LOWER SNAKE RIVER JUVENILE SALMON MIGRATION

FEASIBILITY STUDY

RISK AND UNCERTAINTY ASSESSMENT

2.14.1 INTRODUCTION

This appendix describes the risk and uncertainty assessment of the Lower Snake River Juvenile Salmon Migration Feasibility Study. This study may affect decisions about environmental and economic values people care about and want to protect. As such, it is important to consider the reliability of its findings. That is the purpose of this risk and uncertainty assessment. Its overall conclusion, in its most succinct form, is that unresolved social and economic uncertainties do cause uncertainty about whether it would be more cost-effective to breach the four Lower Snake River dams or not. The driving uncertainties at this point are uncertainties about the value of future recreational and passive use benefits if the dams are breached, uncertainties about future anadromous fish stocks and uncertainties about how social and economic costs will be distributed. Other economic uncertainties, though significant in an absolute sense, are unlikely to affect decisions about whether it would be more cost-effective to breach the four Lower Snake River dams or not.

How best to assess risks and uncertainties in studies of natural resources management options is a difficult question to answer, in that ignoring uncertainties can lead to bad decisions but considering them can bog down the decision-making process. Two of the best references on the topic are *Confronting Uncertainty in Risk Management: A Guide for Decision Makers* (Finkel 1990) and *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis* (Morgan *et al*. 1990). Both advocate uncertainty analysis, but warn against "paralysis by analysis." A classic paper on right and wrong ways for dealing with uncertainty in making risk management decisions is "Witches, Floods and Wonder Drugs: Historical Perspectives on Risk Management" (Clark 1980). A compilation of classic papers on making risk management decisions under uncertainty can be found in the Resources for the Future book *Readings in Risk* (Glickman and Gough 1990). Finally, a more recent and somewhat more technical treatment of the topic can be found in *Uncertainty Analysis in Ecological Risk Assessment* (Warren-Hicks and Moore 1998).

The approach for this particular risk and uncertainty assessment draws from the U.S. Army Corps of Engineers' *Guidelines for Risk and Uncertainty Analysis in Water Resources Planning* (USACOE 1992) (the Guidelines) and was designed to incorporate their general recommendations. The Guidelines define a risk and uncertainty analysis as being composed of an *assessment* and an *evaluation*. Under the Guidelines' definition, this study is a risk and uncertainty assessment. When describing the end use of the risk and uncertainty assessment in the planning process, the Guidelines identify two basic issues:

- *The risk and uncertainty assessment should provide a clear picture of the reliability of the overall assessment.*
- *The assessment should provide useful taxonomies and identification of important questions relevant to risk management. It should highlight just where political and social judgments have to be made.*

The remainder of this appendix addresses the methods and results of dealing with these issues for the Lower Snake River Juvenile Salmon Migration Socio-Economic Feasibility Study.

2.14.2 METHODS

The primary source of information for the risk and uncertainty assessment was the DREW workgroups. The workgroups provided three general types of information:

- Point and range estimates of NED costs and benefits of alternatives under consideration.
- Verbal and/or written responses to a questionnaire designed to help ascertain the reliability of cost and benefit estimates, and identify potentially important unanswered questions risk managers should be aware of.
- Risk and uncertainty discussions for their sections of the Economic Appendix.

2.14.2.1 National Economic Development

The NED risk and uncertainty assessment used a combination of quantitative and qualitative methods described below. NED has the most fully developed risk and uncertainty assessment. Brief, qualitative risk and uncertainty assessments for social and regional analysis and tribal circumstances were conducted as well. The methods for these assessments are discussed following the NED methods section.

<u>2.14.2.1.1 Quantitative Methods</u>

The quantitative methodology used for the risk and uncertainty assessment is nominal range sensitivity analysis (NRSA). Other methods developed by the DREW risk and uncertainty workgroup included a spreadsheet tool for estimating probability distributions of cost variables and an expert elicitation protocol for estimating probability distributions. NRSA provided a simpler way to identify important uncertainties than these probabilistic methods. That in turn allowed the workgroups to spend more time refining their models and assumptions, rather than trying to assign probabilities to variables that, with the advantage of hindsight, might be shown through NRSA to be unlikely to affect the cost effectiveness ranking of alternatives.

NRSA involves holding all cost parameters except one at their nominal values (i.e., best estimates), while varying the remaining parameter from its low-end to high-end range estimate. Thus for an additive model (e.g., a model that computes net benefit from component benefits and costs) the NRSA gives a set of 2*n* outputs describing the range of possible model outputs (net benefit) given the input (component benefit and cost) uncertainties:

$$Y_{i,low} = \sum_{\substack{j=1 \\ j \neq i}}^{n} X_{j,nom} + X_{i,low} \qquad (i = 1, \ldots, n)$$

$$Y_{i,high} = \sum_{\substack{j=1 \\ j \neq i}}^{n} X_{j,nom} + X_{i,high} \qquad (i = 1, \ldots, n) \tag{1}$$

Nominal and range estimates were provided by individual workgroups on an average annual basis. These data, presented in Table 1, were used to compute the nominal net benefit associated with Alternatives A-2a (maximum fish transport without major system improvements), A-2c (maximum fish transport with system improvements, low cost) and A-3 (dam breaching) relative to A-1 (existing conditions) at 6.875, 4.75 and 0% discount rates. This simply involved using the benefit and cost estimates reported in the Nominal Value column of Table 1. For example, the nominal net benefit, at the 6.875% discount rate, for Alternative A-3 relative to A-1 is computed using the A-3 data from the Nominal Value column of the 6.875% discount rate table from Table 1:

