

US Army Corps of Engineers Walla Walla District

1992 Reservoir Drawdown Test Lower Granite and Little Goose Dams

0/

December 1993

1992 Reservoir Drawdown Test

Lower Granite and Little Goose Dams

by:

Wik, Sarah J. Shoulders, Andrea L. Reese, Lynn A. Hurson, David F. Miller, Thomas D. Cunningham, Lester L. Leier, John P. Mettler, Lonnie E. Poolman, Peter F. Buck, James A. Wolff, Carol A. Smith, Janet S.

Acknowledgments

The support of a multitude of people from within the Corps, and from other agencies, contractors, and interested groups was required to accomplish the March, 1992, Lower Granite-Little Goose Reservoir Drawdown Test. We wish to thank all those who were involved in the preparation and implementation of this operation, and those who assisted in the evaluations and documentation. Special thanks go to Tamara Gabin, Jerry Miller, and Heather McDonald of the Portland District Corps of Engineers for their incredible efforts and long hours to produce this document.

Foreword

This report on the March, 1992, reservoir drawdown test includes an executive summary, located at the beginning of the document. No details, photographs, or explanatory figures are included within the executive summary, nor is any background provided. The reader is encouraged to take the time to read the complete report, and then subsequently refer back to the summary, as needed. Additional detailed information is contained within the appendices, which can be obtained by writing to the following address:

> U.S. Army Corps of Engineers Walla Walla District Environmental Resources Branch Walla Walla, WA 99362

Contents

Foreword	v
Table of Contents	vi
List of Figures	
List of Tables	
List of Appendices	
List of Appendices	xvii
Executive Summary	·····xix
Chapter 1: Introduction	_
Chapter 1: Introduction	1
Chapter 2: Background	
A. Columbia River Basin Salmon Runs	
B. Events Leading to 1992 The Drawdown Test	6
C. Description of Dam Features	
1. General	
2. Key Features at Lower Granite Dam	
a. Stilling Basin and Related Descriptions	
b. Juvenile Fish Facilities	
c. Adult Fish Facilities	
D. Factors Affecting Salmonid Passage and Survival at	Columbia River Basin
Hydroelectric Dams	
1. River Flow	
2. Project Operations	
a. Turbine Operations	
b. Spillway Operations	
1) Dissolved Gas Supersaturation	
2) Juvenile Fish Passage	
3) Adult Fish Passage	

С	hapter 3: Pre-test Activities	
	1991 Lower Granite Spill Test	
	Planning and Preparatory Operations	
	1. Project Preparations	22
	2. Physical Scale Model Testing	24
	3. Pre-drawdown Spill Tests	25

A.	. Test Design	27	
	1. General	27	
	2. Modifications to Test Plan		
	a. Refill Sequence		
	b. Additional Spill Test Flow Rate of 65,000 cfs		
	c. Additional Test at Elevation 710 fmsl		
	d. Drafting Range Increase	32	
	3. Spill Tests		
	a. 100 Percent Spill Tests		
	1) Test 1a and 1b (March 15)		
	2) Tests 3a and 3b, 4a and 4b, 5a and 5b, and 7a, 7b, and 7c (March 17, and 23, respectively)	19, 21,	
	3) Test 9a and 9b (March 28)		
	b. Combination Spill and Powerhouse Tests		
	1) Tests 2a and 2b (March 16)		
	2) Tests 6a and 6b (March 22)		
	3) Test 9c (March 28)		
	c. Free-flow Spill Test - Tests 8a and 8b (March 26)		
В.	3. Project Operations	35	
	1. Navigation Lock Outages and Boat Docking	35	
	2. Natural Resources Management Activities		
C.			
D.	0. External Coordination		

