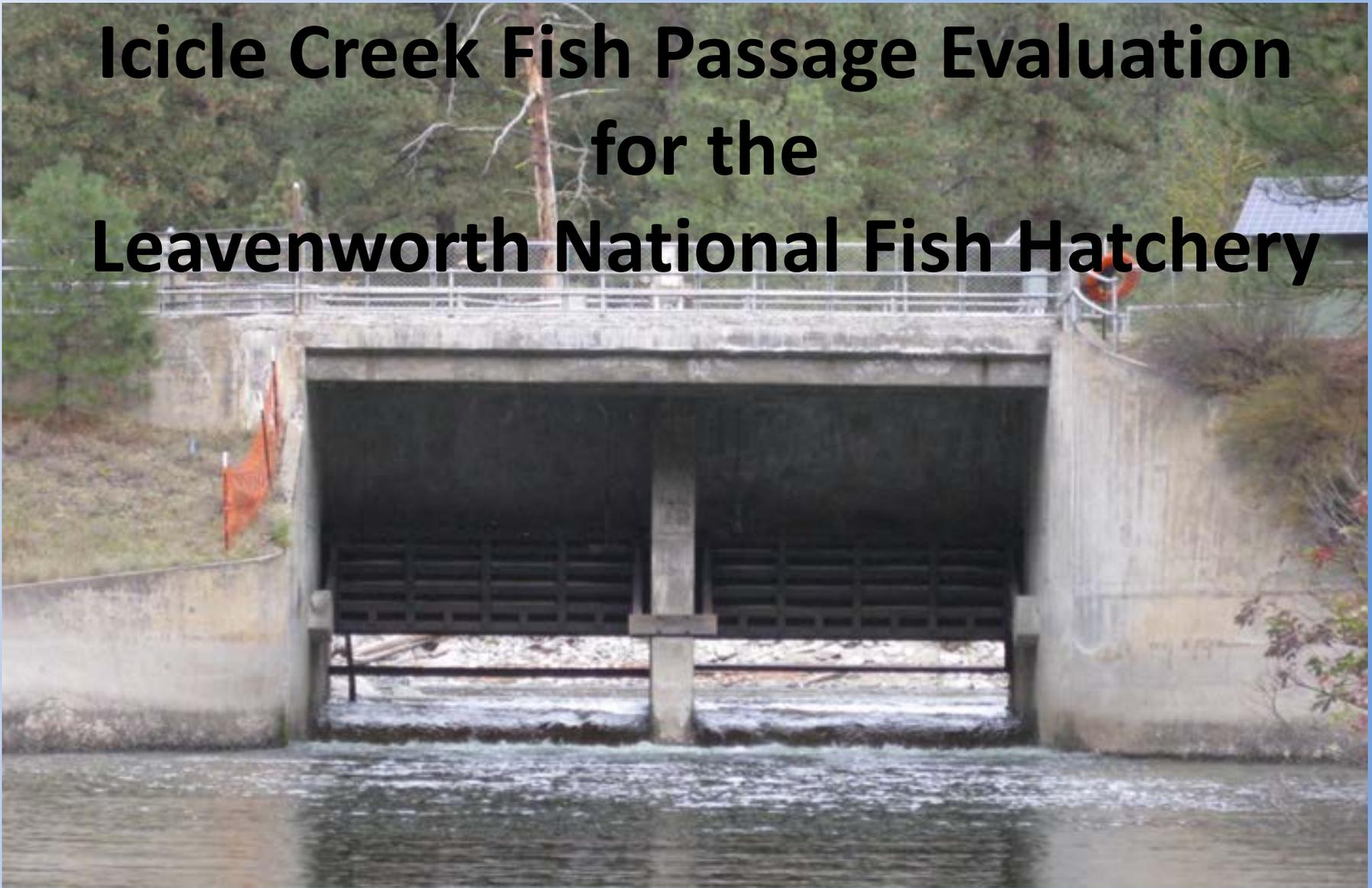


Icicle Creek Fish Passage Evaluation for the Leavenworth National Fish Hatchery



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

CONSERVING
America's
Fisheries

Conserving America's Fisheries



Goals

- Characterize physical and hydraulic conditions at three instream structures in Icicle Creek
- Relate those conditions to passage criteria for the target species
- Determine the time periods when passage may or may not be affected by Icicle Creek streamflow conditions at the structures



