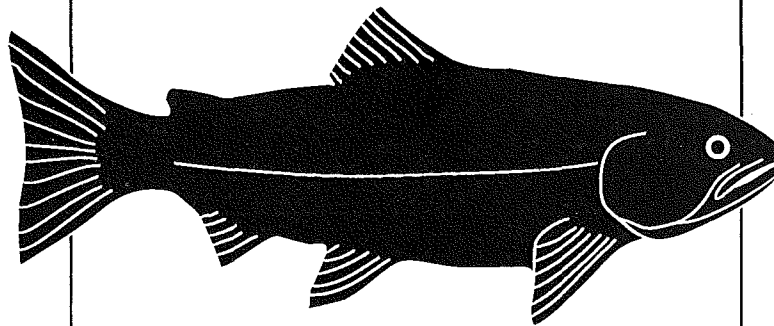

ALTERNATIVE ACTIONS FOR

RESTORING &
MAINTAINING
SALMONID
POPULATIONS

ON THE
COLUMBIA RIVER
SYSTEM



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THE UNIVERSITY TASK FORCE ON SALMON AND THE COLUMBIA RIVER SYSTEM

The Task Force is a group of faculty from the University of Idaho, Oregon State University, Washington State University, and the University of Washington with interest and expertise relating to the Columbia river system. They were appointed by the Agricultural Experiment Station and Extension Service directors of Idaho, Oregon, and Washington and given the following charges:

- Identify research and educational issues that the universities can address within the framework of their missions, capabilities, and resource bases;
- Identify resources and create working networks in each state to address identified issues relating to the Columbia River system salmon and steelhead runs;
- Develop a working plan to organize research and public education programs:
 - Document the current knowledge base;
 - Prepare educational materials;
 - Plan and conduct workshops with interested agencies, organizations, and interest groups; and
 - Conduct research and education programs.

The Land Grant and Sea Grant universities of Idaho, Oregon, and Washington are repositories for a substantial amount of information relating to the resources of the Columbia River system. They also are home for many highly trained scientists with relevant expertise. These scientists and the knowledge available to them could have considerable bearing on improving solutions to the problems arising from reduced populations of native salmon. Although the issues will, in the end, be decided by the public through a variety of political processes, the quality of public decisions will depend to a substantial degree on the quality of information on which the decisions are based.

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I. INTRODUCTION

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This report contains brief descriptions and evaluations of a reasonably comprehensive set of alternative recovery actions for increasing the size of salmonid populations in the Columbia River system. The purpose of the report is to provide concise and readable information on a complex topic to the general public to enable an informed public to participate in the policy dialogue on this important issue. Although the concern over the size of salmon populations is of long standing, the announcement of intent by the National Marine Fisheries Service (NMFS) in April and June 1991, to declare some species of salmon as endangered or threatened has increased the urgency to examine alternative recovery actions.

This report is intended to be read by people who have an interest or stake in the issue. Because of the complexity of the issue, the group of people with an interest or stake in the issue includes most of us. That is to say, an expert in fish genetics may have very limited understanding of irrigation, navigation, or power generation. Some readers may find the discussions lacking in technical detail, but the report is written to address all members of the public, not only technical experts.

In order to enable the reader to make comparisons amongst alternative recovery actions the report is written in an outline format. This will allow the reader to make comparisons of one action with another on such aspects as effect on energy production, implementation issues, likelihood of success, etc. The "Alternative Summary Table" (Appendix A) is also useful for quick comparison purposes.

In describing and evaluating alternative recovery actions, emphasis is put on salmon. However, the Columbia River system is managed as a multi-purpose system. Therefore, for each recovery action discussed, likely effects on navigation, power generation, irrigation, flood control, other fisheries and

wildlife, and recreation are identified. To the extent possible, cost estimates of implementing various recovery actions are attempted.

The set of alternative recovery actions described is reasonably comprehensive in that most conceivable alternatives are addressed in a general sense. The many recovery actions are not comprehensive in the sense that many people, agencies, and institutions continue to search for additional ways of protecting salmon runs. Other alternatives will no doubt be discovered and formulated in the future. Discussions of the alternatives in this report, in most cases, are not at the level of detail that would identify action at a particular dam, at a particular hatchery, or at a particular stream site. Doing so would result in a voluminous report and negate the report's objective of conciseness.

Discussion throughout this report shows that even the experts may not have many of the answers or that there are differences of opinion about the correct answer. Also, as the various actions may affect groups differently, some groups will support a particular measure while others oppose it. Thus, agreement regarding the various actions should not always be expected.

This report does not describe a "recovery plan" as legally required for threatened or endangered species by the Endangered Species Act (ESA). Such a recovery plan is likely to be made up of a combination of a number of recovery actions. Thus, a recovery plan is potentially far more comprehensive and complex than any one of the recovery alternatives discussed in this report, both because of the number of alternatives involved and the interactions between individual alternatives. Development of the recovery plan is the explicit responsibility of the appropriate federal agency (in this case the NMFS) with input from the public.

II. THE COLUMBIA RIVER SYSTEM

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The Columbia River system is of fundamental importance to the history, culture, and economic activity of the Pacific Northwest. It includes the Columbia and Snake Rivers and their tributaries. The Columbia River system drains significant portions of Washington, Oregon, and Idaho as well as southern British Columbia (Canada) and smaller parts of Montana, Nevada, Utah, and Wyoming (Figure 1). The mainstem of the Columbia River is approximately 1,200 miles long. The Snake River joins the Columbia River about 325 miles from the Pacific, with its origin more than another 1,000 miles inland. The Columbia River system encompasses about 260,000 square miles, an area larger than all of France.

Prior to the construction of the system of dams on the Columbia that began in 1936, the average maximum rate of flow at the mouth of the Columbia was in excess of 4.9 million gallons per second. At present there are 11 major mainstem dams and 4 major lower Snake River dams. The number of impoundments of some sort in the entire system is more than 190. These impoundments permit a managed and regulated flow. The average annual flow at the mouth of the Columbia is slightly over 2 million gallons per second.

The river system is managed as a multi-purpose resource, intended to support fisheries, wildlife, power generation, navigation, irrigation, flood control, and recreation. For some time the enormous amount of water carried by the system was viewed as being fully adequate to support the identified multiple uses. During the past several decades conflicts regarding water use and concerns about the best management of the resource have steadily increased. They have most recently culminated in extensive public attention due to identification of certain stocks of salmon as being potentially threatened or endangered.

by the particular way in which the Columbia River resource has been managed. There is now general awareness that the Columbia River system can no longer supply water to meet all of the demands placed upon it at any time and at any location within the system. Trade-offs will have to be managed prudently.

The management structure for the Columbia River system is complex. There is no single organization which makes decisions regarding reservoir levels, river flows, diversions, wildlife and fish, in- or near-river construction, and so on. The decision-making structure is also evolving. One of the more significant developments of the last decade is the creation of the Power Planning Council as a result of the Pacific Northwest Electrical Power Planning and Conservation Act (1980). Nevertheless, the decision-making and management structure of the Columbia River system remains complex. This, along with varied demands on the resource and the fundamental importance of the resource to the region, will be subject to extensive future public debate over the management of the Columbia River system.

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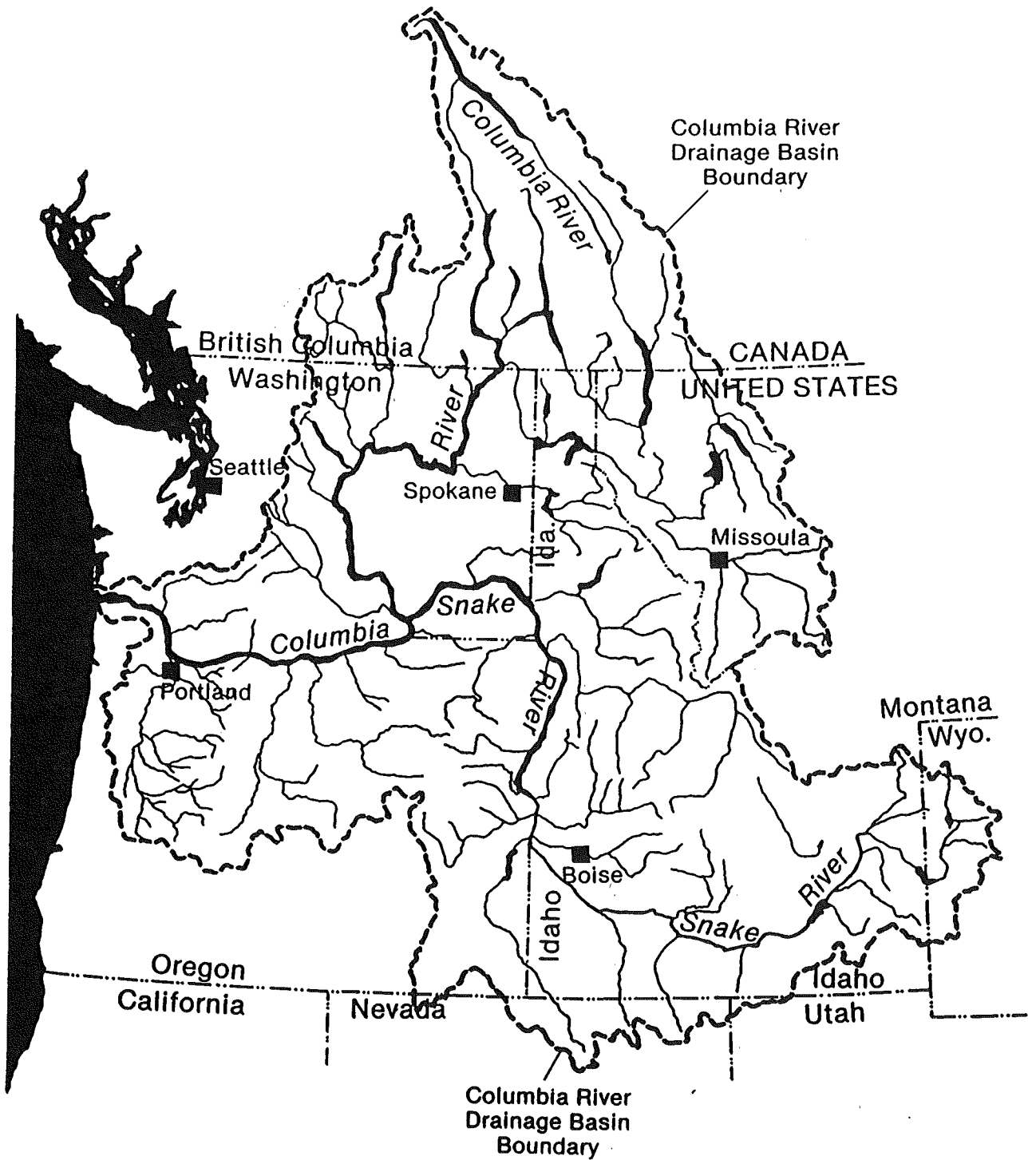


Figure 1. The Columbia River System (Source: Queirolo, 1981)

III. ALTERNATIVES FOR RESTORING AND MAINTAINING SALMONIDS

A. FISH PROPAGATION

1. Cryopreservation of Sperm to Maintain Genetic Diversity

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a. Description: Techniques for cryopreservation of sperm which have been applied to sperm of cattle and other mammals have also been successfully applied to sperm of salmon and trout. The sperm is mixed with an "extender" solution of defined chemical composition and can be cryopreserved in liquid nitrogen for long periods (years or decades). This approach could help address the concern that the genetic material of some endangered strains may be permanently lost if recovery actions are slow in implementation and the strain goes extinct. Cryopreserved sperm could provide genetic material which could be useful in recovery programs for endangered strains. It could also be useful for introducing genes from wild fish into hatchery strains. By maintaining the original genetic material used to found a hatchery, the effects of hatchery rearing of a strain over many generations could be monitored and wild genes would be available to reintroduce into the hatchery strain.

b. Time Frame: Techniques are developed well enough that large-scale efforts to cryopreserved sperm from endangered strains could begin immediately. A comprehensive gene bank of cryopreserved sperm from endangered strains in the Columbia Basin could take 5-10 years to develop.

c. Anticipated Effects:

- Fish: A gene bank of cryopreserved sperm from endangered strains of salmon and steelhead could be useful in recovery programs for endangered strains. For example, sperm from the endangered strain could be used to fertilize eggs from a closely related strain

with a larger population to reconstitute progeny with half their inheritance from the endangered strain which should show a high level of adaptation to the native environment. Through additional generations of backcrossing to the cryopreserved sperm, fish with higher proportions of local inheritance could be produced. In the absence of the locally adapted inheritance, recovery efforts might be much less likely to succeed.

The gene bank approach has several obvious limitations, however: (1) good habitat and survival during migration would still be essential if the recovery program is to have a good chance of success, (2) collection of the sperm from endangered wild stocks would not be a simple matter and, if not done with care, could actually stress and further endanger the stock, and (3) it is essential that all concerned realize that cryopreserved sperm is not a substitute for viable stocks of wild fish, but simply a tool which could be used in recovery programs.

- Energy: No effect.

- Irrigation: No effect.

- Navigation: No effect.

- Recreation. Sports as well as commercial fisheries will benefit in the intermediate- and long-run.

d. Implementation Issues: Sperm cryopreservation has not been a widely used tool to date in fish management or aquaculture, and technologies need to be transferred from the universities where they are currently being used to the agencies which would use them in gene banks and recovery programs. Training sessions would be an important step in the technology transfer. Additional research to refine the already relatively successful methods also should be done in universities and government agencies. Collection of sperm from endangered wild stocks would have to be done with care and with the authorization of the appropriate federal and state agencies. Agencies or

entities responsible for cryopreservation of the sperm and maintenance of the gene banks would have to be identified. It is essential that the responsible entity have a long-term commitment to maintaining the gene bank and that funds would be available to maintain the facility. A mechanism would also have to be agreed on to authorize withdrawals from the gene bank for use in recovery programs.

e. Likelihood Of Success: If a program can be initiated, likelihood of success is high. The technology for sperm cryopreservation in salmonids is substantially developed, although further refinement would be desirable. The biggest obstacles to successful implementation is the large number of agencies that would need to be involved and to agree on a program, and the need for a long-term commitment of personnel and funds to the program.

f. Estimated Costs: It is estimated that costs of implementation of cryopreservation would be modest. A rough estimate of cost per individual sperm sample in 1991 dollars would be \$20 for initial cryopreservation and \$2 per year for maintenance. This includes the cost of equipment (liquid nitrogen refrigerators), labor (sample processing but not field collection), and supplies (chemicals for extender, sample containers, and liquid nitrogen). Samples should be taken from 50-100 individuals per river system per species. The number of systems to be sampled would need to be determined but should include the major geographic regions in the basin.

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2. Develop and Adopt Methods to Reduce Mortality of Juvenile Fish Due to Stress and Disease

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a. Description: Both wild and hatchery juvenile fish are subject to substantial losses to stress and disease. Fish which are stressed have a reduced capacity to respond to disease organisms and show increased mortality. Wild fish are primarily subject to stress and disease when they are crowded and handled during their downstream migration in bypass facilities at dams, in trucks, and in barges. Hatchery fish are subject to the same hazards as the wild fish and are also subject to stress and disease in hatcheries. Examples of modifications which might reduce stress and disease include: Modifications to traveling screens at dams to reduce descaling, modifications to bypasses to reduce flow velocities, more raceways for short-term holding of fish before transfer onto barges to reduce crowding, more barges to reduce crowding, and bypass canals to avoid use of barges. In hatcheries, reduced crowding and improved water quality could reduce stress and disease.

b. Time Frame: Improvements to reduce stress and disease could be initiated immediately and over time as research identifies the critical events causing stress and disease. Subsequently, the improvements would have to be maintained.

c. Anticipated Effects:

- Fish: Substantial improvements in the survival of downstream migrants and resulting returns of both hatchery and wild adults could result from reduced stress- and disease-related mortalities.
- Energy: No appreciable effects.
- Irrigation: No appreciable effects.
- Navigation: No appreciable effects.
- Recreation: Sports as well as commercial interests will benefit in the intermediate- and long-run.

d. Implementation Issues: Reducing stress in hatcheries would involve many different agencies responsible for salmon and steelhead hatcheries in the Columbia Basin. Reducing stress of wild and hatchery downstream migrants would be the responsibility of agencies involved in the fish passage programs for downstream migrants at the dams (e.g., Corps of Engineers, National Marine Fisheries Service). Agency and university researchers would need to identify the critical events responsible for stress and disease and suggest modifications to reduce stress and disease.

e. Likelihood of Success: High. Reduced mortality due to stress and disease would directly improve survival and lead to improved returns of wild and hatchery adults.

f. Estimated Costs: High. All the modifications described above would be quite expensive to establish as well as to maintain.

