Chapter 6
Hydro Decision Pathway and Review of Existing Information

PATH Hydro Work Group
(Toole, Giorgi, Weber, McConnaha, etc.)

6.1 Introduction

The PATH Hydro Work Group was assigned to complete a "Level 3" retrospective analysis of survival of Snake River spring/summer chinook salmon, as related to configuration and operation of the Federal Columbia River Power System (FCRPS; alternately referred to as "hydro system" throughout text). The retrospective task evaluates available information within the context of a hierarchical management decision framework. Upon completion of this task, a prospective analysis will evaluate implications of additional information that may be collected in the future. That analysis may use a non-hierarchical decision analysis technique.

The approach pursued by the PATH Hydro Work group for the retrospective analysis was to:

(1) identify the key regional FCRPS management decisions that must be addressed during the next few years;

(2) develop a general management decision flow chart that describes a logical order for management decisions and the general implications of each alternative;

(3) develop more specific questions that must be answered before making each management decision;

(4) provide a summary of currently available information relating to each question;

(5) determine which, if any, of the questions can be resolved with currently available information; and

(6) identify the necessary information that must be collected in order to resolve remaining questions.

This work is still in progress and this draft of Chapter 6 represents the current state of our endeavors.

PATH Hydro Work Group members first attempted to identify the key management decisions that had been proposed in the National Marine Fisheries Service's (NMFS) Proposed Recovery Plan For Snake River Salmon, the Northwest Power Planning Council's (NPPC) Columbia River Basin Fish and Wildlife Program, and the Nez Perce, Umatilla, Warm Spring, and Yakama Tribes' (Tribes) Wy-Kan-Ush-Mi-Wa-Kish-Wit recovery plan. Section 4.1 of the PATH Information Package For Workshop 1 (September 28, 1995) contained a summary of these key decisions.

PATH Hydro Work Group members met with members of the Coordination and Planning Team (CPT; now re-named the Implementation Team), a multi-agency group of Columbia Basin managers, to ensure that the key hydropower management issues identified by the PATH Hydro Work Group matched those being considered by regional managers. The CPT concurred and provided additional guidance regarding the format of a management decision chart that would be of use to them. They suggested that the chart: (1) begin with consideration of operations closest to those currently being implemented and proceed to progressively more drastic changes; (2) that it focus initially on the question of transportation, since most other decisions were dependent upon that one; and (3) that it proceed in a hierarchical manner such that decisions at each step did not require answers to questions at subsequent steps. The CPT concurred that nearly all of the management alternatives are concerned with juvenile survival, so the decision framework focuses on these. However, it is important to note that some of the management alternatives also affect adult survival, and these effects must also be considered when decisions are made.

Section 6.2 describes a general management decision framework that has received acceptance by the CPT. Figure 6-1 summarizes information on the subsequent four pages. The first two boxes identify decisions that will be common to all sources of human-induced mortality. A determination of the improvement in spawner-to-spawner survival necessary to achieve survival and recovery of each species is necessary, followed by a determination of the proportion of that improvement expected from changes in operation and configuration of the hydropower system. The larger PATH group will be addressing the necessary survival improvements for combined life stages during the prospective analysis. In the meantime, the PATH Hydro Work Group suggested an interim smolt-to-adult return (SAR) general goal (Question 0.0 of Sections 6.3 and 6.4) and an interim passage survival goal (Question 0.1 of Sections 6.3 and 6.4) specific to FCRPS-induced mortality, against which available information related to each management question could be evaluated. These interim goals will be re-evaluated and possibly modified following completion of the PATH prospective analysis.

Subsequent boxes in Figure 6-1 describe the three primary options for hydropower system management, in order of increasing modification of the present system. If it is determined that none of these changes will result in the needed increase in survival, the increase in survival expected from modification of the hydropower system must be re-examined. Greater survival improvements may be necessary from modification of other sources of human-induced mortality to balance the shortfall from hydro modifications. Figures 6-2 to 6-5 show details of the management decisions and underlying questions.

The remainder of this chapter provides three levels of increasing detail regarding each question. Section 6.3 is a summary of Hydro Work Group conclusions regarding each question in the decision flow chart. A preliminary list of additional information needs is also included in this section. Preliminary conclusions were prepared by a drafting subcommittee (Toole, Giorgi, and Weber) and then reviewed by the larger Hydro Work Group (Anderson, Wilson, McConnaha, Williams, Pinney, Geiselman, [Ward - not available at 9/4 decision meeting]). We have tried to indicate those questions for which available evidence led to a common conclusion by all Hydro Work Group members and those questions for which available evidence was inadequate to draw common conclusions. We note that the full Hydro Work Group was not able to comment on preliminary conclusions for Question 1.6 because the narrative (Section 6.4) for Question 1.6 was not sufficiently developed at the time of the last Hydro Work Group meeting.

Section 6.4 is the more detailed review upon which the summary is based. Some redundancy is unavoidable with this approach, but our purpose was to allow readers with different levels of interest to follow the decision flow chart at different levels of detail. Each section begins with italicized conclusions and summary, followed by a more detailed narrative.

Several of the points in the narrative (Section 6.4) required even greater explanation, particularly those that involved new analyses. Therefore, a series of appendices is included. Appendix 8 defines some of the acronyms and terminology used in this chapter.

Notes Specific to This Draft: This draft had a drop-dead completion date of September 5, 1996. We were unable to have a meeting of the full Hydro Work Group to review the drafting subcommittee's recommendations until September 4. During the full Hydro Work Group meeting, many changes and clarifications of the text were recommended and the drafting subcommittee was not able to incorporate all of the changes in one day. Additionally, many comments on the previous draft of this chapter were received from a variety of reviewers and we were not able to incorporate all comments or resolve all discrepancies among conflicting comments. Therefore, this is still very much a work in progress with some parts written quite hurriedly and many known shortcomings. No one person has had a chance to read carefully through the entire text of this draft, so if it looks like it was written by committee, it was. Hopefully, we have worked closely enough and carefully enough to tell a coherent story - but we are counting on comments of reviewers to suggest ways to improve it.

6.2 Hydro Decision Path Flow Diagram

Figure 6-1: Hydropower decision tree.

Figure 6-2: Transportation page of flow diagram.

Figure 6-3: In-River page of flow diagram.

Figure 6-4: Hybrid page of flow diagram.

Figure 6-5: Drawdown Page of Flow Diagram.

6.3 Summary and Recommendations

The following is a summary of conclusions for each of the questions in the decision flow chart. Details regarding the basis for these conclusions is contained in the narrative (Section 6.4). We urge you to read the more detailed account because the summary has necessarily simplified the issues and relevant information greatly. In addition to conclusions, we present a preliminary list of some of the research needs that follow from uncertainties remaining for most of the questions.

Question 0.0 What is the overall survival goal for Snake River fish from smolt to returning adult (SAR)

The PATH "prospective analysis," which will identify necessary life-cycle survival improvements, will not be completed until fall 1996. Until that is available, we propose the following interim goal.

SAR Goal. Although this goal includes survival through more than the hydrosystem, we suggest an interim smolt-to-adult return (SAR) goal of 2-6%, based on: (1) Snake River SARs during the 1960s, when stocks were believed to be healthy; (2) Warm Springs SARs during a period in which the stocks was believed to be healthy; and (3) theoretical SARs associated with a range of Snake River egg-to-smolt survival rates from the last three decades. The SAR goal has the advantage of incorporating any delayed mortality resulting from passage through the hydro system, but has the disadvantage of including additional mortality caused by factors unrelated to FCRPS passage. We suggest that the full range of values be considered because, while the low end of the suggested SAR range may be sufficient for stabilizing populations at low levels, higher SARs will likely be necessary to encourage population growth and to maintain larger populations, which are expected to experience density-dependent egg-to-smolt survival.

Question 0.1 What Is the Survival Goal for Salmon Passing Through the Hydro System?

Conclusion: The general goal is to provide sufficient smolt passage survival, with a minimum of delayed effects, such that the hydropower system does not prevent adult return rates that will ensure survival and recovery of the species. The PATH "prospective analysis," which will identify necessary life-cycle survival improvements, will not be completed until fall 1996. Until that is available, we propose the following interim goal.

Smolt Passage Survival Goal. Since Snake River stocks were strong and stable during the 1960s with 4 dams in place, smolt passage survival under those conditions appeared to be adequate. We estimate that survival ranged from 42-68% during that era, and propose the upper end of this range, 50-70%, as an interim smolt passage survival goal. We do not know the level of delayed mortality that may have occurred below Bonneville Dam historically. We make the conservative assumption that this goal includes any post-release delayed mortality attributable to passage through the FCRPS. We stress that the full range, not just the lower bound, should be considered when evaluating management actions, due to a variety of uncertainties inherent in this estimate.

Needed Information: Results of the PATH "prospective analysis" are necessary to confirm or modify these interim survival goals. Additional information needed in the future to evaluate stock performance relative to these goals includes standardizing methods and continuing to monitor reach survival, SAR, and index stock replacement rates.

Page 1 of Decision Flow Diagram - Transportation (Figure 6-2)

Question 1 Can operation of the hydroelectric system within the existing authority of the operating agencies compensate for human-induced habitat modifications in the mainstem river that affect juvenile salmonid survival?

We approach hydrosystem management decisions by asking two general questions.

Question 1 considers whether survival and recovery can be achieved within the capabilities of the current hydroelectric system configuration and current operating authority of the Corps of Engineers. If the conclusion is "no," Question 2 asks if survival and recovery can be achieved with major configuration changes that have been proposed by some management agencies. Questions 1.1 through 1.9 address more detailed issues that must be resolved in order to answer Question 1.

Question 1.1 Does *transportation* provide a high rate of juvenile survival for a broad range of life histories and environmental conditions without subsequent adverse impacts?

Conclusion: Available information is not sufficient to answer this question. While survival to the point of release appears to exceed the passage survival goal of 50-70% (Question 1.1A), evidence regarding the likelihood and magnitude of delayed effects is conflicting (Question 1.1B).

Needed Information: See Questions 1.1.A and 1.1.B.

Question 1.1.A Is survival of transported fish Ahigh enough@ within the hydropower system from collection sites to a release site downstream of Bonneville Dam?

Conclusion: Available evidence supports the conclusion that survival of transported fish to the point of truck or barge release is approximately 96-98%, exceeding the interim smolt passage survival goal of 50-70%.

Needed Information:

(1) Confirm anecdotal direct mortality estimates with more rigorous assessments and documentation of barge and truck mortality.

(2) Assess whether all subpopulations experience the same low mortality rate or if tails of the run experience higher mortality rates.

Question 1.1.B Do subsequent adverse effects following barge or truck release occur and, if so, are they of sufficient magnitude to change conclusions regarding survival of transported fish in Question 1.1.A?

Conclusion: Different lines of evidence provide conflicting results, and each line of evidence has limitations.

Information supporting the hypothesis of significant delayed effects occur among transported fish includes: (1) estimated SAR of wild transported fish (expanded from return rates to account for approximate trap efficiency and in-river harvest) averaged 1.33% in recent years (1983-1990), compared to the SAR goal of 2-6%; (2) Appendix 7 SAR analysis indicates that differences in adult upstream survival do not explain differences in SARs, suggesting that delayed transport mortality is the cause; (3) potential for differential mortality of transported and non-transported fish as a result of stress and disease (possibly expressed as higher post-release predation mortality) and (4) possibility that the timing of transported fish entering salt water is off. Some members of the work group also considered impaired homing ability a potential mortality factor; others did not believe available evidence supported this as a potential mechanism. Limitations of the primary lines of evidence include: (1)transport studies were not designed to estimate SARs, so numerous assumptions were required to adjust return rates in an attempt to make them comparable to SAR goal (adjustments do not account for delayed handling and marking mortality), and to distinguish among hatchery and wild return rates;(2) handling effects may have biased some SAR data sets more than others, (3) transport studies not conducted throughout the season and may be biased and (4) while available evidence regarding stress and disease demonstrates the potential for delayed transport mortality, explicit links between these mechanisms and delayed mortality caused by transportation have yet to be demonstrated.

Evidence suggesting that delayed effects are not of sufficient magnitude to change the conclusion in Question 1.1A primarily comes from: (1) the one available estimate of the SAR of wild transported fish (in 1990), which is >2%. Additional evidence relies on comparisons of delayed transport mortality and delayed in-river mortality: (2) no difference in survival of transported and in-river migrating radio-tagged smolts between Bonneville Dam and the estuary was observed in 1995. Data for 1994 and preliminary data for 1996 are similar; and (3) comparison of T/C ratios from the 1986 and 1989 transport survival studies and in-river reach survival estimates from the 1993-1996 mark/recapture studies suggest that delayed mortality of transported fish is $\leq$ that of in-river migrants under 1989 conditions and the high end of 1986 assumptions, while it is higher under other 1986 assumptions. Limitations of these lines of evidence include: (1) transport studies were not designed to estimate SARs, so numerous assumptions were required to adjust the 1990 transport return rate (overall 0.37%) to an SAR and to account for wild/hatchery composition, and 1990 appeared to be a particularly high survival year, rather than an example of the normal return condition for wild fish; (2) small sample size of radio-tagged smolts below Bonneville Dam; (3) the difficulty of and hence the limitations of studies that attempt to find sources of delayed mortality and (4) absence of reach survival estimates concurrent with T/C estimates in 1986 and 1989, limitations of T/C estimates (e.g., Mundy et al 1994), and limitations of expanding 2-5 project LGR-JDA reach survival estimates to six-project LMO-BON estimates. The comparisons of transport and in-river delayed mortality are only useful if it is assumed that in-river delayed mortality is insignificant or at least "acceptably low." This has not been demonstrated (Question 1.5.B), so utility of these lines of evidence is questionable.

Needed Information:

(1) Estimate SAR for transported wild and hatchery fish over a number of years with a range of environmental conditions. Determine SARs for additional downriver indicator stocks. To avoid confounding hydro-related effects and experimental tagging and handling effects, estimates should be based on fish marked upstream of LGR, not on fish handled and marked for experimental groups at LGR. Determine if SAR rates are significantly different than the interim SAR hydro goal. Determine if there are differences among SARs for cohorts that replace parental stock and those that don't.

(2) Compare SARs of transported and downriver indicator stocks to determine if there are similar trends developing.

(3) Conduct field and lab evaluations of susceptibility of barged and trucked smolts to fish, bird, and mammal predation following release, compared to susceptibility of non-transported migrants below Bonneville Dam. Is there a significant difference in survival rate; if so, what is magnitude?

(4) Conduct field and lab evaluations of susceptibility of barged and trucked fish to disease and impaired saltwater adaptation, compared to susceptibility of non-transported migrants. Is there a significant difference in mortality; if so, what is the magnitude?

(5) Conduct homing studies of transported and non-transported fish. Is there a significant difference in proportion of population that returns to LGR dam but does not arrive at spawning ground? If so, what is the magnitude of effect?

(6) Estimate T/C ratio and in-river survival concurrently over a number of years with a range of environmental conditions.

Question 1.2 ***If it is determined in Question 1.1 that transportation does not provide a high rate of juvenile survival*****, can transport survival be substantially increased?**

Conclusion: Based the conclusion for Question 1.1.A, this question would not be addressed unless it was determined that substantial post-release delayed mortality does occur. Available information is not sufficient to answer this question due to uncertainties regarding the magnitude and causes of delayed mortality of transported fish (see Question 1.1.B) and the potential of the four identified management actions to reduce delayed mortality. Because direct mortality associated with transportation is already very low, it is highly unlikely that significant reductions in direct mortality are possible.

Needed Information:

(1) Collect "Needed Information" in 1.1.B to determine if delayed effects are occurring and, if so, the magnitude of those effects.

(2) If it is determined that significant delayed mortality is occurring, determine the reduction in mortality possible by:

(2a) direct-loading transported fish;

(2b) improving barge release mechanisms or release strategies;

(2c) improving collection facilities (e.g., size separation, elimination of pressurized pipe at LGR, etc.);

(2d) installing surface collectors at LGR or other collector projects. Specifically, evaluate whether the surface collector reduces delay in the forebay and, if so, determine effect of reduced delay on survival; and determine if surface collector reduces collection mortality, compared to that associated with existing screen, gatewell, and orifice passage. Note that surface collection has the potential to increase transport mortality due to the need for a large screening system to reduce water volumes during collection.

Question 1.3 ***If it is determined in Questions 1.1 or 1.2 that transport survival is or has the potential to be high enough to meet the hydro goal,*** **has a sufficient percentage of yearling chinook salmon been collected in recent years?**

Conclusion: Available information is not sufficient to answer this question, but it is likely that the answer would be "yes" if the system, as configured in 1997, was operated to maximize collection. Collection proportions in the last decade have ranged from approximately 50-66% of the smolts arriving at the head of LGR reservoir, under a strategy that included planned and involuntary spill at some collector projects under some conditions. These collections rates do not appear to be sufficient to meet the passage survival goal unless delayed transport mortality is insignificant. However, if the configuration that will be in place in 1997 is operated with a goal of maximizing collection of fish for transportation, then collection efficiency could be as high as 74-87% if no spill occurs. This collection level would clearly meet the low end of the 50-70% passage goal, and would also meet the 70% survival goal if transport survival (including delayed mortality) is $\geq$80%.

Needed Information: See Question 1.6. Studies are needed to more accurately determine collection efficiency and project survival.

Question 1.4 ***If it is determined in Question 1.3 that a high percentage of yearling chinook are not being collected with the facilities as planned through 1997,*** **can collection rate be increased substantially with additional modifications**?

We approach this question by examining the potential to increase collection rate of each of the proposed management actions most likely to achieve this: addition of extended-length screens at LMO and installation of a surface collector at LGR or other collector projects.

There is insufficient information to answer this question, but there was general agreement among work group members that opportunities for increasing the proportion of transported spring/summer chinook are limited and/or highly uncertain. Additional extended-length screens at Lower Monumental Dam would have an insignificant effect. A surface collector at Lower Granite Dam could have a significant effect (about 6-14% higher collection than maximum collection with 1997 configuration) if it performed as well as the Wells Dam surface bypass system. However, given the difference in the configuration of Lower Granite Dam compared to Wells, similar performance will be difficult to achieve. Results of current and future prototype tests are required to draw a final conclusion.

<u>Question</u> <u>1.4.A</u> Can extended-length screens at Lower Monumental Dam substantially increase the proportion of transported Snake River salmon?

Conclusion: Addition of extended-length screens at Lower Monumental Dam would have little effect on the proportion of Snake River spring/summer chinook collected, above that achievable with the same in place at LGR and LGO dams.

Needed Information: See Question 1.6.A "Needed Information," in particular, PIT-tag mark/recapture estimates of FGE associated with extended-length screens.

<u>Question</u> <u>1.4.B</u> Can surface collectors substantially increase the proportion of transported Snake River salmon?

Conclusion: Available information is not sufficient to answer this question. With extended screens in place at both LGR and LGO dams, the additional installation of a surface collector at LGR has the potential to increase the total number of smolts transported from the Snake River by about 6-13%, if it is as effective as the surface bypass system at Wells Dam. If a surface collector at Lower Granite Dam is less efficient than the Wells collector, the increase in the proportion transported will be minimal. There is insufficient information at this time to determine potential efficiency of a surface collector at Lower Granite Dam; however, it appears unlikely that it will be as efficient as the Wells surface bypass due to differences in dam configuration.

Needed Information: Tests of prototype surface collector designs at LGR are necessary to determine the percentage of spring/summer chinook approaching the forebay that can be collected with the device. We assume that, unless the surface collector efficiency is extremely high, this device would be operated in conjunction with the current bypass structures (e.g., extended screens). For this reason, the evaluation should include determination of the percentage of smolts collected by all methods to ensure that the collector does not reduce guidance of screens.

<u>Transportation Summary</u> At this point we are finished with the first page of the decision flow diagram that deals with transportation (Figure 6-2). The continued declines of Snake River spring chinook and other stocks indicate either that the survival of transported fish is too low or not a high enough proportion is being collected, given prevailing environmental conditions and any additional mortality attributable to other human activities. While the group feels that direct mortality (while the fish are in the barge) is probably very low, we could not conclude that there is not delayed mortality. We generally agreed that, in the absence of delayed mortality, a sufficient proportion was being transported that, combined with inriver survivors, should meet our passage survival goal. If delayed mortality is substantial, it is unlikely that the proportion transported in recent years has been sufficient. Some opportunities for improving transport survival exist but the opportunities for substantial gains are limited. Opportunities for increasing the transported proportion above recent levels appear to be somewhat greater.

<u>Page 2 of Decision Flow Diagram - Inriver Survival (Figure 6-3)</u>

<u>Question</u> <u>1.5</u> ***If it is determined in Question 1.1 or 1.2 that transportation cannot provide a high rate of juvenile survival*****, do present passage measures provide a high rate of juvenile survival across a broad range of life histories without subsequent adverse effects? [This refers to conventional, non-structural measures to improve survival outside of transportation. Implicit in this question is the need to provide benefits across a range of fluctuating environmental conditions.]**

Conclusion: No, at best the current survival of inriver migrants to the Bonneville Dam tailrace may be 40-50%, which does not meet the interim passage survival goal. Available information is not sufficient to determine if additional delayed effects occur, but such effects would only reinforce the conclusion that current survival of in-river migrants does not meet the passage survival goal. See Questions 1.5.A and 1.5.B in narrative for additional details.

Needed Information:

(1) Conclusions should be confirmed with survival studies to lower Columbia River projects, to determine if our expansions of reach survival estimates from lower Snake River projects are valid.

(2) Studies in (1) should be conducted over a number of years to determine a range of survival estimates under a variety of environmental conditions.

(3) The information needed to assess delayed mortality of transported fish below Bonneville Dam (Question 1.1.B "Needed Information") should also be conducted in a manner that will allow assessment of delayed effects to in-river migrants.

