ERDC Spill Pattern Agency Trip: Report for The Dalles Dam 1:80 Model
Week of September 17th, 2017

Attendees to The Dalles Model:

USACE NWP (Portland District):

Steve Schlenker, *Hyd. Engineer*
Aaron Litzenberg, *Hyd. Engineer*
Jon Rerecich, *Biologist*
Erin Kovalchuk, *Biologist*
Laurie Ebner, *Hyd. Engineer*
Amy Lynn, *Hyd. Engineer*
Sean Tackley, *Biologist*
Ida Royer, *Biologist*

Agencies:

ODFW - Erick Van Dyke
WDFW - Michael Garrity
NPT - Jay Hesse
CRITFC - Tom Lorz
NOAA - Trevor Conder, Gary Fredricks, Blane Bellerud, and Ed Meyer
PNWA/tow boaters – Fred Harding (Shaver Transportation Company)

USACE ERDC:

Don Wilson, *Model PI*
Kevin Pigg, *Technician*

SUMMARY TRIP RECORD FOR THE DALLES 1:80 MODEL:

Day 0 9/17/2017 Corps of Engineers (NWP) & Agencies traveled to Vicksburg, MS.

Day 1 9/18/2017

AM: Viewed The Dalles 1:80 Model in the dry.
PM: Viewed uniform spill patterns through bays 1-8
at River Flow = 120 kcfs @ 40% spill & 53% spill, & median[1] and min[2] tailwater

Day 2 9/19/2017

AM: Viewed uniform spill patterns through bays 1-8
at River Flow = 250 kcfs @ 40% spill & 60% spill, & median and min tailwater
PM: Viewed various spill patterns at median tailwater as follows:
at River Flow = 410 kcfs @ 40% uniform spill in bays 1-8
at River Flow = 440 kcfs @ 40% uniform spill in bays 1-8, & lower flow in bay 12
at River Flow = 440 kcfs @ 40% uniform spill in bays 1-8, & lower flow in bay 9
at River Flow = 440 kcfs @ 40% adult[3] spill in bays 1-8, & lower flow in bays 12, 14

Day 3 9/20/2017

AM: Viewed uniform spill in bays 1-8 and alternative spill outside wall at median tailwater
at River Flow = 453 kcfs @ 40% uniform spill in bays 1-8, & lower flows in bays 12, 14, 15
at River Flow = 453 kcfs @ 40% uniform spill in bays 1-8, & lower flows in bays 9-11
at River Flow = 453 kcfs @ 40% uniform spill in bays 1-8, & lower flows in bays 9, 10
Viewed uniform spill in bays 1-8 with spill-gate 5 out of alignment at median tailwater
at River Flow = 250 kcfs @ 40%, gate 5 at low, high and closed settings
PM: USACE NWP left Vicksburg, MS.

Day 4 9/21/2017 Corps of Engineers (NWP) traveled back to Portland; Agencies continued on at Lower Mon.

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[1] *Median tailwater means tailwater for given river flow rate at approximate median Bonneville forebay.*
[2] *Min tailwater means tailwater for given river flow rate at minimum Bonneville forebay.*
[3] *Gate openings lower in Bays 1 & 2 compared to bays 3-8 in adult spill patterns.*

OBJECTIVES: A multipurpose agency trip was conducted at Engineering Research Design Center (ERDC) during the week of September 17-22 to observe spill patterns in models representing Bonneville, The Dalles and Lower Monumental dams. This report pertains to the modeling conducted at The Dalles 1:80 general model. The objective of this trip was to review comparative spill patterns between the current Fish Passage Plan at 40% spill and raised spill rates up to the "gas cap" as directed by a recent Court Order. The intent of the increased spill is to maximize juvenile fish passage through the spillway without harming egress. Other possible concerns included potential impacts on navigation, adult passage or the structural integrity of the spillwall and other dam features due to erosion. The raised spill patterns represent higher percentages of spill up to the "gas cap" that have been estimated by SYSTDG modeling conducted by USACE Northwestern Division (NWD).

ASSUMPTIONS: The current Spill Patterns, which reach a maximum of 40% spill, have provided acceptable downstream egress for juvenile fish and have not significantly impacted upstream adult passage. Model runs will be observed at voluntary spill pattern levels closest to the desired change. Differences from the "acceptable" will be noted.

Fish Passage Concerns/Issues

- Will the existing spill pattern provide good juvenile egress at all tailwater levels? (Note gas cap will involve higher spill volumes at lower and medium river flows.)
- Are shore line velocities too high for good adult passage?
- Will higher spill percentages cause juvenile fish entrainment in "North Eddy" (see pictures at end of report)

Integrity of the Structures (spillway, channel slopes, fish ladder, etc.)

- Velocities high enough off apron or at the end of the spill shelf to cause erosion?
- Will possible shelf erosion impact the structural integrity of the 8/9 spillwall?

VELOCITY DATA COLLECTED BY ERDC:
Prior to this trip, ERDC (Don and Kevin) collected velocity data that was included in the agenda handout sent out by Laurie before the trip. The purpose of the data collection was to provide comparative velocities at locations where (a) erosion could be concern (apron and big divot near spill wall) at increase spill percentages and (b) Navlock tailrace approach channel.

The locations of the velocity tests are shown in the photos provided in Figure 1. The picture on the lower left has the apron locations; the picture on top shows the measurement location for velocity on the slope approaching the divot; the picture on the lower right shows the point locations for the Navlock tailwater approach channel.

The velocity data is shown in Table 1. Qr pertains to the total river flow, Qsp is the total spill flow, BON FB is the forebay at Bonneville and TDA TW is the tailwater elevation for The Dalles. The velocity data is provided at each point in model and prototype scales. Test data in the left square represent data collected at approximate median tailwater for the flow rates. Data on the right squares represent low tailwater levels for the flow rates.

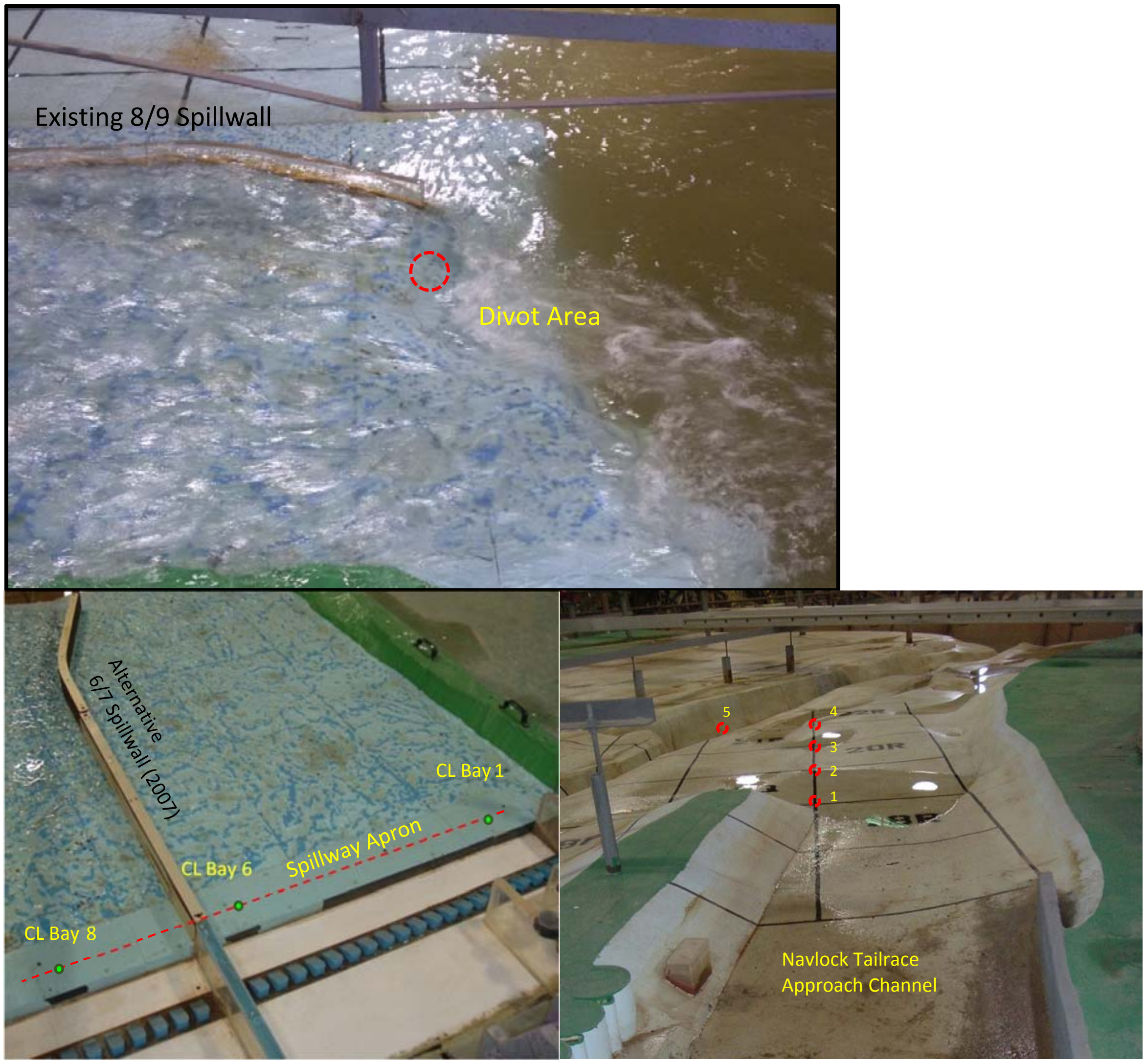


Figure 1 - Velocity Data Measurement Locations

The comparative increase in velocity at each point is shown for each low tailwater case (right) for the same flow conditions in the for the median tailwater cases (left). For test 3 and 7 (in which the spill rate is higher than 40%), the comparative increase in velocity at each point is shown for the 40% case at the equivalent river flow rates (Tests 1 and 5 respectively). The equation for the comparative increase in velocity is:

$$\%\ Increase\ in\ velocity = (High\ spill\ Velocity - 40\%\ spill\ Velocity)/40\%\ spill\ velocity$$

The increased velocities at higher spill do not necessarily mean the erosion rates will be increased, as the fractured basalt geology may have been effectively stabilized since the installation of the spillwall in 2010. Negative numbers mean the velocity went down at higher spill.

Note that the test numbers in Table 1 do not correspond to the test numbers for the tests viewed during this agency trip (in Table 2).

Table 1 - ERDC Velocity Data Collected in August-September 2017.

