Recovery Plan Module
Mainstem Columbia River Hydropower Projects

1.0 Purpose

This module summarizes the general effects of Columbia River mainstem hydropower projects on all 13 Endangered Species Act (ESA)-listed anadromous salmonids in the Columbia basin, including the limiting factors and threats and expected actions (including site-specific management actions), or strategy options, to address those threats. The area to be addressed by the module includes the accessible mainstem habitat in the upper Columbia (i.e., to the tailrace of Chief Joseph Dam) and Snake (i.e., to the tailrace of Hells Canyon Dam) rivers, respectively, downstream to the tailrace of Bonneville Dam.[1] This module supports plans for the Snake River, Upper Columbia, Middle Columbia, Lower Columbia, and Upper Willamette River species, replacing the previous version provided as guidance to regional recovery planners, dated September 25, 2006. The material that follows is a synthesis of information that has undergone public processes for review, including, but not limited to, the Federal Columbia River Power System (FCRPS) 2008 Biological Opinion, Federal Energy Regulatory Commission (FERC) licensing proceedings, and Habitat Conservation Plans (HCPs). This module may, however, be updated as additional information becomes available.

1.1 How Salmon and Steelhead Use the Mainstem

All 13 ESA-listed species of salmon *(Oncorhynchus spp.)* and steelhead *(O. mykiss)* in the Columbia basin use the mainstem Columbia River (and Snake River for Snake River species) for migration to and from freshwater natal areas to the Pacific Ocean, where they grow from juveniles to mature adults. Most of the ESA-listed species spawn and incubate in tributaries, but Snake River (SR) fall Chinook, some populations of Lower Columbia River (LCR) fall Chinook, and Columbia River (CR) chum salmon spawn and incubate redds in the mainstem itself. Historically, the peak period for migration to the ocean has been spring and early summer, corresponding with snowmelt in the upper basin and high seasonal flows. However, individual juveniles from one species/population or another can be found in the system throughout the year.

Downstream travel has been shown to be active rather than passive; in addition to water velocity, the rate of travel is affected by date, temperature, the location where the fish begin their migration, fish size, and the extent of the parr-smolt transformation. Survival through the migration corridor declines with distance traveled, whether due to natural hazards (including predation), mortality due to passage at hydroelectric projects, or other factors associated with

[1] A separate module (the Mainstem Columbia River Estuary Recovery Plan Module) provides the same types of information for the lower river below Bonneville, in the estuary and the ocean plume.

development (exotic predators, habitat conditions that make native predators more efficient, water quality, etc.).

Based on emigration and rearing strategies, Connor et al. (2005) described two juvenile life history types for Snake River fall Chinook. At the time of the ESA listing (June 28, 2005; NMFS 2005), it was assumed that all juveniles of this species were ocean-type fish, characterized by entering saltwater at age 0 and spending their first winter in the ocean. However, some of the smaller, later-migrating fall Chinook salmon from the Snake River basin delay seaward movement, wintering in the lower Snake River reservoirs before resuming their seaward movement the following spring at age 1. According to Connor et al. (2005), although the condition of reservoir-type juveniles decreased over winter compared with ocean-type juveniles, the mean condition factor of the former always exceeded 1.0 in the single year of study.

After growth and maturation, whether in freshwater or the ocean, adult salmonids and steelhead generally return to their natal spawning areas for reproduction, though some straying into other basins is natural. As described in ISG (1996), the timing of adult entry and movement in rivers and tributary streams, and even the size, shape, and strength of adult fish represent adaptations to the physical and biological challenges presented by the upstream route to a specific spawning area. For example, waterfalls and similar physical barriers may be passable only at the range of flows that typically occurs during one month of the year, and then only by fish that have the physical ability to jump over or otherwise ascend the barrier. For fall-spawning fish, warm water conditions in late summer often present thermal barriers to movement and there may be little suitable habitat for resting (Berman and Quinn 1991, cited in ISG 1996). Therefore, at the adult life stage, population-specific behavioral patterns, closely attuned to the available habitats, appear to be critical for survival and successful reproduction.

Preferred spawning habitat is determined by the incubation needs of embryos, i.e., high flow of oxygenated water through the interstitial spaces in the streambed (Quinn 2005). Salmon usually avoid both the slowest water (where fine sand and silt accumulate) and the fastest water. Salmon lay their eggs in nests called redds. In areas where winter freezing can destroy embryos, salmon often build redds at sites with upwelling groundwater, which is warmer than river water. In the Columbia basin, two of the listed species, Snake River fall Chinook and Columbia River chum salmon, spawn both in tributaries and in the mainstem. In the vicinity of Ives Island (downstream of Bonneville Dam), chum spawn in shallow areas where it appears that river water is warmed by its transit through the gravel (Geist et al. 2002). At both Ives Island and in the Hanford Reach, fall Chinook salmon select upwelling sites in preference to non-upwelling sites (Geist 2000; Arntzen et al. 2005), but in other locations, fall Chinook prefer to spawn in downwelling areas at the heads of riffles (Healey 1991). At both Ives Island and the Hanford Reach, fall Chinook salmon select redd sites containing the highest dissolved oxygen concentrations in the river and riverbed, which is consistent with the requirements for incubating relatively large eggs (Healy 1991).

2.0 Habitat Limiting Factors and Threats Related to Mainstem Hydropower Projects and Operations

This section identifies the past and continuing effects of dams and reservoirs located in the mainstem Columbia and Snake River migratory corridors on listed species of salmon and steelhead and their designated critical habitat. The mainstem migratory corridor extends from the base of Hells Canyon Dam on the Snake River, and from Chief Joseph Dam on the Columbia River, to the tailrace of Bonneville Dam on the Columbia River.

Columbia River Basin anadromous salmon and steelhead have been affected by the development and operation of dams. Mainstem dams have extirpated anadromous fish from their pre-development spawning and rearing habitats. Dams and reservoirs, within the currently accessible migratory corridor, have altered the river environment and have affected fish passage and survival. The operation of water storage projects has altered the natural hydrograph of the Snake and Columbia Rivers. Water impoundment and dam operations also affect downstream water quality characteristics, including water temperatures, which are important to the survival of anadromous fish. Detailed descriptions of these effects are provided in Williams et al. 2005 and Ferguson et al. 2005 (NOAA Technical Memoranda NMFS-NWFSC-63 and 64) and summarized in NMFS 2008a (Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and other Tributary Actions – Section 5.1).

2.1 Blocked and Inundated Habitat

The construction of Grand Coulee Dam in 1939 – River Mile 597 (and later Chief Joseph Dam in 1961 – RM 545) blocked access to important historical production areas for Upper Columbia River (UCR) spring Chinook salmon and steelhead (NRC 1996; ICTRT 2003) upstream of River Mile 597 (and RM 545). In addition to mainstem production areas, the Sanpoil, Spokane, Colville, Kettle, Pend Oreille, and Kootenai rivers each may have supported one or more populations of Chinook and/or steelhead.

In the Snake River, the construction of Swan Falls Dam in 1901 blocked access to important historical production areas of salmon and steelhead in the Snake River basin upstream of RM 424.[2] The construction of the Hells Canyon Dam complex (1958–1967) cut off access to the remaining historical habitat upstream of river RM 248, including seven major tributaries that had historically been important for spring/summer Chinook salmon and steelhead (and to sockeye

[2] The area downstream of RM 578 (near the present location of Upper Salmon Falls Dam) was especially important to Snake River fall Chinook salmon, which Evermann (1896) identified as the "... largest and most important salmon spawning ground of which we know in Snake River."

salmon in the Payette River system): Boise, Burnt, Malheur, Owyhee, Payette, Powder, and Weiser rivers (Fulton 1968; Fulton 1970; Gustafson et al. 1997).

Between 1938 and 1971, the construction of Bonneville, The Dalles, John Day, and McNary dams inundated mainstem habitat in the lower Columbia River between Bonneville Dam (RM 146) and the confluence of the Snake River (RM 324). Between 1933 and 1967, the construction of Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams inundated mainstem habitat in the middle Columbia River between the Snake River confluence (RM 324) and Chief Joseph Dam (545). Another 147 miles (RM 0 to RM 147) of mainstem habitat was inundated in the Snake River with the construction of Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams between 1962 and 1975 (Groves and Chandler 1999). Upstream from Bonneville Dam, the 41-mile stretch of the Columbia River known as the Hanford Reach between the head of Lake Wallula (McNary Dam pool – RM 356) and the tailrace of Priest Rapids Dam (RM 397), and the approximately 101-mile stretch of the Snake River, often referred to as the Hells Canyon reach (RM 147 to 248), provide the longest remaining unregulated reach of the mainstem ecosystem between Bonneville Dam and Chief Joseph Dam on the Columbia River and Hells Canyon Dam on the Snake River.

2.2 Mainstem Habitats & the Migratory Corridor

The Columbia and Snake Rivers (mainstem habitat) serve as corridors for migrating salmon and steelhead between the Pacific Ocean and their freshwater spawning and rearing habitats. Features of migration habitat important to these fish generally include: substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food (prey), riparian vegetation, space, and safe passage. For fall Chinook salmon, and to a lesser extent chum salmon, mainstem habitat also serves as important spawning and rearing habitat. Features of spawning and rearing habitat that are important to these fish generally include: spawning gravel, water quality, water quantity, water temperature, food, riparian vegetation, and access to spawning and rearing areas.

Current conditions within much of the mainstem Columbia and Snake Rivers are altered compared to historical conditions. The development of mainstem hydropower projects have resulted in the inundation of many mainstem spawning and shallow-water rearing areas (loss of spawning gravels and access to spawning and rearing areas); altered water quality (reduced spring turbidity levels), water quantity (seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes), water temperature (including generally warmer minimum winter temperatures and cooler maximum summer temperatures), water velocity (reduced spring flows and increased cross-sectional areas of the river channel), food (alteration of food webs, including the type and availability of prey species), and safe passage (increased mortality rates of migrating juveniles) (Williams et. al 2005; Ferguson et. al 2005).

