6.0 EFFECTS OF PROPOSED ACTION

6.1 ANALYTICAL METHODS

The proposed action has been evaluated using the five-part approach for applying the ESA jeopardy standard to Pacific salmon developed in Section 1.3.

6.1.1 Methods for Evaluating Effects on Action-Area Biological Requirements

6.1.1.1 Methods for Up-River ESUs

6.1.1.1.1 Adult Fish Survival

Data from radio-tracking studies (RT) were used to estimate the minimum survival rates of adults during passage through the hydrosystem. Average rates were calculated from the results of multi-year studies at one or more projects, as well as more recent studies over the full hydrosystem reach. Minimum survival rates were derived by dividing the number of radio-tagged fish detected at an upstream dam by the number of fish tagged minus the number of fish accounted for in the study (i.e., tagged fish that entered tributaries, were taken in harvest, were known to have regurgitated tags, etc.). These estimates are considered minimal because some fish may have survived that were not accounted for. The mean losses in the multi-year project and reach studies, the mean survival rates (1-loss) and the per project survival rates (survivals[1]) are shown in Table 6.1-1. Incorporating data from all of the radio-tracking studies, both multi-year project and reach, provides more rigorous loss/survival estimates.

6.1.1.1.2 Juvenile Fish Survival

The primary method for evaluating the effects of the proposed action on migrating juvenile salmonids in the mainstem Columbia and Snake rivers was through simulation modeling. The Biological Effects Team (BET) [1] used NMFS' SIMPAS model to evaluate the biological effects of current FCRPS facilities and operations and the likely benefits of potential measures to improve juvenile salmonid passage survival. This spreadsheet model, developed by NMFS' Northwest Region hydro division staff, is a fish passage accounting model that apportions the run to various passage routes (i.e., turbines, fish bypass system, sluiceway/surface bypass, spillway, and/or fish transportation) based on empirical data and assumptions for fish passage route use. The model then accounts for "successful fish passage" (survival) and "losses" (mortalities) through each of the alternative passage routes to estimate total survival past each project. The model also accounts for dam plus pool survival, the proportion of juvenile fish

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[1] Since late 1999, NMFS has been engaged in ESA Section 7 consultation with the Federal Action Agencies (the Corps, Bureau and BPA) to develop a Biological Opinion on the effects of the Action Agencies' proposed action and future operation and configuration of the FCRPS projects. To facilitate completion of the Section 7 consultation process, the Federal agencies formed five action teams during January 2000, including the BET.

Table 6.1-1. Estimates of Adult Survival and Loss Based on Radio-Tracking Studies and PIT-tag Data in the Eight Project Reach between Bonneville and Lower Granite Dams

	Adult Loss					**Base and Current Condition**			
	Multi-Year/Project Radio-Tracking Studies		**Single Year Reach Studies**						
	1995 BiOp	**1998 BiOp**	**RT 96[2]**	**RT 97[3]**	**PIT 98[4]**	**Mean Loss[1]**	**Mean Survival[1]**	**Number of Dams**	**Per-Project Survival[1]**
Chinook Salmon									
SR spr/sum chinook	0.209[5]	0.252	0.175	0.192	0.358	0.206	0.794	8	0.972
SR fall chinook	0.393				0.293	0.393	0.607	8	0.940
UCR spr chinook[6]							0.891	4	
LCR spr chinook[6]							0		
LCR fall chinook[7]							0.940	1	
Steelhead									
SR steelhead		0.165	0.244		0.196	0.205	0.796	8	0.972
UCR steelhead[8]							0.892	4	
MCR steelhead[8]							0.892	4	
LCR steelhead[8]							0.972	1	
SR sockeye salmon	0.154					0.154	0.846	8	0.979

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[1] Based on radio-tracking studies only.
[2] T. Bjornn, pers. comm., January 2000 (preliminary data from 1996 radio-tracking study).
[3] T. Bjornn, pers. comm., January 2000 (preliminary data from 1997 radio-tracking study).
[4] Fish detected at Lower Granite Dam as juveniles and at Bonneville and Lower Granite dams as adults (source: PITAGIS Database).
[5] Not included in loss/survival estimates (1998 estimate is an update of 1995 estimate).
[6] Calculated from SR spring/summer chinook salmon per-project survival rates.
[7] Calculated from SR fall chinook salmon per-project survival rates.
[8] Calculated from SR steelhead per-project survival rates.

transported, and the proportion left to migrate inriver, the system survival of inriver and transported fish combined, and the survival of inriver fish alone.

The BET reviewed and analyzed fish passage assumptions used by NMFS in earlier fish passage modeling exercises, those developed in the PATH process, and the most recent empirical data information to determine the fish passage parameters for input into the SIMPAS model. The team also used the latest compilation of fish passage information contained in the four white papers recently prepared by the Northwest Fisheries Science Center on (a) "Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams"; (b) "Salmonid Travel Time and Survival Related to Flow in the Columbia River Basin"; (c) "Predation on Salmonids Relative to the Federal Columbia River Power System"; and (d) "Summary of Research Related to Transportation of Juvenile Anadromous Salmonids Around Snake and Columbia River Dams" (NMFS 2000*a,b,c,d*). Detailed descriptions of the SIMPAS model and the results of various simulations are provided in Appendix B.

6.1.1.2 Application to All 12 ESUs

The methods described above are applied to the relatively robust empirical data sets for SR spring/summer chinook salmon (yearlings), SR fall chinook salmon (subyearlings), and SR steelhead migrants. The results are applied to the remaining chinook salmon and steelhead ESUs for which the empirical data are lacking. Because juvenile survival studies do not exist for CR chum salmon, mixed stock LCR fall chinook salmon were used to estimate passage survival through the Bonneville project for this ESU. No adult fish passage studies are available for CR chum salmon. Because juvenile survival studies either do not exist or are inadequate for this purpose, for sockeye salmon, passage survival cannot be evaluated for this ESU.

NMFS assesses the effects of the proposed action on action area-level biological requirements in a qualitative manner for all 12 ESUs, the effects of the proposed action on critical habitat types (i.e., juvenile rearing areas, juvenile migrations corridors, areas for growth and development to adulthood, adult migration corridors, and spawning areas) within the action area. The purpose of the evaluation is to determine whether any of the constituent elements of critical habitat are likely to be adversely modified or destroyed under the proposed action.

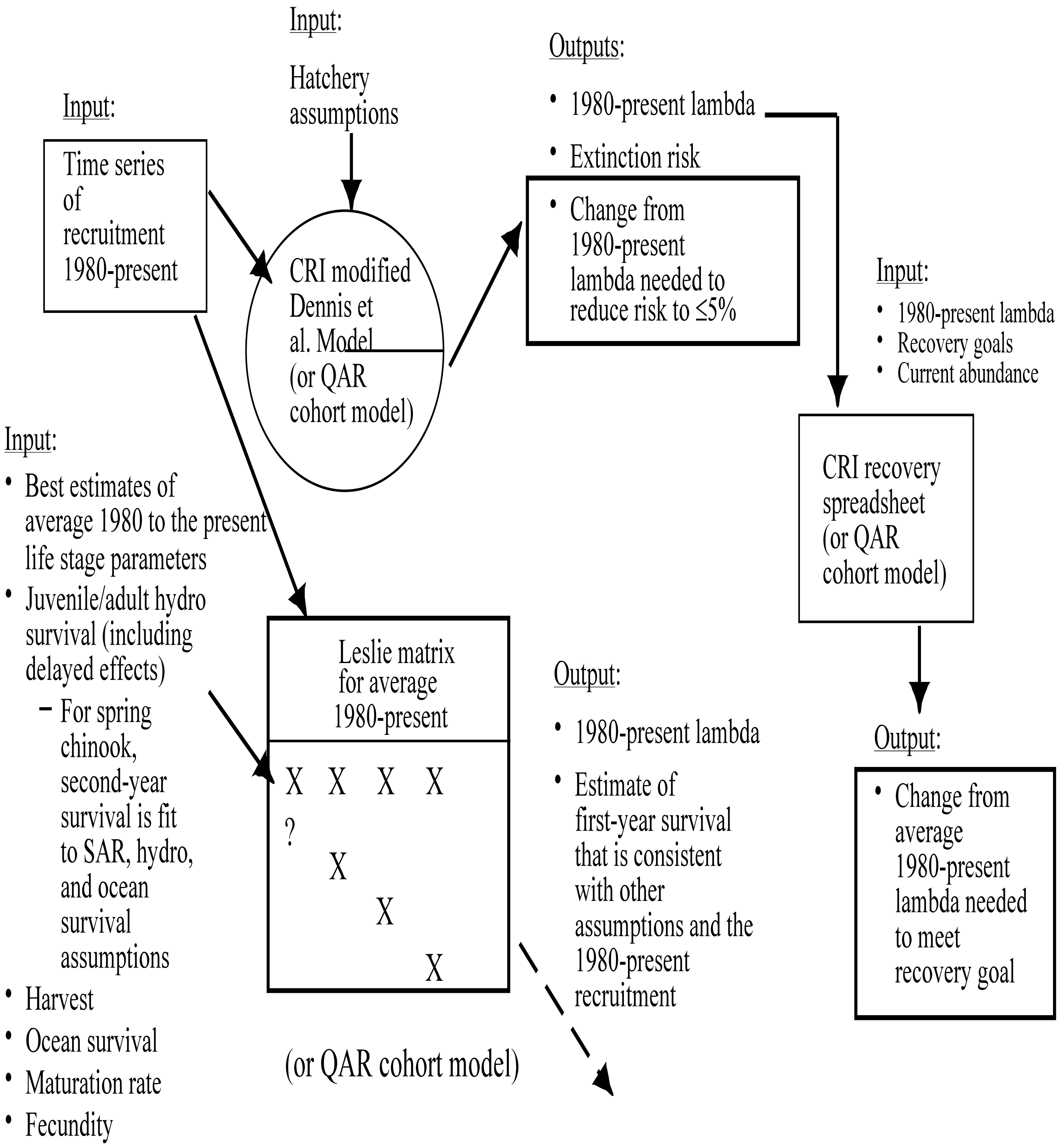
6.1.2 Methods for Evaluating Effects of Hydrosystem Actions on Species-Level Biological Requirements

6.1.2.1 General Method For Up-River ESUs

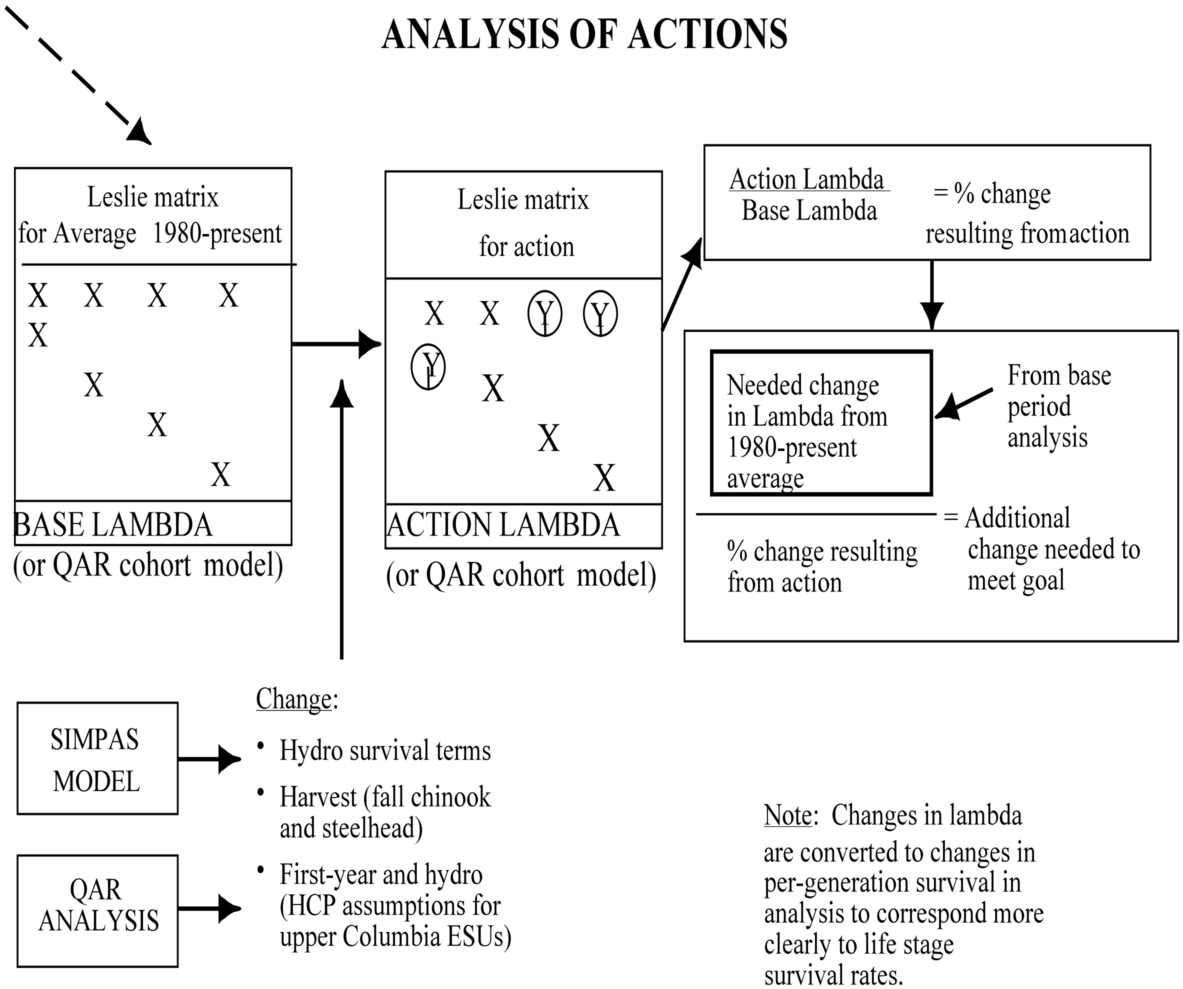
The effects of the proposed action within the action area (Section 6.1.1) must be evaluated within the context of survival throughout the life cycle and compared with the jeopardy standard that is described in Section 1.3.1.1. For five Snake River and Upper Columbia River ESUs, a quantitative approach was taken. Briefly, the analysis includes the steps illustrated in Figure 6.1-1.

Figure 6.1-1. Schematic of Methods Used to Estimate Necessary Survival Changes and to Compare with Expected Survival Changes resulting from the Proposed Action (See text for details)

BASE PERIOD ANALYSIS



ANALYSIS OF ACTIONS



Note: Changes in lambda are converted to changes in per-generation survival in analysis to correspond more clearly to life stage survival rates.

1) Define the proportional change in survival that is necessary to meet the jeopardy standard. The starting point is the NMFS CRI (for 11 ESUs) and QAR (for Upper Columbia River ESUs) assessments of risk, based on adult returns during a series of recent years. These assessments also define the change in annual population growth rate (lambda) that is needed to reduce the risk to levels associated with the jeopardy standard indicator metrics described in Section 1.3.1.1. Two models are used to generate these estimates: a modified Dennis model (CRI) and a cohort replacement model (QAR). Appendix Tables A6, A7, [and others to be added in next draft] define the needed change for each indicator metric in terms of lambda. For convenience, this is converted in the effects analysis to needed changes in per-generation survival (egg-to-adult survival) to place the needed survival change into the same units as the life-stage survival rates estimated in steps 2 and 3.

2) Define the life-stage-specific survival rates that correspond to the adult return observations included in the risk assessment. The risk assessment in step 1 is based on abundance and trends in adult returns during some set of recent years. In this biological opinion, these years are referred to as a base period, which for most ESUs represents the 1980 brood year through the most recently available return year (anywhere from 1996 to 1999, depending on ESU, or with projections to 2004 for two ESUs). To evaluate how new actions that affect only certain life stages may change the base risk, there first has to be an understanding of the mean survival rate in each of those life stages during the base period. Where possible, a simple deterministic model called a Leslie matrix is set up to represent the best estimate of average survival through all but one life stage during the base period. This matrix also incorporates age-specific maturity rates and fecundity estimates. The one “unknown” survival rate is adjusted until the overall combination of estimated life-stage survivals fits the base spawner return observations.

3) Define the life-stage specific survival rates associated with the proposed action and with expected changes in other life stages. FCRPS juvenile survival and adult survival resulting from the proposed action are estimated through methods defined in Section 6.1.1. Expected survival in other life stages, based on actions defined in the All-H Paper, is also estimated. The relevant survival terms in the base matrix are then updated to reflect the expected changes. A new per-generation survival rate, representing the combination of the various life-stage survival changes, is estimated with the new matrix. The new matrix, representing effects of the proposed action and other expected actions defined in the All-H Paper, is referred to in subsequent sections as the current matrix.

4) The change in survival resulting from the proposed action is compared with the needed change defined in step 1. Ratios are constructed that indicate the degree to which the proposed action achieves the change in survival that is indicative of meeting the jeopardy standard. Results presented in subsequent sections display these ratios such that results less than, or equal to, 1.0 indicate that the jeopardy standard indicator metrics are met, given the effects of the proposed action and other expected activities. Values greater than 1.0 indicate that additional improvements in survival are necessary to meet the criterion. These values represent the multiplier by which survival, after the proposed action and other expected actions have been implemented, must be additionally increased.

6.1.2.2 Detailed Methods and Assumptions

<This section is not complete, but will be available later on request from NMFS. Many of the species-specific methods and assumptions are reviewed in the results section of this draft.>

6.1.2.3 Application to All 12 ESUs

The quantitative methods described above cannot be applied to all ESUs because either information on adult-to-adult returns, survival in individual life stages, or effects of the proposed action are unavailable or are inadequate for this type of analysis. These methods are applied to only 5 ESUs (SR spring/summer chinook, SR fall chinook, and UCR spring chinook salmon and SR and UCR steelhead). Fish from these ESUs must traverse at least 4 FCRPS projects during both their juvenile and adult migrations. NMFS assumes that if operation of the FCRPS under the proposed action meets the species-level biological requirements of these ESUs, it is likely that the biological requirements of other species will also be met. For example, as described in Section 6.2, empirical studies suggest that SR steelhead have the same or higher passage survival than SR spring/summer chinook salmon (see NMFS' 1998 Supplemental FCRPS Biological Opinion). This is also likely to be the case for MCR steelhead, which pass the same number of Federal projects as UCR spring chinook salmon and steelhead. Although SR sockeye salmon also pass 8 FCRPS projects, too few of this species exist to make a quantitative assessment of survival through the hydrosystem.

The effects of the proposed action on species-level biological requirements can be assessed in a qualitative manner for all 12 ESUs. That is, NMFS considers the effects of the proposed action on critical habitat within the action area (see above) in the overall context of all of the effects on biological requirements throughout the life cycle. This evaluation draws on a review of the existing literature, including the information summarized in Section 4.1 and Appendix A. Adverse effects on individuals of a species or constituent elements or segments of critical habitat generally do not result in jeopardy or adverse modification determinations unless that loss, when added to the environmental baseline, is likely to result in significant adverse affects throughout the species range, or appreciably diminish the capability of the critical habitat to satisfy the essential requirements of the species (Section 7 Consultation Handbook, p. 4-34). Therefore, NMFS evaluates the range of critical habitat types affected by the proposed action, the geographic scope of the effects, and the degree to which the effects are likely to limit the productivity of each ESU.

6.2 EFFECTS OF FCRPS OPERATIONS – ACTION AREA BIOLOGICAL REQUIREMENTS

Development of the Pacific Northwest regional hydroelectric power system, dating to the early twentieth century, has had profound effects on the ecosystems of the Columbia River basin (ISG 1996). These effects have been especially adverse to the survival of anadromous salmonids. The direct effects of the construction of the Federal Columbia River Power System (FCRPS) on salmon and steelhead in the Columbia basin can be divided into four categories: blockage of habitat; alteration of habitat; barrier to, or modification of, juvenile migration; and barrier to, or modification of, adult migration. Where no fish passage facilities have been provided, hydroelectric dams totally block anadromous fish runs on the river. In addition, dams inundate historical spawning and rearing habitat. For salmon and steelhead, much of this effect occurred when Grand Coulee (1941) and Chief Joseph (1961) dams on the Columbia River, and the Hells Canyon Complex (1959) on the Snake River were constructed. More than 55% of the Columbia River basin accessible to salmon and steelhead before about 1939 has been blocked by large dams (Thompson 1976).

Dams present barriers to the upstream and downstream migrations of anadromous fish. A significant rate of juvenile injury and mortality occurs during downstream passage. Physical injury and direct mortality result from passage through turbines, juvenile fish bypasses, and to a lesser degree, spill. Indirect effects of passage through all routes may include disorientation, stress, delay in passage, exposure to high concentrations of dissolved gases, exposure to warm water, and potential cumulative effects of above. Although the direct mortality of adults is probably minimal during passage at individual dams, each dam presents the potential for delays at fishway facilities, energy expenditure in passage through multiple fishways, involuntary fallback, and, during periods of involuntary spill, increased exposure to high concentrations of dissolved gasses.

The impoundments created by the FCRPS dams greatly increased cross-sectional area in much of the Columbia and lower Snake rivers, reducing water velocity and water particle travel times in the impounded river reaches. Operation of upriver storage reservoirs to regulate water modifies the natural hydrograph and affects the listed species throughout the action area, from the upriver storage reservoirs to the Columbia River plume. Water regulation reduces flows (volume per unit time) to less than those that would naturally occur during spring and early summer.

Water regulation and impoundment also change water quality factors such as water temperatures and turbidity, as well as the production of salmonid prey. Reservoirs provide habitat for salmonid predators. Channel complexity is reduced, affecting fluid dynamics (e.g., ISG 1996) and substrate types. Load-following operations at hydrosystem projects (hourly and daily load following and reduced weekend flows) can affect access to suitable spawning habitat and can trap and strand both adults and juveniles.

6.2.1 Effects on Habitat in the Columbia River Mainstem, Estuary and Plume

The lower Columbia River and estuary habitats have been affected over the past 60 years by the series of mainstem hydrosystem reservoirs and by operation of upstream multipurpose storage projects. These impoundments have also inundated large amounts of salmon spawning and rearing habitat. Historically, fall chinook salmon spawned in mainstem reaches from near The Dalles, Oregon, upstream to the Pend Oreille and Kootenai rivers in Idaho and to the Snake River downstream of Shoshone Falls. Presently, mainstem production areas for fall chinook are confined to the Hanford Reach of the Columbia River, the Hells Canyon Reach of the Snake River, the mid-Columbia River, and below the lower Snake River projects and Bonneville Dam. The Hanford Reach is the only known mainstem spawning area for steelhead. Spawning habitat used historically by LCR chinook and CR chum salmon and by LCR steelhead was probably inundated by Bonneville pool, as well.

The mainstem habitats of the lower Columbia and Willamette rivers has been reduced primarily to a single channel; floodplains have been reduced, off-channel habitat features have been eliminated or disconnected from the main channel, and the amount of large woody debris in the mainstem has been greatly reduced. Finally, most of the remaining habitats are affected by flow fluctuations associated with reservoir water management for power peaking, flood control, irrigation, and other operations.

The Columbia River estuary has also been changed by human activities. Historically, the downstream half of the estuary was a dynamic environment with multiple channels, extensive wetlands, sandbars and shallow habitat areas. Winter and spring floods, low flows in late summer and fall, large woody debris floating downstream and a shallow bar at the mouth of the Columbia River contributed to the estuary's dynamic nature. Today, navigation channels are dredged, deepened, and maintained; jetties and pile-dike fields stabilize and concentrate the flow in navigation channels; and causeways and their support structures cross waterways. Many wetlands in the upper reaches of the estuary have been diked and drained and converted to industrial, transportation, recreation, agricultural or urban use. More than 50% of the original marshes and spruce swamps in the estuary have been lost (Lower Columbia River Estuary Program 1999). As a result, the width of the Columbia River at its mouth has decreased from four to only two miles and the depth of the channel at the bar has increased from less than 20 to more than 55 feet. Sand deposition has extended the Oregon coastline at the mouth about four miles and the Washington coastline about two miles farther seaward (Thomas 1981).

Large multipurpose storage projects, developed in both Canada and the United States, have altered the seasonal runoff pattern and volume of flow into the estuary. Recent model studies by Casillas et al. (in prep.) indicate that the volume and timing of water and sediment delivery has changed since the late 1880s due to hydrosystem operation, even after the effects of climate change and irrigation withdrawals are taken into account. Compared to the 1880s, current operations do the following:

1. Deliver more water to the estuary during winter (October through April) and less water during spring and summer

2. Reduce the peak spring freshet by more than 40% and reduce total freshet-season flow volume by about 30%

3. Lengthen the period of the freshet and move the peak flow earlier (by pre-releasing stored water for flood control, which interacts with recent climate change)

4. Greatly increase fall-winter minimum flows

In addition, the model studies indicate that the hydrosystem and climate change together have decreased suspended particulate matter to the lower river and estuary by about 40% (as measured at Vancouver, Washington) and have reduced fine sediment transport by 50% or more. Overbank flow events, important to habitat diversity, have become rare – in part because flow management and irrigation withdrawals prevent high flows and in part because diking and revetments have increased the "bankfull" flow level (from about 18,000 to 24,000 m^3/s). The dynamics of estuarine habitat have changed in other ways relative to flow: the availability of shallow (between 10 cm and 2 m depth), low velocity (less than 30 cm/s) habitat now appears to decrease at a steeper rate with increasing flow than during the 1880s and the resilience of the estuary to increasing water depth with increasing flow (absorption capacity) appears to have declined.

The significance of these changes to salmonids is unclear at the present time. Estuarine habitat is likely to provide services (food and refuge from predators) to subyearling migrants that reside in estuaries for up to 2 months or more (Casillas 1999 NWPPC Ocean Symposium). Historical data from Rich (1920 citation on Casillas' ISAB slides) indicated that small juvenile salmon (< 50 mm), which entered the Columbia River estuary during May, grew 50 to 100 mm during June, July, and August. Data from a more contemporary period (Dawley et al. 1985; E. Dawley unpubl. [CREDDP] data citations on Casillas' ISAB slides) show neither small juveniles entering the estuary in May or growth over the summer season.

The Columbia River plume also appears to be an important habitat for juvenile salmonids, particularly during the first month or two of ocean residence. The plume may simply represent an extension of the estuarine habitat. More likely, it represents a unique habitat created by interaction of the Columbia River freshwater flow with the California Current and local oceanographic conditions. Ongoing studies show that nutrient concentrations in the plume are similar to nutrient concentrations associated with upwelled waters. Upwelling is a well recognized oceanographic process that produces highly productive areas for fish; primary productivity, and more importantly the abundance zooplankton prey, are higher in the plume compared to adjacent non-plume waters. Further, salmon appear to have a preference for low surface-salinity waters, as the abundance and distribution of juvenile salmon are higher and concentrated in the Columbia River plume compared to adjacent, more saline waters. These findings support the notion that the plume is an important habitat for juvenile salmonids. What is not known is how Columbia River flows affect the structure of the plume during outmigration periods and whether critical threshold flows are needed. Ongoing research will document important relationships between juvenile salmon growth and survival during this stage of their life history.

6.2.2 Effects of Project Operations on Juvenile Salmonid Passage - General Considerations

The presence of dams in the migratory corridor results in some migrational delay (Raymond 1969, 1979), thereby influencing migration speed and timing of juveniles. Additionally, dams impede safe passage of juveniles. Some juvenile mortality is associated with all routes of passage at dams, with highest mortality occurring through turbines (e.g., reviewed in Whitney et al. 1997) and lowest direct mortality through spillways (NMFS 2000a). Some passage routes have additional effects, such as the increase in total dissolved gas (water quality) caused by spill.

For SR and UCR chinook salmon and steelhead, the primary method for evaluating the effects of the proposed action on the biological requirements of listed species in the action area used in this biological opinion is an analysis of effects on survival. An important objective of project operations is to increase survival by routing a high proportion of juveniles past the projects in a manner that avoids passage through turbines. The proportion of smolts that pass a project through bypass systems or over spillways, project FPE (fish passage efficiency), varies by species composition and may vary within a season and between years for a single species with changes in smolt condition, environmental conditions, and project operations.

6.2.2.1 Juvenile Salmonid Passage Through Turbines - General Considerations

Turbine survival studies for juvenile passage published through 1990 at the Snake and lower Columbia River dams have been reviewed by Iwamoto and Williams (1993). The Independent Scientific Group (ISG 1996) and Whitney et al. (1997) reviewed studies published through 1995. Turbine mortality has been estimated primarily for juvenile salmon, although at least two studies have estimated steelhead mortality (Weitkamp et al. 1986; Olson and Kaczynski 1980). Whitney et al. (1997) pointed out that in studies where marked fish were immediately recovered in the tailrace, mortality estimates were less than 7% (average 5.5%). In studies with longer times between turbine passage and recovery, mortality levels averaged 10.9% (Whitney et al. 1997. Whitney et al. (1997) also suggested that the lower survival estimates probably included some level of mortality associated with predation on disoriented smolts after turbine passage. That is, turbine passage not only causes direct mortality but may cause indirect mortality by increasing susceptibility to predation.

6.2.2.2 Juvenile Salmonid Passage Through Bypass Systems - General Considerations

Estimates of the direct survival rate of juvenile salmon and steelhead through bypass systems includes mortality rates associated with turbine intake screens, gatewells, orifices, bypass flumes, dewatering screens, sampling facilities (including holding tanks), and bypass outfall conduits. Although direct survival through mechanical screen bypass systems is higher than through turbines, fish transiting bypass systems often exhibit increased signs of stress (compared to control groups) as measured by blood chemistry, increased descaling, and possibly delayed mortality (NMFS 2000a). Estimates of direct bypass mortality found at sampling facilities for the bypass systems at the Federal hydroelectric projects on the Snake and lower Columbia rivers suggest that the direct mortality of wild yearling steelhead and chinook salmon is generally less than 1% (Martinson et al. 1997; Spurgeon et al. 1997; summarized in NMFS' 1998 FCRPS Supplemental Biological Opinion), although some level of stress or injury may result in mortality later in the life cycle. Bypass survival may be indirectly affected by predation at poorly located outfall sites or by delayed mortality associated with injury or stress caused by passing through one or more bypass systems. Juvenile salmon and steelhead may be especially vulnerable to predation in bypass system outfalls that concentrate fish into relatively small volumes of water.

6.2.2.3 Juvenile Salmonid Passage Through Spill - General Considerations

Whitney et al. (1997) reviewed 13 estimates of spill mortality published through 1995 (three for steelhead and 10 for salmon) and concluded that the most likely range in mortality for standard spill bays is 0 to 2%. However, the authors also pointed out that the presence of local conditions such as back eddies or other features that provide refuge for predators may lead to higher levels of spillway passage mortality. In general, relative to other passage routes currently available, direct juvenile survival is highest through spillbays (NMFS 2000a). Although the FCRPS is currently managed to meet total dissolved gas (TDG) standards, concentrations may rise to levels that induce gas bubble trauma (GBT) in salmonids under high levels of involuntary spill, reducing the survival of both the juvenile and adult life stages. This concern emphasizes the importance of the physical and biological TDG monitoring programs at the Federal dams.

6.2.2.4 Juvenile Inriver Reach Survival - General Considerations

Williams et al. (unpublished manuscript in review) expanded the 1960s and 1970s estimates of direct survival of yearling salmonid migrants from the head of the upstream reservoir (Ice Harbor Dam through 1968, Lower Monumental Dam in 1969, Little Goose Dam from 1970 to 1974, and Lower Granite Dam since 1975) to the tailrace of Bonneville Dam, and compared these with expanded 1993 through 1999 estimates. During the 1960s, with four dams in place, direct survival of yearling migrant fish through the hydrosystem was 32 to 56%. Four more dams were constructed between 1968 and 1975. Estimates of system survival during the 1970s typically ranged from 10 to 30%, but were less than 3% for the drought years 1973 and 1977. During the most recent period, 1995 to 1999, system survival of SR spring/summer chinook salmon has ranged from 42 to 59%, substantially higher than during the 1970s and similar to 1960s levels.

