EVALUATION OF THE INSTREAM FLOW INCREMENTAL METHODOLOGY APPLIED TO THE LOWER SNAKE RIVER

by

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B.S. Civil Engineering
Colorado State University

Submitted to the Department of Civil and Environmental Engineering In Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

The Lower Snake Dam Controversy began in 1990 and continues today with numerous studies and reports that attempt to evaluate the cause of the salmon population decline along the Lower Snake River. Many federal and state government agencies and private parties are involved in determining the best option/options for restoring the salmon populations, with the removal of the four lower Snake River dams as a possibility for salmon habitat restoration. How has the controversy progressed over the last ten years? Has the Corps of Engineers, the organization compiling the most comprehensive study of this region, followed any type of methodology? This report attempts to answer these questions.

First, the Lower Snake River Dam Controversy is introduced by giving background information concerning the issues and stakeholders. Then, the Instream Flow Incremental Methodology (IFIM), including its origins and its four phases, is presented to the reader. The report goes on to explain that, although not formally adopted, the study process to evaluate alternative water management schemes in hopes of restoring the salmon population has followed the general framework of IFIM. Finally, the report addresses concerns about the studies already performed and the issues that have not yet been addressed, and provides recommendations for salmon population restoration in the future.

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Chapter 1: History of the Lower Snake Dams

1.1 Background

Four dams (Lower Granite Dam, Lower Monumental Dam, Ice Harbor Dam, Little Goose Dam) along the lower Snake River have greatly altered the river system, to the extent of disturbing the migration and life cycles of salmon and other fish. See Figure 1, a map of the Northwest region, indicating the location of the four dams. Salmon populations in the Snake River have experienced many significant changes to their environment since at least 1865 (Anderson, 1995a), and the degree to which the dams have affected the salmon population is the subject of much dispute. Some of the pertinent events that have taken place since 1865 are fluctuations in the fishing industry, changes in ocean conditions, the development of the Snake River dam system, and the decreased flow velocities in reservoirs behind the dams (Anderson, 1995b). Figure 2 indicates how fish populations have fluctuated in past years.

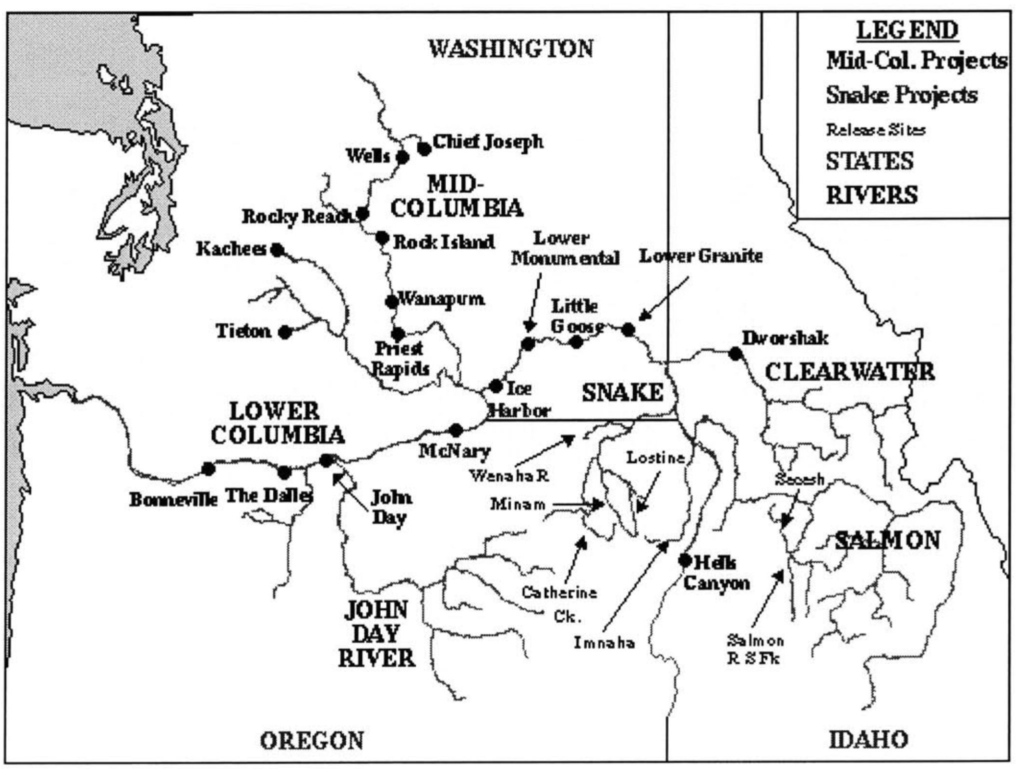

Figure 1 - Map of lower Snake River dams and surrounding region. (UW, 1999)

In its Draft Feasibility Report/Environmental Impact Statement (Draft FR/EIS), the Corps of Engineers investigated several options to rejuvenate the salmon population in the lower Snake River; the most controversial option, and the option that the Corps lists as its first choice, is dam breaching.

There are several viewpoints regarding the issue of dam breaching. For brevity, these viewpoints are summarized broadly into those for and those against dam breaching. Section 1.4 of this report provides detailed position statements from many of the organizations mentioned in the following paragraph.

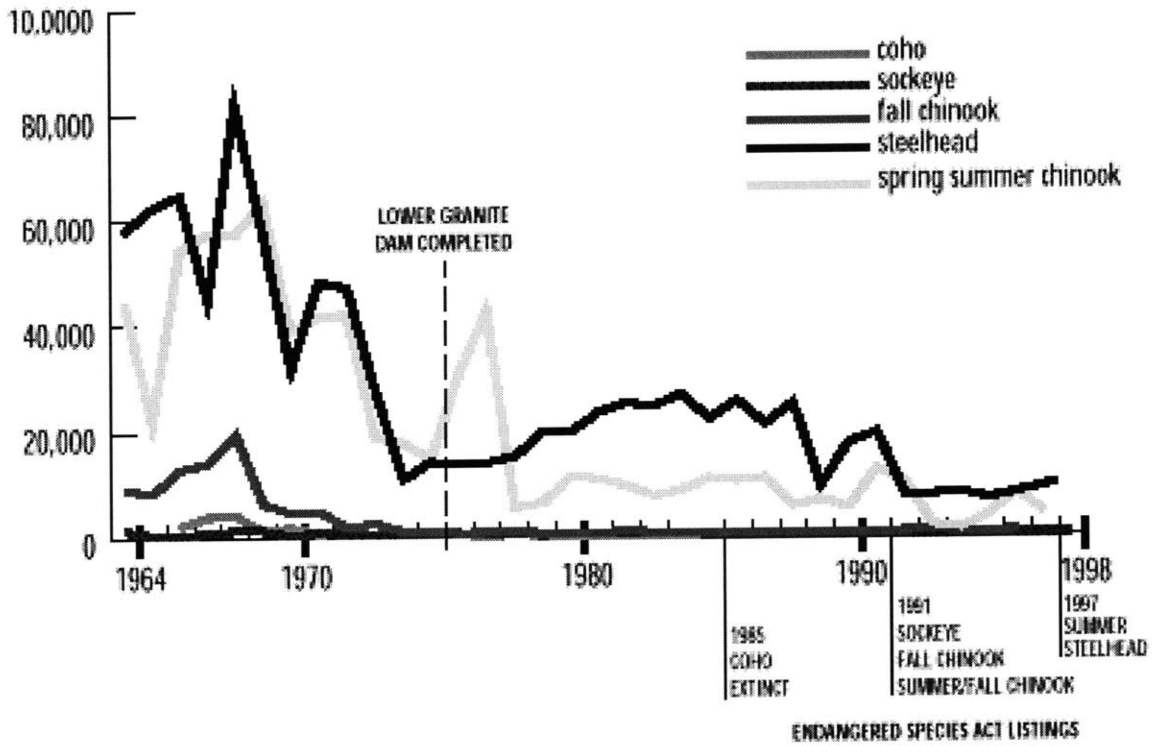

Figure 2 - Decline in Snake River fishes (USACE, NWW, 1999).

Proponents of dam breaching or removal include commercial and sport fishermen, some conservation groups, and several well-respected scientists. Sport fishing advocates such as Idaho Rivers United believe that the dams have caused irreparable harm, the inability of the fish to rejuvenate their own populations, to the salmon. Therefore, only a return to "natural", pre-dam conditions can restore the fish populations (CyberLearn, 1999).

Commercial fishing concerns like the Pacific Coast Federation of Fishermen's Association blame the dams for the majority of juvenile fish kills in the river (CyberLearn, 1999). Public agencies such as the National Marine Fisheries Service agree that decommissioning the dams would restore salmon and steelhead populations (NMFS, 1995), although whether they support dam breaching is unclear. A reason presented for the fish decline is unacceptable habitat and migratory conditions in the lower Snake River caused by the alteration (by the dams) of the once free-flowing Snake River into a combination free-flowing sections and reservoirs. It is believed that these changes to the environment have destroyed salmon spawning and migrating habitat. It is also difficult for the salmon to get through the dams to migrate upstream and downstream.

Those who oppose dam removal claim that there are other ways to restore the fish population that would have less drastic consequences on the Northwest. The opponents include industrial, commercial, and farming industries. The Pulp and Paper Workers Resource Council (Rocky Mountain Region) is one group that opposes dam breaching on the grounds that the expense of the measure does not justify its uncertain benefits. Among the alternatives they propose are more frequent use of dam spillways to transport fish downstream, continued barging of fish, and periodic drawdowns to natural river levels, intended to restore flows to the water surface elevations that existed in the Snake River prior to impoundment. This is also intended to simulate a free-flowing river during spawning and migrating seasons. There is scientific criticism that not enough is known about the effects of the dams on the salmon population to conclude that dam removal will improve conditions for salmon in the river (Bouck, 1999). If the dams are breached, the Lower Snake River will lose its navigation, irrigation, and hydropower generating capabilities. The economic and social consequence of these changes is jobs that depend on these current capabilities, either directly or indirectly, will be affected. The proposal to breach the four dams thus deserves careful examination before a decision is taken on whether to adopt it.

1.2 Controversies

Several controversies surround the issue of the decline of the Snake River salmon. It is unclear exactly why the salmon are in a state of decline, however, there are several theories including: 1) the development of the lower Snake River dams, including navigation, agriculture/irrigation and hydropower, 2) salmon harvest/overfishing, and 3) change in ocean conditions. Descriptions of these possible causes of salmon decline follow.

1.2.1 Development of Lower Snake River Dams

The Snake River, the 1,078-mile principal tributary of the Columbia River, flows from Wyoming to its confluence with the Columbia River near Pasco, WA (USACE, 1999). The lower Snake River has several major tributaries including the Clearwater, Tucannon, and Clearwater rivers. The Clearwater River is the largest tributary of the lower Snake River segment and contributes about 39% of the combined flow in the lower Snake River reach. The Tucannon and Palouse rivers, on the other hand, flow into Lake Sacajawea behind Lower Monumental Dam and contribute only 1.5% of the Snake River flow. The four dams that span the Lower Snake River include, from upstream to downstream, the Lower Granite Dam, Little Goose Dam, Lower Monumental Dam, and Ice Harbor Dam (Figure 1). In addition to these four dams, three other dams were built along the lower Columbia and all seven dams allow varying degrees of passage for salmon (USACE, 1999).

Table 1 indicates the dates that the seven dams were constructed. Since the completion of the last of the dams in 1975, they have been providing irrigation, navigation, and electricity generation capabilities to residents of the Northwest.

The seven dams along the lower Snake and lower Columbia rivers inundated 227 and 294 kilometers of mainstem habitat respectively (USACE, 1999). This changed the lower Snake River from a mostly free-flowing body into a series of reservoirs covering about 70% of the distance between Lewiston, Idaho and the Pacific Ocean (USACE, Main

Table 1 - Construction dates of lower Snake River Dams

Name	Location	Construction Date
McNary Dam	Lower Columbia	1954
Dalles Dam	Lower Columbia	1957
Ice Harbor Dam	Lower Snake	1961
John Day Dam	Lower Snake	1968
Lower Monumental Dam	Lower Snake	1969
Little Goose Dam	Lower Snake	1970
Lower Granite Dam	Lower Snake	1975

Report, Section 4.1, 1999). The reservoirs are slow moving and have decreased the rate of downstream travel for juvenile fish and increased the amount of habitat favorable to exotic and predator species. The operation of the dams may also alter river flows in ways that affect salmons spawning, rearing and migration by preventing fish from accessing spawning grounds and destroying suitable salmon habitat.

1.2.2 Navigation

Part of the function of the lower Snake River dams is to create a waterway capable of allowing large shipping vessels and barges, which transport agricultural products and industry products to market, to travel up and down the river.

Eight mainstem dams and lock facilities along the lower Columbia and Snake rivers provide navigation along a 465-mile waterway, the Columbia-Snake Inland Waterway, from Lewiston, Idaho to the Pacific Ocean. The navigation system is comprised of two segments: the downriver portion, which provides a deep-draft shipping channel, and the upriver portion, which is a shallow-draft channel with a series of navigation locks (USACE, Main Report, Section 4.9, 1999). The portion of the navigation system dealt with in this report is the shallow draft portion of the waterway, a Federally-maintained channel and system of locks that spans from Vancouver, Washington to Lewiston, Idaho.

Specifically, this report is concerned with the section extending from the mouth of the Snake River (Columbia River Mile [RM] 325 to Lewiston, Idaho (Snake River RM 141) where the Lower Monumental, Lower Granite, Ice Harbor, and Little Goose dams are located. This channel has a minimum authorized depth of 14 feet at the minimum operating pool (MOP) elevations of each of the upriver dams. This portion of the channel is 250 feet wide and accommodates numerous types of barges, tugs, log rafts, and recreational boats. The main purpose of navigation along the Columbia and Snake Rivers is barge transportation of commodities, which accounts for virtually all of the commercial shipping activity on the shallow-draft portion of the Columbia-Snake Inland Waterway. Commodities are transported through the waterway system on non-powered barges propelled by tugboats. Typical operations involve a tow, ranging from one to five barges, pushed by a single tugboat (USACE, Main Report, Section 4.9, 1999). The majority of the commodities transported along the lower Snake River include wheat and barley (75.1%), wood products (20%), petroleum products (3.1%), and other farm products, chemicals, and sand and gravel (1.8%) (USACE, Main Report, 1999).

Dam operators regulate water releases to maintain reservoir levels to provide minimum navigation depths year-round because barges and other river traffic need minimum water depths to successfully and safely navigate the river. Besides the release of water to maintain minimum water depths for the channel, periodic dredging of the channel is also done to maintain the channels. Dredging affects the hydrology of the river channel by disturbing the channel bottom, increasing the current and moving suspended sediments that can scour the shoreline and the bottom of the channel. Dredging may also disturb sediments with toxic substances that can be harmful to plants and animals- a possible cause of the salmon population decline. However, channel maintenance is imperative to the economy of the Northwest because large quantities of goods are transported along the waterway.

It is important to note that the Columbia-Snake Inland Waterway is not the only means of transporting goods in the Northwest region. Many commodities are transported by trucks on highways and by rail. However, the Waterway provides transportation for a substantial amount of the total goods shipped and has been vital to the economy of the area.

1.2.3 Hydropower

Another purpose of the dams along the lower Snake River is to generate hydropower to provide the cheapest electricity in the nation for residents of the Northwest (USACE, 1999). All four dams along the lower Snake River (Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, and Lower Granite Dam) have hydroelectric power generation capabilities. Table 2 indicates the power generated by each of the dams.

Table 2 - Hydroelectric Power along the Lower Snake River (USACE, Executive Summary, 1999)

Dam	# of Generators	Size of Generators (MW)
Ice Harbor Dam	3	90
Ice Harbor Dam	3	30
Lower Monumental Dam	6	135
Little Goose Dam	6	135
Lower Granite Dam	6	135

The powerhouse portion of the dam houses large generators for producing electricity. Water upstream of the dam passes through turbines in the powerhouse, rotating them at 90 revolutions per minute, then passes the water downstream of the dam. The release of the water can cause downstream scouring, increased gas supersaturation, increased DO in deeper water, increased turbidity, and re-suspension of contaminated fine sediments. Upstream impact may include decreased water volumes and flows, decreased DO concentrations (water does not move as fast so air is not entrained as easily) and, increased pollutant concentrations" (USACE, Executive Summary, 1999).

Water released through spillways and increased water temperatures can also increase total dissolved gas concentrations, which can cause gas bubble disease in fish and lead to death or behavioral disorders. The degree to which fish are affected has to do with the species, life history stage, water temperature, depth, and length of exposure (USACE, Main Report, Section 4.4, 1999).

Water temperatures may be affected by reservoirs because more water surface area is exposed to wind, solar radiation, precipitation, and evaporation. Reservoirs also become stratified from seasonal temperature differences, however, the reservoirs along the lower Snake River do not stratify in this sense. Instead, there is a temperature difference in the shallower and deeper water because the dams are run-of-river: they have limited storage capacity in the reservoirs and pass water through the dam at about the same rate as water enters the reservoir (USACE, Executive Summary, 1999). The water flowing to the reservoirs from the free-flowing portion of the river is cooler and tends to settle at the bottom of the reservoirs.

1.2.4 Agriculture/Irrigation

An extremely important function of the reservoirs created by the four dams along the lower Snake River is irrigation for approximately 37,000 acres of farmland in the Northwest region. Most of the water diverted for irrigation comes from the Ice Harbor Reservoir. The water used for irrigation transpires, evaporates, seeps into the ground as groundwater, or runs off the fields and eventually returns to the Snake River or its tributaries as potential point or non-point source pollution primarily because pesticides and fertilizers dissolve in the water. This chemical pollution can affect the habitat of the lower Snake River and harm or kill many of the native plant and animal species residing in or near the river.

Irrigation provides fields for livestock grazing, which present another potential problem to the water quality of the lower Snake River and its reservoirs. Grazing near rivers and streams can destroy riparian vegetation and habitat needed to shade streams to prevent erosion (USACE, Main Report, Section 4.4, 1999). Grazing also reduces the holding capacity of watersheds, which can result in increased runoff velocities that lead to excessive erosion and sedimentation of streams.