Within the migratory corridor, both dams and their associated reservoirs influence the current status of Columbia Basin salmon. To a greater or lesser extent specific to each dam, the dams present fish passage hazards, causing passage delays and varying rates of injury and mortality.

2.2.1 Adult Passage

Unlike downstream migrating juveniles, there is no indication that reservoirs substantially delay adult upstream migration (Ferguson et al. 2005). While the upstream migration of adults can be slowed as fish search for fishway entrances and navigate through the fishways themselves, they migrate more quickly through the relatively slow reservoirs.

Adult fish passage, in the form of fish ladders, is provided at the eight mainstem projects in the lower Snake and lower Columbia rivers and the five mainstem FERC-licensed projects in the middle Columbia reach. In general, adult passage facilities are highly effective. Nonetheless, salmon may have difficulty finding ladder entrances, and fish also may fall back over the dam, either voluntarily (e.g., adults that “overshoot” their natal stream and migrate downstream through a dam on their own volition), or involuntarily (entrained in spillway flow after exiting a fish ladder). Some adults that fall back or migrate downstream pass through project turbines and juvenile bypass systems. Adult mortality rates have been estimated at between 22% and 59%, depending on the species and size of the individual fish (larger fish are more likely to contact a turbine blade, etc.) (Ferguson et al. 2005). There is even less data on the survival of adults through juvenile bypass systems. It seems logical to assume that survival rates would be much higher through these systems than through turbine units, and indeed, with the possible exception of passage through the 14 to 16” gatewell orifices, conditions within these systems should be easily navigable by adults.

However, in spite of these potential hazards, average survival estimates using known origin PIT-tagged fish indicate that, after adjusting for known harvest and “natural” straying, survival through the mainstem Snake and Columbia River projects is relatively high (see Table 1 and discussion in Section 4 below).

Steelhead Kelts

Unlike other Pacific salmonids, a large fraction of the adult steelhead does not die after spawning and instead attempts to migrate back to the Pacific Ocean. Termed kelts, very few post-spawn adult steelhead survive downstream passage through the hydrosystem and so do not return and spawn again. Estimates of FCRPS passage survival ranged from 4.1 to 6.0% in the low flow year 2001 to 15.6% in 2002 and 34% in 2003 (Boggs and Peery 2004; Wertheimer and Evans 2005). At present, juvenile collection and bypass systems are not designed to safely pass adult fish including kelts. In addition to injury and mortality, kelt downstream migrations are delayed by the mainstem projects (Wertheimer and Evans 2005) in a manner similar to that previously described for juveniles.

The fraction of repeat spawning kelts in steelhead populations varies widely, from 1 to 51% (Wertheimer and Evans 2005). Boggs and Peery (2004) cite an estimated 2% kelt rate for the Clearwater River in 1954. It is estimated that 17 to 25% of the steelhead that pass Lower Granite Dam return downstream as kelts (Boggs and Peery 2004; Wertheimer and Evans 2005). Thus, while there is a relatively large number of kelts present, their relatively poor survival through the FCRPS (and potentially through the Middle Columbia PUD projects) may limit the contribution that they can make to steelhead populations.

Predation

Additionally, at Bonneville Dam, marine mammals (both the more common California sea lion and ESA-listed Stellar sea lion) are increasingly using the Bonneville Dam tailrace as a foraging area, presumably because the adult Chinook, steelhead, and lamprey upon which they feed are concentrated and delayed in this area as they seek entrance to the dam's adult fishways.

2.2.2 Juvenile Passage

Delay

Prior to the development of mainstem dams (c. 1938–1975), the mainstem migratory corridor was free-flowing with high velocities and a broad complex of habitats including rapids, short chutes, falls, riffles, and pools. It is not known how long it took juvenile salmon and steelhead to traverse the free-flowing river. Today, median travel times for yearling Chinook from the Lower Granite Dam on the Snake River to Bonneville Dam range from 14 days to 31 days depending on flow conditions, an increase of 40 to 50% over travel times measured in 1966 (Raymond 1968 and 1979), when fish encountered only the four mainstem dams (Williams et al. 2005).

This increased travel time (migration delay) presents an array of potential survival hazards to migrating juvenile salmon and steelhead: increasing their exposure to potential mortality vectors in the reservoirs (e.g. predation, disease, thermals stress), disrupting arrival timing to the estuary (which likely affects predator/prey relationships),[3] depleting energy reserves, potentially causing metabolic problems associated with smoltification (smoltification is the process of metabolic changes required to allow juvenile fish to convert from freshwater to saltwater environments), and for some steelhead and all Chinook salmon, contributing to residualism (a loss of migratory behavior).

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[3] During the spring and summer a series of changes occur in the composition of biotic communities the estuary and near-shore ocean environment. The assemblages of species change through time and disrupting arrival timing may increase the exposure of juvenile salmon to predators and/or diminish the availability of prey species to which the fish are adapted.

Migration delays and biological effects of a similar magnitude have likely also occurred in the middle Columbia River as a result of the construction of the middle Columbia PUD projects.

Dam Passage

A substantial proportion of juvenile salmon and steelhead can be killed while migrating through dams, both directly through collisions with structures and abrupt pressure changes during passage through turbines and spillways, and indirectly, through non-fatal injury and disorientation, which leave fish more susceptible to predation and disease and result in delayed mortality. Some juvenile mortality and injury is associated with any route of dam passage, but turbine passage generally has the highest direct mortality rate—8 to 19 percent. Juveniles passing through project spillways, sluiceways and other surface routes generally suffer the lowest direct mortality rates, 2% or less. However, substantially higher mortality rates have been measured through spillways at several mainstem FCRPS projects (Ferguson et al. 2005, NOAA Technical Memoranda NMFS-NWFSC-64).[4]

Additionally, a significant rate of juvenile mortality (approximately 3 to 5%) can occur in project forebays, just upstream of the dams (Axel et al. 2003; Ferguson et al. 2005; Hockersmith 2007), if fish are substantially delayed (median of 15-20 hours) before passing through the dam (Perry et al. 2007).[5] Forebay delay increases the exposure of juveniles to fish and avian predators and increases their exposure time to adverse water quality conditions (e.g. elevated total dissolved gas levels and high water temperatures), where present. (See discussion in NMFS 2008a—Supplemental Comprehensive Analysis, Section 5.1.2.1 for additional information regarding improvements made at the mainstem hydroelectric dams to improve passage since the mid-1990s, including some discussion of how the newly developed surface passage routes are proving effective at reducing forebay delay.)

Predation

The altered habitats in project reservoirs reduce smolt migration rates and create more favorable habitat conditions (increased growth rates, increased consumption rates, and enhanced foraging opportunities) for fish predators (see Dam Passage), including northern pikeminnow (*Ptychocheilus oregonensis*), and non-native walleye (*Sander vitreus*) and smallmouth bass (*Micropterus dolomieu*).

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[4] The route-specific mortality rate values given here are averages across several investigations. Higher and lower moralities have been observed and measured route-specific mortality is influenced by an array of factors ranging from the health and species of the test fish to study methods, the performance characteristics and working condition of the system being studied, and environmental conditions.

[5] This study was conducted at McNary Dam; estimates of delay for individual fish ranged from 0 to 172 hours in this study.

Dams also enhance conditions for avian predators - primarily Caspian terns, double-crested cormorants, and several gull species – because these species can more effectively forage in the forebays and tailraces of the mainstem projects than in a more riverine system.

Transportation Program

Following a decade of research that led to the conclusion that in most cases, the average adult return rates of predominantly stream-type salmonids (spring/summer Chinook and steelhead) that were transported as juveniles exceeded the return rates of fish that migrated inriver, the Corps began large-scale juvenile transportation as a management measure in 1975 (Ebel 1980; Ebel et al. 1973; Mighetto and Ebel 1994). Currently, fish collection and transportation systems are operated seasonally at Lower Granite Dam, Little Goose Dam, and Lower Monumental Dam (and at McNary Dam for summer migrating fall Chinook salmon). Most transported fish are barged to release points downstream from Bonneville Dam. When collection numbers become too small for barging to be cost-effective, collected fish are transported via truck. Approximately 60 to 90% of spring migrating smolts (spring/summer Chinook and steelhead) in the Snake River basin have been transported annually (Williams et al. 2005). Higher proportions (>95%) of Snake River migrants are likely to be transported during low water year conditions (defined as years in which spring flows are expected to be less than 65,000 cubic feet per second at Lower Granite Dam). With the addition of surface passage routes at the Snake River dams, far fewer fish may be transported – especially early in the migration season when adult returns from Chinook salmon smolts left to migrate inriver are relatively high (compared to transported fish) [see discussion below] – than has been possible in the past. For example, in 2007 transport rates were estimated to be much lower than previously estimated (approximately 25% for wild and hatchery yearling Chinook salmon and about 41% for wild and hatchery steelhead) (Smith 2008).

