PNL-8172

DE92 019508

**NATIVE AMERICAN FISHERY ISSUES:
HANFORD INVOLVEMENT IN EVALUATION
OF THE ZONE 6 FISHERY**

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July 1992

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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ABSTRACT

Native American fishers are concerned about the deteriorating quality of salmon and other fish caught from the Columbia River. They fear salmon are not healthy and that eating the fish could jeopardize the health of Native Americans. This fear is compounded because they rely heavily on aquatic food sources for both commercial and personal use.

In 1991, the Pacific Northwest Laboratory (PNL), with the assistance of the Yakima Indian Nation (YIN), monitored the salmon and steelhead fishery in the lower Columbia River (Zone 6 fishery). PNL biologists set up a "hot-line" for Native American fishers to call if they caught fish they suspected were diseased or contaminated. Fish reported to the hot-line were examined by a fish disease pathologist.

Only 3 of 80,700 salmon and steelhead caught during the Zone 6 fishery were reported to the hot-line. One of the two steelhead reported was infected with *Henneguya salminicola*, a myxosporidian parasite that affects appearance but is not harmful to humans. Failure to migrate caused the poor condition of the other steelhead, and it was not examined by the pathologist. The only salmon reported had contusions in the caudal peduncle but was not infected with parasites or bacteria.

Additionally, PNL and YIN staff reviewed water-quality data of the lower Columbia River. Water-quality data collected from 1949 through 1990 showed that 1) water temperature during August and September has steadily increased over the last 40 years; 2) flows are lower now than in the past; and 3) turbidity varies, but is generally lower now than in the past.

Chemical data for the Columbia River water has changed very little. Contamination from human activities (industrial, municipal, agricultural) has been detected in flesh samples from some fish caught from the Columbia River; however, the levels were not detrimental to fish health or to humans consuming the fish.

SUMMARY

The purpose of this study was to address Native American fishery concerns that the quality of habitat in the Columbia River has deteriorated and that many of the fish caught in the Zone 6 fishery (Columbia River from McNary Dam to Bonneville Dam) were contaminated and not fit to sell or eat. A tribal student working at the Hanford Site during August and September of 1991 provided assistance. PNL posted flyers describing the study, established a hot-line for fishers to call when they caught fish they suspected were diseased or contaminated, and made arrangements with a pathologist to examine the fish. PNL also reviewed water-quality data pertaining to the Zone 6 fishery and compiled a bibliography based on abstracts of research articles and annual reports involving environmental studies on the Hanford Site. We intend to provide the listed publications to the Yakima Indian Nation library.

Our survey of the Zone 6 fishery during 1991 indicated that either the hot-line was not an effective means of data collection for this study or that very few salmon *Oncorhynchus* spp. and steelhead *O. mykiss* were diseased, deformed, or unsuitable for sale or human consumption. Only 3 of about 80,700 fish caught in the Zone 6 fishery during the duration of our study were reported to the hot-line.

The most likely connection between fish health and water quality appears to be water temperature. We compared water-quality parameters measured by the U.S. Army Corps of Engineers at Bonneville Dam during the months of August and September. This interval best represents water conditions during the Zone 6 fishing season. Temperature, flow, and turbidity data show how basic physical parameters of the Columbia River have changed over the last 40 years. Water temperatures in August and September at Bonneville Dam have steadily increased. During 1949 and 1950, water temperature in August and September averaged 19.7 and 18.9°C, respectively (67.5 and 66.0°F). For the years 1988 through 1990, the average temperature increased to 21.4°C (70.6°F) in August and 20.3°C (68.5°F) in September.

River flows at Bonneville Dam also changed dramatically between 1949 and 1990. Before dams were added throughout the mid-Columbia River Basin, river flow was uncontrolled except for storage behind Grand Coulee Dam, located some

500 miles upstream. As more dams were added, flows at Bonneville Dam shifted from a steadily declining slope during August and September to a relatively steady flow with a weekly peaks, a cyclical pattern resulting from the production of electricity. Overall, less water now passes over and through Bonneville Dam during the months of August and September than in the past. Lower flow rates contribute to elevated water temperature because the water receives solar insolation for a longer period.

Water turbidity at Bonneville Dam during the months of August and September is highly variable from year to year. Generally, turbidity at Bonneville Dam is lower now (increased visibility) than in 1950. Two main factors affecting turbidity are suspended solids (silt) and aquatic plants (phytoplankton). Although measurements did not differentiate between these sources, the change in visibility is probably due to a smaller suspended-solids load in the lower Columbia River because of flood control provided by dams, as well as to settling of sediments in reservoirs behind dams. The STORET database records of phytoplankton production were not sufficient to evaluate long-term trends.

Most water-quality data for the Columbia River that we reviewed were for basic water chemistry. Samples for contaminants (industrial, municipal, agricultural or other point sources) were not included in routine sampling. During the months of August and September, none of the parameters in the database appeared detrimental to the health of fish or humans that consume fish.

In a survey to monitor polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) in muscle tissue from sport fish, the Washington State Department of Ecology found higher levels of TCDF in fall chinook salmon caught in the mid-Columbia River than in spring chinook salmon returning to the Leavenworth Hatchery in Leavenworth, Washington. The difference was attributed to differences in migration patterns. Levels of TCDF were also higher in fall chinook salmon returning to the Priest Rapids Hatchery at Priest Rapids Dam, Washington, than in fall chinook sampled at the mouth of the Columbia River. Additionally, white sturgeon and carp from Lake Wallula had elevated levels of PCDFs. However, the researchers concluded that

eating Columbia River fish did not pose a significant human health risk based on present consumption patterns.

Our study of the Zone 6 fishery should continue in 1992. A Native American student working at Hanford is essential for establishing a communication link between the Hanford and tribal communities. The hot-line should be reestablished in 1992, and its efficacy evaluated. Fish brokers involved with the Zone 6 fish should be specifically targeted for input to monitor the quality of Zone 6 fish. Publicity about our research should begin in June and July to ensure that tribal fishers and fish brokers are aware of our studies early enough to provide input. We should also expand our monitoring and observation efforts to gain more hands-on experience with the fishery. Arrangements to accompany fishers should be completed before August.

Pathological examination of fish reported as diseased, deformed, or unusable for human consumption should continue. Additionally, reported fish should be sampled for radionuclide and organic pollutant contamination. Since the review of the water-quality data does not indicate any correlation between chemical or radiological pollution and fish health, and because of the limited quantity of data, this uncertainty remains a concern of the Zone 6 fishers. Point and non-point sources of potential pollution in Zone 6 should be identified and reported to the Yakima Indian Nation. This information would complement tissue-sample analyses.

Fish reported through the hot-line showing obvious external symptoms should be documented by photograph and compiled into a brochure that could be distributed to Zone 6 fishers. Brief written descriptions of fish diseases, parasitic infections, and other factors non-threatening to consumers would benefit the fishers.

ACKNOWLEDGMENTS

The involvement and cooperation of many people are greatly appreciated. Robert Tuck, ECO-Northwest, arranged initial contact with tribal fishers. Elmer Schuster, Lynn Hatcher, and Tom Scribner, Yakima Indian Nation, provided support in recruiting Greg Strom to assist in this study. Steve Parker and Bill Bosch, Yakima Indian Nation, provided information on fishing seasons and harvest data. Stuart McKenzie, U.S. Geological Survey, provided water quality data. Steven Leek, Lower Columbia River Fish Health Center, United States Department of Interior, Fish and Wildlife Service, conducted the pathological analyses. Don Watson, Pacific Northwest Laboratory, provided access to his personal library of fish-passage reports. Robert Gray and Dennis Dauble were peer reviewers, and Don Hanley edited the report.

Special thanks go out to Alan Snow, King Fish Trading Company, and Henry Jackson, tribal fisher, who called our hot-line and reported problems with fish. Thanks also to the Virgil Lewis family for allowing Greg Strom to monitor and participate in their fishing activities.

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1.0 INTRODUCTION

Early in fiscal year 1991, Pacific Northwest Laboratory (PNL) met with U.S. Department of Energy, Richland Field Office (RL) staff to discuss whether deteriorating fish health and water quality conditions in the lower Columbia River described by Native American fishers could be related to past or present Hanford activities. The RL staff had previously discussed the fishery with Native American fishers, who were catching fish of poor quality and appearance that they could not sell or use. The fishers requested that the U.S. Department of Energy study the water quality of the Columbia River in the Zone 6 fishery (the Native American fishery in the Columbia River between McNary and Bonneville dams). RL asked PNL to initiate a study in which PNL would collect samples of fish to monitor the quality of fish caught in the Zone 6 fishery, with the help and cooperation of the Native American fishers.

1.1 MEETINGS WITH NATIVE AMERICAN FISHERS

To follow up on these requests, PNL fisheries scientists visited with the Native American fishers and discussed their concerns about water quality, fish health, and the potential effects of Hanford operations and other water users upstream of and within the Zone 6 fishery. During November 1990, we met with Chief Johnny Jackson of the Cascade Tribe. In January 1991, we met with the Zone 6 fishers in Toppenish, Washington.

1.1.1 Meeting with Chief Jackson

Dennis Dauble and Duane Neitzel, senior research scientists at PNL, went to Toppenish, Washington on November 2, 1990, to visit with Chief Johnny Jackson of the Cascade Tribe near Bonneville Dam, who has been a fisher on the Columbia River "all his life." Robert Tuck, a consultant for ECO-Northwest, helped us set up this meeting with Chief Jackson.

Chief Jackson is one of many local Native American fishers concerned about the current Columbia River environment and especially anthropogenic activities that affect fish health. During the 1988 fishing season, Chief Jackson took photographs of adult salmon caught from the Columbia River that he claims were too decomposed for sale. He reported the fish to the Columbia

River Inter-Tribal Fish Commission. One of their game wardens and fisheries biologists from the Fisheries Management Division of the Yakima Indian Nation in Toppenish, Washington, examined the fish but was unable to determine the cause of the problem. He told us that many sturgeon and catfish caught by Native American fishers and commercial and sports fishers were in similar condition. Chief Jackson sees these fish as symptomatic of the degrading condition of the Columbia River environment.

Chief Jackson has shown his pictures "all over the country." He stated that Native Americans in the midwest can no longer rely on traditional aquatic food sources, and he does not want that to happen on the Columbia River. Chief Jackson says he wants to know what is happening to his fish and wants things changed. He wants future generations to be able to fish on the Columbia River as he and his ancestors did. He is concerned that the fish that are being caught are not good to eat; if children eat these fish, the contaminants or whatever is causing the fish to be spoiled will affect their health.

We asked Chief Jackson what specifically should be done to determine what is causing fish to spoil. He said the fish have to be "analyzed." We asked him if he would call us in the future to collect spoiled fish, so that we could send them to a laboratory for analysis. He said he would support this. We also asked if he had any person or laboratory in mind to do the analysis. He said he did not. We asked Chief Jackson if there were any other fishermen that we could talk to who had caught fish that were spoiled. He provided me the following list: David Sohapp, Howard Jim, Willard Cloud, and Sally Buck.

1.1.2 Meeting with Zone 6 Fishers

Duane Neitzel and Dennis Dauble met with several fishers in Toppenish on January 28, 1991, to gather additional information regarding their concerns with fish health in the Columbia River system. The group also represented fish buyers who were concerned about the effects of bad fish on the market. We were introduced to Elmer Schuster who ran the meeting for the tribe. We also spoke to Steve Parker and Lynn Hatcher, both tribal biologists for the Yakima Indian Nation. About 20 tribal members attended the meeting.

