APPENDICES

Appendix A

The Independent Scientific Group:

History and Relation To The Current Independent Scientific Advisory Board Of The Northwest Power Planning Council and National Marine Fisheries Service

History of the Scientific Review Group and the Independent Scientific Group

The Independent Scientific Group (ISG) was formed in February 1995 and evolved directly from its predecessor group, the Scientific Review Group (SRG). The SRG was formed in 1989 from a Memorandum of Understanding between the Bonneville Power Administration (BPA) and the Columbia Basin Fish and Wildlife Authority (CBFWA), the latter acting on behalf of the state, federal, and tribal fisheries managers. The Implementation Planning Process (IPP) established a set of guidelines for selection of the members and for procedures to be followed by the Policy Review Group (PRG) and SRG that were designed primarily to ensure independence and impartiality in the conduct of SRG assignments, to protect the SRG from outside pressures, and to provide mechanisms for separation of policy issues from technical issues. The SRG was devoted to critical scientific review of specific projects or programs conducted under BPA's IPP, as well as synthesis of broader scientific questions, such as identifying critical uncertainties in the Fish and Wildlife Program.

Members were appointed to the SRG (now ISG) in May 1989 by the Policy Review Group. The PRG consisted of managers as well as representatives of institutions concerned with the effects of the FWP on their constituents. Membership in the SRG/ISG included six scientists from both inside and outside the region from a variety of biological and statistical disciplines. Membership in the SRG (and ISG) was based on specific scientific expertise, regardless of institutional affiliation. Initially, three additional members (Participating Technical Advisors) who had technical expertise and were active participants in Columbia Basin fisheries management also participated in the SRG. In 1994, on the recommendation of the ISG members, the distinction was eliminated by the Policy Review Group and the Participating Technical Advisors were designated full members.

The Independent Scientific Group was formed in February 1995 from the SRG in response to measure 3.2B.1 in the Northwest Power Planning Council's 1994 Fish and Wildlife Program. The ISG's duties included conducting a biennial evaluation of the FWP on its scientific merits, identifying specific key uncertainties with respect to the program measures, and responding to questions submitted by the Council or through the implementation process. The latter included

providing objective scientific advice in prioritizing and evaluating actions funded by BPA under the FWP.

The ISG normally meets monthly, or more frequently, depending upon the work load. The ISG operates by consensus, as did the SRG. Our reports are adopted only after full input and agreement from each member . While the matters for action by the SRG and ISG were frequently selected and referred by the PRG, the SRG and ISG have independently identified questions of importance or areas that deserve more emphasis. The ISG may organize panels of scientists and convene meetings to facilitate review of scientific issues.

Relation to the Independent Scientific Advisory Board

The Independent Scientific Advisory Board (ISAB) was established on May 28, 1996 through a joint agreement between the Northwest Power Planning Council (NPPC) and the National Marine Fisheries Service (NMFS). The ISAB is composed of eleven senior scientists from the United States and Canada, from a variety of biological and statistical disciplines. Nominations to the ISAB were provided by constituents throughout the Columbia Basin and elsewhere. Nominations were reviewed by a Selection Panel that included criteria and oversight from the National Research Council. Seven members of the Independent Scientific Group and two members of the National Research Council's Committee on Protection and Management of Pacific Northwest Anadromous Salmonids are among the eleven members of the ISAB.

The duties and procedures of the ISAB follow logically from those of the SRG and ISG. The Independent Scientific Advisory Board will provide independent scientific advice and recommendations regarding scientific issues posed by the respective agencies on matters related to their fish and wildlife programs. The NPPC has specified a series of tasks in its Fish and Wildlife Program of December 1994 (section 3.2), while NMFS has statutory obligations under the Endangered Species Act and other federal laws requiring independent scientific review.

The ISAB will address scientific and technical issues relating to the NPPC fish and wildlife program and the NMFS recovery program for Snake River salmon and other anadromous fish stocks, including related marine areas. Its purpose is to foster a scientific approach to fish and wildlife recovery and the use of sound scientific methods in research related to the programs of the Northwest Power Planning Council and the National Marine Fisheries Service. It is understood that the interests of the National Marine Fisheries Service relate particularly to anadromous fish conservation and management, while those of the Council include all fish and wildlife populations affected by operation and development of the hydroelectric system

Appendix B

Fisheries Restoration Plans

1. Fraser River Restoration

The current program to restore Columbia River salmon can trace its roots back to 1948 and the program developed by fishery agencies to mitigate for impacts on salmon created by federal hydroelectric development in the basin (Laythe 1948). A decade earlier another major restoration program on an important salmon producing river in the northwest was also initiated. On August 4, 1937 the United States and Canada ratified a convention for the protection, preservation and extension of the sockeye salmon fishery of the Fraser River system. The convention which created the International Pacific Salmon Commission (IPSFC) was the culmination of 45 years of negotiation and meetings between the United States and Canada (Roos 1991).

Fishermen from the United States and Canada harvested sockeye salmon returning to the Fraser River so there was a need for an international convention to coordinate and rationalize the fishery and prevent over exploitation. In addition, the sockeye salmon runs to the Fraser River were rapidly depleted after 1913 by a dramatic change in their migratory habitat at Hell's Gate, a narrow gorge in the Fraser Canyon 130 miles from the sea. The velocity of flow through the narrow canyon at Hell's Gate was known to delay sockeye migration under natural conditions. However, in 1911 and 1912, during the construction of a railroad grade, large amounts of rock were dumped into the river creating very turbulent conditions which completely cut off salmon migration at certain flows. In 1913, fishermen took a record harvest of 32 million sockeye salmon bound for the Fraser River. Those fish that escaped the fishery massed below Hell's Gate unable to ascend the river to their natural spawning areas and most dies without spawning. The average annual run of sockeye salmon to the Fraser River between 1894 and 1916 was 11.4 million fish compared to an average run of 3.31 million fish from 1917 to 1949 (Roos 1991).[1]

The IPSFC's initial program had four key elements: 1) Correct the problem at Hell's gate. The blockage at Hell's gate was an obvious bottle neck that had to be corrected. 2) Protect the watershed. One of the early policy statements of the IPSFC put the Canadian Government on notice of its intent to protect salmon habitat in the watershed. 3) Protect the stocks. The IPSFC recognized that sockeye salmon in the Fraser River were separated into different socks, each with

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1916 was the last year of returns to the river from spawning prior to the Hell's Gate construction. 1949 was the last return to be unaffected by actions of the IPSFC.

specific spawning and rearing areas, run timing and environmental requirements. Management had to be based on stock conservation. 4) Hatcheries were given a low priority (Roos 1991).

In 1936, following a ten year research program, British Columbia closed all its sockeye salmon hatcheries (Foerster 1931, 1936, 1938; Pacific Fishermen 1936). The purpose of Foerster's study was to test the primary assumption which had justified the use of artificial propagation during its first 60 years on the west coast. Until Foerster's study it was assumed that artificial propagation was much more efficient than natural reproduction, however, the study found that artificial propagation did not have a statistically significant advantage over natural spawning. Although the fishing industry was interested in artificial propagation as an alternative to reduced harvest, the IPSFC placed it at a low priority and gave highest priority to natural production and the protection and restoration of habitat (Roos 1991).

Although hatcheries were given a low priority, the IPSFC did achieve some success with artificial spawning channels, however when it proposed a major construction program for additional spawning channels, the Canadian Government failed to give its approval so the program was never implemented. The IPSFC had to rely on better harvest management to boost escapement and increase production. The question of artificial propagation came up again in 1960, in response to proposals to build major hydroelectric and flood control dams in the Fraser River, many of them downstream from juvenile rearing areas in the basin. The IPSFC reviewed the prospects of mitigation through hatchery propagation of sockeye salmon and concluded that hatcheries were not a safe and proven method of maintaining even small localized stocks of Fraser River sockeye and pink salmon (Andrew and Green 1960).

The IPSFC's program was successful. From 1950 to 1978 the total annual run averaged 5.55 million fish compared to 3.31 million fish form 1918 to 1946 (after Hell's Gate but before IPSFC actions took effect). Recent run sizes have been 12 million fish in 1991, 13 million in 1985, 15 million in 1986, and 22 million in 1990 (Roos 1991; PSC 1991; PSC 1994). The total budget for the 48 year life of the IPSFC was 42.7 million dollars including about 4.5 million for construction. The IPSFC ceased to exist in December 1985. It was replaced by the Pacific Salmon Commission (Roos 1991).

References for Appendix B

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2. Restoration of east coast Striped bass populations

From a population high in 1970, the east coast striped bass (*Morone saxatilis*) population crashed through the 1970s and early 1980s until drastic management measures were taken in the mid-1980s. The population has since rebounded and measures have been relaxed (Dorazio et al., 1994). The striped bass is an estuarine fish native to the eastern coast of North America from Nova Scotia to north Florida and along the northern coast of the Gulf of Mexico. As adults, the species occupies coastal ocean waters in the northern part of its range and resides mostly in rivers south of Cape Hatteras, North Carolina. As juveniles (up to 2 years old), the species occupies shallow estuarine or lower river waters. Changing water temperature induces long-distance coastal migrations of adults between summer and winter and warm water restricts suitable habitats for adults in summer. Adults spawn in the freshwater tidal zones of estuaries, particularly the Hudson River in New York and rivers tributary to the estuarine complex of Chesapeake Bay in Maryland and Virginia. Historical runs to the Delaware River estuary in Pennsylvania and New Jersey were extirpated by pollution in the lower river at Philadelphia and Trenton.

Major threats to the striped bass in the period of decline were pollution of estuarine spawning grounds, entrainment of eggs and larvae into cooling systems of power plants on estuaries, habitat degradation of estuaries (that reduced macrophyte-populated nursery areas and deoxygenated cool water adult refuges), and overfishing. With recognition that habitat restoration was necessary but a long-term effort, the state of Maryland imposed a total fishing ban for striped bass in 1985. This ban was expanded through the Atlantic States Marine Fisheries Commission and the federal Atlantic Striped Bass Conservation Act to include all coastal waters. Schemes were developed for compensating commercial fishers put out of business by the administrative acts. A federally-funded research program developed credible monitoring programs by states and relevant research studies. A major Chesapeake Bay habitat restoration program was begun, and pollution-control efforts were speeded up on Delaware Bay.

The outstanding parallel with the current Northwest salmon decline is the demonstrated importance of reducing fishing take to allow the population to rebuild while still facing other threats. This temporary measure, though unpopular initially (and causing many of the same social dislocations), provided a decrease in mortality so that striped bass stocks weakened by habitat degradation and other sources of mortality would not continue to decline. Gradual habitat restoration and other measures to enhance survival are presumably acting to facilitate population rebound and to compensate for gradually renewed fishing. A major lesson has been that sustained fishing pressure, especially on reproductive and immediately prereproductive ages (as in the ocean and coastal salmon fisheries) can be devastating when other impediments to survival are high.

Appendix C

Hierarchical organization in genetic structure of Washington state chinook salmon populations.

Marshall et. al. (1995) examined the genetic structure of chinook salmon populations from Washington state waters in the Columbia Basin and identified two major ancestral lineages (MAL) and ten genetic diversity units (GDU) (Table 1). Their hierarchical classification was similar to that shown in Figure 4.2. A GDU is defined as:

> *A group of genetically similar stocks that is genetically distinct from other such groups. The stocks typically exhibit similar life histories and occupy ecologically, geographically, and geologically similar habitats. A GDU may consist of a single stock* (Busack and Shaklee, 1995) p A-3.

A GDU is similar to the evolutionarily significant unit (ESU) of Waples {1991}. A MAL is:

> *A group of one or more GDUs whose shared genetic characteristics suggest a distant common ancestry, and substantial reproductive isolation from other MALs. Some of these groups are likely the result of colonization and diversification preceding the last period of glaciation* (Busack and Shaklee, 1995) p A-5).

Table 1. MALs and GDUs for chinook salmon in Washington waters of the Columbia Basin.

Major Ancestral Units (MAL)	***Genetic Diversity Units (GDU)***
Upper Columbia and Snake River Spring Chinook	Snake River Spring
	Upper Columbia River Spring
	Yakima Spring
Upper Columbia Summer and Fall	Upper Columbia Summer
Snake Fall	Upper Columbia Fall
Mid- and Lower Columbia Chinook	Mid-Columbia and Snake Fall
	Mid and Lower Columbia Spring
	Mid-Columbia "Tule" Fall
	Lower Columbia "Bright" Fall
	Lower Columbia "Tule" Fall

Matthews and Waples (1991) combined the spring and summer chinook of the Snake River into a single ESU which is probably similar to the Snake River Spring GDU in Marshall et al. (1995). Within the Snake River spring/summer chinook ESU, NMFS {1995} identified 12 stocks and 37 breeding units based on genetic and geographic information (Table 2).

