R-03-02

A SURVEY OF SELECTIVE WITHDRAWAL SYSTEMS

May 2003

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

Denver Technical Service Center
Water Resources Services
Water Resources Research Laboratory
Denver, Colorado

Upper Colorado Region
Salt Lake City, Utah

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 2003	Final

4. TITLE AND SUBTITLE
A Survey of Selective Withdrawal Systems

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Bureau of Reclamation
Technical Service Center
Water Resources Research Laboratory
Denver, Colorado

Upper Colorado Region
Salt Lake City, Utah

8. PERFORMING ORGANIZATION REPORT NUMBER
R-03-03

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Same

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DIBR

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Selective withdrawal systems are commonly used to manage the quality of reservoir releases, as well as in-reservoir water quality. The type of selective withdrawal system chosen for a project is usually site-specific and requires detailed limnological studies and engineering analyses. A survey was prepared to gather basic design data and performance information on modern selective withdrawal systems constructed on large dams in the United States. Another survey objective was to update information for selected entries in a register of selective withdrawal works in the United States, compiled by the American Society of Civil Engineers in 1970.

14. SUBJECT TERMS
selective withdrawal systems, survey, reservoirs, water quality, hydraulics, turbines, maintenance, operation

15. NUMBER OF PAGES
15 + appendices

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UL	UL	UL	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

R-03-02

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

Mission Statements

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Federal Disclaimer

ACKNOWLEDGMENTS

This project was conducted by the Water Resources Research Laboratory (WRRL) in cooperation with Reclamation's Upper Colorado Regional Office and the Science and Technology Program. The survey was developed by Tracy Vermeyen, hydraulic engineer; Wayne Delzer, mechanical engineer; and Dennis Kubly, environmental specialist. Connie DeMoyer was responsible for constructing the survey database. Teri Manross was the editor for this report. Connie DeMoyer and Dennis Kubly peer reviewed this report.

The authors would like to acknowledge the survey respondents for taking the time to fill out the survey and supply data and drawings.

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PURPOSE

The purpose of this survey was to gather basic design data and performance information on modern selective withdrawal structures constructed on large dams in the United States. Another objective was to update information for selected entries in a 1970 register of U.S. selective withdrawal facilities compiled by the American Society of Civil Engineers (ASCE 1970). The Bureau of Reclamation and other members of the Glen Canyon Dam Adaptive Management Program will use survey results to evaluate the feasibility of adding selective withdrawal capability to Glen Canyon Dam.

PROJECT BACKGROUND

Prior to construction of Glen Canyon Dam, the Colorado River would warm seasonally, from near freezing to about 85 °F. Since construction of the dam, releases from the dam are consistently cold throughout the year (about 45-50 °F). Cold temperatures limit successful reproduction by warmwater native fish, cause thermal shock to larval native fish as they descend from warm tributaries into the Colorado River, decrease growth rates of the young fish, and render them more vulnerable to the variety of exotic predatory fish that now occupy the mainstem. The Fish and Wildlife Service (Service) concluded in a biological opinion (issued in December 1994) that the operation of Glen Canyon Dam jeopardizes the continued existence of two endangered fish, the razorback sucker (*Xyrauchen texanus*) and humpback chub (*Gila cypha*), and adversely modifies their critical habitats. The reasonable and prudent alternative of that biological opinion provides that Reclamation implement a selective withdrawal program and determine feasibility using stated guidelines.

While evaluating the potential impacts of selective withdrawal, Reclamation found that the majority of scientists involved with the project think that temperature control has been an effective tool at other dams and should aid in the management of the river below Glen Canyon Dam. There are complex ecological interactions that may occur between native and non-native fishes, but the working hypothesis, based on the Service's Reasonable and Prudent Alternative (RPA), is that warmer water will provide more advantages to the native fish than to the non-native fish. If it is deemed feasible and warranted, Reclamation proposes to modify the penstocks and test (confirm) this hypothesis directly. If successful, the selective withdrawal will be used as a permanent temperature management tool. Likewise, selective withdrawal may also be used to manage release water quality from Lake Powell in the future.

Reclamation developed several selective withdrawal system alternatives in a feasibility-level analysis (Reclamation 2000). However, uncertainties in project objectives and reservoir operations have resulted in the need for a more detailed analysis on the operational requirements for the proposed selective withdrawal structure. To gather information on how selective withdrawal systems (SWS) have performed on other dams, a survey was developed. Survey goals were to assemble data on SWS design, related studies, SWS performance and operational criteria, operation and maintenance requirements, and any required modifications to SWS or power generation equipment.

SELECTIVE WITHDRAWAL RELATED STUDIES

In the 1950s and 1960s, SWS were designed using limnological data collected from the reservoir of interest. Likewise, physical models were commonly used to study the hydraulic characteristics of the design and to optimize system performance. Over the last three decades, numerical model studies have been developed to assist with the design and evaluation of SWS, as well as to predict water quality for new and existing reservoirs. Furthermore, the National Environmental Policy Act of 1969 (NEPA) requires that environmental studies be conducted before selective withdrawal structures are constructed to determine the environmental benefits and impacts of the project. However, there have been relatively few post-SWS studies conducted to determine the impacts to downstream ecology. Table 1 summarizes the types of studies conducted for SWS projects that are considered comparable to the Glen Canyon Temperature Control Device (TCD). More detailed information on the studies and some references are included in appendix B.

Table 1.—Summary of selective withdrawal related studies

Water quality	Physical	Numerical	Environmental
Applegate	Hungry Horse	DeGray	DeGray
DeGray	Kinzua	Flaming Gorge	Flaming Gorge
Flaming Gorge	Libby	Folsom	Hungry Horse
Folsom	Lost Creek	Hungry Horse	Jordanelle
Hungry Horse	Oroville	Jordanelle	Kinzua
Jordanelle	Shasta	Lost Creek	Libby
Kinzua	Spring Creek Debris Dam	Oroville	Lost Creek
Libby	Stagecoach	RD Bailey	Shasta
Lost Creek		Shasta	Spring Creek Debris Dam
Oroville			Whiskeytown
RD Bailey			
Shasta			
Spring Creek Debris Dam			
Wynoochee			

SURVEY OVERVIEW

This survey was modeled after a 1970 survey that was used to develop ASCE's Register of Selective Withdrawal Works in the United States (ASCE 1970). Questions were added to gather information on contemporary applications of selective withdrawal, such as habitat restoration, endangered species recovery, and water quality enhancement. Likewise, questions were added related to selective withdrawal operations, pre- and post-construction environmental/water quality studies, selective withdrawal maintenance, and modifications. A copy of a blank survey is included in appendix A. It is important to note that this survey was not intended to be a comprehensive survey of all SWS in the United States. Projects were selected that appeared to have similar attributes to those proposed for Glen Canyon Dam or that might be useful for future SWS designs. The survey was also sent to most Reclamation projects with SWS to gather recent information on these facilities.

Nature of the Sites That Were Surveyed

Forty-six surveys were sent to Reclamation and non-Reclamation (mostly State and other Federal projects) facilities with selective withdrawal capabilities, and 40 of the surveys were completed. Of the 19 surveys sent to Reclamation facilities, 17 responded. Twenty-four surveys were sent to U.S. Army Corps of Engineers (COE) projects, and 20 responded. Three surveys were received from non-Federal projects. Table 2 is a list of survey respondents. Of the 40 survey responses, 16 had selective withdrawal systems that were considered comparable to those proposed for Glen Canyon Dam. Structures were deemed comparable if they were used for hydropower releases, had flow rates greater than 1,000 cubic feet per second (ft^3/s), and were designed for temperature/water quality control. The other 24 facilities used selective withdrawal for municipal and industrial deliveries, for purposes other than temperature/water quality control, or were not practicing selective withdrawal at the time of the survey.

Survey responses from all projects are summarized in appendix B. However, the analysis and presentation of results will emphasize comparable structures. Comparable projects are noted with an asterisk (*) in table 2.

Table 2.—Summary of survey respondents (projects marked with an asterisk (*) are considered comparable to Glen Canyon)

Project	SWS design organization
Alum Creek	COE
Applegate*	COE
Arbuckle	Reclamation
Beech Fork	COE
Burnsville	COE
Cheney	Reclamation
Deer Creek	COE
DeGray*	COE
Dworshak*	COE
East Lynn	COE
Fishtrap	COE
Flaming Gorge*	Reclamation
Folsom*	Reclamation
Fort Cobb	Reclamation
Foss	Reclamation
Grayson	COE
Green River	COE
Helena Valley	Reclamation
Hungry Horse*	Reclamation
Jordanelle*	Reclamation
Kingsley	Central Nebraska Public Power and Irrigation District
Kinzua*	COE
Libby*	COE
Lost Creek*	COE
Martinez	Reclamation
McPhee	Reclamation
Norman	Reclamation
Oroville*	CA-DWR
Paint Creek	COE
Paintsville	COE
RD Bailey*	COE
Sanford	Reclamation
Shasta*	Reclamation
Spring Creek Debris Dam*	Reclamation
Stagecoach	Reclamation
Sutton	COE
Whiskeytown*	Reclamation
Ritschard/Wolford Mountain	Colorado River Water Conservation District
Wynoochee*	COE (multi-outlets), Tacoma Power (temperature panels)
Yatesville	COE

SELECTED SURVEY RESULTS

Of the 40 survey responses received, 38 SWS were described as operational. Martinez Dam no longer operates their outlets for selective withdrawal, and Kingsley Dam operators reported no selective withdrawal capabilities.

Selective Withdrawal Purposes and Methods

The purpose of all SWS surveyed is to control release water temperature or other water quality parameters from a stratified reservoir. A summary of the SWS objectives is as follows:

- Temperature (32)
- Dissolved gas (17)
- Instream flows (8)
- Endangered species (salmon, trout, minnows, and suckers) (7)
- Turbidity (5)
- Habitat restoration (3)
- Acid mine drainage dilution (2)
- Supersaturated dissolved gas (1)
- Taste and odor (1)

Survey respondents for each project were asked to describe all available methods to selectively withdraw water from their reservoir. The available methods were reported as follows:

- Outlet works (33)
- Penstock intakes (11)
- Surface spillways (5)
- Spillway outlets (5)

Some projects reported 2 or 3 different withdrawal options. The location of selective withdrawal systems was as follows:

- Face of dam (18)
- Vertical towers (22)
- Inclined towers (2)

SWS discharge capacities were widely distributed, although most of the surveyed selective withdrawal structures deliver relatively low flows (table 3). In general, the low discharge capacity facilities (flows less than 2,500 ft^3/s) were designed for municipal and industrial water deliveries. Libby Dam, on the Kootenai River in Montana, reported the largest SWS discharge capacity (28,000 ft^3/s).

