fiber and planting of fast growing trees. Where slopes are very steep, terracing and/or covering with woven jute prior to seeding may be necessary to arrest a continuous erosion problem.

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[1] Landscape architects from the provincial Ministry of Highways can provide advice on the appropriate species for any other region in British Columbia.

If soils are unstable, temporary or spur roads on the coast and skid trails in the interior should be rapidly converted to a stable vegetated condition to reduce erosion and recover productive forest lands. Successive 'water bars' of gravel ridges have been used effectively to reduce the erosive energy of water that cause rills in sloping temporary roads. Thus, water carrying sediment is directed laterally into adjacent vegetation and slash.

Public involvement in upland stabilization would have considerable impact on reducing sediment transport into streams. Eroding cut and fill and slopes of roads and slide areas can be readily seeded with grasses and restocked with rapid growing trees, in cooperation with the Forest agency and industry. Costs of grass seeding and fertilizing are low ($50[1] to $500[2] per acre of slope; Wilford 1974). The technique can reduce sediment in streams (Slaney *et al.* 1977) and will contribute indirectly to increasing the harvestable surplus of salmonids (see Fig. 2).

STREAMBANK EROSION

Natural eroding streambanks and those exposed by increased freshets and debris accumulation resulting from land-use, can add substantially to the sediment load and its deposition in salmonid habitat (e.g. Anderson 1971). Large banks consisting of sand and silt are main sources, particularly on rising flows, and several techniques are applicable to stabilizing these sites. Walls of log cribbing, gabions or quarry rock can be constructed by public groups to stabilize these banks and if they are built of coarse material, protruding into the current, improved salmonid rearing capacity is a secondary benefit. Boulder or gabion wing deflectors (similar but less angled and complex than depicted on page 12) are effective in diverting the higher stream flows away from large eroding banks in rivers, but protection of the opposite bank is usually necessary. Combining these structures with vegetation (e.g. willow cuttings) at the base of the slope assists stabilization.

STREAMBANK RESTORATION AND ENHANCEMENT

RESTORATION OF SPAWNING BEDS

In some streams spawning gravels and other materials become highly *impacted* with sediments because of chronic input from various sources. Higher flows and spawning of fish gradually remove this material and transport it out of the system, but it is replaced. However, after erosion points are stabilized in the watershed, the removal process can be accelerated in spawning areas by *renovation techniques* at higher flows. This is carried out annually in some spawning channels by using sophisticated "jetting devices", but also can be done with a simple pipe (diameter 2.5 cm and 100 cm in length) sometimes fitted with a simple venturi valve to provide a high velocity mixture of water (from a fire pump) and air. The pipe is worked systematically across and down gravel riffles, especially in the preferred spawning area at the head of riffles (e.g. Wightman and Taylor 1979). Another simple, although untested method for renovation of

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[1] Includes labour costs which could be excluded through public involvement.

[2] Higher costs are incurred if hydromulching and seeding is employed, although mechanical methods are more effective.

fine gravels is a roto-tiller (M. Brownlee pers. comm.). There are, however, several provisions for success and preventing damage: (1) the work must not be conducted during spawning and incubation periods (i.e. restrict to summer, (2) flows are high enough to flush and re-flush sediment progressively downstream into sloughs, ponds, swamps, or other acceptable areas. A more recent refinement of the pump method is a second suction pump that collects the extruded sediment and sprays it into adjacent vegetated areas. The technique at this stage of evaluation is most applicable to spawning areas of nonrearing species (i.e. chum, pink salmon, and kokanee) and can reduce rearing habitat and food webs if overzealously carried out without guidance from experienced fishery staff.

OBSTRUCTIONS TO FISH PASSAGE

In British Columbia, obstructions to fish passage are mainly natural waterfalls, chute rapids, and to a lesser extent debris-bedload falls, log jams and beaver dams. Various methods from simple hand work with levers, winches and slings, to selective blasting, to elaborate fishways, have been developed to provide fish access into barren or under-utilized areas. These methods are described and illustrated in detail in the SEP Stream Enhancement Guide. Logging and construction companies frequently have the equipment and the expertise to conduct this type of work with some guidance, and company staff have recently proposed a major project on the Queen Charlotte Islands. The pool and weir fishway at Millstone Creek in Nanaimo is typical of what can be accomplished by a fish and game club using a 'jack hammer' and some guidance from fisheries staff (e.g. Fig. 3).