<u>Question</u> <u>1.6</u> ***If it is determined in 1.5 that present passage measures do not provide a high rate of juvenile survival*****, can a high rate of juvenile survival be provided in-river without major modifications to structures?**

[Note: the Hydro Work Group did not develop a group consensus on Question 1.6 or its components, 1.6.A and 1.6.B, because the narrative was not sufficiently developed to draw conclusions at the last work group meeting prior to completing this draft. Conclusions for this question and its components are tentative, pending further Hydro Work Group discussion.]

Strategies that may improve in-river survival generally fall into two categories: those that improve survival past dams and those that improve survival through reservoirs (although some potential measures may improve both). These are addressed by Questions 1.6.A and 1.6.B.

Current mean project (reservoir + dam) survival ranges from 87-92%, based on 1993-1996 PIT-tag survival studies. This results in 8-project system survival of approximately 33-51%. Some preliminary studies suggest that additional delayed effects may occur, but these studies have not yet been completed. To meet the interim passage survival goal of 50-70%, mean project survival must be 92-96%, with no delayed mortality. This means that mean project survival meets the lower end of this range under the best conditions observed in recent years. However, achievement of the full passage survival goal would require an average increase of approximately 4-5%.

Available information is not sufficient to answer this question with certainty, but it appears that available measures are unlikely to achieve this survival improvement. Opportunities for increased project survival lie almost entirely with dam passage improvements that are scheduled for installation in the near future or are currently being designed. Evaluations of these devices (increased spill through gas abatement measures, surface bypass structures, improved turbine designs, and extended-length screens) in 1997 and 1998 will determine potential changes in project survival. We suspect that, optimistically, these devices may increase average dam passage survival by up to 2%, which would not achieve the full range associated with the interim passage survival goal. We stress, however, that this is merely an informed guess and ongoing evaluations may demonstrate a greater potential improvement. We see no opportunity to appreciably increase reservoir survival levels above current levels with any combination of additional measures that are within the Corps of Engineers' current authority (i.e., measures other than drawdowns).

Question 1.6.A Can a high rate of in-river survival be provided by increasing dam passage survival?

Tentative Conclusion (see note under Question 1.6): The primary opportunities for increased dam passage survival are: (1) increased spill (and resulting decrease in percentage of fish through turbines) from gas abatement measures, such as the planned installation of spill deflectors at IHR and JDA; (2) surface bypass structures, of which a prototype powerhouse structure is being tested at LGR and a prototype spillway skimming device is being tested at TDA; (3) improved turbine designs (e.g., reducing gap of turbine blade runners and designing to operate a greater percentage of time at maximum efficiency), a prototype of which will be installed at BON in 1998; and (4) extended-length screens, which will be installed at LGR, LGO, and MCN by 1997 and could also be installed at other projects. The only one of these improvements that has been quantified is installation of extended-length screens, which appears to improve fish guidance efficiency (FGE) approximately 10% above that obtained from standard screens. Based on informed guesses regarding the possible survival improvements associated with these measures, we suspect that they may have the potential to increase average dam passage survival about 2%. This would change the current mean project survival of 87-92% to 89-94%, which would not achieve the full range associated with the interim passage survival goal (92-96%) unless reservoir survival improvements also occurred.

We were unable to evaluate possible delayed effects of dam passage, but many of the same considerations applicable to delayed mortality of transported fish (Question 1.1.B) would also apply to the proportion of in-river migrants passing through turbines and bypasses. Those considerations may be less applicable to migrants that pass over spillways. Any delayed effects of in-river passage would further reduce the likelihood of achieving the interim passage survival goal with new dam passage measures.

Needed Studies:

(1) Concurrent estimates of passage through all dam routes using PIT-tag mark/recovery techniques to confirm estimates of survival through individual passage routes and to aid in separating reach survival estimates into reservoir and dam passage components.

(2) Evaluations of the dam passage survival increases that will result from:

(2a) Increased spill due to gas abatement measures at certain projects;

(2b) Surface bypass systems applied to Snake and lower Columbia River projects,

(2c) Improved turbine designs,

(2d) Extended-length screens (confirm fyke-net estimates with PIT-tag estimates).

(3) Evaluate delayed mortality associated with in-river passage (see Question 1.1.B "Needed Information"). It would be desirable to obtain this information for different in-river passage routes (turbine, spillway, bypass, surface collector) to determine if there are any differences among the different routes.

<u>Question</u> <u>1.6.B</u> Can a high rate of in-river survival be provided by increasing reservoir passage survival?

Tentative Conclusion (see note under Question 1.6): The opportunity to improve reservoir survival above levels already being achieved with the 1995 BIOP actions and the current predator control program is minimal. Additional water for flow augmentation is not readily available. The program has become fully implemented as of 1995-1996 and the benefits have been largely realized but further benefits may occur for several more years. Our assessment treats direct survival through reservoirs to BON tailrace. There is considerable uncertainty with regard to the existence and magnitude of hypothesized delayed effects associated with migration speed. Until these are clarified there is no means to determine if existing mitigation actions can substantially reduce delayed effects.

<u>Needed studies</u>

(1) To properly evaluate surface bypass/collector systems the region will need:

(a) accurate estimates of collector efficiency

(b) Knowledge of the extent of forebay delays throughout the system

(c) Information on whether or not the SB/Cs reduce delays.

(2) Continued monitoring of predator abundance

(3) Continued monitoring of mainstem survival

(4) To resolve the discrepancy in alternative hypotheses contained in the passage models a simple exercise could be performed. Model predicted travel times could be compared with measurements taken on migrating smolts traversing the entire system, or large sections thereof. Specific water velocity/flow conditions accompany the actual observations. There is ample contemporary data available for such an analysis. The migration speed of PIT-tagged fish can be tracked from the uppermost release or detection site in the Snake River, to passage at the last detector site, most recently JD or BON dams. These observations can be compared with model predictions to determine which predictive functions are most representative of actual migrants. This activity could be conducted in a prospective analysis, using the abundant PIT data acquired in recent years, from survival studies, transport evaluations and SMP releases.

(5) It has been argued that the relative change in smolt survival across a range of flows, or smolt travel times, is more meaningful than absolute values predicted by a model. This is consistent with the approach used in the System Operation Review, where change in survival relative to a base case condition was the performance measure of interest. Using this approach as a guide, it may be instructive to compare the model-predicted relative change in survivals with relative change in empirically estimated survival, across a range of flows and/or smolt travel times. We suggest this be performed as a prospective analysis. Reach-specific smolt survival estimates obtained by NMFS , 1993-1996, would constitute the data set representing contemporary passage conditions. Both CRISP and FLUSH would predict survival through the same reaches, under the actual conditions prevailing during those years. Survival would be expressed in terms of percent change from some prescribed base case.

(6) Determine whether important delayed effects are associated with migrational delay of the magnitude observed in the Columbia Basin. Identify the mechanisms and magnitude of the effects. Assess whether proposed mitigation actions will effectively reduce these effects.

Inriver Summary At this point we are at the end of the inriver page of the decision tree (Figure 6-3). In general the tentative conclusion is that, if declines of Snake River stocks continue even with transportation, it is unlikely that inriver survival is high enough. Although there is potential for improvements, we believe that measures to dramatically increase survival at dams or in reservoirs is unlikely at this time.

Page 3 of Decision Tree - Hybrid (Figure 6-4)

Question 1.7 ***If it is determined in 1.1 and 1.4 that transportation survival is high enough but the collection rate is too low to meet the hydro survival goal for the entire spring/summer chinook population,*** **do present passage measures provide a high rate of juvenile survival across a broad range of life histories without subsequent adverse effects? [This refers to conventional, non-structural measures to improve survival outside of transportation. Implicit in this question is the need to provide benefits across a range of fluctuating environmental conditions.]**

Conclusion: This is identical to Question 1.5, but is reached through different assumptions about transportation survival. Rather than the "yes-no" answer to this question in the in-river decision pathway (Questions 1.5 and 1.6), the hybrid decision pathway asks whether in-river survival is sometimes, never, or always high enough to meet the passage survival goal. The work group was in general agreement that the answer to this question, based on current in-river passage estimates, is Anever.@ In-river survival (LGR pool to BON tailrace) under current conditions and operations is, at best, 40-50%, while the interim passage survival goal is 50-70%. Any delayed mortality associated with in-river passage would further reduce the likelihood that current in-river survival is sufficient to meet the passage survival goal.

Needed Studies: See Question 1.5.

Question 1.8 ***If it is determined in 1.7 that in-river survival is high enough to meet the survival goal under some conditions,*** **does a combination of passage and in-river measures provide a high rate of juvenile survival over a broad range of life histories?**

Conclusion: Based on the conclusion for Question 1.7, this question will not be addressed unless additional measures can provide in-river survival sufficient to meet the passage goal under at least some conditions (Question 1.9). We believe that it is likely that dam passage improvements will provide adequate survival under some conditions. However, there was general agreement by the work group that achievement of the survival goal is unlikely under this hybrid scenario. This point in the decision path is not reached unless the goal cannot be reached by transporting fish in any year (because not enough fish can be collected), but the goal can be met in some years by leaving fish in the river. Therefore, there will always be some years in which the goal will not be met, even though transportation in those years may provide higher survival than leaving fish in the river. Under only one condition will a hybrid scenario result in survival and recovery: transportation survival is high enough to meet the goal under some conditions, in-river survival is high enough to meet goal under some conditions, and the conditions that are favorable to each strategy are complementary. We believe that this condition is highly unlikely.

Needed Research: None identified.

Question 1.9 ***If it is determined in 1.7 and 1.8 that in-river passage never meets the goal or that a combination of in-river passage and transport do not meet the goal,*** **can in-river survival be substantially improved without major structural modifications?**

Available information is insufficient to answer this question. However, based on the conclusion for Question 1.6, it is possible that dam passage improvements may provide adequate survival under some conditions. We estimated, based on an "informed guess," that four identified measures may improve mean project survival by a maximum of 3%, resulting in mean per-project survival of 90-95%. This partially overlaps the mean per-project survival necessary to achieve the interim passage survival goal, 92-96%, suggesting that the goal may be achieved under some conditions if our most optimistic assumptions are realized.

Needed Information: See Question 1.6.

Hybrid Summary At this point we are at the end of the hybrid page (Figure 6-4). The utility of a hybrid approach rests on a situation wherein inriver survival is high enough in some circumstances and transport survival is high enough in some circumstances and that they are not the same circumstances. Available information indicates this scenario is unlikely.

Page 4 of Decision Tree -Drawdown (Figure 6-5)

Question 2 ***If the loss of juvenile fish habitat caused by operation and development of the present system cannot be compensated within the existing authority of the operating agencies*****, how can the system be modified to provide a level of impact that will?**

Question 2.1 ***If it is determined in 1.6 that a high rate of juvenile survival cannot be provided without major structural modifications*****, can in-river survival be substantially improved through major structural changes to the projects?**

Conclusion: Primary options considered are spillway crest and natural river drawdowns at up to four Snake River projects and John Day reservoir.

The work group was in general agreement that risks associated with potential increased dam passage mortality (adults and juveniles) probably outweigh potential reservoir survival improvements due to increased velocities resulting from drawing down Snake River projects to spillway crest. We did not attempt new analyses to reach this conclusion, but relied on previous SCS analyses and the discussion of dam passage impacts in the attachment to the NMFS 1995 BIOP.

The work group could not reach agreement on the likelihood that potential survival improvements due to increased reservoir velocity and rearing habitat associated with a spillway crest drawdown of JDA would outweigh risks associated with potential increased dam passage mortality of juveniles and adults. We did not have time to complete a thorough analysis of this option in time for this draft - our discussions to this point have only been qualitative. We do believe that it is important to point out that, while there is uncertainty regarding effects of a JDA spillway crest drawdown on survival of Snake River spring/summer chinook salmon, consideration of this option for other stocks, such as Hanford Reach fall chinook salmon, may lead to more definitive conclusions.

The work group was in general agreement that a natural river drawdown of four Snake River projects (with or without a natural river drawdown of JDA) would substantially increase survival of juvenile migrants and would also substantially increase adult upstream passage survival. With dams in place and current average project survival rates (87-92%), in-river system survival of smolts would be 57-72%, which would clearly meet the passage survival goal. This assessment would only be modified if there were significant delayed effects of dam breaching or of passage through the remaining four projects or if there were significant adverse effects of dam breaching (possibly due to sediment release, adult velocity barriers, or the lag time associated with re-establishing a riverine trophic base) that have yet to be evaluated. The increase in adult passage survival (possibly 10% or more) would also contribute towards meeting the interim SAR goal.

Needed Research:

[Not completed in time for this draft]

Drawdown Summary The group generally feels that the biological benefits may be substantial if both reservoir and dam mortality can be eliminated or greatly reduced through a natural river drawdown. The potential drawbacks are few and manageable.

6.4 Analyses and Narrative

This section of the chapter provides details regarding each question within the Hydro Decision Pathway that were summarized in previous sections. We begin with a discussion of interim survival goals, against which proposed actions and supporting information can be evaluated. We then examine each question individually. Organization is consistent with the Flow Chart and Summary, but more sub-sections are included for some questions. Italicized comments are summary statements and/or conclusions, which are explained in more detail in subsequent text.

Question 0.0 What is the overall survival goal for Snake River fish from smolt to returning adult (SAR)?

We defer setting a goal for the entire life-cycle, pending results of the PATH prospective analysis. We suggest an interim smolt-to-adult return (SAR) goal of 2-6%, which includes direct and delayed hydro mortality, as well as mortality unrelated to hydro effects. Because this goal includes effects of other human activities and environmental variability, it is not defined as a hydro goal. However, the Work Group was in general agreement that hydro effects may be a significant component of smolt-to-adult survival. We propose that the SAR goal be used as a benchmark to judge impacts and correlates of delayed effects.

A reasonable objective for management of dams and reservoirs in the Snake and Columbia River basin (Federal Columbia River Power System [FCRPS]) is that operation of the FCRPS, in conjunction with other human activities, should result in survival rates that allow persistence and recovery of listed Snake River spring/summer chinook salmon. Decisions must take into account the range of environmental variation, which also affects the species' survival, in addition to various sources of human-induced mortality. Methods for estimating the likelihood of survival and recovery of Snake River spring/summer chinook, given a set of management actions, were proposed by the Biological Requirements Work Group (BRWG 1994) and largely adopted by the National Marine Fisheries Service (NMFS) for use in Endangered Species Act Section 7 consultations (NMFS 1995a,b).

One goal of the PATH prospective analysis is to determine the change in current survival, over the entire life-cycle, that is necessary for persistence and recovery of Snake River salmon as described above. That information is a prerequisite for determining the change in survival necessary during any life-history stage, including smolt survival through the FCRPS. The PATH prospective analysis will not be completed until fall 1996, so a goal for the entire life cycle will not be available until that time.

We propose an interim smolt-to-adult return (SAR) survival goal, which includes: (1) direct mortality of smolts and adults passing through the FCRPS that are caused by the hydro effects; (2) any smolt mortality caused by other human effects that are expressed within or below the FCRPS (e.g., pollution, smolt condition related to habitat quality and hatchery effects); (3) below-Bonneville mortality resulting from delayed effects of smolt passage through the FCRPS; (4) natural ocean and estuarine mortality; (5) disease; and (6) ocean and in-river harvest. Our primary interest in this survival estimate is it's inclusion of direct and delayed mortality caused by passage through FCRPS. This was the only useful survival estimate, to our knowledge, that encompassed both direct and delayed hydro effects. The drawbacks of this survival estimate relative to hydro decisions are the inclusion of sources of mortality unrelated to the FCRPS and our inability to determine the proportion of mortality attributable to the FCRPS during the smolt-to-adult stage. There was general agreement of the Hydro Work Group that FCRPS-related mortality may be a significant component of SAR. Because of the non-hydro mortality expressed in the SAR, hydro decisions must be interpreted with great caution relative to this goal.

We suggest three methods of approaching SAR goals. The first is to examine the range of SARs that are associated with Snake River cohorts that survived to at least replace the parental stock for brood years 1962-1982. More recent SAR estimates are not available for Snake River stocks, so the second approach is to examine the range of SARs during a more recent time period (1977-1990 outmigrations) for the Warm Springs stock in years for which that stock replaced itself. The Warm Springs stock was chosen because it is the only other spring/summer chinook stock in the migratory pathway of Snake River stocks with an available time series of smolt estimates. A third approach was to use estimates of adult-to-smolt (at LGR) survival of the aggregate Snake River spring/summer chinook population (Chapter 9 of this report) and estimates of adult survival from LGR to spawning grounds to derive a theoretical estimate of needed smolt-to-adult survival from LGR to LGR. We suggest an SAR goal that we believe is consistent with all three approaches.

Smolt-to-Adult Return (SAR) Goal, Based On Raymond (1988) SAR Estimates

For the first method (Table 0.0.1), estimates of cohort replacement rates for seven wild Snake River stocks were obtained from Petrosky (1996). These replacement rates represent the ratio of total recruits to the spawning ground (from all return years) to the number of parental spawners. Details of methods and calculations are in Beamesderfer et al. (in preparation). Four of the stocks are considered spring chinook stocks, two are considered summer chinook, and one stock is intermediate (Table 0.0.1). Wild spring chinook SAR estimates for 1964-1984 out-migration years (1962-1982 brood years) were obtained from Table 2 of Raymond (1988) and wild summer chinook SARs from 1962-1979 and mixed wild/hatchery SARs from 1980-1984 were obtained from Table 4 of Raymond (1988). The hatchery contribution to out-migrating smolts in 1980-1984 was 8-15% (Raymond 1988). Raymond's SAR estimates represent survival of smolts from the uppermost dam during the year of the estimate to adult return at Ice Harbor Dam, adjusted for in-river harvest below that point. The uppermost dams were IHR (1964-1968), LMO (1969), LGO (1970-1974), and LGR (1975-1984).

Table 0.0.1 Comparison of smolt-to-adult returns (SAR) and replacement rates of wild Snake River spring/summer chinook salmon stocks. Percentage of smolts transported in each year is indicated. **Bold rows** represent years in which the wild SAR is associated with replacement of most wild stocks (at least 3 of 5 stocks for spring chinook and 2 of 3 stocks for summer chinook). Population sizes were much smaller in the 1980s than in the 1960s - SARs associated with replacement at small population sizes may not be sufficient to replace larger populations due to density-dependent effects.

Brood Year	Out Year	CRiSP % Trans-ported[1]	FLUSH % Trans-ported[2]	SAR Estimates[3] (Percent)		Replacement Rate (Percent)						
				Wild Spring Chinook	Summer Chinook	Bear Valley/ Elk Cr. (Spring)	Marsh Cr. (Spring)	Sulphur Cr. (Spring)	Minam R. (Spring)	Imnaha R. (Spring/ Summer)	Pov. Flat (Summer)	Johnson Cr. (Summer)
1962	1964	0		**3.7**	3.7	**1.14**	**2.02**	**2.02**	**0.60**	**0.63**	0.62	0.86
1963	1965	0		3.7	3.7	0.66	1.00	0.92	0.43	2.32	0.45	0.65
1964	1966	0		3.9	3.9	0.86	0.54	4.72	0.56	0.86	0.53	0.54
1965	1967	0		**6.1**	**5.8**	**1.67**	**1.07**	**7.13**	**0.98**	**1.47**	**1.33**	**2.12**
1966	1968	0		3.6	3.5	0.32	0.76	0.54	0.97	0.87	0.48	1.37
1967	1969	0		5.3	5.0	0.43	0.47	0.55	2.50	2.19	0.52	0.79
1968	1970	0		**3.4**	**3.2**	**0.85**	**1.20**	**0.67**	**1.34**	**2.11**	**1.33**	**2.47**
1969	1971	3		2.4	2.3	0.30	0.82	0.23	0.74	0.92	0.44	0.47
1970	1972	7		1.2	0.8	0.68	0.56	0.61	0.75	1.38	0.38	0.94
1971	1973	7		0.4	0.3	0.50	0.17	0.25	0.31	0.24	0.50	0.36
1972	1974	0		1.6	1.1	0.20	0.14	0.06	0.44	0.33	0.18	0.13
1973	1975	10	7	3.7	2.2	0.72	0.65	0.87	1.58	0.95	0.67	0.64
1974	1976	14	22	1.0	0.7	0.50	0.24	0.51	0.43	0.16	0.42	0.30
1975	1977	56	40	0.3	0.2	0.07	0.05	0.05	0.12	0.29	0.18	0.13
1976	1978	48	60	1.0	0.3	0.31	0.65	0.29	0.19	0.55	0.75	0.72
1977	1979	48	64	1.2	0.6	0.37	0.66	1.22	0.34	0.77	0.78	0.55
1978	1980	55	52	0.5	0.3	0.24	0.14	0.12	0.24	0.26	1.31	0.61
1979	1981	44	64	1.5	0.4	0.52	0.86	0.09	1.02	2.20	1.56	0.43
1980	1982	26	43	**2.0**	**0.5**	**6.22**	**10.86**	**3.60**	**4.86**	**2.82**	**1.73**	**2.25**
1981	1983	25	45	**2.1**	**1.1**	**1.64**	**1.74**	**6.94**	**10.18**	**1.38**	**1.78**	**1.40**
1982	1984	43	41	**3.0**	**1.0**	**4.73**	**3.13**	**8.09**	**1.76**	**0.81**	**1.37**	**1.46**
1983	1985	58	65			**7.08**	**8.07**	**12.45**	**4.82**	**1.41**	**3.48**	**2.47**
1984	1986	51	50			0.60	0.55	####	1.62	0.28	0.95	2.65
1985	1987	62	59			0.49	0.44	1.89	0.29	0.20	0.75	0.50
1986	1988	62	60			0.98	0.55	0.63	0.51	0.33	2.95	1.56
1987	1989	57	65			0.34	0.20	0.62	0.09	0.17	0.83	0.59

1988	1990	62	64	0.64	0.69	0.43	0.18	0.68	1.21	1.28
1989	1991	67	66	0.83	0.31	0.39	0.29	0.62	1.08	0.85
1990	1992	58	60	0.10	0.04	0.03	0.04	0.29	0.13	0.12
1991	1993	58								
1992	1994	54								
1993	1995	65								
1994	1996	65								

[1] CRiSP model estimates of LGR Dam arrivals transported (Hayes 1996), adjusted (estimate * 0.95) to represent the proportion of smolts arriving at the head of Lower Granite pool that are subsequently transported at LGR, LGO or LMO dams. Contribution of fish transported from MCN, which is considered inconsequential, is not included in estimates.