3. Develop Improved Techniques for Identifying and Separating Hatchery Fish from Wild Fish

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a. Description: Assessment of supplementation and hatchery programs, management of hatchery fish apart from wild runs, and conservation programs for specific stocks on the Columbia River are affected by the ability of managers to identify those fish upon interception. With the exception of the adipose, fin clips are not suitable marks because of their negative effect on survival. Present marking procedures involve tags, the most preferred being the PIT tag which allows individual identification without sacrificing the fish, but the cost is prohibitive. Coded wire tags are most widely used, but individual application is required, and the fish must be sacrificed to remove the tag. Adipose clips of all hatchery fish as a common mark allows external identification of the "hatchery" category, and has the most promise as the external mark differentiating hatchery fish from wild fish. Fin

clips, however, require fish to be handled individually, which increases the time and cost of marking.

Mass marking procedures to identify hatchery fish are feasible. Otolith marks from abrupt temperature shifts, skeletal marks by feeding erythromycin, or immersing in rare non-radioactive isotopes, and immune system marks by antigen exposure and subsequent assays for antibodies, are possible methods that could be applied to large numbers of fish. These methods are largely untested, and mark recovery and analysis would be expensive and time-consuming.

b. Time Frame: Agreements to adopt a common marking policy among the states, such as adipose clips on all hatchery fish, could be initiated and functional in a year to provide immediate external identification for separating hatchery fish and wild fish.

c. Anticipated Effects:

- Fish: Substantial improvement in the ability to separate hatchery fish and wild fish for purposes of escapement, fishery regulation, and production evaluation would result from adopting a universal mark for all hatchery fish. This could result in larger escapement of natural fish stocks while allowing for an increase in hatchery stock and larger runs and catches of these hatchery stocks.

- Energy: No effect.

- Irrigation: No effect.

- Navigation: No effect.

- Recreation: Sports as well as commercial interests will benefit in the intermediate—and long-run.

d. Implementation Issues: Agreement to adopt a common mark for hatchery fish would have to be achieved among the agencies responsible for managing fishery resources in the Columbia system. The adipose fin clip has proven to be the most reliable mark for easy recognition and minimum effect on the fish. The main problem created by adopting the adipose clip as the universal hatchery mark is that it is presently dedicated for use as the external indicator of the presence of a coded wire tag. However, using the mark to identify hatchery fish would not interfere

with its use to identify fish with coded wire tags, with the exception that assessment of coded wire tag loss rates would no longer be possible. This is not considered a limiting disadvantage, since years of coded wire tag data are available. Funding to support the program would have to be developed.

e. Likelihood of Success: The use of a common mark for hatchery fish would provide the ability to manage hatchery and wild fish independently. The use of the adipose fin as the common mark will provide sure success for visual identification without sacrificing the fish.

f. Estimated Cost: Costs associated with adipose marking programs would be primarily for personnel, once the equipment and facilities were obtained. Estimated time required to mark 1,000,000 fish would be 550 person hours or about \$4,000/million fish.

g. Effect on Genetic Diversity: Effect of an identifying mark for hatchery fish would be beneficial to wild fish management.

4. Improve Forestry and Mining Practices to Reduce Habitat Damage

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a. Description: Forestry practices, including timber harvesting, logging residue treatment, reforestation, and road building, are "nonpoint" sources of pollution that affect water quality. "Nonpoint" pollution does not come from a single identifiable source, but from land surface disturbing activities over a particular geographic area. Water quality standards are designed to protect existing beneficial uses of water bodies. In some states, this includes salmonid spawning and rearing habitat. The Idaho Forest Practices Act, for example, requires that "best management practices" be used to protect water quality. ("Best management practices" are those determined to be the most effective and practicable means of preventing or reducing nonpoint sources of pollution.) Idaho water quality

standards define a feedback loop process for modifying best management practices to assure water quality protection. There are adequate policies in Idaho to protect water quality from mining impacts, where best management practices and a feedback loop process are also defined.

The current policy in Idaho seems to be adequately designed to provide protection. Virtually all of the spawning areas for Snake River runs are in Idaho.

b. Time Frame: In Idaho, adequate processes have been designed to monitor and modify mandatory forestry and surface mining best-management practices. These can be implemented immediately. In general, forestry and mining practices can be designed and implemented—with some lead time and costs—at the state or regional levels, which can significantly impact habitat by abating or reducing damage. However, these beneficial effects generally must be viewed with a long-term perspective. In the case of the petitioned salmon stocks, currently there is more suitable habitat than there are spawnings.

c. Anticipated Effects:

- **Fish:** Positive effect, because water bodies that are designated as capable of supporting salmonids are currently protected by law in Idaho.

- **Energy:** No effect.

- **Forestry and Mining:** There will be increased costs.

- **Irrigation:** No effect.

- **Navigation:** No effect.

- **Recreation:** Positive effect.

d. Implementation Issues: An adequate policy design must be implemented to achieve the intended results. At issue in Idaho is whether current levels of enforcement and monitoring are adequate to protect water quality.

e. Likelihood of Success: To the extent that forestry and mining operators are aware of and comply with mandatory best management practices, the likelihood of success is high.

f. **Estimated Costs:** Without question best-management practices increase the cost of forestry and mining operations. Monitoring and enforcement are expensive.

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5. Improved Hatchery Management to Increase Rate of Return of Adult Fish

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a. **Description:** Appropriate technology is the key to successful artificial propagation programs. Operations need to integrate technology based on the requirements of the fish being released. Conservation hatcheries should be enhancement tools, supplement naturally spawning fish, and avoid becoming major production centers. Given that a sound breeding program is followed to represent the wild-type population in the stock taken for hatchery propagation, hatchery management can take measures to increase the rate of return from hatchery releases.

Differences appear early when the developing fish leaves the confinement of the egg capsule and becomes a free moving alevin. Quality of fry emerging from the incubator is strongly determined by the incubation environment. Alevins have a fixed yolk store that supplies energy for maintenance, growth, and exercise, and if the alevin is forced to exercise, growth will be sacrificed. If comparable fry conditions are sought, darkness and substrate should be employed in incubators to limit the activity of alevins and allow them to reach their maximum size before feeding begins. Volitional emergence allows fry to exercise appropriate timing to initiate feeding, and growth variation or pin-head losses will not be so apt to occur.

Rearing is a matter of applying the appropriate methods which involve knowing your fish and watching for the signs that first forecast potential problems. A

good hatchery rearing environment is the key to minimize problems (Wedemeyer and Wood, 1974). Good care means that sufficient oxygen (7 ppm) and pond flushing rates have to be provided and maintained. Water flow entering the pond should provide flushing rates that replace the volume at least twice an hour. Distribution of the flow has to be uniform as well to assure that no waste or dissolved solids are concentrated. Waste material should be removed from the pond as often as possible. Flows should not create excessive exercise, but sufficient velocity should be present to keep the fish adequately exercised for physical conditioning before release. About one fish length/sec is an appropriate velocity for fry, and the same criteria can be followed throughout the rearing period as the fish grow. It has been demonstrated that exercise increases food conversion, growth, and muscle (Besner, 1980), and improves return survival (Wendt and Saunders, 1973). Tests with salmon demonstrated that preconditioning fingerlings to predator silhouettes with an electrical impulse assisted in making the young salmon avoid predators after release (Thompson, R.B., 1966). Preconditioning the fingerlings to predators and exercise before release should be considered as routine practice.

Except for chinook that can start feeding as alevins (Hopley, 1974), salmonid fry should start feeding when their condition factor ($100 \times \text{g/cm}^3$) reaches 0.9. As fingerlings begin putting on weight, the condition factor will increase above 1.0. As a rule, a condition factor above 1.2 is a sign that too much fat is being laid down and food conversion efficiency, which is the weight gain from the amount of food offered, is dropping. Some salmonid species are more bulky for their length and may normally have a condition factor around 1.2 in freshwater. Upon smolting, however, condition factors generally fall around 1.0.

Pond loadings are typically too high in conservation hatcheries. Crowding will cause behavioral stress which can have serious survival implications. Loading densities in conservation hatcheries should be no more than 40 percent to 70 percent of that usually recommended in guidelines for state and federal hatcheries. Fin erosion occurs at densities higher than five kg/m^3 of water, when fed less than maximum ration, or at low feeding frequencies. The size of hatchery fish at release should be the same as their historical migrant size. Accelerated growth in the hatchery often causes a loss of a year at sea and smaller fish on return. More importantly, however,

releases of fish at sizes much larger than their historical migrant size can result in fish that are out of synchrony with their ancestral distribution, and result in orientation patterns that are premature by several months to a year. Physical characteristics of the fish, such as fin definition, broad tails, and low condition factors, are important for performance when the fish are released. The key to successful timing of release to maximize smolt success is to let the fish select their own migratory timing through volitional releases.

b. Time Frame: Management recommendations can be implemented immediately.

c. Anticipated Effects:

- Fish: Improved return success would be expected. This would have positive effect on sports as well as commercial fisheries.

- Energy: No effect.

- Irrigation: No effect.

- Navigation: No effect.

- Recreation: Sports fishery would be improved.

d. Implementation Issues: Tradition would be the most difficult problem to overcome.

e. Likelihood of Success: Very high likelihood of success.

f. Estimated Cost: Expected increases in cost of hatchery management are modest. This alternative is foremost a change in management practices.

g. Effect on Genetic Diversity: Better return success should improve the genetic variation in hatchery fish and thus improve genetic diversity among hatchery populations. Combined with other measures, such as marking and release of unmarked fish, this alternative will not have negative—and can have positive—impact on the viability of natural stocks.

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6. Improve Riparian Habitat

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a. Description: Riparian lands constitute only about 1 percent of the total area of the semi-arid areas of the West, but they produce a considerable amount of forage and are the primary source of water for wildlife as well as domesticated livestock. Riparian habitat greatly affects aquatic habitat that is important for salmon spawning and rearing of the young until they become smolts and head out to sea. While there are some areas with unused, suitable habitat (due to a decrease in fish runs), suitable spawning habitat for salmonids is generally considered to be limiting. Furthermore, additional habitat degradation is threatened because of resource-based activities and their management. These activities include mining, forestry, and agriculture (sec III.A.4. Improve Forestry and Mining Practices to Reduce Habitat Damage). These activities can lead to increases in water temperature, erosion, siltation, loss of protective cover, and reduction in streamflow. In turn, these changes in the aquatic ecosystem impair the ability of streams to maintain fish populations.

Degraded riparian habitat can be restored and existing habitat can be protected in a variety of ways. Principally, these include rest rotation, replanting of streambanks and riparian areas, fencing, installation of diversion screens, alteration of the physical complexity of the stream, (temporary or permanent) exclusion of livestock from the riparian zone, and improved mining and logging practices (c.f.III.A.4).

b. Time Frame: Improvement of degraded habitat, as well as implementation of a management plan to assure protection of existing habitat, must be viewed from a long-term perspective. Measures to improve degraded habitat will yield few benefits in less than 5 years, and it may take more than 10 years to see major effects. The speed of recovery will depend on the location and condition of the habitat site.

c. Anticipated Effects:

- **Fish:** Effects of habitat improvement on fish production vary widely due to differences in environmental conditions of the habitat site. However, it is generally accepted that the relationship is positive. Furthermore, there are indications that a relatively small improvement in the aquatic ecosystem may result in a fairly substantial increase in fish numbers (Cerde, 1991). Thus, improvement in habitat will have favorable effects on resident as well as anadromous fish. However, those beneficial effects must be viewed with a long-term perspective and for salmonids in general (and not only for the petitioned stocks). This is so because of the long-term nature of rebuilding habitat as well as because with respect to petitioned stocks, there is presently judged to be more suitable habitat than there are spawners.

- **Energy:** These measures have no direct effects on generation of hydro power.

- **Navigation:** These measures have no direct effects on navigation.

- **Irrigation:** These measures have no negative effects on irrigation. They may result in increased stream flows.

- **Livestock Grazing:** Implementation of these measures will almost certainly require changes in livestock management practices. Depending on the required changes, there may be an initial cost of adjustment, an initial investment, and subsequent maintenance costs.

- **Mining and Forestry:** There will be increased costs (c.f.III.A.4).

- **Recreation:** Improved riparian habitat will result in increased fish and wildlife populations and will increase recreation benefits.

d. Implementation Issues: Riparian zones are owned and managed by the public as well as the private sector. On the public sector side, the major agencies are the Bureau of Land Management (BLM), the Forest Service (FS), the Soil Conservation Service (SCS), and various state agencies. The private sector includes ranchers, lumber companies, and others. It is estimated that 40 percent of the habitat of anadromous fish is found on private land. This situation suggests an enormous coordination problem. Further, as habitat protection and improvement measures can be implemented only over time, priorities for implementation must be agreed upon. Given the ownership and management authorities, it may be difficult to reach agreement on priorities. This should not be impossible, however. The various agencies already have plans. It should be possible to find existing common ground.

e. Likelihood of Success: High, although results are several years in the future under even the best of circumstances.

f. Estimated Costs: These measures have costs for reseeding, replanting, establishment of screens, and weirs, etc. The major costs are likely to be for fencing, where this is necessary, and for adjustments in livestock management. Costs of changed livestock management will vary greatly depending upon the particular circumstances. Available evidence suggests that technology may be available to implement environmentally and economically sustainable management practices.

At present there exists a cost sharing program (between the federal government and the private sector) of limited scope to encourage riparian habitat enhancement.

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7. Reducing Hatchery Output

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a. Description: Hatchery output could be substantially reduced to assist in the recovery of wild stocks. This option reveals paradoxes that exist in some proposed broad-based recovery plans. The installation of protective screens on dams (to keep fish from entering the turbines), for example, can sometimes kill more fish than it saves; the drawing down of the Columbia River reservoirs will increase the velocity of water, but might not speed the passage of the fish; and finally, increasing the number of hatchery fish might actually increase the depletion of the wild salmon that proponent groups are trying to save.

As noted in Brannon (III.A.8), salmon are not homogenous. Each stream and tributary can produce a separate subspecies of salmon. Thus salmon "co-evolve" with the stream from which they are born. The genetic composition of the fish reflects it's environment. Hatcheries often release smolts (whose genes reflect a particular stream) on a regional basis. Thus, hatchery smolts are often released into foreign environments (foreign streams) which reduce genetic "fitness." This can reduce the viability of the fish, which results in poor survival rates. A large percentage of hatchery fish fail to make the journey even to Lower Granite Dam. Another difficulty in reduced fitness is disease, particularly Bacterial Kidney Disease (BKD) which may have a genetic component. It has been found that resistance to BKD is greater in smolts whose parents did not have the disease (Bjornn

& Moffitt). It may be possible for hatchery fish to spread disease to wild fish.

There are other major problems with hatchery fish. First of all, they can spawn with wild fish and reduce their genetic viability. This has actually occurred in the upper Yakima River in Washington (see Brannon III.A.8).

