DWORSHAK'S PHASED TEMPERATURE IMPROVEMENTS

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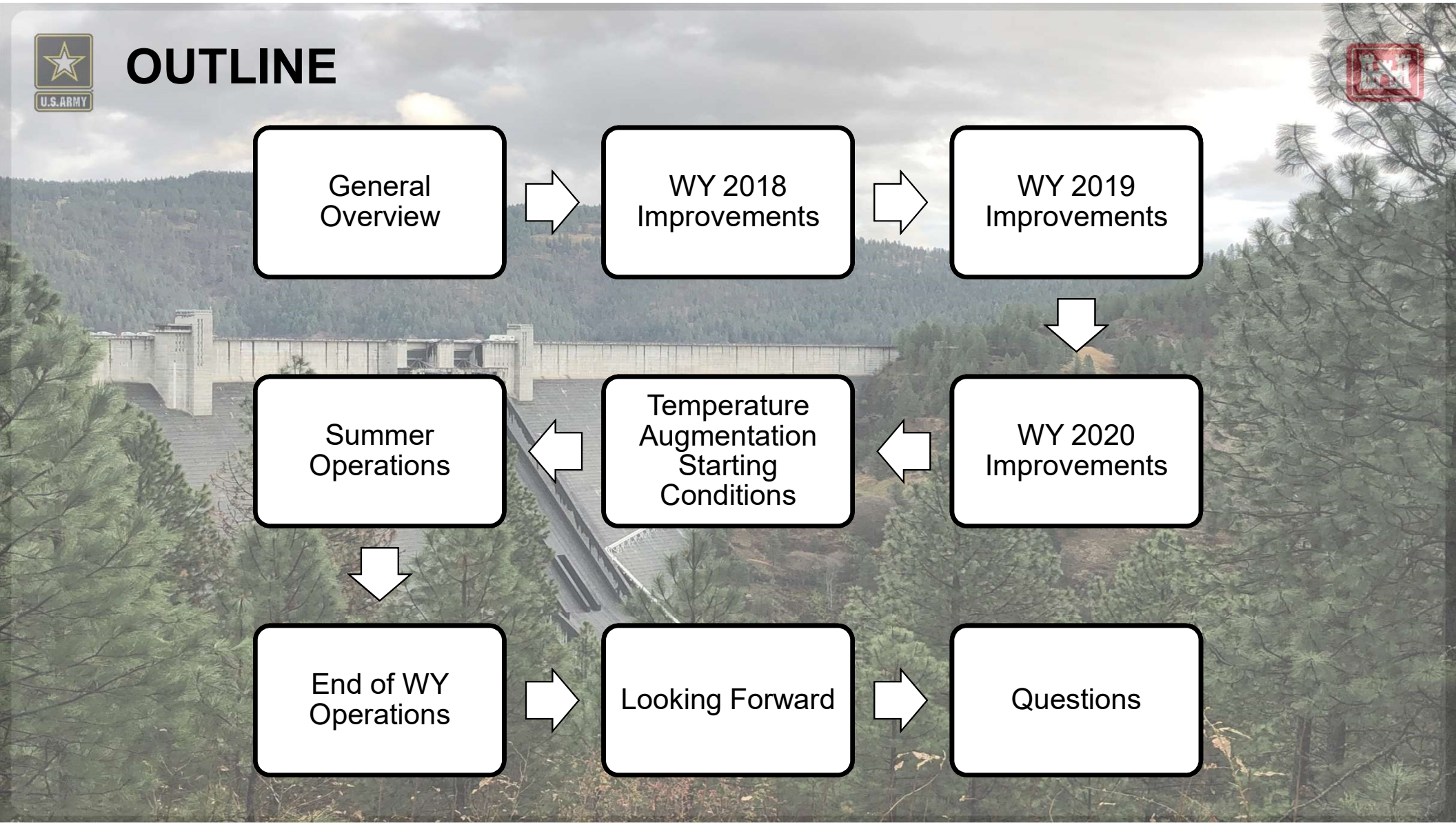
OUTLINE

