Juvenile Passage Cost Effectiveness Analysis for the Columbia River Basin: Description and Preliminary Analysis

Independent Economic Analysis Board

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1. Executive Summary

Bypass spill for juvenile anadromous fish out-migration and passage improvements to assist juvenile migrants together cost ratepayers hundreds of millions of dollars annually. The Northwest Power Act requires that the Northwest Power Planning and Conservation Council (the Council) consider the cost-effectiveness of its fish and wildlife program and determine whether its projects employ cost-effective measures to achieve program objectives. Summer bypass spill is regarded by some to be expensive and not cost-effective, while others believe that summer bypass spill is important for the restoration of wild salmon and steelhead populations.

This report presents principles and examples of the application of cost-effectiveness analysis (CEA) to actions intended to improve mainstem passage survival in the Columbia River Basin. CEA principles are reviewed and related analyses and policy issues are discussed. An example of the application of CEA to bypass spill and facility modifications is developed using information from a hydrosystem model (Genesys, operated by the Council), a model of Western power pricing (AURORA™, licensed by the Council from EPIS, Inc.), a model of juvenile salmon and steelhead survival (SIMPAS, Simulated Passage, developed by the National Marine Fisheries Service), and information on costs of facility modifications.

This juvenile passage CEA is preliminary. It is intended more to illustrate the potential for CEA than to determine the cost-effectiveness of particular passage improvements. CEA might increase the rate of implementation of cost-effective passage improvements because it shows that juvenile passage survival can be increased in the long run at a net cost reduction to power consumers. CEA, combined with the ability to borrow against future power revenues, might do even more to speed the implementation of passage improvements, and ultimately, the recovery of listed species.

Simple cost-effectiveness measures may be developed for actions that have measurable survival and cost effects. The measure chosen for this example is the cost of an action divided by the change in the percent of juvenile migrants surviving through the mainstem to below Bonneville Dam. Table ES-1 shows results.

Table ES-1 suggests that extended length screens at Lower Granite and Little Goose, and the Bonneville powerhouse II corner collector, are all highly cost-effective in comparison to August spill at Ice Harbor dam. For example, the extended length screens at Lower Granite dam appear to be approximately 50 times (600/12) more cost-effective for fall Chinook juvenile passage than August spill at Ice Harbor. The cost-effectiveness of the Bonneville corner collector appears to be approximately 6 times (600/95) that of August spill at Ice Harbor.

Table ES-1.
Summary of Juvenile Passage Preliminary Cost-Effectiveness Analysis. Cost Per Unit of Juvenile Survival for Selected Passage Actions

	Million $ per Year per Percentage Point Increase in Juvenile Survival		
	Fall Chinook	**Spring/ Summer Chinook**	**Steelhead**
August spill at Ice Harbor	$600	No Effect	No Effect
Extended length screens at Lower Granite	$12	$3	$6
Extended length screens at Little Goose	$23	$7	$14
Corner collector at Bonneville	$95	$95	$158

One purpose of our analysis is to show how CEA might be used to identify combinations of actions, or scenarios, that make both "power consumers" and "fish" better off. Results of three such scenario analyses are summarized in Table ES-2. For example, the first scenario combines the cessation of August bypass spill at Ice Harbor with extended length screens at Lower Granite and Little Goose dams. Increased power revenues from reduced spill are expected to be greater than the annualized costs of the extended length screens, so net power system revenue (increased power revenues net of passage improvement costs) of $900,000 could be returned to ratepayers annually. At the same time, survival of Snake River juveniles would be expected to increase by 0.31% to 1.11%, depending on the stock, with no effect on Columbia River stocks. In this case, power revenues from reduced spill could fund passage improvements to increase juvenile survival while increasing net power system revenues.

Removable spillway wiers (RSWs) are expected to reduce bypass spill while maintaining or increasing juvenile passage survival. RSWs at Little Goose, Lower Monumental, and Ice Harbor dams are evaluated. It is assumed that bypass spill is reduced by half, but juvenile survival is not affected. The RSW proposed for Ice Harbor appears to be cost-effective: increased power revenues from reduced bypass spill should be more than enough to finance the cost of the RSW. The third example in Table ES-2 shows that net power system revenues from the Ice Harbor RSW are large enough to finance the Bonneville corner collector, which results in a measurable survival benefit, while still leaving $6.26 million annually for ratepayers.

In contrast, a RSW at Little Goose does not appear to be cost effective: increased power revenues are not even enough to pay for the weir. Results for the RSW at Lower Monumental are too close to call. These RSWs might be cost-effective if survival is increased, or if behavioral guidance systems are not required. In addition to illustrating cost-effective alternatives, CEA can help identify potential passage investments that should be put on hold pending an improved showing of cost-effectiveness.

Table ES-2.
Summary of Juvenile Passage Preliminary Cost-Effectiveness Analysis. Results for Cost-Effective Scenarios

		Change in Percent Survival of Juveniles to Below Bonneville Dam			
Scenario	**Annualized Net Change in Power Revenue plus Facility Costs, Million $ [1.]**	**Snake River Fall Chinook**	**Snake River Spring/ Summer Chinook**	**Snake River Steelhead**	**Columbia River Stocks**
Cease August Bypass Spill at Ice Harbor and Construct Extended Length Screens at Lower Granite and Little Goose	$0.90	0.31%	1.11%	0.61%	none
Cease August Bypass Spill at Ice Harbor and Build Bonneville Corner Collector	$1.26	0.04%	0.05%	0.03%	positive
Build Removable Spillway Weir at Ice Harbor and Build Bonneville Corner Collector	$6.26	0.05%	0.05%	0.03%	positive

1. Net power system revenue. Capital costs of facilities are annualized over 20 years at 4 percent real interest

There are a number of limitations to the preliminary CEA. First, some of the analysis is retrospective in that the extended length screens and Bonneville corner collector are already built. Second, the effects of passage improvements on juvenile survival are uncertain, and some future costs are uncertain. The analysis is based on conservative assumptions regarding biological benefits, and if costs are uncertain, the higher of the range of costs is used. Third, the analysis is based on annual average flow conditions. Results in any given year, or even a short series of years, might be different and affect both cost and effectiveness.

A fourth limitation is that there is currently no direct institutional mechanism whereby power revenues from reduced bypass spill can be used to fund passage improvements. On the other hand, Bonneville Power Administration (Bonneville) has some discretion for funding passage improvements that may be cost-effective. An Implementation Team, made up of representatives from federal and state agencies, the tribes, and utilities, is currently considering possible actions that could offset the juvenile survival effects of reduced summer bypass spill.

One purpose of the analysis is to identify information gaps and uncertainties that limit the identification of more cost-effective ways of increasing juvenile survival. Many information gaps associated with juvenile survival are well known. Delayed mortality, survival through the different passage routes, and spillway survival with RSWs are key uncertainties. On the cost side, the post-installation costs of the RSWs; for research, behavioral guidance systems, and operations should be clarified.

2. Introduction

As a matter of broad social and economic policy, available fish and wildlife dollars should be spent in a way that maximizes the beneficial impacts to fish and wildlife. More specifically, the Northwest Power Act requires that the Council consider whether there is a less costly way of achieving a given biological effect. Section §4(h)(6)(C) requires that the Council "will utilize, where equally effective alternative means of achieving the same sound biological objective exist, the alternative with the minimum economic cost." Section §4(h)(10)(D)(vi) states that "in making its recommendations to BPA, the council shall determine whether the projects employ cost-effective measures to achieve program objectives."[1]

Since the energy crisis of 2000-01 and the ensuing Bonneville financial difficulties, increasing attention has been paid to the cost-effectiveness of fish and wildlife mitigation programs. In particular, the cost-effectiveness of spill for juvenile passage has come under increased scrutiny. The Council's 2003 Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program call for "a rigorous evaluation of the biological effectiveness and cost of spillway passage." The stated goal of the evaluation would be to "determine if it is possible to achieve the same, or greater, levels of survival and biological benefit to migrating fish as currently achieved while reducing the amount of water spilled, thus decreasing the adverse impact on the region's power supply."[2]

Council staff has presented preliminary analyses of the costs and fish population effects of summer spill.[3] These analyses have not addressed whether there is a less costly way of achieving the same biological effect. That is, the additional power revenues associated with reduced spill have been estimated, but it has not been determined if it is possible to achieve the same, or greater, levels of survival using these revenues to offset the cost of other improvements.