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



Objectives

- Characterize physical and hydraulic conditions at S2 including conditions with and without the radial gates adjusted. Relate conditions to species passage criteria and periodicity.
- Characterize physical and hydraulic conditions at S5 including conditions with and without the pickets installed. Relate conditions to species passage criteria and periodicity.
- Characterize physical and hydraulic conditions at the LNFH intake including the fishway conditions, fishway entrance location and attraction flow, diversion dam, and tailrace conditions. Relate conditions to species fishway criteria.
- Assess passage conditions associated with a range of streamflows in the historical channel of Icicle Creek and relate those conditions to species-specific passage criteria.



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries





Site Overview

Leavenworth National Fish Hatchery

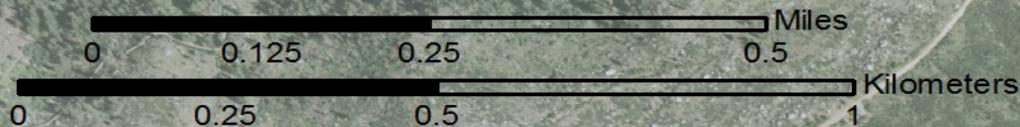
Structure 5 (RM 2.9)

Hatchery Channel

Structure 2 (RM 3.8)

Icicle Creek Historical Channel

LNFH Intake (RM 4.5)



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



Structure 2 (S2) Methods

- System of equations used to model depth and velocity
- Radial gates open
 - $Q = C * W * H^{1.5}$
 - $h_c = ((Q/W)^2 / g)^{0.333}$
 - $v_c = Q / (h_c W)$
- Radial gates adjusted
 - $Q = B * C * W * ((2 * g) * H)^{0.5}$
 - $v_c = Q / (B * W)$
- Downstream pool conditions - observations
- Compare conditions to 10%, 50%, 90% exceedance flows to determine passage



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



Structure 2 (S2) Results



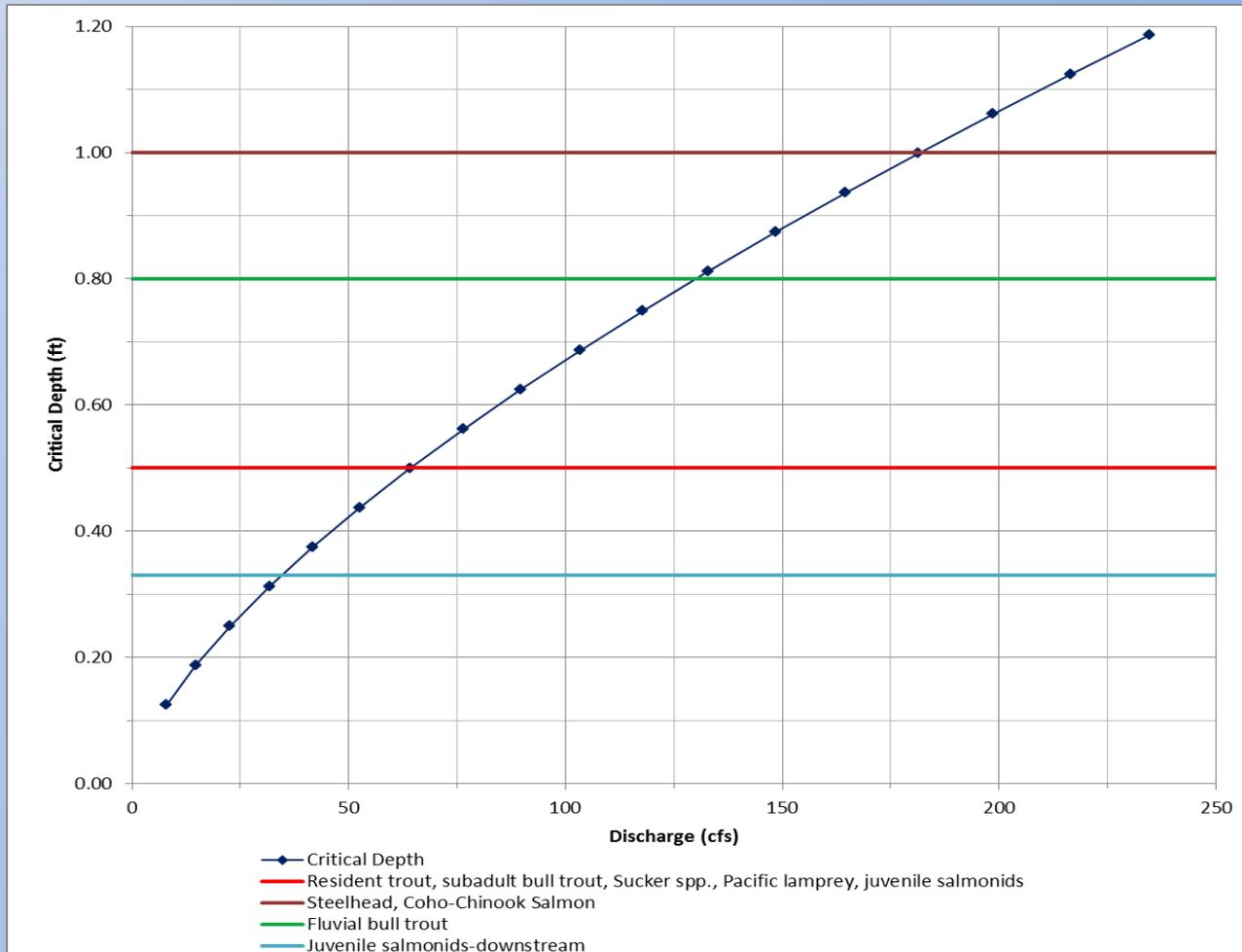
U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