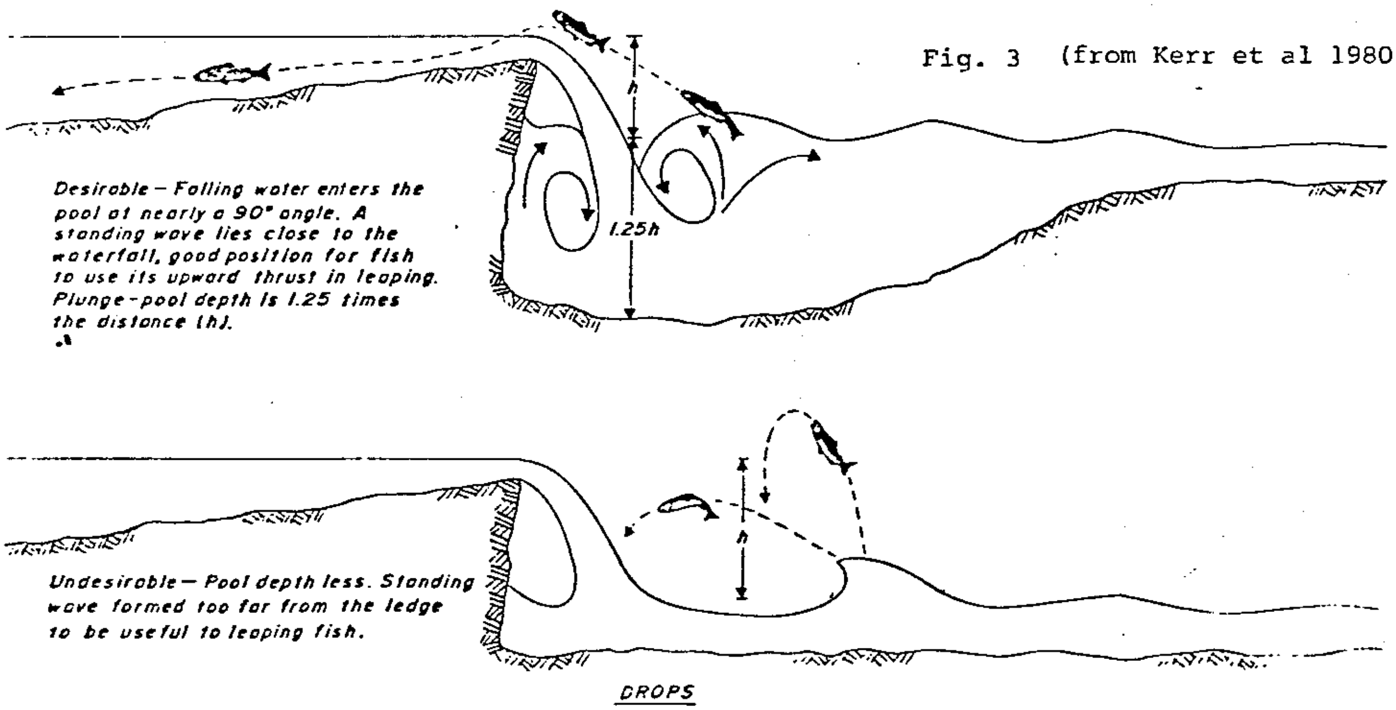


Fig. 3 (from Kerr et al 1980)

Desirable – Falling water enters the pool at nearly a 90° angle. A standing wave lies close to the waterfall, good position for fish to use its upward thrust in leaping. Plunge-pool depth is 1.25 times the distance (h).

Undesirable – Pool depth less. Standing wave formed too far from the ledge to be useful to leaping fish.