Cł	na	pter 5: Monitoring and Evaluation:	
		Objectives and Procedures4	
A.		oject and Reservoir: Facilities and Structures4	
	1.	Lower Granite and Little Goose Dams	
		a. Concrete Structures	
		b. Dam Embankments	
		 Lower Granite Dam North Embankment	
		c. Turbines	
		1) Testing	5
	9207	d. Lower Granite Stilling Basin4	
	2.	Reservoir Embankments	
		b. Road and Railroad Embankments	
	3.	Encapsulated Fill	
	4	Port Facilities	
		Private Facilities/Structures	
B		ater Resources	
D.		Water Velocity	
	1.	a. Velocity Mapping	
		b. Dye-detection Tests	6
		c. Other Instrumentation	
	2.	Water Quality	7
		 a. Dissolved Gas Supersaturation	
		c. Erosion and Sediment Transport	
		d. Contaminants	1
	3.	Groundwater	3
C.	Bi	ological Resources6	4
	1.	Resident Fish6	
		a. Movement within Reservoirs	
		b. Stranding	5
	2	Anadromous Fish	
	4.	a. Adult Passage	6
		1) Operation of Fish Ladder Emergency Exit	
		 2) Spill Effects on Flow Patterns	
		b. Juvenile Passage	
		1) Abundance	6
		2) Migration	
		d. Salmon Spawning	
	3.	Benthic (Bottom-dwelling) Organisms	
		Wildlife	
D.		ltural Resources	
E.		creation	

CI	napter 6: Results and Discussions	73
	General	
В.	Project and Reservoir Facilities and Structures	
2.	1. Lower Granite and Little Goose Dams	
	a. Concrete Structures	
	b. Dam Embankments	
	 Lower Granite Dam North Embankment Little Goose Dam North Embankment 	
	c. Turbines	
	d. Lower Granite Stilling Basin	
	2. Reservoir Embankments	.77
	a. Lewiston Levee Embankments	
	b. Road and Railroad Embankments	
	c. Natural Slopes and Embankments	
	3. Encapsulated Fill	
	4. Port Facilities	
	5. Private Facilities/Structures	.81
С.	Water Resources	.81
	1. Water Velocities	
	a. Velocity Mapping	
	b. Dye-detection Tests	
	2. Water Quality	
	a. Dissolved Gas Supersaturation	
	 Inflow Tests	
	3) High Flow Spill Tests	
	4) Spill/Powerhouse Combinations	.98
	a.) Spill as Major Passage Method	
	b.) Powerhouse as Major Passage Method	
	a.) Objectives	
	b.) Limitations of Testing	100
	c.) Effect of Tailwater	
	d.) Effect of Reduced Head	
	e.) Effect of Spill Amount f.) Effect of Powerhouse Flows	
	g.) Equilibration	
	h.) Location of Highest Concentrations	104
	i.) Travel Time	
	j.) Free-flow spill k.) Dissipation	
	l.) Summary	
	b. Turbidity	107
	c. Erosion and Sediment Transport	
	d. Contaminants	112
	3. Groundwater Levels	113
D.	Biological Resources	115
	1. Resident Fish	115

		 a. Movement within Reservoirs	16
	2.	Anadromous Fish. 1 a. Adult Passage 1 1) Emergency Adult Exit 1 2) Effects of Spill on Flow Patterns 1 3) Movement within Reservoir 1	.18 .18 .19
		b. Juvenile Passage	22 22 22 23 23
	3.	Benthic (Bottom-dwelling) Organisms1	25
	4.	Wildlife 1 a. Waterfowl 1 b. Shoreline Habitat 1 1) Baseline Establishment 1 2) Weekly Monitoring 1 c. Furbearers 1 d. Predators 1	27 28 28 28 28 28 28 29
E.		Iltural Resources	
	2. 3.	Lower Granite	.30 .30
F.		creation and Public Information1	
G.		st of the 1992 Reservoir Drawdown Test	
		Implementation1	
	2.	Damages1	.32