The System Configuration Team (SCT) of the Columbia River Regional Forum was established to review progress on planning/engineering studies, and/or collection of research data, and to make appropriate modifications to passage improvements or their schedules. The Implementation Team (IT) consists of representatives from the Federal operating and regulatory agencies, States (including Alaska), Columbia River Indian Tribes, and Mid-Columbia Public Utility Districts. The IT

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[1] Northwest Power Act, 94 Stat. 2710, as amended by Pub. L. 104-206 §5124(h)(6)(C) §512(4)(h)(10)(D)(vi) September 30, 1996 110 Stat. 3005

[2] Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program, NPCC Council Document 2003-11. Page 19.

[3] For example, Fish and Energy Impacts Resulting from Reductions in Summer Bypass Spill, July 16, 2003; Cost and Energy Impacts of Fish and Wildlife Operations, May 9 2003.

> *[p]rovides a mechanism for coordination, decision, and appropriate and timely implementation of NMFS' Biological Opinions on the Federal Columbia River Power System. These include real time operations of the hydroelectric system for the protection of migrating salmon and other listed species, needs and priority for changes to mainstem Columbia fish passage facilities, fish transportation, and research, monitoring and evaluation needs.*[4]

The IT has recently begun considering reduced summer bypass spill as a method for increasing power revenues, and a spill offset group is considering actions that could be taken to offset the juvenile survival effects of reduced spill. The group has developed a set of nine principles, of which cost-effectiveness is one, and a number of potential actions are being evaluated.

Cost-effectiveness analysis (CEA) evaluates and compares alternative ways to achieve a stated, quantifiable objective. This report provides an example of a preliminary CEA that considers the costs of alternative groups of actions, or scenarios, and their effects on juvenile passage and survival on the Snake River. The alternative actions considered in this brief study are August bypass spill, removable spillway weirs, extended length screens and an improved surface bypass system.

2.1. Purposes of the Report

The purposes of this report are

- To explore the potential for applying CEA to the juvenile passage problem;
- To provide an example of the application of CEA, by comparing spill and other juvenile passage improvements and identifying changes that are cost-effective in that net costs are reduced and juvenile survival is increased;
- To identify information gaps and uncertainties that limit the identification of more cost-effective ways of increasing juvenile survival; and
- To identify impediments and constraints to implementing cost-effective juvenile passage improvements.

The report is structured as follows. First, CEA is defined and described. Types of CEA, their potential for applications to fish and wildlife expenditures and their general limitations are discussed. The significance of the choice of a biological objective in framing a cost effectiveness analysis is discussed. Then, CEA is applied to a simple example of passage spill and passage improvements.

Finally, the limitations of the analysis and its policy implication are discussed. This juvenile passage CEA is preliminary. It is intended solely to illustrate the potential for

[4] From Regional Implementation Forum information (NOAA 2003)

CEA as opposed to fully determining the cost-effectiveness of particular passage improvements. The major limitations of the analysis are numerous biological and cost uncertainties, and the absence of a formal institutional mechanism to allow increased revenue from reduced bypass spill to be channeled to passage improvements.

2.2. Definition and description of cost-effectiveness analysis

2.2.1. Definition

CEA compares the costs and results of alternative actions, or groups of actions, that could be taken to accomplish a specific quantifiable objective. The essential requirements are a measurable objective (or a reasonable proxy) and the economic costs of various actions that could be taken to achieve that objective.

2.2.2. Description as a comparison of scenarios

A CEA is, fundamentally, a comparison of forecasts of what would happen under at least two alternative courses of action. As such, CEA must be concerned with a variety of future conditions that might affect cost-effectiveness.

The status quo scenario is the basis against which the costs and the achievements of other scenarios are compared. For this example of CEA analysis, the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) is considered the status quo.

An action scenario is an action or a group of actions that might be packaged together to accomplish the same objectives. CEA compares their costs and amount of accomplishment (effectiveness) to the status quo scenario.

3. Types of cost-effectiveness analysis

CEA has several variants that could be applied to fish and wildlife costs and improvements. This section describes the types of CEA and the general methods used to determine cost-effective solutions.

3.1. Maximize an objective subject to a fixed budget

In this application, the problem facing managers is that the budget available to meet an objective is fixed and the total costs of all available or potential actions exceed the budgeted amount. The management goal is to select those actions that have the largest positive effect on the objective given the fixed budget.

If the amount of improvement in the objective is additive over all possible actions (that is, if the actions are not in some way interdependent, either in terms of cost or in terms of effectiveness), the easiest way to determine which actions to select is to divide the cost of each action by the amount of objective it accomplishes to obtain a unit cost. The actions are then selected in rank order of increasing unit cost until the budget is exhausted.

This solution method will not work if there are significant interactions among the actions such that the effectiveness of each action depends on which other actions are selected. In this situation, it may be necessary to compare sets of actions to determine which set is most cost-effective.

The selection of cost-effective actions is also more complicated if some actions are not divisible, meaning that only one size of the action is available. If the costs of indivisible actions are large relative to the entire budget, then the cost-effective solution may not include some actions with low unit costs. The most obvious instance of this problem occurs if the total cost of the lowest unit-cost action exceeds the budget. (This does not occur in this study)

3.2 Achieve a fixed objective at least cost

In this form of CEA, the objective is fixed, there are more than enough actions available to meet the fixed objective, and the goal is to achieve the objective at least cost. There are several examples of quantitative objectives in the fish and wildlife program to which this type of CEA could be applied.

- The BiOp includes Tier 2 Hydro System Juvenile Survival Rates by Evolutionarily Significant Unit (ESU). The FCRPS combined juvenile survival rate objectives for Snake River spring/summer chinook, fall chinook and steelhead are 57.6%, 12.7% and 50.8%, respectively.[5] Information on success in meeting these targets in 2001 and 2002 is available.[6]

- The Plan for Analyzing and Testing Hypotheses (PATH) identified a 2 percent minimum Smolt to Adult Ratio (SAR) as a minimum recovery threshold for wild stocks.[7]

The solution method for selecting actions in this application is identical to the fixed-budget problem, except that actions are selected in order of increasing cost per unit of objective, starting with the action with the lowest unit cost, until the objective is reached. Potential problems with interactions among actions and with indivisible actions apply here as well.

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[5] USACE, North Pacific Division. Endangered Species Act Implementation Plan for the Federal Columbia River Power System. Summer 2001

[6] USACE, Northwestern Division. Endangered Species Act 2003 Check-in Report for the Federal Columbia River Power System September 2003.

[7] In 1994, a science panel concluded that there were three major differences between the models used to evaluate actions for recovery of Columbia River Basin salmon stocks: 1) the distribution of survival over the life span; 2) the effect of flow on survival; and 3) the benefit of transportation. The panel concluded that work should be focused on resolving these issues through hypothesis testing. This process became known as the Plan for Analyzing Testable Hypotheses (PATH).

3.3 Analyze scenarios (i.e., groups of actions)

CEA can be used to compare feasible scenarios in terms of total cost and level of effectiveness. This method is preferable where there are many interactions among actions; for example, passage improvements that must be implemented together. Often, one passage improvement cannot be implemented effectively without another. The CEA provides information on cost-effectiveness, but the analysis does not necessarily select the scenario that is most cost-effecticve.