Table 2. Snake River spring/summer chinook salmon classification by subbasin and subpopulation. (Source: NMFS 1995). (sp = spring chinook population; su = summer chinook population)

RIVER SYSTEM/STOCK	BREEDING UNIT/SUBPOPULATION
TUCANNON RIVER	Watershed population (sp)
GRANDE RONDE RIVER	Minam River (sp) Lostine and Upper Wallowa River tributaries (sp) Wenaha River (sp) Catherine Creek (sp) Upper Grande Ronde (sp)
IMNAHA RIVER	Mainstem (sp/su) Big Sheep and Lick Creek
SNAKE RIVER MAINSTEM	Asotin Creek (sp) Mainstem, Sheep Granite (sp)
LOWER SALMON RIVER	Mainstem tributaries, mouth to and including Horse Creek (sp)
LITTLE SALMON RIVER	Watershed expect Rapid River (sp) Rapid River (su)
SOUTH FORK SALMON RIVER	Mainstem, Blackmare to Stolle (su) Mainstem, mouth to Poverty Flats (su) Secesh River (su) Johnson Creek (su) East Fork South Fork (su)
MIDDLE FORK SALMON RIVER	Mainstem, mouth to Indian Creek (su) Mainstem, Indian to Bear Valley Creek (sp) Marsh Creek and tributaries (sp) Bear Valley and Elk Creek (sp) Sulphur Creek Upper Loon Creek and tributaries (sp)

	Lower Loon Creek (below TM 23) (su) Camas Creek (sp) Lower Big Creek (below TM 23) (su) Upper Big Creek and tributaries (sp)
LEMHI RIVER	Watershed population (sp)
PAHSIMEROI RIVER	Watershed population (su)
UPPER SALMON RIVER	North Fork Salmon River (sp) East Fork, mouth to Herd Creek (su) Herd Creek and Upper East Fork (sp) Yankee Fork and tributaries (sp) Valley Creek above Stanley Creek (sp) Lower Valley Creek (su) Mainstem Salmon below Redfish Lake Creek (su) Mainstem Salmon above Redfish Lake Creek (su)
CLEARWATER RIVER	Not listed under ESA

Appendix D

Fluid Dynamics Of River Flows In Relation To Salmon Downstream Migration

INTRODUCTION

Implicit in the relationships among flow, velocity, and survival for salmonids that have so thoroughly gripped the Columbia River basin is an implied relationship between flow and velocity (Cada et al., 1994, see Chapter 6). That is, there is an assumption that as the volume of water passing through a river-reservoir system per unit of time increases so does water velocity increase at each point along the length of the system. The increased velocity is assumed to be the biologically relevant feature of river flow increase for downstream migrating juvenile salmonids. Increased flushing of fish by higher water velocities is believed to be a major factor determining long-term fish survival. Although a general flow-velocity relationship is valid, presumption of a direct relationship between river flow and velocity at the detail seen by a fish is certainly a simplistic view that is not supported by knowledge in the engineering field of fluid dynamics of open channel flow. There is much more to it than that. There is a lot of complexity in the fluid dynamics that a fish must contend with, and we should recognize the opportunities open for them to become cleverly adapted to take advantage of this complexity.

Fluid dynamics of water flowing in rivers (open channels) is a field of scientific study that matured 15 to 20 years ago (Liggett, 1994) but which has not been brought to bear adequately on questions of salmon migrations. Study of the physical biology of flow has generally been concerned with static life in moving fluids, such as the shapes of organisms in flowing waters, or animal design for propulsion, lift, and minimizing drag (Vogel, 1981). Although methods of computer simulations continue to be developed, the basic mathematical expressions of features of water flow, elevation, and velocity in rivers can be found in textbooks such as Chaudhry (1993), Abbott (1979), Abbott and Basco (1989), Chow (1964), Fox (1989), Cunge et al. (1980), and Mahmood and Yevjevich (1975), and field manuals (Benson and Dalrymple, 1967). There are disciplinary barriers between salmon biologists and fluid-flow engineers that are likely the result of different languages. Fluid dynamics engineering is highly mathematical leading to calculations and computer simulations, largely for the design of the physical structures that determine the fluid dynamics of a water body. Biology is conceptual and empirical leading to narrative and visual explanations of the effects on fish and other aquatic life of man-made or natural structures and the fluid dynamics created by them. We often assume that our organism is well designed and try to determine just why the design is a good one. There are urgent reasons to bridge this gap. Vogel (1981) and Statzner et al. (1988) have tried to do so; Vogel in a general sense for all biology and

Statzner with a review oriented primarily toward stream invertebrate ecology and hydraulics that affect stationary points in a stream.

There are several salient features of fluid dynamics of open channel flow (that is, flow in channels with solid sides and bottoms and a water surface exposed to air). Water rarely moves as uniform flow with no change with downstream distance in either the magnitude or direction of the velocity along a streamline. Flow is most uniform when the depth and width are constant along the direction of flow, a situation unlikely to occur in natural rivers or reservoirs. Similarly, natural streams rarely have steady flow, in which the velocity at a point does not change with time. The normal pattern for a stream, viewed at the scale of a 50 mm to 150 mm fish, is to have velocities that change in often complex ways, whether viewed while moving along a longitudinal stretch or from one stationary point over time. These velocity changes can be in other directions as well as longitudinal (turbulence) and can be longitudinal pulses (traveling surges and flood waves).

WAVES

Increases in flow generally cause an increase in the water surface elevation. This increase in elevation travels away from the point of initiation as a wave, just as a stone tossed in the water creates a ring of waves. These waves move faster than the water particles that make them up. Waves in moving streams can be propagated both upstream and downstream, but the upstream wave can be obliterated by the opposing stream flow. Thus, waves in streams caused by changes in flow (elevation) generally move downstream at a rate that is faster than the actual water mass by a factor of 1.3 (a general factor given first by (Corbett, 1943)) to 4 (experimental data from the Snake River below Hells Canyon Dam in {Koski 1974}. Waves tend to be most prominent in the main channel and less obvious in the shoreline areas, due to damping by shoreline topography and vegetation. Waves interact: faster waves overtake and pass through slower ones; waves reinforce or cancel each other. The height of a stream's waves depends on the depth of the water, just as do waves on a beach. Bottom profiles can determine whether waves are standing waves, breaking waves, or ones that continue to propagate downstream. Small waves moving downstream (such as might result from continually changing flows or upstream disturbances) can coalesce as the bottom profile changes (particularly when depth decreases, as in a riffle or shoal) and form large waves or surges (bores). All of these effects have been described mathematically and the various features (depth, velocity, wave shape, etc.) can be related numerically. More attention has been given to waves on ocean beaches than to those in rivers, for reasons of the high economic value of beach erosion processes (Stoker, 1957; U.S. Army Corps of Engineers, 1984).

Waves moving downstream do interesting things to water particle velocities seen at the size scale of a small fish. Most of this information comes from beach erosion studies, for shore protection measures and coastal protection designs are dependent on the ability to predict wave

forms and fluid motion beneath waves, and on the reliability of such predictions. Simple water waves are oscillatory and water particle motion is described by orbits (back and forth movements) that are closed, or nearly so, for the passage of each wave (Figure A.1(a)). However, waves are rarely truly oscillatory and the fluid is generally moved a small amount in the direction of wave advance by each successive wave. Thus, there is mass transport by the wave (for example, submerged jellyfishes just below the surface are moved in the direction of the waves in coastal waters; Figure A.1(b)). The extreme deviation from a pure, oscillatory wave is a solitary wave (also called a wave of translation or a stage wave), which is not oscillatory and has no real trough behind its single crest. It forms by a pulse release of water (naturally, as in a flood or artificially, as from a dam). The crest height is essentially maintained behind the wave front (Figure A.2(a); although here, too, the regularity is broken by a series of small dispersive waves that trail it). In a solitary wave, a significant increase in velocity of water particles occurs at the wave front and a significant amount of water is transported forward. As a solitary wave moves into shallower water (as a downstream-moving wave would in passing from a pool to a riffle area of a stream) the water particle velocity of the wave crest increases further and the wave may break (Figure A.2(b)). Multiple waves tend to coalesce in channel constrictions and become prominent bores with increased velocity . COE (1984, p. 2-55) gives the relevant equations.

It seems likely that a stream would have many "solitary"-type waves, especially in spring when water levels rise with runoff. Pulses of water from tributaries could induce such waves. During the rising limb of a spring freshet, the flow probably increases as a series of "solitary" waves, with velocities quite different from that of the particles of water. Little fluid dynamics study seems to have been directed at this application, even though the theory and general applications are readily available.

With these wave dynamics going on in a stream, it would be surprising if a migratory fish species did not adapt to make use of the localized enhanced velocities and particle movements at wave fronts. Any fish that could position itself in the wave zone of raised velocity and rapid downstream water particle transport would obtain a significant assist. How much assist a fish would get would depend on the initial size of the solitary wave or how much shallower the stream bottom becomes under the wave. The most dramatic assists would occur in riffle areas where waves coalesce and may be on the verge of breaking. The flatter waves in pools may be of little value for migration assists.

Impoundments in a stream and river system could, in principle, affect the suggested wave phenomena (perhaps positively and negatively) and thus influence the migratory capabilities of salmon smolts. Some dams likely release water in pulses, generating a wave effect similar to that in a natural system. On the other hand, the physical barrier of a dam would be an effective terminator of a downstream-propagating wave coming from upstream. Well upstream of the

actual dam, a widening and deepening reservoir would, based on wave propagation theory, serve to diminish the wave height and thus the downstream transport of particles in the wave front. Fish riding waves might be left stranded, so to speak, in a small zone of the upper reservoir where they could be vulnerable to predation or other damaging effects.

TURBULENCE AND VORTICES

Turbulence is another feature of natural river hydraulics that might be used by migrating juvenile salmonids, and which is disrupted by impoundments. Two examples come to mind: turbulent bursts and vortices, although there are probably more. A turbulent burst is the high-speed, turbulent ejection of fluid and suspended solids away from the sediment bed, often after encountering a streambed obstruction (Leeder, 1983). At distances 4-5 times the water depth, there are accelerated flow events acting toward the bed and concurrent rapid fluid movements away from the bed (Figure A.3). The rising burst of flow propagates downstream in the water column and is seen at the water's surface as a "boil." A view of the surface of a swiftly moving river such as the unimpounded Columbia at Hanford, Washington, is of a patchwork of these boils. Water velocities in the leading edge of boils exceeds that of the general surrounding water. Sedimentologists are familiar with these features, for unsteady bedload transport is driven by "bursting-type" cycles in the sea (Thorne and Kuehl, 1989) and Carling (1992) has suggested that riverine sediment transport is also related to the inherent turbulent structure of rivers. These velocity bursts are a function of flow rate and water depth; reduction of flow velocity and increase in depth (as in impoundments) would terminate such turbulence structures. As with solitary waves, it seems reasonable that salmonids emigrating in rivers would have evolved to make use of the zones of accelerated velocity in these turbulent bursts to assist them in downstream movement.

Vortices are another feature of turbulent flow, occurring in the horizontal plane rather than the vertical (as in bursts). Rows of vortices are shed behind solid bodies and trail behind in a wake (Figure A.4(a)). If the body is in midstream, there is a wake of roughly parallel vortices, forming first on one side and then the other. Each vortex rotates in the opposite direction of the preceding and succeeding ones. If the body is a projection from shore, the vortices trail in single file in what is often referred to as a shoreline "rip." In either case, water velocities on the outside of the wake of vortices is more rapid than the general (average) water flow. When two structures are placed in proximity perpendicular to the flow, vortices from each can combine to yield a zone of accelerated velocity between the structures (Figure A.4(b)).

BIOLOGICAL EVIDENCE

What evidence is there that fish do, in fact, make use of such velocity assists from downstream-moving solitary waves or features of turbulence? The information is mostly circumstantial and in need of biological investigation. The following train of logic for physical phenomena and biological evidence seems persuasive enough to stimulate rigorous experimentation and field data collection, leading to modification of rivers to move toward a more normative condition that facilitates fish migration.

1. Solitary waves exist in streams, based on the accumulated knowledge of the field of open channel flow hydraulics and empirical evidence from field studies of the Snake River {Koski 1974}; turbulent bursts also occur in streams (Carling, 1992); vortices are a common phenomenon in turbulent rivers;
2. The waves move much faster than the average water particle travel time for the same reach, again, based on hydraulic theory and field evidence; turbulent bursts have velocities faster than the surrounding flow; and vortices from structures in rivers can create channels of higher velocity;
3. A zone of enhanced particle velocity occurs at the crest of a solitary wave and between the wave crest and the water elevation in front of the wave (i.e., near the water surface); turbulent bursts have zones of accelerated velocity at the leading edges of the bursts; vortices also induce zones of higher velocity;
4. Downstream-migrating yearling salmon and steelhead smolts generally migrate near the surface of a stream in the main flow (where solitary waves, turbulent bursts, and vortices from near-shore obstructions also have their main effect);
5. Experiments with drifting fish at thermal discharges at Hanford in the 1960s showed smolts traveling in the leading edges of boils (Becker and Coutant, 1970; Becker et al., 1971);
6. Ultrasonic-tagged adult chinook salmon and steelhead swam in the centers of shoreline rips (Coutant, 1970), possibly using the upstream assist of vortices and suggesting that downstream-migrating juveniles would also be adapted to using such assists in the downstream direction;
7. Averaged over long distances (several kilometers) in the Snake River with considerable length of riverine reach, steelhead smolts traveled faster than the average water particle (Berggren and Filardo, 1993), suggesting either some assist or intense swimming that is difficult to justify based on the likely energy expenditure (Brett, 1967; Trump and Leggett, 1980);
8. Averaged over similarly long distances, steelhead in the mostly impounded mid-Columbia

River moved slower than water particles (Berggren and Filardo, 1993), suggesting that they did not have the benefit of velocity assists from turbulent flow (consistent with there being fewer wave and turbulence effects in deep water of a reservoir);

9. In both steelhead cases, there was more difference between rates of fish and water particle movement at high flows than at low ones (the likelihood of waves being generated and propagated seems higher at high flows, when there are many changes in flow and water elevation over short time periods);
10. Yearling chinook salmon in the Snake River, although not migrating as fast over the long distance as steelhead, nonetheless showed an average migration rate close to that of water particles (Berggren and Filardo, 1993), which implies movement faster than water particles during the limited hours of the diel cycle when they actually move;
11. Spring chinook salmon migrating past Prosser Dam on the Yakima River did so in pulses that corresponded to rising water levels (Mundy, In press), which may have been in the form of waves or surges;
12. Spring chinook smolts followed in their downstream migration with radiotelemetry moved fastest (and faster than average water particles) in the riffle areas of the Willamette River (Schreck et al., 1995) where wave theory would suggest accelerated velocities at wave fronts and vortices from obstructions would create high-velocity channels;
13. Rainbow trout observed in streams by Northcote (1962) in infrared light headed downstream, near the water surface, and swam at a speed greater than the surrounding water (he did not look for waves or turbulence);
14. All downstream migrants probably do not use these mechanisms, because underyearling chinook salmon migrate slowly and tend to orient head upstream until high velocities make them drift (Nelson et al., 1994);
15. Most smolts migrate downstream at night or at low-light periods of dusk and dawn, when their rapid swimming activity designed to put them in the water surface, perhaps at the leading edge of a wave, would make them more vulnerable to sight-feeding predators in daylight;
16. The historical Snake River between Lewiston and Pasco appears to have been the type of channel that could have propagated solitary waves quite effectively, whereas the present string of reservoirs would be unlikely to do so.

