# Little Goose Dam – 2018 Operations – Lessons Learned

# Little Goose Dam - Forebay Storage - A Tool to Improve Passage Conditions for Adult Chinook Salmon

- When adult Chinook salmon are delayed below Little Goose Dam (LGS) due to high levels of spill, the forebay (FBE) is an effective tool to reduce spill for short periods of time in order to improve passage conditions.

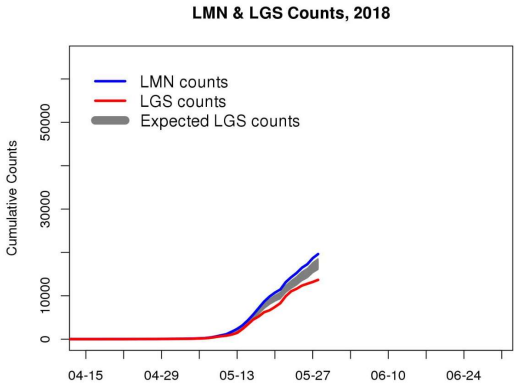
- Concerns regarding spill reductions on juvenile Chinook salmon were addressed by limiting the duration of a spill reduction during the day (e.g. 8 hours).

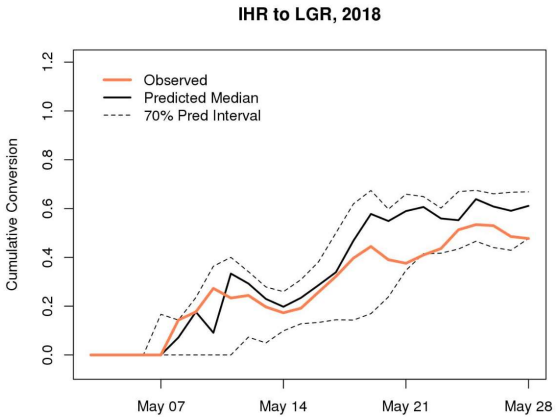
- The use of the LGS FBE was effective at improving the passage of adult Chinook salmon in 2018 and will be effective in future years if necessary to improve passage conditions for adult Chinook salmon.

# Operation to Improve Passage of Adult Chinook Salmon

•**May 29 TMT Meeting.** The cumulative counts of fish for Lower Monumental Dam (LMN) and LGS indicated a disparity between the actual counts and expected counts for LGS, and that there were 6,000-7,000 fewer fish than expected at LGS. The TMT coordinated the following operation Wednesday, May 30, through Friday, June 1.

- 4 AM -12 PM - Operate to maintain 30% spill. Store remaining inflow in the LGS pool above the 1-foot Minimum Operation Pool (MOP) range of 633.0 - 634.0 feet as necessary depending on inflows.
- 12 PM – 4 PM – Increase spill to pass inflow. LGS may be above MOP.
- 4 PM - 4 AM - Increase spill as necessary to draft back to MOP while remaining under 130% TDG (approximately 125 kcfs spill).



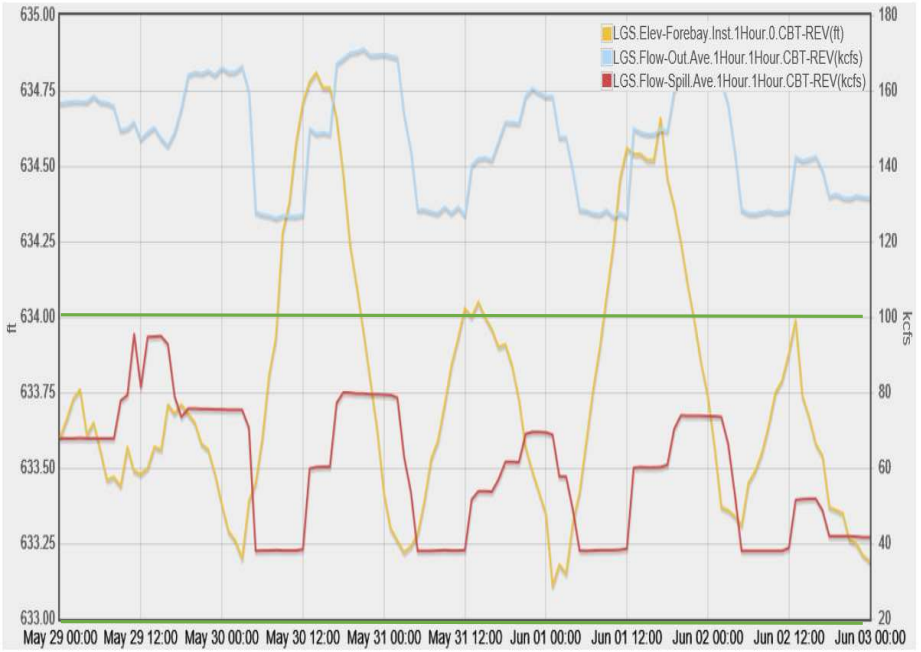



# Operations Data Summary

•4 Day Operation that occurred May 30 through June 2* (*Extended 1 day per the June 1 TMT meeting).

•26 hours of operation above MOP (633.0 to 634.0 feet) over 4 days was the duration of this operation.

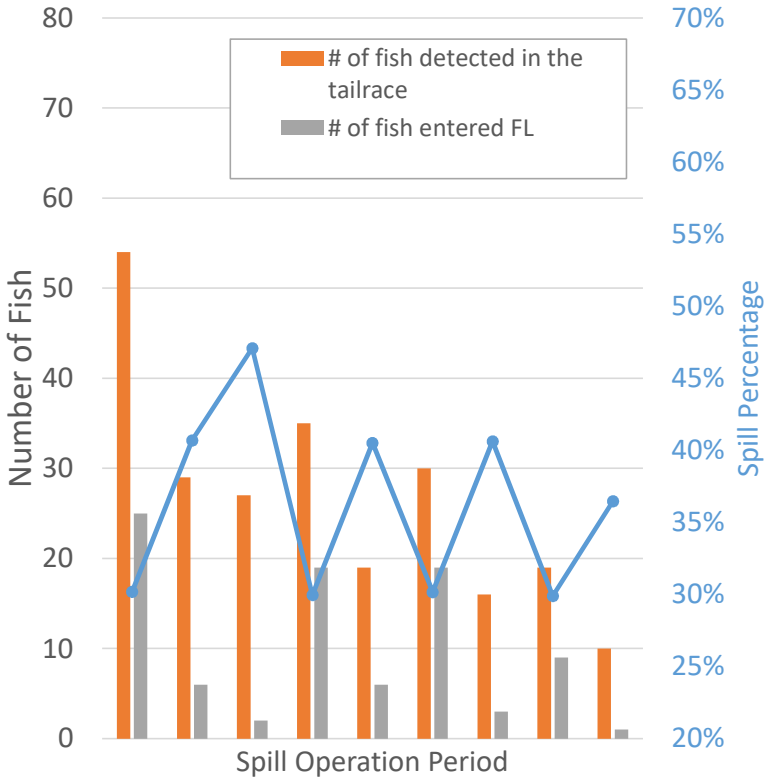
- 5/30 – 12 hours (0800 to 2000 hours) operated above MOP. The maximum FBE during this period was 0.8 feet above MOP. Average FBE during this period was 0.5 feet above MOP.
- 5/31 - 1 hour (1300 hours) operated 0.1 feet above MOP (5/31 at 634.1 feet).
- 6/1 - 13 hours (0800 to 2000 hours) operated above MOP. The maximum FBE during this period was 0.7 feet above MOP. Average FBE during this period was 0.4 feet above MOP.
- 6/2 – 0 hours above MOP.



# Impacts on Adults vs Juvenile Chinook Salmon

- Impacts on adult Chinook salmon. From May 30th to June 2nd, a 30% spill operation was implemented at LGS to aid adult passage. During the 30% spill period, a higher percentage of the tagged adults present in the tailwater entered the fish ladder (40% - 65%) than during previous days (below 20% from May 25 to May 29) **Martinez et al., (2018).

- Impacts on juvenile Chinook salmon. Limited the duration of spill reduction to 30% to 8 hours (4am to 12pm) per day .





- **Martinez, J., Deng, D., Fu, T., Mueller R., Pflugrath, B., Grant, C., Harnish R., Li, X., Titzier, S., Ham, K., Lin, X., Li, H. (2018). Adult Spring Chinook Salmon Passage and Migration Behavior through the Lower Snake River (gas cap spill evaluation) & Post-construction Evaluation of the Little Goose Dam Adult Ladder Passage Temperature Reduction System. November 28, 2018. Pacific Northwest National Laboratory.

# Forebay Storage Calculation

- The storage capacity of LGS is approximately 5 thousand cubic feet per second days per foot (kcfs-days/foot).
- Generally, the relationship between the inflow/outflow differential and change in FBE is linear therefore the following table may be used when estimating spill reduction and associated change in FBE.

| LGS Storage Capacity of 5 kcfs-days/foot | | |
|---|---|---|
| Project Inflow vs Outflow Differential (kcfs) | Delta (+/-) in Forebay Elevation (feet) | Period (day) |
| 5 | 1 | 1 |
| 10 | 2 | 1 |
| 15 | 3 | 1 |
| 20 | 4 | 1 |
| 25 | 5 | 1 |

- 1 foot of forebay space is either gained or lost when the differential of inflow vs outflow is equivalent to 5 thousand cubic feet per second (KCFS) over the period of 1 day. For example if LGS outflow is 100 kcfs while inflow is 105 kcfs over the period of 1 day then LGS would fill 1 foot into the FBE.