Constraints can be imposed on a scenario analysis that might lead some scenarios to be discarded. For example, the management goal might require that costs be reduced from the status quo. If this is the case, any scenario that increases cost must be discarded regardless of the increase in achievement of the objective. On the other hand, a management goal may require that the achievement of the objective be increased or maintained. In this case, scenarios whose net effects are to reduce the objective must be discarded regardless of the cost savings.

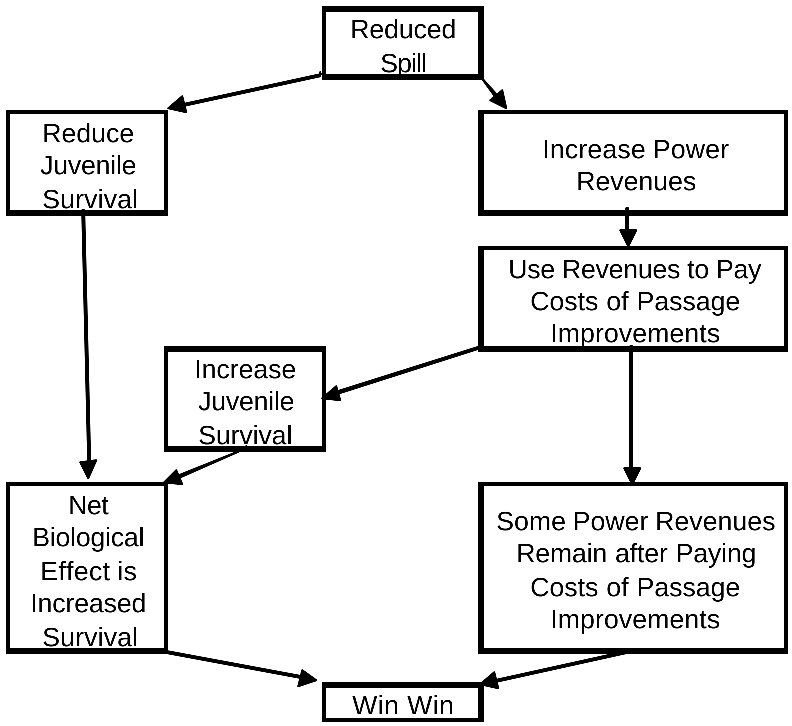
3.3.1 Using CEA to meet the policy objectives of the Power Planning Act and the Mainstem Amendments

CEA can be used to search for and identify scenarios that meet the cost-effectiveness criteria defined by the Power Planning Act and the Mainstem Amendments. The example analysis of juvenile passage in this report seeks to identify scenarios that are expected to increase the objective (juvenile survival) and reduce net costs (power losses plus costs of actions). This criterion is intended to be consistent with the intent of the Northwest Power Planning Act and the Council's 2003 Mainstem Amendments.

For purposes of this analysis we define a *cost-effective scenario* as one that reduces net costs (power revenue losses plus costs of passage actions) and increases the objective (juvenile survival) relative to the status quo scenario. This unambiguous "win-win" analytical constraint is intended to be acceptable to both power and fisheries interests. Figure 1 shows the type of win-win situation that the juvenile passage CEA hopes to identify. To implement a win-win scenario, some of the increased power revenues due to reduced spill would be used for passage improvements that would increase survival. Total survival would be increased and the cost of the passage improvements would be less than the increased power revenues.

This is not to imply that a "win-no lose" scenario could not be selected. However, it may be difficult to obtain agreement for a win-no lose result. The party who is not made better off has no reason to participate. Often, any change from the status quo is viewed as being more risky, so there needs to be some expectation of gain to induce participation. In this case, the winner may be able to compensate the other party so that both are better off.

Figure 1. The Goal of IEAB CEA Analysis: Identify Potential Win-Win Situations



3.3.2 Handling multiple objectives

Multiple objectives increase the complexity of CEA. In the juvenile passage CEA, for example, there will be more than one species for which increased juvenile survival is an objective. Suppose a scenario increases survival of juvenile salmon but reduces that of steelhead? Is this scenario better? CEA does not provide information regarding whether a salmon is preferred to a steelhead. If one objective is increased, but the other reduced, CEA cannot provide a basis for selecting or rejecting the scenario. The information can, however, be useful to decisionmakers who must make such tradeoffs.

3.3.2.1 Win-win-win scenarios

A win-win-win scenario minimizes costs, and maximizes more than one objective; salmon and steelhead, for example. Within the confines of CEA, the problem of multiple objectives can be overcome in only one way: through the existence of scenarios that reduce net costs and do not decrease any objectives, for example, juvenile survival of both salmon and steelhead.

3.3.2.2 Choosing among win-win scenarios

CEA of scenarios could result in the enviable problem that more than one scenario is cost-effective relative to the status quo. In this case, the status quo scenario clearly should be rejected, but which of the other scenarios should be selected?

Among the cost-effective scenarios (those with more survival and less cost than the status quo), one scenario may have less cost and more effectiveness for both species than the others. If so, then this one is clearly preferred, at least within the set of scenarios under consideration.

However, it is more likely that one cost-effective scenario will have both less cost and less effectiveness than another. For example, we might find that a scenario that combines reduced spill with other actions increases survival a little, but net cost savings compared to the status quo are large. Another scenario might increase survival a lot, but net cost savings are small. CEA alone cannot provide a basis for selecting among win-win scenarios.

4. Limitations of cost-effectiveness analysis

CEA has a number of inherent limitations, some of which are discussed above. A particular limitation is where there are multiple objectives that cannot be measured in common units, and so cannot be compared on the same basis. In such cases, there is no definitive basis for choosing among scenarios based on cost effectiveness unless one scenario happens to be the best for all the objectives.

Some objectives might be quantifiable in dollar terms, i.e., as benefits or costs, and these values can be included with all other costs in the CEA. The costs counted in CEA can include any measurable economic costs. Ultimately, if all objectives and effects can be valued in dollars, then CEA reduces to benefit-cost analysis.

4.1 Economic benefit of the objective is not considered

One of the most important limitations of CEA is that it does not consider whether the given objective has a value that is greater than its cost. CEA seeks to meet an objective, but it does not address the value of meeting the objective. The objective is taken as a given. For this reason, many economists argue that CEA is conceptually inferior to benefit-cost analysis. In benefit-cost analysis, all effects are valued in dollar terms and the scenario with the most net economic benefit can be identified. CEA cannot identify the scenario with the most economic benefit because the economic benefit of the objective is not considered.

CEA can be used, however, to identify efficiency improvements. If we are able to produce more fish at less cost, that is clearly an efficiency improvement, even if the most efficient result is to produce more fish at higher cost or fewer fish at lower cost.

In many cases, it is not practical or even desirable to place dollar estimates on the objective, and CEA is the best tool for this situation. For example, most economists would agree that it is difficult to place a dollar value on wild salmon and steelhead. But for CEA, all that is needed is a measure of effectiveness. For example, the BiOp includes quantified survival goals. In this case, CEA may be the most practical tool available.

4.2 Risk and uncertainty

Risk and uncertainty have different meanings. Risk involves a probability distribution that is known or can be estimated. For example, we can estimate an expected distribution for river flows from historical records, but hydropower production is still risky because the amount of flow in any given year is quite variable. With uncertainty, a probability distribution cannot be estimated, usually because there is no precedent. For example, many fish and wildlife improvements have uncertain outcomes because they have not been tried before.

For many reasons, the recovery of an evolutionarily significant unit (ESU) is an exercise in planning under uncertainty. The ESU has never been recovered before. The effects of past and future recovery actions are uncertain. A realistic analysis must recognize that there is risk and uncertainty involving the costs and efficacy of actions, and there is also uncertainty involving whether or not actions can actually be implemented (e.g., due to budget constraints, legal questions, or political opposition).

Some scenarios may be viewed as being more risky or uncertain than others. Risk and uncertainty may be important factors in selecting a scenario. In general, the status quo scenario will be viewed as being less risky and uncertain, though that view may not be reasonable. Scenarios that are less uncertain or less risky should be preferred, all else equal.

