



# Oregon

Theodore R. Kulongoski  
Governor

## Department of Fish and Wildlife

Director's Office  
2501 SW First Avenue  
P.O. Box 59  
Portland, OR 97207-0059  
Voice: 503-872-5272  
Fax: 503-872-5276  
TTY: 503-872-5259  
<http://www.dfw.state.or.us>

February 6, 2003

Ms. Judi Danielson, Chair  
Northwest Power and Conservation Council  
851 SW Sixth Avenue, Suite 1100  
Portland, OR 97204-1348



Dear Ms. Danielson:

On behalf of the State of Oregon (Oregon), the Oregon Department of Fish and Wildlife is submitting the attached recommendations for revisions to Council Document 2002-16, entitled "Draft Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program" (draft mainstem plan) and dated October 2002 (Attachment 1). The revisions reflect specific recommendations Oregon made to the Northwest Power and Conservation Council (Council) on June 15, 2001. Those recommendations were in response to a request by the Council as described in Council Document 2001-4, entitled "Columbia River Basin Fish and Wildlife Program Notice of Request for Recommendations: Mainstem Plan" and dated March 14, 2001. Oregon's recommendations are presented as a "legislative-markup" of the Council Document 2002-16 and describe line-by-line changes to language in the draft. In general, the recommendations reflect the key points contained herein.

1. The Council's Columbia Basin Fish and Wildlife Program (Program) and the draft mainstem plan do not call for any significant changes to the present configuration of the hydropower system. Therefore, measures in the draft mainstem plan should represent an aggressive hydropower operations approach that results in a high likelihood of success; they do not. Oregon's recommended changes to the draft mainstem plan, particularly as they relate to flow and spill, would significantly increase the likelihood of recovery of listed salmon and steelhead, would benefit currently healthy anadromous fish populations, would benefit white sturgeon throughout the basin, and would pose no demonstrable risk of harm to bull trout or other resident fish in or immediately downstream of storage reservoirs.
2. The Program and the draft mainstem plan should represent a precautionary approach to protecting, mitigating and enhancing fish and wildlife. This means that the benefit of the

doubt, when information is uncertain, should be given to measures that benefit fish and wildlife.

3. The primary purpose of measures in the Program and the draft mainstem plan should be to meet the needs of all fish and wildlife in the basin, not to pit the needs of one species or population against the needs of another in the form of a trade-off. Measures in the draft mainstem plan fall far short of meeting the needs of anadromous and resident fish and wildlife. The draft mainstem plan should ensure that the biological impacts and risks of its measures are truly estimated and compared to similarly rigorous estimates of impacts and risks to hydropower system reliability and operations costs, and other rivers uses. Where tradeoffs between biological benefits and other beneficial uses of the hydropower system are necessary, the draft mainstem plan should describe measures that ensure the tradeoffs are equitable.
4. Where true choices exist between measures that benefit one species or population rather than another, those choices should be made based on rigorous biological decision analyses that quantitatively characterize, compare and assess the risks to each based on a comprehensive examination and assessment of the weight of evidence.
5. Oregon considers measures in NOAA Fisheries' 2000 Biological Opinion on Operation of the Federal Columbia River Power System (Biological Opinion) as the minimum necessary to avoid jeopardy to listed salmon and steelhead. If the hydropower system was operated solely or primarily to meet the needs of these stocks, much greater benefits to them would accrue. The draft mainstem plan should characterize the fish and wildlife benefits of its measures. It should also estimate the opportunity costs to fish and wildlife of its measures compared to an operational scenario that maximizes fish and wildlife benefits. This would be a truer estimate of the opportunity costs to fish and wildlife of the draft mainstem plan than a comparison only to the Biological Opinion.
6. Oregon shares the Council's desire to ensure measures are implemented in ways that maximize biological benefit for the dollars spent. However, we doubt that studies to measure incremental changes in biological benefits resulting from incremental changes in flow, spill, or other measures are feasible. Experiments are not precise enough to measure incremental changes in benefits. Nor can they be designed to distinguish between and identify the myriad of factors that may explain the response or lack of response observed. The experimental limitations of studies to delineate incremental effects of measures has been the subject of several of the Council's Independent Scientific Advisory Board's reviews (ex: Review of Lower Snake River Flow Augmentation Studies, ISAB 2001-5 dated April 27, 2001; Review of Giorgi et al. Report, ISAB 2002-1 dated June 4, 2002).
7. The draft mainstem plan should enhance flow and spill above those levels in the Biological Opinion as recommended by Oregon. The flow objectives and spill levels in the Biological

Ms. Judi Danielson

February 6, 2003

Page 3

Opinion are minimum thresholds, below which the consequences to salmon and steelhead are highly uncertain and likely extremely harmful. The flow objectives should also be met weekly, rather than seasonally. Spill should be provided as recommended by Oregon. Spill at those levels provide significant survival benefits for salmon and steelhead with minimal risk to water quality and other aquatic resources. The specific technical and scientific basis for Oregon's recommendations for flow and spill measures are contained in documents we submitted to the Council on June 15, 2001 and in the enclosed comments on the flow and spill measures in the draft mainstem plan developed jointly by the state, tribal and federal anadromous fish managers (Attachment 2).

8. Oregon recognizes that to meet the flow objectives as it recommends requires significantly different hydropower system operations, including changes to flood control operations, than those described in the Biological Opinion or draft mainstem plan. Under the present configuration of the hydropower system more water has to be provided during the spring and summer to meet the biological needs of migrating juvenile salmon and steelhead and in the fall and winter to meet spawning needs of chum and chinook downstream from Bonneville Dam. The draft mainstem plan should contain measures to secure the water or describe ways that the present system configuration may be changed to provide the water velocities needed for meeting fish survival and recovery needs.

Thank you for the opportunity to comment on the draft mainstem plan. Please direct questions to Ron Boyce (503-872-5252 EXT 5403).

Sincerely,

*Signature on Original, Hard Copy to Follow*

Lindsay A. Ball  
Director

Attachments (2)

C: Melinda Eden, Gene Derfler (OR-NPPC)  
Jim Myron (GNRO)  
Core Team

Ms. Judi Danielson  
February 6, 2003  
Page 4

Bc: Bowles, Anglin, Coenen, Nigro, Ward, Sieglitz, Boyce

*File: Danielson MS Amendments Submittal Letter.2a*

**Attachment 1**

RECOMMENDATIONS OF THE STATE OF OREGON FOR REVISIONS TO THE  
DRAFT MAINSTEM AMENDMENTS TO THE COLUMBIA RIVER BASIN FISH  
AND WILDLIFE PROGRAM, DATED OCTOBER 2002

Submitted by the Oregon Department of Fish and Wildlife

February 6, 2002

Council document 2002-16

## **Contents:**

### **Introduction 3**

- Columbia River Basin Fish and Wildlife Program 3
- 2000 Fish and Wildlife Program and the draft Mainstem Plan 3
- Expectations for the elements of the Mainstem Plan 4
- A different mainstem program for a different context 5

### **Vision for the Mainstem Plan 8**

### **Biological Objectives 10**

- Overarching objectives and priorities for the mainstem 10
- More specific objectives and performance standards -- for habitat characteristics and for population performance 12
  - mainstem habitat conditions 12
  - migration/passage conditions 15
  - resident fish/wildlife 17

### **Strategies 19**

- Overarching strategies 19
- Strategies in specific areas 21
  - mainstem habitat 21
  - juvenile and adult passage, in general 23
  - juvenile fish transportation 24
  - spill 25
  - juvenile bypass systems/adult passage 28
  - water management 29
  - monitoring and evaluation 39
  - research 41
  - annual and in-season decisionmaking 43
  - Mid-Columbia Hydroelectric Projects 44

### **Revised Transition Provisions 45**

### **Draft Analysis of the Adequacy, Efficiency, Economics and Reliability of the Regional Power System 46**

## **Introduction**

### **The Columbia River Basin Fish and Wildlife Program**

The states of the Columbia basin, Idaho, Montana, Oregon and Washington, formed the Northwest Power Planning Council, an interstate compact agency, under the authority of the Pacific Northwest Electric Power Planning and Conservation Act of 1980. The Power Act directs the Council to develop a program to protect, mitigate and enhance the fish and wildlife of the Columbia River Basin affected by the development and operation of the basin's hydroelectric facilities, while also assuring the Pacific Northwest an adequate, efficient, economical and reliable power supply. The Act also directs the Council to inform the public about fish, wildlife and energy issues and to involve the public in its decisionmaking.

The Council's Columbia River Basin Fish and Wildlife Program, first adopted in 1982 and periodically revised, is the nation's largest regional effort to recover, rebuild, and mitigate impacts on fish and wildlife. As a planning, policy-making and reviewing body, the Council develops and then monitors implementation of the fish and wildlife program, which is implemented by the federal agencies that manage, operate and regulate the basin's hydroelectric facilities -- the Bonneville Power Administration, the U.S. Army Corps of Engineers, the Bureau of Reclamation, and the Federal Energy Regulatory Commission and its licensees.

### **The 2000 Fish and Wildlife Program and the draft mainstem plan**

In 2000, the Council adopted a set of amendments to the fish and wildlife program to begin what will eventually be a complete revision of the program. In the first phase of the amendment process, the Council reorganized the program around a comprehensive framework of scientific and policy principles. The fundamental elements of the program as revised are the *vision*, which describes what the program is trying to accomplish with regard to fish and wildlife and other desired benefits from the river; basinwide *biological performance objectives*, which describe in general the fish and wildlife population characteristics needed to achieve the vision; implementation *strategies*, which will guide or describe the actions needed to achieve the desired ecological conditions; and a *scientific foundation*, which links these elements and explains why the Council believes certain kinds of actions should result in desired habitat conditions and why these conditions should improve fish and wildlife populations in the desired way.

The program amendments in 2000 set the stage for subsequent phases of the program revision process, in which the Council will adopt more specific objectives and action measures for the river's mainstem and the tributary subbasins, consistent with the basinwide vision, objectives and strategies in the program and its underlying scientific foundation. The Council intends to incorporate these specific objectives and measures into the program in locally developed subbasin plans for the more than sixty subbasins of the Columbia River and in a coordinated plan for the mainstem Columbia and Snake rivers. This document is a draft of the *mainstem plan* that the Council is proposing to adopt into the program.

In preparing this draft mainstem plan, the Council solicited recommendations from the region's state and federal fish and wildlife agencies, Indian tribes, and others, as required by the Northwest Power Act. Various agencies and tribes responded, and the Council also received recommendations from other interested parties. The Council prepared this draft after reviewing the recommendations, supporting information submitted with the recommendations and comments received on the recommendations. The Council will conduct an extensive public comment period on the draft mainstem plan before finalizing the program amendments in early 2003.

### **Expectations for the elements of the mainstem plan**

The role of the mainstem plan and the Council's expectations for the elements of that plan were described in the 2000 Fish and Wildlife Program, in the section on Basinwide Hydrosystem Strategies and in the section entitled Schedule for Further Rulemakings. The mainstem plan is to contain the specific objectives and action measures that the program calls on the federal operating agencies and others to implement in the mainstem Columbia and Snake rivers, including especially the operations of the hydrosystem, to protect, mitigate and enhance fish and wildlife affected by the development and operation of the hydroelectric facilities, while assuring the region an adequate, efficient, economical and reliable power supply. The draft mainstem plan includes objectives and measures relating to, among other matters:

- the protection and enhancement of mainstem habitat, including spawning, rearing, resting and migration areas for salmon and steelhead and resident salmonids and other fish;
- system water management;
- passage spill at mainstem dams;
- adult and juvenile passage modifications at mainstem dams;
- juvenile fish transportation;
- adult survival during upstream migration through the mainstem;

- reservoir elevations and operational requirements to protect resident fish and wildlife;
- water quality conditions; and
- research, monitoring and evaluation.

The Council evaluated the mainstem plan recommendations and these draft program amendments for consistency with the program framework elements adopted in 2000, including the vision, biological objectives, habitat and hydrosystem strategies and underlying scientific principles.

### **A different mainstem plan for a different context**

Past versions of the Council's fish and wildlife program, including the most recent revision in 1994-95, specified in great detail the system operations for fish and wildlife that the Council and recommending entities called for from the federal operating agencies. In December 2000, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service issued Biological Opinions for the operation of the Federal Columbia River Power System to benefit populations of salmon, steelhead, bull trout and white sturgeon listed as threatened or endangered under the federal Endangered Species Act. The hydrosystem measures in these opinions run to hundreds of pages of detail and hundreds of measures on system configuration, river flows, reservoir management, passage improvements, spill, juvenile transportation, predator management and more. These measures are built on foundations developed in the Council's program over the past 20 years.

The Council asked for recommendations addressing, in part, how the Council's mainstem plan should relate to these biological opinions on hydrosystem operations. The relevant recommendations received can be loosely grouped into four categories:

- recommendations that the Council adopt a mainstem plan consistent with the objectives and measures in the biological opinions;
- recommendations that concluded that the biological opinions do not prescribe sufficient flow, spill and passage operations to benefit listed fish, and so the Council should adopt additional measures to that end;
- recommendations that concluded that the biological opinions exceeded what was necessary to benefit listed fish, to the detriment of the power supply and other uses of the river, and so the Council should adopt a mainstem plan with scaled back flow and spill operations that are, in their view, more biologically and economically efficient in how the limited resources of the region are applied; and
- recommendations that concluded that the operations specified in the biological opinions are not sufficient to protect, enhance or mitigate for the adverse effects

of the hydrosystem on non-listed fish and wildlife, and may be especially adverse to resident fish (listed and non-listed), and so the Council should adopt objectives and measures for that purpose, which would be either supplemental to or in some cases in conflict with current implementation approaches to biological opinion operations.

The Council considered and drew from recommendations in all four categories in developing this draft mainstem plan. In some parts of the draft this has meant highlighting alternative operational strategies. The Council is seeking public comment on all parts of the draft mainstem plan, but is particularly interested in receiving comment on resolving the difficult issues represented by these alternatives.

In general, however, two overriding concerns have motivated the Council in deciding what objectives and measures to include in this draft mainstem plan:

- The draft mainstem plan includes a set of habitat considerations, objectives, principles and measures intended to protect, mitigate and enhance *all* the fish and wildlife of the Columbia River Basin that have been affected by the development, operation and management of the hydrosystem and that inhabit the mainstem of the Columbia and Snake rivers during part or all of their lives, whether listed or not, as required of the Council by the Power Act. Objectives, actions and operations intended to protect, enhance and mitigate for the effects of the hydrosystem on species other than those listed as threatened or endangered may require federal agency flexibility or changes in the implementation of the biological opinions, as described below.
- Scientific and policy uncertainty continue to plague a number of mainstem actions intended to benefit anadromous fish, leading to an inability to measure the extent of the benefits gained and to great differences of opinion as to the value of continuing these actions. Moreover, some of these actions may have adverse impacts on resident fish and high costs to the power system. The draft mainstem plan includes provisions for how to improve the way the region engages in fish and wildlife research, power system research, monitoring and evaluation for the mainstem and how and what decisions are made on the basis of that information. This includes describing an approach and set of factors for prioritizing research; recommendations for specific priorities for mainstem research; and suggestions for how to better integrate research, monitoring and evaluation results into decisions made about mainstem actions and power system operations in the context of the Columbia basin as a whole. The Council's ultimate goal is to be able to provide recommendations to the federal operating agencies and fish and wildlife agencies for more biologically effective spill, flow and other mainstem

operations and actions at the minimum economic cost. The Council understands the biological opinions to be sufficiently flexible in implementation to be able to accommodate recommendations of this type; that is, the biological opinions were adopted with the recognition that as new scientific information is developed, actions called for in the opinions could and, where found appropriate, would be changed.

The Council will review the comments on the proposed vision, objectives and strategies in this draft mainstem plan and then decide, consistent with the review procedures and standards in the Power Act, what are the most appropriate mainstem vision, objectives and strategies for both listed and non-listed species.

Another difference between this and past Council mainstem programs concerns the region's power supply requirements. The Power Act requires the Council to adopt a fish and wildlife program that not only protects, mitigates and enhances fish and wildlife but also assures that the region will continue to enjoy an adequate, efficient, economical and reliable power supply. The Council has evaluated current hydrosystem operations, the recommendations for mainstem amendments, and these draft amendments in an effort to ensure that the Council adopts objectives and measures for mainstem system operations that both meet the fish and wildlife requirements of the Power Act and are consistent with its power supply obligations. The Council has also reviewed the latest scientific information and comments on the effectiveness of recommended fish and wildlife strategies in increasing the survival of specific populations.

Energy systems, markets and policy have changed radically since the last revision of the fish and wildlife program in the mid-1990s. Federal hydrosystem operations in 2001 brought a concrete example of a problem that the Council had seen developing over the last half-decade -- the electricity load demands placed on the federal hydrosystem were increasingly greater than what the federal system could produce in a year of historically low runoff and river levels. Yet the dynamics of regional and west coast energy developments prevented the Bonneville Power Administration from acquiring new, long-term resources that could have closed the gap. Problems with west coast power markets in 2000-01 prevented Bonneville from being able to make up the energy deficit in those markets, leading to a situation in 2001 in which the federal agencies were forced to curtail regional load and reduce system operations intended to benefit fish and wildlife in order to maintain the reliability of the region's power system. Even with significant changes to the hydropower operations specified for fish, the system still produced inadequate energy to meet the demands of the region. This forced many of the region's utilities to curtail loads while also spending large sums to purchase power.

For these reasons, the draft analysis of the adequacy, efficiency, economics and reliability of the region's power supply that accompanies the draft mainstem plan includes consideration of the current status of the region's power system. The Council's draft conclusion is that the region's power system should be adequate and reliable for the next few years, due to power supply, demand and loss of load developments that have occurred since early 2001, and that the objectives and measures to protect, mitigate and enhance fish and wildlife included in this draft mainstem plan will not affect that conclusion. The analysis also concludes, however, that the region faces the possibility in later years of spiraling back into the power supply problems seen in 2001, unless measures are taken to ensure that new resources are added to the regional power supply in a more certain fashion than now seems likely. The analysis suggests possible actions by the federal agencies and by others in the region that will ensure that the federal system is better able to provide the specified operations for fish and wildlife and meet appropriate load demands in at least most if not all low-water years. The Council has begun the process of reviewing and revising its 20-year power plan as called for by the Northwest Power Act. The power plan will address in more detail the region's power supply and reliability issues.

## Vision for the Mainstem Plan

The long-term vision of the Council's 2000 Fish and Wildlife Program is for a Columbia River Basin ecosystem that sustains abundant, productive and diverse communities of fish and wildlife, mitigating across the basin for the adverse effects to fish and wildlife caused by the development and operation of the hydrosystem and providing the benefits from fish and wildlife valued by the people of the region. This ecosystem provides abundant opportunities for tribal and treaty right harvest and for non-tribal harvest of fish and wildlife, and for the recovery of fish and wildlife affected by the operation of the hydrosystem. This ecosystem is ecologically resilient and able to maintain its characteristics in the face of environmental variation. This program is to be "habitat-based."

Wherever feasible, the program vision is to be accomplished by protecting and restoring the natural ecological functions, habitats, and biological diversity of the Columbia River Basin.<sup>1</sup> Where this is not feasible, other methods that are compatible with naturally reproducing fish and wildlife populations will be used. Where impacts have irrevocably changed the ecosystem, the program will protect and enhance the habitat and species assemblages compatible with the altered ecosystem. Actions taken under the program will provide conditions that meet water quality standards under the Clean Water Act. They must also be cost-effective and not put at risk the region's adequate, efficient, economical and reliable power supply.

The vision for the mainstem plan is consistent with the broader program vision set out above. Hydrosystem operations, fish passage efforts, habitat improvement investments, and other actions in the mainstem should be directed toward protecting, enhancing, restoring, and connecting<sup>2</sup> natural river processes and habitats to allow for

---

<sup>1</sup> Throughout the provisions of these draft amendments, the Council's position is not contrary to that of the National Marine Fisheries Service's 2000 Biological Opinion with reference to any and all considerations of breaching lower Snake River hydroprojects.

<sup>2</sup> "Restore" as used in the mainstem plan means to take an action in a particular area that currently has no habitat value for spawning or rearing or other desired population condition (because, for example, the area has been blocked, or inundated, or dewatered at an inopportune time), so that the area will have value for that purpose. It does not mean to re-establish the conditions that existed at any particular point in time, including the time before non-Indian settlement and development of the Columbia basin, and it does not mean or imply a Council position in support of the breaching of dams in the mainstem.

abundant, productive and diverse fish and wildlife populations, especially spawning, rearing, resting and migration habitats for salmon, steelhead, sturgeon and resident fish populations. This vision includes providing conditions within the hydrosystem for adult and juvenile fish that: (a) most closely approximate natural physical and biological conditions; (b) support the expression of life history diversity; (c) allow for adequate levels of mainstem survival to support fish population recovery in the subbasins; and (d) ensure that water management operations are optimized to meet the needs of anadromous and resident fish species, including those in upstream storage reservoirs so that actions taken maximize benefits to all species while ensuring an adequate, efficient, economical, and reliable power supply. Any system changes needed to achieve these goals must be implemented in such a way and over a sufficient time period to allow the region to make whatever power system adaptations are needed, if any, to maintain an adequate, efficient, economical and reliable power supply.

---

“Enhance,” by contrast, when referring to habitat conditions, means to take an action in an area that presently has some value for spawning or rearing or other desired condition so as to increase that value.

“Connecting” habitat becomes important when a migrating population has areas of productive habitat that it cannot use to full advantage (or use at all) because they are unable to access that habitat or because the areas in between productive habitat that the population must make use of are not productive without habitat improvements. It also does not mean or imply a Council position in support of the breaching of dams in the mainstem.

## **Biological Objectives**

### **Overarching objectives and priorities for the mainstem**

The biological objectives stated here for the mainstem plan are intended to be based on and consistent with the biological objectives stated in the 2000 Fish and Wildlife Program.

These biological objectives and accompanying operational strategies are designed to improve the life-cycle survivals of important populations of listed and unlisted salmon, steelhead, resident fish and wildlife. The Council's goal is to apply the available resources in the most effective way possible to achieve protection, mitigation, recovery, and delisting in the shortest possible time frame. This demands that the Council set clear priorities for resource expenditures to protect, mitigate and enhance fish and wildlife populations so as to assure that the fish and wildlife benefits are achieved at the least cost to the region's financial and water resources.

One of the overarching biological objectives for the program as a whole is the recovery of the anadromous and resident fish and wildlife affected by the development and operation of the hydrosystem that are listed for protection under the Endangered Species Act. Federal hydrosystem operations to benefit fish are now focused on listed populations through the 2000 Biological Opinions on the Operation of the Federal Columbia River Power System from the National Marine Fisheries Service (anadromous fish) and the U.S. Fish and Wildlife Service (Kootenai white sturgeon and bull trout). The achievement of these biological performance objectives for listed species as stated in the biological opinions is a key biological objective of the Council's program and this draft mainstem plan, *except where these objectives are inconsistent with specific objectives and strategies included in this mainstem plan.*

Although the Council recognizes the importance of mainstem and out-of-subbasin influences as primary limiting factors for listed anadromous salmonids, under the Northwest Power Act, the Council has an obligation to protect, mitigate and enhance *all* the fish and wildlife of the Columbia basin affected by the development, operation and management of the hydrosystem. Concern over populations listed under the Endangered Species Act is but one part of the Council's broader mandate. And so a broader goal of the program, as stated in the overarching objectives of the program framework, is to provide habitat conditions that sustain abundant, productive and diverse fish and wildlife populations, so as to allow for recovery of listed species *and* abundant opportunities for tribal trust and treaty right harvest and non-tribal harvest.

In addition, the science relating to the rebuilding of Pacific salmon, as incorporated into the objectives and habitat strategies in the 2000 Fish and Wildlife Program, indicates that success in protecting and enhancing abundant and diverse naturally spawning populations of salmon and steelhead and other native fish requires an emphasis on protecting, enhancing, connecting and restoring habitats and populations that are relatively productive. This is a priority for actions that should be equal to protecting migration and spawning conditions for listed populations. This priority includes, for example, protecting and improving mainstem migration conditions for important non-listed tributary populations in the middle part of the river, such as spring chinook in the John Day and Deschutes rivers. And in a system in which historically the most productive populations were those that spawned in the mainstem or the lower part of the tributaries, as described in the habitat strategies in the 2000 Fish and Wildlife Program, and which have either been totally extirpated (e.g., the populations in the mainstem of the upper Columbia above Chief Joseph, or spawning in the area now inundated by the John Day Dam pool) or are relatively productive (Hanford Reach fall chinook), this plan provides an emphasis on protecting and restoring mainstem spawning and rearing habitats and populations. These general objectives for the mainstem are consistent with and incorporate the basinwide vision, biological objectives and habitat and hydrosystem strategies in the 2000 Fish and Wildlife Program framework.

## **More specific objectives and performance standards -- for habitat characteristics and for population performance**

### **Mainstem habitat conditions**

- Identify and protect the habitat areas and ecological functions that are at present relatively productive for spawning, resting, rearing and migrating salmon and steelhead in the mainstem. This includes, among other things, protecting the Hanford Reach fall chinook habitat by determining and providing appropriate spawning and rearing flows. In addition, where feasible, restore and enhance habitats and ecological functions that connect to the protected productive areas to allow for the expansion of productive populations and to connect weaker populations to stronger populations and to each other, so as to restore more natural population structures.
- Protect, enhance, restore and connect freshwater habitat in the mainstem for the life history stages of naturally spawning anadromous and resident salmonids. Protect and enhance ecological connectivity between aquatic areas, riparian zones, floodplains and uplands in the mainstem.
  - Enhance the connections between the mainstem sections of the Columbia and Snake rivers and their floodplains, side channels and riparian zones.
  - Manage mainstem riparian areas to protect aquatic conditions and form a transition to floodplain terrestrial areas and side channels.
  - Identify, protect, enhance and restore the functions of alluvial river reaches in the mainstem.
  - Where feasible, reconnect protected and enhanced tributary habitats to protected and enhanced mainstem habitats, especially in the area of productive mainstem populations.
- Allow for biological diversity to increase among and within populations and species to increase ecological resilience to environmental variability.
  - Expand the complexity and range of mainstem habitats to allow for greater life history and between species diversity.
  - Manage human activities in the mainstem, such as passage at mainstem dams, transportation and harvest, to minimize artificial selection or limitation of life history traits.
- Increase the amount of spawning habitat for fall chinook core populations in the lower and mid Columbia area and in the lower Snake area. The Council acknowledges the recommendation from the four tribes of the Columbia River

Inter-Tribal Fish Commission that the federal agencies act to provide 9,000 additional acres of spawning habitat for Snake River fall chinook and 40 additional miles of fluvial spawning habitat for mid-Columbia fall chinook core populations, derived at least in part from the Independent Scientific Group's *Return to the River*. However, the Council does not adopt at this time these or any other numerical targets for increased fall chinook spawning habitat. Instead, the Council will consult with the state and federal fish and wildlife agencies, tribes, federal operating agencies, the Independent Scientific Advisory Board, and the Independent Economic Advisory Board to evaluate the scientific soundness, achievability and implications of the tribes' recommended targets as well as other reasonable alternatives, and then in a public review process consider adoption of a set of numerical objectives for additional mainstem spawning habitat.

- Where feasible, manage the hydrosystem so that patterns of flow more closely approximate the natural hydrographic patterns. Ensure that any changes in water management are premised upon, and proportionate to, scientifically demonstrated fish and wildlife benefits. Examples of management actions or limitations consistent with this objective include:
  - Attempt to provide natural spring freshets below the storage projects, within flood control constraints.
  - Increase the likelihood of storage reservoir refill, and then provide flows out of the storage reservoirs over an extended period of the summer and fall so as to minimize fluctuations determined to be harmful to fish and wildlife.
  - Apply rules of operation for all the storage projects, such as the Integrated Rule Curves developed by the Montana Department of Fish, Wildlife and Parks for Libby and Hungry Horse dams, so that drawdown and refill take local inflows into account, and so that the reservoirs, in concert, can shape the water to benefit fish in and immediately below the reservoirs and then, as the water travels downstream, benefit anadromous fish.
  - Operations should meet the requirements of both resident and anadromous fish.
- Operate the storage projects and manage water through the system consistent with the following objectives:
  - The amount of flow augmentation and the release schedule from storage reservoirs should be based on the best available science for each target species (resident or anadromous) and weighted for the greatest benefit to all species.
  - Protect biological production in the rivers and in the storage reservoirs during the most productive period of the year, by drafting each storage reservoir according to elevation limitations that, when combined with projected inflows, results in fluctuations in outflows in the summer months of July

through September that are not harmful to fish and wildlife, and in biologically appropriate reservoir levels throughout the same period.

- Identify, protect, enhance, restore and connect ecosystem functions in the Columbia River estuary and nearshore ocean discharge plume as affected by actions within the Columbia River mainstem. Evaluate flow regulation and changes to estuary-area habitat and biological diversity to better understand the relationship between estuary ecology and near-shore plume characteristics and the productivity, abundance and diversity of salmon and steelhead populations.
- Where feasible, pursue restoration of anadromous fish into mainstem areas blocked by dams. Where this is not feasible, other measures will be used to protect, mitigate and enhance the related habitat and species assemblages. Other measures will also be used where the Federal Energy Regulatory Commission, in deciding whether to issue a license for a non-federal project on the mainstem, has taken this objective into account to the fullest extent practicable at each relevant stage of decisionmaking -- as required by the Northwest Power Act -- but has decided not to require reintroduction of anadromous fish into an area blocked by that dam.

## **More specific objectives and performance standards -- for habitat characteristics and for population performance (cont.)**

### **Migration/passage conditions for anadromous fish**

- Significantly improve mainstem survival and production of anadromous fish by enhancing in-river migration, habitat, and water quality conditions to meet ESA requirements of NMFS' 2000 FCRPS Biological Opinion, short-term mitigation requirements of the 2000 Program, and state and federal water quality requirements of the Clean Water Act.
- The National Marine Fisheries Service's 2000 Biological Opinion includes project-by-project survival performance rates for in-river passage of affected life stages of listed salmon and steelhead through the eight federal dams in the lower Columbia and lower Snake rivers. Table 9.2-3. The program adopts these objectives. Achieve these objectives at the minimum economic cost.
- On an interim basis, the project-by-project survival performance rates also apply for inriver passage of affected life stages of non-listed salmon and steelhead that migrate through the system. The Council will consult with the state and federal fish and wildlife agencies and tribes, the Independent Scientific Advisory Board and federal operating agencies (a) to evaluate whether these project-by-project performance rates should be adjusted for any affected, non-listed populations, (b) to evaluate whether to adopt project-by-project passage survival performance rates for the non-federal projects in the mid-Columbia area, and (c) to determine the possibility of adopting system survival performance rates for all relevant populations.
- Maximize spillway survival by selecting the most biologically effective level of spillway discharge at each specific project while not exceeding interim gas supersaturation standards.<sup>3</sup> Balance spillway survival probabilities against spillway passage efficiency and the efficiency and probabilities of other passage routes in order to determine the passage methods, including spill volumes, that

---

<sup>3</sup> Under current system operations for migrating anadromous fish, including under 2000 Biological Opinion operations, the federal operating agencies must secure waivers to the existing water quality standards to allow for spill operations that will result in total dissolved gas supersaturation levels of up to 120 percent in tailraces and 115% in forebays. The Council considers current operations as well as any other specific spill operations included in these draft amendments to be "interim" while the Council works with the region to determine the most biologically effective level of spillway discharge at each project and for the system as a whole.

maximize the survival of the fish passing the entire dam and minimize fall back and other effects on adult salmon.

- Improve adult migration survival through the system.
- As an interim objective, contribute to achieving smolt-to-adult survival rates (SARs) in the 2-6 percent range (minimum 2 percent; average 4 percent) for listed Snake River and upper Columbia salmon and steelhead. The Council will consult with the state and federal fish and wildlife agencies and tribes, the Independent Scientific Advisory Board and the federal operating agencies to evaluate the scientific soundness and achievability of, and impact of ocean conditions on, these smolt-to-adult survival rate objectives. The Council will then, in a public review process, either confirm these smolt-to-adult survival rates as program objectives or revise to different objectives. The Council will investigate at the same time the possibility of developing smolt-to-adult survival rate objectives for other populations.

**More specific objectives and performance standards -- for habitat characteristics and for population performance (cont.)**

**Resident fish/wildlife**

- Significantly improve mainstem survival and production of resident fish by enhancing in-river migration, habitat, and water quality conditions to meet ESA requirements of USFWS's 2000 FCRPS Biological Opinion, short-term mitigation requirements of the 2000 Program and state and federal water quality requirements of the Clean Water Act.
- Provide conditions that support the needs of resident fish species in upstream reservoirs and river reaches as well as the needs of anadromous and resident species in the lower parts of the mainstem.
- In accordance with Section 4(h)(11)(A) of the 1980 Power Act, and the Council's primary strategy for hydrosystem (fish) passage and operations under the 2000 Fish and Wildlife Program, the Administrator and other federal agencies responsible for managing, operating or regulating any federal or non-federal hydroelectric facility for purpose of flow or spill advantages to listed species shall assure, in consultation with the Secretary of the Interior and the Administrator of the National Marine Fisheries Service, together with state fish and wildlife agencies and appropriate Indian tribes, that flow and spill operations are optimized to produce the greatest biological benefits for both anadromous and resident fish.
- Enhance abundance and productivity of white sturgeon in the mainstem. Mitigate for lost production by restoring abundance and productivity of naturally-produced white sturgeon so that reservoir populations can sustain annual harvest or the harvestable equivalent of 5 kg/ha. Operate the hydropower system to maximize spawning and rearing success of white sturgeon in reservoirs, while operating consistent with the needs of salmonids.
- The U.S. Fish and Wildlife Service's 2000 Biological Opinion concerning hydrosystem operations that affect listed Kootenai white sturgeon includes specific objectives for that species, which are incorporated here. The water management strategies in this draft mainstem plan (below) include a sturgeon operation strategy that is a minor refinement of the flow strategy in the Fish and Wildlife Service's Biological Opinion, and which is intended to be a more effective operation for achieving the objectives in the opinion and in this program.
- Restore abundance and productivity of bull trout populations using the Columbia River to move between tributary streams. Provide mainstem conditions that help to protect and enhance bull trout habitat and thus help to enhance the abundance and productivity of

bull trout populations. The U.S. Fish and Wildlife Service's 2000 Biological Opinion concerning hydrosystem operations that affect listed bull trout populations includes objectives for that species, which are adopted here.

- Significantly improve survival and production of wildlife species associated with riparian /riverine habitats by achieving and sustaining levels of habitat replacement and species identified in the 1995 Fish and Wildlife Program as a means of fully mitigating wildlife losses caused by the development and operation of the hydrosystem and to meet short-term mitigation requirements of the 2000 Program.
- Contribute to providing the conditions necessary to restore populations of native fish and wildlife in the areas above and below Hungry Horse and Libby Dams to self-sustaining levels capable of supporting harvest. This includes protecting, restoring, and enhancing reservoir, riparian and wetland habitats above and below Hungry Horse and Libby Dams to meet the goals set forth in the management and mitigation plans and the recommendations of the Montana Department of Fish, Wildlife and Parks and the Confederated Salish-Kootenai Tribes.<sup>4</sup> As part of this objective, restore normative conditions in the seasonal pattern and stability of river discharges and reservoir conditions; restore in-channel habitat structure, function, and complexity; restore riparian and wetland habitats and floodplain function, and maintain temperatures within the tolerance range of native fish species.
- Contribute to providing the conditions necessary to protect spawning and rearing habitat for fish in and adjacent to Lake Roosevelt so as to build fish populations to levels capable of supporting harvest consistent with the goals set forth in the management and mitigation plans and the recommendations of the Spokane and Colville Tribes.<sup>5</sup>
- Improve survival and production of wildlife species in the mainstem affected by the development, operation and management of the hydrosystem by reducing limiting factors to wildlife in the mainstem and improving riverine and riparian mainstem habitat conditions for these species.

---

<sup>4</sup> When the Council adopts subbasin plans into the program, which will supersede existing management and mitigation plans, the objective will be to implement the strategies and achieve the objectives in the relevant subbasin plans.

<sup>5</sup> When the Council adopts subbasin plans into the program, which will supersede existing management and mitigation plans, the objective will be to implement the strategies and achieve the objectives in the relevant subbasin plans.

## Strategies

### Overarching strategies

- The strategies stated here for the mainstem plan are intended to be based in and consistent with the general basinwide objectives and habitat and hydrosystem strategies stated in the 2000 Fish and Wildlife Program.
  
- All decisions on actions that affect or are intended to benefit fish and wildlife in the mainstem Columbia and Snake Rivers -- whether embedded in long-range plans, annual plans or in-season management, and whether concerning water management or passage or reservoir operations -- should reflect or be based on the following general strategies:
  - Protect habitat that supports existing populations that are healthy and productive. Efforts should include expansion of adjacent habitats that have been historically productive or have a likelihood of sustaining healthy populations by reconnecting or improving habitat.
  - Restore habitat needed by populations at risk of extinction. As with healthy populations, restoration should protect habitat where portions of those populations are doing relatively well, and expand adjacent habitats that improve production.
  - 
  - Protect biological diversity by benefiting the range of species, stocks and life-history types in the river.
  - Provide conditions that best fit those natural behavior patterns and river processes that most closely approximate the physical and biological conditions needed by the relevant species.
  - With regard to hatchery populations of salmon and steelhead, prioritize mainstem protection and support to those hatchery populations that constitute mitigation by the federal hydrosystem operators for extirpated populations or for reduced productivity of existing populations. In addition, assign a high priority to hatchery populations that provide the most significant contribution to the rebuilding of naturally spawning populations in areas of program habitat investments, or that provide the most significant contributions to harvest while ensuring the least detrimental impacts on the survival of native fish species.

- Optimize actions to produce the greatest biological benefits for the targeted species with the least cost and the least adverse effects on other species while ensuring an adequate, efficient, economical, and reliable power supply.
- In December 2000, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service adopted Biological Opinions for the operation of the Federal Columbia River Power System for the benefit of populations of salmon, steelhead, bull trout and Kootenai white sturgeon listed as threatened or endangered under the Endangered Species Act. The measures in these opinions represent the recommendations of the federal fish and wildlife agencies with jurisdiction over the operational needs of these listed species. The Council accepts these measures as part of the Council’s program for the near term, *except where these measures are inconsistent with specific objectives and measures included in this mainstem plan*. However, many of the Biological Opinion measures must be subject to systematic and rigorous monitoring and evaluation, as described in the more specific strategies below, to determine if the measures have the biological benefits expected and represent the most cost-effective actions to achieve these benefits. These evaluations may result, after the adoption of this mainstem plan, in Council recommendations to the federal operating and fish and wildlife agencies for operations that differ from the current suite of operations called for in the Biological Opinion measures, based on the Council’s conclusion that these different operations provide the same or greater benefits to listed fish and wildlife than current operations at less cost. The Council is confident that changes in operations of this nature can be made consistent with the flexibility built into the Biological Opinions.
- The 2000 NMFS and USFWS Biological Opinion operations may not be optimal when the needs of fish and wildlife other than listed species are taken into account. Based on the vision, the biological objectives and the overarching strategies stated above, the Council is adopting principles and measures that are also intended to benefit fish and wildlife affected by the hydrosystem other than listed species and meet the biological objectives and vision described above. These principles and measures may require changes in certain operations or priorities under Biological Opinion implementation. The Council is confident that these changes can also be made consistent with the flexibility built into the Biological Opinions and without adverse effects on the listed species, and will lead to a more broad-based, sustainable and cost-effective protection and recovery of fish and wildlife in the Columbia basin. The Council calls on the federal operating agencies and fish and wildlife agencies to consult with the Council, the states and the tribes on the implementation of these measures.



## Strategies in specific areas

### Mainstem habitat

- By means of system operations and investments in mainstem habitat improvements, increase the extent, diversity, complexity, and productivity of mainstem habitat by protecting, enhancing and connecting to mainstem spawning, rearing and resting areas to achieve the biological objectives stated above. Actions to consider include, but are not limited to:
  - providing appropriate spawning, rearing and resting flows in the mainstem
  - excavating backwater sloughs, alcoves and side channels
  - reconnecting alcoves, sloughs, and side channels to the main channel
  - dredging/excavation of lateral channels that have silted in
  - enhancement of wetlands
  - creating islands and shallow-water areas
  - adding large woody debris to these systems
  - stabilizing the water levels of the rivers and reservoirs to the extent practicable
  - planting riparian and aquatic plants at appropriate locations
  - acquiring and protecting lands adjacent to the mainstem
- Federal and state fish and wildlife agencies should analyze each proposed action to increase mainstem spawning and rearing habitat to ensure that the proposal may be implemented without adversely affecting the migration of listed populations through the mainstem.
- In instances where proposed operations to protect or enhance mainstem spawning and rearing habitat may conflict with operations intended to benefit juvenile or adult salmon migration, the system operators and the fish and wildlife agencies and tribes should identify potential conflicts, priorities, trade-offs and opportunities, and consult with the Council, affected entities and the public on how best to resolve conflicting needs.
- The National Marine Fisheries Service's 2000 Biological Opinion calls on the federal operating agencies in conjunction with the Environmental Protection Agency and the U.S. Geological Survey to develop a program to (1) identify mainstem habitat sampling reaches, survey conditions, describe cause-and-effect relationships, and identify research needs; (2) develop improvement plans for all mainstem reaches; and (3) initiate improvements in three mainstem reaches. The Council adopts a similar measure as well, provided that this mainstem habitat initiative not focus wholly or even predominantly on the mainstem habitat needs of the populations currently listed. Salmon mitigation, enhancement and

rebuilding opportunities in the mainstem may have greater relation to non-listed populations than for listed populations.

- Evaluate the feasibility of reintroducing anadromous fish into blocked areas, including above Chief Joseph and Grand Coulee dams.
- Identify the level of importance in protecting or improving mainstem habitat for recovering bull trout populations. The Council calls on the relevant state and federal fish and wildlife agencies to conduct the necessary research and report the analysis to the Council at the earliest possible date.
- Develop and implement actions that create littoral habitat and fish structures along the shores of Lake Roosevelt to diversify food available to fish and provide additional rearing habitat.
- Implement recovery actions to stabilize the upper Columbia and Kootenai River white sturgeon.
- Implement recovery actions to stabilize the burbot populations in the upper Columbia.<sup>6</sup>

---

<sup>6</sup> When the Council adopts subbasin plans into the program, which will supersede existing management and mitigation plans, the objective will be to implement the strategies and achieve the objectives relating to white sturgeon, burbot and Lake Roosevelt fisheries stated in the relevant subbasin plans.

## Strategies in specific areas (cont.)

### **Juvenile and adult passage, in general**

- Consistent with the biological objectives and overarching strategies above, all actions to provide or improve juvenile and adult fish passage through mainstem dams should protect biological diversity by benefiting the broad range of species, stocks and life-history types in the river, not just listed species, and should favor solutions that best fit natural behavior patterns and river processes. To meet the diverse needs of multiple species and allow for uncertainty, multiple juvenile passage methods may be necessary at individual projects.
- The U.S. Army Corps of Engineers, working within the regional fish and wildlife project selection process, should report to the Council annually on how decisions on passage improvements take into account the strategies in the Council's program. In addition, the Council (1) expects that the Independent Scientific Review panel will apply these principles during the panel's review of the reimbursable portion of the Bonneville fish and wildlife budget, which includes the Corps' passage program; (2) will itself apply these standards in its review of any Independent Scientific Review Panel report and resulting recommendations to Congress on these passage budget items; and (3) will recommend to Congress, in its reimbursable budget recommendations, that budget requests from the Corps of Engineers be evaluated for consistency with these principles.
- The Corps of Engineers should apply Value Engineering to all projects that exceed \$1 million.
- For the purpose of planning for this fish and wildlife program, and particularly the hydrosystem portion of the program, the Council assumes that, in the near term, the breaching of any dams in the mainstem will not occur. The Council revises its fish and wildlife program every five years, at a minimum. If, within that five-year period, the status of the lower Snake River dams or any other major component of the Columbia River hydrosystem has changed, the Council can take that into account as part of the review process.