= (196,425+1,593) – (48,787 + 271,000 – 29,178 + 24,034 + 15,424)

= -$132,049,000

Table 1 – Point and range estimates for NED costs and benefits relative to Alternative A-1 ($1,000s) (page 1 of 3)

Table 1 – Point and range estimates for NED costs and benefits relative to Alternative A-1 ($1,000s) (page 2 of 3)

Table 1 – Point and range estimates for NED costs and benefits relative to Alternative A-1 ($1,000s) (page 3 of 3)

Similarly, the nominal net benefit at the 0% discount rate for Alternative A-2b relative to A-1 is computed using the A-2c data from the Nominal Value column of the 0% discount rate table from Table 1:

= (-1,180 -188) – (1,390 – 8,000 + 0 + 0 + 0)

= $7,978,000.

The nominal range sensitivity analysis computed net benefits as for nominal net benefits, except that the low-end or high-end range estimate for one parameter was substituted for its nominal value, as described by equation 1. Thus, the low-end nominal range estimate, varying the parameter Recreation Benefits at the 6.875% discount rate, for Alternative A-3 relative to A-1 is computed using the A-3 data from the Nominal Value column of the 6.875% discount rate table from Table 1, for all parameters except Recreation Benefits, for which the value in the Low-End Nominal Range Estimate column is substituted:

= (56,000 1,593) – (48,787 + 271,000 – 29,178 + 24,034 + 15,424)

= -$272,474,000.

As a final example, the high-end nominal range estimate, varying the parameter Power Costs at the 4.75% discount rate, for alternative A-2a relative to A-1 is computed using the A-2a data from the Nominal Value column of the 4.75% discount rate table from Table 1, for all parameters except Power Costs, for which the value in the High-End Nominal Range Estimate column is substituted:

= (1,940 176) – (– 2,556 – 7,000 + 0 + 0 + 0)

= -$11,672,000.

The nominal range sensitivity, computed as the absolute difference between the high- and low-end nominal range estimates, provides an estimate of the overall sensitivity of the nominal net benefit to the uncertainty in a particular parameter. For example, at the 4.75% discount rate, the nominal net benefit for Alternative A-3 relative to A-1 is – $96,321,000. The low- and high-end nominal range estimates for Implementation Costs are – $94,546,000 and – $98,096,000 so the nominal range sensitivity for Implementation Costs at the 4.75% discount rate is the absolute value of the difference:

= | (– $98,096,000) – (– $94,546,000) |

= $3,550,000.

Paraphrasing, the estimate of the annual average net benefit of Alternative A-3 relative to A-1, at the 4.75% discount rate has a sensitivity range of over $3 million due to uncertainty about implementation costs. While this level of uncertainty may seem high, uncertainty about implementation costs creates no uncertainty about the preferred alternative if one accepts the 4.75% discount rate, the nominal cost and benefit estimates, and the Implementation Costs range estimates for A-3 relative to A-1 provided in Table 1. At both the high and low ends of the sensitivity range, the annual net benefit of A-1 exceeds the annual net benefit of A-3 by over $90 million. In other words, uncertainty about Implementation Costs would not change a decision between A-1 and A-3 based on a net benefit criterion; A-1 would be the preferred alternative regardless of the Implementation Costs value used.

The average of the high- and low-end nominal range estimates is a useful summary statistic for evaluating whether, given the parameter uncertainties, the point estimate of net benefits (the nominal value) is more likely to overestimate or underestimate the true value. So, looking again at the previous example, the average change for Implementation Costs at the 4.75% discount rate is:

= 0.5*(– $98,096,000 – (– $96,321,000)) + (– $94,546,000 – (– $96,321,000))

= 0.5*(– $1,775,000 + $1,775,000)

= – $0.

The value of zero for the average change of implementation costs is an indication that the nominal value for A-3 relative to A-1 at the 4.75% discount rate is equally likely to over- or underestimate the relative net benefit of A-1.

A final statistic computed as part of the nominal range sensitivity analysis is the normalized nominal range sensitivity:

$$\text{normalized nominal range sensitivity for parameter } i = \frac{\text{nominal range sensitivity for parameter } i}{\sum_{j=1}^{n} \text{nominal range sensitivity for parameter } j} \qquad (2)$$

The normalized nominal range sensitivity provides an estimate of the relative sensitivity of relative net benefit to each parameter uncertainty. The normalized nominal range sensitivity falls between 0 and 1. Parameters with higher normalized nominal range sensitivities create greater uncertainty about relative net benefit than parameters with lower normalized nominal range sensitivities. Because they are relative values, normalized nominal range sensitivities are only comparable across parameters, not across alternatives or discount rates.