[2] FLUSH estimates from Wilson (1996) represent the proportion of smolts arriving at the head of Lower Granite reservoir that are subsequently transported at LGR, LGO , LMO or MCN dams.

[3] Smolt (at first dam encountered) to adult return to IHR estimates for wild spring chinook from Table 2 and summer chinook from Table 4 of Raymond (1988). Summer chinook are wild through 1979 out-migration. Hatchery composition of smolts 8-15% during 1980-1984 out-migrations. Location of the first dam encountered during the outmigration was IHR (1964-1968), LMO (1969), LGO (1970-1974), and LGR (1975-present). Returning adults were estimated as IHR adult count plus estimated in-river harvest in Zone 1-6 fisheries (below IHR).

[4] Replacement rates are from Petrosky (1996), using data and methods described in Beamesderfer et al. (in prep.). Replacement rate is ratio of recruits to spawning ground (summed over all return years) to parental spawners.

The smolt estimates in Raymond (1988) relied upon assumptions regarding efficiency of juvenile gatewell collection at the uppermost dam (Bentley and Raymond 1978; Raymond 1979) and ability to estimate proportions of wild and hatchery smolts. The hatchery smolt composition was derived from hatchery release records and assumptions regarding survival to the first dam. Wild smolt estimates were the remainder between the hatchery smolt estimates and the estimated total smolt abundance at the first dam. Adult ages at Ice Harbor Dam were estimated from length composition of adults observed in Idaho spawning ground surveys and returns to hatcheries above Ice Harbor. A number of assumptions were required to determine the in-river harvest of Snake River spring and summer chinook.

A majority of Snake River spring chinook stocks (at least 3 of 5) and summer chinook stocks (at least 2 of 3) had replacement rates ≥1.0 for cohorts that out-migrated in 1967, 1970, and 1982-1984. In addition, most spring chinook stocks that out-migrated in 1964 had replacement rates ≥1.0. SARs associated with replacement during the 1970 and earlier out-migrations ranged from 3.2-6.1%. These estimates bound the range of SARs during the entire 1964-1970 period, when populations were believed to be relatively stable and of a large enough size to ensure persistence. In contrast, the 1982-1984 SARs ranged from 1.4-3.0%. These SARs were associated with much smaller population levels. Consideration of the different SARs in the two periods suggest that a smolt-to-adult survival rate <3% may be sufficient to replace Snake River spring/summer chinook populations when they are at relatively low levels, but SARs ≥3% may be required when populations are at higher levels. Presumably, this difference is due to density dependent survival during the egg-to-smolt stage.

Because Raymond's (1988) SAR estimates were adjusted for in-river harvest rate, they must be interpreted carefully. The spawner replacement rates with which these SARs are being compared included in-river harvest mortality. Zone 1-6 in-river spring chinook harvest exploitation rates in the 1960s and early 1970s ranged from 33-63% while harvest rates in the early 1980s ranged from approximately 6-8% (Table A.1 of Beamesderfer et al. In Prep. October 11, 1995 draft). Therefore, the "actual" spring chinook SARs to Ice Harbor in the 1960s may be closer to 2-4%, rather than the 3-6% reported by Raymond (1988), while 1980s actual SARs would still be close to the estimates reported by Raymond (1988). Summer chinook harvest rates were generally between 10-20% in the 1960s and early 1970s, which could change the SAR range to approximately 3-5%%. Summer chinook harvest rates were very low (2-6%) in the early 1980s, so would not change significantly.

Smolt-to-Adult Return (SAR) Goal, Based On Warm Springs SAR Estimates

Smolt-to-adult-return (SAR) data are available from the Warm Springs River, a tributary of the Deschutes River in North Central Oregon, are available for brood years 1975 through 1990. The numbers of wild smolts outmigrating each year were provided by the Warm Springs tribal staff (Fritsch pers. comm.) based on a smolt trap near the mouth of the Warm Springs River. Estimates of numbers of wild adults returning to the mouth of the Deschutes for each brood were provided by Schaller (pers. comm.)

To make Warm Springs SARs comparable to other SAR indices, it was necessary to account for harvest rates. Because Warm Spring spring chinook pass through virtually the entire inriver spring chinook fishing area, the entire inriver harvest rate was applied to the actual estimated SAR. Harvest rates (TAC 19xx) were lagged four years past the brood years because these fish return primarily as four year olds.

Warm springs SARs are shown in Table 0.0.2. The average SAR for this time series is 3.07. As a SAR goal, this number may be viewed as conservative for two reasons. First, the Warm Springs is above two dams and is therefore not unaffected by hydropower. Second, there is a period of decline in the later years during which the stock could be thought of as not being in good health. During this period there was light inriver harvest with an average rate of 8.8% (TAC 1996).

Table 0.0.2 Estimates of smolt-to-adult return for the Warm Springs River spring chinook stock.

BROOD YEAR	OUT YEAR	WS SAR
1975	1977	3.083011

1976	1978	2.322764
1977	1979	4.870075
1978	1980	1.736368
1979	1981	5.455069
1980	1982	5.333418
1981	1983	5.127105
1982	1984	3.490919
1983	1985	2.843732
1984	1986	1.824292
1985	1987	2.192342
1986	1988	2.49367
1987	1989	1.035708
1988	1990	1.220404

Smolt-to-Adult Return (SAR) Goal, Based On Spawner-to-Smolt Survival Estimates

An alternative method of setting an SAR goal is to use estimates of spawner-to-smolt (at LGR) survival and LGR adult-to-spawner survival to calculate the SAR that would be necessary to result in at least one adult recruit to the spawning ground for every parental spawner. Chapter 9 of this report, by Petrosky and Schaller, provides estimates of spawner-to-smolt survival for 1962-1982 and 1990-1993 brood years, using two methods for estimating the number of spawners and a range of sampling efficiency (FGE) estimates for estimating smolts to LGR. Some of the spawner estimates in Chapter 9 are based on assumed (TAC 1996) spawner-to-smolt survival of 80%, so this value is probably most consistent with the spawner-to-smolt estimates. An alternative value of 90% was used by Beamesderfer et al. (In Prep., Oct. 11, 1995 draft) for various run reconstructions in this PATH report because it appears to be consistent with the number of unspawned female carcasses found on spawning grounds in Snake River tributary surveys (Petrosky 1995 DRAFT). Both values were used for LGR adult-to-spawner estimates.

Estimated SARs needed for replacement range from 1.0-1.8% when the period mean spawner-to-smolt estimates of Chapter 9 are applied (Table 0.0.3A). These values represent mean SARs that would be required for both the 1962-1974 period and the 1975-1982 and 1990-1993 period. When the full range of annual spawner -to-smolt estimates is considered, the SAR needed for replacement ranges from 0.5-4.6% (Table 0.0.3.B). The lower values are associated with very high egg-to-smolt survival, which may only be achievable at low population densities. It is likely that these low SARs would not be sufficient for replacement at higher population levels.

It is important to realize that SARs calculated by this method are not directly comparable with SARs estimated by Raymond (1988) because they include harvest mortality and consistently represent survival from LGR to LGR.

Table 0.0.3 Calculations used to estimate SAR necessary to replace spawning stock under several assumptions regarding spawner-to-smolt at LGR survival and LGR adult-to-spawner survival. Values in A.1 and B.1 encompass the full range of survival estimates from the referenced tables. Sources of 0.80 and 0.90 estimates in A.4 and B.4 are Chapter 9 and TAC (1996) for 0.80 and Beamesderfer et al. (In Prep., October 11, 1995 draft) and Petrosky (1995 DRAFT) for 0.90.

A. Necessary SAR Based on Range of Chapter 9 Smolt-Per-Spawner Multi-Year Means in Tables 11 and 12

		Range of Estimates		
1. Smolts to LGR Per Spawner (Chap. 9)	69.50	111.6	69.50	111.6
2. Required LGR-LGR SAR (Calculated as 3) 1)	**0.018**	**0.011**	**0.016**	**0.010**
3. Adults Required at LGR (Calculated as 5) 4)	1.250	1.250	1.111	1.111
4. LGR Adult-To-Spawner Survival (Two Sensitivities)	0.800	0.800	0.900	0.900
5. Adults Required at Spawning For Replacement	1.000	1.000	1.000	1.000

B. Necessary SAR Based on Chapter 9 Annual Smolt-Per-Spawner Ranges in Tables 5,7, and 9

		Range of Estimates		
1. Smolts to LGR Per Spawner (Chap. 9)	27.20	217.3	27.20	217.3
2. Required LGR-LGR SAR (Calculated as 3) 1)	**0.046**	**0.006**	**0.041**	**0.005**
3. Adults Required at LGR (Calculated as 5) 4)	1.250	1.250	1.111	1.111
4. LGR Adult-To-Spawner Survival (Two Sensitivities)	0.800	0.800	0.900	0.900
5. Adults Required at Spawning For Replacement	1.000	1.000	1.000	1.000

Smolt-to-Adult Return (SAR) Goal: Recommendation

While the full range of estimated and "theoretical" SARs associated with stock replacement includes values that are 1% or less, we do not feel that it is appropriate to include these low SARs in the survival goal because they appear to be associated with low population levels (i.e., 1980s Raymond SAR estimates) or exceptionally high adult-to-smolt survival rates. **We suggest a goal of 2-6% SAR for Snake river spring/summer chinook populations**. We suggest that the low end of the suggested SAR range may be sufficient for stabilizing stocks at low levels. However, higher SARs will likely be necessary to encourage population growth and maintain larger populations, which are expected to experience density-dependent egg-to-smolt survival.

As stated previously, the SAR goal includes effects of other sources of human-induced mortality as well as natural mortality affected by environmental variation. The SAR goal does not apply only to hydro actions, but the FCRPS configuration and operation should result in sufficient smolt and adult passage survival, with a minimum of delayed effects, so that the specified adult return rates are not prevented.

Question 0.1 What Is the Hydro Survival Goal for Salmon Passing Through the FCRPS?

Since Snake River stocks were strong and stable during the 1960s with 4 dams in place, smolt passage survival under those conditions appeared to be adequate. We estimate that survival ranged from 42-68% during that era, and propose the upper end of this range, 50-70%, as an interim smolt passage survival goal. We do not know the level of delayed mortality that may have occurred below Bonneville Dam historically. We make the conservative assumption that this goal includes any post-release delayed mortality attributable to passage through the FCRPS. We stress that the full range, not just the lower bound, should be considered when evaluating management actions, due to a variety of uncertainties inherent in this estimate.

We propose a specific smolt survival goal because most of the management actions proposed within the region are designed to improve smolt survival, on the assumption that this is the life stage most severely affected by the FCRPS and on the assumption that the greatest opportunities for improving survival affect this life stage. We attempt to define this Hydro goal in a manner consistent with the SAR goal.

Smolt Passage Survival Goal: Upper Bound, Based On Free-Flowing River From Lower Granite Pool to Bonneville Dam

We adopted juvenile passage survival through the FCRPS as a readily interpretable performance measure with which to gage the success or failure of proposed management actions. We use AHydro survival@ or "passage survival" as a shorthand terms to represent smolt survival through the reach from the head of Lower Granite reservoir to a general location just downstream from Bonneville Dam. To bound the maximum survival attainable through the system we estimated what smolt survival would have been, or could be today, in the absence of dams. To estimate this we relied on smolt survival estimates of Raymond (1979). He estimated average survival (1966-1968) of wild yearling chinook through the free-flowing reach from the Salmon River (Riggins/Whitebird) to Ice Harbor Dam (prior to construction of LGR, LGO, and LMO) at 0.89 (range 0.85-0.95). This is a distance of 241 miles. Assuming the mortality rate is constant, the survival rate through that unimpounded river was 0.99952 per mile (range 0.99933-0.99979).

Recent estimates based on PIT-tagged wild spring/summer chinook comport with those earlier estimates. Muir et al. (1996) estimated that in 1995 the survival of wild yearling chinook from the Whitebird trap to LGR Dam was 0.897 (SE=0.015), and survival from Whitebird to LMO (detections not possible at IHR) was estimated at 0.783 (SE=0.027). They also estimated survival of chinook through LGR pool and dam to be 0.927 (SE=0.007). Assuming that the two observations (Whitebird to LGR Dam and LGR pool to LGR Dam) can be combined to derive a third estimate, we estimate that survival in the unimpounded section from Whitebird to LGR pool in 1995 was about 0.97 (0.897) 0.927). The distance from Whitebird to the LGR pool release site was 113 miles. Assuming smolt mortality rate is constant, we estimate that in 1995, survival through the unimpounded reach was 0.99973 per mile, which is within the range that we derived from the earlier Raymond (1979) data.

Applying the mean Raymond (1979) and recent PIT-tag estimates of per-mile survival rates over the distance from LGR Pool to Bonneville (about 316 miles), smolt survival in the absence of dams would be approximately 0.86-0.92. This is our best estimate of the highest possible smolt survival through the FCRPS, and bounds the uppermost limit of smolt survival.

Smolt Passage Survival Goal, Based On Estimates of Survival During the 1960s With Only Four Dams In Place

The NMFS Proposed Recovery Plan defines the recovery escapement level as an eight-year geometric mean equal to 60% of pre-1971 escapement for 80% of Snake River spring/summer chinook stocks with at least five years of pre-1971 redd counts. Approximately 30 stocks are available for this determination. A secondary criterion is that the eight-year geometric mean of the aggregate of all Snake River spring/summer chinook salmon stocks should equal 60% of the 1962-1968 brood year average count of natural spawners past Ice Harbor Dam (31,440 fish). These criteria are based, in part, on a determination that Snake River spring/summer chinook populations were relatively healthy during the 1960s and that the number of spawners during that period was sufficient to maintain genetic integrity and continued persistence of the stock.

The NMFS Proposed Recovery Plan (NMFS 1995c) does not segregate this life-cycle recovery goal into life-stage specific requirements. We make the simplifying assumption that, if the number of spawners was sufficient to ensure survival during the 1960s, then survival during each life stage must have been sufficient. There are certain risks associated with this simplified approach. For example, favorable ocean conditions in the 1960s (see Chapter 12) may have compensated for low survival during some other life stages. Also, in-river harvest rates on Snake River spring/summer chinook in the 1960s were much higher than current higher rates, suggesting that it would not be wise to recommend these rates as interim harvest goals. However, in the absence of another more obvious method of allocating life-stage specific goals, we cautiously define an interim Hydro survival goal based on survival through the FCRPS during the 1960s. The FCRPS during that period did not include the three most upstream Snake River dams (LMO, LGO, and LGR) or John Day Dam. Passage simulation models (FLUSH, CRiSP, PAM) can and should be used to estimate survival through the FCRPS during this period. However, we describe a more simplistic estimation method below.

Based on per-mile estimates described above, survival from LGR pool to IHR pool (approx. 96 miles) would be 0.955-0.974, if this reach was a free-flowing river. Based on the recent PIT-tag derived average per-project survival during 1993-1996 of about approximately 0.87-0.92 (Muir et al. 1996; Table 1.6.A.2 of this report), survival through IHR and MCN projects would be 0.757-0.846. Based on the per-mile estimates, survival through the free-flowing area between MCN Dam and TDA pool (approx. 76 miles) would be 0.964-0.980. Survival through the last two projects would be 0.757-0.846. Survival from LGR pool to BON Dam with 1960s configuration and 1990s estimates of per-project survival is therefore 0.53-0.68.

Survival through mainstem dams and reservoirs during the 1960s was probably lower than that estimated during the 1990s, because bypasses were nonexistent, limited turbine capacity resulted in high dissolved gas levels at moderate flow levels, and turbine operations were more detrimental to juvenile fish passage than current operations (e.g., Williams and Matthews 1995). Giorgi (1993) summarized per-project survival estimates reported by NMFS between 1973-1984. While the estimation methods are not as robust as those being used in the 1990s and precision was poor, the estimates are useful for generally characterizing survival through the FCRPS during the 1960s. Excluding the very low flow years of 1973 and 1977, per project survival averaged 0.82 and ranged from 0.76-0.91. If project survival of 0.82 is substituted for 0.87-0.92 in the calculations described above, survival from LGR pool to Bonneville Dam during the 1960s would have been approximately 0.42-0.43. Thus, depending on what one assumes the estimated smolt survival per project was during that era, survival though the FCRPS past four dams could reasonably have ranged on average from 0.42 to 0.68.

Smolt Passage Survival Goal: Recommendation

To achieve 0.42-0.68 smolt survival past the eight dams in place today, smolt survival would have to average 0.90 to 0.95 per project, including the survival of transported fish if transportation is in place. The upper end of this range appears to be reasonable in relation to existing life-cycle model analyses of survival and recovery requirements. In life-cycle modeling exercises conducted for the NMFS 1995 FCRPS biological opinion (NMFS 1995a,d), juvenile survival levels consistent with the upper portion of this range (approximately 0.50-0.70) generally yielded results that indicated at least a 70% probability of persistence and >50% probability of recovery for the most of the Snake River spring/summer chinook index stocks included in the analyses. The upper end of the range is also consistent with estimates of survival improvements necessary for survival and recovery in BRWG (1994).

In summary, system survival of spring/summer chinook smolts during the 1960s may have been between 42-68%, using the simplistic estimation method described above. We believe that it is prudent to set the upper end of this range as the interim goal because: (1) 1960s passage survival rates, coupled with climatic conditions less favorable than those in the 1960s, may not be sufficient to ensure species survival and recovery; (2) techniques available in the 1970s and early 1980s may have underestimated project mortality; and (3) available life-cycle modeling in NMFS (1995a) and BRWG (1994) suggest that passage survivals considerably higher than 42% are necessary for survival and recovery, given best estimates of climatic variability and survival in other life stages. **We propose that the interim passage survival goal should be 50-70%, and will refer to this range in subsequent discussions.**

We caution that it is important to consider the full 50-70% range. This range is based on a combination of uncertainty regarding FCRPS passage survival estimates, uncertainty regarding environmental variability, and uncertainty regarding human activities affecting survival in other life stages. In years of good survival in other life stages (i.e., favorable freshwater overwintering conditions or oceanic conditions), smolt passage survival near 50% may be sufficient. However, in years of poor environmental conditions or during periods of high human impacts in other life stages, smolt passage survival closer to 70% may be required.

Question 1: Can operation of the hydroelectric system within the existing authority of the operating agencies compensate for human-induced habitat modifications in the mainstem river that affect juvenile salmonid survival?

We approach hydrosystem management decisions by asking two general questions. The first considers whether survival and recovery can be achieved within the capabilities of the current hydroelectric system configuration and current operating authority of the Corps of Engineers. The majority of this narrative addresses more detailed issues that must be resolved in order to answer that question. If the conclusion is "no," a second general question asks if survival and recovery can be achieved with major configuration changes that have been proposed by some management agencies.

We were not able to answer Question 1 with available information. Key uncertainties include the magnitude of delayed mortality caused by transportation (Question 1.1.B) and in-river passage (Question 1.5.B) and uncertainties regarding the efficacy of various transportation and dam passage measures, such as surface bypass/collectors and improved turbine designs.

Question 1.1 Does _transportation_ provide a high rate of juvenile survival for a broad range of life histories and environmental conditions without subsequent adverse impacts?

We approach transportation by first considering whether transport survival is or can be high enough to meet the hydro passage goal and, if so, whether a sufficient percentage of outmigrating smolts are or can be collected in order to provide a high enough rate of survival for the entire population.

We address the transport survival question by first evaluating transportation survival to the point of smolt release (Question 1.1.A) and further evaluating the possibility of delayed effects (Question 1.1.B). This approach is taken because there is general agreement that available evidence indicates high survival to the point of release. Information regarding the magnitude of post-release delayed mortality is meager, indirect, and conflicting. The work group was not able to draw conclusions regarding this question with available information.

Question 1.1.A Is survival of transported fish Ahigh enough@ within the hydropower system from collection sites to a release site downstream from Bonneville Dam?

It is the consensus of the work group that the available evidence supports the conclusion that survival of transported fish to the point of truck or barge release appears high, perhaps 96-98%, exceeding the interim smolt passage survival goal of 50-70%.

Smolt survival through the collection system at LGR can be indexed using the mortalities enumerated within the collection and holding facilities prior to barge loading. At LGR, over the years 1981-1993 observed mortalities as reported by FTOT have averaged 0.6% (Appendix 1). Since some unobserved mortality likely occurs at the face of the screens and within the gatewells, by convention survival associated with the overall guidance and collection process is presumed to be near but not exceed 98%, and is so described in existing passage simulation models (e.g., FLUSH and CRiSP).

Survival from the time of barge loading to release has not been directly estimated. Over the years low numbers of dead smolts have been observed in barges (undocumented oral reporting by barge biologists), but only obvious floating carcasses would be observed. Those submerged on the tank bottom are not viewable, although attempts are made to remove them with long-handled dip nets (pers. comm., J. Williams, NMFS). Limited video observations of fish release through barge exits also indicate few mortalities (video by C. Schreck available from Corps of Engineers, Walla Walla District). General representation in simulation models is 98% survival within the barge.

Using these collective estimates, survival through collection and transportation to the point of release below Bonneville Dam may be on the order of 96-98%. This estimate is a general approximation, since none of the components of mortality, except direct acute collection system mortality, have been directly estimated.

