A Summary of 22 Years of Fish Screen Evaluations in the Yakima River Basin

Summary Report

1985 – 2007

Prepared by

Mickie A. Chamness
Pacific Northwest National Laboratory
P.O. Box 999
Richland, Washington 99352

Prepared for

U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97208-3621

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Summary

Sixty fish screen facilities were constructed in the Yakima River basin between 1985 and 2006 as part of the Northwest Power and Conservation Council plan to mitigate the effects of federal hydroelectric projects on fish and wildlife populations. This report summarizes evaluations of some of those and other fish screen facilities conducted by Pacific Northwest National Laboratory (PNNL) from 1985 through 2006.

The objective of these studies was to determine if the newly designed and constructed fish screens were effective at providing juvenile salmonids safe passage past irrigation diversions. To answer that question, PNNL conducted release-and-catch studies at eight Phase I sites in the Yakima River basin. Increasing concerns about the impacts of hatchery fish releases on the wild fish population, as well as the cost and time necessary to perform these kinds of biological studies at more than 60 planned Phase II sites, required development of techniques to evaluate the effectiveness of the sites without releasing fish. The new techniques involved collecting information on screen design, operation, and effectiveness at guiding fish safely through the fish screen facility. Performance measures including water velocities and passage conditions provide a good alternative to biological studies at significantly lower cost and time. Physical techniques were used at all 10 Phase I and 28 Phase II sites evaluated by PNNL over the following 19 years.

Results of these studies indicate the Phase I and II fish screen facilities are designed and capable of providing safe passage for juvenile salmonids so long as construction, maintenance, and operations meet the criteria used in the design of each site and the National Marine Fisheries Service criteria for juvenile fish screen design.

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Acronyms and Abbreviations

BPA	Bonneville Power Administration
cfs	cubic feet per second
NMFS	National Marine Fisheries Service
NPCC	Northwest Power and Conservation Council (new name for NPPC)
NPPC	Northwest Power and Planning Council
PNNL	Pacific Northwest National Laboratory
USBR	U.S. Bureau of Reclamation
WDFW	Washington Department of Fish and Wildlife

Acknowledgments

Duane Neitzel was instrumental in initiating and managing this project for Pacific Northwest National Laboratory from 1985 until 2000. He developed strong ties with Washington Department of Fish and Wildlife and U.S. Bureau of Reclamation personnel who design, construct, operate, and maintain the fish screen facilities, and provided valuable technical expertise. Key personnel at PNNL over the years include Scott Abernethy, who assisted with and ultimately conducted much of the Phase I fieldwork; Sue (Blanton) Southard, who helped develop and direct the Phase II fieldwork for the first 2 years; Geoff McMichael, who managed the project from 2000 to 2005; and Jessica Vucelick, who helped conduct Phase II evaluations between 2001 and 2005.

R. Dennis Hudson, U.S. Bureau of Reclamation, provided summary information on fish screen construction schedules and has been very helpful in providing facility design information over the years. Pat Schille, Chuck Lenberg, and Ray Gilmore, Washington Department of Fish and Wildlife, also have been very helpful in providing operating information for many of the sites.

This report benefitted greatly from the reviews by Duane Neitzel, Scott Abernethy, Sue (Blanton) Southard, and Dennis Dauble. They also contributed much of the history on this project. I am also grateful to Andrea Currie (PNNL) for copyediting and to Mike Parker and Kathy Neiderhiser (PNNL) for final formatting of this technical report.

Introduction

The U.S. Congress created the Bonneville Power Administration (BPA) in 1937 to deliver and sell power generated by the recently constructed Bonneville Dam. The BPA was directed to deliver and sell power from 30 more federal hydroelectric dams constructed in the Pacific Northwest between 1937 and 1970. Anadromous fish populations already were declining and continued to decrease dramatically during that same period. Causes for the decline included loss of habitat, increased harvest, and varying ocean conditions, but the decline is attributed primarily to construction and operation of the federal hydroelectric dams (NPPC 2000).

In 1980, Congress created the Northwest Power Planning Council (now the Northwest Power and Conservation Council, NPCC) in response to concerns of the Pacific Northwest states about the need to balance hydroelectric power generation and energy conservation. Congress included provisions for the NPCC to protect and enhance fish and wildlife and mitigate for habitat losses resulting from the construction and operation of the federal dams. The NPCC tasks are to 1) maintain a 20-year electric power plan that will guarantee adequate and reliable energy at the lowest economic and environmental cost to the Northwest; 2) develop a program to protect and rebuild fish and wildlife populations affected by hydropower development in the Columbia River Basin; and 3) educate and involve the public in the Council's decision-making processes. Funding these mitigation efforts, including fish passage projects, fell to BPA.