The Dalles 1:80 Scale General Model							*Nixon Meter Velocity Data* *(Velocity in feet/second)*						
Test 1	Qr =	120	kcfs	Bon FB =	74.6	ft	***Test 2***	Qr =	120	kcfs	Bon FB =	70.0	ft
	Qspill =	48	kcfs	TDA TW =	76.0	ft		Qspill =	48	kcfs	TDA TW =	72.1	ft
		40%	spill						40%	spill			
Centerline of apron:				DATUM:	NGVD 29		Centerline of apron:					% increase over	
	Model	Prototype						Model	Prototype			median TW for Qr	
Bay 1 CL	1.243	11.12	ft/s				Bay 1 CL	1.336	11.95	ft/s		7%	
Bay 6 CL	1.239	11.08	ft/s				Bay 6 CL	1.273	11.39	ft/s		3%	
Bay 8 CL	1.175	10.51	ft/s				Bay 8 CL	1.172	10.48	ft/s		0%	
Screw	1.471	13.16	ft/s				Screw	1.648	14.74	ft/s		12%	
at Divot:							at Divot:						
Nav Lock Grid:							Nav Lock Grid:						
Pt 1	0.047	0.42	ft/s				Pt 1	0.058	0.52	ft/s		23%	
Pt 2	0.06	0.54	ft/s				Pt 2	0.125	1.12	ft/s		108%	
Pt 3	0.084	0.75	ft/s				Pt 3	0.133	1.19	ft/s		58%	
Pt 4	0.21	1.88	ft/s				Pt 4	0.103	0.92	ft/s		-51%	
Pt 5	0.545	4.87	ft/s				Pt 5	0.747	6.68	ft/s		37%	
Test 3	Qr =	120	kcfs	Bon FB =	74.6	ft	***Test 4***	Qr =	120	kcfs	Bon FB =	70.0	ft
	Qspill =	65	kcfs	TDA TW =	76.0	ft		Qspill =	65	kcfs	TDA TW =	72.1	ft
		54%	spill						54%	spill			
Centerline of apron:					% increase over		Centerline of apron:					% increase over	
	Model	Prototype			40% spill			Model	Prototype			median TW for Qr	
Bay 1 CL	1.392	12.45	ft/s		12%		Bay 1 CL	1.397	12.50	ft/s		0%	
Bay 6 CL	1.476	13.20	ft/s		19%		Bay 6 CL	1.541	13.78	ft/s		4%	
Bay 8 CL	1.293	11.56	ft/s		10%		Bay 8 CL	*1.382*	12.36	ft/s		7%	
Screw	1.838	16.44	ft/s		25%		Screw	2.017	18.04	ft/s		10%	
at Divot:							at Divot:						
Nav Lock Grid:							Nav Lock Grid:						
Pt 1	0.03	0.27	ft/s		-36%		Pt 1	0.04	0.36	ft/s		33%	
Pt 2	0.015	0.13	ft/s		-75%		Pt 2	0.084	0.75	ft/s		460%	
Pt 3	0.022	0.20	ft/s		-74%		Pt 3	0.146	1.31	ft/s		564%	
Pt 4	0.068	0.61	ft/s		-68%		Pt 4	0.134	1.20	ft/s		97%	
Pt 5	0.5	4.47	ft/s		-8%		Pt 5	0.767	6.86	ft/s		53%	
Test 5	Qr =	250	kcfs	Bon FB =	74.0	ft	***Test 6***	Qr =	250	kcfs	Bon FB =	70.3	ft
	Qspill =	100	kcfs	TDA TW =	78.5	ft		Qspill =	100	kcfs	TDA TW =	76.0	ft
		40%	spill						40%	spill			
Centerline of apron:							Centerline of apron:					% increase over	
	Model	Prototype						Model	Prototype			median TW for Qr	
Bay 1 CL	1.958	17.51	ft/s				Bay 1 CL	1.999	17.88	ft/s		2%	
Bay 6 CL	1.03	9.21	ft/s				Bay 6 CL	1.951	17.45	ft/s		89%	
Bay 8 CL	1.549	13.85	ft/s				Bay 8 CL	1.547	13.84	ft/s		0%	
Screw	2.214	19.80	ft/s				Screw	2.385	21.33	ft/s		8%	
at Divot:							at Divot:						
Nav Lock Grid:							Nav Lock Grid:						
Pt 1	0.024	0.21	ft/s				Pt 1	0.105	0.94	ft/s		338%	
Pt 2	0.167	1.49	ft/s				Pt 2	0.161	1.44	ft/s		-4%	
Pt 3	0.087	0.78	ft/s				Pt 3	0.08	0.72	ft/s		-8%	
Pt 4	0.304	2.72	ft/s				Pt 4	0.205	1.83	ft/s		-33%	
Pt 5	1.337	11.96	ft/s				Pt 5	1.403	12.55	ft/s		5%	
Test 7	Qr =	250	kcfs	Bon FB =	74.0		***Test 8***	Qr =	250	kcfs	Bon FB =	70.3	
	Qspill =	164	kcfs	TDA TW =	78.5			Qspill =	164	kcfs	TDA TW =	76.0	
		66%	spill						66%	spill			
Centerline of apron:					% increase over		Centerline of apron:					% increase over	
	Model	Prototype			40% spill			Model	Prototype			median TW for Qr	
Bay 1 CL	1.579	14.12	ft/s		-19%		Bay 1 CL	1.36	12.16	ft/s		-14%	
Bay 6 CL	1.051	9.40	ft/s		2%		Bay 6 CL	1.004	8.98	ft/s		-4%	
Bay 8 CL	1.451	12.98	ft/s		-6%		Bay 8 CL	1.429	12.78	ft/s		-2%	
Screw	2.954	26.42	ft/s		33%		Screw	2.986	26.71	ft/s		1%	
at Divot:							at Divot:						
Nav Lock Grid:							Nav Lock Grid:						
Pt 1	0.064	0.57	ft/s		167%		Pt 1	0.201	1.80	ft/s		214%	
Pt 2	0.163	1.46	ft/s		-2%		Pt 2	0.157	1.40	ft/s		-4%	
Pt 3	0.095	0.85	ft/s		9%		Pt 3	0.162	1.45	ft/s		71%	
Pt 4	0.216	1.93	ft/s		-29%		Pt 4	0.242	2.16	ft/s		12%	
Pt 5	1.188	10.63	ft/s		-11%		Pt 5	1.317	11.78	ft/s		11%	
Test 9	Qr =	440	kcfs	Bon FB =	74.4	ft	***Test 10***	Qr =	440	kcfs	Bon FB =	71.1	ft
	Qspill =	164	kcfs	TDA TW =	84.5	ft		Qspill =	164	kcfs	TDA TW =	83.0	ft
		37%	spill						37%	spill			
Centerline of apron:							Centerline of apron:					% increase over	
	Model	Prototype						Model	Prototype			median TW for Qr	
Bay 1 CL	1.514	13.54	ft/s				Bay 1 CL	1.249	11.17	ft/s		-18%	
Bay 6 CL	1.436	12.84	ft/s				Bay 6 CL	1.965	17.58	ft/s		37%	
Bay 8 CL	1.425	12.75	ft/s				Bay 8 CL	1.73	15.47	ft/s		21%	
Screw	2.677	23.94	ft/s				Screw	2.832	25.33	ft/s		6%	
at Divot:							at Divot:						
Nav Lock Grid:							Nav Lock Grid:						
Pt 1	0.136	1.22	ft/s				Pt 1	0.217	1.94	ft/s		60%	
Pt 2	0.181	1.62	ft/s				Pt 2	0.202	1.81	ft/s		12%	
Pt 3	0.568	5.08	ft/s				Pt 3	0.351	3.14	ft/s		-38%	
Pt 4	0.737	6.59	ft/s				Pt 4	0.739	6.61	ft/s		0%	
Pt 5	1.655	14.80	ft/s				Pt 5	1.753	15.68	ft/s		6%	

TEST PROCEDURES DURING AGENCY TRIP:

- For uniform spill within the 8/9 spillwall, Kevin dispensed dye routinely in bays 8, 6, 4 and 1 in the middle of each bay.
- Dye was dispensed in any bays spilled outside of the wall.
- After the dye was dispensed in individual bays, Kevin used the wand (per Erick's request) to apply lines of dye across the channel (with respect to flow) in four locations for flow inside the wall:
    - Just downstream (west) of the concrete apron stilling basin
    - Downstream (west) end of spillway shelf
    - Along axis of north-south thalweg west of spillway shelf
    - Diagonally across spillway thalweg in the bend from north to westward.
    - When spill was outside the wall, similar wand lines were administered outside the wall.
- Periodically (at a median tailwater for the given river flow), Kevin applied the dye at the outlet of the ice and trash chute, and then distributed wand lines along the channel cross-section on the west and east ends of the powerhouse and along the downstream face of the powerhouse.
- Aaron (or Amy) drew lines representing the paths of egress for the dye released into individual bays on the white board that shows a gridded plan view of the TDA tailrace. (Aaron had to add in the outline of the spillway shelf, spillwall, and thalweg in black.) Different colors (blue, purple, red, and some dashed) were used for dye paths for the different bays.
- After the visitors reviewed and perhaps added information, photographs were taken (see Appendix A for photo record).
- As the egress tests were being performed, the tow-boater representative (Fred Harding) ran the barge and tug model in the forebay and tailrace approach channels.

GENERAL CHRONOLGY OF TDA SPILL TESTS:

A detailed listing of the tests run in The Dalles 1:80 model is provided in Table 2.
Appendix A has a photo record of all tests (1 – 13b).

<u>DAY 1, AM: Dewatered model</u>

Observed The Dalles 1:80 model in the dry.   This allowed the visitors to view the unusually rugged bathymetry of the river channel (or thalweg) that abruptly changes direction four times passing through and around the dam.   The dry model also showed how the approach and tailrace channels for the spillway were excavated. The model bathymetry on the spillway shelf between bays 1-9 is based on a February 2006 hydro-survey. Removable square panels were installed during The Dalles Spillway improvements alternative study in 2006.

Steve and Laurie provided a brief history of how the passage of juveniles via the spillway evolved from simple spill patterns canted to the north bays (1, 2, etc.) to the 6/7 spillwall through the stilling basin to reduce retention of fish in the stilling basin, and ultimately to the 8/9 spillwall to address egress. Alternatives were mentioned such as an excavated trough (eliminated due to violent 40 - 50 foot rooster tail and engineering concerns with the high velocity sheet flow) and 6/7 spillwall (lost out to 8/9 spillwall to concerns about gas, higher north shore approach velocities for adults and spilling outside the wall above river flows above about 310 kcfs at 40% spill).

Areas of egress hazard were shown to the visitors and are highlighted in Figure 2. It has been a general consensus that any spill within the spillwall does not send dye into these egress hazard areas. Laurie described the problem with spillway gates 9 (trunnion pin), 10 and 11 (wire ropes).

Jon stated that JSATS data shows that the southern-most Spillbay 8 passes the most yearling chinook and steelhead (~ 30%) compared to the other bays. Passage proportions of both species decline at each bay moving north to Bay 1.

Tailwater elevations were explained to be a function of total river flow rate and Bonneville forebay. Forebay levels between 74 - 74.6 feet represent an approximate median forebay at Bonneville. Other notable facts and considerations:

- The datum for all elevations presented in this report is NGVD 29 or mean sea level.
- The operational range for the Bonneville forebay (BFB) is 70.0 - 77.0 feet.
- The nominal invert for The Dalles spillway shelf is elevation 68 feet. However the surface is rough and there are several holes (near the apron and the large divot on the edge of the shelf just north of the end of the spillwall).
- The Dalles forebay was usually held at median 158.5 feet (but sometimes deviated).
- The tailwater is recorded in a gage outside the spillwall and the water levels inside the spillwall will be higher due to flow bulking and higher total energy.
- The top of model spillwall is at least 2 feet (prototype) lower than the constructed wall.
- The minimum bathymetry elevation is -140 feet prototype in the model and is evident where the thalweg levels out at a bottom. The actual prototype elevations go as low -220 to -225 feet in the big eddy area in the forebay and in the north-south thalweg located southwest of the spillway shelf in the tailrace.

<u>Definitions:</u>

Hydrology:

Percent exceedence: The percent of time during the period of record (1974-2009) that a specific total project discharge is not exceeded. For example: for all the daily project discharge recordings (36 days) on June 7 for the years 1974 through 2009, the project discharge did not exceed 403 kcfs on 34 days, or 95% of the time.

A graph showing the daily flow median, minimum, maximum, and % non-exceedance flows for each day over a record of 1974 – 2009 is provided in Appendix A.

Egress:

Excellent: No dye enters the primary hazard zones (See Figure 2: Bridge Islands, Spillway Shelf or Oregon Channel) and moves directly down the westward channel downstream of spillway.
Acceptable: Majority of dye does not enter primary hazard zones and ultimately moves into and down westward channel.
Poor: Significant proportions of dye enters and/or lingers in recirculation or stagnant zones; is retained or stalls in stilling basin.

