



High Head Bypass Study – Sensor Fish – Cougar Dam, Oregon, 2017



Daniel Deng, Jayson Martinez, Joanne Duncan
PACIFIC NORTHWEST NATIONAL LABORATORY

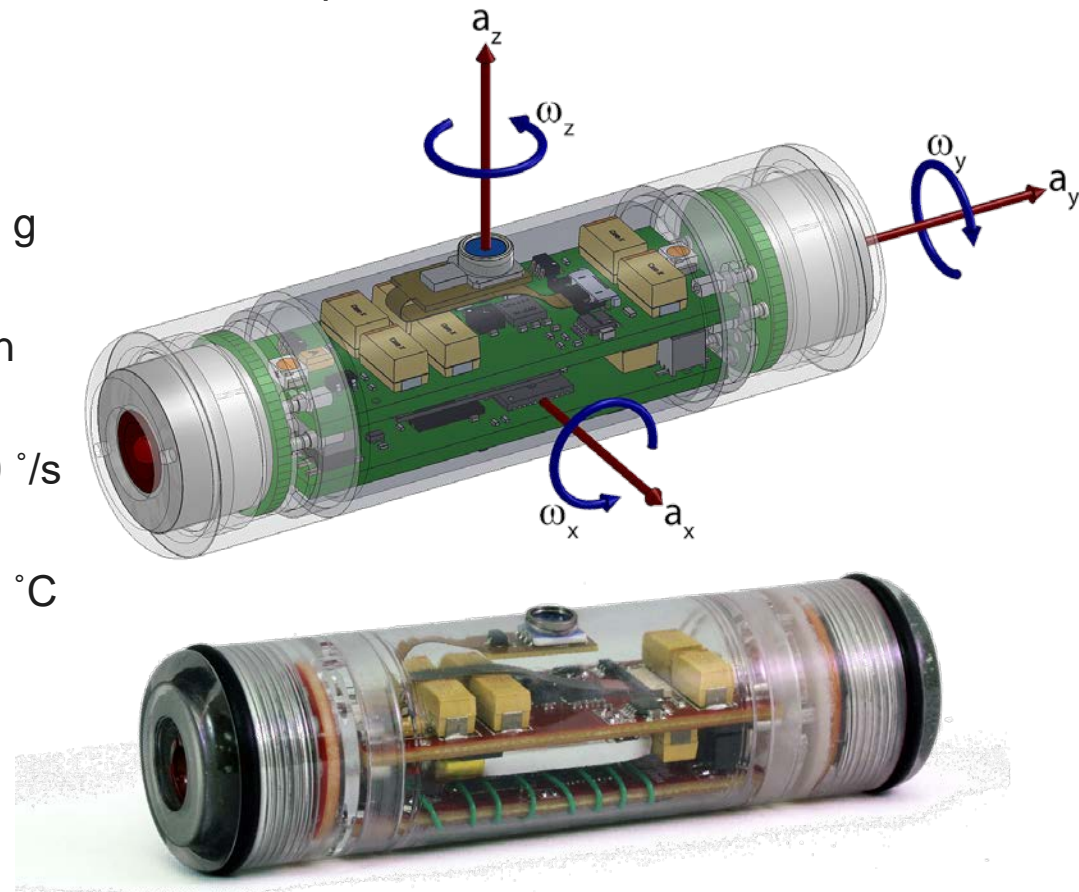
The objectives of the study were to measure the hydraulic conditions for the following test treatments in the RO at Cougar Dam:

- ▶ Sensor Fish and live fish released into the RO, from a release pipe parallel to the RO and just above the water surface, downstream of the head gate at three gate openings (1.3, 1.7*, and 2.0 ft*)

*Due to unexpected delays and limited window of time to perform testing the sample size at 2.0 ft was reduced and the treatment at 1.7 ft was cancelled.