The recent increase is probably the result of good flow conditions combined with implementation of the project operations and fish passage improvements prescribed in the NMFS' 1995 FCRPS Biological Opinion.

The rate of survival of subyearling fall chinook salmon through the hydrosystem is lower than that of yearling chinook salmon. During the 1995 through 1999 outmigrations, NMFS PIT-tagged Lyons Ferry Hatchery subyearling fall chinook salmon and released them above Lower Granite Dam. Survival from the point-of-release in a free-flowing reach of the Snake River to the tailrace of Lower Granite Dam averaged from about 55% for the earliest releases to about 13% for groups released in early July, coinciding with substantial increases in water temperature and decreases in flow and turbidity. These survival estimates incorporate the effects of mortality during rearing (i.e., from parr to active migrant stage), migration through free-flowing reaches, and through Lower Granite Reservoir and Dam. In the reach between the tailrace of Lower Granite Dam and that of Lower Monumental Dam (i.e., encompassing two dams and reservoirs), the survival of summer migrants was estimated within a season and for a given season, among years. Weekly estimates of survival averaged from about 11 to 68%; the lowest pertaining to releases later in the season when environmental conditions were relatively poor (e.g., high water temperature, low flow, and low turbidity). Survival of run-of-the-river subyearling chinook salmon from the tailrace of McNary Dam to the tailrace of John Day Dam was approximately 41.0 and 77.5% in 1998 and 1999, respectively. Estimates of subyearling chinook salmon survival through this reach before the development of the hydrosystem are lacking and thus cannot be compared to recent estimates. However, the recent estimates suggest that passage through the hydrosystem results in high mortality rates for Snake River subyearling chinook salmon during the summer when environmental conditions deteriorate. One caveat to this conclusion is that, based on preliminary data, juvenile subyearlings detected in the Snake River for the first time during September and October have adult return rates that are approximately five-times higher than those of subyearlings detected during summer.

6.2.3 Specific Effects of FCRPS Operations on Juvenile Salmonid Passage and Survival

6.2.3.1 Juvenile Salmonid Passage Through the Turbine Units at FCRPS Projects

In recent years, evaluations of turbine mortality have been conducted under the turbine operations presumed to provide the best conditions for fish (i.e., operations within 1% of peak efficiency). The NMFS' studies of turbine survival for yearling chinook in the Snake River produced estimates of 92.0, 86.5 and 92.7% at Little Goose, Lower Monumental and Lower Granite dams in 1993, 1994 and 1995, respectively. Steelhead survival from turbine passage at Little Goose Dam in 1997 was 93.4% (Muir et al., In review: N. Am. J. Fish. Management.).

The Biological Effects Team (BET) and NMFS[2] used the SIMPAS model to calculate juvenile passage survival rates through the dams under the proposed action (current conditions). Inputs included turbine survival rates that ranged from 90 to 93% for yearling chinook and steelhead migrants and rates that ranged from 90 to 94% for subyearling migrants (the particular rate used for each dam is listed on Tables B-1 through B-3 in Appendix B). These turbine survival estimates are based on information presented in NMFS (2000a), Marmorek et al. (1998), Ledgerwood et al. (1990), and were calibrated using survival estimates developed for the reach between the tailwater of Little Goose Dam to that of Lower Monumental Dam.

6.2.3.2 Juvenile Salmonid Passage Through the Bypass Systems at FCRPS Projects

The FCRPS dams use two submersible fish screen designs to guide fish away from turbine intakes and into juvenile bypass systems: a standard-length submersible traveling screen (STS) and an extended-length submersible bar screen (ESBS). STSs are currently installed at Lower Monumental, Ice Harbor, John Day, and Bonneville dams. ESBSs are currently installed at Lower Granite, Little Goose, and McNary dams. The Dalles Dam does not have a mechanical screen juvenile bypass system.

Intake screens guide migrating juveniles from turbine intakes into gatewells. Fish guidance efficiency (FGE) is a measure of how efficiently intake screens guide juveniles out of turbine intakes. Higher FGE equates with higher diversion of the migrants away from turbine passage and into the bypass system. To calculate juvenile passage survival rates through the dams under the proposed action (current conditions) with the SIMPAS model, the BET and NMFS used FGE rates that ranged from 39 to 83% for yearling chinook, 9 to 62% for subyearling chinook migrants, and 41 to 93% for steelhead migrants. The particular fish guidance rate selected for each dam is listed in Tables B-1 through B-3 in Appendix B. These FGE rates are based on information from NMFS' 1998 FCRPS Supplemental Biological Opinion, NMFS (2000x 1/28/00 memo to Hydro files), NMFS (2000a), and Marmorek et al. (1998).

Once guided into gatewells by intake screens, fish exit through orifices to a collection channel traveling the length of the powerhouse. The channel conveys fish and the orifice flow directly to the tailrace or to a dewatering facility. The dewatering facility reduces bypass system flow to approximately 30 to 40 cfs and then the fish, with the remaining water, are sent via flume to a tailrace outfall or to a holding facility for transportation. Smolt monitoring facilities installed at projects with key bypass systems collect data for estimating species composition, fish condition,

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[2] To facilitate completion of the Section 7 consultation process, the Federal agencies formed five action teams during January 2000. The Biological Effects Team (BET) was charged with estimating the effects of current operations and potential future configurations and operations on the survival of listed juvenile outmigrants. This information was used by NMFS to analyze the listed species' biological requirements in the action area, as well as at the species level. The team included Federal biologists and engineers representing NMFS, the Corps, and BPA. NMFS' Hydro Program staff picked up where the BET analysis left off to complete the biological effects analysis described in this section and in Appendix B.

run timing, and other passage indices. PIT-tagged fish can be detected at these facilities, the time and date of passage noted, and fish diverted for further evaluation, if needed.

Design criteria for mechanical screen bypass systems are described in NMFS (1995b Juvenile Fish Screen Criteria), Corps' bypass system design memoranda (Corps 1995a, 1996a, 1999a), the Corps' annual Fish Passage Plan (Corps 1999d), and the Corps' manual of intake design guidelines (Corps 1995). NMFS' guidelines for locating and designing bypass outfalls are presented in NMFS (1995b).

Bypass system survival has been evaluated using recoveries of marked fish. These estimates include both direct and at least a portion of any indirect effects of bypass systems, depending on where the tagged fish are recaptured and whether (and where) any indirect losses occur. Muir et al. (1995a, 1996, 1998) reported that survival through bypass systems at Snake River dams, based on PIT-tagged fish released into the collection channel, ranged from 95.4 to 99.4% for yearling chinook and from 92.9 to 98.3% for steelhead. Estimated survival was 95.3% for steelhead that passed through the entire bypass system at Little Goose Dam in 1997 (Muir et al. 1998). Ledgerwood et al. (1994) evaluated survival through the Bonneville First Powerhouse juvenile bypass system. They found that recoveries of marked (coded-wire tagged) subyearling chinook in the Columbia River estuary were significantly lower for fish released into the bypass system than for fish released 2.5 km downstream.

To calculate juvenile passage survival rates through the dams under the proposed action (current conditions) with the SIMPAS model, BET and NMFS used bypass survival rates that ranged from 90 to 99% for yearling chinook, 82 to 98% for subyearling chinook, and 90 to 98% for steelhead migrants. The particular bypass survival rate used for each dam is listed on Tables B-1 through B-3 in Appendix B. These bypass survival rates are based on information presented in the NMFS (2000a), Marmorek et al. (1998), Ledgerwood et al. (1990), and Muir (1999 = NMFS unpubl. data ?).

6.2.3.2.1 Juvenile Salmonid Passage Through the Spillways and Sluiceways at FCRPS Projects. The spillway of any FCRPS dam consists of a forebay, multiple spill gates, an ogee, a stilling basin, and a tailrace. Most spillway gates are built from a radial design with a 60-foot radius and 50-foot width. The spillways at Bonneville and McNary dams have vertically-operated lift gates of similar width. The number of gates per spillway varies from 8 to 10 at lower Snake River dams to 18 to 23 at lower Columbia River dams. The ogee section functions to transition spillway flow from below the gates to the stilling basin. Most FCRPS dams are equipped with flow deflectors that help reduce the amount of dissolved gas produced at a given level of flow; these are located on the ogee sections at elevations specific to each project.

The level of spill and daily and seasonal timing currently provided for fish passage at FCRPS dams is specified in NMFS'1998 Supplemental FCRPS Biological Opinion (see Table III-2) and in Appendix A to NMFS' Passage White Paper (NMFS 2000a). Current estimates of spill effectiveness (the proportion of fish approaching a project that pass via the spillway) for FCRPS dams are listed in Tables B-1 through B-3 in Appendix B. Spill efficiency is calculated as spill effectiveness divided by the proportion of total river flow passing over the spillway during the evaluation period. Spill efficiency and effectiveness have been reviewed recently by Steig (1994), Giorgi (1996), Whitney et al. (1997), and Marmorek and Peters (1998). Estimates of spill efficiency vary by project and the values used by BET and NMFS as inputs to the SIMPAS model are listed in Tables B-1 through B-3 in Appendix B. These rates are based on information presented in Marmorek et al. (1998 March 1998 PATH report), Ploskey 1999, Eppard 1999, USGS 1999, Hansel et al. (1999), and, where empirical data were not available, on NMFS' best professional judgement.

Data on juvenile spillway passage survival for FCRPS dams are summarized in NMFS (2000_, p. 64 and Table 9 Passage White Paper). To calculate juvenile passage survival rates through the dams under the proposed action (current conditions) with the SIMPAS model, the BET and NMFS used spillway survival rates that ranged from 90 to 100% for yearling chinook salmon and steelhead migrants and from 88 to 98% for subyearling chinook (see Tables B-1 through B-3 in Appendix B). These rates are based on information presented in NMFS (2000_ Passage White Paper), Marmorek et al. (March 1998 PATH report), Dawley (1999), Homes (1952), and Ledgerwood et al. (1990), and were calibrated using the 1999 estimate of survival in the reach from the tailwater of Little Goose Dam to that of Lower Monumental Dam.

In its Predation White Paper, NMFS (2000_) identifies a key issue that connects these fish passage spill programs with predation at the FCRPS dams. Predator concentrations are typically highest in the immediate forebays and tailraces of dams, areas where smolts are delayed and where structures and back-eddies (refuge for predators) and disorientation make smolts particularly vulnerable. Because the effects of spill volume, spill patterns, and spill duration (e.g., 12- versus 24-hour) on forebay and tailrace survival are unknown (NMFS 2000_, p. 35 Predation White Paper) NMFS considers the effect of dam operations on smolt predation a critical uncertainty.

The NMFS' SIMPAS spreadsheet model combines turbine, bypass, and spillway survival rates with FGE, spill efficiency, and diel passage rates to estimate the survival of juvenile migrants at each FCRPS dam. Diel passage rates are the proportion of juvenile migrants passing during the day and during nighttime hours. The nighttime rates that the BET and NMFS used as inputs to the SIMPAS model are listed in Tables B-1 through B-3 in Appendix B. For yearling and subyearling chinook and steelhead migrants, these range from 50 to 83%, varying by dam and season (NMFS 2000_ Passage White Paper, Marmorek et al. 1998 March 1998 PATH report, Kuehl 1986, Biosonics 1998, HTI 1989, Parametrix 1986, and, where empirical data were not available, NMFS' best professional judgement).

6.2.3.3 Estimates of Post-Bonneville Juvenile Mortality Related to Passage Through the FCRPS Under the Proposed Action

Any mortality of juvenile salmonids that occurs after fish have passed Bonneville Dam can be caused by natural processes such as predation, competition, effects of ocean productivity on growth and health, and climate-induced effects on habitat quality. However, mortality can also be related to a variety of anthropogenic factors such as poor fitness of introduced hatchery stocks, effects such as degradation of rearing habitat (including the estuary and nearshore ocean) on wild stocks, harvest, and delayed effects of passage through the hydrosystem. The latter, which is a subject of this biological opinion, is discussed in two forms, the differential delayed mortality of transported fish (compared to inriver migrants; D) and the delayed mortality of inriver migrants.

6.2.3.3.1 Delayed Mortality of Transported Smolts. The differential delayed mortality of transported fish is expressed as the ratio of the post-Bonneville survival of transported fish to that of non-transported fish (differential post-Bonneville survival, D). If the ratio is 1.0 or greater, then transported fish have an equal or greater post-Bonneville survival rate than non-transported fish. If the ratio is less than 1.0, the post-Bonneville survival of transported fish is lower. In the latter case, the difference is generally attributed to delayed effects of the collection and transportation processes. The NMFS estimated a mean value of D for the combined 1994 through 1997 outmigrations for Snake River spring/summer chinook salmon and Snake River steelhead (NMFS 2000_ Transport White Paper) using two methods for expanding empirical estimates of inriver survival (a step necessary to estimating D; see NMFS 2000_ Transport White Paper). The two methods were used to produce the following range of mean D-values for each species:

	Mean 1994-97 “D” Estimate
SR spring/summer chinook salmon	0.63 - 0.73
SR steelhead	0.52 - 0.58

Although these estimates represent the best scientific information available at this time, NMFS notes that they are based on relatively small numbers of returning adults and that large confidence intervals surround each estimate (2000_ Transport White Paper).

Even more uncertainty exists regarding the differential post-Bonneville mortality of transported SR fall chinook salmon. Because this species has not been the subject of formal transportation studies, the scientific justification for any given estimate of D is weaker than for SR spring/summer chinook salmon or steelhead. NMFS (2000_ Transport White Paper) reviewed the range of alternative assumptions used by Peters et al. (1999) to estimate D for this species: application of returns of transported and non-transported fish PIT-tagged during the 1995 outmigration; application of transport studies from McNary Dam (i.e., based on Hanford Reach fall chinook) to Snake River fall chinook; and comparisons of different assumptions about D and other values in relation to the best fit of a life-cycle model to the observed recruit-per-spawner data**.** The estimates of D derived using these alternative methods ranged from approximately 0.05 to over 1.0. NMFS (2000_ Transport White Paper) reviewed these methods and noted that each had inherent strengths and weaknesses. For purposes of this biological opinion, NMFS considers the PIT-tag method used by PATH more consistent with methods used by NMFS to estimate spring/summer chinook and steelhead Ds than either of the other PATH approaches. Using this method, PATH estimated D=0.24, with very wide statistical confidence limits. NMFS finds that this represents the best fall chinook D-estimate currently available and applies it as a point estimate in the analyses discussed in Section 6.3, below. Because this estimate should be viewed with caution, NMFS presents a sensitivity analysis to a range of possible D-values in Section 6.3.

For purposes of the analyses described in this report, the estimated D-values described above are assumed to have occurred under the conditions of the Proposed Action. Empirical evidence to the contrary is lacking. The D-value for UCR spring chinook salmon transported from McNary Dam is assumed to be equal to that estimated for SR spring/summer chinook salmon transported from all collector projects (between 0.63 and 0.73). The D-value for UCR steelhead transported from McNary Dam is assumed equal to that estimated for SR steelhead transported from all collector projects (0.52 to 0.58). Relatively few individuals from these ESUs would be transported under the Proposed Action (current operations).

6.2.3.3.2 Delayed Mortality of Non-Transported Smolts*.* Time series of adult returns for salmon and steelhead indicate that stocks declined throughout the Pacific Northwest starting in the late 1970s (NRC 1996). However, stocks from the Snake River appeared to decline more than lower Columbia River stocks. PATH modeling on the effects of the hydrosystem on salmonid populations indicated that direct losses through the hydrosystem alone could not account for the changes in spawner/recruit ratios observed between the 1960s and 1980s. The quantification of this unexplained extra mortality depends on the analytical framework from which it is derived, since it is the leftover mortality or loss of productivity that is not accounted for by other predictor variables within a salmon life cycle model. In the biological opinion modeling framework, the extra mortality is based on PATH models and is mortality that is not accounted for (or that may be incorrectly accounted for by the following:

1. Spawner-recruitment productivity parameters

2. Estimates of direct mortality from inriver juvenile passage models

3. Estimates of additional delayed mortality of transported fish relative to inriver fish (D value)

4. A year-effect term that accounts for year-to-year changes in productivity that are common across A large group of stocks and that attempt to capture common environmental effects

PATH developed three hypotheses to explain the potential sources of the unexplained mortality: hydrosystem, ocean regime shift, and stock viability degradation (Marmorek and Peters 1998). Hypotheses of how the hydrosystem could produce delayed mortality include the effects of hydrosystem regulation on flow and the timing of ocean entry, the cumulative effects of stress/injury associated with bypass system or hydrosystem passage, and the effects of disease transmission and delay as fish transit bypass systems or fish ladders. Schaller at el. (1999) analyzed spawner/recruit data and contrasted productivity patterns for yearling chinook salmon stocks from the upper Columbia and Snake rivers with those from the lower Columbia River, concluding that differences in productivity between the upper and lower river stocks are primarily due to the number of dams each must pass (eight or nine versus three or fewer dams). Two hypotheses proposed by PATH contend that the unexplained mortality is not caused by the hydrosystem and, therefore, is not delayed mortality. The ocean regime shift hypothesis attributes the recent low survival of salmonids to cyclical changes in ocean productivity. The stock viability degradation hypothesis represents the potential negative effects of hatcheries on wild stocks, including effects of diseases, inbreeding depression, etc.

Uncertainty continues over importance of the hydrosystem as the source of delayed mortality or whether the effect should be attributed to other factors. The rate at which mainstem projects were added to the hydrosystem is autocorrelated with changes in ocean productivity, changes in Columbia River hydrology affected by increased storage capacity in the upper Columbia and Snake river basins, reliance on hatcheries to meet production goals, habitat degradation, and other factors that came into play during the same period. Because these trends coincide but were not planned as a statistical experiment, statistical methods cannot be used to define the cause of delayed mortality.

Recent PIT-tag studies also bear on the question of delayed mortality of non-transported fish. The smolt-to-adult return rates (SARs) of smolts that were PIT-tagged during the 1995 migration differed according to the number of projects at which they were detected (i.e., in the bypass system). The more frequently a fish was detected, the lower the SAR. These differences cannot be explained by differences in direct passage survival rates. Although there were insufficient returns from the 1996 migration to make similar estimates, and returns from the 1997 migration did not indicate a multiple bypass effect, the pooled 1995 through 1998 data indicate that adult return rates for fish that passed one or more times through the bypass systems are lower than for fish that were never detected (NMFS 2000_ Passage White Paper). These differences are not statistically significant.

In the Passage White Paper, NMFS (2000_) reviews several hypotheses to explain these results. Consistent with the delayed mortality of non-transported fish, the reduced return rate may be a result of cumulative stress or injury associated with the bypass experience. Alternatively, NMFS (NMFS 2000_ Passage White Paper) pointed out the observations may be related to: (1) problems with the PIT tags used in 1995; (2) problems associated with the PIT-tag diversion systems rather than the bypasses (which would not have affected the run at large); or (3) a higher incidence of bacterial kidney disease (BKD) infection in fish moving at greater depths (i.e., fish likely to be guided into bypasses). The second of these hypotheses was tested at Lower Monumental Dam during 1999 and the results indicated no difference between fish bypassed directly to the river and those passing through the juvenile fish monitoring facility (NMFS 2000_ Passage White Paper). The third alternative was tested by exposing juvenile chinook salmon infected with the bacteria that causes BKD to stressors and hypoxia, simulating potential deleterious conditions during bypass passage (Mesa et al. 2000). Infection levels and mortality were unchanged.

NMFS (2000_ Passage White Paper) reviewed the evidence for or against each hypothesis regarding delayed mortality of non-transported fish. No conclusions were drawn and NMFS noted the need for additional research. However, to conduct the analysis described in this biological opinion, it is necessary that NMFS assume either that no delayed mortality exists or that some level of delayed mortality occurs, based on the best available scientific information. The choice can have a significant effect on analytical results, as demonstrated by Marmorek and Peters (1998) and Peters and Marmorek (2000).

Based on its best professional judgement, NMFS applied a range of delayed mortality assumptions to analyses of Snake River ESUs for this biological opinion. At the low end of the range, NMFS assumed no delayed mortality and at the high end, assumed that all of the extra mortality estimated by PATH was caused by passage through the four Snake River dams. For upper- and mid-Columbia ESUs, NMFS assumed that delayed mortality of non-transported fish might be as low as zero but would be no higher than the PATH estimates for the same species in the Snake River. For lower Columbia River ESUs, which pass no more than one FCRPS dam, NMFS assumed no delayed mortality.

6.2.4 Effects of Project Operation on Adult Salmonid Passage - General Considerations

Cumulative loss for adults migrating up the Columbia and Snake rivers through the FCRPS projects can be calculated as the difference in adult counts between dams (after adjustment for legal harvest and tributary turnoff), representing both loss and mortality. Mortality can be caused by delayed migration, fallback through spillways and turbines, illegal harvest, delayed mortality from marine mammal predation, gillnet interactions and disease. Apparent adult loss between dams may also be due to factors other than mortality of adults, such as counting errors, double-counting fish that fall back and re-ascend ladders, straying, and tributary turnoff.

A more reliable method to estimate adult passage loss is through the use of data from adult radio-tracking studies. The method rules out the double-counting error associated with the dam count method because it monitors the passage behavior of specific individual fish. However, even with this method, many adult losses cannot be accounted for, meaning that if a tagged adult does not arrive at the next upstream dam, there may not be any indication of the fish's fate. Though use of data from radio-tracking to calculate adult passage loss results in some uncertainty, NMFS considers adult losses obtained this way to be a more representative estimate of mortality attributable to the passage through the FCRPS dams than comparison of adult counts between dams (1995 FCRPS Biological Opinion, p. 53).

Three specific components of adult migration through the FCRPS corridor may affect listed species: (1) delay at project fishways; (2) passage success at project structures; and (3) injuries and mortalities resulting from upstream and downstream passage through project facilities. Each of these components has the potential to increase prespawning mortality. For fish that do reach spawning areas, indirect effects associated with passage through multiple dams may reduce fecundity and reproductive success. Unfortunately, the relationship between each of these passage components and reproductive success is not clearly understood. Additionally, a percentage of adults fail to enter project fishways and pass upstream. This could be due to a fish's inability to detect fishway entrances or due to the lack of distinguishable environmental cues inducing fish to continue upstream past the project. As a result of these indirect effects, a component of adult populations may not successfully spawn.

The hydrosystem may also have a positive effect on some aspects of the upstream migration. For example, travel time and energy expenditures of upstream migrants are lower in reservoirs than in free flowing rivers. However, NMFS (2000_ Passage White Paper) estimates that the net effect of delay at dams combined with faster passage through reservoirs is a median travel time through the lower Snake River the same or faster with dams in place than with no dams.

Adult salmon and steelhead pass upstream through FCRPS dams via fishways that were installed as part of the original project construction. The fishways typically consist of an entrance gallery and ladder, a diffuser system that provides additional water at the ladder entrances (to attract fish from the tailrace), and a flow control section at the ladder exit that maintains ladder flow over varying forebay elevations. Observation areas have been established in each ladder to monitor upstream progress (i.e., fish counting stations). Additionally, the ladders at Bonneville and Lower Granite dams have traps used for broodstock collection and monitoring. Migrational delays are most likely to occur at fish ladder entrances, in the collection galleries (at junctions between galleries and ladders), and when the traps are operated. Injury related to adult fish passage facilities is usually minimal. However, when system failures take place (e.g., displacement of diffuser gratings in the entrance pools), they have the potential to result in significant injury and mortality.

Adult passage information (e.g., time spent immediately downstream of the dam, success of entry into the collection channel and fishway entrances, time taken to traverse the ladder, etc.) is typically evaluated using radio-telemetry. Therefore, project passage data assess how well radio-tagged fish pass from the tailrace of a dam into and through its fish passage facilities. The behavior of radio-tagged fish is assumed to be similar to that of untagged fish and laboratory assessments of tagged and untagged fish and several years of field evaluations support this assumption (although little information is available regarding tagging effects on subsequent reproductive success). The available data do not establish a direct relationship between project passage times and reproductive success, although hypothetically, any reduction in passage time would reduce the individual's energy expenditure and improve the likelihood that it will survive to spawn. Although specific criteria are not available, obvious delays in passage may indicate a need for operational or structural modifications.

Adult radio-tagged fish are monitored with aerial and underwater antennas as they move through the tailrace and into and through the fish passage facilities. Additional information can be collected by manually tracking radio-tagged fish from a boat or plane. Project passage times are only developed for radio-tagged fish that successfully pass the dam. Although data for fish that do not pass the dam are of equal or greater value, it is very difficult to determine a causative factor for this behavior. Failure to pass a dam may be the result of a poorly designed passage facility, inadequate attraction flows, or complicated flow patterns, exacerbated by project operations. Fish that "fail" to pass a dam may also be destined for a downstream spawning location or may have been injured before reaching the dam (due to natural or other effects). Tagging effects or regurgitated tags, none of which are related to operation of the facilities, can also be manifested in the data set and affect the conclusions. As a result, the detection rate of radio-tagged fish as they advance upstream indicates a rate of adult loss that cannot be entirely attributed to a particular experience, such as dam passage, but must be attributed to a combination of factors. This adult loss rate, termed "unaccountable adult loss" cannot be used to isolate specific cause and effect relationships between passage and reproductive success. However, it can be used to assess the general, overall success of adult salmonids migrating upstream through the Snake and Columbia river corridors and to develop an index for assessing annual improvements in passage conditions. Nevertheless, factors contributing to unaccounted losses must be partitioned so that appropriate improvements can be determined.

6.2.4.1 Effect of FCRPS Project Operation on Adult Salmonid Passage

The survival of radio-tagged spring/summer chinook salmon from Ice Harbor Dam to Lower Granite Dam was high in the 1990s, ranging from 86% (1993) to 98% (1998) for adult fish tagged in the lower Columbia River. Migration rates vary with species, year, season, and environmental conditions. In general, fish appear to move through the projects at rates similar to unimpounded reaches. Bjornn and Peery (1992) concluded that, in the Snake River before impoundment, spring/summer chinook salmon migrated from 18 to 24 km/day. In recent radio-tracking studies (1996 to 1998), spring/summer chinook salmon traveled the reach between Ice Harbor and Lower Granite dams at a median rate of 14 to 20 km/day (Bjornn 1998c citation in Passage White Paper). Further, a 1993 comparison of travel times through impounded and unimpounded Snake River reaches showed little difference in median travel time for this species (Bjornn et al. 1999 citation in Passage White Paper). In 1998, the median migration rates for PIT-tagged adults between Bonneville and Lower Granite dams were 38, 27, and 14 km/day for fall chinook salmon, spring/summer chinook salmon, and steelhead of known Snake River origin, respectively. Steelhead migration rates vary with season and temperature (NMFS 2000_ Passage White Paper).

Adults can be delayed at dams during periods of high daytime spill (Turner et al. 1983, 1984) due to increased difficulty finding ladder attraction flows as well as fallback. Adult migration times increase as fish (re)locate the ladder and re-ascend the dam. Fallback rates as high as 20% have been documented for total dam fallback; a 28% fallback rate has been documented for fish exiting the Bradford Island ladder at Bonneville Dam (Bjornn et al., 1998). Mortality rates of 8% have been observed for adults falling back through spillways (Bjornn 1998a in Passage White Paper) and 14 to 26% for fallback through turbines (Mendel 1995).

The BET used estimates of unaccountable adult loss derived from radio-tracking data to estimate adult survival and loss under the proposed action (current operations) for spring chinook salmon, steelhead, sockeye and fall chinook salmon (Table 6.1-1). The current mean survival for those Snake River species migrating through eight FCRPS dams is estimated to range from 60.7% for fall chinook salmon to 84.6% for sockeye. Mean survival rates for steelhead and spring chinook salmon fall between these values. Based on radio-tracking studies (NMFS' 1998 Supplemental FCRPS Biological Opinion; T. Bjornn, University of Idaho, pers. comm., January 2000), the BET and NMFS estimate that current per-project survival ranges from 94% for fall chinook to 97.9% for sockeye. Unaccountable loss through eight dams, which range from 15.4% for sockeye to 39.3% for fall chinook salmon, are attributable to unaccounted tributary loss, unreported catch, indirect effects of harvest, regurgitated tags, and dam passage (i.e., mortality during fallback through spillways and turbines). The average loss per project ranges from approximately 2% for sockeye to 6% for fall chinook salmon.

6.2.4.1.1 Downstream Migrating Adults (Kelts). Unlike chinook salmon, steelhead may survive to spawn more than once. Before construction of most of the lower Columbia and lower Snake River dams, the proportion of repeat spawning summer steelhead was small, e.g., 3.4% (Long and Griffin 1937). A study of repeat spawners to the Clearwater River showed a 1.6% return (Whitt 1954). More recently, summer steelhead populations that do not pass through any or only one dam (i.e., spawners from lower Columbia River tributaries) have approximately 7% and 3% proportions of repeat spawners, respectively (Howell et al. 1985, cited in Busby et al. 1996).

In 1994, 47 wild steelhead kelts passed downstream via the juvenile bypass system at Little Goose Dam (Hurson et al. 1996). A larger number of kelts probably migrated downstream and passed the dam via other routes (spillway and turbines). The number of Snake River, Upper Columbia River and Lower Columbia River kelts passing FCRPS dams is unknown.

The mortality of kelts passing FCRPS projects has not been estimated. For those that pass through turbines, the mortality is probably similar to that estimated for upstream migrating adults that fall back through turbines. It is unlikely that many kelts survive multiple dam passage to spawn a second time.

6.2.5 Effects of Water Regulation and Impoundments on Salmonid Migration and Survival - General Considerations

One indication of historical trends in salmonid habitat alteration by hydroelectric (and multipurpose) dams is the total amount of water stored by these projects (total storage capacities). The Corps (1984) defines major hydroelectric projects as those having an active storage capacity in excess of 100,000 acre-feet, or with an installed generating capacity greater than 40 megawatts. According to the Corps, there are 89 such projects in the Columbia River basin. Their combined active storage capacity is over 57.3 million acre-feet, and their combined hydrosystem generating capability is over 35.7 gigawatts. This total storage capacity represents over 40% of the Columbia River's average annual runoff volume. Many of the largest storage projects have been developed in the area of the Columbia River above Chief Joseph Dam, the current upstream limit of the range of anadromous salmonids in the Columbia River.

Because reservoirs have greater surface areas and volumes and lower water velocities, changes in water temperature, dissolved oxygen levels, turbidity, water chemistry and aquatic habitat may result. In deep reservoirs, thermal and chemical stratification is likely to occur with potentially significant effects on the aquatic life in the reservoir and further downstream. The downstream effects can be either beneficial or adverse, depending on the site, water quality, and size of the impoundment. Fish that reside in reservoirs are often better adapted to these characteristics of slowly moving water than those than salmonids, which evolved in free-flowing systems.

In addition, because all but the most buoyant types of suspended materials settle out in reservoirs, these impoundments alter suspended loads and patterns of sediment deposition downstream. Altered particulate loads may affect aquatic assemblages in the water column and patterns of deposition in downstream river reaches, the estuary and nearshore ocean environments.

6.2.5.1 General Effects of FCRPS Hydrosystem Operations on Salmon and Steelhead

Development of multipurpose storage dams and hydroelectric projects on the mainstem Columbia and Snake rivers has greatly altered the natural runoff pattern in the basin by increasing fall and winter flows and decreasing spring and summer flows. Spring runoff is now stored in large headwater reservoirs so that it can be used to produce electricity on demand, as well as providing benefits for flood control, irrigation, navigation, and recreation. Fourteen of the 89 basin reservoirs, both inside and outside of the FCRPS, are routinely drafted in the winter and early spring to control mainstem floods and meet winter electrical loads. Changes in the pattern of runoff affect flow and temperature in the river channel as well as the character of the estuary and size of the freshwater plume in the nearshore ocean.