Decision-making will be more transparent if sources of risk and uncertainty are revealed. Research can be used to reduce risk and uncertainty. CEA may reveal potential cost-savings from successful research. In the analysis below, uncertainty associated with survival and cost parameters suggests potential cost-savings from additional research.

5. Implementing CEA

5.1. Selecting an objective

The selection of an objective and the measurement of that objective are critical decisions for CEA. The objective is the physical measure of success in a CEA. Some alternative objectives for CEA for production and recovery of anadromous fish are:

- Juvenile survival of one species at one facility
- Juvenile survival of multiple species at multiple facilities
- Adult returns

- Harvest

The objective determines the scope of analysis in that the analysis should include feasible actions that affect that objective. If the objective involves a fraction of the life cycle of the species, juvenile passage for example, then fewer actions need to be considered, but correspondingly less information is considered about what other actions might be desirable. For example, if juvenile survival is the objective, then harvest actions can be disregarded, but the analysis cannot consider whether harvest actions might be more desirable than passage actions in improving adult returns.

5.2. Counting costs

It is important to consider and define which costs should be counted. The *accounting perspective* of any economic analysis defines precisely whose costs are counted. As an example, one accounting perspective might be all citizens of the Pacific Northwest. Another, more constrained accounting perspective might be ratepayers of the Bonneville Power Administration. The two might differ, for example, when some fish and wildlife costs are paid by state or federal taxpayers rather than power users. The Pacific Northwest region perspective might count certain state taxes paid by regional citizens because they are used to fund fish and wildlife projects. The Bonneville cost perspective would not count such taxes.

5.3. Specifying scenarios

CEA scenarios should be specified that are realistic and acceptable from a variety of perspectives, including legal, cultural, engineering and biological. The scenarios and the analysis must capture all of the important changes that are likely to be associated with each scenario. If there is some doubt as to the feasibility of the scenarios, these issues must be addressed. Again, CEA is just one step in a series of analyses that are likely to be required before a scenario is selected and implemented.

5.4. Evaluating scenarios

With the decisions on objective, accounting perspective, and scenarios resolved, cost data and measures of effectiveness can be collected and the scenarios compared. The evaluation of scenarios may require that they be modified to make them internally consistent and feasible.

6. Review of previous studies of reduced spill

This section describes some recent analyses of reduced bypass spill for the purpose of increasing power revenues, and their results in terms of survival of affected anadromous fish. The studies are from a variety of sources and organizations and reflect a variety of assumptions that are not evaluated here.

6.1. Reducing summer bypass spill

There are numerous examples of calculations showing the opportunity cost of power foregone to provide summer bypass spill.

6.1.1. Council

Council staff presented an analysis of summer bypass spill reductions at the Warm Springs Council meeting on July 16, 2003.[8] Ending August bypass spill would generate about $38 million a year in power revenues.[9] The analysis suggested that the cessation of August bypass spill would have negligible effects on Snake River Fall Chinook (a reduction of 3 fish escapement against an escapement goal of 2,500, which has been reached on average over the last 10 years) and a reduction of 1,000 fish harvested and 1,400 fish escapement on healthy Upper Columbia Fall Chinook.

6.1.2. Bonneville

Bonneville examined the benefits of ending summer bypass spill in mid-August (two weeks early, relative to the status quo) at Bonneville, the Dalles, John Day and Ice Harbor dams.[10] The analysis estimated that power revenues would increase by $17 million, but 585 fewer adult Columbia River fall Chinook would return.[11] The power cost to consumers per returned adult is therefore about $30,000. Most of the reduced escapement is from healthy Columbia River stocks.

6.1.3. Columbia River Inter-Tribal Fish Commission

The Columbia River Inter-Tribal Fish Commission (CRITFC) provided an opinion regarding the BPA analysis of eliminating spill from Ice Harbor and Lower Columbia Dams in the second half of August.[12] They list twelve stocks that would be affected. They state that:

- increased mortality for Hanford Reach fall Chinook would be 16,000 to 26,000 adults;
- direct mortality to Deschutes fall Chinook juveniles not yet passed The Dalles and Bonneville Dams would increase 12%; mortality of other stocks originating higher in the Columbia River system would be even larger;
- there would be relatively large effects to adult returns, because late migrating fall Chinook have a higher SAR than early migrants;

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[8] NPCC. Fish and Energy Impacts Resulting from Reductions in Summer Bypass Spill. July 16, 2003.
[9] The assumed price of power, based on a 1999 price forecast, was $28 per MWH.
[10] From Suzanne Cooper. "2003 Summer Spill - - Two Week Curtailment Option" BPA, 6/2003.
[11] BPA used different power prices than those used in the council study.
[12] CRITFC. To: Steven Wright. From: CRITFC. RE: Summer Spill at Federal Columbia River Power System Dams. July 23, 2003.

- additional losses of adults would be caused by fallback through turbines and screen bypass systems.

While the CRITFC letter does not attempt a cost-effectiveness analysis, it concludes that full summer spill and funding of certain fisheries programs should be provided. The opinion expressed in this letter illustrates some of the uncertainty associated with existing information about the effectiveness of juvenile fish passage strategies.

6.2. Eliminate spill in dry years

In dry years, survival of Snake River migrants may be maximized by transporting fish, and the unit value of power is likely to be higher than average. In another analysis, the cost of bypass spill in a dry year was estimated to be about $150 million annually.[13] In a separate analysis, the total number of adult ESA-listed fish lost by eliminating spill in dry years was estimated to be in the range of 468 to 4,681 fish, depending on smolt to adult survival.[14] The cost of bypass spill per adult fish saved would therefore be $32,000 to $320,000.

7. An Example of Cost Effectiveness Analysis of Juvenile Passage Scenarios

7.1. Purpose and Objective

The purpose of the juvenile passage CEA is to demonstrate the potential for CEA to be used to improve efficiency of passage spill and the implementation of passage improvements in the Columbia River Basin. The analysis seeks to identify potential win-win situations for “fish” and “power.” In these situations, passage improvements could be implemented using a share of revenues from reduced bypass spill in such a way that both passage survival and net returns to the hydropower system would increase.

7.2. Scope

The analysis uses Snake River juvenile mainstem passage survival as the objective, and evaluates only bypass spill and passage improvements. Passage survival is measured from above Lower Granite dam to the Bonneville dam tailrace. There are many ways (timing, location, amounts) in which bypass spill could be reduced to increase power revenues. For this analysis, only spill at Snake River dams is considered, and only survival of Snake River stocks is measured.

Other runs, meaning upper Columbia River stocks or stocks from Lower Columbia tributaries, are not evaluated, and no actions or scenarios are considered that could reduce their survival. These stocks are excluded merely to simplify the example. Some actions

[13] Data on value of power losses caused by spill are from the NPCC presentation "Cost and Energy Impacts of Fish and Wildlife Operations" Slides 10 and 11.
[14] Fish numbers are from NPCC “Recommendations on 2001 Federal Columbia River Power System Operations and Fish Survival," Tables 7, 8 and 9.

that could benefit these other stocks are included in the analysis. Future CEA could consider these stocks using the methods developed here.

Many potential actions to increase salmon and steelhead populations in the Columbia Basin are not considered because they would not affect juvenile passage survival in a measurable way, or because they are not being actively investigated at this time. These actions include hatcheries, habitat improvements in the estuary and natal streams, harvest management, and major hydrosystem changes such as dam removals and flow management. Thus, it is quite possible that there are actions that are more cost-effective than the ones studied here.

There are many actions being considered that could improve Snake River juvenile passage survival. Bonneville provides information on passage improvements that are currently planned.[15] Many more actions are considered or evaluated in other forums.[16] Many of these actions are in the conceptual or development phase, so the information needed to evaluate them in the CEA is not available, or the expected magnitude of their effects is somewhat controversial. For some other actions, their effectiveness depends substantially on which other actions are included.