Table 3.—Distribution of SWS discharge capacities

Discharge capacity (ft^3/s)	No. of projects	Project name
2,500 or less	26	All remaining projects from table 1
5,000	2	Sanford, Flaming Gorge
7,500	5	Applegate, Dworshak, Degray, Kinzua, and Folsom
10,000	0	
12,500	2	Lost Creek, RD Bailey
15,000	1	Hungry Horse
17,500	1	Oroville
20,000	1	Shasta
22,500 to 27,500	0	
30,000	2	Libby
<30,000	0	

Selective Withdrawal System Operations

Fifteen survey responses indicated that downstream water quality goals are achieved by adjusting near-surface control gates. Eleven responses identified that flows from low-level outlets are increased or decreased to adjust downstream water quality. In other words, upper and lower level flows are blended to meet the water quality objectives. Eight projects use three or more gate levels, operated simultaneously, to blend the desired water quality. One project indicated that releases are mixed with other methods of release to attain the desired water quality.

Project operators were asked to estimate the effectiveness of their SWS in achieving the water quality goals (table 4). The average value for all projects was 88 percent compliance. Several projects mentioned that having a SWS allowed them the flexibility to meet multiple water quality objectives or to adapt to changes in project operations.

Table 4.—Frequency of achieving water quality goals for all projects

Projects (n=31)	Percent compliance
2	70%
4	80%
23	90%
1	99%
1	100%

Table 5 shows the responses from projects that are comparable to Glen Canyon Dam. Folsom Dam's release temperature objectives are set by a technical review committee that includes project operators, personnel from several State and Federal resources agencies, and members of public interest groups. Consequently, temperature and discharge goals vary from year to year and are not readily quantifiable.

Table 5.—Frequency of achieving water quality goals for comparable projects

80%	90%	99%	100%	Not applicable
Dworshak	Applegate	Libby	Wynoochee	Folsom
Hungry Horse	DeGray			
Kinzua	Flaming Gorge			
	Jordanelle			
	Lost Creek			
	Oroville			
	RD Bailey			
	Shasta			
	Spring Creek Debris Dam			
	Whiskeytown			

Responses regarding SWS operating seasons for projects comparable to Glen Canyon Dam show that the length of the SWS operating season is usually dictated by the temperature and/or water quality objectives, hydrology, water demands, and the period of reservoir stratification (table 6). For example, the Shasta TCD is operated year round to maximize the amount of cold water stored and to manage downstream river temperatures.

Table 6.—Operating seasons for comparable projects

All year	Spring-fall	Fall-summer	Depends on temperature requirements	No response
Applegate	Flaming Gorge	Spring Creek Debris Dam	Dworshak	Jordanelle
DeGray	Hungry Horse			
Folsom	Kinzua			
Lost Creek	Libby			
Shasta	Oroville			
	RD Bailey			
	Whiskeytown			
	Wynoochee			

The typical frequency of gate operations required for meeting release water quality targets depends on many site-specific factors, which will not be explained here. The majority of the responses were monthly gate changes. Table 7 summarizes the distribution of the frequency of gate operations for projects comparable to Glen Canyon. For these projects, weekly gate changes were most common.

Table 7.—Frequency of SWS gate changes for comparable projects

Daily	Weekly	Monthly	Rarely	As needed
Applegate	Flaming Gorge	Folsom Dam	DeGray	Kinzua
Dworshak	Hungry Horse	RD Bailey		Libby
Lost Creek	Jordanelle			Oroville
	Shasta			Spring Creek Debris Dam
	Wynoochee			Whiskeytown

Selective Withdrawal System Maintenance

Several questions (questions 32-38) were asked to determine the costs associated with SWS operations and maintenance. Detailed responses are included in appendix B. Typically, maintenance is required annually on moving parts and as required on structural components. The average estimated yearly *equipment* maintenance cost was $5,200 for all projects that responded. The average estimated yearly equipment maintenance cost from comparable projects was $10,700 (excluding Oroville, which responded with a $90,000 annual cost). The average estimated yearly *structural* maintenance cost was $8,400 for all projects that responded with a dollar value. The average estimated yearly equipment maintenance cost from the 10 comparable projects that responded was $7,500 (excluding Oroville, which responded with a $185,000 annual cost). The most common problems and repairs were as follows:

- Debris handling – higher debris load caught in bearing cooling water strainers
- Sinking and floating debris accumulating inside trashrack structure
- Debris booms are often ineffective at blocking small floating debris
- Increased number of wicket gate shear pin failures caused by woody debris

Selective Withdrawal Equipment Modifications

The last group of questions (questions 39-41) addressed modifications to selective withdrawal equipment. Only three projects reported any structural changes to their SWS, and only a couple of other projects suggested structural changes. The majority of responses (20) had suggestions on desired design improvements to the SWS. The responses were highly variable, so they will not be summarized here. Design suggestions are summarized later in this report. The majority of the responses (27) to a question on the utility of automating SWS gate operations indicated that it was not practical. The most common reason given for not automating the gates was that gate changes were too infrequent to justify the cost of automation.

Summary of Responses to Selected Questions About Operations, Maintenance, and Modifications

The second half of the survey (questions 21 to 41) was designed to gather information regarding SWS performance, operation and maintenance requirements, and modifications to the SWS or turbines. Responses from comparable projects are presented here; detailed responses from all projects are included in appendix B. If more detailed information is required, an Excel spreadsheet, containing all the survey responses and comments by the authors, can be obtained by sending an e-mail request to: tvermeyen@do.usbr.gov.

Question 21 - Nine projects reported that water quality requirements were modified. Responses from comparable projects are given in the following table.

Affirmative responses to Question 21. Were release water quality requirements modified after selective withdrawal began?

Applegate	In the past 5-6 years, a greater emphasis has been placed on maintaining discharge target temperatures, especially during critical fish periods.
Dworshak	Selective withdrawal was used originally for fish hatchery operation. Now, it is used for flow augmentation for salmon. Releases must also adhere to Idaho dissolved gas standards of 110%.

Affirmative responses to Question 21. Were release water quality requirements modified after selective withdrawal began?

Flaming Gorge	Requirements change, based on wet-year or dry-year hydrology. For example, for dry years, colder releases are requested because the lower volume of water warms more rapidly as it moves downstream. Conversely, during wet years, warmer releases are requested.
Folsom	Originally used for salmon only. Now used to also manage steelhead. Used more to manage in-river fish and less for hatchery fish.
Jordanelle	Secondary objective of temperature control was added to the primary objective of reducing phosphorous levels to control downstream algal blooms. Because reservoir conditions can change with different hydrology and different nutrient loading, selective withdrawal operations will need to be reviewed from time to time to see if any adjustments are needed.
Libby	Temperature curve was adjusted once.
Lost Creek	In the past 5-6 years, a greater emphasis has been placed on maintaining discharge target temperatures, especially during critical fish periods.
Oroville	Additional temperature constraints have been applied downstream of dam.

The majority of the responses (25) to questions 22 and 23 reported that project operators coordinate SWS operations with State or Federal resource agencies. Responses from comparable projects are given in the following table.

Affirmative responses to Questions 22 and 23. Do resource agencies inform the project manager of water quality violations? Which resource agency monitors downstream water quality? Do project personnel meet with the agency to plan efforts to achieve release water quality objectives?

Applegate	Yes. COE district office of water regulation and Oregon Department of Fish and Wildlife (ODFW) meet with project personnel about water quality compliance via phone calls/meetings during the water year, usually in spring (February-May).
Dworshak	Yes. Violations are reported to Reservoir Control Center (RCC) in Portland. Meetings about water quality compliance take place at the division level within USACE.
Flaming Gorge	Yes. Utah Division of Wildlife Resources and Fish and Wildlife Service are responsible for water quality monitoring. No meetings are held with project personnel about water quality compliance.
Folsom	Yes. National Marine Fisheries Service using Reclamation-funded gauging system. Meetings with project personnel about water quality compliance occur biweekly.
Hungry Horse	Yes. Montana Department of Fish, Wildlife and Parks (MDFWP) is the responsible agency for monitoring water quality. No meetings are held with project personnel about water quality compliance.
Jordanelle	Yes. Multi-agency Jordanelle Technical Advisory Committee. Watershed committee meets and reviews monitoring plan quarterly.
Kinzua	No. Meetings with project personnel about water quality compliance occur every few years.
Libby	Yes. MDFWP is the responsible agency for monitoring water quality. No meetings are held with project personnel about water quality compliance.
Lost Creek	Yes. COE district office of water regulation and ODFW meet with project personnel about water quality compliance via phone calls/meetings during the water year, usually in spring (February-May).
Oroville	Yes. Federal Energy Regulatory Commission (FERC). Meetings with project personnel about water quality compliance occur once per year during annual inspection.

Affirmative responses to Questions 22 and 23. Do resource agencies inform the project manager of water quality violations? Which resource agency monitors downstream water quality? Do project personnel meet with the agency to plan efforts to achieve release water quality objectives?

Shasta	Yes. State Water Quality Control Board and State and Federal fishery agencies. Central Valley Project operators meet regularly with various agencies regarding water quality compliance.
Spring Creek Debris Dam	Yes. State Water Quality Control Board and State and Federal fishery agencies. Central Valley Project operators meet regularly with various agencies regarding water quality compliance.
Stagecoach	No. Water quality monitoring occurred initially from 1989-1990. Meetings with project personnel about water quality compliance occur occasionally with Colorado Division of Wildlife.
Sutton	Yes. Resource agencies and COE monitor downstream for violations. No meetings were reported.
Whiskeytown	Yes. State Water Quality Control Board and State and Federal fishery agencies. Central Valley Project operators meet regularly with various agencies regarding water quality compliance.
Wynoochee	Yes. COE monitors for water quality violations. No meetings are held with project personnel about water quality compliance.

The majority of the responses (27) to Question 24 reported NO changes to project selective withdrawal operating criteria. Responses from comparable projects that reported changes are given in the following table.

Affirmative responses to Question 24. Were modifications made to the project operating criteria after installation of the selective withdrawal equipment?

Applegate	Originally, the intake tower ports were intended to be fully open or fully closed. Improvements were made to remotely select incremental gate openings to achieve better temperature control.
Folsom	Blending, more frequent changes, changes to manage for steelhead, and structural modifications.
Hungry Horse	Bearing cooling water alarm set points were raised. Higher temperature-rated bearings were installed during unit overhaul. A 30-foot submergence requirement was added to Standard Operating Procedures (SOP) for unit startup.
Jordanelle	SOP required top selective withdrawal gate to remain fully open. Top gate is now closed after about mid-September to avoid discharging phytoplankton. New operational criteria include flow and velocity past gates.
Lost Creek	Originally, the intake tower ports were intended to be fully open or fully closed. Improvements were made to remotely select incremental gate openings to achieve better temperature control.
Spring Creek Debris Dam	Various issues regarding the dilution of acid mine drainage were addressed.

