EAST COLUMBIA BASIN IRRIGATION DISTRICT

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Federal Caucus Comment Record
c/o BPA-PL
707 West Main Street, Suite 500
Spokane, WA 99201

RE: All-H Paper "Conservation of Columbia Basin Fish – Building a Conceptual Recovery Plan"

The East Columbia Basin Irrigation District is one of three irrigation districts operating the Bureau of Reclamation's Columbia Basin Project. The East District operates canals serving the Moses Lake, Warden and Othello areas providing irrigation water to over 2400 farms, individuals and other businesses with a total irrigated service area of 152,000 acres. The source of this water is the Columbia River at Grand Coulee Dam.

Numerous elements of the habitat and hydropower sections of the All-H Paper touch on factors pertinent to the East District. The element most affecting the East District is flow augmentation. These comments will therefore focus on flow augmentation plus address the breaching of Snake River dams.

Present flow augmentation targets, based largely on the 1995 Biological Opinion, call for up to 16 million acre feet per year of flow augmentation. Most of that water comes from the mainstem of the Columbia but the Snake River portion is also very significant due to the smaller size of that river.

These flow targets exceed the levels that can be successfully shaped by the existing U.S. storage system at the times they are called for. There is mounting evidence that these high levels of flows are not producing the outmigration survival benefits they're intended to produce.

In spite of this the Options and Alternatives presented in the All-H Paper offer choices only for continuing flow augmentation at present levels or for increased levels of flow augmentation. ***The final All-H Paper should include an option to reduce mainstem Columbia flow augmentation to no more than 4 million acre feet per year including a shift in timing to late summer and fall. That option should also become the preferred alternative.***

The discussion of the present flow augmentation strategy on pages 6-8 of the Hydropower Appendix includes the following statement:

> "Juvenile spring fish survival (estimated from the upper dam on the Snake River to Bonneville Dam) has increased since the 1995 FCRPS Biological Opinion (BO) measures were implemented. However, the benefit conferred by flow cannot be isolated form the effects of other management activities. While no direct flow-survival relationship has been detected within the reaches studied, higher flows might improve conditions in the estuary and survival of migrants in the estuary and plume. In addition, higher flows and reduced exposure to stressors during migration through reservoirs might improve fish condition upon arrival in the estuary."

Should this 16 maf annual flow augmentation target continue, or be increased, based on "mights"?

Enclosed for your reference is a complete copy of a February 1998 report entitled "The Columbia – Snake River Flow Targets/Augmentation Program". The report was prepared by a study team of reputable biologists and economists. The report generates no additional science but analyzes already existing Federal Caucus data to conclude present flow augmentation targets are excessive and ineffectual. Figure 2, preceding page 13 of that report presents data indicating present flow targets are hydrologically unrealistic. Figure 10 following page 20 presents NMFS research confirming there is no outmigration survival benefit provided by the present flow targets. The years presented are 1994 (a dry year), 1995 (an average year) and 1996 (a wet year). Survival is measured across a range of flows for each year. If more water equaled more survival, a mean or median line drawn through the data points would slope upwards from left to right. The slope is flat, confirming the lack of a flow-survival relationship. This figure does point out that survival is better in wetter years than in drier years but shaping mainstem flows to mimic wetter years does not result in wetter year survival conditions for average or dry years. This report concludes and recommends that mainstem Columbia flow augmentation targets should not be higher than 4 maf and that Snake River targets should not be higher than the current 427,000 acre feet target. The report also suggests that these levels of flow augmentation may provide better benefits if used in late summer or fall.

The present levels of flow augmentation are causing problems and costs for the East District's service area. These flow targets have caused the Bureau of Reclamation to place an administrative moratorium on the use of 85,000 acre feet of previously authorized Columbia Basin Project water which has eliminated the option for the use of additional surface water for agricultural, municipal or industrial purposes in the District's service area. This same area is also experiencing a shortage of groundwater, the current source for most industrial and municipal uses and a significant portion of agricultural use. The present flow augmentation targets are constraining most opportunities for agricultural, industrial and municipal growth in this area. Such a constraint is not appropriate in view of the lack of an overwhelmingly apparent flow-survival relationship.

Again, the East District strongly urges the Federal Caucus that the final All-H Paper should include an option to reduce mainstem Columbia flow augmentation to no more than 4 million acre feet per year including a shift in timing to late summer and fall. That option should also become the preferred alternative.

The East District recommends that the options and alternatives calling for the breaching of the Snake River dams be dropped from further consideration. Breaching those dams would result in higher energy costs for East District farmers and could result in increased transportation costs for their agricultural supplies and crops.

The costs to eastern Washington as a whole though cause the East District to oppose breaching those dams for reasons beyond just the direct local impacts. The loss of 37,000 highly productive irrigated acres, the loss of 5% of the region's hydropower capacity and the loss of navigation to much of the inland northwest are extremely excessive in view of the statistical, highly theoretical and the long term (50 year) nature of any improvement in salmon recovery.

In addition to the excessive costs and uncertain benefits the dam breaching alternatives should be dropped because the divisiveness of these proposals detract from the region's ability to focus on achievable salmon recovery measures.

Dick Erickson

Richard L. Erickson
Secretary-Manager

RLE:jd

Enclosure

The Columbia-Snake River Flow Targets/Augmentation Program

A White Paper Review With Recommendations For Decision Makers

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Eastern Oregon Irrigators Association
Idaho Water Users Association
Northwest Irrigation Utilities
Washington State Water Resources Association

February 1998

The Columbia-Snake River Flow Targets/Augmentation Program

A White Paper Review With Recommendations for Decision Makers

Executive Summary

1.0. A White Paper Review.

- This white paper examines the Columbia-Snake River flow targets/augmentation program, and its implications for important water management actions within the Pacific Northwest.

- Evaluations of hydrologic, biological, and economic data indicate that the existing NMFS water policy and flow targets/augmentation program needs to be reassessed and changed.

2.0. The Emerging NMFS Water Policy.

- Through its flow targets/augmentation program, the NMFS is developing a water policy within the Columbia River Basin drainage of "zero net loss."

- The NMFS policy calls for no further water withdrawals from the Columbia-Snake River mainstems, tributaries to the main river system, and related groundwater sources; and it directs federal and state agencies to review the impacts of existing water withdrawals on its flow targets program.

- The NMFS policy challenges state authority to grant *future* water rights for municipal, industrial, or irrigation uses. By calling for a "review" of existing water withdrawals, the policy postures toward challenging *existing* state-granted water rights.

- Under the NMFS water policy, future (new) water allocations from within the Columbia River Basin drainage are to be used solely for instream fish flows.

3.0. *NMFS Water Policy Justification, Flow Targets and Augmentation.*

- **The NMFS flow targets/augmentation program follows on the development of the fish flow augmentation program devised by the Northwest Power Planning Council during the 1983-1994 period.**

- **An initial "water budget" requested by the Council amounted to about 3.75 million acre-feet (MAF), but has grown with the preparation of each new Council Fish and Wildlife Program; the NMFS 1995 BIOP now calls for as much as 13-16 MAF for dedicated flow enhancement.**

- **The highest level of flow augmentation produced about 10.6 MAF, occurred during the 1994 drought water-year; about 0.8 MAF was released from the Brownlee Project and above, about 1.9 MAF was released from Dworshak Reservoir, with the remaining water being released from upstream Columbia system reservoirs.**

- **In the 1994 low water-year, about 0.5 MAF was provided from the Brownlee Project and above during the *summer period;* and about 1.0 MAF came from Dworshak Reservoir.**

- **Within the NMFS flow augmentation program, the "flow targets" serve as operational guides for in-season water management, determining when to use available water for flow augmentation.**

4.0. *River System Hydro Regulation Studies and the Flow Targets.*

- **The USBR hydro regulation studies demonstrate that the NMFS flow targets cannot be met in all months (affecting seasonal averages), during low or average water-years, because they require more water than the hydrologic system can provide--with or without the effects of net irrigation depletions from the Snake-Columbia River Basin.**

- **During low and average water years for the summer flow augmentation period, the NMFS flow targets exceed water levels that would be available under natural river system conditions, with or without the effects of net irrigation withdrawals.**

- **During a drought year, net irrigation depletions represent large volumes of water for the months of July and August. But the net irrigation depletions *are not* the primary reason why the NMFS flow targets cannot be met; the problem rests with the flow targets themselves--the targets are well beyond the Basin's hydrologic capability.**

- **The annual natural run-off within the Basin is highly variable; the yearly net variation in flows for a 50-year water record substantially exceeds or overshadows net irrigation withdrawals, measured at McNary Dam.**

- **Given the hydrological capabilities of the river system, the NMFS summer flow targets of 200 kcfs (Columbia River) and 50-55 kcfs (Snake River) cannot be met during low water conditions, even with the complete elimination of all irrigation depletions. Basin hydrology limits summer flows to well below the NMFS target level.**

5.0. Biological Basis for Flow Targets/Augmentation.

- **Largely based on historical data depicting year-to-year flow and juvenile fish survival relationships, it has been assumed that flow augmentation could be used to increase flows during low water-year conditions, in an attempt to produce survival rates observed in high water years.**

- **Data collected for spring migrants since 1992 (1993-1997 data sets) indicate that the *within year relationship* between different flow regimes and fish survival through the hydro system corridor is weak. This means that attempts to use flow augmentation to improve spring migrant survival will provide very little or limited benefits.**

- **The year-to-year correlations between flow and survival--reflecting vastly different flow levels between years--support the hypothesis that ecological factors associated with drought conditions are principally responsible for fish survival.**

- **The year-to-year observations move toward the conclusion that better water-year conditions, in general, provide for greater fish survival than drought conditions.**

- **The flow-survival data collected on fall chinook is more variable and less well defined than for spring migrants. Given the existing data, flow is one variable correlated with survival, in some cases, but it has less predictive capability than other variables (such as migration timing and fish size through the upper river system). Also, some relationships, such as observed numbers of marked fish detections between years, are inconsistent among years (although dam-smolt collection operations may have been different among years, making detection comparisons difficult).**

- **Snake River summer flow augmentation is being used to enhance the transportation collection efficiency for fall chinook. But flow augmentation is not the only method available to increase collection efficiency. Structural changes at the projects, such as the current installation of double-length screens and/or surface collector technology, may be able to achieve the same goal and provide benefits for spring migrants, as well.**

- **During the summer period, Lower Snake River water temperatures can and do exceed levels that negatively affect migrating juveniles and adults. The use of some flow augmentation (from Dworshak Reservoir) to improve migration conditions should continue to be reviewed; and the biological benefits and costs should be better understood.**

- **Because of the uncertainty surrounding the effects of flow augmentation on overall fall chinook survival, it is difficult to support either an increase or decrease in the amount of storage currently being used for flow augmentation (1.5 MAF) to protect summer migrants, for a drought year like 1994.** ***But resource managers should be cautious in making conclusions about the benefits gained from this flow regime, because shaping flows within a drought year will not produce the benefits fish receive under a high water-year.***

6.0. Economic Trade-offs of Flow Augmentation.

- **Using sport and commercial fisheries values and fish abundance estimates for the 1987-1991 period (relatively high catch period), the annual direct net value of the upriver (above Bonneville Dam) salmon and steelhead contributions to ocean and inriver fisheries is about $25 million. It is acknowledged (and has been measured) that salmon do retain an existence value that exceeds their direct commercial or use value.**

- **Applying some favorable economic and biological assumptions to the benefits of flow augmentation, the annual direct net economic value of the upriver contributions to commercial and sport fisheries is about $2.25 million per one million acre-feet of water used for flow augmentation--representing a** ***future value*** **estimate over 10 life-cycles (1995S).**

- **Flow augmentation causes economic impacts to hydroelectric power operations and could create future economic impacts to irrigated agriculture. For one million acre-feet of flow augmentation, the cost to hydro power operations is estimated to be about $8-10 million (BPA system costs). For Basin irrigated agriculture, the direct net value of one million acre-feet of water is estimated to be about $40-70 million; one estimate for the Upper Snake River Basin suggests about $49 million per one million acre-feet of water provided for flow augmentation (includes hydropower benefits).**

- **Both economic trade-off analyses and cost-effectiveness analyses strongly support the position that** ***any flow augmentation program should be optimized to maximize fish benefits for the costs incurred to other water resource sectors.***

7.0 Recommendations for Decision Makers.

7.1 The NMFS Water Policy.

- **Decision makers should be fully aware of the emerging NMFS water policy and its implications for state water management.**

- **The NMFS water policy--bred from the flow targets/augmentation program--directs that all future (new) water allocations from the Columbia River Basin drainage area should be used solely for fish protection.**

- **The NMFS water policy is a single-purpose, resource use strategy that subjugates new water withdrawals for other types of social and economic activity or growth within the Basin. The policy is one-dimensional in nature, and it directly or indirectly challenges state legislative authority to govern water management.**

- **The NMFS senior management, working with state water resource managers, should reevaluate and change this policy to better reach the needs of biological and economic optimization.**

7.2 Review and Restructure the Flow Targets/Augmentation Program.

- **The existing data and analyses strongly suggest that the correlation between incremental flow increases and juvenile spring migrant survival is relatively inelastic, or that the survival benefits are small.**

- **The existing data suggest that estimated river system flow benefits--though limited--favor the fall chinook. But there is considerable uncertainty surrounding the effects of flow augmentation on overall survival. This includes factors related to direct inriver survival benefits, migration timing, inter-year detection differences, and the use of flow to increase transport collection efficiency.**

- **It is more clear that flow augmentation is a measure providing marginal survival benefits and has limited effectiveness as a recovery measure.**

- **In contrast to some of the biological impacts, the economic trade-offs of flow augmentation are more predictable. Flow augmentation does increase costs to the hydropower system, and it could create significant costs to the irrigation (and other) sectors.**

Given the data and analyses presented within this paper, the following review and changes are suggested for the flow augmentation program.

Optimization Review:

- **The flow targets/augmentation program would benefit from a detailed technical review that focuses on the *optimization of water use; its source, delivery timing, temperature effects, and a clear identification of the biological or physical attributes to be targeted. This also includes applying principles of cost-effectiveness, to compare the biological benefits gained for the costs incurred.***

- **The existing flow augmentation program does not optimize water use for either survival benefits (benefit per unit of flow) or economic costs (benefit per dollar cost) to the river system.**

A flow augmentation program that better reflects a step toward optimization of the existing water resources is summarized below.

Low Water Conditions, Snake River System:

- **For the summer period (July-August), provide for experimentation a *maximum of 0.5 MAF* from the Brownlee Project and above consistent with state law and obtained from willing sellers or lessors; and a *maximum of 1.0 MAF* from Dworshak to be used for fall chinook migration and/or adult temperature control. Data to review this experimental regime would be collected through 1999, consistent with the existing NMFS decision-making process.**

Low Water Conditions, Columbia River System:

- **Direct flow augmentation releases solely for the fall chinook migration. For the summer period (July-August), provide for experimentation *0-4.0 MAF, as recommended jointly by federal and state fish and water resources managers.***

Average Water Conditions, Snake River System:

- **For the summer period (July-August), provide for experimentation a *maximum of 0.5 MAF* from the Brownlee Project and above consistent with state law and obtained from willing sellers or lessors; and a *maximum of 1.0 MAF* from Dworshak to be used for fall chinook migration and/or adult temperature control. Data to review this experimental regime would be collected through 1999, consistent with the existing NMFS decision-making process.**

Average Water Conditions for the Columbia River System:

- **Direct flow augmentation releases solely for the fall chinook migration. For the summer period (July-August), provide for experimentation *0-4.0 MAF, as recommended jointly by federal and state fish and water resources managers.***

The Restructured Flow Augmentation Program:

- **The above restructuring of the flow augmentation program would have the greatest deviation from the existing program by eliminating the current spring flow augmentation regime.**

➢ During the summer period, the restructured program would limit flow augmentation in the Snake River Basin to a level not to exceed operations that occurred in the summer of 1994 (drought conditions).