# Summary of Forebay Storage Operation

- Using the LGS FBE to target 30% spill has been an effective tool to increase passage of adult Chinook salmon. During the 30% spill period, a higher percentage of the tagged adults present in the tailwater entered the fish ladder (40% - 65%) than during previous days (below 20% from May 25 to May 29).

- This operation addressed concerns regarding impacts on juveniles Chinook salmon by limiting the duration of the 30% spill operation.

- In the event there is the delay of adult Chinook salmon in periods of high spill in 2019 going to 30% spill in a more timely manner and storing above MOP would likely reduce the delay of adult Chinook salmon in the LGS tailrace.

# Little Goose adult Chinook salmon passage – Brief history

- Many studies conducted before 2006 indicate Snake and Columbia River dams delay upstream migration of adult salmon and steelhead.
- Haynes and Gray (1980) identified variability in average adult passage time (hrs) for adult Chinook salmon, and that individual Chinook salmon passage during 1976 [high flow with spill] and 1977 [low flow no spill] at Little Goose Dam averaged (216 ± 210 hrs and 90 ± 57 hrs, respectively) compared to the same individuals at Lower Granite Dam (<50±19 hours and 58±45 hours, respectively).
- Mann-Whitney test support significantly different travel time (hrs) for Little Goose Dam, especially in 1976.
- However, they indicate that spill and turbine operations are regular events at all dams and would not appear to be solely responsible for excessive delay.

# Little Goose adult spring-summer Chinook passage – Brief history

- Lower Monumental and Little Goose dams adult Chinook ladder counts and ladder usage 2001–2008 different operations (Jepson et al. 2009)
  - *"Specifically, we found no significant differences in $log_e$-transformed mean daily dam counts among spill treatments (P = 0.71, df = 2), blocks (P = 0.10, df = 14), or the spill treatment × block interaction term (P = 0.99, df = 28). Based on K-S tests, there were no significant differences in the distributions of daily counts of adult Chinook salmon passing Lower Monumental and Little Goose dams during 2001-2006 versus 2008 (Figure 10). Distributions during 2007 were significantly different (P < 0.033, df = 1), a likely result of the modified spill patterns during that year."*

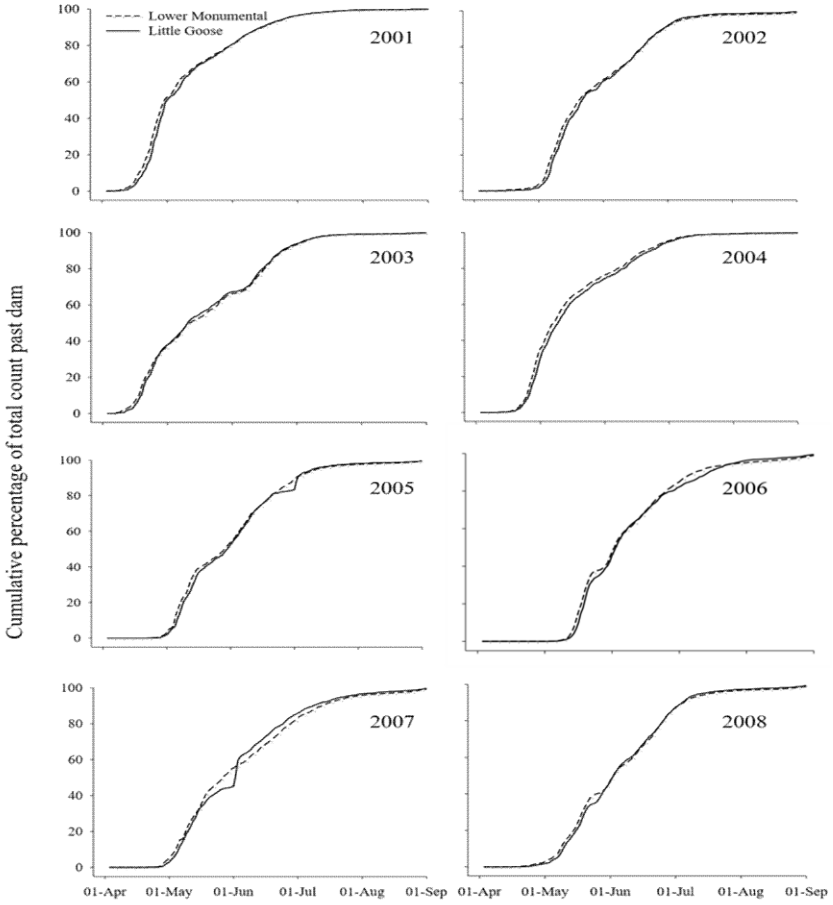



Figure 10. Distributions of cumulative percentage of adult Chinook salmon counted passing Lower Monumental and Little Goose dams from 1 April through 31 August, 2001-2008.

# Little Goose adult spring-summer Chinook passage – Brief history

- Jepson et al. 2009 looked at multiple regression of the effects of dam operations at Little Goose dam on daily ladder counts 2005–2008.
  - *"Most significant predictive factors in 2006 and 2008 were uncontrolled spill and high percentage of unplanned spill. When uncontrolled spill was reduced on 23 May, the frequency of fish passing increased and counts at Little Goose Dam were higher than those at Lower Monumental Dam."*
  - *Results of multiple linear regression analyses indicates several factors related to dam operations could be used as predictors of adult ladder counts, but they did not point to a single condition that should be avoided. There were positive effects of discharge in several of the models, indicating ladder counts generally increased during periods of higher discharge.*

Table 3. Results of multiple regressions of the effects of dam operations on daily ladder counts of adult spring Chinook salmon at Little Goose Dam during 2005 through 2008, and for all years combined. Parameters are defined in Table 1.

| Year | Parameter | Estimate | Std Error | *P* | *r*-square |
|---|---|---|---|---|---|
| 2005 | Intercept | 89.7781 | 25.4210 | 0.0008 | 0.8487 |
| | LMO Adult Count | 0.7288 | 0.0429 | <0.0001 | |
| | Percent Spill | -3.2026 | 0.5839 | <0.0001 | |
| 2006 | Intercept | -59.06514 | 38.5271 | 0.1298 | 0.8486 |
| | LMO Adult Count | 0.75369 | 0.4682 | <0.0001 | |
| | Uncontrolled spill | -7.78912 | 2.5456 | 0.0031 | |
| | PHS discharge | 1.74711 | 0.6210 | 0.0064 | |
| 2007 | Intercept | -2409.2112 | 739.2667 | 0.0016 | 0.7091 |
| | LMO Adult Count | 0.3602 | 0.0707 | <0.0001 | |
| | Spill discharge | -72.3857 | 24.5188 | 0.0041 | |
| | Percent Spill | 73.3857 | 24.6381 | 0.0038 | |
| | Bulk spill pattern | -174.6767 | 38.2239 | <0.0001 | |
| | PHS discharge | 38.0214 | 24.6381 | 0.0005 | |
| | Turbine 1 Online | 103.5204 | 67.6901 | 0.1313 | |
| 2008 | Intercept | -146.9169 | 129.5864 | 0.2602 | 0.7342 |
| | LMO Adult Count | 0.6872 | 0.6900 | <0.0001 | |
| | Uncontrolled spill | -15.0620 | 3.3416 | 0.0051 | |
| | Bulk spill pattern | -228.4486 | 84.4927 | 0.0083 | |
| | Total discharge | 4.3295 | 1.5028 | 0.0051 | |
| 2005-2008 | Intercept | 77.1182 | 26.8050 | 0.0043 | 0.7944 |
| | LMO Adult Count | 0.7263 | 0.0289 | <0.0001 | |
| | Spill discharge | 7.4186 | 1.2971 | <0.0001 | |
| | Uncontrolled spill | -11.6985 | 1.9492 | <0.0001 | |
| | Percent Spill | -9.3233 | 1.2078 | <0.0001 | |
| | Non-bulk pattern | 146.3502 | 26.5567 | <0.0001 | |

# Little Goose adult spring-summer Chinook passage – Brief history

- Jepson et al. 2009 looked at three spill operations (Alternate, Bulk and uniform) at four different total river discharges during 2008 and identified variable patterns of ladder use between south power house entrance and the other two ladder entrances.
  - *"During the Alternate and Uniform spill treatments, the north-shore fishway opening was the site most used by tagged salmon to first approach a fishway (Table 5). It was the site most used across all mean daily flow categories, except at flows less than 50 kcfs during the Uniform treatment. In contrast, tagged salmon tended to use the south powerhouse fishway opening as a first approach site during the Bulk spill treatment, particularly at mean daily flows less than 115 kcfs."*
  - *"Among all spill treatment and mean daily flow categories, ≤10% of tagged salmon used the north powerhouse fishway opening as a first approach site."*

Table 8. Treatment-, flow-, and site-specific frequencies and percentages of first fishway entries made by radio-tagged spring–summer Chinook salmon at Little Goose Dam during 2008.

