



Evaluation of Foster Dam Juvenile Fish Passage: Sensor Fish Evaluation of the New Spillway Weir at Foster Dam, 2018



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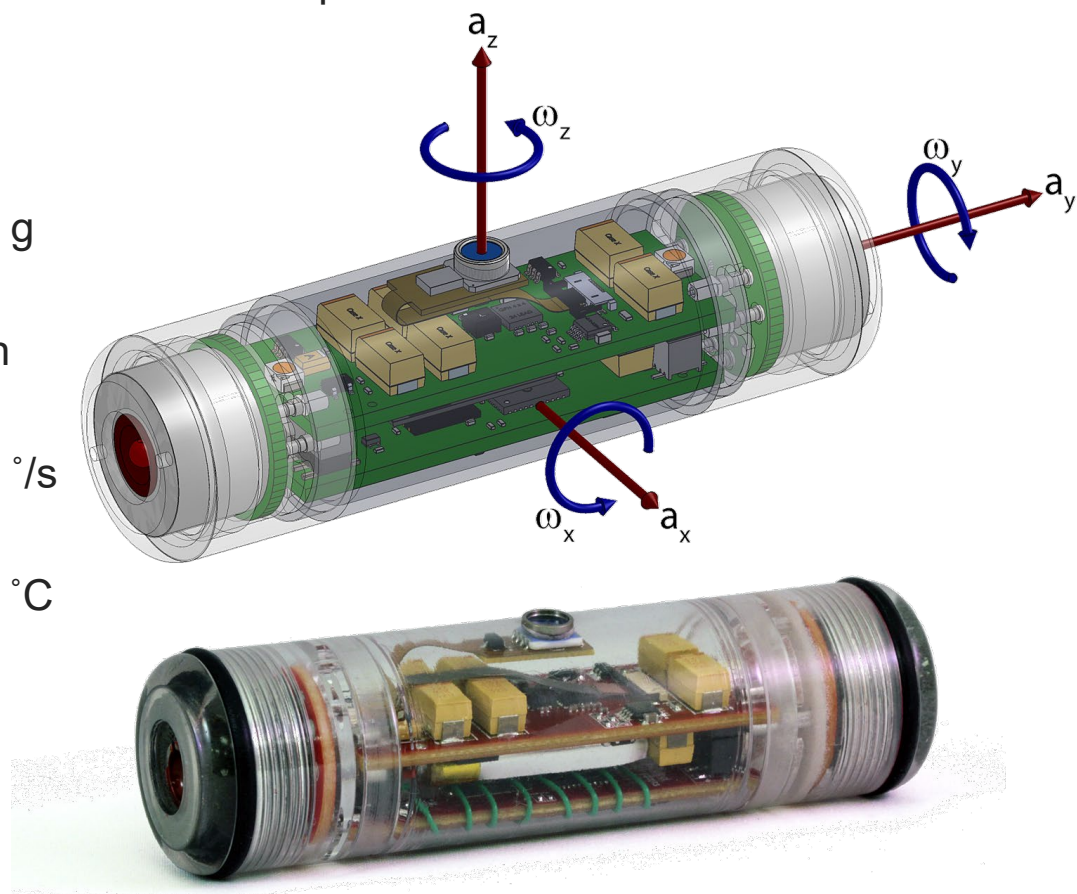
Project Goal and objectives

The goal was to evaluate the hydraulic conditions for the new fish weir using Sensor Fish and determine if the new weir improved the hydraulic conditions for fish passage compared to the previous fish weir. Specific objectives include:

