Once the likely runout (down slope consequences) of a specific road fill failure are known, it is possible to calculate the opportunity cost of "letting nature take it course," or only taking very modest measures to reduce the likelihood of slope failure. Conventional wisdom in the forest sector is that:

- it is rarely cost effective to stabilize road fill that is incapable of triggering a landslide causing <0.05 ha of soil disturbance, or of terminating within a fish bearing, or community watershed, stream;
- it is generally cost effective to prevent road fill failures that would disturb significant quantities (>0.05 ha) of immature regenerative forest, although the pay-back period on such an investment could approach 100 years; and
- it is almost always cost effective to prevent road fill failures that could affect significant quantities of salable timber, fish bearing streams, advanced regenerative forest, homes, highways, railroads, utilities (hydro, gas, fibre optic lines), or forestry bridges.

However, the landslide depicted in the photograph in Figure 3, for example, had numerous severe downslope consequences including the depreciation of an estimated half million dollars worth (about $100 000 stumpage value) of standing timber, and heavy sedimentation of a fish-bearing stream. Thorough deactivation in a timely manner of the roads that produced the slide, would have been a sound forestry and watershed conservation investment.

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Evaluating Resource Benefits from Hillslope and Stream Restoration Programs

Brian L. Scarfe

A. Screening Criteria for Restoration Projects

The fundamental goal of the Watershed Restoration Program (WRP) is to restore, protect and maintain fisheries, aquatic, and forest resources that have been adversely affected by past logging operations. Although a project's rehabilitation costs can be measured in reasonably straightforward ways, the multiple resource benefits that are associated with these projects are time-dependent, and may be uncertain. The restoration of aquatic resources involves improvements in the quality of stream-flows, fish-rearing habitats, riparian forest lands and associated wetlands. It also involves the reduction in hillslope erosion through road-bed restoration, the restoration of forest cover with appropriate species selection and, wherever possible, the restoration of natural drainage channels. Aquatic rehabilitation and forest regeneration are often both required to restore recreational values.

This paper describes in detail a *net present value* (*NPV*) approach to project screening and ranking of a potential set of projects, a necessary approach given that the potential resource benefits associated with aquatic rehabilitation and forest regeneration accrue only gradually. This approach can be used to assess these potential resource benefits and to weigh them against project costs. The *NPV* valuation method can be used to assess the relative merits of alternative rehabilitation projects, or to assess the potential benefits of an integrated restoration program for an entire watershed.

This paper complements my chapter in Fish Habitat Rehabilitation Procedures: WRP Technical Circular

No. 9 (Scarfe 1997). In that chapter, I presented a multiple account evaluation framework for screening watershed rehabilitation projects. The framework relied upon three filters. The economic benefits filter and the environmental standards filter (consistent with the rehabilitation goals of the WRP) evaluate the necessary conditions for project approval and support, and an employment generation and community stability filter acts as a “tie-breaker” when the economic benefits filter provides uncertain results. I further outlined various economic values that can be used in the overall assessment of the fisheries, forestry, recreation, and other benefits of rehabilitation projects, thereby allowing these benefits to be balanced against the costs of such projects. I identified an appropriate *social rate of discount* for the *NPV* calculations that are ordinarily required in assessments of restoration projects and investments in resource conservation (Scarfe 1997).

B. The *Cost-Benefit* Criterion

Specific investments made today in ecosystem restoration have multiple outcomes that may (with some degree of uncertainty) accrue in the future. There may be a potential gain from the recovery of fish stocks available to the commercial, aboriginal and/or recreational fisheries. There may be a benefit from the renewed availability of clean water, from both instream use and consumptive use perspectives. Recreational values may be enhanced by an increased abundance and variety of the flora and fauna of the particular watershed. Forest values may also be enhanced, if watershed restoration activities enable harvestable timber to regenerate more quickly.

In principle, for each relevant future time period, each of these potential gains should be measured and evaluated, and then aggregated into a single time-specific sum before the whole stream of time-specific sums is discounted back to the present using an appropriate discount rate. The present value of the potential resource benefits should then be netted of the present value of the costs of the ecosystem restoration project. In principle, only those projects with positive *NPV*s should be undertaken. Projects with higher *NPV*s should be given preference over projects with lower *NPV*s.

Applying this fundamental *cost-benefit* criterion will guide investment to those projects capable of producing a positive *NPV*. However, the application of this criterion is fraught with difficulties. This paper focuses on methods that minimize these difficulties and thereby enhance the usefulness of the *cost-benefit* criterion. This may be accomplished by applying a number of *rules of thumb*.

The first of these *rules of thumb* is that all calculations should be undertaken in real, or inflation-adjusted, terms and that the appropriate discount rate should be a real discount rate. Discounting converts all resource costs and all resource benefits to dollar values that pertain to the present. For conservation investments, whose goal is the restoration of natural resource capital, a real discount rate of three percent per annum is appropriate. This figure represents the economist's best guess of the social rate of discount, a rate similar to the real rate of return on secure longer-term financial assets such as Government of Canada bonds. This rate is much smaller than the after-tax *hurdle rates of return* that are ordinarily used in the assessment of private sector investments in buildings and equipment.