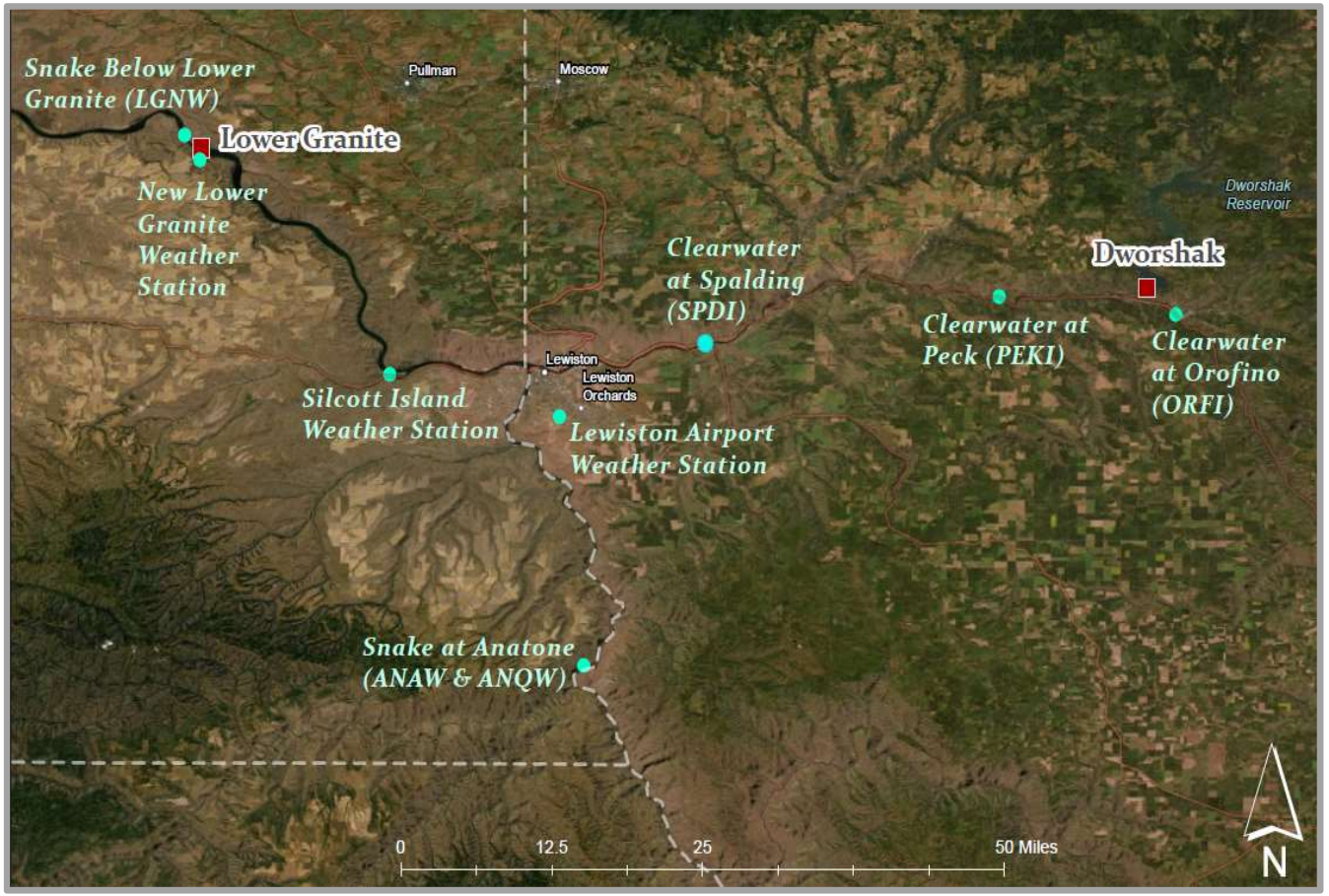

General Overview
WY 2018 Improvements
WY 2019 Improvements
WY 2020 Improvements
Temperature Augmentation Starting Conditions
Summer Operations
End of WY Operations
Looking Forward
Questions

OVERVIEW

Releases from Dworshak are shaped to maintain water temperatures below 68ºF at the Lower Granite tailrace fixed monitoring site.

Other considerations

- Temperature stratifications of LWG pool
- Changing weather conditions
- Efficient releases to provide maximum relief with limited water supply
- September ramping
- Adult fish trap temperatures
- Varying travel times



WY 2018 IMPROVEMENTS

After Unit 3 was repaired in 2017, NWW water management conducted a review of temperature operations.

3-phase improvement plan

- Phase 1 – Enhance modeling and analysis capabilities
- Phase 2 – Data improvements
- Phase 3 – Identifying opportunity for further incremental improvements

Phase 1: Analyzed, tested, and developed a new weighting system to track the three outlet categories to forecast more realistic tailrace temperatures

1. RSW
2. Spillway Weirs
3. Turbines

WY 2018 DISCHARGE WEIGHTING

Water intake depths below surface:

- RSW: 1.5 to 5 meters
- Spillway Weirs: 10 to 20 meters
- Turbines: 20 to 35 meters

7/30/2018 – tailwater temperature

- Max: 69.3°F
- Min: 68.0°F
- Average: 68.6°F

Temperature in the top 10m of water column is sensitive to wind speed and air temperature. Dworshak releases have greater impact when targeting a specific stratification layer.