Although not part of the Federal Columbia River Power System, the Yakima River basin was selected as a site for enhancement of salmon and steelhead runs because these migrating fish are adversely affected by three Columbia River dams that are a part of that system. The Yakima River had under-utilized habitat, dwindling anadromous fish populations, and fish passage facilities that could be improved or constructed to increase adult and juvenile salmonid survival. The BPA and U.S. Bureau of Reclamation (USBR) funded construction of 16 new fish passage facilities, starting in 1984 and completed in 1990. These were part of Phase I of the fish protection and enhancement program in the Yakima River basin (RD Hudson, U.S. Bureau of Reclamation, unpublished data). Sites were redesigned to incorporate new ideas about features to pass fish more safely, such as angling the screens at 26° to the flow, using smaller mesh size to protect younger, smaller fish, and reducing the approach velocity while maintaining a ratio of sweep-to-approach velocity greater than 2:1.

Tom Clune was a fisheries biologist and project manager with BPA in the 1980s. At that time, some people felt fish screens, new or old, killed fish rather than protecting them. Mr. Clune knew staff at Pacific Northwest National Laboratory (PNNL) had experience with screen intakes at nuclear power plants along the Columbia River and in 1984 asked PNNL if it would be able to evaluate the effectiveness of new fish screen designs at protecting juvenile salmonids and guiding them safely back into the river. Mr. Clune also wanted to know if the design and operation of the new fish screen facilities had adverse impacts on the fish as they passed through to the river. Duane Neitzel wrote the initial proposal with the objective to evaluate Phase I fish screen facilities to determine if they were designed, constructed, operated, and maintained as needed to protect juvenile salmonids. This proposal was accepted, and a contract between BPA and PNNL was initiated in 1985.

The contract with BPA was renewed over the next 21 years, covering evaluation of new Phase I and Phase II sites as they were constructed and eventually covering the monitoring, maintenance, and operation of a number of the Phase II sites. Staff from PNNL continued to lead these evaluations until 2006, coordinating efforts with Tribal, federal, and state resource management agencies. Feedback on problems and conditions found at each site was provided in a timely manner to BPA, the USBR, and the Washington State Department of Fish and Wildlife (WDFW), allowing rapid correction if there was imminent danger to fish. Annual reports were usually submitted to BPA discussing the results and findings of each year's work. These reports are listed in Table 1. An Internet site was created to make information and reports readily available to BPA, the operations and maintenance agencies (WDFW and USBR), interested Native American Tribes, and the public.

This report provides a brief summary of fish screen evaluations performed under BPA Project Number 1985-062-00, major findings of that work, and a short discussion of the lessons learned. This report does not discuss the few add-on tasks, unrelated to fish screen evaluation, that were also performed under this contract in the 1980s and 1990s.

Phase I Work Performed

This project to evaluate whether fish screens were effective at protecting juvenile salmonids and guiding them safely back into the river began in 1985, just as the first of the Phase I fish screen facilities was being completed. Between 1985 and 1994, PNNL staff evaluated 12 new fish screen facilities, including 11 Phase I facilities in the Yakima River basin (Figure 1) and 1 facility in the Wenatchee River basin (Figure 2). Table 2 lists these sites evaluated by PNNL by the year in which they were constructed.

Evaluations of the fish screen facilities were designed to answer the following questions:

1. Were fish being injured? If so, what was the extent of injury and which part of the facility caused the injury?
2. Did fish pass safely and quickly through the screen facility?
3. Did predators of juvenile salmonids gather at fish screen facilities?
4. Were juvenile fish going over or through the screens and into the canals?
5. What impacts did changes in operating conditions have on fish condition?