Secondly, hatchery fish are competitors with wild fish for habitat. It has been estimated that the number of smolts released currently by hatcheries in some areas is approximately the same as was naturally produced by the environment before the advent of dams; thus increasing hatchery production may exceed the carrying capacity of the habitat and reduce viability of wild fish.

Thirdly, hatchery fish create a problem in regards to harvest. The ratio of hatchery fish to wild fish is so great, that allowing even a minimal harvest of hatchery fish may over-harvest the wild fish. This problem is particularly severe with "mass" fish methods such as gill-netting which do not distinguish between hatchery and wild fish.

Finally, part of the difficulty in saving the wild fish may be the emphasis of recent recovery plans. As Dale Pearson (1990) noted, the focus to save the fish has been based on engineering and technological "fixes." These include improving hatchery "effectiveness," reducing disease, restoring habitat, and transporting fish by barge or truck (or bypass facilities). Perhaps the emphasis ought to be based on biological considerations. The focus should shift from an emphasis on hatchery fish to an emphasis on wild fish; and overall efforts should shift from "cures" to preventative measures.

Severe limitations on both commercial and recreational fishing will be needed under any recovery plan which reduces hatchery output. Also, all mass fishing methods such as gill-nets may have to be reduced significantly or completely eliminated. Efforts should also be made to eliminate abuses in ocean fishing from drift-nets (c.f. Rettig III.C.1 & III.C.3).

Substantially reducing hatchery output should strengthen wild stocks. Efforts should also be made to reduce disease and strengthen genetic diversity in those hatchery fish which are produced.

Some proposed recovery plans focus on the need to expand and enhance hatchery fish. This article focuses on the need to reduce hatchery fish. These differing foci represent disagreements and uncertainty within the scientific community, suggesting more research is needed.

b. Time Frame: Reducing hatchery output, accompanied by reduced harvesting, can begin immediately.

c. Anticipated Effects:

- Fish: Improvements in the survival rates of wild salmon would begin immediately, but it will take several years to see major improvements in the return rates. At least for a period of time, fish available for harvest will be fewer.

- Energy: No effect.

- Irrigation: No effect.

- Navigation: No effect.

- Recreation: Sports angling opportunities would be reduced, at least for a period of time.

d. Implementation Issues: It will be relatively easy to reduce hatchery output (a much longer time frame is needed to increase output). A key issue will be the ability of officials to reduce and enforce limitations on harvest. Both treaty and non-treaty gill-net fishing may have to be reduced or eliminated altogether.

e. Likelihood of Success: The likelihood of success is high.

f. Estimated Cost: The cost of reducing hatchery output is low (it might even save money). The cost of enforcement on harvest limitations will be higher.

g. Effect on Genetic Diversity: Genetic diversity of wild salmon will be maintained.

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8. Release Wild Stock (or Brood Stock for Hatchery Programs)

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a. Description: Fitness, defined by Falconer (1967) as the proportionate contribution of offspring to the next generation, is critical in the identification of brood stock for conservation hatcheries. In any particular stream, the characteristics of the environment and the native fishes have co-evolved. Populations of salmon and steelhead returning to a river system are not homogeneous, but rather are made up of several subpopulations that return to unique sites or tributaries within the system. These small populations have differences that translate into spatial or temporal traits inherent to their fitness. When fish are removed from their natural habitat, fitness will decrease in proportion to the degree of separation from their environmental requirements. Salmonid life history traits such as spawning time, emergence behavior, orientation, distribution, and migratory patterns, are based on genetic components (Bams, 1976; Groot, 1982; Miller and Brannon, 1982). It is critical that enhancement programs by conservation hatcheries take measures to assure that such population traits are not lost. There is no alternative, therefore, to the use of spawners that originate from the target stream, and the progeny should be returned to the same location when released.

Because of high costs involved in construction of conservation hatcheries, they are often used as production centers, and their fish distributed to many regional streams. However, if fish are planted without regard for their origin, the synchrony between environment and stock is compromised, and the ability of the populations to sustain themselves is limited. More seriously, the reproductive fitness of the native population is at risk because they will spawn with hatchery fish, as demonstrated in the upper Yakima River, Washington (Campton and Johnston, 1985).

Stock degradation occurs even more rapidly by interception of prespawners on their migration upstream in large river systems for hatchery propagation. In large river systems the range of environmental variation can be greater over the length of the river than between tributaries, and the uniqueness of stocks would also be greater. Interception of prespawners, irrespective where they are going, and redistribution of their progeny, would immediately disrupt the continuity between stocks and their environments. Since the young fish imprint on odor cues of the hatchery or site of introduction for homing, they are prevented from returning to match up with their ancestral stream. Examples are the chinook salmon runs in the Columbia River where the early fish intercepted at Bonneville were spring chinook destined for the upper river. Those fish were not the appropriate stock for release in the lower river. Their return time was months too early, and the migratory distance far too short to develop a self-sustaining stock suited for high summer temperatures in the lower river environment.

Even sustained hatchery production can eventually change the nature of the propagated fish unless care is taken to develop a breeding program to maintain the full range of genetic characteristics of present stocks. Efforts need to be taken to maximize the number of spawners used, and to spawn in pairs to maintain as much variability as possible. To avoid using second-generation hatchery fish that make themselves more accessible by homing to the hatchery, fish reared in the hatchery should be marked for recognition. In this way, creating a "hatchery population" can be avoided by using only breeding stock from naturally produced fish. This is not an unrealistic goal. For example, the Idaho Department of Fish and Game already marks all hatchery steelhead with an adipose fin clip and allows fishermen to keep only marked fish to conserve the wild strains (c.f. Brannon, III.A3). Hatchery programs

need to base production on wild-type fish. Care must be taken to capture wild or naturally produced fish as brood stock, and maintain the continuity between environment and phenotype. Redistribution beyond the native range must be rigidly avoided, and wild-type fish should be released in their "home" streams

b. Time Frame: Measures to employ wild brood stock can be taken immediately.

c. Anticipated Effects:

- Fish: Improved return success would be expected, and discontinuity between hatchery and wild fish would disappear.

- Energy: No effect.

- Irrigation: No effect.

- Navigation: No effect.

- Recreation: The long-term effect would be positive. No effect on other types of recreation.

d. Implementation Issues: Methods to initiate wild brood stock would be a problem at many hatcheries, and new facilities would be required in many cases.

e. Likelihood of Success: Very high likelihood of success.

f. Estimated Cost: Expected increase in cost of hatchery management would involve primarily the facilities to maintain the program.

g. Effect on Genetic Diversity: Genetic variation of the wild population would be maintained, and the genetic diversity among hatchery/wild populations would be enhanced.

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B. FISH MIGRATION

1. Columbia River By-Pass Channel

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a. Description: A stream channel is a possible recovery option to conserve natural salmonid runs in the Columbia River and provides the opportunity for their rehabilitation. The stream channel could be developed adjacent to the river to transport smolts past the impoundments to the lower river below Bonneville Dam. This represents an alternative to leaving the fish in the mainstream.

Smolt mortality during out-migration is a serious problem that is largely responsible for the poor return survival of adult salmon and steelhead in the Columbia River system. Smolts migrating downstream experience an average of 15 percent mortality at each dam. Some of the major factors responsible include altered habitat, altered flow regimes, and stress created by dam passage. The successive

reservoir pools, for example, slow smolt migration, confound transit, and disrupt marine entry timing. The pools also enhance predator habitat, increasing the predation rate on migrants. Fish passage is further hampered by an increase in both the gas supersaturation of water and water temperature due to the dams.

Conservation and enhancement of natural salmon and steelhead runs of the Columbia River may not be tenable under the current system. This is due to the extent of the river impoundment and habitat alteration that has occurred in the system. Moreover, it is possible that alterations of the present system to accommodate the needs of salmonid populations will be of little benefit in sustaining or rehabilitating natural reproduction. They may not reduce mortality at the dams or reduce the effects of predation and supersaturation.

The interception and transport of smolts past the dams by barge, for example, does not appear to provide the level of success desired. In many instances the performance of experimental groups has been no better than controls released at the hatcheries. In addition, there is the possibility that the behavior of returning adults from transported smolts may be altered. This should be given serious consideration because of its long-term implications on genetic mixture of stocks, resident location in the system, and timing. Even with the implementation of enhancement, barge transport, and altered flow regimes to improve smolt passage, major problems associated with poor survival in the river might still remain.

A by-pass canal may provide a good viable option to supplement existing efforts (or other proposed solutions) to save the fish. A by-pass canal would probably need a hydraulic capacity of only 300-500 cfs. If the canal operated from April 1 to August 1, for example, approximately 120,000 acre feet would be needed (120 days @ 500 cfs). The canal could provide an optimum velocity (2-5 ft./sec.) for fish migration and would "mimic" pre-dam flows. The channel could be constructed to simulate "near natural" conditions, and might be constructed as much as possible "as an unlined irrigation canal" utilizing natural terrain. Salmon apparently develop their "cues" from water chemistry input along their journey. Water from the main stem and major tributaries would be added continuously to the canal in proportion to their contribution to the main river.

The by-pass channel could be used in addition to existing efforts to improve fish passage, since not all of the fish would probably be captured for canal transport. Also, main stem passage would provide a backup if any problems developed with the canal. The canal could be built with safeguards to protect against chemical contamination, breaks in the canal, and other problems.

b. Time Frame: The canal would probably take 5 to 10 years to complete, but work could begin immediately.

c. Anticipated Effects:

- **Fish:** A separate migratory by-pass stream might eliminate delays in migration caused by reservoirs, and allow for the natural migratory behavior and controlled rates of transit consistent with the historical patterns that stocks displayed. The by-pass stream could also eliminate mortality associated with dam passage, predation while in the channel, and super-saturation problems. As far as the fish are concerned, a passage channel might provide the best resolution to the competing water needs on the Columbia.

- **Energy:** No appreciable effect.

- **Irrigation:** No effect.

- **Navigation:** No effect.

- **Recreation:** No effect.

d. Implementation Issues: A possible approach in developing the by-pass channel option is to implement the plan in four phases.

1) Phase one would be developing the research and implementation plans. Initial funding could be sought for appointment of a coordinator to develop the plan through literature review, interviews with specialists, industry, and meetings with agency personnel.

2) Phase two could be implementing the biological and engineering research with regard to designing considerations and operations. The selection process for research priorities, distribution of effort, team projects, combining theory, and agency experience would be emphasized.

Biological considerations would include:

- a. Guiding responses, light, bubble screens, electrical.
- b. Migratory requirements, velocity thresholds, environmental cues.
- c. Volitional opportunity, holding/feeding needs, spring/fall stocks.
- d. Smoltification conditions, temperature/light/timing factors.
- e. Flow needs, water dept/response differences, habitat.
- f. Imprinting requirements, odor matching, water renewal.

Engineering considerations would include:

- a. Collection facilities, locations, screens, guidance-partial/total.
- b. Operating head, slope, entry points, pumping requirement.
- c. Structural, shape, surface, substrate, drops, % closed.
- d. Route, existing grades, entry sites, exit locations.
- e. Cost alternatives, lined versus earthen, security cover.

3) Phase three could be prototype trials using a channel between two dams to compare by-pass success and provide comparisons of survival, imprinting, passage time, design, and operation considerations.

4) Phase four could be the implementation of the full-length channel by-pass system if studies justify the project as feasible.

e. Likelihood of Success: If the plan is implemented in stages, studies on the possibility of success can begin immediately. If these studies are positive, the likelihood of success of the canal would be high.

f. Estimated Costs: Funding requirements for such a major project probably would not be proposed as a single grant, but rather in phases and based on the results of the previous work phase in developing the funding requirements. The budget requested for the first phase would cover coordinator costs, coordination and travel costs, and basic office support for the planning tasks. The total cost is estimated in the range of \$300 million.

2. Construct Additional Water Storage Facilities in the Snake River Basin (Above Brownlee)

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a. Description: Because of contractual and legal obligations, most existing water storage reservoirs in Idaho are operated to meet the needs of irrigation and hydropower generation. These reservoirs can not be used to provide more water during periods critical for fish migration without disrupting their irrigation and power purposes. The major exceptions are Brownlee Reservoir on the Snake and Dworshak Reservoir on the Clearwater, both of which offer some scope for operational changes to aid fish.

One way to make more water available during the critical period for downstream migration is to store additional water upstream from Brownlee Reservoir. (While attractive dam sites exist below Brownlee and on the Clearwater and Salmon Rivers, such development is precluded by Wild and Scenic River Legislation and other political and environmental considerations.) Several such upstream sites have been considered in recent years. Teton Dam was actually constructed and is occasionally mentioned as a candidate for reconstruction. Galloway damsite above American Falls and a site on the Weiser River have also been studied.

b. Time Frame: Constructing a storage reservoir is a long-term proposition, probably a minimum of 10 years. Both Galloway and the Weiser River sites encompass large amounts of private farmland, a complication which could delay construction.

c. Anticipated Effects:

- **Fish:** Such storage could increase the water budget, making more water available for moving juvenile fish downstream. However, the amount of water that could be stored would be quite small relative to the unaugmented river flow, meaning that the impact on river velocity would not be great. Unless accompanied by other operation changes (such as reducing reservoir levels) the effect of new upstream storage on fish would not be large.

- **Energy:** Most of the water stored in new upstream storage is presently used for power production at downstream dams. Almost all of the water at Snake/Columbia dams is used to generate power; very little gets spilled unused. New storage would change the timing of such flows and would change the market value of the power generated, but not the total amount of power generated.

- **Irrigation:** No direct effect.

- **Navigation:** No direct effect.

- **Recreation:** Creation of additional storage facilities would alter the possibility of the development of recreational facilities.

d. Estimated Costs: Construction of dams is not only a long-term proposition but also very expensive. When the site includes private land this adds to the expense. Because these reservoirs would have to be operated to meet needs for fish passage, rather than to optimize hydropower production, the attractiveness of these projects to private investors would be reduced. Such a storage project might have to be built by, or at least subsidized by, a federal agency.

e. Other Considerations: Additional upstream storage space might not result in a corresponding increase in stored water useful to fish. At present Brownlee does not fill in all years. Preliminary studies of Galloway indicate that it too might not always fill. In dry years when water is critical for fish passage, water to fill storage is also scarce. It does the fish little good if the water captured in a new storage reservoir would alternatively have been captured in Brownlee.

3. Construct/Improve By-pass Facilities

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a. Description: Juveniles are currently transported to below Bonneville from Lower Granite, Little Goose, and McNary Dams to reduce mortality associated with dams and reservoirs. These migrants are generally transported during below-normal flow conditions. Changing the timing and frequency of fish transport, such as under all flow conditions, is an option to present transport procedures. By-pass facilities are an integral part of juvenile fish transport. By-pass improvements at selected dams would enable more fish to be collected and transported to below Bonneville Dam, resulting in higher survival.

b. Time Frame: No structural modifications are required to implement changes in timing of fish transportation from existing transport projects. By-pass facilities at Lower Monumental Dam are scheduled for completion by spring, 1992, with transportation facilities operational by spring, 1993. By-pass improvements at McNary are scheduled for partial installation by spring, 1994, and completion by spring, 1995. Improvements at Lower Granite and Little Goose are tentatively scheduled for installation between 1995 and 1997; a definitive schedule will be established upon completion of prototype testing in 1993.

c. Anticipated Effects:

- **Fish:** BPA estimates that by-pass improvements at Lower Granite, Little Goose, and McNary would increase relative survival to Bonneville Dam of Snake River fish by 7, 16, and 14 percent for spring chinook, fall chinook, and sockeye, respectively. Maximizing transportation once by-pass improvements are made would result in an additional 2 percent increase in survival of spring chinook. Full transportation from Lower Monumental would provide an additional 2 percent relative increase in survival for sockeye. In combination, these measures would increase relative system survival by 9, 16, and 16 percent for Snake River spring chinook, subyearling chinook, and sockeye, respectively. There also would be significant increases in survival for spring and fall chinook originating in the Lower Monumental pool. While

by-pass improvements and transportation at John Day would contribute slightly to survival of Lower Monumental pool spring chinook to below Bonneville, its primary benefit is to fish originating in the John Day and McNary pools.