➢ Without a better technical justification for the summer flow augmentation, *resource managers should refrain from taking actions to increase this flow augmentation regime.*

➢ It is equally important that adequate data be obtained and appropriate analyses undertaken in order to optimize and provide a supportable technical justification for the current summer flow augmentation program.

7.3. Future Considerations for Flow Augmentation Management and Evaluations.

It appears that using flow augmentation within a single season is not an effective recovery tool for spring chinook migration within the mainstem. What is less clear is whether mainstem flow augmentation is an effective management tool for fall chinook within the mainstem; or how flow augmentation can or should be used to improve survival within tributaries. Given these latter uncertainties and issues beyond the scope of this paper, the following recommendations are provided.

➢ In the case of Snake River fall chinook, the existing data on collection efficiency (FGE) and its relationship to flow is difficult to interpret. The need exists to establish data that verifies the interaction between flow augmentation and structural improvements to FGE, and cost-effectiveness analysis should be used to assess risk and economic trade-offs.

➢ Resource managers may want to give consideration to changing the focus of flow augmentation efforts away from mainstem actions to improving habitat conditions within some tributaries. The NMFS Recovery Plan should better recognize this factor by taking into account criteria for demonstrating real biological benefits, prioritizing major production tributaries, and measuring the cost-effectiveness and benefit-cost of tributary flow enhancement actions.

➢ *Direct actions to implement flow augmentation measures should defer to the existing authority of state water rights and should allow for "locally developed" solutions within specific watersheds.* This could include an implementation of efficiency measures, water transfers, and the development of new water storage projects to benefit both fish and economic interests.

The Columbia-Snake River Flow Targets/Augmentation Program

A White Paper Review With Recommendations For Decision Makers

1.0. A White Paper Review.

Intricate technical features underlying the Columbia-Snake River flow augmentation program have likely overwhelmed an ability of many regional decision makers or resource managers to track, much less to understand or fully appreciate. The flow augmentation program, its implementation, and its impacts are complex.

Making this complex technical and policy system more coherent or understandable is difficult, but one approach to doing so is through the preparation of a white paper. A white paper must deal relatively succinctly with several technical, management, and policy issues.

A white paper review should serve three important purposes for decision makers and resource managers. First, it should provide basic information about policies and program actions, clarifying where possible the key implications surrounding their implementation. Second, it should highlight the primary technical features that are an essential component of program actions, addressing their strengths or weaknesses. And third, a white paper should present clear recommendations for improving program actions; for example, by suggesting how resources used for action implementation can be made more effective or *optimized*.

This white paper covers many of the major hydrological, biological, and economic factors relevant to the flow targets/augmentation program.

2.0. The Emerging NMFS Water Policy.

Natural resources policies are usually the foundation for new programs or management actions--programs or actions are derived from policy formulation and establishing objectives. But in the case of the NMFS flow targets/augmentation program, it is the program that is driving the development of the "NMFS water policy," and the program is attempting to shape water policies for the Pacific Northwest states.

The "NMFS water policy" for the Columbia-Snake River Basin drainage area can be viewed from within three sources: 1) the NMFS (1995) Proposed Recovery Plan for Snake River Salmon; 2) a revised draft NMFS (1997a) Recovery Plan still in review and development; and 3) a NMFS (1997b) biological opinion (BIOP) issued as part of a recent consultation with the Corps of Engineers (Corps) concerning building a new irrigation pumping station along the Lower Columbia River.

The first two sources (NMFS 1995, 1997a) contain similar directives to federal and state agencies concerning the issuance of new water rights or permits:

> **In recent years, the states have placed moratoria on new water withdrawal permits from the Snake and Columbia Rivers. These moratoria should continue and the states should expand them to the tributaries and to those groundwater resources that are part of the Snake and Columbia River system. In addition, the BOR should not promote additional irrigation in the Columbia River Basin. The Corps and state water resource agencies should not allow new water withdrawal permits that result in a net loss of flow and should review existing water withdrawal permits that reduce [the] system's ability to meet flow objectives (NMFS 1997a, pg. 70).**

NMFS further states that upstream water diversions from the Snake and Columbia River system are a major reason why instream flow objectives (targets) for fish cannot be met and cites the USBR (1997) report as documentation.

The NMFS water policy also seeks to extend federal regulatory control to cases where existing state water permits are being perfected. This is illustrated by the agency's biological opinion (NMFS 1997b) on the Inland Land Project, regarding a Corps permit for a new Columbia River pump station. Here the pump station permit applicant holds a state-granted water permit that is being perfected--the construction phase is commencing to put the water resource allowed under the state permit to beneficial use. In this circumstance, NMFS brings forth its "zero net impact" goal, calling for no further depletions from the river system and concluding that "issuance by the U.S. Army Corps of Engineers (Corps) of a permit to construct a pumping facility in the Columbia River would jeopardize the continued existence of listed Snake River salmon...and result in destruction or adverse modification of their critical habitat" (NMFS 1997b, pg. i-ii, 14). The NMFS

based its determination on the collective or cumulative effects of water withdrawals within the Columbia River Basin.

Within the Inland Land Project BIOP (NMFS 1997b), NMFS also instructed the Corps to pursue Section 7 (Endangered Species Act) conservation measures that included a review of all existing pump station permits, and to decide whether such permits should be candidates for further consultations with NMFS prior to spring 1999. And NMFS indicated that if the states of Oregon, Washington, and Idaho adopted comprehensive programs to address instream flow restrictions in the Columbia River Basin, then that action may alleviate NMFS' concerns about the cumulative effects of water withdrawals.

NMFS senior staff maintain that the "NMFS water policy" does not deny or restrict the issuance of new water permits (NMFS 1997c). From their perspective, any new development or water use could proceed forward by providing replacement flows for the water withdrawn, by engaging in conservation measures, or by accomplishing water right transfers through open water markets (NMFS 1997b, 1997c).

But essentially, the NMFS water policy seeks to discourage or eliminate any new (additional) water withdrawals for municipal, industrial, or irrigation development within the Columbia River Basin; and it appears to challenge directly or indirectly the legislative authority of states to regulate, manage, and allocate water rights. The NMFS water policy is pervasive and absolute in nature, and it seeks to direct all future water allocations within the Basin to a single priority--instream flows for migrating fish populations.

Summary Observations and Comments:

- Through its flow targets and augmentation program, the NMFS is developing a water policy within the Columbia River Basin drainage of "zero net loss."
- The NMFS policy calls for no further water withdrawals from the Snake-Columbia River mainstems, tributaries to the main river system, and related groundwater sources; and it directs federal and state agencies to review the impacts of existing water withdrawals on its flow targets program.
- If adopted, the NMFS policy would effectively abrogate or challenge state authority to grant future water rights for municipal, industrial, or irrigation uses. By calling for a "review" of existing water withdrawals, the policy postures toward challenging existing state-granted water rights.
- Under the NMFS water policy, future (new) water allocations from within the Columbia River Basin drainage are to be used solely for in-stream fish flows.

3.0. NMFS Water Policy Justification, Flow Targets/Augmentation Program.

Much of the justification for the NMFS water policy may be attributed to the NMFS "flow targets" developed within the its 1995 Biological Opinion (NMFS 1995). The 1995 BIOP calls for dedicated amounts of water storage and releases during the spring and summer migration periods, to enhance existing flow levels through the Snake-Columbia River mainstem system. The NMFS flow augmentation program is principally aimed at attempting to improve survival levels for Snake River Endangered Species Act (ESA) listed salmon.

3.1. Development of the Flow Targets/Augmentation Program.

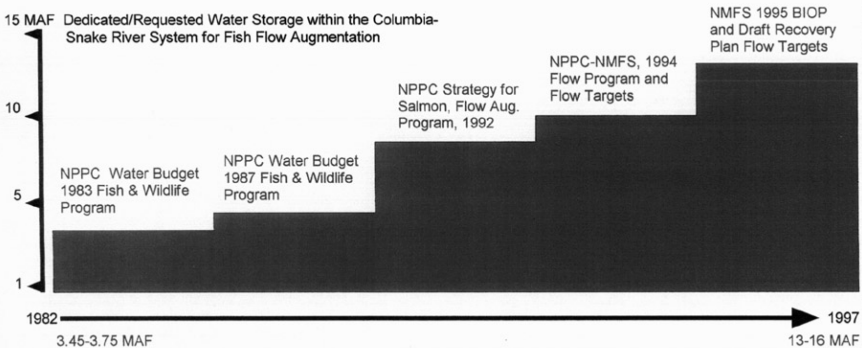
The origin of the NMFS flow targets/augmentation measures can be readily traced to the flow enhancement program produced by the Northwest Power Planning Council (Council) during the 1983-1994 period. The NMFS flow target/augmentation measures are largely an extension of the Council's flow enhancement program, as developed and applied through several Columbia Basin Fish and Wildlife Programs. The Council's authority to recommend flow regimes or adopt flow enhancement measures is derived from the Northwest Power Act.

In 1983, the Council proposed a "water budget" for flow enhancement, to be used during the spring migration period (NPPC 1983; Corps 1994). Water volumes from storage reservoirs were made available specifically to "enhance" existing water regimes, with the water being released during the spring migration period. At this time, much of the emphasis behind the flow enhancement program was to hasten juvenile migrant travel time through the reservoirs and hydroelectric power corridor.

Since 1983, the water volumes either requested or made available for flow enhancement programs have increased substantially, as depicted by the "stair-step" rate of growth presented in Figure 1. The volume of water requested for flow enhancement or augmentation has increased from about 3.75 MAF to about 13-16 MAF. The flow enhancement requests or dedications have increased with the preparation of each successive Council Fish and Wildlife Program and, in more recent years, with the development of the NMFS biological opinions for hydroelectric power system operations (1994 and 1995). Significant increases in dedicated water volumes have resulted from the ESA listings of Snake River salmon.

The present flow augmentation program is part of the NMFS 1995 Biological Opinion (1995) and Proposed Recovery Plan for Snake River Salmon (NMFS 1995). According to NMFS, this program should be capable of providing as much as 13-16 MAF of water for fish flows, to be released during the spring (May 10--June 20) and summer (June 21-August 31) migration seasons.

Figure 1. Milestones of the Flow Augmentation/Targets Program Columbia-Snake River System



The NMFS flow enhancement program adopts flow objectives or "targets" to direct the need for flow augmentation water releases. The NMFS views the flow targets as key to its flow program operating criteria:

> These flow objectives serve two important functions. First they represent the average flows that NMFS believes provide suitable in-river conditions for migrating fish and, as such, they provide a useful yardstick for measuring the acceptability of particular operating strategy...Second they serve to guide the in-season management process which helps determine when to use available water for flow augmentation (NMFS 1995, V-2-19).

The NMFS states that the flow objectives are not "intended as hard constraints on river operations, but as a guide for determining how to allocate scarce water."

The NMFS flow targets are measured at Lower Granite Dam for the Snake River, and at the McNary Dam for the Lower Columbia River system (total river basin system water flow or run-off). For the spring period, the flow targets are 85-100 kcfs and 220-260 kcfs, at Lower Granite Dam and McNary Dam, respectively; for the summer period, the flow targets are 50-55 kcfs and 200 kcfs, respectively at each project. The targets are supposed to reflect water run-off forecasts and the actual water available in the system.

Estimates of the actual water volume releases under the Council and NMFS flow augmentation programs are presented in Table 1 and Figure 2. For example, during a low water-year condition like 1994, about 10.6 MAF of water was provided for fish flows. Most of this water was released during the spring period, about 7.8 MAF. About 1.5 MAF came from the Snake River system during the summer period, with about 0.5 MAF from the Brownlee Project or above.

Summary Observation and Comments:

- The NMFS flow targets/augmentation program follows on the development of the fish flow augmentation program devised by the Northwest Power Planning Council during the 1983-1994 period.

- An initial "water budget" requested by the Council amounted to about 3.75 MAF, but has grown with the preparation of each new Council Fish and Wildlife Program; the NMFS 1995 BIOP now calls for as much as 13-16 MAF for dedicated flow enhancement.

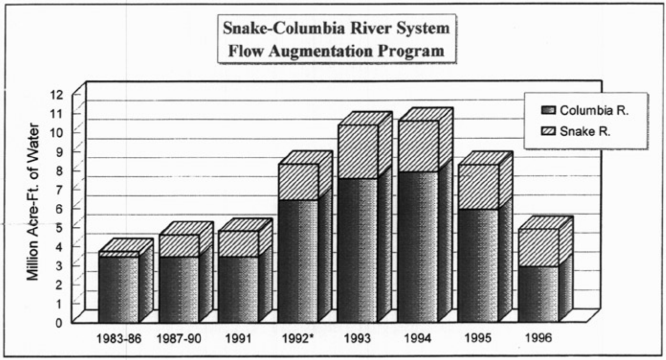
- The highest level of flow augmentation produced, about 10.6 MAF, occurred during the 1994 drought water-year; about 0.8 MAF was released from the Brownlee Project and above, about 1.9 MAF was released from Dworshak Reservoir, with the remaining water being released from upriver Columbia system reservoirs.

Table 1. Columbia-Snake River Flow Augmentation Program 1994-1996

Flow Augmentation	Estimated 1994	Estimated 1995	Estimated 1996
Spring Period:			
Snake River (MAF)			
Dworshak	0.87	0.83	0.27
Brownlee and Above	0.33	0.35	0.41
Total Snake R.	*1.20*	*1.18*	*0.68*
Columbia R. (MAF)			
Arrow (Canada)	------	(1.47)	(0.14)
Libby/Hungry H.	------	1.60	0.36
Grand Coulee	------	3.70	(0.07)
Total Columbia R.	*6.60*	*3.83*	*0.15*
Total Flow Aug.	*7.80*	*5.01*	*0.83*
Summer Period:			
Snake River (MAF)			
Dworshak	1.02	0.92	0.95
Brownlee and Above	0.46	0.26	0.35
Total Snake R.	*1.47*	*1.18*	*1.30*
Columbia R. (MAF)			
Arrow (Canada)	0.20	1.60	1.33
Libby/Hungry H.	0.00	(0.43)	0.35
Grand Coulee	1.13	0.94	1.09
Total Columbia R.	*1.33*	*2.11*	*2.77*
Total Flow Aug.	*2.80*	*3.29*	*4.07*
Spr-Sum Total Flow Aug.	*10.60*	*8.30*	*4.90*

Data Source: Bonneville Power Administration, Dittmer Control Center, Portland, Oregon August-December 1997. Estimates are based on net with/without fish operations impacts to the hydro system.