| | | frequency | | | | Percent | | |
|---|---|---|---|---|---|---|---|---|
| Mean Daily Flow (kcfs) | Spill Trt. | South PH | North PH | North-Shore | Total | South PH | North PH | North-Shore |
| ≤50 | Alternate | 7 | 4 | 6 | 17 | 41% | 24% | 35% |
| >50 & ≤85 | | 13 | 2 | 8 | 23 | 56% | 9% | 35% |
| >85 & ≤115 | | 14 | 3 | 11 | 28 | 50% | 11% | 39% |
| >115 | | 6 | 1 | 21 | 28 | 21% | 4% | 75% |
| All | | 40 | 10 | 46 | 96 | **42%** | **10%** | **48%** |
| ≤50 | Bulk | 5 | 2 | 4 | 11 | 46% | 18% | 36% |
| >50 & ≤85 | | 23 | 1 | 1 | 25 | 92% | 4% | 4% |
| >85 & ≤115 | | 24 | 6 | 3 | 33 | 73% | 18% | 9% |
| >115 | | 5 | 0 | 18 | 23 | 22% | 0% | 78% |
| All | | 57 | 9 | 26 | 92 | **62%** | **10%** | **28%** |
| ≤50 | Uniform | 4 | 2 | 1 | 7 | 57% | 29% | 14% |
| >50 & ≤85 | | 22 | 1 | 4 | 27 | 81% | 4% | 15% |
| >85 & ≤115 | | 13 | 3 | 15 | 31 | 42% | 10% | 48% |
| >115 | | 2 | 0 | 31 | 33 | 6% | 0% | 94% |
| All | | 41 | 6 | 51 | 98 | **42%** | **6%** | **52%** |
| All | All | 138 | 25 | 123 | 286 | **48%** | **9%** | **43%** |

# Little Goose adult spring-summer Chinook passage – Brief history

- Jepson et al. 2009 only report conversion information from Ice Harbor to Little Goose Dam for 2008.
  - *"Among the 360 spring–summer Chinook salmon outfitted with transmitters at Ice Harbor Dam through 11 August 2008, 290 (81%) were recorded on or upstream from the tailrace receiver sites at Little Goose Dam (Table 4)."*

Table 4. Number and percent of adult radio-tagged Chinook salmon recorded at Little Goose Dam from 15 April through 30 August 2008, that were recorded on their first passage of the tailrace, first approach at a fishway opening, first fishway entry, and exit from the top of the ladder.

| 2008 | Freq. | Percent |
|---|---|---|
| Recorded at dam | 290 | 100 |
| Known to pass dam | 283 | 98 |
| Recorded first tailrace passage | 265 | 91 |
| Recorded first (known) fishway approach | 289 | 100 |
| Recorded first (known) fishway entrance | 286 | 99 |
| Recorded ladder exit | 282 | 97 |

# Little Goose adult spring-summer Chinook passage – Brief history

- Jepson et al. 2009 Conclusions.

✓ Counts between Lower Monumental and Little Goose *"The results of these evaluations were broadly consistent with the hypothesis that the Bulk spill pattern slowed the migration of adult spring–summer Chinook salmon at Little Goose Dam."*

✓ Multivariate analysis *"Flow volume categories were evaluated as a covariate because migration rates are reduced in adult salmonids at high river discharges (Keefer et al. 2004; Caudill et al. 2006) and in areas of high hydraulic complexity (Hinch and Rand 1998). Turbulence in the tailrace generally increases with increasing spill volumes, which can result in increased search times and the inability of some individuals to orient to fishway openings. Additionally, spill pattern and gross surface circulation patterns in the tailrace converged among treatments at the highest river discharges."*

✓ *Ladder use at Little Goose* *"Spill operations generally had negative effects, except for spill discharge (volume), which was related to overall discharge. Spill percent and the presence of a bulk spill pattern had negative effects in several years. The amount of uncontrolled spill was an important factor in the 2008 model and the overall model and had a negative effect. The number of variables in the models and examination of the data plots suggest adult ladder counts were affected by several factors in concert, such as the presence of low discharge, high spill percent, and turbine 1 being off. The fit of the models may be improved if the passage dates of the fish that build up in the tailrace when conditions are poor could be predicted. We did not include this effect in our models, but the data plots clearly indicated this occurred. For example, in 2007 there was a lag of passage in late May as indicated by the divergence of counts at Lower Monumental and Little Goose dams and this caused thousands of fish to pass within about 2 days after changes in the spill pattern and powerhouse operations."*

✓ *Conversion rates* *"These observations may have been reflections of the biological imperative for salmon to reach spawning grounds, generally favorable passage conditions inside the Little Goose Dam fishway, unfavorable hydraulic conditions in the tailrace, or perhaps most likely, a combination of the three."*

# FPC Memo 5-18 February 5, 2018

- Several FPC Memos (40-17,2-18,4-18, and 5-18) were developed in preparation that identify numerous factors related to LGS operations and adult passage that were further summarized in February 2015
- Adult passage rate issues have been present at the Little Goose project before the provision of spill for juvenile fish passage
- The configuration of the project and the bathymetry of the tailrace are a primary source for tailrace conditions that affect adult passage rates
- Powerhouse and spill bay operations may contribute to those conditions
- Among operational variables, the operation of spill bay 1 (i.e., the TSW) had the largest effect on the adult passage rates at Little Goose when analyzing hourly project operations and adult passage.
- Operational decisions at Little Goose in May 2010 corroborate these analytical results, illustrating the negative impact the TSW can have on adult passage. On two separate occasions, the TSW was closed (once for 8 hours and once for nearly two days) while maintaining a uniform spill pattern and spill percent. During each of these two occasions, adult passage increased dramatically at Little Goose compared to the days that the TSW was operating.
- The time that spring Chinook spend in the Ice Harbor to Lower Granite river reach does not affect their upstream migration success to or above their hatchery of origin
- The time that spring Chinook spend in the Lower Monumental to Little Goose river reach does not affect their upstream migration success to or above their hatchery of origin.

# FPC Memo 47-18 June 22, 2018

- Adult salmon and steelhead that were subject to the smolt transportation program have slower upstream migration, have lower upstream migration success, and higher dam reascension rates, all contributing to delay.
- When considering adjusting operations to aid adult passage, consideration must also be given to downstream passage of juvenile salmonids. Each juvenile powerhouse encounter reduces subsequent SAR by a relative 9-13% (Chapter 7, McCann et al. 2016).
- Water temperatures, fishway temperatures, TSW operations, seasonality, distance to point of origin, specific project operations, and flow all affect upstream migration rates. The TSW operation in particular appears to negatively affect adult passage rates.
- Little evidence of negative effects on adult upstream survival has been found for Snake River spring Chinook relative to the time spent in the Ice Harbor to Lower Granite reach or the Lower Monumental to Little Goose reach.

# Little Goose Spill – Recent History

- 2005 increased spill to the gas cap but adult delay observed.
- Spill was incrementally reduced until passage resumed at a spill level of 30%
- Observation not universally accepted but became the standard operation.
- 2017 spill under high flow and high spill percentage resulted in apparent adult delay.
- Spill level reduced during morning hours to 30% and water ponded into forebay resulted in increased adult passage.
- 2018 Spill to the gas cap became an operation at the FCRPS projects due to court decision.

# 2018 Monitoring tools requested to inform the decision process

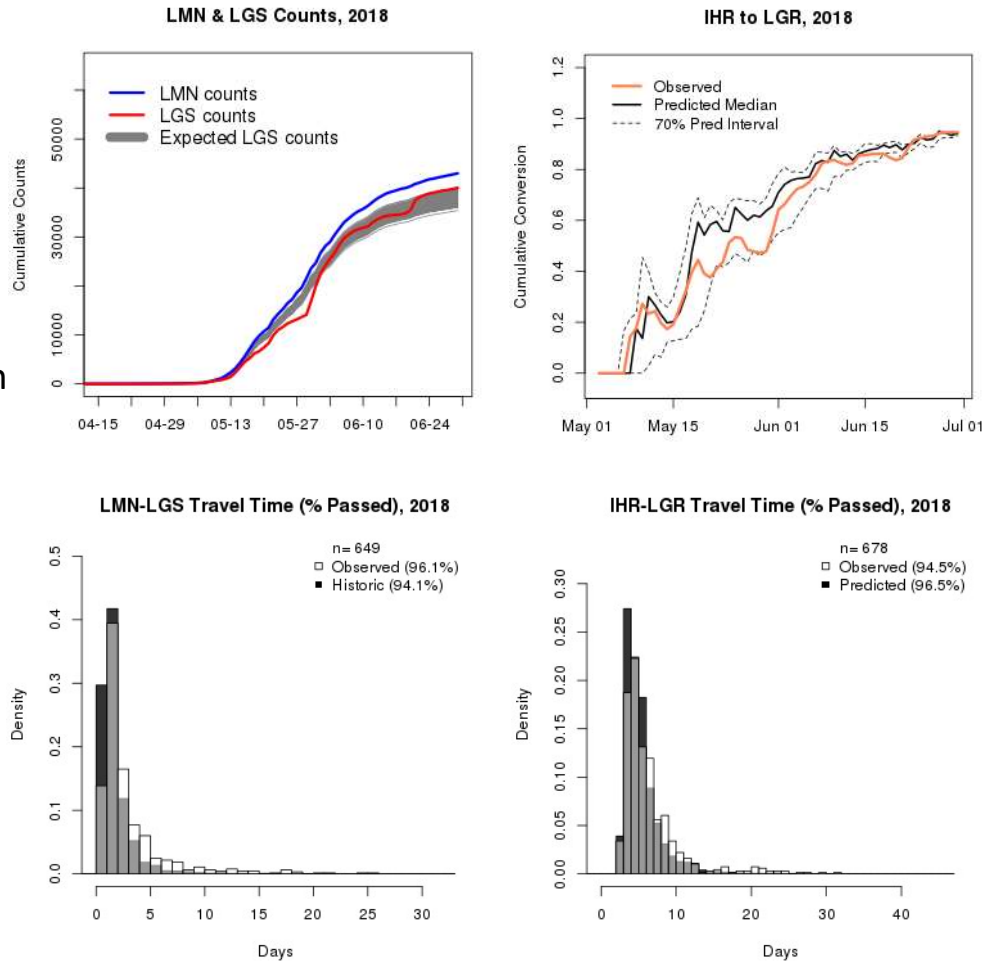
- DART requested to develop a tool to inform the passage timing and success of PIT tagged fish that passed Lower Monumental and Little Goose Dams.
- The Fish Passage Center (FPC) developed a similar tool to inform passage timing of PIT tagged fish that passed Lower Monumental Dams and Little Goose Dams.