Table 2. The Dalles 1:80 Model Test Runs, Agency Trip Sept 17 - 21, 2017

Detailed Record of Tests Performed:

DAY 1: Monday September 18

Visited dewatered model in morning

Project Operation								Spill Bay Operation													
					Forebay		TDA	Inside Spillwall 8/9				Outside wall (if orange), Inside wall (If green), Broken pattern (if grey)									
Test No.	FLOW RATE (Kcfs) Total	PH	Spill	Percent Spill	TDA (ft)	Bonn (ft)	TW (ft)	Type of Pattern	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Est. Σ Spill
1	120	72	48	40%	158.5	74.6	76.0	uniform	1-8	4.1	6.0										
2	120	72	48	40%	158.5	70.0	72.1	uniform	1-8	4.1	6.0										
3	120	56	64	53%	158.5	70.0	72.1	uniform	1-8	5.5	8.0										
4	120	56	64	53%	158.5	74.6	76.0	uniform	1-8	5.5	8.0										

DAY 2: Tuesday September 19

					Forebay		TDA	Inside Spillwall 8/9				Outside wall (if orange), Inside wall (If green), Broken pattern (if grey)									
Test No.	FLOW RATE (Kcfs) Total	PH	Spill	Percent Spill	TDA (ft)	Bonn (ft)	TW (ft)	Type of Pattern	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Est. Σ Spill
5	250	150	100	40%	158.5	74.0	78.5	uniform	1-8	8.6	12.5										
6	250	150	100	40%	158.5	70.3	76.0	uniform	1-8	8.6	12.5										
7	250	100	150	60%	158.5	70.3	76.0	uniform	1-8	13.0	18.8										
8	250	100	150	60%	158.5	74.0	78.5	uniform	1-8	13.0	18.8										
9	410	246	164	40%	158.5	74.4	83.8	uniform	1-8	14.2	20.5										
10	440	264	176	40%	158.5	74.4	84.5	uniform	1-8	14.2	20.5	12	8.3	12.1							176.1
10a	440	264	176	40%	158.5	74.4	84.5	uniform	1-8	14.2	20.5	9	8.3	12.1							176.1
11	440	264	176	40%	158.5	74.4	84.5	adullt	3-8	14.2	20.5	2	10.2	14.8	1	8.2	11.9	12, 14	6.0	8.8	167.3

DAY 3: Wedesday September 20

					Forebay		TDA	Inside Spillwall 8/9				Outside wall (if orange), Inside wall (If green), Broken pattern (if grey)									
Test No.	FLOW RATE (Kcfs) Total	PH	Spill	Percent Spill	TDA (ft)	Bonn (ft)	TW (ft)	Type of Pattern	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Bays	GO (ft)	Q/bay Kcfs	Est. Σ Spill
12	453	272	181	40%	158.5	74.4	84.9	uniform	1-8	14.2	20.5	12, 14, 15	4	5.9							181.6
12a	453	272	181	40%	158.5	74.4	84.9	uniform	1-8	14.2	20.5	9 - 11	4	5.9							181.6
12b	453	272	181	40%	158.5	74.4	84.9	uniform	1-8	14.2	20.5	9	8	11.7	10	4	5.9				181.5
13	250	150	100	40%	158.5	74.4	78.7	broken	1-4, 6-8	8.6	12.5	5	5	7.3							
13a	250	150	100	40%	158.5	74.4	78.7	broken	1-4, 6-8	8.6	12.5	5	11	15.9							
13b	250	150	100	40%	158.5	74.4	78.7	broken	1-4, 6-8	8.6	12.5	5	0	0.0	13	8.6	12.5				

TESTING TERMINATED

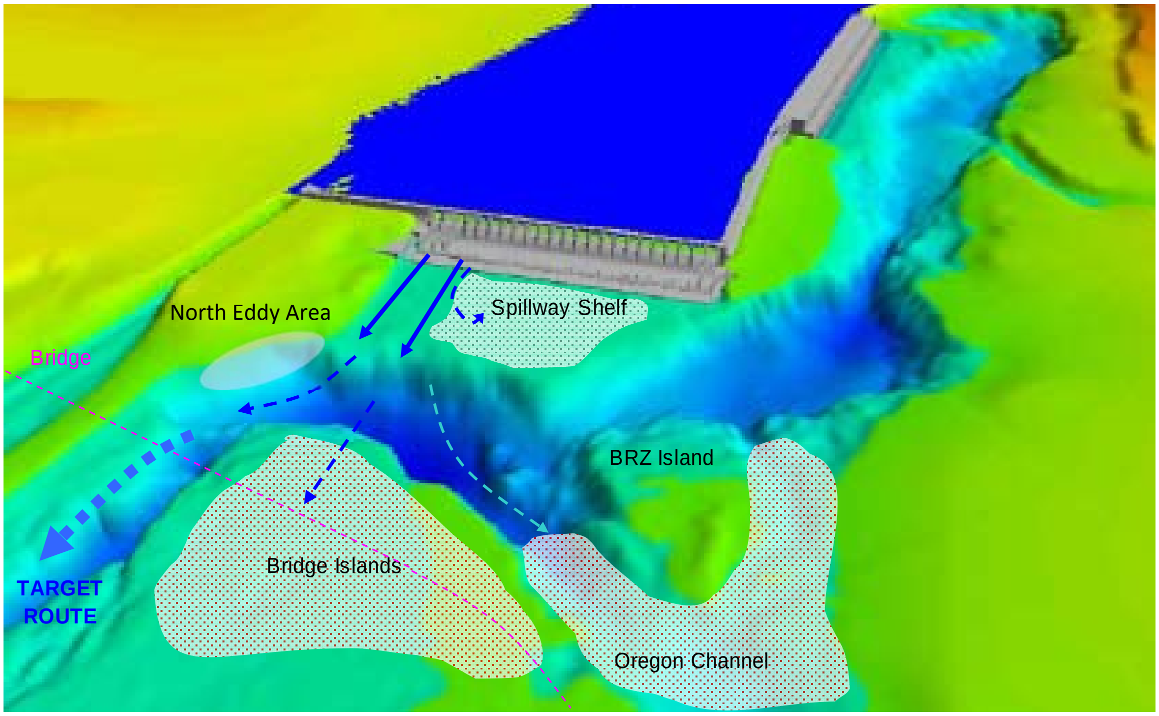


Figure 2 - Egress Destination Zones of High Predator Risk for Juvenile Fish Discharged Through Spillway

<u>DAY 1, PM: 120 kcfs</u>

120 kcfs represents a late August – early September median river flow rate.

Test 1 was at 120 kcfs river flow at The Dalles and 40% spill. The spillway flow was 48 kcfs at 4 feet gate openings within bays 1-8. The 4-feet gate opening represents the minimum allowable gate opening for juvenile spill, below which fish are retained too long in the stilling basin and direct mortality goes up. The Test 1 tailwater represented a median tailwater for river flow 120 kcfs (BFB = 74.6 feet). Egress through bays 8, 6, 4, and 1 was excellent (By 'excellent': meaning no dye entered the primary hazard zones (Bridges Islands, Spillway shelf, or Oregon Channel showed on Figure 2) and all dye moved down the westward channel).

Typically wand lines from the apron showed velocities peaking downstream in line with bays 1 - 3. Bays 1 and 2 are narrower with the pier walls between bays 1 & 2 and 2 & 3, hence have higher velocities exiting the stilling basin. The channel converges downstream with a protruding north shore and the curve of the 8/9 spillwall, concentrating the flow and dye as it comes off the spillwall shelf. Once in the spillway trough, the flow merges in part with the powerhouse flow and moves towards the westward thalweg.

Test 2 retained the exact same flow conditions as Test 1 except with minimum tailwater (BFB = 70 feet) for the river flow rate. The turbulence in roller of the large divot was moderately enhanced by the reduced tailwater. No significant change in egress.

This low tailwater revealed a second divot or bench on the edge of the shelf, located near the north bank of the shelf. This bench tended to shunt the flow and dye towards the southwest and into the main body of the spill flow. While this revealed an interesting hydraulic phenomena, it actually did not hinder the egress in any way.

Test 3 was also at 120 kcfs river with the spill raised to 64 kcfs (53.3%), representing the estimated 125% gas cap level for this river flow rate. The tailwater level was kept the same (for time efficiency) with BFB = 70.0 feet. The turbulence in the divot roller was significantly higher under the combination of higher spill and low tailwater. Egress was excellent, same as 40%. One small difference is the tendency for the dye to plunge deeper off the shelf, which rides the powerhouse current into the north eddy area. However the dye never lingered in the eddy and quickly moved out towards the downstream thalweg. The second northerly divot (or bench) as seen in Test 2 emerged more robustly in Test 3 with the higher spill and deflection of flow towards the southwest, again with no apparent egress concerns.

Test 4 had the same flow rates as Test 3 except at the tailwater was raised to the same median level as in Test 1. The roller turbulence was reduced in comparison to Test 3 and the egress was generally the same.

With the higher spill flow in tests 3 and 4, there is more surface energy and velocity across the spillway trough downstream of the shelf. The spillway flow does not appear to mix as much with the powerhouse flow which passes under the spill flow.

<u>DAY 2, AM: 250 kcfs</u>

250 kcfs represents a late April – early May (or late June – early July) median river flow rate.

Test 5 ran 250 kcfs at 100 kcfs (40% spill) and median tailwater (BFB = 74 feet). The spill flow was 100 kcfs, all within the 8/9 spillwall. Like the tests on Day 1, egress was excellent.

Erin had requested dye be dispensed in the Ice and Trash (I&T) chute on the previous day. Steve recommended waiting until they returned to test with a median tailwater, but it was not done until test 5 on Day 2. The visitors were reminded that the jet trajectory from I&T outlet did not match the prototype due to scale effects incurred in the I&T channel. Dye released from the I&T outlet tended to go in two general paths: some eddied back east (upstream) toward a stagnant area along the shoreline between the outlet and the west powerhouse (poor egress); and the rest moved towards the middle of the powerhouse channel that ultimately moved around the bends toward the target thalweg (generally good egress). Some small amounts of dye ended up in slow areas on the opposite south shore. The fact that the model underrepresents the actual chute trajectory probably means the prototype egress is better than indicated by the model.

Test 6 ran the same flow rates (total and spill) at low tailwater (BFB = 70 feet). The turbulence on the main divot roller was moderately increased. The tailwater was high enough to largely submerge the north bench mentioned in tests 3 and 4 from Day 1. Again the egress was excellent with slightly more dye plunging deep off the shelf and emerging in the north eddy, but effectively moving out as well.

With limited time available, there was only sufficient time to run one additional spill volume before returning to the Bonneville model. The PDT and agency biologists discussed how high the spill rate should be to effectively cover the potential higher side of 125% gas cap spill (Recent SYSTDG modeling for 250 kcfs indicated about 115 kcfs spill, but earlier preliminary results indicated as high as 164 kcfs). The consensus decision was to run 150 cfs spill (60%) for the river flow of 250 cfs.

Test 7 ran the same low tailwater (BFB = 70 feet) and river flow rate (250 kcfs) at 150 kcfs spill (60%). The turbulence on the main divot roller was significantly increased. Again the egress was excellent with somewhat more dye plunging deep off the shelf and emerging in the north eddy, but effectively moving out.

Test 8 ran the same flow rates (total and spill) as Test 6, except at median tailwater (BFB = 74 feet). The turbulence on the main divot roller was significantly reduced. Again the egress was very good, with one difference. Sean noted that with the higher percent spill, the dye plume was wider and more dispersed moving down the main westward channel downstream of the spillway shelf. The reason is that increased percent spill means a larger difference in water surface elevation and energy from the spillway compared to the surrounding ambient tailwater. This larger difference in water surface causes greater lateral spread, hence a wider a more disperse plume of flow and dye. While this difference is noted, the dye egress did not venture unto the bridge island and was still more than acceptable.

With the higher percent spill in Test 8 compared to Test 5, the visitors were interested in seeing dye in the Ice and Trash chute again. In this test, the powerhouse flow was reduced (about 95 Kcfs versus 145 kcfs, excluding miscellaneous flows) compared to Test 5 and more of the dye appeared to move upstream (east) and along the shoreline before becoming entrained in the powerhouse flow. The dye path showed 180 degree turn from east to west. The dye that entered the powerhouse flow had good egress. Some dye lingered in the eddy area between the I&T chute outlet and some dye found the south shore on the opposite side.

<u>DAY 2, PM: 410 kcfs and 440 kcfs</u>

410 kcfs represents a 95% exceedence river flow rate in May – early June. It also represents the maximum river flow rate at which 40% spill can be discharged entirely within the spillwall. Maximum spill gate opening as 14.0 feet at max TDA forebay 160 feet and 14.7 feet at median TDA forebay.

Test 9 ran 410 kcfs at 164 kcfs (40% spill) and median tailwater (BFB = 74.4 feet). The spill flow was 164 kcfs with gate openings of 14.2 feet, all within the 8/9 spillwall. Again the egress was excellent.

The Ice and Trash chute a third and final time, as the visitors were interested in its performance under the higher overall flow compared to the morning tests (5 - 8). In this test, the powerhouse flow (about 240 Kcfs, excluding miscellaneous flows) was higher compared to Tests 5 and 8 (95 – 145 kcfs). Like Test 5 before, the dye took two paths: one directly downstream (west), and the other doubling back upstream into the eddy area before making another 180 degree turn back to the west. Some dye still lingered in the eddy area between the I&T chute outlet. Most dye entered the strong powerhouse current and had good or acceptable egress.

Test 10 ran 440 kcfs at 176 kcfs spill (40% spill) and median tailwater (BFB = 74.4 feet). This spill exceeded the capacity inside the 8/9 spillwall and the remainder of spill (12.1 kcfs) was discharged through Bay 12. Egress from pill in bays 1-8 was excellent as usual. Particular interest was focused on the egress from Bay 12. Much of the dye stays within the stilling basin as there is no supporting flow on either side of the bay. Laurie had previously pointed out that when the Bay 12 flow impinges the baffle blocks, lateral jets of flow are directed toward the backside of the spillwall, potentially undermining it over time. On the south side of Bay 12, dye either went south in the stilling basin or recirculated over the spillway shelf back towards the location where the Bay 12 spillway chute flow plunges into the tailwater. A reduced portion of dye managed to escape the stilling basin and did move downstream, ultimately tracking the backside of the spillwall, clipping the Bridge Islands and ultimately flowing over the south shelf of the westward channel. Overall the egress from Bay 12 was poor.