Figure 2. Columbia-Snake River Flow Augmentation Program 1983-1996



	Usable 1983-86	Usable 1987-90	Est. 1991	Est. 1992*	Est. 1993	Est. 1994	***Est. 1995***	***Est. 1996***
Snake River (MAF)								
Dworshak	------	------	------	------	**2.298**	**1.89**	***1.75***	***1.21***
Brownlee & Above	------	------	------	------	**0.525**	**0.79**	***0.61***	***0.76***
Total Snake R.	**0.3**	**1.18**	**1.36**	**1.9**	**2.823**	**2.68**	***2.36***	***1.97***
Columbia R. (MAF)								
Arrow (Canada)	------	------	------	------	------	------	***0.13***	***1.19***
Libby/Hungry H.	------	------	------	------	------	------	***1.17***	***0.71***
Grand Coulee	------	------	------	------	------	------	***4.64***	***1.02***
Total Columbia R.	**3.45**	**3.45**	**3.45**	**6.45**	**7.58**	**7.93**	***5.94***	***2.92***
Total Flow Aug.	**3.75**	**4.63**	**4.81**	**8.35***	**10.40**	**10.61**	***8.30***	***4.89***

Data Source: Bonneville Power Administration, Dittmer Control Center, Portland, Oregon August 1997; USACE, 1994; and NPPC, Strategy for Salmon, 1992. Estimates are based on net with/without fish operations impacts to the hydro system.

* A 1992 estimate from BPA is higher than the values indicated below. The BPA estimate is about 10.79 MAF, with 8.68 MAF from the Columbia system and 2.11 MAF from the Snake.

- **In the 1994 low water year, about 0.5 MAF was provided from the Brownlee Project and above during the summer period; and about 1.0 MAF came from Dworshak Reservoir.**

- **Within the NMFS flow augmentation program, the "flow targets" serve as operational guides for in-season water management, determining when to use available water for flow augmentation.**

4.0. River System Hydro Regulation Studies and the Flow Targets.

The relationship between Columbia River Basin hydrologic (water run-off) conditions and the NMFS flow targets is best described by the hydro regulation and water depletion studies being conducted by the U. S. Bureau of Reclamation (USBR). These studies (USBR 1997) provide estimates of water flows at specific points along the river system, based on 50-year (or 60-year) water records. The studies further specify the average monthly flow levels given four different hydro (flow) regimes: 1) a natural flow condition; 2) natural flows with irrigation depletions; 3) current flow conditions under the NMFS 1995 BIOP regulation, including irrigation depletions; and 4) current flows with the effects of irrigation depletions removed.

Under the natural flow regime, the effects of all reservoir storage operations and water depletions are removed; natural flows represent a Columbia River system that existed prior to the mid-1800s and before irrigation and hydroelectric power dam were constructed. Under the natural flows with the effects of reservoir storage removed regime, water withdrawals would be met only by natural flow water conditions; irrigation depletions would exist but without water storage reservoirs.

Representing the current flow regime, flow and water depletion conditions would depict the existing 1995 BIOP hydro regulation, with existing water depletions and fish flow enhancement. Under the current flows and with the effects of irrigation depletions removed, the existing reservoir system is assumed to be in place, but no water is being diverted for irrigation, and the reservoirs are operated to their limits to meet the NMFS 1995 BIOP flow targets.

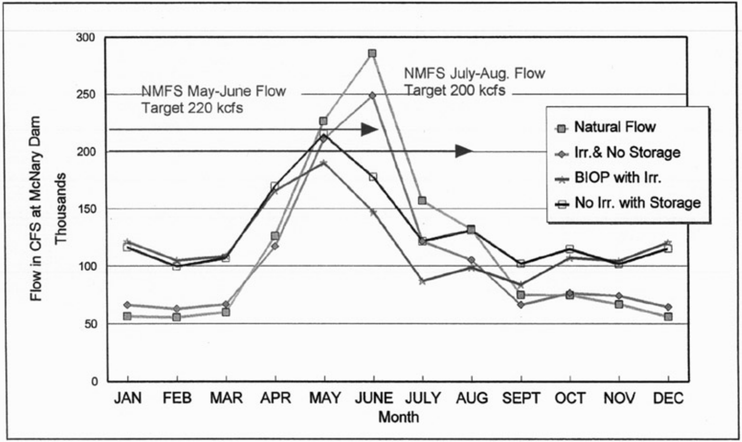
4.1. Flow Regime Hydrology and Flow Target Implications.

Analyses of the USBR (1997) hydro regulation data highlight several operational features inherent to the four major flow regimes, and illustrate an ability of the river system to meet the NMFS flow targets during key water-years and under different water depletion conditions. The analyses also offer a better understanding of how the different net variations in water-year flows compare to net water depletions.

Figure 3 examines the four major flow regimes under a low water-year condition (1976-77), with average monthly flows (across the 50-year water record) measured at the McNary Dam. The regulation data display the "shape" of the different flow regimes and of the peak flow months, May and June. The data also depict the impact of the net irrigation depletion levels, the difference between the BIOP with irrigation versus the no irrigation with storage flow levels.

With low water-year conditions, the Columbia River Basin net system irrigation depletion amounts to about 29% of the total system run-off during the peak irrigation month of July; and about 25% during the month of June.

Figure 3. Columbia River Basin Water Flows
Estimated Low Water Condition (1976-77), Average Monthly Flows at McNary Dam



Data Source: USBR, Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

Figure 3 also displays the river system's ability to meet the NMFS flow targets. For example, during the spring period, the average monthly flows cannot reach the flow target level of 220 kcfs, either with or without the effects of net irrigation depletions. During the summer period, the same situation holds true, with both the BIOP and no irrigation flow regimes considerably less than the flow target of 200 kcfs. It should be emphasized that neither the natural flow nor dedicated reservoir storage for fish flow can meet the 200 kcfs target.

The river flow regimes for average water conditions, measured at McNary Dam, are presented in Figure 4. In July and August, net irrigation depletions account for about 16% and 20% of the total system run-off (see Figure 5). During an average annual run-off period, the net irrigation depletion (about 13 million acre-feet) amounts to about 6-7% of the total flow measured at the mouth of the Columbia River, approximately 200 million acre-feet (Corps 1995).

Under average water conditions, the spring flow target of 260 kcfs is met under all four water regimes. But the summer flow target for August of 200 kcfs cannot be met, either with or without net irrigation depletions. And the natural flow regime falls below the summer flow target, in August, as well.

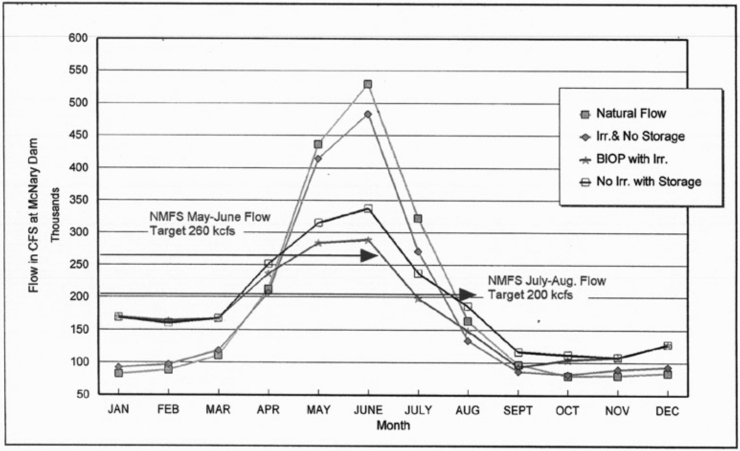
Similar types of hydro regulation analyses can be made for flows measured at the Lower Granite Dam, using the USBR hydro regulations. In Figure 6, a low water-year (1976-1977) condition is examined, in relation to the four major flow regimes. Under this water condition, net irrigation depletions amount to about 40% and 50% of the total run-off during the months of July and August.

From Figure 6, it is apparent that neither the spring (85 kcfs) nor summer (50 kcfs) flow targets can be met, with or without system net irrigation depletions. Even under the natural flow regime, the flow targets are substantially beyond the hydrologic capabilities of the river system to meet. There are no river conditions that can come close to the flow targets under low water conditions.

In Figure 7, flow regimes at Lower Granite Dam are presented under average water conditions (monthly average for the 50-year water record). Net irrigation depletions amount to about 27% and 39% for the peak water use months of July and August (see Figure 8).

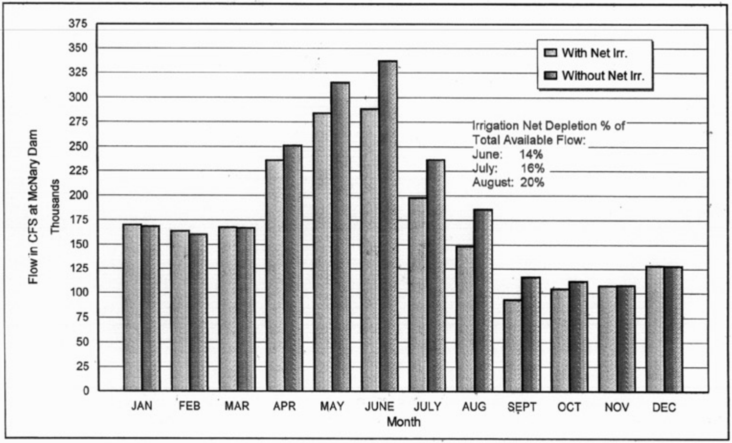
Figure 7 also displays the effects of net irrigation depletions on the ability of the river system to reach flow target levels. During the spring period, the flow target (100 kcfs) can be met by the four major flow regimes. However during the summer period, in August, the monthly average flow for the four water regimes drops below the flow target (55 kcfs) level. *In August, the net irrigation depletion flow is equal to the water level that would occur under a natural flow regime, about 31 kcfs at Lower Granite Dam.* Both the net irrigation depletion and natural flow regimes fail to achieve the flow targets.

Figure 4. Columbia River Basin Water Flows
Estimated Average Water Condition, Average Monthly Flows at McNary Dam



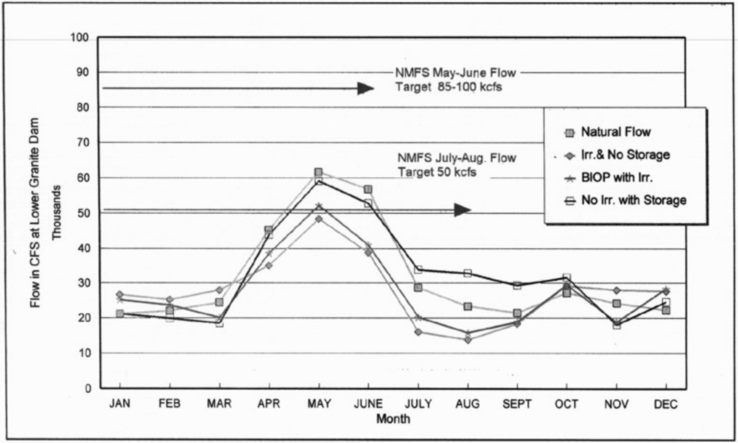
Data Source: USBR, Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

Figure 5. Columbia River Basin Water Flows
With/Without Net Irrigation Depletion, Average Monthly Flows at McNary Dam



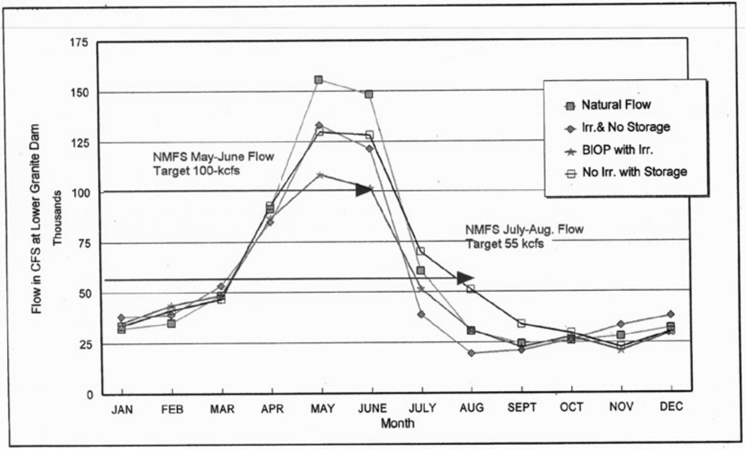
Data Source: USBR, Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

Figure 6. Columbia River Basin Water Flows
Estimated Low Water Condition (1976-77), Average Monthly Flows at L. Granite Dam



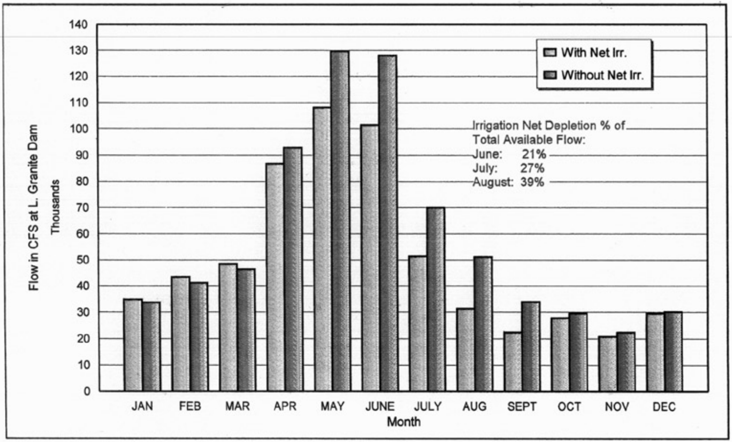
Data Source: USBR, Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

Figure 7. Columbia River Basin Water Flows
Estimated Average Water Condition, Average Monthly Flows at L. Granite Dam



Data Source: USBR, Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

Figure 8. Columbia River Basin Water Flows
With/Without Net Irrigation Depletion, Average Monthly Flows at L. Granite Dam



Data Source: USBR; Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

4.2. *River System Net Flow Variability.*

Another factor to consider in reviewing the effects of either flow augmentation or irrigation net depletions is year-to-year system variability, the dramatic changes that can occur in total volume water run-off. System control is very limited, with or without flow augmentation, and changes to net year-to-year flows typically overshadow the net irrigation depletion for the Columbia River Basin system.

Figure 9 displays the net differences in flow levels, as measured at the McNary Project, using the USBR (1997) hydro regulation for the 1995 BIOP operations (which includes net irrigation depletions). Net flow differences are described for the months of June, July, and August for a 50-year water record. The net flow levels depict between year flow differences. For example, if the flow in one year (for June) averaged 200 kcfs and in the next year increased to 250 kcfs, then the net flow difference would be 50 kcfs; or conversely, if the flow decreased from 250 kcfs to 200 kcfs, the net flow difference would be 50 kcfs.

In Figure 9, it is apparent that the yearly net variation in flows can exceed the net irrigation depletion by as much as a factor of 3.5 to 6 (250 to 500%), depending on the month selected. The 50-year water record indicates that the variation in net flows exceeds net irrigation depletions in a majority of years for the months of June and August. In July (similar net irrigation depletion level as in June), the net yearly variation in flows exceeds the net irrigation depletion in about one-third of the water record years.

This wide-ranging variability in net flow levels means that efforts will be insignificant to use either flow augmentation or marginal decreases to irrigation withdrawals to "recreate" or "simulate" high volume flow years within the Lower Columbia River system.