Recent data show that the effectiveness of transportation, in terms of the ratio of returning adults to transported juveniles (termed smolt-to-adult return ratio or SAR) from the Snake River, varies among species, season, and collection location (Williams et al. 2005; Scheuerell and Zabel 2007). In general, the SARs of both transported and inriver migrating Snake River spring/summer Chinook salmon and steelhead tend to decrease once the day of arrival below Bonneville Dam passes early May. For steelhead, SARs of transported fish are typically equal to or higher than those of the surviving inriver migrants arriving downstream of Bonneville Dam (transport-to-in-river SAR ratios > 1.0). For spring/summer Chinook salmon, SARs of surviving inriver migrating fish often are substantially higher in early to mid May than those of transported migrants (transport-to-in-river SAR ratios < 1.0). However, in late May and June, the differences are generally diminished such that SARs are nearly equal (transport-to-in-river ratios ≈1.0).[6]

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[6] The ISAB (2008) recently reviewed this information and generally agreed with NOAA Fisheries' assessment of the currently available data regarding the relative returns of adult Chinook and steelhead that were either transported or left inriver to migrate as juveniles. However, they advised NOAA Fisheries, the federal Action Agencies, and other regional managers to continue a "spread the risk" approach to spill and transport management to determine if

2.3 Mainstem Hydrologic Conditions

Flow regulation, water withdrawal, and climate change have reduced the Columbia River's average flow, altered its seasonality, and reduced sediment discharge and turbidity (NRC 1996; Sherwood et al. 1990; Simenstad et al. 1982 and 1990; Weitkamp 1994). Annual spring freshet flows through the Columbia River estuary are about one-half of the pre-development levels that flushed the estuary and carried smolts to sea (Figure 1).

Flow affects juvenile travel time and the distribution of individuals among the various routes of dam passage. In general, the lower the flow through the FCRPS reservoirs, the longer the travel time of juveniles that migrate inriver.[7] The longer juveniles remain in project reservoirs, the greater their exposure to predation, elevated temperatures, disease, and other sources of mortality and injury.

Combined with the influence of reservoirs in the migration corridor, reductions in spring and early summer flows slow juvenile fish emigration, increase their exposure to injury and mortality factors within the reservoirs (e.g. predation, temperature stress, disease, and others), and change the timing of ocean entry.

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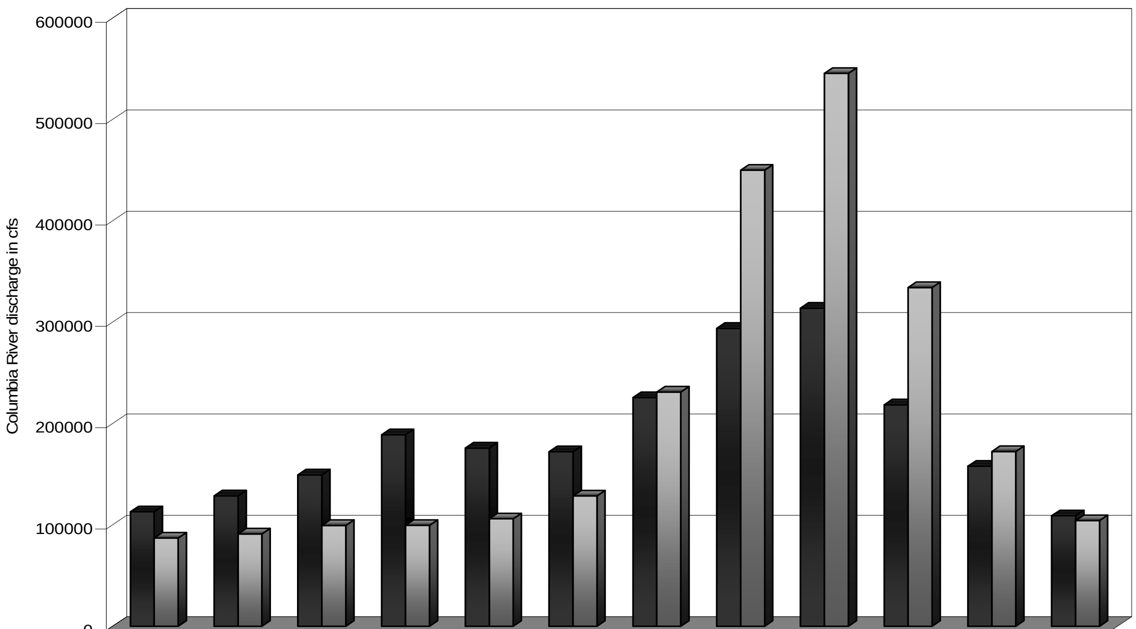
these patterns have been altered by recent structural improvements and operations at the mainstem dams and out of concern for potential effects of spring spill and transport operations [proposed in the 2008 FCRPS biop (NMFS 2008b)] on sockeye and lamprey.

[7] At lower river flows a higher proportion of individuals is collected and transported for some ESUs, thereby avoiding the delay associated with inriver hydrosystem passage.

Figure 1. Simulated mean monthly Columbia River flows at Bonneville Dam under current conditions (black columns) versus flows that would have occurred without reservoir management (gray) (water years 1929 –1978. Source: Current Condition Flows – Bonneville Power Administration, HYDSIM model run FRIII_07rerun2004biop.xls; Pre-Development Flows – USBR (1999) Cumulative Hydrologic Effects of Water Use: An Estimate of the Hydrologic Impacts of Water Resource Development in the Columbia River Basin. (In NMFS' (2008a) Supplemental Comprehensive Analysis, Section 5.1.3.)



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Current	113017	128641	149403	189076	175921	172150	225689	293948	313930	218523	157935	109020
Natural	87115	91029	99387	99496	106033	128580	231047	450040	545561	334238	172430	104310

2.4 Mainstem Water Quality

Water quality characteristics of the mainstem Snake and Columbia Rivers are affected by an array of land and water use developments. Water quality characteristics of particular concern are: water temperature, turbidity, total dissolved gas, and chemical pollutants.

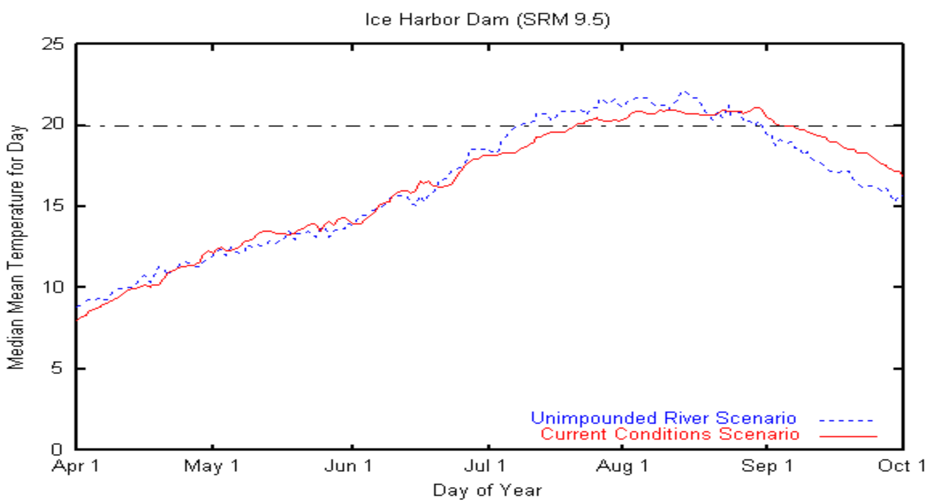
2.4.1 Water Temperature

Changes in water temperatures can have significant implications for anadromous fish survival. Dams and reservoirs influence water temperatures through storage, diversion, and irrigation return flows. Comparisons of long-term temperature monitoring in the migration corridor before and after impoundment reveal a fundamental change in the thermal regime of the Snake and

Columbia rivers. As shown in Figure 2, there are three notable differences between the current and the unimpounded river:[8]

- the maximum summer water temperature has been slightly reduced,
- water temperature variability has decreased, and
- post-impoundment water temperatures stay cooler longer into the spring and warmer later into the fall. The latter phenomenon is termed thermal inertia.

Figure 2. Median daily Snake River water temperatures (°C) at Ice Harbor Dam before and after development of the four lower Snake River projects (20°C denotes Washington Department of Ecology standard). Source: Perkins and Richmond 2001 in NMFS 2008a.



High water temperatures stress all life stages of anadromous fish, increase the risk of disease and mortality, affect toxicological responses to pollutants, and can cause migrating adult salmon to stop or delay their migrations and juvenile steelhead to residualize. Warm water temperatures also increase the foraging rate of predatory fish thereby increasing the consumption of smolts.

Though the duration and magnitude of high water temperatures in the migratory corridor is generally less under current, developed conditions than prior to water development, some juvenile fish are exposed to these conditions for a longer period of time due to the adoption of

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[8] NOTE: Significant land use practices, including the development of a large number of water storage and diversion projects had already occurred by the 1960s. Therefore, the unimpounded river scenario in this graphic does not be equate to the pre-development condition.

alternative life histories (i.e, juvenile fall Chinook that over-summer in the mainstem reservoirs) or increases in migration travel time.

Coincident with and possibly due to climate change, average annual Columbia Basin air temperatures have increased by about 1 degree C over the past century and water temperatures in the mainstem Snake and Columbia rivers have been affected similarly (ISAB 2007). The influence of this and other large-scale environmental variations are discussed in NMFS 2008a – Supplemental Comprehensive Analysis, Section 5.7.

Also, due to the thermal inertia of the reservoirs (both mainstem and upstream storage projects), atmospheric cooling of water temperatures is delayed in the fall and warming is delayed in the early spring. This can affect Snake River fall Chinook by increasing the exposure of adults to elevated temperatures prior to spawning, resulting in an increased potential of pre-spawning mortality, reduced gamete viability, and subsequent impacts to the development and survival of fish through the egg to fry life stages.

2.4.2 Turbidity

Flow regulation and reservoirs reduces turbidity in the Columbia and Snake rivers. Reduced turbidity can increase predator success through improved prey detection, increasing the susceptibility of smolts to predation. Predation is a substantial contributor to juvenile salmon mortality in reservoirs throughout the Columbia and Snake River migratory corridors.