Changes in Operations:
Release timing & updated mixing calibration

Date	Time	0.5m	1.5m	3m	5m	10m	15m	20m	25m	30m	35m	Battery
07/30/2018	00:00	77.6	77.2	75.0	73.2	69.6	68.5	66.2	64.4	63.8	62.1	12.94
	01:00	77.3	76.5	75.0	72.8	69.7	68.6	66.3	64.2	63.8	62.1	12.94
	02:00	76.6	75.7	75.0	72.2	69.6	68.8	66.2	64.5	63.8	62.1	12.71
	03:00	76.1	75.3	74.8	71.9	69.6	68.8	66.6	64.3	63.7	62.1	12.71
	04:00	75.9	75.8	74.8	71.8	69.6	68.9	67.0	64.2	63.7	62.1	12.71
	05:00	75.3	75.1	75.1	73.3	69.7	68.7	66.6	64.6	63.8	62.1	12.71
	06:00	75.1	75.0	75.0	74.6	70.0	68.7	67.1	64.4	63.8	62.1	12.71
	07:00	74.9	74.8	74.8	74.7	70.2	68.7	66.9	64.4	63.8	62.1	12.71
	08:00	74.7	74.6	74.6	74.5	70.4	69.0	66.7	64.2	63.8	62.1	12.94
	09:00	74.8	74.5	74.5	74.4	70.1	69.2	67.0	64.4	63.8	62.1	12.94
	10:00	74.6	74.5	74.5	74.2	70.3	69.5	67.5	64.7	63.8	62.1	13.17
	11:00	75.2	74.7	74.3	74.1	71.7	69.5	67.0	64.4	63.8	62.0	13.17
	12:00	75.7	74.7	74.5	74.3	72.1	69.5	67.4	64.5	63.8	62.0	-
	13:00	76.0	74.9	74.6	74.2	71.7	69.5	66.8	64.4	63.8	62.0	-
	14:00	75.8	75.0	74.6	74.3	71.7	69.4	66.8	64.4	63.8	62.0	13.17
	15:00	77.4	75.5	74.6	74.0	71.4	69.5	67.1	64.3	63.8	62.0	13.17
	16:00	77.4	75.1	74.6	74.1	71.6	69.3	67.5	64.7	63.9	62.0	13.17
	17:00	78.1	76.5	74.8	74.2	70.6	68.3	67.3	64.4	63.8	62.0	13.17
	18:00	77.0	76.0	75.2	74.4	70.5	68.4	67.4	64.2	63.8	62.0	12.94
	19:00	76.8	76.2	74.8	74.6	70.4	68.5	67.6	64.1	64.0	62.0	12.94
	20:00	76.6	76.0	74.9	74.5	70.4	68.7	67.4	64.1	63.9	62.0	13.17
	21:00	77.8	75.9	74.7	74.3	70.2	69.1	67.4	64.1	64.0	62.0	12.94
	22:00	76.8	76.6	75.2	74.0	70.3	69.2	67.2	64.2	64.0	62.0	12.94
	23:00	77.5	76.6	75.1	74.0	70.5	69.4	67.2	64.4	64.0	62.0	12.94

WY 2019 IMPROVEMENTS

Phase 2: Data improvements and revised in-season analysis

- Lower Granite's weather station on-line
- Improvements in May of 2019 to provide better mixing analysis to maintain stratification in forebay
- Better temperature data further up the forebay (S2 and S3)
- Initial trial of ramping September releases for in-season temperature control instead of prescribed ramp-down.

RSW CLOSURE IN 2019

Conditions for LWG from 8/5 to 8/10 during RSW closure from 8/6 at 1400 to 8/9 at 0000
WY2019

Depth In Meters	05 Aug 0000	05 Aug 1200	06 Aug 0000	06 Aug 1200	07 Aug 0000	07 Aug 1200	08 Aug 0000	08 Aug 1200	09 Sep 0000	09 Sep 1200	10 Sep 0000	10 Sep 1200
0.5	72.6	74.3	75.8	75.7	77.1	75.3	75.7	77.3	75.8	76.0	75.8	75.4
1.5	72.3	72.8	75.2	74.1	75.2	74.6	75.3	75.5	75.1	75.9	75.5	74.7
3	71.8	72.3	73.1	73.6	74.6	74.3	73.5	74.3	73.3	75.6	74.1	72.0
5	71.5	71.5	72.0	73.3	73.8	72.9	71.9	71.9	72.2	72.8	72.5	70.9
10	69.3	69.9	69.8	71.3	70.6	70.7	70.5	70.3	70.5	69.7	70.0	69.4
15	68.3	68.7	67.9	69.3	68.3	68.9	68.1	68.6	68.6	67.9	68.1	68.5
20	66.7	67.2	66.3	66.6	66.5	65.2	64.6	65.7	64.9	65.3	64.1	63.7
25	64.2	64.5	64.4	64.7	64.6	64.5	64.3	64.2	63.8	63.5	63.3	63.2
30	63.8	63.9	64.0	64.1	64.4	64.3	64.4	64.0	63.7	63.5	63.3	63.2
35	62.7	62.8	62.8	62.9	63.0	63.1	63.0	63.1	63.0	62.9	62.7	62.6

Denotes missing data | <72°F | 70°F to 71°F | 70°F to 67°F | 66°F to 64°F | 60°F to 64°

SILW Air Max/Low Temp	05 Aug		06 Aug		07 Aug		08 Aug		09 Sep		10 Sep	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
°F	65.1	101.4	66.6	103.6	71.6	103.4	70.8	99.7	70.4	87.0	67.7	89.5
LWG Tailwater	67.33	68.13	67.60	69.06	67.41	68.02	67.12	67.77	67.30	68.00	66.38	67.46