## Strategies in specific areas (cont.)

### Juvenile fish transportation

- Because the existence of the dams and reservoirs creates conditions that are not natural, the Council seeks to improve inriver conditions by increasing flow, providing spill, and improving bypass survival. The Council endorses the strategy of “spread the risk”, by bypassing fish as needed to allow transportation of no more than 50% of the populations during spring and summer, and gives priority to the funding of research that more accurately measures the effect of improved inriver migration compared to transportation. Research should compare returns of adult salmonids to spawning grounds.
- The National Marine Fisheries Service’s 2000 Biological Opinion includes a series of measures concerning the transportation of listed juvenile salmon and steelhead. These are part of the Biological Opinion measures that the Council incorporates into its mainstem plan, as described above.
- In analyzing in any year the potential benefits of maximizing or minimizing transportation, the federal operating agencies must recognize that significant populations of salmon and steelhead important to the biological objectives of this program enter the mainstem hydrosystem either below the transport projects altogether or above McNary Dam but are not effectively transported at McNary. In-river passage of these fish is either the only passage alternative available or the most significant passage alternative.
- The three highest priorities for juvenile transportation studies should be to:
  - (1) evaluate whether the survival benefits of transport of subyearling fall chinook salmon from McNary Dam are sufficiently greater, at least under certain circumstances, than in-river passage to justify continuing (or increasing) the transport effort from that dam;
  - (2) conduct a transportation study that targets Snake River fall chinook; and
  - (3) more clearly determine what delayed survival effects, if any, occur due to transport, such as adverse effects on homing behavior.
- The National Marine Fisheries Service should conduct annual evaluations of the effectiveness of transportation and report the results to the Council and the Independent Scientific Advisory Board.

## Strategies in specific areas (cont.)

### Spill

- Implement 2000 NMFS Biological Opinion and additional spill at Snake and Columbia River dams:

Spill levels and gas caps for FCRPS projects during spring<sup>a</sup> and summer<sup>b</sup>. Modifications to NMFS Biological Opinion spill levels are bolded, with Biological Opinion levels in parentheses.

<u>Project</u>	<u>Spring Spill Amount<sup>c</sup> and (Hours)</u>	<u>Summer Spill Amount and (Hours)</u>	<u>Limiting Factor</u>
Lower Granite	60 kcfs (6PM-6AM)	N/A	Gas cap
Little Goose	45 kcfs (6PM-6AM)	N/A	Gas cap
Lower Monumental	40 kcfs (24 hours)	N/A	Gas cap
Ice Harbor	100 kcfs night and 45 kcfs day (24 hours)	100 kcfs night and 45 kcfs day (24 hours)	Night- gas cap Day- adult passage
McNary	120-150 kcfs (6PM-6AM)	N/A	Gas cap
John Day	85-160 kcfs/60% instantaneous <sup>d</sup> (6PM-6AM) <sup>e</sup>	85-160 kcfs/60% instantaneous (6PM-6AM) <sup>e</sup>	Gas cap/tailrace juvenile passage
The Dalles	<b>64 %</b> (40%) instantaneous (24 hours)	<b>64 %</b> (40%) instantaneous (24 hours)	Tailrace juvenile passage
Bonneville	90-150 kcfs night and 75 kcfs day (24 hours)	90-150 kcfs night and 75 kcfs day (24 hours)	Night- gas cap Day- adult fallback

<sup>a</sup> Spring spill planning dates are April 3-June 20 for the Snake River and April 10-June 30 for the Columbia River.

<sup>b</sup> Summer spill planning dates are June 20-August 31 for the Snake River and July 1-August 31 for the Columbia River.

<sup>c</sup> Estimated spill levels have and will continue to increase for some projects as spillway optimization measures are implemented.

<sup>d</sup> At flows <300 kcfs, spill at John Day is limited by the TDG cap that is estimated at 85-160 kcfs. At flows >300 kcfs, spill is limited by tailrace hydraulics and is 60% of instantaneous flows.

° Spill at John Day will be 7PM-6AM (night) and 6AM-7PM (day) between May 15-July 31.

- Test alternative 24-hr spill regimes at Lower Granite, Little Goose, Lower Monumental, McNary, and John Day dams to determine optimum. Under the Biological Opinion, spill is limited to 12 hr at Lower Granite, Little Goose, McNary, and John Day dams during spring months. During summer months, spill is limited to 12 hr at John Day and no spill is provided at transport collector dams. High spillway effectiveness and high daytime passage were found during 24 hr spill tests at John Day in 1997 and 1999.
- Implement optimum 24-hr spill regimes at Lower Granite, Little Goose, Lower Monumental, McNary, and John Day dams during spring and summer based on the results of the above studies. Implement as soon as improvements to BPA's transmission system (NMFS Biological Opinion Actions 55-57) are made but not later than 2003 at John Day and McNary dams and 2005 at Lower Monumental, Little Goose, and Lower Granite dams.
- Conduct risk assessment of increasing spill levels in the short-term above current 120% TDG waiver to benefit anadromous fish. Request a temporary waiver to the Clean Water Act standard to implement higher spill levels in the short-term if risk assessment indicates that ecological risks are low. A risk assessment by NMFS concluded that TDG in the 120-125% range, coupled with depth compensation "would not cause juvenile or adult salmon mortalities exceeding the expected benefits of spillway passage.
- In the short-term, modify projects to maximize spill and maximize spillway and project survival under temporary TDG waivers issued by the states. Consistent with the NMFS Biological Opinion and schedules developed by the System Configuration Team, the Corps should install end bay deflectors and improvements at John Day (by 2002), Lower Monumental (2004), and Little Goose (2005). Spillway deflector optimization, spill pattern, and spillway and project studies outlined in the NMFS Biological Opinion to maximize spill and maximize spillway and project survival under temporary TDG waivers should be completed.
- In the long-term, modify projects to reduce dissolved gas levels under spill operations to meet the 110% TDG state and federal standard. Federal project operators should significantly reduce total dissolved gas (TDG) under voluntary and involuntary spill operations with the long-term goal of meeting the 110% TDG criteria established by EPA and the states. This effort was initiated in the Corps' Dissolved Gas Abatement Study (DGAS) program, but was abandoned to

meet short-term ESA recovery goals and primarily focused on installation of deflectors and spill optimization testing. These efforts will reduce TDG and improve salmon survival, but will fall far short of complying with CWA standards to address ecological needs of all species. Load allocations for each of the lower Columbia River dams will be established as a part of a TMDL. The federal agencies (Corps and USBR) need to commit to accepting, and in the long term, meeting those allocations. As part of the TMDL, an implementation plan will be developed. The measures suggested and assessed through the Corps DGAS study will form the basis for this plan. The federal agencies will be asked to commit to seeking the required funding to carry out implementation of these measures.

## Strategies in specific areas (cont.)

### Juvenile bypass systems

- Consistent with the NMFS Biological Opinion, surface bypass/collection systems at Corps projects should be tested and installed. This includes continuing surface collector studies at Bonneville I, installation of a surface bypass corner collector at Bonneville II dependent on high flow outfall study results, continuing surface bypass efficiency improvements at The Dalles, testing surface bypass removable spillway weir (RSW) in 2002 as a surrogate for skeleton bay surface collection and continuing longer-term skeleton bay studies at John Day, testing RSW surface bypass at Lower Granite in 2002 in conjunction with 24 hr spill, and to test RSW surface bypass at McNary, Ice Harbor, Lower Monumental, and Little Goose pending results from studies at John Day and Lower Granite.
- Evaluate and if necessary modify screen bypass/sampling systems and outfalls to improve survival of bypassed fish. Evaluate causes of low survival and identify ways to improve survival of bypassed fish and modify screen bypass/sampling systems and outfalls to improve survival. It has been well documented that dewatering, separation, and sampling facilities increase stress in juvenile salmonids. Evidence from recent survival studies demonstrate that survival of juvenile chinook and steelhead is substantially reduced from passage through bypass systems and returned (bypassed) to the river compared to other routes of passage. The Program should emphasize expedited completion of ongoing studies to identify causes of low bypass survival should be expedited, and ways to improve survival identified. Solutions may include modification of bypass systems including relocation of bypass outfalls or retrofitting bypass and sampling systems to allow full-flow bypass and off-line sampling.
- Improve juvenile and adult survival through turbines. Operate all turbine units at FCRPS dams for optimum fish passage survival, continue investigation and installation of minimum gap runners, and implement NMFS Biological Opinion Actions 88-93 to develop new turbine design and technologies to improve juvenile and adult turbine survival. State-of-the-art turbine design technology should be incorporated to improve fish survival during turbine rehabilitation programs.
- To provide passage for juvenile fish that most closely approximates natural physical and biological conditions, and to increase the energy produced by the hydrosystem, the U.S. Army Corps of Engineers should:

- (1) when testing and developing surface bypass systems take into account the widest range of biological diversity as described in the biological objectives and overarching strategies, utilize an expedited approach to prototype development, and ensure full evaluation for the developmental phase;
- (2) relocate bypass outfalls in those circumstances where there are problems with predation and juvenile fish injury and mortality;
- (3) modify turbines to improve juvenile survival; and
- (4) conduct research on fish diseases at fish passage facilities.

### **Adult passage**

- The U.S. Army Corps of Engineers should improve the overall effectiveness of the adult fish passage program. This includes expediting schedules to design and install improvements to fish passage facilities. The ultimate survival and successful spawning of adult fish are a high Council priority because returning adults determine the size and health of future fish populations. Cool water releases from reservoirs where temperature benefits can be attributed should continue to be used to facilitate adult migration. More emphasis should be placed on research, monitoring and evaluation, increased accuracy of fish counts, expansion of fish counting to all species of interest, installation of PIT-tag and radio-tag detectors, evaluation of escapement numbers to spawning grounds and hatcheries, research into water temperature and spill effects on fish passage, and the connection between fish passage design and fish behavior. In particular:
  - (1) as a priority for the Corps of Engineers' capital construction program, correct adult fish passage problems and report annually to the Council on progress;
  - (2) install adult PIT-tag detectors at projects that do not have them;
  - (3) improve fish counting accuracy; and
  - (4) conduct research on fish diseases at fish passage facilities.

## Strategies in specific areas (cont.)

### Water management

- Adopt, and as described below modify, the NMFS Biological Opinion flow objectives in the Snake and Columbia Rivers. Operate FCRPS dams and reservoirs to meet flow objectives on both a weekly and seasonal basis. The Biological Opinion flow objectives are modified to include higher spring (changed from 85-100 kcfs to 100 kcfs for runoff forecasts >16-20 maf) and summer (changed from 50-55 kcfs to 50-100 kcfs for runoff forecasts 16-28 maf) flow objectives for juvenile migration in the Snake River and a higher flow objective for chum and chinook spawning below Bonneville Dam (changed from 125 kcfs instantaneous flow to 125-160 kcfs flow target and initiation of operations that are not conditioned on runoff forecast). The flow objectives should be minimum flow requirements and hard constraints and require the Action Agencies to exceed the objectives utilizing system flexibility and when there is adequate water supply.

Seasonal flow objectives and planning dates for the mainstem Columbia and Snake Rivers. Modifications to the NMFS Biological Opinion objectives are bolded, with Biological Opinion objectives in parentheses.				
<u>Location</u>	<u>Spring Dates</u>	<u>Spring Flow Objective (kcfs)</u>	<u>Summer Dates</u>	<u>Summer Flow Objective (kcfs)</u>
Snake River at Lower Granite Dam	April 3-June 20	<16 maf =85 <sup>a</sup> 16-20 maf= <b>100</b> <sup>ac</sup> (85-100 <sup>ab</sup> ) >20 maf =100 <sup>a</sup>	June 21- August 31	<16 maf =50 <sup>d</sup> 16-28 maf= <b>50-100</b> <sup>df</sup> (50-55 <sup>de</sup> ) >28 maf = <b>100</b> <sup>d</sup> (55 <sup>d</sup> )
Columbia River at McNary Dam	April 10- June 30	<80 maf =220 <sup>g</sup> 80-92 maf=220- 260 <sup>gh</sup> >92 maf =260 <sup>g</sup>	July 1- August 31	200
Columbia River at Priest Rapids Dam	April 10- June 30	135	NA	NA
	<u>Fall/Winter Dates</u>	<u>Fall/Winter Flow Objective (kcfs)</u>		
Columbia River at Bonneville Dam	Oct 15-31 Nov 1-14 Nov 15-30 Dec 1-31 Jan 1 thru emergence	<b>125</b> (125) <b>140</b> (125) <b>150</b> (125) <b>160</b> (125) <b>150</b> (125)		

<sup>a</sup> Sliding scale based on April final runoff forecast at Lower Granite Dam for April-July.

<sup>b</sup> Linear interpolation between 85 and 100 kcfs.

<sup>c</sup> Modified flow objective is 100 kcfs for runoff forecasts >16 maf.

<sup>d</sup> Sliding scale based on June final runoff forecast at Lower Granite Dam for April-July.

<sup>e</sup> Linear interpolation between 50 and 55 kcfs.

<sup>f</sup> Linear interpolation between 50 and 100 kcfs.

<sup>g</sup> Sliding scale based on April final runoff forecast at The Dalles Dam for April-August.

<sup>h</sup> Linear interpolation between 220 and 260 kcfs.

- Adopt, and as described below modify, NMFS Biological Opinion operations to meet flow objectives. Some operations are more likely than the NMFS and USFWS Biological Opinions to meet minimum flow objectives for all anadromous and resident fish species under a wider range of runoff conditions. Under the current configuration of the Federal Columbia River Power System the biological requirements of many fish species, as represented by the minimum flow objectives, are not met during years of low runoff. NMFS's Biological Opinion operations will meet spring and summer flow objectives in the Columbia River only under average to above average runoff conditions and will never meet summer flow objectives in the Snake River (see Table).

Equal priority should be placed on meeting flow needs of spring and summer migrants as well as other fish species under the Program to meet flow requirements of each species. Flow needs of all species should be met, rather than prioritizing one species over another.

Oregon's Program Amendments for the Mainstem Columbia and Snake  
 June 15, 2001

Hydrosystem operations to meet flow objectives in the Columbia and Snake Rivers.						
<u>Biological Opinion Action No.</u>	<u>Purpose of Action</u>	<u>Project(s)</u>	<u>Biological Opinion Operation</u>	<u>Modified Operation</u>	<u>Benefit</u>	<u>Risks</u>
18	Meet spring and summer flow objectives on the Columbia and Snake Rivers.	Albeni Falls Dworshak Grand Coulee Hungry Horse Libby	Operate to meet April 10 flood control elevations; operate to meet spring flow objectives; refill by June 30.	<b>Operate Albeni Falls, Dworshak, Grand Coulee, Hungry Horse, and Libby to meet both spring and summer flow objectives. Do not prioritize operations to meet summer objectives over operations to meet spring objectives.</b>	<b>Equitable probability of meeting spring and summer flow objectives. This, in turn, increases survival of spring and summer migrating juvenile salmonids through the federal hydropower system.</b>	<b>Under low runoff conditions, water elevations in some reservoirs may be lower in the spring. This may decrease probability of refilling these reservoirs by June 30 and may impact certain recreational opportunities in these reservoirs.</b>
19	Provide greater winter power draft. Meet Columbia River summer flow objective while providing protection for bull trout.	Hungry Horse	By January 1, 2001, implement VARQ flood control; provide minimum flows for bull trout and at Columbia Falls; limit summer draft to elevation 3540 ft by August 31.	<b>Implement VARQ for Hungry Horse only when water supply is sufficient to ensure VARQ does not reduce probabilities of meeting April 10 flood control elevations, refill by June 30, and chum and chinook spawning flows. If studies show no biological risk to resident fish, enhance water supply for meeting salmon flow objectives by drafting Hungry Horse below elevation 3540 ft by August 31.</b>	<b>Increased probability of meeting spring, summer, and fall flow objectives. This, in turn increases (a) survival of spring and summer migrating juvenile salmonids through the federal hydropower system and (b) production of chum and chinook salmon downstream from Bonneville Dam.</b>	<b>Water elevations in Hungry Horse may be lower in the summer, fall and winter. This may impact certain recreational opportunities in the reservoir and may reduce the amount of water available for meeting winter power needs.</b>

Hydrosystem operations to meet flow objectives in the Columbia and Snake Rivers.

<u>Biological Opinion Action No.</u>	<u>Purpose of Action</u>	<u>Project(s)</u>	<u>Biological Opinion Operation</u>	<u>Modified Operation</u>	<u>Benefit</u>	<u>Risks</u>
19	Meet Columbia River summer flow objective while providing protection for bull trout.	Libby	By October 1, 2001, implement VARQ flood control; provide minimum flows for bull trout; limit summer draft to elevation 2439 by August 31.	<b>Implement VARQ for Libby only when water supply is sufficient to ensure VARQ does not reduce probabilities of meeting April 10 flood control elevations, refill by June 30, and chum and chinook spawning flows. If studies show no biological risk to resident fish, enhance water supply for meeting salmon flow objectives by drafting Libby below elevation 2439 ft by August 31.</b>	<b>Increased probability of meeting spring, summer, and fall flow objectives. This, in turn increases (a) survival of spring and summer migrating juvenile salmonids through the federal hydropower system and (b) production of chum and chinook salmon downstream from Bonneville Dam.</b>	<b>Water elevations in Libby may be lower in the summer, fall and winter. This may impact certain recreational opportunities in the reservoir and may reduce the amount of water available for meeting winter power needs.</b>
19	Determine if operation improves spawning success for kokanee, an important bull trout forage fish.	Albeni Falls	Draft to elevation 2051 ft by August 31; refill to and maintain elevation 2055 ft during fall/winter for kokanee spawning study. Beginning in 2004, implement operation recommended by USFWS and NMFS.	<b>Refill to and maintain elevation 2055 ft at Albeni Falls during the fall/winter only when water supply is sufficient to ensure the operation does not reduce probabilities of meeting salmon spawning flow objectives.</b>	<b>Increased probability of meeting fall spawning flow objectives. This, in turn increases production of chum and chinook salmon downstream from Bonneville Dam.</b>	<b>Under low runoff conditions, water elevations in Albeni Falls may be lower in fall and winter. This may or may not provide ideal conditions for kokanee spawning and forage for bull trout.</b>

Hydrosystem operations to meet flow objectives in the Columbia and Snake Rivers.

<b><u>Biological Opinion Action No.</u></b>	<b><u>Purpose of Action</u></b>	<b><u>Project(s)</u></b>	<b><u>Biological Opinion Operation</u></b>	<b><u>Modified Operation</u></b>	<b><u>Benefit</u></b>	<b><u>Risks</u></b>
19	Meet Columbia River summer flow objective.	Grand Coulee	Operate to achieve 85% probability of meeting April 10 rule curve and refill by July 4 if a draft is not required to meet flow objectives; limit August 31 draft to elevation 1280 ft when runoff forecast = or >92 maf and to elevation 1278 ft when forecast <92 maf.	<b>If studies show no biological risk to resident fish, enhance water supply for meeting salmon flow objectives by drafting Grand Coulee below 1280 ft (&gt;92 maf) and 1278 ft (&lt;92 maf) by August 31.</b>	<b>Increased probability of meeting Columbia River summer flow objectives. This, in turn increases survival of summer migrating juvenile salmonids through the federal hydropower system.</b>	<b>Water elevations in Grand Coulee may be lower in the summer, fall and winter. This may impact certain recreational opportunities and other uses in the reservoir and may reduce the amount of water available for meeting winter power needs.</b>
19	Meet Snake River summer flow objective and 68F temperature criteria.	Dworshak	Attempt to refill by June 30 while coordinating with TMT to meet spring flow objectives; limit draft to elevation 1520 ft by August 31; manage discharge to achieve 68F at Lower Granite.	<b>If studies show no biological risk to resident fish, enhance water supply for meeting Snake River summer flow objectives by drafting Dworshak below elevation 1520 ft by August 31.</b>	<b>Increased probability of meeting Snake River summer flow objectives. This, in turn increases survival of summer migrating juvenile salmonids through the federal hydropower system.</b>	<b>Water elevations in Dworshak may be lower in the summer, fall and winter. This may impact certain recreational opportunities in the reservoir and may reduce the amount of water available for meeting winter power needs.</b>
20	Increase water velocity to provide faster juvenile emigration and improve survival.	Snake River Projects John Day	Operate Snake River projects within 1 ft of MOP April 3 until small number of juveniles are present and John Day within 1.5 ft of MIP April 10-September 30.		<b>Reductions in travel time and corresponding increase in survival of spring and summer migrating juvenile salmonids through the federal hydropower system.</b>	

Hydrosystem operations to meet flow objectives in the Columbia and Snake Rivers.

<b><u>Biological Opinion Action No.</u></b>	<b><u>Purpose of Action</u></b>	<b><u>Project(s)</u></b>	<b><u>Biological Opinion Operation</u></b>	<b><u>Modified Operation</u></b>	<b><u>Benefit</u></b>	<b><u>Risks</u></b>
21	Improve meeting Snake River flow objectives while only slightly affecting mid-Columbia flow conditions.	Brownlee Dworshak Grand Coulee	If opportunity exists, shift flood control from Brownlee and Dworshak to Grand Coulee.		<b>Increased probability of meeting spring and summer flow objectives. This, in turn increases survival of spring and summer migrating juvenile salmonids through the federal hydropower system.</b>	
22	Improve meeting summer flows at McNary by 10 kcfs by relaxing flood control during average to below average water years.	Libby Hungry Horse	Implement VARQ at Libby by October 1, 2001 and at Hungry Horse by January 1, 2001. Corps complete NEPA compliance and Canadian coordination for Libby VARQ.	<b>Implement VARQ for Libby and Hungry Horse only when water supply is sufficient to ensure VARQ does not reduce probabilities of meeting April 10 flood control elevations, refill by June 30, and chum and chinook spawning flows.</b>	<b>Increased probability of meeting Columbia River spring, summer, and fall flow objectives. This, in turn increases (a) survival of spring and summer migrating juvenile salmonids through the federal hydropower system and (b) production of chum and chinook salmon downstream from Bonneville Dam.</b>	<b>Water elevations in Libby and Hungry Horse may be lower in the summer, fall and winter. This may impact certain recreational opportunities in the reservoirs and may reduce the amount of water available for meeting winter power needs.</b>

Hydrosystem operations to meet flow objectives in the Columbia and Snake Rivers.

<b><u>Biological Opinion Action No.</u></b>	<b><u>Purpose of Action</u></b>	<b><u>Project(s)</u></b>	<b><u>Biological Opinion Operation</u></b>	<b><u>Modified Operation</u></b>	<b><u>Benefit</u></b>	<b><u>Risks</u></b>
23	Improve summer flows by 130 kaf.	Banks Lake	Operate Banks Lake at 5 ft from full during August by reducing 130 kaf water pumped from Lake Roosevelt.		<b>Increased probability of meeting Columbia River summer flow objectives. This, in turn increases survival of summer migrating juvenile salmonids through the federal hydropower system.</b>	
24	Meet summer flow objective at McNary Dam.	Canada Treaty storage	BPA and Corps negotiate agreements to provide 1 maf Treaty storage January-April 15 for release during summer.		<b>Increased probability of meeting Columbia River summer flow objectives. This, in turn increases survival of summer migrating juvenile salmonids through the federal hydropower system.</b>	
25	Meet summer flow objective at McNary Dam.	Canada non-Treaty storage	BPA and Corps request from BC Hydro storage of non-Treaty water during spring for release in July and August if forecasts indicate that stored water can be released.		<b>Increased probability of meeting Columbia River summer flow objectives. This, in turn increases survival of summer migrating juvenile salmonids through the federal hydropower system.</b>	

Hydrosystem operations to meet flow objectives in the Columbia and Snake Rivers.

<b><u>Biological Opinion Action No.</u></b>	<b><u>Purpose of Action</u></b>	<b><u>Project(s)</u></b>	<b><u>Biological Opinion Operation</u></b>	<b><u>Modified Operation</u></b>	<b><u>Benefit</u></b>	<b><u>Risks</u></b>
26	Meet summer flow objective at McNary Dam.	Additional Canada Treaty storage	BPA and Corps negotiate with BC Hydro additional storage of Treaty water for release in July and August.	<b>Increase water supply available to meet salmon flow objectives by 3.5 maf by implementing 1995 Biological Opinion Sections 1C (reallocate 1.5 maf of flood control from Arrow to Mica) and 1D (expand storage above 1 maf realized in current operational agreements). Increase water supply available to meet salmon flow objectives by an additional 1-2 maf by requiring installation of two turbines at Mica and Revelstoke dams.</b>	<b>Increased probability of meeting Columbia River summer flow objectives. This, in turn increases survival of summer migrating juvenile salmonids through the federal hydropower system.</b>	<b>Water elevations in Canadian reservoirs may be lower in the summer, fall and winter. This may impact certain recreational and other opportunities in the reservoirs and may reduce the amount of water available for meeting winter power needs.</b>
32	Meet spring and summer flow objectives at Lower Granite Dam.	USBR Upper Snake projects  Hells Canyon Complex	Action Agencies acquire water from USBR upper Snake projects and IPC Hells Canyon Complex for instream use during spring and summer.	<b>Provide 427 kaf from the upper Snake and 110 kaf spring and 337 kaf summer from Brownlee Reservoir. Provide all upper Snake water in July and August (no shaping operations in Brownlee). Consistent with 1994 Program Measure 5.2A.3, provide an additional 0.5-1.0 maf water from USBR projects including the upper Snake on a willing seller/willing lessor basis.</b>	<b>Increased probability of meeting Snake River spring and summer flow objectives. This, in turn increases survival of spring and summer migrating juvenile salmonids through the federal hydropower system.</b>	<b>Water elevations in USBR upper Snake reservoirs may be lower in the summer, fall and winter. This may impact certain recreational and other opportunities in the reservoirs and may reduce the amount of water available for meeting winter power needs.</b>

Hydrosystem operations to meet flow objectives in the Columbia and Snake Rivers.

<b><u>Biological Opinion Action No.</u></b>	<b><u>Purpose of Action</u></b>	<b><u>Project(s)</u></b>	<b><u>Biological Opinion Operation</u></b>	<b><u>Modified Operation</u></b>	<b><u>Benefit</u></b>	<b><u>Risks</u></b>
34	Evaluate potential benefits to adult fall chinook and steelhead passage.	Dworshak	Draft 20 ft from elevation 1520 to 1500 ft in September.	<b>Draft Dworshak 20 ft from elevation 1520 to 1500 ft in August, not September.</b>	<b>Increased probability of meeting Snake River summer flow objectives and lowering water temperatures. This, in turn increases survival of summer migrating juvenile and adult salmonids through the federal hydropower system.</b>	<b>Water elevations in Dworshak may be lower in the summer, fall and winter. This may impact certain recreational and other opportunities in the reservoir and may reduce the amount of water available for meeting winter power needs.</b>
35	Reduce effects on the spring freshet; minimize flow fluctuations during fall chinook emergence; and achieve higher refill probability while providing acceptable protection from floods.	Columbia River Flood Control Project	Conduct feasibility analysis of modifying flood control operations to benefit Columbia River ecosystem.	<b>Conduct feasibility analysis of modifying flood control operations to benefit Columbia River ecosystem. Implement modified operations beginning in 2007.</b>	<b>Increased probability of meeting spring, summer, and fall flow objectives. This, in turn increases (a) survival of spring and summer migrating juvenile salmonids through the federal hydropower system and (b) production of chum and chinook salmon downstream from Bonneville Dam.</b>	<b>Increased probability of flood events and increased mitigation and maintenance costs due to flooding.</b>

Deficit water volume to meet the NMFS Biological Opinion's summer flow objectives in the Snake and Columbia rivers (Hydro Regulation data from BPA).		
<u>Run-off Volume (maf)</u>	<u>Snake River Deficit (kaf)</u>	<u>Columbia River Deficit (kaf)</u>
50 yr average	1020	2260
53.5-70.9 maf (8 yr)	1680	8800
80.8-96.9 maf (12)	1080	3240
101.8-117.9 maf (20)	1080	1560
121.8-156.1 maf (10)	360	0

*Draft limits on reservoirs-* NMFS should re-evaluate “interim draft limits” on storage elevations established by the 1995 Biological Opinion, including a formal risk assessment that includes conservation requirements for listed and other native species in the Columbia Basin affected by storage reservoir operations. Deeper drafts of each of the reservoirs including Hungry Horse, Libby, Albeni Falls, Grand Coulee, and Dworshak may be possible without jeopardizing other fish species or affecting other project purposes.

*VARQ operations-* VARQ operations should be restricted as necessary to eliminate reduction in spawning flows for chum and chinook below Bonneville. VAR Q flood control operations are intended to improve reservoir elevation in Libby and Hungry Horse to enhance reservoir productivity for resident fish and to improve spring flows for migrating juvenile salmonids in the mid- and lower Columbia rivers. Although reservoir elevations in Libby and Hungry Horse and spring flows have been improved, spawning flows for chum and chinook below Bonneville have been reduced by 868 kaf compared to flows provided under the 1999 Supplemental Biological Opinion. This reduction will seriously reduce the probability of meeting the flow target of 125-160 kcfs to protect ESA listed chum and tule chinook as well as unlisted bright chinook below Bonneville Dam.

*Canadian operations-* The Action Agencies should re-initiate consultation of additional Canadian storage identified in the 1995 NMFS Biological Opinion Sections 1C and 1D. Section 1C of the 1995 opinion states “The COE shall implement for 1996 and beyond the 1.5 MAF reallocation of flood control from Arrow to Mica...” and Section 1D “The BPA and COE shall continue attempting to expand current arrangements for storage in Canadian Reservoirs to allow additional storage for fish flow enhancement, above the current approximate 1 MAF realized in current operational agreements.” According to the opinion Biological Opinion, these improved operations at Arrow, including a 20-ft summer draft could provide an additional 3.5 maf of flow augmentation.

The Action Agencies should negotiate with BC Hydro to install 2 turbines at Mica and Revelstoke dams in Canada, which is estimated to provide 1-2 maf for summer flow augmentation. Summer drafts would have to be balanced with winter operations when this volume is returned to Canada to minimize impacts to flows for chum and chinook spawning below Bonneville.

*Brownlee and upper Snake River operations-* Draft 427 kaf from the upper Snake and 110 kaf during spring and 237 kaf during summer from Brownlee Reservoir as required by the 1995 Biological Opinion. These measures were not included in the 2000 Biological Opinion pending outcome of ongoing Section 7 consultations with FERC. The Idaho Power Company should draft an additional 100 kaf from Brownlee Reservoir to meet Snake River summer flow objectives. All water from the upper Snake should be provided in July and August with no shaping operations in Brownlee. Shaping operations in the past have reduced up to 160 kaf of storage from Brownlee Reservoir that could have been used to meet flow objectives.

U.S. Bureau of Reclamation (USBR) projects including the upper Snake should provide an additional 0.5-1.0 maf to better meet flow targets. The USBR should seek through negotiations with stakeholders in Oregon, Washington, and Montana, as well as Idaho, to determine the regulatory mechanisms to secure 0.5-1.0 maf for flow augmentation on a willing seller/willing lessor basis. State regulatory laws should be enforced to insure that water transferred to in-river rights to benefit fish would not be used by private water users.

*Dworshak operations-* Test whether and to what extent drafting Dworshak to elevation 1500 ft in August benefits adult Snake River steelhead and fall chinook passage. The greatest survival benefits to adult fall chinook is provided by cool water releases in August with less of a benefit in September. Releases in August would also have benefits to juvenile fall chinook.

*Hanford Reach/mainstem and estuary spawning, rearing and resting habitat-* Manage flows, while maintaining consistency with this mainstem plan's flow and reservoir operations, to protect, improve and expand spawning, rearing and resting habitat in the mainstem and estuary, including especially flows to protect habitat conditions for spawning and rearing in the Hanford Reach area, on an equal basis as managing water to support the migration of listed species.

*Operations at Libby Dam to benefit Kootenai River white sturgeon-* The U.S. Fish and Wildlife Service's 2000 Biological Opinion concerning hydrosystem operations that affect listed Kootenai River white sturgeon specifies a "tiered" strategy for flow augmentation from Libby Dam to simulate a natural spring freshet, controlled within flood constraints. Specified discharge volumes are determined by forecasted water availability, so that higher flows are released when water availability is ample and minimal flow augmentation occurs during drought. The Fish and Wildlife Service should modify the Biological Opinion to apply the following volumes from Libby for sturgeon purposes based on the corresponding run-off amounts. This strategy represents a minor revision to volumes specified in the 2000 Biological Opinion.

*Flood control operations-* Implement NMFS Biological Opinion's requirement (Action 35) for expedited completion of a feasibility analysis of modifying system flood control operations to improve flows for anadromous fish while maintaining acceptable protection from floods. The Corps should seek authority to allow implementation of modified flood

control operations in 2007 two years after completion of the feasibility analysis required in the Biological Opinion. In addition to the elements of the feasibility analysis discussed in the Biological Opinion, the analysis should determine how flood control operations could be managed so that releases coincide as closely as possible with fish migrations (i.e., reserve as much of the flood control draft as possible until early April) and how flood control operations could be managed inseason to optimize benefits to migrating fish while meeting flood control responsibilities.

*Contingency Planning-* Conduct necessary planning and evaluations to ensure that alternative water management actions and changes in hydrosystem configuration can be implemented on a timely basis if non-breach options fail to meet performance standards.

1. Include a more aggressive mid-point evaluation point (3 years vs 5-8 years) than the NMFS Biological Opinion because extinction risks are high. Be ready to implement alternative actions after 3-5 years.
2. Assess the likelihood of survival and recovery under alternative actions including dam breaching, assess the lead time for implementing alternative actions, and prescribe steps that must be taken now to have alternative actions ready to go in the near term.
3. Evaluate the merits of alternative actions using criteria developed and endorsed by a collaborate team that includes the states and tribes.
  - Manage water through the hydrosystem so that patterns of flow more closely approximate the natural hydrographic patterns and are directed at re-establishing natural river processes where feasible, and produce the highest possible survival rates for a broad range of affected fish within the physical limitations of the multiple purposes of the region's storage reservoirs and hydrosystem. Assure that any changes in water management are premised upon, and proportionate to, fish and wildlife benefits, while assuring the region an adequate, efficient, economical, and reliable power supply. Elements of this general strategy for water management include:
    - Frame habitat restoration in the context of measured trends in water quantity and quality.
    - Allow for seasonal fluctuations in flow, including flood events. Stabilize daily fluctuations. Reduce or eliminate stranding and other problems associated with fluctuation of the hydroelectric system.
    - Increase the correspondence between water temperatures and the naturally-occurring regimes of temperatures throughout the basin. To the extent possible, use stored water to manage water temperatures below the storage reservoirs where temperature benefits from releases can be shown to provide for improved fish survivals.
    - Identify, protect and restore ecosystem functions in the Columbia River estuary and nearshore ocean discharge plume as affected by actions within the Columbia River hydrosystem. This includes evaluating flow effects, river

operations and estuary-area habitat changes, as well as local effects from activities such as dredging and pollution from urban areas, to better understand and improve the relationship between estuary and near-shore plume characteristics and the productivity, abundance and diversity of salmon and steelhead populations.

- Systemwide water management, including flow augmentation from storage reservoirs, should balance the needs of anadromous species with those of resident fish species in the river and upstream storage reservoirs, and the needs of migrating fish with those of spawning and rearing fish, so that actions taken to advantage one species do not unnecessarily come at the expense of other species. Flow augmentation is defined as the intentional release or drafting of water from storage reservoirs for the purpose of increasing flows to enhance migratory conditions for juvenile and adult life-stages of salmon and steelhead through the reach of the lower river hydroprojects. The federal system operators, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service should identify potential conflicts and seek recommendations from the Council, fish and wildlife agencies and tribes and other affected entities on how best to balance the different needs prior to the implementation of flow actions.

### (3)

#### **Strategies in specific areas (cont.)**

##### **Water Quality**

- In the long-term, modify projects and implement actions to reduce temperature to meet the 68F state and federal standard. Measures in the NMFS Biological Opinion will not meet Clean Water Act requirements.
- In the long-term, modify projects and implement actions to reduce toxic contaminants to meet state and federal standards. The Bi-State Study undertaken in the early 1990's, followed by recent U.S. Geological Survey lipid bag studies indicate the presence of toxics and metal in fish tissue and the water column. Further, recent NMFS studies suggest that certain pesticides deleteriously impact salmonid homing to natal streams. The federal agencies, to the extent they contribute to these exceedances either through hydropower operations or dredging, should undertake cooperatively with the state studies to characterize the extent of toxic contamination, its sources, and help develop and implement a TMDL for the applicable toxics.

## **Predation**

- Improve inriver survival by reducing predation-caused mortality. As specified in the 2000 Biological Opinion, continue program to harvest predator-sized pikeminnow in sport and dam angling fisheries to achieve an exploitation goal of 10-20% and evaluate biological effectiveness. Continue to explore different technologies and increase efficiency of current technologies to remove pikeminnow.

Reduce total predation by Caspian terns, cormorants, and gulls of juvenile salmonid spring and summer migrants arriving to the estuary to 5% by 2004; to 3% in 2006; to 2% in 2008; and to 1% in 2010.

Investigate predation by pinnipeds in the near-ocean, estuary, and lower Columbia River up to Bonneville Dam to determine extent of predation and to evaluate predation control measures. Coordinate study efforts with on-going efforts.

1. Determine current abundance, population structure, and distribution patterns of harbor seals and California sea lions in the near-ocean, estuary, and Columbia River up to Bonneville Dam.
2. Determine areas and times of pinniped predation and identify physical/environmental factors that may contribute to predation success.
3. Determine annual prey and food requirements of pinnipeds occurring in the Columbia River.
4. Determine predation vulnerability of various salmonid runs and levels of mortality caused by pinniped predation.
5. Estimate direct and indirect mortality of salmon by pinnipeds in the Columbia River.
6. Identify and evaluate methods to reduce salmon mortality caused by pinnipeds in-river and in the Columbia River estuary.

## **Resident Fish**

### **White Sturgeon**

- Configure and operate the hydropower system consistent with salmonid recovery to maximize spawning and rearing success of white sturgeon in reservoirs.

Optimize spawning conditions by maintaining minimum discharge of 250 kcfs at McNary Dam during the time period when river temperatures are between 13 and 15

°C. Flow objectives of the NMFS Biological Opinion will meet discharge recommendations for optimal spawning conditions for white sturgeon. Potential yield of white sturgeon from impounded populations has been reduced by dam construction and operation of the hydropower system can have large effects on spawning habitat of white sturgeon. During years of low discharge in spring and summer, the lack of high quality spawning habitat in impounded reaches may preclude successful reproduction. Recruitment to young of the year is poor during these years of low discharge.

- Supplement depleted populations of white sturgeon in reservoirs until changes in configuration and operation of the hydropower system have resulted in restored populations.

Transplant naturally-produced juvenile white sturgeon from below Bonneville Dam into reservoirs. Transplant up to 10,000 juvenile white sturgeon annually from below Bonneville Dam to The Dalles and John Day reservoirs. Recruitment to white sturgeon populations in The Dalles and John Day reservoirs has been low since development of the hydropower system. Though development of the hydropower system has reduced availability of habitat for spawning white sturgeon in these reservoirs, it has increased the area suitable for young of the year and juvenile fish

- Supplement populations with artificially-produced fish where risks to naturally spawning populations are minimal.

White sturgeon populations between Priest Rapids and Grand Coulee dams have little or no natural recruitment under the current hydropower system and there is little potential for providing flows that allow spawning and recruitment. Initiating hatchery release programs in areas of the Columbia and Snake rivers where production has been severely reduced or lost will allow establishment or re-establishment of white sturgeon fisheries.

- Monitor status of white sturgeon populations to evaluate effectiveness of and ensure success of restoration efforts.

Monitor and regulate harvest of white sturgeon in reservoirs based on estimated abundance and exploitation rates that provide optimum sustainable yields. Reduced productivity of white sturgeon populations in reservoirs has complicated fishery management. Sustainable harvest levels have been reduced by low productivity caused by poor recruitment and slow growth. Recruitment and growth have been reduced by altered flow regimes and degraded spawning and rearing habitat. Both limited fisheries and population recovery can be provided through intensive fisheries management.

Conduct periodic assessments of white sturgeon abundance, growth, recruitment, and age distribution in reservoirs. Periodic updates of population status will provide evidence of the success or failure of actions designed to restore white sturgeon

populations. Information collected during assessments can be used to modify management approaches if necessary.

## Bull Trout

- Determine the extent of bull trout use of the lower Columbia River affected by the FCRPS.

Include bull trout in the species counted and recorded at mainstem Columbia River dams. Determine the movements of bull trout from tributary streams into lower Columbia and Snake River reservoirs, and estimate the annual population size of bull trout migrating to and from these reservoirs.

Information regarding bull trout use of the lower Columbia and Snake rivers is limited; however, bull trout are present in some reservoirs and in tributaries to these reservoirs. Actions proposed or underway to improve habitat and passage conditions in tributaries and the mainstem Columbia and Snake rivers are anticipated to increase bull trout populations, and increase migrations within and among tributary and mainstem reaches. Improvements in mainstem dam operations (optimizing flow and spill regimes to reduce entrainment and losses due to gas supersaturation) and fish passage facilities will also help increase populations and improve migration conditions.

- Develop performance standards and measures to ensure that upstream and downstream passage for bull trout are not impeded at FCRPS dams.

Develop information regarding passage needs for bull trout. If it is determined that there is a significant bull trout population in the lower Columbia River that is affected by the FCRPS, then performance standards and appropriate measures should be developed to ensure that passage is not impeded. Information regarding passage needs for bull trout should be applied to bull trout passage measures throughout the FCRPS.

## Wildlife

- Improve riparian/riverine habitat conditions in the mainstem hydrosystem to mitigate for measured construction and inundation wildlife losses.

Protect key habitats through fee-title acquisition, perpetual conservation easement, and/or long-term cooperative management agreement:

1. Protect priority remaining riparian/riverine habitats including floodplain and side channel areas.
2. Focus on protection of existing wildlife populations and habitats that are healthy and productive.

3. Implement habitat improvement initiatives (e.g., shrub steppe initiative, riparian habitat initiative).

Implement habitat restoration activities on protected lands to benefit targeted species:

1. Restore native vegetation to protected lands through control of non-native invasive species and planting/seeding of native vegetation.
2. Restore riparian/riverine systems to more natural hydrologic conditions.
3. Use land management practices to achieve desired wildlife objectives.
4. Manage human use/activity.
5. Focus improvement efforts on restoration of existing populations and habitats that are at risk of extinction.
6. Secure BPA funding for O&M over the life of the project or in-perpetuity, or obtain some other Council-approved long-term funding arrangement.
7. Mitigate all construction/inundation losses on a 3:1 basis (i.e., 3 Habitat Units or acres for every 1 Habitat Unit or acre lost) to account for baseline protection credit and unannualization of losses.
  - Improve riparian/riverine habitat conditions in the mainstem hydrosystem to mitigate for direct operational impacts.

Conduct an assessment of direct operational impacts to wildlife using the HEP methodology.