- **Energy:** No appreciable effect.
- **Irrigation:** No appreciable effect.
- **Navigation:** No appreciable effect.
- **Recreation:** No appreciable effect.

d. Likelihood of Success: Moderate. Available information indicates transportation generally results in an increase in adult production for all species when compared to fish migrating in-river. Some by-pass improvements are known to be effective, but the performance of extended-length screens is unknown.

e. Estimated Costs: Cost of by-pass facilities are available from BPA.

f. Effects on Genetic Diversity: Collection and transportation of migrants that coincides with movement of naturally propagated juveniles should enhance survival and help maintain genetic diversity.

4. Develop and Adopt Irrigation Methods With Increased Water Use Efficiency

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a. Description: There are many different methods of applying irrigation water. Flood or rill irrigation uses larger amounts of water relative to what is needed for actual consumption by the plant. There are variations in sprinkler technology, with low-pressure sprinklers being most efficient because there is less evaporation loss. For permanent crops such as tree fruits and grapes, drip irrigation that goes directly to the roots is the most efficient.

There are possibilities for improving irrigation efficiency and using less water by tailoring irrigation

delivery more closely to specific crop needs. This requires more monitoring of the crop and potential pests. It may also require structural and/or management changes in delivery systems by irrigation districts.

Water rights held by irrigators are such that there are no incentives for them to use less water if the water saved will be taken from them for instream uses. However, reduced costs of application (e.g., pumping) provides incentive for reduced water use even under the current rights.

b. Time Frame: Three to five years would be required to achieve much measurable effect and up to 10 to 15 years would be needed to fully exploit opportunities. There are three factors involved. One is research to improve knowledge and understanding of plant water needs and the best way to time applications for specific crops. The second is that it would take time to replace existing irrigation equipment and move to more water conserving technology. The third is making changes in delivery systems to accommodate the more precise water applications on farms.

c. Anticipated Effects: It is not at all clear that improved irrigation efficiency would provide more water for fish. Improved water use efficiency could result in farmers producing higher yields and still using all the water. They might also use "saved" water to transfer to other higher water using crops. Also, water lost to poor efficiency is not necessarily lost to the system. Close linkage between surface and aquifer water levels in the upper Snake has been established. However, while water may not be lost to the system, flow timing may be delayed.

- **Fish:** Positive effects could result if saved water is made available to increase river flows at critical times for fish passage.

- **Energy:** If the "extra" water passes through turbines it will increase energy production.

- **Irrigation:** There are two major effects. The first is the investment farmers will need to make in new irrigation equipment and the increased demands for monitoring specific crops. As indicated above, this could result in more agricultural production that would still use the water. The second is the investment by irrigation districts to redesign systems to deliver water to farms. Currently there is no way to

limit the deliveries to farms of the water expected to be conserved. This would include control valves, water meters, and perhaps some modification to conveyance systems. There would be a reduction of nonpoint source pollution as there would be less irrigation runoff.

- **Navigation:** No effect.

- **Recreation:** No effect.

d. Implementation Issues: Institutional and legal constraints would have to be overcome. Agriculture has certain water rights and farm operators may be reluctant to release water to be reallocated for fish passage. The water they have available above and beyond their actual crop needs is seen as insurance against dry years and provides flexibility in crop production. In dry years, farmers substitute labor for water and in years of ample water the reverse is true. Some kind of incentive program would likely be needed to induce the water conservation desired and to make it available for instream fish passage.

The water rights issues are complicated by both federal and state laws and existing priorities of Bureau of Reclamation projects.

Irrigation districts would have to make some significant delivery system investments and would be reluctant to do so without compensation.

e. Likelihood of Success: Medium success is about as much as could be expected. This calls for voluntary action by large numbers of people. There are also some gaps in present knowledge about how much more efficient water applications can be for various crops. There is some consensus that many irrigators use the best technology available in irrigation scheduling.

f. Estimated Costs: Cost to irrigators would be high. Installation of drip irrigation on perennial crops could cost as much as two to three thousand dollars per acre.

5. Drafting Lower Snake River Pools to Increase Water Velocity During the Juvenile Migration Period

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a. Description: Since construction of hydroelectric facilities on the Snake River, flows have been altered to a moderate extent. However, the cross-sectional area of the river has been increased significantly, such that a given flow does not produce the same historical stream velocity. An approach to increasing water velocity during the juvenile fish migration period is to reduce the cross-sectional area of the Lower Snake River reservoirs instead of just increasing flow. Increasing water velocity by reducing reservoir cross-sectional area may be more effective and less costly overall to the power system than attempting to increase water velocity by increasing flow.

Several variations of this action could be considered. One proposal would draft the Snake River dam pools only to minimum operating levels, approximately five feet below normal operating levels. This action would not have serious effects on other river uses, including power production. However, neither would it be as effective in increasing flow velocities for fish migration. The extreme implementation of this action would require the drafting of all four lower Snake River dams as far as the original river channel ("run of the river") while eliminating the barge transportation, power production, and possible other uses. In general, the costs to other river uses will increase with the amount of the drafting that is used, while the effectiveness of increasing flow velocities for fish migration will proportionately increase in a positive direction.

b. Time Frame: Pool drafting to minimum operating levels could be implemented immediately. Drafting below that level, say to run of river, would require some preparation of river and water user facilities.

c. Anticipated Effects:

- **Fish:** Increasing river flow velocity would resemble more closely the natural conditions that occurred prior to construction of hydroelectric facilities on the Columbia and Snake Rivers. The ability to

move juveniles should be enhanced. The actual success of this plan or its variations remains an unknown, however, until implementation and a history of record is gained.

Rapid downstream movement will increase overall juvenile survival for hatchery and wild stocks. This action should have a positive effect on the survival of genetically desired wild stocks.

An important issue not previously discussed under this topic relates to the upstream migration of adult salmon and steelhead. Fish passage facilities would have to be modified to accommodate any level of river operation outside current minimum rule curves.

- **Energy:** Drafting reservoir pools will reduce the ability of the system to produce power. However, extreme drafting could reduce the total amount of water required for the fish budget. Some proposals would draft pools to run of river level and budget no additional water to increase flow velocity, letting natural flows from the Salmon and Clearwater rivers provide the necessary flows. In this extreme case the power losses would likely be small.

- **Irrigation:** Irrigators who take water from the Ice Harbor pool would be required to extend irrigation pumping systems if water levels lowered beyond the reach of existing pumps. The cost of pumping facility modification for this purpose is estimated to be about 50-100 \$/acre. Between 50,000 and 75,000 acres may be affected.

- **Navigation:** Drafting of reservoir pools below minimum operating levels, say to run of river, would eliminate barge traffic for the period of drafting. However, prior planning, storage, and use of alternate modes of transportation could minimize this effect. A large shift in grain shipping from barge to rail or truck will not only increase cost of shipping but could also cause disruption of port elevators with limited capacity to handle shipments via rail or truck.

- **Recreation:** It is possible that extreme variations of the pool levels in the Lower Snake in the spring of the year could adversely affect the resident fishery by eliminating spawning opportunities, particularly for smallmouth bass. Some types of recreation boating could also be eliminated or adversely affected by the changing pool levels.

• Other: There are other possible effects on bank sloughing or erosion, railroad and highway damage, and erosion of collected sediment in the upper reaches of the dam pools that would add costs to this action. With the dams in place, it is not physically possible to accomplish the "run-of-the river" objective in its true course.

d. Implementation Issues: Several parties to current river operations would be required to approve or accommodate this action. Primary among them would be barge users and operators, Corps of Engineers (COE), fish management, and irrigators.

e. Likelihood of Success: The likelihood of increasing flow rate for fish migration is high but the effects on fish survival are unknown. Deterrents are lack of experience with pool drafting and desired water velocities, but the major problem is overcoming legal and institutional constraints for operating the reservoir in the desired manner. Research is probably needed prior to implementation. Current speculation is that reservoir elevations required to achieve desired water velocities will need to be lower than the minimum forebay elevations necessary for generation and operation of fish by-pass at river dams. BPA indicates that agreement between BPA and the COE for lowering forebay elevations to these levels may be difficult due to constraints on power generation, as well as navigation, irrigation, recreation, etc. However, if agreement could be attained and desired velocities achieved, then spring juvenile fish passage conditions could be improved.

f. Estimated Costs: This action would impose costs on the energy, navigation, and irrigation sectors. Drafting one or more of the Lower Snake River reservoirs would reduce the capability to produce power for a limited time period. Reduced head at the dam would decrease the energy potential of water flows. Depending upon how far down the pools are drafted, it may be possible to maintain barge traffic by additional dredging. Alternatively, it may be necessary to completely suspend barge traffic for some time period. It may also be necessary to incur costs for additional fish trapping and collection if transportation below Lower Granite Dam is required.

6. Improve/Install Screens at Dams and Irrigation Diversions

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a. Description: Effects on anadromous fish from irrigation diversions and other water withdrawals include the loss of migrating juveniles as well as barriers to adult passage. Tributary streams can be blocked by wing dams or lack of sufficient flow below a diversion. This can block adults from reaching some of the most productive spawning and rearing habitat. Large numbers of migrating juveniles are also lost at dams, primarily through the turbines. Even where turbines are screened, losses at dams are still substantial due to predators and other mortality factors.

Currently half (4 of 8) of the mainstem federal Columbia and Snake River dams are screened. Screens are planned for other dams. Nearly 850 irrigation screens have been constructed in Oregon (598), Idaho (236), and Washington (16). However, significant numbers of diversion ditches remain unscreened. This is particularly true in the upper reaches of some tributaries. These areas tend to be important spawning areas. BPA estimates that a total of 65 irrigation diversions remain to be screened, and approximately 23 existing screens need replacement in northeastern Oregon streams. Recent screen inspections in Idaho have found numerous problems and inadequacies requiring correction.

The action required here is the complete screening of all irrigation diversions and other water withdrawals as well as the addition or improvement of screens at dams. Work would involve installing new screening facilities at diversions or dams as well as improving by-passes on existing screens.

b. Time Frame: The benefits of screening are immediate and long-term. Implementation of a complete screening program would take several years, but remaining major unscreened diversions could be corrected within a year.

c. Anticipated Effects:

• **Fish:** New or improved screens are expected to benefit anadromous fish. Prior to large-scale hatchery releases, it was estimated that a total screen program in Idaho could save up to 1 million juvenile salmon and steelhead per year. According to BPA, one screen in Idaho, tested in 1974, saved nearly 86,000 juvenile chinook salmon.

- **Energy:** No effect.
- **Genetic Diversity:** Beneficial, as the survival of wild/natural populations would be improved.
- **Irrigation:** No effect.
- **Navigation:** No effect.
- **Recreation:** No effect.

d. Likelihood of Success: For irrigation screens the likelihood of success is high, as properly installed and operated screens are effective in protecting juvenile migrants. Screening on dams is likely to have less of an effect, as dams were not designed originally to pass juveniles. However, screening will reduce losses sustained under non-screening conditions. Estimates are that screens will reduce mortality by 30-80 percent, depending on water conditions.

e. Estimated Costs: Unknown, depends on number of screens needing improvement. However, costs can run from several thousand dollars for small screens to several million dollars on large dams.

7. Improve Mainstream Flow by Encouraging Fuel Switching (from electricity to natural gas)

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a. Description: It may be possible to improve fish migration as a result of mainstream flow enhancement associated with reduced use of water for hydroelectric generation. This would require energy users to shift

away from electricity to greater reliance on natural gas. In all likelihood, resident space heat demand could be shifted, in part, from electricity to natural gas.

Fuel shifts may be induced in two ways. First, changing market conditions could create incentives for users to shift to natural gas. Higher peak load electricity rates should reduce the relative cost of gas. The combination of increased regional demand for space heat during winter (peak load) months and decreased or stagnant hydroelectric supply will lead to increased rates. This should cause some residents currently heating with electricity to shift to gas. Also, a larger share of new residential units would likely be designed for gas heat. And spot shortages of electricity during peak periods could cause residential users to seek more reliable supplies of heating fuel. Very preliminary estimates suggest that market factors could result in shifts which would reduce electricity demand by 350 Annual Mega Watts (AMW) over the next two decades.

Second, a targeted program aimed at encouraging residential users to retrofit homes for natural gas to replace electric heat could save another 850 AMW under the most optimistic scenario. Such a program would require incentives and financial assistance for space heat conversion.

Beyond residential switching, some modest shift in commercial fuel use could occur as well. However, for stream flow enhancement, residential switching will have the greatest effect. Reduced winter-season electricity demand will greatly expand upstream water storage for release during spring fish runs.

b. Time Frame: Most estimates suggest that at least 20 years will be required to achieve significant stream flow resulting from fuel switching.

c. Anticipated Effects:

- **Fish:** No estimates on improved fish survival rates are available. It is believed, however, that this will enhance recovery of anadromous fish stocks.
- **Energy:** Total consumer energy cost will likely rise.
- **Irrigation:** No appreciable effect.
- **Navigation:** No appreciable effect.

- **Pollution:** Although natural gas burns relatively cleanly, resulting gases will nevertheless contribute to the greenhouse effect.

- **Recreation:** This should have a favorable impact on recreational use of the river.

d. Likelihood of Success: Some improvement in fish survival is likely to occur. The prospects for an induced shift in fuel usage from electricity to gas are good. Thus, water should be saved and stream flows enhanced if a targeted program is initiated.

e. Estimated Costs: It is estimated that the cost of significant conversion to gas for the projected electricity savings will likely be between \$2.5 billion and \$3.0 billion over 20 years.

f. Other Considerations: Success in switching will depend on the availability of natural gas supplies, willingness and ability of gas suppliers to make capital investments to expand service, willingness and ability of residential users to retrofit for gas conversion, and the long-term growth in total regional energy demand.

8. Increased Flows through Power Exchanges

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a. Description: Seasonal power exchanges between the Pacific Northwest and the Southwest (Arizona, California, Nevada) would be negotiated in order to increase spring and summer flows in the Snake and Columbia. Winter power imports from the Southwest would reduce requirements for reservoir refill during the summer and permit the increased spring and summer flows to assist downstream juvenile migrants. Annual PNW power demand, driven by resident space heat use, peaks during winter months. Power demand in the Southwest U.S. peaks during the summer air conditioning season. Thus, interregional power exchanges may serve to smooth supply-demand relationships in both regions.

b. Time Frame: This strategy would require negotiations among utilities and might take months or years to implement.

c. Anticipated Effects:

- **Fish:** The increased flows would reduce travel times, especially for the subyearling chinook smolts migrating in the summer months.

- **Energy:** The winter-summer diversity in demand between Pacific Northwest and Southwest would be served to a greater extent than now by sharing supplies in the two regions rather than supplying each region from its own resources.

- **Irrigation:** Irrigation would be affected to varying degrees, depending on how far pools are lowered. Impacts would be significant if pools are lowered below minimum operating levels for extended periods of time.

- **Navigation:** There would be minimal effect on navigation, unless pools are lowered below minimum operating levels for extended periods of time.

- **Recreation:** Recreation should not be affected to any significant degree.

d. Implementation Issues: Implementation will require negotiation of the power contracts with special regard for the fish flows. It also may require additions to the transmission capacity between regions. There will be some increase in risk of power interruptions and in transmission loss because of the greater overall distance from source to point of consumption.

e. Estimated Costs: Not estimated.

9. Juvenile Fish Transportation

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a. Description: This action would expand the existing juvenile fish transportation program. There is some ambiguity regarding the effectiveness of juvenile fish transportation for the endangered salmon species.