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



Passage through the Cougar Dam Regulating Outlet



Methods and Deployment

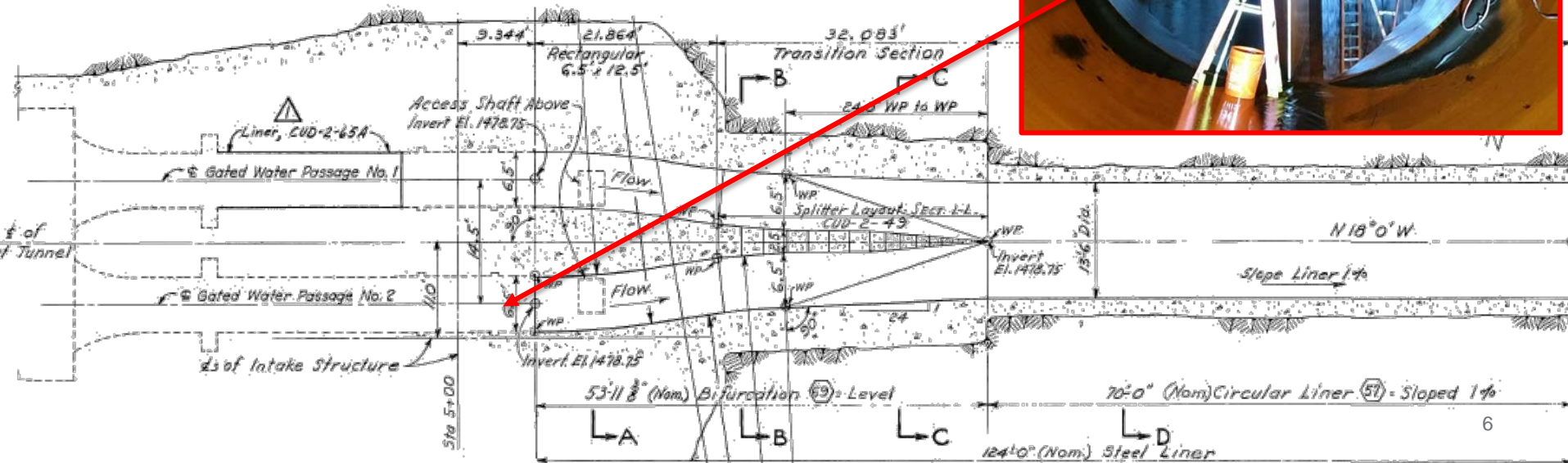
- ▶ Sensor Fish were introduced through the same release pipes used by Normandeau for releasing juvenile Chinook salmon and steelhead.
- ▶ Sensor Fish releases were interspersed among live fish releases.
- ▶ Following deployment, Sensor Fish were recovered from the tailrace by boat.



Methods and Deployment: Treatments

- ▶ Testing was conducted in at Cougar RO at two gate openings.

Treatment	Valid Releases
1.3 ft	70
2.0 ft	25
Controls	17



Results: Timing Marks

Timing marks were added to each data file, separating the passage route into four regions:

- ▶ Induction: Sensor Fish entry into the induction system.
- ▶ RO Tunnel: Sensor Fish exit the release hose/pipe into the RO tunnel.
 - Water level in RO was expected to be below the release pipe exit.