Culverts can be a man-made barrier to salmonid migration, and can be easily overlooked, eliminating fish access to a stream system. They can also prevent dispersal of juvenile fish into traditional summer rearing or over-wintering areas including small backchannels, spring ponds and tributaries where survival is much higher than in the mainstem (Bustard and Narver 1975). Design criteria are available in the Stream Enhancement Guide including specification on capacity, slope, grade, pool and tailwater control, and insert baffles. The pool and tailwater control is generally the main problem but can be easily corrected (Fig. 4), and baffles can be installed to assure fish passage at existing culverts (Fig. 4). Quarry boulders have also been used successfully as baffles in the bottom of some large culverts and are used for rearing by juvenile salmonids (D. Hjorth pers. comm.).

IMPROVEMENT OF REARING HABITAT

Juvenile stages of chinook and coho salmon, steelhead and cutthroat trout, and char rear for extended periods in streams, and some stocks of trout and char are permanent residents (Table 1). Habitat requirements vary with species and fish size, but all require a feeding location at suitable water velocity, an associated current carrying drifting insect food items, concealment from predators and competitors and refugia from extremes of flow and ice formation. Juvenile rainbow, steelhead, cutthroat and char prefer faster velocity areas (particularly bouldered runs and riffles in the yearling or 'parr' stage) until winter or when they reach a large size when deep pools are more important. Juvenile coho salmon prefer slower pool or back eddy pockets, and chinook salmon fry move gradually from this habitat into cobble or boulder areas as they grow larger. Many streams have a dominance of extended riffles with few rearing pockets, small pools or runs, back eddies, or large boulder substrate that would maximize both rearing capacity in summer and over-winter survival during major freshets and ice formation.

Provision of devices that increase the rearing or 'carrying capacity' of the stream, produce more resident fish or sea-ward migrating smolts (Hunt 1969; Ward and Slaney 1979). Successful programs have been carried out in eastern, central and western interior states (Hunt 1969; White and Brynildson 1967; Parkinson and Slaney 1975). However, unsuccessful attempts 40 years ago in California, and a strong emphasis on hatchery programs, prevented further development. More recently, durable structures were developed and evaluated under rigorous west coast conditions, suggesting they are cost-effective when installed correctly in groups or clusters in prescribed sites of extended riffles and shallow runs that lack boulders (Fig. 5).

Appendix 1 outlines details of prescribing and installing of these structures, but should only be attempted with guidance of experienced fisheries staff. As a preliminary rule of thumb, each boulder produces about 1.5 steelhead and 2 adult coho in infertile coastal streams and 7 steelhead and 10 coho in rich streams, assuming 20 years durability. Some associated scouring appears to be required for coho utilization. Wing deflectors (Fig. 5) can also be installed, preferably in association with boulder groupings to prevent shifting of the wetted channel away from the structure. In small stable streams inhabited by coho salmon and cutthroat trout, smaller boulders can be moved by manual methods and used successfully to increase fish abundance (R. Ptolemy pers. comm. 1979). This approach has been used more recently at Hyde Creek and Bear Creek in the lower Fraser Valley, in part by using the assistance of correctional inmates.