# FPC Delay Analysis

- FPC analyzed data of fish that passed the Lower Snake River Projects to assess subsequent passage success at tributary project detection locations.
- FPC analysis includes a conclusion that fish that took up to 20 days to pass lower Snake River Projects showed no reduction in survival to tributary project detection locations.
- No information available on survival from tributary project detection to spawning or spawning success.

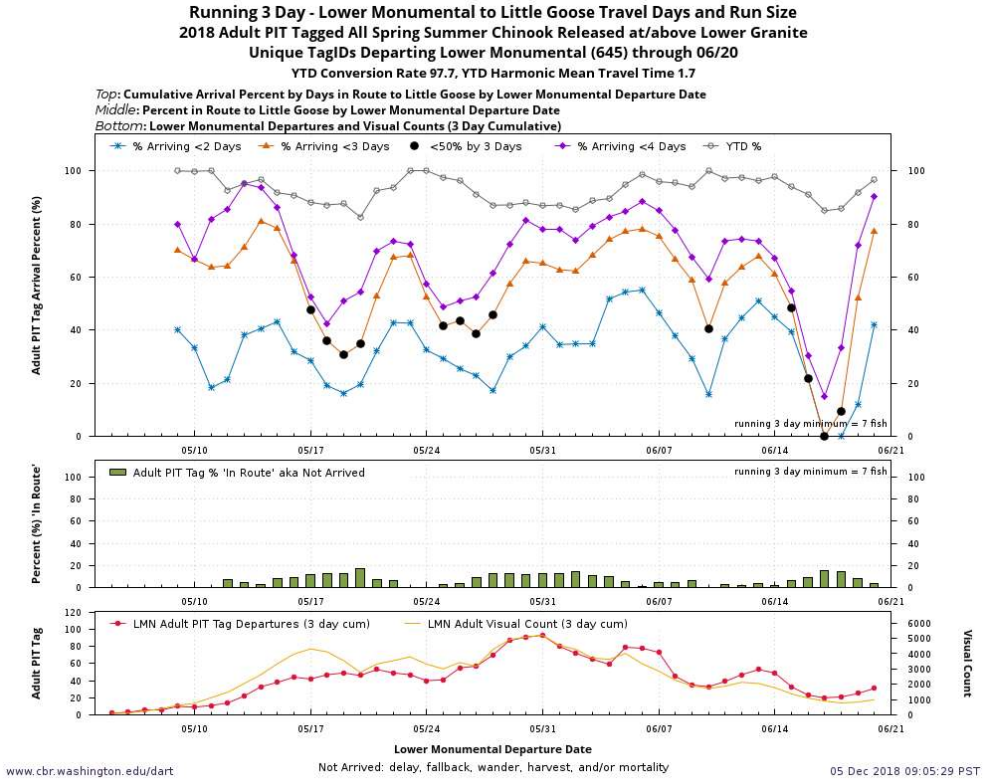
# FPC Passage indicator

- How does one assess passage?
- If the observed LGS counts (upper left panel) ventured below the predicted area, results would suggest a slower than expected passage progress based on adult counts.
- If the observed conversions (upper right panel) fell below the predicted area, it would suggest a slower than expected passage progress.
- During a slow down in passage progress, users may notice the current status of passage (% passed in the bottom panels) at LGS or LGR being lower compared to the historical and/or predicted status of the same time period.
- Once the fish with longer travel time started to pass LGS (and eventually LGR), users may see the observed distributions with taller bars in the sections of long travel time, compared to the historical and/or predicted distributions.

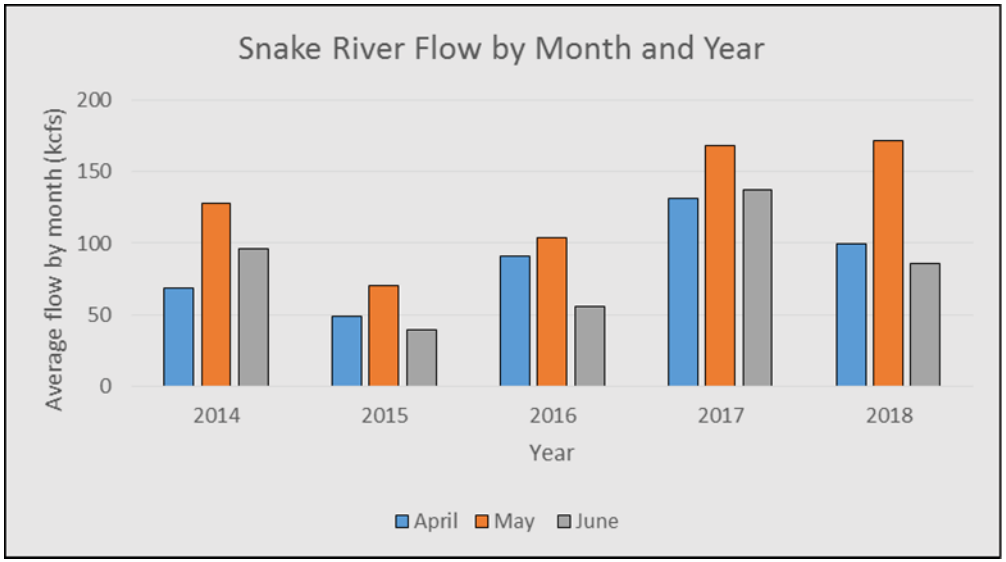


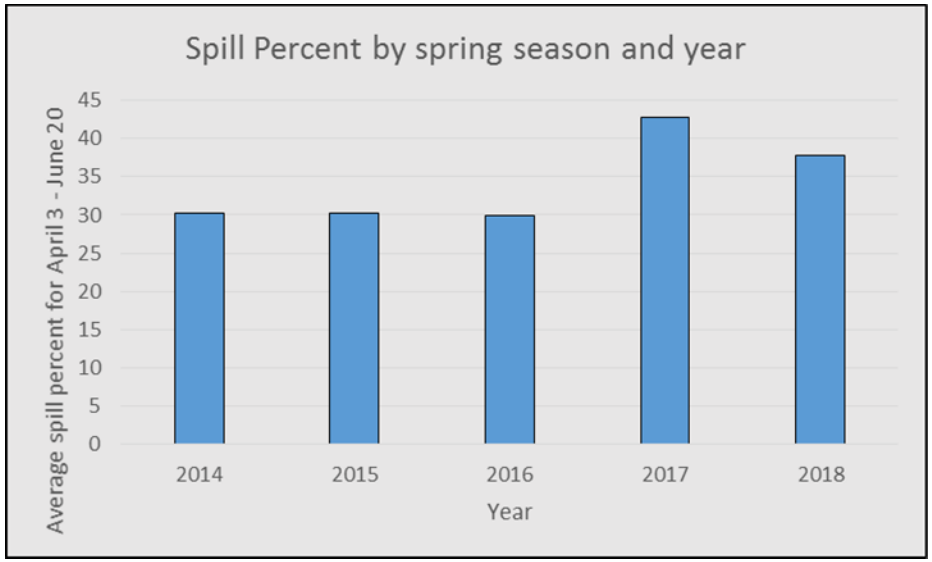
# DART Running Average Passage Tool

- How does one assess passage?
- Black dot indicates <50% arrival for *ith*-day running average arrival percentage (for LMN to LGS = 3; for IHR to LWG = 7).
- Running 3 Day calculations requires a minimum 7 fish departing during 3 day period.
- On a date-specific basis, a unique population departing Ice Harbor is established. Ascent events are not restricted to calendar date. This date-specific unique population is tracked to determine cumulative arrival percent at Lower Granite, harmonic mean TT, conversion rate. A history of more than 1 ascent event for a TagID is tracked. This may impact arrival success and travel time.
- Adult Visual Counts presented are the daily sum of adult and jack counts.
- Shaded red: Date when Daily Cumulative Arrival on Average (6) Day < 50%
- Shaded gray: Daily 50% cumulative arrival day
- Shaded gold: Daily Conversion Rate < 85% (fallback, delay, wander, harvest, mortality can all attribute to <100%).