Despite the sometimes devastating environmental effects of agriculture, it is important to consider that the farmers of the region may experience economic ruin if the irrigation in the Northwest region is halted.

1.2.5 Salmon Harvest/Overfishing

When Lewis and Clark came to the Northwest region they discovered the huge salmon populations and identified them as a food source. Pioneers traveled to the region to settle it, and began commercial salmon fishing after they realized that they could sell the fish for profit. Huge fish nets were used to capture thousands of salmon every year and gigantic canneries were set up along the Columbia River. Fishing became a big business in the Northwest. By the turn of the century wildlife experts realized that salmon populations were very low and warned that they were becoming extinct (CRA, 2000). Overfishing took a severe toll on the salmon of the Northwest even before dams were constructed.

There are 3 types of salmon harvest: recreational, tribal, and commercial. Up until the 1970's catch rates often exceeded 90% of a total run. This means that 9 out of every 10 fish in a given run were caught. To maintain sustainable fish runs most research shows that harvest should not exceed 20% of a run. These unsustainable fishing practices have devastated and continue to devastate many salmon populations.

1.2.6 Change in Ocean Conditions

The dams along the Columbia and Snake Rivers have caused problems for the salmon since the 1930s, but another problem, a more recent one, is also causing problems for the salmon. A change in the ocean conditions in the late 1980s associated with El Nino and warming brought predators northward to the Northwest region and reduced salmon food supplies. Some believe that this ocean warming trend significantly contributes to salmon decline in rivers up and down the West Coast regardless of whether or not they have dams (DSI, 2000). Salmon cannot survive if the ocean temperatures are too warm.

While the Pacific Northwest is experiencing warm temperatures, the cooler water has been pushed up to Alaska where the salmon population is booming (CRA, 2000).

1.3 Salmon Species in the Lower Snake River

The Columbia and Snake Rivers support many different species of anadromous fish. Anadromous fish hatch in freshwater rivers and streams, migrate to the ocean where they mature, then return upstream to the freshwater rivers to spawn. Although there are many species and several stocks of anadromous fish that inhabit the Columbia and Snake River, the only four species dealt with in this report are: sockeye salmon, fall chinook salmon, spring/summer chinook salmon, and steelhead. All of these fish are listed on the Federal Endangered Species Act (ESA). Snake River sockeye salmon were listed as endangered species on November 20, 1991 while Snake River spring/summer and fall chinook salmon were listed as threatened on April 22, 1992 (CyberLearn, 2000). Portions of the Columbia and Snake Rivers used by the above mentioned salmon have been designated as critical habitat under the ESA as a result of the endangered and threatened species listings. The depletion of these and other stocks has probably occurred because of changing ocean conditions, overharvesting, reduced spawning habitat quantity and quality and the dams along the Columbia and Snake Rivers which have interfered with migration.

Before going on to describe each salmon species, it is helpful to understand their lifecycle. Figure 3 shows the lifecycle of a salmon.

1.3.1 Sockeye Salmon (Endangered)

Of the four types of anadromous fish mentioned in the above section, the sockeye salmon is the most depleted in the lower Snake River. Because there are so few fish in the river, it is impossible to experimentally measure the impact of the four dams on their passage survival (USACE, Appendix A, 1999). There are no data available on the migration rates

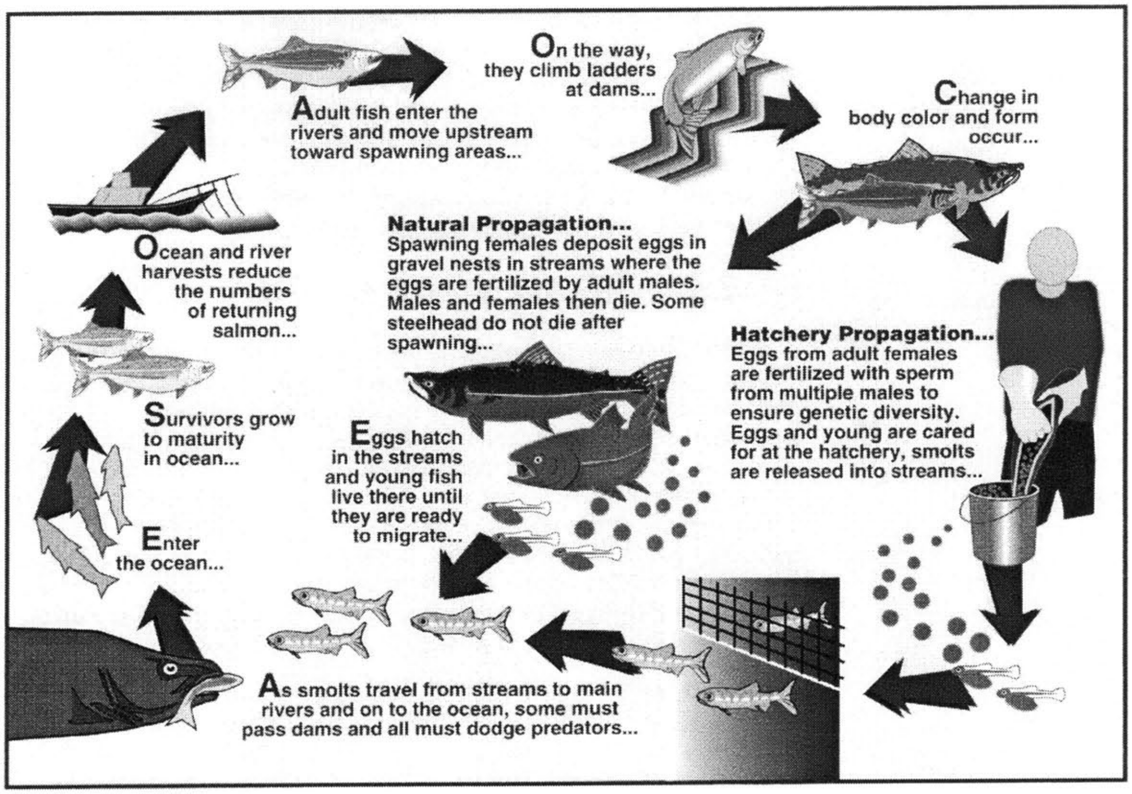

Figure 3 – Lifecycle of a Salmon (Adapted from USACE, 2000)

of adult sockeye salmon through the lower Snake River or the free flowing section above the Lower Granite Reservoir (USACE, Appendix A, Section 8.2.2.2, 1999). Adult sockeye salmon start entering the Columbia River in April and continue to pass the dams through October, with the majority of the passage occurring from June to August. Sockeye salmon, unlike the other types of salmon discussed in this report, require lakes for juvenile rearing areas, thereby limiting their distribution along the Columbia and Snake Rivers to the Wenatchee and Okanogan river areas of the upper Columbia region and the upper Salmon River (a tributary of the Snake River). Juvenile fish reside in the lakes for roughly one to two years, migrate to the ocean from April to July where they spend about two years, then return to the lakes to spawn (Bjornn et al., 1968). Their decline is largely due to agricultural diversions according to Chapman et al. (1990). More than 68 agricultural diversions are along the Salmon River and many completely dewater the streams making it impossible for sockeye salmon to reach the reservoirs necessary for spawning.

1.3.2 Fall Chinook Salmon

Fall chinook salmon are mainstem spawners, meaning they do not spawn in streams or tributaries. They enter the Columbia River in July and pass the mainstem dams by the end of November (USACE, Main Report, Section 4.5.1.1, 1999). There are two groups of fall chinook salmon that inhabit the Columbia and Snake River system- 1) "tules" which reside in the lower Columbia and 2) "upriver brights" which spawn in the upper Columbia and Snake River system. Because this report focuses on the lower Snake River, only the upriver brights are discussed.

Prior to the construction of Hells Canyon dam and the four dams along the lower Snake River, estimates of fall chinook escapement to spawning areas in the lower Snake River averaged 19,447. Production rates (that is, spawners to returning adults) for Snake River fall chinook salmon from 1940 to 1955 ranged from 1.9:11 50 3.2:1 (USACE, Appendix A, Section 6.0, 199; Irving and Bjornn, 1981). This indicates that fall chinook populations were healthy prior to dam construction because the fish were replacing themselves and providing overabundant adult production for harvest. After the construction of the dams, returns to the Snake River dramatically dropped perhaps because the dams greatly reduced the habitat available to fall chinook salmon.

Today the spawning area for fall chinook salmon consists of 103 miles below Hells Canyon Dam including incidental deep water spawning below Lower Granite, Little Goose, and Ice Harbor dams.

1.3.3 Spring/Summer Chinook Salmon

Spring and summer chinook salmon begin migration upstream in April and continue to migrate through October. There are five major spawning and rearing basins for the spring/summer chinook salmon, which include three large river basins (Clearwater, Grande Ronde, and Salmon rivers), and two small basins (Tucannon and Imnaha rivers).

The spring chinook salmon travel further up tributaries to spawn than do summer chinook salmon (Matthews and Waples, 1991). Because the Columbia Snake River System has both spring and summer chinook, the spawning area and timing generally overlap for the two types of salmon, however the spring chinook salmon tend to begin migration a bit earlier than summer chinook salmon. Snake River spring and summer chinook salmon spend about a year in the rivers after they hatch, and begin outmigration as yearlings from March to June. They pass the dams during April and May. The salmon then spend two to three years (some as long as four or five years) in the ocean and then return to the rivers to spawn.

1.3.4 Steelhead

Unlike the other salmon species discussed in the above sections, steelhead enter the Columbia River year-round as winter or summer races. Because this report is concerned only with the lower Snake River and winter steelhead are only found below the Bonneville dam, this discussion will focus on the summer steelhead population.

Summer steelhead are also known as stream-maturing steelhead because they require several months in freshwater to reach sexual maturity (Barnhart, 1986; USACE, Appendix A, Section 7.0, 1999). Upriver summer steelhead are categorized as A-run or B-run based on migration timing, ocean age, and adult size. The A-run steelhead enter the Columbia River from June to August while the B-run steelhead enter fresh water from late August to October. B-run steelhead are larger than A-run steelhead because of their longer residence time in the ocean. Summer steelhead migrate inland toward spawning areas, overwinter in larger rivers (e.g. Snake River), resume migrating in early spring to natal streams and then spawn (Meehan and Bjorn, 1991; Nickelson et al. 1992). Some summer steelhead overwinter in reservoirs before migrating upstream to spawn the following spring. Most steelhead migrate downstream at two or three years of age, spend about two years in the ocean, then return to fresh water to spawn. All steelhead do not die after spawning as the salmon discussed above. Many return to spawn a second time in the following years (Draft FR/EIS, Section 4.5.8, 1999).

1.4 Position Statements

The following position statements are summaries taken from the Cyber Learning Collection web site, which organizes viewpoints on issues, including the removal of the four dams along the lower Snake River. These statements were put online in 1996 and have remained the same since they were completed in 1996. The position statements in this section are organized in the following manner: a brief synopsis of the organization and its history followed by bulleted statements regarding the stake the organization has in the controversy and the position it takes regarding salmon, dam removal, and other alternatives to enhance the salmon population along the lower Snake River.

1.4.1 Organization: Idaho Department of Fish and Game (IDFG)

The department of fish and game was established by legislation in 1938 to "preserve, protect and perpetuate" the fish and wildlife resources of the state. Several laws, including the Endangered Species Act of 1973 and the Northwest Power Act of 1980, The Fish Wildlife Coordination Act of 1958, and the Water Resource Management Act of 1976, mandate (or promise) the restoration of salmon and steelhead (CyberLearn, 2000).

- Idaho's anadromous fish contribute to the fisheries in the neighboring states of Oregon and Washington, and ocean fisheries. The organization recognizes the economic importance of salmon in that it estimates "the value of recovered steelhead and salmon fisheries at $150 million in annual revenue to Idaho" (Cyber Learn, 2000; Reading, 1996).
- The organization supports a salmon recovery strategy that will increase the population of salmon without seriously affecting traditional lifestyles or the economics in the Northwest.
- The IDFG holds the position that the operation of the dams along the lower Snake River is the primary cause of the declining salmon and steelhead

population and believes that other factors such as harvest, habitat, and hatcheries are not critical to salmon recovery.

- The department views the transportation of smolts around the dams by barge or truck " as an interim approach to the problem of getting smolts safely to the ocean" (Cyber Learn, 2000). Transportation is a temporary way of dealing with the fish while in-stream habitat conditions are improved.
- It does not see spilling smolts over the dams, a good method for moving fish past the dams, as a long term solution to the problem. There are other problems, such as increased travel times, reservoir mortality, and the alteration of the ecosystem.
- Flow augmentation, the seasonal increase of flows to simulate pre-dam conditions, is not a viable long-term solution to the problem because there is not adequate water storage in the system.
- The department believes that spillway crest drawdown (lowering the level of the four lower Snake River migration corridor dams) may be biologically inadequate to restore salmon and steelhead.
- Hatchery production alone cannot mitigate the impacts of the dams.
- The department believes that salmon recovery can only be brought about by restoring the river corridor to something as close as the pre-dam migration conditions as possible. Maybe dam breaching/dam removal.

1.4.2 Organization: Pacific Coast Federation of Fisherman's Association (PCFFA)

PCFFA is the largest organization of commercial fishermen on the West Coast. They are a federation of 26 different commercial fishing and port associations whose members span the coast from San Diego to Alaska, with total port association membership in the several thousands. They are the smaller and middle sized boat fleet of fishing families who help put high quality food on America's tables and whose labors help support jobs in many coastal and in-river communities. Many of their fishing families have been at their trades for generations (Cyber Learn, 2000).

- Fish mean business for PCFFA. Fish mean "the economic and cultural support of local fishing-dependent communities and additional taxes to support local public services" (Cyber Learn, 2000; PCFFA, 1996).
- PCFFA believes that the dams have had by far the greatest impact on the salmon population- the dams account for 90% of all human induced salmon mortality by restricting downstream passage (ODFW, 1996).
- The goal should be the production of harvestable run sizes comparable to what might have occurred before the dams were built blocking the vast majority of the river.
- Money should bee used wisely, as an investment, to restore the salmon population and reap long-term benefits. The Institute for Fisheries Resources (1996) estimates that if salmon runs are restored they could yield up to $500 million a year in economic impacts to the Northwest region and support 25,000 family wage jobs.
- Dam removal is the most beneficial option for fish restoration (Harza Northwest, 1996; Independent Science Group, 1996).
- PCFFA believes that the transportation of salmon by barge and truck is ineffective and has not resulted in any increase in the salmon populations.
- Spilling salmon over the dams is an effective tool to increase the number of juvenile salmon that survive to adulthood.
- Flow augmentation is an effective, but not the best, tool to reduce smolt travel time, which is essential to their survival.
- River drawdown, which reduces the downstream travel time for smolts, is the best option for salmon recovery because it is the least expensive option and least intrusive option.
- Hatchery programs are vital to maintaining the fishing industry and must be continued. They cannot fully compensate for the loss of adequate fish habitat though, and the restoration and protection of the habitat should be the highest priority. This includes "freeing more natural habitat by removing some dams" (Cyber Learning, 2000).

1.4.3 Organization: Idaho Rivers United (IRU)

Idaho Rivers United is a statewide, non-profit river conservation group devoted to the protection of Idaho's rivers, streams and riparian areas and the recovery of Idaho's wild salmon and steelhead. The information presented here is derived from "The 1996 Migration Operating Plan for Salmon and Steelhead, a Joint Proposal developed by Idaho Rivers United, Idaho Wildlife Federation, and Idaho Steelhead and Salmon Unlimited" and from an Idaho Rivers United newsletter entitled, "Extinction is Not an Option: Wild Steelhead and Salmon Belong in Idaho" (CyberLearn, 2000).

- The construction and operation of the hydropower dams is a major cause of the salmon population decline because the dams prevent juvenile fish from passing.
- In-river mitigation is necessary and critical to restore salmon populations.
- IRU supports the partial removal of the four dams along the lower Snake River to restore instream fish habitat and the salmon population.
- Barging and transporting salmon by truck is ineffective. Salmon populations have continued to decline with this type of mitigation effort (IRU, 1996).
- Spilling salmon over the dams is the best way to get salmon downstream with the dams in place.
- With the dams in place, flow augmentation is the most effective way to reduce downstream travel time for migrating smolts.
- To solve the problem of salmon decline IRU believes that the Technical Management Team, organized by the Corps of Engineers (Figure 5), appointed to this issue should be expanded to include fishery agencies and Tribes as full working members of the group instead of continuing their "advisory roles" (Cyber Learning, 2000).

1.4.4 Organization: Northwest Power Planning Council (NWPPC)

The Council is an agency of the states of Idaho, Montana, Oregon and Washington and was created under the authority of the Northwest Power Act of 1980, a federal law.

There are two Council members from each state. The central office is Portland, and there are state offices in Portland, Pendleton (OR), Pullman (WA), Olympia (WA), Boise (ID) and Helena (MT). The Northwest Power Act directs the Council to prepare an electric power plan for the Northwest and a fish and wildlife program for the Columbia River Basin to assure the region an adequate, efficient, economical and reliable power supply and to protect, mitigate and enhance fish and wildlife, and related spawning and rearing grounds, of the Columbia River and its tributaries that have been impacted by the construction and operation of hydroelectric dams. They are also directed to involve the citizens of the Northwest to the greatest degree possible in their decision-making. To these ends, they produce the Northwest Power Plan and the Columbia River Basin Fish and Wildlife Program and update them periodically through an intensive public involvement process. Federal agencies that manage hydropower facilities in the Columbia River Basin are required by law to take their plan and program into account in decision-making. Financing for the Council and for the work in their program comes from the Bonneville Power Administration (an agency of the U.S. Department of Energy that wholesales electric power produced at 29 federal dams located in the Columbia-Snake River Basin in the northwestern U.S.). They are not, however, a federal agency, and they are not part of Bonneville (CyberLearn, 2000).