1. Define direct operational impacts as the changes to biological, hydrological, and geomorphic features and resources caused by the operation of the federal hydrosystem including, but not limited to, hydropower, irrigation, slackwater, recreation, navigation, and flood control that result in the loss or alteration of wildlife resources. Operational impacts begin the moment a hydroelectric facility becomes operational and occur until the effects of the hydropower operation are no longer measurable.
2. Finalize the assessment methodology as outlined in the Council's 1995 Draft Wildlife Plan.
3. Conduct an independent audit of the assessment results.
4. Adopt the direct operational losses into the Council's Program.
5. Establish priorities for target species and habitat types once the assessment of direct operational losses is complete.
6. Use the subbasin planning process as the vehicle to provide mitigation for direct operational losses.

Protect key habitats through fee-title acquisition, perpetual conservation easement, and/or long-term cooperative management agreement.

1. Protect priority remaining riparian/riverine habitats including floodplain and side channel areas.

2. Focus on protection of existing wildlife populations and habitats that are healthy and productive.
3. Implement habitat improvement initiatives (e.g., shrub steppe initiative, riparian habitat initiative).

Implement habitat restoration activities on protected lands to benefit targeted species:

1. Restore native vegetation to protected lands through control of non-native invasive species and planting/seeding of native vegetation.
2. Restore riparian/riverine systems to more natural hydrologic conditions.
3. Use land management practices to achieve desired wildlife objectives.
4. Manage human use/activity.
5. Focus improvement efforts on restoration of existing populations and habitats that are at risk of extinction.
6. Secure BPA funding for O&M over the life of the project or in perpetuity, or some other Council-approved long-term funding arrangement.
7. Mitigate all direct operational losses on a 3:1 basis (i.e., 3 Habitat Units or acres for every 1 Habitat Unit or acre lost) to account for baseline protection credit and unannualization of losses.
  - Improve riparian/riverine habitat conditions in the mainstem hydrosystem to mitigate for indirect operational (secondary) impacts.

Address indirect operational impacts to wildlife through subbasin planning:

1. Define indirect operational impacts as the impacts to wildlife and wildlife habitat that occur due to the loss of anadromous and resident fish from the development and operation of the hydropower system.
2. Develop a methodology to assess and mitigate indirect operational impacts through subbasin planning.
3. Assess indirect operational impacts to wildlife.
4. Implement projects to mitigate for indirect operational losses.
5. Secure BPA funding for O&M over the life of the project or in perpetuity, or some other Council-approved long-term funding arrangement.
6. Credit projects not specifically designed to mitigate for defined wildlife construction/inundation or direct operational impacts against indirect operational losses.
  - Reduce limiting factors to wildlife in the mainstem hydrosystem.

Identify limiting factors, needs and opportunities:

1. Compile existing information on mainstem conditions, habitat conditions and needs.
2. Conduct additional inventories as necessary.
3. Identify priority wildlife needs and develop an implementation plan.

Implement specific actions to address needs and opportunities:

1. Minimize artificial water level fluctuations within the mainstem system caused by the FCRPS.
2. Install underpasses for wildlife movement corridors.
3. Create natural and artificial island habitat for nesting and resting waterfowl.
4. Install osprey and eagle roosting and perching structures and nesting platforms.

### **Monitoring and evaluation**

- The 2000 Fish and Wildlife Program describes a general strategy for monitoring and evaluation. The emphasis is on developing and implementing standards and procedures for monitoring and evaluating management activities that are aimed at improving habitat conditions for fish and wildlife. The ultimate goals are to determine whether the biological objectives of the program are being achieved at the basinwide level and at lower levels, and to make sure that the evaluation information is used to adapt or change management strategies that are not achieving the biological objectives. The monitoring and evaluation elements stated above in the various mainstem strategies, and the general provisions in this section, are intended to be consistent with this general strategy.
- The mainstem plan continues the operation of the Fish Passage Center, including a fish passage manager, technical and clerical support, and the services of consultants when necessary. This support will assist the fish passage manager in (1) planning and implementing the annual smolt monitoring program, (2) developing and implementing flow and spill requests, and (3) monitoring results to assist in implementing the biological opinions, spill planning, and in preparing reports.

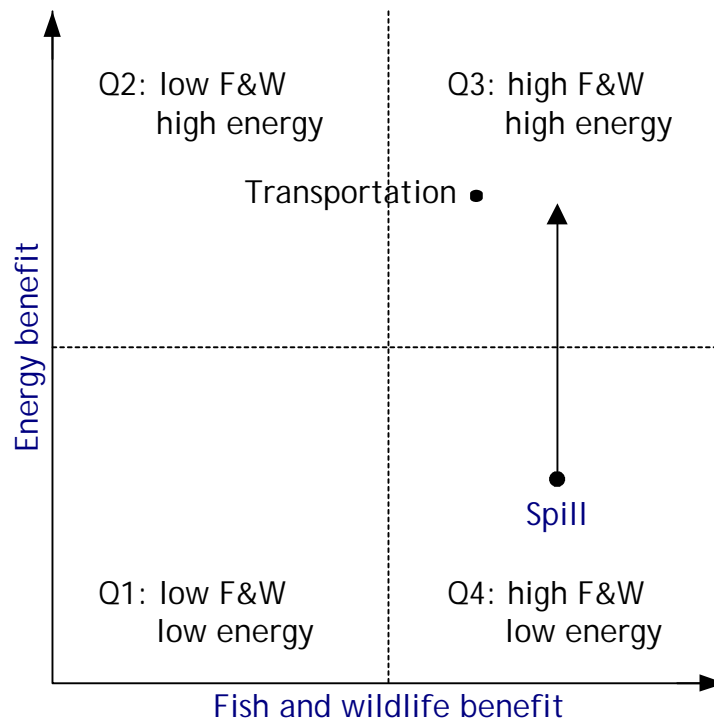
The Council has established an oversight board for the Fish Passage Center, with representation from the National Marine Fisheries Service, the tribes, the Council, and others, to ensure that the Center carries out its functions in a way that assures regional accountability and compatibility with the regional data management system. The Fish Passage Center shall prepare an annual report to the oversight board and the Council, summarizing its activities and accomplishments. No analyses by the Fish Passage Center should be considered proprietary

## Strategies in specific areas (cont.)

### Research

- **2000 Fish and Wildlife Program.** The 2000 Fish and Wildlife Program describes a general approach or strategy regarding research related to the Program, including the development by the Council of an overall or basinwide research plan that identifies key uncertainties for the Program and its biological objectives and the steps needed to resolve these uncertainties, coordination of this overall plan with particular research elements, including ocean research, and a call to make research results and other information important to the Program more readily available. The research elements stated above in the various mainstem strategies, and the general provisions in this section, are intended to be based in and consistent with this general strategy.
- **Research aimed at optimizing fish and wildlife benefits and energy production.** Actions taken to benefit fish and wildlife should also consider and minimize impacts to the Columbia Basin hydropower system if at all possible -- the central goal should be to try to optimize both values to the greatest degree possible. Thus a high priority for mainstem research in general should be to try to determine what actions can be taken to provide both high fish and wildlife and energy benefits, or at least to increase one set of benefits without degrading the other. This diagram expresses the concept:

Specific references to transportation and spill in the figure below should be removed.



Research activities should be prioritized to focus on activities that would fall in quadrant 3 or activities that could potentially push current activities into quadrant 3. As an example, spill is an operation for fish with a serious energy impact for the power system. As described above in the Strategy on spill, this operation should be examined to determine whether spill can be more effectively utilized to help fish and lessen its impacts to the energy production.

- **Approach to prioritization of research ideas and proposals.** In any process for deciding on what mainstem research to fund or implement, the assigning of priorities should take into account a wide array of factors, such as:
  - potential biological benefits to fish and wildlife
  - widespread scientific value -- can what is learned be applied to other situations?
  - management application
  - degree of uncertainty of the question asked
  - cost of the research
  - cost to power system of activity proposed for study
  - potential cost to implement the results of research
  - level of completion/duplication
  - legal relevance -- does the research activity respond to the Biological Opinion and/or to the Fish and Wildlife Program or to other legal requirements?
  - “doability” in the technical sense -- is the proposal a reasonable way to complete this activity?
  - “doability” in the legal/institutional sense

Research proposals should be evaluated against each of the important elements, with the results combined in a variety of ways to expose the weight of different variables. These prioritization efforts should involve a broad set of people and interests in the prioritization efforts to match broad set of factors, including the use of independent scientific panels. People at the policymaking level should be more involved in the final decisions on long-term and annual research plans.

## Strategies in specific areas (cont.)

### Annual and in-season decisionmaking

Through the Biological Opinions, the federal agencies have established an implementation structure for deciding on annual operation plans for fish and wildlife, in-season management of hydrosystem operations for fish and wildlife, and recommendations to Congress for funding for passage improvements. At present, this structure is insufficient to integrate the fish and power considerations in a timely, objective, and effective way. The structure focuses on ESA listed fish, with little consideration for unlisted anadromous and resident fish species and wildlife.

The Council continues to recommend to the federal agencies that this implementation structure, which includes the Technical Management Team and the Implementation Team, be jointly sponsored by the Council and the federal agencies, and allow for effective participation in these considerations by the relevant federal agencies, the Council and states, the tribes of the Columbia River Basin, and other affected entities, in a highly public forum. Discussions to this end began in 2001, but then became overcome by events. The Council will re-initiate the discussions to jointly sponsor these coordination teams. In addition, the Council will seek to broaden the focus of the forum to

- Improve day to day hydrosystem operations decision-making. Specifically, the forum should include state, tribal and federal management expertise in both biological and power system issues. Such a decision making and implementation body should:
  1. Require decision-makers to seek to reach agreement on issues with their full breadth of discretion available;
  2. Have the technical capability to objectively analyze and present power supply forecasts, hydrosystem operational alternatives, and other power related issues. It is anticipated that the Council will play a significant role in this.
  3. Have the technical capability to objectively analyze differing hydrosystem operational proposals relative to impacts on salmon, sturgeon, and resident fish migration, survival, and spawning and rearing and impacts of wildlife.
  4. Regularly schedule meetings, as often as is required to deal with short-term real-time decisions (e.g. weekly in-migration season) as well as middle and long-term issues (e.g. addressing longer-term reliability issues in a way that removes risk to providing operations to meet requirements of salmon).
  5. Operate with a defined set of decision-making criteria and hold participants accountable for the decisions they make according to the established criteria.



## **Strategies in specific areas (cont.)**

### **Mid-Columbia Hydroelectric Projects**

- The Council will review and include as appropriate in the program settlement agreements for the Mid-Columbia hydroelectric projects.

## Revised Transition Provisions

In the 2000 Fish and Wildlife Program amendments, the Council provided that all measures in the program that were “not directly superseded” by the adoption of the basinwide provisions in the 2000 Fish and Wildlife Program amendments would “continue to have force and effect until”:

1. a subbasin plan has been adopted by the Council for the subbasin in which the project [or measure] is located (or, for research and mainstem measures, a research or mainstem plan);
2. the measure has been specifically repealed in a subsequent rulemaking; or
3. three years have elapsed following the final approval of this program, whichever occurs first.

The Council is both applying and revising these transition provisions at this time, in this way:

- Final adoption of the mainstem plan amendments to the Fish and Wildlife Program will supersede all provisions, objectives and measures in the Council’s 1994-95 Columbia River Basin Fish and Wildlife Program that relate to systemwide hydrosystem operations, systemwide water management, mainstem flows, mainstem and storage reservoir operations, spill, bypass systems, smolt monitoring, mainstem operations research and evaluation and other matters related to juvenile and adult salmon migration through the mainstem, including all of Sections 5 and 6 of the 1994-95 program.
- *All* other specific measures in the 1994-95 program that have not been directly superseded by the adoption of the 2000 Fish and Wildlife Program amendments or by the adoption of the mainstem plan amendments remain in effect until 1) a subbasin plan has been adopted by the Council for the area in which the measures is located; or 2) the measure has been specifically repealed in a subsequent program amendment process. This includes any resident fish substitution or mitigation measures, such as the Lake Roosevelt monitoring or production programs, that occur in the mainstem but which are not directly related to systemwide operations or salmon migration.
- Upon final adoption of the mainstem plan amendments, the Council is also deleting the three-year sunset clause from the Transition Provisions in the 2000 Fish and Wildlife Program amendments. *No* specific measure in the Fish and Wildlife Program prior to the adoption of the 2000 program amendments will expire simply because three years have elapsed from the final approval of the 2000 Fish and Wildlife Program amendments.

# Draft Analysis of the Adequacy, Efficiency, Economics and Reliability of the Regional Power System

## Analysis of Adequacy, Efficiency, Economy and Reliability of the Power System

### Introduction

The U.S. Ninth Circuit Court of Appeals' 1994 decision in *NRIC v. Northwest Power Planning Council* characterizes the fish and wildlife provisions of the Northwest Power Act as “[a]ttempting to balance environmental and energy considerations.”<sup>9</sup> The Northwest Power Planning Council’s Columbia River Basin Fish And Wildlife program must consist of measures to “protect, mitigate, and enhance fish and wildlife affected by the development, operation, and management of [hydropower] facilities while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply.”<sup>10</sup> “Assuring” the region of such a power supply implies a reasonable degree of certainty that the objectives of adequacy, efficiency, economy and reliability will be achieved.

The Council must also determine whether the fish and wildlife program is consistent with the purposes of the Northwest Power Act.<sup>11</sup> These purposes include encouraging conservation of electricity and timely repayment of the Bonneville Power Administration’s debt to the federal treasury.<sup>12</sup> An adequate, efficient, economical and reliable power supply that includes a healthy and financially viable Bonneville Power Administration is essential to carrying out those purposes.

In terms of their effect on the power system, the alternative Mainstem Amendments to the Fish and Wildlife program that are under consideration have greater or lesser power system impacts relative to the National Marine Fisheries Service (NMFS) 2000 Biological Opinion. In some cases, the differences are significant. The 2000 Biological Opinion itself has had a sizeable impact on the power system relative to a “power plus non-fish constraints”<sup>13</sup> operation. Council analysis has found that the current Biological Opinion reduces net regional power system output by approximately 1200 average megawatts on average<sup>14</sup> and has an average annual power system cost of approximately \$260 million in reduced value of the output when evaluated using wholesale electricity market prices based on average water conditions and an efficiently functioning market.<sup>15</sup> As the experience of 2000 – 2001 demonstrated, the impacts can be much greater when conditions deviate significantly from those assumptions. Bonneville estimates that for 2001, the additional power purchases and foregone revenues attributable to the flow

---

<sup>9</sup> *NRIC v. Northwest Power Planning Council* slip opinion at p. 10879 (9th Cir. 1994)/

<sup>10</sup> 16 U.S.C. § 839b(h)(5).

<sup>11</sup> 16 U.S.C. § 839 b(h)(7)

<sup>12</sup> 16 U.S.C. § 839(1), (4).

<sup>13</sup> There has never been a true power only operation in that operation of the system has always taken into account multiple purposes such as flood control, recreation, navigation and irrigation, all of which impact the power producing capability of the system.

<sup>14</sup> Average regional hydroelectric generation is about 16,000 average megawatts based on a fifty-year historical water record.

<sup>15</sup> This estimate is based on an annual average wholesale electricity price of about \$28/megawatt-hour.

requirements of the BiOp was \$1.5 billion.<sup>16</sup> Had spill not largely been curtailed, the cost would have been considerably larger. The large increase in costs is attributable to the fact that market prices across the period were approximately a factor of 10 greater than those seen under “normal” market conditions.

The alternative mainstem amendments under consideration are summarized in Table X-1.

Table X-1  
Description of Alternatives

Alternative	Summary
Council Draft Alternative	Remove April fill requirement, fill by June 30 <sup>th</sup> Summer flow augmentation through Sept 30 <sup>th</sup> 10’ draft limit @HHR, LIB (20’ in 20% driest years) LIB & HHR release to achieve flat outflows Jul-Sep GCL specified min elevation Jan-Jun, 1283’ July-Dec DWR specified target summer elevations Biop spill levels
Alternative A Flat HHR, LIB, GCL, DWR 115% gas	Passive spring flow augmentation, fill by June 30 <sup>th</sup> Summer flow augmentation through Sept 30 <sup>th</sup> 10’ draft limit @HHR, LIB (20’ in 20% driest years) LIB & HHR release to achieve flat outflows Jul-Sep GCL & DWR even release Jul-Sep Spill levels not to exceed 115% gas supersaturation
Alternative B Flat HHR, LIB, GCL, DWR Biop spill	Same as A but use the 2000 Biological Opinion spill levels
Alternative C Flat HHR, LIB, GCL, DWR 110% gas	Same as A but limit spill levels not to exceed 110% gas supersaturation
Alternative D Flat HHR, LIB, GCL, DWR No spring fill 115% gas	Same as A but remove the April fill requirement
Alternative E Flat HHR, LIB, GCL, DWR 115% gas 20’ draft HHR, LIB	Same as A but use 20’ draft limits at LIB & HHR in all years
Alternative F Flat DWR	Same as 2000 Biop except provide specific elevation targets at DWR for summer
Alternative G Deeper summer drafts Add US & BC water	Fill by April, active spring flow augmentation Fill by June, 10’ deeper drafts by end of August 24-hour bypass spill at 4 lower Snake and Columbia dams 1 maf of additional Upper Snake water 1 maf of non-treaty water for summer flow augmentation Increase max flow at DWR to 22 kcfs spring and summer
Alternative H Deeper summer drafts	Same as G but Remove the additional 1 maf of Upper Snake water

<sup>16</sup> It should also be noted that the cost of all other non-power hydro operations in 2001 were equally affected by the high electricity prices.

Add BC water	
Alternative I Flat GCL @1288'	Same as BiOp except provide specific elevation targets at GCL, 1288 feet from June through December
Alternative J Flat GCL @1283'	Same as I but January to June elevation targets become minimums, fill by June 30 <sup>th</sup> Draft GCL evenly to 1283' by end of July Keep GCL @1283' from September through December

The power system energy and cost effects of the alternative Mainstem Amendments currently under consideration are summarized in Table X-2. Data are presented relative to the 2000 Biological Opinion for the average annual energy impact in average megawatts, the average annual cost or cost reduction, and the average energy impact in megawatt-months over the winter season, December through March. The latter is of interest from the standpoint of winter (peak season) reliability. Most of the alternatives under consideration result in somewhat greater power system production and lower cost. Some alternatives, however, head in the opposite direction. The most significant deviation from current operations is the reduction in winter season energy associated with alternatives G and H.

Generally speaking, impacts to winter reliability stem from reservoir operations that are rigid and offer little or no flexibility in terms of drafting water below the rule curves during short emergency periods. Having more hydro energy available during the winter months clearly helps in this area but the ability to shape that energy into the peak demand hours is the key component to reliability. Alternatives G & H reduce the amount of winter energy on average, but do not necessarily constrain the reservoirs in a way to inhibit their use during a cold snap. A more detailed reliability analysis of this operation is warranted.

Currently, the Northwest is not facing a reliability concern. Under this condition, it is unlikely that implementing Alternatives G and H will increase the winter loss of load probability (LOLP) beyond acceptable standards. However, when the region gets closer to a demand and resource balance, the effects of Alternatives G and H will have a more significant impact. Analysis done last year by Council staff indicated that having an additional 1,500 megawatt-months of stored energy heading into the winter season reduced the forecasted LOLP from 17 percent to about 12 percent. This is considerably less winter period energy than the reduction associated with Alternatives G & H. This indicates that should Alternatives G or H be adopted, resource acquisitions would be required to maintain an adequate power supply and would have to be made sooner than would otherwise be the case.

Table X-2  
**Average Power System Impacts of 2002 Fish and Wildlife Mainstem Amendment Alternatives**

Difference from 2000 BiOp Operation			
Alternative:	Average Annual Energy (aMW)	Regional Cost/Year (millions)	Dec-Mar Energy (MW-Months)
Council Draft Alternative	41	-\$8	1747
Alternative A Flat HHR, LIB, GCL, DWR 115% gas	345	-\$61	52
Alternative B Flat HHR, LIB, GCL, DWR Biop spill	70	-\$9	52
Alternative C Flat HHR, LIB, GCL, DWR 110% gas	530	-\$102	52
Alternative D Flat HHR, LIB, GCL, DWR No spring fill 115% gas	345	-\$68	950
Alternative E Flat HHR, LIB, GCL, DWR 115% gas 20' Draft HHR, LIB	345	-\$65	-160
Alternative F Flat DWR	40	-\$10	-180
Alternative G Deeper summer drafts Add US & BC water	-235	\$42	-2130
Alternative H Deeper summer drafts Add BC water	-260	\$47	-2130
Alternative I Flat GCL @ 1288'	57	-\$4	1130
Alternative J Flat GCL @ 1283'	42	-\$6	775

There is a very wide spectrum of views in the region regarding the meaning of an adequate, efficient, economical and reliable power supply. Some hold that it must be considered entirely in the context of the power system that existed in 1980. In this view, an acceptable power supply is one whose characteristics are different than those of the 1980 system in only minor respects. For others, it may mean doing whatever is necessary to accommodate the needs of fish and wildlife, so long as some kind of power system can be maintained that is roughly as adequate, efficient, economical and reliable as those in other parts of the nation.

It would be difficult to argue that the power system impacts of the 2000 Biological Opinion have made the power system inadequate, inefficient, uneconomical and unreliable in an absolute sense. For several years the system has been operated under similar fish and wildlife constraints without

disastrous consequences for the system or the regional economy. However, the cost to the power system was nonetheless considerable. Consequently, the Council is very interested in the power system impacts of mainstem actions. The question of how the impacts of fish operations on the power system can be lessened while still fulfilling the objective of protecting, mitigating and enhancing the fish and wildlife of the Columbia Basin is in the forefront of the Council's thinking. The Council recently considered analysis of the power system impacts of specific mainstem actions, e.g. spill at specific projects.<sup>17</sup> This information, considered in light of the uncertainty regarding the effectiveness of flow and spill should help frame a research agenda that would improve the cost-effectiveness of mainstem actions<sup>18</sup>

In 2000-2001, the system was inadequate to meet loads, satisfy the requirements of the Biological Opinion and maintain moderate prices in what turned out to be a very poor water year. However, while the effects of fish operations on the power system contributed in some measure to the problem, they were by no means the cause. As will be discussed in greater detail later, the problem was the consequence of a systemic failure to develop sufficient resources, exacerbated by characteristics of an immature and, particularly in the case of California, poorly designed power market. One of the mechanisms by which the power system coped with the crisis was to dramatically reduce spill in order to be able to increase current power production and reduce purchased power costs and to store energy for future use. Some argue that reliability of the power system was protected at the expense of fish and wildlife.<sup>19</sup> However, as was noted earlier, very large costs were incurred by the power system in meeting the flow requirements of the Biological Opinion.

In general, it is likely that the adequacy, reliability, efficiency and economy of the region's power supply can only be fully gauged in the context of a full revision of the Council's Power Plan, which is currently underway. Congress appears to have had this in mind. Congress anticipated that the Council would develop the fish and wildlife program immediately after passage of the Act.<sup>20</sup> In contrast, the Council was given up to two years to develop the power plan. Among its several purposes, the power plan is intended to lay out a resource strategy that will:

reduce or meet the Administrator's [of the Bonneville Power Administration] obligations with due consideration by the Council for (A) environmental quality, (B) compatibility with the existing regional power system, (C) protection, mitigation and enhancement of fish and wildlife and related spawning grounds and habitat, including sufficient quantities and qualities of flows for successful migration, survival, and propagation of anadromous fish, and (D) other criteria which may be set forth in the plan.<sup>21</sup>

In a sense, the Act establishes a reciprocal arrangement between the fish and wildlife program and the power plan. The fish and wildlife program must still assure the region that it will not cause the power system to be inadequate, inefficient, uneconomical and unreliable. In return, the requirements of fish and wildlife program is a factor to be taken into account in the power plan,

---

<sup>17</sup> Cost and Energy Impacts of Fish and Wildlife Operations, <http://www.nwcouncil.org/library/2002/costenergyimpacts/slide1.HTM>

<sup>18</sup> "Mainstem Passage Strategies in the Columbia River System: Transportation, Spill, and Flow Augmentation" by A. Giorgi, M. Miller, and J. Stevenson of BioAnalysts, Inc. (Giorgi et al. 2002).

<sup>19</sup> In reality, changes in fish operations were only one aspect of the response to tight supplies and high prices. Other responses included very large long-term curtailments of electricity loads and substantial new "emergency" generation.

<sup>20</sup> Remarks of Rep. Dingell, Cong. Rec. p. H10683, November 17, 1980.

<sup>21</sup> 16 U.S.C. § 839b(e)(2).

and the mutual impacts of fish and power measures are intended to be examined together.<sup>22</sup> It may be that the potential impacts of a particular fish and wildlife measure look different in the context of a full revision of the power plan than they do during the fish and wildlife amendment process. Conversely, it is likely that we will be better able to assure an adequate, efficient, economical and reliable power supply that adequately supports the protection, mitigation and enhancement of fish and wildlife in the context of a full revision of the Power Plan and implementation of its key recommendations.

This is almost certainly the case with this revision of the Power Plan. This has very little to do with the current amendments to the Fish and Wildlife Program and much more to do with the power system itself. The experience of 2001-2002 revealed serious problems with the planning, development and operation of the power system in the current market environment and the ability to assure an adequate, efficient, economic and reliable power system. The revision of the power plan that is underway is analyzing these problems and possible solutions. Among the specific issues is the interaction of the fish operations and the power system during periods of power system stress and how to assure equitable treatment of fish in that context.

This does not mean that, in adopting the fish and wildlife measures, the Council need not make a determination that the fish and wildlife program does not jeopardize the ability of the region to have an “adequate, efficient, economical and reliable power supply.” It must do so. But its determination must recognize that a fuller analysis of the issue will follow in the revision of the power plan.

This appendix describes the Council's analysis of the balance between fish and wildlife measures and the power system.

## Summary

The adequacy, efficiency, economy and reliability of the power system is best thought of in two time frames: the short-term (the next 2-3 years) during which period it would not be possible to complete large changes to the system to respond to fish and wildlife program requirements; and the long-term during which there is time to respond, provided the market and/or regulatory incentives are there to do so. In the near term (the next 2-3 years), the region is expected to have an adequate, reliable and efficient power supply under any of the alternatives under consideration, even those that somewhat reduce the power system output. This is largely the result of still-depressed demand for electricity and the number of new power plants that have recently entered service or are under construction here in the Northwest and elsewhere in the West. While the pace of development has dropped off recently, the lowered demand combined with the plants that have been or soon will be completed, provide sufficient adequacy and reliability in the near term.

The “economical” objective is somewhat more questionable. Bonneville and other utilities in the Northwest are facing financial problems as a consequence of both the costs of power purchased at elevated prices during the electricity crisis and reduced revenues as a result of the depression in prices in the wholesale electricity market over the past year. The Northwest economy is in recession and, while increased retail electricity prices are not the cause, they do not help. Bonneville is facing the need to cut costs and either increase rates or risk higher probabilities of being unable to meet its treasury repayment. This is, for the most part, attributable to problems with the structure and operation of the power system that significantly affected Bonneville's costs and revenues. It does, however, mean that incremental costs are more difficult to accommodate.

---

<sup>22</sup> 16 U.S.C. § 839b(e)(3)(F).

The annual cost impact of the alternatives relative to Bonneville’s annual revenue requirement is shown on Table X-3. The Fiscal Year 2000 was chosen as a relatively “normal” year for Bonneville in terms of its revenue requirements and because the cost impacts of the alternatives are based on average conditions and normal market conditions. Most of the alternatives have positive impact Bonneville’s financial condition. The exceptions are alternatives G and H, which increase costs somewhat. The amount of the increase is on the order of 1.5 percent of Bonneville’s revenue requirement.

Table X-3  
Annual Power System Cost of Mainstem Amendment Alternatives in relation to Bonneville Annual Expenses

Alternative	Average Annual Cost Impact - Millions	As percent of Bonneville FISCAL YEAR 2000 Expenses
Council Draft Alternative	-\$8	-0.29%
Alternative A	-\$61	-2.18%
Alternative B	-\$9	-0.32%
Alternative C	-\$102	-3.64%
Alternative D	-\$68	-2.43%
Alternative E	-\$65	-2.32%
Alternative F	-\$10	-0.36%
Alternative G	\$42	1.50%
Alternative H	\$47	1.68%
Alternative I	-\$4	-0.14%
Alternative J	-\$6	-0.21%

In the longer term, assuring the region an adequate, efficient, economic and reliable power supply will depend on the successful resolution of a number of issues: These include:

- The adequacy of financial or regulatory incentives for the development of new resources, both generation and demand-side;
- Mechanisms to increase the responsiveness of retail demand to increases in wholesale prices;
- The adequacy of mechanisms to ensure investment in cost-effective levels of new efficiency resources;
- Barriers to ensuring adequate resource diversity to mitigate risk;

- Development of mechanisms to ensure equitable treatment of fish and power during extreme low hydro years.

These issues are being addressed in the Fifth Power Plan. With successful resolution of these issues, an adequate, efficient, economical and reliable power system can be assured with the fish operations embodied in the Mainstem amendments. A related issue is the efficiency or cost-effectiveness of some fish operations. A focus on reducing the cost to the power system of meeting biological objectives is needed.

## **Adequate, Efficient, Economical and Reliable**

### ***Adequate and Reliable -- Definitions***

Adequate and reliable have specific meanings in the power industry. Adequacy is a component of reliability. A Power system is *reliable* if it is:

–*Adequate* - the electric system can supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.

–*Secure* - the electric system can withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements.<sup>23</sup>

Adequacy refers to having sufficient resources – generation, efficiency and transmission – the serve loads. Simplistically, in determining adequacy, resources are “derated” to take into account expected performance including scheduled and typical forced outages. Hydro resources are evaluated under worst case or “critical” hydro conditions. Similarly, loads are evaluated under extreme temperature conditions. Here in the Northwest, that typically means during a prolonged cold snap.

Security is achieved largely by having reserves that can be brought on line quickly in the event of a system disruption and through controls on the transmission system. These reserves can be in the form of generation or demand side curtailment that can take load off the system quickly. The National Electric Reliability Council (NERC) and the Western Electricity Coordinating Council (WECC) establish reserve requirements. The reserve requirement is frequently expressed in terms of a percentage of load or largest single contingency, e.g., the loss of Energy Northwest’s Columbia Generating Station. The reserves required for security are an additional resource requirement necessary for a reliable power system.

Here in the Northwest, determination of power supply adequacy and reliability is complicated by the fact that the output of the hydroelectric system can vary widely from year to year. This is because the hydro system has limited storage capacity. Consequently, the output of the system can vary widely depending on the amount, timing and form (rain or snow) of precipitation in a given year. In addition, during cold snaps side flows into the system can be reduced, restricting the ability of the system to sustain a high level of output for an extended period.

For purposes of this analysis, adequacy and reliability need to be evaluated in two time frames: the short-term – the two to three years it takes to bring significant new resources into the system; and the long-term – three years a beyond. In the short-term, the question is whether there exist sufficient resources to assure adequacy and reliability. In the long-term, the question is whether

---

<sup>23</sup> “Glossary of Terms,” North American Electric Reliability Council, Glossary of Terms Task Force, August 1996

the incentives, market or otherwise, or regulatory policies and mechanisms exist to ensure that sufficient resources, including demand side resources, will be added to the system.

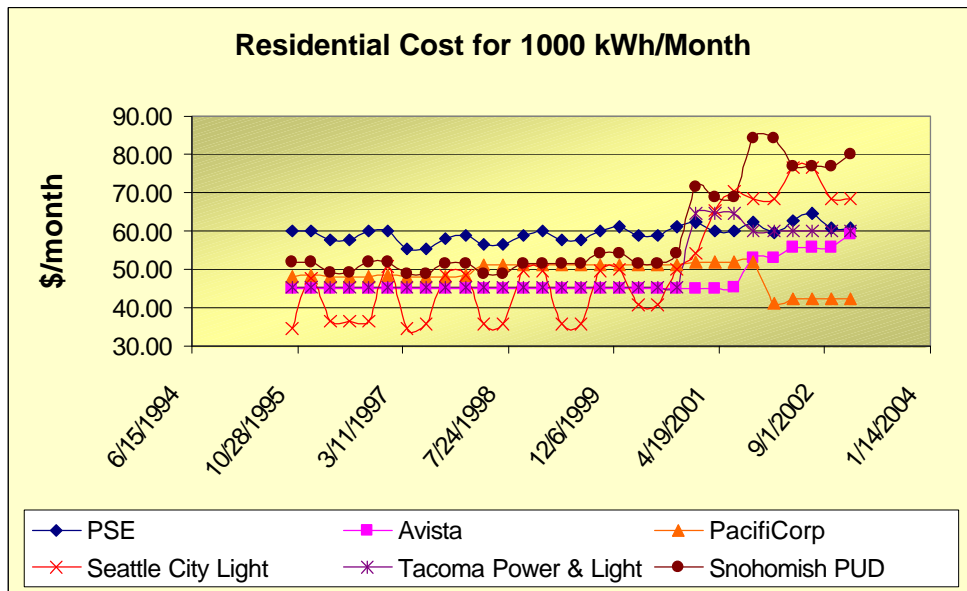
### Adequate and Reliable – Short-Term Analysis

In the short-term, we believe the Northwest has an adequate and reliable power system. The reasons are three: 1) In the worst case, the Mainstem Amendments alternatives do not sufficiently adversely affect the power output of the hydro electric system beyond current operations to cause immediate adequacy/reliability problems. 2) Slowly recovering demand means the stress on the system is less significant than when the Council did its 2000 reliability analysis; and 3) There has been the substantial addition of new resources here in the Northwest and elsewhere in the West, even taking into account recent construction deferrals.

As noted earlier, the 2000 Biological Opinion has had a substantial effect on the power production of the hydro system compared to a “power and non-fish constraints” operation. However the system has been operating successfully under these constraints for some time. In the most severe case, one of the proposed mainstem amendments further degrades the system, particularly in the winter months. In the near-term, however, there is sufficient cushion to avoid adequacy/reliability problems. Other alternatives are expected to improve the system somewhat from a power standpoint.

Regional loads are down substantially from “normal” levels. This is a function of depressed aluminum market (that precludes many aluminum plants from returning to operation), the effects of the economic slowdown, and “hangover” effects of the 2000-2001 power crisis, (e.g., conservation stimulated by the increases in retail rates that have taken place over the last 6 to 12 months). For example, Figure X-1 shows data compiled by the Washington Utilities and Transportation Commission comparing the cost for a 1000 kWh of electricity for 6 Washington utilities.

Figure X-1

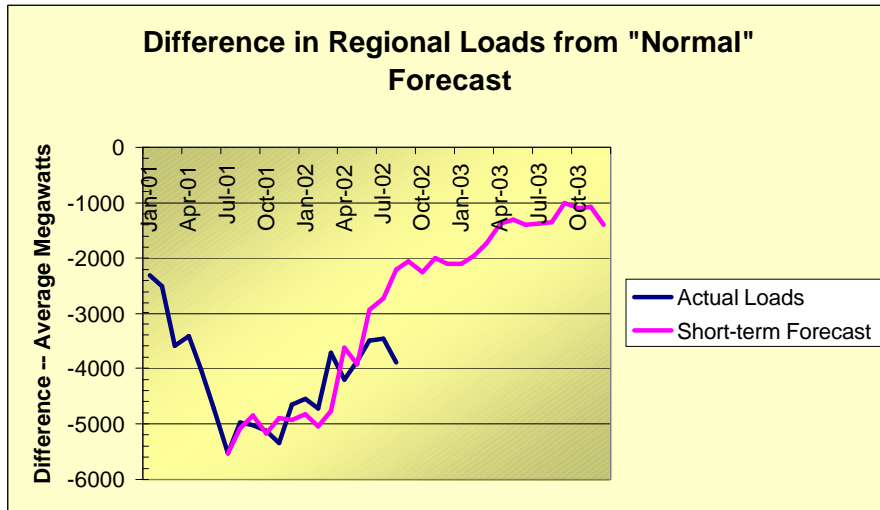


As this chart shows, many of these utilities have experienced substantial increases over the last several months. This is typical of other utilities both within Washington and elsewhere in the

region. The increase in retail rates has stimulated demand for efficiency services that is reflected in lower loads.

A comparison of actual and forecast loads over the next year is shown on figure X-2

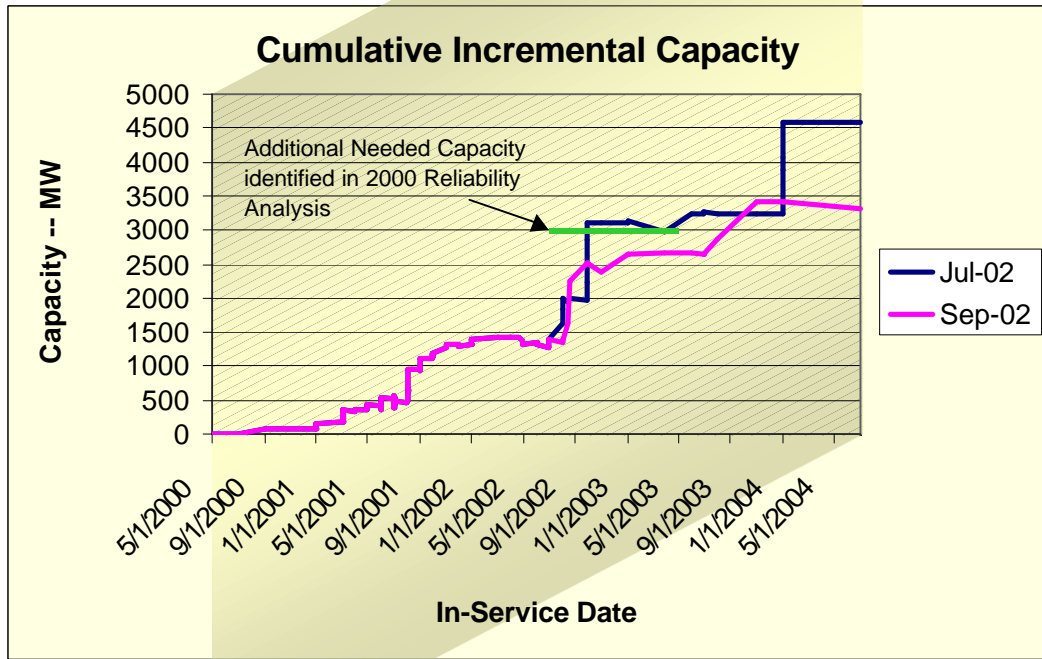
Figure X-2



This figure shows the difference between the Council's long-term demand forecast (used in the 2000 Reliability Analysis) and actual regional loads. Also shown is the difference between the current short-term forecast and the long-term demand forecast. The long-term forecast had been tracking aggregate loads quite well up until the Western Electricity Crisis. The short-term forecast reflects known load reductions, estimates of the effects of the recession, the effects of retail rate increases and estimates regarding the recovery of the aluminum industry loads. The short-term forecast anticipates loads, which remain at least 1000 – 2000 average megawatts below the Fourth Plan forecast for the next year. Actual loads appear to have been diverging from the short-term forecast in recent months. If that trend continues, suggesting a slower than anticipated economic recovery and slower recovery of aluminum industry loads, the difference from normal loads will be even greater.

The high prices during the Western Electricity Crisis also stimulated the development of substantial new generation. Figure X-3 shows the cumulative amount of new generation in the Northwest that has been recently completed or that is under construction judged to be likely to be completed. As the figure indicates, however, our view of what is likely to be completed is imperfect at best. Our estimates as of July of 2002 proved to be optimistic as the suspension of construction was announced at three major plants.

Figure X-3

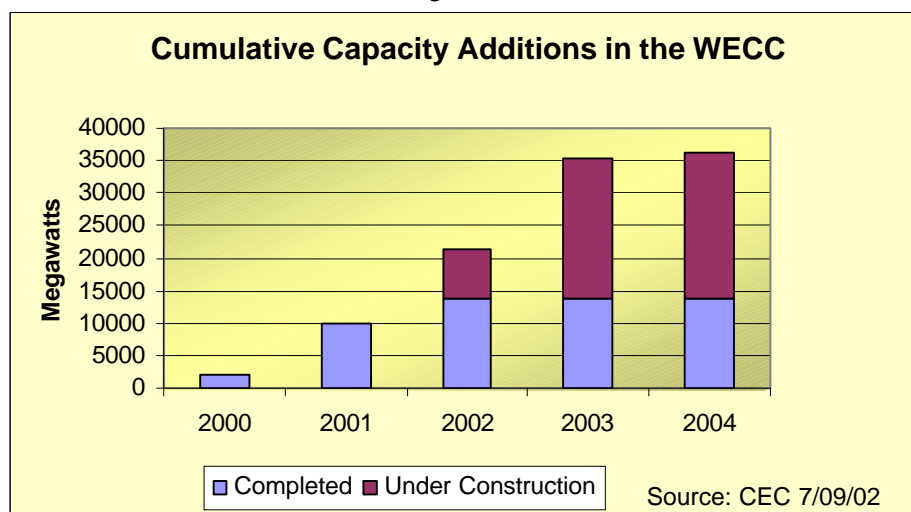


As this figure shows there has been a drop-off in the amount of new generation scheduled to be added to the system. Nonetheless, we believe there will be sufficient generation capacity in relation to the reduced loads to assure adequacy and reliability over the next couple of winters. In addition, those plants that have been deferred should have a relatively short construction period to complete, provided prices recover to the point that the developers can restart or load serving entities contract for a sufficient amount to justify restart.

There have also been significant resource additions in the rest of the WECC. Figure X-4 shows the cumulative resource additions for the entire WECC since 2000. This is in relation to a peak demand in the WECC of about 130,000 Megawatts. As is the case in the Northwest, there have been some deferrals of some of the “Under Construction” capacity since this data was compiled. However, at least in the near term, the WECC expects a margin of resources over peak demand in excess of minimums even without further resource additions.<sup>24</sup>

<sup>24</sup> WECC 10 year Coordinated Plan Summary 2002-2011, Western Electricity Coordinating Council, 2002, P 26.

Figure X-4



Most of the generation in this figure is located in California, Arizona and Nevada. These data suggest that for the next two or three years there will be sufficient generation in the rest of the WECC for the Northwest to draw on in the event of winter emergencies and a substantially reduced likelihood that summer loads in these areas would place unusual demands on Northwest resources.

A complete reliability analysis using the GENESYS model is underway. It is looking at the current year (spanning the winter of 2002-2003) and the year spanning the winter of 2004-2005. The latter period was chosen because if additional permanent generation resources were needed for this period, construction would have to begin now. This will be a stochastic analysis, running several hundred simulations in which water conditions, temperatures (which affect loads) and forced outages are sampled according to their probabilities. This simulation will also estimate the potential supply from outside the region and use imported power where necessary. The data from these simulations can be used to estimate the probability, magnitudes and duration of supply shortfalls.

### Adequate and Reliable – Long Term Analysis

The experience of the past few years has put a somewhat different light on the meaning of an adequate, efficient, economical and reliable power supply. It is this experience that frames the fundamental questions being addressed in the Council's Fifth Power Plan. Are the institutional, regulatory and market structures of the power system such that we can be assured of an adequate, efficient, economical and reliable power system, with or without fish constraints, and if not, what changes are required? While fish operation requirements added to some degree to the magnitude of the supply shortfall during 2000-2001, they did not cause it. It was the fundamental failure of the power system to provide adequate resources that was the root problem. Because of this failure, there is some justification in saying that power system failed in its obligation to protect, mitigate and enhance the fish and wildlife resources of the Columbia Basin. And in fact, one of the tools used to help the power system through this period was to largely eliminate spill at federal projects until resource/load balance had been restored, as permitted by the Biological Opinion in emergency conditions. There is some disagreement about what damage this may have caused to listed and unlisted species. However, that the system failed to provide the operations called for in the 2000 Biological Opinion is very clear. However, the power system and the other

users of the power system also bore major consequences in the form of curtailed load, high purchased power costs and high costs for emergency resources.