<u>2.14.2.1.2 Qualitative Methods</u>

The DREW workgroups were asked to write risk and uncertainty discussions for their sections of the Economic Appendix. These sections tended to focus on describing data, methods and results. Therefore, after reviewing the workgroups' risk and uncertainty discussions, follow-up questioning was conducted to better understand the choices and assumptions used in their analyses, how these affected results, and how they compared across workgroups. The follow-up questioning was necessary to understand the reliability of the overall assessment and important risk management questions, which, again, are the two basic risk and uncertainty assessment issues identified in the Guidelines (USACOE 1992). Workgroup leaders were asked to review an uncertainty worksheet and questionnaire, after which the risk and uncertainty workgroup leader interviewed them. The worksheet and questionnaire used by the workgroup leaders to prepare for their interviews with the risk and uncertainty team leader are provided in Tables 2 and 3.

Information gathered through interviews and other follow-up discussions with workgroup leaders was used to help interpret the results of the NRSA. The results presented below are based on the qualitative and quantitative data obtained by these methods.

2.14.2.2 Social and Regional Analysis

The workgroups that provided input to the social and regional analyses reported that uncertainty about future cost allocation decisions impaired their ability to derive useful data for assessing the social and regional impacts of the alternatives. The regional economic impact analysis suffered from significant errors and omissions that prevented the workgroup from engaging in a meaningful risk and uncertainty assessment, beyond simply documenting the major errors and omissions that exist. Similarly, the methodology for assessing social risks and uncertainties was limited to documenting major sources of uncertainty.

Table 2. Risk and Uncertainty Worksheet

This worksheet breaks out seven specific types of uncertainty. Please identify three to five uncertainties of each type that have the biggest potential impact on your workgroup's results and conclusions. The worksheet is intended to make it easier to respond to the questionnaire, so please complete the worksheet before starting the questionnaire. Thank you.

1. *Incomplete information* – missing data; also could include concerns about the representativeness of the available data.

2. *Natural variability* – conditions that change over time, vary among individuals, or change with location.

3. *Model structural uncertainty* – uncertainties about the correct way to describe something in a model, or approximation errors, due to the fact that models are just models, not perfect representations of the real world.

4. *Missing variables* – things not considered simply because we do not know about them, or enough about them, to include them in the analysis.

5. *Lack of understanding* – inability to fully understand available data and models.

6. *Disagreement* – legitimate differences of opinion about priorities or values that in turn affect the system being assessed or the questions we are trying to answer about it.

7. *Ambiguity* – sloppiness or imprecision in defining objectives, variables, assumptions, or decision criteria.

Table 3. Risk and Uncertainty Questionnaire

- How reliable, representative and complete were your data?
- What nagging concerns do you have about your data?
- How did you decide on the methods you adopted?
- What alternative methods might you have used?
- What nagging concerns do you have about your methods?
- How did you choose the models you used?
- What other models might you have used instead?
- What nagging concerns do you have about your models?
- What key assumptions did you make in your analysis?
- Why did you make these assumptions?
- What information would have been most useful to help you refine your assumptions?
- If you could change any of your assumptions, what would they be and why?
- If you generated scenarios, how extreme are your high and low scenarios?
- What is the most realistic scenario you can think of that would give results outside the range of scenarios you used? How likely is it?
- What is the most realistic scenario you can think of that would change your ranking of alternatives? How likely is it?
- In your opinion, what are the most important unanswered questions about your work group's piece of the project?
- If you had it to do over again, what would you do differently and why?

2.14.2.3 Tribal Circumstances

The methods used by the tribal circumstances workgroup differed from those described above. The tribal circumstances workgroup examined tribal levels of cultural and material wellbeing and distress using measures of self-perception, death rates, health, poverty, unemployment and per capita income. The workgroup also evaluated risk and uncertainty separately, whereas the other workgroups combined the two related concepts.

The tribal circumstances uncertainty assessment focused on the reliability of workgroup's ordinal ranking of the alternatives for the four Lower Snake River dams. They ranked the alternatives based on the estimated relative magnitude of salmon recovered for the tribes, as well as the direction and general effect of the estimated relative magnitude of salmon recovery on tribal culture, rates of death and health, poverty, employment/unemployment and income. They also evaluated the reliability of their ordinal ranking of alternatives based on duration of near-current levels of tribal pain and suffering.

The tribal circumstances risk assessment focused on the consequences of possible errors in PATH estimates on tribal levels of cultural and material wellbeing and distress. They evaluated the consequences of over-estimation and under-estimation errors to determine whether tribal levels of cultural and material wellbeing and distress would increase or decrease, and whether they might undergo qualitative changes instead of just changes in degree (specifically, a change from pain and suffering to extinction). The tribal circumstances workgroup also provided narrative assessments of tribal risks (1) from delays in implementing measures affecting salmon recovery, and (2) if tribal interests are ignored or marginalized in the process of implementing measures affecting salmon recovery.

2.14.3 RESULTS AND CONCLUSIONS

2.14.3.1 National Economic Development

Table 4 presents NRSA results. In general, both A-2a (maximum fish transport without major system improvements) and A-2c (maximum fish transport with system improvements, low cost) provide positive net benefit relative to A-1 (existing conditions). None of the uncertainties reported by the workgroups changed this finding.

Comparing the two fish transport alternatives, A-2a always provides positive net benefit relative to A-2c, although the magnitude of the difference between these two alternatives diminishes as the discount rate is decreased.

Looking at the normalized nominal range sensitivity at the 6.875% discount rate, it can be seen that the greatest contributor to uncertainty about A-2a is power cost uncertainty (90%) followed by implementation cost uncertainty (10%). The greatest contributor to uncertainty about A-2c is power cost uncertainty (83%), followed by implementation cost uncertainty (17%).