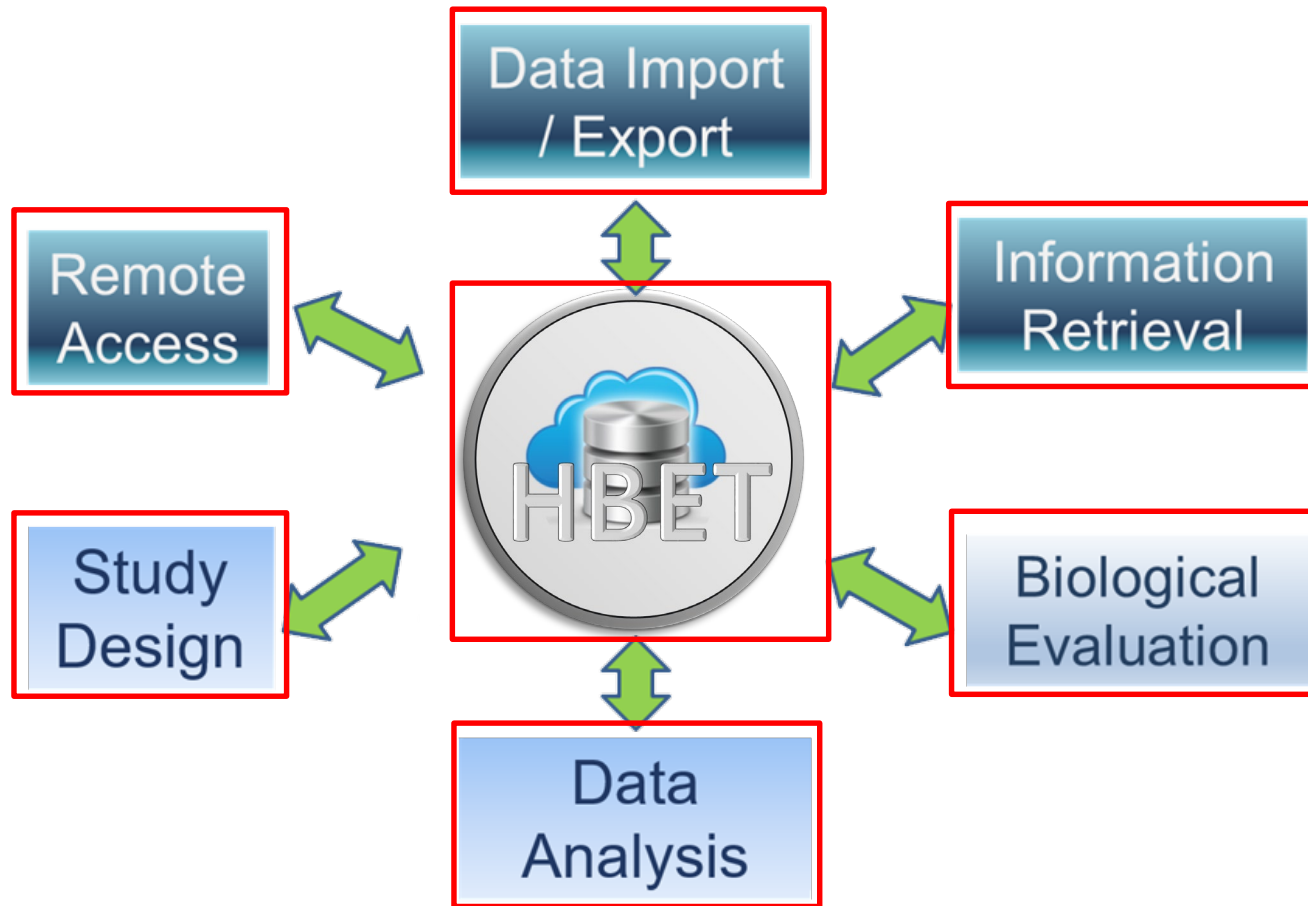
- ▶ Measure the hydraulic conditions for passage through the weir at two forebay elevations (614 ft and 635 ft MSL).
- ▶ Compare the passage conditions of the new fish weir with those of the previous fish weir.
- ▶ Compare the measured passage conditions by Sensor Fish to the fish injury and survival rates acquired by the balloon tag study performed by Normandeau Associates, Inc.
- ▶ Compare the passage conditions of the new fish weir at two discharge rates (530 cfs and 300 cfs).