A three percent real discount rate reflects the fact that most investments in environmental restoration reduce future economic risks by leaning against the tendency for economic development to erode the abundance and diversity of our natural resource assets. It also reflects the fact that, as the pressure on environmental resources intensifies, these resources should appreciate in relative value. If there is a general risk in not undertaking investments in ecosystem health, or if there is an increasing value of ecosystem health to society, then a low rate of discount should be applied to the evaluation of investments in environmental restoration. Three percent per annum seems to be appropriate; discount rates lower than this are not recommended, as it would be unreasonable to use a discount rate significantly below the governmental borrowing rate.

C. Some Simplifying Assumptions

The second *rule of thumb* relates to the quantification of resource benefits. This rule specifies that all biomass additions which may result from an investment in resource conservation be counted as benefits to be valued, without regard to the proportion of each biomass addition that is actually harvested. Since it is necessary to value the entire addition to each resource stock that accrues to the conservation project in any given time period, harvesting rates need not be estimated in order to complete the *NPV* calculations required in *cost-benefit* analyses. The determinants of potential biomass additions are imbedded, nevertheless, within a larger, and inherently dynamic, bioeconomic process.

To place values on relevant biomass additions requires a third *rule of thumb*. This rule involves the assumption that the stock value, or *resource rental value*, of each additional unit of unharvested resource inventory is equal to the (possibly adjusted) net market value of each unit of stock when harvested (that is, the net *flow value*, or *user cost*, of consumed units of the stock, after due allowance is made for harvesting costs). This assumption is derived from the *equilibrium conditions* for a competitive natural resource market, when property rights to resource stocks are fully vested in private firms. Given this assumption, observable (but perhaps adjusted) flow market prices, net of harvesting costs (that is *resource rental values*), may be used to evaluate resource stock additions.

Such an assumption is implicit in most *cost-effectiveness* analyses of investments in resource conservation projects. In these analyses, it is normal practice to form a ratio between the quantitative increase in the biomass stock of a potentially valuable resource and the overall cost of the conservation project. This approach assumes that the value of each unit of the relevant biomass increase is the same whether the unit is consumed or left unharvested. *Cost-effectiveness* analyses, therefore, do not require the estimation of harvesting rates, since it is the entire addition to each resource stock that is to be counted and, implicitly, valued.

One of the main limitations of the *cost-effectiveness* approach is that it becomes difficult to use when there are multiple and diverse resource benefits to be counted, and somehow *monetized*, or otherwise aggregated, especially when these multiple benefits accrue at different rates. It is for this reason that the *cost-benefit* approach is to be preferred, since it forces one to attempt the *monetization* of various resource benefits. It is only by attaching value weights to diverse quantitative benefits that these benefits can be both compared and aggregated, and this is an essential requirement of *cost-benefit* analysis. Nevertheless, the second and third *rules of thumb* bring *cost-benefit* analysis closer to *cost-effectiveness* analysis, but without eschewing the robustness of *cost-benefit* analysis in the assessment of multiple and time-dependent resource benefits.

D. Adjustments for Market Failure and Uncertainty

The adjustments that may be necessary to net harvest values reflect the likelihood that *market failure* is present. For example, in the open access fishery, no single fisher pays attention to the user cost of catching an additional fish. As a result, actual *resource rental values* (or landings values net of harvesting costs) tend to be driven toward zero unless fisheries regulations are effective at preventing excess catching capacity from entering the fishery. However, it is rather an assessment of the *resource rental value* such as would exist in a properly managed fishery (that is, a fishery that assigns and prices property rights in a manner that appropriately reflects user costs) that is required for the evaluation of potential biomass additions. The literature (such as Boardman et al. 1996) refers to this *resource rental value* or *user cost* as a *shadow price*.

Where it is known that open access *market failures* have essentially dissipated *resource rental values* to near zero, it may be better to use the gross market value as an estimate of net market value, without deducting harvesting costs, than to use the distorted *resource rental value* of near zero in the *NPV* calculations that *cost-benefit* analysis requires. In the case of fisheries, the landings value would be used, because catching power may have become so potent that true harvesting costs would be small relative to landings value in a properly managed, and not over-capitalized, fishery. The use of gross market values would seem to apply to the valuation of enhanced Pacific salmon stocks, but not to the valuation of enhanced forest resources and various other resource stock additions, for which open access market failure is not apparent. However, better still would be to estimate the true *resource rental value* or *shadow price* of the resource, although this is difficult to do.