Initial studies to answer these questions involved release-and-capture studies using juvenile salmonids. Between 1985 and 1988, release-and-capture studies at eight Phase I sites established whether fish were descaled, killed, or otherwise harmed in their passage through the sites. Typically, the release-and-capture studies used branded hatchery smolt and/or fry that were released either at specified locations within the screen facility or at the upstream end of the facility. Nets were deployed at specific locations within the facility, at the entrance to the bypass, at the bypass outfall, or in the canal behind the screens. Captured fish were inspected for injuries, primarily descaling. Capture of native fish, both incidental and deliberate, allowed an estimation of predator numbers. Researchers then compared numbers of fish released to those captured, calculated the percentage of injured or killed in relation to the part of the site through which they passed, and determined travel times through the facility to evaluate the effectiveness of the fish screens. Effectiveness of individual sites at protecting juvenile salmonids under different

Table 1. Brief Description of Work Performed and Annual Reports Submitted to the Bonneville Power Administration by Year

Year	Brief Work Description	Report
1985	Phase I biological evaluations	Neitzel DA, CS Abernethy, EW Lusty, and LA Prohammer. 1985. <i>A Fisheries Evaluation of the Sunnyside Canal Fish Screening Facility, Spring 1985</i> . DOE/BP- 01830-1, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
1986	Phase I biological evaluations	Neitzel DA, CS Abernethy, and EW Lusty. 1987. <i>A Fisheries Evaluation of the Sunnyside Canal Fish Screening Facility, Spring 1985</i> . DOE/BP-01830-2, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
1987	Phase I biological evaluations	Neitzel DA, CS Abernethy, EW Lusty, and SJ Wampler. 1988. <i>A Fisheries Evaluation of the Richland and Wapato Canal Fish Screening Facilities, Spring 1987</i> . DOE/BP-01830-3, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
1988	Phase I biological and physical evaluations	<p>Neitzel DA, CS Abernethy, and EW Lusty. 1990a. <i>A Fisheries Evaluation of the Wapato, Sunnyside, and Toppenish Creek Canal Fish Screening Facilities, Spring 1988</i>. DOE/BP-01830-6A, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.</p> <p>Abernethy CS, DA Neitzel, and EW Lusty. 1989. <i>Velocity Measurements at Six Fish Screening Facilities in the Yakima River Basin, Washington, Summer 1988</i>. DOE/BP-01830-4, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.</p>
1989	Phase I biological and physical evaluations	<p>Neitzel DA, CS Abernethy, and EW Lusty. 1990b. <i>A Fisheries Evaluation of the Westside Ditch and Wapato Canal Fish Screening Facilities, Spring 1989</i>. DOE/BP-01830-8, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.</p> <p>Abernethy CS, DA Neitzel, and EW Lusty. 1990. <i>Velocity Measurements at Three Fish Screening Facilities in the Yakima River Basin, Washington, Summer 1988</i>. DOE/BP-01830-10, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.</p>

Table 1. (contd)

Year	Brief Work Description	Report
1990	Phase I biological evaluations	Neitzel DA, CS Abernethy, and GA Martenson. 1990c. <i>A Fisheries Evaluation of the Westside Ditch and Town Canal Fish Screening Facilities, Spring 1990</i> . DOE/BP-01830-9, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
1991	Release-and-capture pit-tagged fish near Phase I sites	no report written
1992	Release-and-capture pit-tagged fish near Phase I sites	no report written
1993	Capture efficiency tests (release and capture) at Kiona, Naches-Cowiche, Gleed	no report written
1994	Biological evaluation of Dryden site ----- Development and testing of non-biological methods for Phase II evaluations	Mueller RP, CS Abernethy, and DA Neitzel. 1995. <i>A Fisheries Evaluation of the Dryden Fish Screening Facility, Annual Report 1994</i> . DOE/BP-00029-2, prepared by the Pacific Northwest Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon. ----- no report written
1997	Phase II physical evaluations	Blanton SL, DA Neitzel, and CS Abernethy. 1998. <i>Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 1997</i> . DOE/BP-00029-5, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
1998	Phase II physical evaluations	Blanton SL, GA McMichael, and DA Neitzel. 1999. <i>Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 1998</i> . DOE/BP-62611-15, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
1999	Phase II physical evaluations	Blanton SL, GA McMichael, and DA Neitzel. 2000. <i>Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 1999</i> . DOE/BP-00000652-4, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Table 1. (contd)