Gen 2 Sensor Fish Device

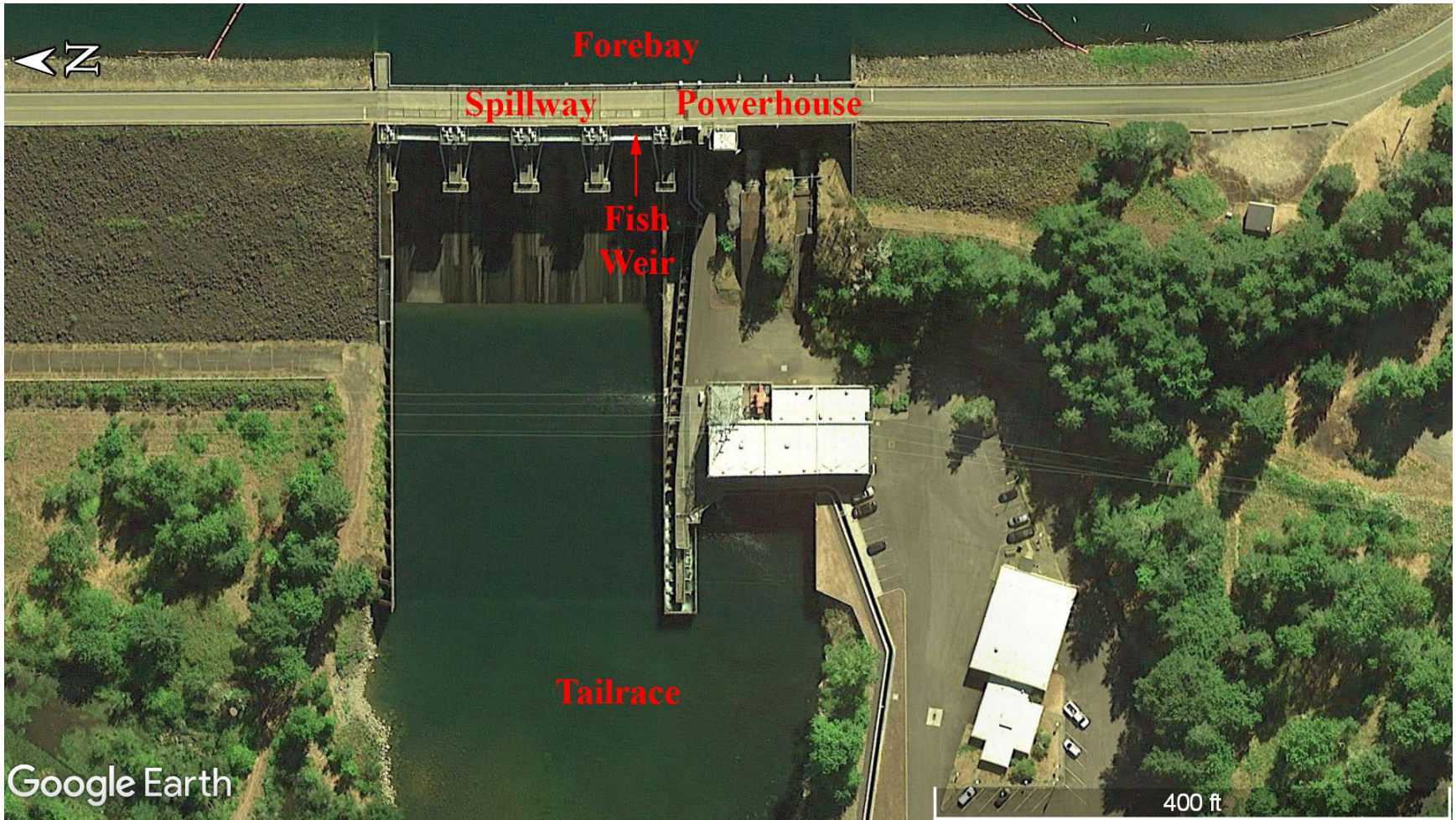
- ▶ Autonomous sensor package
- ▶ Developed to understand physical conditions fish experience
- ▶ Sensor Fish Characteristics
 - Dimensions: 89.9 x 24.5 mm
 - Density: 1.01 mg/mm³
 - Excess mass (wet weight): 0.5 g
 - Sampling rate: 2048 Hz
 - Maximum sampling time: 4 min
 - 3D acceleration: 0 - 200 g
 - 3D rotational velocity: 0 - 2000 °/s
 - Pressure: 0 - 203 psia
 - Temperature sensor: -40 - 125 °C
 - 3D orientation
 - Automatic floatation system
 - Built-in RF-transmitter
 - Significantly reduced cost