RIVER CONTROL OPTIONS

It may reasonably be asked whether the exact mechanism of fish migration matters if the rate of fish movement through the river system is increased by just increasing river flows. Perhaps not, if water were always abundant and reservoir drawdown inconsequential. The increased water

volumes from upstream or decreased depth of mainstem reservoirs could, without our paying any attention, convert slow-moving, non-turbulent, waveless reservoirs into reaches with solitary stage waves, turbulent bursts, and vortices to which salmon may have been adapted. A new perspective of the importance of fluid dynamics to salmon migration may, however, allow experimentation and possible selection of river control options that would provide appropriate waves, turbulence, or vortices without drawing reservoirs down as far and with smaller amounts of water. Reservoir pool elevations might then be selected that would accommodate both fish migration (fish ladders and juvenile bypass systems would not be stranded) and other uses such as navigation and recreation. More upstream water could then be used for other purposes such as irrigation and resident fishes in upstream reservoirs.

Creation of waves.

Diel hydropower peaking or spill might be scheduled at especially important times during juvenile salmon migrations to cause elevation changes in the downstream reservoir that would create waves useful in assisting salmon to migrate. Peaking or pulsed operation during spring runoff might be found preferable for fish migration to strict run-of-the-river modes in which flows are maintained at constant high levels. A distinct hydropower peaking pattern is maintained at Priest Rapids Dam on the Columbia River, which discharges to the Hanford reach that is known for its high production of fall chinook salmon. Spills at selected dam gates might be scheduled so that they provide an advantage to smolt migration through their generation of solitary waves in downstream reaches as well as through assisting fish in dam passage.

Control structures.

Control structures placed in reservoir channels might be used to induce turbulence and changes in water velocity that could aid fish movement. In essence, an understanding of the details of how salmon use increased velocities at a fine scale may increase our efficiency in providing conditions conducive to more natural migration while still providing for other water uses. For example, a pair of simple concrete cylinders placed at the edges of the main channel in a reservoir might induce vortices sufficient to accelerate fish movements in the channel (Figure A.4(b)). If such cylinders were placed at intervals along the reservoir, a channel velocity conducive to fish migration might be maintained well into the reach of the reservoir where most turbulent flow and noticeable current normally disappear. Flow augmentation just enough to ensure functioning of this enhanced vortex velocity pattern in the channel might be provided rather than flows large enough to raise velocities across the whole reservoir cross section.

A control structure that has found application in redirecting water velocities to aid sediment movement is the submerged vane, “Iowa Vane” (Odegaard and Wang, 1991). This

structure may also be capable of creating or redirecting velocity patterns to aid juvenile salmon migration. The vanes are small, flow-training structures (foils), installed near the riverbed, and designed to modify the near-bed flow pattern and redistribute flow across the channel cross section (Figure 6.15). They are installed at an angle of 15-25° with the flow and their initial height is 0.2-0.4 times the local water depth at design stage. The vanes generate a secondary circulation of flow not unlike other midstream obstacles, but with additional avenues of control. A single vane generates a vertical vortex of flow that would push surface water to the center of a channel (where fish migrate). Vanes in groups generate larger, combined vortices (Figure 6.15(b)). When aligned on opposite sides of a channel, sets of vanes can constrict the flow to a more defined channel (Odeggard and Wang, 1991, Figure 6.15(c)). Although submerged vanes have been applied to sediment control, there has been no experimentation with their use as devices to assist fish migration.

SUMMARY

This short review of fluid dynamics is but an indication of the rich opportunities for understanding salmon migration behavior that could come from a rigorous interaction between biologists and hydraulic engineers. None of the examples given here are yet recommendations for implementation. In the context of the review of science behind the Columbia River Basin Fish and Wildlife Program, it should be recognized that there is a body of science dealing with fluid flow in channels that seems to have important but relatively untapped applications to the problems of fish migration. An interdisciplinary program of theoretical and experimental studies should test these ideas and search for others. The results could have significant impact on managing flows and the hydropower system in the Columbia River basin for benefit of both fish and other water users.

Appendix E

BYPASS, Parts 2 and 3

Mortality Of Smolts At Dams And Development Of Bypass Systems. Part 2: Bypass Measures Called For By Federal Energy Regulatory Commission, The NPPC Fish And Wildlife Program And NMFS Recovery Plan

INTRODUCTION

Combinations of mechanical bypass and spill are required to meet the goals for fish passage (90% survival over 80% of the spring and summer emigration at specified projects for the NPPC, and 80% fish passage during specified spring and summer periods for NMFS/NOAA) at each of the Snake River and Columbia River projects, with the exception of Wells Dam. In the case of those projects with mechanical bypass systems in place, the fish guidance efficiency, FGE, is not high enough to meet the 90% FGE standard set by the council in 1986 and in the 1994 FWP, nor is it likely that this standard can be achieved with turbine intake screens, as discussed in Part I. Thus, the goals for fish passage require spill to make up the difference. As will be explained below, the amount of spill required depends upon the FGE of screens that are present and upon spill effectiveness, i.e. the relationship between percentage of flow that is spilled and the percentage of fish that are passed.

A summary of the current (1995) bypass programs in place at the Columbia River and Snake River projects is provided in Table 3. Also shown are the goals established for fish passage compared with fish passage actually achieved in 1995 {NMFS/NOAA, 1995}; (Center, 1995).

SPILL REQUIRED FOR BYPASS

FERC Requirements for Spill

Background

Because spill is generally accepted to be a safe route for passage of juvenile fish, as explained in detail in Part I where survival of smolts in spill was shown to be 98% to 100%, spill has been included as a measure for improvement of survival of smolts beginning with the mid-Columbia Settlement Agreement of 1979 in which there was a provision for a specified amount of spill (10%) at each of the mid-Columbia projects.

Beginning in 1985, with the Stipulation that extended the mid-Columbia agreement in the FERC proceeding, spill has been identified at some projects as an interim measure to be used to

reach a specified percentage of fish passage, with the understanding that as bypass facilities came on line, the successful bypass figure would be included within the percentage figure. The 1985 Stipulation provided for 50% fish passage during an approximate 30 day period at Wells Dam. At Wanapum Dam, a volume of spill was specified that was targeted at achieving 50% fish passage during the 30 day period. At Rocky Reach Dam the target was set at 30% fish passage in spill, because of low spill effectiveness shown by the hydroacoustic studies.

Current FERC Spill Programs

Current (1995) requirements for spill by FERC are shown in Table 3. In a Stipulation for 1994 and 1995, spill levels at Rocky Reach Dam were increased to 15% for 30 days during the spring emigration, (with an option to increase the number of days by up to 6 days if necessary to encompass 90% of the Okanogan River sockeye), and 10% for 34 days between June 15 and August 15.

In 1994, in response to a petition from the fishery parties, FERC required Grant County public utility district, P.U.D., to provide additional spill for juvenile salmonids at Wanapum and Priest Rapids dams, as an interim protection measure. The FERC ordered provision of a spill volume sufficient to ensure passage of 70% of the juvenile salmonids during 80% of the spring emigration and 50% passage during 80% of the summer emigration. (FERC Docket No. E-9569-003, Grant County Phase. Order of May 24, 1994). More on this is discussed under FERC requirements for mechanical bypass, below, and in Part III.

Rock Island Dam has not been included in the FERC mid-Columbia Proceeding after 1984 because issues were undergoing hearing with FERC, which in 1987 culminated in a long-term Settlement Agreement on issues relating to Rock Island Dam, that was adopted by FERC. It included no provision for interim spill, although it contained a clause providing for substitution of spill for bypass development. However, in 1985 FERC ordered spill as an interim measure at a level of 10% spill of the volume of water passing through powerhouse number 2 and 50% of the volume that would have gone through powerhouse number 1 in the absence of spill.

NPPC FISH AND WILDLIFE PROGRAM REQUIREMENTS FOR SPILL

Background

The NPPC Fish and Wildlife Program of 1984 called for a specific percentage of spill (20%) at the mid-Columbia projects. Although no volume of spill was specified for the COE projects on the Snake River or lower Columbia at that time, amendments to the 1984 Fish and Wildlife Program called upon the COE to develop coordinated interim juvenile fish passage plans,

including spilling water over the dams, while developing permanent solutions to passage problems at John Day, The Dalles, Bonneville, Lower Monumental and Ice Harbor dams (NWPPC (1984).

Current NPPC Spill Programs

The NPPC Fish and Wildlife program of 1987 spelled out objectives in terms of total percentage of the fish to be passed, rather than a specified level of spill, Table 3. The 1987 FWP required that levels of spill, along with such other bypass facilities as might be available, should be sufficient to guarantee 90% fish survival for the middle 80% of the spring and summer migrations (Northwest Power Planning Council, 1987). That standard remains in effect in the council's 1994 program. In addition, the 1994 FWP calls for 80% fish passage efficiency at each Snake River project from April 15 to July 31 each year and at each Columbia River project (presumably lower Columbia) from May 1 to August 31. The 1994 FWP refers to a 10-year "Spill Agreement", reached in 1988 by The Mainstem Executive Committee (made up of representatives of BPA, the fishery agencies and tribes, and utility representatives), which was the response to the council's call for coordinated interim fish passage plans in the 1984 FWP. The COE agreed to adhere to the provisions of the agreement as these were described in the NPPC Amendments to the FWP for 1989, with some conditions. Levels of spill were specified for Lower Monumental, Ice Harbor, and The Dalles dams during spring and summer emigration periods, and John Day dam during the summer. These are now superseded by the more stringent requirements of the Proposed Recovery Plan described below (National Marine Fisheries Service, 1995).

Box 21. Spill amounts specified in the Spill Agreement of 1989.

The agreement was somewhat complex as, among other things, it attempted to take load factoring into account in determining an appropriate percentage of flow to be spilled. (Source: Fish Passage Managers, 1990)

	Spring Spill		Summer	
Project	Instantaneous %	Daily Average %	Instantaneous %	Daily Average %
Lower Monumental	70%	35%	70%	35%
Ice Harbor	25%	12.4%	25%	12.5%
The Dalles	--	10%	--	5%
John Day	--	-	20%	8.3%

NMFS/NOAA Recovery Plan Requirements for Spill

Background

Now, and for the foreseeable future, the governing factor in implementation of measures for smolt survival in the Snake River and lower Columbia River, is the 1995 NMFS/NOAA Proposed Recovery Plan for Snake River Salmon, being implemented as a result of listing of certain Snake River stocks of salmon as threatened or endangered under the Endangered Species Act {NMFS/NOAA 1995}. Implementation of the provisions of the Plan is accomplished primarily through the Technical Management Team composed of federal managers from NMFS, the U.S. Fish and Wildlife Service, the Bureau of Reclamation, BPA, and the COE.

Box 22. NMFS/NOAA has made a commitment to the Council to coordinate planning and implementation efforts, (Stelle, 1994). (Statement on actions necessary for the recovery of Snake River salmon presented to the NPPC by William Stelle, Jr., Northwest Regional Director, on November, 1994. - Cited in Recovery Plan p. I-12.)

The Proposed Recovery Plan specifies a general strategy whose first two measures focus on: 1) Improvements in downstream survival through increased flows and controlled spill in the Columbia and Snake Rivers; 2) Modifications to dams and their operations to bring about improvements in juvenile downstream passage survival and upstream adult survival. (National Marine Fisheries Service, 1995), p. I-8)

Current NMFS/NOAA Spill Programs

The Recovery Plan calls for 80% fish passage efficiency at each of the dams on the Snake River and lower Columbia, during specified time periods designed to cover the spring and summer smolt migrations (National Marine Fisheries Service, 1995), p. V-2-30). These are shown in Table 3. None of the Snake River or lower Columbia River projects has in place a mechanical bypass system that will meet the NMFS/NOAA standard. To attempt to achieve that passage efficiency in 1995, spill was required at the four lower Snake River dams from April 10 through June 20, and at the lower Columbia River dams from April 20 through June 30 in sufficient amounts to make up the difference between what could be accomplished with the FGE of the intake screens or sluiceways at the given project and the 80% goal, taking into account spill effectiveness at the project as well. (National Marine Fisheries Service, 1995), p. V-2-31.) The required spill amounts are larger than those in the 10 year spill agreement.