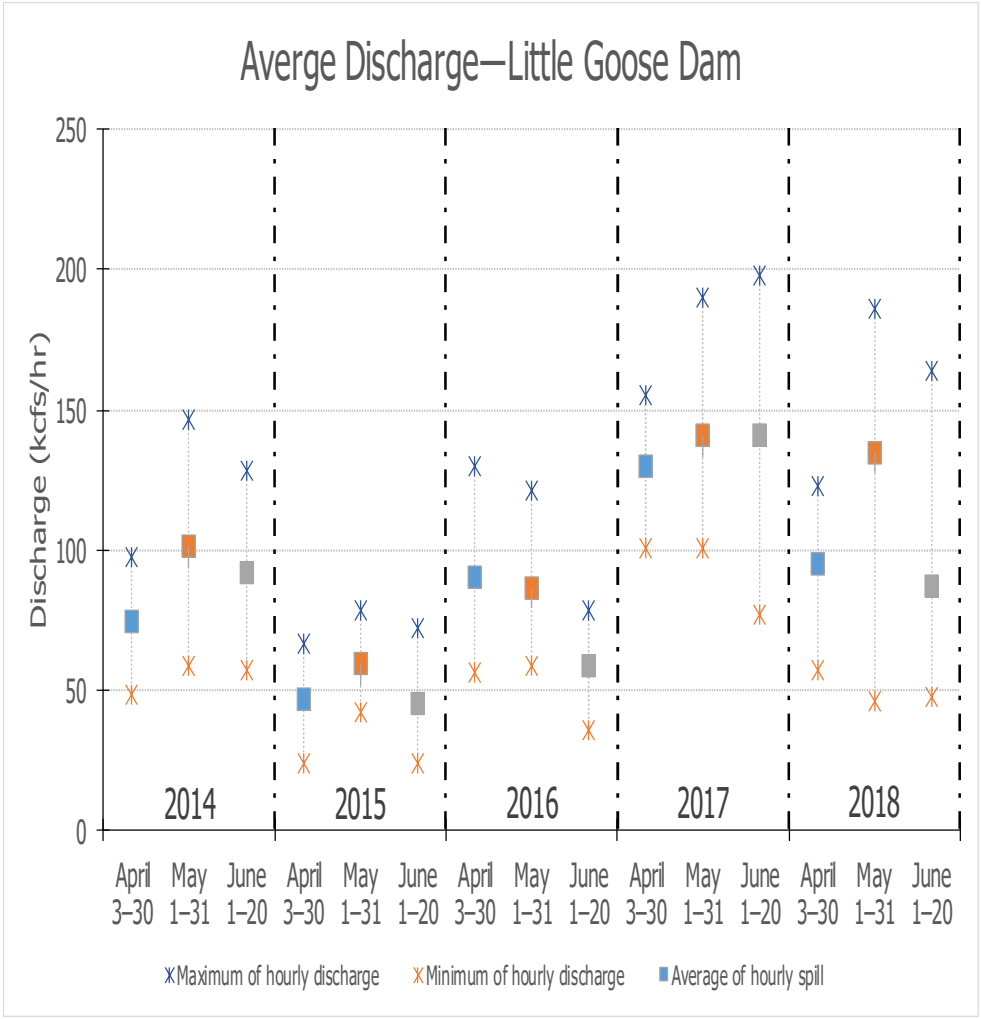


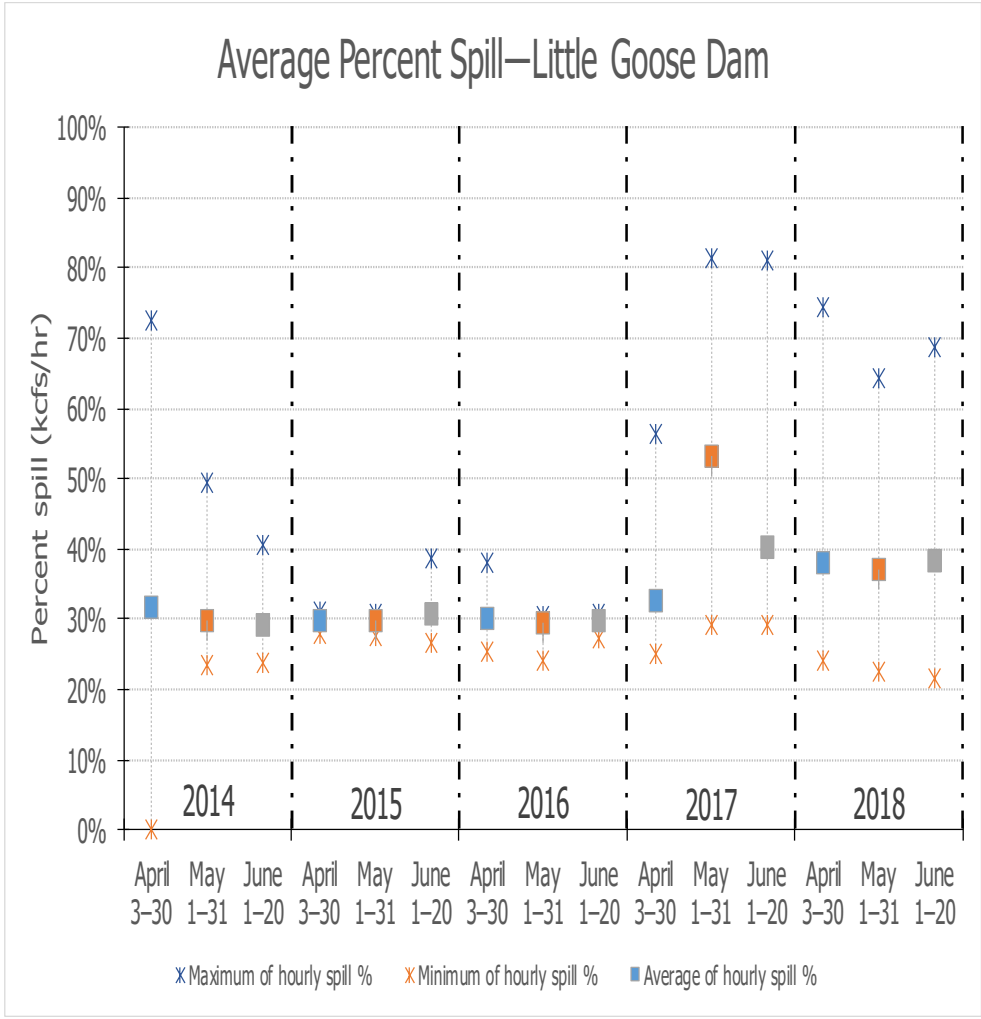
# Environmental Conditions – average flow and spill by month