Table 4 – Nominal range sensitivity analysis of net benefit difference from Alternative A-1 ($1,000s) (page 1 of 3)

Table 4 – Nominal range sensitivity analysis of net benefit difference from Alternative A-1 ($1,000s) (page 2 of 3)

Table 4 – Nominal range sensitivity analysis of net benefit difference from Alternative A-1 ($1,000s) (page 3 of 3)

Looking at the 6.875% discount rate in Table 4, it can be seen that recreational use benefits account for 82% of the normalized nominal range sensitivity for A-3 versus A-1, followed by power cost uncertainty (12%). Power costs do not affect the ranking of alternatives unless the low end nominal range estimate is used with a 0% discount rate. The power costs risk and uncertainty is important because (a) it is large relative to the other cost uncertainties, and (b) as the following paragraph discusses, it is considered by the hydropower workgroup to be a reliable risk and uncertainty estimate. Because the power risk and uncertainty is large relative to other cost uncertainties and reliable (i.e., the risk and uncertainty estimate is unlikely to change), it serves to dampen any effects of possible changes in other cost range estimates. In other words, other cost uncertainties are less important because they are small relative to the reliable power cost uncertainty estimates. Moreover, the power cost uncertainty does not affect the ranking of alternatives, so the other cost uncertainties are even less likely to do so. Therefore, the real driver in this analysis is the uncertainty about benefits. Following the discussion of the hydropower workgroup's NED analysis, the remainder of this section focuses on benefits uncertainty.

The hydropower workgroup reports that the data they used had a fairly high degree of reliability. Because they were forecasting future conditions, the most up-to-date data may have confirmed or slightly changed the forecasted values. However, members of the workgroup had knowledge of recent data and did not suggest any revisions in forecasts. The workgroup used a high-medium-low forecast for each key variable, and is confident that this covered likely future conditions. Of most importance in the workgroup's forecasts was the water supply available for power generation. They used two different hydro-regulation models to define this parameter, with actual historic water conditions over 60 years providing the model input data. The workgroup was not confident that their ancillary benefits estimates were based on the best data, but this element only made up 3% of the economic effects for dam removal. The hydropower workgroup used the 3 available power system models, from the Corps, BPA, and the NPPC. After examining many possible approaches they agreed that a comparison of results from these three models would capture all the team's concerns about risk and uncertainty in the power systems component of their analysis. Any concerns the workgroup had were somewhat overcome once they compared the results of the power system models. The workgroup found the results to be surprisingly close, so any one model's result was confirmed by the others.

The hydropower workgroup identified 3 major assumptions in their analysis: zero price elasticity of electricity demand, the projected natural gas prices on the West Coast, and the projected demand for power (load forecasts). The zero price elasticity assumption does not account for the probable reduction in demand for electricity that will occur if electricity prices increase with the implementation of the Snake River breaching alternative. There is significant evidence that there is price elasticity for electricity at both the wholesale and retail level, but it was considered beyond the scope of the hydropower workgroup to estimate elasticity for each consumer type. The possible significance of this simplifying assumption can be qualified by looking at the examination of demand elasticity for electricity that was done in the Columbia River System Operation Review (SOR) on a cursory basis. The SOR evaluated economic effects of changes in hydropower generation in the Columbia River basin using approaches similar to what was used in this study. The SOR also looked at the economic effects using a price elasticity approach for the different consumer types. The SOR found that once price elasticity was accounted for, the economic effects for losses in hydropower were about eleven percent lower than with the analysis that ignored price elasticity. Though this finding is not directly applicable to the Snake River breaching analysis, it can be used to give a general feeling for the impact of not including price elasticity.

The price and demand assumptions used are well documented in the hydropower workgroup's report. They chose to utilize the forecasts of gas prices and loads developed by the NPPC in recent studies. The NPPC studies were done in a very open public forum and many experts had a chance to review, comment, and revise these forecasts. The workgroup felt that a major change in the natural gas supply would have a significant impact on costs, but while an interruption in natural gas supplies could happen, they believe but impacts would likely be short-lived. Repairs or market shifts would occur to return the gas supply, and prices, within the workgroup's forecasted range in the long run. They reported that a major economic depression would push load forecasts outside their forecasted ranges.

The most important results of the risk and uncertainty assessment are for comparisons of A-3 (dam breaching) to any of the non-breach alternatives. Specifically, the analysis shows that the ranking of A-3 is highly sensitive to uncertainty about power and recreation. For the A-3 to A-1 comparison, the nominal range sensitivity to uncertainty about recreational benefits ranges from $280,850,000 at a 6.875% discount rate to $352,670,000 at a 0% discount rate (difference between the average annual net benefit of A-3 and A-1).

Table 5 shows how passive use benefits affect would the net benefit of A-3 if they were included in the NED analysis. Passive use benefits for salmon were estimated using four different methods, achieving four different estimates. Each of these four salmon passive use benefits estimates was added to the single free flowing river passive use benefits estimate to obtain four different total passive use benefits estimates. Table 5 shows how these four estimates would affect the net benefit of A-3 relative to A-1 at the nominal case, and when power and recreation estimates are at the low or high end of their range estimates for the various discount rates. Adding in any of the four passive use benefits estimates would cause A-3 to become the most highly ranked alternative at all discount rates, regardless of whether power or recreation are at the high or low end of their range estimates.