Question 1.1.B Do subsequent adverse effects following barge or truck release occur and, if so, are they of sufficient magnitude to change conclusions regarding survival of transported fish in 1.1.A?

Available information is not sufficient to answer this question. Different lines of evidence provide conflicting results, and each line of evidence has serious limitations.

Information supporting the hypothesis of significant delayed effects occur among transported fish includes: (1) estimated SAR of wild transported fish (expanded from return rates to account for approximate trap efficiency and in-river harvest) averaged 1.33% in recent years (1983-1990), compared to the SAR goal of 2-6%; (2) Appendix 7 SAR analysis indicates that differences in adult upstream survival do not explain differences in SARs, suggesting that delayed transport mortality is the cause; (3) potential for differential mortality of transported and non-transported fish as a result of stress and disease (possibly expressed as higher post-release predation mortality) and (4) possibility that the timing of transported fish entering salt water is off. Some members of the work group also considered impaired homing ability a potential mortality factor; others did not believe available evidence supported this as a potential mechanism. Limitations of the primary lines of evidence include: (1)transport studies were not designed to estimate SARs, so numerous assumptions were required to adjust return rates in an attempt to make them comparable to SAR goal (adjustments do not account for delayed handling and marking mortality), and to distinguish among hatchery and wild return rates;(2) handling effects may have biased some SAR data sets more than others, (3) transport studies not conducted throughout the season and may be biased and (4) while available evidence regarding stress and disease demonstrates the <u>potential</u> for delayed transport mortality, explicit links between these mechanisms and delayed mortality caused by transportation have yet to be demonstrated.

Evidence suggesting that delayed effects are not of sufficient magnitude to change the conclusion in Question 1.1A primarily comes from: (1) the one available estimate of the SAR of wild transported fish (in 1990), which is >2%. Additional evidence relies on comparisons of delayed transport mortality and delayed in-river mortality: (2) no difference in survival of transported and in-river migrating radio-tagged smolts between Bonneville Dam and the estuary was observed in 1995. Data for 1994 and preliminary data for 1996 are similar; and (3) comparison of T/C ratios from the 1986 and 1989 transport survival studies and in-river reach survival estimates from the 1993-1996 mark/recapture studies suggest that delayed mortality of transported fish is ≤ that of in-river migrants under 1989 conditions and the high end of 1986 assumptions, while it is higher under other 1986 assumptions. Limitations of these lines of evidence include: (1) transport studies were not designed to estimate SARs, so numerous assumptions were required to adjust the 1990 transport return rate (overall 0.37%) to an SAR and to account for wild/hatchery composition, and 1990 appeared to be a particularly high survival year, rather than an example of the normal return condition for wild fish; (2) small sample size of radio-tagged smolts below Bonneville Dam; (3) the difficalty of and hence the limitations of studies that attempt to find sources of delayed mortality and (4) absence of reach survival estimates concurrent with T/C estimates in 1986 and 1989, limitations of T/C estimates (e.g., Mundy et al 1994), and limitations of expanding 2-5 project LGR-JDA reach survival estimates to six-project LMO-BON estimates. The comparisons of transport and in-river delayed mortality are only useful if it is assumed that in-river delayed mortality is insignificant or at least "acceptably low." This has not been demonstrated (Question 1.5.B), so utility of these lines of evidence is questionable.

We approach this question by attempting to identify specific mechanisms that may result in delayed mortality of transported fish below Bonneville Dam (Question 1.1.B.1). We also attempt to identify whether delayed mortality appears to be occurring, regardless of the mechanism, and the magnitude of any effect (Question 1.1.B.2).

Question 1.1.B.1 Have mechanisms that would result in delayed mortality transported fish below Bonneville Dam been identified and demonstrated?

Four mechanisms that may result in delayed mortality or apparent delayed mortality of transported fish are discussed: stress associated with collection, transport and release; disease transmission associated with concentration of smolts during holding and transportation; impaired homing ability, possibly due to improper imprinting as a result of transport; and alteration of timing of arrival in the estuary due to transportation.

Stress and Disease Transmission

Mundy et al. (1994) reviewed numerous studies that have investigated the effects of collection, transport, and release on the health of salmon smolts. Three of the four conclusions of the review were:

"(1) Outmigrating chinook salmon smolts are stressed when subjected to bypass, collection and transport around major dams in the Columbia River. The stress experienced by the fish is transitory in nature and not life-threatening by itself, and most fish appear to recover within a period of up to a few days after release.

(2) Within the period of recovery, however, the fish may be vulnerable to:

(a) other stressors in the environment that may have a cumulative effect on survivorship,
(b) predation, particularly by northern squawfish, and
(c) disease infection.

(3) Comparisons of physiological studies among years and sites are difficult to evaluate because of changes in transport protocols (e.g., single-species vs. mixed-species transport) and fish quality (e.g., high vs. low BKD [bacterial kidney disease] infection) from year to year, and in differences in transport duration from various collection sites to the downstream release site (e.g., Lower Granite vs. McNary dams to Bonneville Dam)."

The conclusion suggesting possible increased vulnerability to predation is based in part on studies indicating that the avoidance response of juvenile salmon decreases as a result of stress, particularly multiple acute stresses (e.g., Sigismondi and Weber 1988; Olla and Weber 1989). Indices of predation below Bonneville suggest that predation is high in this area, although differential rates for transported and non-transported fish have not been investigated. ODFW and NBS investigators reported that the predation index below Bonneville Dam is generally the highest observed in the Snake/Columbia system (Ward et al. 1995). This index incorporates abundance estimates of predatory fish species and estimates of their consumption of smolts. Northern squawfish predominate the index. Their results are based on sampling conducted during 1992 below Bonneville Dam, 1991 at Snake River projects, 1990 at lower Columbia River reservoirs (except John Day, which was also indexed 1991-1993), and 1993 for mid-Columbia River reservoirs. Similar results are apparent in more recent sampling (1994-1996) in the lower Columbia River and Snake River (D. Ward, ODFW, pers. comm., April 17, 1996).

The conclusion regarding disease infection is based in part on evaluations of bacterial kidney disease (BKD) and infection caused by descaling in transported smolts. **[Need a summary of Pascho and Elliott work here - no time for inclusion in this draft]**

While the studies reviewed by Mundy et al. (1994) suggest possible mechanisms for delayed mortality following release from barges or trucks, none appears to have been designed to verify that mortality due to disease or predation below Bonneville Dam is higher in transported fish than in other fish passing from Bonneville to the estuary, which would be necessary to determine that delayed effects due to transportation are occurring. Mundy et al.'s (1994) fourth conclusion was:

"(4) Comparisons of physiological data with controls, by necessity, is relative because the collection of "true" control (i.e., resting state) fish in the river is problematic if not impossible. Moreover, comparisons between transported and natural migrant fish (e.g., that have passed through turbines or spillways instead of the bypass system) have not been made."

Impaired Homing Ability

Mundy et al. (1994) reviewed information pertaining to the effects of transportation on homing and straying. They concluded that the risk of aberrant homing behavior could not be completely eliminated unless fish were not transported. However, based on their three criteria for reducing the possibility of aberrant homing as a result of transportation, the existing transportation program minimizes homing problems, because: 1) it collects fish after they have migrated for some distance as opposed to being loaded into conveyances at the hatchery; 2) smolts are released in the river rather than in marine waters; 3) and barges are the predominant form of conveyance, permitting opportunity for olfactory imprinting. Additionally, Petrosky (1995) indicates that LGR to spawning ground adult conversions did not change from the period prior to transportation to the period in which most smolts were transported, suggesting no noticeable effects of transportation on homing ability. Only one of the cited studies, Olney et al. (1992), presented analyses that suggested homing of Snake River chinook might be impaired due to the transportation program. They examined tag recovery data from the 1986 NMFS transport studies that were opportunistically collected at spawning areas during the low flow years of 1987, 1988 and 1989 when adult traps and stream surveys sampled nearly all adults. Based on limited data (56 tags), they found a decrease in the transport/control ratio from 1.6:1 at Lower Granite Dam to 1.1:1 in the tributaries upstream. However, that analysis was based on sample sizes that were insufficient to perform meaningful statistical comparisons. Although not conclusive, this study suggests the possibility of homing impairment in spring chinook.

While the existing transport program may minimize homing impairment, it may not eliminate it. Early Snake River transport evaluation studies were not designed to fully address the homing issue because fish of unknown origin were collected at marking sites, and mark recoveries occurred only at a mainstem dam instead of being sampled at multiple points including spawning areas (Mundy et al. 1994). Improved study designs, such as those implemented in the 1990s, should improve our understanding of homing impairment due to transportation.

Possible Mortality Caused By Modification of Estuary Arrival Timing

[Insert text from Jim Anderson describing Heinrichson et al. analysis of possible timing effects - not available for this draft. Also refer reader to Question 1.6.B, where this issue is also discussed relative to flow augmentation.]

1.1.B.2 Has transportation-related delayed mortality been demonstrated, regardless of the specific mechanism?

While it is important to identify specific transportation-related mechanisms that may cause delayed mortality, it is also necessary to evaluate whether or not transportation-related delayed mortality is occurring, regardless of the specific mechanism. We approach this question from two perspectives, which are related to the passage survival and SAR goals. We note that comparisons with the passage survival goal suffer from difficulty in determining adequate reference, or "control," groups, from which differential post-Bonneville transport mortality can be determined. We also reiterate that the SAR goal embodies mortality that is not related to the hydro system, so we are not able to differentiate possible delayed mortality due to transportation from other sources of mortality, such as disease in stocks prior to arrival at LGR reservoir or estuarine and ocean mortality. The SAR goal is basically a benchmark for direct and delayed transport mortality, given other sources of mortality also occurring during this life history stanza.

Delayed Mortality Inferred From Survival of Transported Smolts And Inriver Migrants From Below Bonneville Dam to the Estuary

If delayed mortality occurs as a result of collection and transportation, mortality following release should be higher than mortality of fish that were not transported. Ideally, these "control" fish should not have passed through the FCRPS, to ensure that they are not also suffering from stress, disease, or injury caused by their passage, which might also result in delayed mortality. To our knowledge, no experiments with true "controls" have been conducted and, based on the fourth conclusion of Mundy et al. (1994), experiments with true "controls" may never be possible. One comparison that is available is survival of fish that were transported to below Bonneville Dam vs. fish that migrated in-river to below Bonneville Dam. If there is no difference in survival between Bonneville and the estuary for each group, then delayed mortality attributable to each group's passage through the FCRPS (if any) is equivalent. If the mortality of transported fish is higher, one may conclude that this differential mortality is a minimum estimate of that fraction of delayed transport mortality that is expressed between Bonneville Dam and the estuary. The true delayed mortality also includes any delayed mortality experienced by the in-river group between Bonneville and the estuary and any additional transport-related mortality expressed after arrival in the estuary.

Investigators tracked radio-tagged yearling chinook released from a transport barge from the release site below Bonneville Dam to a site near the upper end of the estuary in 1994, 1995, and 1996. They were able to detect 56 to 85% of the fish from Bonneville to this site in 1995 **(Need 1994 and 1996 estimates; 1995 from Davis and Schreck [abstract 1995])**. Since not all tagged fish are detectable, and tag regurgitation and failure occur, these provide only a minimum survival estimate through that reach for transported smolts. In 1995 and 1996 there were simultaneous releases below Bonneville Dam of run-of-river yearling chinook that had been caught in the Bonneville collection facility. **Davis and Schreck (abstract 1995)** reported no significant difference in detection to the estuary between the two groups and preliminary results from 1996 indicate the same (Larry Davis, pers. comm. 1996).

The failure to detect differences in survival between Bonneville and the estuary suggests that any delayed mortality expressed in this river section is the same for transported and untransported fish. However, the usefulness of this comparison for evaluating delayed effects is questionable since the sample sizes were small, the in-river group was handled and tagged at Bonneville Dam, the in-river fish probably were not of Snake River origin, and the detections only provide a minimum estimate of survival.

Delayed Mortality of Transported and In-River Fish Inferred From Saltwater Challenge Tests

[Need more information from John Williams to insert here. Three years of saltwater challenge tests and prolonged holding 100+ days indicated greater delayed mortality for transported than in-river fish, but difference was <10%]

Delayed Mortality Inferred From Survival of Transported Fish and In-River Migrants From LMO to LGR: Implications of T/C Ratios

Delayed mortality of transported fish, relative to delayed mortality of in-river migrants, can be inferred from ratios of smolt-to-adult survival from NMFS transport survival studies, estimates of barge survival, and estimates of in-river survival from the point of release (LGO tailrace) to the point at which the two groups again mix (below BON). A simplified approach, which assumes that none of the in-river fish were subsequently collected downstream and transported, is as follows:

$$SAR_{[T]} = S_{[T\text{-}BARGE]} * (1 - M_{[T\text{-}DELAY]}) * S_{[COMMON]}$$

$$SAR_{[I]} = S_{[I\text{-}LGO:BON]} * (1 - MSUB[I - DELAY]) * S_{[COMMON]}$$

$$T/C\ RATIO = \frac{SAR_{[T]}}{SARSUB\ [I]} = \frac{S_{[T\text{-}BARGE]} * (1 - M_{[T\text{-}DELAY]})}{S_{[I\text{-}LGO:BON]} * (1 - M_{[I\text{-}DELAY]})}$$

where $SAR_{[T]}$ is the transport return rate (not actually a SAR; see next section), $SAR_{[I]}$ is the in-river return rate, $S_{[T-BARGE]}$ is the survival from the point of collection until barge release (where transport and in-river groups mix), $S_{[I-LGO:BON\}}$ is the survival of in-river fish from the point of river release (LGO tailrace) until they reach the barge release site below Bonneville Dam, $S_{[COMMON\}}$ is the presumed common mortality attributable to handling and marking and to common mortality from the point of mixing until recovery as adults at LGR Dam, $M_{[T-DELAY\}}$ is any delayed mortality of transported fish attributable to transportation, and $M_{[I-DELAY]}$ is any delayed mortality of in-river fish attributable to

$$M_{[T-DELAY]} = \left[\frac{T/C * S_{[I-LGO:BON]} * (1 - M_{[I-DELAY]})}{S_{[T-BARGE]}} \right] - 1$$

passage through the FCRPS. The third equation can be re-arranged to estimate delayed mortality of transported fish: Because neither the delayed mortality of transported fish or of in-river migrants has been estimated directly, the two

$$\frac{(1 - M_{[T-DELAY]})}{(1 - M_{[I-DELAY]})} = \frac{T/C * S_{[I-LGO:BON]}}{S_{[T-BARGE]}}$$

sources of mortality can only be evaluated in relation to each other at present:

Adult mark recovery data from transport evaluations conducted in 1986 and 1989 (the most recent evaluations available, believed to be closest to current practices) indicate that recovery proportions of transported to inriver migrants (T/C) were 1.6 (95% CI = 1.01-2.47) in 1986, and 2.4 (95% CI = 1.4-4.3) in 1989 (Matthews et al. 1992, Harmon et al. 1993). When these estimates are coupled with: (1) estimates of survival during post-mark holding in raceways and during barge transport (96-98%; see Question 1.1.A) and (2) recent estimates of average per-project in-river survival (88-92%; Table 1.6.A.2), estimates of delayed transport mortality as a proportion of delayed in-river mortality can be derived.

Table 1.1.B.1 indicates that, based on the 1.6 T/C ratio estimate from the 1986 transportation study, transport delayed mortality was higher than delayed mortality of in-river migrants if in-river migrants survived at less than 92% per project. If in-river survival was 92% per project, delayed mortality was equivalent for the two groups. With the 1989 T/C estimate of 2.4, delayed mortality of transported fish was considerably less than delayed mortality of in-river migrants under all assumptions examined. Delayed mortality of each group would still be equivalent if in-river survival was as low as 86% per project (equal to 30% survival for the entire 8-project system).

Based on 1986 and 1989 estimates of differential returns among transported and in-river migrating groups and 1993-1996 estimates of average per-project inriver survival, it appears that transport delayed effects may be higher than in-river delayed effects in some years and lower in others. If the experiments were to be repeated in an identical manner and the resulting T/C ratio was greater than 1.6, delayed transport mortality would be less than or equal to delayed mortality of in-river migrants, given that barge survival is as high as described and 1990s in-river survival estimates apply. If the T/C ratio was 1.6 or less and the other assumptions are correct, then delayed mortality of transported would be greater than or equal to delayed mortality of in-river migrants. This analysis is limited by several factors, the most important of which are lack of knowledge regarding the magnitude of delayed mortality of in-river fish (see Question 1.5.B) and the lack of concurrent estimates of T/C and in-river survival in 1986 and 1989. Additionally, the environmental conditions associated with the two years of T/C estimates (1986 and 1989) were of a limited range; hatchery and naturally-produced fish were not distinguishable in the experimental groups used in 1986 and 1989, and recovery proportions for returning adults observed at the LGR trap were not adjusted for trap efficiency, adding to the imprecision of T/C estimates. Use of 1993-1996 in-river survival estimates as a surrogate for 1986 and 1989 estimates is limited, among other things, by an untested assumption that 2-5 project mean reach survival estimates (derived primarily from Snake River projects) can be raised to the 6th power to estimate system survival from the LGO tailrace to below Bonneville Dam.

Delayed Mortality Inferred From Smolt-to-Adult Returns of Transported Snake River Stocks:

An analysis of the absolute survival of transported fish appears in Appendix 7. The purpose of the analysis was to determine if the transport SARs were similar to Raymond=s SARs for the mid 1960s, a before-and-after approach, and also if they are similar to Warm Springs SARs for the same period, a contemporaneous upstream-downstream approach. The results of this analysis indicate that with both approaches, Transport SARs fall below those of the comparison groups.

The comparison with Raymond=s data used the SARs for 1964 through 1967 because this the period prior to an era of extensive dam building and represents a time when the Snake River stocks were felt to be in a healthy state. During this period the Snake River spring chinook experienced an average SAR of 4.35% while the Transport SARs for 1983 through 1990, a period felt to be representative of the current transport effectiveness, was 1.33%.

Because the Snake River SARs may have changed over time even without extensive hydro development, the Warm Springs comparison was used as a downstream control. Warm Springs SARs averaged 2.53%, again higher than the 1.33% for transported fish. note that the Warm Springs SARs were declining during this period and, therefore, may not be indicative of a stock in a healthy state. The average Warm Springs SARs for the entire time period (1977 - 1990) was 3.07%.

This analysis indicates that the reason for continued declines of Snake River fish. is low survival rather than low collection rates. Transport SARs were well below those of the 1960s in all years of the recent, Amodern@ transport ere and were below those of the Warm Springs in all but one year when the Warm Springs SAR was unusually low. It appears that although transport fish occasionally survive at a rate high enough to lead to rebuilding, their survival is generally to low.

An additional goal of the analysis was to correct for adult upstream mortality (TAC conversion rates) to determine if differences in SARs was due to differences in adult survival. Results indicate transport SARs are still below either of the others which indicates transported fish are experiencing delayed mortality.

Table 1.1.B.1 Estimates of the complement of delayed transport mortality, expressed as a proportion of the complement of delayed mortality of in-river migrants. An estimate of 1.0 indicates that transport and in-river delayed effects are equal; a value >1.0 indicates that in-river delayed mortality is higher than transport delayed mortality; and a value <1.0 indicates that transport delayed mortality is higher. T/C ratios are mean estimates from 1986 and 1989 NMFS transport studies (Matthews et al. 1992, Harmon et al. 1993), survival of transported fish from marking to barge release ($S_{[T\text{-}BARGE]}$) is from Question 1.1.A; and per-project survival of in-river migrants is from 1993-1996 studies summarized in Table 1.6.A.2. In-river survival from release to mixing ($S_{[I\text{-}LGO:BON]}$) applies per-project survival to six projects. Also displayed are estimates of T/C necessary for proportion to equal 1.0 under range of survival assumptions and estimates of in-river survival necessary for proportion to equal 1.0 under a broader range of T/C ratios.

Question 1.2 ***If it is determined in Question 1.1 that transportation does not provide a high rate of juvenile survival*, can transport survival be substantially increased?**

Based the conclusion for Question 1.1.A, this question would not be addressed unless it was determined that substantial post-release mortality does occur. Available information is not sufficient to answer this question due to uncertainties regarding the magnitude and causes of delayed mortality of transported fish (see Question 1.1.B) and the potential of the four identified management actions to reduce delayed mortality. Because direct mortality associated with transportation is already very low, it is highly unlikely that significant reductions in direct mortality are possible.

Question 1.2.A Can increasing the number of barges and improving release mechanisms substantially increase transport survival?

It is unlikely that direct mortality can be reduced substantially since direct survival is already high, near 96%. Opportunity to reduce possible delayed mortality following release is currently being evaluated (at least partially), but the work is not yet completed. Uncertainties about the current level of delayed mortality make the potential for improvement very difficult to evaluate.

The purpose of providing more barges is to minimize or eliminate holding fish in raceways prior to loading. The intent is to reduce any collection-related stress and minimize the opportunity for disease transmission. As reviewed by Mundy et al. (1994), stress (as indicated by cortisol level) occurs as a result of collection and holding, but recovery generally occurs during barge transport if fish are not additionally stressed by some other factor such as high loading densities or mixed loadings of chinook and steelhead smolts.

[Need someone knowledgeable about Schreck/Congleton studies to address potential for survival improvement]

The purpose of improved release mechanisms (enlarged barge exits) is to reduce stress associated with release and post-release mortality.

[Need someone knowledgeable of Schreck barge stress studies (currently in progress) to address potential for survival improvement]

Question 1.2.B Can alternate release strategies substantially increase transport survival?

We did not have sufficient information to evaluate this proposed management action.

Currently, barge release sites are in high-velocity areas of the channel below Bonneville Dam. Exact release sites are varied throughout the season to avoid predator concentration within a single release site.