Hydropower Biological Evaluation Toolset (HBET)

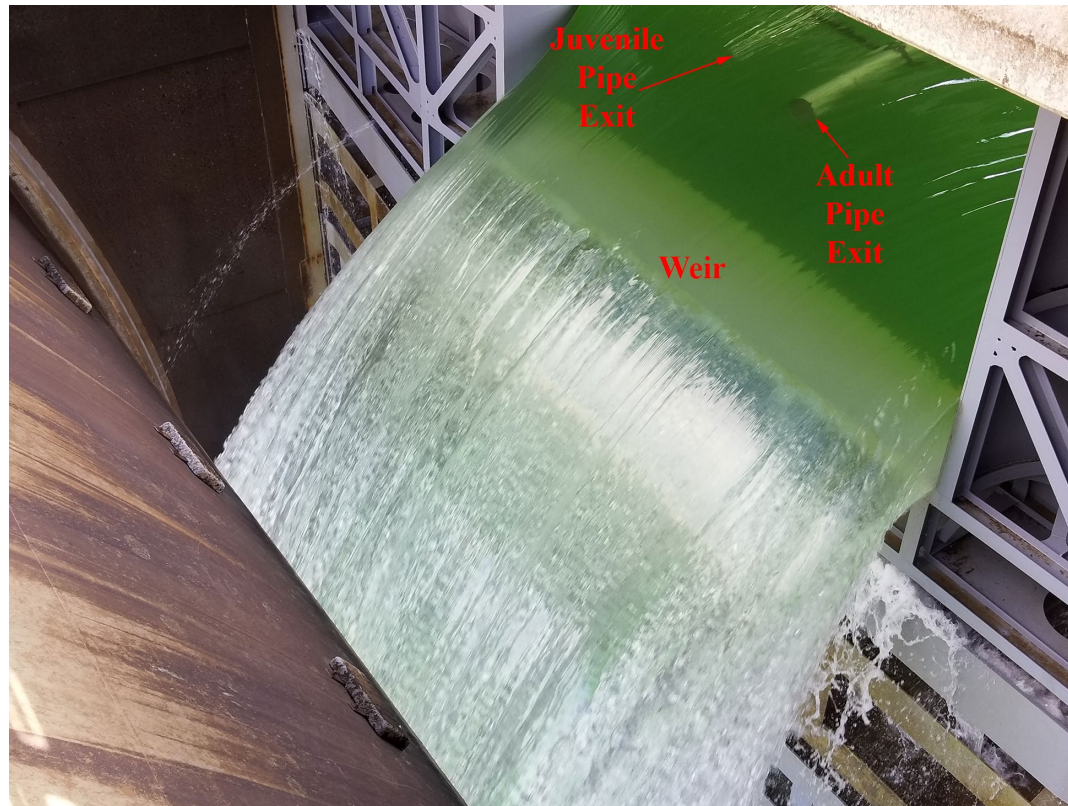


Foster Dam



Methods and Deployment

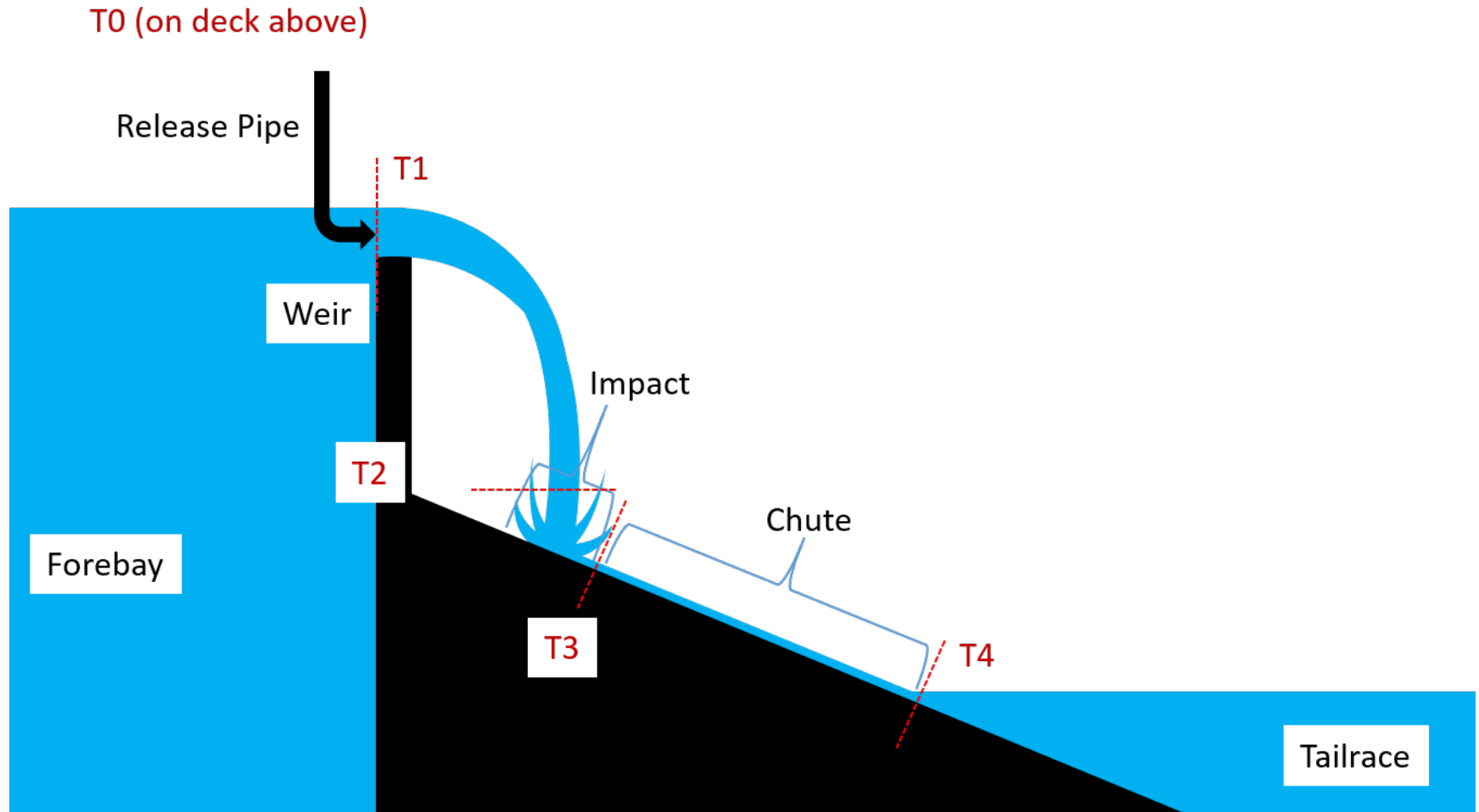
- ▶ Sensor Fish were introduced through the same release pipes used by Normandeau for releasing live fish.
- ▶ Sensor Fish releases were interspersed among live fish releases.
- ▶ Following deployment, Sensor Fish were recovered from the tailrace by boat.