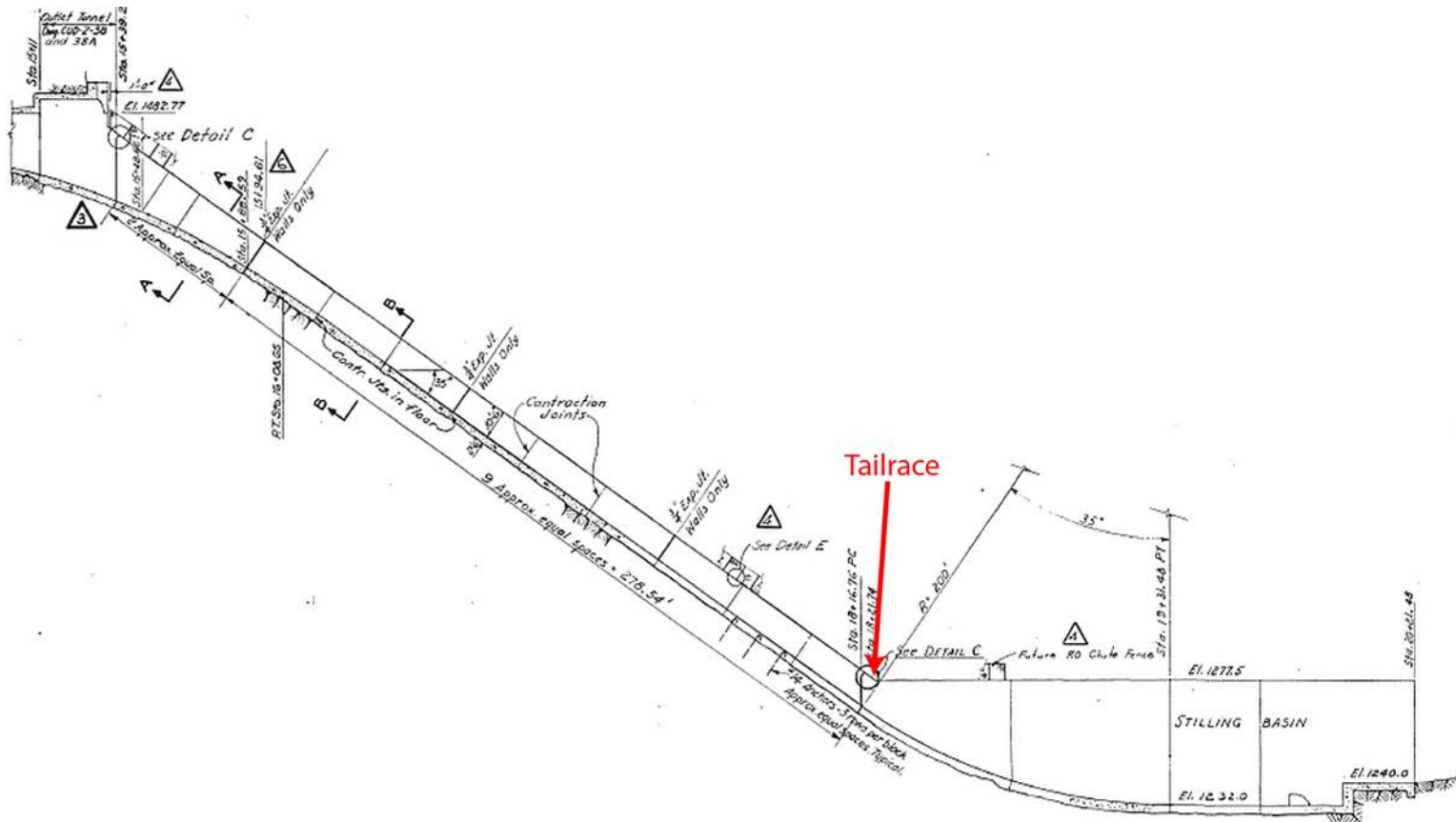
Length of Induction System (ft)	Length of RO Tunnel (ft)	Length of RO Chute (ft)
124.0	840.7	426.0