If we are to avoid or at least to lessen the likelihood and severity of such events in the future, it is probably useful to briefly review the experience of the last few years and the lessons we might derive from that experience.

## **The period leading up to summer 2000-01**

The period of the late 1990's was a period of significant change and uncertainty in the power industry. Years earlier, national policy had set in motion a move to a competitive wholesale power market in which most development of new generation is undertaken by independent power producers (IPP).<sup>25</sup> The vast majority of power plants currently under construction or in the permitting and planning process are IPP projects. Unlike traditional vertically integrated utilities, IPPs do not have a native load customer base from whom to recover the fixed costs of new power plants. To build, they require adequate market prices and/or sufficient long-term sales contracts to justify financing.

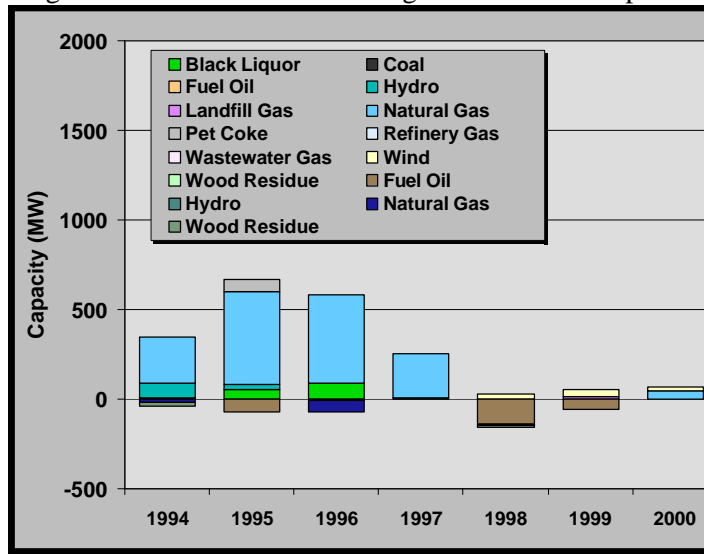
The primary source of uncertainty affecting the industry was the movement toward retail competition in various states and nationally. This raised the concern that a utility's customers today might not be their customers in the future. The potential for investments in new resources becoming stranded investments weighed on heavily on the industry's thinking. This situation coincided with a period of very low market prices in the West brought about by several successive years of average or above average hydro conditions combined with what was initially excess capacity on the system, primarily in California. The availability of low cost market power made it uneconomical for developers to build power plants as merchant plants selling into the spot market. It also further discouraged utilities with load serving responsibility from placing long-term contracts for power supply with IPPs. The prudence of such contracts could be and in some cases were called into question in the face of the then-current low market prices.

The net effect was little development of resources. Figure, X-5 shows Northwest generating resource development from through the 90s. .

---

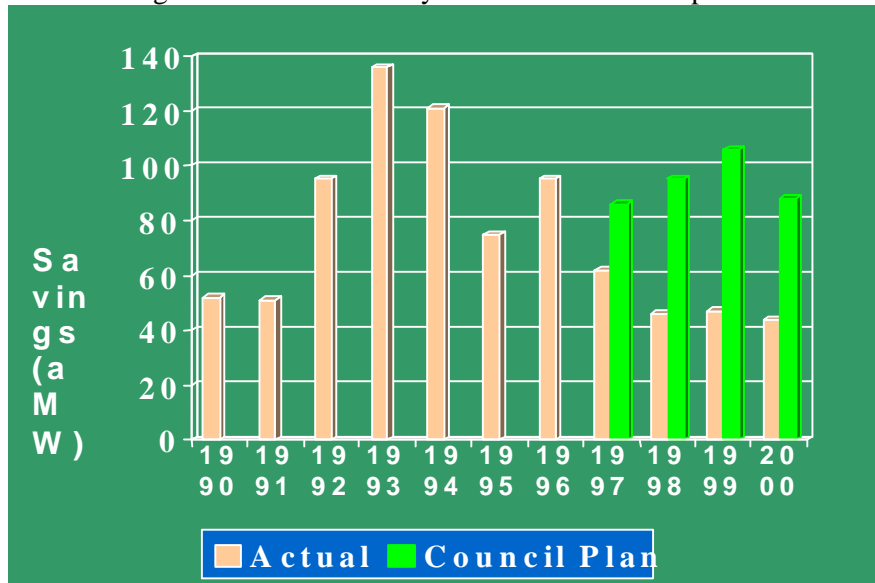
<sup>25</sup> Relevant policies were established as early as 1978 in the Public Utilities Regulatory Policy Act (PURPA) and more recently in the National Energy Policy Act of 1992.

Figure X-5 Northwest Generating Resource Development



The same behavior is evident in the development of efficiency resources as shown on Figure X-6. Conservation development dropped off dramatically from the early 1990s to levels that were less than half the recommended cost-effective level in the Council's Fourth Power Plan.

Figure X-6 Annual Utility Conservation Development

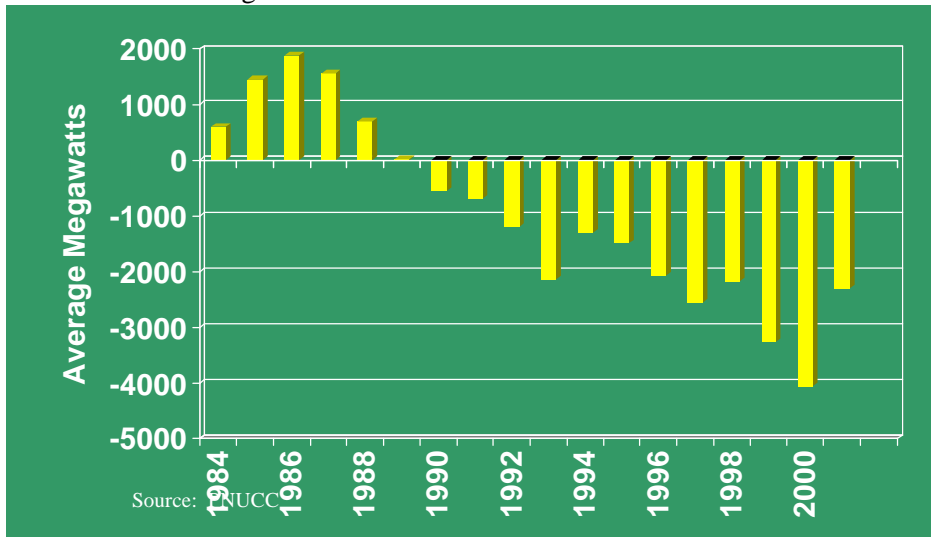


The net effect of this of this low level of development combined with reasonably robust regional growth was plainly evident in the annual estimates of load-resource balance compiled by the Pacific Northwest Utilities Conference Committee (PNUCC).<sup>26</sup> This report compiles from regional utilities the statements of loads (annual energy and January Peak), including export commitments; and resources, including conservation and contracted imports. The analysis assumes critical water hydro. While each year's report includes a forecast going forward 10

<sup>26</sup> Pacific Northwest Regional Forecast, Pacific Northwest Utilities Conference Committee, Portland, OR. [http://www.pnucc.org/2002%20NRF/nrf\\_toc.htm](http://www.pnucc.org/2002%20NRF/nrf_toc.htm)

years, we have compiled the data for each forecast going back to 1984 using only the data for the first year in each forecast. This is shown on Figure X-7.

Figure X-7 Annual Pacific Northwest Load-Resource Balance



These data show that the region has not been in critical water load-resource balance for more than a decade. At some level, this is good. The Northwest has strong electrical interconnections with California and the Southwest. The load diversity between these regions (the NW peaking in the winter, California and the Southwest peaking in the summer) means that there is usually excess power for the Northwest to purchase in the winter when our supplies are tightest as well as a market for excess power in the summer. For several years, regional utilities leaned heavily on the market to fill out their resource needs.

In addition, most years' water supply exceeds the amount observed in the driest (critical) year. Averaged over the 50-year historical record, the hydroelectric system produces nearly 4,000 average megawatts more energy than it does in the driest year. In the highest runoff year, the system produces nearly 8,000 average megawatts more. The combination of having out-of-region supplies and greater than critical water runoff has masked the inadequacy in the power system over the last decade.

However, there is a limit. The increasing deficits observed in Figure X-7 and in Bonneville's "White Book"<sup>27</sup> prompted the Council to undertake an analysis of the region's power supply adequacy. This report, released in early 2000, focused on the ability to meet regional loads in the winter, which is usually the most difficult period for the Northwest. Stochastic analysis techniques were used to estimate the probability of being unable to fully meet loads during one or more periods across the winter season.<sup>28</sup> Hydro conditions, temperatures (and, therefore, loads) and forced outages on generating facilities were sampled according to their statistical probability of occurrence. Several hundred winter seasons were simulated. The analysis found that by the winter of 2002-03, the region faced a 24 percent probability of some level of shortfall (loss of

<sup>27</sup> Pacific Northwest Loads and Resources Study, <http://www.bpa.gov/power/pgp/whitebook/whitebook.shtml>, Bonneville Power Administration

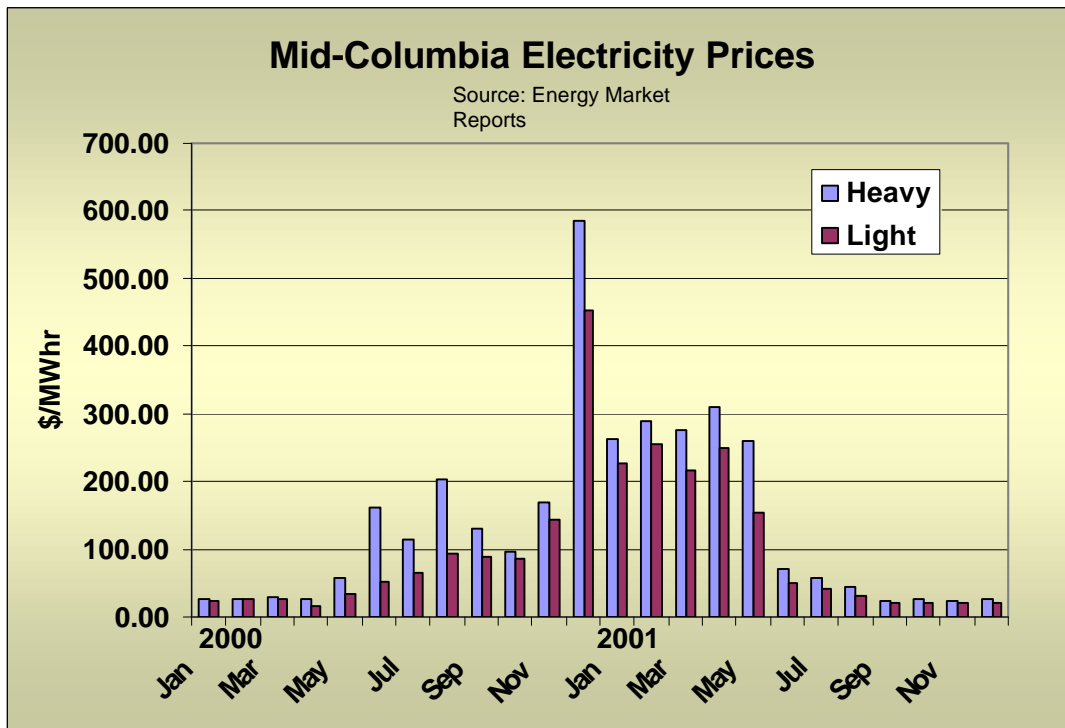
<sup>28</sup> [Northwest Power Supply: Adequacy/Reliability Study Phase I Report](#), Northwest Power Planning Council, March 2000.

load probability – LOLP) despite heavy use of imports and hydro system flexibility<sup>29</sup>. Ordinarily a 5 percent probability would be considered acceptable. It was estimated that the equivalent of 3000 MW of new generating capacity would be required to achieve the desired 5 percent LOLP.

## Summer – Fall 2000

The limit to which we could push our reliance on good water and a healthy market was reached in the summer of 2000. A history of market prices at the Mid-Columbia trading hub from January 1, 2000 up to this writing is shown on Figure X-8. Note that this chart is plotted on a logarithmic scale to permit covering the extreme range of prices with some resolution. In a sense, this chart provides a history of the Western Electricity Crisis.

Figure X-8



The year 2000 began with “normal” prices and, in the spring, good runoff. However, in late June and throughout the summer and fall, the West experienced much higher than normal power prices, punctuated by some extreme price spikes. During the same period, California was frequently on the verge curtailing loads and did so several times. There were a number of factors that lead to this situation. There were physical and economic factors including:

- Declining generation margins resulting from lack of investment in new resources;
- Higher than normal weather-driven demands throughout the West;
- An unusual pattern of hydropower generation – an early run-off followed by reduced hydro generation;
- A high level of planned and forced outages of thermal generating units; and

<sup>29</sup> Hydro system flexibility implies drafting reservoirs deeper than would ordinarily be the case in order to meet extreme loads and then attempting to replace the water to meet April flood control levels through imports and greater use of thermal resources.

- High gas prices in reaction to the high demand for gas-fired generation.

There were also factors related to market immaturity and transitional uncertainties including:

- The lack of a demand-side response to increases in wholesale prices;
- Inadequate utilization of risk mitigation strategies; and
- Factors related to the design and operation of the California market including some level of market manipulation by some market participants.<sup>30</sup>

High power prices and power supply concerns persisted through the fall. The fall was extremely dry and the forecast of a moderately cold weather event in mid-December of 2000 prompted real concern of potential supply problems in the Northwest. In California, large amounts of generation that would normally be available to the Northwest were offline. The reasons were several:

- Older plants that had been run hard through the summer and fall and legitimately were shut down for necessary maintenance;
- So-called QF plants that had contracts for sale of power to California utilities were not run because of the fear that they would not be paid as a result of the increasing financial problems of the California investor-owned utilities;
- Some older plants had used up their emissions allowances and could no longer run;<sup>31</sup> and
- There was some level of withholding plants from production to manipulate prices.

The Northwest responded in many ways:

- The region's governors made appeals for conservation and curtailment of unnecessary use;
- Utilities faced with rapidly declining reservoirs began seeking additional sources of supply – sometimes expensive contracts, sometimes relatively expensive emergency generation, typically diesel generators or small turbines; environmental controls were relaxed to allow older, more polluting regional gas turbines to run for extended periods; and
- Efforts were made to contract for load reduction, particularly in the aluminum industry.

December also marked the first order by the Federal Energy Regulatory Commission to address problems with the California market. The remedies instituted, like eliminating the requirement that utilities purchase their requirements in the day-ahead market and establishing penalties for underscheduling of load, were steps in the right direction. However, they were too little too late.

This period also began to reveal another problem related to the competitive wholesale power market – the inability and/or unwillingness of regional load serving entities (LSEs) to provide information regarding the sources and amounts of purchase power. Similarly, merchant generators located within the region could not or would not provide information regarding the disposition of power from their plants. This information is important to the ability to assess the adequacy of resources available to the region. However, even though the data were only to be used in the aggregate without individual entities identified, most LSEs and merchants were unwilling to provide this information. Some of this may have been concerns about their own competitive position becoming known or that they would be charged much more if it became

---

<sup>30</sup> [Study of Western Power market Prices: Summer 2000, Summary of Final Report](#) Northwest Power Planning Council October, 2000.

<sup>31</sup>

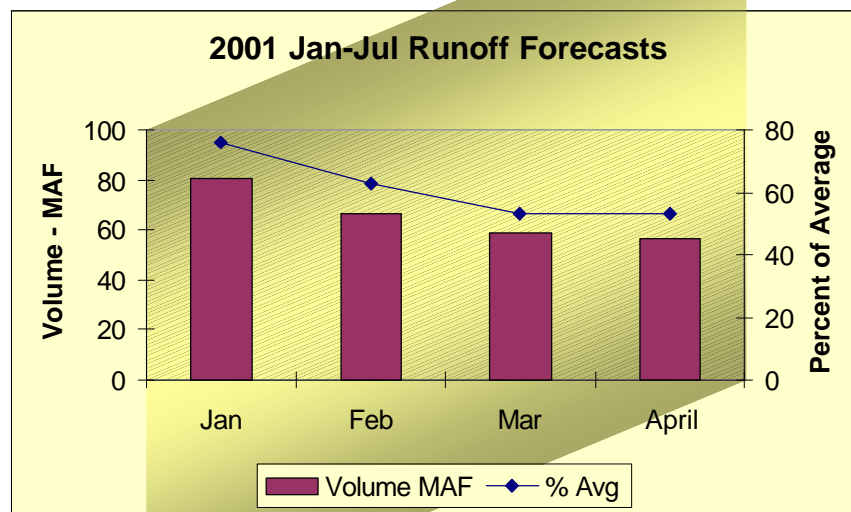
This issue was addressed fairly quickly and most of these plants were returned to service.

known that they were short. In other instances it may be that the source of power behind contracts with power marketers may not be known until after the fact. Whatever the reason, this information gap seriously handicaps the ability to assess power supply adequacy.

## Winter-Spring 2001

High prices persisted through the winter and early spring of 2001 with heavy load hour prices averaging over \$200 per megawatt-hour. There were times during which prices were much higher than that. January also marks the first snow pack measurements and estimates of runoff – essentially an estimate of the amount of water that will be entering the hydro system over the spring and early summer. The runoff forecasts for the first several months of 2001 are summarized on Figure X-9. The anticipation of poor runoff conditions was reflected in high forward prices. By the first of February, publicly quoted forward prices for the second and third quarters of the year were in the \$350 – \$400 per mw-hr range.

Figure X-9



At this time, the Council, Bonneville and others were attempting to look forward and assess power supply adequacy across the summer and into the following winter. These assessments were made difficult by several factors:

- The high degree of uncertainty surrounding runoff early in the season;
- Uncertainty with respect to how successful efforts to reduce loads would be;
- Uncertainty with respect to how much emergency generation might ultimately be brought on line; and
- Uncertainty with regard to the availability of power from California and the Desert Southwest in the fall and winter as well as uncertainty with regard to NW obligations to supply power to California in the summer.

A further and generally unrecognized uncertainty was the economic slowdown that was just beginning.

Across the winter and spring of 2001, the Council did several assessments of power supply adequacy. By the time the Council did its first assessment in early February, the runoff forecast had fallen to 67 MAF, about 63 percent of normal. This analysis focused on the winter season. Under extreme weather conditions, this analysis indicated a significant potential for shortages.

This analysis also looked toward the summer and noted the large amount of energy associated with spill.

A second analysis was done in March. It incorporated updated estimates of load reduction and emergency generation as well as a deteriorating runoff forecast. This analysis looked at summer conditions for two water years that bracketed the current runoff forecast. It then assessed the winter situation. Because the region would be coming off a dry year, it was assumed that fall-winter 2001-02 runoffs would be limited to those of the driest two thirds of water years in the historic record, treating each with equal probability. The findings of this analysis were that it was not possible to avoid summer curtailments AND return reservoirs to Biological Opinion levels by the end of August without significant reductions in spring and summer spill. Failure to return the reservoirs to Biological Opinion levels resulted in very high probabilities of winter power supply problems. Even with reductions in spill, the winter season loss of load probability was 20 percent. Council fish and wildlife staff estimated the effects of downstream migrants and found them to be relatively small. The staff conclusions at that point were:

- Decisions on spill need to be made soon but can be revisited
  - If spring spill is maintained, energy is lost, more stringent and expensive steps may be required later
  - Spill can be restored if conditions improve or other resources become available
- Winter 2001 -- 2002 outlook calls for continued and increased attention to load reduction, conservation and generation.

## **Spring-Summer 2001**

In May, the Council reassessed the power supply situation. This analysis incorporated increased estimates of new generation expected to be available during the period of analysis. It also incorporated increased estimates of load reduction and conservation. It also attempted to refine its look at summer conditions by analyzing a range of 7 “synthetic” run off volumes and patterns that were intended to better represent the range of uncertainty in runoff. The analysis also assumed that no imports were available in the summer while firm export obligations were met. Intertie loadings at the time tended to support this assumption, showing the Northwest as a net exporter during this period, albeit at levels well below levels typical of a normal water year. This analysis found that without reductions in spill, there was still the potential for power supply problems early in the summer for several of the water years analyzed, although the magnitudes of the problems were significantly reduced from the March analysis.

The analysis again looked at the winter 2001-2002 situation, limiting the analysis to the driest 2/3 of the historic water years. While the winter reliability situation looked better than in the earlier analysis, the loss of load probability was still uncomfortably high (17 percent). The analysis went on to assess the value of increased storage in Canadian reservoirs. It found that storing 1500 megawatt-months of energy in Canadian reservoirs could reduce the winter loss of load probability to 12 percent. This was still high but significantly better than 17 percent. The analysis went on to look at the ability to store that amount of energy. It was found that if spill were maintained, we could be confident of storing 1500 megawatt-months of energy only if a January-July Runoff volume greater than 59 MAF were achieved. If there was virtually no spill at federal projects, the storage could be achieved with 56 MAF. Since a runoff of 56 MAF appeared considerably more likely, eliminating spill appeared the prudent choice (2001 runoff

turned out to be 58 MAF). This information was influential in the decision by the federal agencies to largely eliminate spill at the Federal projects.<sup>32</sup>

Later in May and late June the Federal Energy Regulatory Commission issued price mitigation orders, first for California and later for the entire WSCC. The WSCC order established a price cap slightly under \$100/megawatt-hour for sales in the West. As figure X-8 shows, prices had already begun heading down. This may be because the market had already internalized the price caps. Or, it may be that the market was finding that it could not sustain the very high prices in the face of reduced loads and increased generation. It is likely that both had an effect. However, the fact that prices barely paused as they moved below the price cap suggests that the fundamental change in the supply-demand situation played a major role in reducing prices.

### **Fall 2001 – Winter 2001 – 2002**

Wholesale power prices continued downward through the fall and early winter. In one sense, this marked the end of the Western Electricity Crisis, although the effects of the crisis on retail rates and perhaps on future fish runs will extend for some time. In September and October of 2001, the Council reassessed the adequacy and reliability of the power system for the winter of 2001-2002. By this time it had become clear that in addition to utility and government-initiated conservation and curtailment efforts, the slowdown in the economy was having an effect on loads. The analysis found a winter season loss of load probability well under 5 percent. The major factor behind this was a much lower estimate of winter loads. In total, the estimated loads for the period October 2001 through March 2002 were approximately 11000 megawatt-months less than the May estimates for the same period. In addition, approximately 3700 megawatt-months of energy had been stored in Canadian reservoirs (as opposed to the 1500 analyzed in May) and constraints on the use of that water had been reinterpreted in such a way as to make the water much more useful for addressing periods of high demand. In moving the LOLP from about 12 percent in the May analysis to under 1 percent in the October analysis, the greater than expected drop in demand contributed about 7 percent of the drop, the additional water stored in Canadian reservoirs and the greater flexibility in the use of that water contributed another 3 percent and a better forecast of expected winter water conditions contributed 1 percent. The winter remained moderate, precipitation and resulting runoff were close to normal, wholesale prices are again below the full cost of new generation (and much conservation) and everyone is asking what happened to the Western Electricity Crisis.

### ***What issues are raised by the experience of 2000-2001?***

The experience of 2000-2001 was the consequence of actions and inactions in the preceding years that resulted in a power system that was not adequate to maintain a reliable and economical power supply in the event a very dry year. Fish operations had reduced the power capability of the system but those effects were certainly internalized into the thinking and planning of the industry by 2000-2001. The primary causes of the supply and price problems of 2000 – 2001 had much more to do with the changes going on in the industry, the industry structure, particularly in California, the relative immaturity of competitive wholesale markets, and so on.

The experience of 2000-2001 raises two basic sets of issues. First, what changes in power planning, policy, regulation and implementation need to take place to avoid a similar situation in the future? Second, if such situations do arise again in the future, how might they be better managed. The first raises such issues as:

---

<sup>32</sup>Approximately 1000 MW-Months of energy was spilled at federal projects compared to the several thousand that would ordinarily be spilled.

- Are there adequate “incentives” for the development of new resource, both generation and efficiency. If load-serving entities have learned to limit their exposure to the market by making more long-term resource investments even when they are facing very low short-term market prices, the answer may be yes. If not, other mechanisms will have to be explored.
- Are there acceptable and effective ways to better link retail consumption decisions with wholesale prices to achieve quicker and more predictable load reductions in the face rising wholesale prices? To do so would both mitigate prices increases and reduce the likelihood of involuntary curtailments.
- Is the region carrying adequate physical hedges against volatility in electricity prices and the underlying fuel prices? How well do different resource strategies limit risk and at what cost? What barriers exist to implementing such strategies? How might those barriers be overcome?

The experience of 2000-2001 also suggests that to better manage such situations should they occur in the future, will require better information regarding loads, resources, imports and export obligations, conservation and curtailment efforts and so on. It will also require better coordination among the responsible parties. The information requirements and flows need to be worked out in advance and everyone needs to provide such information with confidence that their own competitive position will not be compromised.

It is also clear that attention also needs to be paid to assuring the fish and wildlife needs and reliability needs are balanced appropriately in crisis situations. Staff believes that over this period, there was a balancing that took place. Yes, spill was dramatically reduced but so were power system loads while expenditures for power and new generation were greatly increased. Still, there needs to be a way to ensure that one value is not being sacrificed unnecessarily for the sake of the other – that there is equitable treatment of the two goals. We don’t expect a 0 percent loss of load probability. It would be too expensive to achieve such reliability under all possible circumstances. Similarly, we should not expect a 0 percent “loss of fish operations” probability.

These issues cannot be resolved in the context of the Mainstem Rulemaking. They are issues that are most appropriately left to the Power Plan.

### ***Efficient***

The objective of the planners and operators of the power system is a power system that is as efficient as possible given the multiple objectives for the use of system. From the single objective perspective of power operations, the power system is less efficient than it was at the time of the passage of the Act. This is the result of many factors, some of which are just related to characteristics of new resources available to meet growth and some related to the effects of fish recovery measures. It is still, however, a very efficient system relative to systems elsewhere. The Council does not believe that the framers of the Power Act meant the term “efficient” to establish an absolute standard. The system is currently operated efficiently given the constraints under which it must operate. The consequences of not doing so are economic -- additional costs to supply a given amount of power. In the past, the expansion of the power system has also been efficient. Regulation and least-cost planning requirements encouraged the development of efficient resources. The question of whether or not the power system is structured to assure the most efficient operation and expansion going forward is one that is being addressed in the Fifth Power Plan.

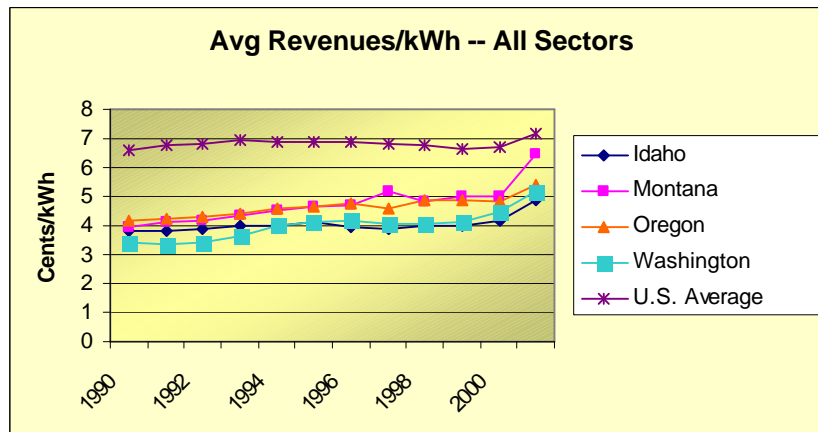
The Northwest Power Act clearly expected a balancing of fish and power objectives, i.e., operating the system with multiple objectives. Fish objectives should also be met as efficiently or cost-effectively as possible. Given the high cost of some fish measures and the relative lack of information regarding their effectiveness in meeting biological objectives, it is imperative that efforts be made to assess and improve the cost-effectiveness of these measures.

## **Economical**

Much of the concerns with respect to adequacy, reliability and efficiency boil down to the question of economics. We can certainly assure ourselves of an adequate and reliable power system if we are willing to spend the money. But will the system still be economical? We can degrade the efficiency of the system, but that will affect its economics.

There are perhaps three ways of thinking about the economical criterion. One is whether the per kilowatt-hour costs of the system have been caused to increase significantly in comparison to other regions. On this basis, the power system is clearly less economical than it was. Figure X-10 shows average revenues from the sale of power for the Northwest states compared to the US average through the 1990s up to 2001 in nominal (not adjusted for inflation) dollars.

Figure X-10



As this figure shows, there was some erosion of the Northwest’s competitive advantage in electricity prices through 1990s, some of which is attributable to the effects of fish operations. However, the largest impact on the economics of the region’s power supply came about over the last two years as a consequence of factors related to the structure, operation and immaturity of the wholesale electricity market as has been described elsewhere in this appendix. Most of the alternatives would somewhat lessen power system costs although two somewhat increase power system costs.

Unfortunately, this kind of aggregate look at the question does not capture the potential impacts on particular elements of the economy. In particular, electricity-intensive industries, such as aluminum smelting, are proportionately harder hit by increases in electricity costs. Many aluminum plants in the region have increasingly become “swing” plants that are only economic to operate when aluminum prices are relatively high. Fish recovery costs have contributed to this, although in the current context, they are only one contributor.

Finally, economical relates to the question of whether the fish and wildlife program is consistent with other purposes of the Act, in particular, timely repayment of Bonneville’s debt to the United

States Treasury. Bonneville is currently in difficult financial circumstances arising primarily from the market circumstances of the last two years, although fish and wildlife costs are a contributor to Bonneville's overall cost structure. An estimate of the effect of the proposed mainstem amendments on Bonneville's annual revenue requirement was previously shown in Table X-3. Most of the alternatives under consideration would reduce costs somewhat. The Oregon alternatives increase costs some. In the context of Bonneville's current financial situation this could be problematic.

The longer-term question of assuring an economical power supply in the future is being addressed in the Fifth Power Plan. The fundamental issues are the same as those related to the adequacy and reliability of the system: Are there adequate incentives for the development of new resources; can retail loads be made more responsive to wholesale prices; and is the region developing a resource portfolio that adequately hedges risks while still achieving low cost.

**Attachment 2**

**State, Federal, and Tribal Anadromous Fish Managers  
Comments on the Northwest Power Planning Council Draft Mainstem  
Amendments as they Relate to Flow/Survival Relationships  
for Salmon and Steelhead**

**FINAL DOCUMENT**

**January 2003**

***Executive Summary***  
***of the State, Federal, and Tribal Anadromous Fish Managers Comments on the***  
***Northwest Power Planning Council Draft Mainstem Amendments as they***  
***Relate to Flow/Survival Relationships for Salmon and Steelhead***

1. The state, federal, and tribal anadromous fish managers reviewed the NPPC's draft Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program, which are contained in Council Document 2002-16. This review focused on the scientific information, as anticipated in section 839(h)(B) of the Northwest Power Act, regarding the effect of flow on salmon and steelhead survival.
2. The Council draft mainstem amendment document relies heavily on a conclusion from Giorgi et al. (2002) questioning the scientific basis of a flow survival relationship. There was little reliance by the Council on recommendations or comments of the fish and wildlife management agencies, scientific support for flow-survival relationships previously summarized in NMFS (2000) white papers, or recently peer-reviewed articles on chinook summer migrants.
3. The Council did not seem to heed the caution from the ISRP review that the Giorgi et al. (2002) report concerning a flow survival relationship was "...very conservative in drawing statistical conclusions. From a purely statistical standpoint, tests that fail to show statistical significance in data can be definitive in stating *no effect was found*, yet these tests do not definitively prove the absence of an effect."
4. The assessment and conclusions of the state, tribal and federal anadromous fish managers regarding the mechanisms by which flow and water velocity may affect juvenile survival in freshwater and from migrating smolt to adult return have been summarized in this paper. This includes a summary on juvenile migratory characteristics related to flow and spill that also provide evidence of flow-survival relationships, and the supporting empirical evidence from patterns of smolt-to-adult return rates (SARs) and life cycle survival analyses (ratio of recruits to the spawning grounds vs. spawners the previous generation; S/S).
5. The conclusion of the state, tribal and federal salmon managers, based on review of the scientific information regarding the effect of flow on salmon and steelhead are:
  - a. **Juvenile steelhead and chinook spring migrants**
    - i. A water travel time/ survival relationship exists for spring migrating chinook and steelhead of Snake River and Mid-Columbia River origin.
    - ii. A water travel time and fish travel time relationship exists for spring migrating chinook and steelhead.
    - iii. Within the management range of the Biological Opinion and the flow spill risk analysis dissolved gas levels of 125% there is minimal risk of reducing survival by increasing spill.
    - iv. It is difficult to define a flow survival relationship because survival is the combined result of many interacting variables and the methodology for

estimating survival does not lend itself to identifying each individual environmental or biotic variable individually.

**b. Juvenile fall chinook migrants**

- i. Wild subyearling fall chinook salmon spend from 20 to 42 days in Lower Granite Reservoir primarily during the months of July and August.
- ii. Meeting summer flow targets decreases the time young fall chinook salmon spend in Lower Granite Reservoir by 1 to 5 days.
- iii. Survival of wild subyearling Snake River fall chinook is influenced simultaneously by flow and temperature.
- iv. Meeting summer flow targets increases flow and decreases temperature
- v. Meeting summer flow targets in July and August increases survival of wild subyearling fall chinook migrants.
- vi. Shifting flow augmentation from July and early August to later times in the year would decrease survival of the largest portion of the wild subyearling fall chinook salmon run.

**c. Adult return analysis**

- i. Numerous mechanisms exist by which flow and water velocity may affect survival from migrating smolt to adult return.
- ii. Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of adult recruitment of Snake River spring and summer chinook (spawner to spawner ratio).
- iii. The BIOP flow targets appear to represent a minimum needed to maintain the Snake River spring summer chinook populations for average to good ocean conditions and provide inadequate protection for poor ocean conditions.
- iv. The Councils proposed relaxation of spring flow targets would increase water travel time and reduce protection against population declines and the likelihood of rebuilding spring and summer chinook stocks.
- v. Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of SARs in Snake River spring and summer chinook and steelhead.
- vi. Relaxation of Spring flow objectives would likely decrease the SARs of wild Snake River spring and summer chinook and steelhead.

## **State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead.**

### **Introduction**

The initial recommendations for the Northwest Power Planning Council Fish and Wildlife Program were submitted to the Northwest Power Planning Council under the auspices of Section 4(h) of the Northwest Power Act by the state, federal and tribal salmon managers in November of 1981. Flow and spill for the juvenile out migration of salmon and steelhead were critical facets of those recommendations. The joint recommendations of the salmon management entities were based upon passage and migration data and analysis collected to the date of the initial Fish and Wildlife Program. Over the past decades significant additional study and analysis has taken place.

The Council draft mainstem amendment document relies heavily on a conclusion from Giorgi et al. (2002) questioning the scientific basis of a flow survival relationship. There was little reliance by the Council on recommendations or comments of the fish and wildlife management agencies, scientific support for flow-survival relationships previously summarized in NMFS (2000) white papers, or recently peer-reviewed articles on chinook summer migrants. The Council did not seem to heed the caution from the ISRP review that the Giorgi et al. (2002) report was "...very conservative in drawing statistical conclusions. This fact needs to be understood for proper interpretation of the report. From a purely statistical standpoint, tests that fail to show statistical significance in data can be definitive in stating *no effect was found*, yet these tests do not definitively prove the absence of an effect." See Peterman (1990) for a review of this problem in fisheries research and management.

This paper briefly summarizes the assessment and conclusions of the state, tribal and federal anadromous fish managers regarding the mechanisms by which flow and water velocity may affect juvenile survival in freshwater and from migrating smolt to adult return. This includes a summary on juvenile migratory characteristics related to flow and spill that also provide evidence of flow-survival relationships, and the supporting empirical evidence from patterns of smolt-to-adult return rates (SARs) and life cycle survival analyses (ratio of recruits to the spawning grounds vs. spawners the previous generation; S/S). The document is organized in terms of juvenile migration characteristics and adult analysis. The conclusion of the state, tribal and federal salmon managers, based on review of the scientific information as anticipated in section 839(h)(B) of the Northwest Power Act, regarding the affect of flow on salmon and steelhead are:

### **Juvenile steelhead and chinook spring migrants**

- A water travel time/ survival relationship exists for spring migrating chinook and steelhead of Snake River and Mid-Columbia River origin.
- A water travel time and fish travel time relationship exists for spring migrating chinook and steelhead.

- Within the management range of the Biological Opinion and the flow spill risk analysis, there is minimal risk of reducing survival by increasing spill up to dissolved gas levels of 125%.
- It is difficult to define a flow survival relationship because survival is the combined result of many interacting variables and the methodology for estimating survival does not lend itself to identifying each individual environmental or biotic variable individually.

#### **Juvenile fall chinook migrants**

- Wild subyearling fall chinook salmon spend from 20 to 42 days in Lower Granite Reservoir primarily during the months of July and August
- Summer flow augmentation decreases the time young fall chinook salmon spend in Lower Granite Reservoir by 1 to 5 days
- Survival of wild subyearling Snake River fall chinook is influenced simultaneously by flow and temperature
- Summer flow augmentation increases flow and decreases temperature
- Summer flow augmentation in July and August increases survival of wild subyearling fall chinook migrants
- Shifting flow augmentation from July and early August to later times in the year would decrease survival of the largest portion of the wild subyearling fall chinook salmon run

#### **Adult return analysis**

- Numerous mechanisms exist by which flow and water velocity may affect survival from migrating smolt to adult return.
- Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of adult recruitment of Snake River spring and summer chinook (spawner to spawner ratio)
- The BIOP flow targets appear to represent a minimum needed to maintain the Snake River spring summer chinook populations for average to good ocean conditions and provide inadequate protection for poor ocean conditions
- The Councils proposed relaxation of spring flow targets would increase water travel time and reduce protection against population declines and the likelihood of rebuilding spring and summer chinook stocks.
- Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of SARs in Snake River spring and summer chinook and steelhead.
- Relaxation of Spring flow objectives would likely decrease the SARs of wild Snake River spring and summer chinook and steelhead

#### **Background of Flow Related Effects on Salmonid Smolt Travel Time, Rate of Seaward Movement, and Survival and Adult Returns**

The analyses are approached in three components, the Snake River from Lower Granite to McNary Dam, Mid-Columbia from Rock Island to McNary and Lower Columbia River reaches from McNary to Bonneville tailrace. The following assessment focuses on the migration characteristics of juvenile salmonids including; travel time (migration speed), rate of seaward

movement, survival and migration timing, addressing these migration characteristics and the suite of biotic and abiotic factors that affect them.

Increases in flow in the hydrosystem are thought to be beneficial to migrating young salmonids for several reasons. These species evolved in systems without dams and were dependent on the river current to aid in their migration to the ocean. The migration of spring/summer and fall chinook and steelhead was timed with periods of high spring runoff. During a free-flowing condition Snake River yearling chinook and steelhead migrated to the ocean in about  $\frac{1}{3}$  to  $\frac{1}{2}$  the time that is now observed with the dams in place. Dam construction changed juvenile fall chinook salmon life history in the Snake River basin by shifting production to areas with relatively cool water temperatures and comparatively lower growth opportunity. Consequently, young fall chinook salmon do not attain migratory status until late spring and the majority of the wild fish are present in lower Snake and Columbia River reservoirs in July and August after spring runoff is complete (Connor et al. 2002). Increases in the time spent in the reservoirs increases the exposure time to higher temperature and predators, now more abundant in the reservoir system than in pre-dam riverine conditions. (Poe et al 1991, Poe et al 1994) In addition to the direct effects of increases in flow on downstream passage of smolts, there are several other flow related mechanisms that manifest in life history constraints hence smolt survival. Increases in flow are associated with decreases in temperature and increases in turbidity. When flow falls to low levels, the accompanying increases in temperature increase the energetic demands for migrating smolts, increase their susceptibility to disease, disrupt smoltification, and increase the energy demands of predators hence predation on smolts. Low turbidity increase the susceptibility of smolts to visual predators such as fish and birds. Studies also suggest that the extended time smolts spend in freshwater affect marine survival by depleting energy reserves before the smolts arrive at the ocean. This phenomenon is especially prevalent under low flow conditions (Congelton, ACOE Delayed Mortality Workshop). A delay in seawater entry might also disrupt physiological changes necessary for adapting to saltwater. Decreased flows may also form greater physical barriers with the freshwater/saltwater interface (Schreck and Stahl 1998).

Travel time is one of the key migrational characteristics reflecting the dynamics of the migration of juvenile salmonids. The physiological condition of smolts changes over time and arrival at the estuary during the “biological window” determines the success of the smolts transition to seawater. Studies conducted since 1998 (Congleton et al., 2000, 2001 and 2002) have observed the rate of energy use and the blood chemistry changes that occur in fish as they migrate from hatcheries above Lower Granite Dam to Bonneville Dam. In general, the juvenile chinook salmon studied were in negative energy balance throughout the downstream migration. The low flows in 2001 caused fish to undergo a migration that was significantly longer and the low flows and extended travel times resulted in the exhaustion of lipid reserves at points further upstream and greater use of protein reserves than in earlier years. The use of protein reserves means that muscle mass is metabolized and the activities of critical rate-limiting enzymes involved in metabolism, saltwater adaptation, and other vital functions may be reduced (Congleton, 2002).

Giorgi et al. (2002) points to these life-history constraints as rationale for flow augmentation. They provided information supporting increased migration rates with increases in flow for yearling chinook and steelhead (Sims and Ossiander 1981, Berggren and Filardo 1993). Most of

these analyses demonstrate increasing migration speeds by increasing flows provides the greatest benefits at lower flows. Regardless of flow level, several studies have produced equivocal results with respect to the relation between flow and seaward movement of summer migrating subyearling chinook salmon. Berggren and Filardo (1993), Giorgi et al. (1997), and Tiffan et al. (2000) studied ocean-type chinook salmon passing downstream in Columbia River reservoirs. Berggren and Filardo (1993) concluded that seaward movement of summer migrants increased as flow increased, thus flow augmentation helps to mitigate dam-caused passage delays. Tiffan et al. (2000) concluded that flow was weakly related to seaward movement. Giorgi et al. (1997) concluded that there is no evidence for a relation between downstream migration rate and flow. A recent study, however, showed that wild subyearling fall chinook salmon progress through a series of complicated migrational behaviors during which their response to changes in flow varies (Connor et al. In press a). Subyearling fall chinook salmon respond to increases in flow as they pass downstream from the free-flowing Snake River to Lower Granite Dam. The Connor et al. analysis, however, failed to find evidence for a flow-migration rate relation as fish passed downstream between Lower Granite and Little Goose dams probably because of limitations on their study. This does not suggest a downstream relationship does not exist, rather that different degrees of smoltification will result in different rates of migration and therefore, complicate such relationships.

Giorgi et al. (2002) reiterate a concern by several researchers that many environmental variables may be responsible for patterns of survival through the hydrosystem. Flow and spill are unlikely the only variables affecting survival; however, many of the variables of concern are a result of changes in flow. Turbidity and temperature, for example, have been suggested to be driving survival patterns, but these are often dependent on flow, flow is not dependent on turbidity and temperature. These factors may make flow/survival patterns more difficult to observe but they should not be used as evidence that flow is not an important driver to relationships that we do observe.