A.	General	5
B.	Project and Reservoir Facilities and Structures	5
C.	Environmental	6

A.	Columbia River Salmon Mitigation Analysis System Configuration Study	\$7
B.	Plans for Future Drawdown Tests	37

References	
------------	--

Figures

1.	Regional map showing Corps and non-Corps dams along the Columbia and Snake Rivers
2.	Anadromous fish life cycle
3.	Estimated minimum combined chinook and sockeye salmon, and summer steelhead counts of adults at Bonneville Dam and the Columbia River downstream of Bonneville Dam, 1939 - 1989.
4.	Snake River spring/summer chinook salmon adult counts at Ice Harbor and Lower Granite Dams, 1962 - 1992
5.	Snake River fall chinook salmon adult counts at Ice Harbor and Lower Granite Dams, 1962 - 1992
6.	Snake River sockeye salmon adult counts at Ice Harbor and Lower Granite Dams, 1962 - 1992
7.	Diagram of the drawdown concept7
8.	Cross-section of Lower Granite Dam showing elevations of project features
	Lower Granite Dam showing the
11.	Cross-section of Lower Granite Dam showing adult and juvenile fish passage facilities11
12.	Illustration of Lower Granite Dam juvenile fish passage facilities, including collection and transport features
13.	Lower Granite Dam juvenile fish facility turbine-intake submerged traveling screens (shown stored on deck)
14.	Lower Granite Dam juvenile fish facility orifice from the gatewell into the juvenile collection channel in the powerhouse
15.	Lower Granite Dam juvenile fish facility upwell (where pipe from the powerhouse juvenile collection channel delivers fish and water downstream) and separator
16.	Lower Granite Dam juvenile fish collection and transport facilities and fish barges
17.	Plan view of Lower Granite Dam showing location of project features and adult fish passage facilities
18.	Diagram of typical adult fish passage facilities14
19.	Adult fish ladder at Lower Granite Dam14
20.	View of spillway and navigation lock wall showing north shore fish entrances into the adult collection channel
21.	View of a) north powerhouse entrances and b) floating orifice gate entrances into the adult collection channel
22.	Lower Granite Dam adult fish passage facility emergency exit
23.	Map of Lewiston, Idaho and Clarkston, Washington, showing location of levees
24.	Lower Granite Dam navigation lock floating guidewall
25.	Hydraulic sectional model of the Lower Granite Dam spillway (1:55 scale) showing24 a) stilling basin and b) flip-lip.
26.	General map of the March, 1992, drawdown test study area

27.	Summary of the March, 1992, drawdown test phases showing reservoir elevation changes at Lower Granite and Little Goose Dams
28.	Average daily inflow to Lower Granite reservoir in Water Years (October - September) 1992, 1977 (lowest in Lower Granite record) and 1984 (highest in Lower Granite record)
29.	Lower Granite reservoir inflow, March, 1992
30.	Lower Granite reservoir elevations, March, 1992
31.	Little Goose reservoir elevations, March, 1992
32.	Lower Granite project discharge, March, 1992
33.	Little Goose project discharge, March, 1992
34.	Boat being moved using slings, March, 1992
35.	Lower Granite reservoir showing the location of physical features and landmarks
36.	Little Goose reservoir showing the location of physical features and landmarks
37.	Illustration of extent of embankment protection against wind and wave erosion
38.	Typical cross-section of Lower Granite Dam north (earth and rock fill) embankment, showing instrument location
39.	Extended-length turbine-intake submerged traveling screen, shown above the deck of the dam in a retracted position
40.	Turbine diagram showing points monitored during the March, 1992, drawdown test46
41.	Location of hydraulic-related instrumentation at Lower Granite Dam, March, 1992
42.	Lewiston levees
43.	Typical cross-section of the Lewiston levee
44.	Railroads and highways on Lower Granite and Little Goose reservoirs
45.	Diagram of Lewiston levee encapsulated fill area53
46.	Lewiston levee encapsulated fill area
47.	Location of Lower Granite and Little Goose reservoir port areas
48.	Location of USGS study area for velocity, turbidity, sediment transport, and dye-detection tests, March, 1992
49.	USGS boats releasing Rhodamine dye into the confluence of the Snake and Clearwater Rivers, March 17, 199257
50.	Locations of primary dissolved gas monitoring sites, March, 1992
51.	Tensionometer and probe
52.	Areas surveyed for sediment, March, 199260
53.	Location of contaminant monitoring sites, March, 1992
54.	Location of groundwater wells monitored during the March, 1992, drawdown test64
55.	Beach-seining for fish65
56.	Electrofishing65
57.	Location of Battelle-Pacific Northwest Laboratories resident fish surveys, March, 199265
58.	Diagram of gatewell dipping67
59.	Gatewell dipping basket
60.	Location of sites of substrate evaluation and monitoring of fall chinook spawning in Little Goose reservoir, March, 199268
61.	Location of sites monitored for fall chinook spawning in the vicinity of Lower Granite reservoir, March, 1992