S2 Results – Depth vs. Discharge



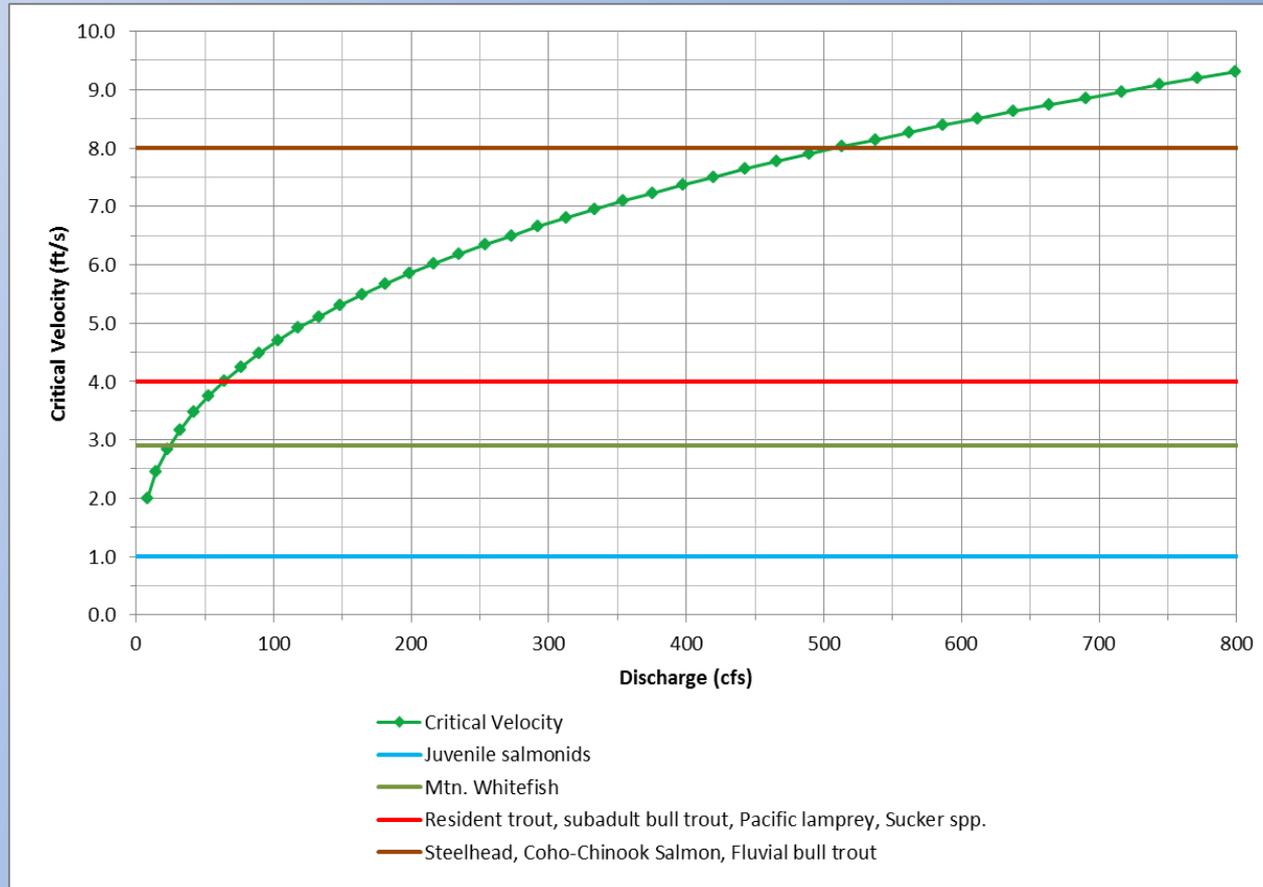
U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