Box 23. The Recovery Plan provided an exception during periods of low flow, during which there was to be less spill in order to divert more fish into bypass systems where they could be transported to below Bonneville Dam for release. Low flow was defined for Lower Granite Dam as less than 100 kcfs, and for Little Goose, and Lower Monumental dams as less than 85 kcfs. In 1995, flow at Lower Granite was beneath the specified 100 kcfs before May 7 and after June 22, 1995. At Little Goose and Lower Monumental, flow was below the 85 kcfs before May 3. McNary Dam and the three lower Snake River projects, Lower Granite, Little Goose and Lower Monumental, were designated as "collector dams" where the focus was to be on transportation of smolts by barge as long as river flows remained below the specified limits

The Recovery Plan set an upper limit on spill to be determined by dissolved gas concentrations. Spill was to be reduced at a project whenever a 12-hour average total dissolved gas concentration exceeded 115%.

REQUIREMENTS FOR INSTALLATION OF MECHANICAL BYPASS SYSTEMS.

FERC Requirements for Mechanical Bypass Systems

Background

In the mid-Columbia Settlement Agreement of 1979 and subsequent Stipulations, the parties agreed to work together to improve production of salmonids. Methods agreed upon were identified as 1) provision of spill, 2) investigate diversion of smolts from intakes, and 3) other, such as collection and transportation of smolts, (Offer of Settlement. Public Utility District Number 2 of Grant County, Washington. 10 FERC 61,257 (1980) Adopted by FERC March 23, 1980).

Accordingly, as a preliminary to design and testing of intake diversions, studies to determine the vertical distribution of juvenile salmonids as they approached the powerhouses began in 1980 at Priest Rapids Dam, and soon thereafter at the other mid-Columbia projects. These found that juvenile fish were concentrated at the upper portion of the intakes, as had been found in the NMFS studies at the COE projects, suggesting that similar screens could be effective, Biosonics, (Biosonics, 1981; Biosonics, 1981; Biosonics, 1982; Biosonics, 1982; Biosonics, 1983; Olson, 1983; Hays, 1984; Olson, 1984). Engineering and model studies of turbine intake diversion devices began soon after, followed by prototype design and testing, as discussed below and summarized in Table 3.

Table 3 provides information on the specific FERC requirement for each mid-Columbia project. One situation, not easily summarized in such tabular form is the one that developed with Grant County P.U.D.. In 1992 Grant County P.U.D. proposed to install a full bypass and

collection system at Wanapum Dam and to provide transportation of the collected fish for release below Priest Rapids Dam, thereby avoiding the need for intake screens and an associated bypass system at Priest Rapids Dam. The parties to the mid-Columbia proceeding were unable to agree on this proposal and Grant P.U.D. requested a hearing before the FERC Administrative Law Judge, who ruled against the Grant P.U.D. proposal and ordered installation of turbine intake screens, (State of Washington Department of Fisheries v Public Utility District No. 2 of Grant County. FERC Proceeding. Docket No. E-9569-003 (Grant County Phase), re Project No. 2134-024. Ruling of March 23, 1992, Hon. Stephen L. Grossman Presiding.) This ruling does not become final until it is formally adopted by FERC.

Goals for Passage

The long-term Settlement Agreement for Wells Dam set a fish passage goal for the bypass of 80% for spring migrants and 70% for the summer. An interim spill standard in place by FERC applies to Wanapum and Priest Rapids dams, pending installation of mechanical bypasses. The FERC order calls for 70% passage of juvenile fish during 80% of the duration of the migration in the spring, and 50% during 80% of the migration in the summer.

Current FERC Bypass Programs

The bypass at Wells Dam is operated during spring and summer periods agreed upon by the Wells project Coordinating Committee, made up of representatives of Douglas County P.U.D., the fishery agencies, and tribes (parties to the mid-Columbia FERC Proceeding).

Bypass at the four other mid-Columbia projects is provided by spill in amounts that are either set by the agreements filed with FERC (Rocky Reach dam), or by an interim order of FERC (Rock Island, Wanapum and Priest Rapids dams). As noted above, the order of the Administrative Law Judge for FERC calls for installation of bypass facilities for juvenile salmonids at Wanapum and Priest Rapids dams, but the order is not final until adopted by FERC. Meanwhile, Grant County P.U.D. is proceeding on a schedule for installation, as indicated in the table.

NPPC Fish and Wildlife Program Requirements for Mechanical Bypass Systems

Background

Whereas the FERC has authority over license conditions for the mid-Columbia projects, the NPPC is an advisory body established to determine regional policy on power issues and fish and wildlife issues in the Columbia Basin as a whole.

In the 1982 FWP the NPPC called for development of mechanical bypass systems at the mainstem dams and at the five mid-Columbia projects. The 1984 FWP reported on the agreements reached among the parties in the mid-Columbia.

Goals for Passage

The 1987 FWP set a standard of 90% FGE as a design criterion for intake screens - if it can be achieved - and established spill as an interim measure to produce 90% survival during the middle 80% of the spring and summer emigrations.

Current NPPC Bypass Program

The standards set in the 1987 FWP remain in the 1994 FWP. The additional operational objective of 80% fish passage efficiency at the Snake River and Columbia River projects, was mentioned above.

In the 1991 Amendments to the FWP and the 1994 FWP, the Council called for completion of turbine intake screens and juvenile fish bypass systems at all eight federal dams on the lower Columbia River and Snake River by 1998. In addition, the 1994 FWP called for installation of extended screens at McNary (1995), Lower Granite (1996), Little Goose (1996), John Day (1998), and The Dalles (1998), if they prove to be effective. No criteria were given.

The 1994 FWP also set a standard of 98% survival to be achieved in bypass and collector facilities throughout the basin.

NMFS/NOAA Recovery Plan Requirements for Mechanical Bypass Systems

Background

The NMFS/NOAA Recovery Plan, "... is based on the premise that there is sufficient uncertainty about the benefits of transportation to warrant an evaluation of whether improved inriver migration might result in as many (or more) returning adults than does the transportation program.", (National Marine Fisheries Service, 1995, p.V-2-50.) Accordingly, specific standards are established for inriver passage and a study is recommended to compare adult return rates from transported fish with return rates from inriver migrants that have had the benefit of improved inriver conditions.

Turbine Efficiency

The Plan calls for operating turbines at the eight federal projects within 1% of peak efficiency during March 15 through October 31 in the Columbia River and March 15 through November 30 in the Snake River.

Recommended Studies

The Plan calls for studies to improve efficiency in the bypass systems at Columbia Basin hydroelectric projects, and lists 5 kinds of studies, including the following: 1) re-evaluating existing bypass systems; 2) evaluating all new systems; 3) developing new means of collection and bypass; 4) developing better methods for counting fish bypassed and held; and 5) assessing the impacts of supersaturated gas on juvenile and adult salmonids.

Goals for Passage

The Plan sets an interim goal of 80% fish passage efficiency at each dam. Spill is to be used to assist in reaching this goal. The NMFS/NOAA goal provides a refinement over the NPPC goal in the manner in which it distinguishes between the spring and summer migrations. Because the salmonid components of the migrations differ in spring and summer, it is necessary in implementing measures to achieve the goals, to define FGE levels separately for spring and summer for each project. Because the species of concern to NMFS/NOAA are the threatened or endangered species, which include sockeye, and fall chinook, that universally have shown low FGE (Spring/summer chinook, also threatened, show a higher FGE), the NMFS/NOAA goal, in practice, is more stringent than the NPPC goal, as will be shown in the Appendix, Part III. Because FGE varies among the projects, the relative spill amounts required to achieve the standard also vary, as previously discussed in the section on spill, Table 3.

Current NMFS/NOAA Bypass Program

For setting spill levels required to achieve the 80% passage goal, the Plan uses two standard sets of FGE levels, one for spring and one for summer, that were adopted by NMFS/NOAA, using the best available information, (Detailed Fish Operating Plan, DFOP, 1993, according to Fish Passage Advisory Committee, FPAC, 1995). In the absence of better information, it assumes a 1:1 relationship between the percentage of flow that is spilled and the percentage of fish that are passed in spill at each project. It also assumes a 98% rate of survival in spill. (Personal communication, Tom Berggren, Fish Passage Center, FPC.) Spill levels required to achieve the NMFS/NOAA bypass goals are shown in Table 3. The Plan provides strategies for installation, improvement, or testing of bypass facilities at each of the eight projects. These are summarized in Part 3, below

APPENDIX E (continued)

Mortality Of Salmonid Smolts At Dams And Development Of Bypass Systems. Part 3 Conformity In 1995 Of Installation And Operation Of Bypass Systems With Requirements Of FERC, The NPPC Fish And Wildlife Program And NMFS Proposed Recovery Plan Conformity in 1995 with FERC Requirements for Spill and Mechanical Bypass

Background

Requirements by FERC for spill and development of mechanical bypass systems at the mid-Columbia projects have for the most part occurred in the context of agreements reached among the parties to the mid-Columbia Proceeding. These are summarized in Table 4. At Wells Dam, a committee established in the Long-term Settlement Agreement has the responsibility of agreeing upon the schedule for operation of the bypass. The decision is made based upon information from hydroacoustic monitoring at the dam.

At Rocky Reach and Rock Island dams, the FERC requirements for spill are in terms of a daily amount specified as a percentage of spill relative to daily average river flow for a fixed number of days, while at Wanapum and Priest Rapids dams the spill amounts are specified as the daily percentage of spill required to pass 70% of the juvenile salmonids that are passing during 80% of the duration of the spring emigration and 50% of the juvenile salmonids passing during 80% of the summer emigration. The intent of the 80% duration specification is to provide an interval at the beginning of the season during which data can be collected that will indicate the timing of the emigration in the particular year, and likewise to provide some latitude at the end of the emigration. The mid-Columbia Coordinating Committee and the Rock Island Coordinating Committee, made up of representatives of the parties to the mid-Columbia Proceeding, was given the responsibility of implementing the requirements. In particular, because the timing of emigration differs from year to year, the committee has the responsibility of determining when the first 10% of the emigration has appeared in order to commence the spill program at each of the four projects, for interrupting it if the data suggest it, and for determining when the 80% goal has been reached at Wanapum and Priest Rapids.

In practice, based on past experience at Wanapum and Priest Rapids dams, the committee has agreed upon a schedule for a fixed number of days (35) of spill, with an option to apply for additional days if it appears the 80% goal has not yet been reached.

In 1994 the mid-Columbia Coordinating Committee, a body made up of representatives of the parties established by agreement in the mid-Columbia Proceeding found itself in a conflict between the FERC order to spill for fish passage and limits on spill because of water quality

standards set by the Washington State Department of Ecology. The FERC order called for sufficient spill to achieve 70% fish passage during 80% of the spring emigration along with 50% for the summer at Wanapum and Priest Rapids dams, while the special permit issued by the Washington Department of Ecology allowed Grant County P.U.D. to exceed the normal limit of 110% gas saturation in the river below the projects, but maintain it below 120% of saturation. In 1994, some exploratory manipulations of spill level were required to comply with the limit on gas saturation.

Spill

A summary of spill programs executed at the mid-Columbia projects in 1995 is provided in Table 3. Operators at Wells, Rocky Reach and Rock Island dams were able to follow the FERC requirements, as described in a previous section. The goal for fish passage was achieved at Wells Dam in spring and summer. And the FERC goal for fish passage in the summer at Priest Rapids was achieved by spill at that project. Achievement of FERC goals at Wanapum Dam in spring and summer and Priest Rapids Dam in the spring was not possible due to limitations on spill because of gas supersaturation. Grant County P.U.D. requested and was granted a variance from Washington state water quality standards, allowing gas saturation levels of 120% at Wanapum and Priest Rapids dams, which permitted higher levels of spill, but not enough to meet the goals.

At Wanapum and Priest Rapids dams in 1995, the committee agreed to a schedule for spill during 24 hours each day that would maintain gas saturation limits within the permitted levels. It was found that effectiveness of spill in passing fish was greatly enhanced by maintaining the spill for 24 hours a day {Hammond, 1995}, when compared to the nightly schedule used in previous years, as discussed in Part I.

Mechanical Bypass

The surface collector at Wells Dam has been fully operational since 1988, with an estimate of 89% fish passage verified over a three year period. Screens tested at Rocky Reach Dam have not performed satisfactorily, as described in Part I. At Rock Island Powerhouse Number 1, tests of an intake screen continue. Screens are not feasible at Rock Island Powerhouse Number 2, Table 3. Although the ruling on the Grant County P.U.D. petition to substitute transportation for screens at Priest Rapids Dam, described above, is not final until it is adopted by FERC, Grant P.U.D. has proceeded with a schedule for installation of intake screens to be completed at Wanapum Dam by 1999 and Priest Rapids by the year 2000.

CONFORMITY IN 1995 WITH NPPC REQUIREMENTS FOR SPILL AND MECHANICAL BYPASS

Background

Since the requirements of the NPPC have been superseded by those in the NMFS/NOAA Proposed Recovery Plan, the reader is referred to the discussion below.

Requirements of the NPPC and NMFS/NOAA with respect to installation and improvement of bypass devices are similar, as shown in Table 4. Although the experiments with the bar screen showed promising results, there were difficulties with debris and the COE elected to proceed with installation of submerged traveling screens (STS's) at all eight of its projects on the Snake River and lower Columbia, (COE Salmon Passage Notes 1992). All but The Dalles are now fully equipped, Table 4. The 1994 FWP called for installation of extended-length screens at McNary Dam by March, 1995, Lower Granite and Little Goose dams by March, 1996, and John Day and The Dalles dams by March, 1998.

CONFORMITY IN 1995 WITH NMFS/NOAA REQUIREMENTS FOR SPILL AND MECHANICAL BYPASS

Background

With respect to the flow and spill requirements, the NMFS/NOAA Recovery Plan set limits on gas saturation at 115% in the forebay, on a 12 hour average, or 120% in the tailrace for 12 hours. The Plan recognizes there are differences among projects in levels of gas saturation produced by given spill volumes, as well as an interaction between gas saturation levels at successive projects, and recommends studies to optimize spill levels within the limits set by gas saturation criteria. The states of Washington, Oregon, and Idaho issued special permits, allowing the COE to exceed their water quality standards normally set at 110% and go to 120%.