Figures 1 – 3 show the relative sensitivity of the difference between the average annual net benefit of A-3 and A-1 to each input at the three discount rates used in the economic analyses. It can be seen from these figures that recreation benefits uncertainties are of predominant importance regardless of which of the three discount rates is used.

Not only are the nominal range sensitivities for recreation and passive use benefits high, but the ranking of alternatives changes. Looking again at Table 4, it can be seen that using the low-end nominal range estimate the ranking is A-2a, A-2c, A-1, A-3, but using the high-end nominal range estimate the ranking switches to A-2a, A-3, A-2c, A-1. In other words, whether breaching the four Lower Snake River dams will give a positive

Figure 1. Nominal range sensitivity expressed as percent change in the difference between average annual net benefit of A-3 and A-1 @ 6.875% discount rate.

Figure 2. Nominal range sensitivity expressed as percent change in the difference between average annual net benefit of A-3 and A-1 @ 4.75% discount rate.

Figure 3. Nominal range sensitivity expressed as percent change in the difference between average annual net benefit of A-3 and A-1 @ 0% discount rate.

or negative net NED benefit is unknown because of the current level of uncertainty about the value of recreational and passive use benefits.

Even though the question of whether to breach the four Lower Snake River dams is already highly sensitive to uncertainty about recreational and passive use benefits, the NRSA probably underestimates the recreational benefits uncertainty because it does not account for uncertainty in PATH estimates. Uncertainties in the PATH analysis are discussed in Section 2.14.3.4. The recreational benefits estimate is based on a point estimate of the size of the recreational fishery that would be available if the four Lower Snake River dams were breached. Current PATH results predict a high level of unfulfilled recreational fishing demand (on the order of 95% of demand unfulfilled) indicating that the recreational fishing benefit is likely sensitive to the PATH estimate.

The interview with the recreation use benefits workgroup revealed two others factors that will tend to increase the average annual net benefits of A-3 relative to A-1. First, the recreation benefits report characterizes the estimates of California visitation as conservative (low). Although the degree of conservatism has not been quantified, any increase would increase the average annual net benefits of A-3 relative to A-1. California households make up about 70% of the study region's population. Second, the analysis has not attempted to account for the value of observing natural recovery of the Lower Snake River if the dams are breached.

Range estimates were not available for the anadromous fish benefits. Non-linearity in the models used did not allow for ranges to be determined. Therefore, it is impossible to evaluate how range estimates for anadromous fish benefits may affect the ranking of alternatives.

There is a great deal of uncertainty in the recreational benefits of alternatives A-1, A-2a, A-2c, and A-3 that is not reflected in the NED analysis. Uncertainties about the best methods for estimating these values are represented, but uncertainties within the methods themselves are not. Reservoir recreation benefits represent three-fourths of the recreational benefits of non-drawdown alternatives (A-1, A-2a, and A-2c) and the confidence intervals are large ($47-148 a trip), indicating a great deal of uncertainty in the values. This uncertainty is not reflected in the NED analysis because only a point estimate was used (mean value of 71.31 per trip). The range of recreational benefits for A3 reflects different treatment of the data based on assumptions about non-respondent behavior. However, the range of recreational benefits used in the NED analysis were based one only one assumption about non-respondent data (middle use estimates, or assuming non respondents use is the same as respondent use, but only utilizing the rates for definite rather than probable visitors). River recreation benefits represent a large portion of the recreation benefits of alternative A-3. The low-end range estimate was based on scaling the river recreation and fishing demand curve using the cost per mile of reservoir visitors (travel cost method). A mean value of $71.36 per trip was used for the low end, but does not reflect the large confidence intervals for this method (95% confidence interval of $39 to $446 per trip). The high end range estimate was based on scaling the demand curve using costs of visitors to free-flowing section as reported in a contingent behavior survey. A mean value of $297 per trip was used for the high end, which does not reflect the large confidence intervals for this method (95% confidence interval of $181 to $831 per trip). The nominal recreational benefits reflects the average of the mean of these two methods. Therefore, the A-3 benefits reflect uncertainty about which method is the best estimator, but does not reflect uncertainty in the methods themselves. Also, recreational suitability recovery for various activities under A-3 was based on point estimates, rather than range estimates, and no confidence limits were determined. If the confidence limits were included in the NED analysis, a larger range of possible values for recreational benefits would have occurred.

Because passive use benefits are not normally included in NED analysis, a number of conservative assumptions were used to err on the side of underestimating passive use benefits:

- Survey respondents were not told that they were evaluating threatened and endangered stocks. Providing respondents with this information would likely result in higher estimates of passive sue benefits.
- Most existing studies evaluated a larger fish increase than is being evaluated in the Lower Snake River. Because studies find that larger increases have diminishing returns on willingness to pay, applying these numbers to the Lower Snake River likely underestimates its passive use benefits.
- The estimate of passive use benefits assumed zero benefit for angler households in the study area and zero benefit for all households outside of the study area.

Passive use benefits consist of salmon values and free-flowing river values. The range of values presented for passive use benefits of salmon reflect different approaches for estimating values, rather than uncertainties in the methods themselves. A single point estimate was available for the free flowing river passive use benefits, and no confidence intervals were determined. Given that a number of conservative assumptions were used, passive use benefits are likely underestimated, but it is difficult to say by how much.