The majority of the responses (29) to Question 25 reported NO changes to project selective withdrawal system to correct for design deficiencies or unforeseen hydraulic conditions. Responses from comparable projects that made changes are given in the following table.

Affirmative responses to Question 25. Were any modifications made to the selective withdrawal structure to correct for design deficiencies, unforeseen hydraulic conditions, or an inability to meet water quality objectives?

Flaming Gorge	Trashracks were placed on the TCD structures after installation because woody debris piled up against the old trashracks.
Folsom	Shutter configuration modified for better coldwater pool management.
Hungry Horse	Replaced pressure relief gate shear pins with stronger pins to reduce number of failures.
Jordanelle	A maximum allowable velocity past each partially open gate was implemented.
Lost Creek	External temperature probes were installed to replace the corroded original in-place piping.
Shasta	Areas of warmwater leakage, due to gaps in construction and fabrication, were corrected by design/fabrication modifications and installed by divers 1 year after initial construction was completed.
Spring Creek Debris Dam	Louvers were added, and trashracks were improved. Original trashracks had larger spacing, and there were no louvers.

The majority of the responses (24) to Question 26 reported NO hydraulic problems associated with the SWS. Responses from comparable projects that reported hydraulic problems are given in the following table.

Affirmative responses to Question 26. Describe any hydraulic problems requiring special attention.

Dworshak	Minimum submergence is greater than 30 ft, as specified in original design.
Flaming Gorge	Wicket gate shear pin failures increased, due to debris associated with surface withdrawal. Debris built up around the lower gate has likely caused more head loss. Operators maintain 50-ft submergence on the control gate to eliminate vortices, since surface circulation has been observed for 40-ft submergence. Bearing cooling water gets too warm during selective withdrawal operations when the release temperatures are higher than 50 to 55 °F.
Folsom	Head required to prevent turbine cavitation limits the use of shutters.
Hungry Horse	Submergence of 30-32 ft was found to limit debris accumulation in cooling water strainers. A minimum submergence of 30 ft was added to SOP for unit startup.
Kinzua/Allegheny	The selective withdrawal system is not operated on the same side of the operating tower as the main gate openings to avoid drawdown of the wet well, which could cause vibration.
Libby	Because of vortex formation, 30 ft submergence is required.
Lost Creek	During high flows through the regulating outlets (approximately 9,000 ft^3/s), the access hatch came loose, due to excessive vibrations when increasing flows went through the transition zone. Current restrictions require flows to be generally less than 7,000 ft^3/s through river outlets. Lake differential alarms if wet well draws down lower than the lake elevation, due to outlet flows greater than adequate inlet port openings. A minimum of 5 ft of submergence is recommended for uppermost inlet ports on tower.
Oroville	Intake vortices occur at El. 640, thus restricting operations below that elevation. A system was designed to eliminate water hammer due to leakage.
Shasta	Minimum number of gate openings required for proper hydraulics and pressures on structure. Operating criteria specifies number of openings and combination of openings versus reservoir elevation. More debris gets into turbines, causing more breaking of wicket gate shear pins.
Spring Creek Debris Dam	Operating criteria requires 5 ft of submergence for intakes to avoid debris entering the louver or intake opening and to prevent vortex formation.

Affirmative responses to Question 26. Describe any hydraulic problems requiring special attention.	
Whiskeytown	At maximum outlet releases, bifurcation to city of Redding's hydroplant and Clear Creek Communities Service District need to be shut down to prevent Venturi effects.
Wynoochee	Hydraulic problems have occurred but were not described.

The majority of the responses (35) to Question 27 reported NO or N/A to changes in turbine operations. Responses from comparable projects that reported changes to turbine operations are given in the following table.

Affirmative responses to Question 27. After installation of the selective withdrawal system, was it necessary to modify turbine unit operation to meet water quality requirements?	
Hungry Horse	Governor timing was changed from 8 to 20 seconds for water hammer prevention. Total dissolved gas increased, and monitoring is now required to prevent water quality violations.
Kinzua	Gate operation was changed to keep sediment from the downstream channel bed from entering the stilling basin to reduce concrete damage to basin.
Shasta	Hydraulics and temperature leakage require the use of units close to side gates during side gate operations to achieve temperature requirements.
Wynoochee	When temperature panels are used, turbine flow is limited by net panel opening.

The majority of the responses (36) to Question 28 reported NO or N/A to changes in turbine operations for water hammer, or pressure drop during unit startup. Responses from comparable projects with water hammer problems are given in the following table.

Affirmative responses to Question 28. Was it necessary to modify turbine unit operations to lessen the effects of water hammer and/or pressure drops?	
Flaming Gorge	Monitoring of shear pin failures.
Hungry Horse	Governor timing was changed, due to different water hammer conditions, and 30-ft submergence requirement was added for SOP for unit startup.

The majority of the responses (33) to Question 29 reported NO or N/A to adding or modifying turbine equipment. Responses from comparable projects that modified turbine equipment are given in the following table.

Affirmative responses to Question 29. Was it necessary to add or modify turbine equipment?	
Hungry Horse	Enlarged secondary strainers were added on bearing cooling water supply lines to filter pollen and pine needles. The strainers now require daily inspection. Cooling water temperature alarm set points were raised because cooling water temperatures were increased, due to withdrawal of surface water.
Lost Creek	External temperature probes were installed to replace the corroded original in-place piping.
Oroville	Trashracks were replaced, due to a vibration problem. Temperature monitoring equipment was added.
Shasta	Wicket gate shear pins break about once per year. Bearing cooling water strainers were often plugged until frequent flushing was routine. Temperature monitoring equipment was installed on all five penstocks.

The majority of the responses (36) to Question 30 reported NO or N/A. Responses from comparable projects that have uprated turbines are given in the following table.

Affirmative responses to Question 30. Since installation of the selective withdrawal system, have any of the turbines been uprated after selective withdrawal installation? Were there any impacts on selective withdrawal?

Flaming Gorge	Generators have been uprated, runners are planned in the future (FY03-FY05). No impact on selective withdrawal.
Libby	Turbine uprated from 100 MW to 120 MW by rewind and improved insulating properties. No impact on selective withdrawal.
Shasta	Units 3, 4, and 5 were uprated from 105 MW to 125 MW from 1998-2001. Units 3, 4, and 5 are going to be 142 MW with new turbines. Governors may have to be adjusted for water hammer, but the new turbines use only slightly more water. Most of the power gain is due to higher efficiency at approximately the same flow.

The majority of the responses (33) to Question 31 reported operating their selective withdrawal facility from Spring to Fall. Responses from comparable projects are given in the following table.

Responses to Question 31. Specify the beginning and ending months of the normal operating season for the selective withdrawal facility.

All year (4)	Spring-fall (8)	Fall-summer	Depends on project requirements	No response
Applegate	Flaming Gorge	Spring Creek Debris Dam	Dworshak	Jordanelle
DeGray	Hungry Horse			
Folsom	Kinzua			
Lost Creek	Libby			
Shasta	Oroville			
	RD Bailey			
	Whiskeytown			
	Wynoochee			

The majority of the responses (16) to Question 32 reported that scheduled maintenance on hoists, gates, or other moving parts occurs monthly; 8 projects reported semi-annual maintenance; and 11 reported annual maintenance.

The majority of the responses (33) to Question 33 reported that equipment is repaired or replaced as needed. Comments from comparable projects are given in the following table.

Comments on Question 33. How often is equipment repaired or replaced?

Hungry Horse	One or two pressure relief panels and approximately six relief panel shear pins are replaced during annual maintenance.

The average estimated yearly *equipment* maintenance cost requested in Question 34 was $5,200 for all projects that responded. The average estimated yearly equipment maintenance cost from comparable projects was $10,700 (excluding Oroville, which responded with a $90,000 annual cost).

Responses to Question 34. What is the estimated yearly *equipment* maintenance cost?	
All Projects	Average cost was $5,200 for 29 projects
Comparable Projects	Average cost was $10,700 for 12 projects
Oroville	Annual cost was $90,000

Responses to Question 35 were mostly directed toward structural inspection schedules, instead of the frequency of equipment repair or replacement. However, 16 projects indicated that structural repairs are made as needed.

The average estimated yearly *structural* maintenance cost requested in Question 36 was $8,400 for all projects that responded with a dollar value. The average estimated yearly equipment maintenance cost from the 10 comparable projects that responded was $7,500 (excluding Oroville, which responded with a $185,000 annual cost).

Responses to Question 36. What is the estimated yearly structural maintenance cost?	
All Projects	Average cost was $8,400 for 13 projects
Comparable Projects	Average cost was $7,500 for 10 projects
Oroville	Annual cost was $185,000

The majority of the responses (33) to Question 37 reported NO or UNKNOWN to increased maintenance requirements downstream from the selective withdrawal system. Yes responses from comparable projects are given in the following table.

Affirmative responses to Question 37. Have maintenance requirements increased for equipment downstream of the selective withdrawal equipment?	
DeGray	Maintenance costs are increasing with aging facility and inflation at approximately 5% annually.
Flaming Gorge	Repair and replacement needed on wicket gate shear pins. Operators keep records for work orders associated with the selective withdrawal system. Debris is accumulating inside the trashrack structure and will need to be removed in the near future.
Hungry Horse	Increased strainer cleaning on bearing cooling water supply. Replace broken wicket gate shear pins (about 12 per year).
Libby	Debris handling changed slightly.
Shasta	More frequent cleaning of strainers for bearing cooling water. Replaced screens in strainers. To stop frequent clogging of strainers and frequent replacement of shear pins, a 42-inch-diameter grating was made to protect the taps to station service units.
Spring Creek Debris Dam	Spring Creek Pumping Plant must run continuous low flow (6-8% wicket gate from the debris dam). After 10+ years of this operation, cavitation has been detected on the curb and crown where the small gate opening water exits. Unknown cost. Minimum: 4 personnel/4 weeks work; maximum: remove turbine.

The majority of the responses (29) to Question 38 reported NO. Responses from comparable projects are given in the following table.

Affirmative responses to Question 38. Have there been any in-reservoir debris problems attributed to selective withdrawal operation?