Uncertainty with respect to outcomes is best handled by the use of an *expected value* approach to the quantification of biomass additions and other potential resource benefits. In such an approach, a probability calculus is applied to alternative quantitative outcomes, using the best available evidence to assess the appropriate probabilities. The *expected* or *mean* outcome is then determined for each relevant time period. Captured in the assumption of a relatively low *social discount rate* of three percent per annum is the fact that decision-makers may be adverse to environmental risks. However, it will ordinarily be correct to undertake a conservation investment whenever the potential costs of not making the investment are unacceptably high. This is consistent with the *safe minimum standards* approach to risk management.

E. Harvest Values, Amenity Values and Existence Values

The three *rules of thumb*, as described above, should be used to estimate the *NPV* of the resource benefits that may result from the restoration project. The *NPV* of potential project benefits should then be compared with the *NPV* of project costs to determine whether or not the project should be recommended to proceed, or to assess the probable success of the project if it has already been undertaken. There are, however, some qualifications to the second and third *rules of thumb*.

All natural resources possess both use values and existence values. Use values accrue when trees are harvested or a forest is enjoyed for its recreational values. Use values also accrue when fish are caught or angling provides recreational pleasure. We shall refer to the first of these two types of use values, which arise from the direct consumption of the resource, as harvest values, and the second type as amenity values. Harvest values arise from the *flow* of the resource into consumption activities, whereas amenity values are derived from the *stock* of the resource that is used to support recreational or leisure-time activities. Both of these types of use values are to be distinguished from existence values.

Existence values accrue from the knowledge that forests are available to provide timber resources, to provide recreational enjoyment, or to provide shelter for numerous plant and animal species, whether or not these resources are in use at present. Existence values would also accrue, for example, from the knowledge that particular salmon stocks are not about to be extinguished by over-fishing or habitat destruction. These values are particularly important when endangered species are involved. However, similar to amenity values, existence values pertain to the resource *stock*, rather than to its *flow* into consumption through harvesting activities.

Conservation investments, that is, investments in environmental restoration, improve the *carrying capacity* of the environment. These investments may also improve *stock productivity*. The rehabilitation of fish habitat enhances the potential for growth in the biomass of particular fish species for both these reasons, for example. Successful investments in habitat restoration thus have the ability both to reduce the number of spawners that are required to fill the environmental capacity with viable progeny and to increase the harvest yields that can be sustained over time with proper management of the fishery. They also may enhance the overall *willingness to pay* for the amenity value of recreational fishing, as measured, for example, by the value of additional angler-days. Non-users may take pleasure in the knowledge that particular fish species have become less vulnerable to extinction. Thus, the resource benefits that result from successful investments in habitat restoration may include harvest values, amenity values and existence values.

Each of these potential resource benefits has both quantity and price dimensions. Quantitative impacts are specific to each restoration project, but prices are generic, since they transcend individual projects. Unit values for resource stocks that are harvested commercially can generally be obtained from actual transactions prices, which are directly observed, netted of unit harvesting costs, although these net resource values may require some adjustment in cases of *market failure*. The *willingness to pay* for recreational amenities (such as the value of an angler-day) can ordinarily be estimated by indirect methods such as the *travel cost method*. In both cases, market observations are used to estimate the unit values of these two types of resource use, although in principle amenity values could also be obtained from the questionnaire survey techniques of *the contingent valuation method*. On the other hand, existence values can only be measured by using the *contingent valuation method*. Indeed, since existence values refer to the *intrinsic value* as opposed to the *use value* of resource stocks, they are inherently *public good* values for which no market prices exist.

These three distinct types of resource values are, at best, only crudely captured in the *cost-benefit* methodology. The third *rule of thumb* assumes the equality between stock values and flow values, or between *resource rental values* and *user costs*. The *stock value*, however, only remains approximately equal to the (adjusted) net harvest value per unit, which is, in principle, generally observable in the market place, on the assumption that the unit amenity value and the unit existence value are sufficiently small so as to be subsumed within the *stock value*. This assumption may be appropriate in cases where the particular biomass stock is valued mostly for its commercial, rather than its recreational, importance and where the particular biological species is not in any danger of extinction.

Where it is applicable, this equality assumption implies that it is not necessary to separately estimate unit amenity values and unit existence values. Instead, these values are assumed to have been captured when (adjusted) net harvest values are applied to potential resource additions, and not just to increases in harvest volumes, in accordance with the second *rule of thumb*. However, amenity values and existence values (which may be available from published studies) should be used as a check on this assumption. (For example, a standard estimate used in the calculation of amenity values is that each recreational-day, such as an angler-day or adult-visitor-day, is worth approximately $40, so that the overall increase in amenity values is equal to the number of additional recreational-days that are generated by particular resource stock enhancements, multiplied by $40 per recreational-day.)