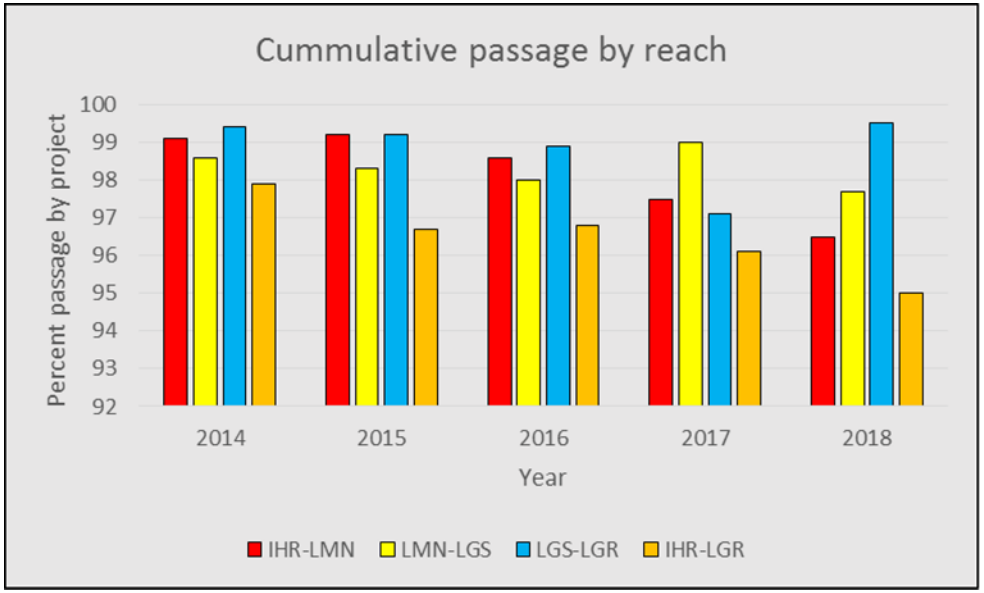



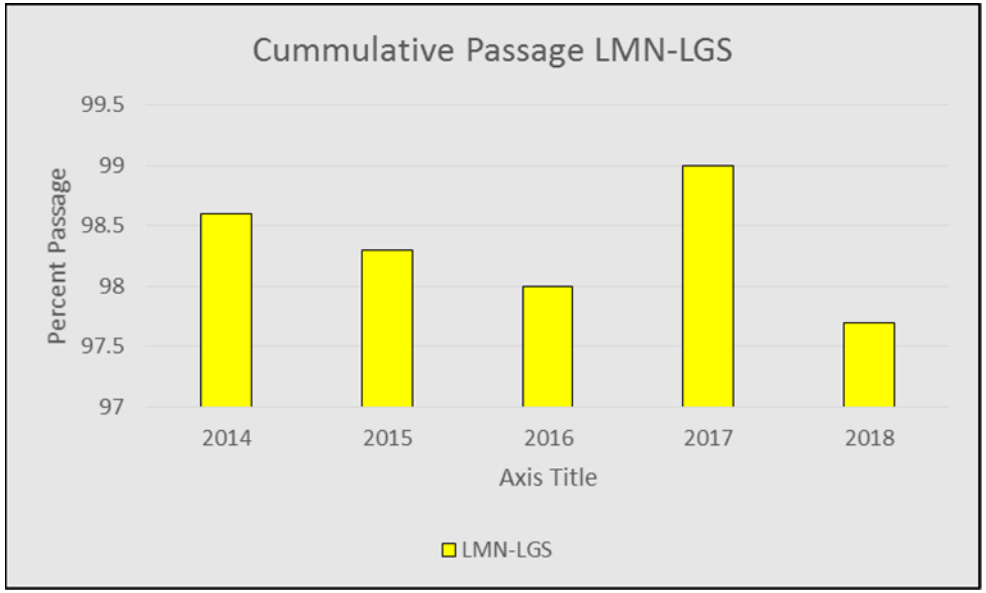
# Flow conditions



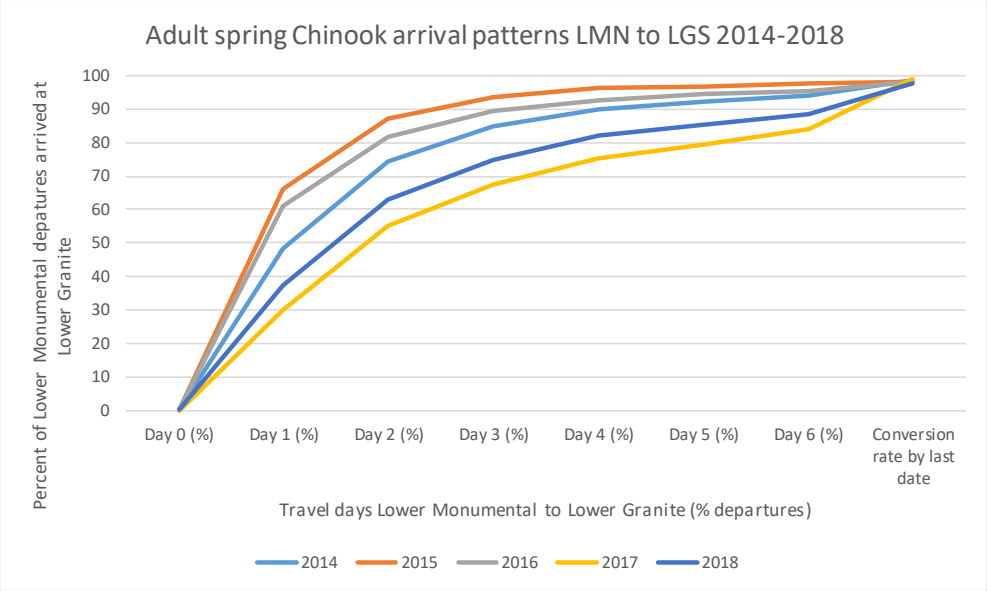



# Cumulative passage by year



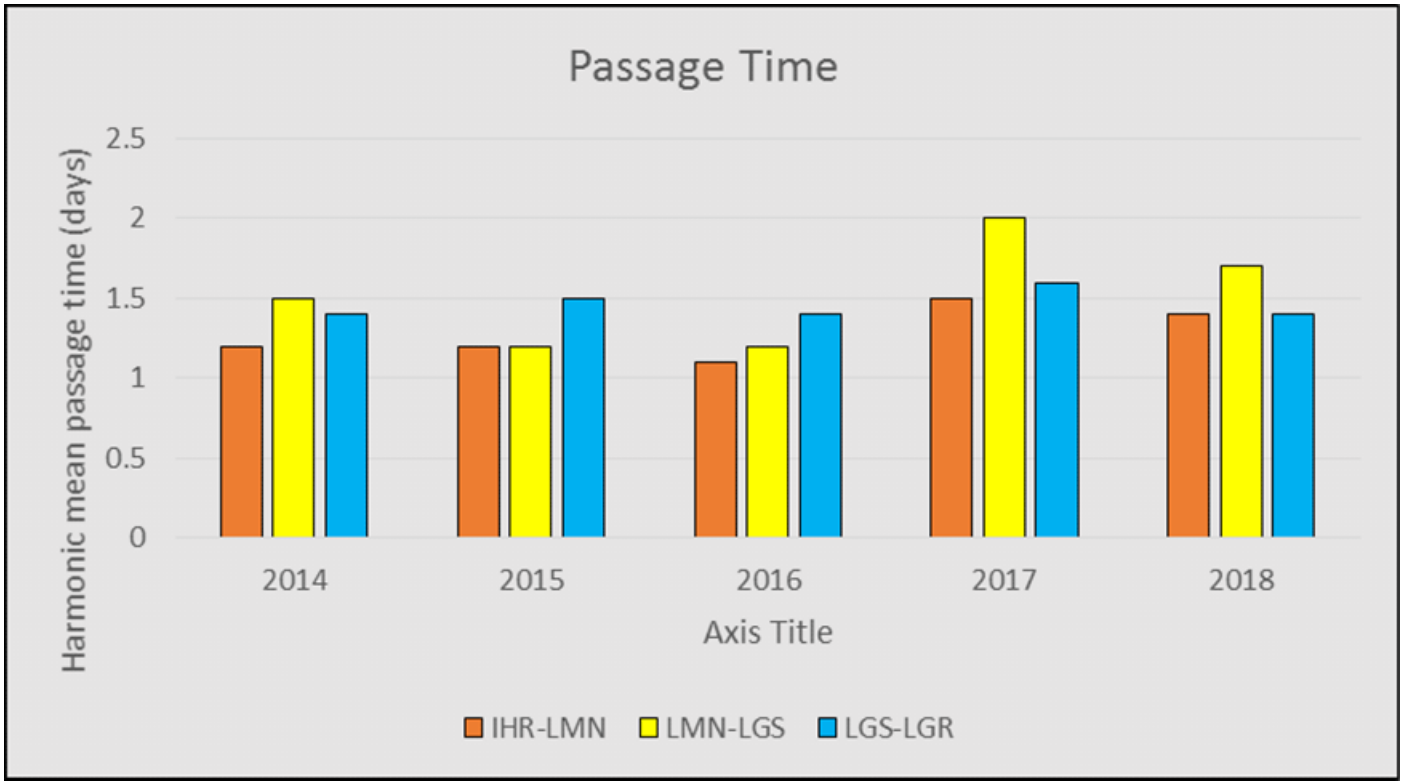



# Cumulative passage from LMN to LGS and LMN to LWG

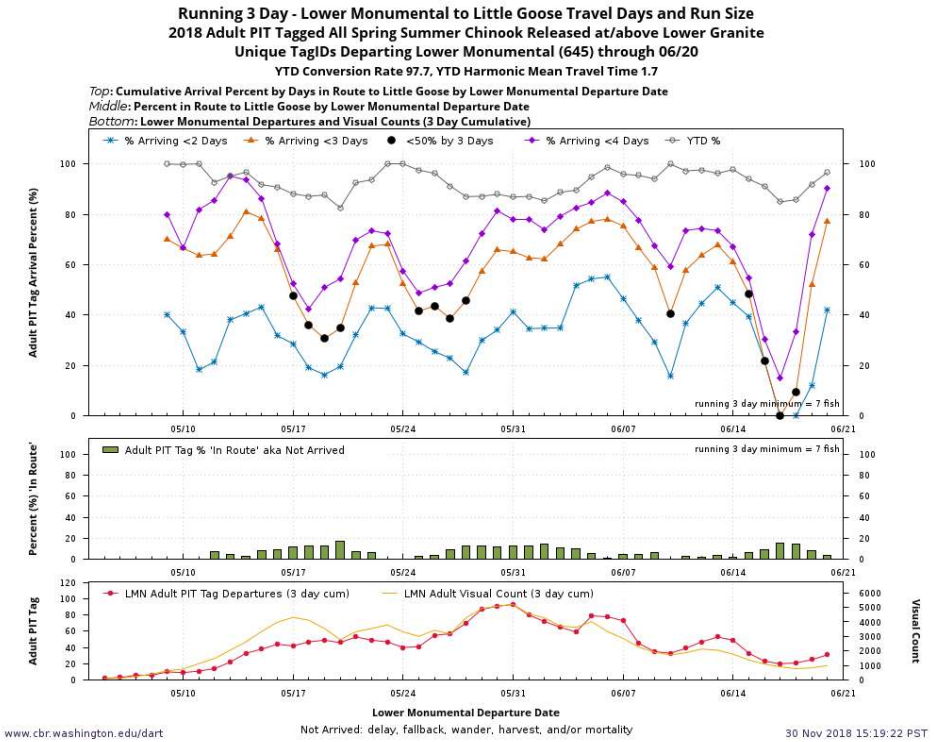


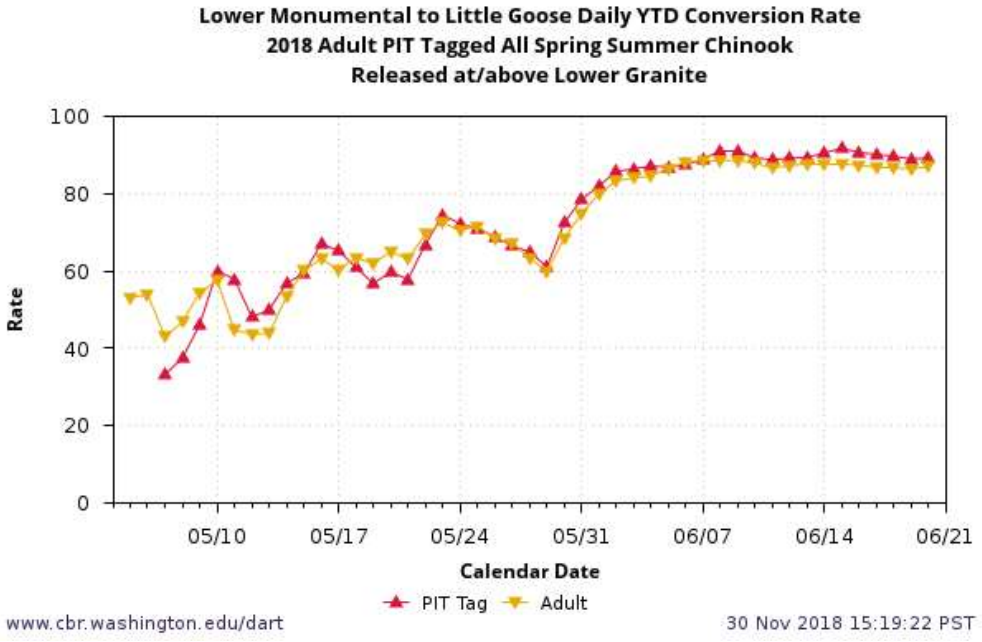

| % of LMN departures that arrived at Little Goose by day i | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Day 0 (%) | Day 1 (%) | Day 2 (%) | Day 3 (%) | Day 4 (%) | Day 5 (%) | Day 6 (%) | Conversion rate by last date | Harmonic mean TT for date |