For this preliminary analysis, passage improvements were selected based on the reliability of information about their cost and effectiveness. Three types of improvements were selected: extended length screens, removable spillway weirs (RSWs), and the corner collector at Bonneville dam.

The actions considered in this analysis and their purposes are shown in Table 1.

Table 1: Actions considered in IEAB Juvenile Passage Cost-Effectiveness Analysis

Action	Purpose
Cease Ice Harbor juvenile bypass spill on July 31- no bypass spill in August	Reduce spill and increase power sales revenue
Build and operate extended length screens, Lower Granite Dam	Improve fish guidance efficiency
Build and operate extended length screens, Little Goose Dam	Improve fish guidance efficiency
Build and operate Bonneville Powerhouse II corner collector	Increase share of migrants passed by the sluiceway
Build and operate removable spillway weir and behavioral guidance system at Little Goose dam	Reduce spill and increase power sales revenue. May increase spillway survival
Build and operate removable spillway weir and behavioral guidance system at Lower Monumental dam	Reduce spill and increase power sales revenue. May increase spillway survival
Build and operate removable spillway weir and behavioral guidance system at Ice Harbor dam	Reduce spill and increase power sales revenue. May increase spillway survival

[15] Bonneville maintains spreadsheets for "Hydro Project Capital Costs, Appropriations, and Estimated Interest & Depreciation" which are updated annually

[16] For example, see Giorgi, Albert, Mark Miller and John Stevenson (2002); Independent Scientific Advisory Board for the Northwest Power Planning Council (2002); USACE, North Pacific Division (2001); Skalski, John R. and Dilip Mathur (undated) and Whitney, Richard R., Lyle D. Calvin, Michael W. Erbo Jr. and Charles Coutant (1997)

7.3. Example Scenarios

Reduced spill and selected passage improvements are combined into scenarios to show how increased juvenile passage survival and increased net power system revenues (increased power revenues net of passage improvement costs) might both be achieved. Reduced spill increases net power system revenues but reduces survival, and RSWs increase net power system revenues and are assumed to maintain survival. Only extended length screens and the Bonneville corner collector increase survival measurably. Since our goal is to increase net power system revenues and increase survival, we need to include at least one of the passage improvements in any scenario. Three example scenarios, or combinations of actions, are evaluated. The scenarios are described in Table 2 below.

Table 2: Example Scenarios for the Juvenile Passage Cost-Effectiveness Analysis
Example 1. Cease August Bypass Spill at Ice Harbor and Construct Extended Length Screens at Lower Granite and Little Goose
Example 2. Cease August Bypass Spill at Ice Harbor and Build Bonneville Corner Collector
Example 3. Build Removable Spillway Weir and Behavioral Guidance System at Ice Harbor and Build Bonneville Corner Collector

In two scenarios, bypass spill would end at Ice Harbor July 31 and increased annual average power revenues of $6 million would be available to finance passage improvements. In one of these two scenarios, bypass spill reduction is combined with extended length screens at Lower Granite and Little Goose dams. Extended length screens at Lower Granite and Little Goose are currently operational. Therefore, the CEA for this scenario is retrospective.

In the second of the first two examples, the July 31 end to bypass spill at Ice Harbor is combined with the corner collector at Bonneville powerhouse II. The corner collector at Bonneville powerhouse II is currently under construction. Therefore, the CEA for this improvement is also retrospective.

In the third example, a RSW and behavioral guidance system (BGS) would be built at Ice Harbor. The RSW at Ice Harbor is currently in the design phase, so the analysis is prospective. The analysis considers the potential for increased revenue from reduced spill enabled by the RSW to be used to increase passage survival by financing and building the corner collector at Bonneville powerhouse II. Therefore, the CEA for this improvement is also retrospective.

7.4. Analysis Methods

The analysis combines three types of information. Increased revenues from reduced bypass spill are estimated from hydrosystem and electricity price forecasting models.

Information on the capital costs of passage improvements was provided by the Bonneville. Changes in juvenile passage survival caused by reduced passage spill and passage improvements were estimated using SIMPAS, a model of juvenile salmon and steelhead survival.

7.4.1. Revenues from Reduced Spill

The measures of hydropower revenues used in the analysis are all derived from an analysis of costs of passage spill presented to the Council by Council staff in 2003.[17] This analysis used the Genesys model to estimate hydrosystem power production, and the Aurora model provided data representing monthly "stable" (i.e., non-crisis) bulk electricity prices at Mid-Columbia. These prices are used to place a dollar value on changes in electricity production. Results are provided by facility.

To simplify the analysis, reduced spill on the Lower Columbia River is not considered. On the Snake River, only Ice Harbor provides spill in summer. The total cost of summer bypass spill at Ice Harbor is about $10.5 million annually in an average water year. The analysis estimates that about 56% of summer spill cost occurs in August, so Ice Harbor bypass spill costs in August are about $6 million. In two example scenarios, this revenue is assumed to be available to cover costs of extended length screens or the corner collector at Bonneville. These passage improvements would not have any additional effects on hydropower production.

RSWs are being considered for three out of four Snake River dams. It is assumed that the RSWs would reduce bypass spill by half year round. Therefore, half of the revenue losses from bypass spill could be avoided at Little Goose, Lower Monumental and Ice Harbor. Annual average revenue loss due to full bypass spill at these three facilities would be about $2 million, $7 million and $29 million, respectively, so about $1 million, $3.5 million and $14.5 million of power revenues could be saved, respectively, by RSWs. Bonneville and the U.S. Army Corps of Engineers (Corps) recently estimated that the RSWs would save power worth an average of $0.6 million annually at Little Goose and $13 to $22 million at Ice Harbor. Therefore, our assumptions probably favor the RSW at Little Goose, but are conservative for Ice Harbor.

It should be noted and recognized that SIMPAS as modified for this CEA uses average monthly flows from a long hydrologic period. Juvenile passage conditions in any given month will differ from SIMPAS results as hydrologic conditions vary from the average. The energy analysis also assumes average hydroelectric conditions in determining energy losses and price. In general, energy losses from spill will be less valuable when hydroelectric supplies are plentiful, and more valuable when supplies are scarce. The improved guidance efficiency of extended length screens may be more important in dry years because in-river survival is lower in low water conditions compared to barging.

[17] Fish and Energy Impacts Resulting from Reductions in Summer Bypass Spill, July 16, 2003;

7.4.2. Costs of Passage Improvements

Capital costs of passage improvements were obtained from Bonneville Power Administration.[18] Actual capital costs may differ from these planned costs. The planned costs generally include planning, design, regulatory and construction costs.

For the RSW's, actual capital costs of the facilities are less than half of the planned cost.[19] The facilities cost about $15 million each, but two years of studies will be required to determine if survival could be improved. If so, then BGSs would be constructed, and more studies would be required. Total costs with the studies and the BGS are less than the budgeted costs provided by Bonneville. To be conservative, it is assumed that the BGSs would have to be included, and the higher budgeted costs are used.

It is assumed that the passage improvement facilities have a useful life of 20 years. A four percent real interest rate is used in the analysis.

Operating, maintenance and replacement (OM&R) costs must be included. For the extended length screens, OM&R costs have been estimated for several maintenance alternatives.[20] For the preferred maintenance alternative, maintenance costs are estimated to be $0.42 million per year at either Lower Granite or Little Goose. This alternative includes the purchase of spare screens and other parts costing $3.09 million to help minimize maintenance costs.

OM&R costs for the other passage improvements are less certain at this time. For the corner collector, OM&R costs are assumed to be the same proportion relative to capital costs as for the extended length screens. OM&R costs, therefore, are equal to the ratio of the capital cost to the capital cost of the extended length screens, times the annual maintenance cost ($0.42 million) or replacement cost ($3.09 million) of the extended length screens.

RSW OM&R costs are believed to be small compared to extended length screens.[21] RSW operating costs are required for raising and lowering once per year, and for pumping water. Costs are assumed to be $100,000 per RSW, annually.

Costs assumed for the analysis are provided in Table 3.