Salmon have been shown to experience greater damages from disease and injury that result from the crowded conditions of barge transport. Nevertheless, some (controversial) studies have shown that the ultimate survival rate for salmon using this method of passage is greater than for the current flushing methods, given the amount of water that has been available for this purpose. Whether or not this is a fair comparison is problematic, since the water budget approach has never been tested and used to the fullest extent possible. In the past, the fishery agencies and tribes have implemented a "partial transportation" strategy where, in average and above average water supply years many spring chinook and steelhead are returned to the river and not transported. In any case, this measure envisions transporting the maximum number of juvenile salmon at all times.

b. Time frame: This action could be implemented immediately. Collection and transportation facilities are in place, though some upgrading might be in order if substantially all fish smolts are to be transported.

c. Anticipated Effects:

- **Fish in general:** It is estimated that the survival rate for returning adult salmon is (1.5-2.0):1 for transported fish over that for non-transported fish. It is possible that a combination of this measure with pool drafting and/or pulsing could increase the survival rate to a greater extent over current methods. It must also be noted that the increased survival rates shown here are based on a very small amount of research data. Some who have studied the data would deny that any benefits to the fish can be claimed. Long-term benefits would depend upon other recovery programs such as predator control, harvest management, and water budget utilization.

- **Genetic diversity of fish:** To the extent that wild salmon stocks can be successfully captured and transported, this measure should help to assure their

survival. Special efforts may need to be made to assure that transportation of fish is timed to benefit wild stocks.

- **Energy:** There should be no direct energy effects from this action. Indirectly, however, the effect of transporting all possible smolts would be to reduce energy losses, as compared to the alternative of relying upon stream flows to accomplish the smolt migration.

- **Irrigation:** Assuming that barge transportation of smolts is an alternative to the option of accomplishing the migration through increased stream flows, irrigation would not be damaged by this alternative. To the extent that this action allows irrigation to avoid a necessary sacrifice of some water for smolt migration, irrigation would benefit from the action.

- **Navigation:** Total river navigation would be enhanced by this action since the transportation of smolts would be an increase in the demand for barge use.

- **Recreation:** This action should have no direct effect on regional recreational activities.

d. Implementation Issues: The major actor in the accomplishment of this action would be the Corps of Engineers which operates the collection and transportation facilities for smolt migration. Federal and state fisheries biologists would likely be involved in the conduct of the operation to insure maximum success. It must be noted that some parties concerned about the survival of smolts during migration do not agree that transportation is a viable option except as a last resort. Hence, any attempt to rely upon the maximization of fish transport for migration in order to avoid stream flow velocity enhancement would likely encounter vigorous opposition from some groups within the region.

e. Likelihood of Success: Medium. Success depends upon other coordinated efforts of recovery and the level of commitment to the transportation action. Again, while being endorsed by some regional interests as a viable option, others have strong doubts about its possible success.

f. Estimated Costs: Unknown. Initial costs could be substantial if additional trapping, collection, and transportation facilities are needed. If successful, this

measure could be one of the more efficient alternatives for overcoming the survival and passage problems that currently exist.

10. Modify Flood Control Curves to Allow Greater Storage of Water in Reservoirs for Release During Critical Periods

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a. Description: Most major Snake River Basin storage reservoirs include flood control in their operations. Brownlee and Dworshak reservoirs provide flood protection to Lewiston and Portland/Vancouver. Modifying the flood control rule curves in these two reservoirs may help enhance lower Snake River flows during the juvenile salmon and steelhead migration period. Basically, this involves reducing the amount of storage space required for a given runoff forecast or delaying evacuation of space to take advantage of greater accuracy in runoff forecast. The increased risk of spill and downstream flooding would be avoided by shifting flood control responsibility from Snake River reservoirs to Columbia River projects. The flood control responsibility for Lewiston might be altered by drawing down the pool behind Lower Granite Dam; additional levee work might be necessary to reduce flooding risk. Flood control responsibility for Portland/Vancouver (about 7 percent in extreme flood conditions, virtually none in dry years) could be shifted to Columbia River projects.

b. Time Frame: Could be implemented each spring, depending on runoff forecasts.

c. Anticipated Effects (adapted from B.5.c):

- **Fish:** Increasing river flow velocity would resemble more closely the natural conditions that occurred prior to construction of hydroelectric facilities on the Columbia and Snake Rivers. The ability to move juveniles downstream may be enhanced. The actual success of this plan or its variations remains an

unknown, however, until implementation and a history of record is attained.

A more rapid downstream movement may increase overall juvenile survival for hatchery and wild stocks. This action should have a positive effect on the survival of genetically desired wild stocks. An important issue is the upstream migration of adult salmon and steelhead. Fish passage facilities would have to be modified to accommodate river levels below the current minimum.

- **Energy:** Drafting reservoir pools will reduce the ability of the system to produce power.

- **Irrigation:** Irrigators who take water from the Ice Harbor pool would be required to extend irrigation pumping systems if water levels lowered beyond the reach of existing pumps.

- **Navigation:** Drafting of reservoir pools below minimum operating levels would eliminate barge traffic for the period of drafting. However, prior planning, storage, and use of alternative modes of transportation could minimize this effect. A large shift in grain shipping from barge to rail or truck will not only increase cost of shipping but could also cause disruption of port elevators with limited capacity to handle shipments via rail or truck.

- **Recreation:** It is possible that extreme variations of the pool levels in the Lower Snake in the spring of the year could adversely affect the resident fishery by eliminating spawning opportunities, particularly for smallmouth bass. Some types of recreation boating could also be eliminated or adversely affected by the changing pool levels.

d. Implementation Issues: Modification of flood control rule curves will not automatically make more water available for fish flow enhancement. Water rights for Bureau of Reclamation and Idaho Power projects would have to be modified to effect a change in flows. Imperfect runoff forecasting and the need to have full reservoirs on July 1 must be considered in quantifying the potential yield from modifying flood control rule curves. System analysis is required to quantify the interaction and potential water yield of modifying hydropower and flood control rule curves.

e. Likelihood of Success: Unknown. To assure benefit to fish, reservoirs should be at or near revised

elevations at the time water budget requests are made. Brownlee and Dworshak need to be full by July 1 each year to meet multiple use objectives.

f. Estimated Costs: Cost of additional levee work at Lewiston, Idaho, is unknown; otherwise, cost of this action would not be substantially beyond those of the other increased flow actions.

References

Office of the Governor, State of Idaho. "Strategies for Recovery of the Snake River Salmon," (1991).

11. Predation

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a. Description: Squawfish predation at dams appears to be a major source of mortality on juvenile salmonids. Control of squawfish through a bounty program is being implemented in the Columbia River. Game fishes have been examined in a few locations to determine impact. Research to date suggests that they may have minimal impact. However, sampling methods for many of these fishes are not efficient (e.g., smallmouth bass) and past research should be viewed with skepticism. Feeding habits of smallmouth bass and squawfish are very similar.

Several problems remain. (1) Partitioning total mortality of juvenile salmonids to various fates has not been examined. Therefore, we do not have evidence to determine if juvenile mortality rates are density independent (i.e., independent of population size—presumably like mortality caused by turbines), density compensatory (i.e., smaller prey populations are more susceptible to that source of mortality), or density compensatory (i.e., losses caused by one factor are compensated by changes in mortality due to other factors). The efficacy of predation control must be measured in order to control problems of confounding influence. (2) Wild fish may experience different survival risks than hatchery fishes. (3) Predation is only being considered in the mainstem of the Columbia. This assumes that mortality by predacious game fishes (all of which are alien species) and terrestrial predators is unimportant. This may be

fallacious,* especially if mortality rates due to predation behave in a density-dependant manner. (4) Better gear to capture game fish and distribution is needed. (5) Other means of controlling predation loss should be developed. (6) More innovative means of controlling predators should be sought (if predation is not density-compensatory).

b. Implementation: Coordination among various institutions (federal, state, tribal, academic) will be needed to conduct this research. Federal, state, and tribal entities may be better suited to examine sources of mortality. The experience of the squawfish study on the Columbia will be helpful in this regard. State agencies can monitor game fish populations and conduct studies concerning the voracity of game fishes in tributaries to the Columbia River. Academic institutions can help with the design of such projects or participate here as needed. Academic institutions are well equipped to develop new approaches to testing ideas concerning susceptibility of wild and hatchery salmonids to predators, designing new release strategies for fish transported around dams, and use of pheromones to alter behavior of predators and juvenile salmonids. Economists can determine cost efficiencies of various strategies.

c. Implementation Issues: One issue is the determination of the relative role of predation on total mortality. If run sizes exceed expected returns for successive years after predator control has been implemented, then additional study to examine sources of mortality may not be warranted. However, if the data are equivocal, then effort to examine all sources of mortality will be worthwhile. This should include all life stages. Such data is needed in any case to improve the accuracy of the Columbia River Subbasin Planning Model. If mortality is found to be density-compensatory, predator control will not provide much of a payoff. Other strategies of reducing predation losses other than the current bounty program may be more economic.

d. Anticipated Effects:

- Fish: Decreased predation will have a positive effect on survival of salmonids.
- Energy: No effect.
- Irrigation: No effect.

- Navigation: No effect.
- Recreation: No effect.

e. Likelihood of Success: Partitioning of mortality sources is difficult and expensive, but is absolutely essential for addressing factors limiting juvenile salmonids in freshwater. Ideally, this study should be integrated with studies designed to examine the impact of fish diseases, the population dynamic studies of adult fish harvest, and rates of fish survival during dam passage.

f. Estimated Costs: Not estimated.

12. Purchase or Lease Private Water Rights to Increase Stream Flow During Critical Periods

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a. Description: Farmers or districts holding water rights may be willing to sell some or all of these rights to an agency which would use the water for fish passage. There are several possible ways to do this, — outright sale of the water right, annual leasing of the water right, or some form of long-term option-lease arrangement.

While water rights have been purchased for urban use in several other western states, the cost of outright purchase is probably too high for purposes of augmenting fish passage. Annual leasing is also a problem, because water either won't be available or will be very expensive when it is needed in dry years.

The option-lease mechanism could be attractive because it would make the water available for irrigation use in most years, but require irrigation to deliver water for fish flows in only the critical dry years. The farmers, as willing signers of the lease, would be compensated for the cost of the cropping adjustments necessary to free up the required water.

b. Time Frame: This option could be implemented in 3 to 5 years. It might take this long to make the required changes in state law, to design the rules for

the option-lease market, to modify irrigation systems to permit such changes in delivery patterns, to put in place measuring systems that would assure contract compliance, and to get farmers to participate in such a market.

c. Anticipated Effects:

- **Fish:** Water from the water market could make more water available for moving juvenile fish downstream. However, it would take a very successful market to have much effect on river velocity, unless the water market is accompanied by other operation changes such as reducing reservoir levels.

- **Energy:** A water market that diverts water from consumptive irrigation use to use for fish passage should result in increased hydropower production. The increased flows needed for fish in dry years can also generate power at a time when such power would be valuable. As joint beneficiaries, power interests could play a role in paying for the market purchases of water.

- **Irrigation:** Using a water market to divert water from irrigation to fish could have a major effect on agriculture in the Columbia River system. However, if the market were well designed, it would not damage the interests of irrigators. Farmers would cut out the lowest valued water uses first, meaning that the effect on agricultural production might not be large and the effect on income of irrigation may be positive. Irrigators would participate as willing sellers only if the payment for the water exceeds the expected loss from giving up the water.

- Navigation: No effect.

- Recreation: No effect.

d. Implementation Issues: Implementing this alternative would require cooperation between the state and federal agencies, such as BPA, which might buy the water.

e. Estimated Costs: There are indications that using an option-lease water market to attract water away from irrigation of some low-valued crops in occasional dry years would involve only a modest cost per acre foot. If the water were needed more frequently than, say, one year in ten, or if it is necessary to attract water away from higher valued crops, the market cost of this water would be higher. In the latter case, there

would also likely be secondary effects which may be considerably larger than the direct effects.

References

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13. Purchase Water from the Snake River Water Bank to Increase Stream Flow During Critical Periods

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a. Description: Idaho Farmers or districts with stored water surplus which is not needed for irrigation in a particular year can allocate that water to the Snake River Water Bank. Water is then purchased from the water bank for irrigation or hydropower purposes. Water from the water bank might also be used to augment flows at times critical for fish passage.

The water bank was started in the late 1970's. In some years as much as 750,000 acre feet of water have been in the bank, and in most years the Idaho Power Company has been the major purchaser. The price for bank water has been set in the \$2.50-\$3.00 range to conform to the "no profit" rules of the Bureau of Reclamation.

In most years some water remains unsold in the water bank. However, since sellers will evaluate their water supply relative to their own needs as they decide how much water to put in the bank, there is no assurance that the water bank can provide enough water to meet fish passage needs in a dry year, or particularly in a series of dry years.

b. Time Frame: With the structure of the water bank already in place, this option could be quickly implemented. Delay might occur if changes in state law are needed to allow water bank sales for use outside of Idaho.

c. Anticipated Effects:

- **Fish:** Water from the water bank could make more water available for moving juvenile fish downstream. However, the amount of water available from the bank would be quite small relative to the unaugmented river flow, meaning that the effect on river velocity would not be great. Unless accompanied by other operation changes, such as reducing reservoir levels, the effect of water bank purchases on fish survival would be small.

- **Energy:** Retaining excess water in upstream storage means that the reservoirs fill quicker and the excess water can go to fill downstream storage. In most years all of the water in the Snake basin can either be stored or used immediately to generate power; very little gets spilled unused. Using the water bank to augment fish flows might change the timing (and hence the market value) of power generation, but probably not the quantity.

- **Irrigation:** The water bank was set up as a mechanism to reallocate excess water among irrigators and has proven useful to shift water to hydro-power generation. If using the water bank for fish flows drives up the price, this would restrict purchases by irrigators. This could erode farmer political support for the concept of the water bank. However, irrigators would only give up water to the extent they were willing sellers, so their interests would be protected.

- **Navigation:** No effect.

- **Recreation:** No effect.

d. Implementation Issues: Implementing this alternative would require cooperation between the State of Idaho, a federal agency such as BPA which might buy the water, and the Bureau of Reclamation which is the major holder of water bank storage space. Changes in state law and Bureau policies might be required.

e. Estimated Costs: The cost of buying water from the water bank at present prices would be quite low.

Costs would increase if it were necessary to raise prices to attract more water into the bank. However, there are indications that only moderate price increases would be needed to attract water away from irrigation of some low-valued crops.

References

Hamilton, Joel, and Norman K. Whittlesey. "Markets for Stored Water in the Pacific Northwest," paper presented at the Western Agriculture Economic Association, Annual Meeting, (July 1988).

14. Reduce Winter Generation of Electricity to Reserve Water for Release During Critical Periods

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a. Description: Under a mandate of the Pacific Northwest Electric Power Planning and Conservation Act of 1980, the Columbia River Basin Fish and Wildlife Program calls for a water budget of 1.19 million acre feet of water to enhance mainstream Snake River flows during the critical fish migration period. This budget is viewed by many as inadequate to insure maximum juvenile survival. In practice, only about 450,000 acre feet of water per year have been available for flow enhancement. One possible method of improving critical period stream flows would be to reduce winter power generation so as to increase stored water in upriver reservoirs for flow enhancement.

Storage of 1.2 million acre feet or more would extend the flow enhancement period to as many as 8 weeks. Recent flow enhancements have been limited to 17 days in 1989 and 25 days in 1990.

To save enough water to enhance flows at this targeted level would require reduced winter period hydroelectric generation. Electricity demand in the Pacific Northwest peaks during the winter, driven by residential space heat use. During this period, BPA frequently has to buy power from out of region

sources. Thus, residential electricity users could face slightly increased rates.