| 2014 | 0.1 | 48.2 | 74.2 | 84.8 | 89.7 | 92.4 | 93.9 | 98.6 | 1.5 |
| 2015 | 0.1 | 66.2 | 87.3 | 93.7 | 96.1 | 97.0 | 97.5 | 98.3 | 1.2 |
| 2016 | 0.3 | 61.1 | 81.8 | 89.3 | 92.7 | 94.4 | 95.4 | 98.0 | 1.2 |
| 2017 | 0.0 | 29.9 | 55.2 | 67.7 | 75.1 | 79.4 | 83.8 | 99.0 | 2.0 |
| 2018 | 0.2 | 37.1 | 62.8 | 75.0 | 82.2 | 85.4 | 88.4 | 97.7 | 1.7 |

# Harmonic Mean Passage Time per Project



# LMN to LGS 2018 passage tracking

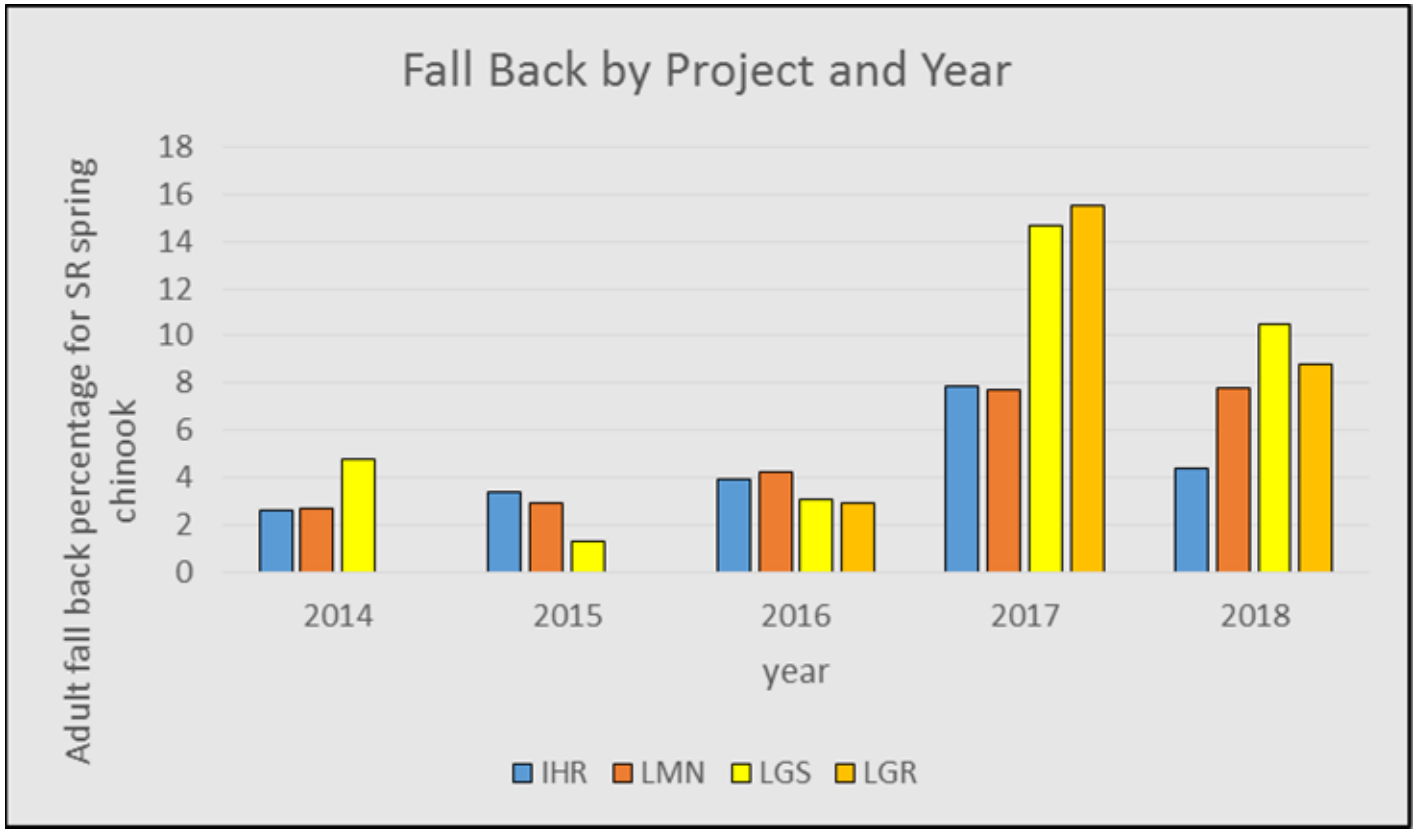


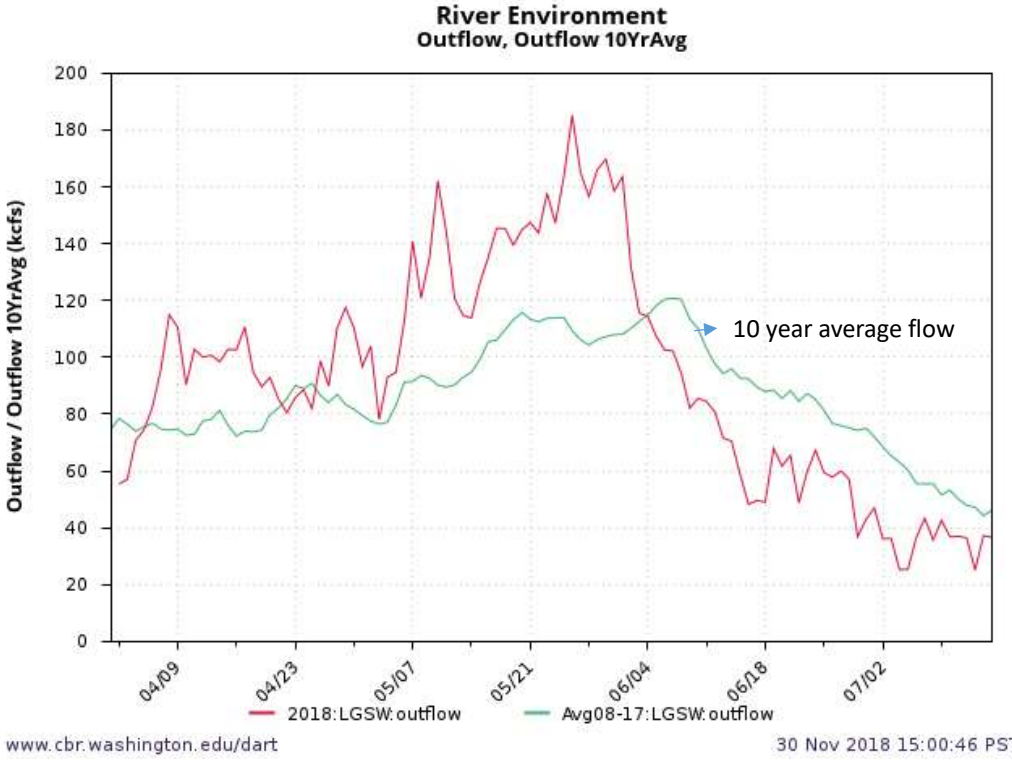
# LMN to LGS end of spring season passage detail