Dam development and reservoir storage on the mainstem Columbia and Snake rivers have reduced spring flows and increased the cross-sectional area of the river, resulting in reduced water velocities and downstream migration delays. Migrating salmon must pass up to nine dams and reservoirs on their migrations to and from the ocean. Increasing travel time affects the migratory behavior of juvenile fish and increases their exposure to predatory fish and birds.

Adult salmon migrating to natal spawning grounds also are delayed at dams during high flow years, due to their difficulty in locating fish ladder attraction flows. For example, high flow and involuntary spill conditions, which can assist downstream migrants at mainstem dams, may hinder the upstream fish migration by masking attraction flows to the fishway or inducing fallback. Adult fallback can cause mortality by fish passing through the turbines or can cause delay by requiring fish to find and re-ascend the ladder. High spills can also result in increased exposure to nitrogen supersaturation, which in extreme cases can result in direct or indirect (delayed) mortality. Increased migration time at several dams may have a cumulative effect, resulting in prespawning mortality of adult fish or reduced success of late spawners.

Operation of FCRPS projects has a system-wide effect on anadromous fish because of the integrated operation of the various Federal projects for power generation and flood control objectives (see below). Operational effects of FCRPS dams on salmonids include:

- Turbine mortality
- Migration delay, which may increase exposure to factors (such as disease) that reduce viability
- Gas bubble disease and mortality
- Increased susceptibility to predation
- Bypass system and spillway mortality
- Combined effects resulting from regulated flows and temperature regimes
- Power peaking operations resulting in stranding and dessication or exposure to bird predators

6.2.5.2 Streamflow Effects of FCRPS and Other BOR Project Operations

The FCRPS affects streamflow primarily through operations designed to produce power, control floods, and supply water for irrigation. The following sections describe the nature of power production, flood control, and water supply operations and estimates the effects of these operations on flow conditions in the mainstem Columbia and Snake rivers.

6.2.5.2.1 Electrical Generation. Each of the FCRPS projects in the lower Snake and Columbia rivers contains one or more powerhouses. The eight projects are operated in a coordinated fashion to meet current and anticipated electrical loads, both within the region and to other areas. Surplus generation is marketed by BPA. Electrical loads are typically highest from 6:00 a.m. to

10:00 p.m., are higher during weekdays than on weekends, and peak with seasonal heating and cooling demands. Operations for power production mimic demand.

The FCRPS and other power generating utilities in the Pacific Northwest are operated under the Pacific Northwest Coordination Agreement (PNCA) to meet anticipated electrical loads. The PNCA calls for annual planning, which must accommodate all the authorized purposes of the Columbia River hydro projects. It establishes processes that coordinate the use of planned U.S. - Canada Salmon Treaty storage operations with Federal and non-Federal project operations in the Northwest and enables the region's power producers to optimize system reliability and power production after giving priority to non-power objectives. It recognizes project and system requirements that are frequently changing to serve multiple river uses. Individual project owners set the requirements for using their own reservoirs.

All PNCA parties coordinate to meet multiple-use system requirements. Power generation, which is planned under terms of the Agreement, complies with these requirements. The PNCA planning process establishes day-to-day rights and obligations to exchange power, draft reservoirs, and associated transactions. The PNCA parties conduct annual planning. Each party to the agreement identifies its anticipated electrical loads, the output of their non-hydro resources, planned maintenance outages, and any existing contracts for firm energy purchases or exchanges. Each reservoir owner submits multiple-use operating requirements and constraints (i.e., flood control, irrigation, fish, wildlife protection, municipal use, and navigation) that must be incorporated into the annual plan. These requirements and constraints are analyzed to determine the firm energy load carrying capacity (FELCC) for the system as a whole and for each PNCA party individually.

The FELCC is the amount of energy, each individual utility system, or the coordinated system as a whole can produce on a firm basis during actual operations. Firm energy is produced over the region's worst water condition, called the critical period, defined as that portion of the 60-year streamflow record that would produce the least amount of power with all reservoirs drafted from full to empty. Reservoir draft limits (critical rule curve and refill curves) are established to facilitate meeting the FELCC while maintaining a high probability of refill. Reservoir operators are obligated to operate within the constraints imposed by these curves or else they incur power exchange obligations.

The effects of load-following are well outside the range of conditions that aquatic organisms might experience in a natural river. Little natural (free-flowing) habitat remains n the Columbia River downstream from Chief Joseph Dam. The reach between the head of McNary pool and Priest Rapids Dam (known as the Hanford Reach) is a notable exception. On the Columbia, the tailrace of one project flows almost immediately into the forebay of the next. Similarly, the natural river has been replaced by reservoirs in the Snake River downstream from Lower Granite Dam.

Through careful coordination, daily peaking operations result in modest changes in reservoir water levels. However, flow velocities within the reservoirs change diurnally in a pattern similar to the daily flow fluctuations, including a lag associated with reservoir hydrodynamics. In riverine sections like the Hanford reach (with shallow margins and gravel bars), flow fluctuations can lead to entrapment and stranding of spawning adults and juveniles in rearing habitat.

6.2.5.2.2 Flood Control. Flood control is an authorized purpose at six FCRPS storage reservoirs (Albeni Falls, Dworshak, Grand Coulee, Hungry Horse, John Day, and Libby). Both Federal and non-Federal storage reservoirs in the basin, including several U.S. - Canada Salmon Treaty reservoirs, are operated in a coordinated fashion to reduce the risk of floods, both in local areas downstream from several of the projects (local flood control) and in Portland, Oregon – Vancouver, Washington, urban area (system flood control). The latter function, system-wide flood control, is accomplished by drafting the major storage reservoirs during fall, winter, and early spring, providing space to protect against unusual rainfall events and to capture the spring freshet. The Corps' objective is to "operate reservoirs to reduce to non-damaging levels at all potential flood damage areas in Canada and the United States insofar as possible, and to regulate larger floods that cannot be controlled to non-damaging levels to the lowest possible level with the available storage space" (Corps 1999).

Runoff is forecast from monthly from snowpack surveys during the January through May period, weather forecasts, soil moisture content, and anticipated future precipitation. These estimates are used to identify flood storage requirements at each project using predetermined storage reservation diagrams. Also termed rule curves, the diagrams anticipate the minimum amount of storage that will be required at the end of each month to reduce flood risk to an acceptable level. As such, these rule curves also define the maximum reservoir water surface elevation allowed under existing conditions and criteria.

Flood control operations can be considered in two steps: reservoir evacuation (drafting) in advance of the spring freshet (most likely flood season in the Columbia basin); and, reservoir refill during the freshet and temporarily during intervening runoff events. Drafting is conducted in two periods. During September through December several projects are drafted to meet predetermined targets (runoff forecasts are not yet available and early drafting facilitates the deep drafts required in the wettest years before the flood/refill season). Early drafts also provide protection from fall floods and increase system generation. During January through March, drafting varies with predicted runoff and available storage space in accordance with established storage reservation diagrams. During April through July reservoirs are gradually refilled to provide flood protection (by reducing river flows that would otherwise occur) while reducing potential spill, generating electric power, and providing the flows needed for outmigrating salmon.

6.2.5.2.3 Flow Depletion Effects of BOR-Based Irrigation. The Action Agencies' proposed action includes continued operation of BOR's 31 irrigation projects in the Columbia River basin

(Table 1-1). With the exception of Hungry Horse, all of these projects deplete streamflows by providing water for irrigation, providing most of the Federally-authorized irrigation water in the basin. About 33 Maf are diverted from the Columbia River for irrigation and about 14 Maf of this total are consumed (i.e., not returned to the river; BOR 1999). Of the 13.5 Maf diverted at BOR projects upstream from McNary Dam, 6.5 Maf are consumed.

Operation and configuration of BOR's irrigation projects could affect salmon survival both directly or indirectly. Direct effects include entrainment at project diversions, attraction to unsafe habitats such as wasteways, and discharge of warm and/or contaminated water from wasteways. Indirect effects are primarily associated with changes in flow timing due to reservoir storage management activities, and streamflow depletion from water withdrawals.

This Biological Opinion focuses on the effects of BOR's projects on streamflow in the mainstem Snake and Columbia rivers and the role these hydrologic effects play in salmon survival. Where they exist, other salmon survival effects of BOR's projects (except the Columbia Basin Project) will be evaluated in supplemental consultations. All known effects of the Columbia Basin Project are described here and in Section 6.2.5.2.5. These effects could occur in the tributaries, the mainstem Snake and Columbia rivers, and the Columbia estuary.

BOR has estimated the streamflow depletion effects of its irrigation projects upstream from McNary Dam (Table 6.2-1).[3] About half the total streamflow depletion in the basin occurs at BOR projects. All but about 925 kaf of this 6.5 Maf depletion occurs at a time when available storage is being managed to achieve the flow objectives (April through August).

Flow depletions caused by BOR-based irrigation activities are a major impediment to meeting NMFS' flow objectives. However, any calculation of the frequency that the flow objectives would be achieved without these BOR-based irrigation activities is speculative. Even if BOR discontinued delivering water for irrigation, it is unlikely that all the released water would remain in-stream. Private diversions would probably capture some fraction, perhaps most of the water. Therefore, although the following analysis attributes substantial streamflow depletion effects to BOR project operations, it is not clear that BOR could, with any reasonable degree of certainty, avoid these effects.

In the following analysis (Tables 6.2-2, 6.2-3, and 6.2-4), NMFS assumes that the fraction of the monthly depletions attributable to BOR-based irrigation in recent years approximates the fraction of BOR depletions for each month in the 50-year period from September 1928 through August

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[3] These water consumption estimates are based on crop consumption data. Actual streamflow depletions may be larger due to evaporation in project reservoirs, conveyance losses, and in the case of the Columbia Basin Project, losses from an extensive network of secondary reservoirs and wetlands. These estimates also assume that diverted water that is not consumed by crops returns to the river during the months in which the diversions occur. This is not always true. Actual streamflow depletion effects of BOR project operations during the juvenile salmon outmigration range between the total amount of diversions (13.5 Maf) and total crop consumption (6.5 Maf).

1978. For example, if data show that BOR-based irrigation has recently been responsible for 45% of the July streamflow depletions observed at a given location, then NMFS assumes that BOR would be responsible for 45% of all July streamflow depletions during the period of record.[1] This assumption is required because whereas total streamflow depletions have been estimated on a monthly basis for the entire period of record (BPA 1993, BOR 1999), no previous study has isolated the effects of BOR-based irrigation depletions from total irrigation depletions.

Table 6.2-1. Estimated Monthly Average Crop Water Consumption (acre-feet of water consumed) at BOR's Irrigation Projects Upstream from McNary Dam

Project	March	April	May	June	July	August	September	October	Project Totals
Columbia Basin Project	53,708	237,659	247,423	228,452	266,389	213,787	141,075	76,479	1,464,972
Yakima Project		13,608	119,524	190,512	217,955	119,524	27,216	7,031	695,370
Snake River		370,865	706,497	692,634	771,906	634,799	419,557	184,905	3,781,163
Green Spots [1]		2,457	17,139	34,400	50,781	29,834	5,529	635	140,775
Upper Basin Totals	53,708	624,589	1,090,583	1,145,998	1,307,031	997,944	593,377	269,050	6,082,280
Umatilla Project			11,456	16,468	21,480	16,468	5,728		71,600
Deschutes River		40,715	69,797	93,062	78,521	11,633			293,728
The Dalles		504	1,890	2,520	3,276	2,646	1,512	252	12,600
Willamette River		297	1,782	9,207	13,662	3,861	891	297	29,997
Basin Totals	53,708	666,105	1,175,508	1,267,255	1,423,970	1,032,552	601,508	269,599	6,490,205

Source: BOR 2000.

[1] Several small projects in the upper Columbia River basin (Bitteroot, Missoula Valley, Frenchtown, Dalton Gardens, Avondale, Rathdrum Prairie, Spokane Valley, Chief Joseph, and Okanogan)

Table 6.2-2. Percent of Years that Simulated Mean Monthly Flows at Lower Granite Dam from 1929 through 1978 (50-year record) Would Meet Flow Objectives[1]

Month (objective)	Without BOR Depletions	Current Operations	BOR-caused Non-attainment
April (85-100 kcfs)	46 %	42 %	4 %
May (85-100 kcfs)	74 %	64 %	10 %
June (85-100 kcfs)	82 %	68 %	14 %
July (50-55 kcfs)	88 %	70 %	18 %
August (50-55 kcfs)	8 %	0 %	8 %

Notes: The flow objectives would be met without BOR-based irrigation depletions, under current operations including the current level of irigation demand, and the frequency of non-attainment caused by BOR's irrigation operations.
Source: NMFS analyses, based on BOR data submitted May 5, 2000, and May 11, 2000, and BPA base case HYDROSIM Run 00FSH26.
[1] The seasonal flow objective is considered met if monthly average flows are within 1,000 cfs of the objective.

Table 6.2-3. Percent of Years that Simulated Mean Monthly Flows at Priest Rapids Dam from 1929 through 1978 (50-year record) Would Meet Flow Objectives [1] Without BOR-based Irrigation Depletions

Month (objective)	Without BOR Depletions	Current Operations	BOR-caused Non-attainment
April (135 kcfs)	62 %	56 %	6 %
May (135 kcfs)	88 %	88 %	0 %
June (135 kcfs)	92 %	78 %	14 %

Notes: The flow objectives would be met without BOR-based irrigation depletions, under current operations including the current level of irigation demand, and the frequency of non-attainment caused by BOR's irrigation operations.
Source: NMFS analyses, based on BOR data submitted May 5, 2000, and May 11, 2000, and BPA base case HYDROSIM Run 00FSH26.
[1] The seasonal flow objective is considered met if monthly average flows are within 1,000 cfs of the objective.

Table 6.2-4. Percent of Years that Simulated Mean Monthly Flows at McNary Dam from 1929 through 1978 (50-year record) Would Meet Flow Objectives [1] Without BOR-based Irrigation Depletions

Month (objective)	Without BOR Depletions	Current Operations	BOR-caused Non-attainment
April (220-260 kcfs)	66 %	52 %	14 %
May (220-260 kcfs)	90 %	70 %	20 %
June (220-260 kcfs)	92 %	52 %	40 %
July (200 kcfs)	66 %	52 %	14 %
August (200 kcfs)	44 %	10 %	34 %

Notes: The flow objectives would be met without BOR-based irrigation depletions, under current operations including the current level of irigation demand, and the frequency of non-attainment caused by BOR's irrigation operations.
Source: NMFS analyses, based on BOR data submitted May 5, 2000, and May 11, 2000, and BPA base case HYDROSIM Run 00FSH26.
[1] The seasonal flow objective is considered met if monthly average flows are within 1,000 cfs of the objective.

No flow depletion effects are expected as a result of BOR-based irrigation operations during the lower Columbia River chum and fall chinook flow management season (November through March).

Beyond these flow depletion effects, there are also some operational effects on the ability meet the flow objectives. For example, BOR operates Lake Roosevelt (Grand Coulee) to be at elevation 1,240 by May 1 to supply water to clients in the Columbia Basin Irrigation Project. Under this operation, BOR can be storing water even though downstream flow objectives are not being met.

6.2.5.2.4 Cumulative Hydrologic Effects. By providing a storage capacity of almost 40% of the average annual runoff of the Columbia River above Bonneville Dam and operating to meet electrical generation, flood control, and irrigation demands, reservoir operations affect streamflow conditions in the river (Figure 6.2-1). The spring freshet (May through July) has been greatly reduced, affecting turbidity and sediment transport, estuary conditions, and the extent and characteristics of the Columbia River plume in the Pacific Ocean. Under the proposed action (current operations), mean monthly flows in August, September, and October mimic natural conditions. During November through March, current operations substantially augment natural flows, potentially benefitting fall spawners in the Ives Island area below Bonneville Dam. Current mean monthly flows during April again mimic natural conditions. However, even in months when current mean flows are similar to natural conditions, the range of weekly, daily, and hourly fluctuations due to load following greatly exceed what would be expected under natural conditions.

Nearly 64% of the total storage capacity in the entire Columbia River basin is located above Chief Joseph Dam. Therefore, most of the change in the natural shape of the hydrograph in the lower Columbia River, as measured at The Dalles Dam, is due to streamflow regulation and storage changes in the upper basin. The Snake River basin below Hells Canyon Dam has only about 7% of the total storage capacity in the basin. Accordingly, storage regulation changes are less pronounced in the lower Snake River than in the Columbia River.

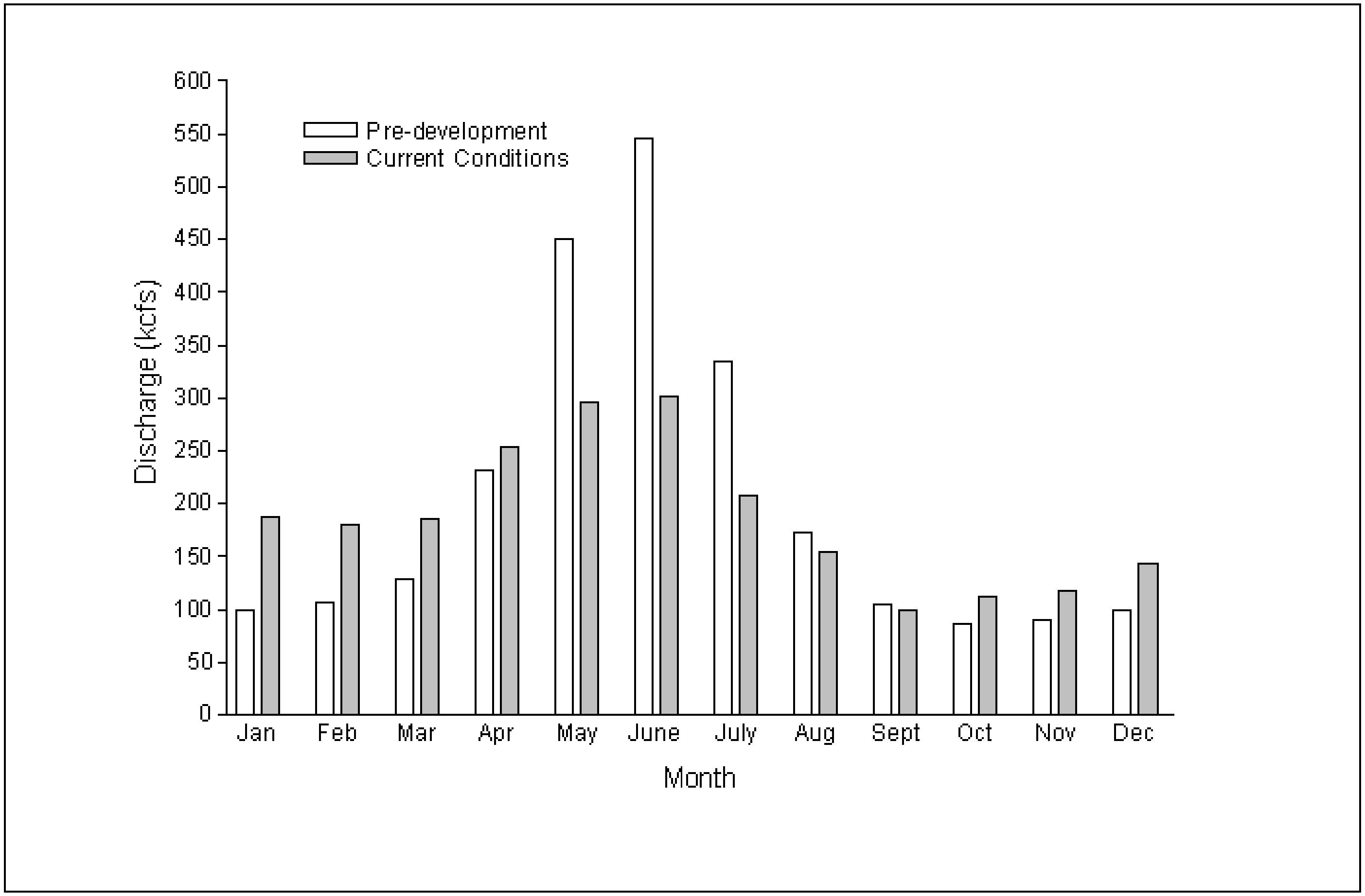
6.2.5.2.5 Additional Effects of the Columbia Basin Irrigation Project. The continued operation of the Columbia Basin Irrigation Project (CBIP) may affect listed salmon and steelhead in ways other than those defined by flow depletion.

Water Quality. CBIP wasteways deliver irrigation waste water to several locations in the Columbia River downstream from Rock Island Dam. The BOR estimates that the total combined capacity of these wasteways to be less than 700 cfs. During the juvenile salmon migration season, flows in the Columbia River are routinely managed to be 200,000 cfs or more. Even at their maximum possible discharge, CBIP wasteway flows provide only about 0.4% of total river flows. Thus, even though water temperatures upward of 90° F have been measured in the wasteways, the effects of return flows on water temperatures in the Columbia River are likely to be negligible. For example, a maximum return rate at 700 cfs @ 90° F to a total river flow at 200 kcfs @ 68° F would result in a water temperature of 68.1° F. This "worst case" analysis suggests that under normal operations, return flows from CBIP have a negligible effect on the water quality parameters considered in this opinion.

Adult Attraction to CBIP Wasteways. Adult chinook salmon have been seen trying to spawn in the lower portions of some of the CBIP wasteways. Given the poor water quality in these wasteways, it is likely that spawning success is low to nonexistent. Spawning fish in this area are primarily unlisted upriver bright Columbia River fall chinook salmon. NMFS is not aware of any information on whether these wasteways attract listed fish.

Entrainment at Unscreened Diversion Pumps. The CBIP owns and operates two pump plants (Burbank No. 2 and Burbank No. 3) in Lake Wallula (McNary pool) that are not currently screened.

Figure 6.2-1. Simulated Mean Monthly Discharge at Bonneville Dam both Before Development and under Current Project Configurations and Operations



Estimates are based on simulation over the 50-year water record (1929 through 1978). Source: BOR 1999.

6.2.5.3 Effects of Water Regulation and Impoundments on Salmonid Migration and Survival

Most of the information in this section is taken from the NMFS White Paper on flow, travel time, and survival (NMFS 2000b).

Hydroelectric system storage and regulation reduces river flows significantly during the spring and early summer months when juvenile salmon and steelhead are migrating downstream to the ocean (Figure 6.2-1).

Reservoirs created by dams have increased the total cross-sectional area of the river, decreasing water velocity and turbidity. These conditions have led to increased travel time for migrating smolts and subjected them to greater exposure to predators and other factors of mortality (Raymond 1979, 1988; Williams 1989). Moreover, the change from free-flowing river to a series of reservoirs substantially modified the river's thermal regime. The large mass of stored water (approximately 48 Maf) has created thermal inertia, making the river slower to cool in the fall and slower to warm in the spring, thus moderating temperature extremes. Through a variety of mechanisms, these flow-related environmental changes have affected the timing of salt-water entry for juvenile migrants. Fall chinook salmon from the Snake River basin are particularly susceptible to changes in the thermal regime as they spawn and rear in the mainstem river. Further, delays in their migration due to slack water impoundments place these juvenile migrants in reservoirs during periods when water temperatures approach chinook salmon's thermal tolerance.

Flow can also affect levels of spill at dams which affects smolt travel time and survival. Spill can be forced (flow exceeds hydraulic capacity of the project) or voluntary. Voluntary spill has been used extensively since 1995 to reduce the proportion of smolts passing through turbines as prescribed in the 1995 Biological Opinion (NMFS 1995). Use of spill increases survival by passing greater numbers of smolts over the spillway, the route of passage with the highest survival. Spill can also reduce smolt travel time by reducing delay in forebays.

Spring migrants (spring/summer chinook salmon and steelhead) and summer migrants (fall chinook salmon) have distinct life histories and migrate downstream during separate time periods. Thus flow augmentation will have different effects on these classes of salmonids.

Spring migrants actively move through the hydrosystem as yearlings (or older). The NMFS has not detected a relationship between flow and survival in the Lower Granite to McNary reach (NMFS 2000 Flow White Paper). However, due to data limitations, these analyses did not examine the relationship through the reservoirs below McNary Dam and thus do not fully address potential flow effects. For example, predation by the northern pikeminnow is considerably higher in lower Columbia River reservoirs and the free-flowing river below Bonneville Dam than in the Snake River (Ward et al. 1995). NMFS (2000 ibid) did demonstrate, through their own analyses and a review of other studies, a strong and consistent relationship between travel time and flow for spring migrants. Thus, by decreasing the residence time of smolts in the lower river, higher spring flows may reduce exposure to predators. This hypothesis has yet to be tested but the existence of survival benefits from increased flow expressed outside the lower Snake River study reaches is supported by relationships between smolt-to-adult return rates or recruits-per-spawner and seasonal flow (NMFS 2000).

A significant negative relationship between smolt travel time through the Snake River and subsequent return of adults (expressed as smolt-to-adult returns, SARs) has been described for wild spring/summer chinook salmon from Marsh Creek, Idaho, for the years 1960-1987 (Petrosky 1992). That is, fewer adults return from years when the juvenile migration takes longer due to low stream flows than during high-flow years when the juveniles move more quickly. A significant relationship was observed between estimates of 1964-1984 smolt-to-adult returns of all wild Snake River spring/summer chinook stocks (Raymond 1988) and estimates of water particle travel time during out migrations. Smolt travel time is fairly well predicted by water particle travel time. Lastly, an analysis of an adult spring/summer chinook wild stock returning to the Imnaha River (tributary of Snake River) indicates SARs are correlated with smolt travel time (Petrosky and Schaller 1992). To summarize, there are several studies which indicate a relationship exists between river conditions when juveniles out-migrated and the rate at which adults returned from those juvenile year classes. Years of higher river flow produced higher rates of adult returns than low water years.

A limitation of survival estimates made by using PIT-tags is that they measure only direct survival through a portion of the hydrosystem. Conditions smolts experience during migration are reflected in the estimates of smolt survival, but the indirect effects, or delayed mortality (mortality caused by passage experience that occurs downstream from PIT-tag detection sites) are not. Slower travel times could result in greater depletion of energetic reserves, reversal of smoltification characteristics, and greater exposure to disease. These factors could lead to delayed mortality not captured in the existing juvenile smolt survival studies.

Snake River fall chinook salmon initiate downstream migration in the late spring/early summer as subyearlings. Downstream migration is protracted over several months and is accompanied by rearing. This complex life history makes interpreting data more difficult compared to spring migrants. NMFS (2000b) concluded that highly significant relationships existed between survival from release points in the Snake River to Lower Granite Dam and the factors flow, river temperature, and turbidity for Snake River fall chinook salmon. Also, survival decreased markedly from early to late release dates. Because environmental variables were highly correlated with each other, determining which factor was most important to subyearling fall chinook salmon survival is not possible. Because the relationships between survival from Lower Granite Dam to Lower Monumental Dam and flow, river temperature, and turbidity were inconsistent from year to year (NMFS 2000b), there is uncertainty created by these confounded factors in the fall chinook analysis. However, releases of cold water in the summer from

Dworshak Dam on North Fork of Clearwater River can not only help reduce elevated water temperatures, but at the same time provide flow augmentation during the summer period when juvenile SR fall chinook are migrating.

River flow, water temperature, and turbidity may affect subyearling fall chinook survival in a number of ways. Fish that migrate under lower flows later in the season may be more susceptible to disorientation, reversal of smoltification, disease (Park 1969, Raymond 1988, Berggren and Filardo 1993), and a decreased tendency to migrate under conditions of low turbidity (Steel 1999). Thus they may experience passage delays. Although the evidence for these effects is inconclusive, they indicate a potential adverse effect of the proposed action in the form of migration delays. In addition, operations at dams change under lower flows (e.g., less spill, greater diel-flow fluctuations) in ways that can decrease fish survival. Warmer water for late season migrants leads to increased metabolic demands of predators (Curet 1993, Vigg and Burley 1991, Vigg et al. 1991) and thus to increased predation rates. Fish guidance efficiency of turbine intake screens is also reduced in warmer water, resulting in more fish passing through turbines (Krcma et al. 1985), which may cause decreased survival. Vulnerability to sight-feeding predators also increases as turbidity decreases (Zaret 1979) by increasing predator reactive distance and encounter rates (Vinyard and O'Brien 1976, Shively et al. 1991). Higher turbidity reduces predation rates on juvenile salmonids by providing protective cover during rearing (Simenstad et al. 1982, Gregory 1993, Gregory and Levings 1998).

Research conducted since 1995 suggest that the spring flow objectives in the Action Agencies proposed action for the Snake and Columbia rivers are reasonable. They do not provide historical flows or provide conditions that will move juvenile migrants through the area of the hydrosystem to the lower river and estuary that matches historical timing because the impoundments create delays that flow management cannot entirely overcome. However, the juvenile spring/summer chinook salmon that migrate downstream through the system have, in some recent years, direct survival rates that approach levels measured in the 1960s. This does not imply that smolt survival levels are high enough to ensure recovery for the species, nor does it suggest that flow management is the primary causative agent for this improvement. Rather it suggests that flow management, in conjunction with all other fish protection measures, has had a beneficial effect on smolt survival.

Evidence for a survival benefit to fall chinook salmon from flow management is supported by research results. Data sets consistently demonstrated strong relationships between flow and survival, and temperature and survival (NMFS 2000b). The provision of suitable environmental conditions would probably provide substantial survival benefits. The data indicate that benefits of additional flow in the Snake River continue at flows well above those recently observed during a wetter than average hydrologic condition that included the use of stored water to augment flows (but below that observed in 1997 when survival was lower). Opportunities to substantially increase flow augmentation in the Snake River to benefit these fish are being pursued by the Action Agencies.

The likelihood of meeting the flow objectives through the Action Agencies' proposed action is presented in the Table 6.2-5.

Table 6.2-5. Percent of year flows at Lower Granite, Priest Rapids, McNary and Bonneville dams are expected to meet or exceed specified flow objectives under the base case based on a 50-year simulation (1929 through 1978)

Period	Project			
	Lower Granite	**Priest Rapids**	**McNary**	**Bonneville**
January	N/A	N/A	N/A	90
February	N/A	N/A	N/A	76
March	N/A	N/A	N/A	76
April	42	56	52	N/A
May	64	88	70	N/A
June	68	78	52	N/A
July	70	N/A	52	N/A
August	0	N/A	10	N/A
September	N/A	N/A	N/A	8
October	N/A	N/A	N/A	30
November	N/A	N/A	N/A	20
December	N/A	N/A	N/A	92

Flow objectives are: Lower Granite Dam – 85 to 100 kcfs (spring) and 50 to 55 kcfs (summer). Priest Rapids – 135 kcfs (spring). McNary Dam – 220 to 260 kcfs (spring); 200 kcfs (summer). Bonneville Dam – 125 kcfs (November through March).
Probability of flows exceeding 125 kcfs at Bonneville Dam during September or October are also shown although there is no flow objective during those months under the proposed action.
Source: BPA Hydrosim Run 0Y00.00FSH26.OPER. (N/A = not applicable)

6.2.5.3.1 Water Regulation Affects Spawning and Rearing Areas. Fall chinook salmon are known to spawn in the tailraces of Lower Granite, Little Goose, and Ice Harbor dams. Dauble et al. (1999 citation in June 2000 mainstem habitat report), conducting spawner surveys using underwater video techniques, found a few redds (<20) per year of study (1993 through 1997). Although within-site fidelity appeared high, the frequency of use of known tailrace spawning areas varied. In addition, the importance of these areas to the viability of the ESU and the effects of FCRPS flow management on habitat use are unknown.