440 kcfs is exceeded about once every 3 to 4 years and represents an approximate 95% non-exceedence flow in mid to late June. We saw flows at or above 440 kcfs at times at Bonneville (TDA essentially the same) during March, April, May and June this year.

Test 10a ran the same river and spill flow rates and median tailwater. The only change was that Bay 9 was discharged outside of the 8/9 spillwall instead of Bay 12. The egress was the same within the 8/9 spillwall. Again the chief interest was on the spill outside the wall, Bay 9. On the south side of the Bay 9, dye behaved similarly to the south side of Bay 12's dye: some staying in the stilling basin and the remainder moving over the spillway shelf and recirculating back to the stilling basin. However a large percentage of the dye did move out of the stilling basin and tracked along the backside of the 8/9 spillwall, ultimately moving towards the westward channel, perhaps some clipping the Bridge Islands en route. In general some of the egress was poor and a large percent of it was acceptable, or certainly improved compared to Bay 12. Also there was no case of lateral jet impinging on the backside of the 8/9 spillwall as was seen with Bay 12.

Test 11 ran the same river flow, total spill and median tailwater. The difference was that an adult pattern was run inside the 8/9 spillwall, and more spill was down outside the wall. (Gary reminded us that an adult pattern is called for in the Fish Passage Plan for situations when the East Fish Ladder is experiencing problems such as an auxiliary water fish unit outage—which occurred for a week in April 2017.) Per Laurie's instructions and the Fish Passage Plan, Bay 2 was set 4 feet lower than bays 3 - 8 (that remained uniform) and Bay 1 was set 2 feet lower than Bay 2. This meant less spill was discharged inside the 8/9 spillwall (about 158 kcfs instead of 164) and the remaining flow (17.6 kcfs) was discharged through bays 12 and 14. In addition to viewing the egress from individual bays (8, 6, 4, and 1), Bay 2 was also viewed. Egress in Bay 2 was surprising good with only a little dye spreading into the stilling basin below bay 3. Bay 1 was perhaps not as good, as more dye spread into the Bay 2 stilling basin area. The egress from bays 1 and 2 could be classified as acceptable at the least. The rest of the egress inside the spillwall was excellent. Outside the wall (bays 12 and 14), the egress was poor. Bay 14 only partially disrupted the Bay 12 south recirculation and there was an ugly setup of dual recirculation cells between then bays tracking back to the stilling basin. South of Bay 14, dye range widely to the south to return to the stilling basin. Some dye lingered.

Don had indicated that 453 kcfs was the maximum discharge capacity of The Dalles general model without additional modifications (that wouldn't happen on this trip). Fred said he wanted to run the barge in this flow, so it was planned for Day 3. Also Jon wanted to later set up a medium flow rate (250 kcfs) to show the undesirable results from a misoperation or misalignment of one of the spillgates inside the wall.

<u>DAY 3, 453 kcfs and 250 kcfs</u>

453 kcfs represents the approximate maximum flow of 2017; the maximum flows recorded at Bonneville was about 460 kcfs in late March and later reached 457.5 kcfs in early May.

Test 12 ran 453 kcfs total river and 181 kcfs spill (40%) at median tailwater (BFB = 74.4). Inside the 8/9 spillwall, the spill pattern was returned to a uniform pattern. Outside the 8/9 spillwall, bays 12, 14, and 14 were open at minimum gate opening 4 feet (per Fish Passage Plan). Dye was not observed inside the spillwall. The egress for the spill outside the wall was poor. The addition of Bay 15 did help the south flank of Bay 14, but transferred the same south flank problems to the south side of Bay 15. Otherwise the egress outside the wall was similar to that described in Test 11. One consolation was that these bays were only open 4 feet compared to > 14 feet inside the wall, so hopefully fewer fish pass through bays 12, 14 - 15 (in spite of being south most bays). Afterwards Erick suggested running the same pattern through bays 9-11 (currently out of service).

Test 12a ran the same total river and spill (40%) at median tailwater. Outside the 8/9 spillwall, the bays were charged from bays 12, 14, and 14 to bays 9, 10 and 11, open at minimum gate opening 4 feet. Again, dye was not observed inside the spillwall. The egress for the spill outside the 8/9 spillwall was partially poor and partially acceptable—definitely improved over the previous test. The south flank of Bay 11 had the same problems as seen with the previous south most bays in tests 11 or 12, with significant retention of dye in the stilling basin south of the bay and a large recirculation zone outside the stilling basin. Much of Bay 10 did also recirculated over the shelf, but some dye joined the Bay 9 flow. With the support of bays 10 and 11, dye from Bay 9 tracked cleanly along the backside of the wall and headed towards the westward channel. Afterwards Steve suggested trying a staggered pattern with more spill in Bay 9 with the hope that the bay could get sufficient support while entraining more fish.

Test 12b ran the same total river and spill (40%) at median tailwater. Outside the 8/9 spillwall, the bays were charged from bays 9, 10 and 11 to bays 9 and 10. Bay 10 remained at 4 feet gate opening and Bay 9 was increased to 8 gate opening. Again, dye was not observed inside the spillwall. The egress for the spill outside the 8/9 spillwall was partially poor and slightly acceptable—and presented a deterioration of the results from the previous test using uniform spill outside the wall. The south flank of Bay 10 had the same problems as seen with the previous south most bays in tests 11 or 12, 12 a. Bay 10 flow did not provide sufficient support for Bay 9, and a large portion south flank of the Bay 9 dye peeled off into a recirculation flow over the shelf. The remainder of dye did track the wall as before.

Test 13 resumed a 250 kcfs river flow rate with a 100 kcfs spill (40%). The spill patterns was initially set up as uniform, but was altered to a 'broken' pattern by setting the Bay 5 gate setting about 2.5 feet lower than the rest of the gates. With the lower gate setting, the tailwater backed up high at Bay 5 and the dye in the stilling basin spread to the adjacent bays with the higher velocities and drawing power. The dye spread to the 2/3 pier and the 6/7 spillwall. It very well could have spread further with the absence of these walls.

Test 13a performed the same procedure except that Bay 5 was raised about 2.5 feet higher than the rest of the bays. With the higher flow in Bay 5, the tailwater was pushed downstream compared to the adjacent bays and the dye also spread to adjacent bays. The spread was not as great as the previous test and did not reach Pier 2/3. Erin suggested closing Bay 5 for the last test.

Test 13b performed the same procedure as test 13 except that Bay 5 was fully closed. This led to the most dramatic result. On the south side of Bay 5, the tailwater banked up in the south east corner of the stilling basin and against the 6/7 spillwall. Conversely on the north side of Bay 5, there was a sink in the stilling basin water surface with an unusually high velocity within the basin. Like Test 13 before, dye spread within the stilling basin from pier 2/3 to the 6/7 spillwall.

Testing terminated at The Dalles.

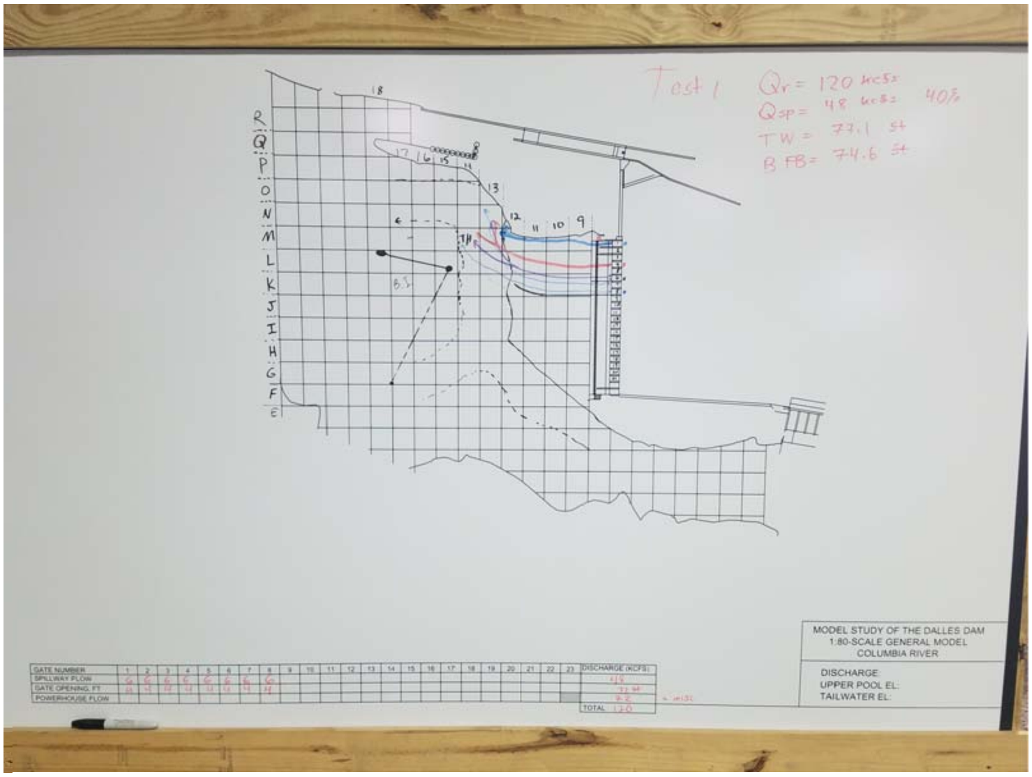
CONCLUSIONS:

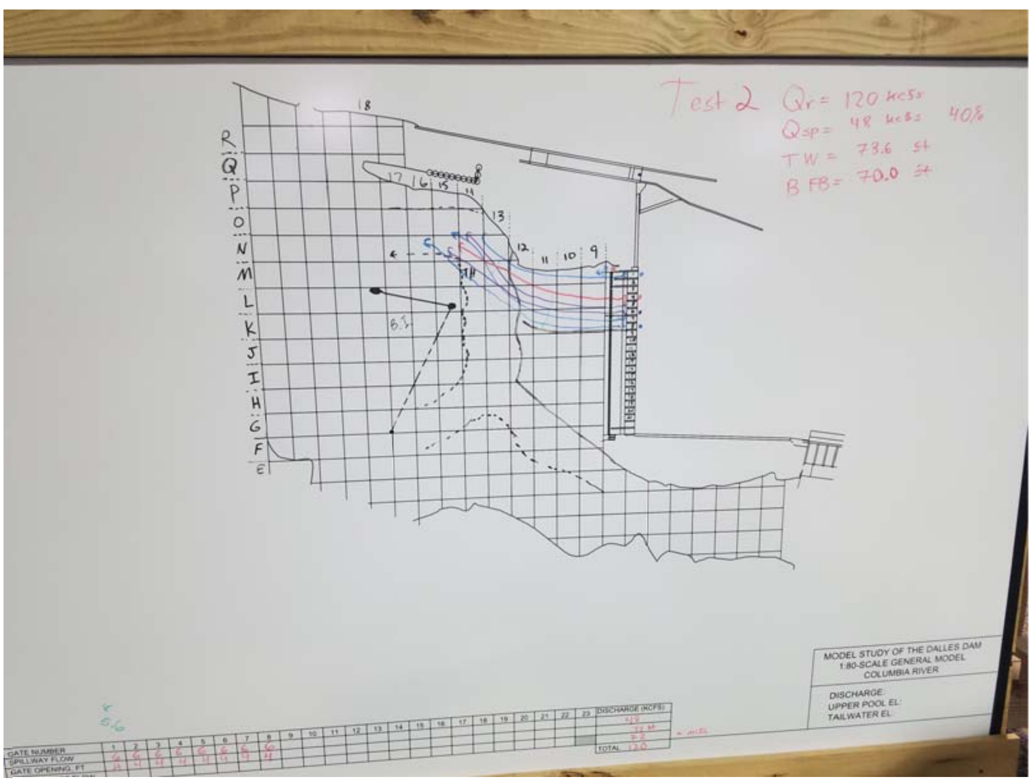
- Egress was excellent for all spill inside the 8/9 spill wall for spill rates between 40% to 60% and all flow rates tested.
  - Confine spill to inside the wall if at all possible.
- Egress was poor outside the spillwall
  - When spilling outside the wall, follow the Fish Passage Plan using minimum gate openings as much as possible.