In some cases, one cannot assume unit amenity values and unit existence values to be small in relationship to *stock values* calculated from adjusted net harvest values. These values will then need to be estimated separately and added to the calculated *stock values*. However, *cost-benefit* analysis is often used only to compare the relative merits of alternative rehabilitation projects that have quantitative impacts on similar combinations of biological species, rather than to assess these projects from an absolute perspective. Existence values (and, with less frequency because they are more likely to be locationally specific, amenity values) may then net out in the project comparison. When this is the case, the preferred project would be that with the larger *NPV* when calculated using adjusted net harvest values.

F. The Valuation of Fisheries Benefits

Habitat improvements enhance the *carrying capacity* of the aquatic environment and improve *stock productivity*, thus providing potential fisheries benefits that should ordinarily be estimated in the following way:

> Let ***A*** be the wetted area in which habitat improvements are likely to occur, measured in hectares (kilometric length of stream-bed times the average wetted width of the stream in metres, divided by ten); let ***F*** be the likely impact per hectare of upgraded stream-bed in the particular watershed on the relevant fish stock (measured in terms of adult fish, which for anadromous species may require some estimate of average oceanic survival rates); and let ***T*** be the average weight in kilograms of adult members of the relevant fish species. Then ***AFT*** is the estimated growth in the biomass of the relevant fish species that potentially may result from the watershed improvements that are undertaken.

It should be noted that *AFT* is a steady-state number which may take several years to materialize. It should, once established, remain in place for a number of years given proper conservation measures. Although the actual harvesting rate should not exceed 60% of *AFT* if sufficient fish numbers are to survive for spawning, all fish biomass restoration should be counted, according to the second *rule of thumb*. This ensures that some consideration is being given to amenity values and existence values, as well as to harvest values. Thus, after some initial stock-building period, *AFT* is the quantitative fisheries benefit that is available in each year over the useful life of the restoration project.

The economic value of this quantitative fisheries benefit will depend upon the particular fish species in question. I have elsewhere recommended that the following resource rental values be used for various fish species in estimating the economic value of biomass restoration activities (Scarfe 1997). Thus, *AFT* should be multiplied by the appropriate member of these suggested price parameters for each time period in which the potential additional biomass is available.

Anadromous salmonid fish resources	
steelhead	$ 4.50 / kg
chinook	$ 5.00 / kg
sockeye	$ 5.00 / kg
coho	$ 4.00 / kg
chum	$ 2.50 / kg
pink	$ 2.00 / kg
Other freshwater fish resources	
kokanee	$ 3.00 / kg
trout	$ 2.50 / kg
other sport fish	$ 2.00 / kg

These suggested price parameters are intended to represent the *resource rental value* to society of marginal additions to fish biomass, whether or not the associated fish become part of the annual catch of a particular fishery. These values are, therefore, intended to represent an amalgam of commercial fishery, recreational fishery, aboriginal fishery, and spawner values. However, sockeye, chum and pink are mostly of importance to the commercial fishery; steelhead and the various freshwater fish resources are mostly of importance to the recreational fishery; and chinook and coho are of importance to both of these fisheries. The aboriginal fishery draws variously on all of these fish resources in different areas of the Province. Fish left uncaught and free to spawn are of importance to the survival of any particular fish stock.

Although these price parameters are all intended to represent the *resource rental values* of various fish species, they are nevertheless based on estimates of landings values from commercial fisheries, without deducting harvesting costs. This methodology is appropriate when the open access problem leads to the dissipation of resource rents. Data sources are provided in Scarfe 1997, but include various reports by ARA Consulting Group Inc. (cf. ARA 1996). These price parameters should be applied in any *cost-benefit* analysis of watershed rehabilitation projects, whether the additional potential biomass (*AFT*) is expected to be harvested in a particular fishery or left to regenerate under the constraints of natural attrition.

G. The Valuation of Forest Resource Benefits

Forest resource values may also be enhanced by successful watershed rehabilitation projects. In particular, the growth function of marketable timber resources may be shifted sufficiently either to increase the eventual harvest volume or to accelerate the date at which harvesting occurs. The harvesting date for the affected timber resources may well be decades in the future. However, for major rehabilitation projects, harvesting gains could occur earlier if the project leads to a (small magnitude) increase in the allowable annual cut (*AAC*) for the timber supply area within which the project takes place. In such a case, it is necessary to offset in the *NPV* calculation the later harvests foregone if earlier timber harvesting is made feasible.

It is important to measure the incremental net value generated from the enhancement of growing timber stands, as this value accrues over time. This measurement must take into consideration ways in which the rehabilitation project is likely to shift the growth function for the relevant tree species. For example, a representative growth function for coastal Douglas fir relates the natural logarithm of the standing timber volume, measured in cubic metres per hectare, linearly to the squared inverse of stand age with a negative slope coefficient. In consequence, the volumetric growth rate of the representative coastal Douglas fir timber stand is inversely proportional to the cube of stand age. Moreover, the growth rate at a stand age of 70 years is about 3.4 percent per annum and the annual increment to timber volume at this stand age is about 11.8 cubic metres per hectare. If a social decision to harvest is made at the stand age for which the growth rate of the timber volume begins to fall below the *social rate of discount*, then (on the assumption that this *social rate of discount* is approximately equal to three percent per annum) harvesting should proceed at a stand age of roughly 73 years. The profit-maximizing harvest decision for a privately-owned Douglas fir forest would no doubt occur at a somewhat younger stand age, given the use of a higher *hurdle rate of return*.