Flaming Gorge	Sinking debris increased wicket gate shear pin failures. Debris collects in the trashracks (both selective withdrawal and penstock intake) at the bottom of the structure. Floating debris is cleared from around and inside the intake in the spring and fall. Currently, there is no debris boom in the forebay, but one is budgeted for in FY07.
Folsom	Debris that accumulates while the shutters are in the raised position prevents the shutters from being fully lowered. Putting the shutters in the down position as soon as the coldest water is no longer needed minimizes this.
Hungry Horse	Debris accumulation around the intake structure. However, no reported problems of debris accumulation between trashracks and control gates.
Kinzua	Some minor sand and gravel piles have accumulated in the structure.
Libby	From time to time, a stick will make it hard to set picking beam for gate retrieval.
RD Bailey	Reservoir debris problems have been reported.
Shasta	Debris boom actually seems to corral and keep debris, rather than stopping it. Much debris collects on and in the selective withdrawal system. It was cleaned twice by hand. Potential future problem of waterlogged debris buildup on the floor of the selective withdrawal system, which may migrate down the penstock.
Spring Creek Debris Dam	Sloping intake is designed to be gradually buried by silt. However, the buried part leaks water into the discharge conduit, producing poor water quality. Extreme problem to dig up and seal the sloping intake under the silt.

The majority of the responses (32) to Question 39 reported NO to any improvements made to the selective withdrawal system. Responses from comparable projects are given in the following table.

Affirmative responses to Question 39. Were any improvements made to the selective withdrawal equipment to make it more efficient and/or to reduce maintenance costs?

Flaming Gorge	A trap door was suggested, to assist in cleaning out debris from structure.
Folsom	Shutters were reconfigured to 4-2-3 design from original 7-1-1 design.
Hungry Horse	There are plans to automate the control gates. There are times when submergence less than 30 ft is needed to meet temperature goals, but SOP restrictions of 30-ft submergence on startup prevent the use of lower submergences.
Lost Creek	External temperature probes were installed to replace the originals located in in-place piping.
Oroville	Replaced the hoist and crane controls with new, electronic programmable controls.
Spring Creek Debris Dam	Louvers and improved trashracks in late 1970s improved operation by better controlling the selectivity.

The majority of the responses (20) to Question 40 reported YES to desired design improvements to the selective withdrawal system. Responses from *all* projects are given in the following table.

Affirmative response to Question 40. How could the design of the selective withdrawal system be modified to make the operation of the equipment easier, more convenient, or less costly?

Alum Creek	Installation of dual wet wells.
Deer Creek	Redesign, due to pool elevation increase.
Dworshak	Need a way to pull out water in the middle of the gate, instead of only "overshot" or "undershot."
East Lynn	Installation of dual wet wells.
Fishtrap	Installation of dual wet wells.
Folsom	Cannot access the bottom 50,000 acre-ft of storage without bypassing the turbines. Continuous selectivity, rather than large increments, would be more efficient. System needs automation, since three people are needed to make shutter changes. A hoist for each shutter bank would require fewer personnel to operate but would require more maintenance.
Grayson	Installation of dual wet wells.
Green River Lake	An increase of outflow capacity would significantly increase the use of the system in the spring.
Hungry Horse	Install a programmable logic controller to position the control gates to meet downstream temperature requirements and submergence criteria.
Kinzua/Allegheny	Remote-control discharges.
Libby	Many improvements are needed.
Lost Creek	System may be improved by having inlet ports at staggered elevations.
McPhee	Selective level outlet works could have been eliminated from the project.
Oroville	Simple designs last longer. Address all the variables at the design stage. Physical models greatly assist in visualizing future problems.
Paint Creek	Installation of dual wet wells.
Paintsville	Fewer problems with equipment.
Sanford/Lake Meredith	Use stainless steel components.
Shasta	Remove or change gate jam hardware. Redesign electrical system for power and control. Redesign gate hoist cable systems.
Spring Creek Debris Dam	Change hoist arrangement for moving blocks/louvers. Make major changes in louvers and blocks with the goal of producing a tight shutoff when closed.
Sutton	Additional intakes are needed.
Wynoochee	Automatic trash rake instead of manual debris removal annually.

The majority of the responses (27) to Question #41 reported NO to automating gate operations. The most common reason for not automating the gates was that gate changes were too infrequent to justify automation. YES responses from comparable projects are given in the following table.

Affirmative responses to Question 41.

Project name	Is automation of the gate operations desirable?	Is automation cost effective?
Dworshak	Yes.	Yes, it would save operator time.
Folsom	Yes, but automated operation could mean lack of oversight of equipment condition and possible greater unavailability.	Unknown.
Hungry Horse	Yes, automating the process of taking the system on- and off-line would save a lot of effort, but this is a complicated task and may not be suited for automation.	Unknown.
Libby	Yes.	No, it would be too expensive.

Affirmative responses to Question 41.

Lost Creek	Yes, the system is already automated. There is a greater selection of inlet port settings within the range of the opening. Prior to automation, personnel jogged gates at the tower. Remote incremental changes are now made from the control room.	Yes.
Oroville	Yes.	Yes, it would save operator time.
Shasta	Yes. The original design was intended for automation, but because problems still occur with gate operations in manual modes, automation has not been installed.	Unknown.

REFERENCES

Bureau of Reclamation, *Glen Canyon Dam Temperature Control Device - Report on Design Alternatives,* Technical Service Center, Denver, CO, December 4, 2000.

ASCE Task Committee on Outlet Works, Register of Selective Withdrawal Works in United States, Journal of Hydraulics Division, Proceedings of the American Society of Civil Engineers, Vol. 96, No. HY9, September, 1970

APPENDIX A
SURVEY FORM

As part of the design, construction, and operation of the proposed Glen Canyon Temperature Control Device, or TCD, we have assembled this questionnaire to research how various existing selective withdrawal facilities are operated.

Please fill out the following information, and return either by e-mail, to tvermeyen@do.usbr.gov or mail to Tracy Vermeyen, D-8560, Technical Service Center, Bureau of Reclamation, Denver, CO 80225, by April 5, 2002.

Questionnaire filled in by (name, agency, phone number, e-mail address):

____

____

Project Background:

1. Name of Dam/Reservoir:__________________ Date Built:__________________

2. Project Purpose (check all that apply):
( ) Power ( ) Municipal/Industrial Water Supply ( ) Irrigation
( ) Fish Propagation ( ) Recreation ( ) Navigation
( ) Flood Control ( ) Low Flow Augmentation ( ) Reservoir Drawdown
( ) Other__________________

3. Location: River __________________ State:__________________

4. Type of dam:
( ) Gravity ( ) Earth/Rock ( ) Earthfill ( ) Rockfill
( ) Variable Radius Arch ( ) Hydraulic Fill ( ) Other __________________

5. Height of dam (indicate in feet or meters):__________________

6. Selective withdrawal system status (check one): ( ) Design, ( ) Construction,
( ) Operational. If not operational, expected completion date? __________________

7. Organization responsible for selective withdrawal design: __________________
____

8. Purposes of selective withdrawal (check all that apply):
( ) Temperature ( ) Dissolved oxygen ( ) Turbidity
( ) Endangered species [please list the species below] ( ) Habitat restoration
( ) Instream flow requirements ( ) Supersaturated dissolved gas
( ) Other __________________
Endangered Species__________________

9. Briefly describe all available methods to selectively withdraw water from the reservoir:
( ) Outlet Works ( ) Penstock Intakes ( ) Spillway (Surface)
( ) Spillway (Outlets) ( ) Intake Tower
( ) Other (short description) __________________

10. Location of selective withdrawal intakes (check all that apply):
( ) Face of dam ( ) Vertical tower ( ) Inclined tower
( ) Face of powerhouse ( ) Other (please describe)______________________________
____

11. Selective withdrawal gates and/or valves:

Type:	Size:	Quantity:
(1)________________	________________	________________
(2)________________	________________	________________
(3)________________	________________	________________

12. Selective withdrawal discharge range: ______________ ft^3/s to ______________ ft^3/s

13. Was a reservoir water quality or limnology investigation completed? (check all that apply)
( ) Before construction ( ) After construction ( ) No study

14. Were physical model (scaled model) or numerical model studies conducted? (check all that apply)
( ) Physical ( ) Numerical ( ) Other__________________________
Please provide the date and title of report, name of author, name of agency, etc.
____

15. Have there been any environmental studies performed which examined changes to the downstream river ecology after the selective withdrawal equipment was operational?
( ) Yes ( ) No If yes, please give any references (date and title of report, name of author, name of agency, etc.).____
____

16. If available, please provide drawings showing general plan, profile, and section of the selective withdrawal structure(s). Please send to mailing address listed at the beginning of the questionnaire.

17. Please provide contact information for the office or individual who can be reached for additional information on this project:____
____

Selective Withdrawal System Operation:

18. What operating criteria are used to obtain desired downstream water quality?
( ) Downstream water quality goals are achieved by repositioning upper level control gates.
( ) Flows are increased/decreased from low-level outlets to adjust downstream water quality (in other words, are upper and lower level flows blended to meet the water quality objectives)
( ) Three or more gates operated simultaneously to blend the desired water quality.
( ) Selective withdrawal releases are mixed with other methods of release to attain the desired water quality.
( ) Other (please describe)____
____

19. Please estimate how often release water quality requirements are met. ( ) 10%, ( ) 20%, ( ) 30%, ( ) 40%, ( ) 50%, ( ) 60%, ( ) 70%, ( ) 80%, ( ) 90% ( ) 100%

20. How often must gate changes be made to meet release water quality targets?
( ) Hourly, ( ) Daily, ( ) Weekly, ( ) Monthly, ( ) Other______________________________

____

21. Have the release water quality requirements been modified after the selective withdrawal equipment was put into service? ( )Yes or ( ) No. If yes, briefly describe how:

____

____

22. Do resource agencies inform the project manager of water quality violations?
( ) Yes ( ) No. If yes, which resource agencies are monitoring the downstream water quality?

____

____

23. Do project personnel meet with the agency in charge of water quality compliance to plan efforts to achieve the release water quality objectives? ( ) Yes ( ) No. If yes, how often do they meet?