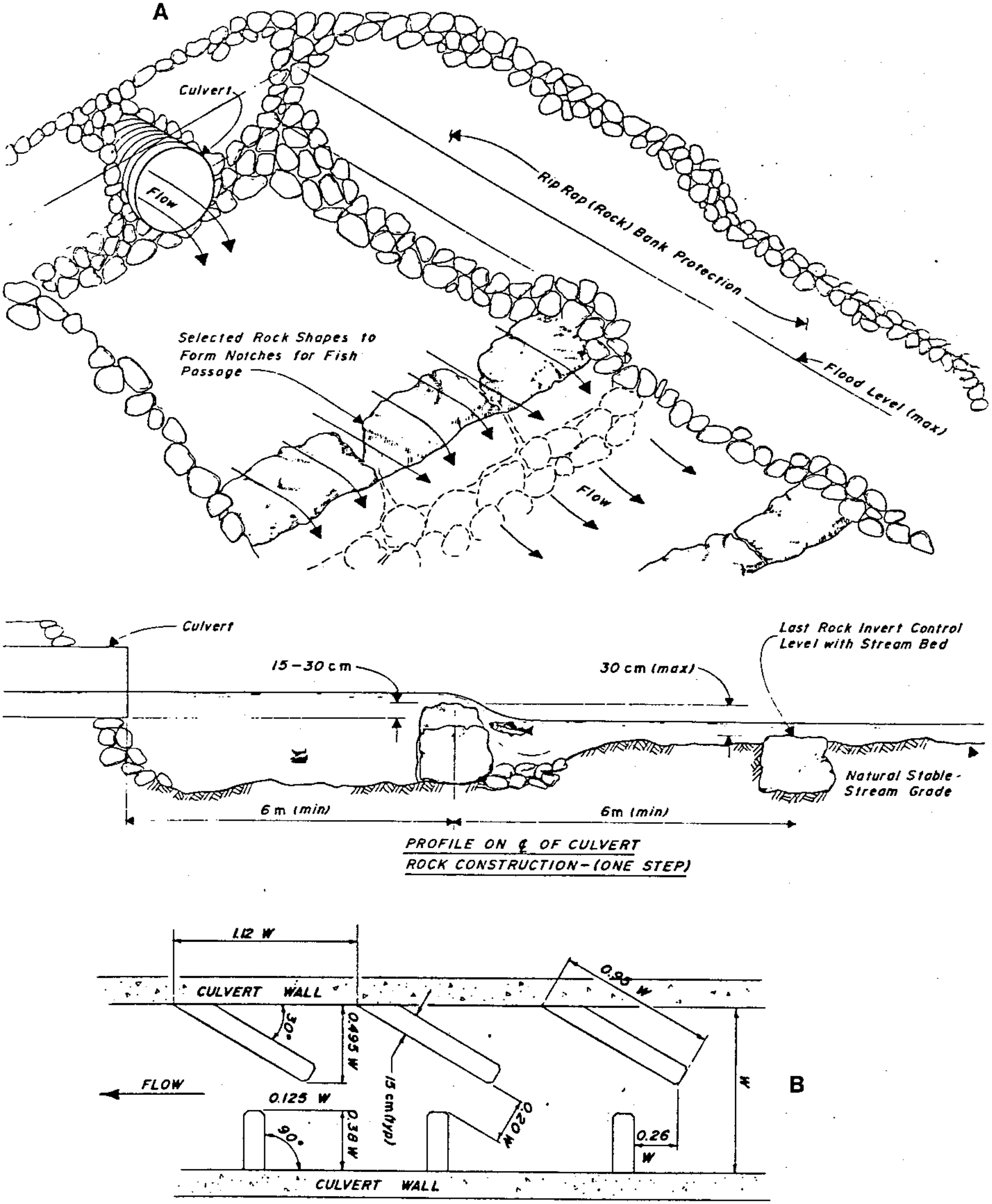
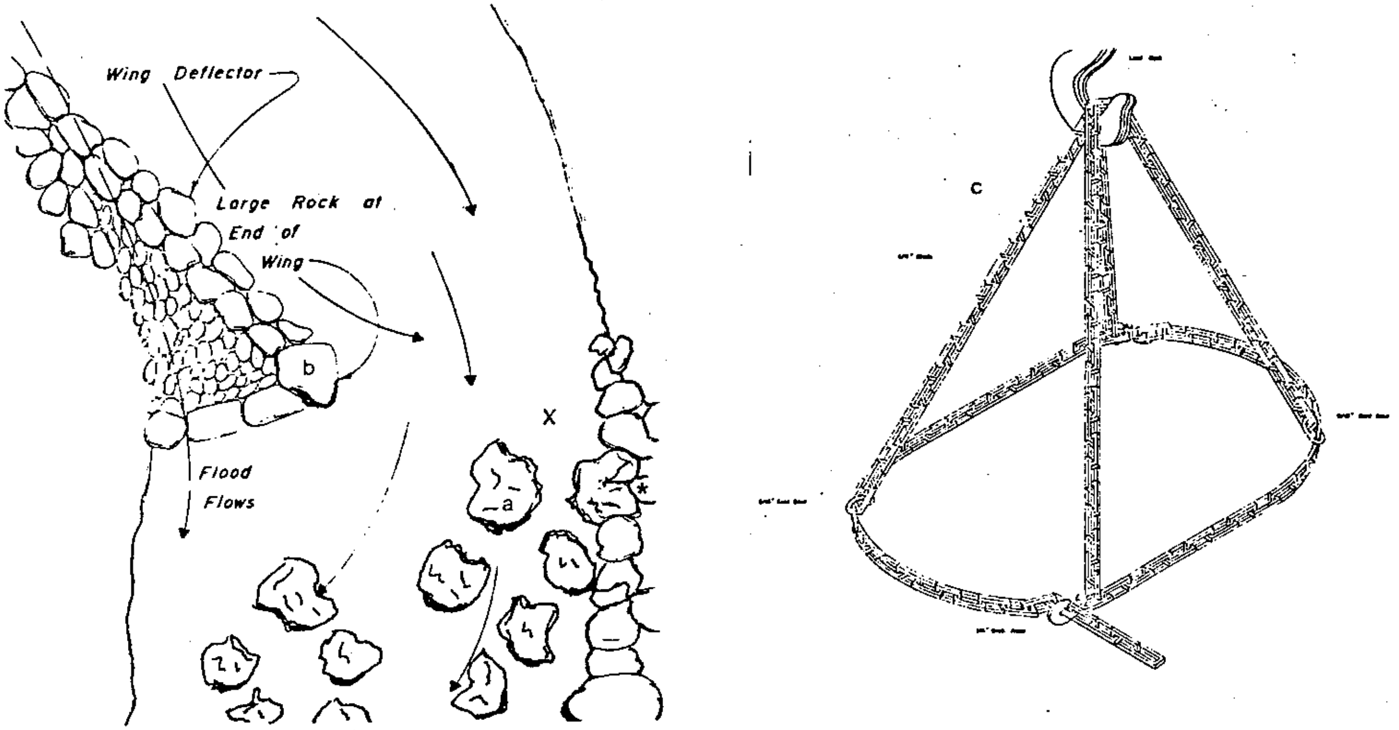