62.	Location of benthic sampling sites, spring and summer, 1992.	.69
63.	Approximate location of islands that were monitored for the occurrence of land-bridge formation, March, 1992.	
64.	Location of Lower Granite reservoir (Lower Granite Lake) recreation sites	
65.	Location of Little Goose reservoir (Lake Bryan) recreation sites.	71
66.	Turbine efficiency versus head for existing units at Lower Monumental, Little Goose, and Lower Granite Dams	74
67.	Changes in turbine guide bearing runout for Unit 4 at Lower Granite Dam, March, 1992.	
68.	Changes in turbine pit and draft tube noise levels for Unit 4 at Lower Granite Dam, March, 1992.	
69.	Typical piece of material removed from Lower Granite Dam stilling basin prior to beginning of the March, 1992, drawdown test.	76
70.	Exposed spillway deflectors (flip-lips) at Lower Granite Dam, March, 1992	76
71.	Exposed rip-rap and rock fill section of the Lewiston levee, March, 1992	77
72.	The confluence of the (a) Snake and (b) Clearwater Rivers during the lowest point of the drawdown test on March 25, 1992.	78
73.	Crack in Camas Prairie railroad embankment, March, 1992	
74.	Typical cracking in Whitman County Road 9000, March, 1992.	
75.	Slough near Port of Wilma, March, 1992.	
76.	Slough at Offield Landing, above Lower Granite Dam, March, 1992.	
77.	Damage to Red Wolf Marina, March, 1992.	
78.	A closer view of damage to Red Wolf Marina, March, 1992	81
79.	Damage to Quality Inn boat loading, March, 1992.	
80.	Surface velocity profiles at river mile 139.43, March, 1992.	
81.	Average velocity profiles at river mile 139.43, March, 1992	83
82.	Velocity map of river mile 139.43, at 27,100 cfs, Lower Granite forebay elevation 737.25 fmsl, on February 25, 1992.	
83.	Velocity map of river mile 139.43, at 27,500 cfs, Lower Granite forebay elevation 724.93 fmsl, on March 5, 1992.	83
84.	Velocity map of river mile 139.43, at 22,700 cfs, Lower Granite forebay elevation 710.11 fmsl, on March 19, 1992.	83
85.	Average velocity profiles at river mile 119.00, March, 1992	84
86.	Velocity map of river mile 119.00, at 30,500 cfs, Lower Granite forebay elevation 734.37 fmsl, on February 28, 1992.	84
87.	Velocity map of river mile 119.00, at 38,700 cfs, Lower Granite forebay elevation 718.52 fmsl, on March 8, 1992.	84
88.	Velocity map of river mile 119.00, at 28,700 cfs, Lower Granite forebay elevation 705.99 fmsl, on March 20, 1992.	84
89.	700.06 fmsl, on March 26, 1992.	
90.	Average velocity profiles at river mile 108.31, March, 1992	85
91.	Velocity map of river mile 108.31, at 85,200 cfs, Lower Granite forebay elevation 735.30 fmsl, on February 27, 1992.	85
92.	Velocity map of river mile 108.31, at 36,000 cfs, Lower Granite forebay elevation 720.55 fmsl, on March 7, 1992.	85

93.	Velocity map of river mile 108.31, at 26,700 cfs, Lower Granite forebay elevation 700.64 fmsl, on March 25, 1992
94.	Travel time of dye released below the confluence of the Snake and Clearwater Rivers, March, 1992
95.	Actual travel time of dye released below the confluence of the Snake and Clearwater Rivers compared to that predicted by the Corps' computer model
96.	Travel time of dye released above the confluence of the Snake and Clearwater Rivers, March, 1992
97.	Actual travel time of dye released above the confluence of the Snake and Clearwater Rivers compared to that predicted by the Corps' computer model
98.	Spill test no. 2a, 100% spill, at Lower Granite Dam, March 16, 1992
99.	Spill test no. 2b, 80% spill, at Lower Granite Dam, March 16, 1992
100.	Total dissolved gas levels observed during spill tests 1a and 1b at the upstream site (deep) in the Lower Granite tailrace on March 15, 1992
101.	Total dissolved gas levels observed during spill tests 2a and 2b at the upstream site (deep) in the Lower Granite tailrace on March 16, 1992
102.	Total dissolved gas levels observed during spill tests 3a and 3b at the upstream site (deep) in the Lower Granite tailrace on March 17, 1992
103.	Total dissolved gas levels observed during spill tests 4a and 4b at the upstream site (deep) in the Lower Granite tailrace on March 19, 1992
104.	Total dissolved gas levels observed during spill tests 5a and 5b at the upstream site (deep) in the Lower Granite tailrace on March 21, 1992
105.	Total dissolved gas levels observed during spill tests 6a and 6b at the upstream site (deep) in the Lower Granite tailrace on March 22, 1992
106.	Total dissolved gas levels observed during spill tests 7a, 7b, and 7c at the upstream site (deep) in the Lower Granite tailrace on March 23, 1992
107.	Total dissolved gas levels observed during spill tests 8a and 8b at the upstream site (deep) in the Lower Granite tailrace on March 26, 1992
108.	Total dissolved gas levels observed during spill tests 9a, 9b, and 9c at the upstream site (deep) in the Lower Granite tailrace on March 28, 1992
109.	Comparison of total dissolved gas saturation percentage of four high discharge spill tests, with consecutively lower tailwater elevations, March, 1992
110.	Relationship of tailwater elevation to dissolved gas levels for high spill tests, March, 1992.
111.	Relationship of tailwater elevation to dissolved gas levels for inflow spill tests, March, 1992
112.	Relationship of total spill discharge to dissolved gas levels, March, 1992
113.	Results of spill tests 6a and 6b showing differences between north, center, and south stations with spill and powerhouse flows, March 22, 1992
114.	Results of spill tests 6a and 6b showing upstream and downstream dissolved gas levels and how the effects of the powerhouse flow are still separate from the spilled flow four miles downstream, March 22, 1992
115.	Results of spill tests 9a, 9b, 9c showing effects of differences between spill and powerhouse flows, March 28, 1992103
116.	Comparison of north, center, and south station dissolved gas levels during spill tests 3a and 3b, March 17, 1992104
117.	Comparison of dissolved gas levels recorded during spill tests 3a and 3b at the upstream and downstream sites, March 17, 1992