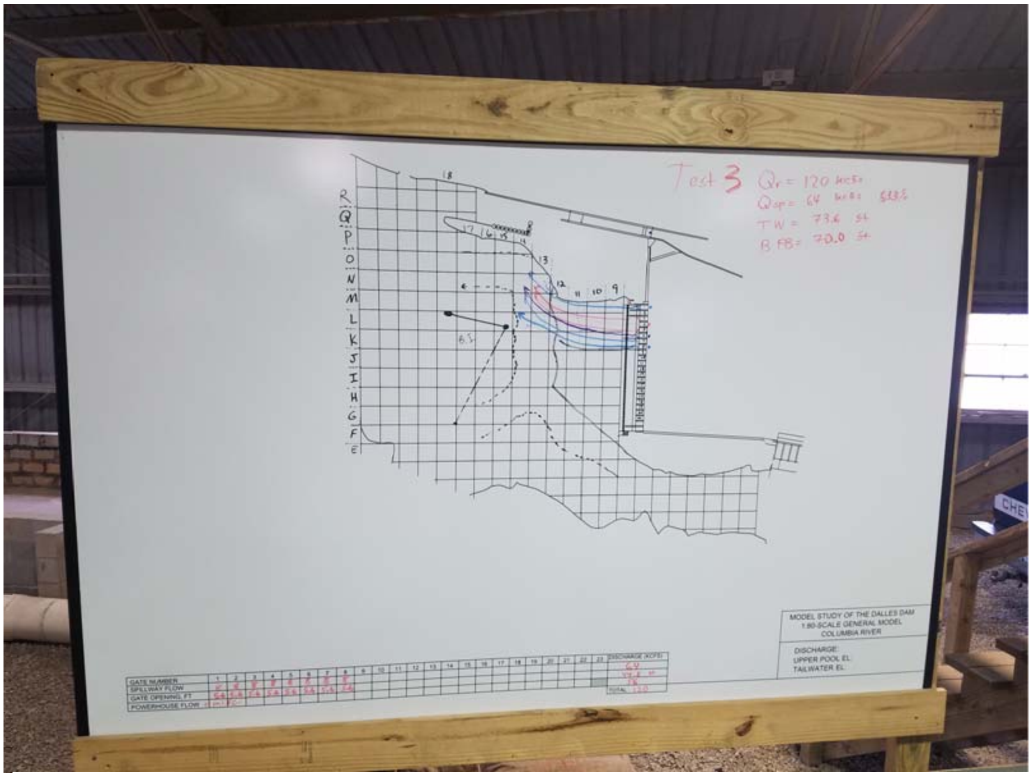
  - The repairs of gates 9 -11 would lead to significantly better egress outside the 8/9 spillwall, though still vastly inferior to spill inside the wall.
- Multiple conversations with Fred indicated that he had no navigations issues with current or increased spill patterns at The Dalles from either the forebay or tailrace approach channels at any of the flow rates that we tested.