A large proportion of Snake River spring/summer chinook and steelhead have been removed from the river for transportation since Snake River dam construction, yet their subsequent survival may also be influenced by the environmental conditions (flow and spill in particular) experienced prior to collection and transportation (Budy et al. 2002; Mundy et al. 1994). Examples of mechanisms by which flow or water travel time may influence post-transport survival of smolts include effects of delayed migration on energetic condition (reduced lipids), exacerbated by stress at the collection projects, holding facilities and in transportation.

As with transportation and spill, considerations to the impacts of flow outside the hydrosystem, including delayed mortality to both transported fish and those that migrated in-river (Budy et al. 2002), must be taken into consideration. Flow may be important below Bonneville where fish and avian predators are most abundant and survival is not currently estimated as fish and avian predators are most abundant in this area. As stated above, smolts undergo dramatic physiological changes to cope with entry into the estuary and saltwater. Changes in flow can greatly affect the physiological timing of this transition. For example, Schreck and Stahl (1998) have documented that smolts that are stressed (from barging or migrating in-river) avoid entry into saltwater by remaining on the floating freshwater lens at the saltwater-freshwater interface. This forces smolts to the surface where they are susceptible to avian predation. Increased flows

out of the Columbia enhance mixing of freshwater and saltwater and aid migrating salmon into the transition to saltwater decreasing this delayed hydrosystem mortality. Through these mechanisms both transported and in-river fish can be greatly affected by the flow regime. How this and other factors in the hydrosystem affect survival back to adults is of prime importance. Giorgi et al. (2002) does not evaluate the impacts of flow on these other life stages but evidence can be found for this in NMFS white papers, and in previous fish and wildlife agency comments to the Council.

## **Methods of Travel time and Survival Data Analysis for Juvenile Steelhead and Chinook Springs Migrants**

### Travel time and survival

The juvenile migrants considered for these analyses represent groups for which travel time and survival was estimated for the entire Snake River (Lower Granite Dam to McNary Dam) reach using PIT tag technology. The first year that PIT tag data was available for survival estimation in the entire Lower Granite to McNary reach was 1995, however, not until 1998 when installation of full bypass PIT tag detection at John Day Dam was completed did we begin to obtain reliable estimation of survival to McNary Dam. Although survival studies using PIT tags were initiated as soon as the PIT tag detection units were installed at the projects, the reaches covered were limited in the early years. In 1993 survival studies could only be conducted between Lower Granite and Little Goose dams. This was expanded in 1994 to the Lower Granite to Lower Monumental river reach when PIT tag detectors were installed at additional projects. In 1995 to 1997, direct estimates of survival in the Lower Granite to McNary Dam reach were possible; however, due to limited detection capability at John Day Dam (detection of sampled fish from one gatewell slot out of 48) and moderate detection capability at Bonneville Dam due to operational spill levels at that facility, the resulting reach survival estimates had low precision. The detection limitations of the early years necessitated the extrapolation of the shorter river reach survival estimates to the longer reach (Lower Granite to McNary). It is now known that these earlier estimates using extrapolation resulted in a miss-representation of survival when applied to the longer reach. Consequently, we have chosen not to include these estimates in our analysis. Reliable estimation of survival to McNary Dam was not possible until installation of bypass detectors at John Day in 1998. For these reasons we have chosen to use survival estimate from 1998 to 2002 in creating the bivariate and multiple regression models. The above detection limitations below McNary Dam do not impact the quality of the travel time data from Lower Granite Dam to McNary Dam and therefore, travel time analyses use data from 1995 to 2002 for yearling chinook and 1996 to 2002 for steelhead. All juvenile yearling chinook and steelhead marked using PIT tags at hatcheries and fish traps above Lower Granite Dam and subsequently recaptured at the initial site, as well as those fish marked and released at Lower Granite Dam, were used in our analysis.

For the analyses pertaining to the Mid Columbia River, travel time and survival was estimated from Rock Island to McNary dams for releases of yearling chinook and steelhead marked and released at Rock Island Dam from 1998 to 2002. The Mid-Columbia fish used in our analysis were marked at Rock Island as part of the Fish Passage Center's Smolt Monitoring Program.

For the Snake River this study used all juvenile yearling chinook and steelhead marked using PIT tags at hatcheries and fish traps above Lower Granite Dam and subsequently recaptured at the initial site, as well as those fish marked and released at Lower Granite Dam. In the Mid Columbia the fish used were marked at Rock Island Dam as part of the Fish Passage Center's Smolt Monitoring Program. The accuracy and precision associated with any estimate of survival or travel time will be dependent on the number of fish in a release group (N) and the number of fish subsequently recaptured. The intent of the analysis was to relate the dependent variables (travel time and survival) to a series of independent environmental variables. As fish migrate through the hydrosystem the initial release group disperses over time making the description of an average environmental condition difficult. The best chance of describing the environmental variable for each group was to limit the time frame over which the variable was estimated before groups became too dispersed and to reduce the overlap among groups. Consequently, when grouping daily releases of PIT tagged groups together over longer periods of time to provide the most accurate and precise estimate, it is important to not group too large a time period to mask the effect of environmental variables. For smolts originating in the Snake River basin, travel time and survival estimates were developed for each weekly release block in the available years of data. Each year was divided into eight weekly periods for wild and hatchery yearling chinook and into six weekly periods for steelhead. For the Mid Columbia migrants, the season was divided into three two-week blocks for each year.

Smolt travel time is amount of time needed for juvenile migrants to transit the river system between any two points. For each temporal block, an estimate of median travel time was calculated from the smolts transiting the entire reach of interest.

Survival is estimated using the Cormack-Jolly-Seber (CJS) tag-recapture methodology. This method estimates survival components between each dam within the index reach having PIT tag detection equipment such as Little Goose, Lower Monumental, and McNary dams (additional detections at John Day and Bonneville dams downstream of McNary Dam also contribute to process of estimating survival in the upstream reaches. In the case of the Snake River reach, the survival estimate is the product of survival from Lower Granite Dam tailrace to Little Goose Dam tailrace, Little Goose Dam tailrace to Lower Monumental Dam tailrace, and Lower Monumental Dam tailrace to McNary Dam tailrace. In the case of the Mid-Columbia River reach, the survival estimate is the single estimate from Rock Island Dam tailrace to McNary Dam tailrace. The Snake River reach includes four reservoirs and dams and the Mid-Columbia River reach includes three reservoirs and dams.

Because the recovery of the PIT tags is dependent on being observed in a bypass system at downstream hydroprojects, the river and project operations exert considerable influence on the ability to obtain sufficient tag recoveries to obtain a valid estimate. Several criteria were employed to distinguish among the resulting estimates to assure their validity. Any temporal blocks which contained less than 300 smolts in the release group provided too few recoveries to

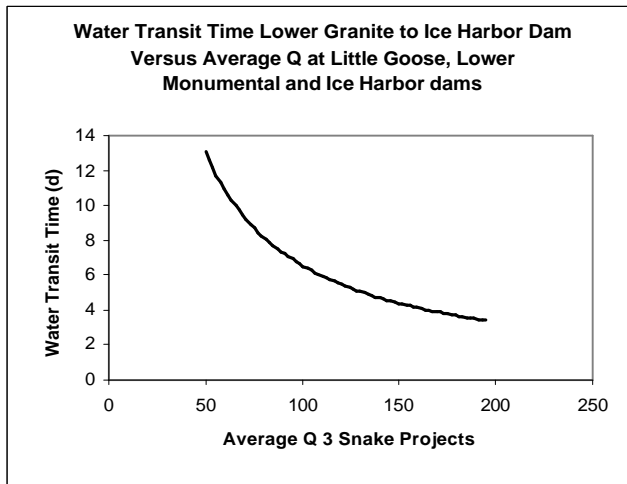
make valid estimates of survival. Consequently, no estimates of survival and travel time were made when less than 300 smolts were available. In addition, another criterion was applied to the estimates of survival. When the coefficient of variation (standard error divided by estimate) of any component survival estimate exceeded 0.25, the full reach survival estimate was excluded from the analysis. This check was made prior to multiplying the several component survival estimates to create a full reach survival estimate, as was the case in the Snake River basin. Whenever a component survival estimate was greater than 1, then the standard error divided by 1 was used as the threshold criteria. In the years 1998 to 2002, only one wild chinook, two hatchery chinook, and one steelhead temporal block needed to be excluded due to the minimum coefficient of variation criterion. In the Snake River reach, the final survival data set contained 66 estimates of survival for yearling chinook (hatchery and wild combined) and 26 estimates for steelhead. In the Mid Columbia, the final survival data set contained 13 estimates for yearling chinook and 15 estimates for steelhead. All survival estimates were accompanied with associated environmental variables.

#### Environmental Variables: Water transit time, spill proportion, and water temperature

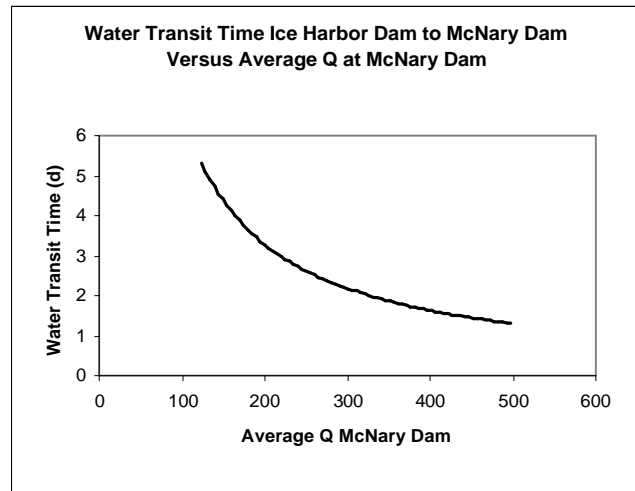
Predictor variables of in-river survival were considered that are related to how flow or velocity may affect the survival of smolts migrating in-river through the hydro system in specific reaches of the Snake and Columbia rivers. The final set of predictor variables included a water velocity related variable, a spill related variable, and river temperature.

#### ***Water Transit Time***

Previous analyses suggested that changes in flow produced changes in water velocity, which determined how quickly smolts migrated through the hydrosystem. The actual flow regime experienced by a group of migrating juvenile fish is difficult to quantify. Past analyses have used an index of flow through a specific reach for a period of time around the median passage dates of the migration or an average flow over the entire passage period. Because of the discrete relation between flow and water transit time (WTT) (also known as water particle travel time) and the implication of velocity as the important determining factor, the flow variable was quantified as the summation of water transit times for each reservoir incorporated in a reach (Figures 1 and 2 showing relation between WTT and average flow in the Snake River and McNary Dam reservoir).



**Figure 1. Relation between water transit time flow in Lower Snake River.**



**Figure 2. Relation between water transit and average time and average flow in McNary Pool.**

The water transit time is the estimated amount of time required for a water particle to travel the fixed distance from the start of the reach to the end of the reach ( $WTT = \text{distance} / \text{average water velocity}$ ). This fixed distance was 140 miles for the Snake River reach from Lower Granite Dam tailrace to McNary Dam tailrace and 161 miles for the Mid-Columbia River reach from Rock Island Dam tailrace to McNary Dam tailrace. The median travel time was estimated to each downstream project for each weekly block. The mid-date of release from LGR was used and to it was added median travel time for the release group to the downstream project. For each day, WTT is computed by dividing each reservoir volume by its corresponding daily average flow to determine the water particle transit time for that day. Reservoir volumes are obtained using COE tables and current reservoir elevations. For each reservoir, an average WTT is computed over a 7-day window of WTT's around the date of median passage of the fish of interest at the reservoir's downstream dam. These average WTT are then summed over the number of reservoirs in the reach of interest. The dates of median fish passage at each dam are obtained from PIT tagged smolts released from or passing during weekly blocks of time at Lower Granite Dam. This process is repeated for each weekly release group of PIT tagged smolts at Lower Granite Dam. Each weekly (7-day) release, starting April 1 for yearling chinook and April 17 for steelhead, was numbered sequentially from first through last week for each year to create a variable for week of entry into the reach.

### ***Spill Proportion***

For each reservoir and dam segment of the reach, survival may be viewed as the product of two components, a reservoir survival component and a dam passage component. In the dam passage component, survival may be viewed as the weighted average survival across each passage route, such as spillway route, turbine route, and bypass channel route (if present), where the weight is equal to the population of smolts using each route. Because the spill passage route has been shown to be the safest route of passage (except during periods of excessively high flows when gas may be a problem), increases in the amount of spill and numbers of fish passing through that route will have a direct effect on the reach survival estimate. Therefore, it is essential to include

a spill related variable in all multiple regression models, otherwise the effect of spill will be confounded within the parameter estimates of the other variables in the model (*i.e.*, a case of model misspecification). The variable representing spill at Little Goose, Lower Monumental, Ice Harbor, and McNary between April and June of 1998 and 2002 was the percentage of daily spill to total discharge. It was calculated using daily average spill and daily average total discharge at each project. Each daily percent Spill/Total Discharge was averaged over a seven-day passage window (centered around the median passage date) for each species and project. The average spill proportion is denoted as SPILLPROP in the subsequent text and tables.

### ***Water Temperature***

The dates of median fish passage at each dam are obtained from PIT tagged smolts released from or passing during weekly blocks of time at Lower Granite Dam. From these same 7-day windows around the dates of median smolt passage at each dam of interest, averages of river temperature are generated. Initially, a variable for the week of entry into the reach was considered, however, it was felt that the river temperature variable would already include the effect of this temporal variable in two ways. First, the general timing of the smolts at Lower Granite Dam is highly influence by river temperature. In years of warmer winters and earlier warming of the river, the smolts begin their migration earlier, whereas in years of cooler winter and later snowmelt, the smolts begin their migration later. Second, river temperature increase over time during the migration period, and so any effects of week of entry into the reach is already confounded within the river temperature variable. Therefore, week of entry into the reach was not used in the multiple regression analyses. The water temperature variable is denoted simply as TEMP in the subsequent text and tables.

### **Results of Travel Time Analysis**

#### Snake River Reach: Lower Granite Dam to McNary Dam

Bivariate relations between smolt travel time and WTT were modeled using linear regression (Table 1). Relations for smolts originating above Lower Granite Dam and migrating between the tailrace of Lower Granite Dam and McNary Dam are shown for wild yearling chinook in Figure 3, hatchery yearling chinook in Figure 4, and steelhead (wild and hatchery) in Figure 5.

**Table 1. Summary of linear regressions of median travel time versus water transit time for wild and hatchery yearling chinook and steelhead.**

<b>Group</b>	<b>Regression Equation</b>	<b>R<sup>2</sup></b>
Wild Chinook	$y = 1.245x + 0.8745$	0.51
Hatchery Chinook	$y = 1.107x + 2.3327$	0.58
Steelhead	$y = 1.250x - 1.2075$	0.87

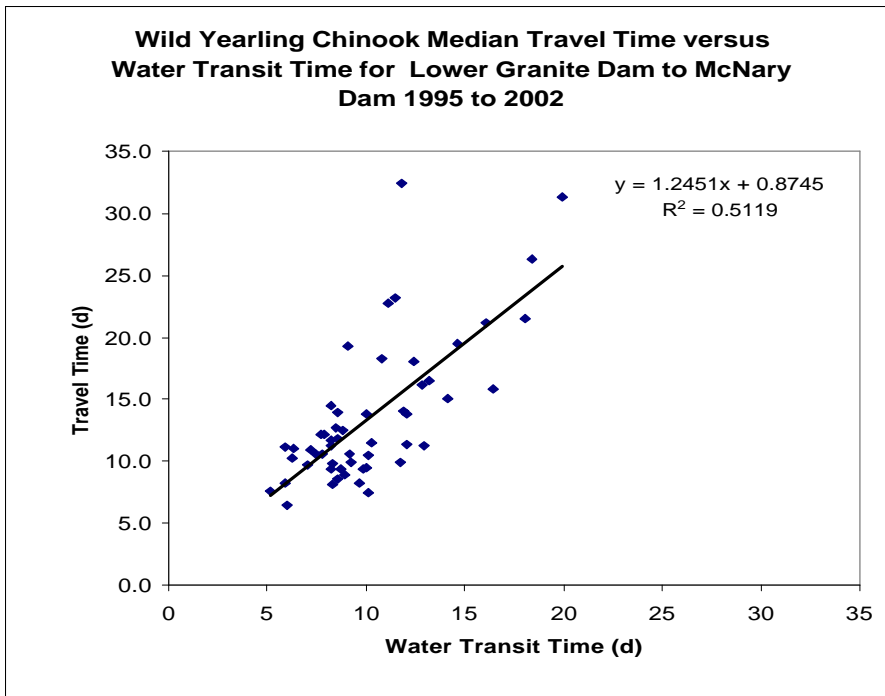


Figure 3. Wild yearling chinook travel time versus water transit time.

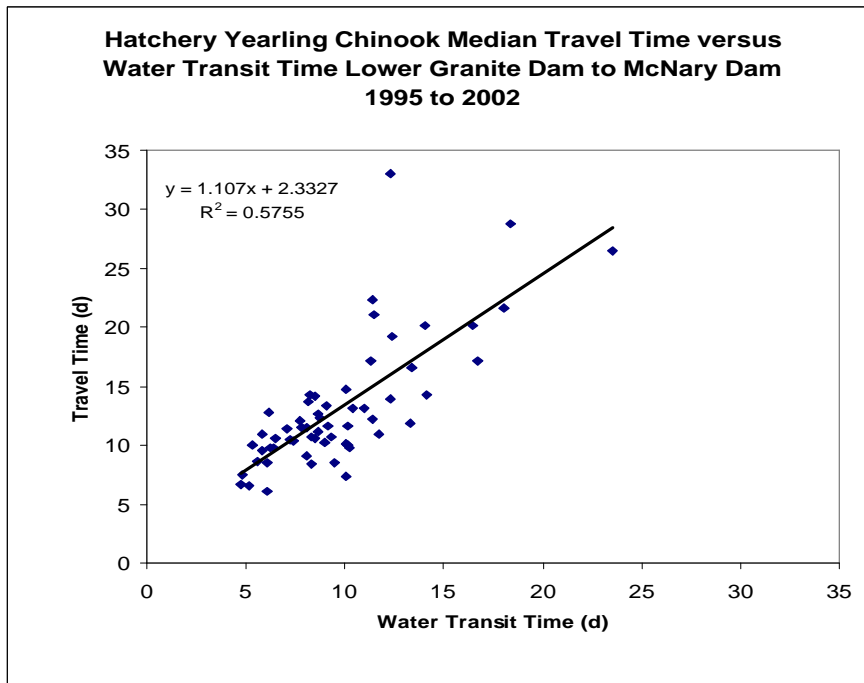
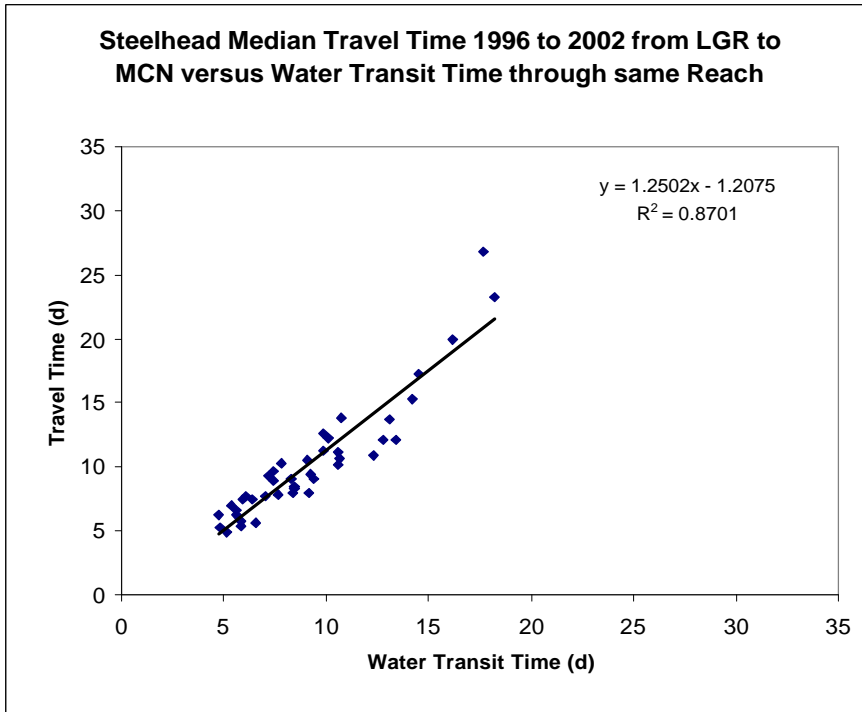


Figure 4. Hatchery yearling chinook travel time versus water transit time.



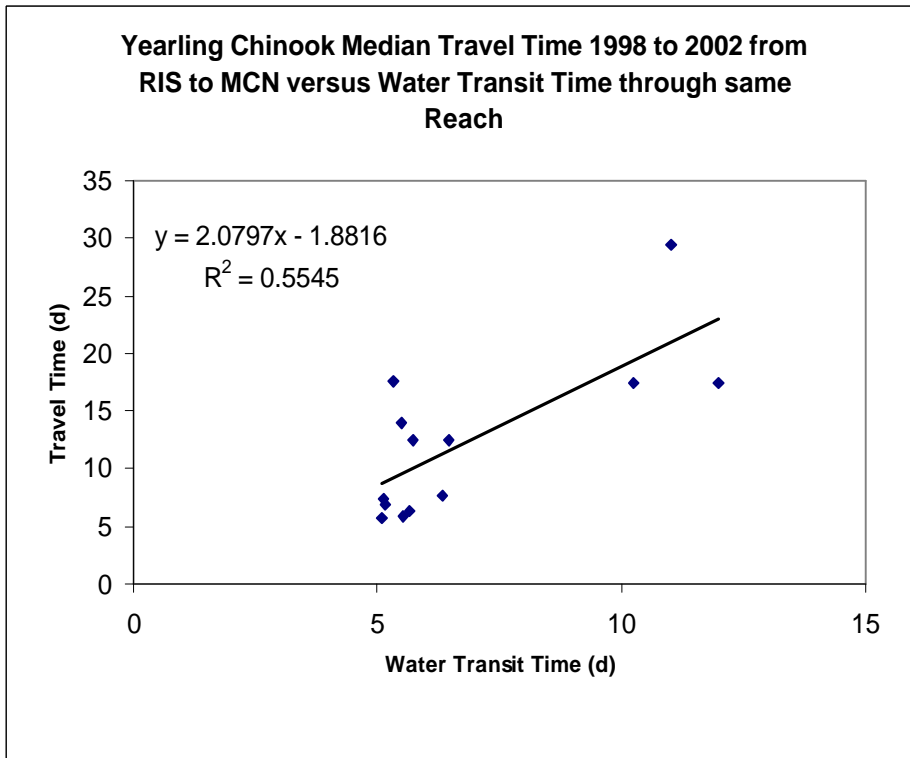
**Figure 5. Steelhead travel time versus water transit time.**

Mid-Columbia River Reach: Rock Island Dam to McNary Dam

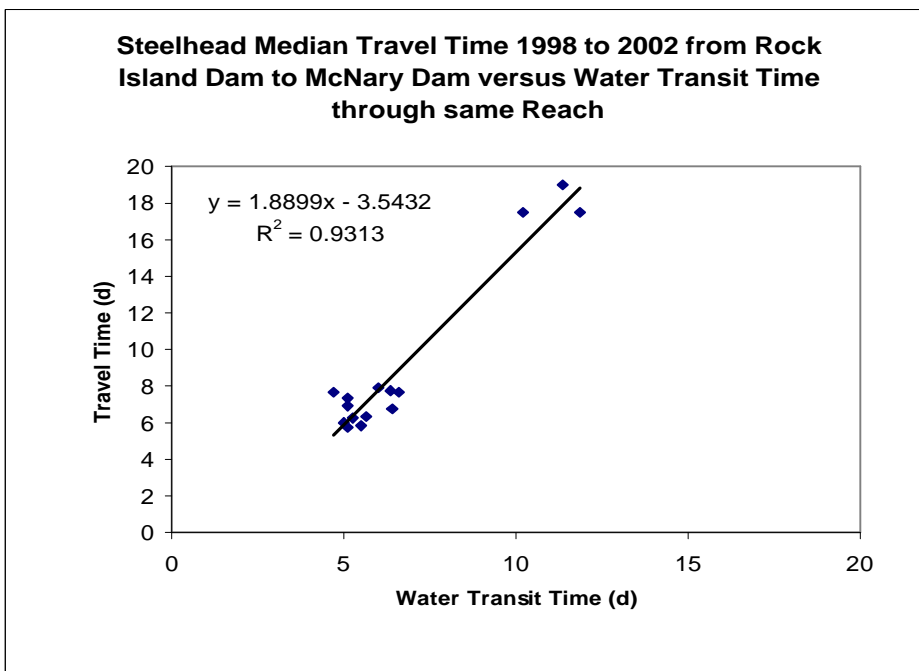
Bivariate relations between smolt travel time and WTT were modeled using linear regression (Table 2). Relations for smolts originating above Rock Island Dam and migrating between the tailrace of Rock Island Dam and McNary Dam are shown for yearling chinook in Figure 6 and steelhead in Figure 7. For each species, the data is a mixture of wild and hatchery smolts.

**Table 2. Summary of linear regressions of median travel time versus water transit time for wild and hatchery chinook and steelhead.**

<b>Group</b>	<b>Regression Equation</b>	<b>R<sup>2</sup></b>
Yearling Chinook	$y = 2.0797x - 1.8816$	0.55
Steelhead	$y = 1.8899x - 3.5432$	0.93



**Figure 6. Yearling chinook travel time versus water transit time.**



**Figure 7. Steelhead travel time versus water transit time.**

## Results of Survival Analysis

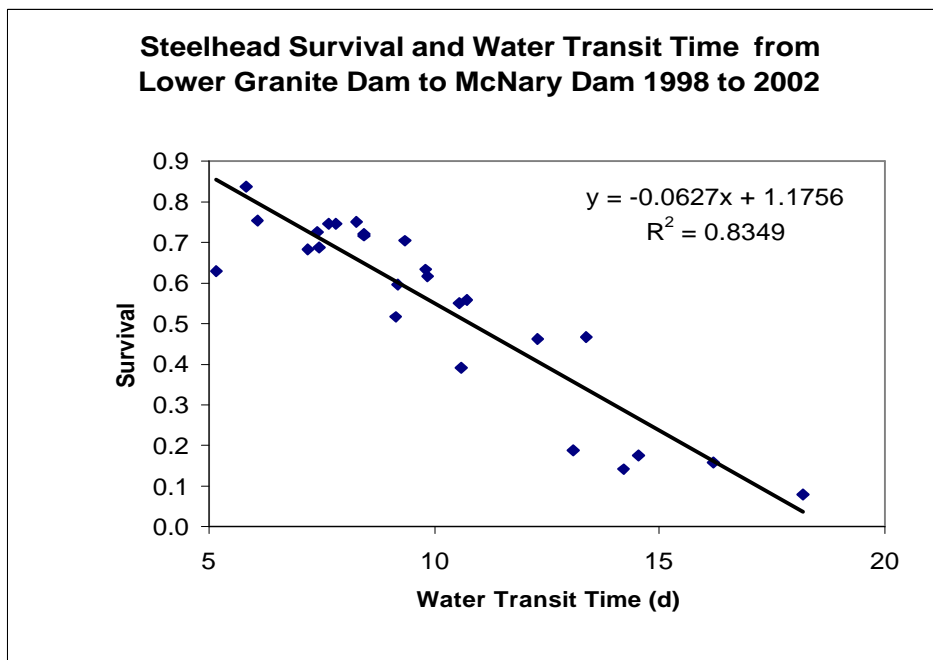
### Snake River Reach: Lower Granite Dam to McNary Dam

#### *Survival Analysis for steelhead*

The water transit time (WTT) and spill proportion (SPILLPROP) variables both had high correlation with the dependent variable survival (Table 3). Correlation between WTT and SPILLPROP was  $r = -0.81$ , a level low enough so that multicollinearity is not a problem. The square root of the variance-inflation factor,  $\sqrt{1/(1-R^2)}$  provides a measure of the extent to which the standard error of the regression coefficients will be inflated due to high correlation between the predictor variables in a model. In the case of our model with WTT and SPILLPROP, the regression coefficient standard error will be inflated by a factor of approximately 1.7. Myers (1990) and Fox (1991) show that multicollinearity doesn't become a problem until the variance-inflation factor exceeds 10, which triples the standard error of the regression parameters. A plot of estimated survival of steelhead from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 8.

**Table 3. Correlation matrix for variables related to steelhead.**

	SURVIVAL	WTT	SPILLPROP
WTT	-0.914		
SPILLPROP	0.869	-0.809	
TEMP	-0.430	0.300	-0.464



**Figure 8. Steelhead survival versus water transit time**

In the multiple regression analysis for steelhead, WTT and SPILLPROP were both significant variables in explaining variation in the dependent variable survival (Table 4). In the presence of these two variables, water temperature (TEMP) did not significantly explain any variation in survival. Since the various routes of passage, each with differential rates survival for passing fish, at a particular dam is an integral component of any reach “true” survival rate, it is encouraging to see a spill-related variable remain in the model. Any mechanistic model should always include the influence of spill, and it does so in the steelhead regression model. The joint model of WTT and SPILLPROP provides the best model for predicting steelhead survival in the Snake River reach.

**Table 4. Multiple regression models for predicting survival of steelhead salmon in the Snake River from the tailrace of Lower Granite Dam to the tailrace of McNary Dam.**

	Variable	Coefficient	SE	P	MSE	R <sup>2</sup>
N = 26	Constant	0.79901	0.13203	0.00000	0.00639	0.87
	WTT	-0.04184	0.00831	0.00004		
	SPILLPROP	0.00527	0.00117	0.00508		

***Survival for Yearling Chinook***

Analysis of covariance was used to determine whether hatchery and wild chinook differed in survival response as a function of the predictor variables. Wild and hatchery chinook did not significantly differ with any of the predictor variables (Table 5). Plots of estimated survival of yearling chinook from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows similar linear relations for hatchery and wild fish (Figures 9a and 9b, respectively). All further analyses were conducted on the combined set of wild and hatchery chinook data.

**Table 5. Analysis of Covariance comparison of hatchery and wild yearling chinook survival when all covariates are accounted for in the model.**

	Variable	SS	df	MSE	F-ratio	P
N = 66	RearType	0.00191	1	0.00191	0.32314	0.57182
H = 32	WTT	0.05225	1	0.05225	8.81804	0.00426
W = 34	SPILLPROP	0.04096	1	0.04096	6.91232	0.01082
	TEMP	0.06892	1	0.06892	11.63241	0.00115
	Error		61	0.00593		

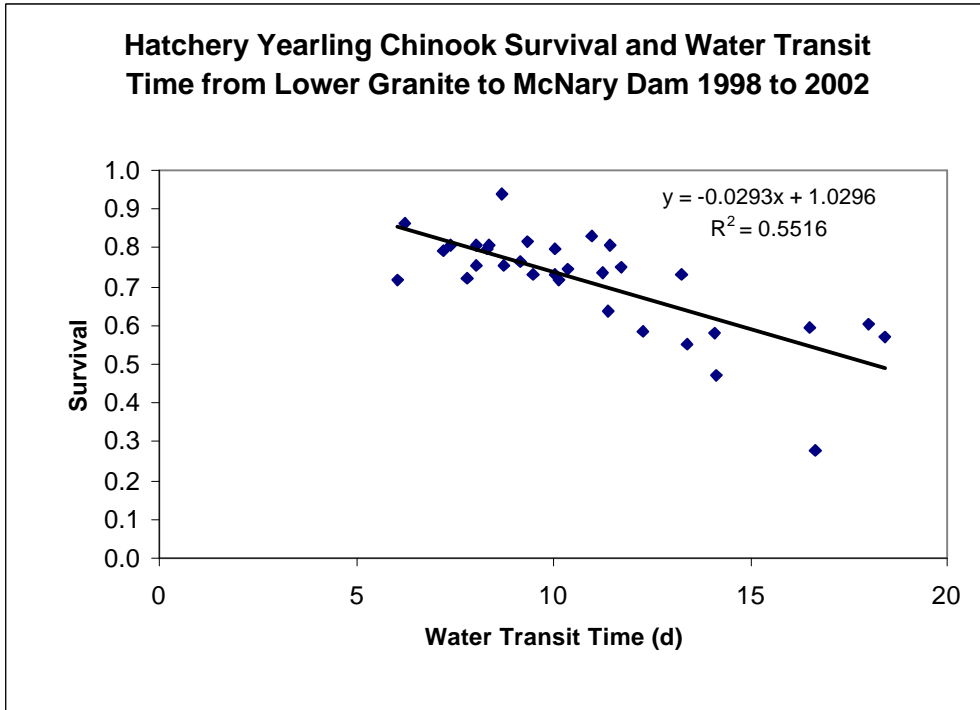


Figure 9a. Hatchery yearling chinook survival versus water transit time.

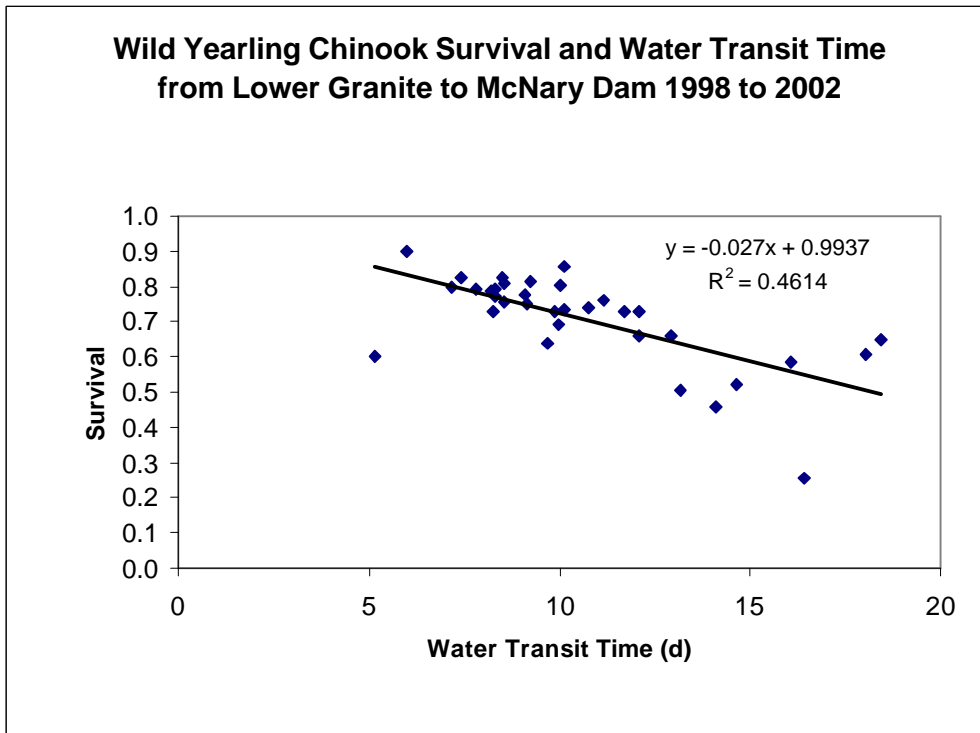


Figure 9b. Wild yearling chinook survival versus water transit time.

For the combined wild and hatchery yearling chinook, the WTT and SPILLPROP variables both had high correlation with the dependent variable survival (Table 6). As was observed with steelhead, the correlation between WTT and SPILLPROP for yearling chinook was  $r = -0.81$ , a level low enough so that multicollinearity is not a problem

**Table 6. Correlation matrix for variables related to wild and hatchery yearling chinook salmon.**

	SURVIVAL	WTT	SPILLPROP
WTT	-0.70898		
SPILLPROP	0.75498	-0.80546	
TEMP	-0.46136	0.16461	-0.34821

In the multiple regression analysis for yearling chinook, WTT and SPILLPROP were both significant variables in explaining variation in the dependent variable survival (Table 7). In the presence of these two variables, TEMP also was significant in explaining variation in survival. The joint model of WTT, SPILLPROP, and TEMP provides the best model for predicting yearling chinook survival in the Snake River reach.

**Table 7. Multiple regression models for predicting survival of combined hatchery and wild yearling chinook salmon in the Snake River from the tailrace of Lower Granite Dam to the tailrace of McNary Dam.**

	Variable	Coefficient	SE	P	MSE	R <sup>2</sup>
N = 66	Constant	1.09264	0.13901	0.00000	0.0586	0.65
	WTT	-0.01497	0.00504	0.0042		
	SPILLPROP	0.00281	0.00106	0.01027		
	TEMP	-0.02624	0.00765	0.00109		

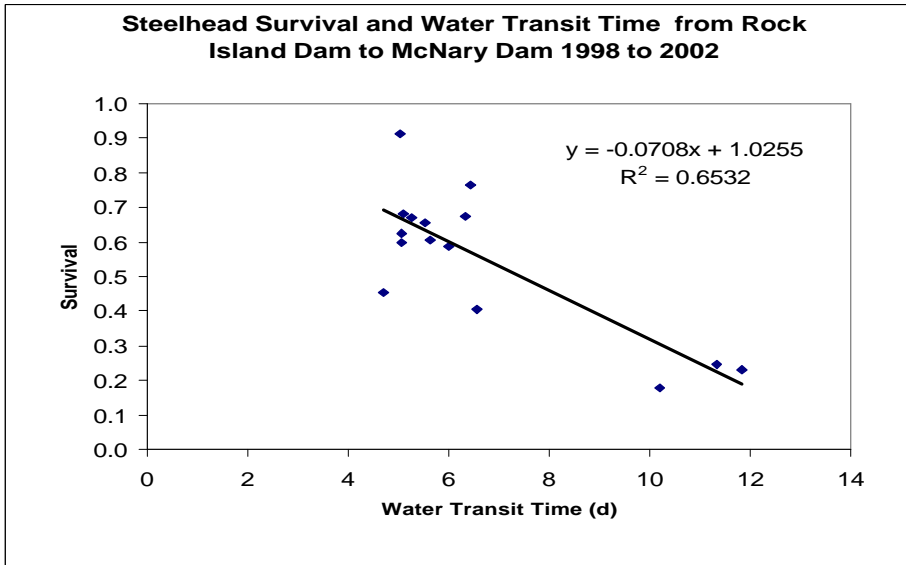
Mid-Columbia River Reach Rock Island Dam to McNary Dam

*Survival Analysis for steelhead*

For steelhead in the Mid-Columbia River reach, WTT had the highest correlation with the dependent variable survival, while both SPILLPROP and TEMP had similar moderate levels of correlation with survival (Table 8). The correlation between WTT and SPILLPROP for steelhead was  $r = -0.87$ , a level still low enough so that multicollinearity is not a problem. A plot of estimated survival of steelhead from the tailrace of Rock Island Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 10.

**Table 8. Correlation matrix for variables related to steelhead salmon.**

	SURVIVAL	WTT	AVGSPILLPROP
WTT	-0.808		
AVGSPILLPROP	0.647	-0.870	
AVTEMP	-0.587	0.312	-0.193



**Figure 10. Steelhead survival versus water transit time.**

In the multiple regression analysis for steelhead, WTT and TEMP were both significant variables in explaining variation in the dependent variable survival (Table 9). In the presence of these two variables, SPILLPROP did not significantly explain any variation in survival. Since the level of spill at Wanapam and Priest Rapids dams remained fairly constant over the years covered in the analysis, it is not surprising that SPILLPROP did not explain additional variation in survival. However, this finding does not reduce the intrinsic benefits of spill. Any mechanistic model should always include the influence of spill, and when it doesn't, the effect of spill becomes confounded within the coefficients of the other parameters in the model. For survival prediction purposes, the joint model of WTT and TEMP provides the best model for predicting steelhead survival from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

**Table 9. Multiple regression models for predicting survival of steelhead salmon in the Mid-Columbia River from the tailrace of Rock Island Dam to the tailrace of McNary Dam.**

	Variable	Coefficient	SE	P	MSE	R <sup>2</sup>
N = 15	Constant	1.6135	0.2425	0.00002	0.01136	0.74
	WTT	-0.06065	0.01256	0.00041		
	TEMP	-0.0553	0.02138	0.02383		

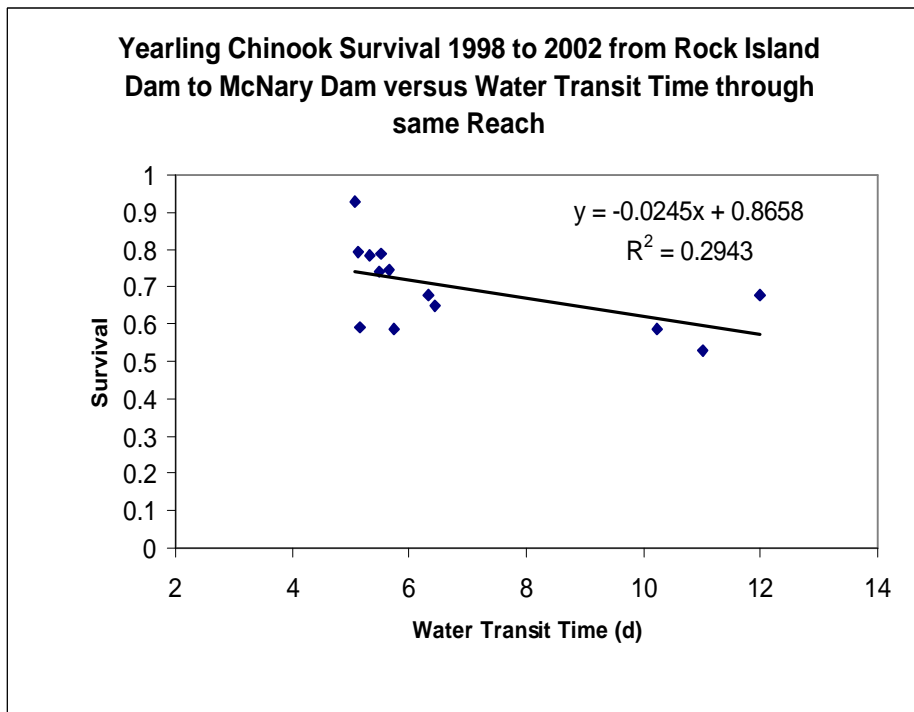
***Survival for Yearling Chinook***

For yearling chinook in the Mid-Columbia River reach, WTT and SPILLPROP had similar moderate correlation with the dependent variable survival (Table 10). The correlation between WTT and SPILLPROP for steelhead was  $r = -0.83$ , a level low enough so that multicollinearity is not a problem, but higher than observed for yearling chinook in the Snake River reach. A plot

of estimated survival of yearling chinook from the tailrace of Rock Island Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 11.