Spill requirements, as applied by NMFS/NOAA, vary with the mix of yearling and subyearling chinook, steelhead, and sockeye, because the FGE varies among the species, with the values for yearling chinook and steelhead being much higher than sockeye and subyearling chinook. A further complication is that yearling chinook and steelhead are early emigrants, with sockeye somewhat later, while subyearling chinook, though present through the season, predominate among the later emigrants (Fish Passage Center Annual Reports). Thus the standard values of FGE used by NMFS/NOAA as a basis for determining required amounts of spill to add in order to reach the 80% fish passage goal during the time periods fixed for spring and summer emigrants, are higher in the spring period than in the summer, which might suggest that more spill would be required in the summer in order to achieve the 80% fish passage goal.

Box 24. Standard FGE Used in 1995 by NMFS/NOAA to Calculate Spill Needed to Achieve 80% Fish Passage. (Personal communication, Tom Berggren, Fish Passage Center). The values to be used for 1996 will be somewhat higher in response to installation of extended screens at Lower Granite, Little Goose, Lower Monumental and McNary dams. (Shown in parentheses. Source: Memo of Margaret Filardo, Fish Passage Center, to FPAC, January 18, 1996)

Project	L. Granite	L. Goose	L. Monumental	Ice Harbor	
4/10-6/20	.50 (.57)	.56 (.63)	.55 (.62)	.73	
Summer	.25 (..50)	.25 (..50)	.31(..54)	.33	
	McNary	J. Day	The Dalles	Bonn.(1 & 2)	
4/20-6/30	.70	.72	.43	.37	.44
Summer	.47 (.58)	.26	.43	.10	.40

This refinement would lead to a situation calling for more relative spill later in the season when FGE is lowest and water is in shortest supply. To circumvent this problem the Plan specifies there should be no spill for summer migrants at Lower Granite, Little Goose, Lower Monumental, McNary or Bonneville dams. The first four are named as “collector dams” where the emphasis is to be on collection of fish for transportation in the barges to below Bonneville Dam.

Box 25. Calculated Spill Amounts (24 hour basis) Required in 1995 to Achieve 80% Fish Passage. Assumes 1:1 relationship of spill % to fish passage %, except at John Day and The Dalles, where specific information is available. (See Part I, and Magne et al 1987, and Willis, 1982.) Sluiceway passage, where present, is included in the 80%. Sluiceway passage at Bonneville Dam is not included. More information is needed there. The complexity of attempting to manage spill levels to attain a passage goal is illustrated in two examples A and B below. Method A is the simplest. It uses the FGE’s averaged over all species, as given in Box 24. The estimation procedure is explained in the footnote. Method B, used in The Detailed Fishery Operating Plan of the Agencies and Tribes (DFOP, 1993) depends upon the FGE’s for each stock, summer and fall, determines spill levels for a 12 hour night period during which a higher percentage of fish are expected to pass and during which there is expected to be less demand for power, and calculates what that spill volume would amount to over a 24 hour period.

Our analysis of diel passage data in Part I suggests both methods probably overestimate the amount of spill required as a percentage of river flow, for two reasons; 1) spill over a 24 hour

period may be nearly twice as effective as spill of the same volume for 12 hours (Based on limited data at Wanapum and Priest Rapids dams), and 2) if surface spill is provided, it is likely that fish passage efficiency can be further increased, but further studies are needed. Both methods suffer from lack of adequate information on spill effectiveness at most of the projects. The assumed 1:1 relationship is not based on studies with an adequate range of spill values. Since the standard spill gates open from the bottom at about the same level as the top of the turbine intakes (generally), diel passage rates through existing spill can reasonably be expected to match passage rates measured through the turbines. But the same will not be true for surface spill, where fish can be expected to pass somewhat uniformly throughout the 24 hour period. See Part I.

	A. See Footnote for Explanation		B. Numbers From DFOP (1993)	
	Spring	Summer	Spring Chinook	Fall Chinook (Summer Migrants)
Project	Spill (%)	Spill (%)	Spill (%)	Spill (%)
Lower Granite	60	73	39	49.5
Little Goose	54	73	24	49.5
Lower Monumental	56	71	27	50
Ice Harbor	26	70	47	47
McNary	33	62	24	45
John Day	36*	73*	17.5	42
The Dalles	31*	31*	40	40
Bonneville I	68	77	68	77
Bonneville II	64	67	(powerhouse should not operate)	

* For John Day and The Dalles dams, spill effectiveness curves were used in method A. They differ from the 1:1 relationship assumed for the other projects. See Part I. Spill percentages required for Method A were calculated from the equation .8N = NX + (FGE)(N-NX), where N is the number of downstream migrants, and X is the spill percentage required to provide 80% fish passage. Percentages for John Day and The Dalles were adjusted according to their

If mortality rates of 2% in spill and 2% in bypass systems are assumed, along with an assumed 15% mortality in turbines, the total survival at each project, with 80% fish passage would be a little over 95%

Note: The spill amounts that will be required in 1996 to achieve the 80% passage goal, with new extended screens in place, have been calculated by Margaret Filardo, Fish Passage Center. Generally, they are less than in 1995 by about 10%. (Memo of January 18, 1996 to FPAC)

Spill and Fish Passage. Spill levels could not be increased enough to meet the 80% passage goal in spite of the provision allowing gas saturation levels to 120%, This was true even though by 1995, five of the eight federal mainstem and Snake River projects were at least partially equipped with flip lip spillway deflectors. All were equipped except John Day, Ice Harbor and The Dalles dams, (Detailed Fishery Operating Plan, (DFOP) 1993, and personal communication Larry Basham, Fish Passage Center). At The Dalles Dam the shallow spill basin is not believed to cause high gas saturation (personal communication, Larry Basham, Fish Passage Center, 1996). Ice Harbor Dam will have spill deflectors in place in time for the 1997 migration. John Day Dam will have partial installation in 1997 and complete installation in 1998, (Bruce, 1995). See Table 4.

Box 26. Installation date and numbers of "flip lip" spill bays at COE projects.

(From DFOP, 1993)

Project	*Date*	*Number of Flip Lips*
Lower Granite	2/75	8 of 8 bays
Little Goose	2/76	6 of 8 bays
Lower Monumental	8/74	6 of 8 bays
Ice Harbor	Recommended by NMFS/NOAA Recovery Plan	
McNary	1/76	18 of 22 bays
	(2 outer bays on each end not equipped)	
John Day		none
The Dalles		none
	(Spill through the shallow basin is thought not to cause high gas saturation)	
Bonneville	3/75	13 of 18 bays
	(3 outer bays on north shore and 2 outer bays on south shore)	

Those spill bays that are equipped are used as the first alternative for spill. Obviously, when spill exceeds the capacity of those bays the remaining spill bays are employed.

At Ice Harbor Dam in 1995, as previously mentioned, outages of units led to forced spill and gas saturation that exceeded the permitted limits, but brought attainment of the fish passage goal. Fish passage goals were not attained elsewhere (except at Wells Dam in spring and summer

and Priest Rapids Dam during the summer) because of the limits on gas saturation. At Ice Harbor Dam, the volume of spill observed during the interval specified in the plan amounted to 35.9% of the daily average flow, which exceeded the 26% calculated to meet the 80% passage goal. Gas saturation levels of 130-138% were recorded from May 25 to June 8 in the tailrace. The 115% criterion was exceeded during most of the days between April 20 and June 30.

Average amounts of spill actually provided at the COE projects over the spring period are shown in Table 3, along with estimates of the percentages of fish passage achieved at those levels, (Spill data from the Fish Passage Center; Estimates of fish passage from Fish Passage Center, 1995) Analysis by the Fish Passage Center (Fish Passage Center, 1995) shows that fish passage efficiencies achieved at projects other than Ice Harbor were below the 80% called for in the Biological Opinion, Table 3. They ranged from 50-60% fish passage at Lower Granite Dam to 78% at The Dalles Dam. With the exception of Bonneville Dam at 55-62%, all of the lower river projects achieved fish passages in the 70% range, while the Snake River projects other than Ice Harbor were in the 50-60% range, Table 3.

At a time from late May into June, 1995 during which Snake River runoff could not be regulated within lower levels, and flows at Lower Granite, Little Goose and Lower Monumental dams exceeded powerhouse capacities, there was “inadvertent spill” that went in part toward the goal of attaining 80% passage efficiency, but led to exceeding the gas saturation limits, (Fish Passage Center, 1995). The 115% criterion was exceeded during half or more of the spill period specified in the plan (April 10 to June 20) at three of the four Snake River projects, (Little Goose, Lower Monumental and Ice Harbor dams) and for most of the spill period (April 20 to June 30) at three of the four lower river projects, (McNary, John Day, and Bonneville dams).

Box 27. The 120% criterion was also exceeded for several days at Little Goose Dam, about 10 days at Lower Monumental, and about 3 weeks at Ice Harbor Dam; for several days at McNary Dam, and intermittently over the spill period at John Day Dam.

Mechanical Bypass

The Proposed Recovery Plan calls upon the COE to reduce loss of juvenile fish through structural and operational improvements of bypass facilities. Based on the studies that demonstrated improved FGE with extended-length screens the COE is proceeding with testing and installation of extended-length screens at the eight projects (U.S. Army COE, 1996). Four of the projects, Lower Granite, Little Goose, Lower Monumental, and McNary dams are expected

to be equipped in time for the 1996 emigration (Filardo, January 18, 1996 Memorandum to FPAC)

Other measures in the NMFS/NOAA Proposed Recovery Plan in addition to spill that are designed to provide improved survival at the COE projects are also shown in Table 4. The Plan produced by the Snake River Salmon Recovery Team, referred to the success at Wells Dam and called for investigation of the application of surface collection technology at the Snake River and Columbia River projects, {Bevan et al, 1994; NMFS/NOAA, 1995}. Surface collector studies are proposed for 1996 in the Portland District of the COE to cover (a) hydroacoustic evaluations of fish passage, (b) fish condition studies, and radio telemetry for fine scale behavior information of juvenile salmonids in the forebay, through surface passage routes, and through the tailrace at Lower Granite, The Dalles, and Bonneville dams, and for 1997 at Ice Harbor Dam, (Draft COE Mitigation Project 11/2/95). These are intended to be observational studies to determine where the fish are and their movement, particularly as they approach the dams. Criteria are to be developed to design, model and evaluate surface bypass devices in future years. {COE Workshop, 1995}

Further project specific details for installation, testing and improvement of bypass facilities at each of the eight COE projects are shown in Table 4.

SUMMARY AND DISCUSSION.

Wells Dam in the mid-Columbia reach is the only project in the basin with a smolt bypass system that can achieve the fish passage goals established by FERC, the NPPC or NMFS/NOAA for all species without the addition of spill. The best FGE's recorded for yearling chinook at projects in the Snake River and lower Columbia river range from 44% to 88%, with most in the 60% to 70% range. For subyearling chinook they range from 32% to 67% , with most in the 30% to 40% range. For sockeye they range from 14% to 73%, and for steelhead from 34% to 93%, with most in the 80% to 90% range (See Table 7.1 in Chapter 7). Survival rate of smolts once they are in properly tuned and maintained bypass systems generally is about the same as survival in spill. Because FGE of most of the existing turbine intake screens in the Snake and lower Columbia rivers is not sufficient to achieve the stated goals, spill must be added at all of the projects, except Wells Dam, Table 3.

Although a loss of smolts because of high gas saturation levels measured in the Snake River would have been predicted based on laboratory studies and studies of captive fish held in the river, recoveries of PIT-tagged smolts led to estimates of survival from the tailrace at Lower Monumental Dam to the McNary Dam tailrace of 84% in the period April 27 - May 10; 98% in

the interval from May 11 to May 24; and 100% in the interval from May 25 to June 11 (Fish Passage Center, 1995). Contrary to expectations the survival of smolts in this river reach was high and did not decrease as the percentage of spill increased.

Box 28. At Ice Harbor Dam, during those three periods, average daily spill was 35.1%, 38.2% and 43.5% of the flow, while at McNary Dam spill was 39.6%, 44.3% and 43.0% of river flow. (Fish Passage Center, 1995)

ACHIEVEMENT OF GOALS

There are difficulties in determining whether the NMFS/NOAA goals are achieved either in terms of fish passage or survival. The standard FGE values used by NMFS/NOAA are projections based on estimates of the probable mix of species and stocks expected at each project at each season, along judgments on the appropriate FGE to use. Among the COE projects, reliable estimates of spill effectiveness are available only for John Day Dam and The Dalles Dam. It is therefore necessary to make an assumption as to the nature of the relationship between spill and fish passage for the other projects. The Fish Passage Center, in calculating fish passage under the given spill levels at the COE projects, followed a generally accepted procedure of assuming a one-to-one relationship of percentage of spill to percentage of fish passed {Fish Passage Center, 1995; DFOP, 1993}. In Part I we reviewed the available information and concluded that this assumption is not warranted at either John Day Dam or The Dalles Dam, where information on spill effectiveness is available. At John Day Dam, the effect would amount to a difference in fish passage of about 10% less at spill levels around 50% of river flow, (See Part I) while at The Dalles Dam, where spill is more effective, 20% spill gives about 50% fish passage {Willis, 1982}. This points to the importance of defining the spill effectiveness relationship for each project, or of grouping projects according to their configurations that would be expected to affect spill effectiveness.