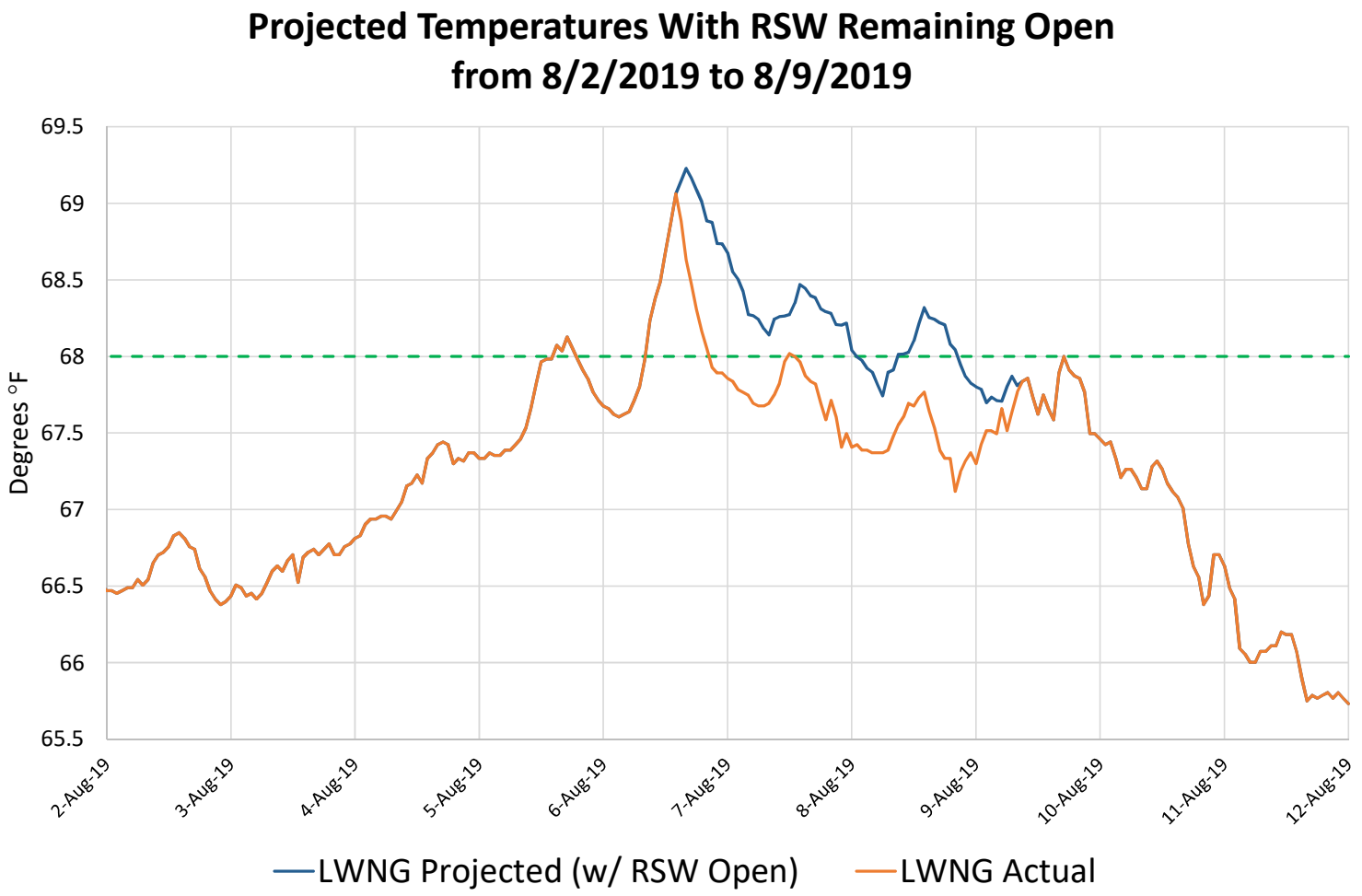
RSW CLOSURE IN 2019

Estimated average temperature improvement: ~0.6°F for 1h increments

Conditions that applied for this result to occur:

- Water temperatures in LWG forebay (in 3m and 15m range) need to have a difference of 4°F (or greater)
- Forecast for light wind and limited cloud cover
- Continued heat wave forecasted for duration of operation in excess of 95°F

*Projected temperatures are based on previous 5-day mixing calibration from model, actual trend that occurred in observed temperature values, correlation of observed solar radiation, wind speed, LWG tailwater elevation, and air temperatures during operation.



TEMPERATURE CONTROL RAMPING IN SEPT.

Previous years:

- Controlled step down by discharge increments
- Targeting elevation 1520 ft by Sept. 20th