Conserving America's Fisheries



S2 Results – Velocity vs. Discharge



S2 Results – Species Periodicity, Passage Limitations Adult Migration

Month	Median Flow (cfs)	Species/Lifestage							
		Spring Chinook Salmon Adult	Summer Chinook Salmon Adult	Coho Salmon Adult	Steelhead Adult	Fluvial bull trout Adult	Pacific lamprey Adult	Mountain whitefish Adult	Sucker <i>spp.</i> Adult
January	198								
February	150				D				
March	191								
April	555				V	V			
May	1150	V			V	V		V	V
June	1310	V				V	V	V	V
July	685	V				V	V	V	V
August	168		D				V		
September	100		D	D			V		
October	137		D	D			V		
November	188								
December	232								



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



S2 Results – Species Periodicity, Passage Limitations Adult, Juvenile Rearing

Month	Median Flow (cfs)	Species/Lifestage			
		Resident trout, subadult bull trout, sucker spp., Pacific lamprey Rearing	Mountain whitefish Rearing	Juvenile salmonids Rearing-upstream	Juvenile salmonids Rearing-downstream
January	198	✓	✓	✓	
February	150	✓	✓	✓	
March	191	✓	✓	✓	
April	555	✓	✓	✓	
May	1150	✓	✓	✓	
June	1310	✓	✓	✓	
July	685	✓	✓	✓	
August	168	✓	✓	✓	
September	100	✓	✓	✓	
October	137	✓	✓	✓	
November	188	✓	✓	✓	
December	232	✓	✓	✓	



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



S2 Results – Radial Gates Adjusted Conditions

Water Surface Elevation (H ₁ , ft)	Radial Gate Opening						No Radial Gates	
	1.0 Feet		1.5 Feet		2.0 Feet		Discharge (cfs)	Critical Velocity (ft/s)
	Discharge (cfs)	Critical Velocity (ft/s)	Discharge (cfs)	Critical Velocity (ft/s)	Discharge (cfs)	Critical Velocity (ft/s)		
2.0	182	5.67					253	6.34
2.5	203	6.34	305	6.34			354	7.09
3.0	222	6.95	334	6.95			466	7.77
3.5	240	7.51	360	7.51	480	7.51	587	8.39
4.0	257	8.02	385	8.02	514	8.02	717	8.97



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



Structure 5 (S5) Methods

- Depths, velocities, water surface elevations measured at three streamflows
- Stage – Discharge rating curves developed
- Rating curves used to model water surface elevations and depths
- Average velocity vs. discharge relationship developed
- Average velocities modeled over a range of streamflows
- Velocities modeled with pickets installed
- Compare conditions to 10%, 50%, 90% exceedance flows to determine passage