Measuring the incremental net value will also require consideration of ways in which enhanced quantities of standing timber may be valued. Again, it is important to use *resource rental values*, which may be estimated by deducting all associated harvesting, silviculture and management costs from the market price of the relevant species of timber when harvested. Not included within these costs are stumpage payments made to the Crown, since these payments represent part of the incremental net value of the timber resource.

Species, quality and location differences are all of considerable importance in assessing the economic value of growing timber stands. Nevertheless, it is recommended that only species differentials be recognized in assessing enhancements to timber values which may incidentally be associated with watershed rehabilitation projects. One of the reasons for this is that the enhancement itself may occur somewhat generically, through a small increase in the *AAC* determination for the particular timber supply area.

Representative data relevant to the required calculations can ordinarily be obtained from the district office of the Ministry of Forests. However, I suggest that the following price parameters, all measured in dollars per cubic metre, may be used, where appropriate, in assessing the incremental net value generated from timber resource enhancements:

Cypress	\$ 60/m^3
Douglas Fir	\$ 50/m^3
Cedar	\$ 45/m^3
Hemlock	\$ 40/m^3
Spruce	\$ 45/m^3
Balsam Fir	\$ 40/m^3
Pine	\$ 35/m^3

Alternatively, an average net value of \$45 per cubic metre could be used.

Note that these price parameters are considerably smaller than those presented in Scarfe 1997, where deductions for harvesting costs were inadvertently neglected. (The resource rent dissipation problem does not arise in the forests sector, at least not for reasons of open access, although resource rents that are *left on the table*, or uncollected by the Crown, may well be dissipated in higher industry costs.) Nevertheless, the price parameters given are somewhat larger than the target rates of stumpage that currently apply in B.C.'s coastal and interior regions. This is appropriate, since some allowance must be made for non-timber stock values, which are additive to timber values calculated on the basis of harvest *flow* values; moreover, there is also the possibility that some resource rents may be *left on the table* when Crown charges (stumpage and royalties) are imposed. However, a recent consulting report completed by BriMar Consultants Ltd. for the Ministry of Forests (BriMar 1998), suggests that, on a cyclical average basis, these uncollected resource rents may be quite small, if not negligible. Thus, the suggested price parameters exceed representative Crown charges largely to make some allowance for non-timber values in the estimated resource rental values.

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H. The Valuation of Other Ecological Improvements

Watershed restoration projects should be assessed within a framework that encompasses the complete ecological health of the watershed. In principle, other ecological improvements that result from watershed restoration projects should also be measured and evaluated: no resource values should be ignored in this process. In particular, improvements in water quality should be valued from the perspective of either instream use or consumptive use, or indeed both perspectives if required. Sometimes these water quality benefits can be measured by the *cost savings* that may accrue in the provision of ample volumes of clean water within a community watershed.

In the assessment of fisheries benefits and forest resource benefits, those amenity values should also be assessed that have not already been captured in the incremental biomass growth approach we have recommended. This would require an estimate of the number of additional recreational-days that may be facilitated by the watershed restoration project, taking due care to avoid the possibility of double-counting potential resource benefits. An estimate of the unit value of a recreational-day can usually be obtained from practitioners of the *travel cost method.*

For example, in cases where the watershed rehabilitation project increases the value of a recreational fishery, an additional benefit equal to the estimated increase in angler-days per year multiplied by a pricing factor of about $40 per angler-day should be specified since the marginal values of chinook and coho resources in the recreational fishery exceed those found for the commercial fishery (ARA 1996). More generally, the same $40 per adult-visitor-day could be used in assigning amenity values to other recreational benefits that may result from the watershed rehabilitation project, although the value of a recreational-day may vary considerably by geographic location.

Assessment of the additional benefits associated with amenity values and especially, existence values (if any), is a complex matter. However, if the fisheries and forest resource benefits can be measured, and their combined present value assessed in relationship to the present value of project costs, one can at least ask the question, "How large would these additional benefits have to be in order that the *cost-benefit* criterion of positive net present value (*NPV*) would be met?" If the answer is plausible and within reasonable bounds, then the watershed restoration project would seem to be justified. However, if these additional benefits would need to be implausibly large for the *NPV* to become positive, then the project would not be justifiable on the *cost-benefit* criterion.