Fig. 4. Culverts frequently impede upstream passage of adult and juvenile salmonids. Most problems are caused by a lack of an outlet pool, corrected as in (A), or velocities are too high within the culvert, corrected as in (B) by attaching offset baffles (from Kerr *et al.* 1980).

Fig. 5. In-stream enhancement structures: (a) boulder grouping or cluster to provide salmon and trout rearing pockets and cover; (b) boulder wing deflector used to create deep pool at (x) and wing used where required to ensure durability of boulder grouping; (c) Tsumura bridle used to sling and lift large boulders during placement by helicopter. The deflector (b) and its revetment (*) is only required where there is a risk of the wetted channel diverting away from the boulder groupings. See Appendix 1 for details.



Large boulders are usually installed with a rubber tire loader in accessible areas, by moving along dry bars to the prescribed sites. Machine access is frequently not possible, but a helicopter with an 800 kg capacity can be used to transport boulders, slung in a Tsumura bridle (Fig. 5). Provided the helicopter operation is conducted efficiently, costs are comparable to a loader, but there is no damage to banks or compaction of stream gravels. Forest companies, mining companies and the Ministry of Highways are frequently in a position to contribute culled quarry rip-rap or boulders, as occurred at the Keogh River in 1977 to 1979, or 'off-season' use of a loader as occurred in 1980 at the Salmon River on Vancouver Island. The best example of public involvement in stream enhancement occurred recently at Springer Creek, a tributary to the Salmon River, where about 1/2 km of salmon and trout rearing habitat was improved with 650 boulders in small clusters. Twenty-four individuals from the local community with guidance of two fishery staff moved the devices into place after equipment donated by the Ministry of Highways, a forest company and a local contractor hauled and unloaded the material. Future cooperative projects involving industry, public groups and fisheries staff may carry this integrated concept further, including use of unused, contracted helicopter time to improve less accessible habitat and thereby survival of salmonids.