2.4.3 Total Dissolved Gas

Spill at mainstem dams (either as a means to pass fish or involuntarily in response to over-generational flows) can cause downstream waters to become supersaturated with dissolved atmospheric gasses. Supersaturated total dissolved gas (TDG) conditions can cause gas bubble trauma (GBT) in adult and juvenile salmonids resulting in injury or death. Biological monitoring shows that the incidence of GBT in both migrating smolts and adults remains between 1-2% when TDG concentrations in the upper water column do not exceed 120% of saturation in FCRPS project tailraces and 115% in project forebays. When those levels are exceeded, there is a corresponding increase in the incidence of GBT symptoms.

However, the effects of total dissolved gas (TDG) supersaturation on aquatic organisms are moderated by depth due to hydrostatic pressure. Each meter of depth compensates for about 10% of gas supersaturation as measured at the water surface. Thus, if the dissolved gas concentration is 120% of supersaturation at the surface, then the condition that the aquatic organism actually experiences at a depth of 2.0 meters is reduced to about 100% (i.e., the fishes tissues will be in equilibrium with the surrounding water and it will not develop gas bubble disease or trauma; Weitkamp 2003).

2.4.4 Pollutants

Background or ambient levels of pollutants in inflows from upstream areas are variable and generally unquantified. Growing population centers throughout the Columbia and Snake River basins and numerous smaller communities contribute municipal and industrial waste to the rivers. Mining areas scattered around the basin deliver higher background concentrations of metals. Highly developed agricultural areas of the basin also deliver fertilizer, herbicide, and pesticide residues to the river. While these pollutants are not caused by the mainstem Snake and Columbia rivers projects, they are transported through them to the estuary.

Current environmental conditions in the Columbia River estuary indicate the presence of contaminants in the food chain of juvenile salmonids including DDT, PCBs, and polyaromatic hydrocarbons (PAH) (NMFS 2001). This data also indicates that juvenile salmonids in the Columbia River estuary have contaminant body burdens in the range where sublethal effects can occur. The sources of exposure are not clear, but may be widespread. Several pesticides and heavy metal contaminants have been detected in Columbia River sediments (ODEQ 2007). In field studies, juvenile salmon from sites in the Pacific Northwest have demonstrated immunosuppression, reduced disease resistance, and reduced growth rates associated with contaminant exposure during their period of estuarine residence (Arkoosh et al. 1991, 1994, 1998; Varanasi et al. 1993; Casillas et al. 1995a, 1995b, and 1998). Some impacts may be occurring within the mainstem Columbia and Snake Rivers, to the extent that juvenile fish are rearing in areas that are contaminated to similar levels as in the estuary.

3.0 Current Recovery Strategies and Actions

Current hydropower programs and operations are the result of completed or ongoing ESA section 7 consultations, Habitat Conservation Plans (HCPs) pursuant to section 10 of the ESA; FERC relicensing proceedings and other regulatory processes. In most cases, hydropower programs and operations are intended to avoid jeopardy and contribute to recovery. There is no distinction between the hydropower actions intended to meet ESA regulatory requirements and those intended purely for recovery.[9]

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[9] Recovery cost estimates do not include costs for implementing mainstem actions, first, because of their basinwide scope and applicability to all 13 Columbia Basin salmonid species listed as threatened or endangered, and second, because they are considered "baseline actions," a term that NMFS' NWR ESA recovery plans use for actions already incorporated into other processes, such as section 7 consultations, FERC licensing agreements, and Habitat Conservation Plans, and these costs would occur regardless of the recovery plans.

3.1 Federally Owned and Operated Projects in the Columbia Basin

3.1.1 Federal Columbia River Power System

The Federal Columbia River Power System (FCRPS) consists of 14 projects, each composed of dams, powerhouses, and reservoirs, that are operated as a coordinated system for power production and flood control (while also effectuating other project purposes) on behalf of the Federal government under various Congressional authorities. These projects are: Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams, power plants, and reservoirs in the Snake River basin; Albeni Falls, Hungry Horse, Libby, Grand Coulee and Banks Lake (features of the Columbia Basin Project), and Chief Joseph dams, power plants, and reservoirs in the upper Columbia River basin; and McNary, John Day, The Dalles, and Bonneville dams, power plants, and reservoirs in the lower Columbia River basin.

The plan for operation of the FCRPS through 2018 is described in U.S. Army Corps of Engineers (USACE) et al.'s Comprehensive Analysis Document (USACE et al. 2007a) and Biological Assessment (USACE et al. 2007b) and in NMFS' Supplemental Comprehensive Analysis Document (NMFS 2008a) and Biological Opinion (NMFS 2008b). The following is a general summary of the performance standards, metrics, and targets required in the 2008 Biological Opinion to maintain or improve salmon and steelhead survival in the mainstem migration and rearing corridor and the strategies that will be pursued to achieve these metrics (see RPA 51 in NOAA Fisheries' Reasonable and Prudent Alternative Table of Actions – NMFS 2008b). These actions are intended to address the needs for survival and recovery of all 13 species of ESA-listed salmon and steelhead in the Columbia basin.

- **Adult Passage Performance Standards.** The Actions Agencies must track and confirm that the relatively high levels of adult survival currently observed are maintained or increased through 2018 (see Table 7 of NOAA Fisheries' Reasonable and Prudent Alternatives Table of Actions – NMFS 2008b). These survival rates, which are based on known-origin fish PIT tagged as juveniles, after accounting for known harvest and "natural" rates of straying, range from 81.2% for Snake River fall Chinook salmon up to 91.0% for Snake River spring/summer Chinook salmon (BON to LGR); and from 84.5% for Upper Columbia River steelhead up to 90.1% for Upper Columbia River spring Chinook (BON to MCN).[10]
- **Juvenile Dam Passage Performance Standards.** The Action Agencies must achieve an average Juvenile Dam Passage Performance Standards of 96% survival across Snake

[10] The discrepancy between adult survivals for Upper Columbia River versus Snake River species in the lower Columbia River is recognized and is the subject of directed research, monitoring, and evaluation programs. The objectives of these programs are to determine why the differences exist and what actions might be effective at increasing the survival of the Upper Columbia River species in the lower Columbia River.

River and Lower Columbia River dams for spring Chinook and steelhead and an average of 93% survival across Snake River and Lower Columbia River dams for Snake River sub-yearling fall Chinook.

- **Achieve Juvenile Inriver Survival Performance Metrics.** The Action Agencies must annually measure the survival of inriver migrating fish and compare these numbers with COMPASS model estimates, which will be based on the conditions actually experienced and the expected benefits of completed hydro actions, to assure that survival improvements are occurring as expected.
- **Juvenile System Survival Performance Targets.** The Action Agencies must achieve the expected increase in juvenile fish survival through the hydrosystem (survival to below Bonneville Dam of both transported and inriver migrating fish) that are associated with the proposed hydrosystem actions.

To achieve these metrics, the Action Agencies will pursue the following general objectives and strategies (see NOAA Fisheries' Reasonable and Prudent Alternatives Table of Actions, NMFS 2008b, for specific details):

- Continue collaboration with States and Tribes in the implementation of RPA actions, progress reporting, and adaptive management using fora such as the Regional Implementation Oversight Group.
- Operate the FCRPS to provide flows and water quality to improve juvenile and adult fish survival.[11]
- Modify Columbia and Snake river dams to maximize juvenile and adult fish survival.[12]
- Implement spill and juvenile transportation improvements at Columbia and Snake River dams.
- Operate and maintain facilities at Corps mainstem projects to maintain biological performance.
- Implement piscivorous predation control measures to increase survival of juvenile salmonids in the lower Snake and Columbia rivers.

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[11] This includes the operation of storage reservoirs to increase the likelihood of achieving seasonal flow objectives: Spring \ 85 – 100 kcfs at Lower Granite dam, 135 kcfs at Priest Rapids dam, and 220 – 260 kcfs at McNary dam; Summer \ 50-55 kcfs at Lower Granite dam and 200 at McNary. It also includes the continued release of cool water from Dworshak dam during the summer to reduce and maintain temperatures in the lower Snake River.

[12] This includes the design, construction, and testing of structures and operations to provide surface oriented routes of passage which should be beneficial to juvenile migrants and downstream migrating adults (overshoots, fallbacks, or steelhead kelts).

- Implement avian predation control measures to increase survival of juvenile salmonids in the lower Snake and Columbia rivers.
- Implement marine mammal control measures to increase survival of adult salmonids at Bonneville Dam.
- Provide information needed to support planning and adaptive management and demonstrate accountability related to the implementation of FCRPS ESA hydropower actions for all ESUs (i.e., implement research, monitoring, and evaluation programs for hydropower actions and predator control actions).

In addition to these objectives, the 2008 FCRPS Reasonable and Prudent Alternative Action Table articulates site-specific management actions that will benefit interior Columbia species (see NOAA Fisheries' Reasonable and Prudent Alternatives Table of Actions, NMFS 2008b, for specific details).

3.1.2 U.S. Bureau of Reclamation Projects in the Upper Snake Basin above Brownlee Reservoir

The USBR's proposed actions in its August 2007 Biological Assessment (USBR 2007) addressed operations at 12 projects in the upper Snake River basin: Baker, Boise, Burnt River, Little Wood River, Lucky Peak, Mann Creek, Michaud Flats, Minidoka, Owyhee, Palisades, Ririe, and Vale (collectively, the Upper Snake Project). The proposed actions encompassed USBR's future operations and routine maintenance, including storage and delivery of water, hydropower generation, and releasing water to augment flows for migrating salmonids. NMFS (2008c) prepared a biological opinion on this proposal and concluded that the action would not jeopardize the listed species nor result in the destruction or adverse modification of their designated critical habitat.

The site-specific action of providing salmon flow augmentation is intended to address the needs for survival and recovery of all 13 species of ESA-listed salmon and steelhead in the Columbia basin. Although the physical project operations take place upstream of the migration barrier at Idaho Power Company's Hells Canyon Complex, water released from the upper Snake River project reaches the lower Snake and Columbia rivers where it benefits juvenile salmon and steelhead migrants.