Some observers argue that 1.2 million acre feet of water for flow enhancement are inadequate and that 4 million acre feet of stored water are required for optimal flow and fish survival enhancement. Holding this quantity of water would likely have significant effects on regional electricity supply during the peak demand season.

b. Time Frame: This is a short term, 2- to 3-year, remedy. The trend for growth in power demand will preclude extended reductions in power generation without alternative power supplies (c.f. III.B.7. and III.B.8.). Thus, longer-term commitments of water for flow enhancement without other power sources would require switching to other fuels such as natural gas and/or a significantly increased energy conservation commitment.

c. Anticipated Effects:

- Fish: Enhanced stream flow should improve survival rates of migrating juveniles. However, no precise estimates of these survival rates are available.
- Energy: Winter energy demand would not likely be fully met by regional suppliers, thus requiring purchases of higher-cost out-of-region supplies.
- Irrigation: No appreciable effect.
- Navigation: No appreciable effect.
- Recreation: No appreciable effect.

d. Likelihood of Success: Improved spring stream flows should increase fish survival. BPA should be able to acquire replacement electricity in the short term.

e. Estimated Costs: Some expansion of upriver reservoirs may be required to accommodate larger volumes of up to 1.2 million acre feet of water. Winter space heat users may experience slight increases in rates. Storage of 4 million acre feet of water would require switching to other fuels and/or would result in significant increases in energy costs in the short and intermediate term. No other major costs of implementation should accrue.

15. River Pulsing

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a. Description: Releases of water from the water budget would be timed in a way that would send periodic large flows of water down the river to assist juvenile fish in downstream passage. Releases would be made for several days, then halted for several days and then repeated. This on/off pattern of water releases likely would continue from April 15 to June 15, and perhaps longer.

b. Time Frame: This strategy can begin immediately and requires no special preparation. The physical implementation of pulsing water budget releases is relatively simple.

c. Anticipated Effects:

- **Fish:** Pulsing would spread out the effects of water budget releases over a longer period in hopes of providing more protection to both wild and hatchery stocks of salmon. This is because existing use of the water budget is to make large-volume releases for only a part of the important two-month period. It is uncertain how the fish will move during these periodic pulses. Although some argue that the most important factor for downstream migration is the velocity of water flow.

The Fish Passage Center in Portland has a model that partially takes account of the pulsing but does not include the wave effect. The model uses experimental data on fish travel times for various flow regimes and a very simple flow model. Their conclusion is that the pulsing is not effective in decreasing fish travel time. They conclude that average flow is the important physical variable.

For pulsing to have a positive effect it will need to provide an increased average velocity for the duration of the critical downstream migration period. If increased flows are offset by lower flows at other times so that the net effect is zero or minimal, there would likely be little or no benefit to fish.

- **Energy:** There should be little or no effects in the aggregate, but there would be variations in power output depending on the volumes of water. There

would be a rolling effect as the "pulse" travels through each successive dam. This would require adjustments in the power produced from other facilities throughout the region to compensate for these variations. There may be some problems of power ownership and differing transmission losses.

- **Navigation:** There would be only a slight negative effect in that upstream traffic would require more fuel to move against the heavier current of the pulsing effects. This would, however, be no different than a sustained high flow. The river levels would not be lowered to the point of disrupting traffic.

- **Irrigation:** No effect since the water releases are already allocated to the water budget and not available for irrigation. Although some pump relocations may be necessary, in general water availability should not be interrupted, at least not for long periods of time.

- **Recreation:** There should be none or limited negative effects. The downstream effects would be very minimal from the pulses of water.

c. Implementation Issues: The physical implementation is straightforward. It would be the responsibility of the Columbia Basin Fish & Wildlife Authority. It would, however, require cooperation from the Fishery Agencies and Tribes to carry out releases in this manner. The physical release of water to do the pulsing is possible at present.

There are possible effects on bank sloughing or erosion, railroad and highway damage, erosion, and resident fish. However, as long as pulsing remains within limits, such dangers are very small.

d. Likelihood of Success: The likelihood of success is unknown, but is probably low. Limited information from 1990 water budget releases showed substantial increases in smolt passage when the water volume was increased. That would have been the result of higher average flows, so it is not clear what the effects on fish would be of on and off heavy flows every few days.

e. Estimated Costs: Very small.

16. Timing Water Budget Releases to Meet Needs of Wild Stock

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a. Description: In order to achieve the water velocities required to move the migrating smolts through the lower Snake and Columbia River pools in a timely manner and without undue mortality, it is necessary to provide large amounts of water for the water budget. Past implementation of the water budget provided water from storage for fish passage during an 8- to 10-day period near the beginning of May when spring migrants, primarily of hatchery origin, are in the river. Wild spring migrants were offered little protection from the water budget as implemented. Timing water budget releases to coincide with the wild spring/summer chinook and sockeye salmon juvenile migration would provide greater protection for these stocks in the Snake River than they currently receive. The major requirements of wild stock salmon for water releases would fall within the April 15 to June 15 period. PIT tag data from the upper Snake River show that hatchery spring chinook juveniles migrate past Lower Granite Dam primarily in mid-May to mid-June. These data would be useful in timing water budget releases to coincide with the period of time when juveniles of wild origin, most importantly ESA petitioned stocks, are primarily in the river. If adequate water for this purpose is not available it may be necessary to combine this action with other actions such as pulsing and drafting of dam pools to effect the desired flow velocity.

b. Time Frame: This action could be undertaken immediately, though some allied actions to improve its effectiveness may require more than one year for implementation. If implemented, this action could have an immediate effect on wild stock survival.

c. Anticipated Effects:

- **Fish:** This action would provide benefit specifically to wild stocks in the Columbia River and Snake River. Timing water budget releases to coincide with the time when wild spring migrants are in the Snake River will provide these migrants with higher flows, moving them downstream more rapidly. It may be possible for the fish to be collected at one of the downstream dams and transported through the

remaining dam pools if that appears to be feasible. The effectiveness of timing water releases for fish migration will depend upon the amount of water available for this purpose and whether it is combined with other actions to increase its effectiveness. BPA has estimated that combinations of water releases and fish transportation could increase survival of wild stock by 1.5-2.0 to one.

This action would assist in preserving the genetic diversity of individual wild stocks in the Columbia/Snake Rivers.

- **Energy:** Reshaping of water flows in the river system for fish migration will have some negative effects on the ability of the system to produce energy. The extent of the effect will depend upon the amount of water used for this purpose and the ability of the system to produce and use the power generated during the fish migration.

- **Navigation:** This action alone should not have negative effects on river navigation. If dam pools are drafted below minimum operating levels to increase the effectiveness of the water budgeted for fish, navigation would be interrupted for brief periods during the year.

- **Irrigation:** This action may or may not have effects upon regional irrigated agriculture. Depending on the magnitude of draw-down, irrigation pump stations may have to be relocated. Negative effects could also occur if agriculture is required to provide some of the water for the fish migration. However, in this case, it is most likely that agriculture would be compensated for income losses.

- **Recreation:** The effects of this action on resident fish production in upstream storage dams and in the river itself is unknown. It is possible that some negative effects of this type would occur. It is also possible that water available to maintain minimum stream-flows during summer and fall months would be reduced to negatively effect other forms of recreation such as rafting and boating.

d. Implementation Issues: To be effective, this action would require the cooperation of several parties to the river management. Corps of Engineers, BPA, state and federal fish management agencies, and the barge industry are examples of those who would be involved.

e. Likelihood of Success: High. Information from the Smolt Monitoring Program, conducted by the Fish Passage Center, and other studies have identified the timing of the wild juvenile outmigration in the Columbia River and the Snake River as an important factor to reduce smolt mortality.

f. Estimated Cost: Additional monetary or energy cost could be incurred by full implementation of the water budget. Also, juveniles of hatchery origin may not receive as much protection from water budget flow augmentation. Major costs would be in the form of lower survival rates for hatchery fish.

C. FISH HARVEST

1. Eliminate Gillnet Harvesting in the Columbia River Mainstem

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a. Description: Fishery managers permit drift gillnet salmon fisheries downstream from Bonneville Dam by people licensed by either the State of Washington or the State of Oregon. Seasons and conditions for capture are set by the two states working cooperatively through the Columbia River Compact. Members of treaty Indian tribes use several types of gear to harvest salmon in designated areas upstream from Bonneville Dam, but most of the catch is taken by set nets.

Seasons and permitted gear in both arrangements are defined to allow reasonable fisheries where reasonability requires that adequate spawning escapements are permitted upstream. Since several anadromous fish stocks are in the river at the same time, seasons are allowed only when runs are predominately from stocks with surplus numbers. Nevertheless, since wild stocks enter the river at a variety of times, any gillnet harvest will take some fraction of threatened or endangered species.

Elimination of gillnet harvests would eliminate the incidental harvest of threatened or endangered species.

b. Time Frame: The non-Indian fishery could be eliminated whenever capture of threatened or endangered species during a harvest period was documented. Elimination of the Indian fishery is more problematic since these fisheries operate under mandates set forth by federal courts.

c. Anticipated Effects:

- **Fish:** Assuming that sport fishing effort and success remained constant, elimination of gillnet fisheries should increase escapement to terminal streams. If sport fishing harvest rises in response to reduced commercial harvest, effects on spawning escapement would be difficult to determine. Since fishery agencies already manage gillnet fisheries to target on hatchery stocks and avoid wild stocks, large surpluses of fish to hatcheries could be expected. Some limited amount of this could go to manufacturers of pet food or others who can use low-quality salmon. Surplus eggs can also be sold. Without a major restructuring of hatchery operations in the Columbia River Basin, much of the hatchery surplus would be wasted.

If the fish caught by nets in the Columbia River are not taken by another group, the commercial value of this catch will be lost. The total ex-vessel value (receipts paid by first buyers to fishermen) in the 1980s ranged from \$2.6 million in 1983 to \$29.3 million in 1988. This value is the sum of landings for chinook salmon, coho salmon, sockeye salmon, chum salmon, white sturgeon, green sturgeon, smelt, shad, and steelhead trout (commercial harvest by Indian fishermen only). Most of the value comes from chinook salmon, although in some years (such as 1986) the value of the coho salmon fishery exceeds that of the chinook fishery.

- **Energy:** No effect.
- **Irrigation:** No effect.
- **Navigation:** No effect.
- **Recreation:** No effect, if sport fishing effort and success remain constant.

d. Implementation Issues: Elimination of non-Indian gillnet fisheries would require the cooperation of the Oregon and Washington legislatures. Bills to eliminate gillnet fishing and increase sport fishing have been introduced in both state legislatures many times.

If the legislatures agree to this action, the Oregon Department of Fish and Wildlife and the Washington Department of Fisheries could implement it immediately. If the legislatures decide that compensation is appropriate, fleet reduction programs can be implemented cooperatively by the fishery agencies in the two states. The Columbia River non-Indian gillnet fleet declined somewhat in the 1980s in response to a license buyback program funded by the federal government. Reducing the rest of the fleet through such a fleet reduction may be more difficult and expensive.

Elimination of the Indian gillnet fishery would require a major change in the administration of court decisions known as the Boldt and Belloni decisions. Since administration of those decisions evolved after several years of complex negotiation, implementation of this proposal would be difficult, costly, and time consuming.

e. Likelihood of Success: Eliminating non-Indian gillnet fisheries for upriver fisheries can be done fairly easily, but few chinook and sockeye salmon will be saved, while wasted surplus escapement to hatcheries is likely.

The institutional constraints to eliminating treaty Indian fisheries are severe. If, however, other harvesters reduce their catch and Indians receive compensation such as expanded harvest opportunities for other species or at other times and locations, some reduction in harvest in current fisheries may be possible.

f. Estimated Costs: The fleet reduction programs for non-Indian fisheries, if compensation is required by the two state legislatures, could cost several million dollars. If management is otherwise likely to reduce or eliminate seasons, little profit is left for the fishery. On the other hand, the legal and political complexity of events likely to follow elimination of the Indian fishery suggest very high costs.

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2. Reduce Ocean Harvest Rates on Petitioned Species

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a. Description: As salmon migrate over vast ranges in the Pacific Ocean, they are captured both as targeted species and as incidental catch in many other fisheries. Chinook salmon originating in Columbia River are taken in ocean salmon fisheries off the coasts of Alaska, British Columbia, Washington, Oregon, and California. Although documentation of exact numbers is difficult, many fear that large numbers are trapped by the very long squid driftnets deployed by several Asian nations in the open ocean. Salmon also appear in small percentages (but not negligible in total numbers) in trawl fisheries operating off the west coast of North America.

Ocean salmon fisheries—both commercial troll and recreational hook-and-line fisheries—are mixed-stock fisheries: they inevitably capture fish returning to many streams and to hatchery catch-and-release sites. Some fraction of these harvests come from threatened chinook salmon stocks. Reducing ocean harvests of all stocks would reduce the capture of Snake River chinook salmon stocks, but this will require substantial reduction in harvest of chinook salmon stocks returning to other locations.

Harvest by the ocean salmon fisheries and the incidental take of chinook salmon by several other marine fisheries have declined since the United States and Canada extended their fishery jurisdiction 200 miles from shore. Many observers fear that the growing open ocean drift gillnet fishery may have sharply reduced this positive trend. Efforts are under way to further reduce incidental harvest in those fisheries operating in the jurisdiction of the United States, to negotiate reduced harvest off British Columbia with the Canadian government, and to ban or reduce the size of ocean gillnet operations.

b. Time Frame: Ocean salmon fisheries are regulated by a variety of techniques, but the central management tool is closure of fishing areas during certain times of the year in order to meet quotas. These regulations are adopted annually by the Secretary of Commerce to carry out amendments to salmon management plans developed by the Pacific Fishery Management Council. The need to reduce harvest rates has been anticipated by the Pacific Fishery Management Council. These regulations will continue to restrict ocean fisheries to permit escapement of wild salmon. If species are listed as endangered or threatened, they may take more restrictive actions than they otherwise would. International negotiations to reduce harvest off the Canadian coast and on the high seas are quite complex and are likely to take much longer.

c. Anticipated Effects:

- **Fish:** Reducing incidental harvest of wild salmon stocks by salmon and other fisheries should increase the number of fish escaping to spawning grounds. Since fishery agencies already manage salmon fisheries to concentrate on surplus hatchery stocks and since they have managed other ocean fisheries to avoid salmon catch, additional reductions may require rather large cutbacks in other ocean fisheries. For example, between 1977 and 1988, the foreign trawl fishery operating off the coasts of California, Oregon, and Washington caught, on average, one salmon for every twelve million metric tons of whiting. During that same time period, U.S. trawl vessels delivering to foreign processing vessels, i.e., the joint venture fishery, caught one salmon for every seven million metric tons of whiting.

The ocean salmon troll fleet and the ocean recreational charter fishing fleet operating off the coasts of

Oregon and Washington adjusted to increased hatchery operations in the Columbia River by developing fishing practices attuned to those stocks. In recent years, ocean fishermen have concentrated more on chinook stocks and ocean recreational fishermen tend to take more coho. Significant reductions in these fisheries would eliminate most of the ocean troll fishing off Washington and move the Oregon fishery southward. Due to droughts in California and concern about California stocks, the southern fisheries may not be able to sustain new effort without dramatic decreases in seasons.

Similar sharp reductions are likely for recreational fisheries, especially those based in northern Oregon and southern Washington. Fishing-related businesses on the Washington and northern Oregon coast would bear the largest costs.