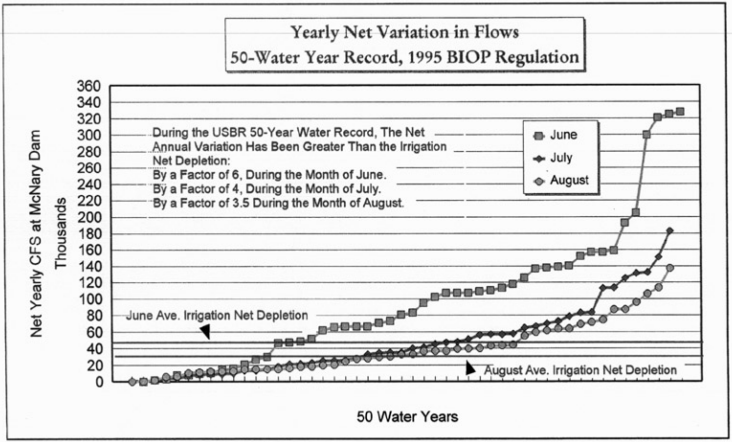
Summary Observations and Comments:

- The USBR hydro regulation studies demonstrate that the NMFS flow targets cannot be met in all months, during low or average water-years, because they require more water than the hydrologic system can provide, with or without the effects of net irrigation depletions.

- During low and average water years for the summer flow augmentation period, the NMFS flow targets exceed water levels that would be available under natural river system conditions, and with or without the effects of net irrigation withdrawals.

- The net irrigation depletions *are not* the primary reason why the NMFS flow targets cannot be met; the problem rests with the flow targets themselves--the targets are well beyond the Basin's hydrologic capabilities.

Figure 9. Columbia River Basin Water Flows
Net Irrigation Diversion Compared to Yearly Net Flow Changes



Data Source: USBR, Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

- **The annual natural run-off within the Basin is highly variable; the yearly net variation in flows for a 50-year water record substantially exceeds or overshadows net irrigation withdrawals, measured at McNary Dam.**

- **Attempts will be insignificant to use either flow augmentation or marginal decreases to irrigation withdrawals to "recreate" or "simulate" high volume flow years within the Lower Columbia River system.**

5.0. Biological Basis for Flow Targets/Augmentation.

5.1. History of the Flow-Survival Relationship.

A central element of the NMFS (1995) Salmon Recovery Plan is flow augmentation, in which spring and summer flows are increased by releases from storage reservoirs or, by implication, through the reduction of irrigation water withdrawals. The justification for these actions is based on the general relationship: *additional river flow = higher fish survival.* This principle, with origins predating any data, is based on the belief that increased river flows decrease fish travel times and thus decreases the exposure of juveniles to predation and other in-river hazards. In addition, in terms of the recent Normative River concept (ISG Review 1996), increased flows create a hydro system that more closely mimics the natural river prior to the development of the dams. While early evidence and analyses appeared to support a strong flow survival relationship, the recent studies do not.

Historically it has been observed that higher yearly average flows are correlated with higher fish survival, measured as either in-river survival of juveniles or as smolt-to-adult return rates. While it is not disputed that the relationship involves complex interactions of environmental and human factors, it also has been believed that some of the benefits of the observed year-to-year correlations can be obtained through manipulation of the hydro system flow *within a year.* Thus, there is a fundamental belief that by increasing the water flow in a dry year some of the benefits of a wet year can be created. This strategy is at the foundation of the flow targets of the 1995 NMFS Biological Opinion. By regulating hydro system flows and reducing system-wide irrigation withdrawals, fish managers attempt to put sufficient water through the hydro system during the smolt migration to avoid low flows and the high mortalities believed to occur with them.

In the past, a strong flow-survival relationship was widely accepted. But the recent evidence supports a weak flow-survival relationship, and the quantitative difference between the strong and weak responses is vast. For example, in 1990, an analysis conducted with the System Planning Model (SPM) predicted that from a base 93 kcfs Ice Harbor flow an additional 47 kcfs of flow would increase spring chinook survival by 180% (CBFWA 1990). But with more recent data and model analyses, we have revised the potential increase to 1.5%. This newer estimate is over a hundred times weaker than the older one.

From an historical perspective, the evidence supporting first a strong response and then a weak response evolved in two distinct periods, with a shift at the beginning of the 1990s (see Table 2). Using research from the '60s, '70s, and '80s, analyses published in the early 1980s purported a strong flow-survival hypothesis. Succeeding studies and analyses in the 1990s have reevaluated the data and key information, and from this work a weak flow-survival hypothesis has emerged. The existing management plans were developed with the belief in a strong flow-survival relationship and place flow augmentation as a central management tool. Although the NMFS Recovery Plan decision scheduled for 1999

Table 2. Historical Progress of the Flow-Survival Relationship
Key Studies and Programs/Plans

Year	Supporting a Strong Flow-Survival Relationship	Supporting a Weak Flow-Survival Relationship
1980s	Sims and Ossinder 1980s (70s-80s Spring Chinook Studies)	
1983	NPPC Fish & Wildlife Program*	
1987	NPPC Fish & Wildlife Program*	
1990	CBFWA Integrated System Plan*	
1992	Petrosky 1992 (Adult Return Rates Correlated with Travel Time)	Marsh and Achord 1992 (PIT Tag Study Suggests High Survival-1973 Water Conditions)
1993	Hilborn, et al, 1993 Berggren and Filardo 1993 ('Fall Chinook Flow-Travel Time Relationship)	
1994	Cada, et al. 1994 (Some Relationship Between Flow and Survival)	Giorgi, et al. 1994 (No Fall Chinook Flow-Travel Time Relationship)
	NMFS 1994 BIOP*	Olsen and Richards 1994 (Ocean Conditions Are Affecting All West Coast Chinook Runs)
1995	NMFS 1995 BIOP*	Williams and Mathews 1995 (Low Survival Tied to Trash Conditions at Dams)
		Skalski, et al. 1996 (Fall Chinook Survival Depends on Lower River Stock Selection)
1996		Anderson 1996 (Climate-Cycle Correlates with Ocean Survival)
1997		Smith, et al. 1997a (1993-1997 Data) (No With-Year Relationship Between Flow-Survival for Spring Migrants
		Giorgi, et al. 1997 Smith, et al. 1997b (No Clear Relationship for Within Year Flow Survivals, Fall Chinook)
1998	FLUSH Model Has Strong Relationship Via Delayed Mortality	CRiSP Model Has Weak Relationship Via Delayed Mortality

* Fish mitigation and recovery programs.

will likely include flow measures, *the Recovery Plan should reconcile its flow augmentation program with the more recent data and modeling analyses.*

5.2. Strong Flow-Survival Relationship.

The early belief of a strong flow effect was based on NMFS studies conducted on a yearly basis between the mid-1960s and the mid-1980s. Fish were tagged and released in Snake River tributaries and collected at John Day or The Dalles Dam on the Lower Columbia. Sims and Ossiander (1981) presented a graph of seven data points displaying average spring chinook smolt survival versus average flow between 1973 and 1979. The data suggested a strong relationship between smolt survival and flow, but it was driven by the two lowest flow years (1973 and 1977). Excluding these years, the relationship was flat; that is, no discernible relationship was evident between the average yearly flow and the estimated survival for the year.

Resource managers embraced the "Sims-Ossiander relationship" and formalized it in a computer model, the Passage Analysis Model, as developed by the Northwest Power Planning Council staff. They concluded that one reason for the decline in stocks over the 1970s was decreased spring flows associated with the hydro system. It was then assumed that, if water from storage reservoirs was released into the river in the spring, the effect of high flow water years could be recreated, and smolt survival would increase.

This leap of faith from seven data points to a fully developed theory of the impact of shaping river flows, within a year, was scientifically overly simplistic and has been criticized in numerous documents (Steward 1994, Williams and Matthews 1995, NMFS 1995). The evidence now suggests that ocean environment, fish condition, poor dam operations and adverse passage conditions, especially in the two lowest flow years, had more to do with the apparent flow-survival relationship than flow itself. These issues were unknown at the time, but managers thought by simply "re-shaping" the seasonal outflow profile from storage reservoirs, they could rebuild the fish runs in the basin.

If the flow survival relationship was only based on the Sims and Ossiander (1981) study, the aggressive flow enhancement measures would not have been adequately justified. In 1991, though, the strong flow-survival hypothesis received additional support through an analysis illustrating that spring chinook adult return rates were larger for years with shorter water travel time during the smolt migration season (Petrosky 1992). The data spanned the period 1960 through 1987, and fish managers refined their hypothesis by inferring that decreasing water travel time would increase adult returns. Although the focus shifted from flow to water travel-time and from smolts to adults, the promise was the same: modest increases in flow, within a year, would recreate the strong benefits in survival that had been observed in earlier years.

Also, evidence for a relationship between flow and travel time for spring chinook was published by Berggren and Filardo (1993). More evidence was added with an analysis

of the coded wire tagged adult returns of fall chinook from the Priest Rapids hatchery on the mid-Columbia (Hilborn, et al., 1993). The authors attempted to remove the impact of variable ocean conditions by comparing survival of the Mid-Columbia stock to a downstream hatchery stock. The authors concluded that a significant relationship existed between smolt-to-adult survival and an index of river flows during smolt out-migration.

The evidence on spring chinook and steelhead smolt survivals (Sims and Ossiander 1981), spring chinook smolt-to-adult ratios (Petrosky 1992) and recruitment of fall chinook adults (Hilborn, et al., 1993) merged in the early 1990s into a qualitative belief that year-to-year differences in flow or travel time were associated strongly with year-to-year differences in survival. Cada, et al., (1994) reviewed historical data and studies and did identify inconsistencies in the flow survival hypothesis. Nonetheless, they concluded that there was a relationship between flow and survival--particularly between large volume flow differences--that needed further definition and elaboration.

The belief also that within a year water shaping and augmentation of flow could benefit smolt or adult survival was accepted, even though it was largely unsupported by empirical data or theory. Consequently, the practice become a foundation of the NMFS 1995 BIOP flow targets and augmentation program. The underlying belief was that changes to the hydro system operations, within a smolt migration year, would produce significant improvements in returning adults.

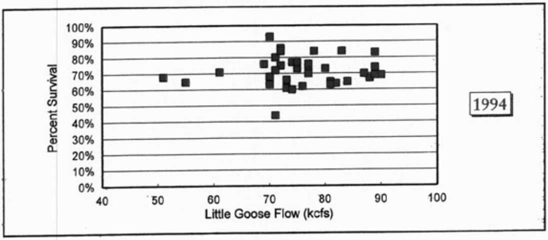
5.3. Weak Flow-Survival Relationship.

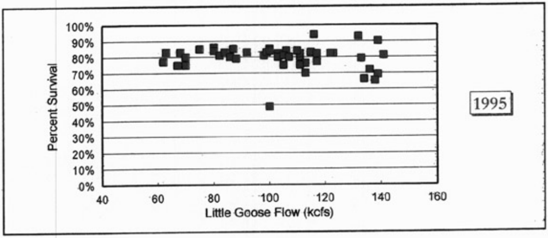
The first evidence for a weak flow-survival relationship evolved out of individual studies on specific species. The work all took place after preparation of the Cada, et al., (1994) report, and it represents a radical departure from the previously accepted belief system. The main evidence is based on new PIT-tag survival studies. This technique allowed tagging and non-invasive detection of individual fish and represented a breakthrough in survival studies by decreasing the error in the statistical estimates to only a few percent.

A prototype study was conducted in 1992, an extremely low flow year comparable to 1973, which had the second lowest smolt survival on record (Marsh and Anchord 1992). The results rattled the foundation of the old belief system. Estimates of survival were nowhere near the 1973 levels. Subsequent expanded studies conducted through 1997 have conclusively proven that a strong flow-survival relationship for spring chinook and steelhead smolts does not exist (Smith, et al., 1997a). A regression of the survival data for spring chinook migrating from Lower Granite tailrace to Lower Monumental tailrace from 1994 through 1996 resulted in a shallow slope with a relatively low statistical relationship.

More important for management, though, were the relationships between flow and survival *within years* (see Figure 10). Whereas a corollary to the strong hypothesis that within-year flows would benefit within-year survivals, the PIT tag analyses indicated no

Figure 10. NMFS/UW Survival Data, 1994-1996
Survival Rates for Juvenile Spring Chinook Release Groups
(L. Granite Tailrace to L. Monumental Tailrace)





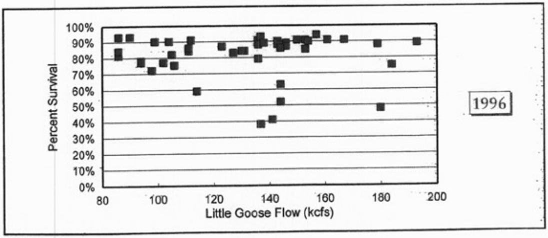
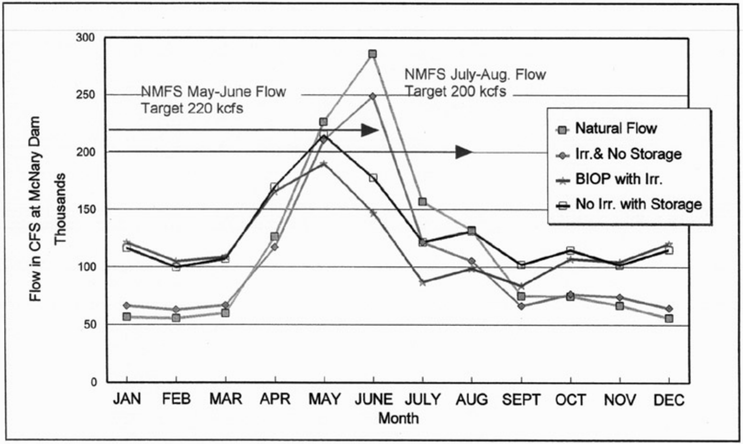


Figure 3. Columbia River Basin Water Flows
Estimated Low Water Condition (1976-77), Average Monthly Flows at McNary Dam



Data Source: USBR, Cumulative Effects of Water Use, Interim and Draft Reports, March-October 1997.

relationship whatsoever (Smith, et al., 1997a). In essence, the PIT tag data and the subsequent analyses conclusively prove that the strong inseason flow-survival hypothesis for spring chinook and steelhead smolts--as was originally claimed from the Sims and Ossiander studies--is not supported.

The old data did have low survivals, and so these survival estimates also must be considered. Although it is often difficult to explain the past, Williams and Matthews (1995) added a key missing factor. They reviewed the hydro system records and data and showed that in the early survival studies, the hydro system was radically different than it is now. Significant accumulations of trash in the forebays of the Upper Snake River dams, intermittent turbine operations in low flow years, and large spills and gas supersaturation levels in high flow years (and in years with reduced dam hydro capacity) all contributed to the mortality reported in the Sims and Ossiander work. Improved dam operations have reduced mortality problems and have increased dam passage survival. As such, reconciliation of the Sims and Ossiander studies and the new PIT tag studies is straightforward.

Having addressed errors in the formulation of the spring chinook flow-survival relationship for smolts, the need also exists to address the relationship between travel time and adult returns presented by Petrosky (1992). The management action implied is that by decreasing water travel time by any means, there will be increases to adult fish returns. Again, the leap of faith to flow augmentation as a management action is wholly unsupported. Although the correlation between smolt-to-adult returns (SAR) and water travel time over 27 years of observations is visually evident, it is a misleading correlation, since flow had very little impact on either variable in the time series.