2.14.3.2 Social and Regional Analysis

The driving uncertainties in the regional analysis are identified errors and omissions, which have been documented in the executive summary to the regional economic impact modeling report. The regional analysis workgroup reports that uncertainty is present in the regional economic impact analysis because of uncertainties in inputs received from other workgroups. The regional economic impacts workgroup did not have the resources to consider the accuracy of the final inputs they received from other workgroups and to used to drive their models. They note that errors in the input data received from the other workgroups will be multiplied when they are used in the regional economic impact model. The social and regional economic impact workgroups identifies specific examples of errors, omissions and uncertainty in the input data they used in their analysis:

- The data for the 100-year fishing and outdoor recreation projections were based on now obsolete PATH analysis and since improved salmon life-cycle analysis. The consequence is that the comparisons of outcomes in the recreation section of the regional economics impact analysis are obsolete.
- The effect of increased shipping costs under alternative A-3 on industry output and employment for firms that use barges shipping was not studied, so changes in outputs and employment in the wood products, grain producer and other sectors are unknown.
- Effects of reduction in irrigated agriculture under A-3 on the food processing sector are unknown.
- Economic impacts on tribes under A-3 are unknown.
- Future locations of power generation and transmission facilities are unknown.
- The required road investment outside Washington under A-3 is unknown, as are future increases in spending for road maintenance.
- The future distribution of electricity rate increases under A-3 across regions, industries or consumers is unknown.

The hydropower workgroup elaborated on this last point in its interview with the risk and uncertainty workgroup. They identified the possible rate impacts to regional power ratepayers as their only major risk and uncertainty concern. The workgroup expressed confidence in the reliability of their NED cost range estimate, but not in their ability to define who will pay these costs. This impacts the regional analysis, and may be of significant social importance. The hydropower workgroup cannot improve the rate analysis until Congress how dam removal would be paid for, which would be done in the authorizing legislation.

The executive summary of Regional Economic Impact Models for the Lower Snake River Juvenile Salmon Migration Feasibility Study also discusses the risk and uncertainty of the input-output economic analysis technique. First, industry spending calibrations are based on national averages which may not apply to the specific region under study. However, estimates using the national averages are likely to be within plus or minus ten percent of multipliers that would be found using survey data. Second, input-output provides a “snapshot” of the economy at a point in time rather than a dynamic structure of changing relationships. However, no model can make accurate predictions of future changes in technology, prices, trade patterns, or consumer tastes and preferences. Therefore, all models would suffer this same uncertainty. Third, the input-output model is driven by exogenous estimates of changes in sale to final demand (exports, investment, and certain components of government spending).

Finally, the social workgroup identified four sources of uncertainty about the appropriateness of the models used in the social analysis:

- Allocation of sub-regional employment impacts to local communities based on a proportion of local employment to regional employment changes may understate or overstate the magnitude of impacts.
- Use of social indicators like steelhead fishing licenses as a representation of the contribution of anadromous fish to local quality of life., poverty rates to identify sensitive populations to economic changes, developed recreation sites as indicators of quality of life.
- Use of county level farm data to make generalizations about the expected changes to farming communities within the county.
- Assuming that positive gains in economic employment are in fact positive and negative losses in employment are negative for a given community.

The social analysis report additionally identified significant uncertainty in the economic effects of A3 on upriver communities because it is unknown how significantly the loss of river navigation will affect the forest paper industry. Also, the effects of electrical rate increases on the aluminum industry are unknown, but could have significant regional impacts. The report also identified five key uncertainties that make the prediction of impact on individual farms, farm regions, counties, and rural farm communities difficult to determine:

1) The future of farm deficiency payments may be extended.

2) International market conditions and future prices received for export agricultural products vary greatly from year to year.

3) The fixed and variable costs of farming and may continue to do so while at the same time new crops and rotations are being introduced to the region.

4) Technological advances in crop production and seasonal variations in rainfall make forecasting average yields difficult for more than one year in advance.

5) The actual magnitude of total transportation cost increases, including pricing adjustments by alternative modes of transportation in the absence of barges, are unknown at this time.

2.14.3.3 Tribal Circumstances

The tribal circumstances risk and uncertainty assessment was performed by the tribal circumstances workgroup and is exerpted here from their report.

2.14.3.3.1 Uncertainty

Meyer (1999) identifies positive associations between abundance of tribal harvest of salmon, and tribal levels of cultural and material wellbeing, or alternatively, of distress – indexed by perception of self, rates of death, health, poverty, unemployment and per capita income.

Given information presently available, it is not possible to establish certain cardinal measurement linkages between such “cause and effect” parameters – either in the immediate term, or cumulatively.

However, based on the evidence presented in Meyer (1999) and the range of difference in salmon recovery between Project Alternatives developed in PATH, as evaluated by Independent Experts, it is possible to develop clear and certain ordinal ranking of the Project Alternatives. These ordinal relationships are clear both respecting the relative magnitude of salmon recovered for the tribes under each Project Alternative, and respecting the direction and general effect of such respective magnitudes of salmon recovery on tribal culture, rates of death and health, poverty, employment/unemployment and income.

Similarly, on an ordinal basis, the analysis provides a clear separation with respect to the length of time over which tribal pain and suffering would continue at close to present levels, under each Project Alternative.