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[18] Spreadsheets for Hydro Project Capital Costs, Appropriations, and Estimated Interest & Depreciation. Updated annually

[19] Barnhart, 2003

[20] Lower Snake and Columbia Rivers Extended Length Screen (ESBS) System-Wide Letter Report. USAC, 2002.

[21] Kalamaz, 2003

Table 3: Assumed Capital, Replacement, and O&M Costs of Passage Improvements (Million $)

Costs	Bonneville 2nd Power House Corner Collector	Extended Length Screens		Removable Spillway Wiers		
		Lower Granite	Little Goose	Little Goose	Lower Monumental	Ice Harbor
Initial Capital	$50.00	$30.00	$30.00	$45.80	$45.55	$42.00
Annualized Capital[1]	$3.68	$2.21	$2.21	$3.37	$3.35	$3.09
Replacement Cost[2]	$5.15	$3.09	$3.09	$0.00	$0.00	$0.00
Annualized Replacement Cost[1]	$0.36	$0.22	$0.22	$0.33	$0.33	$0.31
Annual O&M [3]	$0.70	$0.42	$0.42	$0.10	$0.10	$0.10
Total Annualized Cost	$4.74	$2.85	$2.85	$3.80	$3.78	$3.50
Total NPV Cost	$64.45	$38.67	$38.67	$51.70	$51.42	$47.52

1. 20 years, 4 percent real interest
2. For ELS, buy a spare ESBS and a spare VBS. For others, (capital cost)/(ELS capital cost)x(ELS replacement)
3. For ELS, from USACE 2002. For others, (capital cost)/(ELS capital cost)x(ELS O&M)

7.4.3. Juvenile Survival and SIMPAS Modeling

7.4.3.1. SIMPAS Status Quo Data

SIMPAS is a simple spreadsheet model of juvenile passage survival developed by NMFS. The model can estimate the individual and cumulative effects of spill and passage improvements that affect passage efficiency (the share of smolts that do not go through the turbines), smolt survival through each passage route, and survival through each Snake River reservoir, from above Lower Granite dam to the tailrace at Bonneville Dam. Effects on survival of three stocks are counted: fall Chinook, spring Chinook and steelhead.

Most of the parameters included in SIMPAS for this analysis are documented in the Federal Columbia River Power System 2001 Biological Opinion Appendix D (NOAA, 2001). Several changes were included for this work. The model was split into two separate models: one to represent the April through July period, and one to represent August. This split was used to better represent August bypass spill. Data showing average monthly Snake River outflows, forced spill and bypass spill were obtained from the Council (Fazio, 2003). SIMPAS requires daytime and nighttime spill levels. Forced spill was assumed to occur equally during day and night. Bypass spill was allocated to day and night according to the BiOp rules in place during each month.

With one model for each of two passage periods, it was necessary to estimate the share of each Snake River run that completes its downstream migration in each period. Data were obtained from the Fish Passage Center and from the University of Washington. From the available history, it appears that practically all steelhead and yearling Chinook have passed Lower Monumental dam well before July 31. For subyearling Chinook, being the fall run, the share varies from year to year. It is assumed that 65 percent have passed Ice Harbor dam by July 31, and 35 percent pass after then.

SIMPAS accounts for delayed mortality of transported migrants through the Differential Delayed Effects value, or D-value. The D-value is the proportion of juveniles transported to below Bonneville that survive to escapement. If D is less than the in-river survival rate, then in-river migrants survive at higher rates than transported fish.[22] SIMPAS used a mid-range estimate of the D-value for fall run Chinook (0.24) but no mid-range values were provided for spring Chinook or steelhead. The mid-point of the Lower and Upper D-values are used for spring Chinook (0.68) and steelhead (0.55).

SIMPAS was modified to include sluiceway passage at Bonneville powerhouse II. This was needed to model the new corner collector. Espenson (2003) summarizes research by the Corps of Engineers that showed that "nearly 35 percent of the yearling or spring chinook and 50 percent of the steelhead approaching the second powerhouse passed downriver through the sluiceway." These estimates are used for the status quo SIMPAS model.

Table 4 provides status quo survival estimates from SIMPAS, measured from above Lower Granite dam to the Bonneville tailrace. For comparison, the FCRPS BiOp Tier 2 hydrosystem juvenile survival rate objectives for Snake River fall Chinook, spring/summer chinook, and steelhead are 12.7%, 57.6%, and 50.8%, respectively.

Table 4: Summary of Baseline Survival Estimated from SIMPAS as Modified for CEA

Fall Chinook Apr-Jul	Fall Chinook August	Spring Chinook	Steelhead
13.9%	14.3%	52.4%	47.0%

7.4.3.2. SIMPAS Modeling of Passage Improvements

SIMPAS must be modified for the scenario that includes extended length screens. Corps researchers measured increases in fish guidance efficiency due to the longer screens for spring chinook: from 57 to 72 percent at Lower Granite dam and from 70 to 84 percent at Little Goose dam, or 14 to 15 percentage points.[23] Swan et al. (1992) reported on research using a configuration that simulated an extended length screen. For steelhead, they found a fish guidance efficiency of 83 percent as compared to 77 percent with a standard submerged traveling screen: a seven percentage point improvement.[24]

[22] Giorgi et al. page 7.
[23] Rebecca Kalamasz, USACE, personal communication, 11/20/03. Summary of data from Lower Granite and Little Goose Lock and Dam Turbine and Intake Screen Design Memorandum #42 and #30, December 2001.
[24] As summarized in Whitney et al., 1997, page 26.

The CEA here assumes that fish guidance efficiency was increased by 5 percentage points at each facility when extended length screens were added. This assumption is quite conservative given that research has found the actual improvement to be about 15 percentage points. The conservative assumption allows for possible operational problems and outages that might result in lower fish guidance efficiency.

SIMPAS is also modified for scenarios that include the Bonneville corner collector. Current expectations are that the "corner collector and improved screened bypass completed in 1999 are expected to pass 90 percent of the spring migrants and 75-80 percent of the summer migrants."[25] For steelhead and spring Chinook, 90 percent is assumed, and 75 percent is assumed for fall Chinook.

Information from the new RSW at Lower Granite dam suggests that the RSWs might increase survival, [26] but survival improvements at the new facilities cannot be estimated with any certainty. Therefore, it is assumed that the new RSWs do not increase survival.

8. Results of the Juvenile Passage CEA

8.1. Results for Individual Passage Measures

Simple cost-effectiveness measures, being cost per unit of survival change, can be estimated for actions that have measurable survival and cost effects. By assumption, the RSWs do not affect survival, so a measure of cost per unit survival cannot be provided. Table 5 shows results.

The preliminary analysis suggests that extended length screens at Lower Granite and Little Goose, and the Bonneville powerhouse II corner collector, are all highly cost-effective in comparison to August spill at Ice Harbor dam. For example, the annual cost of spill per one-percentage point increase in fall Chinook passage survival is $600 million (i.e., $6,000,000/-0.01; see Table 6 first line). The same measure for the extended length screens at Lower Granite dam is $11.9 million ($2,260,000/0.19; see Table 6 second line). Therefore, the extended length screens at Lower Granite dam appear to be approximately 50 times (600/11.9) more cost-effective for fall Chinook juvenile passage than spill at Ice Harbor in August. By a similar calculation, the extended length screens at Little Goose dam appear to be approximately 25 times (600/23.8) more cost-effective for fall Chinook juvenile passage than spill at Ice Harbor in August.

The same measure for the corner collector is $94.8 million ($4,740,000/.05, see Table 7 second line). The cost-effectiveness of the Bonneville corner collector appears to be approximately 6 times (600/94.8) that of Ice Harbor August passage spill. This measure does not consider the positive effects of the corner collector on Columbia River stocks.

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[25] CBB, 11/7/2003. $50 Million Bonneville Dam Project Expected To Up Survival.