- Energy: No effect.
- Irrigation: No effect.
- Navigation: No effect.
- Recreation: No effect.

d. Implementation Issues: Consideration of management alternatives for ocean fisheries off the California-Oregon-Washington coast is the responsibility of the Pacific Fishery Management Council, although implementation of new regulations is the responsibility of the National Marine Fisheries Service, the Coast Guard, and state agencies in Idaho, California, Oregon, Washington, and Alaska. Further reductions in fishing opportunities compound pressures now felt by ocean fishery managers to allocate fishing opportunities among competing user groups and to reduce fishing capacity in some fleets. Reduction in ocean fisheries near the Columbia River would be required just at the time that fisheries in other regions are adjusting to cutbacks.

e. Likelihood of Success: Some reduction of ocean fishing rates on salmon, with emphasis on avoiding wild salmon stocks, will occur without new initiatives from the Endangered Species Act. Whether the additional reductions should be undertaken is a matter for wide public debate.

f. Estimated Costs: Most of the costs to be borne by the taxpayer will be made with or without listing. The

size of costs borne by ocean recreational and commercial fishery reduction depends on the size of the reduction. Significant reduction in wild salmon catch is likely to come at substantial loss of revenue to the fishing fleets and coastal communities in Washington and northern Oregon. According to estimates supplied by the Pacific Fishery Management Council, from 1976 to 1989, the troll salmon fishery generated annually \$36 million for California coastal communities, \$24 million for Oregon coastal communities, and \$10 million for Washington coastal communities. During that same time period, the ocean recreational salmon fishing industry annually generated \$14 million for California coastal communities, \$14 million for Oregon coastal communities, and \$16 million for Washington coastal communities.

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3. Reduce Harvest Rates on Petitioned and Other Marginal Species in All Fisheries

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a. Description: Previous sections discussed the elimination of gillnetting on the Columbia River and reduction of ocean harvest of salmon. Another alternative is to reduce harvest rates on petitioned and

other marginal species in all fisheries—those discussed so far plus recreational fisheries and Indian fisheries on upper reaches of the Columbia River and its tributaries. Since salmon are harvested throughout its migratory range, considerations of equity may require that harvest reductions be shared by all parties.

b. Time Frame: Regulations setting harvest guidelines are set annually by all fishery management bodies. Modest reductions in fish harvests can be implemented quickly, but sharp reductions would require an extended planning process.

c. Anticipated Effects:

- **Fish:** Reducing offshore harvests and gillnet harvests in the Columbia River have already been discussed (c.f. III.C.1. and III.C.2). Recreational harvests in the Columbia River estuary (the Buoy 10 fishery) and in the lower Columbia River are managed to target hatchery stocks and viable wild stocks. Reduction in these fisheries should increase escapement to terminal streams.

- **Energy:** No effect.

- **Irrigation:** No effect.

- **Navigation:** No effect.

- **Recreation:** Sharp curtailment of these fisheries to protect selected Snake runs of wild chinook salmon would lead to loss of net economic value from a valuable recreational fishery for Oregon and Washington residents and impact the tourism industry on the Columbia River from Astoria to Portland.

e. Implementation Issues: Salmon fisheries have declined in recent years. Since many of these fisheries are based in small timber-dependent communities that have faced recent hardships from other sources, resistance to a further erosion to their economic base will be heard sympathetically by many managers. As a result, minor reductions in harvesting can be introduced easily, but major reductions will require extensive consultation. Allocation of limited fishing opportunities is already the most difficult issue facing managers; allocation of smaller harvests would require even more extensive consultations.

f. Likelihood of Success: Minor reduction in fishing rates, especially where this can be based on fishery agency analyses of options that minimize harvest of Snake River chinook stocks, should be feasible. Even these measures will require substantial harvest reductions of hatchery stocks to provide minor gains in wild salmon escapement, at least until such time as effective measures of separating wild and hatchery stock at harvest have been introduced.

g. Estimated Costs: Not estimated.

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D. INSTITUTIONAL ISSUES

1. Change Laws Governing Water Use

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a. Description: Water is a public resource in the Pacific Northwest. As a result, public policies (rules) play an important role in the allocation of water resources. The primary rule for water allocation in the Pacific Northwest and most of the U.S. is the prior appropriation doctrine ("first in time, first in right of use"). This rule tends to favor out-of-stream uses such as irrigation, given the seniority of those rights.

Changes in the rules or laws governing water rights to benefit fish must reflect the institutional setting in which these rules are developed. For example, according to Oregon's Water Code (OWC), any firm or individual wishing to use water must acquire a permit or water right from the Oregon Water Resource Department (OWRD). This property right system is known as an "appropriative right" system. Since instream uses, such as fish production, were not recognized as beneficial in Oregon until 1964, these rights are typically junior to out-of-stream uses. In periods of water shortage, the instream minimum flow targets frequently will not be met. These minimum flows could be augmented by water currently being diverted by out-of-stream uses. The feasibility of such actions depends on the transferability of water rights under each state's system of prior appropriation.

In general, a water right is assigned for a given place, use, and amount of water. However, the Oregon water code does allow a water right to be transferred or diverted to other areas or uses with approval by the OWRD. This suggests that water codes are evolving towards a system of transferability.

Of particular interest are the potential benefits to fish from buying water rights (for the purposes of transfer to streamflow) from out-of-stream users. However, a practical problem that limits such transfers is the cost and difficulty associated with organizing the frequently large number of users of instream flows, each of whom has relatively small interest in these instream values. While collective actions in water purchases

have been accomplished by sport fishing and conservation organizations (e.g., the Nature Conservancy) through the purchase of water rights (and the adjoining land), these purchases have generally been for specific resident fishing enhancement or for specific access. Local and state governments could buy water rights to protect the public benefits of instream uses.

b. Time Frame: Changes in water codes tend to occur slowly. Recent developments in Oregon indicate some movement towards water transfers and water markets. It appears that transfers of water to fishing uses is possible under the current water rights system. It is unlikely, however, that major changes in each state's system of prior appropriation will be forthcoming, given the long history of this system and the court's traditional reluctance to redefine established property rights in the area of water.

c. Anticipated Effects:

- **Fish:** An increase in streamflow during critical periods (e.g., summer, fall) of the salmon life cycle will increase survival under some conditions. Thus, augmentation of streamflow via water purchases may increase smolt survival and possibly increase adult survival. However, there is no guarantee that the development of water markets or other transfer mechanisms would allocate more water to fish. Higher-valued use of water may compete for those rights.

Increases in seasonal streamflow, particularly in spawning areas of tributaries, could benefit natural reproduction, and hence maintain genetic diversity. It is uncertain, however, whether changes in western water codes will automatically translate into increases in streamflow.

- **Energy:** Increased streamflow may increase energy production. The extent and value of any increase in energy production depends on timing of the increased streamflow and concomitant changes in the operation of downstream hydropower facilities to take advantage of the increased streamflow. The increased energy value can be used for compensation and transfer cuts.

- **Irrigation:** Changes in water rights that reduce diversions to agriculture may reduce total production of agricultural commodities in the affected region. If the transfers are voluntary via sales of water rights,

participating producers are assumed to benefit from the transfer. Agricultural constituents, such as input suppliers, commodity processors, and consumers may lose from reductions in output.

- **Navigation:** No effect.

- **Recreation:** Increased streamflow to benefit fish is likely to also have modest but positive effects on water-based recreation such as rafting, boating, and fishing. Again, the existence of water transferability mechanisms does not necessarily mean that streamflow would increase.

d. Implementation Issues: Major changes in water laws are likely to be opposed by those parties who benefit from the current distribution of rights. Acceptance of changes is most likely in cases where actions are voluntary or where change tends to be gradual and affects few people. However, movement to water markets has been relatively rapid in some states, perhaps because such transactions are voluntary. There is little evidence to suggest major changes in the underlying water rights system in the western U.S. will be forthcoming.

e. Likelihood of Success: The ability to transfer water from senior rights holders to junior rights such as in-stream flow appears feasible. The likelihood of changes in the prior appropriation doctrine is low.

f. Estimated Cost: Not estimated.

2. Develop and Implement a Monitoring Program

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a. Description: Determining the success of actions to enhance the populations of salmon and steelhead in the Columbia Basin requires that the size and composition of the populations be monitored. Such programs are already taking place but may need to be increased and coordinated to a greater degree as greater efforts are made to enhance endangered populations. Catches of tagged fish are monitored in high seas and coastal and river fisheries. A primary monitoring tool has

been counts of returning adults at fish ladders. Recently, clipping the adipose fin on hatchery fish and the use of electronic tags has increased the information available from observations at the dams. Populations in the individual tributaries are more difficult and expensive to monitor. Methods include: counts of adult spawners and carcasses, counts of nests (redds), and counts of juveniles collected using traps or electrofishing. In addition, the relatedness and levels of genetic variability of the populations can be monitored using biochemical methods studying protein or DNA variations. These methods provide valuable information but are labor-intensive and relatively expensive.

b. Time Frame: Monitoring of populations in the Columbia Basin is ongoing and must continue if their status and the effect of improvements is to be evaluated.

c. Anticipated Effects:

- Fish: Monitoring per se will not directly enhance or depress the populations, but it is essential to measure the impact of other actions. A successful monitoring program will allow other activities to be planned and evaluated more efficiently.

- Energy: No direct effect.
- Irrigation: No direct effect.
- Navigation: No direct effect.
- Recreation: No direct effect.

d. Implementation Issues: Coordination of monitoring programs is critical if they are to be successful. This requires good communication among numerous agencies. Ongoing programs for monitoring tagged fish in fisheries and returning adults at the fish ladders are established, successful, and provide critical information. These programs could be expanded to allow more data to be collected. Monitoring individual populations in the tributaries is difficult and expensive, but critical if the success of actions is to be assessed. The monitoring of particular endangered populations will likely be emphasized as recovery programs are implemented. Genetic monitoring programs are increasingly being carried out in central laboratories (e.g., National Marine Fisheries Service in Seattle, Washington Department of Fisheries in

Olympia) with considerable experience and substantial databases.

e. Likelihood of Success: Monitoring in fisheries and at fish ladders is ongoing and highly successful. Monitoring of individual populations in tributaries is difficult but critical to evaluating the status of the populations. Increasingly sophisticated methods of genetic monitoring are being developed and can be used to assess both the status of existing populations and the success of recovery programs. A coordinated, basin-wide monitoring effort could facilitate the evaluation and planning of other activities.

f. Estimated Costs: Monitoring is expensive but essential to assessing effects of enhancement efforts. Better coordination of current monitoring programs probably could be done at relatively little cost, but increased monitoring would likely be expensive. Monitoring returns of tagged fish in fisheries is expensive but provides critical information. Costs of conventional monitoring programs at fish ladders are low. The use of electronic and coded wire tags is substantial but provides information unavailable by other means. Evaluations of tributary populations are labor-intensive and consequently high in cost. Genetic monitoring programs provide information unavailable by other means, but are expensive.

3. Modeling River System Operations to Evaluate Alternative Management Systems

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a. Description: Currently, several models of river flow and operation, fish passage, and power production exist. An effort is underway to coordinate the use of these models to create a more comprehensive and systematic approach to fish and other resource management in the Columbia River system. The purpose of this action is to construct an additional basin-wide model to aid in the selection of fish recovery plans that maximize the regional social welfare subject to the economic budget for this activity and other existing legal and institutional constraints. This model

would consider the interactions of the various river system parts (e.g., smolt migration, adult passage, harvest, hatchery location and operation, etc.), institutional and political constraints and objectives (e.g., basin wide benefits, genetic diversity, number of harvestable fish, Indian treaty obligations, etc.), the timing of fish recovery, and the cost of accomplishing alternative objectives with regard to fish recovery.

b. Time Frame: The development of a functional model for the above-described purpose would likely take two to three years. Subsequently it would require continual updating and augmentation to remain a useful tool in fisheries policy planning in the future.

c. Anticipated Effects:

- **Fish:** The action of model development itself would have no effects on any part of the river system. However, in the long run, the model could be useful in more accurately assessing the effects of various individual fish recovery actions on regional economic sectors (e.g., energy, navigation, irrigation, recreation, etc.). The model could be used to evaluate the long-run fish recovery results of any constraints that might be imposed by any of these actors. In the end, the model would be useful in allocating available funds for fish recovery and choosing those actions which make the greatest contribution to the regional goals of fish recovery and economic development.

- **Energy:** See above.
- **Irrigation:** See above.
- **Navigation:** See above.
- **Recreation:** See above.

d. Implementation Issues: This action would require the commitment of one or more regional scientists experienced in building large economic/biological models. The university setting is probably best equipped to carry out such a task. The action would also require a commitment of necessary funds to complete the task of model building and evaluation.

e. Likelihood of Success: The success of this action would depend upon the commitment of individuals and necessary funding for its completion. If such commitments are forthcoming, it would be possible to develop a viable and operable model. The value of its

use will depend upon how willing the regional policy interests may be in using it for decision-making.

f. Estimated Costs: Total costs for model development have not been estimated at this time. However, such costs would be relatively small.

g. Other Considerations: Until there is a serious interest by action agencies, as well as scientists, in the conduct of this action, it will not be possible to fully assess its various implications.

4. Reform Institutions to Improve River System Management

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a. Description: According to Douglass North, "Institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, custom, tradition, and codes of conduct), and formal rules (constitutions, laws, property rights). Throughout history, institutions have been devised by human beings to create order and reduce uncertainty in exchange."

By this definition, a large number of institutions and institutional arrangements influence the management of the Snake-Columbia River system. Among the most far-reaching of the government/public sector institutions are (1) the Northwest Power Planning Council (officially the Pacific Northwest Electric Power and Conservation Planning Council) and its authorizing legislation, the PNW Electric Power Planning and Conservation Act—P.L. 96-501, (2) the U.S. Army Corp of Engineers, (3) the Bonneville Power Administration, (4) the National Marine Fisheries Service, (5) the state governments of Oregon, Washington, and Idaho, and (6) Congressional delegations of each of the PNW states. Beyond these, numerous local government units and port districts also play roles or have interests in river system management. In addition, use and control of the river system is influenced by rules, treaties, customs,

private property rights, and a myriad of informal arrangements.

It may well be possible to reform existing institutions in order to create a new institutional arrangement which can significantly improve management and decision-making related to the River System. Institutional reform and institution building are complex, difficult tasks. The recently concluded Salmon Summit was, in effect, an institutional reform effort that met with minimal success.

It has been argued (Buchanan et al., 19) that institutions are created or become instruments of rent seekers. The ability to acquire rents under such arrangements suggests that these groups also have the power to retain rents by resisting significant institutional reforms. In matters as contentious and as far reaching as management of the river system, affecting real institutional change will require a realization on the part of all affected parties that institutional rigidity is impeding socio-environmental-economic progress.

b. Time Frame: Institution building and institutional reform are inherently long-term undertakings. Thus, such a solution should be thought of as multi-year in nature.

c. Anticipated Effects: It is impossible to specifically assess the effects of institutional reform on the multiple use of river system resources unless the specific nature of institutional reform is also identified. It would be expected, however, that decision-making and management of the full system should be improved.

d. Likelihood of Success: Institutional reform cannot, by itself, improve the prospects for salmon survival and recovery. Institutional reform is more a part of the implementation phase of recovery rather than a solution in and of itself. However, if institutions are not adjusted, other solutions are unlikely to succeed.

e. Estimated Costs: Unknown.

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IV. CONCLUDING COMMENTS AND PERSPECTIVES

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In conclusion, it should again be pointed out that, while reasonably comprehensive, the set of potential recovery actions is not complete. With passage of time new alternatives will undoubtedly be developed.

The preceding discussion of alternative actions for restoring and maintaining salmonid populations in the Columbia River system points out several things: First, there is no one single action which, if implemented, will by itself accomplish the desired goal of increasing salmon populations. An eventual recovery plan will be a potentially very complex set of actions to be implemented simultaneously. Second, much remains unknown with respect to the biological, economic, and other effects of many of the potential actions. Third, the costs vary greatly from one action to another and with respect to groups affected.

All this leads to the inevitable conclusion that different interest groups will continue to propose some actions while opposing others. Due to different interests, differing interpretation of facts and lack of certain knowledge on numerous issues, decisions regarding implementation of recovery plans will not be made only on the basis of biological, economic, and other technical considerations. Political and legal processes will also be important.

It is important to emphasize again that the recovery actions herein described and evaluated cannot simply

be added up to arrive at a recovery plan. As presented here, they are treated in terms of their individual effects, costs, and implications. An examination of the potential interaction, complementarity, or conflict between these measures is beyond the scope of this analysis. However, a fully developed plan must consider the interrelatedness of individual remedies.