The fishers were more than willing to talk about problems with the river and its fish. Tribal members were universal in expressing their concern about the fish. Salmon were the main concern, but members also considered other fish they harvest and eat (sturgeon), including incidental catches (walleye). The consensus was that a small but generally consistent number of fish are "contaminated" in some way and that one could tell just by looking at the fish. The list of symptoms included some described before: sores on sides, deformities, deteriorating skin, white cysts in the muscle, fresh fish with soft flesh that separates from the bone, meat that doesn't stay together when you cut it, and back bloodlines that "explode" when you clean the fish. These symptoms were limited to a few fish, but everyone had either seen them or heard about them. The bad fish were usually buried, but one fisher mentioned using them for sturgeon bait. The entire catch might be compromised if they tried to pass them off with the good fish.

The tribal members were fairly knowledgeable about activities that influenced the fisheries runs on the river. They talked about increases in water temperature, effluent input from pulp and paper mills (perceived as a major problem), silt buildup behind the dams because natural flushing during high flows is now restricted, and increased algal growth. Most of these processes point to a general degradation of habitat for anadromous salmonids, particularly in the lower river.

Hanford was listed as one of the Columbia River "polluters." In another association the tribal members seemed to make, they sometimes referred to nuclear pollution and chemical pollution interchangeably. We do not think it was technical error, but rather a common use of words.

We interviewed fishers from several areas including the lower Columbia River (Lyle, Bingen, Celilo, John Day), lower Yakima River, and the Icicle River. We recorded names from most of them including:

Louis Cloud, Allan Coates, Robert Puyette, Terry Lewis, Melanie Gowdy, Georgia Gowdy, Martinez Charles, Carl Settler, James Hudson, and Mary Gowdy.

1.1.3 Summary of Meetings

Some of the concerns and recommendations passed on by the fishers and Yakima Indian Nation biologists include the following:

- Someone or some agency should identify the sources of pollutants in the rivers (Columbia and Yakima).
- They are interested in how chemicals dumped into the river affect the fish and the people who have been eating the fish; they are particularly concerned about the risk of getting cancer.
- The fishers are very interested in issues influencing their lifestyle. Many individuals follow current issues by reading newspaper articles, watching public television, and attending public meetings. Most are hungry for facts regarding activities impacting their lifestyle (fishing).
- One of the common questions put to us by both the fishers and the YIN biologists was, "When are we going see the results of this study?"

1.1.4 Pacific Northwest Laboratory Study Outline for 1991

As a result of the visits, PNL staff set up a study to try to accomplish objectives presented by the suggestions of the Yakima Indian Nation fishers. The study was designed to include a Native American student as a research assistant for the study. PNL staff arranged through the Northwest Colleges and Universities for Science (NORCUS) program to have a Yakima Indian Nation student work at Hanford during the summer 1991. PNL fisheries scientists and the student achieved the following:

- Set up a telephone hot-line number that fishers could call to report the catch of diseased or spoiled fish.
- Made arrangements to have the fish examined by fisheries pathologists.
- Summarized the harvest data for the 1991 for the Zone 6 fishery to evaluate the incidence of deformed or diseased fish reported to PNL.
- Gathered and summarized water-quality data from other government agencies that have studied Columbia River water quality.
- Reviewed abstracts and bibliographies of water-quality literature available at Hanford that pertain to the Columbia River.

2.0 TRIBAL OUTREACH

Two of the primary goals of this study were to nurture a cooperative working relationship with the Yakima Indian Nation and provide educational opportunities for a Native American student. The NORCUS program arranged for Greg Strom, a student from the Yakima Indian Nation, to study at Hanford. In this study, Mr. Strom established and monitored a "hot-line" that fishers called when they caught diseased or deformed fish. The hot-line was monitored during the lower Columbia River Zone 6 fall fishery with seasons in August and September.

Mr. Strom helped develop and distribute a flyer describing our study; it was mailed to Zone 6 fishers and posted at boat launches and campsites along the Columbia River. Mr. Strom attended a meeting at Celilo Village to inform fishers of our study. He also interviewed fishers during the season and accompanied a fisher as an observer/helper to learn about how fish were handled from the time they were caught until they were delivered to a fish broker.

Native American fishers attending earlier meetings expressed concern that deteriorating water quality in the Columbia River may be affecting the health and migration of salmon, as well as the quality of the product sold to the fish broker. Native Americans were also concerned that they may be at a greater health risk than the general population because of their high per capita fish consumption. Mr. Strom participated in the review and retrieval of historical data (flow, temperature, turbidity, and water chemistry) to evaluate these concerns. In addition, Mr. Strom reviewed abstracts of research articles and annual reports, including reports involving environmental research on the Hanford Site, and he developed a bibliography listing of publications that might be of interest to the Yakima Indian Nation. We intend to provide copies of these publications to their library.

3.0 METHODS

The 1991 study required that we

- set up a communication (hot-line) with the Zone 6 fishers and provide a means of analyzing diseased or deformed fish
- review Columbia River water-quality data
- review Hanford water-quality literature.

3.1 COMMUNICATION WITH ZONE 6 FISHERS

3.1.1 "Hot-Line"

We needed a system that would allow Zone 6 fishers to quickly and easily notify PNL that they had a diseased or spoiled fish. To accomplish this, we contracted with a Kennewick, Washington, answering service to monitor a "1-800" number. All calls to the 1-800 number were recorded, and we checked the records each morning and evening during the Zone 6 fishing season. This system enabled us to collect a fish within 24 hours of the time it was caught and deliver it to the pathologist for examination.

3.1.2 Flyer

Information about our study was disseminated by circulation of a flyer (Figure 3.1) printed on bright pink paper. Flyers posted at boat launches and campsites (Table 3.1) were laminated in plastic to protect them from the weather. Flyers were also mailed to 91 Native American fishers whose addresses were obtained from Steve Parker, Fisheries Resource Management, Yakima Indian Nation.

3.1.3 Disease Analysis

Suspect fish were picked up on the same day we received the call to the hot-line. Fish were placed in a plastic bag, covered with ice, and transported in a cooler to the Lower Columbia River Fish Health Center, United States Department of Interior, Fish and Wildlife Service in Underwood, Washington, for examination.

ATTENTION **REGION 6 FISHERS**

**DID YOU CATCH A FISH THAT IS
SPOILED, DEFORMED, OR
DISEASED?**

**CAN'T SELL IT? CAN'T EAT IT?
WE WANT IT!**

**CALL THE
YAKIMA INDIAN NATION FISH HOT LINE**

1-800-222-2306

The hot line is open 24 hours a day, 7 days a week. If you catch a fish in such poor shape that it cannot be sold or eaten, place the fish in a plastic bag with ice and **CALL THE HOT LINE**. We will contact you and arrange to pick up your fish on the same day, Monday through Friday.

Your help is essential! Your fish are our only source of samples. The fish will be examined to try to determine what is causing the fish to be bad.

This is a cooperative project between the Yakima Indian Nation and the Department of Energy. Greg Strom, a Yakima Valley Community College student from the Yakima Indian Nation, is working with scientists from Battelle-Northwest in this study.

THANK YOU FOR YOUR COOPERATION

FIGURE 3.1. Flyer Mailed to Tribal Fishers and Posted at Boat Launches and Campsites Along the Columbia River During the Zone 5 Fishery

TABLE 3.1. Sites Along the Columbia River Where Flyers Were Posted

<u>Location</u>	<u>Date Posted</u>
Washington Side of Columbia River (Plymouth to Bonneville Dam)	
Wishram Post Office	Aug 7, 1991
Lyle Store and Post Office	Aug 7, 1991
Bingen boat launch	Aug 7, 1991
Cook's Landing	Aug 7, 1991
Home Valley Waterfront Park	Aug 7, 1991
Sail Board Park	Aug 7, 1991
Maryhill State Park	Aug 13, 1991
Cliffs Park	Aug 13, 1991
Sundale Park	Aug 13, 1991
Roosevelt boat launch	Aug 13, 1991
Crow Butte boat launch	Aug 13, 1991
Plymouth boat launch	Aug 13, 1991
Oregon Side of Columbia River (Umatilla to Bonneville Dam)	
Celilo Village	Aug 12, 1991
Celilo State Park boat launch	Aug 12, 1991
Memaloose State Park	Aug 12, 1991
Hood River boat launch	Aug 12, 1991
The Dalles boat launch	Aug 12, 1991
Cascade Locks (Wind Surfer Way)	Aug 12, 1991
Cascade Locks (Scaffolds)	Aug 12, 1991
Umatilla Marina and boat launch	Aug 13, 1991
Port of Morrow State Park	Aug 13, 1991
Arlington Recreation Park boat launch	Aug 13, 1991
John Day Recreation Park boat launch	Aug 13, 1991
Biggs Store	Aug 13, 1991

Our goal was to examine 15 diseased or deformed fish reported to the hot-line by Native American fishers and 15 reference fish collected from hatcheries on the lower Columbia River. Pathological examination included external and internal visual examination, microscopic examination of lesions and cysts, and laboratory tests and tissue cultures required to verify bacterial, viral, or parasitic infection.

3.1.4 Harvest Data

Information about the Zone 6 fishing season and the harvest data were obtained from Steve Parker, Fisheries Resource Management, Yakima Indian Nation. Harvest during the Zone 6 fishery was separated into the August and September seasons set by the Columbia River Compact. Harvest for approved supplemental fishing days occurring after the general September season is reported but was not used in our analysis. Other harvest information was gathered by interviewing tribal fishers and participating as observers during the fishing season.

3.2 REVIEW OF WATER-QUALITY DATA

Tribal members who attended early planning meetings expressed concern over activities that might influence fish runs on the river, including increased water temperature, pollution, silt buildup behind the dams, increased algal growth, and a general degradation of habitat for anadromous fishes, particularly in the lower Columbia River. Most of the information contained in this report was retrieved from databases maintained by various government agencies, or from reports generated from these databases.

3.2.1 Physical Parameters

Fish passage reports, compiled by the U.S. Army Corps of Engineers, and published annually since 1948 represent the best and most complete source of information for physical water-quality parameters in the Columbia River. Since physical parameters are dependent on highly variable annual weather patterns, we selected the last 3 years of each decade to identify long-term changes in water temperature, turbidity, and river flow.

3.2.2 Chemical Parameters

Information from "STORET", a database containing water-quality measurements from throughout the United States and maintained by the United States Department of Interior, U.S. Geological Survey (USGS), was used to review chemical water-quality parameters. Again, we selected the last 3 years of each decade as our reference years to compare long-term changes. The data used were collected at sampling stations on the Columbia River at Warrendale

and Umatilla, Oregon. We also obtained data from the John Day River at McDonald Ferry, Oregon, and the Deschutes River at Moody, near Biggs, Oregon.

3.3 REVIEW OF HANFORD WATER-QUALITY INFORMATION

We reviewed abstracts of reports, including past and present activities at Hanford, and prepared a list of reports pertinent to water-quality concerns and issues raised by the tribal members. A complete review of these reports is beyond the scope of this study; however, copies of the reports identified in this review will be provided to the Yakima Indian Nation's library.

We also reviewed radiological data that report results of analyses of salmon flesh collected from the Columbia River near Hanford.

4.0 RESULTS

4.1 COMMUNICATION WITH ZONE 6 FISHERS

Our harvest data came from William J. Bosch, a biologist with the Harvest Management unit of the Yakima Indian Nation Fisheries Management Division. The same data was used to generate "The 1991 Fall Season Report" (Wana Chinook Tymo 1991) published by the Columbia River Inter-Tribal Fish Commission (CRITFC). The harvest numbers are based on analyses of the Zone 6 fishery through November 19, 1991.

Approximately 160 tribal fishers were registered in the Zone 6 gill net fishery. The fishers used up to 1100 nets during the fishery. A typical fishing crew consisted of three fishers checking about 10 nets.

4.1.1 Hot-Line Response

The Columbia River Compact sets tribal fishing seasons in August and September. Supplemental seasons may be added depending on run size and fishing success. We monitored the hot-line twice each day during the August and September fishing seasons to check for reports of diseased or abnormal fish. Few calls were received during the duration of this study. Three fish were collected as a result of these calls.