118.	Free-flow spill test showing tainter gate completely out of the water (taken from trunnion bridge across spillway, looking upstream), March 26, 1992.	106
119.	Spill test no. 6b showing effects of the five unit turbine operation, March 22, 1992.	107
120.	Turbidity changes over time at Lower Granite Dam during, March, 1992	
121.	Turbidity changes at Redwolf Bridge and Silcott Island during, March, 1992	108
122.	Turbidity at various river miles on March 12, 14, and 18, 1992	108
123.	Alpowa Creek delta erosion March, 1992	108
124.	Transmissivity differences between surface and bottom of reservoir at various Snake River miles prior to the March, 1992, drawdown test	109
125.	Transmissivity differences between surface and bottom of reservoir at various Snake River miles at the beginning of the drawdown test on March 5, 6, and 7, 1992.	109
126.	Transmissivity differences between surface and bottom of reservoir at various Snake River miles on March 19 and 20, 1992.	109
127.	Comparison of the surface transmissivity at various river miles during the first and third weeks of the drawdown, March, 1992	109
128.	Vertical transmissivity profiles at various river miles on March 7, 18, and 19, 1992	109
129.	Areas of sediment erosion and deposition resulting from the development of a free-flowing river stretch during the March, 1992, drawdown test	112
130.	Typical contaminant sampling location near the Port of Wilma, March, 1992	113
131.	Typical contaminant sampling location near the Port of Wilma, March, 1992	113
132.	Water level fluctuations observed in well 35N/06W-12CCA1, February 20 through April 8, 1992.	114
133.	Water level fluctuations observed in well 11N/45E-20J01D2, February 21 through April 8, 1992.	114
134.	Approximate location of observed resident fish strandings resulting from the drawdown test as observed by the National Marine Fisheries Service and the Washington Department of Wildlife, March, 1992	117
135.	Resident fish mortalities, March, 1992.	117
	Emergency adult exit weir at Lower Granite Dam	
137.	Emergency adult exit chute at Lower Granite Dam	119
138.	Spill test no. 1a showing eddy formation, March 15, 1992.	120
139.	Diagram of typical tailwater eddy formation observed during 100% spill (28,500 cfs) conditions at Lower Granite Dam, March, 1992	121
140.	Diagram of tailwater eddy formation observed during 53,400 cfs (69%) spill and 24,100 cfs (31%) powerhouse discharges at Lower Granite Dam, March 28, 1992	121
141.	Diagram of tailwater eddy formation observed during 23,300 cfs (21%) spill and 84,000 cfs (79%) powerhouse discharges at Lower Granite Dam, March 22, 1992	121
142.	Diagram of tailwater eddy formation observed during 81,400 cfs (78%) spill and 23,000 cfs (22%) powerhouse discharges at Lower Granite Dam, March 16, 1992	121
143.	Gravel bar below Lower Granite Dam, March, 1992.	124
	Close-up of gravel bar below Lower Granite Dam, March, 1992.	
	Diagram of approximate extent of the gravel bar downstream of Lower Granite Dam exposed during the March, 1992 drawdown test (underwater during normal	
	pool elevations).	124