The *cost-benefit* criterion involves an *NPV* calculation which can be represented by the following discounted sum:

$$\boldsymbol{NPV = B_0 - C_0 + \frac{B_1 - C_1}{(1+r)} + \frac{B_2 - C_2}{(1+r)^2} + \ldots + \frac{B_T - C_T}{(1+r)^T}}$$

where Bi represents the aggregated benefits made available by the project in year i; i = 0...T; Ci represents the costs incurred with respect to the project in the same year; and r is the real discount rate, recommended herein to be set at three percent per annum. Projects which pass the *cost-benefit* criterion will have an *NPV* that is greater than or equal to zero. Projects with larger positive *NPV*s should be given higher priority than those with smaller *NPV*s.

Provided that it is possible to form an estimate of the total value of the potential resource benefits accruing from a watershed rehabilitation project in each future year, it will then be possible to obtain from this stream of benefits and the associated costs, an estimate of the *NPV* of the rehabilitation project and, thus, apply the *cost-benefit* criterion. For most watershed rehabilitation projects, this method will at best provide a gross estimate of the overall resource benefits for comparison with overall project costs. It is, nevertheless, important to attempt this, when assessing the relative merits of proposed watershed rehabilitation projects. Project planners, if required to perform even rudimentary *cost-benefit* analyses on a series of optional projects will develop an appreciation for the types of projects that are likely to be "winners" or "losers."

I. Application to Hillslope and Stream Restoration Programs

As a general rule, within any given watershed, upstream hillslope restoration projects need to proceed before downstream restoration projects that involve the rehabilitation of fish habitat, and especially mainstem projects. Improvements to riparian buffer zones (which should be managed for habitat benefits rather than for timber benefits) can ordinarily be independently scheduled. However, even with an earlier start to hillslope restoration and stabilization projects, potential forest resource benefits are likely to take much longer to materialize than fisheries and water quality benefits.

As indicated earlier, fisheries benefits show up in the form of additional biomass growth. This growth results from a combination of two interactive forces: higher stock productivity and an increased carrying

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capacity of the aquatic environment. The logistic biomass growth function originated in the 1950's (Schaeffer 1954). This function can be represented by the equation $dS/dt = BS(S^* - S)$, where S is the biomass stock and dS/dt is its time rate of change. An increase in B would represent higher stock productivity whereas an increase in S^* would represent a higher carrying capacity of the aquatic environment. If a watershed rehabilitation project is able to increase either B or S^*, or both, it will associate higher biomass growth, dS/dt, with any initial level of biomass stock, S. It will, for example, therefore increase the *maximum sustained yield* (*MSY*) of the fishery, which in the Schaeffer model is associated with a stock level which is brought to, and maintained at, $S^*/2$.

Just as stock productivity and carrying capacity are interactive, so too are hillslope improvements that reduce the quantity of fine sediments that enter watershed streams, riparian improvements that shade and protect the aquatic environment and (eventually) provide it with large woody debris (LWD), and aquatic improvements that result directly from the rehabilitation of fish habitat.

In general, therefore, the fisheries benefits that may result from an integrated (or holistic) watershed restoration program will be larger than the sum of the benefits that are likely to arise from each separate project within the program. This implies that *AFT* may in such a case be trickier to measure than perhaps was earlier implied, since hillslope and riparian improvements may interact with habitat improvements to enhance *AFT*. Nevertheless, it will often be possible to obtain estimates of *AFT* from existing studies on biomass growth which have been undertaken for undisturbed or previously rehabilitated watersheds with similar characteristics.

Another issue which arises from the interactive nature, or synergism, of the various rehabilitation projects that may be carried out on a single watershed is that it is often more beneficial to complete a multi-project restoration program for a single watershed than to commence with the first-stage projects pertaining to another watershed. Non-completion of an integrated, or multi-project, watershed restoration program may simply postpone the resource benefits that may be derived from the whole program, and thereby lower the overall *NPV*.

There may also be economies of both scope and scale on the cost side of the *cost-benefit* criterion. These may make a combination of projects less expensive to complete if they are undertaken together rather than in isolation. Even so, individual projects should be sequenced to maximize both direct benefits and the possible occurrence of productivity gains from "learning-by-doing" effects. Future costs should be discounted to the present using the same three percent discount rate as is applied to future resource benefits. The costs that enter the *cost-benefit* calculation may be somewhat smaller than actual cash outlays, if project inputs that would otherwise be less than fully employed are used in the completion of the restoration project. However, up-front assessment costs may well involve a significant time commitment by individuals employed by the Provincial Government, and these time-costs should be included in *NPV* calculations.

J. A Worked Example

This section of the paper provides a fully-worked example of the application of *cost-benefit* analysis to the assessment of a stylized watershed restoration project. Although the Horizon River project is fictitious, wherever possible an attempt has been made to use representative numbers, from both the cost and benefit sides of the net present value (*NPV*) calculation.