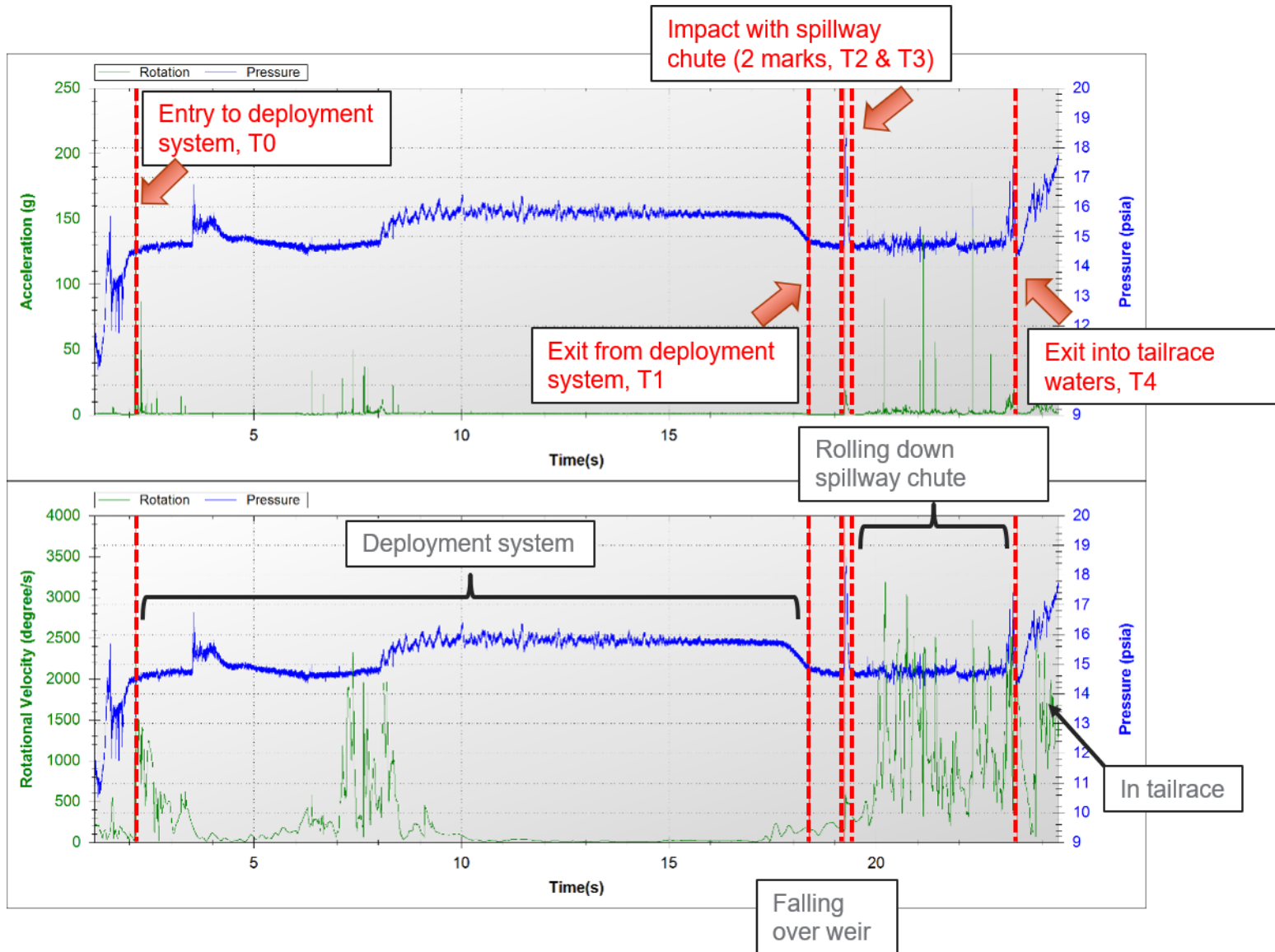
Release Data

Treatment	Forebay Level	Forebay Elevation (ft)	Discharge Rate (cfs)	Release Pipe	Valid Releases	Controls
1A	Low	613	530	Juvenile	88	11
1B	Low	613	530	Adult	6	2
2A	High	635	530	Juvenile	108	5
2B	High	635	530	Adult	4	1
3	High	635	530	Adult	46	3
4	Low	614	300	Adult	42	13

Results: Timing Marks



Results: Timing Marks



Percentage of Sensor Fish Releases with Severe Events in the Impact and Chute Regions

- ▶ Most Sensor Fish releases experienced severe events in the Chute region.
- ▶ For each treatment, fewer Sensor Fish releases experienced severe events in the Impact region than in the Chute region.
- ▶ In the impact region, fewer percentage of Sensor Fish releases experienced severe events at the low forebay level than at the high forebay level.