To Induction Tank ←

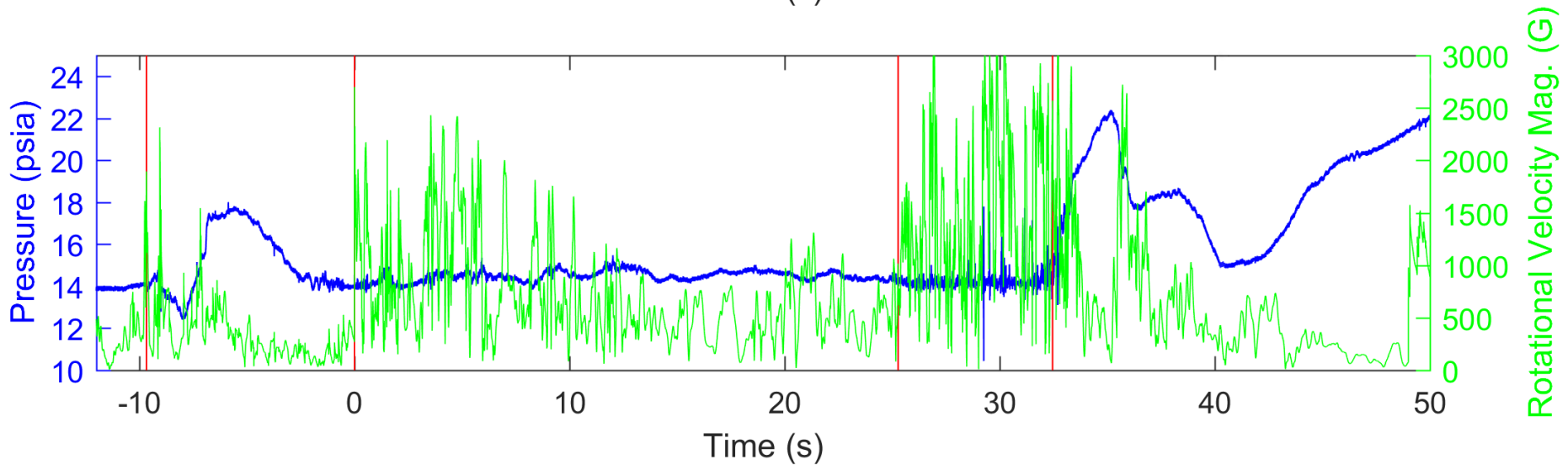
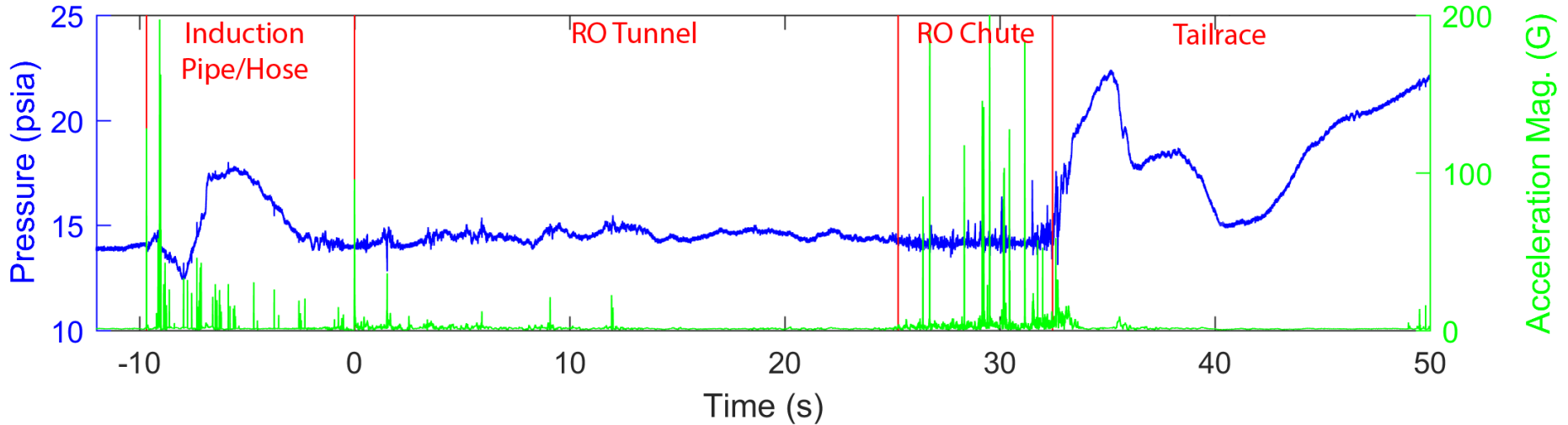


Results: Timing Marks

- ▶ RO Chute: Sensor Fish exits the RO tunnel into the RO chute that leads to the tailrace.
- ▶ Tailrace: Sensor Fish plunges into the tailrace.