Year	Brief Work Description	Report
2000	Phase II physical evaluations	Chamness MA, EV Arntzen, GA McMichael, and PS Titzler. 2001. <i>Washington Phase II Fish Diversion Screen Evaluations in the Yakima River Basin, 2000</i> . DOE/BP-00000652-3, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
2001	Phase II physical evaluations	Carter JA, GA McMichael, and MA Chamness. 2002. <i>Yakima River Basin Phase II Fish Screen Evaluations, 2001</i> . DOE/BP-00000652-8, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
2002	Phase II physical evaluations	Carter JA, GA McMichael, and MA Chamness. 2003. <i>Yakima River Basin Phase II Fish Screen Evaluations, 2002</i> . DOE/BP-00000652-11, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
2003	Phase II physical evaluations	Vucelick JA, GA McMichael, and MA Chamness. 2004. <i>Yakima River Basin Phase II Fish Screen Evaluations, 2003</i> . DOE/BP-00000652-16, prepared by the Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
2004	Phase II physical evaluations	Vucelick JA, GA McMichael, and MA Chamness. 2005. <i>Yakima River Basin Phase II Fish Screen Evaluations, 2004</i> . DOE/BP-00000652-30, prepared by the Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
2005	Phase II physical evaluations	Chamness MA, CS Abernethy, and C Tunnicliffe. 2006. <i>Washington Phase II Fish Diversion Screen Evaluations in the Yakima and Touchet River Basins, 2005</i> . DOE/RP-00000652-31, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.
2006	Phase II physical evaluations	Chamness MA and C Tunnicliffe. 2007. <i>Yakima and Touchet River Basins Phase II Fish Screen Evaluations, 2006</i> . DOE/BP-00026934-1, prepared by Pacific Northwest National Laboratory for the Division of Fish and Wildlife, Bonneville Power Administration, Portland, Oregon.

Figure 1. Phase I Fish Screen Facilities in the Yakima River Basin Evaluated by PNNL

Figure 2. Wenatchee River Basin and the Dryden Fish Screen Facility

Table 2. Fish Screen Facilities Evaluated by PNNL, Listed by Year of Construction

Site	Date Installed	Number of Screens	Screen Type	Canal Flow (max in cfs)
<i>Phase I</i>				
Sunnyside	1985	17	drum	1550
Richland	1986	4	drum	80
Toppenish/Satus	1986	8	drum	650
Wapato	1986	15	drum	1800
Columbia	1986	10	drum	150
Toppenish Creek	1987	3	drum	60
Chandler	1987	24	drum	1400
Westside Ditch	1988	4	drum	100
Roza	1988	27	drum	2000
Easton	1989	18	drum	1200
Town Canal	1989	10	drum	250
<i>Phase II</i>				
Naches-Cowiche	1992	2	drum	40
Gleed	1993	4	vertical traveling screen	42
Kiona	1993	2	drum	
New Cascade	1993	8	drum	147
Lower WIP	1993	2	drum	6.8
Snipes-Allen	1993	2	drum	26
Taylor	1993	2	drum	12
Congdon	1994	4	drum	40
Kelley-Lowery	1994	2	drum	29
Bachelor-Hatton	1994	4	drum	58
Toppenish Pump	1995	6	drum	100
Naches-Selah	1996	6	flat plate	137
Fruitvale	1996	2	flat plate	32
Upper WIP	1997	4	drum	55
Yakima-Tieton	1997	12	flat plate	350
Union Gap	1997	4	flat plate	76
Bull Ditch	1997	2	flat plate	30
Ellensburg Mill	1997	2	flat plate	40
Clark	1997	1	drum	6.5
Lindsey	1997	1	drum	10.6
Younger	1998	2	flat plate	15
Old Union	1998	2	flat plate	18.5
John Cox	1999	2	drum	18
Powell-LaFortune	2001	4	drum	51
Wilson Creek	2001	3	drum	39
Selah-Moxee	2002	12	flat plate	100
Packwood	2004	2	flat plate	30
Fogarty	2006	3	drum	30
<i>Screens evaluated but not part of the Phase I or II programs</i>				
Dryden	1993	7	flat plate	230
Huntsville Mill	2004	1	drum	6

operating conditions was measured using the same techniques described above, comparing injury, swiftness of passage, and movement of fish around the screens under high and low water levels.

In some cases, problems were found in the construction or operation of the sites, such as incorrectly installed blocks meant to prevent sediment buildup beneath the screens at Sunnyside, creating a 6-in. gap beneath the screens that let fish into the canal. When a problem such as this was identified, PNNL researchers notified the agency managing the site so that the problem could be corrected. Researchers from PNNL often provided suggestions and worked with the various agencies to resolve the problems identified.