Snake River fall chinook salmon grow during their migration through the mainstem Snake and Columbia rivers as subyearlings and have biological requirements including food, temperature, and refuge from predators during mainstem passage. As described above, flow management operations that affect travel time, water temperature, and turbidity may affect the growth and survival of subyearling chinook salmon in a number of ways including vulnerability to predation. However, there is no evidence that food resources would be adversely affected under the proposed action.

Hydrosystem operations also influence the ecological conditions (flow, water depth) necessary for the use of the spawning, incubation and rearing habitat in the mainstem area (Ives Island) below Bonneville Dam. Flow management helps to maintain immigration corridors between the mainstem and tributaries used for spawning by chum salmon, as well as emigration corridors for smolts. Average daily flows and flow fluctuations can: (1) affect the areal extent of available spawning habitat; (2) cover or dewater redds; and (3) strand juveniles and adult salmon.

Both LCR chinook salmon and CR chum salmon have been observed spawning in the Ives Island area below Bonneville Dam. Lower Columbia River chinook salmon, tule-type fish that are distinguished from upriver or lower river brights by their body color (brownish tinge) and shape as well as early run timing, were observed there for the first time during October 1999 (pers. comm. [E-mail], J. Hymer, WDFW, Vancouver, Washington, October 20, 1999). Field biologists reported a peak count of 45 redds on October 19th (WDFW, unpubl. data). Columbia River chum salmon were first observed in the Ives Island area during 1967 (“Fact Sheet” presented by WDFW, ODFW, and USFWS to the Fish Passage Advisory Committee on August 30, 1999) and targeted censuses began in 1998 when this species was proposed for listing. Both the hydraulic connection between the backwater area that separates Ives and Pierce islands (and the mainstem Columbia River) from the Washington shoreline, and the areal extent of submerged spawning habitat, are strongly affected by FCRPS flow management and tides. According to USFWS, ODFW, and WDFW field biologists, a Bonneville outflow of at least 125 kcfs is needed to create and sustain the hydraulic connection, with a higher flow needed to counteract any temporary drop in river elevation (e.g., during the lower low of a spring-tide cycle) (FPAC 1999 SOR 99-28). However, before construction of Bonneville Dam Second Powerhouse, flows as low as 90 kcfs may have been sufficient to maintain the connection (tailwater rating curve developed by the Corps, Portland District, January 2000). The slough that separated Hamilton Island from the Washington shoreline was bisected by a dike and backfilled with materials excavated from the construction site for Powerhouse II beginning in the mid-1970s (Harza 2000).

Although chum salmon redds can be superimposed in pristine systems, this condition may be an indication that the carrying capacity of spawning habitat is exceeded (Burner 1951). Keeley et al. (1996) found that the number of migrating fry per m^2 in side channels to tributary streams reached a maximum when female density reached 1 per m^2. The Ives Island spawning area is essentially a side channel to the Columbia River and preliminary results from a piezometer study show that it may share an important habitat characteristic with smaller side channels used by this species, upwelling through at least a portion of the available gravel (unpubl. Data, D. Geist, Pacific Northwest Laboratories, Richland, Washington). Thus, flow management operations that restrict the areal extent of habitat in the Ives Island area, either by limiting access to potential habitat or by degrading habitat quality through fluctuating flows, are also likely to affect carrying capacity. The specifics of these functional relationships (i.e., effects of flow levels on the carrying capacity of spawning habitat in the Ives Island area) are the subject of ongoing research.

Chum salmon spawn in the lower Columbia River during late October through December, typically after local precipitation begins and baseflows increase in the mainstem. At present, access to chum salmon spawning habitat in Hamilton Creek and its tributary, Spring Channel, (and possibly to Hardy Creek, pers. comm. [E-mail] from J. Hymer, WDFW, October 20, 1999) is also maintained by FCRPS flows greater than 125 kcfs. Flows at this level are more likely to occur during November and December than before mid-October. However, as stated above, access may now depend on higher mainstem flows than before the Corps bisected and backfilled Hamilton Slough.

Flow through the Ives Island area is important not just during the fall spawning period but also through incubation, rearing, and emergence. Salmon sac-fry larvae are particularly vulnerable to gas bubble disease.[4] Operations such as spill for debris removal, gas generation/abatement testing, or spill for juvenile fish passage (e.g., the March release of hatchery smolts from Spring Creek NFH) can create total dissolved gas concentrations high enough to kill yolk sac fry. However, mortality can be prevented by providing flows that create a compensation depth over the redds, reducing the effective total dissolved gas concentration to 105% of saturation or less.[5]

Based on seining data, both Lower Columbia River chinook salmon and Columbia River chum salmon leave the area soon after emergence (USFWS 2000 HO at 2/16/00 meeting; Table 6.2-6). Emigrating smolts and any juvenile chinook that rear in the area appear to be subject to stranding and death through dessication or bird predation when Bonneville outflow fluctuates around 275 kcfs (USFWS 2000 HO at 2/16/00 meeting).

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[4] Once the yolk is fully absorbed and the body cavity has "buttoned up," fry are relatively tolerant to high dissolved gas concentrations.

[5] Depth compensation is equal to a 10% reduction in TDG for each meter of water depth (Weitkamp and Katz 1980). For example, if TDG measured in the water over the shallowest redd is 115%, there must be at least one meter of water covering the redds to give an effective TDG of 105% at the redd level.

Table 6.2-6. Hatching and Emergence Timing for LCR Chinook Salmon and CR Chum Salmon

		Hatching		Emergence	
ESU	**Stage**	**Date**	**TUs**	**Date**	**TUs**
LCR chinook salmon	Begin	11/14	506	1/26	1,001
	Peak	12/04	503	3/15	1,002
	End	12/22	504	4/4	998
CR chum salmon	Begin	1/28	602	3/16	998
	Peak	3/15	602	4/12	1,002
	End	4/9	603	4/29	1,006

These data are based on *in situ* temperature measurements and cumulative temperature unit calculations. (Source: Spreadsheet titled \emergence timing [TU]'2000.xls, received by E-mail from W. Vandernaald, ODFW, 062900). Date predictions through February 3, 2000, include the effect of a +2°C differential between water flowing through the redds versus the water column over the redds, as measured by the USFWS Ives Island temperature gauge.

6.2.5.3.2 Food Resources and Physiological Status. The hydropower system has changed the juvenile salmonid migration corridor from a free flowing river to a series of run-of-the-river impoundments. There is little empirical data on the relationship between FCRPS operations, food supply, diet, growth, and the physiological processes that control growth. NMFS is uncertain whether yearling chinook migrants have a biological requirement for food in the juvenile migration corridor or, if food is needed, whether the abundance or composition of the prey assemblage is adversely modified by FCRPS operations. Subyearling SR fall chinook have a biological requirement for food in the juvenile migration corridor/rearing area. Prey resources in mainstem reservoirs are different than those in free-flowing reaches (e.g., terrestrial insects and zooplankton predominate in reservoirs versus aquatic insects in the free-flowing river). However, NMFS is uncertain whether this change in prey assemblage adversely affects biological requirements for food during the juvenile migration. Similarly, water level fluctuations associated with reservoir operations may affect the life cycles of invertebrate prey but the existence of this effect in the Snake and Columbia river reservoirs downstream, and potential implications for SR fall chinook subyearling migrants, are hypothetical at this time.

Although physiological processes in Pacific salmon have received a great deal of attention (Groot et al. 1995), studies have focused primarily on fish reared in production or experimental hatcheries. Smolting is a critical process for cultured fish; fish released from hatcheries as smolts are more likely to show directed migration to the ocean (Zaugg 1981, 1989; Muir et al. 1994). McKenzie et al. (1983, 1984) demonstrated that higher downstream survival of yearling hatchery fish was associated with higher percent body lipid at release. However, little is known of the endocrine and physiological status of naturally reared salmon. In a recent study in the Yakima River using wild yearling chinook salmon, Beckman et al. (2000) observed low lipid and glycogen levels in fish that were only one-third through their migration. This suggests that additional energy to support migration may come from food captured during the migration or from stored protein. If so, the causal mechanisms that lead to a high metabolic rate and catabolic status of smolts are unclear. Moreover, NMFS cannot assign effects on the physiological status of active migrants to specific operations such as alteration of the hydrograph or flow fluctuations.

6.2.6 Effects of Project Operations on Water Quality

The operation and configuration of the FCRPS, as well as other non-Federal projects on the Columbia River, have two primary effects on water quality related salmon survival: dissolved gas supersaturation, and temperature.

6.2.6.1 Total Dissolved Gas Supersaturation

Total dissolved gas supersaturation (TDGS) is generated when water is spilled at dams. Falling water entrains volumes of air and carries the air into the depths of the stilling basin. Stilling basins are designed to dissipate energy and are often 50-60 feet deep. Hydrostatic pressures at depth in the basin force the entrained gasses into solution causing supersaturation. Supersaturated gases in river water can off-gas at any air/water interface, e.g., the river surface, wave action on the surface or air bubbles from rapids and riffles. However, TDGS conditions often persist for many miles below spilling dams.

Water highly supersaturated with (greater than 110% saturation) DG can produce a hazardous condition for aquatic organisms. Fish relying on dissolved oxygen (DO) for their life processes become equilibrated with the gaseous state of the river. Gas is absorbed into the bloodstream of fish during respiration. Supersaturated gases in fish tissues tend to pass from the dissolved state to the gaseous phase as internal bubbles or blisters. This condition is called gas bubble disease (GBD) and can be debilitating and fatal to the afflicted organism, including upstream and downstream migrating salmonids (Ebel and Raymond 1976). Susceptibility to GBD is highest near the water surface because the reduced hydrostatic pressure forces the gas out of solution.

Columbia River fisheries managers and the owner-operators of the hydroelectric projects recognized the TDGS effects of spill and its adverse effects on salmon survival in the early 1960s and began seeking ways to prevent gas from being driven into solution or to augment ways of getting gas out of solution once it had been generated.

The spillway deflector, or “flip lip,” was one of the early structural mechanisms developed for this purpose. The intent of the deflector is to control the plunging water and prevent it from carrying entrained air deep into the stilling basin. When properly built, installed and operated, the flip lip causes the spilled water to be deflected from its downward path and be jetted out in a horizontal, or “skimming” flow. Thus deflectors reduce the amount of total dissolved gas in the tailrace within a given range of spill volumes.

Deflectors have been constructed and operated on the mainstem projects since the early 70's. The more recent deflectors have incorporated improved engineering factors based on lessons learned from earlier deflector design and operation, near-field testing of total dissolved gas levels, and consideration of performance enhancing requirements. The most recent deflectors have been built in the last few years. Nearly all of the Columbia/Snake River projects now have deflectors (Table 6.2-7). DG gas abatement measures installed at a facility upstream can have a beneficial incremental effect on TDGS levels beyond the next project downstream. Moreover, cumulative benefits can be incurred with the implementation of multiple gas abatement actions at multiple dams.

Table 6.2-7. FCRPS Projects with Installed Flip-lips, the Number of Spillway Bays, and the Bays with Flip-lips Installed

Project	Total Number of Spillway Bays	Number of Spillway Bays with Deflectors
Lower Granite	8	8
Little Goose	8	6 (Bays 2-7)
Lower Monumental	8	6 (Bays 2-7)
Ice Harbor	10	10
McNary	22	18 (Bays 3-20)
John Day	20	18 (Bays 2-19)
The Dalles	23	None
Bonneville	18	12 (Bays 4-15)

A number of other total DG abatement alternatives were identified by the 1995 FCRPS Biological Opinion mandated Dissolved Gas Abatement Study (DGAS), conducted by the Corps. This comprehensive, multi-year study included investigations of raised stilling basins (to prevent aeration plunging to supersaturation depths), raised tailraces (to reduce channel depths downstream of stilling basins), side channel spillways, submerged discharge tunnels (to reduce air entrainment at the intake), and other concepts. These were found to have potential for injuring fish at an excessive rate, or creating structural problems. DGAS has not recommended further investigation of these alternatives.

6.2.6.1.1 Risk Assessment of Allowing TDGS to 120% of Saturation. Spilling waters at the projects is the most benign route to move non-transported juvenile downstream migrants past the dams. Spilling large volumes of water sweeps the fish contained in those waters over the dam and avoids passage through the turbines. However, the gas supersaturation generated by this strategy can exceed current water quality standards (110% TDGS standard set by EPA, the affected states, and the Colville Confederated Tribes). As a result, it is necessary for the Federal government to seek waivers of those standards before spilling water to benefit juvenile salmon.

In 1995 the fishery agencies and Indian Tribes developed a “Spill and 1995 Risk Management” report. This updated assessment considered the benefits of spill to increase juvenile fish passage, the risks associated with spill generated gas, and the survival of juveniles through other routes of passage. Since 1995 a small number of dissolved gas research projects has continued. Also, extensive physical and biological monitoring has been implemented to track the effects of the spill program. The intent of the 2000 Biological Opinion Update of Spill and 1995 Risk Management Report is to review the research results and to review the results of five years of monitoring (see Appendix E). The update provides a basis for evaluating the options being considered in the development of the 2000 Biological Opinion.

Work on GBD signs has characterized the incidence, severity, progression and relevance of signs. It has been shown that gas bubble disease signs correlate with exposure, are progressive, and are useful in understanding the biological implications. Five years of physical dissolved gas and biological monitoring have accompanied implementation of the NMFS spill program. Juvenile and adult salmonids, resident fish species and aquatic insects have been monitored for the incidence and severity of gas bubble disease.

The biological monitoring program records the effects of the spill program. The overall number of fish affected with signs of gas bubble disease observed over the years has proven to be less than originally assumed when the 1995 Biological Opinion was developed. The biological monitoring program established action criteria to reduce the level of dissolved gas supersaturation based on the incidence of gas bubble disease signs. Actions should be taken if 15% of the fish examined exhibit any bubbles on unpaired fins or 5% of the fish examined exhibit bubbles covering 25% or more of the surface of any unpaired fin. These action levels are a conservative interpretation of previous research results.

The biological monitoring program has shown the average incidence of signs increases above 1% when dissolved gas exceeds 115%. When fish are exposed to gas levels greater than 120%, there is an increasing trend in incidence and severity of these signs. The most severe signs display a similar trend above 125%. Two of the five years, 1996 and 1997, were characterized by high volumes of involuntary spill with gas levels ranging from 130 to 140% for days. In these two years, the incidence of signs of gas bubble disease was 3.2-3.3% of the fish observed. In 1995, 1998, and 1999 the signs ranged from 0.04 to 0.7% reflecting the effect of the Biological Opinion spill levels with gas managed to the 115/120% levels for forebay and tailrace, respectively.

As indicated above, one of the more critical points assumed in the early risk assessment was that fish migrate at a protective or compensatory depth. The studies conducted since 1995 have shown that juveniles travel at depths sufficient to negate predicted mortalities from the earlier

1970s laboratory studies conducted in shallow conditions. Furthermore, studies of adult swimming depths, that are currently underway, are revealing similar findings. Adults have been tagged with radio transmitters capable of detecting and recording travel depths. The findings thus far have indicated that the fish are moving at depths that would compensate for gas supersaturation of 115 to 140%.

6.2.6.2 Water Temperature

Hydroelectric dams have modified natural temperature regimes in the mainstream Columbia River. Snake River basin storage reservoirs are known to affect water temperatures (Yearsley 1999), by extending water residence times and by changing the heat exchange characteristics of affected river reaches. In particular, below larger storage reservoirs that thermally stratify and that have hypolimnetic discharges, seasonal temperature fluctuations generally decrease. Downstream temperatures are cooler in the summer as cold hypolimnetic waters are discharged, but warmer in the fall as energy stored in the epilimnion during the summer is released (Spence 1996). Because of the thermal storage provided by these reservoirs, seasonal variations in stream temperatures are reduced in much the same way as seasonal variations in streamflow.

Water temperature conditions have a complex array of effects on salmonids. Intergravel water temperatures affect the rate of embryonic development, with about 1000-degree days needed for incubation and emergence (Weatherley and Gill 1995). Post-emergence growth rates are directly related to water temperature. Water temperatures experienced by migrating juvenile salmon have been shown to affect survival (Connor et al. 1998, Smith 1998, Muir et al. 1999).

An emerging issue is potential water temperature effects on juvenile migration timing. It is known that juvenile fall chinook now migrate up to 4 weeks later than they did before development of the Hells Canyon Complex and the Corps' four lower Snake River projects. The working hypothesis is that juvenile migration timing is delayed by cooler than historical water temperatures during incubation and early rearing life stages, which occur primarily above the Lower Snake projects, but directly below the Hell's Canyon complex. This effect may be exacerbated by delayed spawning due to excessively warm fall temperatures. Because water temperatures and juvenile salmon mortality rates increase from mid-July through mid-September, delaying out-migration timing reduces juvenile fall chinook survival through Lower Granite Reservoir.

During July and August of some years, warm water from the lower Snake River enters the Columbia River in the McNary pool. This warm water plume tends to stay along the south bank as it approaches McNary Dam.

Turbine unit operations at McNary Dam during the summer low flow and warm temperature condition can influence the temperature of water drawn into the juvenile fish collection gallery. Thermal profile data collected at McNary Dam have been used to develop special powerhouse operations (i.e., north powerhouse loading) to partially alleviate the potential for thermal stress to juvenile summer migrants that are collected for transportation. However, even when south powerhouse units are not operated, warm water from along the south shoreline can still be drawn toward the northern operating turbine units.

Immigrating adults can be delayed by excessively warm water temperatures (Karr et al. 1998). In addition, fall chinook spawning is inhibited by temperatures above 61° F (McCullough). Delay can reduce the ability of adult fish to survive to spawning and vigor and fecundity during spawning.

Water temperature also indirectly affects salmon survival. Foraging rates of piscivorus fish are directly related to temperature (Vigg and Burley 1991) and the rates of infectivity and mortality of several diseases are known to be directly related to temperature (NMFS 1998).

Thus, operation of storage reservoirs affects both the thermal characteristics of the river and the thermally-regulated aspects of salmon survival. For this reason, the thermal effects of reservoir operation are an important consideration in developing system operations aimed at protecting and restoring listed salmonids.

Water temperatue also affects the rate of physiological development in smolts. Zaugg et al. (1973) and Zaugg (1981) found that exposure of steelhead smolts to water temperatures greater than 12 C resulted in reduced ATPase activity and migratory behavior. Because dams cause migrational delay, smolts are exposed to seasonal increases in water temperature that can result in increased rates of residualism. The effects of increased water temperatures on other salmonids is less clear and warrants further investigation.

6.2.6.2.1 Operation of Dworshak Reservoir to Control Snake River Water Temperatures. Lower Granite Reservoir occupies the Snake River from river mile (RM) 108 to RM 148 and backs water into the Snake and Clearwater rivers a few miles upstream from their confluence near Lewiston, Idaho. It is the first major reservoir encountered by emigrating Snake River juvenile salmon and the last major reservoir negotiated by immigrating adults. A substantial portion of juvenile fall chinook salmon mortality occurs in Lower Granite Reservoir (Smith 1998, Connor 1998, Muir et al. 1999).

During the summer, all emigrating juveniles collected at Lower Granite Dam are transported to release points downstream from Bonneville Dam, the lowermost dam on the Columbia River. In recent years up to 50% of the outmigrating Snake River fall chinook juveniles passing Lower Granite Dam have been collected and transported (Peters et al. 1999). For these transported fish, Lower Granite Reservoir is the last reservoir transited during their seaward migrations.

Survival of PIT-tagged juvenile fall chinook salmon from release points in the Snake and Clearwater rivers to Lower Granite Dam is strongly correlated with water temperature, as well as flow and turbidity, in Lower Granite Reservoir (NMFS 2000 Water Management White Paper). To minimize water temperature-related effects on juvenile fall chinook, Dworshak Dam on the North Fork Clearwater, about two river miles upstream from the Clearwater River and 60 miles from Lower Granite Reservoir, is routinely operated to release relatively large amounts of cool water during the months of July and August to reduce water temperatures in Lower Granite Reservoir and downstream reaches. Dworshak Reservoir is a deep impoundment (over 600 feet at full pool) that stratifies in the summer and Dworshak Dam is equipped with a variable intake depth release structure that facilitates selecting a specific discharge water temperature. During July and August reservoir managers typically release water at 48° to 50° F at the request of regional salmon managers. Cooler releases are possible but may result in adverse juvenile salmon growth conditions at a downstream hatchery and the Clearwater River.

This operation provides reduced ambient water temperature by approximately 4 to 6 degrees F at Lower Granite Dam when elevated temperatures are a concern in the Snake River (July and August).

6.2.7 Effects of Predator Control Programs on Salmonid Migration and Survival - General Considerations

Dams and reservoirs are generally believed to have increased the incidence of predation over historical levels (Poe et al. 1994). Impoundments in the Columbia River basin increase availability of microhabitats within the range preferred by northern pikeminnow and other predators (Faler et al. 1988, Beamesderfer 1992, Mesa and Olson 1993, Poe et al. 1994), may increase local water temperatures which increases digestion and consumption rates by northern pikeminnow (Falter 1969, Steigenberger and Larkin 1974, Beyer et al. 1998, Vigg and Burley 1991, Vigg et al. 1991), decrease turbidity which may increase capture efficiency of predators (Gray and Rondorf 1986), favor introduced competitors which could cause some predators to shift to a diet composed largely of juvenile salmonids (Poe et al. 1994), and increase stress and subclinical disease of juvenile salmonids with could increase susceptibility to predation (Rieman et al. 1991, Gadomski et al. 1994, Mesa 1994). In addition, dam-related passage problems and reduced river discharge can affect the availability, distribution, timing, and aggregation of migrating salmonids, thereby increasing exposure time to predation (Raymond 1968, 1969, 1979, 1988; Park 1969, Van Hyning 1973, Bentley and Raymond 1976) and, in particular, increasing exposure time later in the season when predator consumption rates are high (Beamesderfer et al. 1990, Rieman et al. 1991). [Predator White Paper page 1]

6.2.7.1 Effects of FCRPS Predator Control Measures on Salmonid Migration and Survival

Northern pikeminnow predation throughout the Columbia and Snake rivers was indexed in 1990-1993 based on electrofishing catch rates of predators and the occurrence of salmonids in predator stomachs relative to estimates in John Day Reservoir (Ward et al. 1995). Northern pikeminnow abundance was estimated to total 1,765,000 and daily consumption rates averaged 0.06 salmonids per predator (Beamesderfer et al. 1996). Average index values for predation losses relative to the estimate for John Day Reservoir are reported on Table 9 in the Predator White Paper. These index values would translate into 16.4 million juvenile salmon and steelhead consumed annually by northern pikeminnow based on numbers observed in John Day Reservoir. This is 8% of the approximately 200 million hatchery and wild juvenile salmonid migrants in the system. Other work corroborates findings for the Snake River (Chandler 1993, Curet 1993) and the mid-Columbia between Priest Rapids and Chief Joseph dams (Burley and Poe 1994) [Predator White Paper, page 13].

Predator control fisheries have been implemented in the Columbia basin since 1990 to harvest Northern pikeminnow with a goal of 10% to 20% exploitation, annually. From 1991 to 1996, three fisheries (sport-reward, dam angling, and gill net) harvested approximately 1.1 million northern pikeminnow greater than or equal to 250 mm fork length. Total exploitation averaged 12.0% (range 8.1-15.5) for 1991-1996.

Modeling results indicate that potential predation on juvenile salmonids by northern pikeminnow has decreased 25% since fishery implementation. Friesen and Ward (1999) estimated a long-term reduction in potential predation of 3.8 million juvenile salmonids per year if northern pikeminnow exploitation rates are maintained at mean levels. Projected estimations of system-wide percent reduction in juvenile salmonid mortality from predation by northern pikeminnow (relative to pre-1990 levels) due to the Predator Control Program is 13.0% for 1992-1999 and 14.9% for 2000 to 2006 (Table 10, D. Ward and H. Schaller, pers. comm. to PATH Hydro Work Group, 16 March 1999). The mortality reduction estimates are derived from a spreadsheet model based on predator population size structure and the mean total pikeminnow exploitation rate estimates (David Ward, ODFW, pers. comm., 29 July 1999) [NMFS Predator White Paper page 16].

The annual system-wide reduction in pikeminnow predation is projected to level off at about 15% during 2000 to 2006 (Fig. 1 Predator White Paper, page 17). The mortality reduction below Bonneville Dam shows a similar trend and level of magnitude. The mortality reduction in the lower Columbia River reservoirs also shows a similar trend, but a higher level of magnitude (i.e., a future projection of about 18%). The highest estimated predation mortality reductions are in The Dalles Reservoir, over 30% annual reductions during 1996 through 2006. Pikeminnow populations and predation on salmonids are relatively low in McNary Reservoir, with low potential from predation reductions. The three lower Snake River reservoirs were intermediate (5% to 11%) during 1993 through 1998, and are projected to level off at about 3% to 4% reductions for 1999 through 2006. Lower Granite has 0% reductions due to negligible populations of northern pikeminnow.

6.2.8 Effects of the FCRPS Juvenile Fish Transportation Program on Salmonid Migration and Survival

Transportation increases the survival of listed species from Lower Granite, Little Goose, Lower Monumental, or McNary Dam, to the river below Bonneville Dam as compared to survival of those fish left to migrate inriver. Research has shown that the return of adults, collected and transported as juveniles, is higher than that of juvenile fish that are left to migrate inriver (NMFS, Appendix transport white paper).

The juvenile fish transportation program reduces adverse effects in downstream migrating juvenile salmon and steelhead from adverse environmental conditions created by Corps dams and reservoirs on the lower Snake and lower Columbia rivers. Juvenile salmon and steelhead are collected and transported from Lower Granite Dam, located at river mile (RM) 107.5 on the Snake River, Washington, to the Columbia River below Bonneville Dam, located at RM 146.1, about 40 miles upstream from Portland, Oregon. Endangered Snake River sockeye, threatened Snake River chinook, and threatened Snake River steelhead are collected along with unlisted hatchery and wild salmon and unlisted hatchery steelhead at Lower Granite, Little Goose, and Lower Monumental dams on the Snake River. At McNary Dam, on the Columbia River, transportation of spring migrants continues to be suspended, so primarily summer migrants are transported from that location, although limited numbers of listed endangered hatchery and wild Upper Columbia River steelhead and spring chinook, and threatened Middle Columbia River steelhead are incidentally collected and transported from McNary Dam. Listed and unlisted hatchery and wild salmon and steelhead are transported by truck and barge past three to seven downstream reservoirs and dams. Survival of endangered and threatened species is enhanced because they will be transported around reservoirs and dams where higher levels of mortality would occur than in the transportation process. From 1995 through 1999, the juvenile fish transportation program has been carried out in accordance with the 1995 RPA, the 1998 Supplemental FCRPS Biological Opinion, ESA Section 10 Permit No. 895, and operating criteria contained in the Corps' annual Fish Passage Plan.

From the time juveniles enter the fish collection systems until they are loaded on barges, juvenile fish mortality is documented. Since 1994 at Lower Granite Dam, total collection mortality has been 0.2% or less. Yearling chinook mortality has ranged from 0.3 to 0.9%, wild steelhead mortality has been less than 0.1%, and wild subyearling chinook mortality has ranged from 0.4 to 3.6%. Sockeye salmon mortality has ranged from 0.3% to 5.1% with 0.3% in 1998. At Little Goose Dam, overall mortality has ranged from 0.3% to 0.8% since 1994. Yearling wild chinook mortality has ranged from 0.6% to 2.1%, wild steelhead mortality ranged between 0.1% to 0.3%, and wild subyearling chinook mortality ranged from 1.4% to 7.7%. Sockeye salmon mortality ranged from 2.3% to 8.9% over the same period. Overall mortality at Lower Monumental Dam since 1994 has ranged from 0.1% to 0.4%. Yearling wild chinook mortality has ranged from 0.1% to 0.5%, wild steelhead mortality ranged between 0.1% to 0.3%, and wild subyearling chinook mortality ranged from 0.4% to 2.1%. Sockeye salmon mortality ranged from 0.0% to 4.0% over the same period. At McNary Dam facility mortalities have ranged from 0.4% to 1.5%. Yearling chinook morality has ranged from 0.1% to 1.1%, subyearling chinook from 0.5% to 2.1%, and sockeye salmon from 0.1 to 1.9. With the exception of McNary Dam, seasonal mortality since 1994 has been less than1% at the collector dams. In the trucks and barges, observed seasonal mortality typically is less than1% (Corps' application for Sec.10 permit, dated November 18, 1999).

Under the 1994-99 existing condition, the average proportion of the Snake River mixed stock yearling chinook population potentially collected and transported from the three Snake River collector dams is estimated at 71% (ranging from 60% to 87% depending on average river condition). For summer migrating Snake River fall chinook, the overall proportion of the population collected and transported is small because of significant mortality occurring before the fish reach Lower Granite. Similarly, the proportion of fall chinook potentially collected and transported averages about 48% and ranges from 27% to 62% depending on river conditions (NMFS, SIMPAS analyses, 2000x). For Snake River steelhead, under the 1994-99 existing condition, the average proportion transported is estimated at 73%, with a range of 66% to 79%. Post-season estimates of the proportion of wild Snake River yearling chinook transported from

1995 to 1998 range from 55 to 85% (NMFS'1998 Supplemental FCRPS Biological Opinion and R. Graves, NMFS, memorandum dated October 6, 1998).

Without transportation, survival of combined mixed stock Snake River yearling chinook salmon from Lower Granite Dam to below Bonneville Dam for the 1994-99 existing condition is estimated at 40%, ranging from 25% to 52% depending on river conditions. With transportation, combined transport and inriver survival to below Bonneville Dam is estimated at 78%, ranging from 67% to 86% also depending on river conditions. For summer migrating Snake River fall chinook, the proportion of the population surviving to below Bonneville Dam without transportation is estimated at 10% for the 1994-99 existing condition, ranging from about 1% to 17%. With transportation, estimates of the proportion of the population surviving to below Bonneville range from 26% to 61% (NMFS, SIMPAS analyses, 2000x). For Snake River steelhead, the proportion of the population surviving to below Bonneville Dam without transportation is estimated at 40% for the 1994-99 condition, ranging from about 12% to 51%. With transportation, combined transport and inriver survival to below Bonneville Dam is estimated at 79% ranging from 70% to 86% (NMFS, SIMPAS analyses, 2000x).

6.2.9 Summary of the Effects of the Proposed Action in the Action Area

The effects of the proposed action in the action area are described for each of the 12 listed ESUs in the following section. The action area is defined by NMFS regulations (50 CFR 402) as "all areas to be affected directly or indirectly by the Federal action and not merely the area involved in the action." The action area includes designated critical habitats within the Columbia River basin and estuary. This area serves as a migratory corridor for adult and juvenile life stages of listed anadromous fish and a rearing area for juveniles.[6] Essential features of the adult and juvenile migratory corridor and juvenile rearing habitats are (1) substrate; (2) water quality; (3) water quantity; (4) water temperature; (5) water velocity; (6) cover/shelter; (7) food (juvenile only); (8) riparian vegetation; (9) space; and (10) safe passage conditions (50 CFR 226). This discussion of critical habitat effects is organized by the primary constituent elements of critical habitat in those habitat types relevant to each ESU: (1) juvenile rearing areas; (2) juvenile migration corridors; (3) areas for growth and development to adulthood; (4) adult migration corridors; and (5) spawning areas (Section 5.2.1).