Treatment	Forebay Level	Discharge Rate (cfs)	Valid Releases	Releases with Severe Events (>95 g)		
				Impact & Chute (T2-T4)	Impact (T2-T3)	Chute (T3-T4)
1A	Low	530	88	98.9%	3.4%	98.9%
1B	Low	530	6	100.0%	16.7%	100.0%
2A	High	530	108	99.1%	44.4%	96.3%
2B	High	530	4	100%	100%	100%
3	High	530	46	100.0%	87.0%	91.3%
4	Low	300	42	97.6%	19.0%	95.2%

Comparison by Treatment

- ▶ For Sensor Fish releases through either the juvenile release pipe (treatments 1A and 2A) or the adult release pipe (treatments 3 and 4), there was a significant difference (p-value < 0.05) between the low and high forebay elevations in the Impact region for the Sensor Fish releases experiencing severe events, with the low forebay elevation providing better conditions for fish passage.

Treatment	Valid Releases	Forebay Elevation (ft MSL)	Impact		Chute		Combined	
			% w/ Severe Events	p-value	% w/ Severe Events	p-value	% w/ Severe Events	p-value
1A	88	615	3.4	< 0.01	98.9	0.38	98.9	1
2A	108	635	44.4	< 0.01	96.3	0.38	99.1	1
3	46	635	87.0	< 0.01	91.3	0.68	100.0	0.48
4	42	615	19.0	< 0.01	95.2	0.68	97.6	0.48

Comparison by Forebay Elevation

- ▶ There was a significant difference (p -value < 0.05) between the low and high forebay elevations in the Impact region for the Sensor Fish releases experiencing severe events, with the low forebay elevation providing better conditions for fish passage.

Forebay Elevation	Valid Releases	Impact		Chute		Combined	
		% w/ Severe Events	p-value	% w/ Severe Events	p-value	% w/ Severe Events	p-value
Low	136	8.8	< 0.01	97.8	0.23	98.5	0.6
High	158	58.2		94.9		99.4	

Comparison by Discharge

- ▶ Comparison was for the low forbay elevation (combining treatments 1A and 1B vs. treatment 4).
- ▶ There was a significant difference between the discharge rates of 300 and 530 cfs in the Impact region for Sensor Fish releases experiencing severe event, with the discharge rate of 530 cfs providing better conditions for fish passage.

Discharge Rate (cfs)	Valid Releases	Impact		Chute		Combined	
		% w/ Severe Events	p-value	% w/ Severe Events	p-value	% w/ Severe Events	p-value
530	94	4.3	0.01	98.9	0.23	98.9	0.52
300	42	19.1		95.2		97.6	

Comparison with Old Weir (2012 Study)

- ▶ There were significant differences in the Impact region between the 2018 and 2012 studies at both low and high forebay levels for the Sensor Fish releases experiencing severe events, with the new fish weir design providing significantly improved conditions for fish passage in the Impact region.
- ▶ The largest improvement in the Impact region was at the low forebay level operating condition. The percentage of Sensor Fish experiencing severe events reduced from 81.3% to 3.4% from 2012 study to 2018 study.

Treatment	Valid Releases	Forebay Elevation (ft MSL)	Impact		Chute		Combined	
			% w/ Severe Events	p-value	% w/ Severe Events	p-value	% w/ Severe Events	p-value
1A	88	615	3.4	< 0.01	98.9	1	98.9	1
5 (2012)	16	615	81.3		100.0		100.0	
2A	108	635	44.4	< 0.01	96.3	0.19	99.1	1
6 (2012)	17	635	94.1		88.2		100.0	

Comparison with Live Fish Results

- ▶ There was a statistically significant correlation between 48-hour survival rates (R-value = -0.999; p-value = 0.03) of the juvenile Chinook salmon and the mean maximum severe event acceleration magnitude in the Impact region.
- ▶ No significant correlations between Sensor Fish results and juvenile steelhead results.
- ▶ June 12 has significantly smaller mean max acceleration of SF releases with severe events than June 11, consistent with live fish data.
- ▶ Treatment 4 (low forebay level at 300 cfs flow) has better fish passage conditions than Treatment 3 (high forebay level at 530 cfs flow), consistent to adult fish results.