____

____

24. Were the project's design operating criteria changed after installation of the selective withdrawal equipment to address selective withdrawal operation issues? ( ) Yes ( ) No. If yes, what changes were made?____

____

25. Were any modifications to the selective withdrawal structure required to correct design deficiencies, unforeseen hydraulic conditions, or inability to meet water quality objectives (for example, development of vortices or problems with turbines or related equipment)?
( ) Yes ( ) No. If yes, what modifications were made? ____________________________

____

26. Provide a short description of any hydraulic problems requiring special attention, if any (for example: intake vortices, turbine vibration, excessive head loss, cavitation, water hammer, etc.)
( ) Yes ( ) No. If yes, what operating restrictions have been put in? ________________

____

27. After installation of the selective withdrawal system, was it necessary to modify turbine unit operation so as to not impact release water quality (i.e., reduced peaking flows, reduction of maximum flow rates)?____

____

28. After installation of the selective withdrawal system, was it necessary to modify turbine unit operation so as to lessen the effects of (1) waterhammer due to load rejection, (2) pressure drop within the selective withdrawal equipment due to ramping-up of the turbine units during startup or return to synchronous operation? ____

____

29. After installation of the selective withdrawal system, was it necessary to add or modify turbine equipment, such as requiring larger bearing cooling water strainers, modifying trashracks, changing governor settings, adding temperature monitoring equipment, etc?
( ) Yes ( ) No. If yes, what changes have been made?______________________________

____

30. Since installation of the selective withdrawal system, have any of the turbines been uprated? ( ) Yes ( ) No. If yes, has this impacted selective withdrawal operations? ________________

____

31. Specify the beginning and ending months of the normal operating season for the selective withdrawal facility. ( ) Jan ( ) Feb ( ) Mar ( ) Apr ( ) May ( ) Jun ( ) Jul ( ) Aug ( ) Sep ( ) Oct ( ) Nov ( ) Dec

Maintenance requirements for selective withdrawal equipment:

32. How often is regularly scheduled maintenance performed on hoists/gates/other moving parts? ( ) Daily ( ) Weekly ( ) Biweekly ( ) Monthly ( ) Bimonthly ( ) Quarterly ( ) Semiannually ( ) Annually ( ) Other________________

33. How often is equipment repaired or replaced? ( ) Monthly ( ) Bimonthly ( ) Quarterly ( ) Semiannually ( ) Annually ( ) Other________________

34. What is the estimated yearly equipment maintenance cost? ________________

35. How often are fixed or structural parts maintained, repaired, or replaced? ( ) Monthly ( ) Bimonthly ( ) Quarterly ( ) Semiannually ( ) Other__________

37. Have maintenance requirements increased for equipment downstream of the selective withdrawal equipment (e.g., turbines, gates or valves, penstocks, piping, debris handling) since selective withdrawal operations began? ( ) Yes ( ) No. If yes, how, and what is the estimated yearly increase in cost? ________________

____

38. Have there been any in-reservoir debris problems attributed to selective withdrawal system operation? ( ) Yes ( ) No. If yes, please describe the problems.

____

____

Changes to selective withdrawal equipment:

39. Were any improvements made to the selective withdrawal equipment to make it more efficient and/or to reduce maintenance costs? ( ) Yes ( ) No. If yes, please describe the changes.________________

____

40. How could the design of the selective withdrawal equipment be changed to make the operation of the selective withdrawal equipment easier, more convenient, more effective, or less costly?

____

____

41. Would automating the gate operations at your facility be desirable? ( ) Yes ( ) No. If yes, would this be a cost-effective effort? ( ) Yes ( ) No. Why or why not?________________

____

Control No. ____________

APPENDIX B
DETAILED SURVEY RESPONSES

List of Tables

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Table B1.—Summary of project, purpose, location, and design data

Question	1	2	3	4	5
Dam/reservoir	Date of completion	Purpose of project	Location (river, State)	Type of dam	Dam height (ft)
Alum Creek	1976	Flood control, water supply, recreation, fish and wildlife	Alum Creek, OH	Rolled earthfill/concrete gravity channel section	93
Applegate	1980	Power, M&I water supply, irrigation, recreation, flood control, low flow augmentation, fish and wildlife	Applegate River, OR	Earth/rock	242
Arbuckle Lake	1966	Flood control, recreation, M&I water supply	Rock Creek, OK	Earthfill	142
Beech Fork	1978	Flood control, recreation, fish and wildlife	Beech Fork, WV	Rolled earthfill	88
Burnsville	1978	Flood control, recreation, fish and wildlife, low flow augmentation	Little Kanawha River, WV	Rockfill with impervious core	89
Cheney	1965	Municipal water supply, flood control, recreation	N. Fork of Ninnescah River, KS	Earthfill	86
Deer Creek	1968	Flood control, recreation, fish and wildlife	Deer Creek, OH	Rolled earthfill/concrete gravity channel section	93
DeGray	1971	Power, M&I water supply, flood control, irrigation, recreation, navigation, water supply	Caddo River, AR	Earthfill	243
Dworshak	1973	Power, flood control, recreation, navigation, low flow augmentation	N. Fork of Clearwater River, Idaho	Gravity	717
East Lynn	1971	Flood control, recreation, fish and wildlife	East Fork Twelvepole, WV	Rolled earthfill	113
Fishtrap	1968	Flood control, recreation, fish and wildlife, low flow augmentation	Levisa Fork, KY	Rockfill with impervious core	195
Flaming Gorge	1963, SWS installed 1978	Irrigation, power, flood control, recreation, fish and wildlife	Green River, UT	Concrete arch	455
Folsom	1955, SWS installed 1963	M&I water supply, power, irrigation, navigation, flood control, fish and wildlife, recreation	American River, CA	Gravity	268

Table B1.—Summary of project, purpose, location, and design data (continued)

Question	1	2	3	4	5
Dam/reservoir	Date of completion	Purpose of project	Location (river, State)	Type of dam	Dam height (ft)
Fort Cobb	1959	Flood control, recreation, M&I water supply, irrigation	Cobb Creek, OK	Earthfill	101
Foss	1961	M&I water supply, flood control, recreation	Washita River, OK	Earthfill	139
Grayson	1968	Flood control, recreation, fish and wildlife, low flow augmentation	Little Sandy River, KY	Earth and randon rockfill with impervious core	120
Green River	1965	Flood control, M&I water supply, recreation, low flow augmentation	Green River, KY	Earth/rock	143
Helena Valley	1958	M&I water supply	MT (off stream)	Earthfill	75
Hungry Horse	1948-52	Power, flood control	S Fork of Flathead River, MT	Variable radius arch	565
Jordanelle	1994	Power, M&I water supply, flood control, irrigation, recreation, low flow augmentation, fish and wildlife, reservoir drawdown, phosphorus TDML	Provo River, UT	Earth/rock	296
Kingsley/Lake McConaughy	1939	Power, recreation, irrigation	North Platte, NE	Rockfill	162
Kinzua/Allegheny	1965	Power, fish and wildlife, flood control, M&I water supply, recreation, low flow augmentation, navigation, reservoir drawdown	Allegheny River, PA, NY	Gravity, earthfill	177
Libby	1975	Power, flood control, recreation	Kootenai River, MT	Gravity	422
Lost Creek	1976	Power, M&I water supply, irrigation, recreation, flood control, low flow augmentation, fisheries enhancement	Rogue River, OR	Earth/rock	327
Martinez Dam	1947	M&I water supply	Off stream, CA	Earthfill	42
McPhee	1984	Power, flood control, M&I water supply, recreation, irrigation	Dolores River, CO	Earth/rock	274
Norman	1965	M&I water supply, recreation, flood control	Little River/Hog Creek, OK	Earthfill	144
Oroville	1967	Power, recreation, flood control, irrigation, water storage	Feather River, CA	Earthfill	770
Paint Creek	1974	Flood control, recreation, fish and wildlife	Paint Creek, OH	Earth/rock embankment	118

Table B1.—Summary of project, purpose, location, and design data (continued)

Question	1	2	3	4	5
Dam/reservoir	Date of completion	Purpose of project	Location (river, State)	Type of dam	Dam height (ft)
Paintsville	1983	Flood control, recreation, fish and wildlife, low flow augmentation	Paint Creek, KY	Rockfill with central impervious core	160
RD Bailey	1980	Flood control, recreation, fish and wildlife, low flow augmentation	Guyandot River, WV	Rockfill with concrete face	310
Sanford/Lake Meredith	1965	M&I water supply, flood control	Canadian River, TX	Earthfill	200
Shasta	1938-44	Power, fish and wildlife, flood control, M&I water supply, recreation, low flow augmentation, irrigation, navigation, reservoir drawdown	Sacramento River, CA	Gravity	525
Spring Creek Debris Dam	1963	Water quality	Spring Creek, CA	Earthfill	169
Stagecoach	1989	Power, M&I water supply, irrigation, fish and wildlife, recreation, flood control	Yampa River, CO	Gravity, RCC	140
Sutton	1959	Flood control, recreation, fish and wildlife	Elk River, WV	Concrete gravity	210
Whiskeytown	1963	Power, flood control, recreation, fish propagation, M&I water supply	Clear Creek, CA	Earthfill	252
Ritschard/Wolford Mountain	1993-95	M&I water supply, recreation, low flow augmentation, irrigation	Muddy Creek, CO	Earthfill	138
Wynoochee	1972	Power, fish and wildlife, flood control, M&I water supply, recreation, low flow augmentation	Wynoochee River, WA	Gravity, earth/rock	172
Yatesville	1991	Flood control, recreation, fish and wildlife, low flow augmentation	Blaine Creek, KY	Rockfill with central impervious core	108

Table B2.—Summary of selective withdrawal purpose and design information

Question	7	8	9	10	12
Dam/reservoir	Purpose(s) of SWS system	Design agency	Selective withdrawal method	SWS intake location	SWS discharge capacity (ft^3/s)
Alum Creek	Temperature, DO	COE	Spillway, sluice gates, and the outlet works	Face of dam	600
Applegate	Temperature, turbidity, instream flow requirements	COE - Portland District	Intake tower - water is discharged to a regulating outlet works	Vertical tower	1,000
Arbuckle Lake	Temperature, DO	Reclamation	Outlet works, spillway (outlets), intake tower	Vertical tower	35
Beech Fork	Temperature, DO	COE	Spillway, sluice gates, SW system outlet works	Vertical tower	430
Burnsville	Temperature, DO	COE	Spillway, sluice gates, SW system outlet works	Face of dam	450
Cheney	Taste/Odor	Reclamation	Municipal outlet works, river outlet works	Vertical tower	75
Deer Creek	Temperature	COE	Spillway, sluice gates, SW system outlet works	Face of dam	255
DeGray	Temperature, instream flow requirements	COE - Vicksburg District	Outlet works, penstock intakes, intake tower	Vertical tower	6,700
Dworshak	Temperature	COE - HDC Portland	Penstock intakes, spillway (surface), spillway (outlets)	Face of dam	6,000
East Lynn	Temperature, DO	COE	Spillway, sluice gates, SW system outlet works	Vertical tower	159
Fishtrap	Temperature, DO	COE	Spillway, sluice gates, SW system outlet works	Vertical tower	840
Flaming Gorge	Temperature, endangered species (native sucker species), habitat restoration, instream flow requirements	Reclamation	Outlet works, penstock intakes, surface spillway	Face of dam	4,800
Folsom	Temperature, endangered species: salmon (proposed) and steelhead (threatened)	Reclamation	Penstock intakes	Face of dam	7,500
Fort Cobb	Instream flow requirements, M&I, flood control	Reclamation	Outlet works, spillway (outlets)	Face of dam	35
Foss	Temperature, turbidity	Reclamation	Outlet works, penstock intakes	Face of dam	45