6.2.9.1 Snake River Spring/Summer Chinook Salmon

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[6] Marine habitats (i.e., including the Columbia River plume) are also vital to salmon and steelhead, and ocean conditions are believed to have a major influence on the species' survival. Although NMFS has not included the Pacific Ocean as critical habitat in its final rules on critical habitat (65 FR 7746), the agency will be re-evaluating this issue and may propose including specific marine zones for salmon and steelhead ESUs in a separate notice. However, regardless of the specific areas designated, Federal agencies are required to ensure that their actions, regardless of whether they occur in freshwater, estuarine, or marine habitats, do not jeopardize the continued existence of a listed species.

6.2.9.1.1 Juvenile Rearing Areas. Juvenile SR spring/summer chinook salmon rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this Biological Opinion.

6.2.9.1.2 Juvenile Migration Corridors

Water Quality. Biological monitoring during the previous 5 years shows that the incidence of gas bubble disease in migrating smolts remains below 1% when dissolved gas concentrations in the upper water column do not exceed 115%. During the spring and early summer in high volume water years (e.g.,1996 and 1997), involuntary spill has caused concentrations to exceed 120% with a corresponding increase in the incidence of signs of gas bubble disease. However, studies conducted since 1995 indicate that juveniles avoid exposure by traveling at dissolved gas “compensation” depths (Section 6.2.5.1).

High water temperatures (i.e., generally considered to be greater than 68 degree F. for salmonids) are observed system-wide during late summer and early fall, due in part to thermal storage in FCRPS reservoirs (Section 6.2.5.2). However, juvenile SR spring/summer chinook salmon migrate through FCRPS reservoirs during spring and thus are not subject to thermal effects of the proposed action.

Water Quantity/Water Velocity/Cover/Shelter. Yearling chinook salmon move relatively quickly through the FCRPS during outmigration but have biological requirements for cover and shelter in the sense of refuge from predators. Although NMFS has not detected a relationship between flow and survival for yearling chinook salmon in the Lower Granite to McNary reach, potential survival benefits are untested below McNary Dam, where northern pikeminnow predation rates are particularly high. NMFS has demonstrated a strong and consistent relationship between travel time and flow for spring migrants so that, by decreasing the residence time of yearling smolts in the lower river, higher spring flows may reduce exposure to predators. The hypothesis of survival benefits from increased flow, expressed outside the lower Snake River study reaches, is supported by relationships between smolt-to-adult return rates or recruits-per-spawner and seasonal flow. Under the proposed action, the likelihood of meeting or exceeding flow objectives at Lower Granite and McNary dams during the spring migration season (April through June) is 70% or less (Table 6.2-5).

Food. NMFS is uncertain whether yearling chinook salmon migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Riparian Vegetation. Because yearling chinook salmon migrate mid-channel through FCRPS reservoirs (Batelle and USGS 2000), they do not have biological requirements for riparian vegetation in the juvenile migration corridor.

Space. There is no evidence that the reservoir environment has resulted in loss of the amount of physical habitat required by yearling migrants in the migration corridor (Batelle and USGS 2000).

Migration Conditions. Juveniles are spring migrants with peak movement during April through June. Using SIMPAS, the BET and NMFS estimated that an average of 71% of the run was transported from the Snake River collector projects during 1994 through 1999 (Table 6.2-8). The rest of the run migrated inriver past eight FCRPS projects. The direct survival of transported juveniles over the same period was at least 98% and NMFS estimates that the average system survival rate of inriver migrants was approximately 40%. The total (transported plus inriver) system survival rate for SR spring/summer chinook salmon ranged from 52% to 59% (depending on the level of differential mortality of transported fish assumed in the SIMPAS analysis).

6.2.9.1.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling SR spring/summer chinook salmon. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.1.4 Adult Migration Corridors

Water Quality. Biological monitoring over the previous 5 years has shown that the incidence of signs of gas bubble disease in migrating adults remains below 1% when total dissolved gas concentrations in the upper water column do not exceed 115%. During spring and early summer in high volume water years (e.g., 1996 and 1997), involuntary spill has caused concentrations to exceed 120% with a corresponding increase in the incidence of signs of gas bubble disease. However, studies conducted since 1995 indicate that adults avoid exposure by traveling at dissolved gas “compensation” depths (Section 6.2.5.1).

High water temperatures (i.e., generally considered to be greater than 68 degree F. for salmonids) are observed system-wide during late summer and early fall, due in part to thermal storage in FCRPS reservoirs (Section 6.2.5.2). However, because SR spring/summer chinook salmon migrate through FCRPS reservoirs before July, adults from this ESU are not subject to these thermal effects.

Water Quantity and Velocity. Travel time and energy expenditures of upstream migrants are lower in reservoirs than in free flowing rivers. Adults may be delayed in the tailrace or adult collection channel, but once they begin to ascend the ladder, delays are minimal. Under the proposed action, delay will be minimized by operating to meet water velocity and flow criteria at fishway entrances and channels. The net effect of delay at lower Snake River dams combined with faster passage through reservoirs is a median travel time the same as or faster with dams in place than with no dams.

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. SR spring/summer chinook salmon do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Table 6.2-8. Project and system survival and the proportion of juvenile SR spring/summer and fall chinook salmon outmigrations transported under low-, medium-, and high-flow conditions as estimated using NMFS' spreadsheet model (SIMPAS). Values shown are point estimates, based on juvenile survival studies rather than adult returns, and representing the expected performance of mixed (wild + hatchery) runs. Note: spring/summer chinook salmon are yearling migrants; fall chinook salmon are subyearling migrants.

	Project Survival (% Dam + Pool Survival)													
YEAR	**LGR**	**LGS**	**LMN**	**IHR**	**MCN**	**JDA**	**TDA**	**BON**	**% Inriver Survival (LGR to BON)**	**% Inriver Survival (MCN to BON)**	**Prop. ESU Transported**	**Total System Survival**	**Total System Survival with "D"**	
SR spring/summer chinook salmon													"D"=.63	"D"=.73
1994	91.8	78.8	87.5	88.9	85.5	75.8	84.5	82.6	25.5	45.2	86.8	85.7	54.2	62.7
1995	90.6	89.8	93.8	92.4	90.4	84.5	87.1	86.8	40.6	57.7	64.6	73.8	50.4	56.7
1996	97.4	91.4	94.1	86.9	86.8	85.2	87.3	87.7	41.2	56.6	70.2	79.4	53.8	60.7
1997	83.2	94.2	89.4	89.3	89.3	81.8	86.2	86.2	34.0	54.4	59.7	67.5	45.9	51.7
1998	92.4	98.5	85.3	95.7	95.7	82.2	88.1	88.8	45.8	61.6	72.0	80.5	54.4	61.5
1999	94.3	95.0	92.4	95.0	95.0	85.3	89.3	91.3	52.0	66.1	72.3	82.5	56.4	63.5
6-yr avg	91.6	91.3	90.4	91.4	90.5	82.5	87.1	87.2	39.8	56.9	70.9	78.2	52.5	59.5
SR fall chinook salmon													"D"=.24	
1994	No data collected in 1994													
1995	66.8	89.0	79.5	88.3	82.5	73.4	81.9	80.8	16.7	40.0	59.6	59.1	14.7	
1996	47.9	89.8	78.2	87.9	83.4	72.2	81.6	79.7	11.6	39.2	42.4	42.2	10.6	

1997	35.3	56.6	64.4	69.9	60.2	30.2	69.3	55.3	0.6	7.0	26.5	26.
1998	55.8	77.1	92.1	88.3	83.4	73.3	81.9	80.7	14.1	40.4	48.1	47.
1999	76.6	66.5	89.0	82.0	75.9	58.6	77.7	71.6	9.2	24.7	61.9	61.
6-yr avg	56.5	75.8	80.6	83.3	77.1	61.5	78.5	73.6	10.4	30.3	47.7	47.

	Project Survival (% Dam + Pool Survival)								% Inriver Survival (LGR to BON)	% Inriver Survival (MCN to BON)	Prop. ESU Transported	Total System Survival	Total System Survival with “D”	
YEAR	LGR	LGS	LMN	IHR	MCN	JDA	TDA	BON						
SR steelhead													“D”=0.52	“D”=0.56
1994	72.8	78.2	83.1	83.8	78.9	63.6	80.8	75.1	12.0	30.4	71.0	69.7	36.3	39.1
1995	94.4	90.7	94.7	94.7	93.3	89.9	88.5	89.6	51.0	66.5	71.7	81.7	48.0	50.8
1996	93.4	91.2	94.8	94.7	93.4	89.8	88.5	90.0	51.1	66.8	73.9	82.3	47.6	50.5
1997	96.3	96.6	90.2	91.3	91.4	89.6	88.4	90.5	50.1	65.5	78.5	86.3	49.4	52.5
1998	92.5	93.0	88.9	89.3	89.3	83.2	87.3	87.3	38.8	56.7	75.0	80.3	45.0	48.0
1999	82.4	92.6	91.5	91.3	91.3	92.1	88.9	79.3	37.8	59.3	66.4	72.0	40.7	43.3
6-yr avg	88.6	90.4	90.5	90.8	89.6	84.7	87.1	85.3	40.1	57.5	72.7	78.7	44.5	47.4

Migration Conditions. Based upon recent radio-tracking and PIT-tag studies, the mean survival rate of adult migrants between Bonneville and Lower Granite dams is 79%, equivalent to a per-project survival rate of 97% (Table 6.1-1).

6.2.9.1.5 Spawning Habitat. Spawning habitat for SR spring/summer chinook salmon is not affected by the operations considered in this biological opinion.

6.2.9.2 Snake River Fall Chinook Salmon

6.2.9.2.1 Juvenile Rearing Areas and Migration Corridors

Water Quality. Juveniles are subyearling migrants, moving downstream during June through September and rearing during at least part of this period. The potential for adverse affects on dissolved gas conditions is lower than described above for SR spring/summer chinook salmon because involuntary spill is extremely unlikely during the summer migration season.

Conversely, high water temperatures are observed system-wide during summer and early fall. As described in Section 6.2.5.2, the survival of juvenile fall chinook through Lower Granite Reservoir may be reduced by an interaction between the thermal effects of FCRPS operations and Idaho Power Company's operations at their Hells Canyon Complex. Under the proposed action, cooler water will be released from Dworshak Reservoir during the late summer to reduce water temperatures in the reach between Lower Granite Reservoir and Ice Harbor Dam.

Water Quantity/Velocity/Cover/Shelter. NMFS' research has identified strong, positive relationships between the survival of subyearling migrants and flow, temperature, and turbidity. Operations at dams change under lower flows (e.g., less spill, greater diel-flow fluctuations) in ways that can decrease fish survival. Fish guidance efficiencies of subyearling chinook decrease at higher temperatures so more fish are likely to pass through turbines. Further, vulnerability to sight-feeding predators increases as flows and turbidity decrease.

Riparian Vegetation/Space. Because subyearling chinook salmon migrate mid-channel through FCRPS reservoirs, they do not have biological requirements for riparian vegetation in the juvenile migration corridor. Further, there is no evidence that the reservoir environment has resulted in loss of the amount of physical habitat required by subyearling migrants in the migration corridor (Batelle and USGS 2000).

Food. Subyearling SR fall chinook have a biological requirement for food in the juvenile migration corridor/rearing area. Prey resources in mainstem reservoirs are different than those in free-flowing reaches (e.g., terrestrial insects and zooplankton predominate in reservoirs versus aquatic insects in the free-flowing river). However, NMFS is uncertain whether this change in prey assemblage adversely modifies biological requirements or food during this life stage. Similarly, water level fluctuations associated with reservoir operations may affect the life cycles of invertebrate prey. However, the existence of this effect in the Snake River below Brownlee Dam and in the Snake River below the Hanford Reach, and potential implications for SR fall chinook subyearling migrants, are hypothetical at this time.

Migration Conditions. Juveniles are summer migrants with peak movement past Lower Granite Dam during July. Using SIMPAS, NMFS estimated that an average of 48% of the run was transported from the Snake River collector projects during 1994 through 1999 (Table 6.2-8). The rest of the run migrated inriver past eight FCRPS projects. The direct survival of transported juveniles was at least 98% and NMFS estimates that the average system survival rate of inriver migrants over the same period was approximately 10%. The total (transported plus inriver) system survival rate for SR fall chinook salmon was approximately 12%.

6.2.9.2.2 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River estuary and plume that in turn affect the growth and survival of subyearling SR fall chinook salmon. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.2.3 Adult Migration Corridors

Water Quality. FCRPS operations interact with effects of operations at the Hells Canyon Complex to increase water temperatures in the lower Snake River from mid-July through mid-September. Adults entering the Snake River during this period can be delayed by elevated water temperatures, potentially reducing fish condition and fecundity during spawning.

Water Quantity and Velocity. Effects of the proposed action on biological requirements for water quantity and velocity in adult migration corridors are the same as those discussed for SR spring/summer chinook salmon (above).

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. SR fall chinook salmon do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Based on recent radio-tracking and PIT-tag studies, the mean survival rate of adult migrants between Bonneville and Lower Granite dams is 79%, equivalent to a per-project survival rate of 97% (Table 6.1-1).

6.2.9.2.4 Spawning Habitat. Fall chinook salmon are known to spawn in the tailraces of Lower Granite, Little Goose, and Ice Harbor dams. The effects of FCRPS flow management on use of this spawning habitat is unknown. Spawning may be inhibited at temperatures above 61° F.

6.2.9.3 Upper Columbia River Spring Chinook Salmon

6.2.9.3.1 Juvenile Rearing Areas. Juvenile UCR spring chinook salmon rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.3.2 Juvenile Migration Corridors

Water Quality. Effects of the proposed action on biological requirements for water quality in juvenile rearing areas are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Water Velocity/Cover/Shelter/Food/Riparian Conditions/Space. Effects of the proposed action on these constituent elements of critical habitat in juvenile migration corridors are similar to those discussed for SR spring/summer chinook salmon (above). The likelihood of meeting or exceeding spring flow objectives at Priest Rapids and McNary dams under the proposed action is less than 85%, except at Priest Rapids during May (88%; Table 6.2-5).

Food. NMFS is uncertain whether yearling chinook salmon migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Migration Conditions. Juveniles are spring migrants with peak movement past Rock Island Dam in the mid-Columbia reach during late April and May. Depending on their natal tributary, juveniles pass through five (Methow River), four (Entiat River), or three (Wenatchee River) PUD projects before reaching McNary Dam. Transportation from McNary Dam has not been used as a protection measure for this ESU under existing operations. However, a portion of the run (typically less than 5%; Figure VI-5 in NMFS' 2000 Supplemental Biological Opinion) may have been collected and transported in the past. Although there are no ESU-specific survival rates for UCR spring chinook salmon through FCRPS hydroprojects, NMFS assumes that these are adequate represented by data for SR spring/summer chinook salmon. Using SIMPAS, NMFS estimated that the total system survival rate for UCR spring chinook salmon from the head of McNary pool to below Bonneville Dam averaged 57% during 1994 through 1999 (Table 6.2-8).

6.2.9.3.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling UCR spring chinook salmon. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.3.4 Adult Migration Corridors

Water Quality/Water Quantity/Velocity. Effects of the proposed action on biological requirements for these constituent elements of critical habitat in the adult migration corridor are the same as those discussed for SR spring/summer chinook salmon (above).

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified by the proposed action.

Riparian Vegetation/Food. UCR spring chinook salmon do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Based on recent radio-tracking and PIT-tag studies with SR spring/summer chinook salmon, NMFS estimates that the mean survival rate of adult UCR spring chinook salmon from below Bonneville Dam to the head of McNary pool is 89%, equivalent to a per-project survival rate of 97% (Table 6.1-1).

6.2.9.3.5 Spawning Habitat. Spawning habitat for UCR spring chinook salmon is not affected by the operations considered in this biological opinion.

6.2.9.4 Upper Willamette River Chinook Salmon

6.2.9.4.1 Juvenile Rearing Areas. Juvenile UWR chinook salmon rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.4.2 Juvenile Migration Corridors

Water Quality. Juvenile UWR chinook salmon migrate both as yearlings and subyearlings. Most of the migration moves through the lower Columbia River during February through May, prior to peak spring runoff and periods of involuntary spill. Thus, the proposed action is not expected to adversely modify biological requirements for water quality for this ESU in the juvenile migration corridor.

Water Quantity/Water Velocity/Cover/Shelter. Flow objectives have not been developed to benefit UWR chinook salmon. The proposed action is not expected to adversely modify biological requirements for water quantity and velocity, cover, or shelter in the juvenile migration corridor.

Food. NMFS is uncertain whether either yearling or subyearling UWR chinook salmon migrants have a biological requirement for food in the juvenile migration corridor or, if food is needed, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Riparian Vegetation. UWR chinook salmon do not have biological requirements for riparian vegetation in the juvenile migration corridor.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely modified by FCRPS operations.

Migration Conditions. Juvenile UWR chinook salmon do not pass any FCRPS dams and therefore are not subject to mortality during project passage.

6.2.9.4.3 Areas for Growth and Development to Adulthood. UWR chinook salmon emigrate from the Willamette River basin as a mixture of yearling and subyearling fish. Current FCRPS operations may have effects on rearing habitat in the Columbia River estuary and plume that in turn affect the growth and survival of one or both types of juvenile UWR chinook salmon. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.4.4 Adult Migration Corridors

Water Quality. Adult UWR chinook salmon migrate through the FCRPS during March through June. The latter portion of the run may be exposed to high dissolved gas concentrations during periods of involuntary spill.

Water Quantity/Velocity/Cover/Shelter/Space. Biological requirements of adult UWR chinook salmon for water quantity and velocity and for cover, shelter, and space will not be adversely modified under the proposed action.

Riparian Vegetation/Food. UWR chinook salmon do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Adults leave the Columbia River to enter the Willamette system below Bonneville Dam and thus are not subject to project passage mortality.

6.2.9.4.5 Spawning Habitat. Spawning habitat for UWR chinook salmon is not affected by the operations considered in this biological opinion.

6.2.9.5 Lower Columbia River Chinook Salmon

6.2.9.5.1 Juvenile Rearing Areas

Water Quality/Quantity/Velocity. Spill operations at Bonneville Dam, such as spill for debris removal, gas generation/abatement testing, or juvenile fish passage can create total dissolved gas concentrations high enough to kill yolk sac fry in redds in the Ives Island area. This effect can be prevented by providing flows that create a compensation depth over the redds, reducing the effective total dissolved gas concentration to 105% of saturation or less. During spring 2000, a Bonneville outflow of at least 200 kcfs was needed to create the compensation depth for Ives Island redds (i.e., redds dug at spawning flows of 125 to 165 kcfs). Under the proposed action, the likelihood of providing Bonneville outflows equal to or higher than 125 kcfs 78% during January and 70% or less during February and March (Table 6.2-5).

Cover/Shelter/Food/Riparian Vegetation/Space. LCR chinook salmon emigrated from the Ives Island area soon after emergence (late January through early April). Smolts are subject to stranding and death through dessication and exposure to bird predation when Bonneville discharge fluctuates around 275 kcfs.

6.2.9.5.2 Juvenile Migration Corridors

Water Quality. Juvenile LCR chinook salmon are spring migrants. Effects of the proposed action on biological requirements for water quality in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Water Velocity/Cover/Shelter. Flow objectives have not been developed to benefit LCR chinook salmon. The proposed action is not expected to adversely modify biological requirements for water quantity and velocity, cover, or shelter in the juvenile migration corridor.

Riparian Vegetation. LCR chinook salmon do not have biological requirements for riparian vegetation in the juvenile migration corridor.

Food. NMFS is uncertain whether yearling or subyearling LCR chinook salmon migrants have a biological requirement for food in the juvenile migration corridor or, if food is needed, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely modified by FCRPS operations.

Migration Conditions. Juveniles are late winter/early spring migrants. Only those that emerge from the Wind, Little White Salmon, and [Big] White Salmon rivers in Washington, and the Hood River in Oregon, encounter Bonneville Dam after entering the Columbia River. Although there are no ESU-specific survival rates of LCR chinook salmon past Bonneville Dam, NMFS assumes that these are adequately represented by data for yearling and subyearling chinook salmon migrants emerging from the Snake River. Using SIMPAS, NMFS estimated an average system survival rate of 87% for yearling migrants and 74% for subyearling migrants through Bonneville pool and dam during 1994 through 1999 (Table 6.2-8). However, it should be noted that the potential for these effects is limited to passage at one (i.e., Bonneville) project for a portion of the subbasin populations.

6.2.9.5.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River estuary and plume that in turn affect the growth and survival of subyearling LCR chinook salmon. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.5.4 Adult Migration Corridors

Water Quality/Quantity/Velocity. Effects of the proposed action on biological requirements for water quality, quantity, and velocity are different for the spring- and fall-run components of the ESU. For spring-run chinook salmon, effects are similar to those described above for SR spring/summer chinook salmon. For fall-run fish, low flows during late summer and early fall, related to high temperatures, may delay migration through Bonneville pool and potentially lead to disease transmission between adults delayed in fish ladders. However, it should be noted that the potential for these effects is limited to passage at one (i.e., Bonneville) project for a portion of the subbasin populations.

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. LCR chinook salmon do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Based on recent radio-tracking and PIT-tag studies with SR spring/summer and fall chinook salmon, NMFS estimates that the average survival rate of adult migrants from below Bonneville to tributaries to Bonneville pool is 97% for spring-run fish and 94% for fall-run fish (Table 6.1-1). It should be noted that this type of mortality is limited to passage at one project for a portion of the subbasin populations.

6.2.9.5.5 Spawning Habitat

Water Quality/Water Quantity/Velocity and Cover/Shelter/Food/Riparian Vegetation/Space. The Action Agencies can use reservoir storage from the upper Columbia and Snake River basins to augment mainstem flows below Bonneville Dam, creating access to, and increasing the areal extent of, shallow water spawning habitat in the Ives Island area. Under the proposed action, the likelihood of meeting a minimum spawning flow (125 kcfs at Bonneville Dam) during September and October is 30% or less. Adult LCR chinook salmon do not have biological requirements for food associated with spawning habitat.

6.2.9.6 Snake River Steelhead

6.2.9.6.1 Juvenile Rearing Areas. Juvenile SR steelhead rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.6.2 Juvenile Migration Corridors

Water Quality/Quantity/Velocity/Cover/Shelter. Effects of the proposed action on biological requirements for water quality, quantity, velocity, cover, and shelter in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Riparian Vegetation. Yearling steelhead migrants do not have biological requirements for riparian vegetation in juvenile migration corridors.

Food. NMFS is uncertain whether yearling steelhead migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely modified under the proposed action.

Migration Conditions. Juvenile SR steelhead are spring migrants with peak movement past Lower Granite Dam during April and May. Using SIMPAS, NMFS estimated that an average of 73% of the run was transported from the Snake River collector projects during 1994 through 1999 (Table 6.2-8). The rest of the run migrated inriver past eight FCRPS projects. The direct survival of transported juveniles over the same period was at least 98% and NMFS estimates that the average system survival rate of inriver migrants was approximately 40%. The total (transported plus inriver) system survival rate for SR steelhead ranged from 44% to 47% (depending on the level of differential mortality of transported fish assumed in the analysis).

6.2.9.6.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling SR steelhead. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.6.4 Adult Migration Corridors

Water Quality/Water Quantity/Velocity. Effects of the proposed action on biological requirements for water quality, quantity, and velocity in adult migration corridors are the same as those discussed for SR spring/summer chinook salmon (above).

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. SR steelhead do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Based on recent radio-tracking and PIT-tag studies, the mean survival rate of adult migrants between Bonneville and Lower Granite dams is 80%, equivalent to a per-project survival rate of 97% (Table 6.1-1). Few downstream-migrating adult steelhead (kelts) survive to spawn a second time without passing through dams (7% to lower Columbia River tributaries). The mortality of kelts passing through FCRPS projects has not been investigated. Assuming that turbine survival is similar to that of upstream migrating adults (22% to 57%, p. VI-15 in NMFS 1998), the survival of kelts past multiple dams to spawn a second time is unlikely.

6.2.9.6.5 Spawning Habitat. Spawning habitat for SR steelhead is not affected by the operations considered in this biological opinion.

6.2.9.7 Upper Columbia River Steelhead

6.2.9.7.1 Juvenile Rearing Areas. Juvenile UCR steelhead rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.7.2 Juvenile Migration Corridors

Water Quality. Effects of the proposed action on biological requirements for water quality in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Velocity/Cover/Shelter. Under the proposed action, the likelihood of meeting or exceeding flow objectives at Priest Rapids and McNary dams during the spring migration season (April through June) is 80% or less under the base case, except during May (88%; Table 6.2-5).

Riparian Vegetation. Yearling steelhead migrants do not have biological requirements for riparian vegetation in juvenile migration corridors.

Food. NMFS is uncertain whether yearling steelhead migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely modified under the proposed action.

Migration Conditions. Juveniles are spring migrants with peak movement past Rock Island Dam in the mid-Columbia reach during May. Depending on their natal tributary, juveniles pass through five (Methow River), four (Entiat River), or three (Wenatchee River) mid-Columbia Public Utility District (PUD) projects before reaching McNary Dam. Under existing operations, transportation from McNary Dam has not been used as a protection measure for UCR steelhead. However, a portion of the run (typically less than 5%; Figure VI-5 in NMFS' 2000 Supplemental FCRPS Biological Opinion) has been collected and transported in the past. Although there are no ESU-specific survival rates of UCR steelhead through FCRPS hydroprojects, NMFS assumes that these are adequately represented by data for SR steelhead. Using SIMPAS, NMFS estimated that the total system survival rate of juvenile steelhead from the head of McNary pool to below Bonneville Dam averaged 57% during 1994 through 1999 (Table 6.2-8).

6.2.9.7.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling UCR steelhead. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.7.4 Adult Migration Corridors

Water Quality/Water Quantity/Velocity. Effects of the proposed action on biological requirements for water quality, quantity, and velocity in adult migration corridors are the same as those discussed for SR spring/summer chinook salmon (above).

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. UCR steelhead do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Based on recent radio-tracking and PIT-tag studies with SR steelhead, NMFS estimates that the mean survival rate of adult migrants from below Bonneville Dam to the head of McNary pool is 89% (Table 6.1-1).

6.2.9.7.5 Spawning Habitat. Spawning habitat for UCR steelhead is not affected by the operations considered in this biological opinion.

6.2.9.8 Middle Columbia River Steelhead

6.2.9.8.1 Juvenile Rearing Areas. Juvenile MCR steelhead rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.8.2 Juvenile Migration Corridors

Water Quality. Effects of the proposed action on biological requirements for water quality in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Velocity/Cover/Shelter. Flow objectives have not been developed to benefit MCR steelhead. However, yearling migrants from this ESU would be likely to benefit from flow objectives at Priest Rapids and McNary dams, developed to protect yearling migrants from the upper Columbia River basin. Under the proposed action, the likelihood of meeting or exceeding flow objectives at Priest Rapids and McNary dams during the spring migration season (April through June) is 80% or less under the base case, except during May (88%; Table 6.2-5).

Riparian Vegetation. Yearling steelhead migrants do not have biological requirements for riparian vegetation in juvenile migration corridors.

Food. NMFS is uncertain whether yearling steelhead migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely modified under the proposed action.

Migration Conditions. Juveniles are spring migrants. These fish do not pass Rock Island Dam so there is no ESU-specific information on historical passage patterns. Only those that emigrate from the Yakima and Walla Walla subbasins encounter McNary Dam after entering the Columbia River. Under existing operations, transportation from McNary Dam has not been used as a protection measure for MCR steelhead. However, a portion of the run from the Yakima and Walla Walla subbasins has probably been collected and transported in the past. Although there are no ESU-specific survival rates of MCR steelhead through FCRPS projects, NMFS assumes that these are adequately represented by data for SR steelhead. Using SIMPAS, NMFS estimated that the average FCRPS system survival rate of juvenile steelhead from the Yakima and McNary subbasins, from the head of McNary pool to below Bonneville Dam, during 1994 through 1999 was 57% (Table 6.2-8). Based on the project-specific survival rates shown in Table 6.2-8, the average system survival rates of MCR steelhead emigrating from tributaries to the John Day and The Dalles pools are approximately 63% and 74%, respectively.

6.2.9.8.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling MCR steelhead. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.8.4 Adult Migration Corridors

Water Quality/Water Quantity/Velocity. Effects of the proposed action on biological requirements for water quality, quantity, and velocity in adult migration corridors are the same as those discussed for SR spring/summer chinook salmon (above).

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Food/Riparian Vegetation. MCR steelhead do not have biological requirements for food and riparian vegetation in the adult migration corridor.

Migration Conditions. Based on recent radio-tracking and PIT-tag survival studies with SR steelhead, NMFS estimates that the mean survival rates of adult migrants from below Bonneville Dam to the heads of The Dalles, John Day, and McNary pools are 94%, 92%, and 89%, respectively (Table 6.1-1).

6.2.9.8.5 Spawning Habitat. Spawning habitat for MCR steelhead is not affected by the operations considered in this biological opinion.

6.2.9.9 Upper Willamette Steelhead

6.2.9.9.1 Juvenile Rearing Areas. Juvenile UWR steelhead rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.9.2 Juvenile Migration Corridors

Water Quality. Effects of the proposed action on biological requirements for water quality in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Velocity/Cover/Shelter. Flow objectives have not been developed to benefit UWR steelhead. The proposed action is not expected to adversely modify biological requirements for water quantity and velocity, cover, or shelter in the juvenile migration corridor.

Riparian Vegetation. Yearling steelhead migrants do not have biological requirements for riparian vegetation in juvenile migration corridors.

Food. NMFS is uncertain whether yearling steelhead migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely modified under the proposed action.

Migration Conditions. Juvenile UWR steelhead enter the Columbia River below Bonneville Dam and thus are not subject to passage mortality.

6.2.9.9.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling UWR steelhead. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.9.4 Adult Migration Corridors

Water Quality/Water Quantity/Velocity. Effects of the proposed action on biological requirements for water quality, quantity, and velocity in adult migration corridors are the same as those discussed for SR spring/summer chinook salmon in the adult migration corridor (above).

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. UWR steelhead do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Adults leave the Columbia River to enter the Willamette system below Bonneville Dam and thus are not subject to project passage mortality.

6.2.9.9.5 Spawning Habitat. Spawning habitat for UWR steelhead is not affected by the operations considered in this biological opinion.

6.2.9.10 Lower Columbia River Steelhead

6.2.9.10.1 Juvenile Rearing Areas. Juvenile LCR steelhead rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.10.2 Juvenile Migration Corridors

Water Quality. Effects of the proposed action on biological requirements for water quality in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Velocity/Cover/Shelter. FCRPS flow management, in conjunction with other fish protection measures, benefits smolt survival. Flow objectives have not been developed to benefit LCR steelhead. The proposed action is not expected to adversely modify biological requirements for water quantity and velocity, cover, or shelter in the juvenile migration corridor.

Riparian Vegetation. Yearling steelhead migrants do not have biological requirements for riparian vegetation in juvenile migration corridors.

Food. NMFS is uncertain whether yearling steelhead migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely modified under the proposed action.

Migration Conditions. Juvenile LCR steelhead are yearling migrants. There is no ESU-specific information on historical passage patterns but only those from the Wind River, Washington, and the Hood River, Oregon encounter Bonneville Dam after entering the Columbia River. Although there are no ESU-specific survival rates of LCR steelhead past Bonneville Dam, NMFS assumes that these are adequately represented by data for SR steelhead. Using SIMPAS, NMFS estimated an average survival rate of 85% through Bonneville pool and dam during 1994 through 1999 (Table 6.2-8). However, it should be noted that the potential for these effects is limited to passage at one (i.e., Bonneville) project for a portion of the subbasin populations.

6.2.9.10.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling LCR steelhead. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.10.4 Adult Migration Corridors

Water Quality/Water Quantity/Velocity. Although effects of the proposed action on biological requirements for water quantity and velocity in adult migration corridors are the same as those discussed for SR spring/summer chinook salmon (above), effects are limited to passage at one (i.e., Bonneville) project for a portion of the subbasin populations.