The USBR provides salmon flow augmentation by acquiring water through rental pools and leasing or acquiring natural flow rights. The Nez Perce Water Rights Settlement and the Idaho law that implemented the settlement provide that up to 487,000 acre-feet may be provided for flow augmentation.

3.2 Federal Energy Regulatory Commission-licensed Projects

The Federal Energy Regulatory Commission (FERC) licenses five hydroelectric dams in the middle Columbia reach (i.e., between Chief Joseph Dam and the confluence of the Snake and Columbia rivers): Wells (owned and operated by Douglas County Public Utility District (PUD)), Rocky Reach and Rock Island (Chelan County PUD), and Wanapum and Priest Rapids (Grant County PUD). FERC also licenses Idaho Power Company's (IPC) Hells Canyon Complex in the Snake River basin.

3.2.1 Hydropower Projects Owned and Operated by Chelan and Douglas PUDs

NMFS (2002) entered into three site-specific 50-year anadromous fish agreements and habitat conservation plans (HCPs), one for each of the three mainstem Columbia River hydroelectric projects owned by Chelan (Rocky Reach and Rock Island) and Douglas (Wells) County PUDs, pursuant to section 10 of the Endangered Species Act. The HCPs were developed to protect the five species of Columbia River steelhead and salmon (spring-run Chinook salmon; summer/fall-run Chinook salmon; sockeye salmon, steelhead, and coho salmon, two of which (Upper Columbia River spring-run Chinook salmon and steelhead) were listed as endangered at that time.[13] They satisfied the PUDs' regulatory obligations with respect to anadromous salmonid species under the Federal Power Act, Fish and Wildlife Coordination Act, Pacific Northwest Electric Power Planning and Conservation Act, the essential fish habitat provisions of the Magnuson-Stevens Fishery Conservation and Management Act, and Title 77 RCW, as well as the ESA. The agreements set a "no net impact" standard to protect salmon and steelhead at the Wells, Rocky Reach, and Rock Island projects, and provide some degree of certainty for the long-term operation of these projects.[14]

Each of the three HCPs established a standard of 91% combined adult and juvenile passage survival at each project (Wells, Rocky Reach, and Rock Island) (NMFS 2002).[15] The combined survival standard is composed of 93% juvenile and 98% adult project passage survival for all anadromous salmonids. At the time the Incidental Take Permits were issued (August 20, 2003), NMFS estimated that the HCPs represented a 22 to 45% survival improvement potential over the survival levels observed under the historical operations at these projects.

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[13] NMFS (2006) revised its listing of Upper Columbia River steelhead from "endangered" to "threatened" on January 5, 2006.
[14] The HCPs are intended to help prevent conditions that would lead to the need to list additional species of Upper Columbia River salmon and steelhead in the future.
[15] The HCPs allowed the PUDs to compensate for up to 9% project passage mortality through up to 7% hatchery production and up to 2% funding of tributary habitat enhancement projects. That is, the mitigation is intended to match the level of impact.

3.2.2 Hydropower Projects Owned and Operated by Grant County PUD

Grant County PUD's new FERC license includes survival standards required in NMFS (2004) for the Priest Rapids Project (Priest Rapids and Wanapum dams and reservoirs) that are identical to those described above for the HCPs. Furthermore, the following site-specific measures are also included in the new FERC license and are being implemented to ensure that the standards are met:

- Downstream passage measures, including spill through existing and top spill through future units; turbine operations and the installation of advanced turbines; total dissolved gas abatement; avian predator control; and a northern pikeminnow *(Ptychocheilus oregonensis)* removal program

- Continued operation and maintenance, and where needed, improvements to adult fishways at both Priest Rapids and Wanapum dams

- Design and construction of an off-ladder trap and fish-handling facilities at Priest Rapids Dam

- Sluiceway operations for steelhead fallbacks (kelts)

The FERC has completed consultation with NMFS on the terms of a new, 44-year license for the Priest Rapids Project. With respect to site-specific actions for mainstem facilities and operations, FERC adopted the hydro actions in the Reasonable and Prudent Alternative in NMFS' Biological Opinion on Grant County PUD's Interim Protection Plan (NMFS 2004) and in NMFS' February 1, 2008, Biological Opinion (NMFS 2008d) for listed salmon and steelhead, described above.

3.3 Idaho Power Company's Hells Canyon Project

The relicensing of the Hells Canyon Hydroelectric Project is the subject of ongoing administrative proceedings before FERC involving its owner, IPC; Federal, state, and tribal agencies; and other stakeholders. At present, IPC voluntarily operates the project to protect habitat used by fall Chinook salmon for spawning (i.e., by eliminating flow fluctuations), and incubation (i.e., by providing enough flow to prevent the dewatering of redds downstream of the project). As part of an interim settlement agreement in the license proceedings, IPC has agreed to release about 237 thousand acre-feet (kaf) of water – primarily during July - to improve downstream migration conditions (flow) for juvenile fall Chinook salmon (Tucker 2005).

4.0 Survival Rates at Mainstem Federal and Non-Federal Hydro Projects

4.1 Adult Survival

Adult survival estimates presented in this document are based primarily on a simple, straight-forward "conversion rate" method which relies upon the detection and subsequent re-detection of PIT-tagged "known-origin" adults[16] as they migrate upstream through the fishways (some fitted with PIT tag detectors) at the mainstem hydro projects. Detection rates are typically $\geq$ 99% for an individual PIT tag detector and, because there are typically two or three detectors in series within each of the key fishways –virtually every PIT-tagged adult fish migrating upstream through a mainstem fishways is detected.[17]

Minimum adult survival estimates (or conversion rates) can be calculated as the number of fish re-detected at an upstream project divided by the number of fish initially detected at the downstream project of interest. Estimates of "natural" straying rates and of known harvest are also factored in and the resulting number is the proportion of fish that survived between the two projects. For details regarding this method and how "natural" stray rates and harvest rates were used in these analyses, the reader is advised to read the Adult Survival Estimate Appendix of NOAA's Supplemental Comprehensive Analysis (NMFS 2008a). Otherwise, these estimates capture all sources of mortality manifested within the identified reaches, including those resulting from the existence and operation of the FCRPS, as well as unquantifiable levels of mortality from other potential sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal predator attacks, etc.) and unquantifiable levels of "natural" mortality (i.e., levels of mortality in the migratory corridor that would have occurred "naturally" without human influence).

Adult Survival – Federal Projects

Under the 2008 FCRPS Biological Opinion (NMFS 2008b), the federal action agencies are responsible for ensuring that the relatively high rates of survival currently observed in the Bonneville Dam to Lower Granite Dam (7 dams) reach for Snake River species and Bonneville Dam to McNary Dam (3 dam) reach for Upper Columbia River spring Chinook and steelhead is maintained or increased through 2018. Snake River species, for which the most information is available, were used as surrogates for Middle Columbia River steelhead, and Lower Columbia River species. The average survival estimates, annual estimates (ranges), and additional

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[16] "Known-origin" means that the release locations for all PIT tagged juvenile fish are available in the PITAGIS data base – and the general area to which these fish are attempting to migrate as adults is also known.
[17] It should be noted that some adults may avoid detection by migrating past the dams via the locks at the federal projects. This is evidenced by individuals not being detected at a particular dam, but being detected at another dam upstream.

information are provided in Table 1 (Column 3 titled "Adult Surv. – FCRPS") and the information for Snake River and Upper Columbia River species is also summarized in the text below.

The average survival estimate for Snake River fall Chinook salmon between Bonneville Dam and Lower Granite Dam was 81% for those that migrated inriver as juveniles and approximately 75% for those that were transported as juveniles, equating to a per project survival (7 dams) of 97% and 96%, respectively.[18]

The average survival estimate for Snake River spring/summer Chinook salmon between Bonneville Dam and Lower Granite Dam was 91% for those that migrated inriver as juveniles and about 84% for those that were transported as juveniles, equating to a per project survival (7 dams) of 99% and 98%, respectively.

The estimated average survival of Snake River sockeye salmon between Bonneville Dam and Lower Granite Dam was 81% equating to a per project survival (7 dams) of about 97%. No estimate can be made with the available data for those fish transported as juveniles (see Table 1, footnote 3).

The average survival estimate for Snake River steelhead between Bonneville Dam and Lower Granite Dam was 90% for those that migrated inriver as juveniles and approximately 83% for those that were transported as juveniles, equating to a per project survival (7 dams) of 99% and 97%, respectively.

The average survival estimate for Upper Columbia River spring Chinook salmon between Bonneville Dam and McNary Dam was 90% (all of these fish migrate inriver as juveniles), equating to a per project survival (3 dams) of approximately 97%.

The average survival estimate for Upper Columbia River steelhead between Bonneville Dam and McNary Dam was 85% (all of these fish migrate inriver as juveniles), equating to a per project survival (3 dams) of 95%.[19]

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[18] Average per project survival estimates are calculated as Average Survival Estimate ^ 1/n. Average per project survival estimates are useful because they allow for a comparison between species that migrate past different numbers of dams.

[19] Note: The apparent discrepancy between the survival rates of Upper Columbia River spring Chinook salmon and steelhead through a 3 dam reach and Snake River spring/summer Chinook salmon and steelhead through a 7 dam reach is noted in the 2008 FCRPS biological opinion. Reasonable and Prudent Alternative Action 52 requires an investigation into the possible causes of this apparent discrepancy (NMFS 2008b). Once a likely cause is identified, the Action Agencies, NOAA Fisheries and co-managing agencies will develop appropriate corrective actions and a monitoring plan to ensure that the differential survival is minimized or eliminated.