August Season

The Columbia River Compact set the Zone 6 commercial fishing season to run from August 12 through 16, and August 20 through 24. A total of 11,441 salmon and steelhead and 183 walleye were caught by Zone 6 fishers in August (Table 4.1).

No diseased or deformed fish were reported by fishers during the August fishing season. However, on August 21, Alan Snow of the King Fish Trading Company (The Dalles, Oregon) called to report that an abnormal steelhead had been brought to their warehouse. The fish had been caught in the Dalles Pool that morning, and we picked the fish up the same evening.

TABLE 4.1. A Summary of Fish Caught in the Zone 6 Fishery, 1991 (Data from William J. Bosch, Harvest Management, Yakima Indian Nation.)

	<u>Salmonid Species</u>			
	Steelhead	Chinook	Coho	Walleye
Aug 12-16	5,279	844	0	138
Aug 20-24	<u>3,837</u>	<u>1,480</u>	<u>1</u>	<u>45</u>
Total by Species:	9,116	2,324	1	183
Total Salmonids:	11,441			
Sep 9-14	13,342	34,784	2,838	159
Sep 16-18	<u>6,270</u>	<u>10,239</u>	<u>1,856</u>	<u>43</u>
Total by Species:	19,612	45,023	4,694	202
Total Salmonids:	69,329			
Sep 30-Oct 2	4,455	3,463	1,153	71
Oct 25-28	<u>3,538</u>	<u>860</u>	<u>1,340</u>	<u>24</u>
Total by Species:	7,993	4,323	2,493	95
Total Salmonids:	14,809			
Final Tally by Species:	36,721	51,670	7,188	480
Grand Total Salmonids:	95,579			

The steelhead was transported to PNL for examination. The fish was 46 centimeters long, weighed 676 grams, and had no fin clips or distinguishing marks. Externally, the fish appeared to be normal except that it was very gaunt. No lesions or signs of disease were visible upon internal examination.

The gut contained several grasshoppers, which indicated the fish was actively feeding before its capture. We concluded that this steelhead had probably taken up residence in the Dalles Pool rather than migrating to the ocean. The fish was not sent to the fish disease lab for examination.

September Season

The Columbia River Compact set the Zone 6 commercial fishing season to run from September 9 through 13, and September 16 through 20. However, the season was later changed to run from September 9 through 14 and September 16 through 18. A total of 69,329 salmon and steelhead and 202 walleye were caught by Zone 6 fishers during September (Table 4.1). Although additional fishing opportunities were established for the periods of September 30 through October 2 and October 25 through October 28, the monitoring phase of our study had ended and the hot-line was not in operation. During these supplemental seasons, tribal fishers caught 14,809 salmon and steelhead and 95 walleye.

Two fish were reported to the hot line in September, both fish on September 20 by the same tribal fisher. The fish (one chinook salmon and one steelhead) were caught by dip net in the Klickitat River near Klickitat Falls. The fish were held on ice through the weekend because they could not be delivered to the disease lab for analysis until September 23. The salmon (Case No. 501129, Appendix A) was a female and was classified as an upriver bright (URB) fall chinook salmon. There were no fin clips or other distinguishing marks. Externally, the fish was normal except for "tail swelling" (contusion). Tests for parasitic, bacterial, and viral infections were all negative.

The steelhead (Case No. 501130, Appendix A.) was a male and had no fin clips or distinguishing marks. Externally, the fish had several white cysts filled with a milky liquid in the tail region. The cysts were identified as *Henneguya salminicola*, a myxosporidian parasite. Steven Leek, a fish pathologist at the Lower Columbia River Fish Health Center, United States Department of Interior, Fish and Wildlife Service in Underwood, Washington, advised that the milky liquid in the cysts contained spores of the organism. Myxosporidian and their spores are not harmful to humans (Piper et al. 1982). Tests for bacterial and viral infections were negative.

4.1.2 Onsite Collection of Harvest Data

On September 17, Greg Strom accompanied a tribal crew as they checked their nets on the Washington side of the Columbia River in The Dalles Pool. Six nets were set at about 1100 hours on September 16. The nets were checked from 0700 to 1245 hours the following day. Cleaning the nets (removing algae)

was the most time-consuming aspect of checking the nets. The fishers caught ten steelhead, five chinook salmon, and two coho salmon *O. kisutch*, or about three fish per net. Although many of the fish had light-colored gills, indicating they had been dead for several hours, none of the fish were considered spoiled or "bad." The fish were packed in ice at 1300 hours and transported to a fish broker.

4.2 REVIEW OF WATER-QUALITY DATA

We compared water-quality parameters measured by the U.S. Army Corps of Engineers at Bonneville Dam during the months of August and September (Annual Fish Passage Reports 1948 to 1990). These data best represent water conditions that occur during the Zone 6 fishery. Temperature, flow, and turbidity data show how basic physical parameters of the Columbia River have changed over the last 40 years. The data seem to correlate with the construction and operation of hydroelectric dams on the Columbia and Snake rivers (Table 4.2).

4.2.1 Temperature Data

Water temperatures in August and September at Bonneville Dam have steadily increased over the last 40 years (Figure 4.1 and Appendix B). For the years 1949 and 1950, the water temperature in August and September averaged 67.5 and 66.0°F, respectively. For the years 1988 through 1990, the average temperature increased to 70.6°F in August and 68.5°F in September.

The construction of additional dams on the Columbia and Snake rivers has contributed to elevated temperatures. Although no dams have been built since 1968 (John Day) on the Columbia River or since 1975 (Lower Granite) on the Snake River (Status Report 1989), temperatures in the lower Columbia River continue to rise.

TABLE 4.2. Completion Dates of Columbia and Snake River Dams (Extracted from Status Report - Columbia River Fish Runs & Fisheries, 1960-88, Oregon Department of Fish & Wildlife and Washington Department of Fisheries, August 1989)

	Dam	Year Completed	Miles to Mouth	Gross Head Feet	Miles of Reservoir
Columbia River	Bonneville	1938	146	59	45
	The Dalles	1957	192	86	31
	John Day	1968	216	105	76
	McNary	1953	292	86	61
	Priest Rapids	1959	397	84	18
	Wanapum	1963	416	80	38
	Rock Island	1933	453	40	21
	Rocky Reach	1961	474	93	42
	Wells	1967	515	72	30
	Chief Joseph	1955	545	175	51
	Grand Coulee	1941	597	343	151
Snake River	Ice Harbor	1961	334	100	32
	Lower Monumental	1969	366	100	29
	Little Goose	1970	395	100	37
	Lower Granite	1975	432	100	39
	Hells Canyon	1967	571	220	22
	Oxbow	1961	597	117	12
	Brownlee	1958	609	272	57

4.2.2 Flow Data

River flows at Bonneville Dam changed dramatically between 1949 and 1990. Before dams were added throughout the mid-Columbia basin, river flow was uncontrolled except for storage behind Grand Coulee Dam, located some 500 miles upstream. As more dams were added, flows at Bonneville Dam shifted from a steadily declining slope during August and September to the flat-lined cyclical pattern associated with production of electricity (Figure 4.2 and Appendix B). Overall, less water passes over and through Bonneville Dam

during the months of August and September than in the past. Lower flow rates contribute to elevated water temperature because the water is subjected to solar energy for a longer period of time.

FIGURE 4.1. Average Temperature at Bonneville Dam During the Months of August and September, 1949 to 1990

4.2.3 Turbidity Data

Based on Secchi disc readings at Bonneville Dam during the months of August and September, turbidity is highly variable year to year. Generally, turbidity measurements at Bonneville Dam are lower now than in 1950 (Figure 4.3 and Appendix B). The two main factors affecting turbidity are suspended solids (silt) and aquatic plants (phytoplankton). Although Secchi disc readings cannot differentiate between these sources, the change in visibility is probably due to a smaller suspended solids load in the lower Columbia River because of flood control provided by dams, and to settling of sediments in reservoirs behind the dams.

FIGURE 4.2. Average Daily Flow (KCFS) at Bonneville Dam Before and After Hydroelectric Development and Impoundment of the Mid-Columbia River (data derived from Annual Fish Passage Reports, U.S. Army Corps of Engineers)

4.2.4 Chemistry Data

Stuart McKenzie, the United States Department of Interior, U.S. Geological Survey, concurred that most of the water-quality data in the STORET database (Appendix C) were measurements of basic water chemistry. Samples for contaminants (industrial, municipal, agricultural, or from other point sources) are not included in routine sampling by USGS. During the months of August and September, none of the parameters listed in the database appeared to be detrimental to the health of fish or humans consuming the fish. The Washington State Department of Ecology conducted a survey of polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) in muscle tissue from sportfish caught in the mid-Columbia River (Serdar et al. 1991). These contaminants are byproducts from pulp mills, and the primary areas of concern in the study were Rufus Woods Lake, above Chief Joseph Dam, Washington, and Lake Wallula (McNary Pool) immediately downstream

of the Boise Cascade pulp mill in Wallula, Washington. Walleye, rainbow trout, and lake whitefish were sampled from Rufus Woods Lake, and largemouth bass, channel catfish, carp, and white sturgeon were sampled from Lake Wallula.

FIGURE 4.3. Secchi Disc Readings at Bonneville Dam Before and After Hydroelectric Development and Impoundment of the Mid-Columbia River (data derived from Annual Fish Passage Reports, U.S. Army Corps of Engineers)

Tissue samples were also taken from adult fall chinook salmon collected at Priest Rapids Dam, Washington, and from adult spring chinook salmon that returned to the Leavenworth National Hatchery in Leavenworth, Washington. Concentrations of 2,3,7,8-TCDF were higher for fall chinook salmon than for spring chinook salmon. The results were attributed to differences in migration patterns. Spring chinook salmon adults only spend a few weeks in the Columbia River before entering the hatchery, while fall chinook salmon may spend 1 to 2 months in the river before arriving at the hatchery.

Levels of 3,4,7,8-TCDF were higher in Priest Rapids fall chinook salmon tissues than in those from salmon sampled at the mouth of the Columbia River; white sturgeon and carp from Lake Wallula also had elevated levels of PCDFs. However, the researchers concluded that eating Columbia River fish did not pose a significant human health risk based on present consumption patterns (Serdar et al. 1991).

4.3 REVIEW OF HANFORD WATER-QUALITY INFORMATION

Greg Strom reviewed summaries of Hanford environmental literature and Annual Hanford Site Environmental Reports. He listed about 150 reports (Appendix D) that should be available to the Yakima Indian Nation at the tribal library in Toppenish, Washington.

Whitefish, bass, and salmon have been collected from the Columbia River at Hanford (Jaquish and Bryce 1989). White fish and bass were analyzed for ^{60}Co , ^{90}Sr , and ^{137}Cs . The bones from some fish were analyzed to estimate ^{90}Sr . Maximum and average results for these analyses are shown in Table 4.3. Muscle samples from spawned out fall chinook salmon were collected at the Priest Rapids Dam, which is upstream of Hanford. Samples from similar salmon were collected at Hanford.

Cobalt-60, ^{90}Sr , and ^{137}Cs were detected in a few whitefish muscle samples collected at Hanford, as well as upstream of Hanford. There were no quantifiable differences between samples from the Hanford and upstream samples. Results for radionuclide analyses of special muscle tissue samples for salmon were similar for Hanford and non-Hanford fish. There has been no measurable influence on fish from radionuclides released to the Columbia River during current or past operations at Hanford.