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



Structure 5 (S5) Results



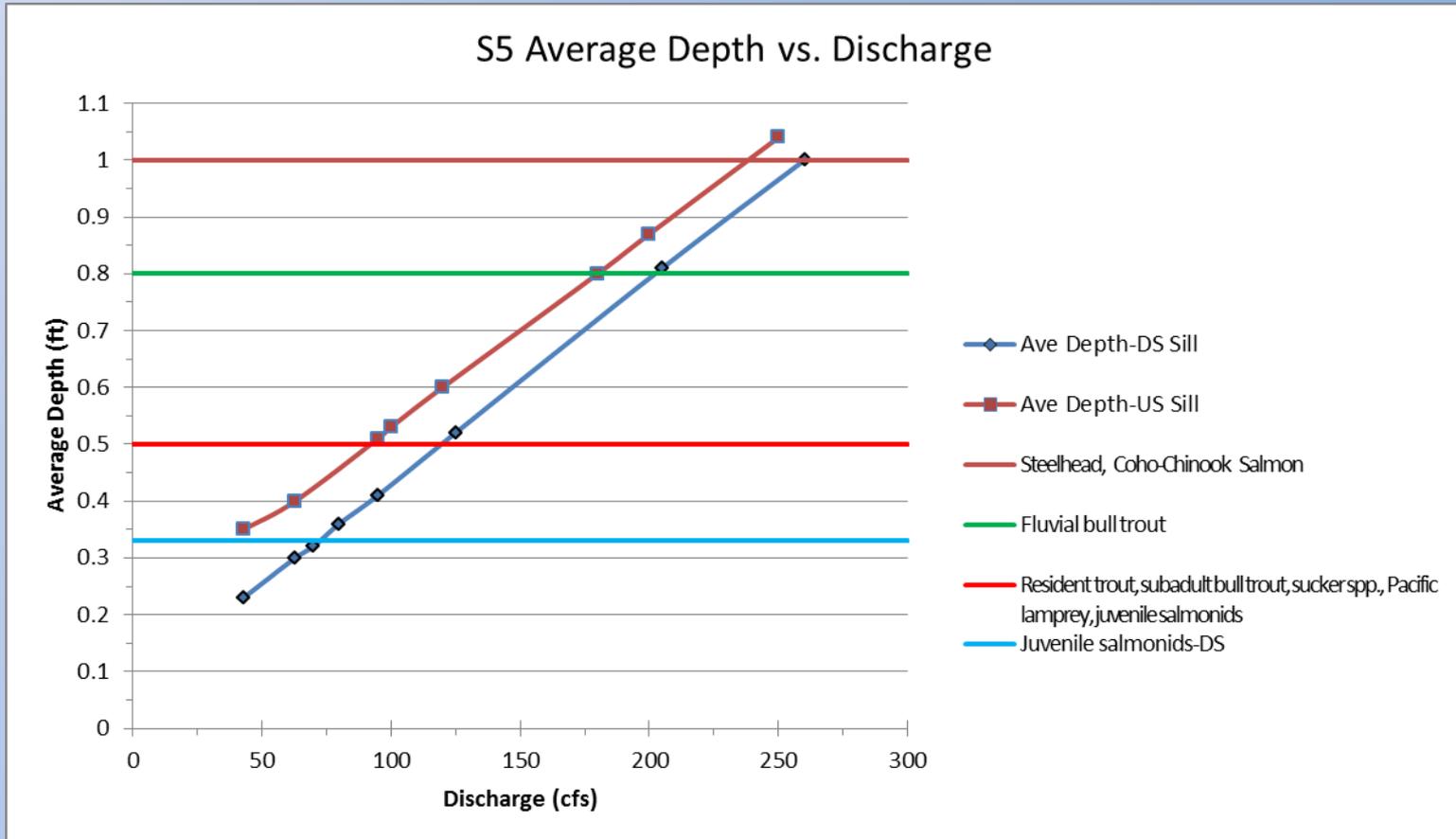
U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