Treatment		Rates without control corrections		Rates with control corrections		Releases with Severe Events			Severe Events per Release			Mean Max Acceleration (g)			Mean Max Acc. (g), Severe Only		
		48-h survival	injury-free	48-h survival	injury-free	Impact	Chute	Combined	Impact	Chute	Combined	Impact	Chute	Combined	Impact	Chute	Combined
		Juvenile Chinook	4/26, 4/27	87.55%	86.35%	98.0%	88.7%	2.6%	97.4%	97.4%	0.1	3.4	3.5	20.4	172.3	172.3	146.0
	11-Jun	77.27%	60.55%	77.3%	62.1%	48.0%	96.0%	100.0%	0.9	3.4	4.3	121.1	158.3	176.5	184.1	161.7	176.5
	12-Jun	89.29%	83.45%	89.3%	85.6%	42.9%	96.4%	100.0%	0.7	3.2	3.9	93.5	156.6	164.1	142.0	162.4	164.1
Juvenile Steelhead	4/24,4/25,4/26, 4/28	99.68%	87.70%	99.7%	87.7%	2.9%	100.0%	100.0%	0.0	4.1	4.1	22.5	171.4	172.2	188.3	171.4	172.2
	13-Jun	97.56%	83.74%	97.6%	83.7%	60.7%	100.0%	100.0%	1.0	3.3	4.3	119.1	177.2	181.9	154.7	177.2	181.9
	14-Jun	94.31%	86.99%	94.3%	87.0%	25.9%	92.6%	96.3%	0.3	3.3	3.6	90.2	170.1	174.9	167.7	176.8	178.3
Adult Fish	3	80.00%	62.00%	89.3%	62.0%	87.0%	91.3%	100.0%	2.7	4.8	7.5	165.0	177.2	204.4	180.9	187.6	204.4
	4	90.38%	71.15%	93.5%	92.8%	19.1%	95.2%	97.6%	0.2	2.4	3.2	54.0	164.4	166.4	167.2	168.9	168.3

Comparison with other Sensor Fish Spillway Studies

- ▶ Comparison was for the Chute region between the 2018 Sensor Fish study at Foster and studies at other dams.
- ▶ For each of the comparison, there was a significant difference for all three of the Sensor Fish parameters, with the hydraulic conditions from the current study at Foster resulting in less favorable hydraulic conditions for fish.

Treatment	Valid Releases	Average Discharge Rate (cfs)	Average Hydraulic Head (ft)	% w/ Severe Events	Severe Events per Release p-value	Severe Events per Release	Mean Max Accel. (g) p-value
Foster 2018	294	530/300	99	96.3%	NA	3.7	169.1 NA
McNary 2007	242	9,500	57	27.7%	<0.01	0.5	66.3 <0.01
John Day 2008	58	9,640	96	50.0%	<0.01	1.1	98.5 <0.01
John Day 2010	45	2,930	56	73.3%	<0.01	1.1	114.9 <0.01
Boundary 2014	31	11,000	214	35.5%	<0.01	0.5	75.8 <0.01
Boundary 2015	59	11,000	214	49.2%	<0.01	1.4	117.8 <0.01
Ice Harbor 2015	86	8,500	96	23.3%	<0.01	0.3	42.5 <0.01

- ▶ The new fish weir design resulted in statistically significant improvements in the Impact region.
- ▶ Fewer Sensor Fish releases experienced severe events in the Impact region than in the Chute region for each treatment.
- ▶ The low forebay elevation provided better conditions for fish passage than the high forebay elevation.
- ▶ The discharge rate of 530 cfs provided better conditions for fish passage than the discharge rate of 300 cfs for the low forebay elevation treatments.
- ▶ There was a statistically significant correlation between 48-hour survival rates of the juvenile Chinook salmon and the mean maximum severe event acceleration magnitude in the Impact region, but not for juvenile steelhead.
- ▶ Treatment 4 (low forebay level at 300 cfs flow) has better fish passage conditions than Treatment 3 (high forebay level at 530 cfs flow), consistent to adult fish results.
- ▶ Hydraulic conditions in the Chute region from the current study at Foster dam were less favorable for fish than other dams.

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