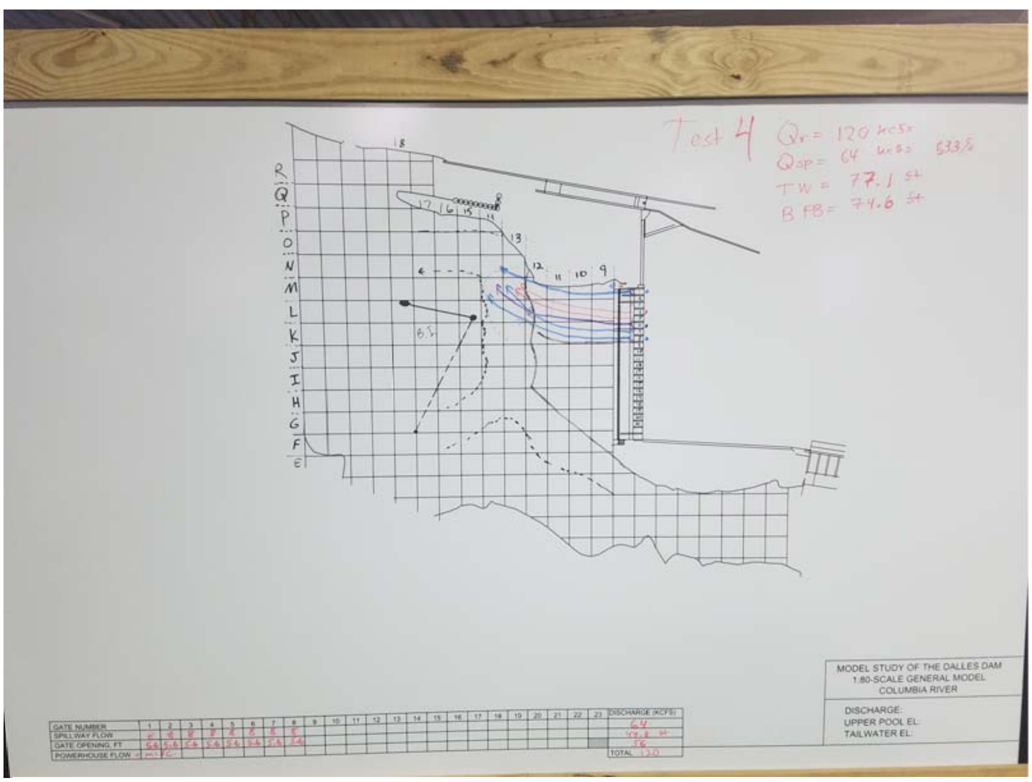
CENWP-EC-HD

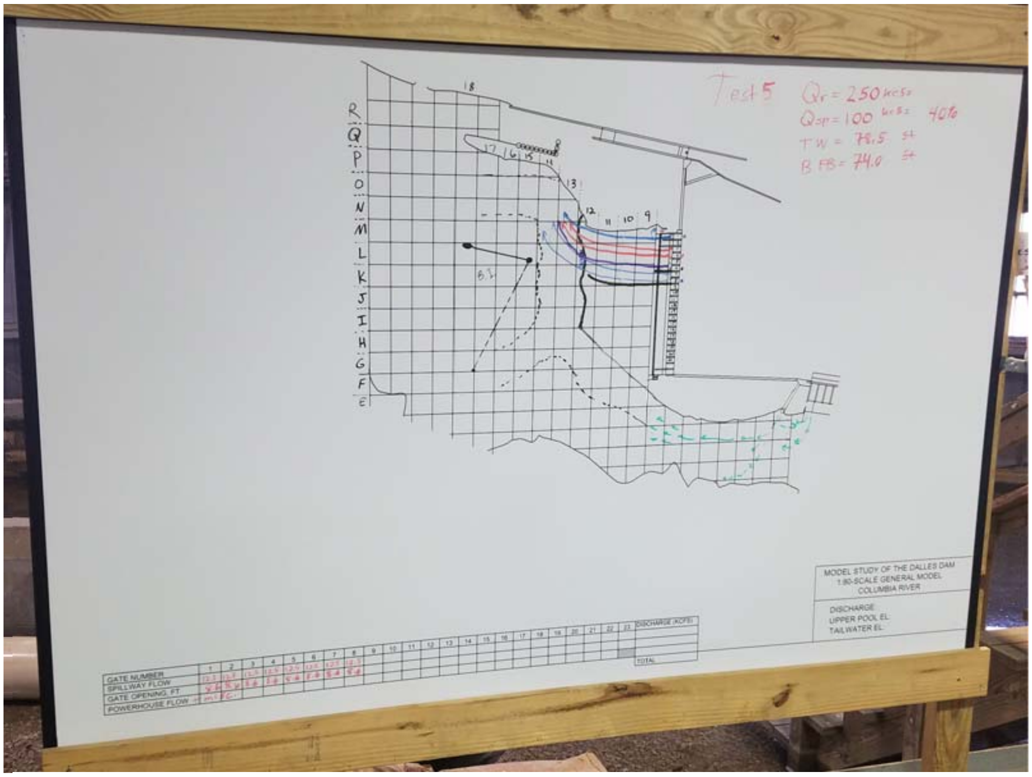
Appendix A:
Board Photos

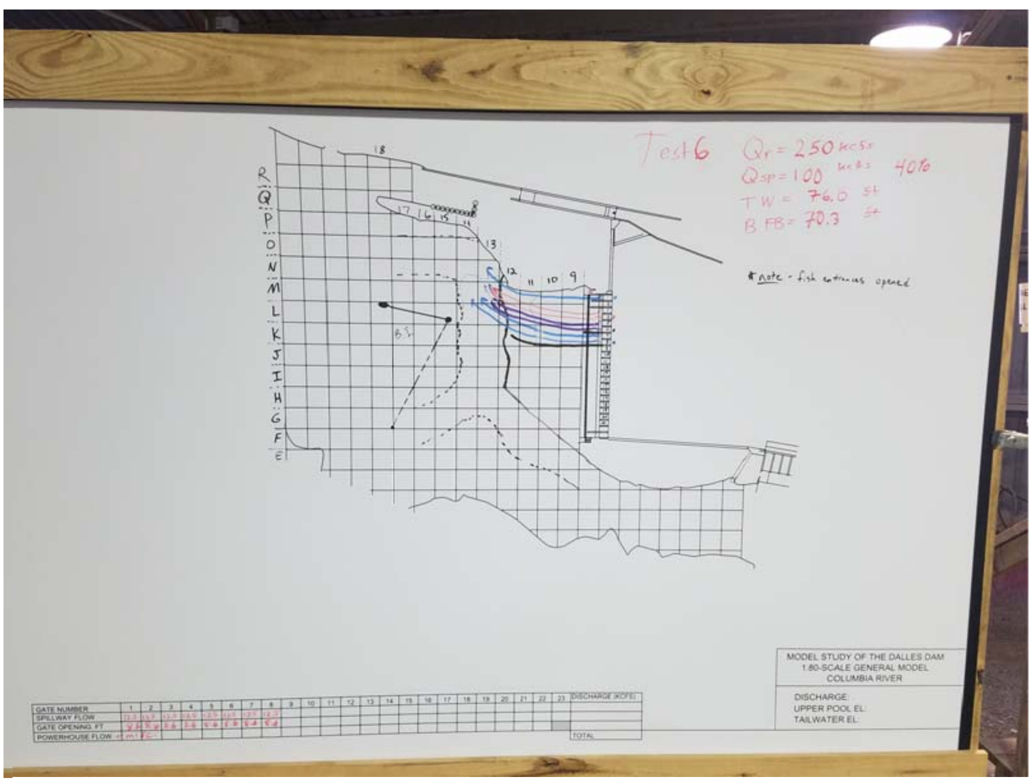


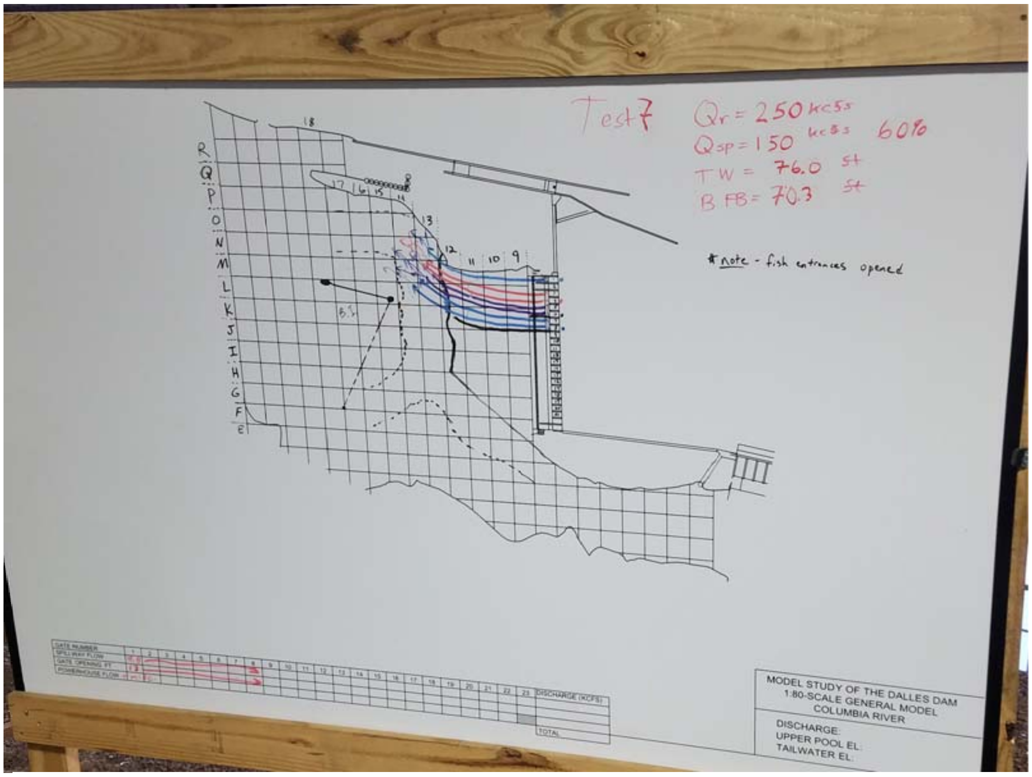


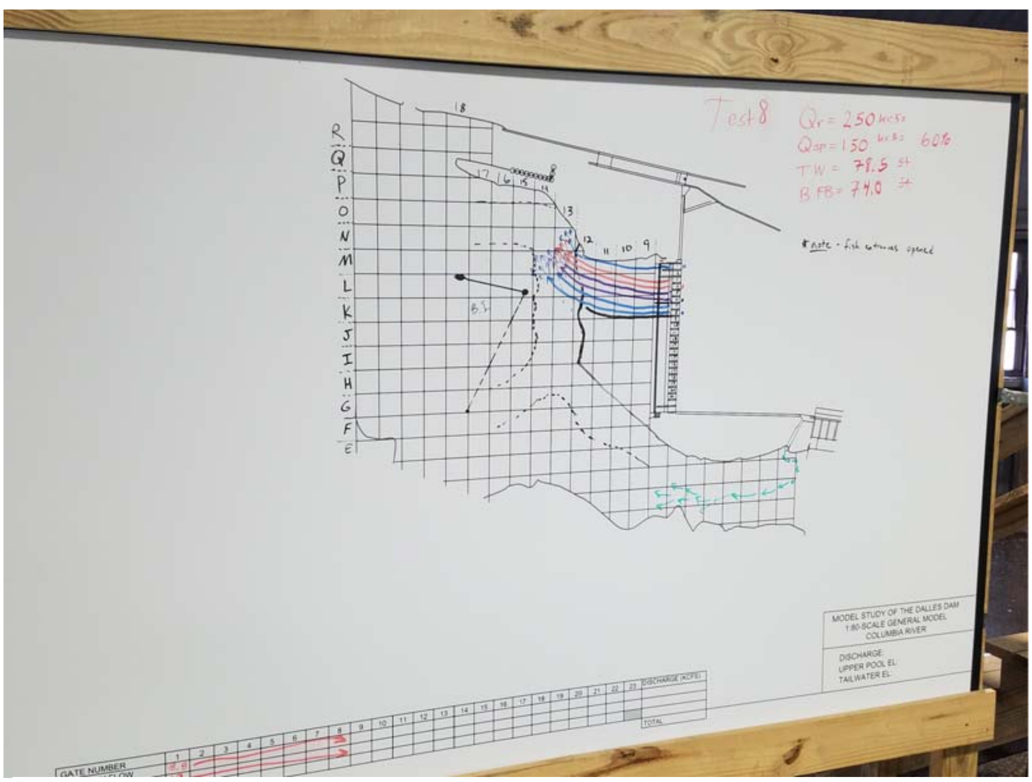

Test 3
Qr = 120 kcfs
Qsp = 64 kcfs 53.3%
TW = 73.6 ft
B FB = 70.0 ft
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

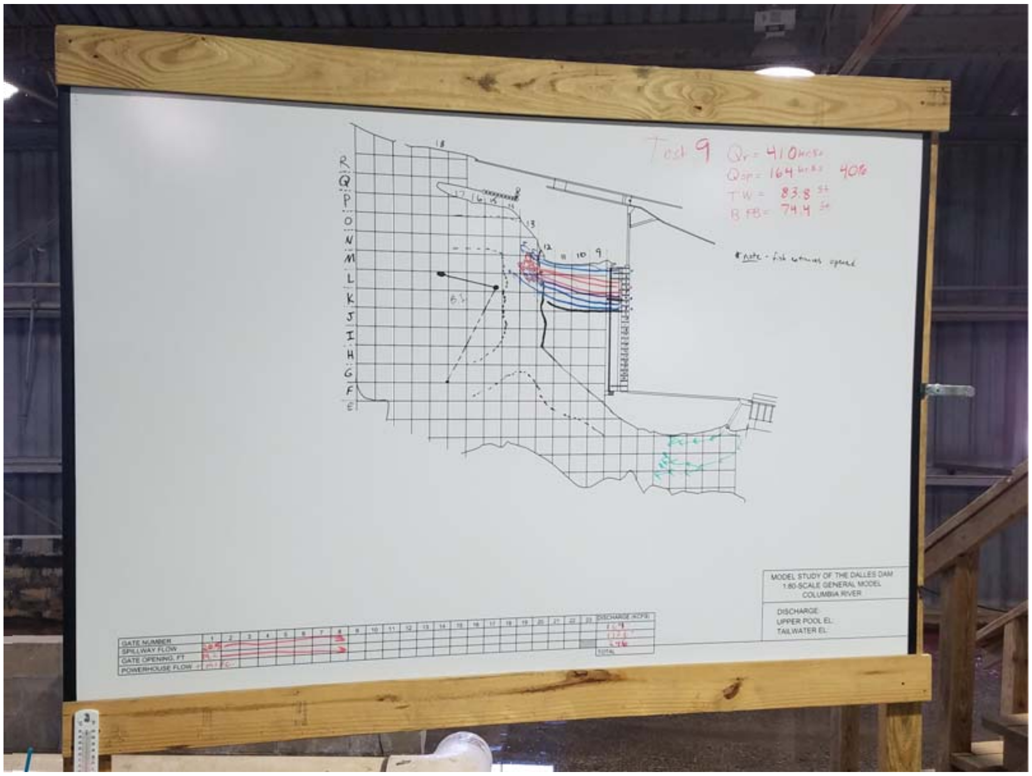

Test 4
Qr = 120 kcfs
Qsp = 64 kcfs 53.3%
TW = 77.1 ft
B FB = 74.6 ft
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

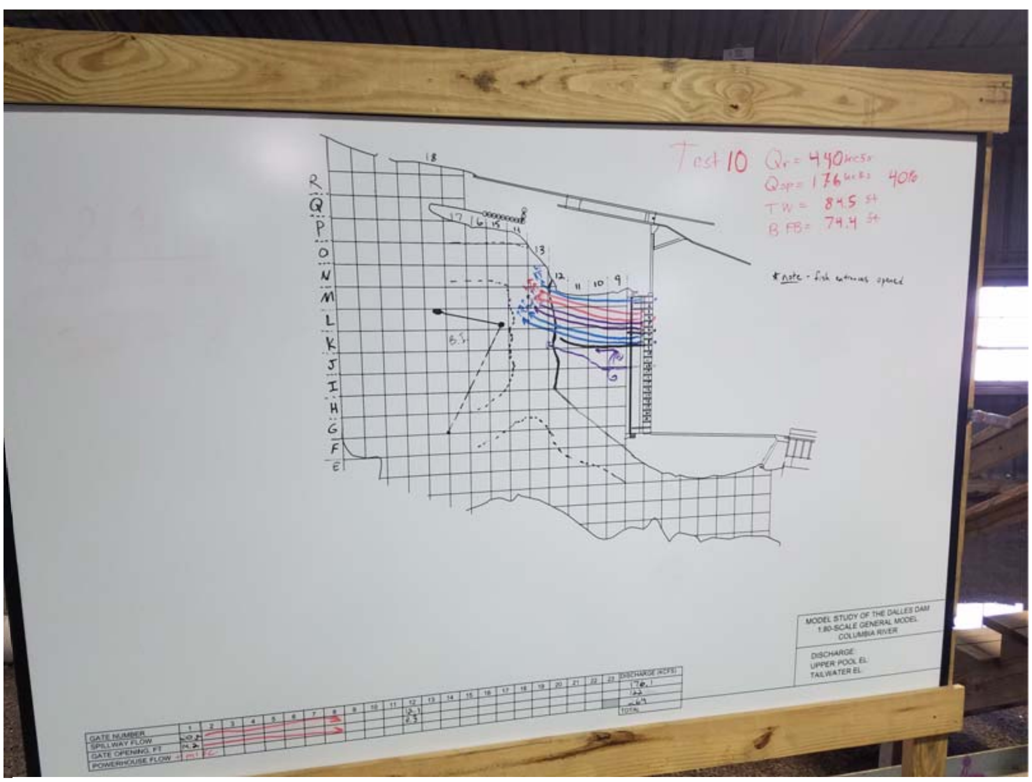

Test 5
Qr = 250 kcfs
Qsp = 100 kcfs 40%
TW = 78.5 ft
B FB = 74.0 ft
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

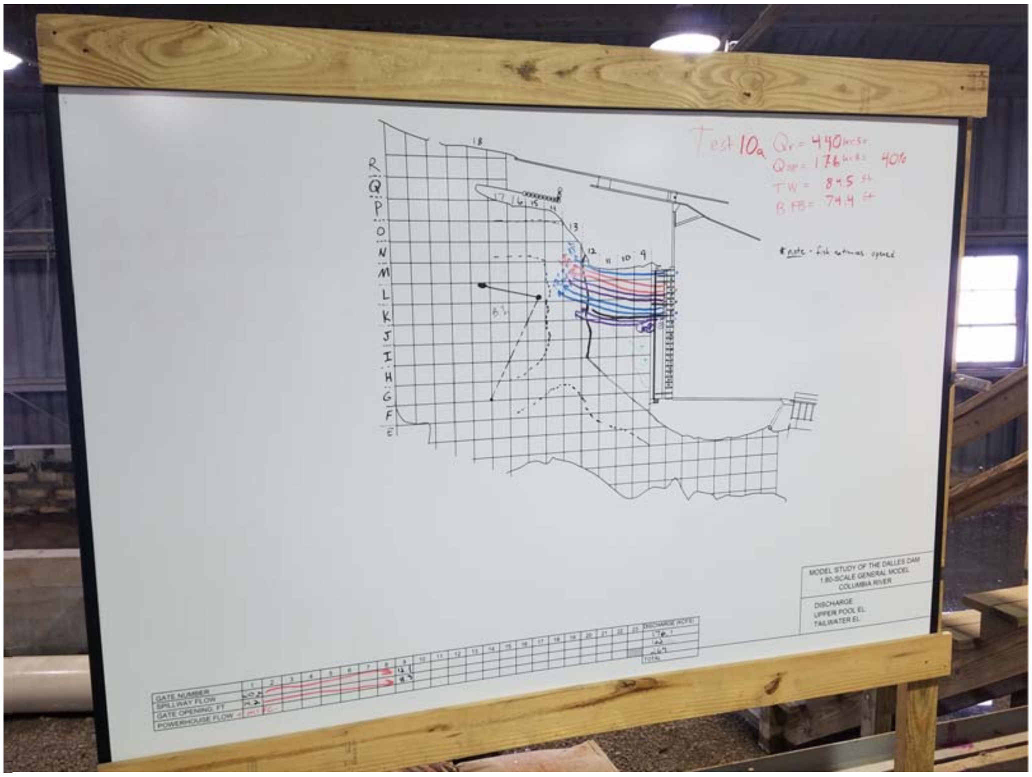

Test 6
Qr = 250 kcfs
Qsp = 100 kcfs 40%
TW = 76.0 ft
B FB = 70.3 ft
*note - fish entrances opened
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

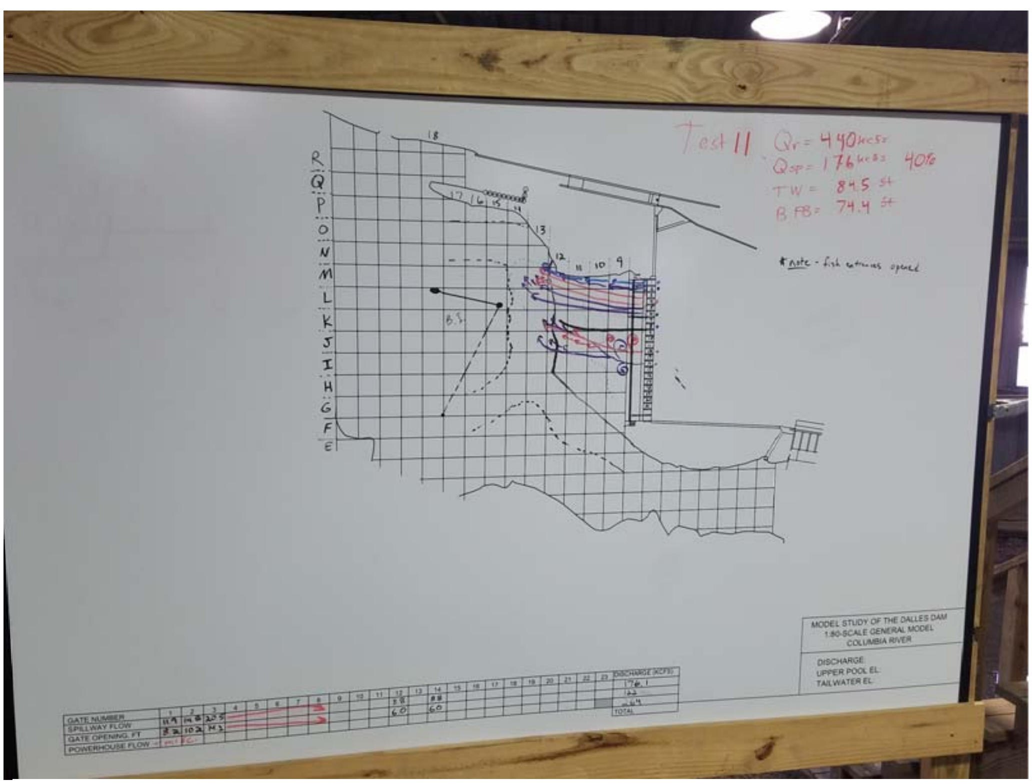

Test 7
Qr = 250 kcfs
Qsp = 150 kcfs 60%
TW = 76.0 ft
B FB = 70.3 ft
*note - fish entrances opened
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:

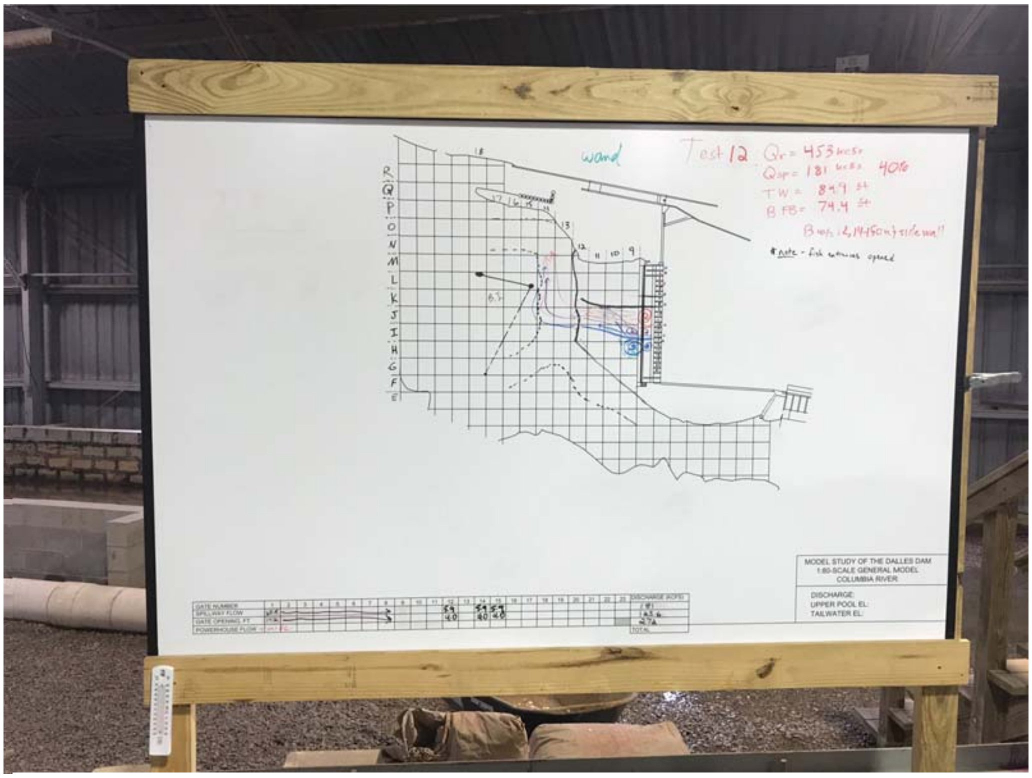

Test 8
Qr = 250 kcfs
Qsp = 150 kcfs 60%
TW = 78.5 ft
B FB = 74.0 ft
*note - fish entrances opened
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:


Test 9
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

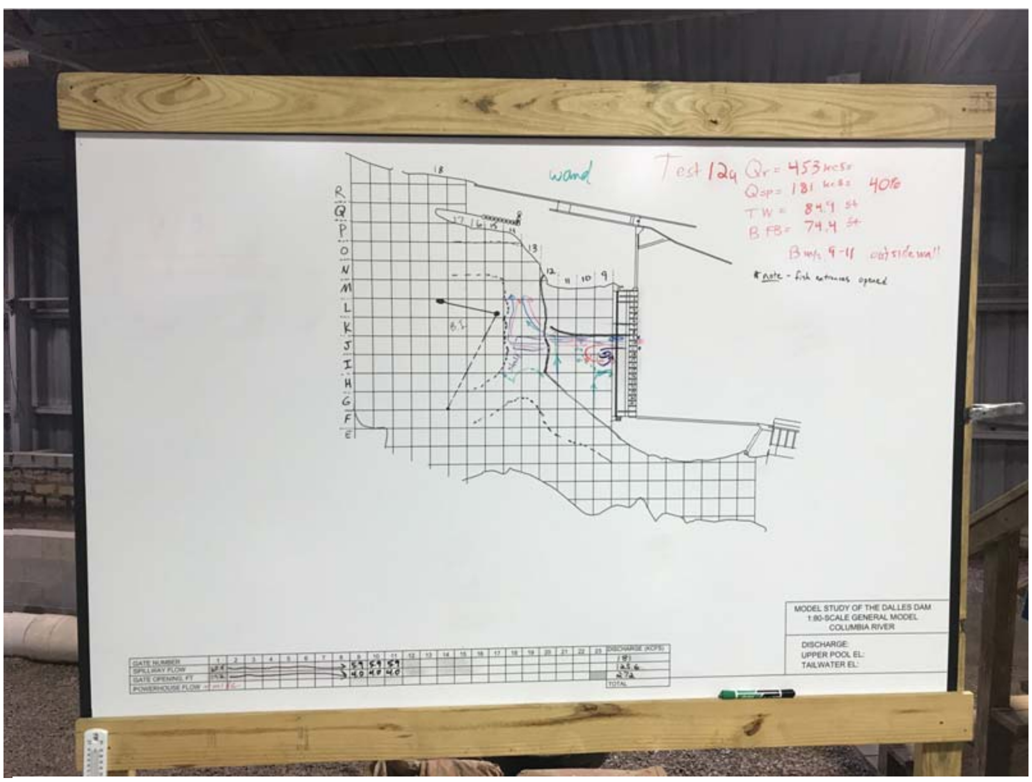

Test 10
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL


Test 10a
Qr = 440 kcfs
Qsp = 176 kcfs 40%
TW = 84.5 ft
B FB = 74.4 ft
*note - fish entrances opened
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE
UPPER POOL EL
TAILWATER EL
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

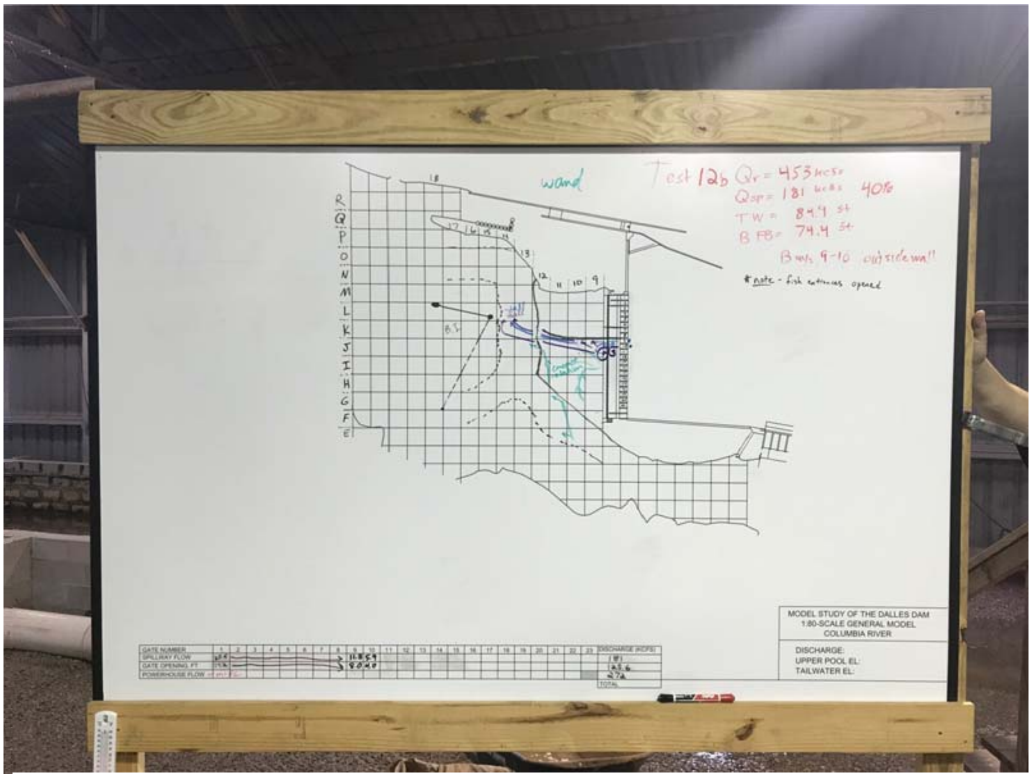

Test 11
Qr = 440 kcfs
Qsp = 176 kcfs 40%
TW = 84.5 ft
B FB = 74.4 ft
*note - fish entrances opened
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

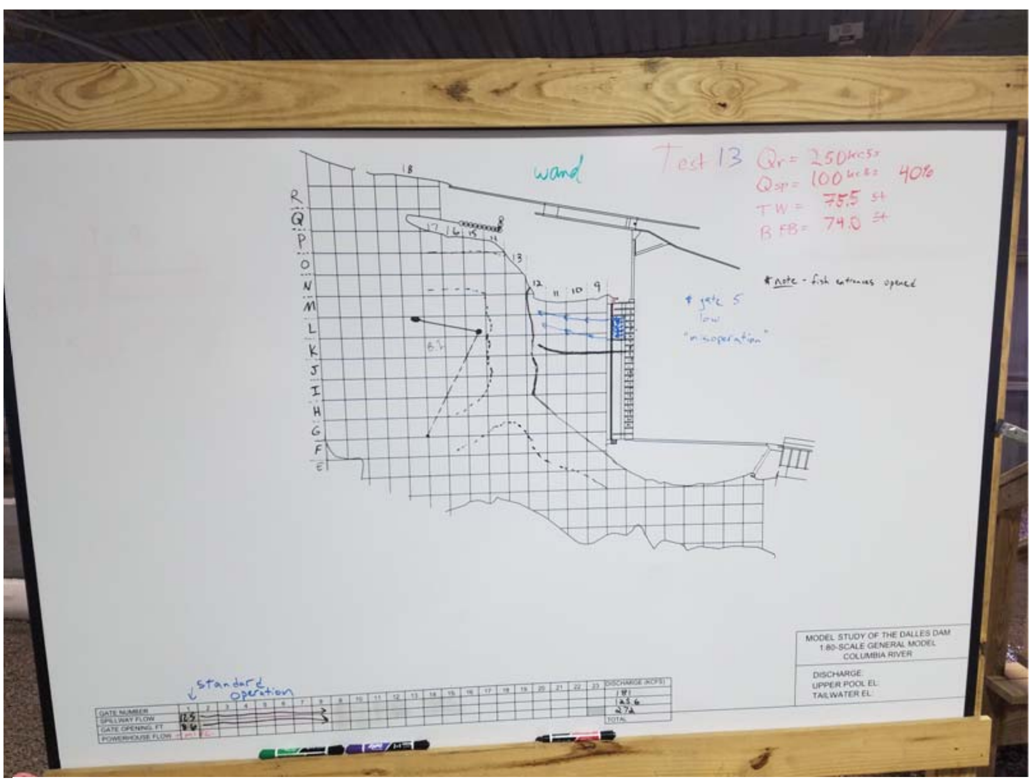


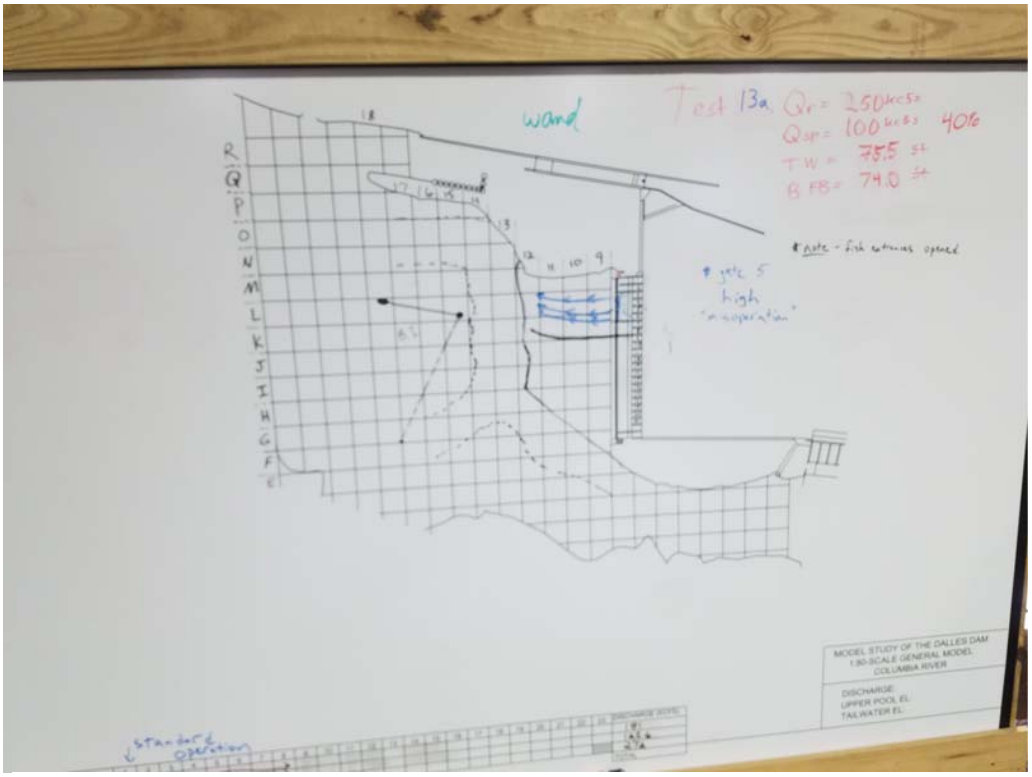
wand
Test 12
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