- The goal is to improve salmon survival and increase salmon population at all stages of their lifecycle while supporting human settlement and protecting the ecosystem. Salmon populations should be increased to a level that will support commercial and sport fishing without the loss of biological diversity in the system.
- The Council has not taken a position on breaching the four dams along the lower Snake River, but recognizes it as one of several options proposed by the Corp of Engineers (see USACE, 1999).
- The Council believes that barging fish makes sense in certain situations, but not others. For example, when river flows are low and temperatures rise in the reservoirs, it makes sense to transport the fish. When flows are high and temperatures are cool, they call for leaving the fish in the river. It recognizes

that there is a debate over whether transportation has any beneficial impact on the fish and calls for an adaptive management experiment (this approach combines the objective approach of scientific methodology with social and political decision making processes) to further investigate the value of transportation versus in-stream mitigation.

- Spilling fish over the dams is an efficient means of moving juvenile salmon past the dams, but may increase dissolved gas levels and may not be appropriate year-round. Increased dissolved gas levels cause gas bubble disease in fish, which can be fatal.
- The Council believes that flow augmentation is a viable alternative to recreate some of the flows seen in pre-dam conditions to help fish reach the ocean.
- The Council's program to mitigate salmon population decline calls for a phased-in drawdown strategy for the lower Snake River dams. This strategy is a gradual drawdown of the reservoir levels to attempt to restore the river to more 'natural' conditions.
- The program also includes provisions to improve existing hatchery practices to focus not only on the number of fish produced, but the quality of the fish produced as well.

1.4.5 Organization: Direct Services Industries (DSI)

Direct Services Industries, Inc. is a non-profit association comprised of six aluminum companies who purchase electric power directly from the Bonneville Power Administration and other suppliers of bulk electric power. Their purpose is to ensure that their member companies have access to a competitively priced, reliable, adequate electric power supply for their Pacific Northwest facilities (Cyber Learning, 2000).

- Because the DSIs purchase large quantities of electricity generated by the dams, they are concerned that if the dams are breached, they will not be able to find inexpensive electricity to run their facilities.

- The DSIs have funded independent research on salmon and state that their goal is to ensure the funds expended to protect the salmon result in concrete benefits for the fish, and that the programs are cost effective (Cyber Learning, 2000).
- Overfishing prior to the construction of the dams is viewed as the primary cause for the declining salmon population. Secondary causes are the dams and fish hatchery production (hatchery fish are not as robust as natural salmon and may have a more difficult time surviving).
- The DSIs recognize that mitigation efforts surrounding the dams (salmon transportation downstream, hatchery fish, and advanced methods to allow salmon to pass through the turbines safely) have not produced an increase in the salmon population.
- The DSIs point out that there is a fundamental conflict between the goal of increasing endangered salmon populations and the goal of providing enough fish for commercial harvest through hatchery operations. Example: Under the Magnuson Act, the national Marine Fisheries Service (NMFS) is directed to promote salmon harvest while under the Endangered Species Act (ESA), the NMFS is directed to ensure the protection of salmon as endangered animals. The DSIs calls for a significant restructuring and rationalization of salmon recovery efforts.
- There is the belief that federal and state agencies tend to promote salmon recovery plans that downplay problems with hatcheries and harvest in favor of plans to increase salmon populations through dam manipulation.
- The DSIs DO NOT support dam breaching along the lower Snake River.
- Salmon barging and transportation is an effective and inexpensive method of moving salmon around the dams.
- The DSIs do not believe that spilling salmon over the dams is effective because it increases the dangers of gas supersaturation, primarily nitrogen, which is lethal to juvenile salmon. High spill levels also impair the ability of returning adult salmon to find and use fish ladders.

- The DSIs also discredit flow augmentation as a solution to increasing the salmon population by saying that salmon migrate downstream at a certain time not only based on flow regimes, but also on temperature and photoperiod. It is also very expensive- sophisticated computer analyses, which assume a flow/travel time/survival relationship, show that efforts to release water from the Upper Columbia River cost over $1 million per returning adult Snake River salmon.
- Drawdown plans are also opposed by the DSIs. They state that drawing down reservoir levels would prevent fish passage through the dams and fish ladders would become inoperable.
- The DSIs believe that the primary problem lies in hatchery operations. They believe that hatchery fish should be marked while wild salmon remain unmarked so commercial fishing operations can identify the hatchery fish and release the wild salmon back into the river/ocean. Wild salmon are more robust than hatchery salmon and are more able to survive in harsh natural environments. The DSIs believe that the survival of wild salmon must be encouraged to replenish the species.

1.4.6 Organization: Pulp and Paper Workers Resource Council (PPRC)

The PPRC is a grassroots organization representing more than 300,000 of the nations Pulp and Paper, solid wood products and other natural resource based industries. They are people dedicated to preserving the environment while taking into account the economic stability of the workforce and the surrounding community (CyberLearn, 2000).

- PPRC recognizes that the lower Snake River dams have changed the surrounding environment, but are quick to point out that these changes were not unexpected and were even discussed at the time they were built.
- Dam removal is not an option because they believe it will cause drastic and as-yet unmeasured damage to the economies of the region.

- They believe that there may be ecological changes brought about by the dams that are not easily reversed with dam removal. Dam removal will also cause damage to the regional economy by eliminating navigation, irrigation, and power generation.
- PPRC believes that barging is a successful method to transport smolts downstream and dam bypass systems will further the cause. They contend that smolts survive the journey around the dams and 'something happens' between their release and journey downstream. They believe that whatever happens between their release below the dams and their returns is still a mystery.

1.4.7 Organization: National Marine Fisheries Service (NMFS)

The National Marine Fisheries Service (NMFS) is a part of the National Oceanic and Atmospheric Administration (NOAA). NMFS administers NOAA's programs, which support the domestic and international conservation and management of living marine resources, including the anadromous species that spend the majority of their lives in the marine environment. NMFS provides services and products to support domestic and international fisheries management operations, fisheries development, trade and industry assistance activities, enforcement, protected species and habitat conservation operations, and the scientific and technical aspects of NOAA's marine fisheries program (CyberLearn, 2000).

- NMFS recognizes that economic losses from the decline of salmon fishes are in the millions of dollars and something must be done to preserve the endangered salmon species.
- Section 4)f) of the Endangered Species Act (ESA) requires that recovery plans be developed for threatened and endangered species. NMFS is involved in this controversy to 1) devise a description of site-specific management action necessary to achieve goals for conservation and 2) determine estimates of time and costs for carrying out actions needed to achieve the plan's goals.

- Many problems contribute to the salmon decline. The NMFS believes that above all there are institutional problems in organizing a recovery effort. There are problems with institutional, international, jurisdictional, state, and federal boundaries that make it difficult to coordinate resource management (water, land and fisheries decisions). However, an institutional structure that involves these parties has been developed. Please see Chapter 4 of this report for a more detailed explanation of this structure.
- The goal of the NMFS's Proposed Recovery Plan is to restore the Columbia and Snake River ecosystems and rejuvenate salmon populations, by examining each stage of the salmon lifecycle, to support fisheries and other Northwest economies.
- Removing the dams will help restore salmon and steelhead runs. Removing the dams will not restore the natural hydrograph, which is controlled by upstream reservoirs. Therefore, flow augmentation still may be necessary if the dams are decommissioned.
- When asked if the costs of decommissioning the dams are worth the benefits to salmon and steelhead the NMFS did not know. *The Lower Snake River Juvenile Salmon Migration Feasibility Study*, conducted by the Corps of Engineers in cooperation with other federal and state agencies and private organizations, is attempting to shed some light on this subject.
- NMFS views fish barging as a temporary tool to improve juvenile fish survival and help stabilize the decline of Snake River Salmon while instream conditions are improved upon.
- NMFS believes that spilling salmon over the dam is an effective way to safely pass salmon downstream.
- Flow augmentation, creating flows that mirror the pre-dam, natural environment conditions, is an acceptable method to enhance salmon survival.
- Reservoir drawdown is also an acceptable solution to the problem, but there is some question as to the degree of drawdown (several feet to dam removal and elimination of the reservoirs).

- NMFS supports experiments to increase natural salmon populations through carefully planned hatchery production.

1.4.8 Organization: United States Army Corps of Engineers (USACE)- North Pacific Division

The US Army Corps of Engineers North Pacific Division consists of the Division office in Portland OR and four District Offices, in Portland OR, Seattle WA, Walla Walla, WA and Anchorage, AK. The Division office, Walla Walla District and Portland District are involved in efforts to improve salmon passage at eight dams on the lower Columbia and Snake Rivers. The Corps operates these and four other mainstem dams in the Columbia/Snake system for multiple purposes: flood control, power generation, fish and wildlife, recreation, navigation, irrigation and water supply uses. The four lower Columbia River dams are: Bonneville, The Dalles, John Day and McNary. The four lower Snake River dams are: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. The remaining four dams are: Chief Joseph on the mid-Columbia River; Dworshak Dam on the north fork of the Clearwater River; Libby Dam on the Kootenai River; and Albeni Falls Dam on the Pend Oreille River.

- The Corps operates the dams along the lower Snake River and strives to improve the existing systems.
- The Corps does not take a stand on the number one factor causing the decline of the salmon population, but indicates that there are many contributing factors. It recognizes that the dams do impact salmon.
- The Corps seeks to provide effective fish passage at the dams and to find solutions to the decline of the salmon.
- The Corps supports river drawdown and dam breaching- dam breaching being the number one choice.
- The Corps supports barging of salmon and spilling of salmon over the dams. The NMFS has provided sufficient evidence in its 1995 Biological Opinion that these methods are effective.

- The Corps supports flow augmentation as part of a mix of different measures for increasing the salmon population.
- Hatcheries have a place in salmon restoration as long as there are no genetic defects that will weaken the wild population.

1.4.9 Organization: Columbia River Alliance for Fish, Commerce, and Communities (CRA)

The CRA is a coalition of Northwest agricultural, navigation, labor, community, food processing, forest products, industrial and electric utility groups dedicated to two major objectives: scientifically sound, economically feasible endangered salmon recovery and the preservation of a multi-use Columbia and Snake River system. Its members are the people and communities whose existence depend on the Columbia and Snake Rivers and its many uses. CRA members agree that Northwest salmon are important to their heritage, culture and way of life. Over the past several years, efforts to recover endangered salmon have focused on the Columbia and Snake Rivers. CRA members have been told that they must sacrifice their way of life to provide water and money for experimental and thus-far unsuccessful, salmon recovery programs. The region's citizens, through their electric bills, have spent more than $3 billion over the past 10 years on salmon recovery.

- The CRA does not oppose Snake River salmon recovery, but asks that the efforts are scientifically sound and economically reasonable.
- Because the causes of the salmon decline are so overlapping, the CRA does not promote one factor as being a greater influence on the population decline.
- The CRA does not endorse breaching of the lower Snake River dams, citing research that indicates that the drawdown of the lower Snake River to its natural levels may not provide any greater benefit than the current program of barging juvenile salmon. It also states that dam removal would have a huge economic impact on the region.
- The CRA supports the smolt transportation program and even supports expansion of the program to barge more salmon.

- The CRA opposes spilling the salmon over the dams saying that spill is "fraught" with biological risks such as 1) excessive levels of total dissolved gases, 2) the decision to spill means that barging the salmon has been rejected and 3) fish ladders do not operate at high spill levels.
- The use of flow augmentation may increase salmon survival slightly, but not enough to 'waste' water that could be used to generate electricity for residents of the Northwest.

1.4.10 Columbia Intertribal Fish Commission (CIFC)

The Columbia River Inter-Tribal Fish Commission represents the interests of the Nez Perce Tribe, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes of the Warm Springs Reservation of Oregon, and the Confederated Tribes and Bands of the Yakama Indian Nation.

- The organization believes that there are many factors contributing to the decline of salmon populations including, hydrosystem passage, irrigation projects, land-use practices, harvesting, and hatchery production.
- Goals of the organization include: 1) Restore anadromous fishes to the rivers and streams that support the historical, cultural, and economic practices of the tribes, 2) Emphasize strategies that rely on natural production and healthy river systems to achieve this goal, 3) Protect tribal sovereignty and treaty rights, and 4) Reclaim the anadromous fish resource and the environment on which it depends for future generations.
- The tribes do not support dam removal.
- The tribes support structural modifications to the dams to allow for natural drawdown of the river to restore river levels to those that occurred before the dams were constructed. They believe this would improve migration conditions for salmon.
- The tribes believe that the salmon should be left in the river rather than being taken out of the river and barged. Smolts, that is, juvenile salmon, do not use

fish ladders. Only migrating adult salmon use ladders. Migrating juvenile salmon need a different kind of help getting across dams. Unless spill, bypass systems or drawdowns are used, smolts are swept into the generating turbines of dams where the juvenile salmon are killed, injured, or disoriented and vulnerable to predation. Alternative passage measures such as increased flows and spill have a proven historical basis (Raymond 1988) and are supported by studies of river basins worldwide (Dodge 1989) for increasing fish production.

- The four Columbia River treaty tribes salmon restoration plan indicates that controlled spill improves passage survival of migrating juvenile salmon, steelhead, and lamprey at mainstem hydroelectric projects. Spill allows juvenile migrations to pass hydroelectric projects without passing through turbines, reduces travel time through reservoirs, and reduces predation. In general, juveniles passed with controlled spill experience only 0 - 3% mortality (Holmes 1952; NPPC 1986; Raymond 1988; Ledgerwood et al. 1990).
- In the long-term, Wy-Kan-Ush-Mi Wa-Kish-Wit, the Columbia River treaty tribes restoration plan, recommends that water flow actions be based on an approach to recreate the natural hydrograph and reduce hourly and daily fluctuations due to power peaking.
- The preferred approach for managing activities along the lower Snake River is adaptive management. This approach combines the objective approach of scientific methodology with social and political decision making processes.
- Use supplementation (hatcheries) to help rebuild salmon populations at high demographic risk of extirpation. Use supplementation to reintroduce salmon to watersheds from which they have been extirpated.

Chapter 2: The History of the Instream Flow Incremental Methodology (IFIM)

As mentioned in Chapter 1 of this report, the era of large reservoir and water development in the mid-twentieth century drastically changed instream riverine habitat in many rivers in the western United States. Resource agencies became concerned over the loss of instream habitat and began issuing rules for protecting existing river and stream resources from water development efforts (USDI, 1995). In the 1960s and 1970s assessment methods were based on hydrologic analysis of the water supply, hydraulic analysis of stream channel segments, empirical observations of habitat quality and riverine fish ecology. This was the beginning of a general class of flow assessment techniques used to reserve a specific amount of water in the channel for the benefit of aquatic life, including fish. The result of these methods usually led to a minimum flow value for stream reaches. Minimum flow means that below a certain level, water may not be removed from the stream reach for consumptive use. In the 1970s, many scientists and natural resource agencies began to see that minimum flow was not the answer to protecting instream habitat.

2.1 What is IFIM?

The Instream Flow Incremental Methodology (IFIM) was developed under the guidance of the U.S. Fish and Wildlife Service in the late 1970s and early 1980s after the enactment of the National Environmental Policy Act (NEPA, 1970). At this time attention changed focus from the evaluation of large federally funded water projects to evaluating license applications for small hydropower facilities (MESC, 1999). NEPA states that multi-purpose water use, allocating water for different purposes such as irrigation, hydropower and instream flow, must be taken into consideration for operation of large hydropower dams. At this time, attention shifted from minimum flows to alternative designs including incremental flows, and research took the form of analyses correlating the well-being of fish populations with physical and chemical attributes in the flow regime (MESC, 1999). After empirical observations, scientists determined that different species of fish have preferences for specific physical and chemical attributes. These attributes include (USDI, 1995):

- Water velocity
- Minimal water depths
- Instream objects such as cover
- Bottom substrate material
- Water temperature
- Dissolved oxygen
- Total alkalinity
- Turbidity
- Light penetration through water column

These elements were integrated into IFIM. IFIM attempts to combine the planning concepts of water supply, analytical models from hydraulic and water quality engineering, and empirically derived habitat versus flow functions (MESC, 1999). The following paragraphs from the Midcontinental Ecological Sciences Center web page describe the purpose of IFIM and its applicability to many flow problems.

> *To influence operating decisions within large-scale water development settings, a tool was needed that illuminated conflicts and complementary water uses, considered and evaluated each user's needs, and was understandable, acceptable, and easy to use by a broad clientele. Such decision arenas involve a diversity of disciplines, including engineers, hydrologists, biologists, recreation planners, lawyers, and political scientists.*
>
> *This interdisciplinary effort led to the conclusion that an analytical methodology should handle a variety of instream flow problems, from simple diversion to complex storage and release schemes involving hydropeaking schedules, and a network of interconnected reservoirs. For such a methodology to be suitable for evaluating alternatives, it had to be useful in identifying, evaluating, and comparing potential solutions, be capable of being tailored to a specific stream reach, and be expandable*

> *such that reach information could be applied through a river basin. With this general charter, IFIM has developed over a period of 15 years into a river network analysis that incorporates fish habitat, recreational opportunity, and woody vegetation response to alternative water management schemes. Information is presented as a time series of flow and habitat at selected points within a river system.*

IFIM is an impact assessment tool as well as a water planning and management tool for establishing policy on river regulation. Incremental methods of evaluation became the method of choice for determining the impacts of alternative ways of managing river water and provided a way to gather comprehensive information for evaluation and negotiation by interest groups and government agencies in hopes of reaching viable solutions to instream flow problems. Natural resource agencies identified opportunities to restore riverine resources that had been impacted for decades when hundreds of relicensing applications were submitted to the Federal Energy Regulatory Commission. Most of these relicensing applications involved reservoirs that did not take into consideration any downstream instream flow in their operation and had been in place for 30 to 50 years (USDI, 1995).

2.2 The Development of IFIM

As stated above, the driving force for the development of the IFIM was NEPA, which forced all federal water resource agencies to consider alternative water development and management schemes. This placed more responsibility on natural resource agencies to evaluate methods and give recommendations for the release and storage of reservoir water. Because of this increased responsibility among different agencies, IFIM was developed by an interdisciplinary team and was founded on the understanding and description of the water supply and habitats within the stream reaches of concern (USDI, 1995).

Based on the request from the U.S. Fish and Wildlife Service Directorate that other agencies give input into the development of the IFIM, water resource professionals were assigned to work on the methodology for up to four years. These professionals included engineers, water quality experts, and planning experts from the U.S. Bureau of Reclamation, Soil Conservation Service, Army Corps of Engineers, Environmental Protection Agency, and university scientists. Experts in aquatic ecology, water law, fishery biology, institutional arrangements, and planning came from state agencies. The Intergovernmental Personnel Act made these assignments from state organizations possible.