**Table 10. Correlation matrix for variables related to yearling chinook salmon.**

	SURVIVAL	WTT	AVGSPILLPROP
WTT	-0.543		
AVGSPILLPROP	0.461	-0.828	
AVTEMP	-0.230	0.421	-0.211



**Figure 11. Yearling chinook survival versus water transit time.**

In the multiple regression analysis for yearling chinook, only WTT was moderately significant in explaining variation in the dependent variable survival (Table 11). In the presence WTT, SPILLPROP did not significantly explain any variation in survival. Since the level of spill at Wanapam and Priest Rapids dams remained fairly constant over the years covered in the analysis, it is not surprising that SPILLPROP did not explain additional variation in survival. For survival prediction purposes, the simple bivariate model of WTT provides the best model for predicting yearling chinook survival from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

**Table 11. Multiple regression model for predicting survival of yearling chinook salmon in the Mid-Columbia River from the tailrace of Rock Island Dam to the tailrace of McNary Dam.**

	Variable	Coefficient	SE	P	MSE	R <sup>2</sup>
N = 13	Constant	0.86052	0.08282	0.00000	0.00956	0.23
	WTT	-0.02446	0.54250	0.05543		

Lower Columbia River Reach: McNary Dam to Bonneville Dam

*Survival Analysis for steelhead*

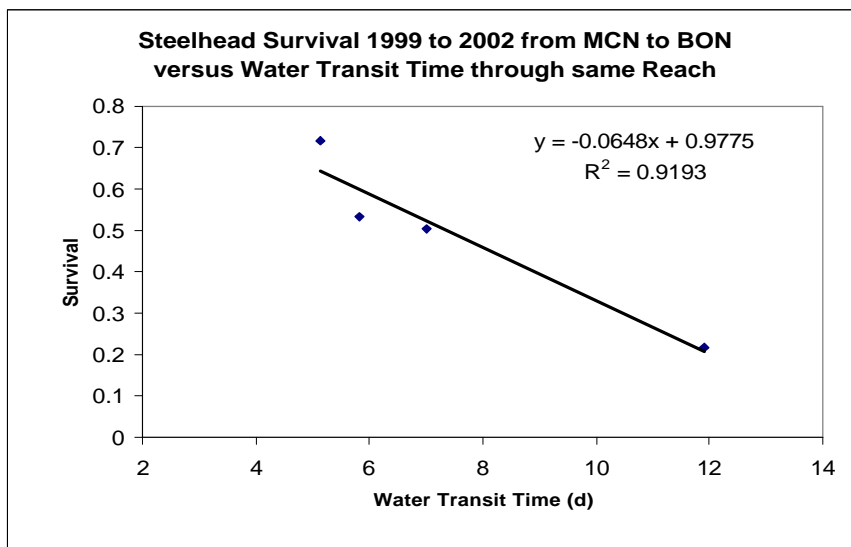
For combined hatchery and wild steelhead, the water transit time (WTT), spill proportion (SPILLPROP), and water temperature (TEMP) variables each had high correlation with the dependent variable survival (Table 12). Correlation between each pair of predictor variables was also very high, which lead to problems of multicollinearity when trying to include more than one predictor variable in the model. Thus, a model with only one predictor variable was obtained. Since WTT had the highest correlation with steelhead smolt survival, it entered into the bivariate model that explained the most variation in the dependent variable survival (Table 13). A plot of estimated survival of steelhead from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 12. Although a multiple regression model was not attainable, one must keep in mind that SPILLPROP still has a direct influence on the resulting magnitude of the survival estimate. This is because, as stated earlier, the survival of smolts that pass through the spill route is typically higher than any other passage route at a dam.

**Table 12. Correlation matrix for variables related to steelhead.**

	SURVIVAL	WTT	SPILLPROP
WTT	-0.959		
SPILLPROP	0.871	-0.969	
TEMP	-0.948	0.985	-0.930

**Table 13. Bivariate regression model for predicting survival of steelhead salmon in the lower Columbia River from the tailrace of McNary Dam to the tailrace of Bonneville Dam.**

	Variable	Coefficient	SE	P	MSE	R <sup>2</sup>
N = 4	Constant	0.97747	0.10775	0.0119	0.00518	0.92
	WTT	-0.06481	0.01358	0.0412		



**Figure 12. Steelhead survival versus water transit time**

***Survival for Yearling Chinook***

For combined hatchery and wild yearling chinook, both WTT and SPILLPROP variables had high correlation with the dependent variable survival (Table 14), whereas AVTEMP had only a moderate correlation. Correlation between WTT and SPILLPROP was not high enough to create multicollinearity problems, but it was high enough to both variables from remaining together in a multiple regression model.

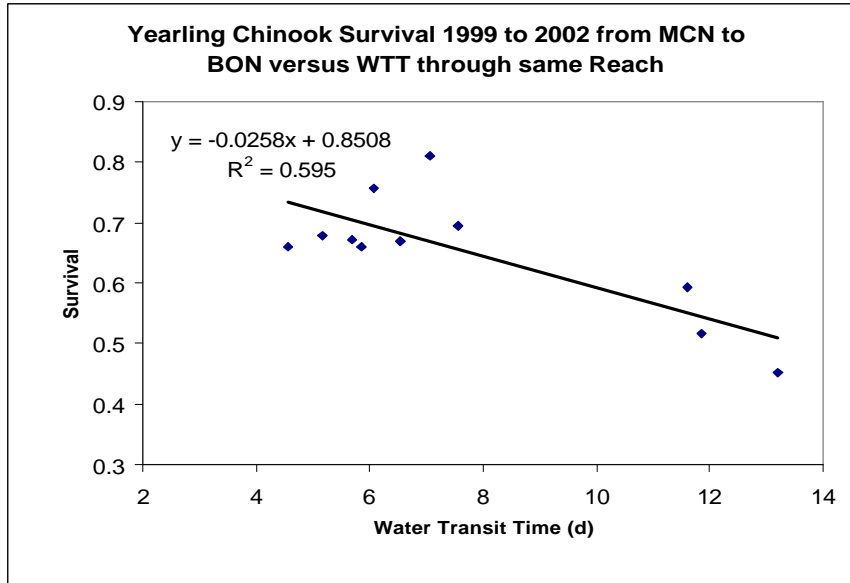
**Table 14. Correlation matrix for variables related to yearling chinook salmon.**

	SURVIVAL	WTT	SPILLPROP
WTT	-0.771		
SPILLPROP	0.870	-0.882	
TEMP	-0.433	0.431	-0.341

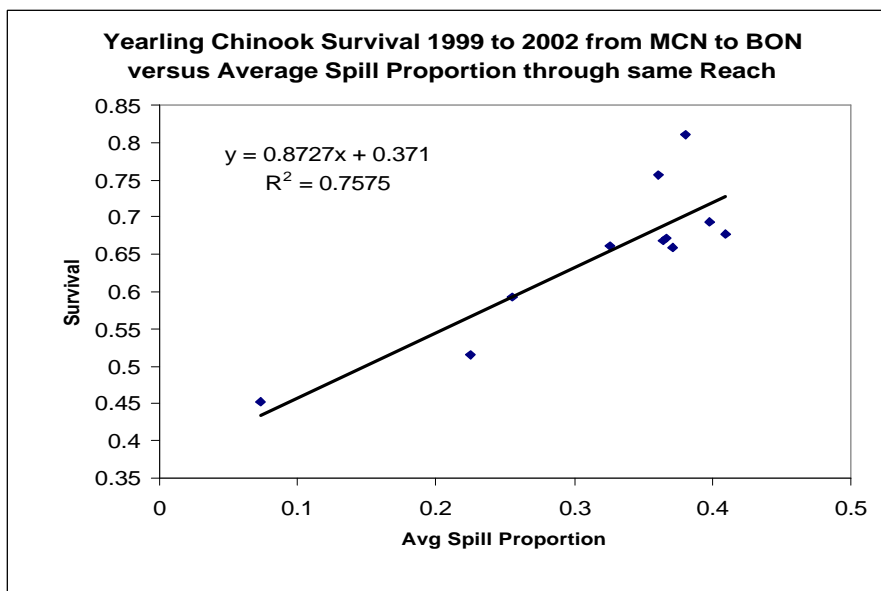
Since SPILLPROP had the highest correlation with yearling chinook smolt survival, it entered into the bivariate model that explained the most variation in the dependent variable survival (Table15). This is not to say that WTT is less important than SPILLPROP with regards to yearling chinook survival though. But it does show a major weakness in using regression techniques to pick the most important “causative” factors from the set of factors being considered in the modeling exercise. Although SPILLPROP has a direct influence on the resulting magnitude of the survival estimate, it level in the hydro system operation does not occur independent of the prevailing flows. Thus flows have a direct influence on WTT and so both variables must be considered as key elements affecting the inriver survival of smolts thorough the hydro system. A bivariate plot of estimated survival of yearling chinook from the tailrace of McNary Dam to the tailrace of Bonneville Dam is shown in Figure 13 relative to WTT and in Figure 14 relative to SPILLPROP.

**Table 15. Bivariate regression models for predicting survival of yearling chinook salmon in the lower Columbia River from the tailrace of McNary Dam to the tailrace of Bonneville Dam.**

	Variable	Coefficient	SE	P	MSE	R <sup>2</sup>
N = 11	Constant	0.37096	0.05513	0.00009	0.00272	0.76
	SPILLPROP	0.87267	0.16458	0.00049		



**Figure 13. Yearling chinook survival versus water transit time.**



**Figure 14. Yearling chinook survival versus average spill proportion.**

### Migration Timing in the Lower Columbia River as measured at John Day Dam

The population of juvenile salmon is not homogeneous throughout the entire migration season. Consequently, the concept of migration timing is extremely important in fish management. Some fish migrate in discrete time periods that may be significantly different from the timing displayed by the migration as a whole. We observed PIT tagged yearling chinook and steelhead at John Day Dam in 2001 and quantified their timing in the Lower Columbia River. Yearling chinook and steelhead stocks that originated in the Walla Walla, Umatilla and John Day rivers are the earliest stocks to pass John Day Dam in 2001. In 2001, the percent of PIT tagged yearling chinook from the John Day and Umatilla rivers detected at John Day Dam in April was approximately 53% and 13%, respectively (Table 16), whereas virtually no PIT tagged yearling chinook from the Snake and Mid-Columbia River basins were detected until May. The percent of PIT tagged steelhead from the John Day and Umatilla rivers detected at John Day Dam in April was approximately 31% and 11%, respectively (Table 17), and again virtually no PIT tagged steelhead from the Snake and Mid-Columbia River basins were detected until May.

**Table 16. Proportion of PIT tagged yearling chinook detected at John Day Dam over specific periods of the 2001 migration season.**

Dates of PIT tag detections at John Day Dam	Snake R basin	Mid-Columbia R basin at/above Rock Island Dam <sup>1</sup>	Yakima R basin	Umatilla R basin	John Day R basin
Total detections	14,086	2,091	4,041	1,291	1,743
3/30 – 4/30	0.0002	0.0000	0.0084	0.1332	0.5295
5/1 – 5/24	0.3369	0.1836	0.3606	0.7854	0.4509
5/25 – 6/15	0.5422	0.6738	0.5048	0.0736	0.0132
6/16 – 9/15	0.1207	0.1425	0.1262	0.0077	0.0063

<sup>1</sup> PIT tagged hatchery chinook released on alternating days at Rock Island & Rocky Reach dams in large numbers for specific studies were omitted because they do not represent the timing of the run-of-the-river fish.

**Table 17. Proportion of PIT tagged steelhead detected at John Day Dam over specific periods of the 2001 migration season.**

Dates of PIT tag detections at John Day Dam	Snake R basin	Mid-Columbia R basin at/above Rock Island Dam	Walla Walla R basin	Umatilla R basin	John Day R basin
Total detections	440	59	23	1,005	97
3/30 – 4/30	0.0045	0.0000	0.0000	0.1124	0.3093
5/1 – 5/24	0.4841	0.1525	0.8696	0.7532	0.6082
5/25 – 6/15	0.3886	0.5254	0.0870	0.1085	0.0825
6/16 – 9/15	0.1227	0.3220	0.0435	0.0259	0.0000

## **Rate of Seaward Movement of Subyearling Fall Chinook Summer Migrants Measured from Release in the Free-flowing Snake River to Passage Lower Granite Dam**

### Fall Chinook Rate of Seaward Movement Methods

From 1992 to 2001, U.S. Fish and Wildlife Service personnel used a beach seine to capture juvenile fall chinook salmon in the free-flowing Snake River (Connor et al. In press a). Sampling typically started in April soon after fry began emerging from the gravel. Sampling was conducted at permanent stations 1 d/week in the upper reach of the Snake River, and 2 d/week in the lower reach. Supplemental sampling was conducted 1 or 2 d/week for three consecutive weeks at additional stations within each reach once the majority of fish were at least 60-mm fork length. Sampling was discontinued in June or July when the majority of fish had moved into Lower Granite Reservoir. Passive integrated transponder tags were inserted into fall chinook salmon 60-mm fork length and longer. Data were pooled the data across reaches and years (1992-2001) to increase the range of the predictor variables (Berggren and Filardo 1993; Giorgi et al. 1997).

Tagged fish were released at the collection site after a 15-min recovery period. Some of the PIT-tagged fish were detected after they passed into the fish bypass systems of Lower Granite Dam. Rate of seaward movement for PIT-tagged fall chinook passing downstream from initial tagging sites to Lower Granite Dam was calculated as the distance traveled to Lower Granite Dam (located 173 km from the Snake River mouth) divided by travel time to Lower Granite Dam.

The predictor variables analyzed included: flow, the mean stream discharge ( $\text{m}^3/\text{s}$ ) measured by U. S. Army Corps of Engineers personnel at Lower Granite Dam between initial tagging of a PIT-tagged fall chinook salmon and its detection at Lower Granite Dam; temperature, the mean temperature ( $^{\circ}\text{C}$ ) measured by U. S. Army Corps of Engineers personnel in the forebay of Lower Granite Dam between initial tagging and detection at Lower Granite Dam; tagging date, day of year a fish was initially tagged; fork length, fork length (mm) measured on at initial tagging; and, riverine distance, the distance (km) traveled in the free-flowing Snake River before entering Lower Granite Reservoir.

Rate of seaward movement was natural-log-transformed to improve linearity and remedy heteroscedasticity of residuals, and bivariate and multiple regression models were fit from every possible combination of predictor variables. The slope coefficients of each predictor variable in every model were examined for sign change, and for inflated standard errors (hence, failure to reject  $H_0: B = 0$ ). Sign changes and large standard errors are indications of problematic multicollinearity (Dielman 1996). A Pearson correlation matrix was calculated to examine the level of collinearity between each factor. Models with problematic multicollinearity, or that included factors with non-significant ( $P > 0.05$ ) slope coefficients, were removed from further analysis. Fit was compared among the remaining regression models based on the coefficient of determination ( $R^2$ ). The three regression models that had the highest  $R^2$  values were reported.

Residual plots were made for flow and temperature as described for flow in the following example. Natural-log-transformed rate of seaward movement was regressed against fork length and riverine distance. The residuals from this regression were then plotted against flow. A line

was then fit to the residuals by regressing them against flow. The resulting residual plots provided a better graphical representation of the relation between flow and rate of seaward movement because the variability in downstream migration rate attributable to fork length and riverine distance had been removed.

### Fall Chinook Rate of Seaward Movement Results

A total of 2,808 observations were available (years 1992-2001) to describe the factors affecting rate of seaward movement of PIT-tagged fall chinook salmon from initial tagging to detection at Lower Granite Dam. After pooling the data across reaches and running every possible regression model, the slope coefficient for flow changed from being positive to negative when flow and temperature were entered into the same regression models. The correlation coefficient for the relation between flow and temperature was  $r = -0.77$  ( $P < 0.0001$ ). The slope coefficient for tagging date changed from being negative to positive when tagging date and temperature were entered in the same regression models. The correlation coefficient for the relation between tagging date and temperature was  $r = 0.60$  ( $P < 0.0001$ ). All models containing both flow and temperature, and tagging date and temperature, were removed from the analysis because of problematic multicollinearity.

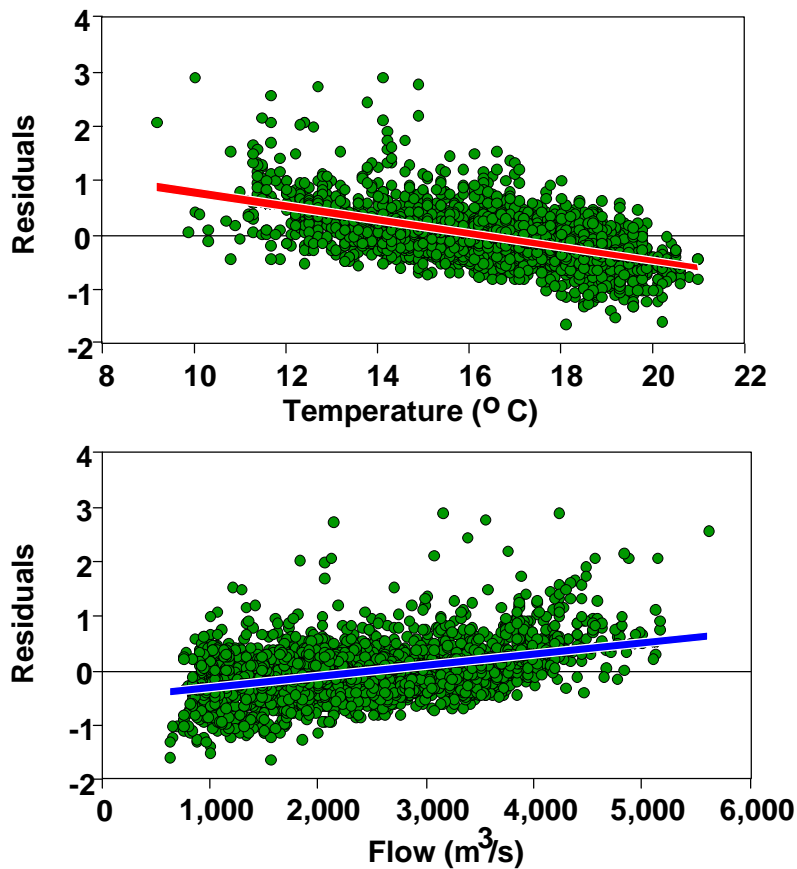
The regression model with the best fit included the predictor variables temperature, fork length and riverine distance (Table 18). The slope coefficients for each of the three factors differed significantly from zero, and together the three factors explained 73% of the variability observed in natural-log-transformed rate of seaward movement (Table 18). Natural-log-transformed rate of seaward movement generally decreased as temperature increased, and increased as fork length and riverine distance increased, as shown by the sign and  $P$  values of the slope coefficients (Table 18). The slope in the residual plot indicates that rate of seaward movement decreased as temperature increased throughout the range of 9 to 21°C (Figure 15).

The regression model that had the second-best fit included the factors flow, fork length, and riverine distance (Table 18). Flow, fork length, and riverine distance explained 66% of the variability observed in natural-log-transformed rate of seaward movement. Natural-log-transformed rate of seaward movement generally increased with increases in each of the three factors based on the slope coefficients, all of which differed significantly from zero (Table 18). The slope in the residual plot shows that rate of seaward movement increased as flow increased over the entire range of observed flows (Figure 15).

The regression model that had the third-best fit included the factors tagging date, fork length, and riverine distance (Table 18). Natural-log-transformed rate of seaward movement generally decreased with increases in tagging date, and increased as fork length and riverine distance increased, as shown by the signs and  $P$  values of the slope coefficients (Table 18). Together, these three factors explained 58% of the variability observed in natural-log-transformed rate of seaward movement (Table 18).

**Table 18. Results from multiple regression models fit to describe rate of seaward movement of PIT-tagged wild subyearling fall chinook salmon from initial tagging in the Snake River and detection at Lower Granite Dam, 1992 to 2001.**

Variable	coefficient	SE	t value	Probability	R <sup>2</sup>	P
Constant	0.81598	0.07490	10.89	≤ 0.0001	0.726	≤ 0.0001
Temperature	- 0.15190	0.00382	- 39.73	≤ 0.0001		
Fl	0.02773	0.00060	46.16	≤ 0.0001		
Km	0.00798	0.00018	44.42	≤ 0.0001		
Constant	- 2.07197	0.05627	- 36.82	≤ 0.0001	0.659	≤ 0.0001
Flow	0.00024	0.00001	26.73	≤ 0.0001		
Fl	0.02498	0.00066	37.66	≤ 0.0001		
Km	0.00876	0.00020	43.88	≤ 0.0001		
Constant	-1.17620	0.10755	-10.94	≤ 0.0001	0.575	≤ 0.0001
Date	-0.00304	0.00083	-3.68	0.0002		
Fl	0.02568	0.00090	28.64	≤ 0.0001		
Km	0.01061	0.00022	49.56	≤ 0.0001		



**Figure 15. Wild subyearling chinook rate of seaward movement versus temperature and flow.**

## Fall Chinook Rate of Seaward Movement Discussion and Conclusions

Though the regression model that predicted natural-log-transformed rate of seaward movement from the predictor variables temperature, fork length, and riverine distance had the best fit of all models tested, Connor et al. (In press a) concluded that it is unrealistic to expect an inverse relation between temperature and rate of seaward movement over the entire range of temperatures studied (9 to 21°C). Fall chinook salmon that are exposed to mean temperatures of 20°C and above before they become smolts would be expected to move seaward at slower rates than those that experience cooler temperatures because of a reduced likelihood of successful smoltification (e.g., Marine 1997). However, rate of seaward movement should have increased as temperature increased up to at least 17°C as a result of increased growth and normal patterns of smolt development (Banks et al. 1971; Boeuf 1993; Marine et al. 1997; Connor and Burge in press). Connor et al. (In press a) concluded that the decrease in rate of seaward movement as temperature increased to 17°C was most likely caused by the accompanying decreases in flow.

The regression model with the second-best fit included the predictor variables flow, fork length, and riverine distance. This regression model showed that the relation between rate of seaward movement and flow was positive consistent with the results of other studies (Berggren and Filardo 1993; Tiffan et al. 2000). Higher rates of seaward movement at higher flows (or vice versa) can be explained by the relation between discharge and water velocity. Water velocity in reservoirs is proportional to the ratio of discharge to channel volume. Since the length of Lower Granite Reservoir presumably changes little over time, the change in volume can be described by changes in pool elevation. Lower Granite Reservoir was held at minimum operating pool elevations ranging from approximately 223 to 224 m above mean sea level during the summer (U. S. Army Corps of Engineers, unpublished data). Therefore, the flow values Connor et al. (In press a) used in their regression modeling were proportional to velocities in Lower Granite Reservoir upstream of Lower Granite Dam forebay suggesting that rate of seaward movement increased as velocity increased. These results support a flow-migration rate relation.

Rate of seaward movement from release in the Snake River to passage at Lower Granite Dam decreased as tagging date increased according to the results of the regression model with the third-best fit. Tagging date (a.k.a., release date) is used as a surrogate for time-based physiological, behavioral, and environmental processes when describing seaward movement of juvenile anadromous salmonids (e.g., Berggren and Filardo 1993; Giorgi et al. 1997; Connor et al. 2000). There was no significant tagging date effect when flow and tagging date were entered into the same regression model. Problems with multicollinearity were encountered when tagging date and temperature were entered into the same regression model. In the Connor et al. In press a) analyses, tagging date apparently functioned as a surrogate for flow and temperature. To a lesser extent, increases in date also reflected the decreased potential for successful smoltification of fish initially tagged late in the seining season.

Connor et al. (In press a) concluded that the increases in flow and decreases in temperature resulting from summer flow augmentation increases the rate of seaward movement of fall chinook salmon in Lower Granite Reservoir (where fish spend prolonged periods of time) provided that augmentation occurs when the fish have moved offshore in the free-flowing river and are behaviorally disposed to being displaced downstream. The regression model that

included flow predicts an increase in rate of seaward movement of approximately 0.1 km/d with each increase of 100 m<sup>3</sup>/s in flow when fork length and riverine distance are held at 74 mm and 40 km (the overall 1992-2001 medians). At temperatures above 17°C, the regression model that included temperature predicts an increase in rate of seaward movement of approximately 0.2 km/d with each decrease of 1°C when fork length and riverine distance are held at 74 mm and 40 km. Increasing the rate of seaward movement by 0.1 to 0.2 km reduces travel time to Lower Granite Dam by 1 to 5 d (Connor 2001).

## **Survival of Wild Subyearling Fall Chinook Summer Migrants Measured from Release in the Free-flowing Snake River to Passage at Lower Granite Dam and Passage Timing at the Dam**

### Fall Chinook Survival Methods

Data collected on fall chinook salmon from 1998 to 2000 were analyzed. Data for these years were selected because sample sizes of tagged fall chinook salmon were large, and tagged fish were not handled as they passed Lower Granite Dam. Field personnel captured and PIT tagged fall chinook salmon by using a beach seine as described for analyses on rate of seaward movement. After detection at Lower Granite Dam, the PIT-tagged smolts were routed through flumes back to the river. Smolts then had to pass seven more dams to reach the Pacific Ocean. Little Goose, Lower Monumental, McNary, John Day, and Bonneville dams were also equipped with monitoring systems that recorded the passage of PIT-tagged smolts that used the bypass systems, and then routed the bypassed fish back to the river.

The first step in the analysis was to divide the annual samples of PIT-tagged fall chinook salmon into four sequential within-year release groups referred to as cohorts. The annual samples into cohorts based on estimated fry emergence dates. Fry emergence date was estimated for each fish in two steps. First, the number of days since each PIT-tagged fish emerged from the gravel was calculated by subtracting 36 mm from its fork length measured at initial capture, and then dividing by the daily growth rate observed for recaptured PIT-tagged fish (range 0.9 to 1.3 mm/d; Connor and Burge in press). The 36-mm fork length for newly emergent fry was the mean of the observed minimum fork lengths. Second, emergence date was estimated for each fish by subtracting the estimated number of days since emergence from its date of initial capture, tagging, and release. The data in ascending order by estimated fry emergence date, and then divided it into four cohorts of approximately equal numbers of fish. The single release-recapture model (Cormack 1964; Skalski et al. 1998) was used to estimate survival probability to the tailrace of Lower Granite Dam for each cohort. Three assumption tests described by Burnham et al. (1987) and Skalski et al. (1998) were applied to insure that the single release-recapture model fit the data.

Cohort survival was the dependent variable for the analysis. The predictor variables were: tagging date, median day of year fish from each cohort were captured, tagged, and released; fork length, mean fork length (mm) at capture, tagging, and release for the fish of each cohort; flow, a flow (m<sup>3</sup>/s) exposure index calculated as the mean flow measured at Lower Granite Dam by U.S. Army Corps of Engineers personnel during the period when the majority of smolts from

each cohort passed the dam; and temperature, a water temperature ( $^{\circ}\text{C}$ ) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam by U.S. Army Corps of Engineers personnel during the period when the majority of smolts from each cohort passed the dam.

To determine when the majority of smolts passed Lower Granite Dam, the PIT-tag detection data were used to calculate a passage date distribution for each cohort including the 25th percentile, median, 75th percentile, range of non-outliers, and mild outliers. The date cutoffs for mild outliers were calculated as the 25th percentile minus the inter-quartile range multiplied by 1.5 (i.e., the lower fence; Ott 1993), and the 75th percentile plus the inter-quartile range multiplied by 1.5 (i.e., the upper fence; Ott 1993). All but the mild outliers were considered to be in the majority. See Connor et al. In press b for more details on calculating flow and temperature exposure indices.

A Pearson correlation coefficient ( $r$ ) was calculated to test for collinearity among the predictor variables. Predictor variables that were correlated ( $r \geq 0.6$ ;  $P \leq 0.05$ ) were not entered into the same model. Multiple regression models were fit from every combination of non-collinear predictor variables. Fit was compared among models based on Mallow's Cp scores (Dielman 1996), Akaike's information criteria (AIC; Akaike 1973), and the coefficient of determination ( $R^2$ ). The final (i.e., best) regression model had a Mallow's Cp score similar to the number of parameters, the lowest AIC value, the highest  $R^2$  value, and predictor variables with slope coefficients that differed significantly ( $t \geq 2.0$ ;  $P \leq 0.05$ ) from zero. Only the top three models are reported.

We made residual plots for each predictor variable in the final regression model as described for flow in the following example. Estimated survival was regressed against temperature. The residuals from this regression were then plotted against flow. A line was then fit to the residuals by regressing them against flow. The resulting residual plots provided a better graphical representation of the relation between survival and flow because the variability in survival attributable to temperature had been removed.

We assessed the effect of summer flow augmentation on cohort survival to the tailrace of Lower Granite Dam by comparing two predictions. First, we predicted cohort survival to the tailrace of Lower Granite Dam by entering the observed mean flow and water temperature exposure indices for each cohort into the final regression model. Cohort survival was then predicted a second time by entering mean flow and water temperature exposure indices into the final regression model that were recalculated to remove effects of summer flow augmentation.

The flow exposure index was recalculated after subtracting the daily volume of water released for summer flow augmentation. The water temperature exposure index was recalculated using temperatures that were simulated for the tailrace of Lower Granite Dam under the flow conditions had the summer flow augmentation not been implemented. Water temperatures were simulated using a one-dimensional heat budget model developed for the Snake River by the U.S. Environmental Protection Agency (Yearsley et al. 2001). Past model validation showed that daily mean water temperatures simulated for July and August were within an average of  $1.1^{\circ}\text{C}$  of those observed (Yearsley et al. 2001).

### Fall Chinook Survival and Passage Results

During the 3 years, 5,030 fall chinook salmon were captured, PIT tagged, and released along the free-flowing Snake River. Annual sample sizes of PIT-tagged fall chinook salmon were 2,060 in 1998, 1,761 in 1999, and 1,209 in 2000. The number of fall chinook salmon in the resulting 12 cohorts ranged from 302 to 515 (Table 19). Emergence dates, tagging dates, fork lengths, and water temperature exposure indices generally increased from cohort 1 to 4 (Table 19). Flow exposure indices and survival estimates decreased from cohort 1 to 4 (Table 19).

Tagging date and fork length were negatively correlated ( $N = 12$ ;  $r = -0.76$ ;  $P = 0.004$ ). Therefore, tagging date and fork length were not entered into the same multiple regression model. Fork length and flow ( $N = 12$ ;  $r = 0.47$ ;  $P = 0.12$ ), fork length and temperature ( $N = 12$ ;  $r = -0.54$ ;  $P = 0.07$ ), and flow and temperature ( $N = 12$ ;  $r = -0.45$ ;  $P = 0.15$ ) were non-collinear.

The model that predicted cohort survival from flow and temperature had a Mallow's Cp score one less than the number of parameters, the lowest AIC value, and an  $R^2$  of 0.92 (Table 20). The models that included fork length or tagging date had Mallow's Cp scores that equaled the number of parameters, relatively low AIC values, and  $R^2$  values of 0.92 (Table 20), but the slope coefficient for fork length ( $t = 0.05$ ;  $P = 0.96$ ) and tagging date ( $t = 0.07$ ;  $P = 0.94$ ) did not significantly differ from zero.

**Table 19. Emergence dates, predictor variables, and estimates of survival probability (%±SE) to the tailrace of Lower Granite Dam for each cohort of wild subyearling fall chinook salmon, 1998 to 2000. Predictor variables: Tagging date, median day of year of tagging; Fl, mean fork length (mm) at tagging; Flow, a flow (m<sup>3</sup>/s) exposure index calculated as the mean flow measured at Lower Granite Dam during the period when the majority of smolts passed the dam; and Temperature, a water temperature (°C) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam during the period when the majority of smolts passed the dam.**

Cohort	N	Emergence date	Tagging date	Fl	Flow	Temperature	Survival
<b>1998</b>							
1	515	7 April	140	80	2,344	17.6	70.8±2.9
2	515	15 April	141	75	2,021	18.7	66.1±3.3
3	515	23 April	153	73	1,898	19.0	52.8±3.1
4	515	7 May	167	70	1,299	19.8	35.6±2.9
<b>1999</b>							
1	441	20 April	147	80	2,378	16.3	87.7±4.6
2	440	30 April	153 <sup>A</sup>	77	1,963	17.1	77.0±3.8
3	440	5 May	152 <sup>A</sup>	70	2,116	16.7	81.2±5.8
4	440	13 May	167	68	1,353	18.3	36.4±3.5
<b>2000</b>							
1	303	6 April	130	77	1,510	16.7	57.1±4.1
2	302	15 April	144	77	1,296	17.6	53.4±4.2
3	302	22 April	146	77	1,274	17.8	44.4±3.6
4	302	29 April	158	71	859	18.5	35.7±4.3

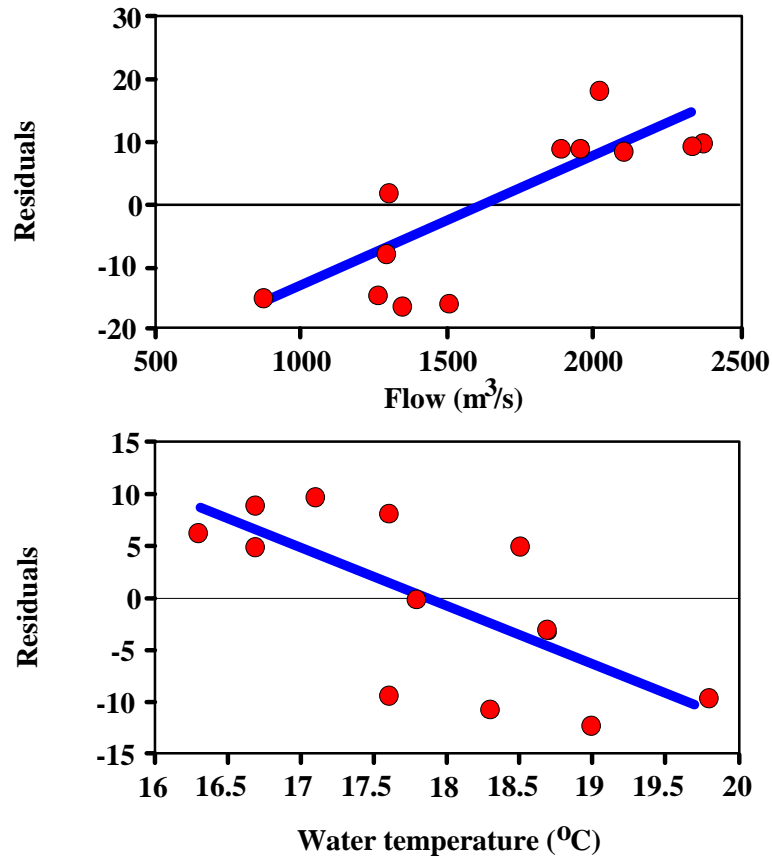
<sup>A</sup> Fish from cohort 2 emerged earlier than fish of cohort 3, but they were initially captured, tagged, and released later than fish of cohort 3.

**Table 20. Mallows’ Cp scores, Akaikes information criteria (AIC), and coefficients of determination ( $R^2$ ) used to compare the fit of multiple regression models describing the survival of cohorts of wild subyearling fall chinook salmon from tagging in the Snake River to the tailrace of Lower Granite Dam, 1998 to 2000. Predictor variables: Tagging date, median day of year of tagging; Fl, mean fork length (mm) at tagging; Flow, a flow ( $m^3/s$ ) exposure index calculated as the mean flow measured at Lower Granite Dam during the period when the majority of smolts passed the dam; and Temperature = a water temperature ( $^{\circ}C$ ) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam during the period when the majority of smolts passed the dam.**

C(p)	AIC	$R^2$	Variables in model
2	44	0.92	Flow, Temperature
4	46	0.92	Fl, Flow, Temperature
4	46	0.92	Tagging date, Flow, Temperature

The final multiple regression model was: Cohort survival = 140.82753 + 0.02648 Flow - 7.14437 Temperature. The final model was significant ( $N = 12$ ;  $P \leq 0.0001$ ) as were the coefficients for flow ( $t = 6.81$ ;  $P \leq 0.0001$ ) and temperature ( $t = - 3.96$ ;  $P = 0.003$ ). Flow and temperature explained 92% of the observed variability in cohort survival to the tailrace of Lower Granite Dam. Cohort survival generally increased as flow increased, and decreased as temperature increased (Figure 16).

The majority of fall chinook salmon passage occurs in July and August (Figures 17-19). Water releases for summer flow augmentation in 1998, 1999, and 2000 were generally timed to coincide with the passage of smolts from mid-July through August at Lower Granite Dam (Figures 17-19). Therefore, these later migrants were usually predicted to accrue greater survival benefits than the earlier migrants cohorts (Table 21). For all cohorts, estimated survival to the tailrace of Lower Granite Dam was predicted to be higher when summer flow augmentation was implemented than when it was not implemented (Table 21; Figure 20). Notably, eliminating flow augmentation in early July and August would likely decrease survival of a large portion of the smolts.



**Figure 16. Residuals plots for flow and temperature. Residuals are from ordinary least-squares multiple regression models fit to predict cohort survival from the predictor variables that is not on the X-axis. The line in each plot was predicted by regressing the residuals against the predictor variable on the X-axis.**

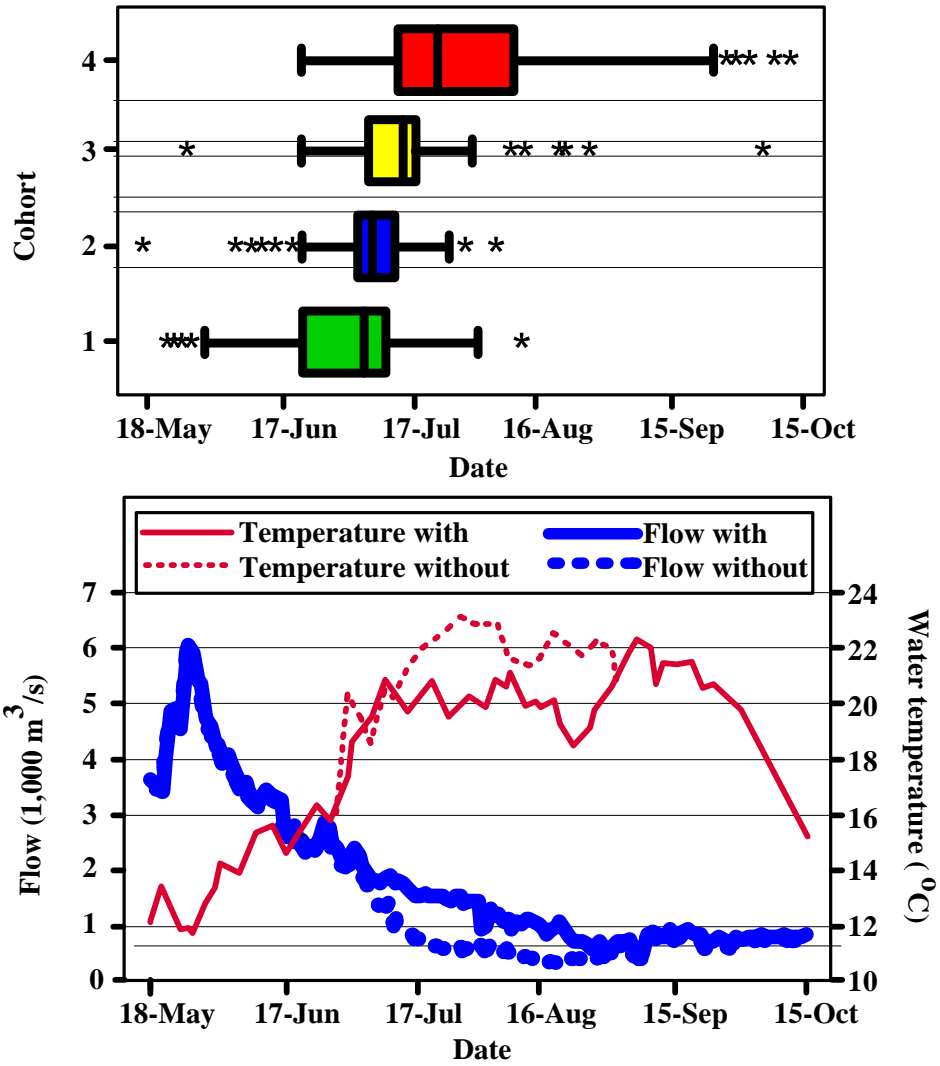


Figure 17. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 1998 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

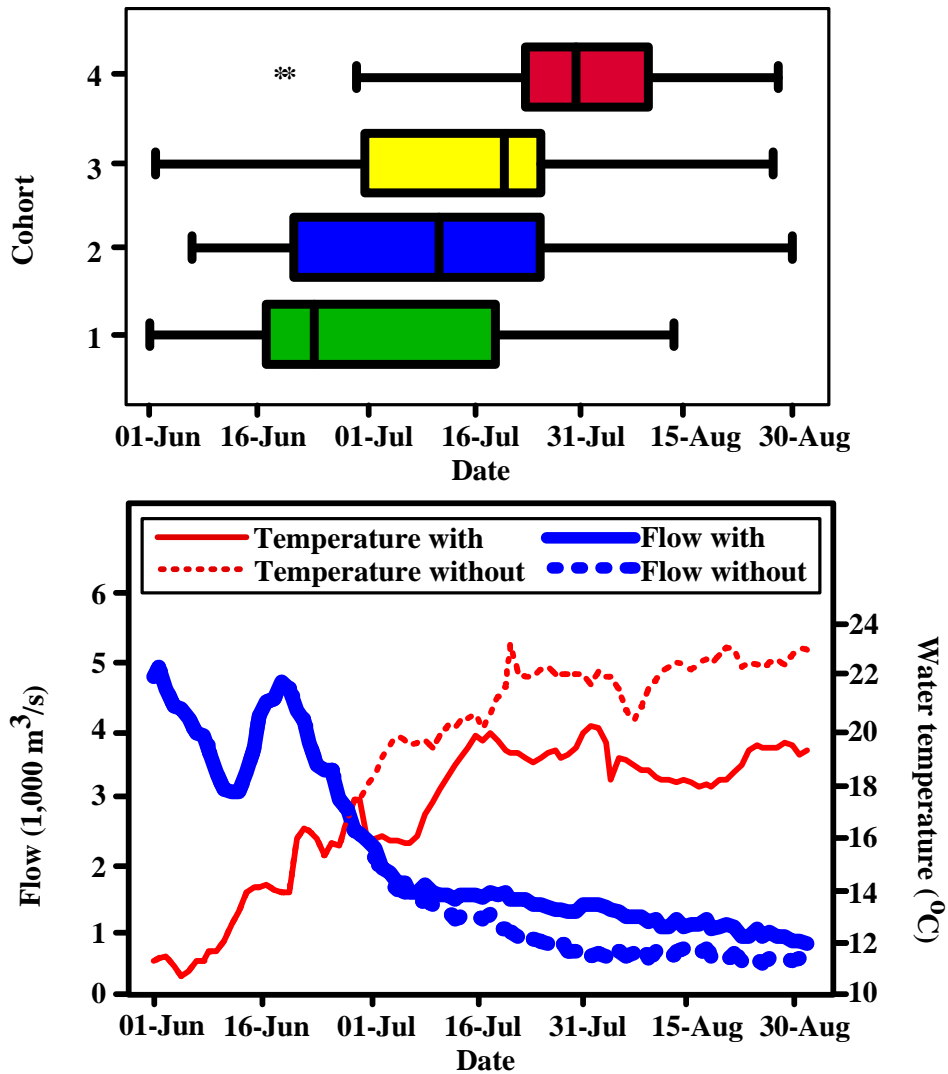


Figure 18. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 1999 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