The calculated spill values in the DFOP depend upon an assumption (or conclusion) that there is an advantage to spilling 12 hours at night versus 24 hours a day as a benefit to power production. Our review suggests that it would be worthwhile to conduct a more detailed examination of fish passage data related to duration of spill and of surface spill versus standard spill, in conjunction with costs and benefits to the power system in various scenarios of spill duration, to find an optimum strategy for fish and power.

CONCLUSIONS

None of the turbine intake screens in place or tested to date in the Columbia basin, shows a high enough FGE to meet the 90% standard for all stocks or species or the 80% fish passage standard, particularly for subyearling chinook or sockeye. Spill must be added in sufficient quantities to make up the difference.

As long as limits on gas saturation restrict the relative volume of spill permitted at Snake River or Columbia River projects, spill cannot be used either alone or as a supplement to intake screens, at levels required to achieve fish passage goals established either by FERC, the NPPC, or NMFS/NOAA at any projects except Wells Dam spring and summer (where no spill is required), except Priest Rapids Dam in the summer, and perhaps The Dalles in spring, Table 3. In the summer, out of the 13 projects on the Snake River and Columbia River mainstem, only Wells Dam with a bypass and Priest Rapids with spill will meet fish passage requirements. The flip lip spillways that are in place at some of the COE projects are not effective enough to circumvent this problem.

Although Wells Dam is the only project where surface collection has been successfully applied to date, and the configuration of that project does not allow for direct transfer of the technology to other projects on the river, comparing its performance with other bypass systems in existence, it appears that surface collection offers the best alternative for achieving the fish passage goals, Table 3.

Recommended Study of Spill Effects on Survival Analysis by the Fish Passage Center showing high survival rates of smolts in reaches where gas saturation levels exceeded permitted levels, raises questions about those levels that have been established. One question raised about studies that established those permitted levels is whether fish migrating in the open river would be able to find areas where they could establish an equilibrium with gas levels, for example by seeking water of greater depth and pressure. Further analysis, such as that of the Fish Passage Center, using tagged fish in transit through the river, should be undertaken. The NMFS/NOAA Proposed Recovery Plan states that the spill program it specifies is experimental. The Plan also calls for study of gas saturation. In view of the Fish Passage Center analysis showing high survival of smolts from Lower Granite to McNary Dam during high spill episodes in the Snake River in 1995, we believe further consideration of the limits are in order. Specifically, a study, such as the sort derived by the FPC from data available from the NMFS Snake River survival study, should be designed for the purpose of measuring survival of smolts from upper river to lower river projects under varying volumes of spill relative to river flow

Some studies of survival in spill and in passage through turbines appear to include an element of mortality due to predation below the project. There is a need to be able to separate

direct mortality due to spill and turbine passage from indirect sources, such as predation, in order to be able to properly design mitigation procedures.

It is dangerous, in these years of low flow, to overlook the fact that in many years, in spite of increased storage capacity upstream, flow in the river in the spring will exceed the hydraulic capacity of the hydroelectric projects. A foretaste of that was seen in the Snake River runoff in the spring 1995. Forecasts indicate that 1996 will also be one of those years. In other cases, as at Ice Harbor Dam in 1995, turbines will go off line for various reasons, necessitating inadvertent spill. In all of these situations, gas saturation levels will probably exceed permitted limits. Therefore, a critical uncertainty is raised with respect to this issue, i.e. what levels of smolt mortality can be expected during years of high inadvertent spill. Studies should be undertaken to find ways of further reducing gas saturation levels below those currently experienced.

Generalizations

Recent studies have raised a question whether it is reasonable to assume a 15% turbine mortality. The mid-Columbia system mortality studies estimated a loss of 15-16% per project over five projects, which includes reservoir mortality. The study of Iwamoto et al, (1994) produced an estimate of 10% mortality in passing through Lower Granite reservoir and dam, and 14% in passing through Little Goose reservoir and dam. Muir et al, (1995) confirmed the estimate for Lower Granite reservoir and dam (8% to 10% in 1994), and developed estimates of mortality through Little Goose reservoir and dam amounting to 21% for yearling chinook and 22% for steelhead. These estimates all include losses in the reservoir as well as at the project. It must be observed that measures, such as spill and provision of other bypass systems at the projects themselves, can not be expected to ameliorate mortalities in the reservoir. This is not to say that reservoir mortality is not associated with construction and operation of the hydroelectric system, but that other measures must be found to address that source of mortality. It seems advisable to separate smolt mortality into at least four areas where it can occur; turbine, tailrace, reservoir, and forebay of the next project {Ferguson, 1993}; (National Research Council, 1995). Approaches to reduce mortality will be different in each area. Priorities may differ at each project, depending on the location of highest mortality.

The NPPC FWP of 1994 sets a goal of 90% survival at each project, and 80% fish passage efficiency over 80% of the duration of the emigration, while the NMFS/NOAA goal is for 80% fish passage efficiency. As noted previously, if the 80% fish passage goal is achieved, survival at each of the projects would be about 95%. If 90% survival were taken as the primary criterion, rather than 80% fish passage efficiency, then less spill would be required.

Box 29. If McNary Dam is used as an example, assuming 15% mortality of smolts in turbines, 2% mortality in the bypass, and 2% mortality in spill, using the estimate of 70% FGE for the spring, and given the 80% fish passage goal, thus providing 33% spill under the same assumptions previously used, then mortality at the project would be estimated as 3% in turbines, (0.70 X 0.67 = 0.469; 0.67 - 0.469 = 0.201; 0.201 X 0.15 = 0.03): perhaps 0.6% in spill, (0.33 X 0.02 = 0.006), and 0.9% in the bypass (0.469 X 0.02 = 0.009), for a total of 4.5% mortality at the project. The 90% survival criterion of NMFS/NOAA would thus be exceeded by means of the 80% fish passage criterion

The studies at Rocky Reach Dam and Lower Granite Dam suggested an estimate of about 8% would be reasonable for direct turbine induced mortality at those projects. This may be the best number that could reasonably be expected to be achieved as a goal for minimum smolt mortality through the powerhouse, given the performance of present bypass systems and the 80% fish passage goal. Carrying this number for turbine mortality through the procedure just described, we would find total mortality of 2.1% at McNary Dam with 80% fish passage. This is mortality at the concrete, and does not include mortality in the bypass, at the outfall, in the tailrace or in the reservoir below, all of which may be mortality associated with the project.

As a comparison, at Wells Dam, even if we use the estimate of 16% turbine mortality, as estimated for steelhead in 1980 (Weitkamp et al., 1980), and the estimate of 100% survival in spill estimated at that project (Weitkamp et al., 1980), then smolt mortality is perhaps 1.6% at the present time (0.16 X 0.11 = 0.018; with fish passage of 89%).

Box 30. It should be noted that there is a seeming incongruity between the turbine mortality study at Wells Dam and the systems mortality studies, (McKenzie et al., 1983): {McKenzie et al, 1984}**,** each of which produced an estimate of about 15% mortality. This would lead to <u>the conclusion</u> that reservoir mortality, tailrace mortality, and spill mortality would all be zero at Wells Dam

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Table 3. Bypass Measures Required and Executed at Columbia River and Snake River Projects in 1995. (Sources: **Skalski, 1991**; Chelan County P.U.D.; Grant County P.U.D.; Fish Passage Center, 1995; others listed in text.)

Mid-Columbia Projects		**Requirements in Terms of Fish Passage (FP) or Spill (S)**			**Fish Passage Achieved (Estimated %)**	
Project	**Measure**	**FERC**	**NPPC**	**NMFS**	**(%)**	**Conformity**
Wells Dam						
	Spill	None	None	NA		(Water required to operate the bypass varies with flow from 3-10% of average river flow.)
	Mechanical Bypass (Surface Attraction)					
	Spring	80% FP	80% FP	NA	(89%)	Operation during spring and summer period as agreed upon by representative committee.
	Summer	70% FP	70% FP	NA	(89%)	
Rocky Reach Dam						
	Spill					
	Spring	15% S	20% S	NA		30 days during spring, plus possible 6 more for Okanogan sockeye, if necessary.
		(spill effectiveness equation estimate			10% FP)	
	Summer	10% S	20% S	NA		Two weeks during summer emigration.
		(spill effectiveness equation estimate			6.6% FP)	
	Mechanical Bypass (Screens)	tests	tests	NA	(Table 7.1)	Prototypes tested: STS 1985 to 1988; bar screen 1989 - 1992 and 1994. Not successful
	(Surface Attraction)	-	-	NA		Prototype tested 1995. Results encouraging. Modified prototype to be tested in 1996.

Table 3. Continued
Mid-Columbia Projects - Continued

Project	Measure	Requirements in Terms of Fish Passage (FP) or Spill (S)			Fish Passage Achieved (Estimated %)	Conformity
		FERC	NPPC	NMFS	(%)	
Rock Island Dam						
	Spill					
	Spring	17% S	20% S	NA		FERC formula calls for spill of 10% of flow through powerhouse number 2 and 50% of flow through powerhouse number 1. Therefore varies with flow and load distribution.
		(spill effectiveness line estimate			27% FP)	
	Summer	3.3%	20% S	NA	(?)	
R.I. Powerhouse Number 1						
	Mechanical Bypass (Screens)	tests	tests	NA	(Table 7.1)	Prototype tested 1992-1995 shows promise. Further tests scheduled in 1996.
	Surface Attraction	-	-	NA		Being investigated
R.I. Powerhouse Number 2						
	Mechanical Bypass (Screens)	tests	tests	NA	(Table 7.1)	Settlement Agreement provided for tests. Tests indicated screens not feasible due to lack of space in front of horizontally oriented turbines. Agreement provides for spill in lieu of further development of bypass at the option of fishery agencies. Option not exercised to date (1995)
	Surface Attraction	-	-	NA		Any such device would probably serve both powerhouses.

Table 3. Continued
Mid-Columbia Projects - Continued

Project	Measure		Requirements in Terms of Fish Passage (FP) or Spill (S) FERC	NPPC	NMFS	Fish Passage Achieved (Estimated %) (%)	Conformity
Wanapum Dam							
	Spill						
		Spring	70% FP	20% S	NA	(52%)	FERC order requires passage of 70% of fish during 80% of emigration. Spill of 17% for 24 hours a day for 47 days passed 52% of fish. Spill limited by limits on gas saturation imposed for water quality.
		Summer	50% FP	20% S	NA	(25%)	FERC order requires passage of 50% of fish during 80% of emigration. Spill of 14% for 14 hours a day for 63 days passed 25% of fish. Spill limited by gas saturation limits for water quality.
	Mechanical Bypass (Screens)		tests	tests	NA	(Table 7.1)	Prototype bar screens tested. FERC order for installation is not yet final. Grant P.U.D. proceeding on schedule for installation. See Table 4.
	Surface Attraction		-	-	NA		Prototype tested in 1995 will be enlarged for further tests in 1996.
Priest Rapids Dam							
	Spill						
		Spring	70% FP	20% S	NA	(54%)	FERC order requires passage of 70% of fish during 80% of emigration. Spill of 17% for 24 hours a day for 47 days passed 52% of fish. Spill limited by limits on gas saturation posed for water quality.
		Summer	50% FP	20% S	NA	(62%)	FERC order requires passage of 50% of fish during 80% of emigration. Spill of 14% for 14 hours a day for 63 days passed 25% of fish. Spill limited by gas saturation limits for water quality.
	Mechanical Bypass (Screens)		tests	tests	NA	(Table 7.1)	Prototype bar screens tested. FERC order for installation is

Table 3. Continued
Mid-Columbia Projects - Continued

Project	Measure	Requirements in Terms of Fish Passage (FP) or Spill (S) FERC	NPPC	NMFS	Fish Passage Achieved (Estimated %) (%)	Conformity
Priest Rapids Dam - Continued						
	Surface Attraction	-	-	NA		Any device suitable for Wanapum Dam would probably be applied to Priest Rapids Dam.
Snake River Projects						
Lower Granite Dam						
	4/10 through 6/20 Spill	NA	80% FP	80% FP		14.6% of average flow spilled May 3 to June 20, 1995.
	Mechanical Bypass (Screens)					
	Combined spill and bypass				(50-56%)	
Little Goose Dam						
	4/10 through 6/20 Spill	NA	80% FP	80% FP		21.7% of average flow spilled April 14 to June 30, 1995. Spill volume limited by gas saturation standards.
	Mechanical Bypass (Screens)					
	Combine spill and bypass				(60%)	
Lower Monumental Dam						
	4/10 through 6/20 Spill	NA	80% FP	80% FP		16.6% of average flow spilled April 14 to June 30, 1995. Spill volume limited by gas saturation standards.
	Mechanical Bypass (Screens)					
	Combined spill and bypass				(58-60%)	

Table 3. Continued
Snake River Projects - Continued

Project	Measure	Requirements in Terms of Fish Passage (FP) or Spill (S) FERC	NPPC	NMFS	Fish Passage Achieved (Estimated %) (%)	Conformity
Ice Harbor Dam						
	4/10 through 6/20					
	Spill	NA	80% FP	80% FP	(35-44%)	35.9% of average flow spilled April 6 to June 20, 1995 and beyond. Two turbines off line, necessitating spill when river flow exceeded plant capacity.
	Mechanical Bypass (Screens)					
	Combined spill and bypass				(79-84%)	
Lower Columbia River Mainstem Projects						
McNary Dam						
	20 through 6/30					
	Spill	NA	80% FP	80% FP	(40-44%)	39.8% of average flow spilled April 4 to July 4, 1995. Volume of spill limited by gas saturation standards.
	Mechanical Bypass (Screens)					
	Combined spill and bypass				(73-77%)	
John Day Dam						
	4/20 through 6/30					
	Spill	NA	80% FP	80% FP		3.8% of average flow spilled April 25 through June 30, 1995.
	Mechanical Bypass (Screens)					
	Ice and Trash Sluiceway					
	Combined spill and bypass				(72-72%)	
The Dalles Dam						
	4/20 through 6/30					
	Spill	NA	80% FP	80% FP		57.2% of average flow spilled April 27 through June 30, 1995.