[Need to discuss the exact intent of this proposal and how it may relate to both barge and truck releases. Need someone knowledgeable of lower river predation studies and alternate release site experiments to address potential for survival improvement]

Question 1.2.C Can collection facility improvements substantially increase transport survival?

Since direct mortality observed at the collection facilities is near 1% there is little room for improvement. Opportunity to reduce possible delayed mortality following release has not been evaluated.

Improvements to the LGR collection facility as specified in the NMFS 1995 BIOP includes modification of the collection channel, elimination of pressure pipe, and redesign of a new wet separator (to separate large steelhead smolts from smaller chinook smolts). The intent is to reduce stress and smolt mortality. No estimates of potential improvement are available. However, the collection system at LGR already appears relatively benign if facility mortality observed at the dam is a useful guide. Annual estimates of direct mortality at LGR averaged less than 1% over the years 1981-1993 (Appendix 1). At Little Goose Dam, over the same years, mortality observed at the fish collection facility was higher at 1.6%. However, following improvements at that site in the late 1980s, mortality dropped considerably, averaging 0.7% for the years 1990-1993. Based on these observations, it appears that there is little opportunity for improving immediate survival of collected fish at these sites under normal operating conditions. Occasionally, deleterious temperature conditions develop at McNary Dam that can result in large fish kills and opportunities for improving immediate survival at this project may be greater than at others. However, previous episodes are rare and have been brief, primarily affecting summer-migrating fall chinook smolts, not spring-migrating spring/summer chinook smolts.

Facility design improvements may reduce potential delayed effects, but we were not able to identify information that would allow us to evaluate this possibility. Most of the general considerations discussed above regarding stress associated with smolt collection and holding may apply to facility improvements.

Question 1.2.D Can installation of surface collectors at one or more Snake River projects substantially increase transport survival?

Surface collectors are unlikely to substantially reduce direct transport mortality and the risk associated with the requisite dewatering structures has the potential to increase current mortality levels. Opportunity to reduce forebay delay and possibly-related direct or delayed transport mortality is possible, but has not been evaluated.

Since research and evaluation of prototype surface collectors has just recently been initiated, few results are available. Surface collectors used in conjunction with transportation might reduce direct mortality associated with collection by avoiding mortality associated with contact with extended bar screens, traveling screens or vertical barrier screens. Since total direct mortality (which includes subsequent passage, dewatering, and wet separation) is generally considered to be $\leq$2% (mortality of smolts that make it into the collection facility is less than 1%; Appendix 1), the magnitude of the potential improvement is small.

Furthermore, surface collectors pose some risk for increasing collection mortality, because dewatering large volumes of water is required. The dewatering screens must be very large, possibly increasing the likelihood of contact and injury. The design engineering of these devices is currently underway.

It has been suggested that surface collectors may reduce forebay residence time and presumably some amount of reservoir-related mortality. NBS radio-tracking studies in 1994 **(citation???)** and 1995 (Rondorf et al. 1995) indicate that spring/summer chinook delay in the forebay at LGR ranged from 2-4 days; whereas, in 1996 delay averaged only 0.8 days (Rondorf et al. 1996). A surface collector may reduce any reservoir mortality experienced by smolts that are destined for collection and transport, if migratory delay observed in the forebay is diminished. This assumes that reduced delay can be associated with reduced predation mortality or some characteristic of improved fish condition that can be related to survival. While there are plausible mechanisms that may relate reduced delay to increased survival, none of these mechanisms have been demonstrated or quantified, and there is no direct evidence indicating that a surface collector will reduce forebay delay.

Question 1.3 *If it is determined in Questions 1.1 or 1.2 that transport survival is or has the potential to be high,* is a high percentage of yearling chinook salmon being collected?

Available information is not sufficient to answer this question, but it is likely that the answer would be "yes" if the system, as configured in 1997, was operated to maximize collection. Collection proportions in the last decade have ranged from approximately 50-66%, under a strategy that included planned and involuntary spill at some collector projects under some conditions. These collections rates do not appear to be sufficient to meet the passage survival goal unless delayed transport mortality is insignificant. However, if the configuration that will be in place in 1997 is operated with a goal of maximizing collection of fish for transportation, then collection efficiency could be as high as 74-87% if no spill occurs. This collection level would clearly meet the low end of the 50-70% passage goal, and would also meet the 70% survival goal if transport survival (including mortality to the collection point and delayed mortality) is $\geq$80%.

Question 1.3.A. What is the percentage of smolts that needs to be collected to meet the passage survival goal?

We have suggested an interim hydro passage survival goal of 50-70% from LGR pool to below Bonneville Dam, with no additional delayed mortality. The proportion of smolts that would have to be transported to meet this goal under various combinations of in-river and transport survival are displayed in Table 1.3.A.1.

Table 1.3.A.1 Proportion of smolts arriving at LGR reservoir that would have to be transported, given a range of transport and in-river survivals (each of which includes any delayed mortality caused by passage

$$P_{[TRANSPORT]} = \frac{S_{[TOTAL]} - SSUB[INRIVER]}{S_{[TRANSPORT]} - S_{[INRIVER]}}$$

through the FCRPS). Proportion transported ($P_{[TRANSPORT\}}$) was estimated as:
where $S_{[TOTAL]}$ is total (transport + in-river) survival (set at 50% and 70%), $S_{[TRANSPORT]}$ is transport survival, and $S_{[INRIVER\}}$ is in-river survival. Transport survival includes survival from the head of LGR pool to the collection point, as well as survival through the collection facility to truck or barge release. **Bold** values indicate proportions that can be achieved with current configuration and operation, as described in Question 1.3.B.

Table 1.3.A.1 indicates that many combinations of transport and in-river survival that will result in achievement of a 50% combined survival goal, but fewer will result in achievement of the 70% goal. To put this table in perspective, we conclude for Question 1.5 that current in-river survival to below BON is no higher than 40-50% (not counting any delayed mortality), we conclude for Question 1.1.A that survival of transported fish from collection to the point of release is approximately 96-98%, survival from LGR reservoir to the collection point is 87-92% per project, for up to three projects (LGR, LGO, and LMO), and we conclude for Question 1.1.B that delayed mortality of transported fish cannot be determined with available information. Given these conditions, we are constrained by current survivals to the lower left quadrant of each section of the table. Therefore, to meet the 50% goal, between 20-100% of smolts must be transported, depending upon the estimates of transport and in-river survival, and 60-100% must be transported to meet the 70% goal.

Question 1.3.B What is the seasonal average percentage of fish that can be collected with the configuration and methods used in recent years?

Based on Table 0.0.1, seasonal average collection between 1985-1996, relative to the population of smolts entering LGR pool, has ranged from 50-66%. The mean multi-year collection rate has been 60-61%. Management during this period included a "spread-the-risk" policy and NMFS 1995 BIOP management that allowed spill at some collector projects during some years. Uncontrolled spill due to flows that exceeded turbine capacity and BPA "lack-of-market" reduction in turbine generation also resulted in reduced collection efficiency at some projects in some years. Given this range of recent collections, Table 1.3.A.1 indicates that the 70% end of the passage survival goal can only be met if there is no delayed transport mortality (transport survival ≥90%) and in-river survival is >30%. The 50% end of the passage survival goal can be met under a wider range of plausible transport and in-river survivals.

Question 1.3.C What is the maximum seasonal average percentage that could be collected with facilities that will be in place by 1997?

Once the extended screens planned through 1997 are installed at Lower Granite, Little Goose, and McNary Dams, transport from the Snake River has the potential to be high, with approximately 74-87% of the fish arriving at the head of Lower Granite pool collected if no spill occurs at collector projects. This percentage is considerably higher than recent collection levels (50-66%) and can be compared to a theoretical maximum. If every fish arriving at Lower Granite Dam were collected, a maximum of approximately 88-93% of the fish arriving at the head of Lower Granite pool would be transported. Therefore, the potential to increase collection above the level possible in 1997 is at best 6-14%.

With the system configuration scheduled to be in place in 1997, (extended-length screens installed at LGR and LGO and standard screens at LGO and LMO), fish guidance efficiency (FGE) will be high enough to collect approximately 74-87% of smolts arriving at the head of LGR pool under a management strategy that maximizes collection for transportation (i.e., no spill). This estimate is calculated using a range of estimates of FGE, turbine survival, and reservoir survival applied from the head of Lower Granite pool through Lower Monumental Dam, as well as an estimated bypass survival of 0.98 (Section 1.1.A). Appendix 2 describes details of calculations. Table 1.3.C.1 summarizes the results for a population arriving at the head of Lower Granite Pool.

Table 1.3.C.1. Of a population of yearling chinook salmon arriving at the head of Lower Granite Pool, and passing Lower Monumental Dam, the estimated percentage of smolts transported, dying en route, and alive in Lower Monumental tailrace, based on high and low estimates of FGE in the system by 1997, with extended length screens at LGR and LGO. Ranges of turbine and reservoir survival are also considered. Details are included in Appendix 2.

	To Estimate % fish collected and transported:

Parameters	Low Range	High Range
FGE @:		
LGR	0.60	0.74
LGO	0.60	0.74
LOMO	0.45	0.55
Turbine Survival	0.89	0.93
Reservoir Survival	0.90	0.95
Results		
Fish collected (%)	74%	87%
Fish die en route (%)	21.5%	11%
Fish alive below LOMO (%)	4.5%	2%

With respect to the entire ESU, this illustration does not apply to the Tucannon River population of smolts entering the system downstream from LGO Dam. Inclusion of these fish would reduce the proportion of the total ESU transported. Involuntary spill at collector dams due to hydraulic capacity or market limitations also would reduce the proportion transported. Uncertainty regarding the range of reservoir and turbine survival estimates as well as FGE estimates are described in Sections 1.6.A and 1.6.B.

The maximum potential collection, assuming every fish arriving at Lower Granite Dam entered a collection facility, is the product of Lower Granite reservoir survival and survival through the collection facility. Using the passage parameter estimates described above, the maximum potential collection is 88-93% (Appendix 2). Thus, the maximum potential increase from the 1997 capability of 74-87% transported is approximately 6-14%.

Question 1.3.D. Seasonal Average Collection Proportion vs. Collection of All Segments of the Run

Conclusions based upon seasonal average proportions of the smolt outmigration that are transported may need to be tempered by considerations of differential collection for different components of the run. Timing of operation of collection facilities probably has little effect on spring/summer chinook smolts. A small percentage of the run begins migrating before collection begins (approximately April 1), but the tail of the run is probably collected since the transportation program continues until fall for other species. Changes in collection efficiency during the course of the run may have a more pronounced effect on the proportion of early, middle, and late-migrating spring/summer chinook stocks actually transported. Giorgi et al. (1988) noted that intraseasonal changes in FGE have been observed at LGR Dam. They identified an association with the physiological disposition of the smolt population and hypothesized that smolts further along in the smoltification process may be more susceptible to guidance by screens. However, the general population of yearling chinook upstream from LGR is dominated by hatchery fish, which are not typically well smolted immediately upon arrival at LGR, and likely account for the observed trend in increasing FGE as the season progresses.

Question 1.4 ***If it is determined in Question 1.3 that a high percentage of yearling chinook are not being collected with the facilities as planned through 1997*, can collection rate be increased substantially with additional modifications**?

There is insufficient information to answer this question, but there was general agreement among work group members that opportunities for increasing the proportion of transported spring/summer chinook are limited and/or highly uncertain. Additional extended-length screens at Lower Monumental Dam would have an insignificant effect. A surface collector at Lower Granite Dam could have a significant effect (6-14% higher collection) if it performed as well as the Wells Dam surface bypass system. However, given the difference in the configuration of Lower Granite Dam compared to Wells, similar performance will be difficult to achieve. Results of current and future prototype tests are required to draw a final conclusion.

Question 1.4.A Can extended-length screens at Lower Monumental Dam substantially increase the proportion of transported Snake River salmon?

Addition of extended-length screens at Lower Monumental Dam would have little effect on the proportion of Snake River spring/summer chinook collected, above that achievable with the same in place at LGR and LGO dams.

Addition of extended-length screens at Lower Monumental Dam would have little effect on the proportion of Snake River spring/summer chinook collected, under the range of assumptions and methods described in Section 1.3.C and Appendix 2. With extended screens at Lower Granite and Little Goose Dams (1977 condition), approximately 74-87% of the smolts arriving at the head of Lower Granite pool would be collected under an operation maximizing transport. With the addition of extended screens at Lower Monumental Dam, this increases by only 1% to 75-88% (Appendix 2).

Question 1.4.B Can surface collectors substantially increase the proportion of transported Snake River salmon?

With extended screens in place at both LGR and LGO dams, the additional installation of a surface collector at LGR has the potential to increase the total number of smolts transported from the Snake by about 6-13%, if it is as effective as the surface bypass system at Wells Dam. If a surface collector at Lower Granite Dam is less efficient than the Wells collector, the increase in the proportion transported will be minimal. There is insufficient information at this time to determine potential efficiency of a surface collector at Lower Granite Dam; however, it appears unlikely that it will be as efficient as the Wells surface bypass due to differences in dam configuration.

Potential Efficiency of a Surface Collector, Based on Wells Experience:

Thus far, the Wells Dam surface bypass system is the only permanent one in place and it sets the standard for performance, collecting an average of 89% of the smolts arriving at the dam over a three-year period (Skalski 1993). Johnson (1995) detailed the annual passage estimates at that site:

Wells Surface Bypass ATotal Project Bypass Efficiency[*]@

Year	Average	Range
1990	84.3+/-8.0	53-99
1991	95.0+/-0.4	73-99
1992	89.0+/-0.5	69-96

ATotal project bypass efficiency@ is the percentage of the total smolt passage at the dam that passes through the bypass, as determined with hydroacoustic sampling.

Potential, Based on a Range of Collector Performance at LGR Dam

Table 1.4.B examines the percentage of fish collected between Lower Granite and Lower Monumental Dams under a range of assumptions regarding dam and reservoir passage survival (Section 1.3.C and Appendix 2) and three configurations of the upper three projects. The percentage of fish collected is expressed relative to the number of fish first entering Lower Granite pool, for consistency with definition of the hydro passage survival goal. This analysis suggests that a surface collector at Lower Granite Dam that achieves the efficiency of the Wells Dam surface bypass system (i.e., collects 80-90% of the fish arriving at Lower Granite Dam) would result in a total collection rate of about 85-93%. This is a 6-13% increase from the expected collection rate with extended screens at Lower Granite and Little Goose Dams (1997 condition), which appears to be a substantial increase. On the other hand, if only 20-40% of fish arriving at Lower Granite Dam enter the surface collector, the increase in total collection is minimal (2-6%).

Table 1.4.B Change in total collection rate that is likely over a range of surface collector performance, based on assumptions and methods described in Appendix 2. The 1985-1996 condition is based on CRiSP and FLUSH estimates from Table 0.0.1 and includes spill at some projects in some years. All other conditions are standardized to an assumption of no spill at collector projects. The 1997 condition includes extended screens (ESBS) at Lower Granite Dam (LGR) and Little Goose Dam and standard screens at Lower Monumental Dam (LMO). This base condition is compared with (1) installation of ESBS at LMO and (2) the 1997 condition, coupled with a surface bypass/collector (SBC) at LGR. Various SBC efficiencies are evaluated. Change in percent of smolts collected, relative to 1997 condition, is indicated in parentheses. Collection is expressed as a percent of the smolts first entering LGR pool.

	Percent of Smolts Collected In Surface Collector at LGR	**Percent of Smolts Arriving at LGR Pool That Are Transported**
1985-1996 Estimated	n/a	50-66%
1997 Max. Transport	n/a	74-87%
Add ESBS at LMO	n/a	75-88%(+1%)
With SBC at LGR	20%	77-89%(+2-3%)
With SBC at LGR	40%	80-90%(+3-6%)
With SBC at LGR	60%	83-91%(+4-9%)
With SBC at LGR	80%	85-92%(+5-11%)
With SBC at LGR	90%	87-93%(+6-13%)
With SBC at LGR	100%	88-93%(+6-14%)

With respect to the entire ESU, this illustration does not apply to the Tucannon River population of smolts entering the system downstream from LGO Dam. Inclusion of these fish would reduce the proportion of the total ESU transported. Involuntary spill at collector dams due to hydraulic capacity or market limitations also would reduce the proportion transported. Uncertainty regarding the range of reservoir and turbine survival estimates as well as FGE estimates are described in Sections 1.6.A and 1.6.B.

It may be unreasonable to expect that a new surface collector at Lower Granite, or any other Snake River project, will perform as well as the Wells system. The design of Wells Dam differs from that of Snake River dams, and this may limit performance of Snake River surface collectors. Wells is a Ahydrocombine@ project, where the spillways (and surface bypass) are located directly above the powerhouse. The entire river flow is concentrated into a 300-m wide section of river and the surface bypass structure spans that entire width. Johnson (1995) concluded that this arrangement is important for both vertical and horizontal concentration of fish in the vicinity of the bypass. In contrast, at Snake River projects, spillways and powerhouses are separated horizontally across the river. Fish at these projects may need to be attracted horizontally to the area of the surface collector, which isn=t required at Wells.

Conclusions regarding the likelihood of increasing the proportion of transported smolts by installing a surface collector at Lower Granite Dam or other Snake River dams cannot be reached with available information. Performance of a prototype surface bypass/collector was evaluated at Lower Granite Dam in 1996, but results are not yet available. Continued prototype tests are planned in 1997 and 1998.

Question 1.5 ***If it is determined in Question 1.1 or 1.2 that transportation cannot provide a high rate of juvenile survival,* do present passage measures provide a high rate of juvenile survival across a broad range of life histories without subsequent adverse effects? [This refers to conventional, non-structural measures to improve survival outside of transportation. Implicit in this question is the need to provide benefits across a range of fluctuating environmental conditions.]**

No, at best the current survival of inriver migrants may be 40-50%, which does not meet the interim passage survival goal. Available information is not sufficient to determine if additional delayed effects occur, but such effects would only reinforce the conclusion based upon survival to below Bonneville Dam.

Question 1.5.A Do reach survival studies indicate in-river survival is Ahigh enough?@

No, reach survival studies indicate that, at best, in-river survival is 40-50%. In some years it is likely much lower.

Recall, that this node in the decision tree was reached only by concluding that the survival of transported fish is not Ahigh enough.@ Ratios of transported to in-river migrating fish generally show that survival of transported fish is equal to or greater than survival of in-river migrants. Therefore, if transported fish survival is not Ahigh enough,@ in-river survival cannot be Ahigh enough.@

Recent passage survival studies using PIT-tag mark-recapture procedures have been conducted between 1993-1996 (Iwamoto et al. 1994; Muir et al. 1995,1996; Schiewe 1996). A summary of results is presented in Table 1.6.A.2. Reaches included in the studies were two to five projects, expanding each year between LGR and JDA. The studies primarily used hatchery fish, but comparisons in 1995 indicated similar survival of wild fish.

Average per-project survival estimated by these studies has ranged from 87-92%, depending upon year. If these mean per-project estimates are expanded, without weighting, to eight projects, corresponding system survivals range from range from 33-51%. Alternative estimation procedures, which weight survivals by fish travel time through each reservoir are presented in Appendix 3. These provide similar estimates. If cumulative effects of passage express themselves in the lower Columbia River, system estimates could be lower. The estimate of survival between McNary and John Day Dams in 1996 (91%, SE=14%), does not support an assumption of higher mortality in the lower Columbia projects due to cumulative passage effects, but this cannot be ruled out at present.

[Placeholder for <u>new</u> HARZA cumulative effects analysis]

In-river conditions in 1995 and 1996 were designed to provide the best possible conditions for in-river migrants while still maintaining a transportation program, according to the NMFS 1995 BIOP. Flow conditions in both years were above average. Therefore, it is reasonable to assume that survival rates estimated in 1995 and 1996 were among the highest obtainable with current system configuration and operational priorities. Clearly, maximum survival of 40-50% does not achieve the passage survival goal. Based on 1993 and 1994 estimates of 33-36% system survival, it is likely that in-river survival has been substantially below the passage survival goal during many recent years.

There are several limitations associated with the estimates of in-river survival described above. Foremost is the assumption that reach estimates encompassing a few projects can be applied to the entire eight-project system. Additional estimates for lower Columbia River projects will be required to determine the validity of this approach. Second, most of these estimates are for hatchery chinook - it is possible that, in spite of the similarity between hatchery and wild estimates in 1995, differences generally may be significant. Third, some statistical concerns regarding variance of reach survival estimates (not the estimates themselves) have been raised by the University of Idaho. However, a peer review commissioned by the Northwest Power Planning Council found the reach survival studies to be applying reasonable statistical techniques. Other reach survival estimates, such as those displayed in Table 1.6.A.1 may also be considered. However, these estimates are generally lower than those derived from recent studies, which would only reinforce our conclusion that current survival is too low.

Question 1.5.B Do subsequent adverse effects following passage below Bonneville occur and, if so, are they of sufficient magnitude to change conclusions regarding survival of fish migrating in-river in 1.5.A?

Because the work group was in general agreement that current in-river survival is too low to meet the interim passage survival goal, any delayed mortality would only re-enforce that conclusion. However, there is currently insufficient information to determine if, and to what extent, delayed mortality occurs. Because most in-river migrants are exposed to the same bypass systems that transported fish are exposed to, as well as turbine passage, most of the mechanisms proposed for delayed mortality of transported fish would also apply to in-river migrants under current system configuration and operation. Nearly all of the lines of transport delayed mortality evidence discussed in Question 1.1.B also apply to the question of in-river migrants. If future operations can provide significantly higher in-river survival, resolution of this issue will become more important.

[Placeholder for new Harza cumulative effects analysis - cumulative effects become delayed effects once fish pass Bonneville Dam]

Question 1.6 ***If it is determined in 1.5 that present passage measures do not provide a high rate of juvenile survival*****, can a high rate of juvenile survival be provided in-river without major modifications to structures?**

Strategies that may improve in-river survival generally fall into two categories: those that improve survival past dams and those that improve survival through reservoirs (although some potential measures may improve both). These are addressed by Questions 1.6.A and 1.6.B.