The main factor was simply the change in the number of dams over the 27 years. In the early part of the time series (1966-1969), smolts and adults passed three dams, while in the latter part of the series (after 1976), they passed eight. Dams increase water travel time and the cumulative mortality in dam passage, but increasing flow would only have a minor impact on travel time and would only improve dam passage survival as a consequence of spill, albeit in a minor but measurable way.

A second factor driving the correlation is the change in ocean/climate conditions over the analysis period. In the early part of the time series, climate was in a wet regime favorable to the survival of the Columbia River salmon and, in 1977, it shifted into a dry regime unfavorable to their survival (Anderson 1995; also see Olsen and Richards 1994).

The final issue relevant to the earlier data analyses is that after 1977, about 80% of the Snake River spring chinook spawners were barged through the river as smolts. Thus their passage through the hydro system was independent of water velocity, and so it is incorrect to identify a mechanistic relationship between the survival of transported fish and water travel time.

In their 1995 BIOP, the NMFS recognized that the data supporting the recommended flow augmentation program contained limitations, and the agency has continued to better define and understand the flow-survival hypothesis.

5.4. Flow-Survival Factors Affecting Fall Chinook.

The effect of flow on fall chinook is less defined and has been confounded because the fish feed and grow as they move slowly through the river system in the summer and late fall. And since temperature changes can have both a positive and potentially negative (thermal shock and changes to FGE) impacts on the fish, the implications of flow augmentation are very complex and are yet to be well understood.

Most studies on smolts have focused on the relationship of flow to travel time. Giorgi (1994) reevaluated an expanded data set, encompassing that used by Berggren and Filardo (1993), and found no significant flow-travel time relationship for fish in the Lower Columbia. Evaluating data from the Mid-Columbia above McNary Dam, Giorgi, et al., (1997) found similar results. Fish length was the major determinant of fall chinook travel time, and flow was of secondary importance. Flow, by itself, explained about 28% of the observed variation in migration rate.

The fall chinook flow-recruitment to age two relationship found by Hilborn, et al., (1993) was reanalyzed by Skalski, et al., (1996), who expanded the analysis to include more explanatory factors than just river flow and included more downstream comparison stocks. Skalski, et al., (1996) concluded that the 24 years of Priest Rapids hatchery returns yielded little insight into key in-river factors that may be influencing hatchery return rates. In fact, of all the variables analyzed, *flow provided the least amount of predictive capability*. Also, the choice of the downstream comparison stocks greatly influenced the outcome of the analysis.

The recent PIT tag data provides a better picture of the complexity of the within season (year) survival of fall chinook in the Snake River. Smith, et al., (1997b) observed a trend between flow and survival that was not statistically significant (.05 level) within years but held moderate correlation. But it is noteworthy that the survival relationship was better described by the date fish passed Lower Granite or Little Goose dams. In general though, the factors affecting fall chinook in-river survival are not fully understood. A prolonged migration with the tendency of later migrating fish to residualize (stop migration and over-winter in the reservoir) complicates the interpretation of the effect of flow, temperature, release date, or fish size on their survival while passing through the hydro system.

Another affect flow may have on overall survival can be seen by examining the preliminary fall chinook adult PIT tag returns from both the 1994 and 1995 migration years (PITAGIS data base, 1998). The adult PIT tag data indicate that fall chinook juveniles detected at collector facilities from October 1, to December 10, produce about as many returning adults as juveniles detected during the peak migration period (July-September)--a period when flow augmentation was used to protect juvenile migrants (see Figure 11). These data indicate a survival advantage for juveniles that delay migration until late fall. As such, management actions that attempt "to force" juveniles to migrate during a certain time frame may actually be detrimental to the overall survival of a given year class.

Still, the relationship between year-to-year flows and Lower Granite PIT tag detection of Hells Canyon fall chinook has an apparent correlation over the years 1992 to 1997. But as with the PIT tag results reported by Smith, et al., (1997b), the year-to-year correlation is complicated by protracted migration, temperature, and environmental factors. For example, 1992 was identified as a low flow year with a low detection rate. Yet 1997, an extremely high flow year, experienced substantially lower detection probabilities than the two previous years. Detections are not a measure of survival, so the relationship is complicated by these year-to-year changes in dam operations.

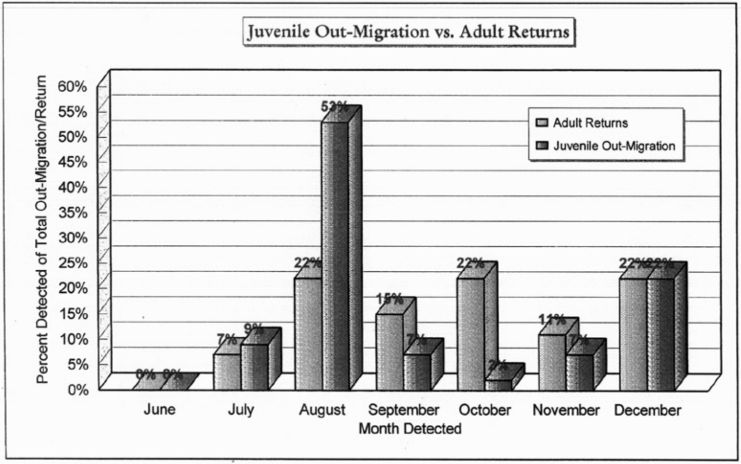
Further, the relationship between juvenile detection rate and survival from year-to-year is complicated by changes in project fish passage facilities. For example, from 1995 through 1997, extended-length screens were incorporated into both Lower Granite and Little Goose dams. These screens increase overall fish guidance efficiency which results in an increase in PIT tag detections. In addition, in 1996 and 1997, a prototype surface collector was installed at Lower Granite Dam. Because this system is not equipped with PIT tag readers, any tagged fish passing the project through this system would not be detected.

Even with these problems associated with the fall chinook detection results (only six average annual data points), the data present a story that is apparently being accepted by resource managers (Stelle 1997). This is cause for concern, given the region may fall into the same dilemma created by the seven data points representing the early Sims and Ossiander analysis.

Other patterns in the fall chinook data caution us about jumping to conclusions. A fundamental characteristic of mortality models is survival increases with decreasing travel time. This relationship exists for the within-year data evaluated by Smith (1997b), in which no flow-survival relationship could be identified, but is absent from the year-to-year data, which has a simple linear flow-survival relationship. In fact, if anything, the opposite pattern exists in the year-to-year data. The lowest detection rates (5%) correspond with the shortest travel time (25 days), while the highest detections (30%) correspond with the longest travel time (50 days).

A second germane outcome of the recent research is that summer flow augmentation may have a negative effect on juvenile fall chinook migrating from the Clearwater River below Dworshak Dam. Researchers indicate (Conner 1995) that reduced water temperatures in the Clearwater River reduced the growth rate and delayed migration

Figure 11. Juvenile Fall Chinook Run-Timing at McNary Dam Versus the Percent of the Corresponding Adult Returns Based on PIT Tag Detection History



timing of fall chinook juveniles. This change in migration timing may have contributed to reduced detection rates, and possibly survival, in 1994.

Still, under low flow conditions, summer water temperatures in the Lower Snake River can exceed 74 F. (Bennett, et al., 1997), a temperature level that can be lethal to chinook salmon survival. Researchers have documented that flows from Dworshak Reservoir can be used to lower water temperatures to levels more favorable (< 70 F.) for both juvenile and adult survival (Bennett, et al., 1997). But researchers have been unable to determine the change in juvenile survival resulting from decreased water temperatures or the amount of water needed to achieve survival changes.

The lack of precision in current fall chinook survival estimates is caused by many factors, including inadequate analysis tools, inadequate sample sizes, and the extended migration timing of the fish themselves. As research continues, future studies will provide data to judge more accurately the merits of flow augmentation.

To conclude, the results of recent PIT tag analyses, as well as other analyses surrounding the benefits of increased flows, serve as a warning to fish managers not to jump to expedient conclusions regarding flow impacts to fall chinook survival.

5.5. The Delayed Mortality Issue and Models.

Although the previous data supporting a strong flow-survival relationship has been largely discounted, the debate on the impacts of flow still remains and has been recast in terms of the impact of mortality in the hydro system, influencing mortality in the estuary and ocean. This mortality has been termed "delayed" mortality. Again, hypotheses on the effect of flow on this delayed mortality divide into two camps: one in which flow has a strong influence on delayed mortality (tribal-agency FLUSH/delta model analyses); and another in which flow has a weak influence on delayed mortality (University of Washington, CRiSP/alpha model analyses).

The decades old argument on the value of flow may now depend on which model system is a better representation of the Columbia River and their salmon stocks. This evaluation is taking place through the regional PATH process, where arguments for and against each model system are being developed and will be reviewed by independent scientists. The merits of each model system will be judged on how well they fit the existing data and their ecological realism.

But the University of Washington analyses have identified technical issues within the FLUSH/delta model system, including: 1) a weak fit of FLUSH to in-river survival studies; 2) the lack of a well-defined biological basis for connecting hydro system mortality to delayed mortality; and 3) the use of historical data without accounting for the unique factors contributing to the historically poor passage conditions.

In general summary, flow augmentation is likely to have limited benefits as a tool for salmon recovery. Previous claims of large benefits for flow augmentation have been overestimated. What remains of the contention for a strong flow-survival relationship is now being addressed in the PATH process.

5.6. *CRiSP Modeling Analyses Results.*

To provide some additional insight into the flow-survival relationship, the results from CRiSP modeling analyses, surveying different flow augmentation levels, are presented within Tables 3-4 and Figures 12-13. These modeling analyses match closely the survival relationships within the mainstem Snake-Columbia River corridor exhibited by the NMFS spring/summer chinook data and the available fall chinook data sets.

In Table 3 and Figure 12, the modeling analyses suggest that spring migrant survival rate improvements--gained by incremental flow enhancement--are generally small. During a low water-year condition, the absolute change in Snake River fish survival would be about 2.3% (56.9% survival to 59.2%), with 6.5 MAF of flow augmentation (flow augmentation from both the Snake and Columbia river systems). During average water-year conditions, the absolute change in survival would be about 1.4% (59.2% survival to 60.6%).

As portrayed within Table 4 and Figure 13, the fall chinook survival estimates, with flow augmentation, are higher than the estimates for spring chinook. This is true for both absolute survival improvements and for incremental percentage increases, because of the lower overall survival rates of the migrating fall chinook. The range of absolute change is about 2-4% for Snake River fall chinook and Mid-Columbia fall chinook. But the incremental percentage change in survival for the Mid-Columbia fall chinook is about 40%.

The fall chinook modeling analyses in Table 4 and Figure 13 are preliminary and are based on high range value estimates (data sets); but they are presented here with the recognition that work on the fall chinook is still incomplete. Other modeling analyses of the fall chinook data produces estimates of far less elasticity between incremental flow augmentation and survival increases, within years.

Also, it is important to note that these flow-based survival rate improvements are influenced by other recovery plan measures--most importantly being the juvenile transportation program. As higher percentages of fish are removed from the river system due to transportation program operational changes, the effectiveness of the flow augmentation program for mainstem survival diminishes.

Snake River summer flow augmentation is currently being used to enhance the transportation collection efficiency for fall chinook. But flow augmentation is not the only method available to increase collection efficiency. Structural changes at the projects, such

Figure 12. Spring Chinook Survival Estimates

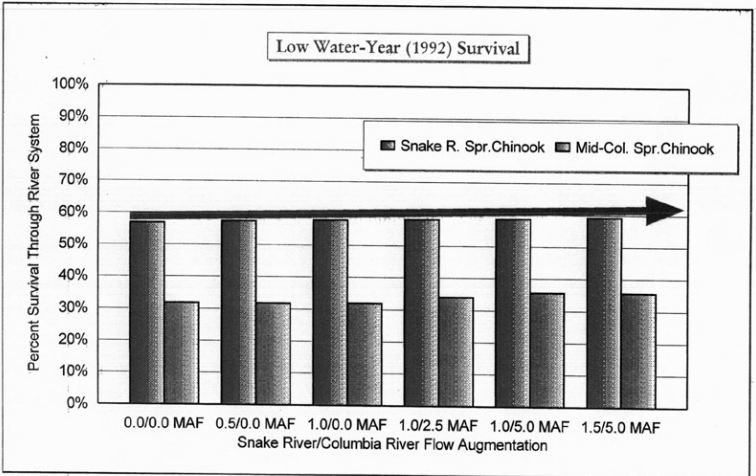


Table 3. Estimated Impacts to Mainstem Survival University of Washington CRiSP 1.5 Analyses

Flow Augmentation under 1995 BIOP Operations with Juvenile Salmon Transportation Survival From L. Granite Head-Water to the Estuary

Estimated Survival:

Flow Augmentation At: Snake R.	Columbia R.	Low Water Year (1992) Spring Chinook: Snake	Mid-Columbia	Raw Score Percent Increase: Snake	Mid-Columbia
0.0 MAF	0.0 MAF	56.9%	31.7%	------	------
0.5 MAF	0.0 MAF	57.4%	31.8%	*0.5%*	*0.1%*
1.0 MAF	0.0 MAF	57.9%	31.9%	*1.0%*	*0.2%*
1.5 MAF	0.0 MAF	58.5%	31.9%	*1.6%*	*0.2%*
1.0 MAF	2.5 MAF	58.3%	34.0%	*1.4%*	*2.3%*
1.0 MAF	5.0 MAF	58.6%	35.5%	*1.7%*	*3.8%*
1.5 MAF	5.0 MAF	59.2%	35.5%	*2.3%*	*3.8%*
No Transportation, In-River Survival Only					
0.0 MAF	0.0 MAF	35.8%	31.7%	------	------
0.5 MAF	2.5 MAF	36.8%	33.9%	*1.0%*	*2.2%*
1.0 MAF	5.0 MAF	37.7%	35.5%	*1.9%*	*3.8%*

Estimated Survival:

Flow Augmentation At: Snake R.	Columbia R.	Average Water Year (1995) Spring Chinook: Snake	Mid-Columbia	Raw Score Percent Increase: Snake	Mid-Columbia
0.0 MAF	0.0 MAF	59.2%	36.3%	------	------
0.5 MAF	0.0 MAF	59.7%	36.3%	*0.5%*	*0.0%*
1.0 MAF	0.0 MAF	59.4%	36.3%	*0.2%*	*0.0%*
1.5 MAF	0.0 MAF	59.9%	36.3%	*0.7%*	*0.0%*
1.0 MAF	2.5 MAF	59.8%	38.3%	*0.6%*	*2.0%*
1.0 MAF	5.0 MAF	60.1%	39.8%	*0.9%*	*3.5%*
1.5 MAF	5.0 MAF	60.6%	39.8%	*1.4%*	*3.5%*
No Transportation, In-River Survival Only					
0.0 MAF	0.0 MAF	37.8%	36.3%	------	------
0.5 MAF	2.5 MAF	38.8%	38.3%	*1.0%*	*2.0%*
1.0 MAF	5.0 MAF	39.8%	39.8%	*2.0%*	*3.5%*

Data/Analyses Sources:

Columbia Basin Research Office, University of Washington, CRiSP 1.5 Analyses, August-December 1997.

Note: The flow augmentation scenarios are for water released into the Snake and Mid-Columbia headwaters over a 60-day period during the migratory season.