Pacific Northwest National Laboratory researchers concluded that release-and-capture studies were providing information needed to evaluate the impacts of the facilities' design on the condition of fish passing through the fish protection facilities. They also concluded that more detail on whether the fish screens met design criteria was needed. For example, these new fish screens were designed assuming uniform flow through the site and across the screens. If flow was not uniform, small areas with high approach velocities might develop that could impinge or injure fish. Potential entrainment problems such as poorly fitting seals or drums out-of-round had been observed at some sites. Therefore, after 3 years of biological evaluations, attention focused on whether the sites were constructed, operated, and maintained within the design criteria for the site.

Techniques already used to inspect the underwater portions of the sites and measure water velocities near the screen faces were expanded upon to develop a physical evaluation methodology to meet the needs of this new focus. Starting in 1988, physical evaluations were conducted at several Phase I sites for this purpose. Physical evaluations consisted of comparing measurements of water velocities in front of the fish screens and in the bypass structures to the design criteria for each site and using underwater videography to examine screen integrity, predators, or other underwater factors that could adversely affect juvenile salmonids passing through the site. Both physical and biological evaluations had been conducted at most of the 11 Phase I sites plus the Dryden fish screen in the Wenatchee River basin by the end of 1990 (Table 3). Construction of Phase I sites was completed in 1990 (RD Hudson, U.S. Bureau of Reclamation, unpublished data).

Regular meetings were held with the BPA, WDFW, and USBR to discuss the findings, and PNNL staff attended the multi-agency Technical Working Group meetings for the Yakima River basin. After discussions with the Technical Working Group and the Yakama Nation, PNNL worked with the Yakama Nation in 1991, 1992, and 1993 to answer their concerns about overall survival of fish as they moved through multiple fish screen facilities on their way to the ocean. Consequently, pit-tagged fish were released just upstream, within, and just downstream of both the Wapato and Sunnyside fish screen facilities. Temporary detectors were set up at both sites and used with permanent detectors at McNary and Bonneville dams to estimate survival over extended distances. A report on this work was never written (Table 1).

Table 3. Phase I Fish Screens Evaluated by PNNL

Site	Year Evaluated	Type of Evaluation
Sunnyside	1985, 1988	Biological, physical
Richland	1986, 1987, 1988	Biological, physical
Toppenish/Satus	1986	Biological, physical
Wapato	1987, 1988, 1989	Biological, physical
Columbia	1988	Physical
Toppenish Creek	1988	Biological
Chandler	1989	Physical
Westside Ditch	1988, 1989, 1990	Physical, biological
Roza	1988	Physical
Easton	1989	Physical
Town Canal	1990	Biological
Dryden ^(a)	1994	Biological, physical
(a) Dryden is not a Phase I site, but the work performed was identical to that for other Phase I sites.		

Annual reports and information on the screen facilities were made available at <http://ecology.pnl.gov/projects/screen/screens.asp> and at <http://www.efw.bpa.gov/searchpublications/>. Annual reports submitted to BPA (see Table 1) and Neitzel et al. (1990d) concluded that so long as the Phase I fish screens facilities were operated as designed, the following conditions prevailed:

- New designs incorporating features such as drum screens set at a 26° angle to flow, smaller mesh size on the screens, and a sweep-to-approach ratio of 2:1 with approach velocities of ≤5 cfs (regarded as a safe velocity prior to the release of the NMFS fish screen design criteria in 1995) were protective of juvenile salmonids. The fish screen facilities usually caused injury or death to less than 2% of juvenile salmonids released at the site, similar to those in the control groups. Descaling was the primary form of injury.
- The screens allowed fish to pass quickly and of their own volition when adequate bypass flow was provided. Some smaller fish were flushed through sites when velocities were high. There were variations in passage rate noted between species, with steelhead often slower to move out of the screen facility. Passage rate also varied based on time of day and degree of smoltification.
- The screens did not cause predators to concentrate within the facility or at the bypass outfall. Few predacious fish were caught on the incline planes in bypasses, in nets at the bypass outfall, or during electrofishing of the forebay and canal. Gut contents of predacious fish indicated that some but not all had eaten test fish. Predacious birds did not concentrate at any of the sites, although the area near the Richland fish screen typically has a higher concentration of gulls. The bypass outfall at the Richland screen site emptied into a riffle rather than a pool, and gulls may be able to find more disoriented fish at the outfall.
- Maintenance of each site with particular attention to screen seals and debris was important in preventing fish from moving over or through the screens and into the canal. If there is any way to get by a screen, fish will find it. Excessive approach velocities and/or submergence could allow fish to rollover a drum screen, faulty or worn seals, gaps around the screen frame, and irregularities in the concrete portion of the structure could allow fish to move around the screen.