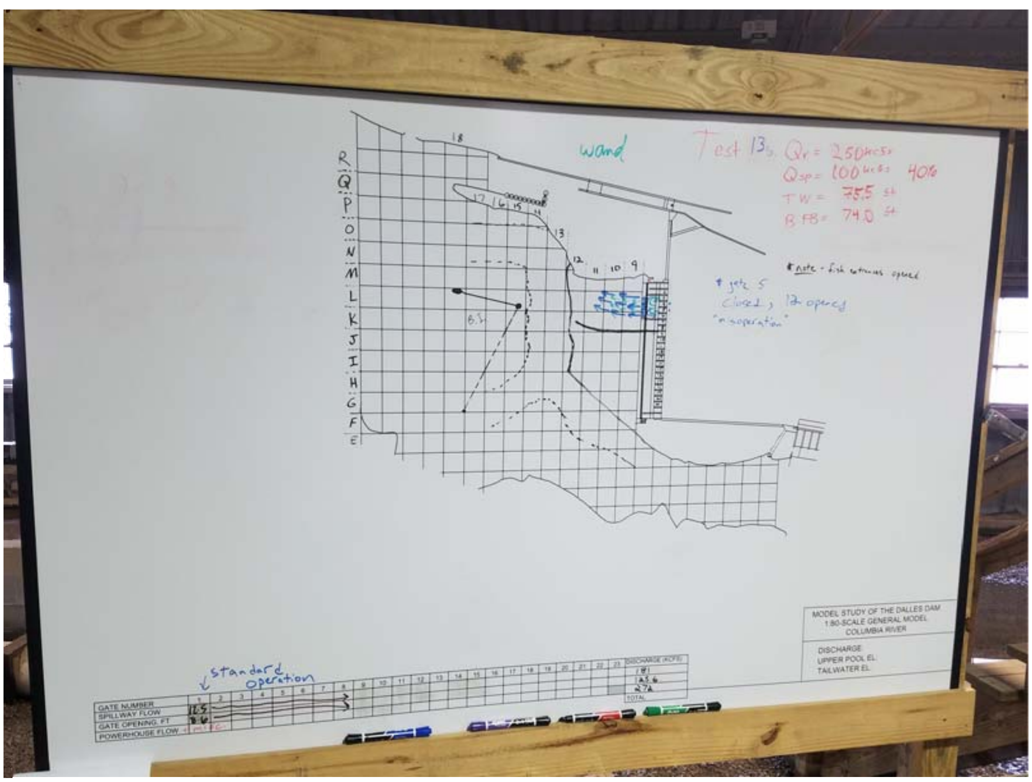


wand
Test 12a
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL

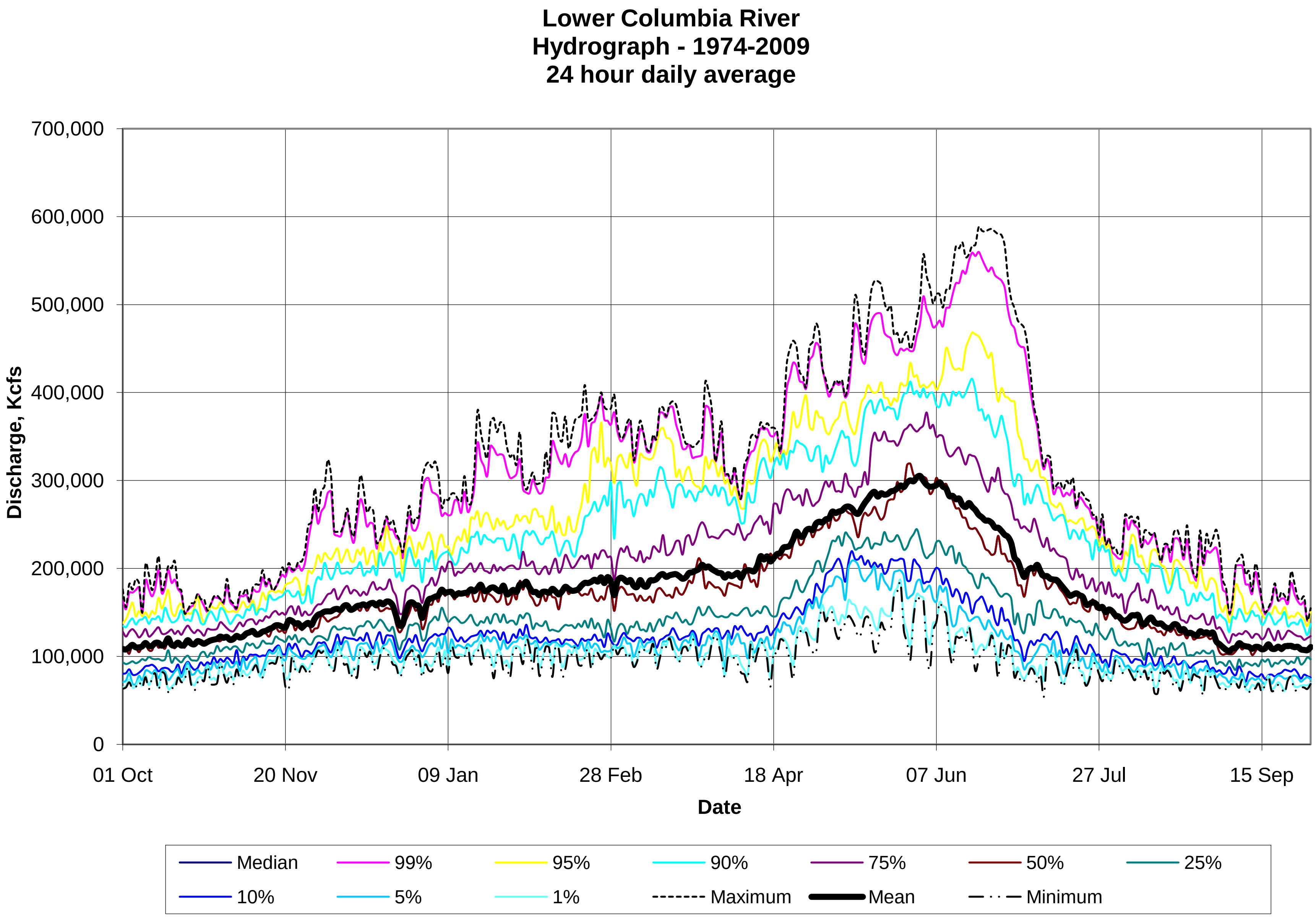

wand
Test 12b Qr = 453 kcfs
Qsp = 181 kcfs 40%
TW = 84.4 ft
B FB = 74.4 ft
Bays 9-10 outside wall
* note - fish entrances opened
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL


wand
Test 13 Qr = 250 kcfs
Qsp = 100 kcfs 40%
TW = 75.5 ft
B FB = 74.0 ft
* note - fish entrances opened
* gate 5
low
"misoperation"
standard operation
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL


wand
Test 13a Qr = 250kcfs
Qsp = 100kcfs 40%
TW = 75.5 ft
B FB = 74.0 ft
* note - fish entrances opened
* gate 5 high "in operation"
standard operation
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:


wand
Test 13b Qr = 250kcfs
Qsp = 100kcfs 40%
TW = 75.5 ft
B FB = 74.0 ft
* note - fish entrances opened
* gate 5 closed, 12 opened "in operation"
standard operation
GATE NUMBER
SPILLWAY FLOW
GATE OPENING, FT
POWERHOUSE FLOW
DISCHARGE (KCFS)
TOTAL
MODEL STUDY OF THE DALLES DAM
1:80-SCALE GENERAL MODEL
COLUMBIA RIVER
DISCHARGE:
UPPER POOL EL:
TAILWATER EL:

The Dalles Dam 24 hour Daily Average Exceedence Graph



The Dalles Dam Mean Daily Flow Exceedence Table

The Dalles Mean Daily Flow - data in cfs

Percent	Observed for Water Years WY1974 - WY2014											
Exceedence	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
99%	119,700	106,000	73,340	74,360	66,429	68,550	79,616	90,900	97,166	98,785	95,350	92,629
95%	164,000	136,000	89,800	87,150	75,345	78,050	94,490	107,000	112,000	114,000	112,000	115,000
90%	192,000	160,900	107,000	93,300	80,990	85,100	104,000	117,000	121,000	121,000	119,000	127,970
85%	207,100	178,000	120,000	101,000	85,335	89,700	109,205	122,000	127,000	125,000	124,000	140,000
80%	217,000	190,720	132,000	107,000	89,500	93,300	113,000	127,000	133,880	130,000	130,000	148,980
75%	224,000	204,400	142,000	114,000	93,100	97,300	117,000	131,000	138,125	134,000	135,000	156,000
70%	233,000	215,000	150,000	118,000	95,970	101,000	120,000	135,000	143,000	139,000	142,000	166,000
65%	241,100	231,000	157,000	123,000	99,000	104,000	122,000	138,000	149,000	146,000	149,000	175,135
60%	250,000	245,620	164,000	127,000	102,000	106,000	124,000	141,000	154,000	150,920	158,000	185,000
55%	258,000	261,000	171,000	131,950	104,505	109,950	126,000	145,000	160,000	156,000	165,350	198,000
50%	265,000	274,000	178,000	135,000	108,050	113,000	128,000	148,000	165,000	165,000	173,000	213,000
45%	273,000	285,000	185,000	140,000	111,000	115,000	131,000	152,000	171,000	172,000	182,000	224,000
40%	283,000	299,000	194,000	144,000	114,000	118,000	133,000	157,000	177,000	181,000	191,000	234,000
35%	294,000	314,000	205,450	149,000	117,000	121,000	136,000	161,500	183,000	189,010	202,000	243,970
30%	311,800	331,000	215,000	155,000	120,000	125,000	140,000	167,000	190,000	197,000	216,000	254,000
25%	324,350	344,000	227,000	162,000	123,825	128,000	144,000	172,700	197,000	203,750	227,000	266,000
20%	344,000	358,000	241,000	172,000	128,000	132,000	147,680	179,000	203,180	212,320	238,800	281,000
15%	362,000	373,585	257,150	181,000	133,000	136,000	153,000	188,500	211,000	224,000	255,000	296,000
10%	384,000	405,000	275,300	196,300	140,000	142,000	160,190	200,000	224,110	236,000	285,700	315,040
5%	413,000	458,065	315,000	214,500	151,550	152,000	172,550	221,000	252,465	275,435	322,300	341,865
1%	499,786	565,491	406,500	243,000	185,927	176,580	200,420	258,300	322,895	374,530	369,210	409,014
Maximum	526,800	588,000	496,000	261,000	244,000	214,000	291,000	323,600	379,000	408,400	412,100	458,900
Average	277,301	280,384	188,506	140,449	109,969	113,531	131,056	154,407	171,134	191,384	187,797	216,505
Median	265,000	274,000	178,000	135,000	108,050	113,000	128,000	148,000	165,000	188,000	173,000	213,000
Minimum	95,900	75,500	53,900	55,600	59,300	61,100	62,200	75,500	75,200	77,500	83,300	65,600