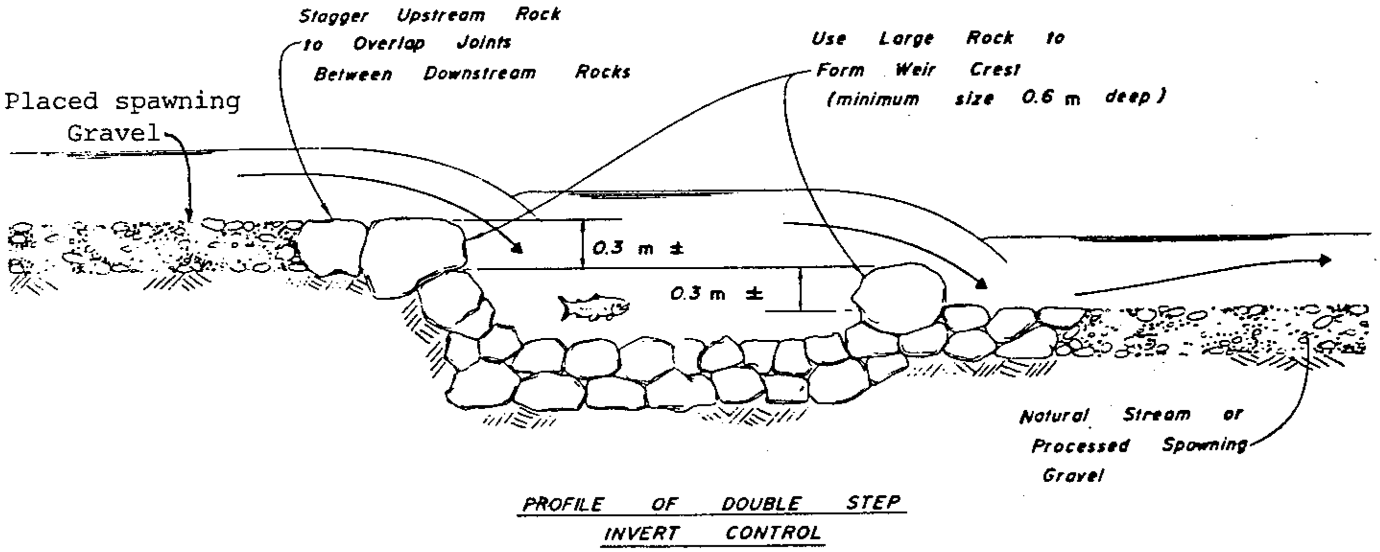
Similar techniques, including addition of secured overhead cover in streams, are described in the Stream Enhancement Guide, although some have not been adequately evaluated in the rugged conditions of west coast streams.

DEVELOPMENT OF SPAWNING AREA

Some stream reaches have few spawning areas in the mainstem and spawning may be restricted to small tributaries. Species rearing for extended periods in streams are not usually limited in abundance by the availability of spawning habitat because the amount of rearing space generally limites the annual numbers of seaward migrants. However, those reaches of streams classed by experienced fishery workers as 'gravel poor' can, in some instances, benefit from additions.

Placement of gravel has been relatively unsuccessful in streams owing to hydraulic washout. However, successful placements can be made in some sites: (1) stable lake outlets, (2) stable side channels not subject to flooding each year, and (3) ground water fed streams receiving limited run-off. Rock weirs, and to a lesser extent, log weirs are most suitable for retaining gravel and maintaining a natural appearance. Up to 30 cm depth of gravel comprised of little coarse sand, and no fine sand, silts or clays can be placed upstream of these structures (Fig. 6). A reach of stream at the outlet of Chilliwack lake received gravel additions and the cost of the project was reduced markedly by public assistance (R.J. Finnigan pers. comm.).

Fig. 6. Placement of platforms of spawning gravel in stable stream sections. Boulder weir is used to retain gravel; abutments must be protected with rip-rap to prevent scouring (adapted from Kerr *et al.* 1980).



It is a serious conflict, though, to create spawning areas by destroying prime rearing habitat that was formed by stable forest debris. Some well intended "stream clearance projects" on the Pacific west coast have inadvertently reduced salmon and trout rearing habitat by overzealously clearing debris from chum, sockeye and pink salmon spawning areas.

Side channel development, which in its simplest form involves opening closed side channels (particularly those fed by ground water) can make substantial gains in this productive and preferred habitat for chum and coho salmon. An example of a recent cooperative effort between a forest company, and a fisheries agency occurred at the Vancouver River in Jervis Inlet where past logging practices inadvertently closed off side channels and channelized flow into the mainstem (D. Marshall pers. comm.).