These experts aim for efficiency of use- "the greatest return in the number and quantity of uses, with emphasis on simultaneous use" (USDI, 1995). An understanding of the timing of seasonal events, such as snow-melt, as it relates to the reproductive success and strength of the salmon population is imperative to the IFIM methodology. An examination of temporal flows and the ensuing health of the salmon population gives an indication of the amount and availability of suitable salmon habitat. Computer models such as the PHysical HABitat SIMulation System (PHABSIM) are used to determine the amount of suitable habitat available at different flows. This output can then be used as input in time series models to determine the amount of suitable habitat available over many years.

An essential component of the IFIM, and one used extensively in the water resource engineering profession, is an historical analysis of the flow regime using either a monthly or weekly time step to describe the baseline hydrologic conditions within a system. Examining the stream flow over time allows the comparison of the frequency and duration of wet and dry periods including determining the difference between snow-melt and rain-driven systems, and determining the intensity and duration of short term events such as peaking cycles. IFIM uses the baseline hydrology, with some transformation, to describe the available (usable) habitat present during the historical period. If scientists are able to calibrate computer models to reflect the historical flows and habitat (over a 10 to 20-year period) the model may be used with credibility, to determine the flows and habitat for future water resource management alternatives.

"IFIM has been designed for river system management by providing an organizational framework for evaluating and formulating alternative water management options. It has been built on the philosophical foundation of hydrological analyses to understand the limits of water supply. Analysis offers a description, evaluation, and comparative display of water use throughout a river system" (USDI, 1995). The goal is to display usable habitat across several years to determine variability in habitat and water supply.

2.3 Multiple Use Ethic

Through the late 1970s to the early 1990s there was a shift from applying a set of minimum flow standards for rivers to the multiple-use ethic. The multiple-use ethic, the possible reuse of water if it is managed so that the timing of release serves instream purposes while still being delivered to downstream consumptive users, emerged as the dominant philosophy (USDI, 1995). This philosophy was demonstrated by the Pacific Northwest Electric Power Planning and Conservation Act of 1980. Ensuing efforts by the Bonneville Power Authority allowed federal, state, and tribal fishery biologists to characterize management options for the restoration of the anadromous salmon in the Columbia River Basin. These management options, or water budgets, set aside water stored in upstream reservoirs for use to benefit fisheries. These reserve flows are released when downstream water users are not calling for delivery, to improve instream habitat in critical spawning reaches along the river. Over the last several years, water budgets have been seriously considered as management options for large federal water storage projects such as those in the Columbia River Basin.

Traditional water user groups such as irrigated agriculture, industry, and municipalities may prefer this type of management because the water reserved for fish is treated the same as other water in the system- the release of water must be decided by the fishery manager. This relieves the reservoir operator and other water users from having to determine when and how the instream flows are to be released. The multiple-use ethic changes the role of fisheries managers because now water is set aside specifically for fisheries purposes. In order to protect the interest of the instream habitat and the salmon inhabiting the rivers, fisheries managers must become water and habitat managers. This implies that natural resource agencies should procure an interdisciplinary mix among their employees to determine water delivery on a daily basis during seasons critical to the survival of salmon. They must determine which river reaches will be favored and which river reaches will be sacrificed during droughts.

It is important that the fishery managers "gain a seat at the management table" so that the interest of instream fisheries are addresses-- they get part of the water stored during high flow periods in the reservoirs so that critical conditions downstream can be mitigated (USDI, 1995).

2.4 Interdisciplinary Analysis

It is widely recognized that multiple-use water management is essential in the western United States and that reservoir management for a single use such as hydroelectric production or irrigation is socially unacceptable. In order to manage the water stored in reservoirs under the multiple-use philosophy, it is imperative that an interdisciplinary group is established that is equipped to establish procedures for equitably distributing the water supply and sharing the consequences of a low water supply among users. "Resolving conflicts among states and user groups sharing the same river system calls for interjurisdictional river boards or commissions to manage water stored in public reservoirs for instream and out-of-stream uses" (USDI, 1995).

Chapter 3: IFIM Implementation

IFIM is appropriate for use in The Lower Snake River Dam Controversy because there are many complex issues, numerous stakeholders, and questions regarding alternative dam operation methods that may help to restore salmon populations. This chapter attempts to outline and describe the four phases of an IFIM study to familiarize the reader with the complexity of the methodology before moving on to discuss how IFIM applies to the Lower Snake River Dam Controversy in Chapter 4 of this report.

3.1 IFIM Phases

It is important to understand that IFIM is a general problem solving approach consisting of four phases. These phases are all interrelated and lead to alternatives for water management, one of which is optimal based on negotiations among stakeholders. The four phases of IFIM are listed below.

1. Problem Identification (legal-institutional and physical analysis)
2. Study Planning
3. Study Implementation
4. Alternatives Analysis and Problem Resolution

The following sections in Chapter 3 of this report describe each phase of the IFIM process.

3.2 Phase I- Problem Identification

Phase I- Problem Identification, consists of two components (Bovee et al., 1998):
1) a legal and institution analysis to define the problem (a diagnosis of the institutional setting of the problem), and 2) an issue analysis to determine the concerns of the stakeholders involved.

Because IFIM is used to investigate alternative management options involving riverine habitats, many people believe that the only solutions generated involve changing the streamflow. IFIM recognizes changing the streamflow as an option to managing riverine habitat, but it is not the only option. In order to gather the necessary information to generate comprehensive solutions it is important to create a dialogue among stakeholders to determine their concerns and gather information. After all, the methodology was "developed for the express purpose of providing a common language and rationale for assessing the viability of competing operating scenarios" (Bovee et al., 1998). It is crucial to involve all parties and involve IFIM practitioners who are adept at problem solving. Use of IFIM is a problem solving activity that requires knowledge of many different disciplines and an orientation towards human aspects of negotiation since multiple parties are involved in the problem resolution.

3.2.1 Levels of Analysis

Every problem can be divided into three contexts: 1) individual, 2) institutional (group) and 3) systemic (intergroup). Individual involves one-on-one interaction where a person attempts to convince another of an idea. The institutional context involves groups of people and how they decide. The systemic context involves bargaining among different organizations. Use of these three contexts allows professionals to dissect problems.

The individual level of analysis involves understanding how different personalities approach problems, assimilate information, and form conclusions since much of IFIM involves discussion and negotiation. Bargaining over instream flow recommendations at the individual level is a process of introducing information to an individual who may resist change and attempting to convince them that the new ideas are good ones.

Institutional analysis differs from individual analysis in that groups are now making decisions. They are influenced by both the organizational/agency culture and by group members. Because groups usually refer to past problems and resolutions, new resolutions to similar past problems are often nearly identical. It is difficult to implement radical change, change that may be needed in the case of the lower Snake River.

At the systemic level of analysis behavior is determined by the organizations ultimate mission as expressed in positions and solutions from past negotiations. Representatives of each organization should be aware of the positions and relative power among other organizations involved in the negotiations.

To ease the analysis of the individuals and organizations involved, the Legal-Institutional Analysis Model (LIAM) is used to guess sources of agency power and determine primary decision strategies (Lamb, 1980; Wilds, 1986). The LIAM involves four steps: 1) determining roles, 2) describing context, 3) calculating power, and 4) assessing strengths and weaknesses. For more information on this topic see chapter 2 of *Stream Habitat Analysis Using the Instream Flow Incremental Methodology* (Bovee et al., 1998).

3.2.2 Issue Analysis

During IFIM's initial phase negotiators need to identify as many of the issues of concern (from the stakeholders) as possible. There are important natural resources and human values that need to be considered in IFIM. These determine how the changes resulting from a proposed action will be measured, analyzed, and evaluated (Bovee et al., 1998).

After NEPA was passed, several impact assessment techniques were created including checklists, matrix tables, and cause and effect diagrams. All of these methods are subjective because they rely heavily on knowledge and expertise of individuals (Bovee et al., 1998). However, these are the best methods available today and continue to be used to organize the issues.

Major issues surrounding controversies dealt with using IFIM include macrohabitat issues and microhabitat issues. Macrohabitat is the set of abiotic conditions or other characteristics in a river segment that "define suitability for use by organisms" and control the longitudinal distribution of aquatic organisms (Bovee et al., 1998). Microhabitat is defined by "spatial attributes (e.g., depth, mean column velocity, cover type, and substrate) of physical locations occupied or used by a life stage of a target species sometime during its life cycle"(Bovee et al., 1998). Critical microhabitats include those for spawning and incubation, rearing areas for newly emerges fry, and optimal feeding/predator avoidance areas for fingerlings (Nehring and Anderson, 1993; Bovee et al., 1994). The following lists include the specific components inherent to macro and microhabitat issues. Below are brief descriptions of the subcategories.

Macrohabitat Issues

- Hydrologic Issues (flow regime)
  - Water budgets
  - Quantifying hydrologic changes
  - Reservoir issues
- Channel Dynamics and Stability
  - Channel enlargements and reductions
  - Aggradation and degradation
  - Channel materials
- Temperature
- Water Quality

Microhabitat Issues

- Selection of Target Species
- Critical Microhabitats, Life Stages, and Habitat Bottlenecks
- Determining Habitat Requirements and Temporal Variations
- Spatial Composition, Configuration, and Continuity

IFIM indicates that identification of macrohabitat issues, the physical location and geographic extent of probable physical and chemical changes to the system, and the identification of microhabitat issues including the aquatic resources of greatest concern, are important. In this study, the aquatic resources of greatest concern are the four salmon species inhabiting the Lower Snake River.

3.3 Phase II- Study Planning

The focus of this phase is to identify the information needed to address the problems stated in the Phase I section above. It is important to identify (Bovee et al., 1998):

1. The temporal and spatial scale of evaluations.
2. The important variables for which information is needed.
3. How information will be obtained.

Because IFIM is designed for maximum flexibility, investigations can be tailored for any instream flow problem or analysis of riverine habitat. It is completely up to the study designer to determine the variables, including the location and amount of data to be collected, and used in the investigation. The latitude allowed with IFIM may seem chaotic, but IFIM manuals include ten essential components of a study plan that investigators should follow to organize a study. They are:

1. A comprehensive description of the proposed action (e.g dam breaching) and a characterization of the stakeholders' issues (e.g. power production, river restoration, etc.).
2. Identification of target species or valued natural resources (e.g. salmon).
3. Selection and rationale of a methodology to address the issues.
4. A concise statement of study objectives.
5. Study area and segment boundaries (e.g. specify stream reaches in which to run models).
6. Identification of baseline or reference conditions (e.g. baseline flow conditions in the river).
7. Details of geographical coverage, data collection, calibration, and quality control for IFIM models.
8. Assignment of responsibilities and authorities.
9. Schedules of activities, milestones, and deadlines.
10. Reconciliation of resource needs with resource availability.

The first two components are completed in Phase 1, discussed in the previous section. Phase II involves the completion of the remaining eight study design components, some of which can be grouped together to shorten the discussion. A complete discussion of these components can be found in *Stream Habitat Analysis Using the Instream Flow Incremental Methodology* (Bovee et al., 1998). Study plan components 3 through 10 are discussed in the order listed above.

3.3.1 Study Plan Component #3 (Methodology)

There are two different methodologies that can be implemented depending on the objectives of the study: standard-setting or incremental. Standard-setting techniques are used when the analyst is called upon to recommend a minimum instream flow requirement below which water cannot be diverted. Standard-setting techniques address minimum flow issues only and are used in low-intensity (minimum controversy) situations.

In contrast to standard-setting techniques, incremental techniques are used in high-stakes negotiation over a development project. Use of the incremental technique attempts to answer the following question: What happens to the variables of interest (e.g. aquatic habitat, recreation value) as a result of a proposed action (Bovee et al., 1998)?

These two methodologies are discussed further in Section 3.2 of this report.

3.3.2 Study Plan Component #4 (Study Objectives)

Objectives are subunits of goals, where the goal is what is to be achieved overall. Objectives should be precise, measurable, and achievable and when objectives are met, they should indicate progress towards the ultimate goal. Often, in IFIM studies, the goals set by the analysts are too ambiguous. Sometimes the opposite is true- there is too much attention to detail and the analysts lose sight of the ultimate goal. Objectives should be specific and agreed upon by all of the parties involved in the project; all parties must understand and document their agreements. It is also important to classify objectives based on motives of the stakeholders. If stakeholders withhold their true motives, there can be problems with negotiations further along in the process. The study objectives must also be scientifically, technically, and institutionally feasible. Methods must be defensible and assumptions made must be rational. Finally, deadlines for objectives must be set and performance criteria established.

3.3.3 Study Plan Component #5 (Bounding the Study Area)

Four study area configurations are mentioned and completely described by Bovee et al. (1998) and are listed here from the simplest and most straightforward to the most complex: 1) site specific, 2) linear network, 3) parallel network, and 4) composite network. The analyst should determine what configuration best approximates the study area and then bound the area by defining the upstream location where the proposed action will take place and the downstream location where the effects of the proposed action are no longer felt. However, it is often difficult to ascertain the downstream location where the effect of the action ends and a new effect begins. Often IFIM practitioners locate the lower boundary where the study stream converges with a large reservoir, another river, or the ocean. The best guidance offered by Bovee, et al. (1998) is "to restrict the study area to the portion of the stream where the impact of a proposed action, or opportunities for mitigation, will be greatest."

One of the philosophical tenets of IFIM is that alternatives evaluate the total amount of habitat under baseline conditions and various management conditions. In order to do this the study area must be divided into stream segments, each stream segment having a homogeneous flow regime. A rule-of-thumb is to insert a segment boundary whenever the flow regime changes by 10%. Segments can also be subdivided by channel slope, channel morphology, or valley orientation.

3.3.4 Study Plan Component #6 (Baseline Conditions)

"Baselines serve as benchmarks for developing and evaluating alternatives. They establish the reference points against which comparisons are made" (Bovee et al., 1998). Time series baselines are continuous chronological records of a variable and include hydrologic, thermal, water quality, and biological baselines. The length of the time series data is known as the period of record for a baseline. It is the general consensus that the longer the period of record the better. The period of record should be about twice as long as the planning horizon. Time series data are often averaged over time intervals known as time-steps, and an important part of study planning is to determine the appropriate time-step to use. Typically daily, weekly, and monthly time-steps are used. Any time step shorter than a week is too detailed to use and any time step longer than a month does not give enough information.

Depending on the application of IFIM, the baseline can represent existing conditions of water use or can represent predevelopment or natural conditions. It is important NOT to combine predevelopment conditions and postdevelopment conditions in the same baseline. Baselines should not incorporate trends or periodicity shifts either.

3.3.5 Study Plan Components #7, #8, #9, #10 Combined (Scope of Work)

In IFIM, information generation relies on a combination of empirical data and model output. Models are useful in that they can quantify the effects of proposed actions that have not yet been put in place. They can also quantify immeasurable conditions and identify second-order effects where the impacts to organisms are subtle or extend over a long period of time. Modeling is economical yet, requires that users have an understanding of the theories used to build the models and the data required to run them. The practitioners of IFIM must also be able to identify which models to use.

Because models need input data, practitioners must determine what data are needed, conduct an inventory of available data, and find a way to fill in information gaps (Bovee et. al, 1998). Data regarding hydrology, channel geomorphology, water temperature, and water quality must be gathered in order to run the necessary models. Below, are descriptions of the type of data needed and sources of data.

Hydrology

Data Requirements: A measure or estimate of discharge in the previously identified stream segments for every time-step during the baseline period.

Sources of Data:
1) Water Resource Divisions of the USGS
2) Commercially available CD-ROM database (EarthInfo or Hydrodata)
3) U.S. Army Corps of Engineers
4) Bureau of Reclamation

Channel Geomorphology

Data Requirements: Depends on the physical scenario: (1. The stream is in a state of dynamic equilibrium and will remain so when the project is complete, 2. The stream is in a state of disequilibrium and will not be affected by the project, 3. The stream is in a state of dynamic equilibrium and will change when the project is complete, and 4. The stream is in disequilibrium that will be exacerbated or reversed when the project is complete). Need data that reflect the channel structure under baseline conditions and postproject configuration.

Sources of Data: 1) U.S. Army Corps of Engineers

Water Temperature

Data Requirements: 1) Continuously recorded air and water temperature data are needed for water temperature regression models. 2) Variables related to heat flux and transport equations (stream geometry, meteorology, hydrology, water temperature) are needed to run heat flux/transport models.

Sources of Data: 1) USGS
2) National Climatic Data Center
3) U.S. Environmental Protection Agency
4) U.S. Weather Service
5) Universities

Water Quality

Data Requirements: Channel geomorphology, forcing functions (loads), oxygen demand coefficients, nutrient coefficients, algal coefficients, and meteorology.

Sources of Data: National Water Data Exchange (NAWDEX)

The models of the microhabitat simulation part of IFIM are known as the Physical Habitat Simulation System (PHABSIM), which consists of three parts: 1) channel structure, 2) hydraulic simulation, and 3) habitat suitability criteria. Below are the data requirements and sources of data needed for PHABSIM.

PHABSIM

Data Requirements: 1) Channel Structure: distances between transects, dimensions of stream cells, channel geometry data, description of substrate composition.
2) Hydraulic Data: water surface elevations and corresponding discharges at each cross section (if flow is not steady there must be several cross sections per stream segment), nose velocities, mean column velocities.
3) Habitat Suitability Criteria: habitat suitability for the species of interest.

Sources of Data: The project team must go into the field and measure to obtain this type of data. Existing river cross sections are usually not taken at the correct place along the stream segment. Habitat suitability criteria may be obtained from the USGS Biological Resources Division, but the transferability must be examined.

Difficulty or ease of obtaining the necessary information depends on the geographical extent and complexity of the study area. The cost of the study is also a function of these variables. A comprehensive schedule should be created to stay on task, to determine milestones, and to evaluate progress on the project. Because there is field work involved in running PHABSIM and perhaps other models, a field work schedule must be created taking into account seasonal variability.