Adult Survival – Non-Federal Projects

Under the terms of the Middle Columbia Habitat Conservation Plans for the Wells, Rocky Reach, and Rock Island projects; and under the 2008 biological opinion for the Priest Rapids Project (Wanapum and Priest Rapids dams, NMFS 2008d), the Public Utility Districts must meet or exceed a per project survival of 98% for all adult migrants. At this time, it appears that the average per project survival between Priest Rapids and Wells Dam is 98.7% and 98.2% for Upper Columbia River spring Chinook salmon and steelhead, respectively. The average survival estimates, annual estimates (ranges), and additional information for Upper Columbia River species are provided in Table 1 (Column 4 titled "Adult Surv. – Mid-Columbia" and Column 5 titled "Adult Surv. - Total) and also summarized in the text below.

The average survival estimate for Upper Columbia River spring Chinook salmon migrating between Priest Rapids and the Wenatchee, Entiat, and Methow rivers is approximately 95%, 96%, and 97%, respectively. This survival multiplied by the Bonneville to McNary survival estimate[20] yields a Bonneville to Wenatchee, Entiat, and Methow river survival estimate of about 85%, 87%, and 88%.

The average survival estimate for Upper Columbia River steelhead migrating between Priest Rapids and the Wenatchee, Entiat, and Methow rivers is approximately 93%, 95%, and 96%, respectively. This survival multiplied by the Bonneville to McNary survival estimate[19] yields a Bonneville to Wenatchee, Entiat, and Methow river survival estimate of about 79%, 80%, and 82%.

4.2 Juvenile Survival

Juvenile survival levels are estimated for two periods (See Tables 2 and 3). The "Current" scenario generally translates to survivals recently observed or estimated (modeled using COMPASS) to have occurred due to operational and configuration changes at the mainstem hydroelectric projects through about 2006. The "Prospective" scenario generally translates to attaining survival levels (if not already attained or exceeded) that are required by the Habitat Conservation Plans for the Wells, Rocky Reach, and Rock Island projects; the 2008 biological opinion for the Priest Rapids project (Wanapum and Priest Rapids Dam) (NMFS 2008d); or modeled using COMASS for the 2008 FCRPS biological opinion (NMFS 2008b). Full attainment of these standards is expected when the FCRPS biological opinion is fully implemented from 2015 to 2018.

[20] A McNary to Priest Rapids (Hanford Reach) survival estimate has not yet been calculated, but is likely less than 100%.

Juvenile survival through the federal projects under both the “Current” and “Prospective” cases was estimated using NOAA Fisheries’ COMPASS model. The COMPASS model was populated with the best empirically derived estimates of route-specific passage and survival rates available for juvenile Chinook or steelhead to reflect the “Current” configuration of the hydrosystem. The Federal Action Agencies assessed the likely benefits (specific survival improvements) that should result from additional dam configuration actions required in the 2008 FCRPS biological opinion and these improvements were included in the modeling runs of the “Prospective” scenario. Both the “Current” and “Prospective” configurations and operations were modeled across a 70-year (1928 through 2000) historical water record.

The model provides estimates of survival to below Bonneville Dam for inriver (and transported, if applicable) migrants, proportion of the migrants that would likely be transported (if applicable), and the arrival timing of migrants to the Bonneville dam tailrace for ESA-listed spring and summer Chinook salmon and steelhead from the Snake River, Upper Columbia River, and Middle Columbia River populations.[21] For the purpose of this module, the most relevant pieces of information are likely the survival estimates.

4.2.1 Juvenile Survival – Current

Estimates of “Current” juvenile survival through the federal projects, ranges of expected survival, and proportion of juveniles expected to be transported are provided in Table 2 (Column 3 - Juv. Survival – FCRPS). These results are broken into two categories (expected average flows at Lower Granite Dam of less than 65 kcfs or greater than >65 kcfs) for Snake River populations to display the likely effect of the “full transport” operation that would occur in the low flow years – which occurs in about 19% (13 of 70) of the years modeled. Estimates of survival for juveniles migrating from the Methow, Entiat and Wenatchee rivers are provided in Column 4 – Juv. Survival – Mid-Columbia; and combined survival estimates are provide in Column 5 – Juv. Survival – Total. A brief summary of this information is provided for spring migrating Snake River and Upper Columbia River Chinook salmon and steelhead populations in the text below.

The average juvenile survival estimate for Snake River spring/summer Chinook salmon is 56% in the LGR > 65 kcfs years and 37% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 64% and 95% in these flow conditions, respectively.

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[21] Insufficient data, primarily resulting from the multiple life-history strategies exhibited by Snake River fall Chinook salmon, was available to populate the COMPASS model to estimate juvenile fall Chinook survival through the FCRPS projects. Instead, NOAA Fisheries derived survival estimates from Fish Passage Center data (see NMFS 2008a and 2008b).

The average juvenile survival estimate for Snake River steelhead is 39% in the LGR > 65 kcfs years and 8% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 79% and 94% in these flow conditions, respectively.

The average juvenile survival estimate for Upper Columbia River spring Chinook salmon is 67% through the four FCRPS dams in the lower Columbia River, and 68%, 71%, and 77% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 45%, 47%, and 51%, respectively.

The average juvenile survival estimate for Upper Columbia River steelhead is 48% through the four FCRPS dams in the lower Columbia River, and 69%, 72%, and 75% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 33%, 34%, and 36%, respectively.

4.2.2 Juvenile Survival – Prospective

Estimates of "Prospective" juvenile survival through the federal projects, ranges of expected survival, and proportion of juveniles expected to be transported are provided in Table 3 (Column 3 - Juv. Survival – FCRPS). These results are broken into two categories (expected average flows at Lower Granite Dam (LGR) of less than 65 kcfs or greater than >65 kcfs) to display the likely effect of the "full transport" operation that would occur in the low flow years – which occurs in about 19% (13 of 70) of the years modeled. Estimates of survival for juveniles migrating from the Methow, Entiat and Wenatchee rivers are provided in Column 4 – Juv. Survival – Mid-Columbia; and combined survival estimates are provide in Column 5 – Juv. Survival – Total. A brief summary of this information is provided for spring migrating Snake River and Upper Columbia River populations in the text below.

The average juvenile survival estimate for Snake River spring/summer Chinook salmon is 63% in the LGR > 65 kcfs years and 52% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 64% and 95% in these flow conditions, respectively.

The average juvenile survival estimate for Snake River steelhead is 45% in the LGR > 65 kcfs years and 9% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 74% and 89% in these flow conditions, respectively.

The average juvenile survival estimate for Upper Columbia River spring Chinook salmon is 73% through the four FCRPS dams in the lower Columbia River, and 72%, 75%, and 81% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 53%, 55%, and 59%, respectively.

The average juvenile survival estimate for Upper Columbia River steelhead is 53% through the four FCRPS dams in the lower Columbia River, and 75%, 78%, and 81% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 40%, 41%, and 43%, respectively.

Table 1: Recent Adult Survival Estimates for ESA-listed Columbia River Basin Salmon and Steelhead Populations Migrating Past Mainstem Hydroelectric Projects Based on PIT-tagged, Known-Origin Adults.[1]

Species	Population	Adult Surv.[2] – FCRPS ***Reach*** **Average** Range *Special Info.*	Adult Surv. – Mid-Columbia[5] ***Reach*** **Average** Range *Special Info.*	Adult Surv.[2] – Total **Average** Range *Special Info.*
SR fall Chinook[3]	Single Pop.	***BON – LGR*** **Inriver:** **81.0** (58.8 – 98.6) **Transported:** **74.9** (62.4 – 94.7)		***BON – LGR*** **Inriver:** **81.0** (58.8 – 98.6) **Transported:** **74.9** (62.4 – 94.7)
SR spr/sum Chinook[3]	All Pops.	***BON – LGR*** **Inriver:** **91.0** 81.6 – 97.9 **Transported:** **84.1** *73.7 – 88.0*		***BON – LGR*** **Inriver:** **91.0** 81.6 – 97.9 **Transported:** **84.1** *73.7 – 88.0*
SR sockeye[3]	Single Pop.	***BON – LGR*** **Inriver:** **81.1** 79.1 – 83.2 **Transported:** **(No Est. Available)**		***BON – LGR*** **Inriver:** **81.1** 79.1 – 83.2 **Transported:** **(No Est. Available)**
SR steelhead[3]	All Pops.	***BON – LGR*** **Inriver:** **90.1** 85.6 – 93.8 **Transported:** **83.3** *78.2 – 89.8* (BON – LGR)		***BON – LGR*** **Inriver:** **90.1** 85.6 – 93.8 **Transported:** **83.3** *78.2 – 89.8* (BON – LGR)

Species	Population	Adult Surv.[2] – FCRPS *Reach* **Average** Range *Special Info.*	Adult Surv. – Mid-Columbia[5] *Reach* **Average** Range *Special Info.*	Adult Surv.[2] – Total **Average** Range *Special Info.*
UCR spring Chinook[6]	Methow Entiat Wenatchee	***BON - MCN*** **Inriver:** **90.1** 86.1 – 96.1	***PRD - WEL*** **94.7** ***PRD - RRE*** **96.2** ***PRD – RIS*** **97.4**	***BON – WEL*** **85.3** ***BON – RRE*** **86.7** ***BON – RIS*** **87.8**
UCR steelhead[6]	Methow / Okanogan Entiat Wenatchee	***BON - MCN*** **Inriver:** **84.5** 77.6 – 90.7	***PRD - WEL*** **93.0** ***PRD - RRE*** **94.7** ***PRD – RIS*** **96.4**	***BON - WEL*** **78.6** ***BON - RRE*** **80.0** ***BON – RIS*** **81.5**
MCR steelhead[4,7]	Yakima / Walla Walla Umatilla / John Day Deschutes and BON pool	***BON - (MCN, JDA, and TDA)*** **Inriver:** **95.6** 93.5 – 97.3 **97.0** 95.6 – 98.2 **98.5** 97.8 - 99.1		***BON-(MCN, JDA, and TDA)*** **Inriver:** **95.6** 93.5 – 97.3 **97.0** 95.6 – 98.2 **98.5** 97.8 - 99.1
LCR Chinook[4]	Spring-run adults Fall-run adults	***BON Pool*** **Inriver:** **98.6** 97.1 – 99.7 **96.9** 92.7 – 99.8		***BON Pool*** **Inriver:** **98.6** 97.1 – 99.7 **96.9** 92.7 – 99.8
LCR steelhead[4,8]	BON pool	***BON Pool*** **>98.5** >97.8 - >99.1		***BON Pool*** **>98.5** >97.8 - >99.1
CR coho[4]	BON pool	***BON Pool*** **96.9** 92.7 – 99.8		***BON Pool*** **96.9** 92.7 – 99.8
CR chum[4]	BON pool	***BON Pool*** **96.9** 92.7 – 99.8		***BON Pool*** **96.9** 92.7 – 99.8

Sources: NMFS' 1) Supplemental Comprehensive Analysis Document (May 5, 2008a); and 2) Biological Opinion – Consultation on Remand for Operation of the Federal Columbia River Power System, 11 bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (May 5, 2008b).