Figure 13. Fall Chinook Survival Estimates
High Range Survival Rate Values

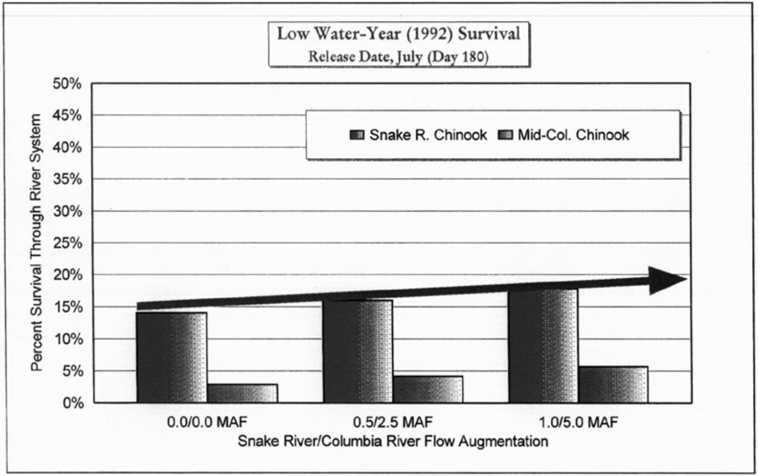


Table 4. Estimated Impacts to Mainstem Survival
University of Washington CRiSP 1.5 Analyses

Flow Augmentation under 1995 BIOP Operations with Juvenile Salmon Transportation
Survival from the Lower Granite Head-Water to the Estuary

Estimated Survival:

Flow Augmentation At: Snake R.	Columbia R.	Low Water Year (1992) Fall Chinook Snake High-Range Value	Low Water Year (1992) Fall Chinook Mid-Columbia High-Range Value	Raw Score Percent Increase Snake High-Range Value	Raw Score Percent Increase Mid-Columbia High-Range Value
Release Date: July (Day 180)					
0.0 MAF	**0.0 MAF**	**14.1%**	**2.9%**	------	------
0.5 MAF	**2.5 MAF**	**16.0%**	**4.2%**	***1.9%***	***1.3%***
1.0 MAF	**5.0 MAF**	**17.8%**	**5.7%**	***3.7%***	***2.8%***
Release Date: Day 200					
0.0 MAF	**0.0 MAF**	**10.4%**	**2.3%**	------	------
0.5 MAF	**2.5 MAF**	**12.2%**	**3.0%**	***1.8%***	***0.7%***
1.0 MAF	**5.0 MAF**	**13.8%**	**3.9%**	***3.4%***	***1.6%***

Estimated Survival:

Flow Augmentation At: Snake R.	Columbia R.	Average Water Year (1995) Fall Chinook Snake High-Range Value	Average Water Year (1995) Fall Chinook Mid-Columbia High-Range Value	Raw Score Percent Increase Snake High-Range Value	Raw Score Percent Increase Mid-Columbia High-Range Value
Release Date: July (Day 180)					
0.0 MAF	**0.0 MAF**	**26.4%**	**9.3%**	------	------
0.5 MAF	**2.5 MAF**	**28.0%**	**11.5%**	***1.6%***	***2.2%***
1.0 MAF	**5.0 MAF**	**29.4%**	**13.7%**	***3.0%***	***4.4%***
Release Date: Day 200					
0.0 MAF	**0.0 MAF**	**23.1%**	**5.8%**	------	------
0.5 MAF	**2.5 MAF**	**25.5%**	**7.2%**	***2.4%***	***1.4%***
1.0 MAF	**5.0 MAF**	**27.2%**	**8.8%**	***4.1%***	***3.0%***

Data/Analyses Sources:

Columbia Basin Research Office, University of Washington, CRiSP 1.5 Analyses, August-December 1997.

Note: The flow augmentation scenarios are for water released into the Snake and Mid-Columbia headwaters over a 50-day period during the migratory season.

Data for fall chinook migrations is more limited than for spring chinook; as such, the above survival estimates reflect high range values--for flow augmentation response-- that are under continued review and evaluation.

as the current installation of double-length screens and/or surface collector technology, may be able to achieve the same goal, more cost-effectively, and provide benefits for spring migrants as well.

5.7. Ecological Considerations Concerning Flow and Mainstem Passage.

The scientific protocols used for determining a survival versus flow relationship are to mark juveniles during migration, recapture them as older juveniles or as adults, plot their survival rate against some estimator of flow they experienced during migration, and calculate a regression statistic. Since this has been done for many groups of fish over many years and by many scientists, the results, not surprisingly, are variable (see, for example, the Cada et al., 1994 review and the studies cited in Appendix A). But probably the best data we now have is the NMFS PIT tag data base (Smith, et al., 1997a).

Beginning in 1993, NMFS and University of Washington researchers combined state-of-the-art PIT tag technology with sound statistical study design to quantify the relationship between juvenile migration survival and flow discharge in the Snake River. These data are now being collected under improved in-river test conditions of high spill and flow, as prescribed by NMFS in the 1995 BIOP. Smith, et al., (1997a) have published NMFS findings to date, covering multiple-year flow conditions data.

The results of the multi-year juvenile survival data in the Snake River probably give us the most definitive picture of how flow affects spring chinook and steelhead migrating through the Lower Snake and Lower Columbia hydropower corridor. Key points from the NMFS data come readily to light.

When comparing juvenile survival between years, there is higher survival in years with higher flows. This parallels the findings of Sims and Ossiander (1981), a study whose data have been criticized as statistically inadequate (see Kreeger and McNeil, 1992; Steward, 1994). Among other considerations, the inter-annual relationship seems to depend on the fact that there are very large differences in seasonal discharge from year-to-year--larger than we observe in weekly or monthly variations within each year. Examination of the data tends to suggest that it may not be the provision of higher flows that elicits the survival benefit.

In reviewing these data, it appears that for years when the average spring discharge is below 80-90 kcfs in the Snake River, survival is much lower than when it is above this value. Smith, et al., (1997a) characterize this phenomena well. In particular, the *within year* survival data strongly suggest that there is no apparent relationship between survival and flow. The biological or physical cause of why there is a strong between-year survival relationship, but no within-year relationship, is speculative; it is likely based in ecological factors that are well beyond the effects of the single flow rate variable.

For example, an examination of week-to-week survival of migrating juveniles indicates that the specific weekly discharge does not seem to greatly influence survival. That is,

in examining the flow-survival relationship within a specific year, the same kind of strong relationship does not manifest, as noted between years. Is it possible that this situation exists because there is not a significant change in flows from week-to-week to elicit a survival response?

In answering this question, it can be observed that flows within a season can vary by as much as 50 to over 100 kcfs (see Figure 10). Thus, it can be said that fish are exposed to highly variable flows within a year. It is not unusual to see Snake River flows at the beginning of the season at 40-60 kcfs and reach 120-140 kcfs as run-off proceeds. Snake River discharge history from 1994-1997 illustrates this point well. In 1994, flows began near 30 kcfs but never exceeded 100 kcfs--a very low flow year. In 1996, by contrast, flows began around 90 kcfs and peaked near 200 kcfs. In both years, flows fluctuated greatly within the season (sometimes within a week), yet no survival relationship emerged. Both years presented natural experimental opportunities for survival to show weekly fluctuations, because flow conditions were often highly variable week-to-week. But the survival data do not correspond to the flow variations. This observation suggests that survival is not a function of week-to-week discharge; it is not the instantaneous flow condition that is providing a measurable survival benefit. Instead, it appears that it is the overall annual condition of low flow (drought) versus high-flow (flood) years. Seasonal, not daily or weekly, volume water discharge is a predictor (or a correlate) of annual in-river survival percentages--likely due to multiple variables stemming from wet seasons versus dry years.

Consider, as well, even if total seasonal discharge was the only variable driving survival--an unlikely assumption--is it possible to "turn a low-flow year into a high-flow year" by using reservoir storage and thereby increasing survival? If we compare the volume of water that passed Lower Granite Dam in the spring of 1994 and 1996, we find that total river flow in 1996 (14.6 MAF) was nearly twice that of 1994 (7.6 MAF). In order to make river conditions in 1994 resemble 1996, it would require an additional 7 MAF of flow augmentation. Currently, the total Snake River storage is about 12 MAF (System Operations Review estimate). Therefore, we would need to evacuate two-thirds of the entire storage in Idaho and release it in a two-month period. Even if this were hydrologically possible, it would leave negligible storage or available instream flows for other purposes; and the region would need to forego most uses for water later in the year, including fish and wildlife in the Middle and Upper Snake River.

It appears likely that the use of storage as a mitigation tool is relatively limited in how much increased in-river survival it can provide, within the hydropower corridor. A major objection to previous juvenile survival data has been inadequate in-river conditions to maximize in-river survival. NMFS has provided improved conditions to test this hypothesis since 1993, in the form of both higher spill and flow target levels.

Based on their own data, the NMFS recovery strategy should anticipate that survival of juveniles will vary year-to-year, and survival appears to be contingent especially on whether we anticipate a drought year and therefore low survival in-river. For now, it appears that flow as a tool to enhance in-river survival of spring migrants, within seasons, has severe limitations in the Snake River; and that the survival benefits of simply drafting

storage will be small, first by storage limitations themselves, and second by the survival benefits--no matter what we may be willing to pay biologically or economically in the way of upstream costs. The benefits to fall chinook are less understood and flow may offer some benefits (undefined at the present time) during the summer migration season. This appears to be hydrologically possible and holds more promise than the current program of enhanced flows during the spring runoff. It also is recommended that appropriate monitoring and evaluation continue.

Summary Observations and Comments:

- Largely based on historical data depicting year-to-year flow and juvenile fish survival relationships, it has been assumed that flow augmentation could be used to increase flows during low water-year conditions, in an attempt to produce survival rates observed in high water years.

- Data collected for spring migrants since 1992 (NMFS 1993-1997 data sets) indicate that the *within year relationship* between different flow regimes and fish survival through the hydro system corridor is weak. This means that attempts to use flow augmentation to improve spring migrant survival will provide very little or limited benefits.

- The year-to-year correlations between flow and survival--reflecting vastly different flow levels between years--support the hypothesis that ecological factors associated with drought conditions are principally responsible for fish survival.

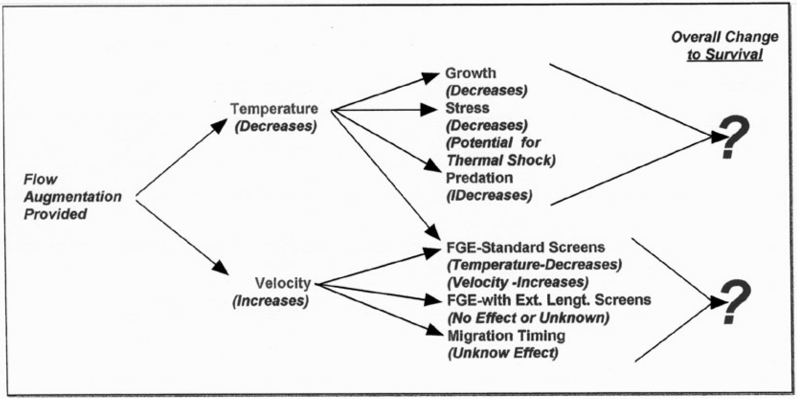
- The year-to-year observations move toward the conclusion that better water-year conditions, in general, provide for greater fish survival than drought conditions.

- The flow-survival data collected on fall chinook is more variable and less well defined than for spring migrants. Several variables and factors affect overall survival, including growth, stress, predation, migration timing and rearing, and changes to FGE at the Lower Snake River projects (see Figure 14).

- Given the existing data, flow is one variable correlated with survival in some cases, but it has less predictive capability than other variables (such as migration timing and fish size through the upper river system). Also, some relationships, such as observed numbers of marked fish detections between years, are inconsistent with the flow-survival hypothesis within years.

- During the summer period, Lower Snake River water temperatures can and do exceed levels that negatively affect migrating juveniles and adults. The use of some flow augmentation (from Dworshak Reservoir) to improve migration conditions should continue to be reviewed; and the biological benefits and costs should be better understood.

Figure 14. Factors Affecting Fall Chinook Survival and Flow Augmentation



- **Snake River summer flow augmentation is being used to enhance the transportation collection efficiency for fall chinook. But it is yet to be verified by empirical data, beyond the detection rate data. Flow augmentation is not the only method available to increase collection efficiency. Structural changes at the projects, such as the current installation of double-length screens and/or surface collector technology, may be able to achieve the same goal, more cost-effectively, and provide ancillary benefits for spring migrants as well.**

- **For the spring period (May-June), pulsed flows (small water volumes) should be reviewed for potential experimentation as a migratory stimulator, primarily to benefit fish leaving the Salmon River tributary and entering the mainstem Snake River system--as recommended jointly by federal and state fish and water resources managers.**

- **Flow augmentation may hold some incremental benefits (undefined) for improving fall chinook survival.** ***However, resource managers should exercise great caution before increasing flow levels beyond the program levels employed in 1994 (summer flow augmentation) given existing uncertainties.***

6.0. *Economic Trade-Offs of Flow Augmentation.*

6.1. *Direct Net Value Measures of Economic Change.*

In evaluating actions affecting the hydro system and related operations, both net economic costs and benefits should be considered. If an action's net benefits exceed costs relative to other hydro system impacts, then society (the region) has received a monetary gain to overall net social welfare. The region is not being economically "penalized" by this allocation of resources--use of river water--but enjoys a net economic benefit.

Real changes to economic efficiency are measured in terms of direct net value. *Direct value* refers to the economic benefits derived from primary economic activities or sectors, such as: the crop value of irrigated agriculture; the marginal value (or opportunity costs) of electric power; or the ex-vessel or sport-effort value of commercial and sport salmon fishing. *Direct net value* represents the net benefits (monetary dollars) derived from primary activities, over and above the cost of providing or engaging in such activities.

For irrigated agriculture and commercial fisheries, direct net value (benefits) represents monetary returns above costs to proprietors and management. For sport fishermen, net value reflects willingness-to-pay to enjoy the sport activity above actual costs. For the hydro power sector, direct net value (costs) would be foregone electric power generation due to water reallocations (the loss of power revenues due to changes in hydro system operations).

Direct net value is recognized by the (National) Water Resources Council, the System Operation Review EIS (Corps 1995) economic workshop group, the NMFS Economics Technical Committee (Hubbert 1996), and the Corps Drawdown Review Economic Workshop group as an appropriate economic measure for assessing net economic impacts or changes to the region's (and nation's) social welfare. Direct net value is the best measure to use in understanding an activity's true economic benefits and costs; it can be used to assess and standardize the relative benefits and costs of different types of economic activities.

6.2. *Flow Augmentation Impacts.*

In the case of flow augmentation impacts, dedicated water volumes for flow augmentation reduce the amount of water available for system hydroelectric power production; and under some circumstances or scenarios, the fish flows could restrict the amount of water available for irrigated agriculture. For hydropower impacts, the economic value of this direct net cost can be measured in terms of dollars per acre-feet of water (dedicated for flows), taking into account average power generation losses throughout the system during the flow augmentation period. The direct net value of irrigation losses can be calculated on a dollars per acre-feet basis, as well, relying on a range of regional value estimates.

The Bonneville Power Administration has prepared power cost estimates associated with the flow augmentation program (BPA 1997), reflecting several variables affecting system-wide costs and changing power prices, during different types of water-year conditions. This estimate suggests a direct net cost of about $8-10 million per one million acre-feet of flow augmentation (BPA system costs). For irrigated agriculture impacts, a net benefit range estimate of about $40-70 million per one million acre-ft of water is available (NEA 1997; Olsen 1996a; Olsen 1996; and Hamilton and Whittlesey 1996).