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. LCR steelhead do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Based on recent radio-tracking and PIT-tag studies with SR steelhead, NMFS estimates that the mean survival rate of adult migrants from below Bonneville Dam to tributaries in Bonneville pool is approximately 97% (Table 6.1-1). However, it should be noted that the potential for these effects is limited to passage at one (i.e., Bonneville) project for a portion of the subbasin populations.

6.2.9.10.5 Spawning Habitat. Spawning habitat for LCR steelhead is not affected by the operations considered in this biological opinion.

6.2.9.11 Columbia River Chum Salmon

6.2.9.11.1 Juvenile Rearing Areas

Water Quality/Quantity/Velocity/Cover/Shelter/Riparian Vegetation/Food/Space. Effects of the proposed action on biological requirements for these constituent elements of juvenile rearing habitat are the same as those discussed for LCR chinook salmon in juvenile rearing areas (above).

6.2.9.11.2 Juvenile Migration Corridors

Water Quality. Effects of the proposed action on biological requirements for water quality in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Velocity/Cover Shelter. Under the proposed action, the likelihood of meeting or exceeding flow objectives at Bonneville Dam during the late winter/early spring migration season is 76% (i.e., during February and March, Table 6.2-5).

Riparian Vegetation. Subyearling chum salmon migrants do not have biological requirements for riparian vegetation in the juvenile migration corridor.

Food. NMFS is uncertain whether subyearling chinook salmon migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely affected under the proposed action.

Migration Conditions. Juvenile chum salmon are late winter/early spring, subyearling migrants. Although chum salmon spawned historically in the lower reaches of several tributaries to Bonneville pool and along the Washington shoreline, this habitat was inundated by Bonneville pool in 1938 (Fulton 1970). Although some adult chum salmon still pass Bonneville Dam (see below), the Smolt Monitoring Program has no record of juvenile chum salmon passage at Bonneville Dam between 1985 and the present (memorandum from D. Wood to M. Dehart (Fish Passage Center) dated February 11, 2000). Thus, it is unlikely that more than a very small proportion of any year class is affected by project passage.

6.2.9.11.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River estuary and plume that in turn affect the growth and survival of subyearling CR chum salmon. However, the evidence for these relationships is largely inferential and is the subject of ongoing research

6.2.9.11.4 Adult Migration Corridors

Water Quality/Water Quantity/Velocity. Adult CR chum salmon are late fall/early winter migrants. Biological requirements for water quality, quantity, or velocity in the adult migration corridor for this ESU will not be adversely modified under the proposed action.

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. CR chum salmon do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. The latest available full count of chum salmon over Bonneville Dam is 195 adults during 1998. Complete counts for 1999 are not yet available. There are no estimates of adult passage survival of CR chum salmon at Bonneville or any other FCRPS dam.

6.2.9.11.5 Spawning Habitat

Water Quality/Water Quantity/Velocity and Cover/Shelter/Food/Riparian Vegetation/Space. The Action Agencies can use reservoir storage from the upper Columbia and Snake River basins to augment mainstem flows below Bonneville Dam, creating access to, and increasing the areal extent of, spawning habitat in the Ives Island area. Under the proposed action, the likelihood of meeting a minimum spawning flow (125 kcfs at Bonneville Dam) during November and December is less than 55% (Table 6.2-5). Adult CR chum salmon do not have biological requirements for food associated with spawning habitat.

6.1.9.12 Snake River Sockeye Salmon

6.2.9.12.1 Juvenile Rearing Areas. Juvenile SR sockeye salmon rear in tributaries and migrate through the FCRPS as yearlings. Therefore, juvenile rearing areas for this ESU are not affected by the operations considered in this biological opinion.

6.2.9.12.2 Juvenile Migration Corridors

Water Quality. Effects of the proposed action on biological requirements for water quality in juvenile migration corridors are the same as those discussed for SR spring/summer chinook salmon in the juvenile migration corridor (above).

Water Quantity/Velocity/Cover/Shelter. Under the proposed action, the likelihood of meeting or exceeding flow objectives at Lower Granite and McNary dams during the spring migration season (April through June) is 70% or less (Table 6.2-5).

Riparian Vegetation. Yearling sockeye salmon migrants do not have biological requirements for riparian vegetation in the juvenile migration corridor.

Food. NMFS is uncertain whether yearling sockeye salmon migrants have a biological requirement for food in the juvenile migration corridor or, if food is required, whether the abundance or composition of the prey assemblage would be adversely modified under the proposed action.

Space. Biological requirements for space in the juvenile migration corridor will not be adversely affected under the proposed action.

Migration Conditions. Snake River sockeye salmon are spring migrants with peak movement past Lower Granite Dam during May. An unknown proportion of the juvenile migration is transported from the Snake River collector projects. Studies at John Day and Wanapum dams with run-of-the-river unlisted UCR sockeye salmon found that the FGE of juvenile sockeye salmon was lower than that of spring chinook salmon or steelhead. If this finding also applies to the Snake River ESU, it is likely that a smaller proportion of the sockeye salmon outmigration is transported compared to those of spring/summer chinook salmon or steelhead. If transport rates are lower, it is likely that the total direct survival of this species is also less than that of other yearling migrants.

6.2.9.12.3 Areas for Growth and Development to Adulthood. Current FCRPS operations may have effects on rearing habitat in the Columbia River plume that in turn affect the growth and survival of yearling SR sockeye salmon. However, the evidence for these relationships is largely inferential and is the subject of ongoing research.

6.2.9.12.4 Adult Migration Corridors

Water Quality/Quantity/Velocity. Effects of the proposed action on biological requirements for water quality, quantity, and velocity in adult migration corridors are the same as those for SR spring/summer chinook salmon in the adult migration corridor, discussed above.

Cover/Shelter/Space. Biological requirements for cover, shelter, and space in the adult migration corridor will not be adversely modified under the proposed action.

Riparian Vegetation/Food. SR sockeye salmon do not have biological requirements for riparian vegetation or food in the adult migration corridor.

Migration Conditions. Because few adult sockeye salmon have returned to the Snake River basin in recent years, little information has been collected on their survival through the mainstem FCRPS projects. Tagging studies using adult sockeye salmon from the unlisted Upper Columbia River ESU measured an average per-project survival of 98% through the lower Columbia River. Expanding the per-project rate over the 8-project (Bonneville to Lower Granite) reach, NMFS estimates an adult survival rate of 85% for this ESU (Table 6.1-1).

6.2.9.12.5 Spawning Habitat. Spawning habitat for SR sockeye salmon is not affected by the operations considered in this biological opinion.

6.3 ANALYSIS OF THE EFFECTS OF PROPOSED ACTION ON BIOLOGICAL REQUIREMENTS OVER THE FULL LIFE CYCLE

Tables A-5a through A-5d and A-6a through A-6d show the average population growth rate (lambda) at the ESU and, where applicable, subbasin levels and the risk of absolute extinction, where data are adequate for the latter type of calculation. In this section, NMFS looks at the likely effects of the proposed action on the risk of extinction metric, which NMFS considers an indicator of status relative to the jeopardy standard (Sections 1.3.1.1 and 6.1.2). That is, NMFS evaluates the importance of the effects described in the preceding section, as likely to occur within the action area, in the context of the full life cycle. Where sufficient data are available (five ESUs), NMFS uses a quantitative model to compare the expected survival changes associated with the proposed action to the jeopardy standard indicator metrics. However, the data for most ESUs considered in this biological opinion are too scarce or are not of adequate quality to permit a quantitative life cycle analysis. The NMFS therefore discusses the importance of FCRPS operations restricting population growth necessary to ensure a high likelihood of survival and limiting an adequate potential for recovery for each ESU. For some ESUs, inferences can be drawn from the quantitative results described above.

Details of the quantitative analyses used to evaluate the effects of the proposed action on biological requirements over the full life cycle are described in Section 6.1.2 and Appendix C. Results are summarized for five ESUs in the following sections.

6.3.1 Snake River Spring/Summer Chinook Salmon

Evaluation of species-level effects of the proposed action requires placing the action-area effects in the context of the full life cycle. The factors described in Section 6.2.9 affect elements of critical habitat and the survival and recovery of SR spring/summer chinook salmon in the action area. A large number of additional factors (summarized in Myers et al. 1998, Section 4.1, and Appendix A) limits this ESU over its full range, including habitat degradation in many areas due to forest, grazing, and mining practices (loss of pools, high temperatures, low flows, poor overwintering conditions, and high sediment loads).

In this section, NMFS evaluates quantitatively the action-area effects associated with the proposed action and the effects of human activities affecting survival in other parts of the life cycle.

6.3.1.1 Survival and Recovery Components of the Jeopardy Standard

NMFS used Leslie matrices (Section 6.1.2) to evaluate the likely status of stocks under the proposed action relative to the jeopardy standard indicator metrics (Sections 1.3.1.1 and 6.1.2). The matrix analysis incorporated the survival rates in other life stages that NMFS expects to result from likely actions described in the All-H Paper. One matrix was developed for each of seven index stocks in the Snake River basin (Appendix A). As described in Section 6.1.2, the elements of the Leslie matrices were first parameterized to reflect, as closely as possible, the average survival rates that influenced the 1980 to 1994 brood year returns (base matrix). Run reconstructions for these brood years were obtained from PATH (Beamesderfer et al. 1997). Smolt passage direct survival rate estimates for the 1982 to 1996 migration years (1980 to 1994 brood years) also were obtained from PATH (Marmorek and Peters 1998) for the base matrix. The equilibrium rate of annual population growth was then estimated from the base matrix.

NMFS then changed juvenile smolt survival rates to reflect effects of the proposed action, generated a new current matrix, and estimated a current population growth rate. Table 6.2-8 shows smolt passage direct survival estimates. A new equilibrium rate of annual population growth was then estimated from the current matrix and compared to the base population growth rate.

Two estimates of total (direct and indirect) juvenile passage survival were included in both the base and the current matrices. Each represented an average of the 0.63 to 0.73 range of differential delayed mortality (D) estimates described in Section 6.2. The high and low juvenile passage survival estimates differed only in the treatment of delayed mortality of non-transported fish. Under the low delayed mortality assumption, no post-Bonneville mortality of non-transported fish was attributed to the hydrosystem. Under the high delayed mortality assumption, post-Bonneville mortality attributed to the hydrosystem was the average of the PATH lambda-n estimates (Marmorek and Peters 1998) associated with D equals of 0.63 and 0.73. These estimates of mortality were 0.709 and 0.743, respectively.

No other survival rates were estimated to have changed between the average base and the current condition. For example, adult survival through the hydrosystem was determined to be unchanged under the proposed action, compared to average adult survival between 1983 (first adult returns from 1980 brood year) and the present. For example, elements of Table 6.1-1 are based on 1970s and 1980s radiotelemetry studies.

Estimates of survival rates that were included in the base and current matrices are displayed in Tables 6.3-1 and 6.3-2. The current (proposed action) average per-generation survival rate represents a 19% increase (1.19 multiplier) from the base survival rate for all seven Snake River spring/summer chinook index stocks. This estimated change is comparable to PATH's 23% (FLUSH) to 34% (CRiSP) increase in direct passage survival from the 1980 to 1994 brood year average (retrospective analysis) to the 1995 Biological Opinion conditions (A1 analysis) (Marmorek and Peters 1998).

The estimated change in base to current population growth rate was then compared with the changes needed to achieve the following:

- Reduce extinction risk to 5% or less in 24 and 100 years (Tables A-6 and A-7)

- Increase the likelihood of meeting 8-year geometric mean recovery levels to 50% or more in 48 and 100 years (Tables A-8 and A-9)

This comparison was made after converting the necessary incremental changes in lambda (annual population growth rate) in those tables to necessary incremental changes in survival over a generation (i.e., egg-to-spawner survival rate).

Table 6.3-3 displays the additional improvements in survival that would be necessary, beyond the 19% improvement associated with the proposed action, to reduce the extinction risk to 5% and increase the likelihood of recovery to 50%. Values less than or equal to 1.0 indicate that no further survival improvements are necessary to achieve the risk levels associated with these indicator metrics. Values greater than 1.0 indicate the multiplier by which survival would have to improve to achieve these indicator risk levels. For example, the survival change necessary to reduce the risk of extinction in 24 years to 5% (the third column of Table 6.3-3) is 0.77 to 0.84 for the Marsh Creek index stock. This means that the proposed action, combined with expected survival in other life stages, is sufficient to reduce the 24-year extinction risk to 5% or less. On the other hand, the survival change necessary for a 50% likelihood of meeting proposed recovery abundance levels in 48 years (the fourth column of Table 6.3-3) is 1.24 to 1.48 for the Marsh Creek index stock. This means that an additional 24 to 48% increase in egg-to-adult survival, or any component life-stage-specific survival rate, would be necessary to achieve a 50% likelihood of recovery in 48 years.

Table 6.3-1. Snake River Spring/Summer Chinook Matrix Life-Stage Survival and Harvest Rate Estimates, 1980 to 1994 Brood Year Base Leslie Matrix

			Low Delayed Mortality Assumption		**High Delayed Mortality Assumption**								
Snake River Spring/ Summer Chinook	**Mean Egg-to-Smolt Survival**	**Mean Smolts per Spawner**	**Mean Juvenile FCRPS Hydro Survival (including delayed effects)**	**Mean "Non-Hydro" Estuary/ Early Ocean Survival**	**Mean Juvenile FCRPS Hydro Survival (including delayed effects)**	**Mean "Non-Hydro" Estuary/ Early Ocean Survival**	**Mean Ocean Exploitation Rate**	**Mean Ocean "Non-Harvest" Survival Rate (Multiply [1-exp. Rate] for total O2+ ocean survival)**	**Mean Inriver Harvest Rate**	**Mean Adult FCRPS Passage Survival Rate**	**Mean Upper Dam to Spawning Survival Rate**	**Mean Egg-to-Adult Survival Rate**	**Mean Adult-to-Adult Return**
Marsh	0.019	52.700	0.470	0.062	0.128	0.227	0.000	0.566	0.082	0.794	0.900	0.00020	0.569
Sulphur	0.039	109.800	0.470	0.062	0.128	0.227	0.000	0.566	0.082	0.794	0.900	0.00042	1.184
Bear Valley	0.029	80.400	0.470	0.062	0.128	0.227	0.000	0.566	0.082	0.794	0.900	0.00031	0.867
Johnson	0.027	75.500	0.470	0.062	0.128	0.227	0.000	0.566	0.025	0.794	0.900	0.00031	0.865
Poverty Flats	0.024	68.600	0.470	0.062	0.128	0.227	0.000	0.566	0.025	0.794	0.900	0.00028	0.786
Imnaha	0.013	36.500	0.470	0.062	0.128	0.227	0.000	0.566	0.025	0.794	0.900	0.00014	0.406
Minam	0.025	69.600	0.470	0.062	0.128	0.227	0.000	0.566	0.082	0.794	0.900	0.00027	0.751

Note: All non-bold survival rates were estimated through methods described in Section 6.1.2 and Appendix C and input to the matrix, with two exceptions. Mean egg-to-smolt survival was adjusted to other elements of the matrix and to mean 1980 to 1994 ln (recruits/spawner) estimates. Mean non-hydro estuary/early ocean survival was adjusted to estimates of direct and indirect hydro survival and total smolt survival. **Bold** survival rates are summary statistics derived from the other survival rates.

Table 6.3-2. Snake River Spring/Summer Chinook Matrix Life-Stage Survival and Harvest Rate Estimates for the Current Leslie Matrix Representing the Proposed Action

			Low Delayed Mortality Assumption		**High Delayed Mortality Assumption**								
Snake River Spring/ Summer Chinook	**Mean Egg-to-Smolt Survival**	**Mean Smolts per Spawner**	**Mean Juvenile FCRPS Hydro Survival (including delayed effects)**	**Mean "Non-Hydro" Estuary/ Early Ocean Survival**	**Mean Juvenile FCRPS Hydro Survival (including delayed effects)**	**Mean "Non-Hydro" Estuary/ Early Ocean Survival**	**Mean Ocean Exploitation Rate**	**Mean Ocean "Non-Harvest" Survival Rate (Multiply [1-exp. Rate] for total O2+ ocean survival)**	**Mean Inriver Harvest Rate**	**Mean Adult FCRPS Passage Survival Rate**	**Mean Upper Dam to Spawning Survival Rate**	**Mean Egg-to-Adult Survival Rate**	**Mean Adult-to-Adult Return**
Marsh	0.019	**52.700**	0.560	0.062	0.153	0.227	0.000	0.566	0.082	0.794	0.900	**0.00024**	**0.678**
Sulphur	0.039	**109.800**	0.560	0.062	0.153	0.227	0.000	0.566	0.082	0.794	0.900	**0.00050**	**1.412**
Bear Valley	0.029	**80.400**	0.560	0.062	0.153	0.227	0.000	0.566	0.082	0.794	0.900	**0.00037**	**1.034**
Johnson	0.027	**75.500**	0.560	0.062	0.153	0.227	0.000	0.566	0.025	0.794	0.900	**0.00037**	**1.031**
Poverty Flats	0.024	**68.600**	0.560	0.062	0.153	0.227	0.000	0.566	0.025	0.794	0.900	**0.00033**	**0.937**
Imnaha	0.013	**36.500**	0.560	0.062	0.153	0.227	0.000	0.566	0.025	0.794	0.900	**0.00017**	**0.484**
Minam	0.025	**69.600**	0.560	0.062	0.153	0.227	0.000	0.566	0.082	0.794	0.900	**0.00032**	**0.896**

Note: All non-bold survival rates were estimated through methods described in Section 6.1.2 and Appendix C and input to the matrix, with two exceptions. Mean egg-to-smolt survival was adjusted to other elements of the base matrix and to mean 1980 to 1994 ln (recruits/spawner) estimates. Mean non-hydro estuary/early ocean survival was adjusted to estimates of direct and indirect hydro survival and total smolt survival in the base matrix. **Bold** survival rates are summary statistics derived from the other survival rates.

NMFS estimates both best- and worst-case situations. Best case represents the high estimate of juvenile smolt survival (Tables 6.3-1 and 6.3-2), coupled with needed survival improvements based on (1) the 1980 to 2004 observed and projected spawning escapements (Table A-7 and A-9) which represent higher average survival than during the 1980-1999 period, and (2) an assumption that productivity of wild-origin spawners is high when the spawning population includes hatchery-origin fish. In this case, productivity of hatchery-origin spawners is assumed to be low (20% as effective as naturally produced spawners). Worst case represents the low estimate of juvenile smolt survival, coupled with needed survival improvements based on (1) the 1980 to 1999 observed spawning escapements (Tables A-6 and A-8), and (2) an assumption that productivity of wild-origin spawners is low when the spawning population includes hatchery origin fish. In this case, productivity of hatchery-origin spawners is assumed to be high (80% as effective as naturally produced spawners).

Under the best-case assumptions, the increased survival expected from the proposed action, coupled with expected survival in other life stages, is sufficient to reduce the likelihood of extinction to 5% and to result in at least a 50% likelihood of recovery for three of the seven index stocks (Bear Valley Creek [Middle Fork Salmon River], Johnson Creek [South Fork Salmon River], and the Poverty Flats reach of the South Fork Salmon River). Additional survival improvements ranging from 19 to 127% (1.19 to 2.27 survival multipliers) would be necessary to reduce extinction risk and increase the likelihood of recovery for the other four index stocks.

Under the worst-case assumptions, only Johnson Creek meets the identified extinction risk and recovery levels under the proposed action. Additional survival improvements ranging from 12 to 1,207% (1.12 to 13.07 survival multipliers) would be necessary to reduce extinction risk and increase the likelihood of recovery for the other six index stocks.

6.3.1.2 Full Mitigation Component of the Jeopardy Standard

As described in Section 6.1.2, a metric indicative of the full mitigation component of the jeopardy standard is NMFS' best estimate of the natural survival rate of juveniles and adults that would occur without the FCRPS. The estimated Snake River spring/summer chinook natural survival through the hydrosystem is approximately 82% for juveniles, 85% for adults, and 70% for combined juvenile and adult survival.

As described in Table 6.3-2, the high estimate of juvenile survival (as described above, including indirect effects) associated with the proposed action is 56%, while the low estimate is 15.3%. The estimate of adult survival is 79.4%, which leads to 12.1 to 44.5% combined juvenile and adult survival when passing through the hydrosystem.

The estimated survival when passing through the hydrosystem under the proposed action is clearly lower than that estimated to occur in the absence of the FCRPS. Table 6.1-3 describes the additional change in passage survival (including indirect effects) that would be necessary to

Table 6.3-3. Snake River Spring/Summer Chinook Estimated Range of Per-generation Survival Improvements

Population	**5% extinct, 100 years**	**5% extinct, 24 years**	**50% Recovery, 48 years**	**50% Recovery, 100 years**	**Natural River**
Marsh Creek					
Best Case	0.94	0.77	1.24	1.06	1.57
Worst Case	1.19	0.84	1.48	1.26	5.75
Sulphur Creek					
Best Case	1.19	0.84	1.18	1.01	1.57
Worst Case	1.54	1.14	1.32	1.12	5.75
Bear Valley Creek					
Best Case	0.84	0.84	1.00	0.89	1.57
Worst Case	0.92	0.84	1.12	1.00	5.75
Johnson Creek					
Best Case	0.84	0.84	0.84	0.79	1.57
Worst Case	0.84	0.84	0.97	0.91	5.75
Poverty Flats					
Best Case	0.84	0.84	0.91	0.85	1.57
Worst Case	1.11	0.84	1.33	1.24	5.75
Imnaha River					
Best Case	1.75	0.84	2.04	2.27	1.57
Worst Case	11.33	7.25	8.83	9.44	5.75
Minam River					
Best Case	1.88	1.02	2.08	1.84	1.57
Worst Case	13.07	8.89	10.70	9.45	5.75

Note: These improvements are needed to satisfy five jeopardy standard indicator metrics, given implementation of the proposed action. Numbers less than or equal to 1.0 indicate that additional survival improvements are not necessary. Numbers greater than 1.0 are the necessary survival multipliers. See the text for details and definition of best and worst cases.

meet NMFS' estimate of natural survival. The additional survival improvement ranges from 57% (1.57 multiplier) for the high survival estimate to 475% (5.75 multiplier) for the low survival estimate.

6.3.1.3 Consideration of All Components of the Jeopardy Standard

For five of the seven Snake River spring/summer chinook index stocks, the incremental change in survival needed to meet the survival and recovery indicator risk metrics is lower than that needed to achieve a natural survival rate through the FCRPS. Based on the construction of the jeopardy standard described in Section 1.3.1.1, the survival and recovery components are relevant for evaluating the effects of the proposed action on the Salmon River index stocks (the Poverty Flats reach of the South Fork Salmon River and Marsh, Sulphur, Bear Valley, and Johnson creeks). The full mitigation component of the jeopardy standard is most relevant for evaluating the effects of the proposed action on the Imnaha and Minam River index stocks.

6.3.2 Upper Columbia River Spring Chinook Salmon

Evaluation of species-level effects of the proposed action requires placing the action-area effects in the context of the full life cycle. The factors described in Section 6.2.9 affect elements of critical habitat and the survival and recovery of UCR spring chinook salmon in the action area. Additional factors (summarized in Myers et al. 1998, Section 4.1, and Appendix A) limit this ESU over its full range. Chief Joseph Dam and Grand Coulee Dam prevent access to historical spawning grounds farther upstream. There are local problems related to irrigation diversions and hydroelectric development, as well as degraded riparian and instream habitat from urbanization and livestock grazing along riparian corridors.

In this section, NMFS evaluates quantitatively the action-area effects associated with the proposed action and the effects of human activities affecting survival in other parts of the life cycle.

6.3.2.1 Survival and Recovery Components of the Jeopardy Standard

NMFS used a Leslie matrix (Section 6.1.2) to evaluate the likely status of stocks under the proposed action relative to the jeopardy standard indicator metrics (Sections 1.3.1.1 and 6.1.2). The matrix analysis incorporated the survival rates in other life stages that NMFS expects to result from likely actions described in the All-H Paper. One matrix was developed for the Wenatchee population of UCR spring chinook ESU. The Wenatchee population was chosen as an indicator of effects of the proposed action on the ESU because, of the three populations tentatively identified as comprising this ESU (Ford et al. 2000), this is the one that requires the greatest change in survival to recover and avoid extinction (Cooney et al. 2000; McClure et al. 2000). Ford et al. (2000) identified interim recovery goals and included the criterion that all three populations must meet these goals for delisting. Therefore, the population requiring the greatest change is the critical population for this analysis.

As described in Section 6.1.2, NMFS first parameterized the elements of the Leslie matrix to reflect, as closely as possible, the average survival rates that influenced the 1980 to 1994 brood year returns (base matrix). The QAR analytical group (Cooney et al. 2000) provided all survival rate estimates applicable to the 1980 to 1994 brood years for the base matrix, with the exception of the range of delayed mortality assumptions described below. These estimates included juvenile and adult passage survival through three dams operated by the Mid-Columbia PUDs and the four lower Columbia River FCRPS dams. The equilibrium rate of annual population growth was then estimated from the base matrix.

NMFS then changed three survival rates (egg-to-smolt and juvenile survival for PUD projects and juvenile survival through the FCRPS projects) to reflect effects of the proposed FCRPS action and expected future survival improvements at the PUD projects as a result of the proposed Mid-Columbia Habitat Conservation Plan (HCP). The All-H Paper identified implementation of the HCP as a probable element of recovery planning that is, therefore, included in the analysis, consistent with Step 4 of the jeopardy analysis framework described in Section 1.3. NMFS increased both juvenile and adult survival from the base matrix estimates to reflect the survival rates anticipated in the proposed HCP (Cooney et al. 2000). Juvenile survival through the four FCRPS projects was modified to reflect the expected survival rate described in Section 6.2.8.3. NMFS then estimated a new equilibrium rate of annual population growth from the current matrix and compared it to the base population growth rate.

Two estimates of total (including direct and indirect) juvenile passage survival were included in both the base and the current matrix. Each represented an historical differential delayed mortality (D) estimate of 1.0 from McNary dam, based upon historical McNary transportation studies (Cooney et al. 2000; reviewed in NMFS 2000x - transportation white paper). Only a small fraction of the run is transported for the proposed action, so estimating current D is not necessary for this ESU. Like SR spring/summer chinook salmon, the high and low juvenile passage survival estimates differed only in their treatment of delayed mortality of non-transported fish. Under the low delayed mortality assumption, no post-Bonneville mortality of non-transported fish was attributed to the hydrosystem. Under the high delayed mortality assumption, post-Bonneville mortality attributed to the hydrosystem was assumed to be no higher than that estimated for SR spring/summer chinook salmon (0.709 to 0.743).

No other survival rates were estimated to have changed between the average base and current condition. For example, adult survival through the four FCRPS dams and reservoirs was determined to be unchanged under the proposed action, compared to average adult survival between 1983 (first adult returns from the 1980 brood year) and the present (e.g., elements of Table 6.1-1 are based on 1970s and 1980s radiotelemetry studies).

Estimates of survival rates that were included in the base and current matrices are displayed in Table 6.3.4. The current (proposed action) average per-generation survival rate represents only a 2 to 4% change from the base survival rate for the Wenatchee spring chinook population. This survival change is low because juvenile survival from McNary Dam to Bonneville is estimated to have declined from the average rate during the base period, when a significant proportion of the smolts were transported, to the survival rate expected from the proposed action. The proposed action specifies that nearly all fish shall remain in the river because of very low returns of transported smolts in 1994, following construction of the new McNary bypass system (1998 FCRPS Biological Opinion, Appendix B). The magnitude of the estimated decline in McNary-Bonneville juvenile survival is approximately equal to the increased survival that is estimated to occur following implementation of the Mid-Columbia HCP.

Table 6.3-4. Wenatchee River Spring Chinook Life-Stage Survival and Harvest Rate Estimates, 1980 to 1994 Brood Year Base and Proposed Action Current Leslie Matrices

			Low Delayed Mortality Assumption		High Delayed Mortality Assumption										
UCR spring Chinook - Wenatchee	Mean Egg-to-Smolt Survival	Mean Non-Fed. Juvenile Hydro Survival	Mean Juvenile FCRPS Hydro Survival (including delayed effects)	Mean “Non-Hydro” Estuary/ Early Ocean Survival	Mean Juvenile FCRPS Hydro Survival (including delayed effects)	Mean “Non-Hydro” Estuary/ Early Ocean Survival	Mean Total Fed. and Non-Fed. Juvenile Survival	Mean Ocean Exploi-tation Rate	Mean Ocean “Non-Harvest” Survival Rate (Multiply [1-exp. Rate] for total O2+ ocean survival)	Mean Inriver Harvest Rate	Mean Adult FCRPS Passage Survival Rate	Mean Adult Non-Fed. Passage Survival Rate	Mean Upper Dam to Spawn-ing Survival Rate	Mean Egg-to-Adult Survival Rate	Mean Adult-to-Adult Return
Base	0.050	0.662	0.707	0.030	0.194	0.111	0.014	0.000	0.583	0.088	0.891	0.860	0.900	**0.00030**	**0.651**
Current (Proposed Action)	0.053	0.804	0.569	0.030	0.156	0.111	0.014	0.000	0.583	0.088	0.891	0.860	0.900	**0.00031**	**0.670**

Note: All non-bold survival rates were estimated through methods described in Section 6.1.2 and Appendix C and input to the matrix, with one exception. Mean non-hydro smolt survival was adjusted to other elements of the base matrix and mean 1980 to 1994 ln (recruits/spawner) estimates. **Bold** survival rates are summary statistics derived from the other survival rates.

NMFS then compared the estimated change in base to current population growth rate with the changes needed to reduce risk to levels associated with the jeopardy standard indicator metrics, as described above for SR spring/summer chinook salmon. For UCR spring chinook, the range of necessary survival improvements include both those estimated by CRI (McClure et al. 2000) and QAR (McClure et al. 2000). Table 6.3-5 displays the additional improvements in survival that would be necessary, beyond the level of survival expected from the proposed action and implementation of the HCP, to reduce extinction risk to 5% and increase the likelihood of recovery to 50%. Interpretation of values above and below 1.0 is as described above for SR spring/summer chinook salmon. Estimates were made for best- and worst-case assumptions. Definitions of these cases were the same as those described above for SR spring/summer chinook salmon.

Table 6.3-5. Wenatchee River Spring Chinook Estimated Range of Additional Needed Per-generation Survival Improvements

Population	5% extinct, 100 years	5% extinct, 24 years	50% Recovery 48 years	50% Recovery 100 years	Natural River
Wenatchee					
Best Case	1.69	1.04	2.60	2.46	1.63
Worst Case	3.08	1.46	4.62	3.92	5.94

Note: These improvements would satisfy five jeopardy standard indicator metrics, given implementation of the proposed action. Numbers less than or equal to 1.0 indicate that additional survival improvements are not necessary. Numbers greater than 1.0 are the necessary survival multipliers. See the text for details and definition of best and worst cases.

Under the best-case assumptions, the survival rate expected from the proposed action and the HCP, coupled with expected survival in other life stages, is not sufficient to achieve indicator metrics. Additional survival improvements, ranging from 4 to 160% (1.04 to 2.60 survival multipliers), are needed to reduce the likelihood of extinction to 5% and to result in at least a 50% likelihood of recovery for Wenatchee River spring chinook. Under the worst case assumptions, additional survival improvements ranging from 46 to 362% (1.46 to 4.62 survival multipliers) would be necessary to reduce extinction risk and increase the likelihood of recovery for this population.