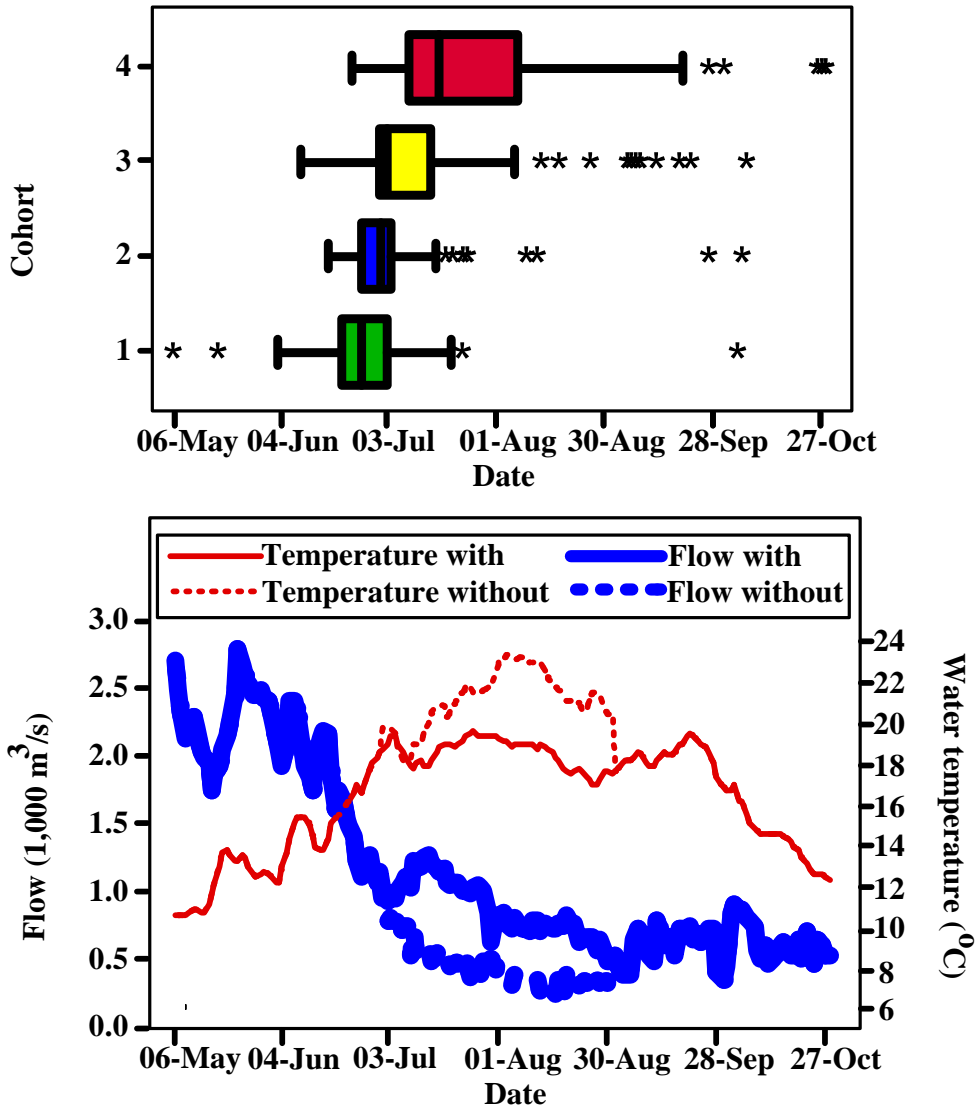


Figure 19. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 2000 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

**Table 21. Predicted survival (%±95% C.I.) to the tailrace of Lower Granite Dam for cohorts of wild subyearling fall chinook salmon tagged in the Snake River from 1995 to 1998. Predictions were made using the observed flow and water temperature indices in Table 1 (Survival with), and by using flow (m<sup>3</sup>/s) and water temperature (°C) exposure indices recalculated to approximate conditions that would have occurred if flow had not been augmented (Survival without).**

Cohort	Survival with	Recalculated		Survival without	Difference in survival
		Flow	Temperature		
<b>1998</b>					
1	77.2±6.5	2,066	18.3	64.8±5.8	12.4
2	60.7±6.6	1,689	19.3	47.7±7.0	13.0
3	55.3±6.8	1,468	20.1	36.1±9.3	19.2
4	33.8±8.0	988	21.3	14.8±13.1	19.0
<b>1999</b>					
1	87.3±7.5	2,128	17.1	75.0±5.2	12.3
2	70.6±4.7	1,667	18.4	53.5±4.3	17.1
3	77.5±5.8	1,837	18.0	60.9±4.0	16.6
4	45.9±4.6	943	20.1	22.2±9.4	23.7
<b>2000</b>					
1	61.5±6.7	1,314	17.0	54.2±6.8	7.3
2	49.4±5.5	1,078	17.9	41.5±6.5	7.9
3	47.4±5.3	978	18.6	33.8±6.7	13.6
4	31.4±7.5	587	20.1	12.8±10.6	18.6

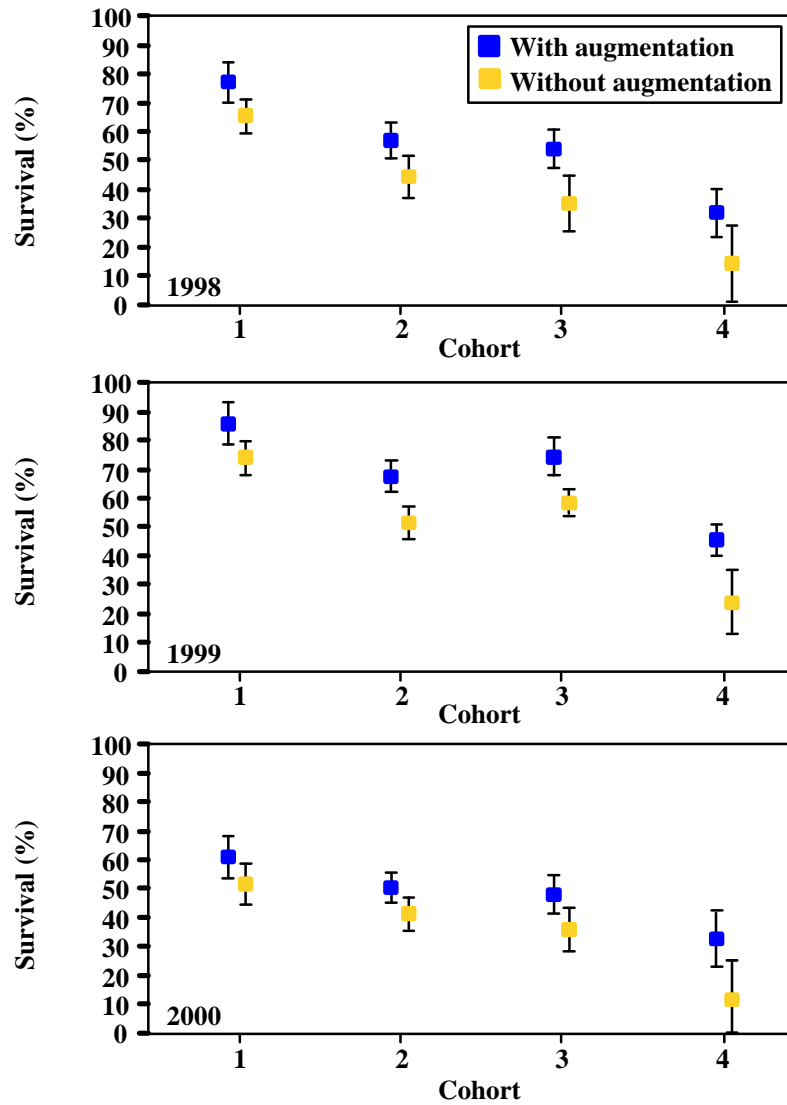


Figure 20. Survival ( $\pm 95\%$  C.I.) to the tailrace of Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon (1998 top; 1999 middle; 2000 bottom) predicted from observed mean flow and water temperatures (from Table 1), and from mean flows and water temperatures recalculated to represent those that would have occurred if flow were not augmented (from Table 3). The equation Cohort survival =  $140.82753 + 0.02648 \text{ Flow} - 7.14437 \text{ Temperature}$  was used to make both sets of predictions.

## Fall Chinook Survival and Passage Discussion and Conclusions

Survival of wild subyearling fall chinook salmon from release in the Snake River to the tailrace of Lower Granite Dam generally increased as flow increased and decreased as temperature increased. Based on the regression model developed by Connor et al. (In press b) and reported herein, survival is predicted to change by approximately 3% with each change of 100 m<sup>3</sup>/s in flow when temperature is held constant. The change in survival is approximately 7% for each 1°C increase or decrease in temperature when flow is held constant. Kjelson et al. (1982), Kjelson and Brandes (1989), and Connor et al. (1998) also reported that survival of subyearling chinook salmon during seaward migration is directly proportional to flow and inversely proportional to temperature.

Flow and temperature were closely correlated in the above three studies (e.g.,  $r = -0.999$ ; Connor et al. 1998), thus the researchers could not determine if the high correlation between survival and one variable was caused by the other variable. Flows and temperatures were atypically uncorrelated ( $r = -0.45$ ) in the 1998-2000 Connor et al. (In press b) study, therefore the researchers were able to enter both of these predictor variables in the same multiple regression equation without detectably biasing the regression coefficients. Both regression coefficients differed significantly from zero (flow  $P \leq 0.0001$ ; temperature  $P = 0.003$ ). Connor et al. (In press b) conclude that flow and temperature act together to influence fall chinook salmon survival.

After a candid discussion on the shortcomings of their study, Connor et al. (In press b) concluded that summer flow augmentation increased the survival of young fall chinook salmon passing downstream in Lower Granite Reservoir especially when flow releases were timed to the passage of smolts in July and August.

### **Spill**

Employing the use of spill for juvenile migrants has long been used as an effective management tool for improving passage survival of migrating juvenile salmon at mainstem hydroelectric projects. Routing smolts through spillways at hydroelectric projects in the Columbia and Snake rivers is generally considered to be the safest passage strategy, when compared to the passage survival through bypass systems and turbine routes. Recently, analyses conducted by Muir et al. (2001) reconfirmed the findings of numerous earlier studies by demonstrating that spillway survival of smolts exceeds that incurred through both turbines and collector/bypass systems at dams on the Snake River.

Spill is also an effective tool in decreasing the amount of delay experienced by fish in forebays and tailraces of dams where predator populations and predation rates are highest. Spill can greatly reduce delay of smolts as demonstrated at the forebay of The Dalles Dam by Snelling and Schreck (1994). Spill establishes a large flow net with increased velocity that disperses predators from the forebay and tailrace areas thus reducing the potential for predator/prey interactions (Faler et al., 1988).

Spilling water can cause high dissolved gas to concentrate by entrainment of air in the form of bubbles as it passes over the spillway and plunges to the tailrace. The air is forced into solution, causing the water to become “supersaturated” at ambient atmospheric pressure with respect to dissolved gas. Water that is supersaturated with respect to dissolved gases may cause gas bubbles to form in the bodies of fish and other aquatic animals under certain conditions that impair their ability to function, or in extreme situations may lead to death. Consequently, spill management must recognize the tradeoff between survival benefits and the detrimental effects of high total dissolved gas levels.

The “Spill and 1995 Risk Management” report was developed by the region’s fishery agencies and tribes document and provided part of the biological justification for the implementation of the 1995 Biological Opinion spill program. The document reviewed all available studies and quantified the trade-off between the increase in salmon survival associated with an increase in spill passage, against the potential fish mortality that might be incurred from increased levels of total dissolved gas (TDG). The assessment concluded that the benefits of spill passage outweighed the risk up to TDG levels between 120 to 125%. The annual voluntary spill program has been implemented within these constraints since that time.

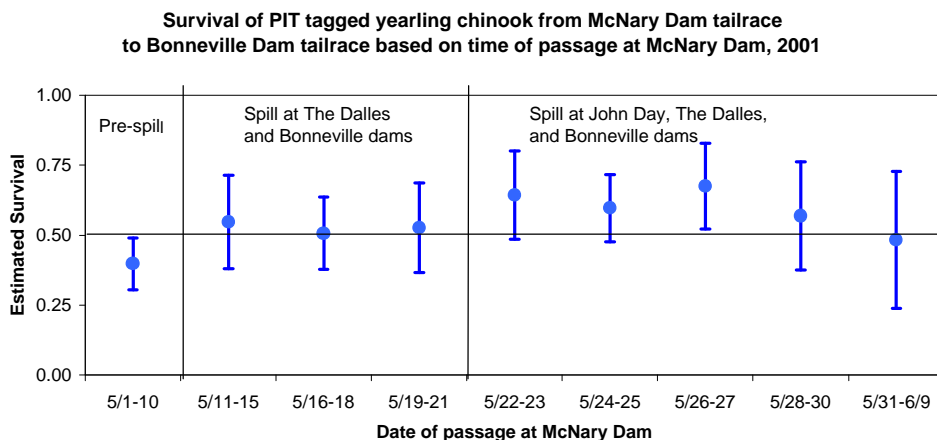
In 2000 the NMFS included Appendix E in their Biological Opinion. This appendix was meant to serve as the justification and risk assessment for the spill program included in the 2000 Biological Opinion. The appendix addresses the 120% dissolved gas ceiling and builds on the findings of the 1995 document with information collected subsequently. The NMFS also uses the SIMPAS model as a means of quantifying an amount of system survival attributable to the 120% TDG spill program. The NMFS concludes, “the risk associated with a managed spill program to the 120% total dissolved gas (TDG) level is warranted by the projected 4% to 6% increase in system survival of juvenile salmonids. Recent research and biological monitoring results support the findings of the 1995 report, which predicted that the TDG in the 120% to 125% range, coupled with vertical distribution fish passage information indicating that most fish migrate at depths providing some gas compensation, would not cause juvenile or adult salmon mortalities exceeding the expected benefits of spillway passage. NMFS finds little evidence that this expected survival improvement would be reduced by the mortality related to gas bubble trauma (GBT). NMFS also concludes that physical and biological monitoring of GBT signs can continue to be used to indicate dissolved gas exposure in adult and juvenile salmon migrants.”

#### Evidence for Spill Survival Benefits

The multiple regression analyses conducted for survival of steelhead and chinook from Lower Granite Dam to McNary Dam all include a spill related variable in the models. This suggests the importance of spill in the determination of juvenile survival.

An analysis of smolt survival in the lower Columbia River index reach was possible based on the implementation of a limited spill program during the drought year, 2001. The McNary Dam passage distribution of PIT tagged yearling chinook was split into nine multi-day blocks with at least 10,000 PIT tagged smolts per block. The plot (Figure 21) of the estimated survival from McNary Dam tailrace to Bonneville Dam tailrace shows evidence of shifts in estimated survival for yearling chinook smolts passing McNary Dam in the May 1-10, May 11-21, and May 22 to

June 9 periods. Spill at The Dalles and Bonneville dams only began on May 16 and at John Day Dam on May 25. It is likely that the survival data is grouped due to the impacts of spill, with higher survivals estimated during periods of higher spill. Further evidence implicating spill as a causal factor in increasing survival is based on the significant change in collection efficiency at John Day Dam, dropping nearly 45% for yearling chinook post initiation of spill, suggesting a far greater proportion of fish passing over the spillway at John Day Dam.



**Figure 21. Survival of PIT tagged yearling chinook from McNary Dam tailrace to Bonneville Dam tailrace based on time of passage at McNary Dam, 2001.**

#### Evidence for the Appropriateness of the Current Total Dissolved Gas Standards

The effects of elevated dissolved gas on migrating juvenile and adult salmon due to voluntary spill have been monitored each year of spill program implementation. Based on seven years of data from the biological monitoring program, the average incidence of gas bubble disease signs has been low, although the state-allowed maximum TDG due to spill was 120 percent in the tailrace and 115 percent in forebays during periods of voluntary spill. A high percentage of the spill that did occur in some years was involuntary, and often resulted in dissolved gas levels above the 120% waiver. The following graphs (Figures 22 and 23) depict the incidence and severity of signs of GBT in fish collected for observation over the seven years, grouped in 5 percent TDG levels. Increases in the incidence of signs were observed with increases in the levels of TDG. The severity of signs also increased, but not until dissolved gas levels were above the 120 to 125% level.

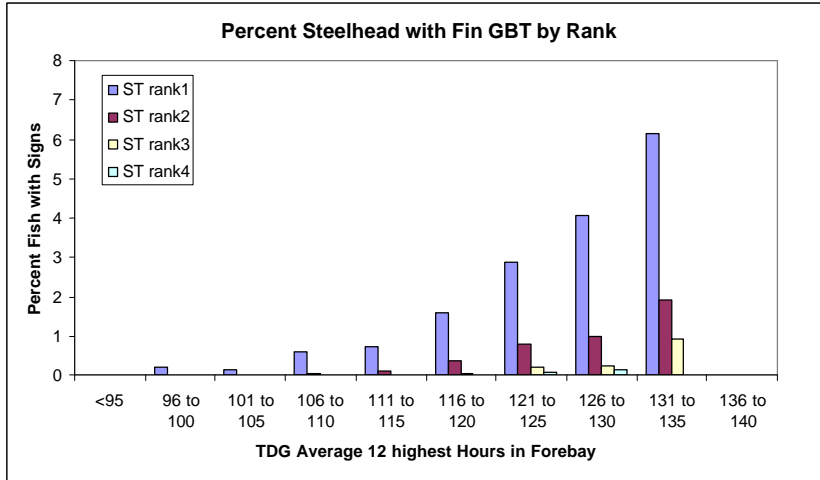


Figure 22. Percent Steelhead with Fin GBT by Rank.

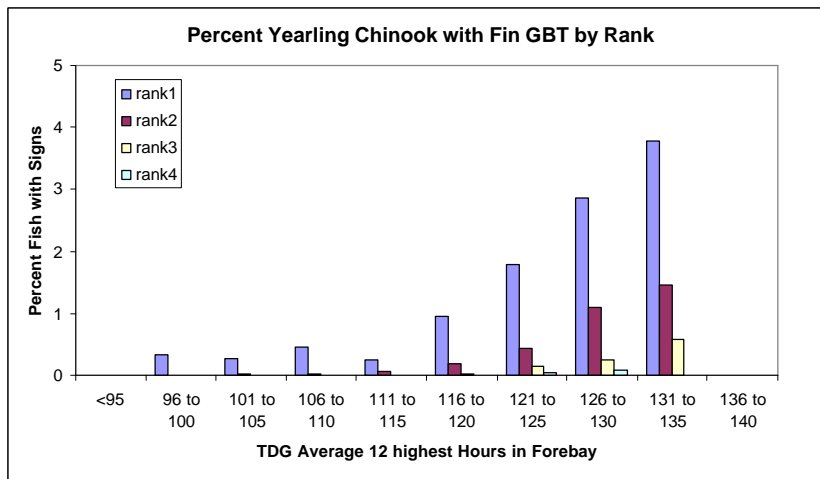
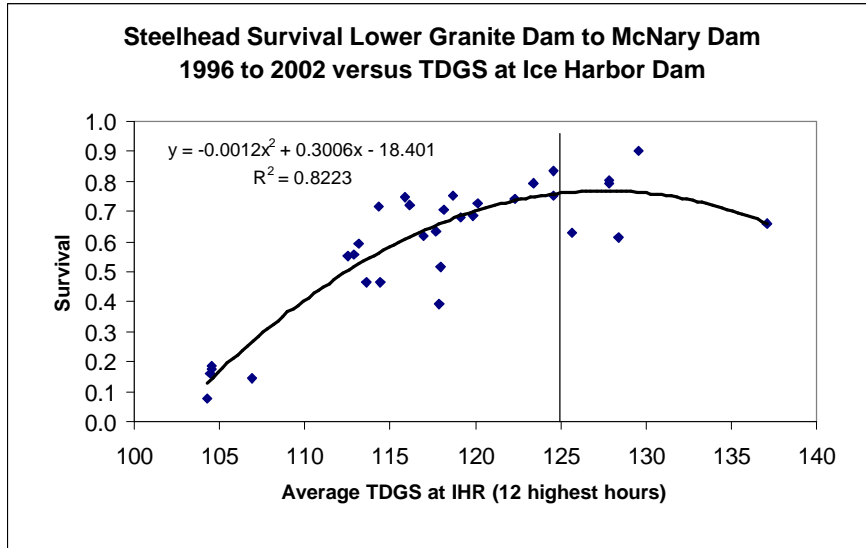
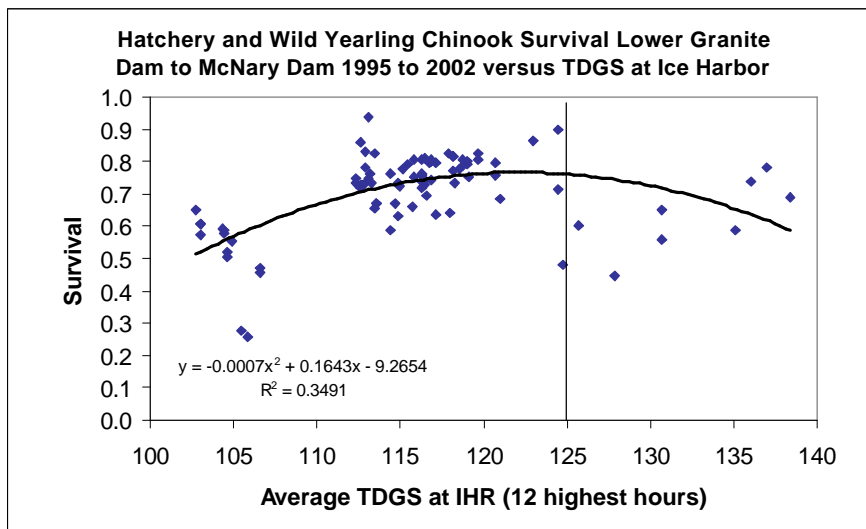


Figure 23. Percent Yearling Chinook with Fin GBT by Rank.

Additional information regarding the effects of total dissolved gas on the survival of juvenile salmonids can be ascertained from the relation between juvenile survival and total dissolved gas concentrations. The following graphs (Figures 24 and 25) depict the relation between smolt survival between the tailrace of Lower Granite to the tailrace of McNary Dam plotted as a function of the average total dissolved gas concentration at Ice Harbor indexed as described in the multiple regression analyses performed previously in this document.



**Figure 24. Steelhead Survival Lower Granite Dam to McNary Dam 1996 to 2002 versus TDGS at Ice Harbor Dam.**



**Figure 25. Hatchery and Wild Yearling Chinook Survival Lower Granite Dam to McNary Dam 1995 to 2002 versus TDGS at Ice Harbor.**

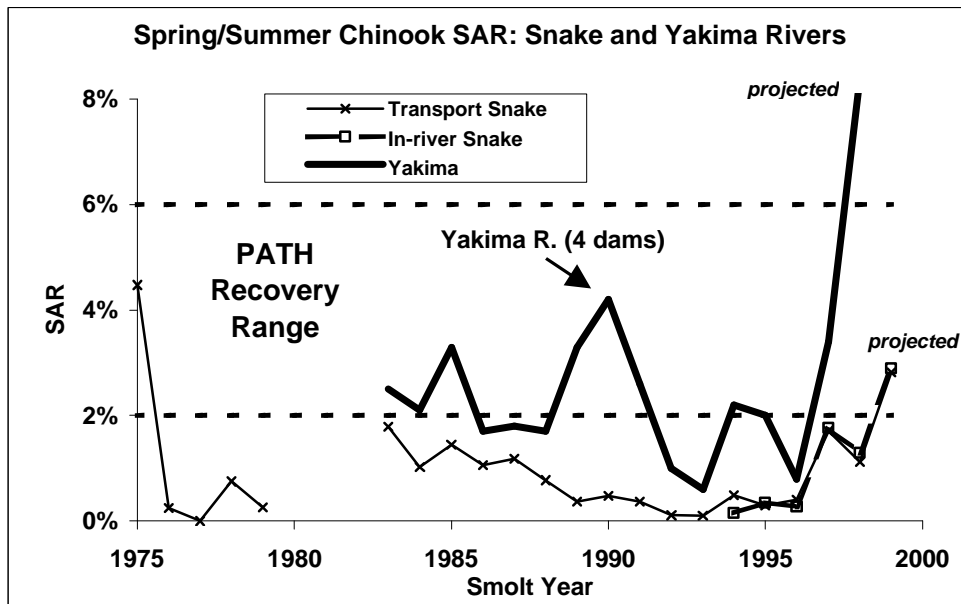
These data suggest that total dissolved gas concentrations above 125% may have had a negative impact on survival. These high total dissolved gas measurements are a function of uncontrolled spill that occurred in the hydrosystem because of flow in excess of the hydraulic capacity of the project, or due to spill in excess of generation needs. They are not caused by the implementation of the Biological Opinion Spill Program.

All of the information collected to-date of survival and the benefits associated with spill indicate that spill provides a significant benefit to juvenile survival at levels up to 125% in the tailrace of the dam. The data suggest that the spill program has a built-in margin of error for total dissolved

gas. This allows the implementation of the Biological Opinion Spill Program with little or no impact due to small excursions from the 115% forebay and 120% tailrace total dissolved gas criteria.

### Adult Return Analysis

We evaluated the impacts of flow and spill on the survival of smolts-to-adults and spawner-to-spawner to investigate the total impact of these factors on overall survival. The data set used in the adult analyses is presented in Table 1 (Appendix A). Because the ocean has a very large influence on these survival rates we included a measure of climate and ocean conditions in this analyses. We used the parameter delta derived in the Plan for Analyzing and Testing Hypotheses (PATH), which is a measure of climate/ocean mortality influences that are common to both spring/summer chinook stocks originating lower in the Columbia (e.g. John Day River) and in the Snake River (Deriso et al. 2001). Because these stocks are genetically very similar, have similar migration, ocean entry and adult return timing, we expect both to respond to ocean changes in a similar manner (Schaller et al. 1999, 2000). This is evidenced by the large returns occurring for all stocks during recent good ocean conditions (see Figure 26). The Yakima SARs averaged (geometric mean) nearly 4 times higher than Snake River SARs, but were similar in pattern over time to the Snake River SARs (Figure 1; Joint Technical Memorandum to NWPPC, March 19, 2002).



**Figure 26. Smolt to adult return rates (SAR) Snake River spring/summer chinook, (transported 1975-1999; inriver migrants 1994-1999), and Yakima spring chinook, 1983-1998.**

Dependent variables were wild Snake River chinook and steelhead SARs; spawner to spawner ratios from index stocks of Snake River spring/summer chinook used in PATH and NMFS Biological Opinion; and the direct and delayed hydrosystem survival of Snake River spring/summer chinook relative to downriver spring/summer chinook, estimated in PATH by the parameter mu (Deriso et al. 2001). Snake River wild chinook SARs for 1975-1994 were from

PATH and reported in NMFS (2000) white papers; SARs for 1995-1999 from the CSS annual report (Bouwens et al. 2002). Snake River steelhead SARs for 1975-1994 were from PATH and reported in NMFS (2000) white papers. The chinook spawner to spawner ratios (S:S) used in the analysis were from updated run reconstructions, as of March 2002. The S:S ratio used in this analysis was the median of the seven index stocks. Independent variables included water travel time, two measures of spill, updated estimates of climate effects (delta), and the proportion of smolts that were transported in barges and trucks. Annual water travel times (WTT) were the average times for water to move through the hydrosystem, LGR reservoir to BON dam, between April 16-May 31 and estimated as function of reservoir volume and flow. The proportion of water spilled each migration year (PropSpill) was represented as the daily spill/flow averaged over the migration season and across the 8 projects. Average volume spilled was calculated as daily spill averaged over the migration season and across all projects. The transport proportion was calculated as the number of smolts arriving at LGR dam divided by the number of smolts transported at LGR, LGS, and LMN over the whole season. The number of smolts arriving at LGR dam was estimated by methods described in Petrosky et al. (2001). The data source for the number of smolts transported came from Park (1985) for migration years 1975-1980, FTOT reports for migration years 1981-1984 and from the Fish Passage Center database from 1985-1996. Calvin Peters (ESSA Technologies, personal communication, March 2002) provided updated estimates of the climate effect (delta) and relative hydrosystem survival of Snake River versus downriver stocks (mu) (Deriso et al. 2001), through the 1995 migration year.

We transformed the dependent (SAR and S:S) variables by natural logarithms. We regressed Snake River spring/summer chinook  $\ln(\text{SARs})$  between 1975 (the year the last dam went in on the Snake River) and 1996 (SARs were not available between migration years 1985-1991) to all possible combinations of the above water travel time, spill, climate, and transportation proportion variables. In addition, we conducted a stepwise regression between these response and explanatory variables to avoid using explanatory variables that were highly correlated with each other.

Both BIC scores and the stepwise regression suggested that the most parsimonious model (the model with the fewest number of explanatory variables explaining the greatest amount of variability in survival) that best explained spring/summer chinook SARs was the transportation proportion (Appendix A, Tables 2 and 3). We found a moderate to strong relationship between chinook SARs and transportation proportion ( $r^2=0.64$ ,  $p<0.001$ ); however this relationship was negative suggesting years in which the proportion transported increased the SARs decreased (Figure 27).

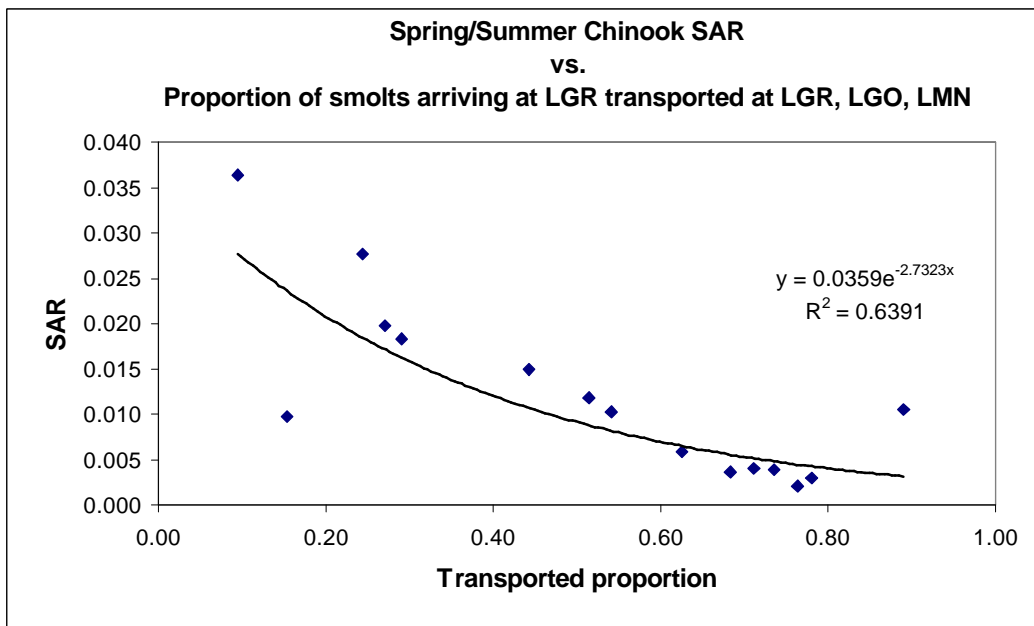
After demonstrating the large negative influence of transportation proportion on spring/summer chinook SARs (the best 10 models all included this variable), we evaluated the influence of other variables on survival of transported and non-transported fish over these life-stages by removing this variable from the model. BIC scores and the stepwise regression suggested that spring/summer chinook SARs were best explained by WTT and climate effects (Appendix A, Tables 4 and 5). A moderate relationship was observed between SARs explained by WTT and climate effects ( $r^2=0.48$ ,  $p<0.03$ ).

We also did a similar regression analyses for spring/summer chinook spawner-to-spawner ratios  $\ln(S:S)$  because we had a more complete time series and data were collected in a similar fashion over the time series. The spawner/spawner ratio for chinook was best explained by WTT and climate effects ( $r^2=0.63$ ,  $p<0.001$ ; Appendix A, Tables 6 and 7).

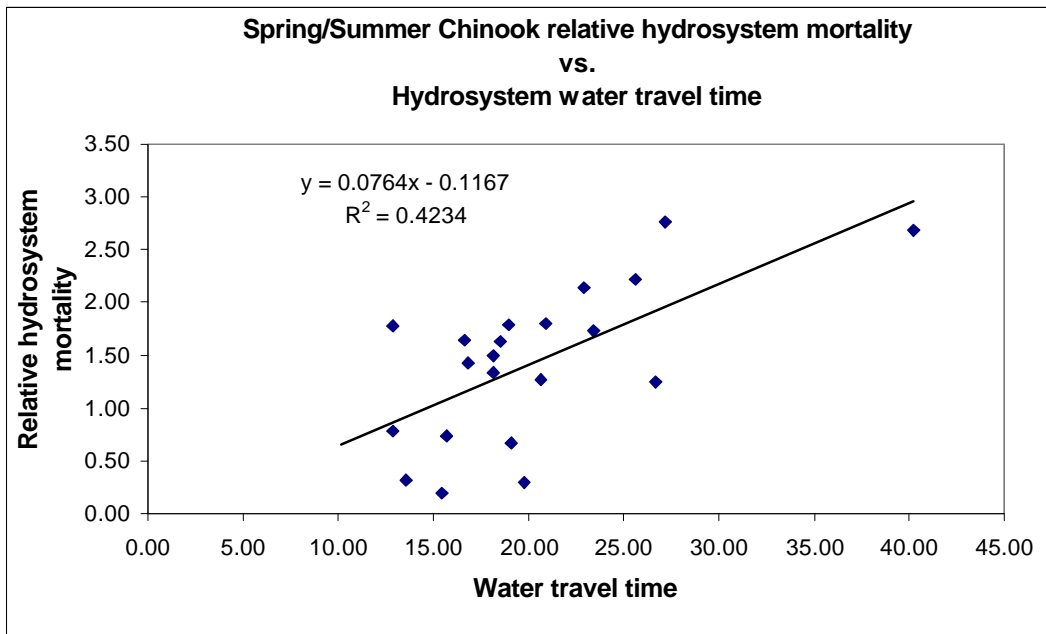
Regression analyses were also performed on the relative hydrosystem mortality ( $\mu$ ) using the explanatory variables. The best model explaining relative hydrosystem mortality was WTT ( $r^2=0.42$ ,  $p<0.002$ , Appendix A Tables 8 and 9). As WTT increased the relative hydrosystem mortality also increased (Figure28).

Finally, using the same regression analyses we evaluated the variables that influenced steelhead SARs. The best model selected suggested a moderate relationship between steelhead SARs and water travel time, the interaction between spill and water travel time, and climate ( $r^2=0.52$ ,  $p<0.007$ ).

Although these relationships are not driven by water travel time in itself, given the numerous environmental factors that influence survival of salmonids over this large portion of their life cycle as well as the large variability in the data, this factor remained as an important contributor to salmon survival.



**Figure 27. Relationship between Snake River spring/summer chinook smolt-to-adult survival (SAR) and the proportion of smolts arriving LGR that were transported at LGR, LGO, LMN.**



**Figure 28. The relationship between water travel time through the hydrosystem and the hydrosystem mortality for Snake River spring/summer chinook relative to Lower-Columbia River spring/summer chinook ( $\mu$ ). Relationships of Spawner:Spawner Ratios to Water Travel Time and Climate/Ocean Conditions.**

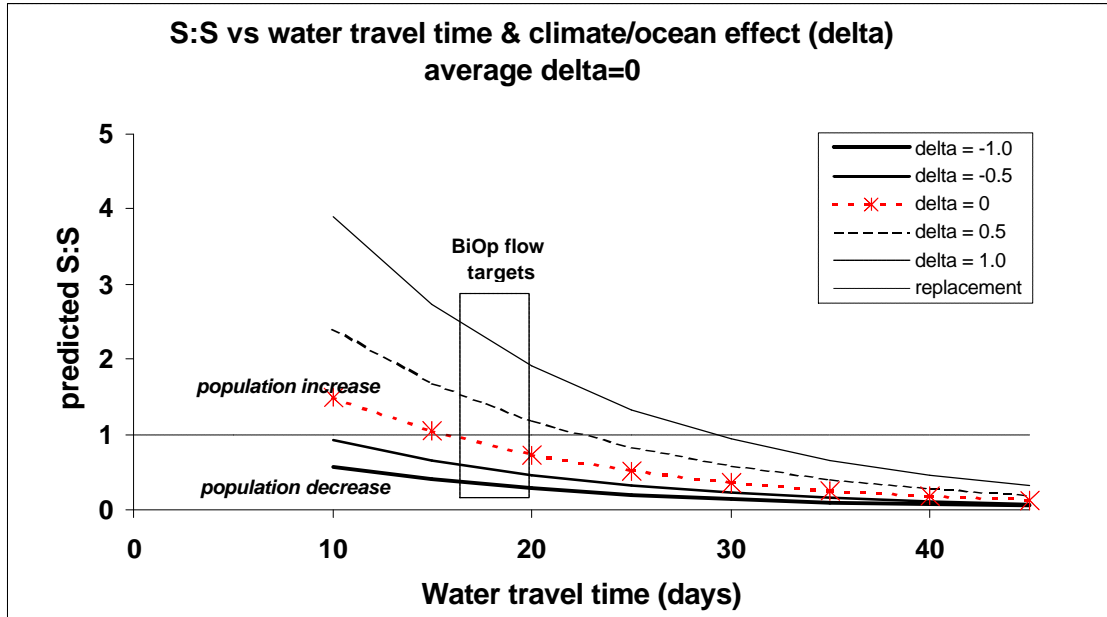
Juvenile migration conditions and climate/ocean conditions were both influential in explaining patterns of adult recruitment of wild Snake River spring/summer chinook. The relationship of predicted spawner-to-spawner ratios to water travel time and the climate/ocean influence ( $\delta$ ) is shown in Table 22 and Figure 29. The water travel times from Biological Opinion spring flow targets range from approximately 16.5 to 20 days, and are shaded in Table 22 and Figure 29. Observed water travel times ranged from 14 to 46 days in the fitted data (11 days was observed in 1997); and  $\delta$  ranged from  $-1.9$  (poor ocean) to  $1.0$  (favorable ocean). Salmon managers have no control of climatic/ocean conditions, thus we focus this discussion on predicted life-cycle survival (S:S ratio) at different water travel times, for average ( $\delta = 0$ ), good ( $\delta = 1.0$ ) and poor ( $\delta = -1.0$ ) climate/ocean conditions. A  $\delta$  value of  $1.0$  indicates climate/ocean influence resulted in nearly a three-fold higher than average survival ( $\exp(1.0)$ ); a  $\delta$  value of  $-1.0$  indicates ocean survival was only about  $1/3$  as high as average. The time frame in designating “average”, “poor” or “good” climate/ocean conditions was 1959-1995 smolt migration years (Deriso et al. 2001).

**Table 22. Predicted spawner:spawner ratios from observed ln(S:S), water travel time (WTT) and climate/ocean influence (delta), Snake River spring/summer chinook, smolt migration years 1975-1995. Combinations of WTT and delta that predict population declines (S:S < 1.0) are in red, those that predict population increases (S:S > 1.0) are bolded. BiOp flow targets produce WTT in the range of 16.5 to 20 days (shaded cells). Good, average, and poor climate/ocean conditions are represented by delta = 1.0, 0, and -1.0 respectively.**

WTT	DELTA								
	-1	-0.75	-0.5	-0.25	0	0.25	0.5	0.75	1
10	0.57	0.73	0.93	<b>1.18</b>	<b>1.50</b>	<b>1.90</b>	<b>2.42</b>	<b>3.07</b>	<b>3.90</b>
15	0.40	0.51	0.65	0.82	1.05	1.33	1.69	2.15	2.73
20	0.28	0.36	0.45	0.58	0.73	0.93	1.18	1.50	1.91
25	0.20	0.25	0.32	0.40	0.51	0.65	0.83	1.05	1.34
30	0.14	0.17	0.22	0.28	0.36	0.46	0.58	0.74	0.93
35	0.10	0.12	0.16	0.20	0.25	0.32	0.40	0.51	0.65
40	0.07	0.09	0.11	0.14	0.18	0.22	0.28	0.36	0.46
45	0.05	0.06	0.08	0.10	0.12	0.16	0.20	0.25	0.32

Under average climatic/ocean conditions (delta = 0), the predicted spawner-to-spawner ratio exceeded 1.0 (indicating population growth) only when water travel times were faster than 16 days (Table 22; Fig. 29). Predicted spawner to spawner ratios for water travel times associated with the Biological Opinion flow targets would approach or meet replacement of the populations for average climatic/ocean conditions. At 30 days WTT, the predicted recruits to the spawning ground were only 36% of the parent generation. At 20 days WTT, 73% of the parent generation was predicted to return to the spawning grounds, over a doubling of life cycle survival for a 10 day reduction in WTT, but insufficient for the population to increase.

Under good climatic/ocean conditions (delta = 1.0), the predicted spawner-to-spawner ratio exceeded 1.0 (indicating population growth) when water travel times were faster than 29 days (Table 22; Fig. 29). Predicted spawner to spawner ratios for water travel times associated with the Biological Opinion flow targets would exceed replacement of the populations for good climatic/ocean conditions. At 30 days WTT, the predicted recruits to the spawning ground were 93% of the parent generation. At 20 days WTT, 191% of the parent generation was predicted, again over a doubling of life cycle survival for a 10-day reduction in WTT.



**Figure 29. Predicted spawner:spawner ratios from observed  $\ln(S:S)$ , water travel time (WTT) and climate/ocean influence ( $\delta$ ), Snake River spring/summer chinook, smolt migration years 1975-1995. Population increases when  $S:S$  exceeds 1.0; and decreases when  $S:S < 1.0$ . BiOp flow targets produce WTT in the range of 16.5 to 20 days.**

Under poor climatic/ocean conditions ( $\delta = -1.0$ ), the predicted spawner-to-spawner ratio was always less than 1.0 (indicating population decline) at all water travel times (Table 22; Fig. 29). Predicted spawner-to-spawner ratios for water travel times associated with the Biological Opinion flow targets would provide protection for the populations for poor climatic/ocean conditions, but be insufficient to prevent declines. At 30 days WTT, the predicted recruits to the spawning ground were only 14% of the parent generation. At 20 days WTT, 28% of the parent generation was predicted to return to the spawning grounds.

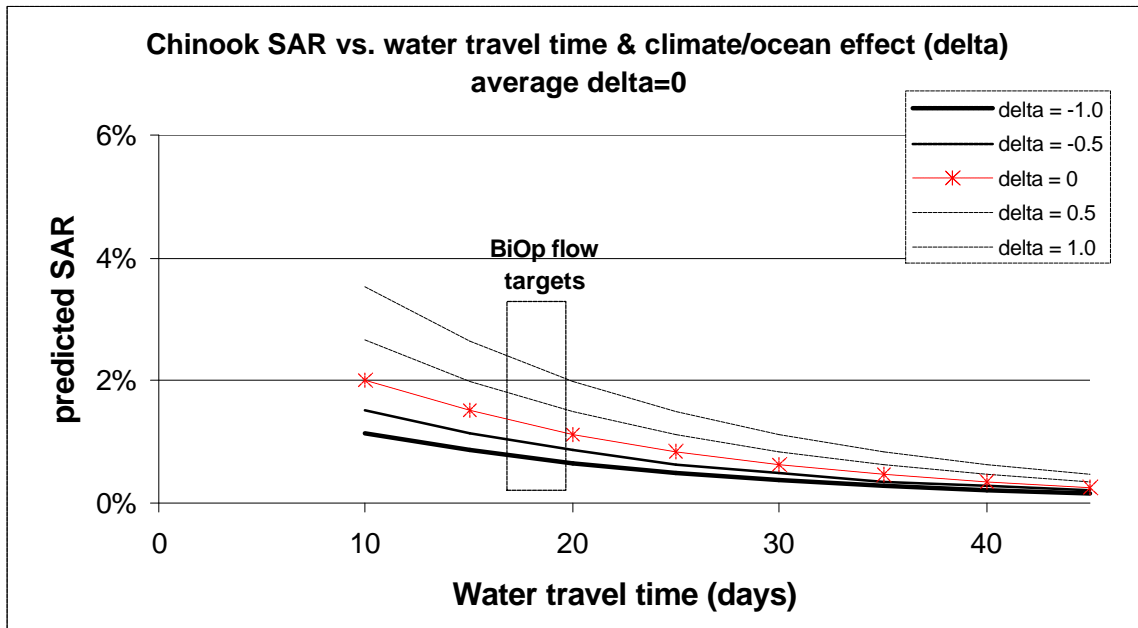
It is important to recognize that the relationships described above are inherently optimistic because we fit a density independent model. In reality, as the population increased toward carrying capacity, egg-to-smolt survival would decrease, and higher SARs would be needed for population growth to occur. For a given ocean condition, faster water travel times would be needed to maintain or rebuild the populations at higher spawner levels, particularly if regional harvest goals were to be achieved.