TABLE 4.3. Radionuclide Concentrations in Columbia River Fish in 1988

Fish/Tissue	Location	Average pCi/g wet weight		
		⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs
Whitefish/ Muscle	Upstream Hanford	0.005	0.001	0.008
Whitefish/ Muscle	At Hanford	0.016	0.001	0.023
Whitefish/ Carcass	Upstream Hanford		0.031	
Whitefish/ Carcass	At Hanford		0.026	
Bass/ Muscle	At Hanford	0.009	0.002	0.053
Bass/ Carcass	At Hanford		0.040	
Salmon/ Muscle	Upstream Hanford	-0.007	0.001	0.023
Salmon/ Muscle	At Hanford	0.002	-0.001	0.017

5.0 DISCUSSION

Based on the small number of calls received, it appears that either the hot-line was not an effective means of data collection for this study or very few salmon and steelhead from the Zone 6 are diseased, deformed, or unsuitable for sale or human consumption. Some factors that may have contributed to the low number of calls include: 1) arrangements to obtain a Native American student through the NORCUS program were delayed, which resulted in late postings and mailing of our hot-line flyers; 2) many of the Native American fishers identified on the mailing list provided by the Yakima Indian Nation may have already left their homes and moved to riverside camps for the August fishery by the time the mailing went out; and 3) in conversations with fishers along the Oregon side of the Columbia River midway through the August season, no fishers acknowledged receiving the flyers, although many had seen the flyers posted at boat launches.

Because of our concern about the lack of response to the hot-line, we attended a meeting at Celilo Village on August 26, 1991. The main purpose of the meeting was to discuss the fishing season options proposed by the Columbia River Compact for the September Zone 6 fishery. About 35-40 tribal fishers were at the meeting. We spoke at the beginning of the meeting and informed the Native American fishers of our study and asked for their cooperation. Flyers were left on the table for anyone who wanted one. Despite the added effort to publicize our study and solicit input, only one fisher called the hot-line during the September season.

Of the 80,700 salmon and steelhead caught during the August and September seasons when our hot-line was operational, only 3 fish (2 steelhead and 1 chinook salmon) were reported to the hot-line. Two of these fish were caught by a subsistence fisher in the Klickitat River using a dip net. The other fish was reported by the King Fish Trading Company, a fish broker in the Dalles, Oregon. Based on official catch statistics, less than 0.0037 percent of salmonids (fewer than 1 out of 25,000) caught during the Zone 6 fishery were diseased, deformed, or rotten.

The scheduling of the fishing seasons may make it difficult for tribal fishers to report diseased fish to a hot-line. Fishing seasons run around the

clock for several consecutive days. Most of the fisher's time appears to be spent setting or checking nets. Travel to and from the fish brokers with the day's harvest can also consume considerable time. Many fishers may not have enough time in the day to report diseased fish and make arrangements for us to pick up the fish for analysis. As long as fish brokers are willing to buy their fish, the fishers have little to gain by reporting bad fish.

Although we wanted to involve tribal fishers directly in the reporting of diseased fish, reliance on fish brokers appears to be a more productive approach. On August 21, 1991, Alan Snow, King Fish Trading Company, The Dalles, Oregon, advised that a small (but consistent) percentage of salmon brought in were "abnormal." Mr. Snow was willing to cooperate if he was compensated for any fish we took for our study.

At the August 26 meeting at Celilo Village, one tribal fisher mentioned that a fish broker in Lyle, Washington, claimed that about 20 percent of fish brought in by tribal fishers were "sour" or spoiled. Spoilage was attributed to fishers not checking their nets often enough and to poor handling of the fish from the time they were removed from the nets until they were delivered to the broker. Warm water temperatures, poorly insulated transport containers, and rough handling were cited as the primary causes of spoiled fish.

The gradual increase in water temperature we observed in our review of the fish passage reports could be the most crucial factor affecting the quality of fish caught in the Zone 6 fishery. The decision to fully use the power-production potential of water flowing down the Columbia River has resulted in lower average daily flows. The warmer, slower-moving water may result in increased algae and phytoplankton production. As sediment deposits build, mud flats are created that support the growth of undesirable rooted aquatic plants. These, and many other factors associated with increased water temperatures and changes in flows, have caused a gradual deterioration of water quality in the Columbia River. However, it is beyond the scope of this study to evaluate in detail how each of these factors might affect fish quality.

6.0 REFERENCES

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APPENDIX A

FISH DISEASE REPORTS

REPORT OF HEALTH EXAMINATION OF FISH

Location: 2000KLIK Date: 09/23/91 Brood Year:
Lot No.: ADULT Species: STT Case: 501129 Container ID:
Exam type: D
Pond. No. or Descr.: KCLICKITAT FALLS
Water Source: KCLICKITAT RIVER
Examiner: STONE, PELTON, NIELSEN

REMARKS

Fish had been caught 3-4 days before being brought to lab. There were no fin clips on the two fish. The STT had white color cysts in tail area. On examination this was Henneguya salminicola (myxosporidian). One STT male and one URFB female.

REMARKS

URB had a caudal contusion. Fish were actually in good condition and were brought in only to check cysts and tail swelling (contusion) Overall condition was good considering they were caught 3 days earlier.

NO RECOMMENDATIONS FOUND FOR CASE # 501129
Tissue records for case=501129

<u>Type of Analysis</u>	<u>Tissue Tested</u>	<u>Comments</u>
B	KD	TSA - Negative
V	VS	2 Cell lines - negative
B	KD	DFAT - negative

NO DISEASE DATA FOUND FOR CASE=501129

REPORT OF HEALTH EXAMINATION OF FISH

Location: 2000KLIK Date: 09/23/91 Brood Year:
Lot No.: ADULT Species: STT Case: 501130 Container ID:
Exam type: D
Pond. No. or Descr.: KCLICKITAT FALLS
Water Source: KCLICKITAT RIVER
Examiner: STONE, PELTON, NIELSEN

REMARKS

Nice steelhead brought in with URB for examination. Net-caught STT had caudal cysts which contained myxosporidian, Henneguya. Otherwise, fish was in good condition except for 3-4 days on ice before received in lab.

REMARKS

Hold on ice for good examination

NO RECOMMENDATIONS FOUND FOR CASE # 501130
Tissue records for case=501130

<u>Type of Analysis</u>	<u>Tissue Tested</u>	<u>Comments</u>
B	KD	Negative
P	MS	<u>Henneguya</u> cysts
V	VS	Negative on epcand CHSE 214

Disease records for case=501130

<u>Disease</u>	<u>Incidence Percent</u>	<u>Incidence (L.M.H)</u>	<u>Comments</u>
	0.0	L	No real harm

APPENDIX B

PHYSICAL WATER-QUALITY PARAMETERS AT BONNEVILLE DAM DURING THE ZONE 6 FISHERY

APPENDIX B

PHYSICAL WATER-QUALITY PARAMETERS AT BONNEVILLE DAM DURING THE ZONE 6 FISHERY

This appendix contains data extracted from annual fish passage reports published by the U.S. Army Corps of Engineers. Temperature, average daily flow, and turbidity measurements have been recorded since 1949. Records for the months of August and September (the time period in which the Zone 6 fishery occurs) for 3 years of each decade were selected to document gradual changes occurring in the Columbia River as dams were added throughout the Columbia and Snake river basins.

TABLE B.1. Physical Water-Quality Parameters at Bonneville Dam During August 1949 (Extracted from 1949 Annual Report - Passage of Fish Over Bonneville Dam, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	65.0	161.0	5.0
Aug 02	65.0	161.0	5.0
Aug 03	65.0	156.0	5.0
Aug 04	65.0	153.0	4.5
Aug 05	65.5	153.0	5.0
Aug 06	70.0	150.0	4.8
Aug 07	70.5	148.0	4.5
Aug 08	70.0	148.0	4.5
Aug 09	70.5	148.0	4.5
Aug 10	70.5	145.0	4.5
Aug 11	70.0	150.0	4.0
Aug 12	67.0	145.0	4.0
Aug 13	67.0	138.0	4.2
Aug 14	67.0	133.0	4.4
Aug 15	67.0	133.0	4.5
Aug 16	67.0	133.0	4.5
Aug 17	67.0	131.0	4.5
Aug 18	67.0	131.0	5.0
Aug 19	66.5	134.0	5.0
Aug 20	67.0	125.0	5.0
Aug 21	67.0	114.0	5.0
Aug 22	67.0	114.0	5.0
Aug 23	67.0	114.0	5.0
Aug 24	67.0	121.0	5.0
Aug 25	67.0	112.0	5.0
Aug 26	67.0	107.0	5.3
Aug 27	67.0	102.0	5.0
Aug 28	67.0	104.0	5.1
Aug 29	67.0	109.0	5.3
Aug 30	67.0	107.0	5.0
Aug 31	67.5	107.0	5.0
Average	67.3	131.8	4.8

TABLE B.2. Physical Water-Quality Parameters at Bonneville Dam During September 1949 (Extracted from 1949 Annual Report - Passage of Fish Over Bonneville Dam, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	67.0	104.0	5.0
Sep 02	67.5	107.0	5.6
Sep 03	68.0	102.0	5.6
Sep 04	68.5	97.0	5.5
Sep 05	68.5	97.0	5.5
Sep 06	69.0	100.0	4.5
Sep 07	70.0	102.0	5.0
Sep 08	70.0	100.0	5.0
Sep 09	70.0	100.0	5.0
Sep 10	70.0	100.0	5.0
Sep 11	69.0	102.0	5.0
Sep 12	69.0	100.0	5.0
Sep 13	69.0	97.0	5.0
Sep 14	66.0	100.0	5.6
Sep 15	66.0	100.0	4.5
Sep 16	65.0	95.0	4.2
Sep 17	64.0	97.0	5.0
Sep 18	64.0	97.0	4.5
Sep 19	64.0	102.0	4.5
Sep 20	62.0	102.0	4.5
Sep 21	62.0	102.0	4.5
Sep 22	61.0	100.0	4.5
Sep 23	61.0	100.0	4.5
Sep 24	62.0	97.0	4.5
Sep 25	62.0	95.0	4.5
Sep 26	62.0	93.0	5.5
Sep 27	62.0	90.0	3.5
Sep 28	61.0	88.0	3.5
Sep 29	63.0	90.0	3.5
Sep 30	63.0	88.0	4.0
Average	65.5	98.1	4.7

TABLE B.3. Physical Water-Quality Parameters at Bonneville Dam During August 1950 (Extracted from 1950 Annual Report - Passage of Fish Over Bonneville Dam, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCES)</u>	<u>Secchi Disc (ft)</u>
Aug 01	65.0	289.7	3.5
Aug 02	65.0	281.8	3.2
Aug 03	65.0	274.5	3.2
Aug 04	65.0	263.7	3.3
Aug 05	66.0	263.1	3.3
Aug 06	66.0	247.0	3.4
Aug 07	66.0	243.5	3.4
Aug 08	66.0	240.0	3.3
Aug 09	66.0	233.3	3.4
Aug 10	66.0	226.4	3.4
Aug 11	66.0	216.2	3.6
Aug 12	66.0	213.1	3.6
Aug 13	67.0	197.0	4.4
Aug 14	67.0	172.6	4.4
Aug 15	67.0	166.5	4.4
Aug 16	67.0	164.0	4.4
Aug 17	68.0	166.5	4.4
Aug 18	69.0	169.0	4.4
Aug 19	69.0	157.8	4.4
Aug 20	69.0	157.6	4.2
Aug 21	70.0	157.6	4.3
Aug 22	70.0	166.5	4.2
Aug 23	71.0	167.0	4.2
Aug 24	69.0	164.1	4.2
Aug 25	69.0	165.3	4.2
Aug 26	70.0	156.3	4.4
Aug 27	70.0	162.4	4.5
Aug 28	70.0	165.3	4.5
Aug 29	69.0	158.2	4.3
Aug 30	68.5	155.7	4.3
Aug 31	69.0	157.2	4.3
Average	67.6	197.4	4.0