Passage Example: 1.3 ft RO Gate Opening



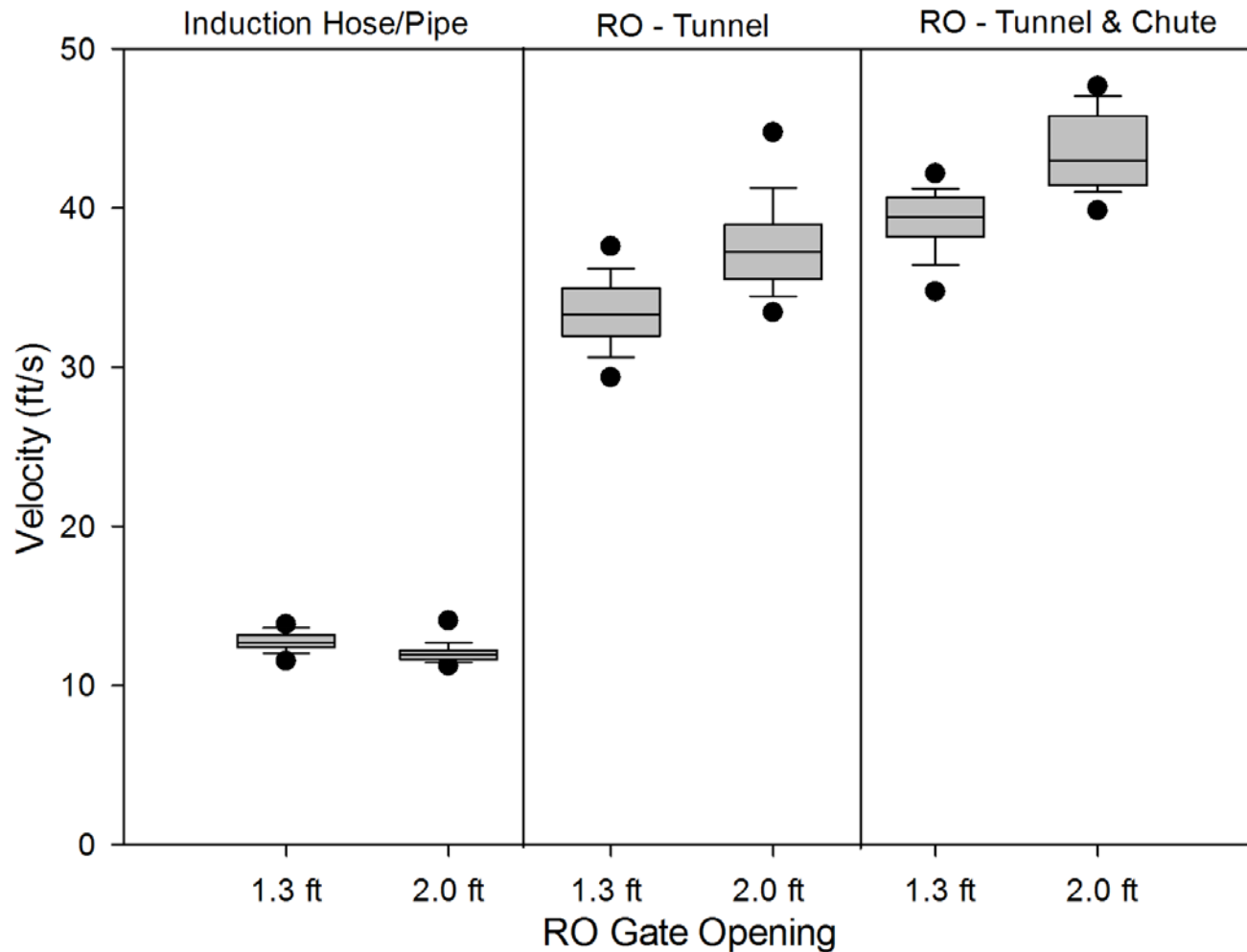
Median travel times from the times per region