Undoubtedly, manipulation of underlying biological assumptions regarding recovery would result in some changes of cardinal estimates of salmon recovery. However, it is clear that such manipulation is not likely to substantially change the certainty associated with the ranking of tribal impacts from alternative project choices.

2.14.3.3.2 Tribal Risk

There are four major elements of risk the tribes face, within the context of the lower Snake River Feasibility Study process.

First, Meyer (1999) has identified the close dependence of the study tribes on salmon, the massive declines in salmon available to the tribes from Treaty times to the present, and the consequent endangerment of not only the salmon, but the cultural and material wellbeing of the tribes as well.

If PATH estimates are too optimistic, and given present diminished stock levels, there is a risk the subject salmon species will become extinct – with attendant risks for continued survival of tribal peoples.

Second, if PATH recovery estimates are too pessimistic, differences in the magnitude and timing of salmon recovery between alternatives would be understated – reducing comparative net benefits posed for the alternative most likely to restore salmon.

Third, if the selected alternative forecasts salmon recovery that will need a time period far into the future before significant harvests are returned to the tribes, Meyer (1999) identifies that tribal peoples will continue to risk unacceptable levels of pain, suffering and premature death, while bureaucrats “test and study.”

Finally, Meyer (1999) identifies that in almost all prior processes concerning Columbia/Snake River system dams, tribal concerns, and the impact on tribes, have been ignored or marginalized. If such marginalization occurs during the present process, the cumulative transfer of the river system’s wealth from tribal to non-tribal residents of the region will continue – tribal peoples will continue to suffer and be disempowered, regardless of existing Treaty protections – and environmental injustice, as defined by EPA, will be exacerbated.

2.14.3.4 PATH Analysis

Data from the PATH analysis are used for a number of parts of the Lower Snake River Juvenile Salmon Migration Socio-Economic Feasibility Study. Changes in the PATH results will directly affect estimates under different alternatives for commercial and recreational fishing, regional and social analysis, tribal circumstances, and passive and recreation use benefits. Uncertainties in each of these areas are multiplied by uncertainties in the PATH analysis; therefore changes in the PATH analysis can potentially change the ranking of alternatives (A1, A2 and A3). PATH has recently (November 1999) revised its estimates, but the economic appendices were created using its previous estimates. This is a significant source of uncertainty in the NED analysis and may affect the ranking of alternatives.

The conclusions and recommendations from the PATH weight of evidence workshop quantified the relative degree of belief in the seven key uncertainties that have the greatest effect on the outcomes of management actions. The seven key uncertainties are:

1). Passage and transportation assumptions (uncertainty in direct survival of in-river fish, the partitioning of in-river survival between dam and reservoir survival, and survival of transported versus non-transported fish after they have exited the migration corridor).

2). Extra mortality outside of the juvenile migration corridor which is not accounted for by productivity parameters in spawner/recruit relationships, by estimates of direct mortality in the migration corridor, or common year effects affecting both Snake River and Lower Columbia River Stocks (delta model only).

3). Uncertainty in the extent to which Snake River and Lower Columbia share common mortality effects.

4). Length of the transition period between removal of dams and establishment of equilibrium in the drawndown section of the River (reflecting uncertainty in physical and biological responses to drawdown).

5) Uncertainties in historical estimates of bypass and turbine mortality.

6) Uncertainty in the effect of the predator removal program (i.e., squawfish bounties) on future survival of salmon smolts in reservoirs.

7) Uncertainty of juvenile survival rate once equilibrium conditions have been reached.

Alternative hypotheses for each of these seven uncertainties were identified, and expert elicitation was used to determine an expert's belief in the hypothesis used versus the alternatives. Weighted averages were derived by four different experts for each hypothesis under each of the seven uncertainties. These weights were used to determine weighted averages for 24-year survival, 100-year survival, and 48-year recovery standards. The weighted averages show what the most likely outcomes of the actions will be, given uncertainties that affect future projections. Table 6 shows how meeting the standards is affected by using the sets of judgements from the different experts. The following conclusions were reached based on this analysis:

- The analysis determined that outcomes for A3 are better than those of A1 or A2 for all jeopardy standards, regardless of the expert used. The magnitude of the differences depends on the jeopardy standard used and assumptions about when drawdown will be implemented.
- The ability of actions to meet the 24-year survival standard varies with different experts. A1 meets the standard with 1 out of 4 experts. A2 fails the standard regardless of the expert. Drawdown with a three year delay meets the standard with 3 of the four sets of experts, while drawdown with an eight year delay meets the standard with 2 of the 4 experts.

- A1 and A3 (both 3-year and eight-year) meet the 100-year survival standard regardless of the expert. A2 meets the 100-year survival standard with 3 of 4 experts
- A1 and A2 meet the 48-year recovery standard with 1 of 4 experts. A3 meets the 48-year recovery standard with all experts regardless of whether a three-year or eight-year delay is assumed.

PATH probabilities for achieving 24, 48, and 100 year escapement levels for survival and recovery were generally used as fixed point values in the NED analysis. The PATH numbers were generated using Monte Carlo simulations that established distribution ranges for the returning salmon stocks. The NED analysis did not use these distribution ranges but instead used fixed point estimates from the ranges. This represents a significant uncertainty that was not accounted for in the NED analysis. Using a point estimate could significantly over- or underestimate the salmon population.