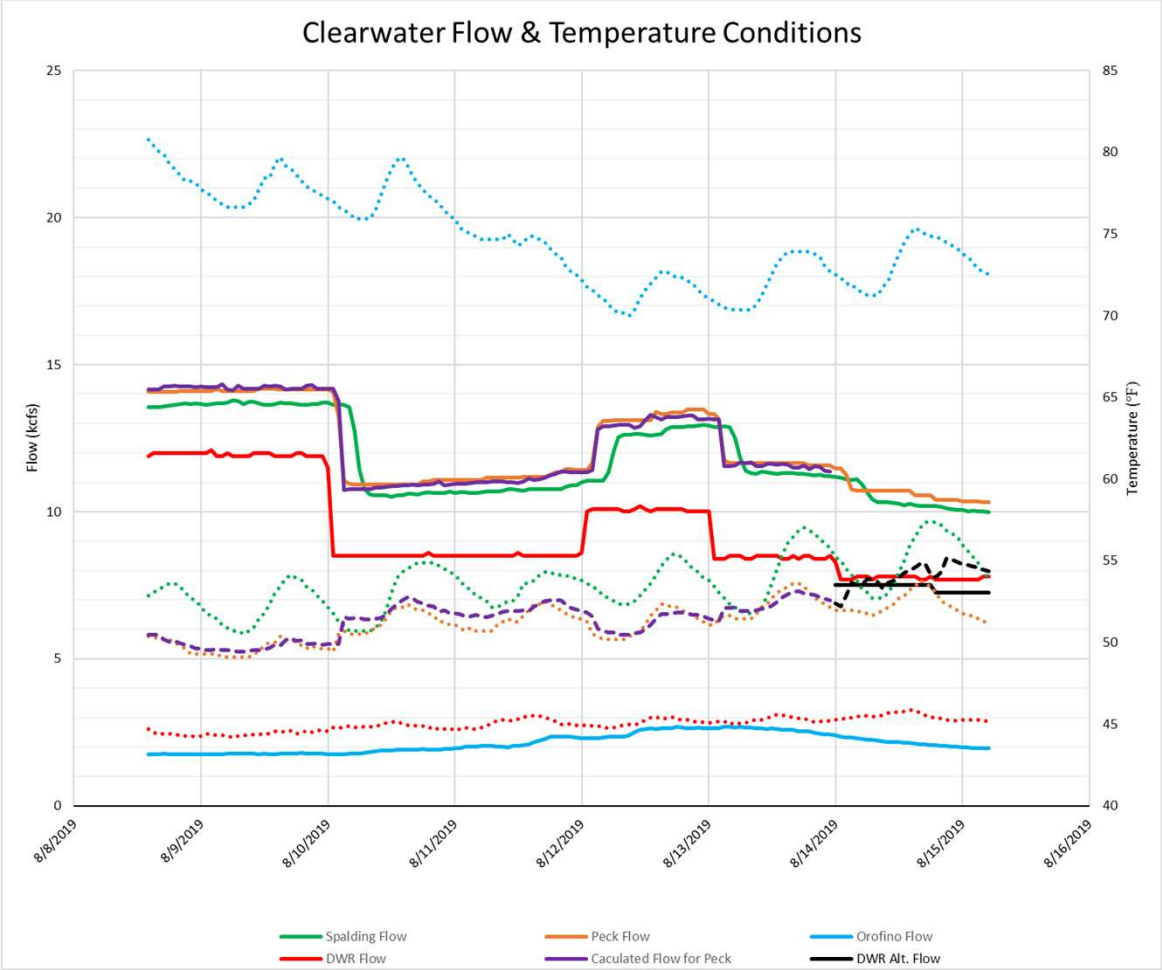
Alternative approach with new criteria:

- Target LWG Tailwater temperatures not to exceed 68°F
- Target Clearwater River at Spalding daily average water temperatures not to exceed 56°F
- Target Clearwater River at Peck and Spalding daily average water temperature change of no more than 1°F

Extend augmentation until natural temperature returned to 56° F to minimize temperature spike in Clearwater

Lessons Learned:

- Adult fish trap temperatures
- Unit outages and maintenance



WY 2020 IMPROVEMENTS

Phase 3: Identifying opportunity for further incremental improvements

- Analog year corrections for Orofino and Anatone
  - Corrected over 7,500 hours of data across 30 years to provide better in-season calibration optimization
- Extended flow augmentation by analyzing refill and runoff conditions
- September ramping improvements
  - Lessons learned from initial temperature modeling of Clearwater to make discharge improvements
  - Overhauling modeling technique to target adult fish ladder temperatures

WY 2020 EXTEND HEAT WAVE

Conditions:

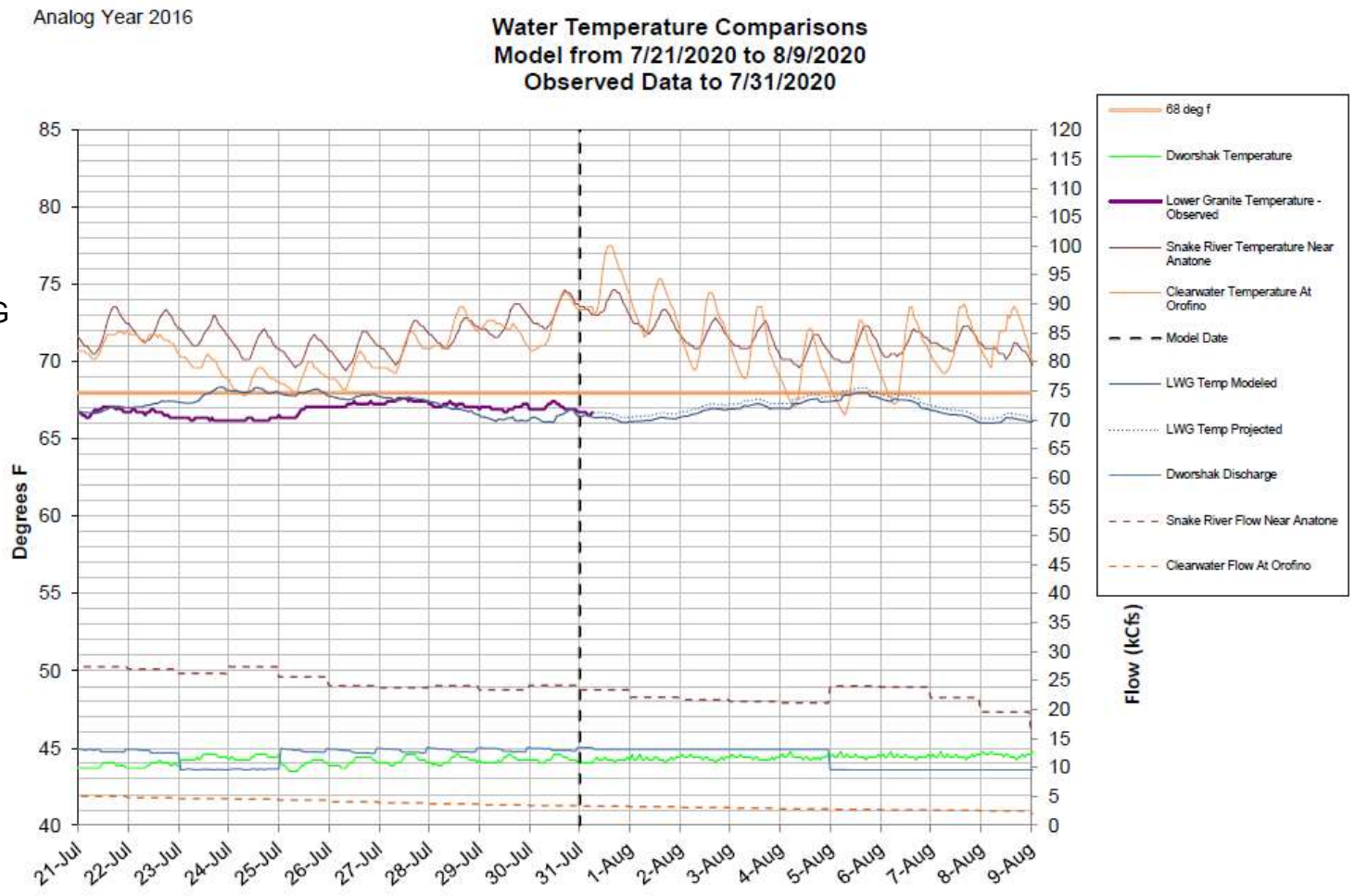
- Extended heat wave in late July/ early August

Outcome:

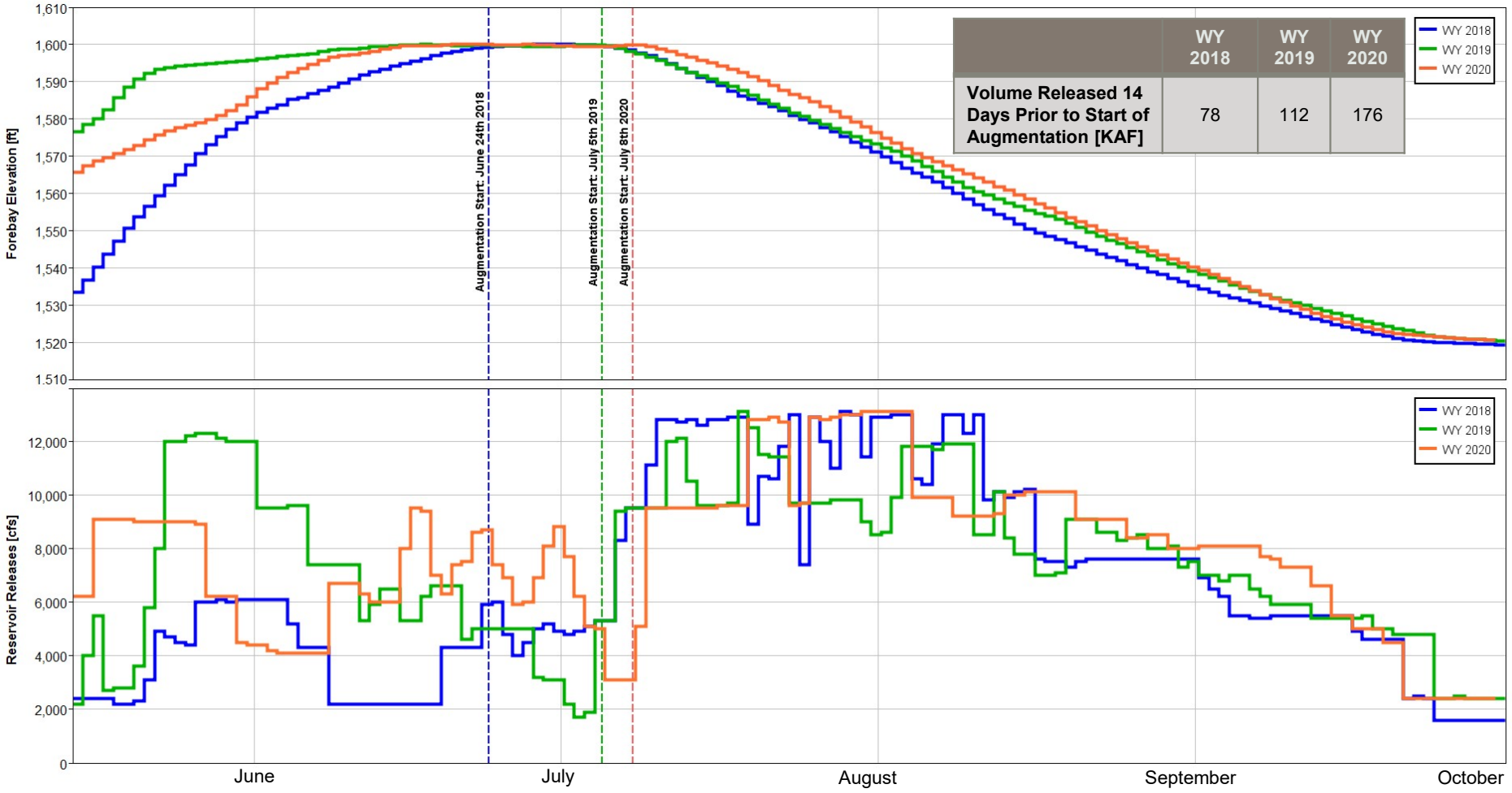
- No exceedances on the 12-hour moving average in the tailwater
- DWR outflow remained at max. TDG discharge for over 13 days straight