Table 3. Continued

Lower Columbia River Mainstem Projects (Continued)

Project	Measure	Requirements in Terms of Fish Passage (FP) or Spill (S) FERC	NPPC	NMFS	Fish Passage Achieved (Estimated %) (%)	Conformity
The Dalles Dam (Continued)						
	Ice and Trash Sluiceway					
	Combined spill and bypass				(78%)	
Bonneville Dam						
	4/20 through 6/30					
	Spill	NA	80% FP	80% FP		34.5% of average flow spilled April 12 through June 30, 1995.
	Mechanical Bypass (Screens)					
	Combined spill and bypass				(55-62%)	

Table 4. Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules. (Sources: NPPC Fish and Wildlife Program, 1987, 1991 and 1994 Amendments; NMFS/NOAA Proposed Recovery Plan for Snake River Salmon, 1995; COE Columbia River Fish Mitigation Project Draft Plan, November 2, 1995; COE Salmon Passage Notes 1992; Various documents part of the FERC record for mid-Columbia Projects.)

MID-COLUMBIA PROJECTS

Project **Requirements by the Federal Energy Regulatory Commission (FERC) and The Northwest Power Planning Council (NPPC)**

Wells Dam

FERC Requirements

Surface Collector Bypass.

In place. Since 1990, operate the bypass spring and summer as scheduled by a representative committee.

Rocky Reach Dam

FERC and NPPC Requirements

Intake Screens.

Tests of bypass systems since 1985. Prototype STS's of various configurations tested 1985-1988, (Peven and Keesee, 1992). Tests 1989-1992 of bar screens, various configurations None performed satisfactorily. Highest measured FGE for chinook yearlings about 50%. Usually lower. Concluded that it would not be possible to meet criteria with intake screens at that project, (Peven and Keesee, 1992). The peculiar configuration of the project with a powerhouse nearly parallel to the river flow and a cul-de-sac between the powerhouse and the right bank leading to development of unusual flow patterns that affect fish behavior, are thought to be factors in the inability to apply the screen technology to this project.

Surface Collector.

In 1995, testing began of a surface collection device. Prototype in test shows promise. Further test of modified device scheduled for 1996.

Rock Island Dam

FERC and NPPC Requirement.

Intake Screens.

License condition requires tests of intake screens. According to terms of Long-Term Settlement Agreement of 1987, adopted by FERC. Rock Island Dam removed from the mid-Columbia proceeding. Included a provision for evaluation of prototype intake screens at powerhouses. Tests continue at powerhouse number 1, but Chelan County P.U.D. concluded that installation at powerhouse number 2 was not feasible due to the limited space available in front of the horizontally oriented bulb turbines. The Agreement allowed for substitution of spill valued at $1 million (in 1986 dollars) if no screens are installed at powerhouse number 2, at the option of the fishery parties to the proceeding. This has not been invoked. Tests at powerhouse number 1 have shown some promise, with FGE's measured in the range of 70 to 75% for chinook yearlings, about 60% for chinook subyearlings, and 45 to 55% for sockeye in 1994, (Peven et al., 1994).

Table 4. Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules. (Continued)

Project	**Requirements by the Federal Energy Regulatory Commission (FERC) and The Northwest Power Planning Council (NPPC)**
Rock Island Dam (Continued)	
	Surface Collector (Not in requirements)
	Chelan P.U.D. is investigating the feasibility of using a surface collection device at Rock Island Dam that might serve both powerhouses.
Wanapum Dam	FERC and NPPC Requirements
	Intake Screens
	Require tests of intake screens. Intake geometry at Wanapum Dam is similar to Priest Rapids, such that the screen con-configuration tested was also similar. Attainment of FGE near 75% for yearling chinook during the spring and 50% for yearlings during the summer, led to design and testing of an orifice passage system beginning in 1993. Grant P.U.D. is proceeding with design and installation of a full bypass system with completion scheduled for 1999, but same time is testing a prototype surface attraction device as an alternative. Prototypes tested in 1990-93 produced satisfactory to representatives. Installation scheduled for 1999.
sub-County at the FGE's	
	NMFS/NOAA Recovery Plan Requirements
	Calls upon Grant County P.U.D. to install flip lip spillways and/or a stilling basin at Wanapum Dam. Grant P.U.D. plans to begin design for installation of flip lips in the spillway at Wanapum Dam in 1996.
	Not in Requirements
	Surface Collector
	Alternative surface collection device being tested in prototype. Enlarged prototype scheduled for testing in 1996.
Priest Rapids Dam	FERC and NPPC Requirements
	Intake Screens
	Require tests of intake screens. Based on the success of the fixed bar screen design that demonstrated by the earlier NMFS/NOAA tests, the Grant County P.U.D. design for tests in prototype at Priest Rapids Dam used that and other features shown to be desirable. Prototypes tested 1986-1988 produced FGE's satisfactory to representatives, (mid-Columbia Coordinating Committee, 1988). P.U.D. is proceeding with an installation schedule for completion in the year 2000.
	Not in Requirements.
	Surface Collector
	P.U.D. is evaluating surface collection as an alternative to intake screens. Alternative surface collection device being

Table 4. Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules. (Continued)

SNAKE RIVER PROJECTS

Project	**Requirements by The Northwest Power Planning Council (NPPC) and National Marine Fisheries Service (NMFS/NOAA)**
Lower Granite Dam	NPPC Requirements. Improve Bypass The 1987 FWP called upon the COE to continue to evaluate and improve the effectiveness of the juvenile bypass system, to improve FGE, and continue studies to determine whether it was necessary to modify the existing juvenile fish bypass system to reduce mortalities and injuries. The 1976 studies at Lower Granite Dam required updating. The 1991 amendments to the FWP called for improvement of the existing fish collection and bypass system at Lower Granite Dam by March, 1996. The COE modified gates in the bypass system in 1992. Extended Screens COE has scheduled installation of extended screens by March 1996 (COE Salmon Passage Notes 1992). NMFS/NOAA Recovery Plan Requirements Improve Bypass System By 1997, or as soon as possible, the COE should develop a plan and proceed with improvement of the juvenile facility. Some specific requirements for improvement are listed in the Plan. Extended Screens The Plan calls upon the COE to continue its planned installation of extended length screens in time for the 1996 smolt migration season. Will be ready March, 1996. Surface Collector The Plan calls upon the COE to investigate the application of surface collection technology by June, 1996. The Walla Walla District has proposed a test of a prototype surface bypass and collection device at Lower Granite Dam in 1996, with full installation to follow in 1997 and 1998, depending on the results of tests. The prototype to be tested in 1996 will include configurations similar to those found to be most successful at Ice Harbor in 1995.

Table 4. (Continued) Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules.

Project	**Requirements by the NPPC and NMFS. With Compliance**
Little Goose Dam	NPPC Requirements. Improve Bypass Little Goose was equipped with turbine intake screens when it began operation in 1970. The 1987 Fish and Wildlife Program called upon the COE to study whether it was necessary to modify the bypass system to reduce mortalities to juvenile fish. However, since 1979-1980 when the conduit was reconstructed to enlarge the system, juvenile mortality had increased. The FWP called for installation of improvements by April, 1989. The COE modified gates in the bypass in 1991. Extended Screens The COE has scheduled installation of extended screens at Little Goose by March 1996, (COE Salmon Passage Notes 1992). NMFS/NOAA Recovery Plan Requirements Extended Screens Calls for the COE to continue its plans to install extended length screens at Little Goose in time for the 1996 smolt migration season.
Lower Monumental Dam	NPPC Requirements. Intake Screens The FWP of 1987 called upon the COE to develop a plan for installation of a juvenile fish bypass system and install a screening and bypass system by April, 1990. There is no sluiceway at Lower Monumental. The COE developed an alternate plan to use Lower Monumental as a collection facility for transportation. However, the Council felt the results were uncertain, and called for prototype testing of turbine intake screens there. The 1991 amendments to the FWP called for Lower Monumental Dam to be equipped with screens and a bypass system by 1992. The COE complied with installation. NMFS/NOAA Recovery Plan Requirements Extended Screens Calls upon the COE to plan for installation of extended length screens and structural modifications to improve gatewell hydraulics, contingent upon the results of prototype testing at Little Goose and Lower Granite dams.

Table 4. (Continued) Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules.

Project	**Requirements by NPPC and NMFS. With Compliance**
Ice Harbor Dam	NPPC Requirements.
	Improve Bypass System
	The COE was called upon to complete a sluiceway injury and mortality study, to develop a feasibility study of alternative juvenile fish passage plans and an installation schedule for a permanent bypass system.
	Intake Screens
	Conduct testing of turbine intake screens in prototype, using a 90% FGE standard, and to install a juvenile fish screening and bypass system by April, 1990. The 1991 amendments to the FWP called for installation of screens and a bypass system at Ice Harbor by 1994. The COE complied. Screens were in place in 1993 and the full bypass by 1994.
	NMFS/NOAA Recovery Plan Requirements
	Extended Screens
	Extended length screens and structural improvements to improve gatewell hydraulics should be planned, contingent upon the results of prototype screen testing at Little Goose and Lower Granite dams.
	Flip Lip
	The Plan calls for the COE to install stilling basins and spillway modifications (such as a flip lip) to reduce dissolved gas levels at Ice Harbor Dam as soon as possible. The COE plans to design a flip lip spillway for Ice Harbor Dam in 1996 and construct it in 1997. (COE Columbia River Fish Mitigation Project Draft Plan, November 2, 1995.)
	Surface Collector
	The Proposed Recovery Plan adopted by NMFS/NOAA in 1995 states that testing of the surface collector approach will begin in 1995 at Ice Harbor and The Dalles dams, to be followed by tests in 1996 at Lower Granite Dam. The Plan states that if successful, they should be installed in 1996 at the spillways tested. In 1995 the COE conducted several studies of prototype surface attraction configurations at Ice Harbor Dam.
	Not in the NPPC or NMFS Requirements
	Surface Spill
	The COE is investigating the possibility of employing surface spill at Ice Harbor Dam, (Biosonics, 1995) (Abstract presented at COE meeting of September, 1995).

Table 4. (Continued) Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules.

LOWER RIVER PROJECTS

Project	**Requirements by NPPC and NMFS. With Compliance.**
McNary Dam	NPPC Requirements
	Improve Bypass
	The Council's FWP of 1987 called for the COE to continue to evaluate and improve the effectiveness of the juvenile fish bypass system at McNary Dam, because of changes that had been made since 1968 when installation of the system was begun.
	Extended Screens
	To be installed by April, 1994. The COE scheduled prototype tests for 1995, (COE, 1992).
	NMFS/NOAA Recovery Plan Requirements
	Operate Bypass
	The bypass system should be operated according to criteria that will mitigate adverse warm water conditions in the summer. It calls for shading over the raceways by the end of 1995.
	Extended Screens
	The Plan calls upon the COE to continue the scheduled installation of extended-length screens for the 1997 season. The COE completed installation in time for the 1996 emigration. (Filardo memo, January 18, 1996)
John Day Dam.	NPPC Requirements
	Intake Screens
	Called upon the COE to proceed with its plan to install a complete bypass system with turbine intake screens by March, 1987, and to evaluate and improve its effectiveness. Screens were in place by 1992 (COE Salmon Passage Notes, 1992)

Table 4. (Continued) Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules.

Project	**Requirements by NPPC and NMFS. With Compliance.**
John Day Dam (Continued)	
	NMFS/NOAA Recovery Plan Requirements
	Extended Screens
	Extended length screens should be installed at John Day Dam by spring, 1998.
	Flip Lip. The Plan calls for the COE to install stilling basins and spillway modifications (such as a flip lip) to reduce dissolved gas levels at Ice Harbor and John Day dams as soon as possible. The COE intends to design a flip lip spillway in 1996 and begin construction in 1997 for completion in 1998. (COE Columbia River Fish Mitigation Project Draft Plan, November 2, 1995)
	Surface Collector
	If testing of surface attraction is successful at Ice Harbor and The Dalles, the COE should proceed with testing at John Day Dam in 1997. The COE has scheduled studies at John Day in 1997 and 1998.
The Dalles Dam.	NPPC Requirements
	Intake Screens
	The 1987 FWP says that at the Dalles, where the COE had depended upon an ice and trash sluiceway for juvenile fish bypass, the COE should proceed with installation of turbine intake screens.
	Extended Screens
	The COE was called upon to complete prototype testing of extended screens by April, 1991, and to complete design and installation of a juvenile fish screen and bypass system by April, 1993. The 1991 amendments to the FWP called for the installation of screens and a bypass system at The Dalles by 1998. In 1992 extended length screens were scheduled by the COE for installation by March 1998 (Salmon Passage Notes. Special Edition, 1992)
	NMFS/NOAA Recovery Plan Requirements
	Intake Screens
	The COE should continue designing a conventional intake screen system for installation at The Dalles. Following prototype testing, a decision should be made whether to continue developing a surface collection system or to proceed with installation of the screens by 1999.
	Surface Collector
	(See previous entry - Intake Screens.) The Proposed Recovery Plan notes that the COE plans to test a surface collector at The Dalles Dam in 1995. The COE will test the surface collector in 1996.

Table 4. (Continued) Requirements for Installation of Bypass Systems (Flip Lip Spillways, Intake Screens, Extended Screens, Surface Attraction Devices, and Other) at Snake River and Columbia River Projects, With Compliance Schedules.