3.4 Phase III- Study Implementation

The implementation of an IFIM study involves running all types of models described in Section 3.3.5. This section describes the Physical Habitat Simulation Model (PHABSIM). Other models are not discussed in this section primarily because the Corps has already run them. PHABSIM has not yet been run on the lower Snake River, but could be a useful tool in the future. Detailed information about the models used in an IFIM study is found in *Stream Habitat Analysis Using the Instream Flow Incremental Methodology* (Bovee et al., 1998). The text also includes information regarding uncertainty in the models and error analysis.

Table 3 indicates the models used in an IFIM study and some of their characteristics.

3.4.1 PHABSIM

PHABSIM is a specific model designed to calculate an index to the amount of microhabitat available for different life stages at different flow levels. It was designed specifically with the IFIM in mind and is frequently used when implementing IFIM. PHABSIM has two major analytical components: stream hydraulics and life stage-specific habitat requirements (see Figure 4) (MESC, 1999).

Table 3 – IFIM Models

	Model Name	Purpose of Model	Model Description/Concepts
Hydrology	Mass Balancing	Synthesis of baseline hydrographs for IFIM analyses.	Discharges for coincidental time-steps are added or subtracted to determine the stream flow above or below the confluence of two or more gauged streams.
	Station Regression	Synthesis of baseline hydrographs for IFIM analyses.	Involves the development of a model relating the streamflow records at one station to those at another station and is commonly used when all the records are not concurrent.
	Modified Station Regression	Synthesis of baseline hydrographs for IFIM analyses. Used for ungaged streams.	This method can be used to create a hydrograph for an ungaged stream if there is at least one long-term gage somewhere in the vicinity. Must first develop a short-term hydrologic record in the ungaged stream by establishing and calibrating a semipermanent gage (often giving instantaneous discharge estimates). Time-lag effects can be troublesome with instantaneous discharge estimates.
Channel Geomorphology	HEC-6	To determine the shape, pattern, and dimensions of a new channel following a change.	Uses hydraulic data (water surface elevations and discharges) to predict new water surface elevations and other hydraulic variables for a range of simulated discharges. Able to calculate sediment transport rates in suspension and bedload. Output can be used in one-dimensional temperate or water quality models. To use output in PHABSIM, extra detail necessary for microhabitat analysis must be added using an analogous stream model.
Water Temperature	SNTEMP	Predict the daily mean and maximum water temperature as a function of stream distance and environmental heat flux.	SNTEMP is a one-dimensional heat transport model and is applicable to a stream network of any size or order. Net heat flux is calculated as the sum of heat from long-wave atmospheric radiation, topographic radiation, short-wave solar radiation, convection, conduction, evaporation, streambed fluid friction and the water's back radiation.
	SSSHADE	Used for shade estimation	A shade model that quantifies riparian and topographic shading.
	SSSOLAR	Used for solar radiation estimation.	A solar model to predict the solar radiation penetrating the water as a function of latitude and time of year
Water Quality	QUAL-2E	To simulate water quality constituents (up to 15 constituents).	The standard (as recognized by academic and industry professionals) water quality model for small streams and medium-sized rivers. It is a one-dimensional steady-state model, it is easy to calibrate and validate, and it is user-friendly. It accepts multiple external loads and point discharges, nonpoint sources and sinks, unsimulated tributaries, and water withdrawls.
Physical Microhabitat	PHABSIM	To determine a functional relationship between discharge and unit microhabitat area for a specific target organism.	This model divides stream segments into a mosaic of stream cells (areas) chosen by the model operator. At a particular stream flow, each stream cell has a unique combination of surface area, depth, velocity, substrate, and cover. Multiple discharges are modeled with PHABSIM. The model requires detailed hydraulic information about the stream cross section and habitat suitability criteria.

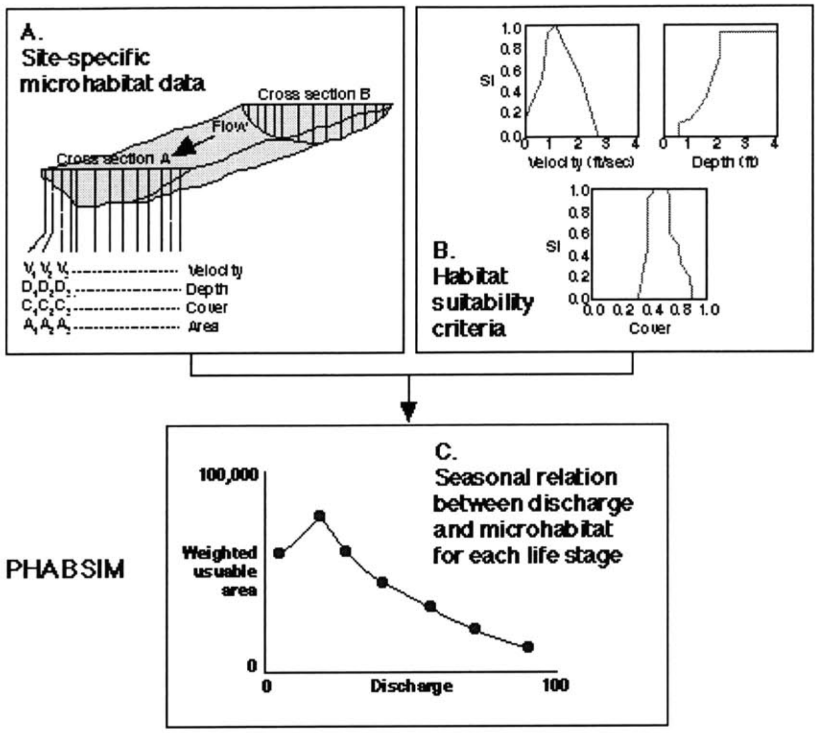

Figure 4 - How PHABSIM calculates habitat values

Conceptualization of how PHABSIM calculates habitat values as a function of discharge. (A) First, depth (*Di*), velocity (*Vi*), cover conditions (*C*i), and area (*A*i) are measured or simulated for a given discharge. (B) Suitability index (*SI*) criteria are used to weight the area of each cell for the discharge. The habitat values for all cells in the study reach are summed to obtain a single habitat value for the discharge. The procedure is repeated through a range of discharges to obtain the graph (C).

PHABSIM contains hydraulic models that use depth, velocity, substrate material, and cover to calculate the water surface elevation for a specified flow and to simulate velocities across a river cross section. The river reaches are then divided into cells based on velocity. In order to calibrate the hydraulic models in PHABSIM it is necessary to obtain field measurements of depth, velocity, substrate material, and cover at points on a cross section at different flows (MESC, 1999). The hydraulic models also use a baseline flow, or reference condition that is determined from hydrologic information. Information necessary to run the hydraulic models is gathered from site visits, the Corps of Engineers, the United States Geological Survey (USGS), and Soil Conservation Services (SCS).

The habitat component of PHABSIM then uses the habitat suitability indices/criteria to weight each stream cell for different flows. Habitat Suitability Criteria (HSC) assign a relative value between 0 and 1 for each habitat attribute indicating how suitable that attribute is for the life stage (this paper focuses on one or more life stages of salmon) under consideration (MESC, 1999). After the hydraulic component of PHABSIM has calculated flows and velocities in the cells, the habitat component sums the weighted values and graphs the weighted usable area (WUA) against the flow (see Figure 4). HSC are usually obtained using direct observation of attributes most often used by a species. Because IFIM has been used in the Columbia River Basin before, there should be indices already in existence. It is important to note that PHABSIM can only be used "if the species under consideration exhibit documented preferences for depth, velocity, and substrate material/cover" (MESC, 1999). This is the case for salmon.

The graph of WUA versus flow does not take into account the time over which these flows are present. This function should be combined with water availability to develop an idea of what life stages are impacted by a loss or gain of available habitat at what time of the year. Time series analysis plays this role, and also factors in any physical and institutional constraints on water management so that alternatives can be evaluated.

3.5 Phase IV- Alternatives Analysis and Problem Resolution

Before discussing the final two phases of an IFIM study, a few concepts should be repeated. They are listed below.

- The purpose of an IFIM study is to address the issues and impact associated with a proposed action that will alter the stream and its habitat characteristics.
- The measure by which alternatives are evaluated is total habitat (not just microhabitat), numbers of fish, or money.
- IFIM is not intended to produce one best answer. The best answer is the one that all of the stakeholders can agree upon.

3.5.1 Negotiation

Alternatives analysis and problem resolution go hand in hand because they are part of an iterative problem-solving cycle. Prior to Phase IV there has already been a considerable amount of negotiating among the groups involved in choosing the study area, which models to run, which habitat metrics to include, etc. Negotiation at this point is a repetitive process by which 1) an alternative is proposed, 2) the effects of the alternative are evaluated, and 3) improvements on the alternative are proposed, tested, and negotiated. This process can lead to two outcomes: 1) a mutually agreeable solution or 2) an impasse where the decision is passed on to a higher authority. This may be an arbitrator or a court of law (litigation). Bovee et al. (1998) discusses negotiation strategy.

3.5.2 Idealized Objectives

Because individual stakeholders (negotiators) attempt to protect only their objectives, a practice known as positional bargaining, attacks in negotiations may become personal and opposition tends to challenge the importance of some issues. A possible solution to this problem is designing idealized objectives by answering the question: what would the perfect solution to this problem look like? The intent of an idealized objective is to make the goals of the individual stakeholders the goals of the group while building trust within the group.

3.5.3 Biological Objectives

If a new project is going to be built and operated, a biological goal may be to maintain the same amount of habitat available for all life stages of a species as there was before the project was put in place. If mitigation is the goal, the biological objective may be to restore the available habitat to the amount that existed before the project was built. Knowledge of critical habitat types[1] and bottlenecks[2] can help in formulating alternative

[1] Habitat known to be important to the well being of a species.

solutions. Bovee et al. (1998) provides several pertinent questions to ask when discussing biological alternatives.

3.5.4 Testing Alternatives

Effectiveness

"Effectiveness of an alternative is determined by comparing the amount of habitat available under the alternative with the habitat available under the baseline" (Bovee et al., 1998). The tool used in an IFIM study to quantify the differences between the two is a habitat time series. There are two ways to construct a habitat time series: 1) use the programs available in the IFIM time series library (TSLIB) or 2) program it yourself! Habitat time series are displayed in graphical or tabular form and provide comparative information between alternative and baseline conditions.

Habitat Duration Curves

Habitat time series and hydrologic time series can be superimposed to determine what type of flow events caused reductions or increases in habitat throughout the year. However, because it is difficult to quantify habitat availability from habitat time series, the information must be manipulated to create a habitat duration curve. Habitat duration curves are constructed in the same manner as flow duration curves, but use habitat values instead of discharges.

3.5.5 Feasibility and Risk Assessment

Bovee et al. (1998) lists two basic approaches to risk planning: 1) overdesign and 2) risk containment. In overdesign the goal is to reduce the probability of failure to as close to zero as possible. It is often not a very useful approach to instream flow problems because

[2] Cumulative constraint on an individual species population size caused by the repeated reductions in habitat capacity through time due to microhabitat or macrohabitat limitations.

of economic feasibility issues and if the solution fails, there is often no alternative strategy. A more useful approach, one that operates under the assumption that all alternatives eventually fail, is risk containment. A contingency plan is incorporated into an alternative using this approach.

Chapter 5 of *Stream Habitat Analysis Using the Instream Flow Incremental Methodology* goes on to describe time-independent and time-dependent risk analysis and contingency plans. For more information on these topics see pages 101 to 103.

3.5.6 Networks

Network habitat problems present issues and problems not seen in single segment analysis (analysis along a simple stream segment). These problems include cumulative impacts, synergism, and feedback mechanisms. Definitions are given below (Bovee et. al, 1998).

> Cumulative Impacts: originate from dispersed sources, the effects of which are additive on river resources
>
> Synergism: occurs when two or more projects produce an effect neither could have produced alone.
>
> Feedback Mechanisms: occurs when management options in one part of the system are contingent upon operations in another part, such as multiple reservoir operations (even reservoirs arranged serially)

Models developed to handle flow routing, water supply, and storage networks must be used to analyze networks. Network models can show effects on habitat from combined reservoir operations. It is important to monitor the distribution of habitat in the network, not simply the amount of habitat. Network habitat analysis is driven by the network flow model which accounts for all water moving in the system (in both space and time), schedules reservoir operations, accounts for water rights and delivery schedules, and determines where and when violations to rules are occurring. The flow model regulates the microhabitat and macrohabitat models.

Habitat (biological) connectivity, the accessibility of all parts of the network to all life stages, is an important issue in network analysis. This is also referred to as network habitat utilization. Several potential connectivity problems present themselves in a network, but two stand out. The first is a flow-related passage barrier within the network that prevents migration of a species at very low or very high discharges, usually affecting fish that migrate upstream to spawn. The effects of passage barriers can be analyzed using the hydraulic models in PHABSIM, but PHABSIM does not keep track of the linkage between what is going on at the barrier and what is going on in the rest of the stream segment. The second problem has to do with the life stages of the species and whether an alternative in the network will provide the necessary habitat to support reproduction of the species.

3.6 IFIM Methodologies

Every analyst taking on an IFIM project must decide on the appropriate instream flow assessment technique to use based on both the political and environmental problems and the technology used to meet scientific standards. There are two methodologies to choose from: standard-setting or incremental. However, it should be noted that several IFIM studies fall in between these two categories. Standard-setting problems usually warrant that the analyst recommends an instream flow requirement, a minimum flow requirement, to guide low intensity decisions. An incremental problem, on the other hand, involves a high intensity, high stakes negotiation and attempts to answer the question: What happens to the variable of interest when flows change? Table 4, adapted from *The Instream Flow Incremental Methodology: A Primer for IFIM* (USDI, 1995) outlines some differences between standard-setting and incremental techniques.

Table 4 - Characteristics of Standard-Setting and Incremental Techniques

Standard-Setting	Incremental
Low controversy project	High controversy project
Reconnaissance-level planning	Project-specific
Few decision variables	Many decision variables
Inexpensive	Expensive
Fast	Lengthy
Rule of thumb	In-depth knowledge required
Less scientifically accepted	More scientifically accepted
Not well-suited for bargaining	Designed for bargaining
Based on historical water supply	Based on fish or habitat

3.6.1 Standard-Setting Techniques

Standard-setting usually occurs in statutory state instream flow protection programs. An instream flow standard should include (Beecher, 1990): 1) the goal, 2) resources (fish species), 3) unit of measurement (cfs, or weighted usable area), 4) benchmark period, and 5) protection statistic.

There are many techniques for standard-setting related to fisheries; two of them, hydrologic records and the Tennant Method, are mentioned here. Hydrologic records requires the use of stream gage records that assume the measured flows support aquatic resources at acceptable levels. This assumption applies to undeveloped streams or where development has been stable for a long period of time. If the stream under investigation is developed it may be possible to construct the natural flow regime from gage records, but this approach is suitable only if the analyst has information on the condition of fisheries before development.

The Tennant Method "arrays flow levels for seasonal periods based on percentages of the mean annual flow. Hydrologic records should be available, but when they are not available another indicator, drainage area, may be used" (USDI, 1995).

3.6.2 Mid-Range Techniques

Standard-setting and incremental techniques are extreme cases, but many instream flow problems fall somewhere in between. This presents a challenge for the analyst; he/she must apply an instream flow technique for the mid-range case. *A Primer for IFIM* provides three different approaches in this case: 1) Modified Tennant Approach, 2) wetted perimeter technique, and 3) multiple attribute standard-setting methods. Because the lower Snake Dam controversy does not fall in this category a detailed explanation of these methods is not given in this report. Please see *The Instream Flow Incremental Methodology: A Primer for IFIM* for more information.

3.6.3 Incremental Techniques

Incremental techniques are used in cases where negotiation or court proceeding are imminent and require a more in-depth look at the instream flow problem/question. Knowledge of how aquatic habitat changes as a function of changes in flow is necessary to find solutions to these types of problems. Detailed analyses must be prepared for negotiations or litigation.

The use of PHABSIM, a mid-range tool, in conjunction with a time series analysis is appropriate for use as an incremental technique. IFIM computer software can be used to combine microhabitat and macrohabitat variables and relate them to flow over time to create a Habitat Time Series, which displays the availability of suitable habitat over a period of record. The PHABSIM method is used to "look at hydroelectric power projects, to set standards for controversial streams, and to develop conditions on federal permits and licenses" (USDI, 1995).

The assumptions of all methodologies and computer models must be well understood by those operating them. The result of these methodologies and computer models is to predict changes in habitat over time and to make recommendations for wet and dry situations.

Chapter 4: Phase 1: Problem Identification

Now that the four phases of IFIM have been explained, it is time to determine if IFIM was and/or is currently being applied to the Lower Snake River Dam Controversy. The Corps and other organizations have run the models discussed in the previous chapter of this report, but has a specific methodology been followed? This chapter is an evaluation of the events over the past decade that lead to the initiation of what the author of this report sees as Phase I of IFIM.

Problem identification includes summarizing the stakeholders' viewpoints and determining the central issues specific to the Lower Snake River Dam Controversy. The following sections of this chapter gives a brief history of the institutional setting in this controversy as documented in the *Lower Snake River Juvenile Salmon Migration Feasibility Study: Draft Feasibility Report/Environmental Impact Statement* released by the Corps of Engineers in December 1999.

4.1 Historical Perspective

The U.S. Army Corps of Engineers' (Corps) *Lower Snake River Juvenile Salmon Migration Feasibility Study* was initiated in 1994 to evaluate the technical, environmental, social, and economic effects of potential modifications to the configuration of four federal facilities (Ice Harbor Dam, Lower Monumental Dam, Little Goose Dam, Lower Granite Dam) on the lower Snake River. The purpose of these modifications is to increase the survival of juvenile anadromous fish (salmon) as they migrate through the lower Snake River system.

The *Lower Snake River Juvenile Salmon Migration Feasibility Study* is part of a large, multiyear, multiagency effort to restore salmon stocks in the Federal Columbia River Power System (FCRPS). Several agencies are involved in this effort: The Corps of Engineers, Bonneville Power Administration (BPA), the Bureau of Reclamation (BOR), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS). In order to understand the purpose and goals of this study and the organizations involved, it is helpful to examine the history of significant events related to salmon restoration over the past decade.

See Table 5 for a summary of events occurring from 1990, the start of the controversy, to the present. This table was created from information obtained in the Draft FR/EIS found in Appendix R: Historical Perspectives. For more detailed information about the events over the last ten years, please see Appendix R (USGS, 1999).