- ▶ At the 1.3 ft gate opening the travel times were slightly longer than for the 2.0 ft gate opening.
- ▶ In each region, except for the induction system, the travel times were slightly longer at the 1.3 ft gate opening .

RO Gate Opening (ft)	Induction Region (s)	RO Tunnel Region (s)	RO Chute Region (s)	RO Tunnel to Tailrace (s)	Induction to Tailrace (s)
1.3	9.8	25.2	7.0	32.1	41.9
2.0	10.4	22.6	6.6	29.5	39.5

Velocity in each region

- ▶ For all velocities compared below, $p < 0.001$



Sensor Fish severe acceleration events by treatment and passage region

RO Gate Opening (ft)	Valid Releases	Induction Region		RO Tunnel Region		RO Chute Region		Tailrace	
		%	p-value	%	p-value	%	p-value	%	p-value
1.3	70	67.1%	0.045	80.0%	0.222	98.6%	0.442	55.7%	0.091
2.0	25	88.0%		68.0%		96.0%		36.0%	

Average number of severe events per release for entire passage and per region

RO Gate Opening (ft)	Induction Region	RO Tunnel Region	RO Chute Region	Tailrace Region	RO Tunnel to Tailrace	Induction to Tailrace
1.3	1.21	1.94	5.90	0.86	8.70	9.91
2.0	1.48	1.28	4.08	0.76	6.12	7.60

Sensor Fish maximum severe event magnitude and maximum acceleration

▶ Average maximum severe event magnitude

RO Gate Opening (ft)	Induction Region			RO Tunnel Region			RO Chute Region			Tailrace Region		
	Mean	SE	p-value	Mean	SE	p-value	Mean	SE	p-value	Mean	SE	p-value
1.3	158.8	5.6	0.463	151.0	5.3	0.478	190.3	3.2	0.447	153.5	6.2	0.954
2.0	150.0	9.4		161.1	8.5		186.8	5.2		153.8	13.1	

▶ Average maximum acceleration

RO Gate Opening (ft)	Induction Region			RO Tunnel Region			RO Chute Region			Tailrace Region		
	Mean	SE	p-value	Mean	SE	p-value	Mean	SE	p-value	Mean	SE	p-value
1.3	131.5	6.1	0.358	136.6	5.6	0.716	188.7	3.6	0.358	112.6	6.7	0.017
2.0	140.6	9.8		130.7	10.9		182.7	6.5		84.9	11.9	

- ▶ Characterized the hydraulic conditions in the RO channel at two gate openings (1.3 ft and 2.0 ft)
- ▶ The median travel times at the 1.3 ft gate opening were slightly longer than those at the 2.0 ft gate opening. In each region, except for the induction system, the trend for the travel time was consistent.
- ▶ In the RO, the velocities of Sensor Fish at 2.0 ft gate opening were significantly higher than those at 1.3 ft gate opening ($p < 0.001$).
- ▶ In the RO, there was no significant difference in the percentage of Sensor Fish releases with severe events between the two treatments.
- ▶ In the tailrace region, the average maximum acceleration at 1.3 ft gate opening was significantly higher than that at 2.0 ft gate opening.
- ▶ Results are preliminary. We will finalize the results and compare live fish results and results obtained from other Sensor Fish studies involving spillways.

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