The direct net economic benefit for fish flows can be calculated by using an estimated increase in survival due to flow augmentation, for all Columbia River stocks, and using sport and commercial fishing values as representing a realistic (or measurable) economic value for the runs. For a favorable baseline condition (average annual run size during the 1987-1991 period), the System Operation Review EIS (Corps 1995) provides a direct net value estimate of about $25 million, for the sport and commercial value of all up-river origin (above Bonneville Dam) salmon and steelhead. If the average survival rate (incremental) effects from the multi-year flow augmentation program are assumed to be about 5%--based on CRiSP modeling runs--and the effects are "compounded" for ten future life-cycles, then a direct net benefit estimate would be about $2.25 million per one-million acre-feet of flow augmentation. This dollar value estimate represents a *future value estimate--as opposed to an annualized present value estimate--and should be considered as reflecting a high value perspective for comparison purposes here.*

The value estimates for comparing the direct net economic trade-offs of flow augmentation versus irrigation and hydro power operations are provided in Table 5. These estimates indicate that even when favorable assumptions are applied to the estimation of the flow program, the direct net fish benefits do not exceed the costs to hydro power production or irrigated agriculture. This would indicate that the region receives negative economic trade-offs when relying on flow augmentation.

Additional studies are being prepared to address other economic benefits and costs associated with the flow augmentation program--in addition to those identified in Table 5. For example, there are recreation sector costs at the Upper Columbia-Snake River Basin storage projects that are not included in Table 5; and potential recreation benefits or other environmental benefits are not included. As well, the values presented in Table 5 do not take into account any costs or benefits incurred between sectors--like irrigation and hydropower--that could occur through joint operations or increases to efficiency. For example, Hubbert and Fluharty (1996) estimated an average annual cost of 1 MAF of flow augmentation from Idaho (Snake Basin) at about $49 million--with additional hydro power production benefits included (this cost is clarified in Hamilton and Whittlesey 1996). Also, the USBR has estimated that a permanent acquisition of .427 MAF from the Upper Snake Basin could remove 425,000 acres from production, with an acquisition cost of $294 million (depending on reservoir refill requirements).

Still an initial review provided here suggests that it is ever-more-important to structure the flow augmentation program in a way that will prioritize or optimize program

Table 5. Estimated Economic Benefits of Water Use For Major Sectors and Types of Economic Sector Trade-Offs (Direct Net Economic Value Estimates)

Economic Sector/Purpose	Estimated Benefits Annual $/MAF	Economic Trade-Offs For Water Diversion
Irrigated Agriculture*	**$40-70 Million**	Reduces water for hydropower production and fish flow augmentation.
Hydroelectric Power**	**$8-10 Million (BPA System Costs)**	Reduces water availability for fish flow augmentation; could conflict with irrigated agriculture.
Flow Augmentation--Fish Impacts Estimated Sport and Commercial+ Fisheries--Columbia Basin Origin (High Value Estimate)	**$2.25 Million**	Flow augmentation reduces hydropower production and can affect irrigated agriculture under NMFS BIOP-Recovery Plan.
Flow Augmentation--Fish Impacts Estimated Use and Existence++ Values for Columbia River Basin Salmon and Steelhead	**$4.80 Million**	Flow augmentation reduces hydropower production and can affect irrigated agriculture under NMFS BIOP-Recovery Plan.

* Assumes Direct Net Value of $40-70/acre ft. of water.

** Estimated marginal power cost impacts to Bonneville Power Administration.

\+ Assumes baseline economic value of $25 million (1995$), with compounding future value of 5% attributed to flow augmentation, for 10 migration periods (with average annual flow augmentation of about 7 MAF). The value represents a future value estimate and should be considered as presenting a high value perspective for comparison purposes here.

++ Assumes "total value" estimate (use, option and existence value) based on Columbia Basin Salmon and Steelhead study for use and non-use values; assumes that about 53% of the total value would reflect existence value (Olsen and Richards 1991). Use value based on future value estimate.

Data and Analyses Sources:

D. Huppert and D. Fluharty, Economics of Snake River Salmon Recovery: A Report to the National Marine Fisheries Service, School of Marine Affairs, University of Washington, Seattle, Washington, 1996 (and data/sources cited therein, SOR EIS).

Personal communications with Dittmer Operations staff, Bonneville Power Administration, Vancouver, Washington, August-September 1997.

D. Olsen, The Columbia Basin Project: Project Operations and Economic Benefits, A Regional Overview, The Pacific Northwest Project, Kennewick, Washington, 1996 (and Technical Memorandum Prepared for the Public Purposes Work Group of the Comprehensive Energy Review, 1996, Evaluating Irrigation, Power System, and Flow Augmentation Benefits and Costs).

J. Hamilton and N. Whittlesey, Cost of Using Water from the Snake River Basin to Augment Flows for Endangered Salmon, Paper Presented at the Annual Western Regional Sciences Association, Napa, California, February 1996.

implementation. The economic trade-offs (costs) of the program are, and could be, substantial. From an economic trade-off perspective, the program should be implemented to prioritize fish benefits, while acknowledging significant economic constraints and reducing costs to other sectors.

6.3. Cost-Effectiveness Analyses for Salmon Recovery Measures.

Another economic perspective that is being brought to bear on salmon recovery policy involves cost-effectiveness analysis. Flow augmentation is only one of several measures being pursued by the region to protect and enhance fish resources. And it is not unexpected to ask the question: how does flow augmentation compare to other recovery actions?

While detailed, quantitative cost-effectiveness reviews have been completed (Olsen and Anderson 1994) and are being undertaken to estimate the benefits of flow augmentation (and within the Corps' Lower Snake River Drawdown EIS), the subject can be investigated briefly within this paper using some basic qualitative and quantitative indicators. A framework for reviewing these indicators is presented in Table 6.

This framework assesses recovery measures according to six criteria or observations: 1) the measure is operational or currently being implemented; 2) empirical data is available to evaluate measure performance; 3) using empirical data, the measure is or can be confirmed as effective; 4) the measure's potential impact on survival is measured across one life-cycle; 5) the measure's estimated economic cost is identified; and 6) the maximum economic risk of pursuing the measure is considered.

With regard to the first three criteria, flow augmentation is operational, empirical data has been collected, but flow augmentation's range of effectiveness is uncertain. The NMFS within-year data and CRiSP modeling analyses discussed in previous sections would suggest limited to uncertain levels of effectiveness, particularly for spring migrants. With regard to cost, flow augmentation is similar to the incremental costs associated with a full transportation improvement scenario, with increased collection efficiency and direct loading facilities included within transport costs. It is more costly than measures like the law enforcement program or turbine improvements, but it is less costly than proposed Snake River reservoir drawdowns. These dollar costs also define the level of maximum economic risk, if the measures fail to perform.

In terms of dollar cost per unit of measured survival benefits, across one life-cycle, flow augmentation benefits could fall within the $16-92 million dollar range per 1% increase in survival, for spring chinook. This range is based on CRiSP modeling analyses and the assumptions discussed in Table 6. For example, the dollar per survival improvement range for flow augmentation suggests that it is likely more cost-effective (and less risky) than a reservoir drawdown measure, but it would be less cost-effective than

Table 6. Cost-Effectiveness Review

For Salmon Mitigation and Recovery Measures

Measure	Measure Is Operational	Empirical Data Exists for Review	Effectiveness Confirmed	Estimated Incremental Increased Survival+	Estimated Annual Cost+	Est. $ per 1% Survival Improv.	Maximum Economic Risk
Flow Augmentation	Yes	Yes	Uncertain Results	1 to 4% (Snake Sp.Chin.)	$56-70 Mil./Year (Ave. 7 MAF/Year)	**$14-70 Mil.**	**(>$50 Mil. Loss)**
Turbine Improvements	Being Installed or Reviewed	Yes	Generally Effective	1 to 3% (Snake Sp.Chin.)	$10-20 Mil./Year	**$4-20 Mil.**	**(<$25 Mil. Loss)**
Snake R. DD 4-Pool Nat. R.	No (5 Years)	No	No, But Definite In-River Improv.	-28% to 72%** (Snake R. Fish)	$150-250 Mil./Year***	**>$2 Mil.**	**(>$100 Mil. Loss)**
Surface Collectors	No* (Experimental)	Yes (Limited Data)	No* (Experimental)	0-9% (Snake Sp.Chin.)	$32-40 Mil./Year 2 to 4 Projects	**>$4 Mil.**	**(<$50 Mil. Loss)**
Existing Project Spill	Yes	Yes	Uncertain Results At High Levels	0-8%++ (Snake Sp.Chin.)	$40-60 Mil/Year	**>$5 Mil.**	**(>$50 Mil. Loss)**
Snake R. MOP DD	Yes	Yes (Flow-Surv. Data)	No	<1% or Not Measurable	$20 Mil./Year	**>$20 Mil.**	**(<$50 Mil. Loss)**
Smolt Transport Improvements (Full Transport)	Yes	Yes	Empirical Data Suggests Yes	10%+++ Total Survival >60% (Snake Sp.Chin.)	$90 Mil./Year All Improvement Features	**$9 Mil.**	**(>$50 Mil. Loss)**
Law Enforcement	Yes	Yes	Yes	>0% 319/104 (fish/nets)	$3-4 Million/Year	**<$3-4 Mil.**	**(<$25 Mil. Loss)**

Notes:

* Does not include Wells Dam structure on the Mid-Columbia River; refers to existing dam retrofits.

** Depends on assumptions concerning existing smolt transportation program. If program is not more effective than existing in-river conditions, then drawdown would likely produce about 72% gain. If existing program is 100% more effective than existing in-river conditions, then drawdown would reduce survival by about 28%.

*** Cost depends on assumptions about flow augmentation and power/construction costs.

\+ Based on data and analyses contained within the Harza, "Salmon Decision Analysis" (1996) Report, and University of Washington Analyses, Aug-Sept., 1997.

++ Depends on assumptions concerning transportation effectiveness.

+++ Assumes that existing transportation program is effective (provides about 100% survival improvement above existing in-river conditions).

Data Sources and Estimates: Harza, "Salmon Decision Analysis" Report (1996); Corps System Operation Review EIS (1995); Corps System Configuration Study, Phase I (1994) and Interim Status Report (1996); BPA Loads and Resources (1995); Harza-BPA Technical Memorandum, July 1997; University of Washington CRiSP 1.5 Model Analyses, Aug.-Sept., 1997; and Harza and Pacific Northwest Project (1997).

transportation program improvements, if the existing NMFS transportation benefit estimates are correct.

So in taking into account some fundamental cost-effectiveness criteria, given available data and assumptions, this economic perspective also would encourage resource managers to optimize the use of the flow augmentation program. Flow augmentation costs directed toward limited or undefined survival benefits detract from an ability to allocate finite dollars to more beneficial salmon benefit measures, or other types of mitigation and compensation strategies.

Summary Observations and Comments:

- **Using sport and commercial fisheries value and fish abundance estimates for the 1987-1991 period, the annual direct net value of the upriver (above Bonneville Dam) salmon and steelhead contributions to ocean and in-river fisheries is about $25 million.**

- **Applying some favorable economic and biological assumptions to the benefits of flow augmentation, the annual direct net economic value of the upriver contributions to commercial and sport fisheries is about $2.25 million per one million acre-feet of water used for flow augmentation--representing a *future value* estimate over 10 life-cycles (1995$).**

- **Flow augmentation doe causes economic impacts to hydroelectric power operations and could create future economic impacts to irrigated agriculture. For one million acre-feet of flow augmentation, the cost to hydropower operations is estimated to be about $8-10 million (BPA system costs). For irrigated agriculture across the Columbia Basin, the value of one million acre-feet of water is estimated to be about $40-70 million; one estimate (Huppert and Fluharty 1996) for the Upper Snake River Basin suggests about $49 million per one million acre-feet of water provided for flow augmentation (includes hydropower benefits).**

- **Both economic trade-off analyses and cost-effectiveness analyses strongly support the position that *any flow augmentation program should be optimized to maximize fish benefits relative to the costs incurred to other water resource sectors.***

7.0. *Recommendations for Decision Makers.*

7.1. *The NMFS Water Policy.*

The NMFS water policy--bred from the flow targets/augmentation program--directs that all future (new) water allocations from the Columbia River Basin drainage area should be used solely for fish protection.

The NMFS water policy is a single-purpose, resource use strategy that subjugates new water withdrawals for other types of social and economic activity or growth within the Basin. The policy is one-dimensional in nature, and it directly or indirectly challenges state legislative authority to govern water management.

The NMFS senior management, working with state water resource managers, should reevaluate and change this policy to better reach the needs of biological and economic optimization.

7.2. *Review and Restructure the Flow Targets/Augmentation Program.*

The river system benefits of flow augmentation are best estimated by relying on NMFS/UW data for flow-survival relationships (1993-1997 data), the CRiSP modeling analyses (which corroborate the NMFS/UW data), as well as other data and analyses being developed for fall chinook impacts. These data and analyses strongly suggest that the correlation between incremental flow changes and juvenile spring migrant survival is relatively inelastic, or that the survival benefits are small. *Flow benefits are best considered by examining the within year data relationships.*

To date given the data available, estimated river system flow benefits--though limited--appear to favor fall chinook. But the uncertainty surrounding the effects of flow augmentation on overall fall chinook survival is great. Several factors are unclear or unresolved concerning direct inriver survival benefits within years, migration timing and flow conditions, and the use of flow to improve transport collection efficiencies. It is more clear that flow augmentation is a measure providing marginal survival benefits, while factors independent from the mainstem river system, such as ocean/climatic conditions, will govern total productivity levels.

In contrast to some of the biological impacts, the economic trade-offs of flow augmentation are more predictable. Flow augmentation does increase costs to the hydropower system--one of the single largest costs of the salmon recovery program--and it could create significant costs to the irrigation (and other) sector, through either direct water curtailments or abrogating state water permits.

It should be further underscored that the flow augmentation program is directly affected by the collection efficiency of the smolt transportation program. Under a full or "maximized" transport collection program, the flow augmentation benefits within the mainstem corridor become very limited. For example, in the case of Snake River spring chinook collection at Lower Granite and Little Goose dams, 80% collection efficiencies will leave less than 5% of the migrating fish within the river system (below Little Goose Dam). If transport collection efficiencies improve at the McNary Project, then the flow benefits for Mid-Columbia fall chinook will decrease as well. And as technical modifications are made at the collection facilities to improve fish guidance, the upriver effects of flow augmentation to improve fish guidance are diminished.

Given the data, analyses, and observations noted above and presented throughout this paper, the following review and changes are suggested for the flow augmentation program.

Optimization Review:

- The existing flow augmentation program does not optimize water use for either survival benefits (benefit per unit of flow) or economic costs (benefit per dollar cost). to the river system. This optimization review should include changes to hydro system management, requiring new hydro regulation analyses.

- The flow augmentation program would benefit from a detailed technical review that focuses on the *optimization of water use. This would include applying principles of cost-effectiveness, to compare the biological benefits gained for the costs incurred.*

A restructured flow augmentation program that better reflects a step toward optimization of the existing water resources is described below:

Low Water Conditions, Snake River System:

- For the summer period (July-August), provide for experimentation a *maximum of 0.5 MAF* from the Brownlee Project and above consistent with state law and obtained from willing sellers or lessors; and a *maximum of 1.0 MAF* from Dworshak to be used for fall chinook migration and/or adult temperature control. Data to review this experimental regime would be collected through 1999, consistent with the existing NMFS decision-making process.