[1] Key to Dams: BON = Bonneville Dam, TDA = The Dalles Dam, JDA = John Day Dam, MCN = McNary Dam, PRD = Priest Rapids Dam, WAN = Wanapum Dam, RIS = Rock Island Dam, RRE = Rocky Reach Dam, WEL = Wells Dam, IHR = Ice Harbor Dam, LMN = Lower Monumental Dam, LGS = Little Goose Dam, and LGR = Lower Granite Dam.

[2] These estimates are based on detections of known origin fish returning to the Columbia River, detected passing Bonneville Dam, and redetected at upstream locations. These estimates have been adjusted to account for estimated harvest and "natural" straying rates of adults within the FCRPS migration corridor, but otherwise capture all other sources of mortality manifested within the identified reaches, including those resulting from the existence and operation of the FCRPS, unquantifiable levels of mortality from other potential sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal predator attacks, etc.), and unquantifiable levels of "natural" mortality (i.e. levels of mortality in the migratory corridor that would have occurred "naturally" without human influence).

[3] Adult survival rates for SR fall Chinook, SR spr/sum Chinook, and SR steelhead are reported separately as either inriver or transported (via barge or truck) to properly reflect their migration history as juveniles. Survival estimates for adult SR sockeye are primarily based on unknown origin (though likely from the Lake Wenatchee or Okanogan River sockeye populations) adults PIT tagged at Bonneville Dam and detected at McNary Dam. The average per dam survival is expanded to a seven dam reach (Bonneville Dam to Lower Granite Dam).

[4] The estimates for these ESUs only apply to those adults migrating to tributaries entering the reservoir upstream of Bonneville Dam, or in the case of MCR steelhead, the adult populations migrating to tributaries entering the Columbia River between Bonneville Dam and McNary Reservoir.

[5] Recent adult survival estimates from Priest Rapids to Wells dam are reported in Anchor Env. and Douglas PUD (2008): 93.0% and 94.7% for summer steelhead (2004-2007) and spring Chinook salmon (2003-2007), respectively. The average per project survival estimates ($1/4^{th}$ root of the reach survival estimate) are 98.2% for steelhead and 98.7% for spring Chinook.

[6] NOTE: A separate estimate for the McNary Dam to Priest Rapids Dam reach has not yet been generated. This will be addressed in the next update of the Recovery Planning Hydro Module.

[7] Within the Bonneville pool, Klickitat River and 15 Mile Creek populations of steelhead are part of the Mid Columbia River steelhead Distinct Population Segment.

[8] Within the Bonneville pool, Hood River and Wind River populations of steelhead are part of the Lower Columbia River steelhead Distinct Population Segment.

Table 2. "Current" (2002-2009) Juvenile Survival Estimates for ESA-listed Columbia River Basin Salmon and Steelhead Populations Migrating Inriver Past Mainstem Hydroelectric Projects.[1]

Species	Population	**Juv. Survival - FCRPS *Reach*** **Average** (Range) *Special Info.*	**Juv. Survival[3] – Mid-Columbia *Reach*** **Average** (Range) *Special Info.*	**Juv. Survival – Total** **Average** (Range) *Special Info.*
SR fall Chinook	Single Pop.	***LGR - BON*** **18.7 - 55.4** (12.4 – 71.7) *≈ 52% of the juveniles would be transported*		***LGR - BON*** **18.7 - 55.4** (12.4 – 71.7) *≈ 52% of the juveniles would be transported*
SR spr/sum Chinook	All Pops.	***LGR – BON*** **LGR >65 kcfs** **56.3** (47.5 – 60.8) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **37.3** (33.8 – 51.3) *≈ 95% of the juveniles would be transported*		***LGR – BON*** **LGR >65 kcfs** **56.3** (47.5 – 60.8) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **37.3** (33.8 – 51.3) *≈ 95% of the juveniles would be transported*
SR sockeye[4]	Single Pop.	***LGR - BON*** **LGR >65 kcfs** **36.4** (19.9 – 57.0) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **8.2** (Unknown) *≈ 95% of the juveniles would be transported*		***LGR - BON*** **LGR >65 kcfs** **36.4** (19.9 – 57.0) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **8.2** (Unknown) *≈ 95% of the juveniles would be transported*
SR steelhead	All Pops.	***LGR – BON*** **LGR >65 kcfs** **38.9** (20.3 – 56.9) *≈ 79% of the juveniles would be transported* **LGR <65 kcfs** **7.5** (3.3 – 23.1) *≈ 94% of the juveniles would be transported*		***LGR – BON*** **LGR >65 kcfs** **38.9** (20.3 – 56.9) *≈ 79% of the juveniles would be transported* **LGR <65 kcfs** **7.5** (3.3 – 23.1) *≈ 94% of the juveniles would be transported*

Species	Population	Juv. Survival - FCRPS *Reach* **Average** (Range) *Special Info.*	Juv. Survival[3] – Mid-Columbia *Reach* **Average** (Range) *Special Info.*	Juv. Survival – Total **Average** (Range) *Special Info.*
UCR spring Chinook	Methow Entiat Wentachee	***MCN – BON*** **66.7** (60.9 – 72.9)	***WEL – PRD*** **67.9** ***RRE – PRD*** **70.6** ***RIS – PRD*** **76.7**	***WEL – BON*** **45.3** ***RRE – BON*** **47.1** ***RIS – BON*** **51.2**
UCR steelhead	Methow / Okanogan Entiat Wentachee	***MCN – BON*** **47.9** (16.8 – 67.4)	***WEL – PRD*** **68.9** ***RRE – PRD*** **71.7** ***RIS – PRD*** **74.8**	***WEL – BON*** **33.0** ***RRE – BON*** **34.3** ***RIS – BON*** **35.8**
MCR steelhead[2,5]	 Yakima / Walla Walla Umatilla / John Day Deschutes BON pool	***(MCN, JDA, TDA) – BON*** **47.6** (17.2 – 67.1) **53.6** (23.2 – 72.1) **73.0** (61.5 – 77.6) **90.0** (80.6 – 93.0)		***(MCN, JDA, TDA, BON Pool) – BON*** **47.6** (17.2 – 67.1) **53.6** (23.2 – 72.1) **73.0** (61.5 – 77.6) **90.0** (80.6 – 93.0)
LCR Chinook[2]	BON pool	***BON Pool*** **95.1** (94.4 – 95.9)		***BON Pool*** **95.1** (94.4 – 95.9)
LCR steelhead[2,6]	BON pool	***BON Pool*** **90.6** (80.3 – 94.7)		***BON Pool*** **90.6** (80.3 – 94.7)
CR coho[2]	BON pool	***BON Pool*** **95.1** (94.4 – 95.9)		***BON Pool*** **95.1** (94.4 – 95.9)
CR chum[2]	BON pool	***BON Pool*** **95.1** (94.4 – 95.9)		***BON Pool*** **95.1** (94.4 – 95.9)

Sources: NMFS' 1) Supplemental Comprehensive Analysis Document (May 5, 2008a); and 2) Biological Opinion – Consultation on Remand for Operation of the Federal Columbia River Power System, 11 bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (May 5, 2008b).

[1] Key to Dams: BON = Bonneville Dam, TDA = The Dalles Dam, JDA = John Day Dam, MCN = McNary Dam, PRD = Priest Rapids Dam, WAN = Wanapum Dam, RIS = Rock Island Dam, RRE = Rocky Reach Dam, WEL = Wells Dam, IHR = Ice Harbor Dam, LMN = Lower Monumental Dam, LGS = Little Goose Dam, and LGR = Lower Granite Dam.

[2] The estimates for these ESUs only apply to those juveniles migrating from tributaries entering the reservoir upstream of Bonneville Dam, or in the case of MCR steelhead, the juvenile populations migrating from tributaries entering the Columbia River between Bonneville Dam and McNary Reservoir.