TABLE B.4. Physical Water-Quality Parameters at Bonneville Dam During September 1950 (Extracted from 1950 Annual Report - Passage of Fish Over Bonneville Dam, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	69.0	161.7	4.5
Sep 02	69.0	148.9	4.8
Sep 03	69.0	154.7	4.5
Sep 04	69.0	166.2	4.5
Sep 05	69.0	160.2	4.5
Sep 06	69.0	160.2	4.5
Sep 07	69.0	157.3	4.5
Sep 08	69.0	143.1	4.5
Sep 09	69.0	126.9	4.5
Sep 10	68.0	132.2	5.0
Sep 11	68.0	119.1	4.5
Sep 12	67.0	116.5	5.0
Sep 13	67.0	119.0	5.3
Sep 14	67.0	124.0	5.0
Sep 15	66.0	121.4	4.5
Sep 16	66.0	116.7	4.5
Sep 17	66.0	111.7	4.5
Sep 18	66.0	111.7	4.5
Sep 19	65.5	119.2	4.5
Sep 20	65.5	109.2	4.5
Sep 21	65.5	109.2	4.5
Sep 22	64.0	116.7	4.4
Sep 23	64.0	113.8	4.4
Sep 24	64.0	111.3	4.4
Sep 25	64.0	107.2	4.0
Sep 26	64.0	109.6	4.0
Sep 27	64.0	100.6	4.3
Sep 28	64.0	102.4	4.3
Sep 29	63.0	102.4	3.5
Sep 30	63.0	104.6	3.4
Average	66.4	125.3	4.5

TABLE B.5. Physical Water-Quality Parameters at Bonneville Dam During August 1958 (Extracted from 1958 Annual Fish Passage Report - Bonneville, The Dalles & McNary Dams, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCF/S)</u>	<u>Secchi Disc (ft)</u>
Aug 01	73.0	142.0	6.5
Aug 02	72.0	151.0	6.9
Aug 03	72.0	149.0	6.9
Aug 04	72.0	148.0	6.5
Aug 05	72.0	144.2	7.0
Aug 06	72.0	145.8	7.0
Aug 07	72.0	139.0	6.0
Aug 08	72.0	142.1	6.0
Aug 09	72.0	132.0	6.9
Aug 10	72.0	119.0	7.2
Aug 11	72.0	105.6	7.0
Aug 12	70.0	110.2	7.2
Aug 13	72.0	111.3	7.2
Aug 14	72.0	107.5	7.2
Aug 15	72.0	109.2	7.2
Aug 16	72.0	115.0	7.2
Aug 17	71.0	116.0	7.2
Aug 18	71.0	112.7	6.0
Aug 19	71.0	119.8	6.5
Aug 20	72.0	116.7	6.5
Aug 21	72.0	114.2	6.5
Aug 22	72.0	113.2	6.5
Aug 23	72.0	118.0	7.0
Aug 24	72.0	117.0	7.0
Aug 25	73.0	112.0	6.5
Aug 26	73.0	108.0	6.7
Aug 27	73.0	110.0	6.0
Aug 28	71.0	107.0	5.8
Aug 29	70.0	104.8	5.7
Aug 30	70.0	107.5	6.2
Aug 31	70.0	102.9	6.5
Average	71.7	121.0	6.7

TABLE B.6. Physical Water-Quality Parameters at Bonneville Dam During September 1958 (Extracted from 1958 Annual Fish Passage Report - Bonneville, The Dalles & McNary Dams, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	70.0	103.5	6.6
Sep 02	70.0	102.0	5.0
Sep 03	68.0	98.3	5.0
Sep 04	68.0	89.3	5.0
Sep 05	68.0	91.0	5.8
Sep 06	69.0	96.2	6.1
Sep 07	68.0	95.2	5.8
Sep 08	68.0	97.5	5.6
Sep 09	68.0	94.0	5.3
Sep 10	69.0	98.0	5.5
Sep 11	69.0	98.0	5.0
Sep 12	69.0	96.0	5.0
Sep 13	68.0	98.0	5.9
Sep 14	67.0	99.0	6.2
Sep 15	67.0	98.0	6.8
Sep 16	68.0	95.9	6.8
Sep 17	66.0	95.0	6.5
Sep 18	66.0	96.5	6.8
Sep 19	66.0	96.5	6.8
Sep 20	65.0	93.8	7.2
Sep 21	65.0	98.7	7.0
Sep 22	65.0	98.0	6.8
Sep 23	64.0	99.0	6.5
Sep 24	64.0	97.8	6.5
Sep 25	63.0	99.5	6.5
Sep 26	62.0	97.5	6.8
Sep 27	62.0	100.1	7.0
Sep 28	62.0	98.0	7.2
Sep 29	62.0	98.0	6.2
Sep 30	62.0	103.0	6.5
Average	66.3	97.4	6.2

TABLE B.7. Physical Water-Quality Parameters at Bonneville Dam During August 1959 (Extracted from 1959 Annual Fish Passage Report - Bonneville, The Dalles & McNary Dams, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	66.0	262.9	4.9
Aug 02	66.0	246.8	4.5
Aug 03	66.0	243.8	4.9
Aug 04	66.0	232.5	4.9
Aug 05	66.0	220.7	5.4
Aug 06	66.0	218.4	5.9
Aug 07	66.0	203.6	6.5
Aug 08	68.0	119.9	6.3
Aug 09	68.0	182.0	6.5
Aug 10	67.0	187.8	5.9
Aug 11	68.0	188.2	6.0
Aug 12	68.0	180.2	6.0
Aug 13	68.0	182.1	6.1
Aug 14	68.0	177.3	6.1
Aug 15	68.0	164.1	6.0
Aug 16	68.0	163.5	6.0
Aug 17	68.0	157.7	6.0
Aug 18	68.0	159.1	6.0
Aug 19	68.0	152.7	6.0
Aug 20	67.0	156.0	6.0
Aug 21	66.0	141.5	5.8
Aug 22	66.0	141.2	5.9
Aug 23	67.0	134.4	6.5
Aug 24	65.0	137.1	6.5
Aug 25	67.0	134.5	7.0
Aug 26	67.0	136.9	7.0
Aug 27	66.0	129.5	6.4
Aug 28	66.0	132.8	6.3
Aug 29	67.0	143.6	6.5
Aug 30	66.0	127.2	6.2
Aug 31	66.0	120.8	6.5
Average	66.9	170.3	6.0

TABLE B.8. Physical Water-Quality Parameters at Bonneville Dam During September 1959 (Extracted from 1959 Annual Fish Passage Report - Bonneville, The Dalles & McNary Dams, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	66.0	133.6	6.5
Sep 02	66.0	126.3	6.0
Sep 03	66.0	134.3	6.0
Sep 04	66.0	123.0	6.0
Sep 05	66.0	134.8	5.8
Sep 06	66.0	124.2	5.8
Sep 07	66.0	138.1	6.2
Sep 08	65.0	128.4	5.6
Sep 09	64.0	128.5	5.0
Sep 10	64.0	135.0	5.5
Sep 11	64.0	134.4	5.0
Sep 12	64.0	125.5	6.5
Sep 13	64.0	139.2	6.5
Sep 14	65.0	135.3	6.5
Sep 15	64.0	145.8	6.5
Sep 16	64.0	137.7	6.5
Sep 17	64.0	147.3	6.5
Sep 18	63.5	150.1	6.0
Sep 19	64.0	172.4	6.5
Sep 20	64.0	182.6	5.8
Sep 21	64.0	185.5	5.5
Sep 22	64.0	185.6	5.9
Sep 23	63.0	191.6	5.5
Sep 24	63.0	193.8	5.7
Sep 25	63.0	188.5	6.0
Sep 26	63.0	179.4	5.5
Sep 27	62.0	168.4	5.2
Sep 28	63.0	168.4	5.5
Sep 29	61.0	181.3	6.0
Sep 30	60.0	181.7	4.0
Average	64.1	153.4	5.8

TABLE B.9. Physical Water-Quality Parameters at Bonneville Dam During August 1960 (Extracted from 1960 Annual Fish Passage Report - Bonneville, The Dalles & McNary Dams, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	68.0	233.0	4.5
Aug 02	68.5	190.1	5.5
Aug 03	68.0	174.4	4.5
Aug 04	68.0	181.9	4.5
Aug 05	68.0	166.5	4.5
Aug 06	69.0	195.2	5.2
Aug 07	69.0	193.1	5.1
Aug 08	70.0	190.9	5.0
Aug 09	70.0	192.0	5.1
Aug 10	70.0	176.4	5.1
Aug 11	70.0	162.2	4.8
Aug 12	70.0	171.9	5.0
Aug 13	70.0	174.5	5.0
Aug 14	69.0	174.0	4.8
Aug 15	69.0	162.2	5.2
Aug 16	68.0	156.9	5.2
Aug 17	68.0	152.3	5.8
Aug 18	68.0	151.8	5.6
Aug 19	68.0	146.6	5.6
Aug 20	68.0	150.0	5.0
Aug 21	68.0	169.9	5.2
Aug 22	68.0	108.7	6.5
Aug 23	67.0	138.2	5.4
Aug 24	66.0	132.9	6.0
Aug 25	65.0	120.7	6.1
Aug 26	64.0	122.6	6.5
Aug 27	64.0	121.4	6.3
Aug 28	65.0	124.2	6.5
Aug 29	65.0	113.2	6.6
Aug 30	66.0	116.4	6.5
Aug 31	64.0	107.9	6.4
Average	67.7	157.2	5.5

TABLE B.10. Physical Water-Quality Parameters at Bonneville Dam During September 1960 (Extracted from 1960 Annual Fish Passage Report - Bonneville, The Dalles & McNary Dams, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	64.0	107.2	6.5
Sep 02	64.0	108.1	6.5
Sep 03	64.0	100.7	6.0
Sep 04	64.0	115.9	6.2
Sep 05	64.0	93.6	6.0
Sep 06	64.0	96.6	6.2
Sep 07	64.0	100.8	6.8
Sep 08	64.0	100.0	4.5
Sep 09	64.0	100.4	5.5
Sep 10	64.0	96.5	6.0
Sep 11	65.0	89.9	6.0
Sep 12	65.0	110.5	6.0
Sep 13	66.0	107.2	6.0
Sep 14	66.0	107.0	6.0
Sep 15	67.0	106.6	6.2
Sep 16	66.0	102.9	6.6
Sep 17	66.0	104.5	7.2
Sep 18	66.0	108.1	6.5
Sep 19	66.0	105.1	6.2
Sep 20	66.0	103.5	6.2
Sep 21	66.0	107.4	6.2
Sep 22	64.0	99.8	6.5
Sep 23	64.0	101.7	6.5
Sep 24	65.0	101.4	6.5
Sep 25	65.0	98.0	6.8
Sep 26	65.0	116.5	6.8
Sep 27	65.0	112.5	6.8
Sep 28	65.0	115.7	6.8
Sep 29	65.0	113.9	6.8
Sep 30	65.0	115.2	6.8
Average	64.9	104.9	6.3

TABLE B.11. Physical Water-Quality Parameters at Bonneville Dam During August 1968 (Extracted from 1968 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	68.0	144.2	6.0
Aug 02	69.0	143.5	5.9
Aug 03	70.0	144.7	5.7
Aug 04	70.0	138.3	6.4
Aug 05	70.0	138.7	6.4
Aug 06	70.0	173.8	6.5
Aug 07	69.0	179.2	7.0
Aug 08	69.0	179.8	7.0
Aug 09	69.0	168.4	7.0
Aug 10	70.0	147.5	7.0
Aug 11	71.0	128.5	7.0
Aug 12	71.0	146.9	7.0
Aug 13	71.0	159.2	5.5
Aug 14	70.0	141.0	6.2
Aug 15	69.0	125.3	6.2
Aug 16	69.0	117.2	6.8
Aug 17	69.0	84.3	7.0
Aug 18	69.0	79.3	7.5
Aug 19	67.0	109.8	6.2
Aug 20	67.0	106.0	7.2
Aug 21	68.0	107.6	7.2
Aug 22	68.0	132.7	7.0
Aug 23	68.0	160.7	6.2
Aug 24	67.0	153.6	7.0
Aug 25	67.0	144.5	6.8
Aug 26	66.0	135.5	7.1
Aug 27	66.0	176.4	6.7
Aug 28	66.0	160.8	6.0
Aug 29	67.0	131.9	6.0
Aug 30	67.0	131.0	6.0
Aug 31	68.0	151.0	6.0
Average	68.5	140.0	6.6