[26] Quoting from the Columbia Basin Bulletin (12/8/03) "Preliminary results of an evaluation of the RSW at Lower Granite Dam show that survival probability rises from 93.1 percent with spill to 98 percent with the RSW and that survival is more consistent over the entire spill season with the RSW."

Table 5: Summary of Juvenile Passage Preliminary Cost-Effectiveness Analysis. (Cost Per Unit of Juvenile Survival for Selected Passage Actions)

	Million $ per Year per Percent Increase in Juvenile Survival		
	Fall Chinook	**Spring/ Summer Chinook**	**Steelhead**
August spill at Ice Harbor	$600.0	No Effect	No Effect
Extended length screens at Lower Granite	$11.9	$3.2	$5.7
Extended length screens at Little Goose	$23.8	$7.0	$14.3
Corner collector at Bonneville	$94.8	$94.8	$158.0

8.2. Example 1: Cease August bypass spill at Ice Harbor dam and build extended length screens at Lower Granite and Little Goose dams

Table 6 shows results for this example scenario. Results of this analysis are retrospective in that the extended length screens are already completed at Lower Granite and Little Goose dam. Ending August bypass spill at Ice Harbor would reduce survival of fall Chinook by about 1-hundredth of 1 percent, or 1 in 10,000 out-migrants. There would be no effect on spring Chinook or steelhead because they have all migrated past Ice Harbor by July 31.

Revenues generated by ending August spill at Ice Harbor would be worth $81.54 million in present value terms ($6 million per year at 4 percent for 20 years). This amount of revenue could fund construction of both extended length screens and still leave $12.21 million in present value terms for other purposes. With both extended length screens, survival of fall Chinook, spring Chinook and steelhead would increase by 0.31%, 1.11% and 0.61%, respectively. It should be noted that the assumed improvement in fish guidance efficiency (five percent) is much less than recently observed improvements, up to 15 percent for yearling spring Chinook.

There are many uncertainties embedded in this analysis. The screens are used to divert fish into transportation facilities, which may reduce survival compared with spill. To consider effects of a different assumption about delayed mortality, the D-values for fall Chinook, spring Chinook and steelhead were reduced to 0.20, 0.63 and 0.52, from 0.24, 0.68 and 0.55, respectively. For spring Chinook and steelhead, these values are the low end of the range suggested by the BiOp.

With this change, SIMPAS estimates the change in cumulative survival for the three groups following completion of extended length screens is 0.19%, 0.99% and 0.56%, as compared to 0.31%, 1.11%, and 0.61% with the baseline D-values. Even with the lower survival rate for transported fish, the screens are still highly cost-effective compared to Ice Harbor August bypass spill.

Table 6: Cease August Bypass Spill at Ice Harbor and Construct Extended Length Screens at Lower Granite and Little Goose						
			Change in % Survival to Below Bonneville			
Action	Annualized Net Change in Power Revenue plus Facility Costs, Million $	Net Present Value of Net Change in Power Revenue plus Facility Costs, Million $ [1]	Snake River Fall Chinook	Snake River Spring/ Summer Chinook	Snake River Steelhead	Columbia River Stocks
Power revenue and survival effects, no Ice Harbor August spill	$6	$81.54	-0.01%	0.00%	0.00%	None
Add Extended Length Screens, Lower Granite	($2.26)	($30.67)	0.19%	0.70%	0.40%	None
Cumulative Effect on Revenue Plus Costs, or Survival	$3.74	$50.87	0.18%	0.70%	0.40%	None
Add Extended Length Screens, Little Goose	($2.85)	($38.67)	0.12%	0.41%	0.20%	None
Cumulative Effect on Revenue Plus Costs, or Survival	$0.90	$12.21	0.31%	1.11%	0.61%	None
1. 20 years, 4 percent real interest						

8.3. Example 2: Cease August bypass spill at Ice Harbor dam and build Bonneville corner collector

Table 7 shows results for this scenario. Results of this analysis are retrospective in that the corner collector is already being built.

The Bonneville corner collector appears to be cost-effective for increasing passage survival of fall Chinook. Revenues from ending August spill at Ice Harbor could fund construction of the corner collector and still leave $17.1 million in present value terms for ratepayers or other purposes. With the corner collector, survival of fall Chinook, spring Chinook and steelhead would increase by 0.04, 0.05 and 0.03 percentage points, respectively. Survival of Columbia River stocks would also be increased, but this improvement has not been measured.

Table 7: Cease August Bypass Spill at Ice Harbor and Build Bonneville Corner Collector

			Change in % Survival of Juveniles to Below Bonneville			
Action	Annualized Net Change in Power Revenue plus Facility Costs, Million $	Net Present Value of Net Change in Power Revenue plus Facility Costs, Million $ [1]	Snake River Fall Chinook	Snake River Spring/ Summer Chinook	Snake River Steelhead	Columbia River Stocks
Power revenue and survival effects, no Ice Harbor August spill	$6	$81.54	-0.01%	0.00%	0.00%	None
Effects of Bonneville Corner Collector	($4.74)	($64.45)	0.05%	0.05%	0.03%	Unknown
Cumulative Effect on Revenue Plus Costs, or Survival	$1.26	$17.10	0.04%	0.05%	0.03%	Positive

[1] 20 years, 4 percent real interest

8.4. Removable Spillway Weirs, Power Revenues and Costs

By assumption, the RSWs do not directly affect survival. However, if increased power revenues exceed total implementation costs, then the positive net power system revenues could be used to fund passage improvements that increase survival, so that RSW is cost-effective.

With the costs shown in Table 3, the RSW at Little Goose dam does not appear to be cost effective. The annual value of reducing bypass spill is $1.0 million, but the annualized capital cost of the RSW is $3.8 million. It is possible that increased power revenues are understated, because more than 50 percent of bypass spill might be avoided, and costs could be overstated because most capital costs are already spent, costs of behavior guidance systems might be avoided, and annual operations and maintenance costs could be less than assumed. At a minimum, more detail in the revenue and cost estimation is clearly justified before this facility is built.

At Lower Monumental, results for the RSW are much closer. Annual power revenues of $3.5 million compare to annual costs of $3.78 million, which would make this project not cost-effective. However, if costs are overstated, or if increased power revenues are understated (perhaps more than 50 percent of bypass spill can be avoided), then completion may be economically justified.

At Ice Harbor, the power revenue savings from the RSW easily justifies its costs: annualized costs of $3.5 million compare to additional power revenues of $14.50 million. Therefore, this RSW appears to be cost-effective.

8.5. Example 4. Build Removable Spillway Weir at Ice Harbor and Build Bonneville Corner Collector

Net power system revenues from the RSW at Ice Harbor are more than enough to finance the Bonneville corner collector, thereby ensuring that fish and power are both better off. Table 8 shows the results.

Table 8: Build Removable Spillway Weir at Ice Harbor and Build Bonneville Corner Collector

			Change in % Survival of Juveniles to Below Bonneville			
Action	Annualized Net Change in Power Revenue plus Facility Costs, Million $	Net Present Value of Net Change in Power Revenue plus Facility Costs, Million $	Snake River Fall Chinook	Snake River Spring/ Summer Chinook	Snake River Steelhead	Columbia River Stocks
Power Revenue from RSW at Ice Harbor	$14.50	$197.06	0.00%	0.00%	0.00%	None
Add RSW at Ice Harbor	($3.50)	($47.52)	0.00%	0.00%	0.00%	None
Cumulative Effect on Revenue Plus Costs, or Survival	$11.00	$149.54	0.00%	0.00%	0.00%	None
Add Bonneville Corner Collector	($4.74)	($64.45)	0.05%	0.05%	0.03%	Unknown
Cumulative Effect on Revenue Plus Costs, or Survival	$6.26	$85.09	0.05%	0.05%	0.03%	Positive

9. Interpretation of Results

The preliminary CEA suggests that the method might be very helpful in assisting managers with decisions about investments in passage improvements. Although there are uncertainties in survival and cost parameters, results of some of the calculations suggest that order-of-magnitude cost-effective improvements may be possible. In this situation, a large amount of uncertainty can be accommodated while still leading to a fairly certain result.