Table B2.—Summary of selective withdrawal purpose and design information (continued)

Dam/reservoir	Purpose(s) of SWS system	Design agency	Selective withdrawal method	SWS intake location	SWS discharge capacity (ft^3/s)
Question	7	8	9	10	12
Grayson	Temperature, DO	COE	Spillway, sluice gates, and the SW system outlet works	Vertical tower	164
Green River	Temperature	COE	Outlet works	Vertical tower	750
Helena Valley	M&I water supply, irrigation	Helena Valley Irrigation District	Outlet works	Face of dam	50
Hungry Horse	Temperature, habitat restoration	Reclamation-TSC	Outlet works, penstock intakes, surface spillway (morning glory)	Face of dam	13,000
Jordanelle	Temperature, DO, instream flow requirements, phosphorus TMDLs to improve water quality in a downstream M&I water supply reservoir for the Greater Salt Lake City - Wasatch Front metropolitan area	Reclamation	Outlet works, intake tower, single wet well tower with 6 sliding gates (SLOW), bottom outlet (LLOW) spillway	Vertical tower and separate low level outlet works	2,400
Kingsley/Lake McConaughy	N/A	Central Nebraska Public Power and Irrigation District	N/A	N/A	N/A
Kinzua/Allegheny	Temperature, DO, instream flow requirements, habitat restoration, supersaturated dissolved gas, endangered species, AMD	COE	Outlet works	Face of dam	7,000
Libby	Temperature, endangered species	COE	Spillway (sluice gates)	Face of dam	28,000
Lost Creek	Temperature, turbidity, instream flow requirements	COE Portland District	Intake tower, penstock intakes	Vertical tower	11,460
Martinez Dam	Turbidity	Reclamation	Spillway (surface), intake tower	Vertical tower	70
McPhee	Temperature	Reclamation	Outlet works	Vertical tower	205
Norman	DO	Reclamation	Outlet works, spillway (outlets), intake tower	Vertical tower, face of pumping plant	52

Table B2.—Summary of selective withdrawal purpose and design information (continued)

Dam/reservoir	Purpose(s) of SWS system	Design agency	Selective withdrawal method	SWS intake location	SWS discharge capacity (ft^3/s)
Question	7	8	9	10	12
Oroville	Temperature	CAL DWR	Shutter system, penstock intakes	Inclined tower	17,500
Paint Creek	Temperature, DO	COE	Spillway, sluice gates, SW system outlet works	Vertical tower	565
Paintsville	Coldwater fishery	COE	Spillway, sluice gates, SW system outlet works	Vertical tower	800
RD Bailey	Temperature, DO	COE	Spillway, sluice gates, SW system outlet works	Vertical tower	11,400
Sanford/Lake Meredith	Temperature, DO	Reclamation	Outlet works	Vertical tower	3,100
Shasta	Temperature, endangered species (fall and winter run chinook salmon)	Reclamation	Penstock intakes, spillway (surface), spillway (outlets)	Face of dam	19,500
Spring Creek Debris Dam	Acid mine drainage (various metals), endangered species (fall and winter run chinook salmon)	Reclamation	Sloping intake with controllable louvers, one intake (top) with no louvers, outlet works	Face of dam, inclined tower, sloping intake structure	710
Stagecoach	Temperature, DO	Reclamation	Intake tower, penstock intakes	Face of dam, vertical tower	90
Sutton	Temperature, turbidity	COE	Spillway, sluice gates, SW system outlet works	Riser on face of dam	3,800
Whiskeytown	Temperature, endangered species (fall and winter run chinook salmon)	Reclamation	Outlet works, morning-glory spillway	Vertical tower with two fixed openings	1,200
Ritschard/Wolford Mountain	Temperature, DO	Colorado River Water Conservation District	Intake tower, outlet works	Vertical tower	750
Wynoochee	Temperature instream flow requirements	COE (multi-outlets), Tacoma Power (temp. panels)	Outlet works, penstock intakes	Face of dam	230
Yatesville	Temperature, DO	COE	Spillway, sluice gates, SW system outlet works	Face of dam	800

Table B3.—Summary of selective withdrawal related studies

Question	13	14	15
Dam/reservoir	Water quality/ limnological	Physical/ numerical	Environmental
Alum Creek	Yes	Numerical	Unknown
Applegate	Yes, after construction. COE report, Applegate Lake 1981 Water Quality Investigations, Portland District	Unknown	Yes, COE Report HL-86-3. See Hansen and Cassidy paper in COE E-87-3.
Arbuckle	No	None	No
Beech Fork	Yes	Numerical	Unknown
Burnsville	Yes	Numerical	Unknown
Cheney	Yes, water temp study after construction	No	Unknown
Deer Creek	Yes	Numerical	Unknown
DeGray	Yes, after construction (1) Ford, B., and Stein, A.B. (1984). "The hydrometeorology of DeGray Lake, Arkansas." Miscellaneous Paper E-84-3, Corps of Engineers Waterways Experiment Station, Vicksburg, MS, NTIS No. AD A140 099. (2) Kennedy, R.H., and Nix, J., eds. (1987). "Proceedings of the DeGray Lake symposium." Technical Report E-87-4, Corps of Engineers Waterways Experiment Station, NTIS No. AD A183 751.	Numerical, Martin, J.L. (1987). "Application of a 2-D model of hydrodynamics and water quality (CE-QUAL-W2) to DeGray Lake, Arkansas." Technical Report E-87-1, Corps of Engineers Waterways Experiment Station, Vicksburg, MS, NTIS No. AD A182 202.	Yes. Kimmel, B.L., and Groeger, A.W. (1986). "Size distribution of planktonic autotrophy and microheterotrophy in DeGray and West Point Reservoirs: A comparative study." Technical Report E-86-8, Corps of Engineers Waterways Experiment Station, Vicksburg, MS, NTIS No. AD A171 651.
Dworshak	Unknown	Unknown	Unknown
Fishtrap	Yes	Numerical	Unknown
East Lynn	Yes	Numerical	Unknown

Table B3.—Summary of selective withdrawal related studies (continued)

Question	13	14	15
Dam/reservoir	Water quality/ limnological	Physical/ numerical	Environmental
Flaming Gorge	Yes, before and after construction	Numerical, Jim Sartoris 1976, Reclamation report REC-ERC-76-7, Temperature model of Green River below Flaming Gorge Dam	Yes, numerous fish growth reports. Utah Division of Wildlife Resources has reservoir water quality profile data. USFS/USU (insect lab) has tailwater temperature data. Paper by J.C. Peters, Reclamation, September 1978, is a good reference. EIS is in progress (2003)
Folsom	Yes, after construction	Numerical, several models have been done – Reclamation	Unknown
Fort Cobb	No	None	No
Foss	No	Unknown	No
Grayson	Yes	Numerical	Unknown
Green River	No	No	No
Helena Valley	Unknown	Unknown	No
Hungry Horse	Yes, before construction	Physical, numerical (1) Kubitschek, Hungry Horse Selective Withdrawal Model Study, Reclamation report R-94-10 (2) Brian Marotz, Montana Fish, Wildlife and Parks	Yes, MT Dept. of Fish, Wildlife, and Parks - fish stocking and macroinvertebrate surveys. Environmental Assessment, Reclamation PN Regional Office, May 1994
Jordanelle	Yes, before and after construction	Numerical, Jerry Miller, Reclamation, Upper Colorado Region, draft copy still in progress	YES, EIS for river restoration project - Provo River

Table B3.—Summary of selective withdrawal related studies (continued)

Question	13	14	15
Dam/reservoir	Water quality/ limnological	Physical/ numerical	Environmental
Kinzua/Allegheny	Yes, after construction	Physical/numerical - COE WES TR No. 2-621 (1963) and COE WES HL-89-17	Yes. (1) Simulation of Stream Flow Regulation Effects on Water Quality, Feb. 1983, COE (2) Dortch, 1981, Investigation of Release Temperature for Kinzua Dam, COE Report HL-81-9 (3) Drummond, Robey, 1975, Natural stream temperature analysis, Allegeny River, COE Special Report No. 8 (4) Outflow Fish Loss Investigations 1977-1994, May 1994, COE (5) The Effect of Kinzua Dam on Water Temperature and Aquatic Life in Allegeny River, COE Pittsburgh District, 1974
Libby	Yes, before and after construction, Bonde and Bush 1967-1972 USCOE Seattle District Storm, Bonde, Bush and Helms, Part 3 Cold Region Research Special Report 82-23 Woods and Falter, Limno and primary productivity Special Report 82-15	Physical, COE Technical Report No. 125-2, Division Hydraulic Laboratory, North Pacific, Dec 1975, three models tested: 1:50, 1:20 and 1:5. Vortices were a problem. Relief panel studies measured torque for head differential.	Yes, May and Juston, 1979. Report documenting changes in flow, sediment, temp, water quality, and aquatic environment after construction of dam, but not for selective withdrawal
Lost Creek	Yes, after construction, COE report, Lost Creek Lake 1978-83 Annual Water Quality Investigations, Portland District	Physical/numerical, COE WES TR No. 2-621, 1963. Howington, COE Report HL-89-13, Intake Structure Operation Study, Lost Creek Dam, OR, July 1989	Yes, COE Report HL-86-3, pp. 28-33, Proceedings from workshop on SW Design and Operation, May 1986.
Martinez	No	None	No
McPhee	No	Unknown	No
Norman	Unknown	Unknown	Unknown
Oroville	Yes, after construction. ASCE Register says before construction	Physical and numerical, physical model: Reclamation Reports HYD-509, HYD-540, and HYD-549	No
Paint Creek	Yes	Numerical	Unknown

Table B3.—Summary of selective withdrawal related studies (continued)