Current mean project (reservoir + dam) survival ranges from 87-92%, based on 1993-1996 PIT-tag survival studies. This results in 8-project system survival of approximately 33-51%. Some preliminary studies suggest that additional delayed effects may occur, but these studies have not yet been completed. To meet the interim passage survival goal of 50-70%, mean project survival must be 92-96%, with no delayed mortality. This means that mean project survival meets the lower end of this range under the best conditions observed in recent years. However, achievement of the full passage survival goal would require an average increase of approximately 4-5%.

Available information is not sufficient to answer this question with certainty, but it appears that available measures are unlikely to achieve this survival improvement. Opportunities for increased project survival lie almost entirely with dam passage improvements that are scheduled for installation in the near future or are currently being designed. Evaluations of these devices (increased spill through gas abatement measures, surface bypass structures, improved turbine designs, and extended-length screens) in 1997 and 1998 will determine potential changes in project survival. We suspect that, optimistically, these devices may increase average dam passage survival by up to 2%, which would not achieve the full range associated with the interim passage survival goal. We stress, however, that this is merely an informed guess and ongoing evaluations may demonstrate a greater potential improvement. We see no opportunity to appreciably increase reservoir survival levels above current levels with any combination of additional measures that are within the Corps of Engineers' current authority (i.e., measures other than drawdowns).

1.6.A Can a high rate of in-river survival be provided by increasing dam passage survival?

The primary opportunities for increased dam passage survival are: (1) increased spill (and resulting decrease in percentage of fish through turbines) from gas abatement measures, such as the planned installation of spill deflectors at IHR and JDA; (2) surface bypass structures, of which a prototype powerhouse structure is being tested at LGR and a prototype spillway skimming device is being tested at TDA; (3) improved turbine designs (e.g., reducing gap of turbine blade runners and designing to operate a greater percentage of time at maximum efficiency), a prototype of which will be installed at BON in 1998; and (4) extended-length screens, which will be installed at LGR, LGO, and MCN by 1997 and could also be installed at other projects. The only one of these improvements that has been quantified is installation of extended-length screens, which appears to improve fish guidance efficiency (FGE) approximately 10% above that obtained from standard screens. Based on informed guesses regarding the possible survival improvements associated with these *measures, we suspect that they may have the potential to increase average dam passage survival about 2%. This would change the current mean project survival of 87-92% to 89-94%, which would not achieve the full range associated with the interim passage survival goal (92-96%) unless reservoir survival improvements also occurred.*

We approach this question by first looking at reach (dam + reservoir) survival estimates, which generally were not conducted in a manner that allows partitioning of dam and reservoir mortality. The maximum possible dam mortality would be equal to the full project mortality if there were no reservoir mortality. We attempt to partition this mortality by examining various estimates of survival and routing through the three dam passage routes: turbines, bypasses, and spillways. We describe uncertainties associated with these estimates, which result in a broad range of estimates of the proportion of reach mortality attributable to dam passage. Finally, we examine proposed methods of attempting to improve dam passage survival to evaluate the likelihood that they can significantly improve survival.

Reach Survival Estimates: A Bound to Maximum Potential Dam Passage Improvement

Project survival estimates from two series of reach survival studies set the bounds for maximum dam passage mortality. Reach survival estimates between 1973-1983 (Sims et al. 1983, 1984) that encompassed 5-6 projects are summarized in Table 1.6.A.1 and reach survival estimates between 1993-1996 that encompassed 2-5 projects are summarized in Table 1.6.A.2. Average per-project survivals are expanded to estimate the 8-project system survival by raising project survival to the eighth power. This system survival estimate makes the simplifying assumption that per-project survival is equivalent in each reservoir, an unrealistic assumption that is provided only to give an idea of the approximate system survival implied by the reach survival results. A more complex method of expanding reach survival estimates, which apportions project survival in relation to fish travel time and an index of predator density, is presented in Appendix 3.

Table 1.6.A.1 A compilation of flow indices and survival estimates (per project) for yearling chinook salmon migrating from the uppermost dam on the Snake River (Lower Granite or Little Goose) to either The Dalles or John Day Dam, 1973-1983. Estimates were taken from tables presented in Sims et al. (1983, 1984). Last column is theoretical system survival estimate, based on an assumption of equal survival through all projects, for comparison with 1993-1996 reach survival estimates in Table 1.6.A.2.

Year	Flow Index (kcfs)	Average Per-Project Survival Estimate	Average System Survival (Per-Project Survival^8)
1973	71	0.55	0.01
1974	158	0.82	0.20
1975	140	0.79	0.15
1976	110	0.79	0.15
1977	40	0.52	0.01
1978	106	0.85	0.27
1979	85	0.79	0.15
1980	110	0.82	0.20
1981	94	na	na
1982	120	0.76	0.11
1983	109	0.91	0.47

Table 1.6.A.2. Reach survival estimates based on releases of PIT-tagged hatchery yearling chinook salmon into Lower Granite reservoir, unless otherwise noted. From Muir et al. (1996) and Schiewe (1996). Last column is theoretical system survival, based on assumption that survival is equal through all eight projects.

	LGR Pool Release to LGR[1]	**LGR Dam to LGO**	**LGO to LMO**	**LMO to MCN (Includes IHR)**	**MCN to JDA**	**Average Per-Project Survival**	**Average System Survival (Per-Project Survival^8)**
1993 (Hatchery)	0.902 (0.008)	0.862 (0.013)	----------	----------	-------	0.88	0.36
1994 (Hatchery)	0.922 (0.010)	0.794 (0.026)	0.891 (0.023)	----------	-------	0.87	0.33
1995 (Hatchery)	0.927 (0.007)	0.900 (0.015)	0.939 (0.016)	----------	-------	0.92	0.51
1995 (Hatchery)[2]	----------	0.883 (0.006)	0.928 (0.007)	0.852 (0.050)	-------	0.91	0.47
1995 (Wild)[3]	----------	0.877 (0.012)	0.896 (0.017)	0.831 (0.038)	-------	0.91	0.47
1996 (Mixed)[4]	----------	0.914 (0.005)	0.918 (0.011)	0.735 (0.028)	0.907 (0.137)	0.89	0.39
Average	0.92	0.87	0.91	0.81	0.91	0.90	0.42

[1] Lower Granite pool release sites: Nisqually John Landing (1993), Silcott Island (1994), and the Port of Wilma (1995).
[2] Hatchery yearling chinook released into tailrace of Lower Granite Dam for comparison with transported smolts.
[3] Wild yearling chinook released into tailrace of Lower Granite Dam for comparison with transported smolts.
[4] Combined wild and hatchery chinook released into the tailrace of Lower Granite Dam. Preliminary information, based on incomplete recoveries.

Each of the reach survival data sets has limitations associated with it. The 1975-1983 estimates have been extensively critiqued by various authors, including Matthews and Williams (1985). The primary concerns are the mark/recapture and statistical techniques (or lack thereof) available at the time of the studies and the contention that various operational effects influenced survival in ways that are not applicable to the current system. The primary critique of the recent studies are the relatively few projects encompassed by the estimates and the relatively narrow range of environmental conditions represented (e.g., Chapter 6 Appendix 5, Section 6.0). The statistical techniques used to estimate variance of survival estimates has also been criticized (but not the estimates themselves); however, a peer review commissioned by the Northwest Power Planning Council found the methods to be reasonable.

We note that, given procedures for attempting to partition dam and reservoir effects embodied in the reach estimates, the most of the resulting reservoir survival estimates are not markedly different between the two data sets (Appendix 3; pers. comm. J. Anderson, Univ. of Washington, September 1996).

In the remainder of this section, we primarily use the range of more recent estimates for evaluating effects of proposed actions, rather than the older estimates. We do this because: (1) the newer estimates are generally higher, so if analyses based on these estimates fail to show that proposed management actions will meet the survival goal, then the older data set would also do so; (2) many, but not all, of the Work Group members find convincing Williams and Matthews (1995) contention that dam operations in the earlier studies are not relevant to current operations; and (3) many, but not all, of the Work Group members believe that the PIT-tag technique is a much more informative and statistically valid estimation method than mark/recapture of brand groups.

Dam Passage Estimates Necessary To Partition Reach Survival Into Dam and Reservoir Survival

Concurrent estimates of reach survival and routing and survival through all dam passage routes has not occurred to date. Estimates of dam and reservoir mortality are dependent upon using available estimates of dam passage mortality and routing (derived at various locations and times) to infer that which occurred during the reach survival studies. There is considerable uncertainty regarding dam passage survival and routing for some projects. A detailed review of currently available information is included in Appendix 6 **[not available for this draft]**. A summary of the various issues follows.

Determination of dam passage survival involves estimation of at least three passage survivals (survival through turbines, spillway, and bypass) and two routing measures (spill efficiency [proportion of fish over spillway relative to proportion of flow] and fish guidance efficiency [proportion of fish approaching turbine intake that are guided into the bypass]). A summary of some of the uncertainties regarding these measures follows.

Turbine Survival

Work group members generally agreed that recent studies, which estimate turbine survival at the higher end of the range ($\geq$90%), are probably more reliable and representative than estimates derived from previous studies.

Major uncertainties surrounding turbine survival are as follows.

PIT-tag Derived Estimates at LGR Among Years: Recent estimates of turbine mortality range from at least 18% to as low as 7%. Turbine survival estimate in 1993 was 0.82 (Iwamoto et al. 1994); no estimate was derived in 1994, although J. Williams (NMFS, pers. comm.) indicates it was approximately 0.50; survival estimate in 1995 was 0.93 (Muir et al. 1996).

> Resolution: According to J. Williams (NMFS), the 1995 estimate is much more reliable than the 1993 and 1994 estimates because the release methodology was improved. In 1993 and 1994 there appeared to be an insufficient volume of water used to flush fish through the draft tube effectively **C** fish may have been hung up in the tube without water for varying lengths of time before eventually dropping down and being released into the turbine. This was more of a problem in 1994 than 1993 because the same volume of flushing water was used but the tube diameter increased from 3@ to 4@. A new tank system that supplied water continuously during release was used in 1995.
>
> Another possibility: releases were made into turbine unit 6B during 1993 and 1994 studies. 1995 releases were into turbine unit 4B. Differences between turbine units may account for the discrepancy.

PIT-tag Derived Estimates Between Dams During Same Year: In 1993, estimates of turbine mortality ranged from 8-18%, depending upon the project. Turbine survival at LGR was 0.82 and survival estimate at LGO was 0.92. Identical release methods were used at each site, the same turbine unit was used at each site, and the same turbine load was applied [135 MW - within 1% of peak efficiency] (Iwamoto et al. 1994).

> Resolution: No explanation available. As discussed, the release method used at LGR in 1993 is unreliable, but the same release method was used at LGO, so those results are also unreliable.

PIT-tag vs Balloon Tag Estimates: Recent balloon-tag estimates of direct turbine mortality at Lower Granite Dam ranged from 3-6% in 1995, depending upon release location and turbine load (Normandeau Associates et al. 1995 [2-page summary at AFEP Program Review]). These results were similar to 1994 balloon-tag estimates at LGR. These results were nearly identical to 1995 PIT-tag releases at LGR (which were released at the same location and with the same method), but indicated much higher survival than 1993 PIT-tag estimates.

> Resolution: 1993 release method was flawed, as described above. Results are consistent with 1995 PIT-tag estimates.

Older Studies: Nine relevant Columbia River turbine survival studies prior to 1993 are reviewed in Iwamoto and Williams (1993). Turbine survival estimates range from 80-98%, and average 90% for the nine studies. Most of the estimates were based on conditions which no longer exist because fish guidance devices were not installed, turbine units were operated solely for power (i.e., out of peak efficiency), composition of the migrant fish population was different, and predation was not isolated as a source of mortality.

> Resolution: Authors suggest that most recent studies are most reliable for these reasons and because of improvements in estimation methodology.

Spillway Survival

There is no great controversy regarding estimates of spillway survival, which are reviewed in Appendix 5. Survival is generally considered 98% or greater and a value of 98% is generally included in model analyses.

Bypass Survival

Direct measures of bypass survival are lacking, but survival of fish entering collection systems is reviewed in Appendix 1 and other relevant information is included in Appendix 5. There is no great controversy regarding estimates of direct bypass survival, which is generally considered to be 98%.

Spill Efficiency

There is a general lack of information regarding the percentage of fish passing the spillway relative to the percentage of water discharged as spill. That proportion is generally assumed to be 1:1, but some studies have indicated that it may be 2:1 or higher under some conditions (e.g. Wilson et al. 1991). Appendix 3 summarizes existing studies and concludes that the precision of spill efficiency estimates was generally poor or undefined, limiting the reliability of the point estimates. The common default estimate of 1.0 has not been properly verified.

Work group members generally agreed that there is insufficient evidence to determine spill efficiency under current conditions. A range of values should be assumed (1-2), rather than relying on the unvalidated assumption that spill efficiency is 1.0.

Fish Guidance Efficiency

Most estimates of FGE at Snake and Columbia River projects were derived from studies using fyke net recoveries of marked fish. Since 1993, estimates have also been derived from PIT-tag interrogations at Snake River projects. Estimates from PIT-tag detections are significantly lower than estimates from fyke-net studies: e.g. for standard screens at LGR, the fyke-net estimate in 1989 was 57% (Swan et al. 1990) while pooled PIT-tag FGE estimate in 1993 was 0.495, pooled PIT-tag detection probability (lower than FGE due to point of estimation and spill) in 1994 was 0.49, and 1995 (variable spill conditions) PIT-tag detection probabilities were 0.31-0.52 (Iwamoto et al. 1994; Muir et al. 1995, 1996).

Work group members generally agreed that uncertainty regarding FGE at most projects requires use of a range of estimates. FGE estimates from PIT-tag studies appear to be more reliable than estimates from fyke-net studies; however, these estimates are very limited. PIT-tag detection rates should not be used as FGE estimates without adjustment. For projects with only fyke-net estimates, the range of likely values should include a scaler to reduce estimates based on expectation that PIT-tag estimates would be lower.

Major uncertainties surrounding FGE estimates are as follows.

Time Period Investigated: Fyke-net studies were generally conducted in early evening for a few days during a given season. PIT-tag studies include 24-hour interrogations over longer time periods. J. Williams (NMFS, pers. comm. cited in Anderson et al. 1996 [CRiSP Documentation]) states that fyke-net estimates may be biased because of the time period chosen. Fyke net studies characterize fish milling in front of dams in early evening. These surface oriented fish are likely to enter the turbine intake higher in the water column, and subsequently have better guidance, than fish passing at other times of day. [Note: this hypothesis has not been tested]. Additionally, the longer time period of the PIT-tag detections should provide a better representation of average FGE.

> Resolution: the longer time period suggests that estimates based on PIT-tag detections are more representative of the general population.

Position of Collection/Detection Device: Fyke nets were placed in one of two positions during previous studies. For most studies of standard-length screen FGE, the fyke nets were placed under the STSs. This may have affected flows near the tip of the screen, which may have affected guidance (J. Williams, NMFS, pers. comm.). For studies of extended-length screens, fyke nets were placed in downstream slots of gatewells. This position, coupled with the greater screen length, suggests that the fyke nets were less likely to affect flows at the tip of the screens during ESBS tests. Support for this hypothesis comes from tests of STSs using fyke nets placed in the downstream slot at McNary Dam in 1992 and at The Dalles Dam in 1993. In these studies, the fyke-net estimates of FGE were significantly lower than previous estimates of FGE at those projects, which had been derived from fyke nets placed below the screens.

> Resolution: Estimates of STS FGE based on fyke-net studies with nets placed below screens appear to over-estimate FGE, possibly due to effect of the nets on hydraulics at the tip of the screens. Fyke-net derived estimates of ESBS FGE are probably more accurate since positioning the nets in the downstream slot is less likely to affect screen hydraulics.

Remaining Problem - ESBS: While fyke-net estimates of ESBS FGE may not have been biased due to hydraulic effects, they still may have been biased by the timing considerations described above. Currently, PIT-tag estimates of ESBS FGE are not available.

Effects of Dam Passage Uncertainties on Estimates of Dam Passage Survival

Tables 1.6.A.3 and 1.6.A.4 illustrate the sensitivity of dam passage survival estimates to the ranges of uncertainty described above. Table 1.6.A.5 illustrates some of the site-specific differences in survival parameters, based on configurations at various Snake and Columbia River mainstem projects.

Table 1.6.A.3. Estimated FPE at a dam at different levels of FGE, spill proportion, and spill efficiency.

	Spill = 0 Spill Efficiency		Spill = 0.2 Spill Efficiency		Spill = 0.4 Spill Efficiency		Spill = 0.6 Spill Efficiency	
FGE	1.0	1.5	1.0	1.5	1.0	1.5	1.0	1.5
0.40	0.40	0.40	0.52	0.58	0.64	0.76	0.76	0.94
0.45	0.45	0.45	0.56	0.62	0.67	0.78	0.78	0.95
0.50	0.50	0.50	0.60	0.65	0.70	0.80	0.80	0.95
0.55	0.55	0.55	0.64	0.69	0.73	0.82	0.82	0.96
0.60	0.60	0.60	0.68	0.72	0.76	0.84	0.84	0.96
0.65	0.65	0.65	0.72	0.76	0.79	0.86	0.86	0.97
0.70	0.70	0.70	0.76	0.79	0.82	0.88	0.88	0.97
0.75	0.75	0.75	0.80	0.83	0.85	0.90	0.90	0.98

Table 1.6.A.4. Estimated total survival at a dam as influenced by different levels of FPE and turbine survival.

	Turbine Survival		
FPE	**0.85**	**0.89**	**0.93**
0.40	0.90	0.93	0.95
0.45	0.91	0.93	0.95
0.50	0.92	0.94	0.96
0.55	0.92	0.94	0.96
0.60	0.93	0.94	0.96
0.65	0.93	0.95	0.96
0.70	0.94	0.95	0.97
0.75	0.95	0.96	0.97
0.80	0.95	0.96	0.97
0.85	0.96	0.97	0.97
0.90	0.97	0.97	0.98
0.95	0.97	0.98	0.98

Table 1.6.A.5. Characteristics of lower Snake River and lower Columbia River dams relevant to spring/summer chinook salmon passage survival.

Project	Turbine Units	Hydraulic Capacity (kcfs)	Flip Lips?	Spill Cap @ 120% TDG (kcfs)[1]	Percent Spill to Meet 80% FPE[2]	Screens[3]	Transport Capability?	Spring Chinook FGE[4]
Lower Granite	6	130	YES	40	0.80	ESBS	YES	60-74
Little Goose	6	130	YES	35	0.80	STS (ESBS in 1997)	YES	45-55
Lower Monumental	6	130	YES	50	0.81	STS	YES	45-55
Ice Harbor	6	106	NO (6 by 1997; remainder by 1998)	25	0.27	STS	NO	55-64
McNary	14	232	YES	120	0.50	STS+ESBS (All ESBS in 1997)	YES	73-77
John Day	16	362	NO (5 by 1997; remainder by 1998)	50	0.33	STS + test ESBS	NO	--------
The Dalles	22	(344)	YES	230	0.64	STS	NO	--------
Bonneville	18	(255)	YES	120	N/A	STS	NO	--------

[1] Spill cap from 1996 Water Management Plan (COE 1996).
[2] Spill percentage necessary to achieve 80% fish passage efficiency from NMFS 1995 biological opinion (NMFS 1995). Note that these estimates may be outdated for some projects. Spill periods are 24 hours at Ice Harbor, The Dalles, and Bonneville Dams and 12 hours at all others. N/A at Bonneville indicates that 80% FPE is not attainable given a daytime spill cap of 75 kcfs to prevent adult fallback and current project FGE.
[3] STS = Submerged traveling screen; ESBS = extended-length submerged bar screen
[4] Lower Snake River fish guidance efficiency (FGE) estimates from Ceballos (1996)

Estimates of Reservoir Mortality, Given Dam Survival and Reach Survival Estimates

When the range of dam passage estimates considered in Tables 1.6.A.3 and 1.6.A.4 are combined with the range of project survivals from Tables 1.6.A.1 and 1.6.A.2, a range of reservoir survival estimates follows (Table 1.6.A.6). Based on the full range of values considered so far in this chapter, per-project reservoir survival could range from 51-100%. Based solely on 1993-1996 reach survival estimates, per-project reservoir survival could range from approximately 87-100%. Implications of these estimates are discussed in other sections of this report.

Table 1.6.A.6. Estimated reservoir survival at different levels of dam survival and total survival per project. N/A = values that would have to exceed 100%.

Total Survival Per Project	Dam Survival								
	0.90	**0.91**	**0.92**	**0.93**	**0.94**	**0.95**	**0.96**	**0.97**	**0.98**
0.50	0.56	0.55	0.54	0.54	0.53	0.53	0.52	0.52	0.51
0.55	0.61	0.60	0.60	0.59	0.59	0.58	0.57	0.57	0.56
0.60	0.67	0.66	0.65	0.65	0.64	0.63	0.63	0.62	0.61
0.65	0.72	0.71	0.71	0.70	0.69	0.68	0.68	0.67	0.66
0.70	0.78	0.77	0.76	0.75	0.74	0.74	0.73	0.72	0.71
0.75	0.83	0.82	0.82	0.81	0.80	0.79	0.78	0.77	0.77
0.80	0.89	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.82
0.85	0.94	0.93	0.92	0.91	0.90	0.89	0.89	0.88	0.87
0.90	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92
0.95	N/A	N/A	N/A	N/A	N/A	1.00	0.99	0.98	0.97

<u>Opportunities For Increased Dam Passage Survival</u>

Opportunities for increased dam passage survival are most likely to result from the following proposed measures: (1) increased spill through gas abatement measures (e.g., spill deflectors at IHR and JDA); (2) surface bypass structures; (3) improved turbine designs; and (4) extended-length screens for bypass systems. We attempt to set some bounds on expectations for survival improvements associated with each measure, but do so based on a great deal of judgement, rather than fact. We stress that these assessments are merely an informed guess and ongoing evaluations may demonstrate a greater potential improvement.