Low Water Conditions, Columbia River System:

- Direct flow augmentation releases solely for the fall chinook migration. For the summer period (July-August), provide for experimentation *0-4.0 MAF, as recommended jointly by federal and state fish and water resources managers.*

Average Water Conditions, Snake River System:

- For the summer period (July-August), provide for experimentation a *maximum of 0.5 MAF* from Brownlee Project and above consistent with state law and obtained from willing sellers or lessors; and a *maximum of 1.0 MAF* from Dworshak to be used for fall chinook migration and/or adult temperature control. Data to review this experimental regime would be collected through 1999, consistent with the existing NMFS decision-making process.

Average Water Conditions for the Columbia River System:

- Direct flow augmentation releases solely for the fall chinook migration. For the summer period (July-August), provide for experimentation *0-4.0 MAF, as recommended jointly by federal and state fish and water resources managers.*

Such restructuring of the flow augmentation program would have the greatest deviation from the existing flow augmentation program by eliminating the current spring flow augmentation regime. But the limited benefits gained from the spring flow augmentation program could be off-set by a full transport regime, particularly during low water-year conditions.

During the summer period, the restructured program would limit flow augmentation in the Snake River Basin to a level not to exceed operations that occurred in the summer 1994 (drought conditions). Without a better technical justification for the summer flow augmentation, resource managers should refrain from attempts to increase this flow regime.

It is equally important that better data and analyses are provided in order to justify adequately the use of water currently being used for summer flow augmentation.

7.3. Future Considerations for Flow Augmentation Management and Evaluations.

It appears clear that using flow augmentation within a single season is not an effective recovery tool for spring chinook migration within the mainstem. What is less clear is whether mainstem flow augmentation is an effective management tool for fall chinook within the mainstem; or how flow augmentation can or should be used to improve survival within tributaries. Given these latter uncertainties and issues beyond the scope of this paper, the following recommendations are provided.

- In the case of Snake River fall chinook, the existing data on collection efficiency (FGE) and its relationship to flow is difficult to interpret. The need exists to establish data that verifies the interaction between flow augmentation and structural

improvements to FGE, and cost-effectiveness analysis should be used to assess risk and economic trade-offs.

- **Resource managers may want to give consideration to changing the focus of flow augmentation efforts away from mainstem actions to improving habitat conditions within some tributaries. Greater fish benefits may be obtained within tributaries, using less volumes of water. This factor has been generally ignored within the present flow augmentation program. Understanding and optimizing water use in tributary habitats may offer a more biologically productive, and cost-effective approach, to water management.**

- **Low flow years exacerbate temperature stress to fish in both tributaries and the mainstem. The use of flow augmentation to minimize temperature stress may be beneficial in some habitat areas and applications, but it should be carefully modeled to determine benefits on a *site-specific basis.***

- **Drought years are especially difficult for both fishery resources and agricultural enterprises (as well as other economic and industrial water uses). This is particularly true for tributaries and their habitat conditions. The NMFS Recovery Plan should better recognize this factor, and take into account criteria for demonstrating real biological benefits, prioritizing major production tributaries, and measuring the cost-effectiveness and benefit-cost of tributary flow enhancement actions.**

- **Water use efficiency is an important objective for many water withdrawal sectors within the Columbia River Basin. The use of efficiency measures to accomplish well evaluated flow augmentation actions within tributaries--and support economic activities--should be encouraged.**

- ***Direct actions to implement flow augmentation measures should defer to the existing authority of state water rights and should allow for "locally developed" solutions within specific watersheds.* This could include an implementation of efficiency measures, water transfers, and the development of new water storage projects to benefit both fish and economic interests.**

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National Marine Fisheries Service. 1997b. Biological opinion, Inland Land, Inc., Columbia River. NMFS Seattle, Washington.

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APPENDIX A. ANNOTATED BIBLIOGRAPHY

1979 Raymond , N. L. 1979 Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River 1966 to 1975. Transactions of the American Fisheries Society. Volume 108, No. 6, November 1979.

Raymond monitored migrations of juvenile chinook salmon and steelhead from Snake River tributaries to as far downstream as the Dalles dam. Conclusions include " Major causes of mortality were passage through turbines at dams, predation, and delays in migration through reservoirs in low flow years." Raymond also states that "…I determined that rate of migration, depending on river flow ranged from 24 to 54km/day through a free flowing river, and 8 to 24 km/day through an impounded river."

1981 Sims, C.W., and F. Ossiander. 1981. Migrations of juvenile chinook salmon and steelhead trout in the Snake River, from 1973 to 1979, a research summary. US Army Corps of Engineers. Contract DACW68-78-C-0038.

"The correlation of river flow at Ice Harbor Dam and smolt survival from the upper Snake River dam to the Dalles Dam was significant over the period of the study. "…survival levels of greater then 20% can be expected only when river flows at Ice Harbor Dam during the peak migration period exceed 100,000 cfs." "Both travel time and rates of downstream movement are more sensitive to changes in river flow during periods of low river flow than during periods of high river flow".

1982 Miller, D. R. and C. W. Sims. 1982. Effects of flow on the migratory behavior and survival of juvenile fall and summer chinook salmon in John Day reservoir. Prepared for Bonneville Power Administration. Contract DE-A179-81BP27602.

"There was no statistical evidence that to indicate that instream flows effected either the rate of movement or the residence time of 0-age chinook salmon in John Day Reservoir in 1981."

1983 Miller, D. R. and C. W. Sims. 1983. Effects of flow on the migratory behavior and survival of juvenile fall and summer chinook salmon in John Day reservoir. Prepared for Bonneville Power Administration. Contract DE-A179-81BP27602.

"There was no statistical evidence that to indicate that instream flows effected either the rate of movement or the residence time of 0-age chinook salmon in John Day Reservoir.

1984 Miller, D. R. and C. W. Sims. 1984. Effects of flow on the migratory behavior and survival of juvenile fall and summer chinook salmon in John Day reservoir. Prepared for Bonneville Power Administration. Contract DE-A179-83BP39645.

This study was conducted to refine flow/travel time relationships and distributional behavior of 0-aged chinook salmon. "Regression analysis was used to develop a description of the relationship of river flow to the rate of downstream movement… The slope of this line and the correlation coefficient (R) were not significantly different from zero".

1989 Anderson, J. A., D. D. Dauble, and D. A. Neitzel. 1989. Smolt survival workshop proceedings of a workshop held at University of Washington Laboratory, Friday Harbor WA. Prepared for Bonneville Power Authority. Project number 87-413 and 86-118, Portland, OR.

This workshop was held to evaluate measures of juvenile steelhead and salmon survival on the Columbia River. "Speakers noted that uncertainty in the existing survival studies made it difficult to evaluate the effect of river flow on smolt survival. Some doubted that any single factor affecting juvenile survival could be isolated from any other factor, either natural or programmed...Overall, workshop recommendations suggest that current survival estimates have sufficient uncertainty and variability to limit their use in evaluating the effectiveness of the Water Budget Program.

1990 Giorgi, A. E., D. R. Miller, and B. P. Sanford. 1990. Migratory behavior and adult contribution of summer outmigrating sub-yearling chinook salmon in John Day reservoir, 1981-1983. Prepared for Bonneville Power Administration. Contract DE-AI79-83BP39645.

This study investigates the effects of river flow volumes on the travel time of sub-yearling chinook salmon migrating through John Day reservoir. Travel time data was largely inconclusive. This was due to poor mark recovery capability coupled with the difficulty of isolating flow from other closely related variables.

1991 Berggren, T. J. and Filardo, M. J. An analysis of variables influencing the migration of juvenile salmonids in the Snake and Lower Columbia Rivers. Fish Passage Center. Portland, OR.

"Smolt travel time estimates for yearling chinook and steelhead released from 1981-1990 in the Snake River, and sub-yearling chinook in the lower Columbia River were inversely related to flow." The authors summarized that the data "...tended to support a causative, rather then a simple correlative relationship, between smolt travel time and river flow." The authors acknowledge that "changes in the level of smoltification development over the outmigration also influences travel time." And " Predicting smolt travel time through key index areas in the Snake and lower Columbia rivers is best accomplished using multiple regression model containing both flow-related and smoltification-related variables".

1991 National Marine Fisheries Service. 1991. Factors for decline, a supplement to the determination for Snake River fall chinook salmon under the endangered species act. NMFS environmental and technical services division. Portland, OR.

This document states that the 1991 system for management of water in the Columbia River basin does not provide flows that move fall chinook salmon sub-yearling migrants expeditiously through the reservoirs.

1991 National Marine Fisheries Service. 1991. Factors for decline, a supplement to the determination for Snake River spring/summer chinook salmon under the endangered species act. NMFS environmental and technical services division. Portland, OR.

This document states that; " In reservoirs, loss of juvenile migrants is closely related to travel time" No evidence is given to support this statement. The document does cite Raymond 1979 as a source for increased travel time data.

1992 Beeman, J. D., and D. W. Rondorf. 1992. Effects of flow and smoltification on the migration rates of spring chinook salmon. . In: Passage and survival of juvenile chinook salmon migrating from the snake river basin. Proceedings of a technical workshop,, University of Idaho, February 26-28, 1992. Pp91-106.

This study summarizes analyses of gill ATPase activity levels, river flows, and migration times of juvenile spring chinook salmon. The model of spring chinook migration through a Snake River reach, indicates both flow and ATPase activity are important variables in explaining variation in migration time. The gill ATPase variable appeared to be more influential then the flow data, however the years data were collected had a narrow range of flows. With a wider range of flows the influence of the flow variable would have increased.

1992 Kreeger, K. Y. and W. J. McNeil. 1992. A literature review of the factors associated with migration of juvenile salmonids. For Direct Service Industries Inc.

The authors review over 90 references and summarize that, "...speed and time of migration are associated with age and size of juveniles as well as with time. Older and larger smolts tend to migrate faster and earlier then younger and smaller smolts. Smolts migrating earlier tend to move more slowly then smolts migrating late."

1992 Marsh, D. M., and S. Achord. 1992. A comparison of PIT-tagged spring and summer chinook salmon detection rates with Snake River flows at Lower Granite Dam. In: Passage and survival of juvenile chinook salmon migrating from the snake river basin. Proceedings of a technical workshop,, University of Idaho, February 26-28, 1992. Pp. 88-90

In 1989, 1990, and 1991 flows at LGD differed substantially during spring salmonid out-migration, "...flow had little effect on the dynamics of the out-migration of hatchery or wild spring/summer chinook populations. There was virtually no difference in fish movement patterns for the three years in each of the three groups of chinook salmon. Since flow at Lower Granite Dam had little effect on the passage pattern of PIT-tagged fish, we believe that other environmental and physiological factors, in addition to flow, influenced the movement patterns of fish."

1992 Petrosky, C. E. Analysis of flow and velocity effects on smolt survival and adult returns of wild spring and summer chinook salmon. In: Passage and survival of juvenile chinook salmon migrating from the snake river basin. Proceedings of a technical workshop,, University of Idaho, February 26-28, 1992. Pp 107-120.

This paper presents an overview of the NMFS smolt survival data set and reports the following. "Yearling chinook smolt survival rates from NMFS studies in 1970-80 are significantly related to flow and water velocity for aggregate wild/natural and hatchery fish. Smolt-to-adult returns were significantly correlated with water particle travel times for wild spring chinook from Marsh Creek, Idaho, as well as for Snake River aggregate spring and summer chinook and steelhead of wild/natural origin."

1994 Cada, G. F., M. D. Deacon , S. V. Mitz, and M. S. Bevelhimer. 1994. Review of information pertaining to the effect of water velocity on the survival of juvenile salmon and steelhead in the Columbia River basin. Prepared for the U.S. Department of Energy, contract No. DE-AC05-84OR21400.

The authors reviewed over 130 references and concluded that. "Despite the problems with existing data sets, the general relationship of increasing flow in the Columbia River Basin still appears to be reasonable." Flow survival models tend to produce similar results at low flows, but diverge in their predicted survivals at higher flows, therefore the bounds for this relationship are presently undetermined.

1994 Steward, C. R. 1994. Assessment of the flow-survival relationship obtained by Sims and Ossiander (1981) for Snake River spring/summer chinook salmon smolts, final report. Prepared for Bonneville Power Administration, project number 93-013. Portland OR. 78 p.

The author questions the validity and usefulness of the Sims and Ossiander (1981) flow-survival relationship. "From my assessment of the methods and data used by Sims and Ossiander (1981), I recommend that the flow-survival relationships *not* be generalized to existing populations and passage conditions. Fisheries managers, the public, and the fish themselves would be better served by data collected under present conditions using current technological and analytical techniques."

1994 Bevan, D., J. Harville, P. Bergman, T. Bjornn, J. Cruchfield, P. Klingemen, and J. Litchfield. 1994. Snake River Salmon Recovery Team: Final Recommendations to National Marine Fisheries Service.

The authors state that "there is a lack of information on which to base a scientific decision on the size and timing of the water budget that will maximize smolt survival."

1995 National Marine Fisheries Service Biological Opinion 1995

This document provides recommended flows and spills during juvenile salmonid migrations. Endorses transportation as primary mitigation tool: "...it is appropriate to continue to rely on transportation as a major means to mitigate the adverse impacts of the FCRPS."(p.111). "Spill and transportation operations are intended to be interim. Ideally these interconnected programs would be based on a rule curve that establishes the relationship between flow conditions, in-river survivals, and the relative benefits of transportation. " (p.112).

1995 National Marine Fisheries Service. 1995. Basis for minimum flow ranges for operation of the federal Columbia River power systems.

Cites several references that their is a significant relationship between flow and travel time, then states: "At least three mechanisms can be identified that link increased travel time resulting from lower flows to higher mortality". These are: 1) Increased exposure to predators, 2) Later arrival means higher temperatures which means increased predator mortality, and 3) Later arrival means higher river temps which means decreased bypass efficiency.

1995 NMFS. 1995. Proposed recovery plan for Snake River salmon.

This document states that. "In general, there is a direct relationship between juvenile fish survival and flow..."it goes on to say "...it is difficult to determine the exact mechanism by which increased flow increases survival, and it is difficult to establish a particular level as being ideal or necessary. NMFS believes that changes in river management should be made, within the constraints of available water, to increase during the spring and summer salmon migration, restoring to some extent the natural hydrographic conditions under which listed salmon stocks evolved.

1997 Smith, S. G., W. D. Muir, E. E. Hockersmith, S. Achord, M. B. Eppard, T. E. Ruehle, J. G. Williams, and J. R. Skalski. Survival Estimates for the passage of salmonids through Snake River dams and reservoirs, 1996 annual report. Prepared for Bonneville Power Administration. Project 93-29. Portland, OR.

This study uses PIT tag data to reach the following conclusions. The relationship between flow exposure and travel time was relatively strong and consistent between years for both steelhead trout and yearling chinook salmon; higher flows were associated with shorter travel times. There was a decreasing trend in travel time throughout the season that could not be attributed to flow. Relationships between survival probabilities and flow volumes and other exposures were not consistent between years. There was no relationship between flow and survival within years.