The SRP also considered whether there were any new hypotheses that should be included in the PATH models. One hypothesis that the SRP thought was worth evaluating is the hypothesis that hatchery fish can affect the survival of wild fish. This hypothesis was believed to have significant results on survival The implementation of this hypothesis was not considered feasible because:

- Hatchery effects are confounded with development of the hydrosystem.
- The distinction between the hatchery hypothesis and other mortality hypotheses was not clear.
- The responses of different actions under this hypothesis is not clear.

The SRP also noted that in some cases the evidence for evaluating alternative hypotheses was poor or lacking. Because of this, the SRP recommended taking actions that 1) result in the best chance at survival and recovery of stocks, and 2) generate information to reduce uncertainties and improve future decision-making. Significant increases in mortality has the potential to change the rankings of the alternatives (A1, A2, and A3).

The scientific review panel (SRP) reviewed the PATH preliminary decision analysis report on Snake River spring/summer chinook. They concluded that uncertainties are extensively considered within the constraints imposed by bounding the system as that between the nursery habitat and that above Bonneville. However, the SRP found that there is not a consensus on the assumptions or analyses that precede the quantitative evaluation of uncertainty, and are therefore uncertain about what the PATH models tell us. The SRP suggested designing and conducting a management experiment to resolve uncertainty. The SRP also believes that the role of uncertainty in the identification of models for spring and summer chinook salmon, and in the application of these models to prediction of management alternatives may be underestimated. The SRP identified four problem areas for these models:

1) uncertainty about the model structure;
2) uncertainty in the estimated model parameters;
3) the propagation of model prediction errors; and
4) the design of experiments in order to reduce the critical uncertainties associated with the models.

The SRP felt that progress had been made on each of these problems, but more was needed, especially for 1) and 2). The SRP also felt that the three alternative hydrosystem actions (A1, A2, and A3) may have been too narrowly defined and other alternatives or modeling approaches should have been evaluated at the beginning, rather than just focussing on uncertainty in the current models and alternatives. The SRP also suggested that an adaptive management approach could be used to resolve some of the remaining uncertainties. An adaptive management approach would involve systematically varying management options while carefully monitoring biological, economic, and social consequences of actions, in an attempt to reduce uncertainty and apply new information to the quantitative models.

The SRP also provided comments on the PATH final report for fiscal year 1998, some of which were relevant to uncertainties in the modeling. The SRP suggested that some of the uncertainties in the models could be evaluated more thoroughly using sensitivity analysis especially for 1) predator modeling (particularly the importance of temperature fluctuations), 2) evaluation of hatchery supplementation assumptions (including the hypothesis that hatcheries diminish returns), and 3) turbine mortality. The SRP suggested that PATH could calculate the expected value of perfect information for key uncertainties. These calculations would suggest how much it is worth to resolve key uncertainties. The SRP also suggested that PATH could extend the prospective models to stimulate the collection of new data and thereby the rate of learning about uncertain hypotheses. Alternative methods were suggested for incorporating uncertainty into the models, such as interval analysis and fuzzy arithmetic.

PATH made different assumptions about the current salmon population than the anadromous fish benefits group. PATH assumed that the current salmon populations have reached a steady state and based future predictions on this. In contrast, the anadromous fish benefits group assumed the current salmon populations are in a declining state, and based their predictions for the no action alternative accordingly.

2.14.3.5 Summary of Conclusions

In conclusion, the purpose of the risk and uncertainty assessment was to help (1) assess the overall reliability of the socio-economic feasibility study, and (2) identify important unanswered questions for risk managers. There remain significant unresolved uncertainties about the economic costs and benefits of the alternatives considered by the Drawdown Regional Economic Workgroup for the four lower Snake River dams. The most important uncertainties from a national economic development perspective are:

- uncertainties about the value of future recreational and passive use benefits if the dams are breached and
- uncertainties about the size of future anadromous fish stocks and the fisheries they will support.

Further work by PATH, the anadromous fish workgroup and the recreational and passive use workgroup could significantly improve the reliability of the socio-economic feasibility study. The new PATH estimates determined in November 1999 need to be evaluated in the economic appendices. In most cases A-2 is the preferred alternative in the NED analysis. However, inclusion of passive use benefits would make A-3 the preferred alternative. Other NED uncertainties, though significant in an absolute sense, are unlikely to affect decisions about whether it would be more cost-effective to breach the four Lower Snake River dams or not.

The driving uncertainties for the regional analysis are of two types: uncertainties due to errors and omissions in the currently available data, and uncertainties about how costs will be distributed. The latter cannot be resolved until decisions are made about how the future power supply system would be configured if the four Lower Snake River dams were breached. At least some of what has been characterized as errors and omissions in the currently available data also cannot be resolved until specific information is developed about how the future power supply system would be configured.

In conclusion, uncertainties about dam breaching remain that prevent us from concluding whether it would be more cost-effective to breach the four Lower Snake River dams or not. In order to determine the economic feasibility of retaining or breaching the dams, further effort is needed to (1) more precisely quantify the recreational and passive use benefits of the Lower Snake River if the dams are breached, (2) more thoroughly assess the effect of dam removal on future anadromous fish stocks, and (3) further specify the configuration of the future power supply system if the dams are breached.

2.14.4 REFERENCES

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