- Changes in operating conditions as water levels dropped through the irrigation season did not affect efficiency of the sites when sufficient bypass flow was maintained. Operating procedures need to be in place and followed to provide optimum passage conditions during the normal range of flows. Fish movement is generally slower when water levels are low.

Phase II Work Performed

The USBR began planning for construction of Phase II sites in 1989 as the Phase I project was nearing completion. Phase II fish screen facilities are generally smaller than Phase I sites, with many on smaller tributaries or upper reaches of the mainstem Yakima River. Up to 66 Phase II fish screen facilities were initially planned, and the first were completed in 1992 (Table 2). Phase I studies had shown that the new fish screen designs were generally protective of juvenile fish. Phase II evaluations were requested by BPA to confirm that similar fish screen designs on a smaller scale also provided safe and effective passage past the diversions. More emphasis was to be placed on screen integrity and proper site function, rather than injury incurred during passage as was the case in Phase I biological evaluations.

Preliminary release-and-capture evaluations of new Phase II facilities were conducted at Kiona, Naches-Cowiche, and Gleed in 1993 by releasing fish in the aftbay and capturing them in fyke nets behind the screens to measure capture efficiency. Once capture efficiency was known, screen integrity could be estimated without the use of marked fish by deploying the nets behind the screens—any fish captured was presumed to have gone through or over the fish screens.

However, this type of study was time-intensive and would not directly provide data on whether the site operated within its design criteria. Consequently, PNNL developed a new procedure based on Phase I physical studies that employed velocity measurements, underwater video, and other observations to determine if a site was passing fish safely and quickly. This procedure could be performed relatively quickly, allowing more sites to be visited, and provided rapid feedback to construction, operation, and maintenance agencies on conditions that affected fish passage and safety. In 1994, the procedure was tested on nine Phase II sites (Table 4). Results of that work were never formally reported, although discussions were held with the operations and maintenance agencies.

Between 1995 and 1997, PNNL researchers were involved in several other projects for the BPA concerning fish screens, including fish screen evaluations in Idaho, laboratory studies on the effects of various screen and bypass configurations on juvenile salmonids, and the effectiveness of underwater sound generators at guiding fish away from diversions (Abernethy et al. 1996; Neitzel et al. 1997; Mueller et al. 1998). In 1997, PNNL began evaluations of 19 new Phase II fish screen facilities in the Yakima River basin (Table 4; Figure 3). Objectives of the evaluations were to determine whether screen facilities were constructed, maintained, and operated to provide safe passage for juvenile salmonids. Their performance was assessed by measuring and comparing velocities in front of the screens and in the bypass to the designers' operating criteria and the NMFS criteria (NMFS 1995), as well as visual inspection of the site both above and below water. Evaluations were conducted three times a year as river flows changed, providing data on conditions across a range of canal flows. The first evaluation was generally conducted in April or May, during the juvenile salmon outmigration period. The second evaluation was in June/July, after river levels started to drop and water usage for irrigation increased. The

third evaluation was in September, before most sites were closed for the season and often coinciding with “flip-flop,” when water released from reservoirs on the Naches River replaced that from the now-depleted reservoirs on the upper Yakima River.

Table 4. Phase II Sites and Year of First Physical Evaluation

Site	Year First Evaluated
Kiona	1994 ^(a)
Naches-Cowiche	1994
Snipes-Allen	1994
Lower WIP	1994
Bachelor-Hatton	1994
Congdon	1994
Taylor	1994
Kelley-Lowery	1994
Gleed	1994
New Cascade	1994
Union Gap	1997
Bull Ditch	1997
Clark	1997
Ellensburg Mill	1997
Lindsey	1997
Toppenish Pump	1997
Naches-Selah	1997
Upper WIP	1997
Yakima-Tieton	1997
Fruitvale	1997
Younger	1999
John Cox	2000
Wilson Creek	2001
Powell-LaFortune	2001
Selah-Moxee	2004
Packwood	2004
Fogarty	2006
Old Union	2006
Not a Phase II site but evaluated with them	
Huntsville Mill	2005
(a) Kiona screens were removed in 1996.	