Question	13	14	15
Dam/reservoir	Water quality/ limnological	Physical/ numerical	Environmental
Paintsville	Yes	Numerical	Unknown
RD Bailey	Yes	Numerical	Unknown
Sanford/Lake Meredith	Unknown	No	No
Shasta	Yes, before and after construction. U.S. Geological Survey open-file report 98-251.	Physical, numerical, other	Yes, technical memorandum (Bureau of Reclamation) No. 8220-01-15
Spring Creek Debris Dam	Yes, after construction	Yes, Hydraulic Model Study of the Spring Creek Debris Dam Selective Withdrawal System, February 1995, Reclamation Report R-95-03	Yes, contact Reclamation's Central Valley Operations or Mid-Pacific Regional Office
Stagecoach	No	Physical	Yes, initial effects of Stagecoach Reservoir on discharge, water-quality characteristics, and suspended-sediment loads in the Yampa River (USGS Water resources investigations report; 95-4101)
Sutton	Yes	Physical/numerical, COE report HL-80-4, Selective Withdrawal Riser for Sutton Dam, West Virginia	Yes, studies indicate an improvement of the benthic community in tailwater after SW Ref. COE Report HL-86-3
Whiskeytown	No	Unknown	Yes, contact Reclamation's Northern California Area Office or Central Valley Operations. Value planning, final report, Lower Clear Creek hydraulic analysis at Whiskeytown Dam, Bureau of Reclamation, Denver, CO, 1999.
Ritschard/Wolford Mountain	Yes, before construction	Numerical	No
Wynoochee	Yes, after construction	No	No
Yatesville	Yes	Numerical	Unknown

Table B4.—Summary of selective withdrawal system operations

Question	31	18	19	20
Dam/reservoir	Normal operating season	Operating criteria	Frequency of compliance	Frequency of gate changes
Alum Creek	April - Sept.	Up to two gates blended; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
Applegate	Jan. - Dec.	(1) Downstream water quality goals are achieved by repositioning upper level control gates; (2) upper and lower level flows blended to meet the water quality objectives; (3) three or more gates operated simultaneously to blend the desired water quality	90%	Daily or weekly, depending on time of year and lake elevations
Arbuckle	Year round	N/A, no downstream release requirements	90%	None, gates are not changed
Beech Fork	April - Nov.	Blend two wet wells; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
Burnsville	April - Nov.	Blend three conduits; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
Cheney	Unknown	Selective withdrawal used to withdraw water for optimal treatment by municipal treatment plant	Unknown	Unknown
Deer Creek	April - Sept.	Up to two gates opened; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	70%	Quarterly
DeGray	Year round	Gate settings are fixed and do not require frequent adjustment to obtain desired downstream water quality.	90%	Rarely
Dworshak	April - Nov.	Selective withdrawal releases are mixed with other methods of release to attain the desired water quality.	80%	Weekly
East Lynn	April - Nov.	Up to two gates opened; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
Fishtrap	April - Nov.	Up to three gates opened; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
Flaming Gorge	May - Oct.	Downstream water quality goals are achieved by repositioning upper level control gates	90%	Every 2 weeks to monthly
Folsom	Year round	Three operating criteria given in comment	Unknown	Monthly

Table B4.—Summary of selective withdrawal system operations (continued)

Question	31	18	19	20
Dam/reservoir	Normal operating season	Operating criteria	Frequency of compliance	Frequency of gate changes
Fort Cobb	Year round	N/A	Unknown	None, gates are not changed
Foss	Year round	Downstream water quality goals are achieved by repositioning upper level control gates	90%	Rarely, gate changes are not routinely needed
Grayson	April - Dec.	Up to two gates opened; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
Green River	May - Nov.	Downstream water quality goals are achieved by repositioning upper level control gates	70%	Monthly
Helena Valley	October only	Not given	Unknown	Unknown
Hungry Horse	May - Oct.	Downstream water quality goals are achieved by repositioning upper level control gates. Mid-level slide gates are available but they have never been used	80%	Weekly
Jordanelle	Unknown	Many, see comment	90%	Weekly
Kingsley/Lake McConaughy	N/A	N/A	N/A	N/A
Kinzua/Allegheny	May - Oct.	(1) Downstream water quality goals are achieved by repositioning upper level control gates; (2) upper and lower level flows blended to meet the water quality objectives; (3) three or more gates operated simultaneously to blend the desired water quality	80%	Rarely, when downstream conditions require a change
Libby	March - Nov.	Downstream water quality goals are achieved by repositioning upper level bulkheads. Follow a temperature curve established by MT Fish, Wildlife, and Parks	99%	Weekly to monthly
Lost Creek	Year round	(1) Downstream water quality goals are achieved by repositioning upper level control gates; (2) upper and lower level flows blended to meet the water quality objectives; (3) three or more gates operated simultaneously to blend the desired water quality	90%	Daily or weekly, depending on time of year and lake elevations

Table B4.—Summary of selective withdrawal system operations (continued)

Question	31	18	19	20
Dam/reservoir	Normal operating season	Operating criteria	Frequency of compliance	Frequency of gate changes
Martinez	N/A	Selective withdrawal not currently used	Unknown	None, gate settings are not changed
McPhee	Year round	Only the lower gate is used because the desired water temperature is at this elevation. Selective level outlet works (SLOW) feeds McPhee Powerplant. When the plant is not running, water is then released from the bottom of the reservoir.	Unknown	Rarely
Norman	Year round	N/A, no downstream release requirements	N/A	None, gate settings are not changed
Oroville	April - Oct.	Starting from the bottom of the intake, control shutters are placed up to the elevation of the required temperature layer. The increment of shutter control is approximately 20 feet of elevation.	90%	Monthly, depends on time of year and lake elevation
Paint Creek	April - Sept.	Up to two gates opened; upper gate fully opened, lower gate opened 10 to 20%. Hourly downstream temperature data and project-specific "temperature rule curve" is used for operation	80%	Monthly
Paintsville	April - Dec.	Blend two wet wells; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
RD Bailey	April - Nov.	Blend two wet wells; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly
Sanford/Lake Meredith	N/A	Selective withdrawal was only tried in March 2002 to lower chloride concentrations - didn't make any difference	0%	Unknown
Shasta	Year round	Operating criteria given in comment	90%	Weekly
Spring Creek Debris Dam	Oct. - July	Releases are made from the intake close to the surface, but 5 ft+ submergence needed for debris/vortices. As reservoir rises or falls, different intakes are selected	90%	Rarely, rainy season
Stagecoach	Year round	(1) Downstream water quality goals are achieved by repositioning upper level control gates; (2) upper and lower level flows blended to meet the water quality objectives; (3) three or more gates operated simultaneously to blend the desired water quality	90%	Monthly
Sutton	April - Oct.	One or three gates opened; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly

Table B4.—Summary of selective withdrawal system operations (continued)

Question	31	18	19	20
Dam/reservoir	Normal operating season	Operating criteria	Frequency of compliance	Frequency of gate changes
Whiskeytown	April - Nov.	Temperature goals are achieved by using lower level outlets. Water district may request one of two levels for better water quality (turbidity, etc.)	90%	Quarterly
Ritschard/Wolford Mountain	Year round	Downstream water quality goals are achieved by repositioning upper level control gates	90%	Weekly
Wynoochee	May - Oct.	Temperature panels are moved to select lake depths for turbine intake operation. Flows are increased/decreased from low-level outlets to adjust downstream water quality	100%	Weekly
Yatesville	April - Dec.	Blend two wet wells; hourly downstream temperature data and project specific "temperature rule curve" is used for operation	90%	Monthly

Table B5.—Summary of selective withdrawal system maintenance

Question	32	33	34	35	36	37	38
Dam/Reservoir	Frequency of scheduled maintenance on moving parts	Frequency of equipment repair or replacement	Estimated annual equipment maintenance cost	Frequency of structural parts repair or replacement	Estimated annual structural maintenance cost	Has maintenance increased for equipment downstream of SWS equipment?	Has SWS operation caused any in-reservoir debris problems?
Alum Creek	Monthly	As needed	$1,000	Monthly	$0	Unknown	No
Applegate	Monthly	As needed	$12,000	As required	$12,000	No	No
Arbuckle	Quarterly	Quarterly	Unknown	Quarterly	Unknown	No	No
Beech Fork	Monthly	As needed	$1,000	Monthly	$0	Unknown	No
Burnsville	Monthly	As needed	$1,000	Monthly	$0	Unknown	No
Cheney	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Deer Creek	Monthly	As needed	$1,000	Monthly	$0	Unknown	No
DeGray	As needed	As needed	Unknown	As needed	$1,000	Yes	No
Dworshak	Semiannually	As needed	$2,000	N/A	$0	No	No
East Lynn	Monthly	As needed	$1,000	Monthly	$0	Unknown	No
Fishtrap	Monthly	As needed	$1,000	Monthly	$0	Unknown	Yes
Flaming Gorge	Annually	As needed	Unknown	Infrequently	$1,500	Yes	Yes
Folsom	Annually	As needed	$10,000	As required	$10,000	No	Yes
Fort Cobb	Monthly	As needed	Unknown	As required	Unknown	N/A	Unknown
Foss	Annually	As needed	Unknown	As required	Unknown	No	No
Grayson	Monthly	As needed	$1,000	Monthly	$0	Unknown	Yes
Green River	Annually	Unknown	Unknown	Unknown	Unknown	No	No
Helena Valley	Unknown	As needed	$200	Not given	$200	No	No
Hungry Horse	Annually	Annually	Unknown	Annually	$5,000	Yes	Yes

Table B5.—Summary of selective withdrawal system maintenance (continued)

Question	32	33	34	35	36	37	38
Dam/Reservoir	Frequency of scheduled maintenance on moving parts	Frequency of Equipment repair or replacement	Estimated Annual Equipment Maintenance Cost	Frequency of structural parts repair or replacement	Estimated annual structural maintenance cost	Has maintenance increased for equipment downstream of SWS equipment?	Has SWS operation caused any in-reservoir debris problems?
Jordanelle	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Kingsley/Lake McConaughy	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Kinzua/Allegheny	Semiannually	Annually	$20,000	As required	$60,000	No	No
Libby	Monthly	As needed	$20,000	Rarely	Unknown	Yes	Yes
Lost Creek	Monthly	As needed	$12,000	As required	$12,000	No	No
Martinez	Annually	Annually	$12,000	Annually	0	No	Yes
McPhee	Annually	As needed	$2,000	As needed	$2,000	No	No
Norman	Semiannually	As needed	Unknown	As required	Unknown	N/A	No
Oroville	Semiannually	Semiannually	$90,000	Semiannually, annually	$185,000	No	No
Paint Creek	Quarterly	As needed	$200	Annually	$0	Unknown	No
Paintsville	Semiannually	As needed	$2,000	Annually	$2,000	Unknown	No
RD Bailey	Weekly	As needed	$3,000	Monthly	$0	Unknown	Yes
Sanford/Lake Meredith	Monthly	As needed	$1,000	Annually	0	No	No
Shasta	Annually	As needed	$40,000	As needed	0	Yes	Yes
Spring Creek Debris Dam	Annually	As needed	$3,000	Annually	$3,500	Yes	Yes
Stagecoach	Monthly	Annually	$1,000	Annually	Unknown	No	No
Sutton	Semiannually	As needed	$1,000	Annually	$100	Unknown	No
Whiskeytown	Annually	As needed	$5,000	Annually	0	No	No
Ritschard/Wolford Mountain	Semiannually	As needed	$500	None needed yet	$0	No	No
Wynoochee	Monthly	As needed	$600	As needed	$350	No	No
Yatesville	Monthly	As needed	$1,000	Annually	$0	Unknown	No