TABLE B.12. Physical Water-Quality Parameters at Bonneville Dam During September 1968 (Extracted from 1968 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	67.0	122.2	6.0
Sep 02	67.0	115.4	6.0
Sep 03	68.0	118.6	6.0
Sep 04	67.0	123.8	6.2
Sep 05	68.0	126.1	6.4
Sep 06	67.0	129.8	6.2
Sep 07	68.0	132.6	6.3
Sep 08	68.0	124.7	6.8
Sep 09	68.0	136.7	7.5
Sep 10	68.0	139.4	6.5
Sep 11	68.0	139.2	7.0
Sep 12	68.0	137.9	6.5
Sep 13	67.0	140.1	5.5
Sep 14	67.0	140.9	6.0
Sep 15	65.0	87.8	6.0
Sep 16	65.0	120.1	7.5
Sep 17	65.0	113.7	6.2
Sep 18	65.0	88.6	7.0
Sep 19	65.0	120.2	7.0
Sep 20	65.0	120.6	7.0
Sep 21	64.0	124.7	7.0
Sep 22	64.0	103.3	7.0
Sep 23	64.0	155.3	7.0
Sep 24	64.0	142.5	7.0
Sep 25	65.0	148.5	6.6
Sep 26	65.0	166.8	6.6
Sep 27	66.0	154.1	5.5
Sep 28	66.0	112.1	5.3
Sep 29	64.0	86.6	7.1
Sep 30	64.0	101.3	6.8
Average	66.1	125.3	6.5

TABLE B.13. Physical Water-Quality Parameters at Bonneville Dam During August 1969 (Extracted from 1969 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCF/S)</u>	<u>Secchi Disc (ft)</u>
Aug 01	70.0	130.9	4.8
Aug 02	69.0	121.0	4.6
Aug 03	70.0	116.0	4.6
Aug 04	69.0	146.4	4.6
Aug 05	69.0	121.8	4.9
Aug 06	68.0	123.9	5.8
Aug 07	69.0	128.7	5.3
Aug 08	69.0	125.8	5.4
Aug 09	69.0	121.5	5.6
Aug 10	69.0	121.5	5.4
Aug 11	69.0	128.0	5.5
Aug 12	68.0	140.1	5.2
Aug 13	68.0	121.1	5.6
Aug 14	68.0	123.0	5.7
Aug 15	69.0	158.8	5.5
Aug 16	69.0	136.2	5.6
Aug 17	68.0	148.5	5.8
Aug 18	68.0	147.8	5.8
Aug 19	68.0	144.3	5.8
Aug 20	68.0	128.0	6.8
Aug 21	69.0	121.8	6.7
Aug 22	69.0	123.9	6.5
Aug 23	69.0	122.2	6.5
Aug 24	70.0	117.2	6.2
Aug 25	69.0	119.8	6.5
Aug 26	69.0	121.6	7.0
Aug 27	69.0	122.4	6.7
Aug 28	69.0	115.2	7.0
Aug 29	68.0	105.9	7.0
Aug 30	69.0	83.5	7.2
Aug 31	68.0	77.3	7.5
Average	68.8	124.6	5.9

TABLE B.14. Physical Water-Quality Parameters at Bonneville Dam During September 1969 (Extracted from 1969 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	68.0	88.3	7.8
Sep 02	69.0	103.2	7.0
Sep 03	69.0	104.8	6.5
Sep 04	67.0	107.5	6.5
Sep 05	67.0	113.9	6.5
Sep 06	66.0	121.0	7.1
Sep 07	67.0	96.1	7.1
Sep 08	67.0	103.3	7.2
Sep 09	67.0	87.8	7.2
Sep 10	68.0	105.8	7.2
Sep 11	69.0	112.3	7.4
Sep 12	69.0	117.4	7.4
Sep 13	69.0	109.9	7.4
Sep 14	69.0	82.1	7.2
Sep 15	67.0	82.9	7.2
Sep 16	67.0	86.9	7.1
Sep 17	66.0	88.5	6.2
Sep 18	66.0	101.9	6.1
Sep 19	66.0	111.3	6.0
Sep 20	66.0	114.4	6.2
Sep 21	66.0	76.9	6.5
Sep 22	66.0	103.9	6.4
Sep 23	66.0	106.9	6.6
Sep 24	66.0	119.2	7.0
Sep 25	66.0	93.5	6.5
Sep 26	66.0	124.1	7.0
Sep 27	66.0	101.1	7.0
Sep 28	66.0	99.3	7.0
Sep 29	65.0	109.3	7.0
Sep 30	65.0	121.0	7.0
Average	66.9	103.2	6.9

TABLE B.15. Physical Water-Quality Parameters at Bonneville Dam During August 1970 (Extracted from 1970 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	70.0	138.4	4.5
Aug 02	70.0	92.1	4.5
Aug 03	69.0	130.7	5.5
Aug 04	69.0	163.3	5.5
Aug 05	70.0	153.0	5.5
Aug 06	70.0	155.1	5.1
Aug 07	71.0	162.8	5.1
Aug 08	71.0	132.9	5.1
Aug 09	71.0	96.7	5.1
Aug 10	71.0	131.5	5.1
Aug 11	69.0	159.0	5.1
Aug 12	70.0	165.2	5.3
Aug 13	70.0	145.9	5.2
Aug 14	70.0	151.0	5.2
Aug 15	70.0	126.7	5.2
Aug 16	70.0	73.1	5.5
Aug 17	70.0	117.0	5.6
Aug 18	70.0	122.6	5.6
Aug 19	70.0	134.4	5.7
Aug 20	69.0	124.2	5.6
Aug 21	70.0	121.7	5.9
Aug 22	69.0	122.9	6.0
Aug 23	70.0	93.6	6.1
Aug 24	70.0	127.4	6.0
Aug 25	70.0	125.5	6.0
Aug 26	70.0	115.9	6.2
Aug 27	70.0	121.5	6.1
Aug 28	70.0	105.8	6.0
Aug 29	70.0	103.8	6.2
Aug 30	70.0	74.7	6.2
Aug 31	70.0	109.6	6.2
Average	70.0	125.8	5.5

TABLE B.16. Physical Water-Quality Parameters at Bonneville Dam During September 1970 (Extracted from 1970 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	70.0	122.6	6.4
Sep 02	70.0	124.4	6.0
Sep 03	70.0	113.2	6.0
Sep 04	69.0	108.3	6.0
Sep 05	69.0	72.4	6.0
Sep 06	68.0	71.8	6.0
Sep 07	68.0	112.0	5.5
Sep 08	66.0	119.8	5.5
Sep 09	68.0	112.7	5.5
Sep 10	66.0	113.1	5.0
Sep 11	66.0	108.3	5.5
Sep 12	66.0	116.8	5.0
Sep 13	66.0	82.1	4.5
Sep 14	66.0	116.4	5.5
Sep 15	66.0	123.2	5.4
Sep 16	66.0	122.1	5.4
Sep 17	65.0	120.9	5.4
Sep 18	64.0	113.5	5.2
Sep 19	65.0	94.8	5.0
Sep 20	65.0	88.3	5.0
Sep 21	65.0	113.0	5.5
Sep 22	64.0	123.1	5.2
Sep 23	64.0	111.6	5.3
Sep 24	62.0	120.5	5.2
Sep 25	62.0	109.2	5.3
Sep 26	61.0	98.9	5.3
Sep 27	60.0	93.6	5.3
Sep 28	60.0	110.3	5.4
Sep 29	61.0	97.6	5.5
Sep 30	61.0	105.4	5.3
Average	65.3	108.0	5.4

TABLE B.17. Physical Water-Quality Parameters at Bonneville Dam During August 1978 (Extracted from 1978 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	70.0	174.3	2.6
Aug 02	70.0	183.8	2.6
Aug 03	70.0	174.7	2.6
Aug 04	70.0	146.0	2.6
Aug 05	70.0	104.5	2.7
Aug 06	71.0	101.5	2.7
Aug 07	71.0	125.6	2.7
Aug 08	72.0	151.2	3.0
Aug 09	72.0	141.4	4.0
Aug 10	72.0	141.0	4.3
Aug 11	72.0	145.1	4.6
Aug 12	72.0	101.0	4.6
Aug 13	71.0	100.1	4.6
Aug 14	70.0	109.0	4.0
Aug 15	70.0	133.5	4.0
Aug 16	70.0	139.7	3.5
Aug 17	70.0	138.6	4.7
Aug 18	69.0	139.9	4.7
Aug 19	70.0	114.9	4.1
Aug 20	70.0	101.9	4.2
Aug 21	69.0	140.4	4.5
Aug 22	69.0	128.5	4.2
Aug 23	69.0	125.6	4.2
Aug 24	69.0	139.3	4.2
Aug 25	69.0	123.1	4.2
Aug 26	67.0	101.4	4.2
Aug 27	68.0	111.3	4.4
Aug 28	68.0	120.9	4.6
Aug 29	68.0	156.5	4.2
Aug 30	68.0	145.1	4.6
Aug 31	69.0	181.8	4.6
Average	69.8	133.6	3.9

TABLE B.18. Physical Water-Quality Parameters at Bonneville Dam During September 1978 (Extracted from 1978 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFs)</u>	<u>Secchi Disc (ft)</u>
Sep 01	69.0	149.5	4.6
Sep 02	69.0	109.1	4.7
Sep 03	69.0	100.0	4.7
Sep 04	68.0	100.0	4.7
Sep 05	68.0	111.5	4.2
Sep 06	68.0	159.4	4.2
Sep 07	68.0	211.1	4.2
Sep 08	68.0	209.0	4.2
Sep 09	67.0	183.7	4.2
Sep 10	67.0	141.6	4.2
Sep 11	67.0	149.7	4.2
Sep 12	67.0	151.6	4.2
Sep 13	66.0	165.4	4.2
Sep 14	66.0	208.7	4.2
Sep 15	66.0	162.1	4.2
Sep 16	66.0	140.2	4.2
Sep 17	66.0	133.9	4.2
Sep 18	64.0	149.2	4.2
Sep 19	64.0	190.8	4.2
Sep 20	64.0	174.9	4.4
Sep 21	64.0	165.3	4.2
Sep 22	64.0	157.6	4.0
Sep 23	64.0	129.3	4.0
Sep 24	64.0	122.0	4.0
Sep 25	64.0	147.2	4.0
Sep 26	64.0	143.0	4.0
Sep 27	64.0	142.7	4.0
Sep 28	64.0	133.9	4.0
Sep 29	64.0	127.3	4.0
Sep 30	64.0	138.8	4.0
Average	65.9	150.3	4.2

TABLE B.19. Physical Water-Quality Parameters at Bonneville Dam During August 1979 (Extracted from 1979 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFES)</u>	<u>Secchi Disc (ft)</u>
Aug 01	72.0	125.5	3.8
Aug 02	72.0	121.7	4.0
Aug 03	70.0	123.4	3.8
Aug 04	70.0	93.1	3.8
Aug 05	70.0	95.5	3.8
Aug 06	69.0	124.6	4.2
Aug 07	69.0	130.0	4.2
Aug 08	69.0	129.2	4.2
Aug 09	70.0	134.9	4.1
Aug 10	70.0	126.4	4.1
Aug 11	71.0	96.1	4.1
Aug 12	71.0	96.4	4.1
Aug 13	71.0	103.8	4.1
Aug 14	71.0	98.8	4.1
Aug 15	71.0	124.6	4.1
Aug 16	71.0	108.3	4.1
Aug 17	71.0	101.9	5.0
Aug 18	71.0	83.4	5.0
Aug 19	71.0	89.9	5.0
Aug 20	71.0	102.4	5.0
Aug 21	70.0	102.0	5.0
Aug 22	70.0	118.4	4.8
Aug 23	70.0	131.9	4.4
Aug 24	71.0	133.8	4.5
Aug 25	71.0	105.9	4.2
Aug 26	71.0	98.8	4.2
Aug 27	71.0	125.9	4.2
Aug 28	71.0	146.8	4.2
Aug 29	70.0	128.7	4.2
Aug 30	70.0	98.1	4.3
Aug 31	70.0	96.9	4.3
Average	70.5	112.8	4.3