FLOW CONTROL

Fish production is also affected by stream flow because as wetted width and velocities decrease during droughts, rearing and spawning capacity decreases. The latter can also occur during extended freezing periods and marginal deposits of eggs can be frozen in the gravel. Therefore, additional benefits to salmonid production can be achieved by increasing flows during these periods. Carried further, some control of peak freshets is possible, for example Big Qualicum River, but these opportunities are rare and complicated. Storage of water for low flow control can be granted approval by the provincial Water Management Branch which acts as a referral agency to interested groups and fisheries and forest agencies. This agency also ensures the design is structurally sound from an engineering perspective. The number of cfs days gained from storage of water within a lake or ponds can be calculated by the use of the equation: no. of cfs days = lake area (acres) x available storage ÷ 2 (Kerr *et al.* 1980). One of the more successful small projects was carried out by a conservation society at Demaniel Creek at Victoria.

SUMMARY

In summary, there is an exciting, broad scope for public or industrial involvement in improving land-use practices, and for application of watershed stabilization techniques, thus leading to the benefit of a greater *harvestable surplus* of salmonids in addition to some gains in forest production. Direct improvement of salmonid production is also possible through various stream enhancement techniques, which are most effective when both natural or man-made problems within watersheds are corrected.

Increased *harvestable surpluses* of our salmonid species can be *partly* achieved through this integrated approach to multiple resource management. However, public involvement can only assist in turning around the decline of many of our salmon and trout stocks; there must also be a similar commitment by all commercial and sport fishermen. We must also accept greater voluntary kill reduction of sport fish and greater commercial fishery restrictions, such as phasing more to terminal fisheries (ie. away from multi-stock fisheries). "Biting the bullet" with tough fishery closures can also assist in rapidly building stocks to historical levels, as has been effectively demonstrated in 1980 in Alaska.

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Appendix 1. Guidelines for In-stream Structures to Improve Steelhead Parr and Coho Fry Rearing Habitat (from Ward and Slaney 1979)

In this study, boulder groupings were the design most highly utilized by salmonids and, in addition, the most cost-effective. Several guidelines are evident from the experience gained in selecting sites, placing structures and evaluating durability and fish utilization. These guidelines are directed at boulder groupings and secondly to wing deflectors where the latter is necessary to ensure channel stability and durability of groupings. Guidance from a biologist or technician who has experience in this type of stream enhancement technique, is advisable both in the prescriptive and installation phases.

PRESCRIPTIVE PHASE

1. Determine, *apriori*, if fry density (i.e. fry recruitment) is adequate to completely utilize existing and potential rearing habitat. Efforts to increase summer and winter habitat of steelhead parr and coho underyearlings could be unsuccessful or premature if few fry are initially available to utilize or subsequently move into the structures.

   Critical levels of fry abundance, either in density or biomass, are difficult to ascertain, but an estimate could be made by systematic electrofishing and/or pole seining in 100 m sections of diverse pools and riffles. There is no definitive level and it would vary, regardless, as a function of stream benthic productivity, complexity of rearing habitat and expected magnitudes of freshets. Based on preliminary data from the Keogh River, average minimum densities of steelhead and coho fry during July that appear minimal relative to subsequent smolt production are $0.2/m^2$ ($20/100\ m^2$) and $0.3/m^2$ ($30/100\ m^2$) respectively. Comparative lineal densities would be 1.7/m and 2.6 m respectively. The latter would vary with stream width and be more useful on larger streams, where fry utilize margins more exclusively. Also, for steelhead, comparison of age 0+ and 1+ densities can be instructive, unless the stream has had poor fry recruitment for more than one year.

2. The stream should be inspected during average summer flow and, if possible, maximum and minimum flow to record the dominant thalweg, unstable sections and to quantify available rearing habitat. Each reach should be classified into pool, run or riffle, estimating by area (more detailed division by gradient, depth and width is desirable):

   a) length of pool, run or riffle
   b) mean depth of each habitat class
   c) per cent in-stream protruding boulders (> 30 cm, creating rearing space behind them)
   d) per cent in-stream logs and debris
   e) per cent over-stream 'cover' > 1 m from the surface; cutbanks, over-stream logs and roots, and vegetation.