4.2 Institutional Setting

The events over the past decade have shaped the current institutional setting put in place to conduct the *Lower Snake River Juvenile Salmon Migration Feasibility Study*. Figure 5 shows the current institutional/organizational setting put in place to solve the issue of the declining salmon population in the lower Snake River. Before examining the current organization of stakeholders, it is helpful to review its evolution.

From the beginning of this controversy, when Senator Mark Hatfield of Oregon organized the Salmon Summit to address the declining salmon population in the lower Snake River, many organizations have been involved. The Salmon Summit gathered members of organizations responsible for water management, power production or marketing, and fisheries management. Gathering such a diverse group of people, all involved in different aspects of a large-scale water development setting, to tackle the problem of salmon decline follows the IFIM suggestion of interdisciplinary analysis to solve large, complicated problems. Although the Salmon Summit was not successful in reaching any definitive conclusions on salmon population management, its participant's attempts set the ball rolling in the right direction. It is quite possible that at this early stage in the salmon population debate no one fully understood the scope of the problem, and the controversy that possible solutions to salmon population mitigation would generate in the public eye. It was a good first effort in identifying problems and possible solutions.

Table 5 – History of Events (1990-Present)

Year(s)	Activity Name	Description
1990-1991	Northwest Salmon Summit	Organized by Senator Mark Hatfield of Oregon to address the issue of declining salmon stocks. The Summit included the governors of Washington, Oregon, Idaho, and Montana, as well as 30 official members representing 28 organizations responsible for water management, power production or marketing, and fisheries management. Participants divided into four separate task groups to study fish harvest, river flow, salmon production, and enforcement problems. Although members developed various proposals, the divergent interests represented at the Summit did not reach an agreement on a fundamental approach to the problem. By the last formal meeting, held in early March 1991, Summit participants had not reached a consensus on a comprehensive plan of action or mitigation of impacts.
1990-1997	Endangered Species Act Listings of Northwest Salmon	Snake River sockeye salmon were listed as endangered on November 20, 1990. Snake River spring/summer chinook and Snake River fall chinook salmon were listed as threatened on April 22, 1992. Snake River spring/summer chinook and Snake River fall chinook were reclassified as endangered by an emergency ruling from NMFS, dated August 18, 1994, but have since been classified as threatened. Snake River wild steelhead was proposed for threatened status on August 9, 1996, and was formally listed on August 18, 1997.
1991	Northwest Power Planning Council (NPPC) Fish and Wildlife Amendments	NPPC is made up of representatives from the States of Idaho, Montana, Oregon, and Washington and is entrusted with the responsibility of finding ways to acquire and market new power sources while giving equitable treatment to fish and wildlife. In 1991, the NPPC began a series of amendments to the Fish and Wildlife Program to institute a regional salmon and steelhead rebuilding plan. The NPPC was responding to a request from the Northwest Governors, the congressional delegation, and NMFS to develop a comprehensive salmon plan. The purposes of the NPPC's amendments are to preserve the ecological and genetic diversity of the runs while rebuilding their overall numbers. Phase I of the amendment process (summer, 1991), focused on emergency habitat and production actions. Phase II amendments (December, 1991), concentrated primarily on fish survival during migration in the mainstems of the Columbia and Snake rivers and on harvest and introduced the concept of a framework that ties existing and future salmon rebuilding efforts.
1991-1992	Columbia River Salmon Flow Measures Options Analysis/Environmental Impact Statement	In May 1991, the Corps, with BPA (Bonneville Power Association) and BOR (Bureau of Reclamation) as cooperating agencies, began preparation of the 1992 Options Analysis/Environmental Impact Statement (OA/EIS) on the effects of operational changes at certain Federal water projects in the FCRPS. The OA/EIS was undertaken to analyze effects of proposed changes to the FCRPS in response to several actions: the November 20, 1991 listing of the Snake River sockeye salmon as endangered under the ESA; the proposed listing of several other wild salmon stocks as endangered or threatened; discussions during the Salmon Summit; and recommendations contained in the Phase II amendments of NPPC's Fish and Wildlife Program. The OA/EIS considered several alternative water management actions that could be taken in 1992 at dam and reservoir projects along the lower Snake and Columbia Rivers to improve juvenile and adult anadromous salmon migration conditions.
1992	Reservoir Drawdown Test	As part of the 1992 Operation Plan, the Corps conducted a test drawdown at the Lower Granite and Little Goose facilities on the lower Snake River. The test was intended primarily to determine the physical effects of partial drawdown. As such, the test was scheduled to occur when few anadromous fish are present in the river. The idea behind the drawdown concept is to increase river velocities to more closely resemble natural juvenile migration conditions. In March 1992, the Corps drafted Lower Granite 11 meters (36 feet) and Little Goose 3.8 meters (12.5 feet) below the MOP levels for which they were designed. Nine spill tests were also conducted during the drawdown to determine impacts to structures, gas supersaturation levels from spilling, and potential adult passage conditions at these lower reservoir elevations.
1992	NMFS Biological Opinion on Proposed 1992 Operations of the Federal Columbia River Power System	Because the Snake River sockeye salmon was listed as endangered under the ESA, the Corps was required to make a formal consultation with NMFS. Such consultation would involve the preparation of a Biological Assessment (BA) on the part of the Corps, and the issuance of a biological opinion by NMFS. The BA presents the Corps' assessment of whether or not the proposed actions would jeopardize the listed species, while the biological opinion is NMFS's opinion. The Biological Opinion concluded "that the proposed operations are not likely to jeopardize the continued existence of listed or proposed salmon species." However, in its transmittal letter NMFS included the caveat that it was "concerned that if operation of FCRPS continued as is proposed for 1992, it would not be sufficient to reverse the decline over one lifecycle of the salmon; therefore, additional steps will likely be needed in 1993 and future years."

Table 5 - History of Events (1990-Present)

Year(s)	Activity Name	Description
1992	Corps Operations Plan	After NMFS issued its Biological Opinion, the Corps issued a Record of Decision (ROD) that described its Operations Plan for 1992. The plan included a drawdown test at Lower Granite and Little Goose dams, specifications on how deep to keep reservoirs during spring, summer, winter and fall, available water monitoring, fish monitoring, continued fish transport, and fish transport improvements.
1992-1993	Interim Columbia and Snake Rivers Flow Improvement Measures for Salmon Final Supplemental Environmental Impact Statement	The Interim Columbia and Snake Rivers Flow Improvement Measures for Salmon Final Supplemental Environmental Impact Statement (SEIS) evaluated the impacts of several alternatives for operating certain dams and reservoirs on the FCRPS during 1993 and future years until a long-term plan of action could be developed (based on results of ongoing long-term studies). The Corps in cooperation with BPA and BOR prepared the SEIS. The proposed action was being considered in response to the ESA listing for Snake River salmon. The SEIS was issued in March 1993. As with the 1992 OA/EIS, the environmental impacts of the proposed actions considered in this SEIS included the effects of altering normal river operations on a number of resource areas: water quality, anadromous fish, resident fish, wildlife, soils, air quality, transportation, agriculture, power, recreation, aesthetics, cultural resources, socioeconomics, and project structures.
1993	NMFS Biological Opinion on Proposed 1993 Operations of the FCRPS	On May 26, 1993, NMFS issued its Biological Opinion for 1993 operations of the FCRPS (NMFS, 1993). This Biological Opinion was based on a number of documents provided by the Corps, including the SEIS, as well as modifications to the 1993 Operations Plan developed during the intense consultation process. It concluded that operation of the FCRPS contributed to the salmon population decline, but that measures such as fish transport and improved bypass systems have and will continue to reduce fish mortality.
1994-1999	NMFS Biological Opinion on Proposed 1994-1999 Operation of the FCRPS and Juvenile Transportation Program in 1994-1998	The Biological Opinion and the action agencies' RODs concluded that the proposed operation of the FCRPS was not likely to jeopardize the continued existence of the endangered or then threatened Snake River salmon species.

Table 5 - History of Events (1990-Present)

Year(s)	Activity Name	Description
1994	Law Suit and Court Decision (Idaho Department of Fish and Game v. National Marine Fisheries Service)	The Idaho Department of Fish and Game (IDFG), the State of Oregon, and four treaty tribes challenged the legal adequacy of NMFS' 1993 Biological Opinion for FCRPS Operations in Federal district court proceedings. The court stated that the Biological Opinion was arbitrary and capricious and otherwise not in accordance with the purposes of the Endangered Species Act, Section 7(a)(4). NMFS lost. NMFS and the action agencies, the defendants in this lawsuit, opted to reconsider the newly issued 1994-1998 FCRPS Biological Opinion rather than expend limited resources reconsidering the challenged 1993 opinion about FCRPS actions that were then completed. The Federal agencies further decided to work cooperatively with all the other parties, and particularly with the states and treaty tribes, rather than appealing the judgment and continuing to litigate the issues raised in the case. The court asked for a new Biological Opinion to be issued in 1995.
1994	Snake River Salmon Recovery Team's (SRSRT) Final Recommendations to the National Marine Fisheries Service	Following the listing of Snake River sockeye salmon as an endangered species, NMFS appointed the SRSRT to independently develop recommendations for a Recovery Plan for the species (as required under Section 4(f) of the ESA). It developed a draft recovery plan over the course of 27 months using an open public process and issued their final recommendations in May 1994.
1994	Lower Snake River Biological Drawdown Test Draft Environmental Impact Statement	The Corps and NMFS as joint lead agencies, along with the BPA as a cooperating agency, analyzed four general alternatives intended to provide information on the biological effects of reservoir drawdown on migrating juvenile salmon and steelhead. The test would also provide an opportunity to study the effects of reservoir drawdown on adult salmonids, resident fish, wildlife, and other components of the lower Snake River ecosystem. The drawdown test was never implemented and an EIS was never completed because it was shown that salmon survival rates were already high at Lower Granite Dam (where the drawdown test was to take place).
1995	NMFS Biological Opinion on Reinitiation of Section 7 Consultation on Proposed 1994-1998 Operation of the FCRPS and Juvenile Transportation Program in 1995 and Future Years	On March 2, 1995, NMFS issued its Biological Opinion. The Biological Opinion concluded that "the operation of the FCRPS as described in the 1994-98 Biological Opinion is likely to jeopardize the continued existence of listed salmon stocks (spring/summer chinook, fall chinook, sockeye). The Biological Opinion also concluded that the only way to achieve significant improvements is with long term system reconfigurations. The Biological Opinion states that immediate salmon survival improvements such as transportation and limited handling must be implemented immediately while system improvements/modifications are considered. Two decision paths were also implemented: one in 1996 and one in 1999. If a decision on drawdown could not be made in 1996, then one would be made in 1999 after more research.

Table 5 - History of Events (1990-Present)

Year(s)	Activity Name	Description
1995	Issuance of Corps' Record of Decision on Operations Plan for 1995 and Future Years	On March 10, 1995, the Corps issued its ROD on proposed operations of the FCRPS for 1995 and future years. The ROD documented the Corps' intent to fulfill the recommended measures in the NMFS Biological Opinion in an expeditious and responsive manner.
1995	A Proposed Recovery Plan for Snake River Salmon	In March 1995, NMFS published a Proposed Recovery Plan for Snake River Salmon, which aimed "to restore the health of the Columbia and Snake River ecosystem and to recover listed Salmon River stocks" (NMFS, 1995b). The proposed recovery plan was developed from recommendations made by the SRSRT in its May 1994 report to NMFS (SRSRT, 1994). Goals of the recovery plan included increased riparian area, consideration of salmon in resource allocation, and improved migration conditions for juveniles and adults.
1995-1997	Final Environmental Impact Statement for Columbia River System Operation Review (SOR)	The Columbia River SOR, a joint effort of the Corps, BPA, and BOR, was initiated (1990) to review multipurpose management of the Columbia-Snake River System with focus on salmon recovery. The Draft EIS for SOR was issued in July 1994 and contained 7 System Operating Strategies (SOS). While SOR agencies were finishing the Draft EIS in spring 1994, the U.S. District Court issued its ruling in IDFG vs. NMFS that the 1993 Biological Opinion had failed to meet the necessary legal standard. Key issue: was enough water in Columbia River System dedicated to salmon recovery & if new Biological Opinion must incorporate more water for fish. The 9th Circuit Court of Appeals issued a ruling in another case, stating that NPPC had not considered the recommendations of state resource agencies and tribes in preparing its Fish and Wildlife Program. The Federal operating agencies realized that the SOS that came out of SOR needed to take these legal decisions into account. In March 1995, NMFS issued its Biological Opinion.
1996	Independent Scientific Group Review of NPPC's Fish and Wildlife Program	In the December 1994 amendments to the Columbia River Basin Fish and Wildlife Program, the NPPC called on the BPA to fund the Independent Scientific Group (ISG) to conduct a biennial review of the science underlying salmon and steelhead recovery efforts and Columbia River Basin ecosystem health. The NPPC's objective was to provide the region, to the greatest extent possible, clear analysis conducted by impartial experts. On September 18, 1996, the ISG delivered its report Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem to the NPPC (ISG, 1996). The report contains the first biennial review and a proposed conceptual foundation for the Fish and Wildlife Program.
1996	Memorandum of Agreement for BPA Funding (System Configuration Team)	On September 16, 1996, five federal agencies involved in salmon and other fish and wildlife restoration activities in the Columbia River Basin signed a Memorandum of Agreement (MOA) to maintain BPA funding for Columbia Basin fish and wildlife activities at an average of $435 million per year for fiscal years 1996 through 2001. Signers of the MOA represented the Department of the Army (for the Corps), the Department of Energy (for BPA), the Department of Interior (for USFWS and BOR) and the Commerce Department (for NMFS).

Table 5 - History of Events (1990-Present)

Year(s)	Activity Name	Description
1991-1999	System Configuration Study	The System Configuration Study (SCS) was initiated by the Corps in 1991 to evaluate the technical, environmental, and economic effects of potential modifications to the configuration of Federal dams and reservoirs on the Snake and Columbia rivers with the goal of improving survival rates for anadromous salmonids migrating downriver (Corps, 1996). The SCS evolved in response to the NPPC's Fish and Wildlife Program Amendments (Phase Two) issued in December 1991 (Corps, 1996).
1994-1995	System Configuration Study: Phase I	Phase I, a reconnaissance-level assessment of multiple concepts, including drawdown, upstream collection, additional reservoir storage, a migratory canal, and several other alternatives, was completed in June 1995.
1994-1999	System Configuration Study: Phase II	Phase II is a detailed assessment of the alternatives that emerged from Phase I as holding the greatest potential benefit for anadromous salmonids. SCS Phase II has developed into a major program containing many separate and specific studies (Corps, 1996). The Lower Snake River Juvenile Salmon Migration Feasibility Study is part of SCS Phase II, and is considered separately in the following section. This growth in the scope of Phase II was considered necessary to adequately and efficiently respond to the requirements for multiple evaluations addressed in the NMFS 1995 Biological Opinion.
1994-1999	Lower Snake River Juvenile Salmon Migration Feasibility Study	The current study is one of several studies under Phase II of the SCS. It was initiated in 1994 to evaluate the technical, environmental, social, and economic effects of potential modifications to the configuration of four projects on the lower Snake River in order to increase the survival of juvenile salmon as they migrate through the project areas, as directed by the NMFS 1995 Biological Opinion. The current study includes engineering work; biological investigation (i.e., effects to salmon and steelhead, resident fish, and wildlife); effects on recreation, cultural resources, and water quality; and socioeconomic effects, including implementation costs, navigation, irrigation, and power. Also included is the development of an EIS and public involvement, both of which are essential to the NEPA process. The initial pathways being evaluated in the study included: 1) the existing system, 2) major system improvements, and 3) natural river drawdown.
1993-1999	Process for Analyzing and Testing Hypotheses (PATH)	In 1993, fishery modelers from NMFS, BPA, NPPC, the Corps, Washington, Oregon, Idaho, and the Columbia River Inter Tribal Fish commission formed the Analytical Coordination Work Group (ANCOOR). The objective of this work group is to compare and enhance smolt passage survival and lifecycle models. Previous model comparison and peer-review efforts demonstrated that each modeling system has differences in basic assumptions regarding the effects of recent and potential management actions. In 1994, a Scientific Review Panel was convened to provide technical oversight to ANCOOR. The Panel concluded that there were three major differences between the modeling systems: 1) The distribution of survival over the life span, 2) The effect of flow on survival and 3) The benefit of smolt transportation. The panel believed that as long as these differences exist, the models would output different answers in a predictable manner, rendering further analysis of model structure, behavior, and usefulness unproductive.