The watershed restoration project at "Horizon River" has five phases, each requiring one year of work and each requiring an outlay of $50,000. In year 2000, an assessment is made of the Horizon River watershed and, in year 2001, hillslope restoration commences. This restoration work involves 10 kilometres of forest road de-activation (at an average width of 10 metres) at $1,000 per kilometre, gully stabilization costing $10,000, and $30,000 of reforestation activities leading to earlier green-up of 30 hectares of high productivity Douglas fir timberlands at $1,000 per hectare.

Hillslope restoration is followed by riparian improvements to two kilometres of the Horizon River mainstem, scheduled for 2002. These improvements affect a 20 metre buffer zone on both sides of the river, and therefore a land area of eight hectares (two kilometres times a 20 metre riparian zone for both sides of the river) at an average cost of $6,250 per hectare. A fish habitat rehabilitation initiative involving the same stretch of the mainstem is to commence the following year, and take two years (2003 and 2004) to complete, at a cost of $50,000 per year. The average wetted width of the relevant reach of the Horizon River is ten metres, so that the wetted area subject to aquatic rehabilitation measures two hectares (two kilometres times ten metres, divided by ten) at an average cost of $50,000 per hectare.

Water quality improvements, valued at $3,000 per annum, commence in year 2003 and continue until year 2025, after which they become too uncertain to evaluate. The useful aquatic life of the watershed restoration project is assumed to be equal to twenty-five years. However, the water quality value is assumed not to include the value of any increase in fish productivity.

An enhancement of trout stocks is expected to begin in 2004, but takes two years to reach steady state. Two hundred additional trout are anticipated per improved wetted hectare of the Horizon River in the first instance, rising to four hundred additional trout per wetted hectare the following year. If each trout, on average, weighs half a kilogram, and trout are valued at $2.50 per kilogram, then the total additional value of trout production in year 2004 is $500. Restated, *AFT* = 2 hectares x 200 trout/hectare x 0.5 kg/trout, or 200 kg, which is then multiplied by $2.50 per kg. In year 2005 and beyond, this value increases to $1,000. However, again the continuation of this enhanced trout value after the year 2025 is assumed to be too uncertain to measure.

An enhancement of coho stocks is expected to begin in 2005, but takes four years to reach steady state. Estimates indicate that 60, 120, 180, and 240 additional coho are expected to survive to adulthood for each improved wetted hectare of the Horizon River in successive years during the 2005 to 2008 period. On average, each additional adult coho is expected to weigh 3.2 kilograms. In this case, in year 2005, *AFT* = 2 hectares x 60 coho/hectare x 3.2 kg/coho, or 384 kg. *AFT* increases steadily to reach 1,536 kg in 2008. If coho are valued at $4.00 per kilogram, then the sequence of coho enhancement values from 2005 to 2008, respectively, is $1,536, $3,072, $4,608, and $6,144. It is assumed that the final value remains in place until the year 2025, when again fish values become too uncertain to measure. This (admittedly arbitrary) assumption allows a clear temporal separation of fisheries benefits from forest resource benefits, as seen below.

Both the additional trout production and the additional coho production provide amenity benefits, measured in angler-days, to the recreational fishery. These benefits are assumed to begin in the year after the relevant fish stock reaches its steady-state value. Each four additional trout or each four additional coho are assumed to generate one additional angler-day. (Only one-half of the additional coho are assumed to provide recreational benefits, since some of the coho are absorbed in the commercial fishery.) Thus, 200 additional angler-days (800 x 0.25) are generated for the years 2006 to 2025, inclusive, each valued at $40 per angler-day, for an amenity benefit with respect to trout of $8,000 per annum, and a further 120 additional angler-days (480 x 0.25) are generated for the years 2009 to 2025 inclusive, each also valued at $40 per angler-day, for an amenity benefit with respect to coho of $4,800 per annum.

After 25 years, enhanced forest values begin to be observable. Hillslope restoration leads to an increase in Douglas fir productivity of two cubic metres per hectare per year. It is assumed that 30 hectares of young Douglas fir stands have been beneficially affected by the restoration project. The additional timber growth continues until the Douglas fir stands are 73 years of age, which is assumed to be the normal rotation age at which harvesting occurs. However, the growing timber stands are assumed to allow volume-equivalent *AAC* additions to become available elsewhere in the timber supply area, commencing in the year 2026. Thus, 60 additional cubic metres of harvestable timber become available in each of the 48 years from 2026 to 2073, inclusive. If this additional timber is valued at $50 per cubic metre, timber benefits equal to $3,000 accrue in each of these years.

It is now possible to place all costs and benefits into spread-sheet form, as seen in Figure 1. A three percent real discount rate is used in all present value calculations.

Since the *NPV* of the watershed restoration project is positive, the project is justified on the basis of the *cost-benefit* criterion. It is also possible that the project has additional benefits, such as non-fisheries amenity benefits or an existence value associated with the larger coho stocks, that have not been accounted for in the *NPV* calculation. Any additional benefits would provide further justification for proceeding with the project.