6.3.2.2 Full Mitigation Component of the Jeopardy Standard

As described in Section 6.1.2, a metric indicative of the full mitigation component of the jeopardy standard is NMFS' best estimate of the natural survival rate of juveniles and adults that would occur without the FCRPS. In the case of UCR spring chinook, the river reach of interest extends from the head of McNary pool to Bonneville Dam. The estimate of natural survival through this reach is approximately 86.5% for juveniles, 95.5% for adults, and 82.6% for the combination of juvenile and adult survival.

As described in Table 6.3-4, the high estimate of juvenile survival (as described above, including indirect effects) associated with the proposed action is 56.9%, while the low estimate is 15.6%. The estimate of adult survival is 89.1%, which leads to 13.9 to 50.7% combined juvenile and adult survival when passing through the hydrosystem.

The estimated survival when passing through the hydrosystem under the proposed action is clearly lower than that estimated to occur in the absence of the FCRPS. Table 6.3-5 describes the additional change in passage survival (including indirect effects) that would be necessary to meet NMFS' estimate of natural survival. The additional survival improvement ranges from 63% (1.63 survival multiplier) for the high survival estimate to 494% (5.94 survival multiplier) for the low survival estimate.

6.3.2.3 Consideration of All Components of the Jeopardy Standard

For the Wenatchee River UCR spring chinook population, the incremental change in survival needed to meet the survival and recovery indicator metrics is higher than that needed to achieve the risk levels associated with the natural survival indicator metric under the best-case assumptions. Based on the construction of the jeopardy standard described in Section 1.3.1.1, the full mitigation component is relevant for evaluating the effects of the proposed action. Based on this indicator metric, at least a 63% improvement in survival would be needed in addition to the effects of the proposed action and implementation of the HCP. Under the worst-case assumptions, the survival and recovery indicator metrics are lower, and at least a 562% improvement in survival (4.62 multiplier) is needed.

6.3.3 Snake River Fall Chinook Salmon

Evaluation of species-level effects of the proposed action requires placing the action-area effects in the context of the full life cycle. The factors described in Section 6.2.9 affect elements of critical habitat and the survival and recovery of SR fall chinook salmon in the action area. Additional factors (summarized in Myers et al. 1998, Section 4.1, and Appendix A) limit this ESU over its full range. Specifically, almost all of the historical spawning habitat in the Snake River basin is blocked by the Hells Canyon Complex. Other irrigation and hydroelectric projects block access to habitat in tributaries to the Columbia River below Hells Canyon. Habitat quality is degraded by agricultural water withdrawals, grazing, vegetation management, and forestry and mining practices (lack of pools, high temperatures, low flows, poor overwintering conditions, and high sediment loads).

In this section, NMFS evaluates quantitatively the action-area effects associated with the proposed action and the effects of human activities affecting survival in other parts of the life cycle.

6.3.3.1 Survival and Recovery Components of the Jeopardy Standard

NMFS used a Leslie matrix (Section 6.1.2) to evaluate the likely status of stocks under the proposed action relative to the jeopardy standard indicator (Sections 1.3.1.1 and 6.1.2). The matrix analysis incorporated the survival rates in other life stages that NMFS expects to result from likely actions described in the All-H Paper. One matrix was developed for the Snake River fall chinook ESU. The Snake River Salmon Proposed Recovery Plan (NMFS 1995) indicated that this ESU is composed of a single population, so this analysis represents the entire ESU.

As described in Section 6.1.2, the elements of the Leslie matrix were first parameterized to reflect, as closely as possible, the average survival rates that influenced the 1980 to 1991 brood years, represented by adult returns through 1996 (base matrix). Run reconstructions for these brood years were obtained from PATH (Peters et al. 1999). Run reconstructions for subsequent brood years are not currently available. Mean smolt passage direct survival rate estimates and mean harvest rates for corresponding migration years were obtained from PATH (Peters et al. 1999) for the base matrix. The equilibrium rate of annual population growth was then estimated from the base matrix.

NMFS then changed juvenile smolt survival rates to reflect effects of the proposed action, changed harvest rates to reflect new exploitation rates implemented since 1993, and generated a new current matrix. Table 6.2-8 shows smolt passage direct survival estimates. A new equilibrium rate of annual population growth was then estimated from the current matrix and compared to the base population growth rate.

Two estimates of total (direct and indirect) juvenile passage survival were included in both the base and the current matrices. Each represented the PATH estimate of differential delayed mortality (D) derived from PIT-tag returns (D = 0.24), as described in Section 6.2. The high and low juvenile passage survival estimates differed only in their treatment of delayed mortality of non-transported fish. Under the low delayed mortality assumption, no post-Bonneville mortality of non-transported fish was attributed to the hydrosystem. Under the high delayed mortality assumption, post-Bonneville mortality attributed to the hydrosystem was the PATH lambda-n estimate (Peters et al. 1999) associated with D equals 0.24. This estimate of mortality was approximately 0.19.

Changes were also estimated in both ocean and inriver harvest rates between the average base and current condition. As described in the All-H Paper, NMFS expects that fall chinook harvest rates will stay at their recent lower levels in the future, as this ESU recovers.

Table 6.3-6 shows estimates of survival rates included in the base and current matrices. The current (proposed action) average per-generation survival rate represents a 56% increase (1.56 survival multiplier) from the base survival rate for SR fall chinook.

Table 6.3-6. Snake River Fall Chinook Life-Stage Survival and Harvest Rate Estimates, 1980 to 1991 Brood Year Base and Proposed Action (Current) Leslie Matrices

Snake River Fall Chinook	High Delayed Mortality Assumption		Low Delayed Mortality Assumption		Mean Ocean Exploitation Rate	Mean Ocean "Non-Harvest" Survival Rate (Multiply [1-exp. Rate] for total O2+ ocean survival)	Mean Inriver Harvest Rate	Mean Adult FCRPS Passage Survival Rate	Mean Upper Dam to Spawning Survival Rate	Mean Egg-to-Adult Survival Rate	Mean Adult-to-Adult Return
	Mean Juvenile FCRPS Hydro Survival (including delayed effects)	Mean "Non-Hydro" Combined Egg-to-Smolt and Estuary/Early Ocean Survival	Mean Juvenile FCRPS Hydro Survival (including delayed effects)	Mean "Non-Hydro" Combined Egg-to-Smolt Estuary/Early Ocean Survival							
"Base"	**0.082**	**0.056**	**0.101**	**0.046**	**0.170**	**0.412**	**0.315**	**0.607**	**0.900**	**0.00059**	**0.850**
"Current" (Proposed Action)	**0.095**	**0.056**	**0.117**	**0.046**	**0.121**	**0.498**	**0.174**	**0.607**	**0.900**	**0.00092**	**1.322**

Note: All non-bold survival rates were estimated through methods described in Section 6.1.2 and Appendix C and input to the matrix, with two exceptions. Mean first-year survival was adjusted to other elements of the base matrix and to mean 1980 to 1991 ln(recruits/spawner) estimates. Smolt survival during the first year was estimated independently, as described above, and the non-hydro first-year survival (including egg-to-smolt and estuary/early ocean survival) was the survival remaining after accounting for hydro and total smolt survival in the base matrix. Bold survival rates are summary statistics derived from the other survival rates.

NMFS then compared the estimated change in base to current population growth rate with the changes needed to reduce risk to levels associated with the jeopardy standard indicator metrics, as described above for SR spring/summer chinook salmon. Table 6.3-7 displays the additional improvements in survival that would be necessary, beyond the level of survival expected from the proposed action and continuation of harvest reductions, to reduce extinction risk to 5% and increase the likelihood of recovery to 50%. Interpretation of values above and below 1.0 is as described above for SR spring/summer chinook salmon. Estimates were made for best- and worst-case assumptions. Definitions of these cases were the same as those described above for SR spring/summer chinook salmon.

Table 6.3-7. Snake River Fall Chinook Estimated Range of Additional Needed Per-generation Survival Improvements

Population	5% extinct, 100 years	5% extinct, 24 years	50% Recovery 48 years	50% Recovery 100 years	Natural River
Snake River Falls					
Best Case	1.18	0.64	1.63	1.47	4.78
Worst Case	3.66	1.64	4.90	4.41	5.55

Note: These improvements would satisfy five jeopardy standard indicator metrics, given implementation of the proposed action. Numbers less than or equal to 1.0 indicate that additional survival improvements are not necessary. Numbers greater than 1.0 are the necessary survival multipliers. See the text for details and definition of best and worst case.

Under the best-case assumptions, the survival rate expected from the proposed action and continuation of low harvest rates, coupled with expected survival in other life stages, results in 5% or less risk of extinction in 24 years. However, additional survival improvements, ranging from 18 to 63% (1.18 to 1.63 survival multipliers) are needed to reduce the likelihood of extinction in 100 years to 5% and to result in at least a 50% likelihood of recovery for SR fall chinook. Under the worst-case assumptions, additional survival improvements ranging from 64 to 390% (1.64 to 4.90 survival multipliers) would be necessary to reduce extinction risk and increase the likelihood of recovery for this ESU.

6.3.3.2 Full Mitigation Component of the Jeopardy Standard

As described in Section 6.1.2, a metric indicative of the full mitigation component of the jeopardy standard is NMFS' best estimate of the natural survival rate of juveniles and adults that would occur without the FCRPS. The estimate of natural survival of juveniles through free-flowing river reaches was estimated using two alternative methods by PATH (Peters et al. 1999). NMFS considers both methods equally valid; therefore, it evaluated a range of natural survival estimates for this ESU (Section 4, Appendix C). The estimate of juvenile survival through the hydrosystem reach under natural conditions ranges from 32 to 77%, depending upon the method. Adult survival is estimated as 72%, and the combined juvenile and adult natural survival rate is 45.4 to 64.9%.

As described in **Table 6.3-6**, the high estimate of juvenile survival (as described above, including indirect effects) associated with the proposed action is 11.7%, while the low estimate is 9.5%. The estimate of adult survival is 60.7%, which leads to 5.8 to 7.1% combined juvenile and adult survival when passing through the hydrosystem.

The estimated survival when passing through the hydrosystem under the proposed action is clearly lower than that estimated to occur in the absence of the FCRPS. **Table 6.3-7** describes the additional change in passage survival (including indirect effects) that would be necessary to meet NMFS' estimate of natural survival. The additional survival improvement ranges from 378% (4.78 multiplier) for the high survival estimate to 455% (5.55 multiplier) for the low survival estimate.

6.3.3.3 Consideration of All Components of the Jeopardy Standard

For SR fall chinook salmon, the incremental change in survival needed to meet the survival and recovery indicator risk metrics is lower than that needed to achieve a natural survival rate through the FCRPS. Based on the construction of the jeopardy standard described in Section 1.3.1.1, the survival and recovery components are relevant for evaluating the effects of the proposed action. Based on these indicator metrics, at least 63% improvement in survival would be needed in addition to the effects of the proposed action and the continuation of recent low harvest rates.

6.3.4 Snake River Steelhead

Evaluation of species-level effects of the proposed action requires placing the action-area effects in the context of the full life cycle. The factors described in Section 6.2.9 affect elements of critical habitat and the survival and recovery of UCR spring chinook salmon in the action area. Additional factors (summarized in Section 4.1 and Appendix A) limit this ESU over its full range. Hydrosystem projects create several substantial habitat blockages for this ESU. The major ones include the Hells Canyon Dam complex on the mainstem Snake River and Dworshak Dam on the North Fork of the Clearwater River. Minor blockages are common throughout the region. Steelhead spawning areas have been degraded by overgrazing, as well as by historical gold dredging and sedimentation due to poor land management practices. Hatchery fish are widespread and stray to spawn naturally throughout the region. In the 1990s, an average of 86% of adult steelhead passing Lower Granite Dam were of hatchery origin. However, hatchery contribution to naturally spawning populations varies across the region. Some stocks are dominated by hatchery fish, whereas others are composed of all wild fish.

In this section, NMFS evaluates quantitatively the action-area effects associated with the proposed action and the effects of human activities affecting survival in other parts of the life cycle.

6.3.4.1 Survival and Recovery Components of the Jeopardy Standard

NMFS could not construct a Leslie matrix (Section 6.1.2) for SR steelhead at this time. Therefore, it conducted a simple incremental analysis and applied results to aggregate A-Run and aggregate B-Run SR steelhead. This analysis simply estimates expected proportional changes in average survival from the base (1980 brood year through approximately 1992 brood year [1997 returns]) to the current (proposed action) condition, without attempting to estimate survival rates through the entire life cycle. The analysis focuses only on those life-stage survival rates likely to have changed from base to current conditions.

CRI estimated the needed change in annual population growth rate (lambda) with respect to each survival metric (McClure et al. 2000), and results are presented in Section 4 and Appendix A. When converted to changes in per-generation survival, the needed changes from average 1980 to 1992 brood survivals range from 242 to 51,453% (3.42 to 515.53 survival multipliers), depending upon the metric, run, and hatchery effectiveness assumption. NMFS has not proposed recovery abundance levels for this ESU, so evaluation of the recovery metric was not possible at this time.

Two survival rates appear to have changed from the average 1980 to 1992 brood survivals to current conditions. Harvest rates were reduced in the early 1990s, compared to average harvest rates during the base period (TAC 2000 - **Beamesderfer 2/24/00 tables**). For A-Run steelhead the recent 1993 to 1998 average harvest rate (10.7%) declined from the 1984 to 1998 average harvest rate (13.7%). This represents a 3.6% increase in survival (1.036 survival multiplier). For B-Run steelhead, the corresponding harvest rates are 20.1% recently and 25.9% on average during the base period. This represents a 7.8% increase in survival (1.078 multiplier) for B-Run steelhead.

Juvenile passage survival probably was lower, on average, during the migration years associated with the 1980 to 1992 broods than the estimate under the proposed action. Section 6.2.8 contains juvenile survival estimates for the proposed action, but no estimates of average juvenile survival are available during the base period. Neither PATH nor NMFS has attempted to estimate the SR steelhead survival rates, including transported fish and possible indirect effects. Because direct estimates of historical steelhead juvenile passage survival are not available, NMFS assumes that the proportional change in juvenile SR steelhead survival from the base to current (proposed action) condition equals the proportional change estimated for SR spring/summer chinook salmon (19%; 1.19 survival multiplier). Improvements to the system over that period (e.g., new bypasses, increased spill levels, increased flow rates, and new transportation facilities) probably have affected spring-migrating yearling steelhead and yearling chinook in a similar manner. The 1998 FCRPS Biological Opinion contains details regarding similar effects of the hydrosystem on the two ESUs. The 1998 FCRPS Biological Opinion relied on a comparison of SR spring/summer chinook and SR steelhead to draw conclusions for steelhead. Additional information about effects of the hydrosystem on each ESU is available in NMFS (2000 **x,y,z - the passage, transportation, and flow white papers**).

Two estimates of total (direct and indirect) juvenile passage survival were included explicitly in the current matrix and implicitly in the base matrix. Each represented an average of the 0.52 to 0.58 range of differential delayed mortality (D) estimates described in Section 6.2. The high and low juvenile passage survival estimates differed only in the treatment of delayed mortality of non-transported fish. Under the low delayed mortality assumption, no post-Bonneville mortality of non-transported fish was attributed to the hydrosystem. Under the high delayed mortality assumption, post-Bonneville mortality attributed to the hydrosystem was assumed to be no higher than that estimated for SR spring/summer chinook salmon (0.709 to 0.743).

Table 6.3-8 contains estimates of survival rates included in the incremental analysis. The current (proposed action) average per-generation survival rate represents a 23% increase (1.23 survival multiplier) from the base survival rate for A-Run steelhead and a 28% increase (1.28 survival multiplier) from the base survival rate for B-Run steelhead.

NMFS then compared the estimated change in base to current population growth rate with the changes needed to reduce risk to levels associated with the jeopardy standard indicator metrics, as described above for SR spring/summer chinook salmon. **Table 6.3-9** displays the additional improvements in survival that would be necessary, beyond the level of survival expected from the proposed action and continuation of harvest reductions, to reduce extinction risk to 5%. Interpretation of values above and below 1.0 is as described above for SR spring/summer chinook salmon. Estimates were made for best- and worst-case assumptions. Definitions of these cases were the same as those described above for SR spring/summer chinook salmon.

Under both the best- and worst-case assumptions, survival improvements additional to those resulting from the survival rate expected from the proposed action and continuation of low harvest rates are necessary to reduce the likelihood of extinction to 5% or less. The magnitude of the necessary change ranges from 177 to 40,026% (2.77 to 401.26 survival multipliers), depending upon the metric and the assumption. The main factor influencing these results is the assumption regarding productivity of wild-origin spawners, because the spawning population includes a high percentage of hatchery-origin fish. Very high survival improvements are needed if productivity of wild-origin spawners is low (hatchery-origin spawner effectiveness is 80%).

6.3.4.2 Full Mitigation Component of the Jeopardy Standard

As described in Section 6.1.2, a metric indicative of the full mitigation component of the jeopardy standard is NMFS' best estimate of the natural survival rate of juveniles and adults that would occur without the FCRPS. The estimate of juvenile survival through the hydrosystem reach under natural conditions is approximately 84%, adult survival is estimated as 85%, and the combined juvenile and adult natural survival rate is 71.3%.

Table 6.3-8. Snake River Steelhead Juvenile and Adult Passage Survival and Harvest Rate Estimates, 1980 to 1992 Brood Year Base Period and Proposed Action (Current)

Snake River Steelhead	Mean Egg-to-Smolt Survival	Low Delayed Mortality Assumption: Mean Juvenile FCRPS Hydro Survival (including delayed effects)	Low Delayed Mortality Assumption: Mean "Non-Hydro" Estuary/Early Ocean Survival	High Delayed Mortality Assumption: Mean Juvenile FCRPS Hydro Survival (including delayed effects)	High Delayed Mortality Assumption: Mean "Non-Hydro" Estuary/Early Ocean Survival	Mean Ocean Exploitation Rate	Mean Ocean "Non-Harvest" Survival Rate (Multiply [1-exp. Rate] for total O2+ ocean survival)	Mean Inriver Harvest Rate	Mean Adult FCRPS Passage Survival Rate	Mean Upper Dam to Spawning Survival Rate	Mean Egg-to-Adult Survival Rate	Mean Adult-to-Adult Return
Base												
A-Run	N/A	0.391	N/A	0.107	N/A	0.000	1.00	0.137	0.796	0.90	N/A	N/A
B-Run	N/A	0.391	N/A	0.107	N/A	0.000	1.00	0.259	0.796	0.90	N/A	N/A
Current (Proposed Action)												
A-Run	N/A	0.466	N/A	0.128	N/A	0.000	1.00	0.107	0.796	0.90	N/A	N/A
B-Run	N/A	0.466	N/A	0.128	N/A	0.000	1.00	0.201	0.796	0.90	N/A	N/A

Note: This information is used in an analysis of proportional changes in these specific life-stage survival rates.

Table 6.3-9. Snake River Steelhead Estimated Range of Additional Needed Per-generation Survival Improvements

Snake River Steelhead	5% extinct, 100 years	5% extinct, 24 years	50% Recovery 48 years	50% Recovery 100 years	Natural River
A-Run					
Best Case	9.19	2.77	N/A	N/A	1.53
Worst Case	273.12	81.81	N/A	N/A	5.58
B-Run					
Best Case	11.60	3.73	N/A	N/A	1.53
Worst Case	401.26	118.82	N/A	N/A	5.58

Note: These improvements would satisfy five jeopardy standard indicator metrics, given implementation of the proposed action. Numbers less than or equal to 1.0 indicate that additional survival improvements are not necessary. Numbers greater than 1.0 are the necessary survival multipliers. See the text for details and definition of best and worst case.

As described in Table 6.3-8, the high estimate of juvenile survival (as described above, including indirect effects) associated with the proposed action is 46.6%, while the low estimate is 12.8%. The estimate of adult survival is 79.6%, which leads to 10.2-37.1% combined juvenile and adult survival when passing through the hydrosystem.

The estimated survival when passing through the hydrosystem under the proposed action is clearly lower than that estimated to occur in the absence of the FCRPS. Table 6.3-9 describes the additional change in passage survival (including indirect effects) that would be necessary to meet NMFS' estimate of natural survival. The additional survival improvement ranges from 53% (1.53 multiplier) for the high survival estimate to 458% (5.58 multiplier) for the low survival estimate.

6.3.4.3 Consideration of All Components of the Jeopardy Standard

For SR steelhead, the incremental change in survival needed to achieve a natural survival rate through the FCRPS is lower than that needed to meet the survival and recovery indicator risk metrics. Based on the construction of the jeopardy standard described in Section 1.3.1.1, the full mitigation component is relevant for evaluating effects of the proposed action. Based on this indicator metric, at least 53% improvement in survival would be needed in addition to the effects of the proposed action and the continuation of recent low harvest rates.

6.3.5 Upper Columbia River Steelhead (Methow River Population)

Evaluation of species-level effects of the proposed action requires placing the action-area effects in the context of the full life cycle. The factors described in Section 6.2.9 affect elements of critical habitat and the survival and recovery of UCR steelhead salmon in the action area. Additional factors (summarized in Busby et al. 1996, Section 4.1, and Appendix A) limit this ESU over its full range. Specifically, Chief Joseph and Grand Coulee dams block substantial portions of the historical spawning range. Habitat problems are largely related to irrigation diversions and hydroelectric dams, as well as degraded riparian and instream habitat from urbanization and livestock grazing. Hatchery fish are widespread and escape to spawn naturally throughout the region. The relative contribution of these hatchery spawners to natural production rates is unknown.

In this section, NMFS evaluates quantitatively the action-area effects associated with the proposed action and the effects of human activities affecting survival in other parts of the life cycle.

6.3.5.1 Survival and Recovery Components of the Jeopardy Standard

NMFS used a Leslie matrix (Section 6.1.2) to evaluate the likely status of stocks under the proposed action relative to the jeopardy standard indicator metrics (Sections 1.3.1.1 and 6.1.2). The matrix analysis incorporated the survival rates in other life stages that NMFS expects to result from likely actions described in the All-H Paper. One matrix was developed for the Methow population of UCR steelhead ESU. The Methow population was chosen as an indicator of effects of the proposed action on the ESU because, of the three populations tentatively identified as comprising this ESU (Ford et al. 2000), it requires the greatest change in survival to recover and avoid extinction (Cooney et al. 2000; McClure et al. 2000). Ford et al. (2000) identified interim recovery goals and recommended that all three Upper Columbia River steelhead populations meet these goals for delisting. Therefore, the population requiring the greatest change (Methow River) is the critical population for this analysis.

As described in Section 6.1.2, NMFS first parameterized the elements of the Leslie matrix to reflect, as closely as possible, the average survival rates that influenced the 1980 to 1994 brood year returns (base matrix). The QAR analytical group (Cooney et al. 2000) provided all survival rate estimates applicable to the base period estimate, with the exception of assumptions about delayed mortality of transported fish. These delayed mortality assumptions, used in analyses throughout in this Biological Opinion, are explained above for SR spring/summer chinook. The base period survival estimates included juvenile and adult passage survival through five dams the Mid-Columbia PUDs operate and the four lower Columbia River FCRPS dams. NMFS used mixed hatchery and wild egg-to-smolt survival from empirical information because it was available for UCR steelhead, in contrast to other ESUs. The estimated survival of wild fish in the egg-to-smolt stage was then calculated. This estimate varied with the effectiveness assumed for hatchery spawners. Second-year smolt survival unrelated to the hydrosystem (“Non-Hydro Estuary and Early Ocean” survival) was adjusted to provide the best fit to the other estimated stage-specific survival rates and the adult return estimates. Because egg-to-smolt survival varied with the hatchery spawner effectiveness assumption, the “non-hydro” smolt survival estimate also varied. NMFS estimated the equilibrium rate of annual population growth from the base matrix.

NMFS then changed three survival rates (egg-to-smolt and juvenile survival-PUD projects, and juvenile survival through the FCRPS projects) to reflect the effects of the proposed FCRPS action and expected future survival improvements at the PUD projects as a result of the proposed Mid-Columbia HCP. The All-H Paper identified implementation of the HCP as a probable element of recovery planning that is, therefore, included in the analysis, consistent with Step 4 of the jeopardy analysis framework described in Section 1.3. NMFS increased both egg-to-smolt and juvenile survival from the base matrix estimates through the three PUD projects to reflect the survival rates anticipated in the proposed HCP (Cooney et al.). Juvenile survival through the four FCRPS projects was modified to reflect the expected survival rate described in Section 6.2.8.3. NMFS then estimated a new equilibrium rate of annual population growth from the current matrix and compared it to the base population growth rate.

Two estimates of total (including direct and indirect) juvenile passage survival were included in both the base and the current matrix. Each represented an historical differential delayed mortality (D) estimate of 1.0 from McNary Dam, based upon historical McNary transportation studies (Cooney et al. 2000; studies reviewed in NMFS 2000**x - transportation white paper**). Only a small fraction of the run is transported for the proposed action, so estimating current D is not relevant for this ESU. Like SR spring/summer chinook salmon, the high and low juvenile passage survival estimates differed only in their treatment of delayed mortality of non-transported fish. Under the low delayed mortality assumption, no post-Bonneville mortality of non-transported fish was attributed to the hydrosystem. Under the high delayed mortality assumption, post-Bonneville mortality attributed to the hydrosystem was assumed to be no higher than that estimated for SR spring/summer chinook salmon (0.709 to 0.743).

No other survival rates were estimated to have changed between the average base and current condition. For example, adult survival through the four FCRPS dams and reservoirs was determined to be unchanged under the proposed action, compared to average adult survival between 1983 (first adult returns from the 1980 brood year) and the present (e.g., elements of Table 6.1-1 are based on 1970s and 1980s radiotelemetry studies). Harvest rates also were not estimated to have changed, or be likely to change in the future (All-H Paper), from base harvest rates.

Estimates of survival rates that were included in the base and current matrices are displayed in Table 6.3-10. The current (proposed action) average per-generation survival rate represents a 15% change (1.15 survival multiplier) from the base survival rate for the Methow River steelhead population.

NMFS then compared the estimated change in base to current population growth rate with the changes needed to reduce risk to levels associated with the jeopardy standard indicator metrics, as described above for SR spring/summer chinook salmon. For Methow River steelhead, the range of necessary survival improvements included both those estimated by CRI (McClure et al. 2000) and QAR (Cooney et al. 2000). Table 6.3-11 displays the additional improvements in survival that would be necessary, beyond the level of survival expected from the proposed action and implementation of the HCP, to reduce extinction risk to 5% and increase the likelihood of recovery to 50%. Interpretation of values above and below 1.0 is as described above for Snake River spring/summer chinook salmon. Estimates were made for best- and worst-case assumptions. Definitions of these cases were the same as those described above for SR spring/summer chinook salmon.

Under the best case assumptions, the survival rate expected from the proposed action and the HCP, coupled with expected survival in other life stages, results in 5% or less risk of extinction for the 24-year extinction metric. However, additional survival improvements, ranging from 35 to 87% (1.35 to 1.87 survival multipliers), are needed to achieve all four metrics. Under worst-case assumptions, survival improvements ranging from 1,673 to 6,461% (17.73 to 65.61 survival multipliers) are needed.

6.3.5.2 Full Mitigation Component of the Jeopardy Standard

As described in Section 6.1.2, a metric indicative of the full mitigation component of the jeopardy standard is NMFS' best estimate of the natural survival rate of juveniles and adults that would occur without the FCRPS. In the case of UCR steelhead, the river reach of interest extends from the head of McNary pool to Bonneville Dam. The estimate of natural survival through this reach is approximately 90.7% for juveniles, 92.2% for adults, and 83.6% for the combination of juvenile and adult survival.

As described in Table 6.3-10, the high estimate of FCRPS juvenile survival (as described above, including indirect effects) associated with the proposed action is 57.5%, while the low estimate is 15.8%. The estimate of adult survival is 89.2%, which leads to 14.1 to 51.3% combined juvenile and adult survival when passing through the hydrosystem.

The estimated survival when passing through the hydrosystem under the proposed action is clearly lower than that estimated to occur in the absence of the FCRPS. Table 6.3-11 describes the additional change in passage survival (including indirect effects) that would be necessary to meet NMFS' estimate of natural survival. Given the low estimate of effectiveness of the proposed action described above, an additional survival improvement of 494% (5.94 survival multiplier) would be needed to achieve the natural survival goal. Given the high estimate of effectiveness, an additional survival improvement of 63% (1.63 survival multiplier) would be needed.

Table 6.3-10. Methow River Steelhead Life-Stage Survival and Harvest Rate Estimates, 1980 to 1994 Brood Year "Base" and Proposed Action Current Leslie Matrices

			High Delayed Mortality Assumption		Low Delayed Mortality Assumption										
UCR Spring Chinook - Wenatchee	**Mean Egg-to-Smolt Survival**	**Mean Non-Fed. Juvenile Hydro Survival**	**Mean Juvenile FCRPS Hydro Survival (including delayed effects)**	**Mean "Non-Hydro" Estuary/ Early Ocean Survival**	**Mean Juvenile FCRPS Hydro Survival (including delayed effects)**	**Mean "Non-Hydro" Estuary/ Early Ocean Survival**	**Mean Total Fed. and Non-Fed. Juvenile Survival**	**Mean Ocean Exploi-tation Rate**	**Mean Ocean "Non-Harvest" Survival Rate (Multiply [1-exp. Rate] for total O2+ ocean survival)**	**Mean Inriver Harvest Rate**	**Mean Adult FCRPS Passage Survival Rate**	**Mean Adult Non-Fed. Passage Survival Rate**	**Mean Upper Dam to Spawn-ing Survival Rate**	**Mean Egg-to-Adult Survival Rate**	**Mean Adult-to-Adult Return**
Base	0.038- 0.063	0.550	0.190	0.113- 0.240	0.692	0.031- 0.065	0.012- 0.025	0.000	0.668	0.110	0.892	0.859	0.900	**0.00018- 0.00064**	**0.461- 1.607**
Current (Proposed Action)	0.042- 0.069	0.690	0.158	0.113- 0.240	0.575	0.031- 0.065	0.012- 0.026	0.000	0.668	0.110	0.892	0.859	0.900	**0.00021- 0.00074**	**0.529- 1.845**

Notes: All non-bold survival rates were estimated through methods described in Section 6.1.2 and Appendix C and input to the matrix, with one exception. Mean non-hydro smolt survival was adjusted to other elements of the base matrix and mean 1980 to 1994 ln (recruits/spawner) estimates.
Bold survival rates are summary statistics derived from the other survival rates.

Table 6.3-11. Methow River Steelhead Estimated Range of Additional Per-generation Survival Improvements

Population	5% extinct, 100 years	5% extinct, 24 years	50% Recovery 48 years	50% Recovery 100 years	Natural River
Methow Steelhead					
Best Case	1.87	0.87	1.35	1.35	1.63
Worst Case	43.88	17.73	65.61	58.17	5.94

Notes: These additional improvements would satisfy five jeopardy standard indicator metrics, given implementation of the proposed action. Numbers less than, or equal to, 1.0 indicate that additional survival improvements are not necessary. Numbers greater than 1.0 are the necessary survival multipliers. See text for details and definition of best and worst case.

6.3.5.3 Consideration of All Components of the Jeopardy Standard

For the Methow River UCR steelhead population, the incremental change in survival needed to meet the survival and recovery indicator metrics is higher than that needed to achieve the risk levels associated with the natural survival indicator metric under the best-case assumptions. Based on the construction of the jeopardy standard described in Section 1.3.1.1, the full mitigation component of the jeopardy standard is relevant for evaluating the effects of the proposed action. Based on this indicator metric, an additional improvement in survival of 63% to 494% (1.63 to 5.94 survival multipliers) would be needed in addition to the effects of the proposed action and implementation of the HCP.