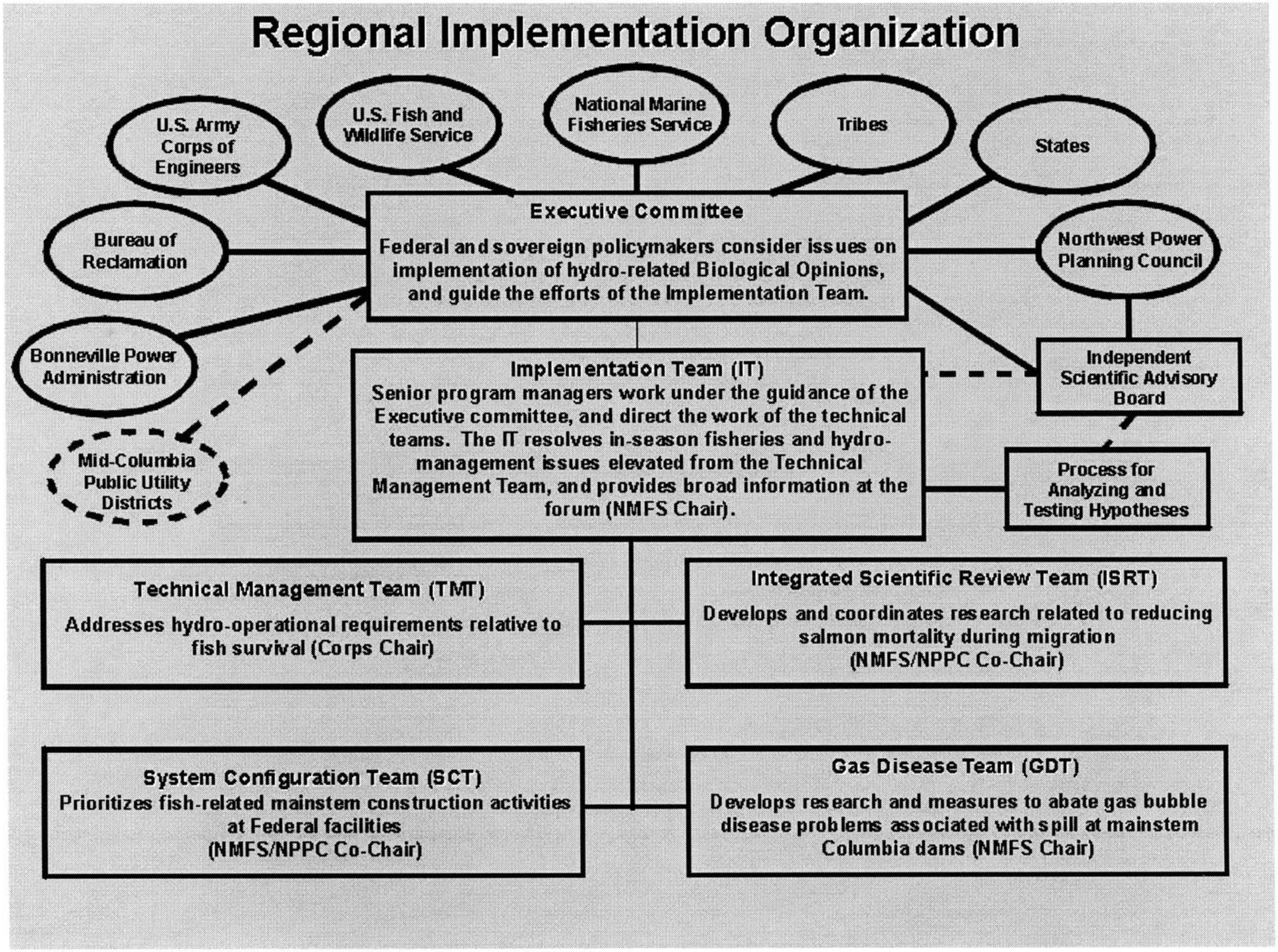

Figure 5 – Organizational Structure

Following the Salmon Summit, the Northwest Power Planning Council (NPPC) Fish and Wildlife Amendments were put into place in 1991 at the request of the governors of Washington, Idaho, Montana and Oregon. The amendments focused on emergency habitat production measures and the concept of a framework that ties existing and future salmon rebuilding actions together into a comprehensive plan; the plan was based on stated goals and objectives, with performance standards and schedules to measure progress. While the intentions of this plan were good, the range of participants (representatives from each state) was not diverse enough and did not contain the expertise necessary to find a viable solution. As mentioned above, IFIM suggests that experts from all areas of a water development setting be involved in determining solutions to problems.

From this point on, experts from all technical areas of water development were key players in studies such as environmental impact statements, reservoir drawdowns, and biological opinions. The organizations involved in these studies were and still are: The U.S. Army Corps of Engineers (the organization that originally designed and built the dams along the lower Snake River), the National Marine Fisheries Service (NMFS), Bonneville Power Association (BPA), and the Bureau of Reclamation (BOR). The purposes of the studies these agencies conducted over the last eight to nine years were to determine if the dams were a major cause of the salmon population decline and to propose actions to mitigate salmon population decline such as river drawdown. Notice that these are all government agencies tackling the problem of salmon population decline and no other stakeholders are involved. IFIM suggests that all stakeholders are identified in the beginning of a possible study, something these agencies apparently did not do.

A critical turning point in the lower Snake Dam controversy was a lawsuit and court decision over the 1993 Biological Opinion issued by NMFS in 1994: Idaho Department of Fish and Game (IDFG) vs. National Marine Fisheries Service. The IDFG and four treaty tribes sued the NMFS, stating that the Biological Opinion was capricious and without merit. The 1993 Biological Opinion stated that the operation of the dams cause salmon population decline, but fish bypass facilities and monitoring activities reduce the anticipated mortality of ESA listed salmon species to a level that will not jeopardize the existence of the species. The court agreed with IDFG and the tribes- the plaintiff won.

The court also ordered NMFS to deliver a new Biological Opinion by 1995. Instead of fighting the decision and expending limited resources, "the Federal agencies further decided to work cooperatively with all the other parties, and particularly with the states and treaty tribes, rather than appealing the judgment and continuing to litigate the issues raised in the case" (USACE, 1999). The Federal agencies' decision to work with all other stakeholders in the controversy follows IFIM. Only when all stakeholders are identified, their positions clarified, and they have a say in the manner in which studies are conducted and decisions are made, are feasible solutions possible. NMFS and the Corps did not realize the relative power that other stakeholders possessed until the court proceedings. Neither agency took the time to investigate other interested parties and issues that the parties may bring to the table. The following paragraph, taken from the *Lower Snake River Salmon Migration Feasibility Study*: Appendix R, shows how the Federal agencies later worked with other stakeholders to gather information after the court decision.

> *From May 9, 1994, through November 30, 1994, NMFS and the action agencies (the Corps and BOR) participated in a series of discussions and working groups with the parties to this litigation. The purpose of these discussions was to better facilitate the collection and consideration of credible and relevant scientific evidence in a re-evaluation of the application of the standards of ESA Section 7(a)(2) to the FCRPS and of alternatives and measures for FCRPS operation and facilities. The Federal agencies and other parties to the litigation were aided by technical assistance provided through interagency working groups of technical personnel; one to consider the biological requirements of the listed species and the other to inventory and evaluate alternative actions and measures for the FCRPS.*

This type of discussion and information gathering is exactly what IFIM suggests as the optimal procedure. All sides have the opportunity to determine ALL of the issues and observe agency cultures, agency operating procedures, agency perceptions, and the behavior of all participants. In these joint discussions, information gathering and understanding how agencies, interest groups, and other interested parties are likely to behave in negotiation are of primary concern. If all interested parties had been involved in writing the Biological Opinion from the start, each stakeholder would have had a better understanding of the other stakeholders and the lawsuit probably could have been avoided. It is unfortunate that the lawsuit was the driving force in bringing the stakeholders together; a great deal of time and valuable resources were expended in the lawsuit.

The court decision influenced the new Biological Opinion released in 1995 which states that continued operation of the lower Snake River dams will jeopardize the existence of the ESA listed salmon species. It also states that immediate action must be taken to restore salmon populations such as fish transportation and fish bypass while solutions that included long-term system reconfiguration are investigated.

At the time of the court's opinion, the Corps had already initiated the System Configuration Study (SCS) to evaluate the technical, environmental, and economic effects of modifications to the configuration of federal dams and reservoirs with the goal of improving migrating salmon survival rates. The four dams along the lower Snake River are included in this study. The SCS was a response to the NPPC's *Fish and Wildlife Program Amendments (Phase Two)* issued in December 1991, and was conducted in two separate phases. (Corps, 1996). Phase I, a reconnaissance-level evaluation of multiple concepts, including drawdown, upstream collection, reservoir storage, a migratory canal, and several other alternatives, was completed in June 1995 (Corps, 1996). Phase II is a detailed assessment of the alternatives that emerged from Phase I as holding the greatest potential benefit for anadromous salmonids (Corps, 1996).

The *Lower Snake River Juvenile Salmon Migration Feasibility Study* Draft FR/EIS is one study under Phase II of the SCS and explores a number of alternatives that address both hydropower actions on the four lower Snake River dams and the much broader needs of the ESA-listed salmon. In order to meet the needs of the salmon the 1995 Biological Opinion created an inter-Governmental forum that involves federal, state, tribal, and other representatives for decision-making (USACE, Introduction: Section 1.44, 1999). The objective of the multi-leveled Regional Forum (Figure 5) is to allow technical teams to investigate pertinent facts and analyze them in order to define the central issues affecting ESA-listed salmon and steelhead in the Columbia River Basin. The intent of the Regional Forum is to allow the Executive Committee, the Implementation Team, and the numerous technical teams to have opportunities for discussions of both scientific and management issues (USACE, Introduction: Section 1.44, 1999). The Draft FR/EIS states that "if an issue cannot be resolved at the technical levels, the issue is raised to the manager level for resolution" (USACE, Introduction: Section 1.44, 1999)

The Regional Forum includes several teams, each of which performs a separate function. However, the teams are interrelated; this is important for knowledge sharing and discussion. The Technical Management Team makes decisions about the in-season (migration season) operation of the dams to benefit salmon. The Regional Forum also includes a parallel System Configuration Team (SCT) established to discuss changes to the physical structures of dams in the system. The Water Quality Team provides scientific and technical recommendations on water quality issues with current emphasis on water temperature and total dissolved gas in the Columbia River Basin. The Integrated Scientific Review Team develops and organizes research in the Columbia River Basin on approaches for reducing salmon and steelhead mortality during migration season. The Implementation Team helps with the resolution of the issues produced by the various technical teams. The Executive Committee deals with issues at the policy level. It is important to note that the results of the *Lower Snake Juvenile Salmon Migration Feasibility Study* Draft FR/EIS are major components of the overall Regional Forum's decision-making process.

Section 1.4 of this report gives position statements of many of the organizations and agencies involved in this controversy. The Draft FR/EIS report lists the groups involved (USACE, 1999). They are listed below.

- **U.S. Army Corps of Engineers**
- **Bureau of Reclamation**
- **Bonneville Power Administration**
- **U.S. Federal Energy Regulatory Commission**
- **U.S. Fish and Wildlife Service**
- **U.S. National Marine Fisheries Service**
- **U.S. Environmental Protection Agency**
- **Federal Caucus** (Includes: NMFS, Corps, BOR, BPA, EPA, Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), USFWS, and United States Department of Agriculture (USDA) Forest Service)
- **Columbia River Basin Forum** (allows regional governments, interested parties, and the general public the opportunity to discuss management approaches for Columbia River Basin resources and to determine if regional agreement can be made on possible alternatives)
- **Tribal Caucus** (Thirteen Indian tribes have management authority for fish, wildlife, and water resources within their reservations, as well as other legal rights included in Treaties and Executive Orders.)
- **Columbia River Inter-Tribal Fish Commission** (The Columbia River Inter-Tribal Fish Commission (CRITFC) is the technical support and coordinating agency for fishery management policies of the four Columbia River treaty tribes.)
- **Wy-Kan-Ush-Mi Wa-Kish-Wit** (Wy-Kan-Ush-Mi Wa-Kish-Wit is the Columbia River anadromous Fish Plan of the Nez Perce, Umatilla, Warm Springs, and Yakama tribes.)
- **State Agencies** (Washington, Oregon, Idaho, and Montana represent distinct management entities with authority over fish, wildlife, and water resources within their jurisdictions.)
- **Columbia Basin Fish and Wildlife Authority** (The Columbia Basin Fish and Wildlife Authority (CBFWA) was established to coordinate the efforts of its members (state, tribal, and Federal fish managers) to protect and enhance fish and wildlife.)
- **Northwest Power Planning Council**
- **Multi-Species Framework** (A science-based framework was initiated to help guide management policy. The framework is used to develop options for future management of the Columbia River Basin, including the biological, social, and economic effects of the options.)

The Draft FR/EIS is a complete report that addresses issues regarding all aspects of the Lower Snake River Dams Controversy and has taken many years to produce. It has been a process of gathering information, understanding multiple viewpoints from stakeholders, running and evaluating models, and analyzing possible solutions to the declining salmon population. The creation of the Regional Forum organized this process and allowed cross-functional teams to share information and knowledge and work together to analyze the problem. This type of organization is precisely what IFIM encourages in order to determine and evaluate all of the issues surrounding a controversy. The Draft FR/EIS is a successful result of the organization of stakeholders' opinions, information, and people.

4.3 Issue Analysis

Since November 20, 1991 the National Marine Fisheries Service (NMFS) has declared four species of salmon (sockeye, spring/summer chinook, fall chinook, and steelhead) that inhabit the lower Snake River as either endangered or threatened. The decline of the salmon populations is of great concern to many parties who reside in the Northwest Region and has also become the focus of numerous studies mentioned in Table 5. Salmon decline in the lower Snake River is the primary problem being addressed in this report.

As mentioned in Chapter 1 of this report, there are many possible reasons for salmon decline including overharvest, loss of habitat, influence of hatchery salmon problems associated with dams and reservoirs, and human related problems (water quality, irrigation). Each of these is an issue in itself and must be addressed. These issues lead to other issues regarding hydropower, navigation and transport of goods, and habitat issues discussed in Chapter 1 of this report. The Draft FR/EIS recognizes all of these issues, but focuses primarily on the dams and their influence on the declining salmon population in the lower Snake River. However, the final decision on whether to breach the dams, use drawdown, or use salmon transportation options greatly affects many of the stakeholders involved in the controversy.

The general issues addressed by the stakeholders in the lower Snake River salmon controversy are displayed in Table 6. More detailed information regarding general issues is found in Section 1.2: Controversies of this report. Table 7 deals with macrohabitat issues while Table 8 deals with microhabitat issues.

Table 6 – General Issues

General Issues	Who is Concerned?	Issue Description
Salmon Population Decline	Everyone!	Since 1990, ESA listing of salmon have been a cause for concern. Several salmon species inhabiting the Lower Snake River are listed as endangered or threatened. All parties involved in this controversy agree that salmon populations must be rejuvenated, however, not all parties agree on the methods to accomplish this.
Dam Removal	Everyone!	A central issue to salmon recovery is the possibility of partial dam removal. The hydropower portion of the dams would no longer be functional, thereby eliminating the production of electricity once provided for residents of the Northwest and businesses operating along the lower Snake River. The cost of dam breaching is also of concern. It is the most expensive alternative proposed in the Draft FR/EIS.
Navigation	People and companies that rely on the river for transportation of goods.	The lower Snake River dams have provided a navigable waterway to transport goods (agricultural, industrial, etc.) up and down the river all the way from the Pacific Ocean to Idaho.
Transport of Commodities (Economics)	Farmers, Industrial Companies (aluminum manufacturers, etc.), Barging Companies: Bernert Barge Lines, Brix Maritime Company, James River/Western Transportation Company, Shaver Transportation, and Tidewater Barge Lines, Inc.	Farmers, industrial companies and residents of the Northwest region rely on the lower Snake River for transport of goods. Without this capability commodities will have to be transported using highways and rail (both are available in this region).
Hydropower	Residents of the Northwest, industrial users of electricity	The four dams along the lower Snake River provide electricity. Residents and other users of electricity are concerned that without the dams there will be a shortage of electricity in the region.
Irrigation	Farms located along the lower Snake River	The lower Snake River dams create reservoirs that provide water storage. This water can then be diverted to provide irrigation to farms along the lower Snake River. Farmers are concerned that without the irrigation capabilities they will go out of business.
Salmon Harvest	Commercial, recreational and tribal harvesters	Without a healthy supply of salmon, people who depend on the harvest of salmon will be out of business. This includes commercial and tribal fishers. Recreational fishing attracts tourists who spend money in the region. With no salmon, tourism will drop and economic impacts will be felt in the region.

Table 7 – Macrohabitat Issues

Macrohabitat Issues	Description
Hydrologic Issues	
Water Budgets	A water budget (takes into account evaporation, groundwater storage, open channel runoff, evapotranspiration and soil moisture) is not very useful in the case of the lower Snake River dam controversy. It involves the operation of dams, a major change to the environment, and one that overpowers a simple water budget.
Hydrologic Changes	A hydrologic time series is needed to compare the pre-dam lower Snake River conditions, the current conditions (dams in place), and the conditions after the implementation of a plan (dam breaching or system improvements where the dam functions would be the same as the existing functions).
Reservoir Issues	Involves how the reservoir should operate. The Draft FR/EIS has identified four alternatives: 1) Existing Conditions, 2) Maximum transport of Juvenile Salmon, 3) Major System Improvements, and 4) Dam Breaching. The dams will operate in much the same way they do today with intermittent seasonal drawdowns to accommodate salmon in the first three alternatives. Dam breaching will drastically change the operation of the dams, creating a free-flowing river. All of these issues must be addressed.
Channel Dynamics & Stability	
Channel enlargements/reductions	With the dams in place the lower Snake River has undergone many modifications. The pre-dam conditions consisted of a free-flowing river with a pool-riffle system while conditions today consist of free-flowing portions and reservoirs. The reservoirs have drastically enlarged the channel and slowed the flow. The width and depth of alluvial (a channel free to adjust dimensions in response to a change in flow) channels are largely a function of discharge (Schumm, 1996) The Corps' proposal to remove the lower Snake River dams will reduce the channel width and perhaps return the river, an alluvial channel, to a state similar to the pre-dam conditions. A drawdown test at Lower Granite and Little Goose Dams was completed in 1992 and indicated that reservoir drawdown reduces channel width and speeds up river velocities (USACE, 1993). Large amounts of sediment behind the dams that had built up over time were transported downstream because of the increased flow velocities.
Aggradation/Degradation	Dams, by altering flows, cause both aggradation and degradation. Sediment aggrades behind dams because flows are not high enough to transport the sediment downstream. Where flows are higher, just downstream of a dam, sediment can be transported from the channel bottom and sides. Dam removal will affect aggradation and degradation and possibly restore the channel to pre-dam conditions. The rehabilitation and enhancement of pre-dam biotic and abiotic components in the lower Snake River depends on the extent to which pre-dam morphological characteristics can be restored— particularly alluvial and partially-alluvial reaches. This approach assumes that those characteristics supported healthy salmonid populations in the past and have the capacity to do so in the future (USACE, 1999, Appendix H).