Gas Abatement Measures

The work group generally agreed that significant increase in dam passage survival resulting from gas abatement measures is unlikely because of the limited number of projects at which major gas abatement measures are applicable or planned.

Currently, projects are being operated to provide spill sufficient to achieve 80% fish passage efficiency (FPE - proportion of fish passing dam via non-turbine routes), provided safe total dissolved gas (TDG) saturation limits are not exceeded. Safe TDG levels are defined by state environmental quality agencies as 110% saturation, but variances have been obtained in recent years for 120% saturation in tailraces or 115% saturation in forebays (12-hour average). Using best available estimates of the spill levels needed to achieve 80% FPE (see section 1.6.1.A.1.b for difficulties in estimation procedure), it appears that TDG limitations prevent achievement of the FPE goal except under a limited range of flows. Spill levels associated with TDG limits vary, based on many factors such as water temperature and spill duration, but approximate limits are described in Table 1.6.A.5.

Gas abatement strategies/structures are possible means of increasing allowable spill levels to achieve higher dam passage survival. Spill deflectors are in place at all projects except Ice Harbor and John Day Dams. Installation is planned at these projects by 1997-1998. The Corps of Engineers has estimated that spill deflectors at Ice Harbor will raise the spill cap from 25 kcfs to 35 kcfs. **[Estimate of improvement at JDA?]**

[**Need summary of expected effects of other gas abatement measures being implemented by COE - We're not aware of any significant measures]**

Surface Bypass Structures

The work group generally agreed that there is insufficient information to determine the effect of this technology on dam passage survival in lower Snake and Columbia.

Based on Wells Dam surface bypass system, there is a potential to bypass up to 90% of smolts at a project, using about 10% of the flow. Because gas limits during spring are not reached with 10% flow, this could be a method of achieving 90% FPE (which is equivalent to approximately 97% dam passage survival if bypass survival is 0.98 and turbine survival is 0.85-0.90) without generating high TDG levels. However, the Wells Dam configuration is much different than that of Snake and lower Columbia mainstem projects, so efficiency may be much lower (see Question 1.4.B). Tests of a 1/2 powerhouse prototype are currently underway at Lower Granite Dam. The likelihood that this technology can substantially decrease either direct or delayed dam passage mortality cannot be determined until prototype tests are completed.

Improved Turbine Designs

Reducing direct mortality of smolts passing through turbines may be possible by redesigning turbine runners (reduce gaps) and designing turbines that operate for a higher percentage of the time near optimum efficiency. Both the Corps of Engineers and some Public Utility Districts have been exploring designs with turbine manufacturers. Prototype tests of a new turbine design will commence in spring 1998 at Bonneville Dam. Until such tests occur, the possible change in survival resulting from new designs can not be determined. An informed guess by the Corps of Engineers (John Ferguson, pers. comm., August 1996) is that new turbine designs may improve smolt turbine survival 1-3% (i.e., from about 90% to 91-93% survival).

Extended-Length Screens

The work group generally agreed that uncertainty about FGE of extended-length screens (as well as FGE of standard screens) makes it difficult to determine the likely improvement that will result from installation at three projects. If FGE increases by 10% at these three projects, that would not be sufficient, by itself, to significantly increase cumulative dam passage survival.

Extended-length screens may increase FGE at a given project by approximately 10%, based on comparisons of prototypes relative to standard-length screens **(citation)**, but performance of operational ESBS has not been evaluated. ESBSs have recently been installed at Lower Granite Dam and in approximately 1/2 of the units at McNary Dam. Installation at McNary and Little Goose Dams will be completed in 1997. ESBS installation is also being evaluated at some lower Columbia River projects.

Quantifying Anticipated Gains In Dam Passage Survival

NOTE: This section needs further development and an appendix to detail calculations. At this point this should just be considered a general indication of an approach that we will be following in a subsequent draft of this report.

We attempted an "educated guess" regarding the magnitude of survival gains that may be obtained through the installation and development of certain devices. The passage survival goal requires project (dam+reservoir) survival of 50-70%, which is approximately 92-96% per project. Based on 1993-1996 average project survival, current levels range from about 87-92%, indicating that the passage survival goal is not generally met. A survival increase of 4-5% per project would clearly meet the goal, lesser increases would meet it under some conditions/assumptions and not others. We recognize that the potential for dam passage improvements varies by projects, but we treat all generically for the purposes of this simple demonstration.

We estimate that there may be the opportunity to increase dam passage survival of smolts by 0.5-2.0 percentage points above current levels, if a suite of proposed measures are found to be sufficiently effective over the next few years. If as we suggest turbine mortality currently rages from 5-10%, then/and:

1. A 10% increase in FGE with extended screens would increase FPE accordingly and yield a survival gain of 0.5-1.0%.

2. Surface bypasses are found to be effective enough to increase FPE by 10% above, or in combination with existing screens, another 0.5-1.0 % gain in passage survival may be realized.

3. New turbine designs may eventually yield a survival gain of 0.5-1.0%, as per some projections.

Collectively, these devices could improve passage survival at the dam by 0.5 to near 2.0 percentage points above current levels. This equates to a potential improvement in project survival from approximately 87-92% (current average) to 88.5-94.0% per project. Past eight projects this yields a system survival probability of 38-61%. The upper end of this range falls within our established passage survival goal. Also, increased spillage due to deflector installation at IH and JD may increase overall system survival slightly. An important point is that we assume delayed effects are negligible for our goals and realized performance estimates to be instructive. It is incumbent on the Region to quantify any delayed effects associated with inriver passage by empirical methods over the next few years. Furthermore, it is essential that any delayed effects associated with a specific passage route be identified. This will aid in selecting the safest devices (screens, surface collectors or spill) as we consider redesigning the system. Currently no such estimates exist.

Question 1.6.B Can a high rate of in-river survival be provided by increasing reservoir passage survival?

The opportunity to improve reservoir survival above levels already being achieved with the 1995 BIOP and the current predator control program is minimal. Additional water for flow augmentation is not readily available. Further expansion of predator harvest effort is not likely. Our assessment treats direct survival through reservoirs to BON tailrace. There is considerable uncertainty with regard to the existence and magnitude of hypothesized delayed effects associated with migration speed. Until these are clarified there is no means to determine if existing mitigation actions can substantially reduce them.

Maximum Potential Improvement

To assess the opportunity for improving reservoir survival we need to identify what current levels are. If reservoir survival is already very high, then there is little room for improvement through mitigation. However, direct estimates of reservoir survival are not available. It is necessary to derive them from system survival estimates, through river reaches, in conjunction with independent estimates of route-specific passage mortality and population proportions coursing those routes.

Estimating Reservoir Mortality From Reach Survival Estimates

As described in Table 1.6.A.2, recent lower Snake River reach survival studies (Iwamoto et al. 1994; Muir et al. 1995; Muir et al. 1996, Scheiwe 1996), show project mortality (combined reservoir and dam mortality) averaging 8-13% per project, depending upon the year, specific project estimates range from 6-21%. Clearly reservoir passage mortality is something less than the total project mortality, but no studies have clearly delineated the reservoir and dam passage mortality components. The range of reservoir mortality currently expressed in the system can be inferred by examining total project mortality and considering a reasonable range, we need to apply reasonable ranges of FPE and passage route mortality. **Table 1.6.A.6** specifies reservoir survival at different levels of total project (dam + reservoir) and dam-specific survival. The dam survival component varies in accordance with FGE, spill efficiency and passage route-specific mortality (Tables 1.6.A.3, 1.6.A.4). Table 1.6.A.6 indicates that, given a range of dam survival between .90 to .98 (Table 1.6.A.4) and project survival of approximately .90, reservoir survival must be approximately .92-1.0.

In addition to these recent reach survival estimates, reach survival estimates through the Snake and lower Columbia River are also available from the 1970's and early 1980's.

This historical data set indicates a broader survival range, from 0.52-0.91 per project, potentially expanding the range of reservoir survival, depending how severe dam mortality was in any year.
The data sets differ in several regards. The historical set is based on brand recovery data, whereas the contemporary set is PIT tag based. The geographic range was generally longer in the historical set extending to either JD or TD dams. Furthermore, the analytical models used for survival estimation were fundamentally different. Also, the contemporary studies rigorously tested model assumptions, which was not the case in the historical studies. Generally, the contemporary estimates are considered more quantitatively robust.

Estimates of dam passage survival, spill efficiency and/or FGE do not typically accompany system survival estimates. Thus, deriving estimates of reservoir survival from reach survival estimates often requires using generalized estimates of these parameters as previously described. The uncertainties attending estimates of dam passage parameters, as described in section 1.6.1, apply here. Contemporary survival estimates attempt to improve this situation by providing concurrent dam- and/or passage route-specific survival estimates at some sites within the reach. However, not all passage routes have been evaluated concurrently in any study, e.g., spill efficiency has never been estimated during the course of any survival evaluation.

Appendix 3 explores the sensitivity of the reservoir survival estimates in FLUSH to variation in FGE, turbine survival and inferred gas effects. Additionally, that analysis reveals that contemporary estimates of reservoir survival appear to be generally higher than those acquired during the historical period, under the similar river discharge levels.

Mechanisms Causing Reservoir Mortality

Sources of mortality in reservoirs include predation, gas saturation, temperature related processes, and expression of disease or poor fish condition.

Migration Speed/Travel Time

Exposure time: Reasonably, the longer smolts are within reservoirs the longer they are exposed to these mortality agents, increasing the probability of mortality. Increased exposure time increases the probability of encountering both piscivorous and avian predators. Furthermore, gas-related mortality is positively related to both the saturation level as well as the exposure time to the gas dose. CRISP applies gas mortality functions as described in Appendix 5. As a separate consideration, mortality observed while fish traverse a reservoir could have nothing to do with reservoir processes. For example, if fish have a severe disease acquired during rearing that expresses itself in the form of mortality that is continually expressed at some rate during migration. The slower they migrate the more likely the death will occur in a reservoir, although the cause is not due to reservoir processes.

Residualization: It has been suggested that when migrational delay is particularly pronounced, residualism and/or holdover may occur. Steelhead commonly residualize in the system, and laboratory evidence suggests temperatures in excess of 54 degrees F may cause reversion from smolt to parr (Zaugg and Wagner 1973). It is plausible that if steelhead migration is too slow, smolts could be exposed to seasonally increasing water temperatures reaching this level, thus increasing the risk of residualization. However, such mechanisms have not been documented for juvenile chinook. Mullan et al. (1992) suggest that residualism may be a common behavior for precocious male chinook in the Columbia River. However, their proclivity to residualize, primarily in tributaries, is associated with precocious sexual maturation rather than environmental conditions within the migration corridor.

Bioenergetics: It has also been suggested that slow migrations deplete energy stores potentially contributing to mortality, perhaps following ocean entry. However, this has not been observed o described, albeit research directed specifically toward this topic is lacking.

Temperature: Migrational delay exposes smolts to seasonally increasing water temperature. Some have expressed concern that this could result in acute thermal-induced mortality, or disease expression. However, this is unlikely since temperatures encountered by spring migrants rarely exceed any recognized tolerance levels during their migration period.

Biological Window: Apart from mortality incurred during passage through the hydro system, it has been suggested that migrational delay impairs survival at seawater entry (a delayed effect). The theory holds that the timing of seawater entry was dictated by the hydrographs in the Snake and Columbia rivers and synchronized with a "biological window". Since impoundment has increased yearling chinook migration time by two- to three-fold (Bentley and Raymond 1976, Ebel and Raymond 1976), this has altered the timing of ocean entry and diminished the probability that smolts can enter the presumed biological window. It is implied that this period is of limited duration and well defined. The theory is appealing in that fish evolved under a prescribe set of conditions. However, there is little empirical evidence that would permit us to determine how much delay is too much.

In 1996, NMFS estimated (Steve Smith, personal communication) that hatchery yearling chinook migrated from LGR to BON dam in approximately 12 to 23 days. These estimates are based on the median travel times of groups PIT-tagged smolts released at LGR from 18 April through 20 May, 1996. Thus, absent dams, the trip may have taken somewhere between 4 and 12 days. This yields a shift in timing of about one to two weeks. 1996 was a high flow year, we have not performed or seen similar comparisons presented for other water years, but certainly in low water years the delay will be greater. Table A5-8 in Appendix 5 offers some insight on this matter; observed travel times through various reaches across years 1966-1995 are presented. The question remains, as to how large the delay has to be to critically disrupts synchrony with the proposed biological window. Research in this area is lacking.

The theoretical window has two aspects; the physiological preparedness of the smolts for seawater entry, and the ecological condition of the estuarine and nearshore marine waters in terms of productivity, competition, and predation. However, our understanding of the requirements for smolts is poor, and assessments of their performance in estuarine and nearshore marine waters are lacking. Coupled with our lack of information regarding the condition of these fish when they enter the estuary, we can not confidently predict the consequences.

With respect to the issue of osmoregulation or seawater adaptation there is some instructive information. Regarding chinook salmon Hoar (1976) notes; "This species, unlike the coho or steelhead, acquires high salinity resistance gradually while in fresh water without any sharp increase associated with a smolt transformation." In support of this contention he cites and displays results from Wagner et al. (1969). Their laboratory test of seawater adaptation showed that chinook survival following seawater entry steadily increased with the age of the fish. In contrast, steelhead survival drops off sharply from nearly 100% to near 0% over a period of approximately eighty days. From this we could infer that migrational delay on the order of a few weeks may be of considerable concern in the seawater adaptation of steelhead, but may not be so important for chinook salmon. There is no information supporting the existence of a physiologically based, time-constrained window for chinook salmon, at least with respect to time-steps on the order of days to a few weeks. Nevertheless, research has not been directed to specifically address this issue.

> **Conclusion:** The importance of migration speed itself in affecting the magnitude of direct reservoir mortality and proposed delayed effects associated with migrational delay remains to be resolved.

Predator Dynamics

The principal mechanism responsible for mortality associated with migration speed is considered to be predation by piscivorous fish. Northern squawfish are the most effective predators in the system. For example, Rieman et al. (1991) estimated that 2.7 million juvenile salmon were consumed annually in John Day Reservoir, during the years 1983-1986; and squawfish were responsible for 78% of that loss. Since squawfish consume both live and dead smolts (Poe 1992), consumption does not directly equate to predator caused mortality, nevertheless current system-wide estimates of consumption (Shively et al. 1991) indicate the mortality is substantial and pervasive throughout Snake and Lower Columbia River reservoirs. However, recent research has indicated that squawfish prefer dead juvenile chinook to live ones (Gadomski and Hall-Griswold 1992). Thus, previous estimates of predation mortality, derived from consumption rate information, may be too high. Recent analyses by Peterson (1994) also indicate that smolt consumption by predatory fish may be half that originally estimated.

One aspect of predation that has received little attention concerns the population dynamics of the predatory fish species. Smolt survival through the system is certainly sensitive to fluctuations in abundance and size structure of the predatory fish populations. This factor has not been considered in evaluations of smolt survival estimates or modeling thereof. We previously noted that contemporary estimates of smolt survival are generally higher than was estimated historically. That change could be due to both passage improvements and a change in the demographics of the predatory populations, especially considering the predator control program implemented in recent years.

Feeding efficiency or consumption rate of predatory fish can vary with environmental conditions. Increased by temperature elevates the metabolic rate of predators leading to increased consumption. Vigg and Burley (1991) found that the maximum daily consumption of northern squawfish increased exponentially as a function of water temperature, up to some maximum above which it decreases. CRISP incorporates such mechanisms as one of several components affecting reservoir mortality. A factor not explicitly incorporated in either model is the potential that increased turbidity associated with freshets may decrease the capture effectiveness of predators.

Disease Expression

There is the potential for the increased expression of certain diseases at high temperatures. However, yearling chinook migrate seaward during the cool spring period. A yet unresolved issue is whether extended freshwater residence of smolts, exacerbates disease expression either in fresh- or seawater, and how much of a reduction in migratory delay is necessary to offset any effects.

Temperature Effects

Apart from the temperature-related processes already discussed there are a number of additional sublethal effects that may be of interest. Smolt metabolic rate and growth are sensitive to water temperature. Generally, water temperature does not increase substantially during the spring migratory period, and concern or such effects are likely minimal, except perhaps for late migrating wild springs that pass Lower Granite Dam during the end of June. Certain parasites may become epizootic at elevated temperatures, but the topic has received little attention.

Reservoir Survival Dynamics

Smolt Speed

Water management actions directed at increasing the migration speed of smolts are meant to improve reservoir survival and perhaps survival at seawater entry, by reducing the reservoir effects just described. Both flow augmentation and reservoir drawdown are two strategies directed at increasing water velocity through impoundments with the intention of increasing smolt migration speed. The extent to which smolt speed changes in response to fluctuations in water velocity is of concern, since it is a key parameter in predicting reservoir survival. Within the impounded Snake and lower Columbia River a number of studies have identified positive correlations between flow, water velocity, and migration speed of yearling chinook salmon (e.g., Berggren and Filardo 1993; Zabel 1994). It is generally recognized that the physiological disposition of the migrants is at least equally as important in influencing smolt travel time, as indicated in those papers and Beeman et al. (1991). These points are not in dispute.

However, the functional relationship between these variables is characterized differently within the two regional fish passage models, even though both models predict similar water velocity at a given discharge volume. This leads to different conclusions regarding the relationship between fish sped and water speed. Both models depict a positive relationship between fish and water speed, but the collective CRISP functions yield a relatively flat response curve in comparison with steep response curve in FLUSH (Appendix 5, Figure C6 A5-4). To compare model output, Appendix 5 reports the model-predicted smolt travel time in a high (1982) and low (1992) flow-year, from Lewiston to BON:

	High Flow (1982)	Low Flow (1992)
CRISP smolt TT (days)	22.5	27.5
FLUSH smolt TT (days)	18.0	30.6

In this illustration CRISP predicts the travel time of an Aaverage@ age smolt. CRISP predicts only a five day difference in travel time between years, whereas FLUSH predicts a 12.6 day difference. The reason the models predict different smolt speeds is that they use different marked-fish data sets to construct their respective travel time/flow functions. The CRISP functions are based on observations of smolts PIT-tagged at the Lewiston Trap and subsequently observed at dam sites downstream to MCN, for the years 1989-1995. These data are used to construct fish age/ water velocity/ fish speed functions that predict travel time through the lower river projects. FLUSH uses different data sets and derived functions to characterize travel time through each of three separate reaches: For the LGR Pool, Lewiston Trap PIT-tagged fish (1988-1993) are used; for LGR to MCN Brand data from the 1982-1990 are used; for MCN to JD brand data from 1986-1993 were used. Furthermore, in CRISP fish age (meant to reflect smoltification status and the propensity to engage in migration) is an important component that is fixed in this example and may explain some of the difference.

Minimum Operating Pool: Lowering reservoir elevations to MOP is a means to increase water velocity that does not involve major structural modifications at most dams, so we discuss it under this section. During the migration period, all Snake River dams are operated at MOP, so if any gains were to be attained most have likely been realized. Drawing down the reservoirs to MOP yields minor changes in water velocity in many reservoirs, and none of the other presumed flow-related effects accrue. For example, In their final recommendations to NMFS, the Recovery Team estimated the increase in water velocity in Lower Granite forebay. They estimated that MOP compared to full pool; water velocity would increase approximately 6% at 120 kcfs , and would be negligible at 30 kcfs. Currently water management in the Snake is meant to achieve a water velocity equivalent to 85 kcfs, and MOP contributes to this.

John Day Dam remains as a site where some contend MOP may offer more substantive benefits. According to NPPC staff estimates, water velocity will increase by about 27% through John Day Reservoir accompanying the lowering of pool elevation from full level (268') to MOP (257') (letter from J. Ruff to NMFS, July 1996), regardless of the prevailing river discharge. But absolute water velocity (ft/sec) is still quite low:

Flow (kcfs)	Full Pool = 268'	MOP = 257'
100	0.37	0.47
200	0.73	0.93
300	1.10	1.40

John Day has been operated at MIP (262') in recent years. Thus, the remaining gain in water velocity is less. However, other Columbia River pools may offer additional opportunity. Survival gains associated with swifter migration with the entire system at MOP have not been predicted.

> **Conclusion:** There is no dispute that migration speed varies with flow volume. Furthermore, it is agreed that migration speed is a factor affecting predicted survival in both models. However, alternative hypotheses and data sets embedded in regional passage models predict different migration speeds at a given water velocity, as a consequence their survival estimates differ. FLUSH predicts greater change in migration speed due to actions which increase water velocity, than does CRISP.

Translating Smolt Speed Into Reservoir Mortality

In addition to having fish travel at different speeds, each passage model imposes reservoir mortality in different manners, which results in different mortality estimates. Within FLUSH smolt speed is the primary parameter affecting reservoir mortality. The FLUSH reservoir survival function is based on system survival estimates reported by Sims and Ossiander (1981) and Sims et al. (1981) as described in Appendix 5. Reservoir mortality estimates were derived from those system estimates, assuming certain levels of dam effects occurred. Reservoir survival is then expressed in terms of the predictor variable, fish travel time. Agency and tribal biologists have selected this set because: 1) it spans a broad range of flow conditions, and 2) the survival estimates extend from the upper dam to JD or TD dams, providing a long river segment for observing the expression of mortality. Critics contend: 1) the estimates are of poor quantitative quality (Steward 1994), 2) the reservoir mortality estimates reflect effects other than those associated with reservoir processes (Williams and Matthews 1995), and 3) Passage conditions were so different in that era that any survival estimates are not applicable today. During the last decade or more, numerous bypass systems have been emplaced or upgraded, and spill and flow augmentation programs have been implemented as have predator control efforts. Thus, the relevance of those historical estimates is questioned by some investigators (Iwamoto et al. 1994, Muir et al. 1995).