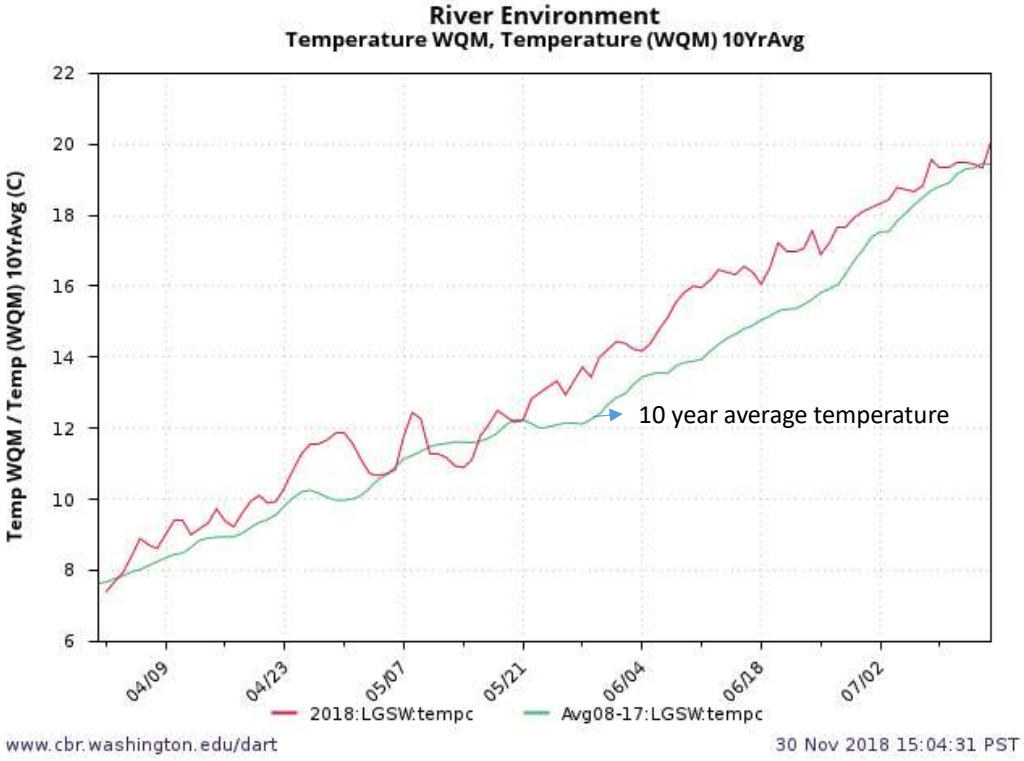
| Lower Monumental Departure Date | Adult PIT Tag | | | | | | | | | | | | | | Calendar Date | Unique TagIDs Entry LGS on calendar date for Fish departing LMN | Adult Visual Counts | | MAD Adult PIT Tag and Visual Counts Cumulative Arrival % LGS | LGS Hour of 50% Entry for date | Little Goos | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Departure Events LMN on date | LGS Entry Events for Fish departing LMN on date | Unique TagIDs LMN on date | Fish departing LMN on date with history of >1 ascents | % Fish departing LMN on date with history of >1 ascents | Cumulative Arrival Percent Little Goose Calendar Days after LMN Departure ▹ shaded gray: 50% arrival day ▹ shaded gold: ConRate < 85% (fallback, delay, wander, harvest, mortality can all attribute to <100%) | | | | | | | | Harmonic Mean Reach TT (days) for date | | | LMN | LGS | | | Outflow | Spill | Spill% |
| | | | | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Conversion Rate | | | | | | | | | | |
| YTD | 688 | 631 | 645 | | | 0.2 | 37.1 | 62.8 | 75.0 | 82.2 | 85.4 | 88.4 | 97.7 | 1.7 | YTD | 630 | 40688 | 39714 | | | | | |
| 2018-06-22 | | | | | | | | | | | | | | | 2018-06-22 | 9 | 345 | 715 | | 8 | 48.7 | 14.7 | 30.2 |
| 2018-06-21 | | | | | | | | | | | | | | | 2018-06-21 | 40 | 294 | 2004 | | 7 | 65.4 | 19.6 | 30.0 |
| 2018-06-20 | 13 | 13 | 13 | | | 0.0 | 76.9 | 84.6 | 92.3 | 92.3 | 92.3 | 92.3 | 100.0 | 1.0 | 2018-06-20 | 13 | 481 | 639 | 2.3 | 13 | 61.7 | 27.9 | 45.2 |
| 2018-06-19 | 13 | 13 | 13 | 3 | 23.1 | 0.0 | 23.1 | 84.6 | 92.3 | 92.3 | 100.0 | 100.0 | 100.0 | 1.7 | 2018-06-19 | 5 | 337 | 216 | 1.8 | 13 | 67.9 | 33.0 | 48.6 |
| 2018-06-18 | 5 | 4 | 5 | | | 0.0 | 0.0 | 40.0 | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 | 2.5 | 2018-06-18 | 1 | 178 | 56 | 1.6 | | 49.0 | 32.9 | 67.1 |
| 2018-06-17 | 7 | 6 | 7 | 2 | 28.6 | 0.0 | 0.0 | 0.0 | 28.6 | 85.7 | 85.7 | 85.7 | 85.7 | 3.6 | 2018-06-17 | 2 | 320 | 87 | 1.6 | | 49.6 | 32.9 | 66.3 |
| 2018-06-16 | 9 | 8 | 9 | | | 0.0 | 0.0 | 0.0 | 11.1 | 33.3 | 66.7 | 77.8 | 88.9 | 4.7 | 2018-06-16 | 1 | 281 | 144 | 1.5 | | 48.2 | 32.9 | 68.3 |
| 2018-06-15 | 4 | 3 | 4 | | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 50.0 | 75.0 | 6.0 | 2018-06-15 | 11 | 305 | 270 | 1.7 | 11 | 58.8 | 32.7 | 55.6 |

# Fallback Percent by Project and Year



# River Environment flow and temperature



# Effect on spill at the project

| Date | Time | Outlet SW SB1 | SB2 | SB3 | SB4 | SB5 | SB6 | SB7 | SB8 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 06/08/2017 | 00:00 | 11.27 | 11.54 | 11.45 | 11.24 | 11.27 | 11.25 | 11.23 | 9.70 | 88.95 |
| | 01:00 | 11.26 | 11.52 | 11.53 | 11.38 | 11.41 | 11.40 | 11.38 | 9.70 | 89.58 |
| | 02:00 | 11.27 | 11.54 | 11.54 | 11.39 | 11.43 | 11.41 | 11.39 | 9.72 | 89.70 |
| | 03:00 | 11.24 | 10.86 | 9.91 | 9.61 | 9.35 | 9.51 | 9.47 | 9.31 | 79.27 |
| | 04:00 | 11.24 | 7.68 | 7.62 | 7.52 | 7.31 | 7.60 | 7.51 | 7.70 | 64.18 |
| | 05:00 | 11.25 | 6.68 | 5.64 | 6.33 | 5.39 | 6.12 | 5.52 | 6.22 | 53.14 |
| | 06:00 | 11.27 | 5.69 | 3.66 | 3.60 | 3.48 | 3.64 | 3.54 | 3.75 | 38.63 |
| | 07:00 | 11.28 | 5.69 | 3.66 | 3.60 | 3.49 | 3.65 | 3.54 | 3.76 | 38.67 |
| | 08:00 | 11.31 | 5.72 | 3.67 | 3.61 | 3.50 | 3.66 | 3.55 | 3.77 | 38.79 |
| | 09:00 | 11.33 | 5.75 | 3.68 | 3.62 | 3.50 | 3.66 | 3.56 | 3.77 | 38.87 |
| | 10:00 | 11.35 | 5.73 | 3.68 | 3.63 | 3.51 | 3.66 | 3.57 | 3.78 | 38.90 |
| | 11:00 | 11.37 | 5.71 | 3.69 | 3.63 | 3.52 | 3.67 | 3.57 | 3.78 | 38.93 |
| | 12:00 | 11.38 | 5.76 | 3.69 | 3.63 | 3.51 | 3.67 | 3.57 | 3.79 | 39.00 |
| | 13:00 | 11.38 | 7.66 | 7.70 | 5.60 | 5.57 | 5.61 | 5.53 | 5.79 | 54.85 |
| | 14:00 | 11.39 | 7.71 | 7.71 | 5.61 | 5.57 | 5.63 | 5.54 | 5.81 | 54.97 |
| | 15:00 | 11.41 | 7.79 | 7.81 | 5.74 | 5.74 | 5.80 | 5.71 | 5.98 | 55.99 |
| | 16:00 | 11.41 | 9.65 | 9.72 | 9.61 | 7.61 | 7.64 | 7.56 | 7.78 | 70.97 |
| | 17:00 | 11.41 | 11.57 | 9.72 | 9.62 | 9.62 | 9.62 | 9.56 | 9.77 | 80.89 |
| | 18:00 | 11.39 | 11.56 | 9.70 | 9.60 | 9.59 | 9.60 | 9.55 | 9.76 | 80.73 |
| | 19:00 | 11.35 | 11.54 | 9.67 | 9.57 | 9.57 | 9.57 | 9.52 | 9.78 | 80.57 |
| | 20:00 | 11.35 | 11.52 | 9.67 | 9.58 | 9.58 | 9.59 | 9.52 | 9.79 | 80.59 |
| | 21:00 | 11.34 | 11.52 | 11.12 | 11.02 | 11.03 | 9.58 | 9.51 | 9.78 | 84.90 |
| | 22:00 | 11.31 | 12.00 | 11.91 | 11.48 | 11.50 | 11.48 | 11.45 | 10.25 | 91.39 |
| | 23:00 | 11.29 | 13.47 | 13.50 | 11.46 | 11.48 | 11.46 | 11.43 | 11.67 | 95.74 |

# Lessons Learned—Action Tools

- Multiple levels of evidence provided a better atmosphere for further discussion during adaptive management discussions.
- Both action tools were useful for identifying important periods to begin discussing coordination options.
- More evaluation is needed to verify if the action tools provided an early warning of an unintended consequence.
- The tools could benefit from additional sensitivity evaluation to support what time-step best reflects the precision of metrics at alerting in-season management discussions.
- Still need to work together to establish an agreed upon criteria, other than status quo operations to help in-season management decisions.

# Lessons Learned—Fish Passage

- Adult cumulative passage Percentage to Lower Granite Dam exceeded 96% and were with ≤1.7% spread 2014–2018.
- Little Goose operation changes meant to address adult passage concerns increased PIT PH at more than Little Goose Dam. Each juvenile powerhouse encounter reduces subsequent SAR by a relative 9-13%.
- Additional evaluation is needed to identify operations that retain the necessary survival benefits for both juvenile and adult salmon and steelhead traveling through the FCRPS.