TABLE B.20. Physical Water-Quality Parameters at Bonneville Dam During
September 1979 (Extracted from 1979 Annual Fish Passage Report
- Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	70.0	94.5	4.3
Sep 02	70.0	90.1	2.3
Sep 03	70.0	91.1	2.0
Sep 04	69.0	95.9	5.0
Sep 05	70.0	109.8	5.0
Sep 06	70.0	113.4	5.0
Sep 07	70.0	133.2	5.0
Sep 08	70.0	91.6	5.0
Sep 09	70.0	102.2	5.0
Sep 10	70.0	121.5	3.5
Sep 11	69.0	126.1	3.5
Sep 12	69.0	121.0	4.8
Sep 13	70.0	101.5	4.8
Sep 14	69.0	101.0	4.8
Sep 15	69.0	88.4	4.8
Sep 16	70.0	95.8	4.8
Sep 17	69.0	111.5	4.8
Sep 18	69.0	111.6	4.6
Sep 19	70.0	102.5	4.6
Sep 20	70.0	112.3	4.6
Sep 21	70.0	92.9	4.6
Sep 22	69.0	97.0	4.6
Sep 23	69.0	102.6	4.8
Sep 24	69.0	110.4	4.8
Sep 25	68.0	91.7	4.8
Sep 26	68.0	97.8	4.8
Sep 27	68.0	109.2	4.8
Sep 28	68.0	88.9	4.8
Sep 29	68.0	81.3	4.8
Sep 30	68.0	78.6	4.8
Average	69.3	102.2	4.5

TABLE B.21. Physical Water-Quality Parameters at Bonneville Dam During August 1980 (Extracted from 1980 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	70.0	138.3	4.0
Aug 02	70.0	111.0	4.0
Aug 03	70.0	108.6	4.0
Aug 04	70.0	131.8	4.0
Aug 05	71.0	137.9	4.0
Aug 06	70.0	135.9	4.4
Aug 07	70.0	135.2	4.4
Aug 08	70.0	128.9	4.2
Aug 09	70.0	101.3	4.2
Aug 10	70.0	100.6	4.0
Aug 11	71.0	130.4	4.2
Aug 12	71.0	150.3	4.2
Aug 13	71.0	130.7	5.2
Aug 14	71.0	108.2	5.0
Aug 15	70.0	104.7	5.0
Aug 16	69.0	116.7	5.0
Aug 17	69.0	113.9	5.0
Aug 18	69.0	116.9	5.0
Aug 19	68.0	138.8	5.0
Aug 20	68.0	129.7	5.0
Aug 21	69.0	128.1	5.0
Aug 22	68.0	110.6	5.0
Aug 23	68.0	100.1	4.8
Aug 24	68.0	96.0	4.8
Aug 25	69.0	102.3	4.7
Aug 26	69.0	121.4	3.7
Aug 27	68.0	120.7	4.0
Aug 28	68.0	119.2	4.4
Aug 29	69.0	119.6	4.4
Aug 30	68.0	119.4	4.4
Aug 31	68.0	120.6	4.4
Average	69.4	120.3	4.5

TABLE B.22. Physical Water-Quality Parameters at Bonneville Dam During September 1980 (Extracted from 1980 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	67.0	123.4	4.7
Sep 02	67.0	123.0	4.5
Sep 03	67.0	103.9	4.5
Sep 04	67.0	107.4	4.7
Sep 05	67.0	104.7	4.7
Sep 06	68.0	97.5	4.7
Sep 07	68.0	97.9	4.4
Sep 08	68.0	105.8	4.4
Sep 09	68.0	114.1	4.4
Sep 10	68.0	106.0	4.6
Sep 11	68.0	101.9	4.6
Sep 12	67.0	101.1	4.7
Sep 13	67.0	91.5	4.2
Sep 14	67.0	86.2	4.2
Sep 15	67.0	95.4	4.2
Sep 16	67.0	110.3	5.5
Sep 17	67.0	115.7	5.0
Sep 18	67.0	117.0	5.0
Sep 19	67.0	117.9	3.5
Sep 20	67.0	108.9	3.3
Sep 21	67.0	100.8	3.5
Sep 22	67.0	100.3	3.5
Sep 23	67.0	101.4	3.3
Sep 24	66.0	102.8	4.0
Sep 25	66.0	106.3	4.0
Sep 26	66.0	117.5	4.0
Sep 27	66.0	115.0	4.0
Sep 28	66.0	116.6	4.0
Sep 29	66.0	109.8	4.3
Sep 30	66.0	114.2	4.3
Average	67.0	107.1	4.3

TABLE B.23. Physical Water-Quality Parameters at Bonneville Dam During August 1988 (Extracted from 1988 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Aug 01	71.0	94.7	4.8
Aug 02	70.0	101.9	4.8
Aug 03	71.0	93.6	4.8
Aug 04	70.0	107.9	3.3
Aug 05	71.0	94.1	4.5
Aug 06	71.0	91.2	4.0
Aug 07	71.0	96.0	4.0
Aug 08	70.0	103.1	4.0
Aug 09	70.0	94.9	4.2
Aug 10	70.0	97.5	4.2
Aug 11	70.0	113.4	4.2
Aug 12	70.0	118.1	5.2
Aug 13	70.0	108.3	5.6
Aug 14	70.0	86.2	5.5
Aug 15	70.0	97.1	5.5
Aug 16	72.0	108.4	5.4
Aug 17	70.0	113.6	5.3
Aug 18	70.0	96.1	5.8
Aug 19	71.0	102.2	6.4
Aug 20	70.0	106.0	6.5
Aug 21	70.0	97.5	6.3
Aug 22	70.0	94.9	6.5
Aug 23	70.0	97.6	6.0
Aug 24	70.0	116.3	5.8
Aug 25	70.0	122.1	6.2
Aug 26	70.0	116.5	5.5
Aug 27	70.0	98.3	5.8
Aug 28	70.0	100.4	7.0
Aug 29	70.0	100.3	6.5
Aug 30	70.0	122.8	6.5
Aug 31	70.0	123.9	6.5
Average	70.3	103.7	5.4

TABLE B.24. Physical Water-Quality Parameters at Bonneville Dam During September 1988 (Extracted from 1988 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	70.0	138.2	6.5
Sep 02	70.0	140.3	6.5
Sep 03	70.0	110.7	6.5
Sep 04	70.0	102.0	6.5
Sep 05	70.0	101.3	6.5
Sep 06	70.0	141.7	6.5
Sep 07	70.0	120.5	6.5
Sep 08	71.0	123.5	6.5
Sep 09	70.0	115.5	3.0
Sep 10	69.0	116.7	5.0
Sep 11	69.0	127.1	5.0
Sep 12	68.0	99.5	5.0
Sep 13	68.0	98.1	5.0
Sep 14	68.0	103.7	5.0
Sep 15	68.0	128.2	5.2
Sep 16	68.0	103.6	5.2
Sep 17	67.0	103.1	5.3
Sep 18	67.0	114.5	5.4
Sep 19	67.0	100.9	5.8
Sep 20	66.0	123.0	5.5
Sep 21	66.0	122.1	6.0
Sep 22	66.0	121.7	6.0
Sep 23	66.0	130.4	6.0
Sep 24	66.0	101.1	6.0
Sep 25	66.0	98.5	5.6
Sep 26	66.0	118.8	6.0
Sep 27	66.0	115.2	4.0
Sep 28	66.0	110.2	5.6
Sep 29	66.0	117.6	5.5
Sep 30	65.0	113.3	5.5
Average	67.8	115.4	5.6

TABLE B.25. Physical Water-Quality Parameters at Bonneville Dam During August 1989 (Extracted from 1989 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCF/S)</u>	<u>Secchi Disc (ft)</u>
Aug 01	69.0	129.3	4.2
Aug 02	69.0	99.4	4.0
Aug 03	69.0	80.0	4.4
Aug 04	69.0	83.8	5.3
Aug 05	69.0	84.8	5.7
Aug 06	70.0	84.9	5.5
Aug 07	70.0	110.2	5.5
Aug 08	71.0	103.5	5.5
Aug 09	71.0	87.1	5.0
Aug 10	71.0	84.8	5.0
Aug 11	71.0	104.9	4.5
Aug 12	70.0	106.6	4.5
Aug 13	70.0	97.2	4.2
Aug 14	70.0	117.6	4.5
Aug 15	70.0	107.7	4.5
Aug 16	70.0	84.5	4.3
Aug 17	70.0	95.2	5.5
Aug 18	70.0	80.2	6.3
Aug 19	70.0	80.6	5.8
Aug 20	70.0	78.9	5.2
Aug 21	70.0	83.5	6.0
Aug 22	70.0	116.0	5.7
Aug 23	70.0	99.0	5.0
Aug 24	70.0	89.2	5.3
Aug 25	69.0	90.7	5.2
Aug 26	69.0	95.2	5.4
Aug 27	69.0	81.2	5.2
Aug 28	70.0	94.5	5.5
Aug 29	70.0	109.9	4.3
Aug 30	70.0	86.2	4.3
Aug 31	70.0	101.3	5.2
Average	69.9	95.1	5.0

TABLE B.26. Physical Water-Quality Parameters at Bonneville Dam During September 1989 (Extracted from 1989 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCFS)</u>	<u>Secchi Disc (ft)</u>
Sep 01	70.0	126.1	5.0
Sep 02	69.0	102.0	4.8
Sep 03	70.0	100.5	4.9
Sep 04	70.0	89.1	4.0
Sep 05	70.0	108.0	5.1
Sep 06	70.0	111.1	5.2
Sep 07	70.0	123.7	5.2
Sep 08	70.0	119.8	7.0
Sep 09	70.0	113.3	5.7
Sep 10	70.0	109.7	5.8
Sep 11	69.0	90.3	5.9
Sep 12	68.0	87.8	6.3
Sep 13	68.0	94.2	6.4
Sep 14	68.0	110.4	6.7
Sep 15	68.0	113.5	6.5
Sep 16	68.0	100.2	5.5
Sep 17	68.0	100.2	5.3
Sep 18	67.0	106.5	5.2
Sep 19	67.0	104.1	5.2
Sep 20	66.0	95.3	5.0
Sep 21	65.0	107.2	5.2
Sep 22	66.0	110.0	5.5
Sep 23	66.0	105.2	6.0
Sep 24	66.0	107.3	6.6
Sep 25	67.0	100.8	5.8
Sep 26	67.0	103.6	6.2
Sep 27	66.0	105.0	5.4
Sep 28	67.0	123.3	6.1
Sep 29	67.0	130.8	6.0
Sep 30	67.0	103.1	6.0
Average	68.0	106.7	5.7

TABLE B.27. Physical Water-Quality Parameters at Bonneville Dam During August 1990 (Extracted from 1990 Annual Fish Passage Report - Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCF/S)</u>	<u>Secchi Disc (ft)</u>
Aug 01	72.0	155.2	5.5
Aug 02	71.0	148.5	5.3
Aug 03	71.0	166.4	5.6
Aug 04	71.0	143.2	4.8
Aug 05	71.0	144.9	5.8
Aug 06	72.0	163.7	5.5
Aug 07	72.0	152.5	5.3
Aug 08	73.0	155.6	5.3
Aug 09	73.0	144.0	5.3
Aug 10	72.0	147.5	5.2
Aug 11	72.0	137.9	5.5
Aug 12	74.0	113.8	5.8
Aug 13	75.0	111.9	5.7
Aug 14	74.0	130.1	4.8
Aug 15	74.0	126.1	4.8
Aug 16	74.0	125.2	4.8
Aug 17	73.0	129.7	6.0
Aug 18	73.0	115.5	6.0
Aug 19	72.0	99.4	6.2
Aug 20	72.0	115.8	6.0
Aug 21	72.0	110.3	5.8
Aug 22	71.0	128.1	5.5
Aug 23	71.0	127.7	5.2
Aug 24	70.0	148.7	4.8
Aug 25	70.0	141.0	5.0
Aug 26	70.0	145.7	5.2
Aug 27	70.0	159.0	5.5
Aug 28	70.0	155.5	5.7
Aug 29	70.0	126.2	4.8
Aug 30	70.0	117.5	4.3
Aug 31	70.0	123.8	4.5
Average	71.8	135.8	5.3