Table B6.—Summary of comments on SWS modifications for all projects

Question	Project	Response
24		**Were modifications made to operating criteria after installation of SWS?**
	Applegate	Originally, the intake tower ports were intended to be fully open or fully closed. Improvements were made to remotely select incremental openings to achieve better temperature control.
	Folsom	Blending, more frequent changes, changes to manage for steelhead, and structure modifications.
	Hungry Horse	Bearing cooling water alarm set points were raised. Higher temperature-rated bearings were installed during unit overhaul. A 30-ft submergence requirement was added to SOP for unit startup.
	Jordanelle	SOPs required top gate in the water to remain fully open. New criteria are flow and velocity past gate. The original goals of temperature and phosphorus concentrations are still maintained. Avoidance of discharging phytoplankton in the fall keeps top gate in the water closed after about mid-September.
	Lost Creek	Originally, the intake tower ports were intended to be fully open or fully closed. Improvements were made to remotely select incremental openings to achieve better temperature control.
	Spring Creek Debris Dam	Various issues regarding the dilution of acid mine drainage were addressed.
25		**Were modifications made after installation of SWS due to design deficiencies?**
	Flaming Gorge	Trashracks were placed on the TCD structures after installation. Trashracks were not originally included, but it was soon discovered that woody debris piled up against the old trashracks. They did not remove the wood when this was done.
	Folsom	Shutter configuration modified for better coldwater pool management.
	Hungry Horse	Replaced relief gate shear pins with stronger pins to reduce number of failures.
	Jordanelle	A maximum allowable velocity past each partially open gate was implemented.
	Lost Creek	External temperature probes were installed to replace the corroded, original, in-place piping.
	Shasta	Areas of warmwater leakage, due to gaps in construction/fabrication, were corrected by design/fabrication modifications and installed by divers 1-2 years after initial construction was completed.
	Spring Creek Debris Dam	Louvers were added, and trashracks were improved. Originally, trashracks had larger spacing and there were no louvers.

Table B6.—Summary of comments on SWS modifications for all projects (continued)

Question	Project	Response
26		**Any specific hydraulic problems with SWS?**
	Dworshak	Minimum submergence is greater than 30 ft, as specified in original design.
	Flaming Gorge	Wicket gate shear pin failures increased, due to debris associated with surface withdrawal. Debris built up around the lower gate has likely caused more head loss. Operators maintain 50-ft submergence on the control gate to eliminate vortices since surface circulation has been observed for 40-ft submergence. Bearing cooling water overheats during selective withdrawal operations when the temperatures are higher than 50 to 55 °F.
	Folsom	Head required to prevent turbine cavitation limits use of shutters.
	Libby	Because of vortices, 30 ft of submergence is required.
	Lost Creek	During high flows through the regulating outlets (approx. 9,000 ft^3/s), the access hatch came loose, due to excessive vibrations when increasing flows went through the transition zone. Current restrictions require flows to be generally less than 7,000 ft^3/s through river outlets. Lake differential alarms if wet well draws down lower than the lake elevation, due to outlet flows greater than adequate inlet port openings. A minimum of 5 feet of submergence is recommended for uppermost inlet ports on tower.
	Oroville	Intake vortices occur at El. 640, thus restricting operations below that elevation. A system was designed to eliminate water hammer due to leakage.
	Shasta	Minimum number of gate openings required for proper hydraulics and pressures on structure. Operating criteria specifies number of openings and combination of openings versus reservoir elevation. More debris gets into turbines, causing more breaking of wicket gate shear pins.
	Spring Creek Debris Dam	Operating criteria requires 5-ft submergence for intakes to avoid debris entering the louver or intake opening and to prevent vortex formation.
	Whiskeytown	At maximum outlet releases, bifurcation to City of Redding's hydroplant and Clear Creek Communities Service District (CCSD) need to be shut down to prevent Venturi effects.
	Wynoochee	Hydraulic problems have occurred but were not described.
27, 28		**Were turbine unit operation modifications necessary?**
	Flaming Gorge	Bearing cooling water overheats during selective withdrawal operations when the temperatures are higher than 50 to 55 °F. Wicket gate shear pins break more frequently.
	Hungry Horse	Governor timing was changed from 8 to 20 seconds for water hammer prevention. Total dissolved gas increased, and monitoring is now required to prevent water quality violations.

Table B6.—Summary of comments on SWS modifications for all projects (continued)

Question	Project	Response
	Kinzua	Gate operation schedule was changed to keep sediment from the downstream channel bed from entering the stilling basin to reduce concrete damage to basin.
	Shasta	Hydraulics and temperature leakage require the use of units close to side gates during side gate operations to achieve temperature requirements.
	Spring Creek Debris Dam	Spring Creek pumping plant is not part of the debris dam, but both discharge water to the same stream. SCPP is now run at a constant minimum flow (about 250 ft^3/s) to dilute and carry the SCDD water/sediments.
	Wynoochee	When temperature panels are used, turbine flow is limited by net panel opening.
29		**Adding/modifying turbine equipment:**
	Hungry Horse	Enlarged secondary strainers were added on bearing cooling water supply lines to filter pollen and pine needles. The strainers now require daily inspection. Cooling water temperature alarm set-points were raised because cooling water temperatures were increased, due to withdrawal of surface water.
	Lost Creek	External temperature probes were installed to replace the corroded, original, in-place piping.
	Oroville	Trashracks were replaced due to a vibration problem. Temperature monitoring equipment was added.
	Shasta	Wicket gate shear pins break about once per year. Bearing cooling water strainers were often plugged until frequent flushing was routine. Temperature monitoring equipment was installed on all five penstocks.
30		**Have uprated turbines had impacts on the SWS?**
	Flaming Gorge	Generators have been uprated, runners are planned in the future (FY03-FY05). No impact on selective withdrawal.
	Libby	Turbine uprated from 100 MW to 120 MW by rewind and improved insulating properties. No impact on selective withdrawal.
	Shasta	Units 3, 4, and 5 were uprated from 105 MW to 125 MW from 1998-2001. Units 3, 4, and 5 are going to be 142 MW with new turbines. Governors may have to be adjusted for water hammer, but the new turbines use only a little more water. Most of the power gain is due to higher efficiency at approximately the same flow.
39		**Any improvements made to SWS for efficiency or reduced maintenance costs?**
	Flaming Gorge	A trap door was suggested, to assist in cleaning out debris.
	Folsom Dam	Shutters reconfigured to 4-2-3 from original 7-1-1.

Table B6.—Summary of comments on SWS modifications for all projects (continued)

Question	Project	Response
	Hungry Horse	There are plans to upgrade the reservoir temperature probes and to include some automation to the control gates. There are times when submergence less than 30 ft is needed to meet temperature goals, but SOP restrictions of 30-ft submergence on startup prevent the use of lower submergences.
	Lost Creek	External temperature probes were installed to replace the originals located in in-place piping.
	Oroville	Replaced the hoist and crane controls with new, electronic, programmable controls.
	Shasta	No, but improvements are necessary
	Spring Creek Debris Dam	Louvers and improved trashracks in late 1970s improved operation by better controlling the selectivity.
40		**How could S/W design be modified for better performance?**
	Alum Creek	Installation of dual wet wells.
	Deer Creek	Redesign, due to pool elevation increase.
	Dworshak	Need a way to pull out water in the middle of the gate, instead of only "overshot" or "undershot."
	East Lynn	Installation of dual wet wells.
	Fishtrap	Installation of dual wet wells.
	Folsom	Cannot access the bottom 50,000 acre-ft of storage without bypassing the turbines. Continuous selectivity, rather than large increments, would be more efficient at saving cold water. Needs automation. Presently requires three people to make shutter changes. A hoist for each shutter bank would require fewer personnel to operate, but it would require more maintenance.
	Grayson	Installation of dual wet wells.
	Green River Lake	An increase of outflow capacity would significantly increase the use of the system in the spring.
	Hungry Horse	Install a programmable logic controller to position the control gates to meet downstream temperature requirements and submergence criteria.
	Kinzua/Allegheny	Remote-control discharges.
	Libby	Many improvements are needed.
	Lost Creek	System may be improved by having inlet ports at staggered elevations.
	McPhee	Selective level outlet works could have been eliminated from the project.

Table B6.—Summary of comments on SWS modifications for all projects (continued)

Question	Project	Response
	Oroville	Simple designs last longer. Address all the variables at the design stage. Physical models are of great help to visualize potential problems.
	Paint Creek	Installation of dual wet wells.
	Paintsville	Fewer problems with equipment.
	Sanford/Lake Meredith	Use stainless steel components.
	Shasta	Remove or change gate jam hardware. Redesign electrical system for power and control. Redesign gate hoist cable systems.
	Spring Creek Debris Dam	Change hoist arrangement for moving blocks/louvers. Make major changes in louvers and blocks with the goal of producing a tight shutoff when closed.
	Sutton	Additional intakes are needed.
	Wynoochee	Automatic trash rake, instead of manual debris removal, annually.
41		**Would automating gate operations be desirable?**
	Dworshak	Yes
	Flaming Gorge	No, operators make gate changes so infrequently that this would not save much time.
	Folsom	Yes, but automated operation would probably mean lack of oversight of equipment condition and possible unit unavailability.
	Libby	Yes
	Lost Creek	Yes, the system is already automated. There is a greater selection of inlet port settings within the range of the opening. Prior to automation, personnel opened gates at the tower. Remote incremental changes are now made from the control room.
	Shasta	Yes, original design was intended for automation, but we are still experiencing problems with gate operations.
	Spring Creek Debris Dam	No, louvers are not operated frequently enough to automate. Outlet valves are now automated.
	Whiskeytown	No, guard gates are not operated frequently enough to justify automation.

Table B6.—Summary of Comments on SWS Modifications for All Projects (continued)

Question	Project	Response
41a		**Would automating gate operations be cost effective?**
	Dworshak	Yes, it would save operator time.
	Folsom	Don't know
	Hungry Horse	Don't know
	Libby	Extremely expensive option. Not cost effective.
	Lost Creek	Yes
	Shasta	Unknown