Within CRISP several mechanisms and parameters kill smolts in reservoirs. Speed of migration dictates exposure time to the agents, which include predatory fish and gas saturation levels. Water temperature is an important modulating factor influencing the metabolic rate of piscivores as reflected in increased smolt consumption with increasing temperature. These act in concert to yield overall smolt loss through reservoirs. CRISP has been calibrated to some existing reach survival estimates. To achieve compliance with those estimates predator activity becomes the free variable used for tuning.

Figure C6 A5-5 from Appendix 5 depicts the difference in reservoir survival at given smolt travel times for each model. Clearly CRISP predicts higher reservoir survival across the range of travel time. The difference in model predicted mortality increases substantially as travel time increases above about 15 days from LGR to BON.

Flow-Related Effects Other Than Water Velocity/Migration Speed

Sims and Ossiander (1981) first identified the relationship between smolt survival (yearling chinook and steelhead) and prevailing flow volumes. They estimated smolt survival from the uppermost dam on the Snake River (Little Goose or Lower Granite) to The Dalles Dam. They noted that for the years they analyzed (1973-1979), as the annual indices of flow increased, corresponding increases in migration rate, spill proportions and smolt survival indices were observed. They could not determine which mechanism or combination thereof caused the change in smolt survival.

Recent estimates of yearling chinook survival through impounded sections of the lower Snake River provide additional information on this topic. Using PIT data acquired during the years 1993-1996 (Smith et al. 1996 abstract). NMFS investigators have acquired survival estimates through sections of the Snake River from 1993-1996. Preliminary results presented at the AFS conference in Eugene Oregon in the summer 1996, indicate a positive relationship between migration speed and flow, but not survival and flow (Smith et al. 1996, abstract), under flow conditions prevailing during those years. PATH should review his material once it is finalized. Even with the 1993-1996 smolt survival estimates in hand, direct estimates of reservoir mortality are not available, they still need to be derived from reach estimates.

Turbidity: Increased turbidity can accompany high flows, which may reduce predator feeding efficiency and overall reduce predation mortality. The relationship between water clarity and flow has not been described. However, this could be an important flow-related mechanism affecting reservoir mortality. Thus, mitigation actions that specifically decrease travel time without increasing turbidity could be less effective than anticipated. There are no data available that permit these effects to be clearly identified. This mechanism is not contained in either passage model.

Dissolved Gas: Increased spill volumes, or proportions, are often prescribed or naturally accompany high flows once powerhouse capacity is exceeded. Increased spill elevates dissolved gas levels, which can be detrimental and result in smolt mortality when excessive. When severe, gas saturation levels can create reservoir conditions that may offset any survival gains attributable to migration speed. These effects need to be separated, but it is difficult to do so.

There is no dispute that too much gas is undesirable and should be avoided through spill caps or implementing gas abatement strategies. However, there is considerable dispute as to what acceptable gas levels are. One school, reflected in CRISP mechanisms, indicates that as gas levels exceed 120%, smolt mortality increases dramatically. The interaction between exposure time (migration speed), fish depth, and the gas saturation levels are important factors determining the gas-related mortality. The current functions are based on laboratory bioassays using smolts at different gas levels, and an estimate of the vertical distribution of smolts, based on a study conducted in the forebay of Lower Monumental Dam. Critics contend he extrapolation of laboratory results to the field are inappropriate. The FLUSH model does not explicitly impose gas-related mortality. This is a fundamental difference between the reservoir mortality imposed in the models.

Passage Model Characterizations of flow/survival relationship: While there is general agreement that some relationship between survival and flow exists, the shape of the relationship is the subject of considerable debate. That debate boils down to two different model characterizations as reflected in FLUSH and CRISP. Be advised that such a relationship is not necessarily the same as the reservoir survival/travel time functions depicted in Appendix 5 (Figure C6 A5-5), since other flow-related reservoir mechanisms as discussed previously also come into play. This is evident in the construct of the CRISP model, but less so for the FLUSH Model. Furthermore, Dam passage mortality is sensitive to flow volumes once powerhouse capacity is exceeded, and increasing proportions of smolts pass over spillways.

Predicting The Change In Survival Associated With Mitigation Actions

The Region relies on model predictions as one means to evaluate the magnitude of survival gains anticipated with certain mitigation actions. Passage model analyses have been applied in forums like the System Operation Review, and NMFS Recovery Team analyses. Changes in survival can be expressed in either absolute or relative terms, and there has not always been agreement as to which is most appropriate.

Altering Predation Rates On Smolts

Reduce predator numbers: The harvest of northern squawfish throughout the impounded Snake and Columbia rivers is an ongoing major effort directed toward specifically reducing reservoir mortality. The most recent published evaluation of this program is the 1994 Annual Report produced by Oregon Department of Fish and Wildlife (Knutsen et al. 1995). They report that in 1994 the exploitation rate was well within the prescribed 10-20% target range. Furthermore, they estimated that the potential predation on smolts may be reduced by 32% by 1995, relative to pre-program levels. They go on to suggest the same benefits should accrue for Snake River stocks. However, these estimates do not apply specifically to yearling chinook migrating during the cool spring period, but the overall smolt population including summer migrants. So, although the program appears quite effective, the magnitude of improved survival of yearling chinook has not been determined. Even so, these results suggest that if predation is the primary mechanism causing the reservoir mortality of yearling chinook (it is not clear what else could be), then this appears to be a most, if not the most, effective strategy for increasing reservoir survival.

Reduce Predator Effectiveness: Another strategy to reduce predation by piscivores involves implementing actions to disrupt their effectiveness at capturing smolts. One possibility is to use spill to displace northern squawfish and other predators from staging areas in the spillway tailrace. Observations by Isaak and Bjornn (1996) support this scenario, at least as witnessed at Lower Granite Dam. Those investigators report that during spill periods, radio-tagged northern squawfish shifted their distribution in the trail race away from the stilling basin. However, they still appeared to reside in other areas within the tailrace.

Increased spill in combination with high total river discharge, may increase tailrace velocities sufficiently that predators are displaced from the immediate. Although piscivores may be displaced from staging areas near the dam, they may re-establish equally efficient feeding stations a little further downstream. The assumption appears to be that disoriented smolts may recover sufficiently, reducing the probability of capture under such conditions. This presumption has not been verified. However, laboratory observations by Mesa (1994) suggest that juvenile chinook salmon are capable of avoiding predators within one hour after being subjected to multiple acute stressors associated with dam passage. Using this as a guideline, if predatory fish were displaced far enough some benefits might accrue.

It is commonly held that predatory fish key on bypass discharge ports where smolts are concentrated. Although there is some indication this may be a concern for subyearling chinook (Ledgerwood et al. 1990) migrating during the summer when water temperatures are high and northern squawfish concentrate near dams (Isaak and Bjornn 1996), there is little evidence for spring migrants. Thus, any actions taken to alleviate a suspected but undocumented problem are questionable.

Since the activity of predatory fish and associated consumption of smolts increases with water temperature, maintaining cool water temperatures may be advantageous. It has been suggested that increasing discharge from storage reservoirs may provide this capability. However, cooling mainstem reservoirs only becomes a consideration during mid to late summer when both water temperature and predator activity is high. By that time, yearling spring/summer chinook have left the system and subyearling fall chinook predominate. It has also been suggested that flow augmentation can result in increased turbidity, thereby reducing predator feeding efficiency. There is no evidence that controlled, sustained storage releases produce any measurable change in visibility relative to ambient levels.

An Assessment Of The Opportunities For Improving Reservoir Survival

In summary, there are three general strategies for potentially reducing reservoir mortality for yearling chinook within the system as currently configured: 1) reduce predator numbers, 2) increases flows to create a complex of flow-related effects, and 3) Operate all dams at MOP to increase water velocity. We recognize that it is not possible to confidently predict the true change in smolt speed through the entire system, let alone any improvement in survival change in reservoir survival associated with changes in these collective actions. Apart from that consideration, what is likelihood that any of these three conditions will change significantly above those current prescribed under the 1995 BIOP

1. At this juncture, given demands on water from other users and constraints of state water rights laws, it appears very unlikely that a significant amount of additional water can be expeditiously acquired. The only possibility is that water currently dedicated to summer migrants could be redirected to spring migrants.

2. Since the Snake River dams currently operate at MOP, and John Day Dam already operates at MIP, it does not appear implementing this action at remaining sites will appreciably increase overall system velocity above current levels.

3. It appears that any gains in smolt survival attributable to predator removal may have been realized or will plateau in the next few years. Major changes in the predator population structure are not envisioned beyond 1999. More comprehensive assessments will likely be forthcoming in the next two years.

Conclusion for 1.6B: The opportunity to improve reservoir survival above levels already being achieved with the 1995 BIOP and the current predator control program is minimal. This pertains to direct survival through reservoirs to BON tailrace. There is considerable uncertainty with regard to the existence and magnitude of hypothesized delayed effects associated with migration speed. Until these are clarified there is no means to determine if mitigation actions can substantially reduce them.

Question 1.7 <u>If it is determined in 1.1 and 1.4 that transportation survival is high enough but the collection rate is too low to meet the hydro survival goal for the entire spring/summer chinook population</u>, do present passage measures provide a high rate of juvenile survival across a broad range of life histories without subsequent adverse effects? [This refers to conventional, non-structural measures to improve survival outside of transportation. Implicit in this question is the need to provide benefits across a range of fluctuating environmental conditions.]

This is identical to Question 1.5, but is reached through different assumptions about transportation survival. Rather than the "yes-no" answer to this question in the in-river decision pathway (Questions 1.5 and 1.6), the hybrid decision pathway asks whether in-river survival is sometimes, never, or always high enough to meet the passage survival goal. The work group was in general agreement that the answer to this question, based on current in-river passage estimates, is Anever.@ In-river survival (LGR pool to BON tailrace) under current conditions and operations is, at best, 40-50%, while the interim passage survival goal is 50-70%. Any delayed mortality associated with in-river passage would further reduce the likelihood that current in-river survival is sufficient to meet the passage survival goal.

Question 1.8 <u>If it is determined in 1.7 that in-river survival is high enough to meet goal under some conditions</u>, does a combination of passage and in-river measures provide a high rate of juvenile survival over a broad range of life histories?

Based on the conclusion for Question 1.7, this question will not be addressed unless additional measures can provide in-river survival sufficient to meet the passage goal under at least some conditions (Question 1.9). We believe that it is likely that dam passage improvements will provide adequate survival under some conditions. However, there was general agreement by the work group that achievement of the survival goal is unlikely under this hybrid scenario. This point in the decision path is not reached unless the goal cannot be reached by transporting fish in any year (because not enough fish can be collected), but the goal can be met in some years by leaving fish in the river. Therefore, there will always be some years in which the goal will not be met, even though transportation in those years may provide higher survival than leaving fish in the river. Under only one condition will a hybrid scenario result in survival and recovery: transportation survival is high enough to meet the goal under some conditions, in-river survival is high enough to meet goal under some conditions, and the conditions that are favorable to each strategy are complementary. We believe that this condition is highly unlikely.

Question 1.9 If it is determined in 1.7 and 1.8 that in-river passage never meets the goal or that a combination of in-river passage and transport do not meet the goal, can in-river survival be substantially improved without major structural modifications?

Available information is insufficient to answer this question. However, based on the conclusion for Question 1.6, it is possible that dam passage improvements may provide adequate survival under some conditions. We estimated, based on an "informed guess," that four identified measures may improve mean project survival by a maximum of 3%, resulting in mean per-project survival of 90-95%. This partially overlaps the mean per-project survival necessary to achieve the interim passage survival goal, 92-96%, suggesting that the goal may be achieved under some conditions if our most optimistic assumptions are realized.

Question 2 ***If the loss of juvenile fish habitat caused by operation and development of the present system cannot be compensated within the existing authority of the operating agencies*****, how can the system be modified to provide a level of impact that will?**

Question 2.1 If it is determined in 1.6 that a high rate of juvenile survival cannot be provided without major structural modifications, can in-river survival be substantially improved through major structural changes to the projects?

Primary options considered are spillway crest and natural river drawdowns at up to four Snake River projects and John Day reservoir.

The work group was in general agreement that risks associated with potential increased dam passage mortality (adults and juveniles) probably outweigh potential reservoir survival improvements due to increased velocities resulting from drawing down Snake River projects to spillway crest. We did not attempt new analyses to reach this conclusion, but relied on previous SCS analyses and the discussion of dam passage impacts in the attachment to the NMFS 1995 BIOP.
The work group could not reach agreement on the likelihood that potential survival improvements due to increased reservoir velocity and rearing habitat associated with a spillway crest drawdown of JDA would outweigh risks associated with potential increased dam passage mortality of juveniles and adults. We did not have time to complete a thorough analysis of this option in time for this draft - our discussions to this point have only been qualitative. We do believe that it is important to point out that, while there is uncertainty regarding effects of a JDA spillway crest drawdown on survival of Snake River spring/summer chinook salmon, consideration of this option for other stocks, such as Hanford Reach fall chinook salmon, may lead to more definitive conclusions.

The work group was in general agreement that a natural river drawdown of four Snake River projects (with or without a natural river drawdown of JDA) would substantially increase survival of juvenile migrants and would also substantially increase adult upstream passage survival. With dams in place and current average project survival rates (87-92%), in-river system survival of smolts would be 57-72%, which would clearly meet the passage survival goal. This assessment would only be modified if there were significant delayed effects of dam breaching or of passage through the remaining four projects or if there were significant adverse effects of dam breaching (possibly due to sediment release, adult velocity barriers, or the lag time associated with re-establishing a riverine trophic base) that have yet to be evaluated. The increase in adult passage survival (possibly 10% or more) would also contribute towards meeting the interim SAR goal.

Spillway Crest Drawdown

Currently there is little interest in spillway crest because of the extensive dam retrofitting that would be involved and the uncertainty associated with the success of such a venture. One exception is John Day Dam. This project has a very large reservoir volume, approximately equal to that of all four Snake River projects combined, and spillway crest drawdown would eliminate approximately two third of the volume. In addition, predator abundance appears to be highest in John Day Reservoir (Ward et al. 1995) which makes the extended fish travel times more detrimental. The forty miles of natural river that would accompany spillway crest drawdown may serve as an oasis for stocks of salmon migrating form the Snake River and elsewhere and would considerably increase the spawning area for fall chinook.

Natural River Drawdown

Natural river drawdown, as currently envisioned, involves breaching the earthen fill adjacent to a dam thus leaving the dam in place but allowing the river to return to a natural state. The latest Biological Opinion (NMFS 1995) lists the drawdown of four Snake River projects as one option for rebuilding Snake River salmon stocks. While direct evidence of its efficacy is not available, there is information that may be useful when evaluating the natural river option.

As noted in Appendix 3, juvenile mainstem mortality appears to occur as a result of both dams and reservoirs with the balance between the two varying among years depending on passage conditions. The survival past dams has been studied extensively and methods to reduce mortality from various sources are in place. Reservoir mortality is invariably associated with problems resulting from substantial increases in fish travel time. One likely result of delays is increased predation which is being addressed through predator reduction approaches. Transportation is aimed at improving the survival of juveniles both through the reservoirs and past the concrete. The presence of dams and reservoirs may also increase the mortality of returning adults. Fishways are the primary means for increasing adult survival.

Natural river drawdown has received serious consideration in recent years because it would eliminate dam mortality altogether and would greatly reduce reach mortality as a series of lakes returns to a riverine condition. It may also improve adult upstream survival. Although this chapter focuses on spring chinook, drawdowns, both in John Day and the Snake River, would make additional spawning areas available for fall chinook.

Examples of dam removal are not common but the successful reintroduction of salmon stocks following the removal of Lewiston and Harpster Dam indicates such a measure can safely be done. If dams are left in place, however, care must be taken to prevent a situation in which constricted flows present velocity barriers. Some type of sediment management may also be necessary.

The increase in survival expected from dam decommissioning is not known exactly but several types of information shed light on the subject. First, very simply, if you remove half the dams it seems reasonable to assume mainstem juvenile survival would approximatly double. Similarly, from the SAR standpoint, if only four dams were in place it seems reasonable to assume the SARs would increase to approximately what they were in the mid 1960s when only four dams were in place. Survival in the Snake River in the 1960s when Ice Harbor Dam was the only one constructed was approximately 90%. while, in recent years, survival to Lower Monumental Dam alone (i.e. through three dams) was approximately 70% so that survival to Ice Harbor Dam, on a per project basis, would be approximately 62%. Based on this information, removal of three dams would be expected to increase survival from 62% to 90% and removal of four dams could increase survival through this reach to nearly 100%. Simulations by different modeling frameworks indicate that these types of increases are those that are required to meet survival goals (NMFS 1995).

In summary, natural river drawdown has the potential to approximately double survival and therefore has the potential to lead to rebuilding. In contrast, flow augmentation, while increasing survival, does not appear to have the potential to rebuild stocks. This is in part due to the fact that flow augmentation does nothing to improve dam survival per se. This is also because reservoirs act to slow down fish to such a great extent, drawdowns can increase fish velocity well beyond that achievable through any realistic level of flow augmentation. Note, however, that drawdown does not mean that flow augmentation is unnecessary because flows may still be important in the estuary and in ocean entry.

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2. Description of calculations used to address Question 1.4.B: can surface bypass/collectors substantially increase the proportion of transported Snake River spring/summer chinook salmon? - Chris Toole

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7. An Analysis of Transport Survival - Earl Weber

8. Acronyms and Other Nomenclature

Chapter 6 Appendix 8
Acronyms and Other Nomenclature

BIOP:	NMFS 1995 biological opinion regarding operation of the Federal Columbia River Power System; Endangered Species Act document
BKD:	Bacterial kidney disease
BON:	Bonneville Dam
BRWG:	Biological Requirements Work Group; formed to quantify biological requirements of listed Snake River salmon
CRiSP:	Columbia River Salmon Passage model; smolt mainstem passage survival simulation model developed by the University of Washington
Cumulative Transport Survival:	Survival of transported fish to point of release, adjusted for any delayed mortality
Drawdown:	For purposes of this chapter, it refers to lowering reservoir elevation below MOP
ESBS:	Extended-length submerged bar screen; device for guiding fish away from turbines
Forebay:	Portion of reservoir immediately upstream of dam
FCRPS:	Federal Columbia River Power System; the collection of dams, reservoirs and transmission facilities in the Snake and columbia River basin. In this report, the term is generally used to describe the impounded portion of the lower Snake and Columbia Rivers
FGE:	Fish guidance efficiency; proportion of fish approaching a turbine that are guided into bypass system
FPE:	Fish passage efficiency; proportion of fish passing a project through non-turbine routes (spill or bypass/collection)
FTOT:	Fish Transportation Oversight Team; inter-agency group reponsible for managing transportation program prior to 1995
FLUSH:	Fish Leaving Under Several Hypotheses model; smolt mainstem passage survival simulation model developed by the states of Oregon, Washington, and Idaho; the Columbia River Inter-Tribal Fish Commission; and the Columbia Basin Fis and Wildlife Authority
Hydro:	Shorthand term used throughout chapter to represent certain aspects of the FCRPS; e.g., "**hydro operations**" = operations of hydroelectric dams and reservoirs of the FCRPS; "**hydro system**" = system (see below); "**hydro goal**" = survival goal through FCRPS as defined in 6.3.2 "Initial Consideration".

Hydro Survival:	Survival of salmon smolts through the FCRPS from the head of the Lower Granite reservoir to a general location just downstream from Bonneville Dam. Discussed in relation to "passage survival goal"
IHR:	Ice Harbor Dam
JDA:	John Day Dam
LGO:	Little Goose Dam
LGR:	Lower Granite Dam
LMO:	Lower Monumental Dam
MCN:	McNary Dam
MOP:	Minimum operating pool; lowest reservoir level at which navigation locks can operate; lowest level reservoirs can be lowered within Corps of Engineers' current authority at most projects
NMFS:	National Marine Fisheries Service
Out-Migration:	Migration of juvenile salmon downstream from natal areas towards the ocean
PAM:	Passage Analysis Model; smolt mainstem passage survival simulation model developed by the Northwest Power Planning Council
Passage Survival Goal:	Goal against which "hydro survival" (see above) is evaluated; interim suggestion for this goal is 50-70%.
PATH:	Plan for Analyzing and Testing Hypotheses
PIT-tag	Passive integrated transponder tag; integrated microchip inserted with unique code for each fish that is decoded as fish pass detectors at dams or other sites
Project:	A dam and reservoir combination; project survival is equal to the survival through the reservoir times survival past the dam
Reach:	For purposes of this chapter, length of river encompassing more than one project; i.e., more than one dam and reservoir combination
SAR:	Smolt-to-adult return; survival of a fish from the smolt stage to the adult stage - exact definitions of where the "smolt" and "adult" are defined and censused may vary, depending upon the study or context
Smolt:	Juvenile salmon that is in the process of making the transition from freshwater to saltwater residence, including moving downstream through the FCRPS
Spill	Ratio of proportion of fish passing spillway to proportion of flow passing over spillway

Efficiency:

Spillway Crest	The elevation at which the reservoir behind a dam is level with the top of the dam's spillway
STS:	Submerged travelling screen (also referred to as "standard-length screen" in text); device for guiding fish away from turbines
System:	In this chapter, "system" is used synonymously with FCRPS to represent the impounded portion of the lower Snake and lower Columbia Rivers; system survival is survival past eight projects
Tailrace	Portion of reservoir immediately downstream from dam
T/C, TCR:	Transport-to-control ratio; a ratio of the returns of marked fish in experimental groups that were transported to the returns of marked fish that migrated in-river
TDA:	The Dalles Dam