Given the considerable knowledge gaps and the complexity of the multi-purpose river system, managers, agencies, and the general public should recognize from the outset that implementation of any one action or a recovery plan (composed of several actions) must be viewed as tentative. Implementation of actions must be planned to allow for revisions as new information becomes available.

Finally, petitioning for listing of several salmon species under the ESA has awakened strong public consciousness regarding the management of the multi-purpose river resource. This concern, coupled with the desire of the public for being heard in the decision processes, is likely to increase over the next several years whether or not the salmon are listed as threatened or endangered. New challenges face the private, public, and political institutions throughout the Pacific Northwest and the nation as a result of public concerns now expressed through the vehicle of the ESA. New opportunities for the resolution of these issues through cooperative efforts must be sought.

APPENDIX A. ALTERNATIVE ACTION SUMMARY TABLE¹

Actions	Implementation Time Frame	Anticipated Effects on:						Likelihood of Success	Estimated Costs	
		Salmon			Energy	Irrigation	Navigation			Recreation*
		Commercial	Sports	Gen. Divers						
Fish Propagation										
1. Cryopreservatoin of sperm	Begin immediately; complete in 5-10 yrs.	0	0	+	0	0	0	0	High	Low
2. Reduce juvenile mortality	Begin immediately	+	+	+	0	0	0	0	High	High
3. Manage wild and hatchery fish separately	Begin within one year	0	0	+	0	0	0	0	High	Modest
4. Improve forestry and mining practices	Begin immediately; results long-term	+	+	+	0	0	0	+	High	High
5. Improve hatchery management	Begin immediately	+	+	+	0	0	0	0	High	Modest
6. Improve riparian habitat	Begin immediately; results long-term	+	+	+	0	0	0	+	High	Modest
7. Reducing hatchery output	Begin immediately	-	-	+	0	0	0	0	High	Modest
8. Release wild stock	Begin immediately	+	+	+	0	0	0	0	High	Modest
Fish Migration										
1. Columbia River by-pass channel	5-10 years	+	+	+	0	0	0	0	High?	High
2. Additional water storage	10+ years	+	+	+	0	0	0	+	Moderate?	High
3. More by-pass facilities	2-5 years	+	+	+	0	0	0	0	Moderate	Moderate
4. Increase irrigation efficiency	3-15 years	+	+	+	+	-	0	0	Medium	High**
5. Drafting lower Snake River pools	Immediately/ several years	+	+	+	-	-	-	-	Unknown	High
6. Improve screens at dams and diversions	1+ years	+	+	+	0	0	0	0	High	Not estimated
7. Fuel switching	20 years	+	+	+	-	0	0	+	Moderate	High

- * = other than salmon sport fishing
- + = positive or probably positive effect
- = negative or probably negative effect
- 0 = no effect or no direct or appreciable effect
- ? = unknown or questionable
- ** = high to irrigators

¹ Assistance by Diana Burton in the preparation of this summary table is gratefully acknowledged.

Appendix A: Alternative Action Summary Table (continued)

Actions	Implementation Time Frame	Anticipated Effects on:						Likelihood of Success	Estimated Costs	
		Salmon			Energy	Irrigation	Navigation			Recreation*
		Commercial	Sports	Gen. Divers						
Fish Migration (continued)										
8. Power exchanges	Years	+	+	+	+	0/-	0	0	Unknown	Not estimated
9. Juvenile fish transport	Immediately	+	+	+	0	0	+	0	Medium	Unknown
10. Modify flood control curves for greater water storage	Immediately/several years	+	+	+	-	-	-	-	Unknown	Low/moderate
11. Predations	Immediately/several years	+	+	+	0	0	0	0	Moderate	Not estimated
12. Purchase/lease water rights from private parties	3-5 years	+	+	+	+	0/+	0	0	Moderate	Moderate?
13. Obtain water from Snake River water bank	Immediately	+	+	+	+	0/+	0	0	Moderate	Low
14. Reduce winter generation of electricity	2-3 years	+	+	+	-	0	0	0	Moderate	High
15. River pulsing	Immediately	0	0	0	0	0	0	0	Low	Low
16. Timing water budget release	Immediately	+	+	+	-	0	0/-	?	High	Unknown
Fish Harvest										
1. Eliminate gillnets	Immediately	-	-	+/?	0	0	0	0	High?	High
2. Reduce ocean harvest of salmonids	Immediately/years	-	+	+/?	0	0	0	0	Moderate	High
3. Reduce ocean harvests of salmonids and related species	1 year	-	-	+	0	0	0	-	Moderate	Not estimated
Institutional Issues										
1. Change water use laws	Years	+	+	+	+	+/?	0	+	Low	Not estimated
2. Develop monitoring program	Immediately	+	+	+	+	+	+	+	High	Medium
3. Modelling river systems	2-3 years	+	+	+	+	+	+	+	Moderate	Low
4. Improve river system management	Years	+	+	+	+	+	+	+	Unknown	Not estimated

- * = other than salmon sport fishing
- + = positive or probably positive effect
- = negative or probably negative effect
- 0 = no effect or no direct or appreciable effect
- ? = unknown or questionable

APPENDIX B. GLOSSARY

acre-foot: Unit of volume measurement used to describe a quantity of water stored in a reservoir. One acre-foot of water is equivalent to 1 acre of area, 1 foot deep.

adipose fin clip:** A fin clip is a marker (tag) placed on the fin of a hatchery fish for identification to distinguish it from wild fish. The fish do not have to be sacrificed in order to retrieve information (unlike the coded-wire tag). A fin clip placed on the adipose fin of a fish is called an adipose fin clip. This type of fin clip causes less fish mortality than other types of fin clips.

alevin: Newly hatched salmon or steelhead with the yolk sac still attached.

anadromous fish: Fish such as salmon or steelhead that hatch in fresh water, migrate to the ocean where they mature, and then return to fresh water to spawn.

best management practice (BMP)*: A practice or combination of practices [or a measure] determined [by an agency] to be the most effective and practicable means of preventing or reducing the amount of pollution generated by nonpoint sources. May include structural or nonstructural controls and operation and maintenance procedures.

BKD (bacterial kidney disease): As the name implies, this disease affects the kidneys of fishes, including most species of salmonids. It is caused by a bacterium, *Renibacterium salmonarium*, and in the Columbia system this disease causes mortalities among juvenile chinook during their migration to the ocean.

barrier: A physical block or impediment to the movement or migration of fish, such as a waterfall (natural barrier) or a dam (man-made barrier).

brood stock: Adult fish used to produce the subsequent generation of hatchery fish.

bypass system: A channel or conduit associated with a dam or other barrier to migration, such as an irrigation diversion, designed to route juvenile fish around the dam's turbines or the barrier.

carrying capacity: The number of individuals of one species of a specified quality that a habitat can sustain.

cfs (cubic feet per second): A volumetric flow measurement.

coded-wire tag: A small (0.25 mm diameter x 1mm length) wire etched with a distinctive binary code and implanted in the snout of a salmon or steelhead, which, when retrieved, allows for the identification of the origin of the fish bearing the tag.

collection facility: Generally refers to mainstem Snake and Columbia dam facilities that intercept and collect migrating juvenile salmon and steelhead for transportation to the mouth of the Columbia River via truck or barge. Collection facilities are located at Lower Granite, Little Goose, and McNary dams.

drip irrigation:** Irrigation water is applied directly to the root zone of perennial crops through a permanent system that releases small amounts directly to the root zone.

endangered species: A stock of population in danger of becoming extinct because (1) runs are consistently decreasing with higher return rates not expected; (2) all essential habitat needed by any life stage is destined to become unavailable or it is no longer available and has been degraded to the point that returns are consistently less than needed to replace the parent stock; and (3) a persistent downward trend in abundance is evident in all indices, and spawning escapements are only a small fraction of former levels.

escapement: The number of adult fish returning to a particular point that have "escaped" natural mortality and harvest. Spawning escapement refers to the adults that return to an area for purposes of spawning (this might include pre-spawner mortality; therefore, not all of the spawning escapement may survive to spawn).

estuary: The part of a river's mouth where river water, current, and aquatic life are met and influenced by salt water and ocean tides.

fingerling: A young fish from the time of yolk-sac absorption to 1 year of age, approximately 1 to 3 inches long (roughly the length of a finger)

fishery: A term used to describe a season set for the purpose of taking or catching fish, either by a specific area (Area 2-S fishery), during a specific time of the year (Zone 6 winter fishery), or for a specific target species (lower river spring chinook fishery). A fishery may be for commercial purposes, sport (or recreational) purposes, for experimental purposes, or for ceremonial and subsistence use. Also a specific group of fishers.

fish ladder: A system for facilitating passage of upstream migrating fish over a natural or artificial barrier. A fish ladder usually consists of a series of resting pools separated by low obstructions easily passable for fish.

flood irrigation:** irrigation water applied to crops via siphon hoses from a ditch at high end of field with water reaching the entire field by gravity flow.

fry: Young fish from the time they hatch until the time they reach 1 inch long.

gene: The chemical unit of hereditary information that can be passed on from generation to generation.

genetic diversity: The range of genetic resources among individuals in a population or among populations in an ecosystem.

genetic integrity: The ability of a breeding population to remain adapted to its native environment without genetic changes caused by human intervention.

genotype: The entire genetic constitution (collection of genes) of an organism.

gill-net fishery: Any fishery where the gear is limited to the use of gill nets only. A gill net is designed to catch a fish by allowing it to insert its head into the net mesh far enough that the mesh will slip over the gill "flaps" or opercles. When the fish tries to extricate itself from the net, the mesh catches in the fish's gill cavity and the fish becomes "gilled." Gill nets come in different mesh sizes, may be designed to fish from the surface down to the depth of the mesh panel, from the bottom up to the height of the mesh panel,

set in one fixed spot, or drifting free with the current. The gill-net fisheries consist of the non-treaty commercial fishery below Bonneville Dam and the treaty Indian fishery from Bonneville Dam upstream to McNary Dam.

habitat: The locality or external environment in which a plant or animal normally lives and grows.

harvest: The act of taking or catching fish in a fishery set for that purpose. Usually used to denote a fishery where the fish are killed.

hatchery stock: A stock of fish that is sustained by artificial production. For example, brood stock is collected at a hatchery rack and spawned; progeny are reared and released at the hatchery rack site. Some of these return as adults and are collected as brood stock to continue the artificial production cycle.

homing: The ability of salmon or steelhead to correctly identify and return to their natural stream (or the area upon which they have imprinted) following maturation at sea.

hybrid: An offspring of two fish of different stocks or species.

imprinting: In salmon and steelhead, refers to the fixation of fish on the smell or taste in water at a particular location, which is then recognized as their natal area. This acquired learning is coupled with an innate tendency to return to their natal area following maturation at sea.

indigenous: Native; having originated and living in a particular region or environment.

irrigation district:** A special district local government unit with responsibility for delivering irrigation water to farms in a given geographic area.

irrigation diversion: Generally, a ditch or channel that deflects water from the stream channel for irrigation purposes.

juvenile: In this document, refers to a young fish generally from 1 year of age until sexually mature.

mainstem: The main channel of a river into which smaller streams flow. In this document, mainstem usually refers to the Columbia and Snake Rivers.

minimum streamflow: Refers to the minimum amount of water flow needed in a stream for a particular activity or species. Minimum streamflow for fish spawning may be very different than minimum streamflow needed for whitewater boating.

mitigation: The act of alleviating or making less severe. In this document, generally refers to efforts to alleviate the impacts of hydropower development to the Columbia Basin's salmon and steelhead runs.

mortality: Refers to the number of fish lost or the rate of loss.

natural stocks: Fish originally released from hatcheries, but allowed to reproduced naturally as adults in rivers and streams.

nonpoint pollution source (surface water)*: A source of surface water pollution that is diffuse and intermittent and related to land surface disturbing activities such as mining, grazing, crop production, or forest practices. Nonpoint sources of pollution are generally geographic areas yielding pollutants to surface water in contrast to point sources that have identifiable points of entrance to surface waters.

non-treaty fishery (or harvest): Also called non-Indian fisheries. All fisheries subject to United States or state jurisdiction except those open only to members of federally recognized American Indian tribes.

Pacific Salmon Treaty: A treaty signed by the United States and Canada in 1984 (ratified by Congress in 1985) that governs the harvest of certain salmon stocks in the commercial fisheries of Alaska, Canada, and the western continental United States.

phenotype: The sum total of the observable or measurable characteristics of an organism produced by its genotype interacting with the environment.

PIT (passive inductive transponder) tag: A computer chip attached to a wire antennae, encapsulated in glass and injected into a fish. Allows individual fish to be identified when the tag is "read" electronically as fish pass detectors. The fish does not have to be sacrificed to retrieve information, unlike coded-wire tags.

predator: An animal that consumes other animals (as opposed to plants).

raceway: A concrete, rectangular fish-rearing unit generally associated with a hatchery.

riparian: Refers to the area directly along the banks of a stream.

riparian habitat*: Relating to or living or located on the bank of a natural watercourse. The zone of stream vegetation between the water's edge and the start of upland plants such as sagebrush, grass, or forest. Typical riparian vegetation includes willows, cottonwoods, and wild rose at lower elevations and aspen and alder at higher elevations.

redd: A depression in the gravel of a riverbed formed by spawning salmon and steelhead and where they deposit and fertilize their eggs.

rule curve: A graphic guide to the use of stored reservoir water. Developed to define certain operating rights, entitlements, obligations, and limitations for each reservoir.

salmonid: A member of the Salmonidae family, which includes salmon, trout, char, and whitefish.

smolt: A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes (smoltification).

spawn: The act of fish releasing and fertilizing eggs.

species: A group of individuals of common ancestry that closely resemble each other structurally and physiologically and that can interbreed, producing fertile offspring.

spillway: The channel and or passageway around or over a dam through which excess water is released or "spilled" without going through the turbines. A spillway is a safety valve for a dam and must be capable of discharging major floods without damaging the dam, while maintaining the reservoir level below some predetermined maximum level.

storage: The volume of water in a reservoir at a given time.

stock: A population of fish that spawns in a particular stream during a particular season. Such fish generally do not breed with fish spawning in a different stream or at a different time.

transportation [fish]: Generally refers to collecting migrating juvenile salmon and steelhead at collection facilities and transporting them in trucks or barges around the mainstem dams.

threatened species: A stock or species that would be threatened with extinction when (1) barely more than one adult is being produced per spawner; and (2) the production rate has been consistently decreasing with no improvement expected under existing conditions; and (3) the return per spawner of barely more than one-to-one is a reduction from former years and has occurred with optimum or smaller than optimum numbers of spawners.

troll fishery: A type of commercial salmon fishery taking place in marine waters where gear is limited to multiple lures or baits trolled behind the boat, attached to lines suspended from long poles or outriggers.

turbine: A mechanism in a dam that rotates with the force of water and produces electricity.

water budget: A provision in the Columbia River Basin Fish and Wildlife Program that calls for increasing Columbia and Snake River flows during the spring fish migration with the intent of increasing downstream survival of migrating juvenile salmon and steelhead.

water rights:** The right to use water granted by the state. State laws use the procedure that gives highest priority to rights that are senior in time. In other words, "first in time, first in right."

watershed: An area from which water ultimately drains to a particular river or body of water.

wild stocks: Genetically unique populations of fish that have maintained reproductive success without supplementation from hatcheries.

SOURCES: Unless otherwise specified, adapted from the Integrated System Plan, June 1, 1991, Northwest Power Planning Council.

* Adapted from Turner, A.C. and J. O'Laughlin, "State Agency Roles in Idaho Water Quality Policy," Report No.5, Idaho Forest, Wildlife, and Range Policy Analysis Group, University of Idaho, Moscow, ID, (1991).

** Other sources

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