Improvements that lead to success:

- Enough water available due to later start of flow augmentation
- DWR flow adjustments to maximize discharge while maintaining TDG under 110%
- Improved mixing calibration from previous years
- Improved baseline data sets from data corrections

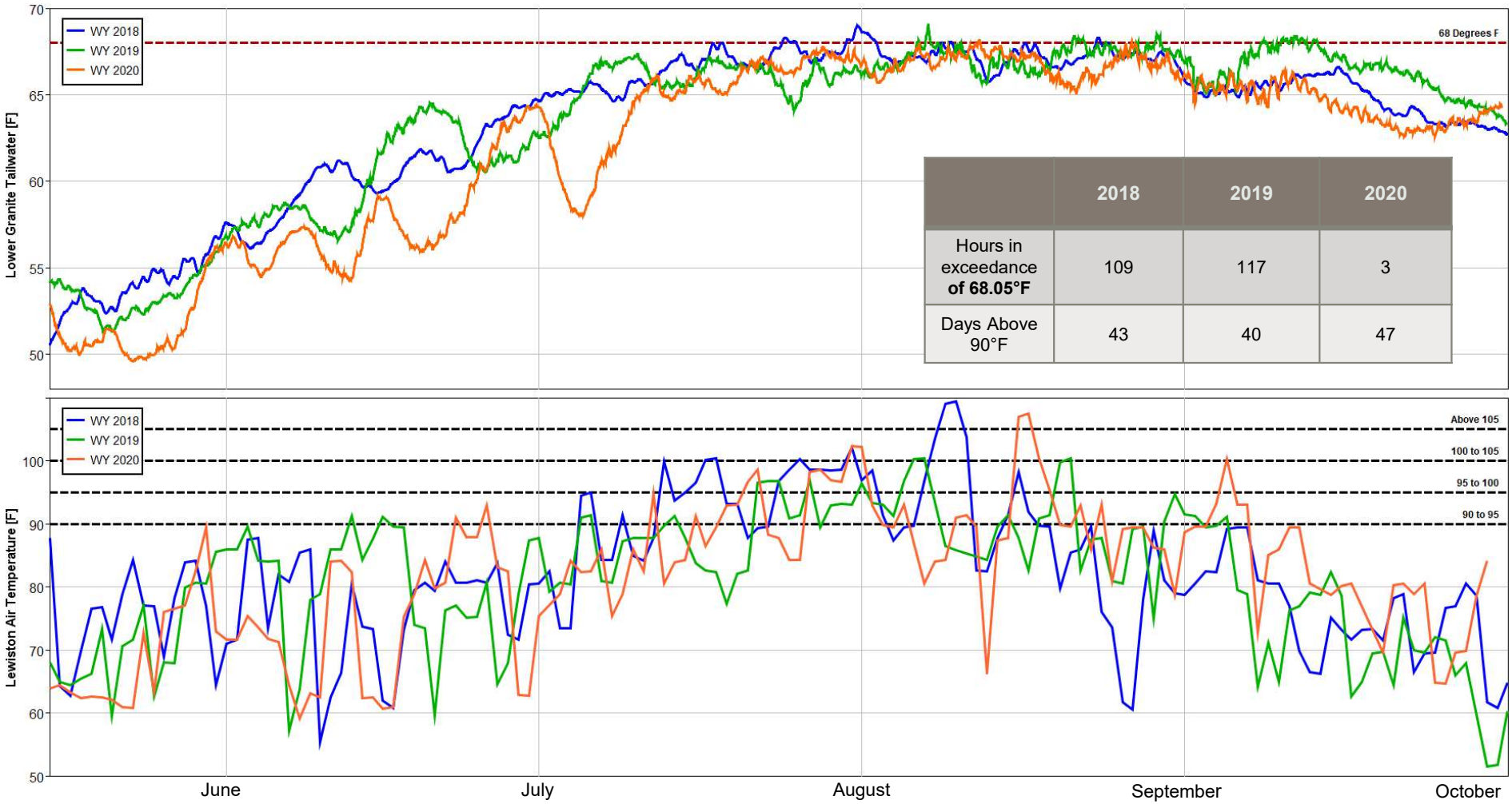


WATER YEAR COMPARISON - OPERATIONS SUMMARY



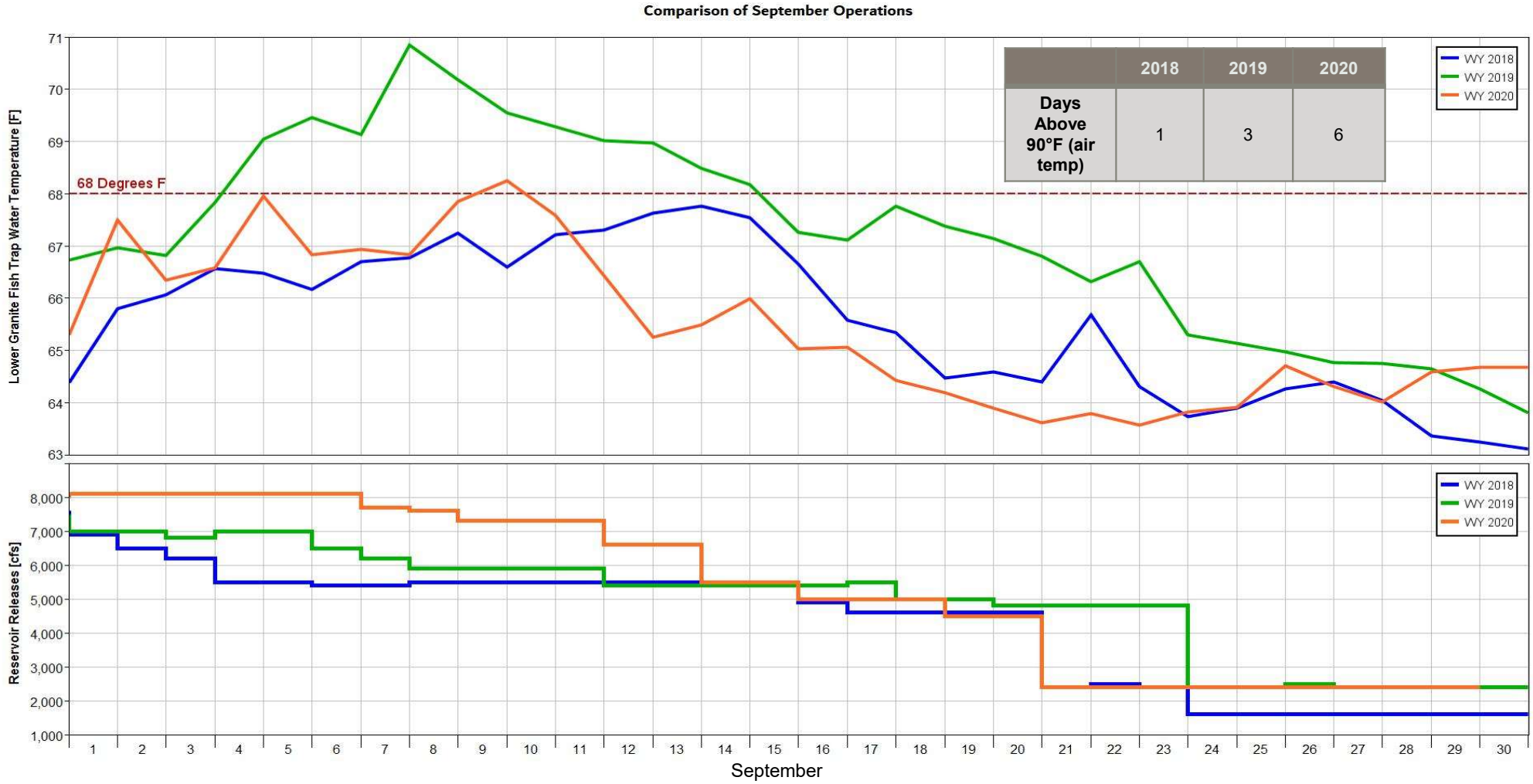
	WY 2018	WY 2019	WY 2020
Volume Released 14 Days Prior to Start of Augmentation [KAF]	78	112	176

WATER YEAR COMPARISON - OPERATIONS RESULTS



	2018	2019	2020
Hours in exceedance **of 68.05°F**	109	117	3
Days Above 90°F	43	40	47

WATER YEAR COMPARISON – SEPTEMBER RESULTS



	2018	2019	2020
Days Above 90°F (air temp)	1	3	6

FUTURE IMPROVEMENTS & TESTING

Operational Improvements:

- Optimize refill to provide best initial conditions for temperature augmentation
- Targeting specific stratification layers with Dworshak releases
- Review changes and analyze effects from new MOP and EIS/ROD criteria
- Work with project staff and regional partners to review maintenance and testing timeframes

Temperature Model Improvements:

- CWMS temperature model with daily ESP trace routing (work started this year)
  - Parallel testing for next two years with current CEQUAL-W2 model and new model
  - Benefit to risk-based decision making by looking further than 10-day forecast window. Provides projections for 60 days out based on 25 alternatives
- Continue training additional staff on temperature modeling to facilitate better hand-off and new perspectives
- Improve the transition from augmentation releases to the natural hydrograph at the end of September

QUESTIONS