The three example scenarios indicate that some passage improvements are highly cost-effective compared to bypass spill, and results suggest that additional bypass survival could be obtained at a lower total cost. Extended length screens and the Bonneville corner collector appear to be highly cost-effective relative to August bypass spill. The RSW at Ice Harbor would increase power revenues enough to pay for itself and other passage improvements, even without considering that the Ice Harbor RSW might increase survival. In all of the scenarios, the analysis indicates that juvenile survival could be increased at reduced cost.

On the other hand, the RSW at Little Goose dam does not appear to be a cost-effective investment. Its cost exceeds the present value of power revenue savings by a considerable margin, and it is currently assumed that it does not increase survival. Additional research on costs and survival at Little Goose and Lower Monumental might result in more certain results.

9.1. Limitations in Applying Results of these Examples

The quantitative results of our juvenile passage CEA have limited policy implications for several reasons. First, some of the passage improvements analyzed in the examples are already completed or planned for implementation. The passage improvements in our example were selected for analysis because their characteristics, their costs and effects on juvenile passage, are relatively well known.

Second, a CEA should be just one in a series of increasingly detailed biological, hydrologic, and engineering studies that may be required to implement any set of cost-effective hydrosystem actions. A number of non-economic uncertainties are being debated outside of this report. Uncertainties associated with some of the actions are discussed below. Some impediments and possible solutions to implementing cost-effective juvenile passage improvements are also discussed.

Third, there are institutional constraints to implementing cost-effective improvements. Passage improvements are not universally viewed as substitutes for bypass spill. Also, there is currently no formal mechanism whereby increased power revenue from reduced spill could be used to fund passage improvements. Additional research would help to resolve the best role for CEA in decision-making about passage improvements.

9.1.1. Uncertainty about survival improvements

Some advantages of bypass spill relative to passage improvements are not covered by the CEA. The survival benefits of bypass spill are fairly well documented. The survival improvements for some passage improvements are less certain. In particular, some passage improvements such as extended length screens achieve survival benefits, in part, by allowing more fish to be transported. The survival benefits of juvenile transportation are viewed by some as being uncertain. SIMPAS is a very simple model of passage survival, and it may be viewed by some as inappropriate for this analysis.[27] The Independent Scientific Advisory Board (ISAB) stated that:

> These are only “point estimates” and are subject to a considerable degree of uncertainty. For this reason, it is not appropriate to develop a long-range management plan just on the basis of results from assuming that these uncertain estimates are true. The importance of uncertainty in assessments of this type needs to be evaluated carefully.”

[27] A letter from the Columbia Basin Fish and Wildlife Authority to the Council dated October 16, 2002 (Sando, 2002) quotes from the Independent Scientific Advisory Board.

9.1.2. Uncertainty about costs

Costs associated with a passage improvement are often uncertain, and cost uncertainty is often related to survival uncertainty. In the case of RSWs, the need for a BGS and its future cost is related to survival obtained by the RSW. Operations and maintenance costs for new passage improvement technologies are often uncertain.

9.1.3. Uncertainty regarding future policies

The CEA presented here uses a 20-year period of analysis. Many values used in the analysis become increasingly uncertain as the length of the forecast period increases. In particular, the value of passage survival due to passage improvements in the far future (10 to 20 years out) is unclear. The long-term status of the listed species, the hydrosystem, and the laws that set survival goals are not all clear. Uncertainty about the future argues for a shorter period of analysis and implementation of only those passage improvements that are highly cost effective in the short term.

9.1.4. The maximum survival perspective

Some interests would not agree that bypass spill should be decreased to fund passage improvements, even if they agreed that the change would be cost-effective. In this view, all feasible passage improvements and bypass spill should be implemented, regardless of the cost to obtain, at a minimum, the amount of survival required by the BiOp. This view is supported by the fact that some passage survival goals are not being met, and the perspective that implementation of passage improvements should not be limited by the availability of funds.

It is true that many passage improvements are being implemented throughout the FCRPS almost as quickly as they can be shown to be feasible and funding can be secured. In a sense, this fast pace of implementation is driven by the belief that the passage improvements will be cost-effective: they will be able to meet survival goals at a cost less than spill.

Even if the goal is to achieve survival targets as soon as possible, CEA could help reach these goals sooner. Decisions made by the IT and the SCT must take the availability of funds into account. Because of the nature of the funding mechanisms that are currently in place, there are *de facto* budget constraints facing policy-makers. To the extent that annual funding limits constrain the implementation of cost-effective passage measures, CEA and an ability to borrow against future power revenues might speed the implementation of passage measures, and ultimately, recovery of listed ESUs.

9.1.5. Institutional Constraints

The ability to fund a more cost-effective set of mainstem actions is somewhat limited by the institutional arrangements that currently govern the source of capital for investments at Corps and Bureau of Reclamation (Bureau) hydro projects. Capital investments for fish passage improvements at Corps/Bureau projects are funded through appropriations made by Congress. Additional revenues that BPA might earn through reduced spill do not have any direct connection to the Congressional appropriations process. As a result, there is no formal mechanism currently available for BPA to provide funds to the Corps and Bureau in excess of what Congress has chosen to appropriate. Under current rules, if additional (or accelerated) capital investments for fish at Corps/Bureau projects are determined to be part of a more cost-effective mainstem program, these (new or accelerated) projects would have to survive the Congressional appropriations process.

On the other hand, there is considerable flexibility within the annual Fish and Wildlife budget to prioritize and allocate funds. The Implementation Team (IT) and its technical teams provide a mechanism for coordination, decision, and appropriate and timely implementation of the BiOp.[28] Currently, the IT of the Columbia River Regional Forum is evaluating potential offsets to reduced summer bypass spill. This process demonstrates that there is some flexibility to change bypass spill and implement new passage improvements.

10. Fuller Implementation of Juvenile Passage CEA

This juvenile passage CEA is preliminary. Many limitations of this preliminary CEA were discussed in Section 9. The scope of this CEA was limited to bypass spill on the Snake River, and only a few types of passage improvements were considered. Many other types of actions that could increase survival or escapement could be evaluated. Additional analysis is subject to the available data on survival and costs.

10.1. Focus on unfunded passage improvements

It would be useful to identify and investigate changes in system operation and configuration that might be cost-effective, and to analyze cost-effective improvements that would not be implemented without additional funds. In these situations, detailed analysis might have more immediate benefits, because they would help get projects funded. A list of potential projects has been provided by the IT.[29]

10.2. Apply additional hydrologic/survival modeling

The analysis of hydrology and survival provided from secondary sources could be improved to provide more insight into cost-effective measures. Better information about

[28] From Regional Implementation Forum information (NOAA 2003)
[29] Palensky, 2003. Spreadsheet of offset opportunities and principles.

the timing and survival parameters of wild and hatchery stocks would be helpful. CEA should be conducted with other passage models such as CRISP.

10.3. Resolve key uncertainties

Many types of uncertainties limit the utility of the analysis. In particular, uncertainties involving D-values, long-run efficacy of passage improvements in the far future could be investigated. CEA sensitivity analysis should be used to identify which uncertain parameters matter most to cost-effectiveness decisions.

One useful area of research might be to investigate more complex models and objective functions for endangered species recovery that consider risk and uncertainty. For example, the objective function might be to minimize social cost where (a) social cost is assumed to increase with the risk of extinction, (b) this cost becomes very high at a high risk of extinction, and (c) the results of recovery measures are also uncertain. This is similar to a portfolio management problem where the decision-maker is highly risk averse.

10.4. Expand scope to mainstem Columbia and non-federal projects

Our analysis intentionally limited the scope to Snake River improvements. Mainstem improvements, including non-federal facilities, should be investigated. The potential for using cost-effective projects at FCRPS projects to fund passage improvements at non-federal projects should be considered.

11. References

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