Variations in water conditions throughout the irrigation season, occasional maintenance or operational problems, and increasing efficiency in the evaluation techniques as better equipment became available led to continuing the evaluations three times each year. Between 1997 and 2006, an additional 9 new or never previously evaluated fish screen facilities were added to the list of sites, resulting in 27 sites in the Yakima and Touchet basins (Huntsville Mill; Figure 4) evaluated in 2006. The last Phase II fish screen was formally completed in 2006 and was added to the evaluation list at that time.

Annual reports documented observed conditions and any impacts on juvenile salmonids (Table 1). Phase II fish screen designs were found to be protective of juvenile salmonids, passing them safely back to the river. Problems were found with construction, maintenance, and operation at individual sites, but

the problems were not systematic or widespread. Problems that could be immediately harmful to fish were brought to the attention of either the WDFW or USBR, depending on which agency was responsible for maintenance of the site.

Figure 3. Phase II Fish Screen Facilities in the Yakima River Basin

Figure 4. Huntsville Mill Fish Screen Facility in the Touchet River Basin

Problems at Phase II sites tended to fall into one of three categories discussed below.

1. **Design.** Design problems were general or site-specific. For example, the only site with vertical traveling screens (Gleed) needs more protection from heavy debris than was allowed for in the design. Metal plates are necessary to protect Gleed's fish screens, and these metal plates perturb the flow, causing excessive water velocities (Chamness 2007). A usually minor but more general design problem is that most drum screens have a back eddy at the upstream corner where water curls around the piernose between screen bays, although the design criteria (NMFS 1995) call for uniform sweeping flow across the screen faces.
2. **Maintenance.** Issues related to woody debris, sediment accumulations, and periphyton buildup in screen openings was common in the first few years of Phase II evaluations. Because debris in front of the screens can cause velocity hot spots, provide shelter for predators, and cause excessive wear on drum screens and seals, these were noted as undesirable conditions. In-season feedback from underwater videography and velocity measurements gave WDFW and USBR the opportunity to correct the problems in-season instead of waiting until the end of the irrigation season when the water was drained from the sites. The WDFW in particular used this information to help it schedule the frequency of cleaning and maintenance and has worked hard to develop methods to keep sediment and debris to a minimum.
3. **Operation.** Issues related to how the irrigation district fulfills its responsibilities continue to arise on occasion. Generally it is each irrigation district's responsibility to control water through the facility within its water rights and within the site design criteria, and to remove debris from trash racks. Although varying from one irrigation district to another, most have agreements whereby WDFW or USBR provide general maintenance, including lubricating moving parts, keeping screens and seals in good condition, and flushing the sediment through the bypass when necessary. PNNL researchers found that there are several sites, such as Powell-LaFortune and Kelley-Lowry, where the irrigation district does not fulfill its responsibility, allowing excessive debris or sediment to accumulate. Operating procedures with clear information on the forebay elevations and bypass flow settings necessary for proper site function are not available at all sites, although some irrigation district personnel may carry a copy with them.

Conclusions

Fish screens in the Yakima River basin prior to 1985 were outdated and did not meet more recent criteria to safely and quickly divert juvenile salmonids back to the river. Phase I fish screen designs had several new components meant to be more protective of these smaller juvenile salmonids, and PNNL evaluations in 1985 gave facility designers the valuable feedback on the safety of different components of these large fish screen facilities. Not all sites function properly in the beginning; operations and maintenance personnel need time and information to determine how to most effectively operate and maintain each individual facility within its design criteria. Evaluations of Phase I and Phase II fish screen facilities were able to pinpoint any problems in design, construction, maintenance, or operation that could cause impingement or entrainment of juvenile salmonids, giving the WDFW and USBR operations and maintenance personnel feedback they needed. The two agencies, in turn, have responded differently to this

information. In general, the WDFW has been responsive and often proactive in keeping the sites operating effectively, while the USBR priorities lie with larger Phase I sites. The smaller Phase II sites are dealt with as required with limited remaining resources.

Information from these studies over 22 years has provided an independent check on design, construction, maintenance, and operations of fish screens, all of which are often funded by BPA. No counts are available on the number of juvenile salmonids that benefitted from the repairs and changes in operating conditions resulting from these evaluations, but there has undoubtedly been a net improvement in juvenile fish survival (relative to fish screening facilities) as a direct result of this evaluation program. A similar evaluation program of spot-checks on construction, operation, and maintenance of large and small fish screens installed in other basins and subbasins, whether by PNNL or another organization, can help ensure the sites function to protect juvenile salmonids.

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