S5 Results – Depth vs. Discharge



U.S. Fish and Wildlife Service

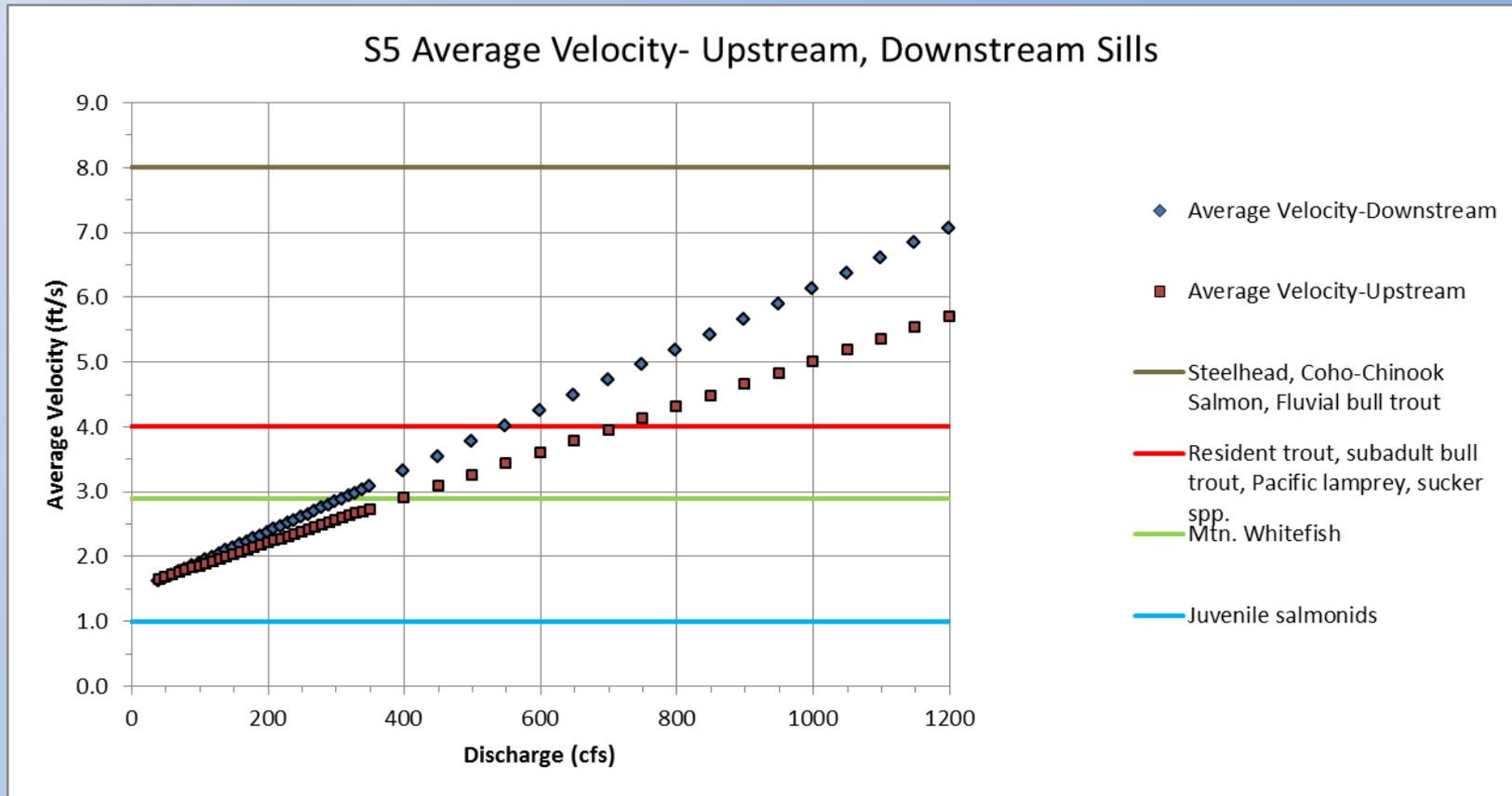
Columbia River Fisheries Program Office



Conserving America's Fisheries



S5 Results – Velocity vs. Discharge



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



S5 Results – Species Periodicity, Passage Limitations Adult Migration

Month	Median Flow (cfs)	Species/Lifestage							
		Spring Chinook Salmon Adult	Summer Chinook Salmon Adult	Coho Salmon Adult	Steelhead Adult	Fluvial bull trout Adult	Pacific lamprey Adult	Mountain whitefish Adult	Sucker <i>spp.</i> Adult
January	198				D				
February	150				D				
March	191				D				
April	555								
May	1150						V	V	
June	1310						V	V	
July	685						V	V	
August	168		D						
September	100		D	D			D		
October	137		D	D					
November	188			D					
December	232			D					