TABLE B.28. Physical Water-Quality Parameters at Bonneville Dam During
September 1990 (Extracted from 1990 Annual Fish Passage Report
- Columbia and Snake Rivers, Corps of Engineers)

<u>Date</u>	<u>Temperature (°F)</u>	<u>Flow (KCF/S)</u>	<u>Secchi Disc (ft)</u>
Sep 01	70.0	107.1	5.5
Sep 02	70.0	103.3	5.8
Sep 03	70.0	100.7	4.5
Sep 04	70.0	106.1	4.7
Sep 05	69.0	117.8	5.8
Sep 06	69.0	115.9	5.5
Sep 07	71.0	95.9	5.8
Sep 08	70.0	104.5	6.2
Sep 09	71.0	93.7	6.1
Sep 10	71.0	103.8	6.5
Sep 11	71.0	109.7	5.8
Sep 12	70.0	108.4	5.5
Sep 13	70.0	119.4	5.5
Sep 14	70.0	125.0	6.0
Sep 15	70.0	107.1	5.5
Sep 16	69.0	89.3	5.0
Sep 17	69.0	115.3	5.8
Sep 18	69.0	119.0	5.5
Sep 19	69.0	115.9	5.2
Sep 20	69.0	115.2	5.2
Sep 21	69.0	113.3	5.2
Sep 22	69.0	97.9	6.8
Sep 23	69.0	90.5	6.0
Sep 24	69.0	98.9	6.2
Sep 25	69.0	115.9	6.4
Sep 26	69.0	115.8	6.4
Sep 27	69.0	119.1	6.5
Sep 28	69.0	115.8	6.2
Sep 29	69.0	108.6	6.0
Sep 30	69.0	97.0	6.5
Average	69.6	108.2	5.8

APPENDIX C

CHEMICAL WATER-QUALITY DATA

APPENDIX C

CHEMICAL WATER-QUALITY DATA

Information from the "STORET" database maintained by the United States Department of Interior, U.S. Geological Survey (USGS), was used to review chemical water-quality parameters. Again, we selected the last 3 years of each decade as our reference years to compare long-term changes in water quality. Tables C.1 and C.2 were created from data collected at sampling stations on the Columbia River at Warrendale and Umatilla, Oregon, respectively. Table C.3 contains data collected from the Deschutes River at Moody, near Biggs, Oregon. Table C.4 contains data collected from the John Day River at McDonald Ferry, Oregon.

Other measurements presented in the STORET database, but not summarized in this table are temperature, barometric pressure, discharge (cfs), specific conductance ($\mu\text{s}/\text{cm}$), alkalinity (mg/L as CaCO_3), carbontae, bicarbonate, nitrogen (as dissolved ammonia, total ammonia, dissolved nitrite, dissolved $\text{NO}_2 + \text{NO}_3$ total), ortho phosphate total (mg/L as PO_4), sodium percent, silica dissolved (mg/L), beryllium ($\mu\text{g}/\text{L}$), molybdenum ($\mu\text{g}/\text{L}$), strontium ($\mu\text{g}/\text{L}$), vanadium ($\mu\text{g}/\text{L}$), aluminum ($\mu\text{g}/\text{L}$), lithium ($\mu\text{g}/\text{L}$), fecal coliform (cols/100 ml), fecal streptococci (cols/100 ml), residue solids (mg/L), and total dissolved solids (mg/L). Some samples were also analyzed for a variety of heavy metals; however, sporadic sampling made it difficult to look for trends in the data over time.

TABLE C.1. Water-Quality Measurements from Samples Taken from the Columbia River Near Warrendale, Oregon (Data derived from the STORET database maintained by the USGS)

Parameter	Month/Year of Sample Collection							
	8/78	8/79	9/79	8/80	9/80	8/88	9/89	8/90
Turbidity (NTU)		2.8	1.8	2.7	2.7	2.4	1.1	20
Oxygen, Dissolved (mg/L)	--	8.6	9.8	8.5	9.5	8.4	8.3	8.2
pH (Standard Units)	--	7.7	7.9	8.0	8.2	7.8	7.8	8.0
Nitrogen, Organic, Total (mg/L as N)	0.32	0.08	2.3	0.19	0.55	0.38	--	0.26
Phosphorus, Total (mg/L as P)	0.03	0.03	0.03	0.03	0.04	0.04	0.01	0.02
Carbon, Organic, Total (mg/L as C)	2.1	1.5	1.6	3.2	4.7	--	--	--
Hardness, Total (mg/L as CaCO ₃)	57	61	67	63	67	59	59	49
Calcium, Dissolved (mg/L as Ca)	16	17	19	18	19	16	16	13
Magnesium, Dissolved (mg/L as Mg)	4.1	4.5	4.7	4.5	4.8	4.6	4.6	4.0
Sodium, Dissolved (mg/L as Na)	7.1	4.6	6.2	4.9	5.4	4.8	5.6	3.9
Potassium, Dissolved (mg/L as K)	1.0	1.1	1.4	1.1	1.3	1.0	1.1	0.90
Chloride, Dissolved (mg/L as Cl)	2.1	2.0	2.5	2.3	3.1	2.5	2.7	2.3
Sulfate, Dissolved (mg/L as SO ₄)	10	14	19	16	8.4	11	10	8.7
Fluoride, Dissolved (mg/L as F)	0.20	0.20	0.20	0.20	0.20	0.10	0.20	<0.10
Sediment, Susp. (mg/L)	11	8	6	10	--	8	6	5

TABLE C.2. Water-Quality Measurements from Samples Taken from the Columbia River Near Umatilla, Oregon (Data derived from the STORET database maintained by the USGS)

<u>Parameter</u>	<u>Month/Year of Sample Collection</u>							
	<u>8/78</u>	<u>8/79</u>	<u>9/79</u>	<u>8/80</u>	<u>9/80</u>	<u>8/88</u>	<u>9/89</u>	<u>8/90</u>
Turbidity (NTU)	--	--						
Oxygen, Dissolved (mg/L)	9.3	8.6	9.0	8.8	8.7			
pH (Standard Units)	8.4	8.4	8.0	8.4	8.2			
Nitrogen, Organic, Total (mg/Las N)	0.37	0.23	0.56	0.51	0.49			
Phosphorus, Total (mg/L as P)	0.02	0.02	0.03	0.03	0.03			
Carbon, Organic, Total (mg/L as C)	2.5	2.2	2.4	--	--			

TABLE C.3. Water-Quality Measurements from Samples Taken from the Deschutes River at Moody, Near Biggs, Oregon (Data derived from the STORET database maintained by the USGS)

Parameter	Month/Year of Sample Collection							
	8/78	8/79	9/79	8/80	9/80	9/88	8/89	9/90
Turbidity (NTU)	3.1	4.8	3.3	2.6	1.4	2.0	1.6	2.5
Oxygen, Dissolved (mg/L)	10.7	9.1	9.6	10.8	10.7	11.0	11.0	7.2
pH (Standard Units)	8.7	8.5	8.6	8.8	9.0	8.2	8.3	8.1
Nitrogen, Organic, Total (mg/Las N)	0.79	0.29	0.40	1.6	--	--	0.16	--
Phosphorus, Total (mg/L as P)	0.07	0.09	0.06	0.06	0.07	0.09	0.05	0.04
Carbon, Organic, Total (mg/L as C)	1.6	1.5	1.9	1.6	2.7	--	--	--
Hardness, Total (mg/L as CaCO ₃)	40	40	41	42	40	41	38	40
Calcium, Dissolved (mg/L as Ca)	7.6	8.0	8.2	8.3	7.5	7.6	7.4	7.5
Magnesium, Dissolved (mg/L as Mg)	5.0	4.9	5.1	5.1	5.1	5.4	4.8	5.2
Sodium, Dissolved (mg/L as Na)	9.7	11	10	10	9.9	11	10	11
Potassium, Dissolved (mg/L as K)	1.9	2.1	2.0	2.1	2.1	1.8	1.9	1.9
Chloride, Dissolved (mg/L as Cl)	2.4	2.2	2.1	3.0	3.1	2.1	1.9	2.8
Sulfate, Dissolved (mg/L as SO ₄)	3.9	6.1	5.5	2.8	0.50	2.5	2.0	1.9
Fluoride, Dissolved (mg/L as F)	0.10	0.20	0.20	0.10	0.20	0.10	0.10	<0.10
Sediment, Susp. (mg/L)	37	36	8	14	10	--	11	11

TABLE C.4. Water-Quality Measurements from Samples Taken from the John Day River at McDonald Ferry, Oregon (Data derived from the STORET database maintained by the USGS)

Parameter	Month/Year of Sample Collection							
	8/78	8/79	9/79	8/80	9/80	8/88	8/89	8/90
Turbidity (NTU)	2.6	54	5.7	1.1	2.3	10	0.6	1.5
Oxygen, Dissolved (mg/L)	10.2	9.1	9.6	10.0	11.5	9.5	10.1	10.0
pH (Standard Units)	8.9	8.4	8.5	9.0	8.9	8.3	8.5	8.9
Nitrogen, Organic, Total (mg/L as N)	0.44	0.49	0.55	0.63	0.64	0.49	--	0.59
Phosphorus Total (mg/L as P)	0.10	0.18	0.02	0.10	0.03	0.03	<0.01	0.06
Carbon, Organic, Total (mg/L as C)	3.4	6.5	4.3	4.1	4.5	--	--	--
Hardness, Total (mg/L as CaCO ₃)	110	110	120	100	110	110	120	88
Calcium, Dissolved (mg/L as Ca)	24	24	25	22	26	22	26	17
Magnesium, Dissolved (mg/L as Mg)	12	13	14	11	12	13	13	11
Sodium, Dissolved (mg/L as Na)	20	26	22	16	22	23	23	21
Potassium, Dissolved (mg/L as K)	3.0	3.8	2.9	3.1	2.5	3.0	3.1	3.0
Chloride, Dissolved (mg/L as Cl)	4.0	4.8	3.9	3.6	3.9	7.5	4.4	5.8
Sulfate, Dissolved (mg/L as SO ₄)	13	19	21	15	18	11	13	9.7
Fluoride, Dissolved (mg/L as F)	0.10	0.20	0.20	0.20	0.30	0.20	0.20	<0.10
Sediment, Susp. (mg/L)	8	341	12	3	8	2	2	2

APPENDIX D

REVIEW OF HANFORD WATER-QUALITY INFORMATION

APPENDIX D

REVIEW OF HANFORD WATER-QUALITY INFORMATION

The following references were compiled by Greg Strom of the Yakima Indian Nation during 1991. Copies of these reports are scheduled to be provided to the Yakima Indian Nation library in Toppenish during 1992. The topic and subtopic headers and identification numbers refer to notations in the literature reviews that Greg used to compile this list.

Water-Quality Parameter

1. GENERAL

- C-10 Corley, J. P., H. A. Kramer, and J. K. Soldat. 1961. A Compilation of Basic Data Relating to the Columbia River. Section I-IV. HW-69368, Hanford Atomic Products Operation, Richland, Washington. (Temperature, Chemical Characteristics, Radioactivity & Effects of Effluents on River Biota)
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A SUMMARY OF ENVIRONMENTAL EFFECTS STUDIES
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