Table 7 - Macrohabitat Issues

Channel Materials	The bed and bank materials are critical for sediment transport, hydraulic influences, and modifying the form, plan, and profile of the river (Rosgen, 1994). Appendix H of the Lower Snake River Juvenile Salmon Migration Feasibility Study contains detailed information regarding substrate material along the lower Snake River. Channel substrate data were also incorporated into the level 2 classification. The 1934 Corps maps contained handwritten notations of substrate types for the river channel and shoreline. The notes are qualitative assessments of substrate type, and provide only a general idea of grain sizes and spatial distribution. The handwritten notations of substrate type were incorporated into the GIS as point samples. The notes for each point sample were converted into one of five classes according to the appropriate American Geophysical Union) AGU grain size classification.
Temperature	Temperatures in the free-flowing portions of the lower Snake River and the reservoirs must be studied to determine if the temperatures are adequate for salmon survival. The flow velocity, stream width, and exposed water surface area all affect the water temperature. For instance, the reservoirs along the lower Snake River have a larger water surface area exposed to radiation while the free-flowing portions are not exposed as much. The free-flowing river sections have cooler water. The Draft FR/EIS contains results from extensive temperature modeling along the lower Snake River as it exists.
Water Quality	Water quality is also of concern for salmon survival. Have the dams altered the water quality (suspended sediment, dissolved gases, etc.)? Spilling water over the dams increases dissolved gases which may suffocate fish. Dams also cause sediment that would normally be carried downstream, to settle behind the dams. The amount of sediment (suspended, bedload) and gradation of sediment is altered by dams. This may affect salmon.

Table 8 – Microhabitat Issues

Microhabitat Issues	Description
Selection of Target Species	The salmon species on the ESA listings are sockeye salmon, spring/summer chinook salmon, fall chinook salmon, and steelhead. These are the species of most concern.
Critical Microhabitats, Life Stages, & Habitat Bottlenecks	An Assessment of Lower Snake River Hydrosystem Alternatives on Survival and Recovery of Snake River Salmonids (an Appendix in the Draft FR/EIS) contains information regarding critical microhabitats. The dams prevent migration of juvenile salmon both upstream and downstream and also prevent them from reaching spawning areas upstream in lower Snake River tributaries. The dams have also altered spawning areas with the construction of reservoirs. The alterations of key habitat types are known as habitat bottlenecks. The lifestages of primary concern are the smolt stage (juvenile salmon 1-2 years old) when salmon migrate to the oceans to mature and the adult salmon stage when they return to the freshwater river to spawn.
Habitat Requirements & Temporal Variations	An Assessment of Lower Snake River Hydrosystem Alternatives on Survival and Recovery of Snake River Salmonids contains information regarding the habitat requirements of the ESA listed salmon species. Defining critical habitat for the species of interest is critical for running PHABSIM. Habitat Suitability Criteria are necessary to define critical habitat. Because PHABSIM has been run in the Columbia-Snake River system there should be adequate habitat suitability criteria available. If not, habitat suitability criteria must be created through empirical observation of the species of interest. However, because of the limited number of salmon inhabiting the lower Snake River, observation could be difficult. Also, a decision will be made soon about how the dams should be operated in the future. There is little time to create habitat suitability criteria, a time consuming task.
Spatial Composition, Configuration, and Continuity	These refer to the spatial distribution of different kinds of microhabitats in a river. Because the lower Snake River has been divided into free-flowing sections and reservoir sections there are many different types of microhabitat. The physical distribution and spatial arrangement (configuration) of patches of salmon microhabitat must be identified. Continuity refers to the extent that organisms are able to move among different parts of the river. This is of concern since a large part of the problem concerning salmon involves their inability to move longitudinally along the river.

Information on Corps alternatives to restore salmon populations taken from Chapter 3 in the main report of the Draft FR/EIS (USACE, 1999).

Chapter 5: The Snake River Dam Controversy: Problems and Issues

Chapter 5 of this report attempts to address four major issues/problems encountered by the author during the investigation of The Lower Snake River Dam Controversy. First, and most importantly, the author believed that there would be obvious, indisputable evidence that IFIM was applied to this controversy and that this would be a wonderful case study to show readers IFIM's applicability to a large, controversial project. Although not formally adopted, the process has followed the general framework of IFIM. Second, sifting through thousands of pages of studies and opinions has proven to be a learning experience in itself. In such a highly controversial issue, where stakeholders' release information that is stated as fact but in reality is opinion, readers must be careful to evaluate information. Third, it is unclear exactly how the dams have affected the salmon population. Could it be that they act as barriers that prevent salmon from migrating or have the dams changed the instream conditions to the point that there is no suitable salmon habitat? Fourth, the Corps has released four of what it thinks are the best options regarding the operation of the dams and the restoration of the Snake River salmon population. Yet it remains unclear if any will be implemented. What will happen now and in the future?

Most of the studies discussed in this thesis have been carried out by the Corps and NMFS, or at least under their supervision and are well-documented and reliable sources of information if the reader has the technical background to sift through the information. However, many stakeholders have attempted to skew the results of some of these to reflect their opinions about the declining salmon population. An important issue discussed in this section of the report is the numerous opinions voiced by different stakeholders. Examples are included throughout this chapter.

5.1 IFIM Implementation?

Section 4.1 of this report gives a brief history of some of the main events leading up to the present day *Lower Snake River Juvenile Salmon Migration Feasibility Study* Draft FR/EIS that the U.S. Corps of Engineers has completed. Since 1990, when the Snake

River sockeye salmon was listed as endangered, there have been numerous studies and even lawsuits that have defined the controversial and uncertain nature of the declining salmon population and its possible causes.

After investigating this controversy for over 8 months it is somewhat unclear to the author of this report as to whether or not IFIM was applied to the Lower Snake River Dam Controversy. Members of the Corps of Engineers cannot say with certainty that any methodology was explicitly followed to gather information, define issues, implement studies, or outline alternatives. However, the author believes that a defining moment in the timeline of events from 1990 to the present, one that drastically changed the path of the investigation of the declining salmon population, was the lawsuit (IDFG vs. NMFS) over the validity of the 1993 NMFS Biological Opinion. Until this lawsuit, various government organizations (the Corps, NMFS, NPPC, BOR, BPA) took responsibility for evaluating the impact that the dams along the lower Snake River had on the salmon population decline and ignored any other stakeholders' views. The IDFG vs. NMFS lawsuit, won by IDFG, was a wake-up call to NMFS and the Corps. NMFS decided not to dispute the verdict (the 1993 NMFS Biological Opinion was found to be arbitrary and capricious and otherwise not in accordance with the purposes of the Endangered Species Act, Section 7(a)(4)). NMFS lost and instead allow stakeholders to be a part of further investigations, including the re-issuance of the Biological Opinion in 1995. At this time the Corps invited any and all to become a part of an organizational structure (Figure 5) to investigate dam operations and salmon population decline. NMFS and the Corps finally realized that there were many stakeholders who had opinions, opposing views, and general input that could be valuable in creating positive synergies in the process of deciding the fate of the dams. The author sees this as the beginning of the IFIM process. The matrix organization allows the different teams such as the Technical Management Team, the Gas Disease Team, the Implementation Team, and all other teams to investigate specific areas while communicating with other teams to share knowledge and information. This type of matrix structure is important to foster communication since there are so many intertwining issues and problems. It also allows for easy compilation of the individual studies into a cohesive report- *The Lower Snake River Juvenile Salmon Migration Feasibility Study.*

The smaller groups within the organization were able to determine the variables and issues (Phase II: Study Planning) regarding their portions of the project and the implementation of their individual studies (Phase III: Study Implementation). The transfer of information between the groups is crucial in Phase II and Phase III since many variables are dependent on other variables; for instance, spilling water affects the Gas Disease Team since spilling increases dissolved gases and it also affects the Technical Management Team which investigates dam operations. The matrix organization fostered the compilation of the information gathered in Phases II and III into *The Lower Snake River Juvenile Salmon Migration Feasibility Study*, which outlines four alternatives to dam operations.

There are definite similarities between IFIM and the evolution of The Lower Snake River Dam Controversy, especially since 1995, when the Corps formed the matrix organization (Figure 5). Right now, the study appears to be in Phase IV: Alternatives Analysis/Problem Resolution. Four alternatives have been proposed by the Corps- now a decision must be made. Further discussion of the alternatives follows in Section 5.4.

5.2 Why is there so much conflicting information out there?

In 1995, when the Corps invited anyone to participate in the multidisciplinary matrix organization, many groups (mostly environmental groups) declined and decided to create their own Snake River salmon campaigns using newsletters, press releases, and web pages. Many environmental groups believed that the Corps would not give them a fair say in the controversy. Section 1.4 of this report outlines the various position statements from stakeholders. It is worthy to note that some of the claims made by these organizations do not have any scientific evidence as backing; many of the statements are speculation. Yet many readers, the author of this report included, may make the mistake of believing these statements to be fact after a first read. However, upon further review of the statements it is clear that there are no references to studies, scientific journals, or any other valid references to back the statements. For instance, the Pulp and Paper Workers Resource Council (PPRC) claims that the juvenile salmon survive the journey around the dams but "something" happens to the salmon between their release and the journey downstream. There is no reference cited to back this claim. It is extremely important that readers of documents concerning the Lower Snake Dam Controversy be critical of the information and that they make a point to look for scientific evidence or references to back the claims made in articles, on web sites, and in studies.

The controversial and political nature of the problems surrounding the lower Snake River has created heated debates and blatantly conflicting opinions. Many of the special interest groups involved in this controversy are so adamant that their opinions are correct that they will do almost anything to voice their opinions in a public forum. As an example, a recent Denver Post article reported that American Rivers (an environmentalist organization) listed the Snake River as America's most endangered river. The reader must ask several critical questions. Why are they claiming it is the nation's most endangered river? What is their motive? Why are they claiming this NOW and not several months or even years ago? What evidence supports the statement that the Snake River is America's most endangered river? What does most endangered mean? American Rivers does not define 'most endangered.' These types of questions must be asked when reading virtually anything that has to do with the Lower Snake River Dam Controversy.

Much of the information gathered for this report comes from *The Lower Snake River Juvenile Salmon Migration Feasibility Study* since the models, studies and individual reports within the study are backed by scientific evidence, include references, and address the uncertainty surrounding the issues. The Corps recognizes that there is a great deal of uncertainty in many of the models and goes into great detail to explain this. Overall, the author of this report believes that *The Lower Snake River Salmon Migration Feasibility Study* is by far the most reliable, comprehensive analysis of the biological and economic issues surrounding the Lower Snake River Dam Controversy.

5.3 Exactly how have the dams affected the salmon?

Even after ten years of investigation into the declining salmon population, it is still unclear as to exactly how the four dams along the lower Snake River have impacted the salmon. Appendix A of the *Lower Snake River Juvenile Salmon Migration Feasibility Study* is an evaluation of the PATH analytical framework, which attempts to quantitatively examined the biological consequences of alternative hydropower system actions. There is great uncertainty about how to define two variables crucial to running the PATH model: 1) carrying capacity and 2) productivity potential of spawning habitat (especially if reservoirs are drained). Therefore there is uncertainty in the output of the PATH analysis. These points are discussed below.

No one knows exactly whether it is the salmons' inability to pass the dams or the lack of suitable salmon habitat in the lower Snake River that is contributing to the salmon population decline. PHABSIM, discussed earlier in this report, is a model that attempts to quantify the amount of suitable salmon habitat. PHABSIM has not been run along the lower Snake River, perhaps because the model is generally used for free-flowing river sections and the free-flowing portions of the lower Snake River experience backwater effects from the dams. If the model were run to determine the amount of suitable salmon habitat currently in the lower Snake River, the output would most likely be inaccurate. But how do we determine if there is suitable salmon habitat already in existence along the lower Snake River? Without this information it cannot be determined with any certainty, how the dams are impacting the salmon. If the amount of suitable salmon habitat could be determined and suitable habitat was found along the lower Snake River, it would support the theory that the salmon population is declining because the fish are unable to reach suitable spawning habitat; better transportation methods should be employed. If, on the other hand, it was possible to determine that there is no suitable salmon habitat along the lower Snake River, the theory that the dams have altered the instream habitat to the point that the river is not able to support migrating and spawning salmon is supported. It is important to note that even if a model could produce output that indicates there is no suitable salmon habitat, salmon passage around the dams still may be considered a contributor to the population decline.

It is unfortunate that the time a monetary cost involved in running a habitat model such as PHABSIM is unrealistic at this point in the process, now that lawsuits are beginning to pop up with more frequency. The information/output from a well-run PHABSIM model run along the lower Snake River would be invaluable in deciding the fate of the dams.

5.4 The Future of the Dams

The Lower Snake River Juvenile Salmon Migration Feasibility Study draft report outlines four alternatives for dam operations along the lower Snake River. They are as follows:

1. Existing Conditions: Continued operation of the lower Snake River dams according to their current configuration.
2. Maximum Transport of Juvenile Salmon: Maximize salmon passage using the existing collectors and trucks and barges for salmon transport downriver.
3. Major System Improvements: Incorporates a full-length surface bypass collector at Lower Granite Dam (the first dam fish encounter on their downstream journey) a logical point to collect the majority of the fish.
4. Dam Breaching: Removal of the earthen embankment section of each dam, eliminating the reservoirs behind the dams.

The most controversial and expensive option is breaching the four dams in an attempt to return the lower Snake River to its pre-dam condition. While the idea of dam breaching seems to be a good one to restore salmon habitat, there is far too much uncertainty about the type of environment dam breaching will bring. Would conditions really be the same as those of the pre-dam era? If the conditions are restored to the pre-dam era, will the new instream habitat be sufficient to restore salmon populations or are there other factors, such as the numerous downstream dams, that will continue to affect salmon populations? There are so many unanswered questions, questions that are perhaps unanswerable with the available technology or a lack of an understanding of fish ecology and river hydrology in this situation.

5.4.1 Basin-wide Effects

Because the salmon species listed as endangered and threatened migrate to and spawn in the lower Snake River, focus has been placed on the four dams along the river. Many people believe that removing these dams will restore the instream habitat and with it, the salmon population. However, there are basin-wide issues, primarily issues regarding the other dams along the Columbia River, that have not been evaluated. Salmon migrate from the Pacific Ocean upstream to the lower Snake River where they spawn. Along this journey, they must pass four other major hydropower dams and countless smaller dams. Many questions remain about the effect of these dams on salmon populations. If the dams along the Columbia River are contributing to the salmon population decline, what good will it do to remove the four dams along the lower Snake River? Many scientists and engineers working for the Corps of Engineers believe that there must be a basin-wide study to attempt to determine the impact of ALL dams on the salmon populations.

5.5 Who will decide the fate of the dams?

Unfortunately, there may not be time to run a basin-wide study considering the Corps will be releasing the final draft of *The Lower Snake River Juvenile Salmon Migration Feasibility Study* by the end of 2000. There is also a civil lawsuit underway: National Wildlife Federation, Sierra Club, Idaho Rivers United, American Rivers, Pacific Coast Federation of Fishermen's Associations, Institute for Fisheries Resources, Washington Wildlife Federation, and Idaho Wildlife Federation (Plaintiffs) vs. The U.S. Army Corps of Engineers. The plaintiffs claim that the Corps operates the lower Snake River dams in a manner that violates the Clean Water Act, specifically Washington state water quality standards for temperature and dissolved gas as well as the state's antidegradation standard. The plaintiffs want the Corp to comply with Washington's water quality standards and set a schedule for such compliance.

The plaintiffs' have completely skipped the negotiation step of IFIM and have gone directly to litigation. Most likely the Lower Snake River Dam Controversy will not be decided through negotiation, but rather a series of lawsuits that could easily continue into the next decade or two.

It is unfortunate that all of the stakeholders in the controversy could not work together in an interdisciplinary team to investigate the salmon population decline and possible mitigation techniques. The Corps made a valiant attempt to include all those concerned with the possible extinction of salmon species in the lower Snake River. However, not all parties chose to participate. Countless hours and money may have been saved if a complete team could have been formed early on; a possible solution may have been determined without wasting time in the litigation process. However, hindsight is 20/20, and all parties involved must now attempt to evaluate all scientifically relevant information to determine the best solution for dam operations along the lower Snake River.

One aspect of IFIM that the author of this report believes the Corps has diligently followed is the scientific documentation and evaluation of uncertainty in the studies conducted. Documentation by scientists and engineers brings 'believability' to the report. *The Lower Snake River Juvenile Salmon Migration Feasibility Study* is a thorough report and an extremely valuable compilation of the economic and biological studies of the lower Snake River region- the documentation will surely stand up in current and future court proceedings. Hopefully, the courts will objectively evaluate *The Lower Snake River Juvenile Salmon Migration Feasibility Study* and effectively use the information presented to make the wisest decision for dam operations along the Lower Snake River for the benefit of the declining salmon population.

5.6 Recommendations

This section of the report includes my (the author's) recommendations for further action concerning the lower Snake River dams. After speaking to fishery experts, IFIM experts, modeling experts, and ecology experts and reading the majority of the *Lower Snake River Juvenile Salmon Migration Feasibility Study* and numerous documents from special interest groups and scientists, I am able to make two recommendations for further action within the Columbia River Basin.

The litigation process concerning the fate of the lower Snake River dams is only beginning. It is very possible that there will be no decision reached in the near future. In the mean time, salmon populations will continue to decline and some species may become extinct- the sockeye salmon is well on its way to extinction. There is far too much uncertainty and controversy surrounding the lower Snake River dams to effectively and efficiently determine a pro-active solution in the near future. Some type of action must be taken now. Since no action will be taken to implement any of the four Corps alternatives in the immediate future and a decision to remove the four dams will cost billions of dollars in the coming years, I propose that the money used in litigation and dam removal be spent in areas within the Columbia River Basin where there is definite evidence that stream restoration is possible. After speaking to Mike McDowell of Pentech Environmental, an expert in IFIM, stream restoration, and fishery biology in Seattle, Washington, I realize that there are numerous other streams within the Columbia River Basin that are in need of restoration. These are streams that support salmon populations. I recommend that time and money be spent on those rivers that need restoration; rivers more restorable than the lower Snake River. Restoration of smaller streams will help support salmon populations.

Along with the restoration of smaller streams within the Columbia River Basin, I recommend implementing a plan to discourage salmon harvest. This includes using money that would be spent on litigation and dam removal to pay fishermen to stop fishing. Supplementing their incomes is a less expensive alternative to dam removal and may allow salmon populations to restore themselves.

Perhaps the Corps and all others involved should consider these options instead of concentrating on the lower Snake River dams. However, with the time and money already spent on the investigation of the lower Snake River and the salmon species inhabiting the river, my recommended solutions will most likely be overlooked in the litigation process in favor of the four alternatives proposed by the Corps.

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