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



S5 Results – Species Periodicity, Passage Limitations Adult, Juvenile Rearing

Month	Median Flow (cfs)	Species/Lifestage			
		Resident trout, subadult bull trout, sucker spp., Pacific lamprey Rearing	Mountain whitefish Rearing	Juvenile salmonids Rearing-upstream	Juvenile salmonids Rearing-downstream
January	198			V	
February	150			V	
March	191			V	
April	555	V	V	V	
May	1150	V	V	V	
June	1310	V	V	V	
July	685	V	V	V	
August	168			V	
September	100	D	D	D	
October	137			V	
November	188			V	
December	232			V	



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



LNFB Intake Methods

- Depths, widths, velocities, and hydraulic drop were measured in the fishway for two conditions
- Flow conditions in the tailrace were described on drawings and in photos to evaluate fishway entrance location
- Flow conditions over the diversion dam were estimated and described on drawings and in photos to evaluate upstream and downstream passage over the dam
- Adult upstream passage periodicity was compared to passage conditions over the diversion dam



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



LNFH Intake Results



U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



LNFH Intake Results

Fishway conditions - flow=4.5 cfs

Weir #	Width (ft)	Head Diff. (ft)	Depth-Weir (ft)	Depth-Notch (ft)	Velocity-Notch (ft/s)	Velocity-Nappe (ft/s)
1	5	0.8	0.25	0.60	3.06	7.19
2	5	1.1	0.30	0.70	2.25	8.41
3	5	0.8	0.05	0.50	2.98	7.19
4	5	1.2	0.20	0.65	2.41	8.79
5	5	1.1	0.25	0.70	2.42	8.41
6	Not used					
7	5	1.0	0.25	0.70	2.93	8.02
Average	5	1.0	0.22	0.64	2.68	8.02

Pool #	Width (ft)	Length (ft)	Depth Range (ft)	Depth-Average (ft)	Velocity-Average (ft/s)
1	5	13.4	6.10-6.80	6.50	0.14
2	5	16.1	3.90-6.10	4.70	0.19
3	5	16.0	3.60-5.40	4.80	0.19
4	5	8.0	4.20-4.20	4.20	0.21
5	5	16.1	3.00-3.30	3.20	0.28
Entrance 2.5 ft DS	5	2.5	2.55-2.90	2.70	-0.09
Entrance 4.0 ft DS	N/A	1.5	2.35-2.45	2.42	0.57
Entrance 8.0 ft DS	N/A	4.0	N/A	2.10	1.42



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



LNFH Intake Results

Fishway conditions - flow=0.75 cfs

Weir #	Width (ft)	Head Diff. (ft)	Depth-Weir (ft)	Depth-Notch (ft)	Velocity-Notch (ft/s)	Velocity-Nappe (ft/s)
1	5	0.75	0	0.30	1.60	6.97
2	5	1.10	0	0.40	1.41	8.41
3	5	0.95	0	0.30	1.10	7.82
4	5	0.90	0	0.35	1.46	7.60
5	5	0.90	0	0.35	1.23	7.60
6	5	1.00	0	0.30	1.42	8.02
7	5	0.90	0	0.35	1.35	7.60
Average	5	0.93	0	0.34	1.37	7.74

Pool #	Width (ft)	Length (ft)	Depth Range (ft)	Depth-Average (ft)	Velocity-Average (ft/s)
1	5	13.4	6.05-6.75	6.39	0.02
2	5	16.1	3.80-5.40	4.54	0.03
3	5	16.0	3.50-5.10	4.60	0.03
4	5	8.0	4.55-4.55	4.55	0.03
5-US	5	8.1	3.40-3.40	3.40	0.04
5-DS	5	8.0	2.40-2.40	2.40	0.06
Entrance 2.5 ft DS	5	2.5	1.60-1.60	1.60	0.36
Entrance 4.0 ft DS	N/A	1.5	1.40-1.80	1.63	-0.17
Entrance 6.5 ft DS	N/A	2.5	1.20-1.60	1.40	0.12