It should be noted that the present values of the water quality, fisheries, recreational, and forest resource benefits are, respectively, $46,499 (14%), $90,492 (28%), $152,556 (47%), and $36,202 (11%), which sum to a present value of total project benefits of $325,750, against a present value of project costs of $235,855. The overall benefit-cost ratio is 1.38, which is greater than unity, again indicating that this hypothetical conservation project is economically justified, without considering whether or not there are additional unmeasured benefits. The internal rate of return on the project is 5.30%, which is larger than the real discount rate of 3.0%, again indicating that the project makes economic sense at the assumed discount rate. However, the conservation project would not be economic at any alternative discount rate that is greater than 5.30%.

The recreational benefits resulting from the additional angler-days associated with enhanced fish stocks are particularly important to the generation of a positive *NPV*, but it is important to be sure that these benefits do not involve double-counting. In the worked example,

Year	Cost	Water Benefit	Fisheries Benefits		Angler Benefit	Forest Benefit	NPV
			Trout	Coho			
2000	$50,000						-$50, 000
2001	$50,000						-$48,544
2002	$50,000						-$47,130
2003	$50,000	$3,000					-$43,012
2004	$50,000	$3,000	$500				-$41,315
2005		$3,000	$1,000	$1,536			$4,775
2006		$3,000	$1,000	$3,072	$8,000		$12,623
2007		$3,000	$1,000	$4,608	$8,000		$13,504
2008		$3,000	$1,000	$6,144	$8,000		$14,323
2009		$3,000	$1,000	$6,144	$12,800		$17,585
2010 to 2025	sixteen more years similar to *2009*						$220,883
2026						$3,000	$1,391
2027 to 2073	forty-seven more years similar to *2026*						$34,811
Net present value of project							**$89,895**

Figure 1. Spread sheet showing the worked example (J) of the fictitious watershed restoration project ("Horizon River").

these benefits were taken to be additive to the resource rental value of the larger fish stocks themselves. This resource rental value was essentially derived from the harvest value of the additional fish biomass. Insofar as non-commercial fish species have no particular harvest value above and beyond their amenity value, or commercial fish species have no particular amenity value above and beyond their harvest value, the joint attribution of both of these types of value could in some cases lead to double-counting. Existence values should probably only be considered when endangered species are involved. Care needs to be taken to ensure that these existence values are not contaminated with use values, again to prevent the possibility of double-counting.

K. Concluding Remarks

This paper has provided a valuation methodology that can be used to assess the potential resource benefits that are associated with watershed restoration projects, and to weigh these benefits against project costs. As the various potential resource benefits depend on local conditions and may take time to develop, the preferred valuation method involves the estimation of *net present value* (*NPV*), which is commonly used in *cost-benefit* analysis.

There are three *rules of thumb* to use when undertaking *cost-benefit* analyses of investments in environmental restoration:

1. use a three percent real discount rate in the calculation of *NPV*s;
2. quantify and include as resource benefits all important biomass additions that will likely result from the restoration project, regardless how these biomass additions are ultimately used; and
3. use the best available approximations to resource rental values in the valuation of these biomass additions.

Harvest values, amenity values and existence values have been distinguished as potentially separate sources of resource benefits.

This valuation methodology is applicable to fisheries, forest resource, water quality and recreational benefits that are associated with hillslope and stream restoration projects. These methods take into account the interactive nature of multiple projects affecting the same watershed, and a fully-worked example has been included to guide practitioners in the use of the valuation methods.

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Technical Tip

Monitoring and Evaluation of the Fish Response to West Kettle River Habitat Restoration

Wendell Koning and Pat Slaney

Figure 1. Lateral log jam structure ballasted 2.5 - fold to account for debris collection before scour.

An integral part of all watershed restoration work is monitoring, without which it is impossible to assess project effectiveness. Monitoring provides a level of accountability in the restoration process; it also offers opportunities for learning and adaptation as new knowledge is gained (Koning et al. 1998; based on the earlier work of Gaboury and Feduk 1996). Through monitoring, restoration successes can be noted and refined; recognition of project elements that have led to failures can provide equally valuable lessons. Such evaluation provides an adaptive management tool that increases the probability of restoration success.

In the past, most fish habitat restoration projects allocated insufficient time and resources to post-project evaluations. If conducted, evaluations frequently lasted for only the first one or two years following restoration. Typically, even these limited evaluations frequently found physical failures in instream structures such as log and boulder placements, rock weirs and groynes. Restoration works can fail due to variety of reasons, including:

- a general lack of biological understanding of fish habitat and stream hydrology (Kauffman et al.1997);
- failure to use natural analogues as design templates;
- imposing structures purely for mitigation purposes, e.g., to replace habitat lost to hydro-electric developments;
- failure to account for high channel instability and bedload movement due to upslope impacts;
- too narrow a focus on instream palliative treatment instead of watershed husbandry (Chapman 1996);
- failure to work within an interdisciplinary team which includes stream, riparian and upslope specialists (Roper et al. 1997).