146.	Approximate location of observed anadromous fish strandings resulting from	
	the March, 1992 drawdown test	5
147.	Stranded salmonids, March, 1992	5
148.	Track of a mussel as it attempted to reach the receding water, March, 1992126	3

Tables

1.	Water surface elevations at near spillway crest operation at Lower Granite Dam
2.	Agencies and groups represented on the Reservoir Drawdown Test Design Team
3.	Summary of spill tests performed at Lower Granite Dam in March, 199229
4.	Lower Granite drawdown test resources management patrol schedule, March, 1992
5.	Turbine tests at Lower Granite Dam, March, 1992
6.	Turbine operation at Lower Granite Dam during March, 1992
7.	Location of USGS velocity mapping sites, February and March, 199255
8.	Location of USGS sediment, temperature, velocity, and turbidity monitoring sites, March, 1992
9.	Location of Lower Granite reservoir contaminant monitoring sites, March, 1992
10.	
11.	Summary of spill test dissolved gas data at Lower Granite Dam, March, 1992
12.	Summary of average dissolved gas levels for each spill test at Lower Granite Dam, March, 1992
13.	Snake River sediment discharge data collected by the USGS during February and March, 1992.
14.	Clearwater River sediment discharge data collected by the USGS during February and March, 1992.
15.	Results of contaminant analyses, March, 1992
16.	Groundwater well data collected by the USGS, February and March, 1992114
17.	Number of fish sampled by the ICFWRU for gas bubble trauma during the March, 1992, drawdown test
18.	National Marine Fisheries Service estimates of fish mortality resulting from stranding during the March, 1992, drawdown test
19.	Washington Department of Wildlife estimates of fish mortalities resulting from stranding during the March, 1992, drawdown test
20.	Adult fish counts, Lower Granite Dam, March, 1992
21.	Summary of fish rescued at Lower Granite Dam by gatewell dipping during the March, 1992, drawdown test
22.	Comparison of the Lower Granite and Little Goose project visitation data during March, 1991, and March, 1992
23.	Summary of estimated cost of physical damages resulting from the March, 1992, drawdown test

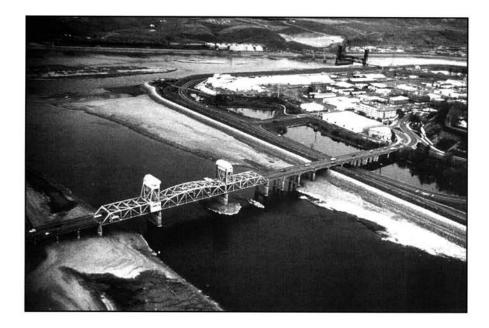
Appendices

Engineering

- A. Hydraulic Evaluation
- B. Wave Erosion Analysis for Embankments
- C. Settlement Gages
- D. Piezometer Study
- E. Structural Instrumentation
- F. Existing Structures and Facilities Surveillance
- G. Impact on Power Plant Operation
- H. Lewiston Levee Pumping Plants
- I. Road and Railroad Embankments
- J. Emergency Equipment and Materials
- K. Lewiston Levee Waste Area (3 Volumes)

Environmental

- L. Groundwater Investigations
- M. Results of Hydrology Studies
- N. Dissolved Gas Data
- O. Water Quality and Sediment Quality Data
- P. Evaluation of the 1992 Drawdown in Lower Granite and Little Goose Reservoirs
- Q. Impacts of the Snake River Drawdown Experiment on Fisheries Resources in Little Goose and Lower Granite Reservoirs
- R. Impact of Experimental Dewatering of Lower Granite and Little Goose Reservoirs on Benthic Invertebrates and Macrophytes
- S. Lower Snake Reservoir Drawdown Test plan
- T. Evaluation of 100 Percent Spill on Fish Passage Conditions at Lower Granite Dam
- U. Reservoir Drawdown Test Design Team Meeting Minutes
- V. Snake and Columbia Rivers Sediment Sampling Project
- W. Lower Granite and Little Goose Project Operation Data
- X. Daily Environmental Reports



Confluence of the Snake and Clearwater Rivers, during the March, 1992, reservoir drawdown test.