The available data do not allow quantitative, population-level analyses of the combination of actions, affecting all life stages, needed to result in a high probability of survival and a moderate to high likelihood of recovery for UWR chinook salmon, LCR chinook salmon, MCR steelhead, UWR steelhead, LWR steelhead, CR chum salmon, or SR sockeye salmon. Therefore, in the following sections, NMFS reviews the factors for decline and ongoing limitations to recovery throughout the range of each ESU.

6.3.6 Upper Willamette River Chinook Salmon

The factors described in Section 6.3.6 affect elements of critical habitat and thus the survival and recovery of UWR chinook salmon in the action area. A large number of additional factors (summarized in Section 4.1 and Appendix A) limit this ESU over its full range. These include the loss of habitat due inundation or blockages resulting from the construction of numerous tributary hydroelectric and irrigation facilities; and habitat degradation due to timber harvest, development (agricultural, municipal, and industrial), dam development, and river channelization and dredging. Many of these activities result in poor water quality, high sediment loads, altered thermal regimes, and a large reduction in available spawning and rearing habitat. In addition, over-harvest and hatchery production have also contributed to the decline of this ESU.

Because UWR chinook salmon do not migrate past any mainstem dams on the lower Columbia River, NMFS has not estimated natural system survival or total system survival under the proposed action for this ESU.

6.3.7 Lower Columbia River Chinook Salmon

The factors described in Section 6.3.7 affect elements of critical habitat and thus the survival and recovery of LCR chinook salmon in the action area. A large number of additional factors (summarized in Section 4.1 and Appendix A) limit this ESU over its full range. These include the impacts of timber harvest (altered riparian vegetation, unstable streambanks, and decreased habitat complexity), agricultural practices (channelization and loss of riparian vegetation), road construction, and urban and industrial development; dams on the Cowlitz, Lewis, (Big) White Salmon, Clackamas, Sandy, and Hood rivers, which block fish passage to historical spawning areas; residual effects of mudflows from the Mt. St. Helens eruption (1980), which significantly disrupted and degraded habitat in the South Fork Toutle and Green rivers – as did post-eruption dredging, diking, and bank protection works in the Cowlitz River (below its confluence with the Toutle River); hatchery programs, beginning in the 1870s, released billions of fish, homogenizing stocks between subbasins and introducing others from outside the ESU such that the majority of the fall-run chinook salmon spawning today in the Lower Columbia River ESU are first-generation hatchery strays; and an average total exploitation rate on fall-run stocks from this ESU of 65% for the 1982 through 1989 brood years (approximately 45% in the ocean and 20% in freshwater).

The proposed action is not likely to increase the total hydro survival rate (juvenile * adult survival) of LCR chinook salmon to the level expected to occur under natural conditions. NMFS estimated a total system survival rate resulting from the proposed action of 72% through Bonneville Dam and pool for spring-run fish and 70% for fall-run fish. The estimated natural survival rate is approximately 97% (Table 1.3-2) for this ESU. No actions that affect other life stages have been proposed that are likely to result in survival increases of this magnitude.

6.3.8 Middle Columbia River Steelhead

The factors described in Section 6.3.8 affect elements of critical habitat and thus the survival and recovery of MCR steelhead in the action area. A large number of additional factors (summarized in Section 4.1 and Appendix A) limit this ESU over its full range. These include timber harvest (altered riparian vegetation, unstable streambanks, and decreased habitat complexity), agricultural practices (channelization and loss of riparian vegetation), road construction, and urban and industrial development; Pelton Dam on the Deschutes River blocks access to historical spawning areas; and there are numerous minor blockages from smaller dams and impassable culverts throughout the region. In addition, the genetic integrity of the ESU is threatened by past and present hatchery practices; hatchery fish are widespread and escaping to spawn naturally throughout the region so that adults of hatchery origin make up a substantial portion of the spawning population in several basins (e.g., the Umatilla and Deschutes rivers).

The proposed action is not likely to increase the total hydro survival rate (juvenile * adult survival) of MCR steelhead to the level expected to occur under natural conditions. The total system survival rate resulting from the proposed action is expected to range from 51% for steelhead passing through four projects to the Yakima subbasin to 70% for those migrating to tributaries to The Dalles pool. The estimated natural survival rate is approximately 84% (Table 1.3-2) for this ESU. No actions that affecting other life stages have been proposed that are likely to result in survival increases of this magnitude.

6.3.9 Upper Willamette River Steelhead

The factors described in Section 6.3.9 affect elements of critical habitat and thus the survival and recovery of UWR steelhead in the action area. A large number of additional factors (summarized in Section 4.1) limit this ESU over its full range. These include the loss of habitat due inundation or blockages resulting from the construction of numerous tributary hydroelectric and irrigation facilities; and habitat degradation due to timber harvest, development (agricultural, municipal, and industrial), dam development, and river channelization and dredging. Many of these activities result in poor water quality, high sediment loads, altered thermal regimes, and a large reduction in available spawning and rearing habitat. In addition, over-harvest and hatchery production have also contributed to the decline of this ESU.

Because UWR steelhead do not migrate past any mainstem dams on the lower Columbia River, NMFS has not estimated natural system survival or total system survival under the proposed action for this ESU.

6.3.10 Lower Columbia River Steelhead

The factors described in Section 6.3.10 affect elements of critical habitat and thus the survival and recovery of LCR steelhead within the action area. A large number of additional factors (summarized in Section 4.1 and Appendix A) limit this ESU over its full range. These include timber harvest (altered riparian vegetation, unstable streambanks, and decreased habitat complexity), agricultural practices (channelization and loss of riparian vegetation), road construction, and urban and industrial development. Upstream passage is blocked by dams on the Lewis, Clackamas, Sandy, and Hood rivers and there are minor blockages (such as impassable culverts) throughout the region. Mudflows from the eruption of Mt. St. Helens (1980) significantly disrupted and degraded habitat in the South Fork Toutle and Green rivers as did post-eruption dredging, diking, and bank protection works in the Cowlitz River below its confluence with the Toutle River. In addition, the genetic integrity of the ESU is threatened by past and present hatchery practices. Each year, hatcheries release approximately 3 million steelhead smolts within basins occupied by the ESU (Busby et al. 1996). In many basins, hatchery strays comprise the majority of the spawning population.

The proposed action is not likely to increase the total hydro survival rate (juvenile * adult survival) of LCR steelhead to the level expected to occur under natural conditions. NMFS estimates a total system survival rate under the proposed action of 82% through Bonneville pool and dam. The estimated natural survival rate is approximately 97% (Table 1.3-2) for this ESU. No actions that affecting other life stages have been proposed that are likely to result in survival increases of this magnitude.

6.3.11 Columbia River Chum Salmon

The factors described in Section 6.3.11 affect elements of critical habitat and thus the survival and recovery of CR chum salmon within the action area. A large number of additional factors (summarized in Section 4.1 and Appendix A) limit this ESU over its full range. The listing notice for CR chum salmon described the following as factors affecting the species as a whole: water withdrawal, conveyance, storage, and flood control, resulting in insufficient flows, stranding, juvenile entrainment, and instream temperature increases; logging and agriculture (loss of large woody debris, sedimentation, loss of riparian vegetation, and habitat simplification); mining (especially gravel removal, dredging, and pollution); urbanization (stream channelization, increased runoff, pollution, and habitat simplification); development of many small hydropower facilities in lower river areas; passage mortality at Bonneville Dam; and substantial habitat loss in the Columbia River estuary and associated areas.

The CR chum salmon ESU also supported a large commercial fishery until the runs collapsed in the 1950s. The lack of response after nearly all fishing pressure was removed indicates that the ESU is habitat limited, as described above. However, most of the tributaries Fulton (1970) listed as “principal” spawning areas (Elokomin [sic], Lewis, and Washougal rivers and Big, Mill, Abernathy, Germany, and Milton creeks) are not known to be occupied. Either chum salmon have lost access to habitat in these tributaries, historical habitat is accessible but has been adversely modified (e.g., by land-use practices) since the 1970s, or else the habitat is available and of adequate quality but is underseeded due to high levels of mortality in other life stages. The latter seems unlikely because several subbasin populations have been observed to respond when habitat has been created or restored. In recent years, CR chum salmon have been most productive in areas that have been altered, purposefully or otherwise, by human activity. Habitat in Gorely Creek appears to have been created incidental to construction of a shoreline dike, which caused water to upwell through the gravel (pers. comm., Dan Rawding, WDFW). This habitat in Gorely Creek, which has recently supported approximately 25% of the production in the Grays River system, was lost when the dike washed out during a December 1999 rainstorm. The WDFW improved habitat in another tributary to the Grays River system, Crazy Johnson Creek, during the 1970s and more recently removed a large beaver dam that impeded access to semi-protected habitat; record numbers of spawners were counted in this system during 1999 (per. comm., J. Hymer, WDFW, July 2000). Biologists at the Pierce National Wildlife Refuge have enhanced spawning habitat in Hardy Creek by fencing out the cattle and building a vehicle bridge, and have created additional spawning gravels in a man-made side channel. Spring Channel, a spring-fed tributary to Hamilton Creek, was created by WDFW in the 1970s. Because habitat quality declined over time due to scour and overgrowth by invasive stream-side vegetation, Spring Channel was recently the subject of a major restoration project. Again, record numbers of spawners were counted in this system in 1999.

There are no records of juvenile CR chum salmon passing Bonneville Dam between 1985 and the present and no studies of juvenile chum salmon passage survival. Although some adult chum salmon are seen in the Bonneville ladders, there is a similar lack of information on passage survival. Therefore, NMFS has not estimated natural system survival or total system survival under the proposed action for this ESU.

6.3.12 Snake River Sockeye Salmon

The factors described in Section 6.2.9 affect elements of critical habitat and the survival and recovery of SR sockeye salmon in the action area. Additional factors (summarized in Section 4.1 and Appendix A) limit this ESU over its full range including tributary hydropower and irrigation storage projects that block or restrict fish passage, water withdrawls that dewater streams), and unscreened diversions.

Because the abundance of SR sockeye salmon is extremely low, the risk of extinction cannot be calculated using the methods that NMFS employs in this biological opinion. However, the risk is undoubtedly very high. Due to the extreme low abundance of SR sockeye salmon in recent years, this ESU has not been used in passage survival studies. Therefore, NMFS has not estimated natural system survival or total system survival under the proposed action for this ESU. Assuming that juvenile mortality in the action area is similar to that of other yearling migrants, the proposed action is likely to contribute to the ongoing high risk of extinction. Neither the survival rate in the action area or the likely natural survival rate in the absence of the FCRPS are known with certainty, but survival resulting from the proposed action is clearly lower than that expected under natural conditions. Other factors also affect elements of critical habitat and thus contribute to this ESU's high risk of extinction (summarized in Section 4.1 and Appendix A), but the FCRPS is a significant factor. The high risk of extinction is partially mitigated by a captive breeding program that is funded by the Action Agencies and this program provides some assurance that Snake River sockeye will not go extinct in the immediate future. However, long-term survival and recovery in the wild requires a substantial increase in survival through the FCRPS and in other life stages.

6.3.13 Summary – Effects of the Proposed Action on Biological Requirements Over the Full Life Cycle

Effects of the proposed action on biological requirements over the full life cycle are detailed in Sections 6.1.1 through 6.1.12, above. Here, NMFS summarizes these findings, which will be applied in its jeopardy analysis in Section 8. Qualitative information on effects over the full life cycle are summarized for all 12 ESUs in Section 6.3.13.1; quantitative results are summarized in Section 6.3.13.2.

6.3.13.1 Summary of Findings for All 12 ESUs

A large number of factors affect current population trends of Columbia basin salmonids. These include tributary land use practices, interactions with hatchery fish, and ocean conditions, as well as the likely effects of the FCRPS under the proposed action. For convenience, effects are organized by critical habitat type (juvenile rearing areas, juvenile migration corridors, areas for growth and development, adult migration corridors, and spawning habitat) in Table 6.3-12. The FCRPS has the potential to be an important limiting factor across much of the life cycle for SR fall chinook salmon, which spawn in the tailraces of several lower Snake River projects and rear in the FCRPS during their juvenile migration, as well as experiencing the effects of project passage. In fact, the limiting effect of transit through up to eight FCRPS projects on the likelihood of survival and recovery for this ESU (as well as SR spring/summer chinook salmon, UCR spring chinook salmon, SR steelhead and UCR steelhead) is demonstrated quantitatively in Section 6.3.3 (and summarized below). In contrast, based on the best scientific information available at this time, the effects of current FCRPS operations appear to be relatively minor for UWR and LCR chinook salmon and for UWR and LCR steelhead. The Upper Willamette River ESUs do not pass any FCRPS projects and only a portion of the subbasin populations comprising each of the Lower Columbia River ESUs pass even one project. Current FCRPS operations do not affect mainstem spawning or rearing habitat for these species, although flow regulation may affect critical habitat for rearing in the estuary and plume. Available evidence is inferential, however, and thus insufficient for concluding that the proposed action will appreciably diminish the capacity of estuary or plume habitat to meet the biological requirements of listed fish. This is an area that clearly requires additional study.

The abundance of SR sockeye salmon is so low that the risk of extinction is undoubtedly very high. Assuming that juvenile mortality in the action area is similar to that of other yearling migrants, transit through eight FCRPS projects under the proposed action is likely to contribute to the ongoing high risk of extinction. Other factors also affect elements of critical habitat and thus contribute to this ESU's high risk of extinction, but the FCRPS is a significant factor. The risk is partially mitigated by a captive breeding program funded by the Action Agencies, providing some assurance that Snake River sockeye will not go extinct in the immediate future. However, long-term survival and recovery in the wild will require substantial increases in survival through the FCRPS and in other life stages.

Although some adult CR chum salmon are known to pass Bonneville Dam each year, spawning is essentially restricted to two areas below Bonneville: the Grays River basin in the Columbia River estuary and the Hardy and Hamilton creek/Ives Island complex. According to BPA's 50-year simulation of base case operations, the proposed action would adversely affect use of much of the latter spawning habitat in a high proportion (80%) of water years. Load-following operations further reduce habitat quality by alternately watering and dewatering redds and stranding juveniles and adults. As described in Section 6.3.11, the productivity of CR chum salmon appears to be limited by the availability of spawning habitat. Although much of the historical range has been lost due to detrimental land use practices in lower river tributaries, the proposed action is likely to limit spawning habitat quantity and quality in a large proportion of the species' current range. Thus, even though CR chum salmon do not experience adverse effects in the juvenile or adult migration corridor, the FCRPS is likely to be a limiting factor for this ESU.

It is not immediately apparent from the distribution of effects in Table 6.3-12 that the FCRPS has a significant adverse effect on MCR steelhead. The proposed action will not affect critical habitat in juvenile rearing areas or in spawning areas and potential effects on areas for growth and development to adulthood (i.e., the Columbia River plume) are largely inferential. Thus, known effects are limited to mortality in the juvenile and adult migration corridors. NMFS relies on a comparison to the effects of project passage on SR and UCR steelhead past the 4 lower Columbia River projects on the likelihood of survival and recovery to support a qualitative assessment that the proposed action has significant adverse effects:

- The relative change in survival needed to avoid extinction for the largest of the four MCR steelhead stocks for which estimates are available (i.e., the Deschutes River) is higher than that required for UCR steelhead (Table A6).

- The total system survival of steelhead passing through 4 lower Columbia River hydroprojects appears to have declined in recent years (Section 6.3.1.5), because transportation from McNary Dam stopped after high mortalities were noted for the 1994 outmigration (1998 Supplemental FCRPS Biological Opinion, Appendix B).

- Even assuming survival improvements elsewhere in the life cycle(i.e., the Mid-Columbia HCP) to offset reduced system survival, UCR steelhead need more than a doubling in survival to achieve the jeopardy standard indicator metrics (Section 6.3.1.5). Without a similar program of improvements underway for MCR steelhead, it is likely that at least the same incremental change in survival (i.e., 2 times survival that estimated for the base period) would be necessary for this ESU to meet the indicator metrics.

6.3.13.2 Summary of Quantitative Findings for Five ESUs

The metrics for assessing jeopardy described in Section 1.3.1.2 yield information on extinction risks and on probabilities and timeframes for recovery. A full mitigation metric is also given. NMFS considers the critical metric to be the survival improvement necessary to achieve either the highest of the four extinction/recovery metrics or the full mitigation standard, whichever is lower.

The tables in Sections 6.3.1 and 6.3.5 summarize all five metrics for the ESUs and populations analyzed. Table 6.3-13 summarizes the range of values for the critical metric for each ESU and population. For the Upper Columbia River spring chinook ESU, the critical metric varies with key assumptions — the 48-year recovery metric is critical under some assumptions, the full mitigation metric is critical under others.

For the survival and recovery indicator metrics, the minimum and maximum changes necessary under the base case depend on assumptions about the productivity of hatchery spawners and future ocean conditions. The effectiveness of hatchery spawners ranges from a high of 80% to a low of 20%. The estimated productivity of wild fish increases with decreases in the assumed effectiveness of hatchery spawning in the wild. For future ocean conditions, returns from 1980 to 1999 were used as the minimum value. The maximum value was returns for spring chinook ESUs from 1980 to 2004. Returns for 2000 through 2004 were estimated using 1) preliminary 2000 returns, 2) returns for 2001 projected from 2000 jack returns, and 3) for 2002 to 2004, revised averages for 1980 to present. Recent adult returns indicate higher ocean survival than for most other years of the base period. For the Upper Columbia ESUs, a range results from using two different analyses (CRI and QAR). Where differences between the two methods could not be reconciled, the lower and higher estimates were incorporated in the range.

For the full mitigation indicator metric, the minimum and maximum changes necessary under the base case depend on assumptions about the delayed mortality of non-transported smolts. An assumption of no delayed mortality gives the minimum needed survival change. The maximum change is associated with delayed mortality, assumed equal to the PATH "extra mortality" estimate, fully attributed to hydrosystem effects. (PATH also offered other potential causes.)

Table 6.3-13 summarizes the expected survival change resulting from the proposed action. NMFS incorporated changes in survival through some other life stages into the analysis to reflect ongoing and anticipated future actions. They include recent changes in harvest rates for SR steelhead, SR fall chinook, and UCR steelhead (projected by the All-H Paper to continue into the future), and attainment of the survival standard in the proposed Mid-Columbia HCP.
The expected change in survival (either FCRPS passage or per-generation, depending on the critical metric) ranges from approximately -19% for UCR spring chinook to +56% for SR fall chinook (Table 6.3-13). SR spring/summer chinook index stocks are expected to improve 19%, and UCR steelhead are expected to improve 15%. The expected change in FCRPS passage survival is identical to the change in per-generation survival for SR spring/summer chinook because no changes in other life stages are expected. The change in FCRPS passage survival for UCR stocks represents a reduction in survival (-17% to -19%). Sections 6.3-2 and 6.3-5 explain the reduction.

The last two columns of Table 6.3-13 summarize additional survival changes necessary to meet the critical metrics, after accounting for the proposed action and recovery measures described above. The lowest estimates of additional survival changes range from zero for three SR spring/summer chinook index stocks to 63% for UCR spring chinook and UCR steelhead. At least a 57% change in survival would be necessary for 80% of available SR spring/summer chinook index stocks to meet the critical metrics. These low estimates are based on the minimum estimate of the critical metric, coupled with the highest estimates of the survival change expected from the action. The highest estimates of necessary survival changes range from zero for one SR spring/summer chinook index stock to 494% for UCR steelhead.

Some of the uncertainties associated with these estimates are described above. Others are described in Sections 6.3.1 through 6.3.5 and in Appendix C. They include the following:

- The analysis does not consider the effects of ongoing habitat and hatchery recovery efforts by other Federal agencies and non-Federal recovery efforts, except for the Mid-Columbia HCP. These efforts are described in the All-H Paper and discussed in Section 8.

- The analysis projects the effect of immediate implementation of the survival improvements expected from the proposed action. It is clear that actions will not produce immediate biological effects. The estimate of risk would be higher if a schedule for attainment of biological benefits were included. Because this analysis is intended primarily to provide a standardized measure of risk against which to judge the significance of the action to the continued existence of the ESU, rather than a strict pass/fail test, NMFS has not attempted to quantify the effects of delays.

Table 6.3-12. Effects of the Proposed Action, Current FCRPS Operations (shown in **bold**), and Other Ongoing Actions on Critical Habitat at the Species-Level

ESU	Juv Rearing Areas	Juv Migration Corridors	Areas - Growth/Develop	Adult Migration Corridor	Spawning Habitat
SR spr/sum chinook	- some habitat (incl. water) quality is degraded by tributary land use practices - hatchery practices potentially lead to adverse interactions with wild fish - some habitat access is depleted by water diversions	**For inriver migrants:** **- water quality (dissolved gas) declines during involuntary spill** **- mortality due to passage past 8 FCRPS projects** **- potential exposure to predators in LCR reservoirs** **- potential delayed mortality due to FCRPS passage** **For transported fish – potential delayed mortality** - hatchery practices potentially lead to adverse interactions with wild fish	**- potential habitat degradation in the plume** - incidental ocean harvest - hatchery practices potentially lead to adverse interactions with wild fish	**- mortality due to passage past 8 FCRPS projects** **- water quality (dissolved gas) is degraded during involuntary spill** - incidental mainstem harvest	- some habitat quality is degraded by tributary land use practices and water diversions - some habitat access is impeded by water diversions
SR fall chinook	**For inriver migrants:** **- decline in water quality (temperature) during summer and early fall (by heat capacity of mainstem reservoirs) in the Snake River is partially mitigated by cold water releases from Dworshak Reservoir** **- mortality due to passage past 8 FCRPS projects** **- mortality in reservoirs due to low summer flows** **- potential delayed mortality due to FCRPS passage** **- exposure to predators in reservoirs** **For transported fish – potential delayed mortality** - hatchery practices potentially lead to adverse interactions with wild fish		**- potential habitat degradation in estuary and plume** - incidental ocean harvest - hatchery practices potentially lead to adverse interactions with wild fish	**- mortality due to passage past 8 FCRPS projects** **- decline in water quality (temperature) during summer and early fall (by heat capacity of mainstem reservoirs) in the Snake River is partially mitigated by cold water releases from Dworshak Reservoir** - incidental mainstem harvest	**- unknown effects of flow management on use of spawning habitat below Lower Granite, Little Goose, and Ice Harbor dams** - irrigation and hydroelectric projects block access to habitat in some tributaries below HCC - water quality in lower ends of some tributaries is degraded by land use practices - hatchery practices potentially lead to adverse interactions with wild fish

ESU	Juv Rearing Areas	Juv Migration Corridors	Areas - Growth/Develop	Adult Migration Corridor	Spawning Habitat
UCR spring chinook	- some habitat (incl. water) quantity and quality is degraded by irrigation diversions and tributary land use practices - hatchery practices potentially lead to adverse interactions with wild fish	**- water quality (dissolved gas) declines during involuntary spill** **- mortality due to passage past 4 FCRPS projects** **- potential delayed mortality due to FCRPS passage** **- potential exposure to predators in LCR reservoirs** - mortality due to passage past up to 5 PUD projects - hatchery practices potentially lead to adverse interactions with wild fish	**- potential habitat degradation in the plume** - hatchery practices potentially lead to adverse interactions with wild fish	**- mortality due to passage past 4 FCRPS projects** **- water quality (dissolved gas) is degraded during involuntary spill** - mortality due to passage past up to 5 PUD projects - incidental mainstem harvest	- some habitat quantity and quality degraded by tributary hydropower development, irrigation withdrawals and land use practices - hatchery practices potentially lead to adverse interactions with wild fish
UWR chinook	- some access is reduced and quality is degraded by tributary hydropower and irrigation development and land use practices	- water quality degraded by tributary land use practices	**- potential habitat degradation in estuary and plume** - incidental ocean harvest - hatchery practices potentially lead to adverse interactions with wild fish	- water quality and quantity degraded by tributary land use practices	- some habitat quantity and quality degraded by tributary hydropower development and land use practices
LCR chinook	- some access is reduced and quality is degraded by tributary hydropower development and land use practices	- water quality degraded by tributary land use practices **- mortality due to passage past 1 FCRPS project for a limited number of subbasin populations**	**- potential habitat degradation in estuary and plume** - incidental ocean harvest - hatchery practices potentially lead to adverse interactions with wild fish	- water quality and quantity degraded by tributary land use practices **- mortality due to passage past 1 FCRPS project for a limited number of subbasin populations**	- some habitat quantity and quality degraded by tributary hydropower development and land use practices **- access to and quantity and quality of habitat at Ives Island affected by FCRPS flows**

ESU	Juv Rearing Areas	Juv Migration Corridors	Areas - Growth/Develop	Adult Migration Corridor	Spawning Habitat
SR steelhead	- blockages to tributary habitat are common - some habitat (incl. water) quality is degraded by tributary land use practices - hatchery practices potentially lead to adverse interactions with wild fish	**Inriver migrants:** **- water quality (dissolved gas) declines during involuntary spill** **- mortality due to passage past 8 FCRPS projects** **- potential delayed mortality due to FCRPS passage** - **potential exposure to predators in LCR reservoirs** **Transported fish – potential delayed mortality** - hatchery practices potentially lead to adverse interactions with wild fish	**- potential habitat degradation in the plume** - hatchery practices potentially lead to adverse interactions with wild fish	**- mortality due to passage past 8 FCRPS projects** **- water quality (dissolved gas) is degraded during involuntary spill** - incidental mainstem and tributary harvest	- blockages to tributary habitat are common - some habitat (incl. water) quality is degraded by tributary land use practices - hatchery practices potentially lead to adverse interactions with wild fish
UCR steelhead	- some habitat (incl. water quality) is degraded by irrigation diversions and tributary land use practices - hatchery practices potentially lead to adverse interactions with wild fish	**- water quality (dissolved gas) declines during involuntary spill** **- mortality due to passage past 4 FCRPS projects** **- potential delayed mortality due to FCRPS passage** - **potential exposure to predators in LCR reservoirs** - mortality due to passage past up to 5 PUD projects - hatchery practices potentially lead to adverse interactions with wild fish	**- potential habitat degradation in the plume** - hatchery practices potentially lead to adverse interactions with wild fish	**- mortality due to passage past 4 FCRPS projects** **- water quality (dissolved gas) is degraded during involuntary spill** - mortality due to passage past up to 5 PUD projects - incidental mainstem harvest	- some quantity and quality degraded by tributary hydropower development, irrigation withdrawls and land use practices - hatchery practices potentially lead to adverse interactions with wild fish

ESU	Juv Rearing Areas	Juv Migration Corridors	Areas - Growth/Develop	Adult Migration Corridor	Spawning Habitat
MCR steelhead	- some access is reduced and quality is degraded by tributary hydropower and irrigation development and land use practices	- some water quality degraded by tributary land use practices **- elevated [TDG] during involuntary spill** **- mortality due to passage past up to 4 FCRPS projects**	**- potential habitat degradation in the plume** - hatchery practices potentially lead to adverse interactions with wild fish	- some water quality and quantity degraded by tributary land use practices **- mortality due to passage past up to 4 FCRPS projects** - incidental harvest in the mainstem Columbia River and tributaries	- some quantity and quality degraded by tributary hydropower development and land use practices - hatchery practices potentially lead to adverse interactions with wild fish
UWR steelhead	- some access is reduced and quality is degraded by tributary hydropower and irrigation development and land use practices - hatchery practices potentially lead to adverse interactions with wild fish	- water quality degraded by tributary land use practices - hatchery practices potentially lead to adverse interactions with wild fish	**- potential habitat degradation in estuary and plume** - hatchery practices potentially lead to adverse interactions with wild fish	- some water quality and quantity degraded by tributary land use practices - incidental harvest in the mainstem Columbia River and tributaries	- some quantity and quality degraded by tributary hydropower development and land use practices - hatchery practices potentially lead to adverse interactions with wild fish
LCR steelhead	- some access is reduced and quality is degraded by tributary hydropower development and land use practices - hatchery practices potentially lead to adverse interactions with wild fish	- water quality degraded by tributary land use practices **- mortality due to passage past 1 FCRPS project for a limited number of subbasin populations**	**- potential habitat degradation in the plume** - hatchery practices potentially lead to adverse interactions with wild fish	- some water quality and quantity degraded by tributary land use practices **- mortality due to passage past 1 FCRPS project for a limited number of subbasin populations** - incidental harvest in the mainstem Columbia River and tributaries	- some quantity and quality degraded by tributary hydropower development and land use practices - hatchery practices potentially lead to adverse interactions with wild fish

ESU	Juv Rearing Areas	Juv Migration Corridors	Areas - Growth/Develop	Adult Migration Corridor	Spawning Habitat
CR chum	- some quality is degraded by tributary land-use practices	- water quality degraded by tributary land use practices **- unknown mortality of smolts due to passage past 1 FCRPS project**	**- potential habitat degradation in estuary and plume**	- some water quality and quantity degraded by tributary land use practices **- unknown mortality of adults due to passage past 1 FCRPS project** - incidental harvest in the mainstem Columbia River and tributaries	- some quantity and quality degraded by tributary land use practices **- access to Hamilton Creek and Spring Channel affected by FCRPS flows** **- access to, quantity of, and quality of habitat at Ives Island affected by FCRPS flows**
SR sockeye	- access is reduced and quality is degraded by land use and tributary hydropower and irrigation development	**- mortality of smolts due to passage past 8 FCRPS projects** **- potential exposure to predators in reservoirs**	**- potential habitat degradation in the plume**	**- mortality of adults due to passage past 8 FCRPS projects** - incidental harvest in the mainstem Columbia River and tributaries	- quantity and quality degraded by tributary land use practices

Table 6.3-13. Summary of Quantitative Estimates of Effects of Proposed Action on Achievement of Jeopardy Standard Indicator Metrics

		Needed Survival Change		Survival Change Expected from Proposed Action[1]		Additional Needed Survival Improvements	
Species ESU Stream	**Critical Metric**	**Minimum Estimate**	**Maximum Estimate**	**Low Delayed Mortality**	**High Delayed Mortality**	**Low Estimate[2]**	**High Estimate[3]**
Chinook Salmon							
Snake River Spring/Summer ESU							
Bear Valley Creek	48-recovery	1.20	1.30	1.19	1.19	1.00	1.12
Imnaha River	full mitigation	1.87	6.86	1.19	1.19	1.57	5.75
Johnson Creek	48-recovery	1.00	1.15	1.19	1.19	0.84	0.97
Marsh Creek	48-recovery	1.48	1.77	1.19	1.19	1.24	1.48
Minam River	full mitigation	1.87	6.86	1.19	1.19	1.57	5.75
Poverty Flats (S. Fork Salmon R.)	48-recovery	1.09	1.59	1.19	1.19	0.91	1.33
Sulphur Creek	100-extinction	1.41	1.84	1.19	1.19	1.19	1.54
Snake River Fall ESU	48-recovery	2.54	7.63	1.56	1.56	1.63	4.90
Upper Columbia River Spring-run ESU							
Wenatchee River	48-recovery	2.70	4.71	1.02	1.04	2.60	4.62
	full mitigation	1.31	4.78	0.81	0.81	1.63	5.94
Steelhead							
Upper Columbia River ESU							
Methow River	full mitigation	1.36	4.94	0.83	0.83	1.63	5.94
Snake River ESU							
A-Run component	full mitigation	1.82	6.65	1.19	1.19	1.53	5.58
B-Run component	full mitigation	1.82	6.65	1.19	1.19	1.53	5.58

Note: Units are multipliers for changes in survival per generation. Numbers in "Needed Change" columns less than or equal to 1.0 indicate that additional survival improvements are not necessary. Numbers greater than 1.0 in these columns are the necessary survival multipliers.

[1] Change in per-generation survival, except when referenced to "Full Mitigation." In that case, survival represents juvenile times adult passage survival, including any delayed effects.

[2] Minimum estimate of needed survival change, coupled with high estimate of action effect.

[3] Maximum estimate of needed survival change, coupled with low estimate of action effect.