   Ground and low level aerial photography is useful in reaches where the stream is visible through the forest canopy. The latter can be used for mapping sites for various structures.

3. Prescribe in-stream enhancement structures for sections of stream reaches that have: a) a dominance of riffle over pool, and b) where riffles are comprised of coarse gravel to cobble substrate, with few boulders and other associated 'cover'.

4. Prescriptions should emphasize multiples of boulder groupings within the wetted width of the stream, utilizing other designs, i.e. wing deflectors, only to ensure stability of the thalweg.

SITE SELECTION FOR BOULDER GROUPINGS

Each section of stream will require modification of techniques according to channel configuration, stability and velocity.

1. Avoid braided, unstable sections because durability of structures could be less than five years.

2. Minimize placements throughout slow velocity areas, i.e. shallow, non-turbulent pools or 'flats'. Structures in these areas will not significantly increase summer habitat of steelhead although may be beneficial for increasing over-winter survival. This also applies to deep pools and deep runs, because no correlation has been evident between summer carrying capacity of parr and frequency of boulders in the middle or head of pools and runs (Keogh River, data on file).

3. Large boulders (> 0.6 m diam) are recommended owing to their stability during freshets, and effectiveness both for use by steelhead parr and for scouring of rearing 'pockets' in the substrate. In sections where substrate is comprised mainly of cobble, velocities of 3 to 4 m/sec can be predicted for peak flows from standard hydraulics information. Boulders > 0.6 m are not transported at these velocities (placement of large boulders by helicopter requires a machine with a lift capacity of 800 kg or 1800 lbs).

4. Boulders must be placed in higher velocity areas that lack in-stream cover, i.e. within riffles and very shallow runs. Stream gradient at the proposed structure site must be greater than 0.2% to be most effective.

5. Avoid placement of structures, particularly boulder groupings, near the upper end of riffles. This will cause diversion around the structure and 'backwatering'. It is also desirable to maintain sufficient (e.g. 5 m) riffle leading into structures to maximize insect drift.

6. Establish in which direction the thalweg of the stream tends to turn and concentrate the groupings on the outside of the bend to minimize probability of the stream shifting, decreasing durability.

7. Boulders in groupings should cover the wetted width and be well spaced (ca. 1 m between boulders). Three to five boulders in a triangular configuration in staggered groups or clusters along the riffle or very shallow run appear to be most effective because each group guides turbulent 'overhead cover' into a downstream group.

8. In coarse substrate, i.e. cobble, pre-excavation of material at lower sides and downstream of boulders is necessary to create 'pockets', although preliminary data from 1979 suggests this is only a necessity for juvenile coho salmon.

9. Small log cover, cabled securely and tightly into the lead boulder in each grouping may promote higher utilization although this has not been confirmed. No log ends should project during higher water levels because serious snagging of floating debris will occur.

DEFLECTOR PLACEMENTS

Boulder groupings were found to be more cost-effective than deflector designs. However, in some hydraulic conditions (undefined or multiple thalweg) it can be advantageous to use a small wing deflector to guarantee high durability of groupings. Guidelines are as follows:

1. Keep the wing profile low to minimize bank scour and avoid catching debris (0.5 m maximum).

2. Locate the deflector down the riffle to avoid impounding of water.

3. Peninsular deflectors are more prone to bank and side erosion (creating backwaters) than triangular deflectors. The deflector will guide the current into the area where deepening is desired, amongst the groupings.

4. Deflector angle should be 45° if scouring is desired.

5. Revet the opposite or outside bank with 'rip rap' and place several larger boulders in the wetted channel to maximize salmonid habitat. In some locations, where the opposite bank is comprised of large stable materials, revetment is unnecessary, but addition of boulder cover is required.

6. Log cover, cabled securely and tightly into the lead boulders will increase salmonid carrying capacity of the revetment. Potential for snagging floating debris can only be minimized by ensuring the cover is submerged at high flows.

Accordingly, structures should be designed and located to maximize structure durability and salmonid utilization. Cost effectiveness, compared to other enhancement options, can only be attained where there is adequate fry recruitment, a significant lack of in-stream cover, particularly few boulders in extended riffles, and a stable thalweg within the stream channel.