[3] Current reach survival estimates for the Mid-Columbia projects are based on the following:

- ***Wells (96.2% for spring Chinook and steelhead)*** - average of the 1998 (99.7%) Chinook study, and 1999 (94.3%) and 2000 (94.6%) steelhead studies as reported in NMFS 2002;
- ***Rocky Reach (92.1% for spring Chinook)*** – average of 2004-2005 studies (93.0% and 91.1%, respectively) as reported in Skalski et al (2006), and ***(95.8% for steelhead)*** - average of 2004-2006 studies (98.3%, 93.0%, and 96.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);
- ***Rock Island (93.4% for spring Chinook)*** – average of 2002-2004 studies (95.6%, 93.4%, and 91.4%, respectively) as reported in Anchor Env. and Chelan PUD (2004) and Skalski et al (2006), and ***(94.1% for steelhead)*** – average of 2004-2006 studies (96.6%, 91.6%, and 94.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);
- ***Wanapum and Priest Rapids (82.0% for spring Chinook)*** – estimated using data from PIT tag studies conducted by Chelan PUD in 1998, 2001, 2002, and 2003 as reported in NMFS 2004 – Table A-2 (90.5% per project); and ***(79.5% for steelhead)*** - estimated using data from PIT tag studies conducted by Chelan PUD in 1999 and 2000 as estimated in NMFS 2004 – Table A-2 (89.1% per project).

[4] Williams et al. 2005 provided estimated survival rates ranging for PIT tagged SR sockeye migrating from Lower Granite to McNary Dams in 2000 to 2003. Of these years, 2001, is most representative of the <65 kcfs flow condition – though still conservative because little spill was provided at the mainstem dams for passage in that year. Survival in this year was estimated at 23.9 percent. The remaining years are representative of the >65 kcfs flow condition. Survival rates ranged from 39.7% to 72.5% (average of 56.1%) in these years. An average per project survival was estimated for this reach (LGR to MCN survival ^ (1/4) = 86.5% per project) and then expanded to a Lower Granite to Bonneville Dam (7 project) reach survival estimate (LGR to BON (per project survival estimate ^ 7 = 36.4%).

[5] Within the Bonneville pool, Klickitat River and 15 Mile Creek populations of steelhead are part of the Mid Columbia River steelhead Distinct Population Segment.

[6] Within the Bonneville pool, Hood River and Wind River populations of steelhead are part of the Lower Columbia River steelhead Distinct Population Segment.

Table 3: "Prospective" (approximately 2014 and beyond) Juvenile Survival Estimates for ESA-listed Columbia River Basin Salmon and Steelhead Populations Migrating Inriver Past Mainstem Hydroelectric Projects.[1]

Species	Population	Juv. Survival - FCRPS *Reach* **Average** (Range) *Special Info.*	Juv. Survival[3] – Mid-Columbia *Reach* **Average (**Range) *Special Info.*	Juv. Survival – Total **Average (**Range) *Special Info.*
SR fall Chinook	Single Pop.	***LGR - BON*** **18.7 - 55.4** (12.4 – 71.7) *≈ 52% of the juveniles would be transported*		***LGR - BON*** **18.7 - 55.4** (12.4 – 71.7) *≈ 52% of the juveniles would be transported*
SR spr/sum Chinook	All Pops.	***LGR – BON*** **LGR >65 kcfs** **62.8** (58.0 – 67.8) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **51.9** (46.7 – 57.2) *≈ 95% of the juveniles would be transported*		***LGR – BON*** **LGR >65 kcfs** **62.8** (58.0 – 67.8) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **51.9** (46.7 – 57.2) *≈ 95% of the juveniles would be transported*
SR sockeye[4]	Single Pop.	***LGR - BON*** **LGR >65 kcfs** **42.8** (23.5 – 64.6) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **9.8** (Unknown) *≈ 88% of the juveniles would be transported*		***LGR - BON*** **LGR >65 kcfs** **42.8** (23.5 – 64.6) *≈ 64% of the juveniles would be transported* **LGR <65 kcfs** **9.8** (Unknown) *≈ 88% of the juveniles would be transported*
SR steelhead	All Pops.	***LGR – BON*** **LGR >65 kcfs** **45.3** (23.9 – 64.5) *≈ 74% of the juveniles would be transported* **LGR <65 kcfs** **9.1** (4.0 – 20.7) *≈ 89% of the juveniles would be transported*		***LGR – BON*** **LGR >65 kcfs** **45.3** (23.9 – 64.5) *≈ 74% of the juveniles would be transported* **LGR <65 kcfs** **9.1** (4.0 – 20.7) *≈ 89% of the juveniles would be transported*

Species	Population	Juv. Survival - FCRPS *Reach* **Average** (Range) *Special Info.*	Juv. Survival[3] – Mid-Columbia *Reach* **Average** (Range) *Special Info.*	Juv. Survival – Total **Average** (Range) *Special Info.*
UCR spring Chinook	Methow Entiat Wentachee	***MCN – BON*** **72.6** (65.4 – 79.6)	***WEL – PRD*** **72.3** ***RRE – PRD*** **75.1** ***RIS – PRD*** **80.8**	***WEL – BON*** **52.5** ***RRE – BON*** **54.5** ***RIS – BON*** **58.7**
UCR steelhead	Methow / Okanogan Entiat Wenatchee	***MCN – BON*** **52.8** (17.3 – 73.8)	***WEL – PRD*** **75.0** ***RRE – PRD*** **78.0** ***RIS – PRD*** **81.4**	***WEL – BON*** **39.6** ***RRE – BON*** **41.2** ***RIS – BON*** **43.0**
MCR steelhead[2,5]	Yakima / Walla Walla Umatilla / John Day Deschutes BON pool	***(MCN, JDA, TDA) – BON*** **52.4** (17.9 – 73.3) **57.9** (23.9 – 77.7) **76.8** (64.5 – 82.2) **90.3** (80.3 – 93.2)		***(MCN, JDA, TDA, BON Pool) – BON*** **52.4** (17.9 – 73.3) **57.9** (23.9 – 77.7) **76.8** (64.5 – 82.2) **90.3** (80.3 – 93.2)
LCR Chinook[2]	BON pool	***BON Pool*** **95.5** (94.6 – 96.2)		***BON Pool*** **95.5** (94.6 – 96.2)
LCR steelhead[2,6]	BON pool	***BON Pool*** **90.8** (79.9 – 94.8)		***BON Pool*** **90.8** (79.9 – 94.8)
CR coho[2]	BON pool	***BON Pool*** **95.5** (94.6 – 96.2)		***BON Pool*** **95.5** (94.6 – 96.2)
CR chum[2]	BON pool	***BON Pool*** **95.5** (94.6 – 96.2)		***BON Pool*** **95.5** (94.6 – 96.2)

Sources: NMFS' 1) Supplemental Comprehensive Analysis Document (May 5, 2008a); and 2) Biological Opinion – Consultation on Remand for Operation of the Federal Columbia River Power System, 11 bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (May 5, 2008b).

[1] Key to Dams: BON = Bonneville Dam, TDA = The Dalles Dam, JDA = John Day Dam, MCN = McNary Dam, PRD = Priest Rapids Dam, WAN = Wanapum Dam, RIS = Rock Island Dam, RRE = Rocky Reach Dam, WEL = Wells Dam, IHR = Ice Harbor Dam, LMN = Lower Monumental Dam, LGS = Little Goose Dam, and LGR = Lower Granite Dam.

[2] The estimates for these ESUs only apply to those juveniles migrating from tributaries entering the reservoir upstream of Bonneville Dam, or in the case of MCR steelhead, the juvenile populations migrating from tributaries entering the Columbia River between Bonneville Dam and McNary Reservoir.

[3] Prospective reach survival estimates for the Mid-Columbia projects are based on the following:

- ***Wells (96.2% for spring Chinook and steelhead)*** - average of the 1998 (99.7%) Chinook study, and 1999 (94.3%) and 2000 (94.6%) steelhead studies as reported in NMFS 2002;

- ***Rocky Reach (93.0% for spring Chinook)*** – assumes that the minimum survival requirement of the Rocky Reach Habitat Conservation Plan will be met (NMFS 2002), and ***(95.8% for steelhead)*** - average of 2004-2006 studies (98.3%, 93.0%, and 96.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);

- ***Rock Island (93.4% for spring Chinook)*** – average of 2002-2004 studies (95.6%, 93.4%, and 91.4%, respectively) as reported in Anchor Env. and Chelan PUD (2004) and Skalski et al (2006), and ***(94.1% for steelhead)*** – average of 2004-2006 studies (96.6%, 91.6%, and 94.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);

- ***Wanapum and Priest Rapids (86.5% for spring Chinook and steelhead)*** – assumes the minimum survival standard (93.0% per project) for these species will be achieved (NOAA 2004).

[4] Williams et al. 2005 provided estimated survival rates ranging for PIT tagged SR sockeye migrating from Lower Granite to McNary Dams in 2000 to 2003. Of these years, 2001, is most representative of the <65 kcfs flow condition – though still conservative because little spill was provided at the mainstem dams for passage in that year. Survival in this year was estimated at 23.9 percent. The remaining years are representative of the >65 kcfs flow condition. Survival rates ranged from 39.7% to 72.5% (average of 56.1%) in these years. An average per project survival was estimated for this reach (LGR to MCN survival ^ (1/4) = 86.5% per project) and then expanded to a Lower Granite to Bonneville Dam (7 project) reach survival estimate (LGR to BON (per project survival estimate ^ 7 = 36.4%). To estimate the expected increase in survival between the "current" and "prospective" conditions, these estimates were adjusted by the estimated survival improvement of SR steelhead in the >65 kcfs flow year condition (45.3% [Prospective] - 38.9% [Current] = 6.4%) resulting in an estimate of 42.8% (36.4% + 6.4%). This was also done for the <65 kcfs flow year condition (9.1% [Prospective] – 7.5% [Current] = 1.6%) resulting in an estimate of 9.8% (8.2% + 1.6%).

[5] Within the Bonneville pool, Klickitat River and 15 Mile Creek populations of steelhead are part of the Mid Columbia River steelhead Distinct Population Segment.

[6] Within the Bonneville pool, Hood River and Wind River populations of steelhead are part of the Lower Columbia River steelhead Distinct Population Segment.

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