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

Conserving America's Fisheries

Conserving America's Fisheries



LNFH Intake Results

Fishway, tailrace conditions – high, low flows

2,663 cfs



1,271 cfs



121 cfs



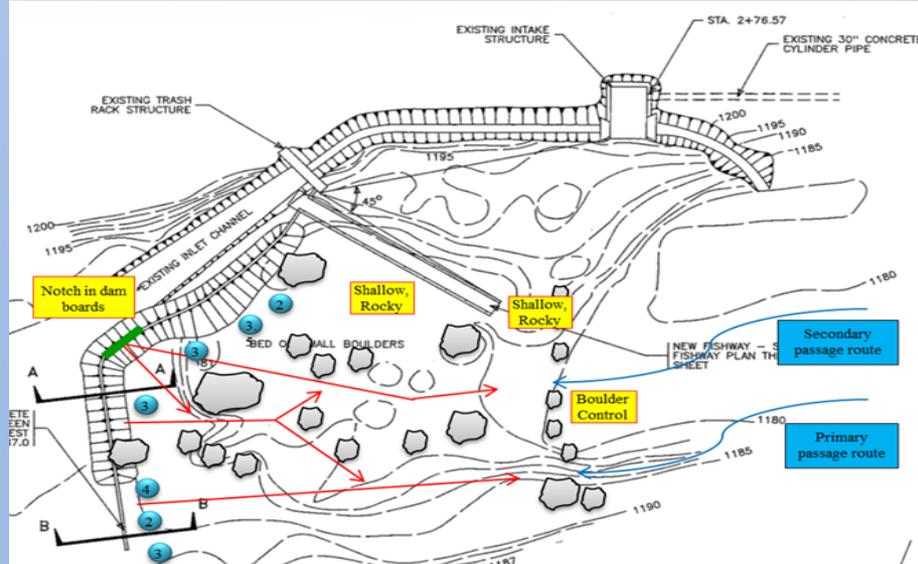
U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

Conserving America's Fisheries



LNFH Intake Results

Fishway entrance location, conditions



U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

Conserving America's Fisheries



LNFH Intake Results

Upstream passage over the diversion dam

Streamflow (cfs)	WSE Differential FB-TR (ft)	Passage Over Dam
2663	2.5	YES
1271	3.5	YES
324	4.5	Jump pool-YES
121	5.5	Jump pool-MAYBE

Species	Passage Periodicity	Median Flow Range (cfs)	Passage Over Dam
Spring Chinook Salmon	May-July	784-1539	YES
Summer Chinook Salmon	August-October	142-228	PARTIAL
Coho Salmon	September-December	142-304	PARTIAL
Steelhead	January-May	206-1539	PARTIAL
Fluvial Bull Trout	April-July	653-1919	YES



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries



LNFH Intake Results

Downstream passage over the diversion dam

324 cfs



121 cfs



U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

CONSERVING
AMERICA'S
Fisheries

Conserving America's Fisheries



Icicle Creek Historical Channel Passage Methods

- Compile depth grids from hydrodynamic modeling
- Grids were reviewed to determine streamflows that corresponded to depth passage criteria
- Flows were determined that did not satisfy passage criteria
- The threshold flow that provided continuous passage was identified



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office

Conserving America's Fisheries



Icicle Creek Historical Channel Passage Results

Criteria=0.4 ft

Criteria=0.5 ft



U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

Conserving America's Fisheries



Icicle Creek Historical Channel Passage Results

Criteria=0.8 ft

Criteria=1.0 ft



U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office

Conserving America's Fisheries



Icicle Creek Passage Evaluation Summary

Species/Lifestage Group	Depth Criteria (ft)	S2 Discharge (cfs)	S5 Discharge (cfs)	Open Channel (cfs)	Velocity Criteria (ft/s)	S2 Discharge (cfs)	S5 Discharge (cfs)
Salmon/Steelhead	1.0	181	250-260	200	8.0	512	>1200
Fluvial bull trout	0.8	132	180-205	120	8.0	512	>1200
Resident trout, Subadult bull trout, Sucker spp., Pacific lamprey	0.5	64	95-125	60	4.0	64	550-700
Mountain whitefish	0.5	64	95-125	60	2.9	23	310-400
Juvenile salmonids-upstream	0.5	64	95-125	60	1.0	NONE	NONE
Juvenile salmonids-downstream	0.33	35	40-70	30	N/A	N/A	N/A



U.S. Fish and Wildlife Service

Columbia River Fisheries Program Office



Conserving America's Fisheries