Project	**Requirements by NPPC and NMFS. With Compliance.**
Bonneville Dam.	NPPC Requirements Improve Bypass The 1987 FWP called upon the COE to continue feasibility studies of means to improve juvenile fish guidance at the second powerhouse. Because of low FGE measured for the screens at the second powerhouse, the second powerhouse was to be closed when necessary to achieve an 85% juvenile fish passage through combinations of spill and bypass operation at Bonneville Dam. The COE was called upon to provide annual progress reports until an 85% juvenile fish passage is achieved. As of 1995 this goal had not been attained. The 1991 amendments to the FWP called for installation of improved screens and bypass at Bonneville Dam's second powerhouse by March, 1993, and evaluation of FGE at the first powerhouse. NMFS/NOAA Recovery Plan Requirements Improve Bypass Calls upon the COE to relocate the downstream migrant outfalls by spring 1999. {Bypass survival tests at Bonneville Dam suggest that predation in the tailrace may be substantial, (Ledgerwood et al., 1990). The COE should improve hydraulic conditions at the dewatering systems in both bypass systems at Bonneville Dam by the year 2000. The Plan also calls for improved FGE at the Bonneville first powerhouse, with no date specified.

Appendix F

History of the Juvenile Transportation Program

Transportation of juvenile fish began in the late 1960s and early 1970s (Mighetto and Ebel, 1995) The National Marine Fisheries Service originally used modified tanker trucks to transport fish from Little Goose Dam and later expanded to include transport from Lower Granite Dam. In 1976, the Corps acquired a fish trailer for transportation research with a water capacity of 13,253 liters, accommodating 794 kg of fish, which is the equivalent of 10,500 emigrant steelhead or 24,500 emigrant spring and summer chinook. As NMFS design criteria developed, the Corps purchased four more trucks for the transportation program. In 1977, the Corps leased two barges and converted them for fish transportation. After the 1977 season, the Corps purchased two barges with a capacity of 174,167 liters which each could accommodate 10,433 kg fish, 138,000 emigrant steelhead, or 322,000 emigrant spring and summer chinook, for operation in 1978. A third barge of 22,727 kg capacity was completed in 1980 and the fourth barge 378,624 liters, 22,680 kg fish, or 300,000 emigrant steelhead, or 700,000 emigrant spring and summer chinook was completed in 1981. Improvements in the barges included better pumps, better circulation systems, shut off valves, and improved release systems. NMFS continued research on the effects of transportation on stress and survival in juvenile salmon.

In 1981, after 13 years of NMFS research, the Corps began mass transportation of juvenile fish using barging and trucking. The Corps used the existing five tanker trucks and the four barges. This collection and transportation equipment was used through the 1980s.

In 1990, the Corps acquired two new barges to meet the need of transportation as more hatcheries were completed above Lower Granite Dam. The Corps barging was now at full fish capacity, using six barges, as follows: two at 10,455 kg each, two at 22,727 kg each, and two at 567,935, liters, accommodating 34,000 kg fish, which is the equivalent of 450,000 emigrant steelhead, or 1,050,000 emigrant spring and summer chinook each. For 1993, the Corps acquired three fish tanks 568 liters, 34 kg fish, or 450 emigrant steelhead, or 1,050 emigrant spring and summer chinook that can be transported in a pickup truck. During 1994, the Corps added four new tanker trailers similar to the design and capacities previously described, except with stainless steel construction.

Juvenile fish detection systems have been developed and installed in the dams. During the 1980s, the passive integrated transponder, PIT, tag was developed. Juvenile PIT tag detection exists at Lower Granite, Little Goose, Lower Monumental and McNary dams. At these locations, all the fish pass through a slotted gatewell allowing detection. Flip gates, deflecting fish back to

the river on detection, are installed in Lower Monumental Dam and McNary Dam. Juvenile PIT tag evaluation systems are installed in John Day Dam and Bonneville Dam, however, only about one percent of the fish are sampled for detection at these dams.

Currently, the Corps operates the juvenile fish collection and transportation system for chinook and steelhead from Lower Granite, Little Goose, Lower Monumental and McNary dams to release sites at Bradford Island and below Bonneville Dam, between River Mile 144 to 141 (Figure 5.1). Fish are collected by screens at the entrance to the turbine galleries, after which they pass through a tunnel or flume to the collection facility. Juvenile fish are separated from adult fish and debris. Then, they are routed into holding tanks, sample tanks, or directly into barges for transportation down the river.

All transported fish are handled according to criteria established with the Fish Passage Advisory Committee (FPAC) of the Columbia Basin Fish and Wildlife Authority {FTOT 1993}. Maximum holding density is currently 0.5 lbs./gallon in raceways. Early and late in the season, when fish numbers are less than 20,000 per day at Lower Granite Dam, the 3,500 gallon fish trucks are used to transport fish. The Corps uses two at Lower Granite Dam, one at Little Goose Dam, one at Lower Monumental Dam, two at McNary Dam and one held in reserve as a spare. These trucks are insulated, equipped with refrigeration, aeration, oxygenation and recirculation equipment. At a maximum density of 0.5 lbs./gallon, each truck can haul up to 1,750 pounds of fish. When fish numbers are higher, the barges are used. Six barges are available, two at 23,000 lbs., two at 50,000 lbs., and two at 75,000 lbs. fish capacity. Pumps are used to circulate river water through aeration chambers to ensure adequate dissolved oxygen and to reduce gas supersaturation. Due to low fish numbers present for summer and fall transport, the three mini-tankers are used. Mini-tankers are not used at McNary Dam because of the presence of large numbers of American shad mixed in with the juvenile salmon and steelhead.

The length of time in transit varies according to location of collection from each dam and whether transportation is by truck or barge. Truck transport from Lower Granite Dam takes 8 to 10 hours; from Little Goose Dam takes 6 to 8 hours; from Lower Monumental Dam takes from 5 to 7 hours, and from McNary Dam takes 4 to 5 hours. Completion of barge transport from Lower Granite Dam takes about 36 hours, while completion of transport from McNary dam takes about 15 hours.

The transportation and release of fish to mid-April is by truck from Lower Granite and McNary Dams to Bradford Island (north end of Bonneville First Powerhouse), where they are released through a pipe into the river (see Figures 7.1 and 7.4). Fish are barged during mid-April to mid-June, from Lower Granite, Little Goose, Lower Monumental and McNary dams to random release sites between buoy No. 92 (RM 144) and Warrendale, Oregon (RM 141). After fish collection drops to about 1,750 pounds per day at Lower Granite Dam, barging shifts to

McNary dam, and trucking resumes from Lower Granite, Little Goose, and Lower Monumental dams. Barging continues from McNary Dam until about the end of July, when trucking resumes. After mid-June to the end of the transportation season, large fish trucks and the 150 gallon mini-tankers are used from the Snake River dams. Trucking continues through the transportation season ending about October 31, but may continue into early December. The transportation system is planned to operate through October 31.

The practice of transportation evolved from research conducted in the Fish Passage Development and Evaluation Program (FPDEP; *see* (Ebel et al., 1973), {Ebel 1980}, (Mighetto and Ebel, 1995) within the North Pacific Division of the COE. The program became a part of the operations within the Walla Walla District of the COE and functioned under the oversight and coordination of the Fish Transportation Oversight Team (FTOT), composed of representatives of COE, state fisheries agencies (Idaho Department of Fish and Game) and federal fisheries agencies (National Marine Fisheries Service). For a time, 1984 to 1987, a representative of the Columbia River Inter-Tribal Fish Commission also participated as a member of the FTOT. The responsibilities of the FTOT can be found on page 5 of Basham et al. {1983}. The Walla Walla District, COE, is preparing a technical appendix to the System Operations Review EIS that will also contain a detailed discussion on the background of transportation. Park {1985}**,** (1993) also discusses the history of transportation facility development.

The research on fish transportation conducted prior to 1981 was generally accepted, on an interim basis, by the state and federal fisheries management agencies as having demonstrated positive effects in the form of increased survival of juvenile migrants through the hydroelectric system {FPC 1993}. Transportation was perceived within the region to be one of several means that could be employed to reduce losses of juvenile salmon in the hydroelectric system during their annual seaward migration. Other mitigative measures pursued included installation of mechanisms allowing the juveniles to bypass the turbines, and hydroelectric project operation modes that included passing migrants over the spill ways, a path that also allowed the juveniles to avoid the turbines. In addition, short term increases in the volume of water released into the hydroelectric system from storage reservoirs at critical points in the spring in an attempt to move fish more rapidly into collection facilities, and through the hydroelectric system.

As one of a number of survival enhancement techniques of potentially critical importance to the survival of Columbia River Basin salmon, juvenile salmon transportation has received intense scrutiny over an extended period of time, since the possibility was first considered for the Snake Basin by NMFS in 1965 (Ebel et al., 1973). Moving juvenile salmonids around hydroelectric dams and reservoirs by truck or barge in the Columbia River Basin was first tested by the National Marine Fisheries Service, NMFS, in 1968 at Ice Harbor Dam and it has been studied extensively by a number of authorities since then (Matthews et al., 1992). For the

purposes of research and evaluation, NMFS implemented transportation of all juvenile salmon collected at Little Goose Dam in 1975, followed in 1976 by Lower Granite Dam, and in 1979 by McNary Dam (Figure 5.1). The concept of mass transportation evolved from the special operations (Operation Fish Run) conducted in 1977 in response to severe drought conditions. A description of this activity can be found in the October, 1977 report, prepared by the Committee on Fishery Operations, titled "Special Drought Year Operation for Downstream Fish Migrants." (D. Geiger, COE, North Pacific Division, personal communication). Based on the apparent success of experimental programs at reducing mortalities of juvenile salmon associated with hydroelectric passage, the mass transportation program was implemented as an operational program under the U.S. Army Corps of Engineers in 1981 at the same three dams {Basham et al. 1982}.

What may have been the earliest transportation work in the Columbia River was done by the Washington Department of Fisheries using 1954 brood year Klickitat River (lower Columbia River above Bonneville Dam) fall chinook {Ellis and Noble 1960}. At the time of the work of Ellis and Noble {1960}, the lower Columbia River had only one dam below the release areas, Bonneville, so the hydroelectric system of that time is not comparable to that of today. In addition, differences in juvenile fish marking procedures make much early work, such as this, difficult to compare with modern transportation research. Transportation research has also been conducted by the Public Utility District of Grant County, Washington, in cooperation with the NMFS {Carlson and Matthews 1992}. The evaluation of transportation from the hydroelectric dams operated by Grant County P.U.D. is part of a Federal Energy Regulatory Commission proceeding bearing on the scientific aspects of transportation (Chapman et al., 1991).

Most recent studies of transportation have been done at Lower Granite Dam (Matthews et al., 1990; Matthews et al., 1992); {Matthews et al. 1985, 1987, 1988, see Figure 5.1}. Transportation research has also been done by NMFS at McNary Dam, below the confluence of the Snake and Columbia Rivers, as it has been done at the Grant County research at Priest Rapids and Wanapum Dams {Carlson et al. 1987a, 1987b, 1988, 1989, and Carlson and Matthews 1992}. Although survival trends and general principles may be similar among all Columbia River Basin transportation programs, the specifics of each species-life-history type-dam combination may be expected to be unique, until proven otherwise. While the physical circumstances of the Columbia River sites are similar to those of the Snake River studies, the comparability of the maturity of the juvenile salmon at McNary, Priest Rapids and Wanapum Dams to the maturity of the juveniles arriving at the Lower Granite Dam on the Snake River is one uncertainty among many. The work at Lower Granite Dam is part of a larger program of study conducted by NMFS (see (Matthews et al., 1992)), and all of this work was also considered by the team.

Other work on the transportation of juvenile salmonids in the Columbia Basin is of interest, but it may not be directly comparable to the physical circumstances of the NMFS research. For example, Slatick has attempted to examine the effects of imprinting prior to transportation and degree of smoltification on the homing ability of transported smolts {*see* Slatick et al. 1988a, 1988b, 1988c}, and experiments involving direct transportation of juveniles from hatcheries have been conducted (for example, R. Bugert, Washington Department of Fisheries and Wildlife, Lyons Ferry fall chinook). In one of the few Snake River studies that was specifically designed to measure rate of return to the point of natal origin, Bjornn and Ringe {1984} looked at return rates of hatchery chinook and steelhead allowed to migrate a short distance before transportation. Return rates of transported fish to the hatchery in Idaho were lower in all cases than those of control fish allowed to transit the river, while return rates to the mainstem below the Snake were higher for transported fish. A survey and synthesis of the literature on fish transportation has been recently completed by Wedemeyer {1994}, and a bibliography on transportation that reviews all aspects of transportation, dam passage, and stress physiology separately, in an interactive electronic format, has also been recently completed {Davis and Schreck 1994}.

Further details on the history of the NMFS transportation program may be found in reviews (Ebel et al., 1973), {Ebel 1980}; {Park 1985 and 1993}; {Shepard 1988; Matthews 1992}, (Matthews et al., 1992); {FPC 1993}; (Mighetto and Ebel, 1995)). The literature reviews provide substantial insights into the scientific and philosophical origins and accomplishments of the program. It is clear that the transportation program was a reaction to the development of the Columbia Basin hydroelectric system. The central thesis of transportation was expressed by Donn Park {1985}, " ... survival of salmonid smolts[i] could be substantially increased if the fish were collected at an uppermost dam, transported to a safe release site below Bonneville Dam, and released into the Columbia River -- thereby bypassing as many as seven dams and their associated problem areas." (p. 2-1; see also {Ebel 1980}.

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[i] The term, *smolt*, designates the life history stage of the salmon that is in the process of making the transition from freshwater to salt water residence.