The Biological Opinion flow targets appear to represent a minimum needed to maintain the Snake River spring/summer chinook populations for average to good ocean conditions, and provide inadequate protection for poor ocean conditions. The Council’s proposed relaxation of spring flow targets would increase water travel times and reduce protection against population declines and the likelihood of rebuilding Snake River spring/summer chinook.

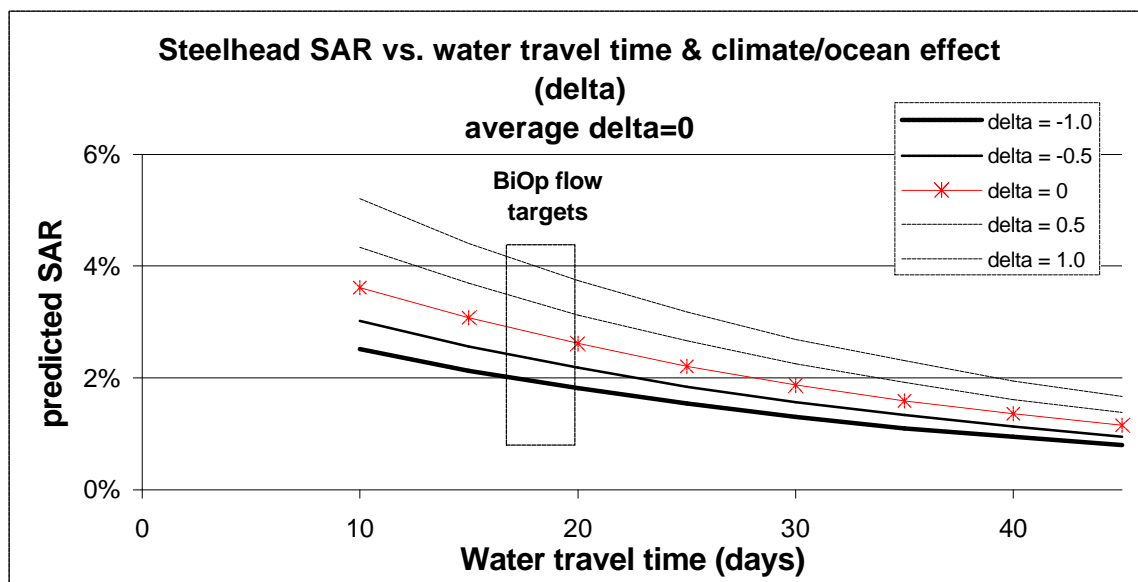
### Relationships of Chinook and Steelhead SARs to Water Travel Time and Climate/Ocean Conditions

Juvenile migration conditions and climate/ocean condition were both influential in explaining patterns of smolt-to-adult survival rates (SARs) of wild Snake River spring/summer chinook and steelhead. The relationships of predicted chinook and steelhead SARs to water travel time and the climate/ocean influence (delta) are shown in Figures 30 and 31. The water travel times from Biological Opinion spring flow targets range from 16.5 to 20 days, and are shaded in the figures. Observed water travel times ranged from 14 to 46 days in the fitted data; and delta ranged from - 1.9 (poor ocean) to 1.0 (favorable ocean). We again focus this discussion on predicted smolt-to-adult survival at different water travel times, for average (delta = 0), good (delta = 1.0) and poor (delta = -1.0) climate/ocean conditions.

PATH estimated a median 4% SAR was needed for spring/summer chinook recovery, and 2% SAR to meet survival criteria. PATH did not establish a steelhead SAR range associated with survival and recovery criteria.



**Figure 30. Predicted SAR from observed ln(SAR), water travel time (WTT) and climate/ocean influence (delta), Snake River wild spring/summer chinook, smolt migration years 1975-1995. Estimated SAR range needed for recovery is 2%-6%. BiOp flow targets produce WTT in the range of 16.5 to 20days.**



**Figure 31. Predicted SAR from observed ln(SAR), water travel time (WTT) and climate/ocean influence (delta), Snake River wild steelhead, smolt migration years 1975-1995. SAR range needed for recovery has not been established. BiOp flow targets produce WTT in the range of 16.5 to 20days.**

Under average climate/ocean conditions (delta = 0), the predicted SARs for spring/summer chinook exceeded 2% only at the high flows and water velocities (WTT = 10 days; Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 1.1% to 1.4% for average climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 0.6%. At 20 days WTT, predicted SARs were 1.1%, a 78% improvement in life stage survival for a 10-day reduction in WTT, but less than the SAR range identified in PATH as needed for survival and recovery.

Under average climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 2.6% to 2.9% (Fig. 31). At 30 days WTT, the predicted SARs were 1.9%. At 20 days WTT, predicted SARs were 2.6%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Under favorable climate/ocean conditions (delta = 1.0), the predicted SARs for spring/summer chinook exceeded 2% at average and above flows and faster water velocities (WTT = 20 days; Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 2.0% to 2.4% for good climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 1.1%. At 20 days WTT, predicted SARs were 2.0%, a 78% improvement in life stage survival for a 10-day reduction in WTT, and within the SAR range identified by PATH as needed for survival and recovery.

Under good climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 3.75% to 4.2% (Fig. 31). At 30

days WTT, the predicted SARs were 2.7%. At 20 days WTT, predicted SARs were 3.75%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Under poor climate/ocean conditions ( $\Delta = -1.0$ ), the predicted SARs for spring/summer chinook never approached 2% at any flows and water velocities (Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 0.65% to 0.8% for poor climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 0.36%. At 20 days WTT, predicted SARs were 0.65%, a 78% improvement in life stage survival for a 10 day reduction in WTT, but much lower than the SAR range identified by PATH as needed for survival and recovery.

Under poor climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 1.8% to 2.0% (Fig. 31). At 30 days WTT, the predicted SARs were 1.3%. At 20 days WTT, predicted SARs were 1.8%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Results from this study suggest that relaxation of spring flow objectives from those specified in the Biological Opinion would likely decrease the SARs of wild Snake River spring/summer chinook and steelhead.

## **TRANSPORTATION**

Several studies summarized in Giorgi et al. (2002) provide mechanisms and empirical information that suggests that increasing flow decreases the amount of time a smolt spends in the hydrosystem and subsequently mortality. Giorgi et al. (2002) also summarizes results reported by NMFS, which have not been able to reject hypotheses that increases in flows have no benefit to salmon survival. Based on this study, the Council has suggested relying mainly on transportation as mitigation for the impacts of the hydropower system rather than meeting flow targets. However, the benefits to transportation also remain equivocal. The Giorgi et al. (2002) report reviewed Bouwes et al. (2001) and Sandford and Smith (2002) as recent studies evaluating the benefit of transportation relative to migrating through the hydrosystem. Giorgi et al. (2002) concluded that transported fish generally exhibited higher SARs than fish that migrate in-river. Giorgi et al. (2002) failed to emphasize the important conclusions to these studies relevant to actual hydrosystem operations. Emphasis should have been placed on the comparison between wild smolts transported at all sites to the control, wild smolts that experienced a migration through the hydrosystem as if the transportation/collection system were not in place. Bouwes et al. (2001) found in 4 out of the 6 years analyzed, transported wild fish actually exhibited slightly lower SARs (point estimates) than wild fish that migrated through the hydrosystem undetected. Sandford and Smith (2002) also demonstrated equivocal differences between transported (they did not evaluate total transport SAR from all projects) and control in-river migrants as only 4 out of 20 data sets demonstrated significant benefits to an optimistic representation of transportation. See Joint Technical Memorandum to NWPPC, March 19, 2002.

Our analysis also does not support the hypothesis that transportation provides a benefit to the overall survival of wild spring/summer chinook and steelhead. The spring/summer chinook S:S and steelhead SARs were not significantly influenced by the transportation proportion, and the spring/summer chinook SARs actually decreased as the proportion of smolts transported

increased. Because transportation has failed to demonstrate statistically significant increases over fish that migrate in-river, by applying similar logic used to reject flow target as a management tool, we would expect the Council to adopt a management action that ceased transportation as well. The Council's draft mainstem amendments to the Fish and Wildlife program appear to apply a double standard to what are acceptable and unacceptable management strategies.

Because the benefits of flow and transportation are not clear the region has adopted a spread the risk approach whereby both flow augmentation and transportation strategies be used as partial mitigation to the hydrosystem. The Council has proposed a spread the risk approach only for transportation, however; based on our results removing flow targets will increase the risk to populations evaluated in this analysis.

## **References**

- Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Proceedings of the Second International Symposium on Information Theory.
- Banks, J. L., L. G. Fowler, and J. W. Elliot. 1971. Effects of rearing temperature on growth, body form, and hematology of fall chinook fingerlings. *The Progressive Fish Culturist* 33:20-26.
- Berggren, T. J., and M. J. Filardo. 1993. An analysis of variables influencing the migration of juvenile salmonids in the Columbia River basin. *NAJFM*. 13(1):48-63.
- Boeuf, G. 1993. Salmonid smolting: a pre-adaptation to the oceanic environment. Pages 105-135 in J. C. Rankin and F. B. Jensen, editors. *Fish ecophysiology*. Chapman and Hall, London.
- Bouwes, N., C. Petrosky, H. Schaller, P. Wilson, E. Weber, S. Scott, R. Boyce. 2001. Comparative survival study (CSS) of PIT tagged spring/summer chinook draft status report for migration years 1997 – 2000 mark/recapture activities. BPA Contract #8712702
- Budy, P., G. P. Thiede, N. Bouwes, C. Petrosky, H. Schaller. 2002. Evidence linking delayed hydrosystem mortality of Snake River salmon to their earlier hydrosystem experience. *North American Journal of Fisheries Management*. 22:35-51.
- Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5, ISBN 0362-1715, Bethesda, Maryland.
- Congelton, J. 2002. Physiology as a Factor in Delayed and Extra Mortality. Presentation at the Army Corps of Engineers' Transportation and Delayed Mortality of Juvenile Salmonids Workshop.
- Congleton, James L., William LaVoie, Joe Evavold, Derek Fryer and Boling Sun, 2001. Evaluation of the effects of multiple dam passage on the physiological condition of migrating juvenile salmon. Annual Report, 1999 to the U.S. Army Corps of Engineers, MPE-W-95-3.
- Congleton, James L., William LaVoie, Joe Evavold, Derek Fryer and Boling Sun, 2001. Evaluation of Physiological Differences in Transported, In-river Migrating and Multiple bypassed juvenile salmon. Annual Report, 2000 to the U.S. Army Corps of Engineers, DACW68-00-027.
- Congleton, James L., Tyler Wagner, Joe Evavold, Derek Fryer and Boling Sun, 2002. Evaluation of Physiological Changes in Migrating Juvenile Salmonids and Effects on Performance and Survival. Annual Report to the U.S. Army Corps of Engineers, DACW68-00-C-0031.
- Connor, W. P. 2001. Juvenile life history, downstream migration rate, and survival of wild Snake River fall chinook salmon. Ph. D. dissertation. University of Idaho, Moscow, Idaho.
- Connor, W. P., and H. L. Burge. In press. Growth of wild subyearling chinook salmon in the Snake River. *North American Journal of Fisheries Management*. Expected publication date May 2003.
- Connor, W. P., H. L. Burge, and D. H. Bennett. 1998. Detection of subyearling chinook salmon at a Snake River dam: Implications for summer flow augmentation. *North American Journal of Fisheries Management* 18:530-536.

- Connor, W. P., R. K. Steinhorst, and H. L. Burge. 2000. Forecasting survival and passage for migratory juvenile salmonids. *North American Journal of Fisheries Management* 20:650-659.
- Connor, W. P., H. L. Burge, R. Waitt, and T. C. Bjornn. 2002. Juvenile life history of wild fall chinook salmon in the Snake and Clearwater rivers. *North American Journal of Fisheries Management* 22:703-712.
- Connor, W. P., R. K. Steinhorst, and H. L. Burge. In press a. Migrational behavior and seaward movement of wild subyearling fall chinook salmon in the Snake River. *North American Journal of Fisheries Management*. Expected publication date May 2003.
- Connor, W. P., H. L. Burge, J. R. Yearsley, and T. C. Bjornn. In press b. The influence of flow and temperature on survival of wild subyearling fall chinook salmon in the Snake River. *North American Journal of Fisheries Management*. Expected publication date May 2003.
- Cormack, R. M. 1964. Estimates of survival from the sightings of marked animals. *Biometrika* 51:429-438.
- Dielman, T. E. 1996. *Applied regression analysis for business and economics*. Wadsworth Publishing Company, Belmont, California.
- Deriso, R.B., Marmorek, D.R., and Parnell, I.J. 2001. Retrospective patterns of differential mortality and common year effects experienced by spring chinook of the Columbia River. *Can. J. Fish. Aquat. Sci.* (58: 2419-2431).
- Fox, J. 1991. *Regression Diagnostics: An Introduction*. Sage University Paper Series on Quantitative Applications in the Social Sciences, 07-079. Newbury Park, CA
- Giorgi, A. E., T. W. Hillman, J. R. Stevenson, S. G. Hayes, and C. M. Pevan. 1997. Factors that influence the downstream migration rates of juvenile salmon and steelhead through the hydroelectric System in the mid-Columbia River Basin. *North American Journal of Fisheries Management* 17:268-282.
- Giorgi, A., M. Miller, J. Stevenson. 2002. Mainstem Passage Strategies in the Columbia River System: Transportation, Spill, and Flow Augmentation. Prepared for the Northwest Power Planning Council, Portland, OR.
- Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1982. Life history of fall-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. Pages 393-411, in V. S. Kennedy, editor. *Estuarine comparisons*. Academic Press, New York.
- Kjelson, M. A., and P. L. Brandes. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin rivers, California. Pages 100-115, in C. D. Levings, L. B. Holtby, and M. A. Henderson, editors. *Proceedings of the national workshop on effects of habitat alteration on salmonid stocks*. Canadian Special Publication of Fisheries and Aquatic Sciences 105.
- Marine, K. R. 1997. Effects of elevated water temperature on some aspects of the physiological and ecological performance of juvenile chinook salmon (*Oncorhynchus tshawytscha*): Implications for management of California's Central Valley Salmon Stocks. Master's thesis. University of California, Davis.

Joint Technical Comments. March 19 2002. Submitted to the Northwest Power Planning Council. [http://www.fpc.org/fpc\\_docs/joint-technical/41-02.pdf](http://www.fpc.org/fpc_docs/joint-technical/41-02.pdf).

Muir, W. D., S. G. Smith, J. G. Williams, and B. P. Sanford. 2001. Survival of juvenile salmonids passing through bypass systems, turbines, and spillways with and without flow deflectors at Snake River dams. *North American Journal of Fisheries Management* 21:135-146.

Mundy, P. R., D. Neeley, C. R. Steward, T. P. Quinn, B. A. Barton, R. N. Williams, D. Goodman, R. R. Whitney, M. W. Erho, Jr. and L. W. Botsford. 1994. Transportation of juvenile salmonids from hydroelectric projects on the Columbia River Basin; an Independent Peer Review. Final Report. U. S. Fish and Wildlife Service.

Myers, R.H. 1990. *Classical and Modern Regression with Applications*. [2<sup>nd</sup> Ed]. The Duxbury Advanced Series in Statistics and Decision Sciences. PWS – Kent Publishing Co. Boston, MA

National Marine Fisheries Service (NMFS). 2000. White Paper: Salmonid travel time and survival related to flow in the Columbia River Basin. Seattle, WA. 68 p.

Ott, R. L. 1993. *A introduction to statistical methods and data analysis*. 4th edition. Wadsworth Publishing Company, Belmont, California.

Park, D.L. 1985. A review of smolt transportation to bypass dams on the Snake and Columbia Rivers. CZES, NMFS, NOAA/US COE Tech. Rep.

Peterman, R.M. 1990. Statistical power can improve fisheries research and management. *Canadian Journal of Fisheries and Aquatic Sciences* 47:2-15.

Petrosky, C. E., H. A. Schaller, and P. Budy. 2001. Productivity and survival rate trends in the freshwater spawning and rearing stage of Snake River chinook salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries and Aquatic Sciences* 58:1196-1207.

Poe, P. P., H. C. Hansel, S. Vigg, D. E. Palmer and L. A. Pendergast. 1991. Feeding of predacious fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. *Transactions of the American Fisheries Society* 120: 405-420.

Poe, T. P., R. S. Shively and R. A. Tabor. 1994. Ecological consequences of introduced piscivorous fishes in the lower Columbia and Snake rivers. In: D. J. Stouder, K. L. Fresh, and R. J. Feller (eds), *Theory and Application in Fish Feeding Ecology*. University of South Carolina Press. Columbia, South Carolina.

Sandford, B. P., and S. G. Smith. 2002. Estimation of Smolt-to-Adult Return Percentages for Snake River Basin Anadromous Salmonids, 1990-1997. *Journal of Agricultural, Biological, and Environmental Statistics*.

Schaller, H. A., C. E. Petrosky, and O. P. Langness. 1999. Contrasting patterns of productivity and survival rates for stream-type chinook salmon (*Oncorhynchus tshawytscha*) populations of the Snake and Columbia rivers *Canadian Journal of Fisheries and Aquatic Sciences* 56:1031-1045.

Schaller, H. A., C. E. Petrosky, and O. P. Langness. 2000. Reply to Zabel and Williams' comments on "Contrasting patterns of productivity and survival rates for stream-type chinook salmon (*Oncorhynchus*

*tshawytscha*) populations of the Snake and Columbia Rivers” by Schaller et al. (1999). Canadian Journal of Fisheries and Aquatic Sciences 57:1742-1746.

Schreck, C. B., and T. P. Stahl. 1998. Evaluation of migration and survival of juvenile salmonids following transportation. 1998 Annual Report to the U.S. Army Corps of Engineers. Project MPE-W-97-4. Walla Walla, Washington.

Sims, C. W., and F. Ossiander. 1981. Migrations of juvenile chinook salmon and steelhead in the Snake River, from 1973 to 1979, a research summary. Report to U. S. Army Corps of Engineers, Portland, OR. Prepared by National Marine Fisheries Service, Contract No. DACW68-78-C-0038.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffman. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences 55:1484-1493.

Snelling, J. C., and C. B. Schreck. 1994. Movement, Distribution, and Behavior of Juvenile Salmonids Passing through Columbia and Snake River Dams (draft). Bonneville Power Administration. 82-003. Portland.

Yearsley, J., D. Karna, S. Peene and B. Watson. 2001. Application of a 1-D heat budget model to the Columbia River system. Final report 901-R-01-001 by the U.S. Environmental Protection Agency, Region 10, Seattle, Washington.

APPENDIX A

**Table 1: Information used in analysis. See text for details on data compilation of SARch (Snake River spring/summer chinook smolt-to-adult survival), lnSSch (Snake River spring/summer chinook ln Spawner to Spawner), mu (direct and delayed hydrosystem survival of Snake River spring/summer chinook relative to Mid-Columbia spring/summer chinook survival), SARst (Snake River steelhead smolt-to-adult survival), wtt (water particle travel time through Lower Granite Reservoir to Bonneville Dam), spill (average proportion of the flow spilled over dams), avgspill (average volume-kcfs-spilled over dams), climate (climate affect), ptranss (proportion of Snake River spring/summer chinook smolts arriving at LGR, LGO, LMN that were transported in barges and trucks), ptranst(proportion of Snake River steelhead smolts arriving at LGR, LGO, LMN that were transported in barges and trucks)**

Obs	year	SARch	lnSSch	mu	SARst	wtt	spill	avgspill	climate	ptranss	ptranst
1	1975	0.036	-0.347	0.74	0.021	15.71	0.406	69.74	0.22	0.09	0.17
2	1976	0.010	-0.905	1.78	0.020	12.89	0.481	112.36	-0.18	0.15	0.14
3	1977	0.004	-2.031	2.68	0.010	40.23	0.004	0.82	-0.41	0.68	0.64
4	1978	0.010	-0.641	1.33	0.033	18.16	0.145	29.28	-0.50	0.54	0.65
5	1979	0.012	-0.410	0.29	0.034	19.75	0.073	16.46	-1.26	0.51	0.66
6	1980	0.006	-1.405	1.49	0.027	18.11	0.081	19.34	-0.45	0.63	0.79
7	1981	0.015	-0.153	1.27	0.012	20.65	0.089	20.72	-0.33	0.44	0.74
8	1982	0.018	1.281	0.32	0.040	13.55	0.355	85.41	0.15	0.29	0.53
9	1983	0.020	0.504	0.19	0.034	15.45	0.326	74.31	-0.33	0.27	0.67
10	1984	0.028	0.489	0.78	0.046	12.84	0.300	74.92	0.22	0.24	0.65
11	1985	.	1.556	0.67	0.040	19.06	0.109	22.36	0.87	0.69	1.00
12	1986	.	-0.240	1.64	0.041	16.64	0.210	48.27	0.33	0.64	0.92
13	1987	.	-0.786	2.22	0.052	25.58	0.053	11.73	0.42	0.64	0.96
14	1988	.	-0.425	1.25	0.027	26.67	0.031	5.17	-0.03	0.58	0.87
15	1989	.	-1.116	1.79	0.012	18.93	0.117	22.71	-0.49	0.60	0.80
16	1990	.	-0.444	2.14	0.030	22.92	0.108	19.45	0.58	0.64	0.85
17	1991	.	-0.570	1.81	0.019	20.91	0.161	38.75	-0.35	0.81	0.93
18	1992	0.002	-2.318	2.77	0.013	27.18	0.150	22.28	-1.09	0.76	0.93
19	1993	0.004	-2.199	1.43	0.013	16.80	0.231	56.65	-1.94	0.74	0.85
20	1994	0.010	-0.269	1.73	0.015	23.40	0.199	28.98	0.34	0.89	0.92
21	1995	0.003	-0.379	1.63	.	18.49	0.258	51.96	0.07	0.78	0.86
22	1996	0.004	-0.608	.	.	13.38	0.395	107.41	.	0.71	0.82

**Table 2: Model comparisons with parameter estimates for ln (spring/summer chinook SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt\*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.**

Adjusted r <sup>2</sup>	r <sup>2</sup>	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.6363	0.6923	-15.7283	-12.7173	-3.36120	.	.	.	0.33405	-2.36221
0.6262	0.7124	-14.6778	-10.7195	-2.89070	.	-1.18510	.	0.38215	-2.74048
0.6210	0.7085	-14.4861	-10.6477	-3.14694	-0.01862	.	.	0.34198	-2.05827
0.6126	0.7020	-14.1795	-10.5319	-3.09728	.	.	-0.05143	0.37047	-2.48514
0.6064	0.6367	-15.4047	-13.4093	-3.34185	.	.	.	.	-2.66249
0.5868	0.6504	-13.9412	-11.7168	-3.14497	-0.01707	.	.	.	-2.39034
0.5842	0.6802	-13.1887	-10.1480	-2.29878	-0.03303	-1.65791	.	.	-2.72556
0.5789	0.6437	-13.6753	-11.5658	-3.07160	.	-0.67668	.	.	-2.90316
0.5722	0.6380	-13.4555	-11.4406	-3.24728	.	.	-0.01828	.	-2.71782
0.5643	0.6649	-12.5347	-9.8858	-2.83270	.	-4.47013	0.24669	.	-3.50571

**Table 3: Relationship between SAR and WTT, PropSpill, and ptrans stepwise regression for sp/su chinook SARs**

**Dependent Variable: lnSARch**

**Stepwise Selection: Step 1**

**Variable ptrans Entered: R-Square = 0.6367 and C(p) = 4.0159**

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	6.13535	6.13535	21.03	0.0006
Error	12	3.50086	0.29174		
Corrected Total	13	9.63620			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-3.34185	0.32457	30.92697	106.01	<.0001
ptranss	-2.66249	0.58058	6.13535	21.03	0.0006

**Bounds on condition number: 1, 1**

**All variables left in the model are significant at the 0.1500 level.**

**No other variable met the 0.1500 significance level for entry into the model.**

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	ptranss		1	0.6367	0.6367	4.0159	21.03	0.0006

**Table 4: Model comparisons with parameter estimates for ln (spring/summer chinook SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt\*spill), climate (see definitions to variables in Table 1). Ptrans was not included in this analysis. Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.**

Adjusted $r^2$	$r^2$	AIC	BIC	Parameter Estimates				
				Intercept	wtt	spill	inter	climate
0.3842	0.4789	-8.3548	-4.5910	-3.33244	-0.05754	.	.	0.55993
0.3710	0.5161	-7.3927	-2.3054	-2.53110	-0.07474	.	-0.11762	0.65058
0.3298	0.4844	-6.5046	-1.9849	-2.98382	-0.06657	-0.70309	.	0.60322
0.2816	0.4474	-5.5327	-1.6264	-4.52431	.	7.07556	-0.41603	0.49688
0.2474	0.3053	-6.3283	-4.3370	-3.38346	-0.06618	.	.	.
0.2160	0.3969	-4.3100	-1.1582	-3.73312	-0.04500	5.68111	-0.36117	.
0.2130	0.3340	-4.9207	-2.6783	-4.89273	.	1.88233	.	0.50695
0.2068	0.3288	-4.8120	-2.6167	-4.91379	.	8.10073	-0.42484	.
0.1927	0.2548	-5.3475	-3.6359	-4.41290	.	.	.	0.66837
0.1901	0.3147	-4.5199	-2.4507	-3.79631	-0.05458	0.84218	.	.

**Table 5: Stepwise regression for sp/su chinook SARs w/o ptrans**  
**Dependent Variable: lnSARch**  
**Stepwise Selection: Step 2**  
**Variable climate Entered: R-Square = 0.4789 and C(p) = 2.5236**

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	4.61479	2.30740	5.05	0.0277
Error	11	5.02141	0.45649		
Corrected Total	13	9.63620			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-3.33244	0.54054	17.34979	38.01	<.0001
wtt	-0.05754	0.02646	2.15917	4.73	0.0523
climate	0.55993	0.29245	1.67332	3.67	0.0819

**Bounds on condition number: 1.0299, 4.1198**

**All variables left in the model are significant at the 0.1500 level.**  
**No other variable met the 0.1500 significance level for entry into the model.**

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	wtt		1	0.3053	0.3053	4.0304	5.27	0.0405
2	climate		2	0.1736	0.4789	2.5236	3.67	0.0819

**Table 6: Model comparisons with parameter estimates for ln (spring/summer chinook spawner:spawner survival) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt\*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.**

Adjusted r <sup>2</sup>	r <sup>2</sup>	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.6026	0.6622	-16.1548	-11.5179	1.95728	-0.09331	.	-0.12420	0.96941	.
0.5928	0.6335	-16.4417	-13.0381	1.11800	-0.07148	.	.	0.95809	.
0.5926	0.6537	-15.6327	-11.2172	1.87762	-0.09459	-1.56578	.	0.97455	.
0.5725	0.6366	-14.6194	-10.6302	1.16529	-0.06596	.	.	0.94862	-0.29051
0.4598	0.5139	-10.5078	-8.8338	0.36724	.	.	.	0.94382	-1.25700
0.4309	0.5163	-8.6127	-7.0065	0.17478	.	0.49460	.	0.94239	-1.07498
0.4292	0.5148	-8.5496	-6.9668	0.26871	.	.	0.01959	0.94290	-1.19218
0.4249	0.5111	-8.3906	-6.8666	-0.39686	.	5.40226	-0.29117	0.95190	.
0.4241	0.4817	-9.1622	-7.8601	-0.63634	.	1.69162	.	0.96638	.
0.4039	0.4337	-9.3035	-8.1231	-0.31694	.	.	.	0.99816	.

**Table 7: Stepwise regression for ln(spawner/spawner) sp/su chinook  
Dependent Variable: lnSSch**

**Stepwise Selection: Step 2  
Variable wtt Entered: R-Square = 0.6335 and C(p) = 1.7233**

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	12.46888	6.23444	15.56	0.0001
Error	18	7.21289	0.40072		
Corrected Total	20	19.68177			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.11800	0.48035	2.17074	5.42	0.0318
wtt	-0.07148	0.02282	3.93244	9.81	0.0058
climate	0.95809	0.21664	7.83736	19.56	0.0003

**Bounds on condition number: 1.0035, 4.014**

**All variables left in the model are significant at the 0.1500 level.  
No other variable met the 0.1500 significance level for entry into the model.**

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	climate		1	0.4337	0.4337	8.8409	14.55	0.0012
2	wtt		2	0.1998	0.6335	1.7233	9.81	0.0058

**Table 8: Model comparisons with parameter estimates for mu (relative hydrosystem mortality of spring/summer chinook) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt\*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.**

Adjusted $r^2$	$r^2$	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.4828	0.5604	-23.4717	-18.6082	-1.55562	0.08454	2.46368	.	.	1.48165
0.4690	0.5487	-22.9186	-18.2906	-1.21933	0.07934	.	0.13625	.	1.10161
0.4291	0.4862	-22.1964	-19.0993	-0.27614	0.05803	.	.	.	0.96012
0.4084	0.4675	-21.4466	-18.5718	-0.88393	0.09649	.	0.11352	.	.
0.3965	0.4870	-20.2298	-16.7277	-0.67953	0.08538	-2.65864	0.27399	.	.
0.3955	0.4862	-20.1964	-16.7081	-0.27613	0.05803	.	.	0.00074325	0.96040
0.3929	0.4232	-21.7680	-19.5162	-0.11758	0.07647	.	.	.	.
0.3783	0.4405	-20.4048	-17.8369	-0.63183	0.09221	1.06168	.	.	.
0.3751	0.4689	-19.4995	-16.2959	-0.89277	0.09639	.	0.11439	-0.04097	.
0.3600	0.4240	-19.7952	-17.4054	-0.11979	0.07628	.	.	-0.03055	.

**Table 9: Stepwise regression for relative mortality sp/su chinook**  
**Dependent Variable: mu**  
**Stepwise Selection: Step 1**  
**Variable wtt Entered: R-Square = 0.4232 and C(p) = 2.7175**

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	4.51739	4.51739	13.94	0.0014
Error	19	6.15630	0.32402		
Corrected Total	20	10.67370			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-0.11758	0.43170	0.02403	0.07	0.7883
wtt	0.07647	0.02048	4.51739	13.94	0.0014

**Bounds on condition number: 1, 1**

**All variables left in the model are significant at the 0.1500 level.**  
**No other variable met the 0.1500 significance level for entry into the model.**

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	wtt		1	0.4232	0.4232	2.7175	13.94	0.0014

**Table 10: Model comparisons with parameter estimates for ln (steelhead SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt\*spill), climate, and ptranst (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.**

Adjusted r <sup>2</sup>	r <sup>2</sup>	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranst
0.4323	0.5220	-34.2612	-29.7278	-2.12802	-0.05528	.	-0.13030	0.36968	.
0.3897	0.4861	-32.8129	-28.9194	-2.22112	-0.05625	-1.60427	.	0.37760	.
0.3403	0.4444	-31.2554	-28.0354	-3.20726	-0.03910	.	.	0.35574	0.46735
0.3346	0.4046	-31.8704	-29.3959	-2.99219	-0.03272	.	.	0.36305	.
0.2101	0.2933	-28.4414	-26.9918	-2.19424	-0.05657	.	-0.12575	.	.
0.2049	0.3304	-27.5221	-25.8331	-3.50977	.	3.53358	-0.25331	0.35650	.
0.2000	0.2421	-29.0449	-27.6923	-3.65203	.	.	.	0.37972	.
0.1750	0.3053	-26.7843	-25.3817	-2.29969	-0.05065	1.46060	-0.21558	.	.
0.1694	0.3006	-26.6498	-25.2988	-2.40124	-0.05684	.	-0.10992	.	0.22259
0.1614	0.2497	-27.2451	-26.1373	-3.71540	.	0.34267	.	0.37405	.

**Table 11: Stepwise regression for steelhead SARs**

**Dependent Variable: lnSARst**

**Stepwise Selection: Step 3**

**Variable inter Entered: R-Square = 0.5220 and C(p) = 2.8508**

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2.63954	0.87985	5.82	0.0069
Error	16	2.41735	0.15108		
Corrected Total	19	5.05690			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-2.12802	0.52776	2.45640	16.26	0.0010
wtt	-0.05528	0.01807	1.41428	9.36	0.0075
inter	-0.13030	0.06575	0.59347	3.93	0.0649
climate	0.36968	0.13361	1.15656	7.66	0.0138

**Bounds on condition number: 1.6624, 12.985**

**All variables left in the model are significant at the 0.1500 level.**

**No other variable met the 0.1500 significance level for entry into the model.**

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	climate		1	0.2421	0.2421	7.5439	5.75	0.0275
2	wtt		2	0.1625	0.4046	4.4967	4.64	0.0459

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
3	inter		3	0.1174	0.5220	2.8508	3.93	0.0649

**Appendix B  
Survival Estimates for Survival Analysis**

**Survival Estimates For Survival Analysis For Reach McNary to Bonneville ST 1999 to 2002; CH1 1999 to 2002**

Species	Migr_yr	Release	Reach	Survival	Species	Migr_yr	Release	Reach	Survival
ST	1999	5/11 to 6/8	MCN to BON	0.717	CH1	1999	4/25-5/8	MCN to BON	0.672
ST	2000	5/11 to 6/8	MCN to BON	0.505	CH1	1999	5/9-5/22	MCN to BON	0.756
ST	2001	5/11 to 6/8	MCN to BON	0.217	CH1	1999	5/23-6/5	MCN to BON	0.660
ST	2002	5/11 to 6/8	MCN to BON	0.532	CH1	2000	4/25-5/8	MCN to BON	0.661
					CH1	2000	5/9-5/22	MCN to BON	0.669
					CH1	2001	4/25-5/8	MCN to BON	0.452
					CH1	2001	5/9-5/22	MCN to BON	0.516
					CH1	2001	5/23-6/5	MCN to BON	0.593
					CH1	2002	4/25-5/8	MCN to BON	0.694
					CH1	2002	5/9-5/22	MCN to BON	0.819
					CH1	2002	5/23-6/5	MCN to BON	0.671

**Survival Estimates For Survival Analysis For Reach Rock Island to McNary ST 1998 to 2002; CH1 1998 to 2002**

Species	Migr Yr	Release	Reach	Survival	Species	Migr Yr	Rel Dates	Reach	Survival
CH1	1998	4/21-5/4	RIS to MCN	0.589	ST	1998	4/21-5/4	RIS to MCN	0.586
CH1	1998	5/5-5/18	RIS to MCN	0.926	ST	1998	5/5-5/18	RIS to MCN	0.600
CH1	1999	4/21-5/04	RIS to MCN	0.741	ST	1998	5/19-6/1	RIS to MCN	0.455
CH1	1999	5/05-5/18	RIS to MCN	0.744	ST	1999	4/21-5/04	RIS to MCN	0.670
CH1	1999	5/19-6/01	RIS to MCN	0.794	ST	1999	5/05-5/18	RIS to MCN	0.607
CH1	2000	4/21-5/4	RIS to MCN	0.783	ST	1999	5/19-6/01	RIS to MCN	0.681
CH1	2000	5/5-5/18	RIS to MCN	0.790	ST	2000	4/21-5/4	RIS to MCN	0.913
CH1	2001	4/21-5/4	RIS to MCN	0.527	ST	2000	5/5-5/18	RIS to MCN	0.657
CH1	2001	5/5-5/18	RIS to MCN	0.677	ST	2000	5/19-6/01	RIS to MCN	0.405
CH1	2001	5/19-6/01	RIS to MCN	0.588	ST	2001	4/21-5/4	RIS to MCN	0.247
CH1	2002	4/21-5/4	RIS to MCN	0.649	ST	2001	5/5-5/18	RIS to MCN	0.230

**Survival Estimates For Survival Analysis For Reach Lower Granite to McNary ST 1996 to 2002; CH1H 1995 to 2002; CH1W 1995,1996,1998 to 2002**

Species	Dates	migr_yr	Reach	Survival	Species	Release	Migr_yr	Reach	Survival	Species	Release	Migr_yr	Reach	Survival
ST	4/17-4/23	1998	LGR to MCN	0.616	CH1H	4/1-4/7	1998	LGR to MCN	0.806	CH1W	4/1-4/7	1998	LGR to MCN	0.760
ST	4/24-4/30	1998	LGR to MCN	0.752	CH1H	4/8-4/14	1998	LGR to MCN	0.737	CH1W	4/8-4/14	1998	LGR to MCN	0.741
ST	5/1-5/7	1998	LGR to MCN	0.682	CH1H	4/15-4/21	1998	LGR to MCN	0.744	CH1W	4/15-4/21	1998	LGR to MCN	0.804
ST	5/8-5/14	1998	LGR to MCN	0.688	CH1H	4/22-4/28	1998	LGR to MCN	0.807	CH1W	4/22-4/28	1998	LGR to MCN	0.786
ST	5/15-5/21	1998	LGR to MCN	0.754	CH1H	4/29-5/5	1998	LGR to MCN	0.793	CH1W	4/29-5/5	1998	LGR to MCN	0.799
ST	5/22-5/28	1998	LGR to MCN	0.627	CH1H	5/6-5/12	1998	LGR to MCN	0.805	CH1W	5/6-5/12	1998	LGR to MCN	0.823
ST	4/17-4/23	1999	LGR to MCN	0.746	CH1H	5/13-5/19	1998	LGR to MCN	0.863	CH1W	5/20-5/26	1998	LGR to MCN	0.600
ST	4/24-4/30	1999	LGR to MCN	0.721	CH1H	4/1-4/7	1999	LGR to MCN	0.830	CH1W	4/1-4/7	1999	LGR to MCN	0.776
ST	5/1-5/7	1999	LGR to MCN	0.705	CH1H	4/8-4/14	1999	LGR to MCN	0.754	CH1W	4/8-4/14	1999	LGR to MCN	0.808
ST	5/8-5/14	1999	LGR to MCN	0.632	CH1H	4/15-4/21	1999	LGR to MCN	0.720	CH1W	4/15-4/21	1999	LGR to MCN	0.795
ST	5/15-5/21	1999	LGR to MCN	0.744	CH1H	4/22-4/28	1999	LGR to MCN	0.806	CH1W	4/22-4/28	1999	LGR to MCN	0.790
ST	5/22-5/28	1999	LGR to MCN	0.837	CH1H	4/29-5/5	1999	LGR to MCN	0.815	CH1W	4/29-5/5	1999	LGR to MCN	0.814
ST	4/17-4/23	2000	LGR to MCN	0.715	CH1H	5/6-5/12	1999	LGR to MCN	0.799	CH1W	5/6-5/12	1999	LGR to MCN	0.694
ST	4/24-4/30	2000	LGR to MCN	0.595	CH1H	5/13-5/19	1999	LGR to MCN	0.796	CH1W	5/13-5/19	1999	LGR to MCN	0.756
ST	5/1-5/7	2000	LGR to MCN	0.549	CH1H	5/20-5/26	1999	LGR to MCN	0.716	CH1W	5/20-5/26	1999	LGR to MCN	0.900
ST	5/8-5/14	2000	LGR to MCN	0.559	CH1H	4/15-4/21	2000	LGR to MCN	0.936	CH1W	4/8-4/14	2000	LGR to MCN	0.727
ST	4/24-4/30	2001	LGR to MCN	0.159	CH1H	4/22-4/28	2000	LGR to MCN	0.764	CH1W	4/15-4/21	2000	LGR to MCN	0.825
ST	5/1-5/7	2001	LGR to MCN	0.177	CH1H	4/29-5/5	2000	LGR to MCN	0.717	CH1W	4/22-4/28	2000	LGR to MCN	0.748
ST	5/8-5/14	2001	LGR to MCN	0.187	CH1H	5/6-5/12	2000	LGR to MCN	0.749	CH1W	4/29-5/5	2000	LGR to MCN	0.727
ST	5/15-5/21	2001	LGR to MCN	0.143	CH1H	5/20-5/26	2000	LGR to MCN	0.729	CH1W	5/6-5/12	2000	LGR to MCN	0.731
ST	5/22-5/28	2001	LGR to MCN	0.079	CH1H	4/8-4/14	2001	LGR to MCN	0.573	CH1W	5/13-5/19	2000	LGR to MCN	0.732
ST	4/24-4/30	2002	LGR to MCN	0.461	CH1H	4/15-4/21	2001	LGR to MCN	0.605	CH1W	5/20-5/26	2000	LGR to MCN	0.858
ST	5/1-5/7	2002	LGR to MCN	0.466	CH1H	4/22-4/28	2001	LGR to MCN	0.593	CH1W	4/8-4/14	2001	LGR to MCN	0.649
ST	5/8-5/14	2002	LGR to MCN	0.390	CH1H	4/29-5/5	2001	LGR to MCN	0.578	CH1W	4/15-4/21	2001	LGR to MCN	0.605
ST	5/15-5/21	2002	LGR to MCN	0.516	CH1H	5/6-5/12	2001	LGR to MCN	0.552	CH1W	4/22-4/28	2001	LGR to MCN	0.588
ST	5/22-5/28	2002	LGR to MCN	0.724	CH1H	5/13-5/19	2001	LGR to MCN	0.470	CH1W	4/29-5/5	2001	LGR to MCN	0.521
ST	4/24-4/30	1996	LGR to MCN	0.793	CH1H	5/20-5/26	2001	LGR to MCN	0.276	CH1W	5/6-5/12	2001	LGR to MCN	0.507
ST	5/1-5/7	1996	LGR to MCN	0.792	CH1H	4/22-4/28	2002	LGR to MCN	0.586	CH1W	5/13-5/19	2001	LGR to MCN	0.458
ST	5/15-5/21	1996	LGR to MCN	0.659	CH1H	4/29-5/5	2002	LGR to MCN	0.733	CH1W	5/20-5/26	2001	LGR to MCN	0.258
ST	4/17-4/23	1997	LGR to MCN	0.902	CH1H	5/6-5/12	2002	LGR to MCN	0.638	CH1W	4/22-4/28	2002	LGR to MCN	0.730
ST	4/24-4/30	1997	LGR to MCN	0.611	CH1H	5/13-5/19	2002	LGR to MCN	0.732	CH1W	4/29-5/5	2002	LGR to MCN	0.657
ST	5/1-5/7	1997	LGR to MCN	0.804	CH1H	5/20-5/26	2002	LGR to MCN	0.755	CH1W	5/6-5/12	2002	LGR to MCN	0.660
					CH1H	4/15-4/21	1995	LGR to MCN	0.725	CH1W	5/13-5/19	2002	LGR to MCN	0.640
					CH1H	4/22-4/28	1995	LGR to MCN	0.668	CH1W	5/20-5/26	2002	LGR to MCN	0.773
					CH1H	4/29-5/5	1995	LGR to MCN	0.779	CH1W	4/15-4/21	1995	LGR to MCN	0.825
					CH1H	4/15-4/21	1996	LGR to MCN	0.586	CH1W	4/22-4/28	1995	LGR to MCN	0.669
					CH1H	4/22-4/28	1996	LGR to MCN	0.683	CH1W	4/29-5/5	1995	LGR to MCN	0.795
					CH1H	4/29-5/5	1996	LGR to MCN	0.652	CH1W	5/6-5/12	1995	LGR to MCN	0.759
					CH1H	5/6-5/12	1996	LGR to MCN	0.689	CH1W	4/15-4/21	1996	LGR to MCN	0.736
					CH1H	5/13-5/19	1996	LGR to MCN	0.779	CH1W	4/22-4/28	1996	LGR to MCN	0.480
					CH1H	4/29-5/5	1997	LGR to MCN	0.444	CH1W	4/29-5/5	1996	LGR to MCN	0.556