Fish Passage Plan (FPP) Change Request Form

Change Form # & Title:	16BON003 – PH2 Lower 1% Operation
Date Submitted:	December 17, 2015
Project:	BON
Requester Name, Agency:	Gary Fredricks, NOAA
Final Action:	**APPROVED – January 28, 2016**

FPP Section: BON 5.2.1 - Turbine Unit Operating Range.

Justification for Change: The justification for this change stems from modeling work done at the ERDC (see attached trip report September 21-23, 2015) and to some extent from active tag biological studies conducted at the Bonneville Project summarized in Weiland et al. 2015, *Systematic Review of JSATS Passage and Survival Data at Bonneville and The Dalles Dams During Alternative Turbine and Spillbay Operations from 2008–2012*.

There are two lines of evidence that indicated the lower 1% operating range may not be as safe for fish passage through the turbines as operation in the mid to upper 1% range. The physical model data clearly show deteriorating passage conditions (turbulence and surface strike of test beads) as the unit flow decreased below the mid-range. The biological data collected from tagged fish passing BON appeared to indicate a lower survival rate for juvenile steelhead passing during the lower 1% quartile of operation. However, the overall biological data were neither robust enough nor consistent over the entire season, thus the limited period (effects were only noted in spring migrants) and the reason for a soft vs. hard constraint. Please review the attached ERDC Trip report for further details. Also, there will be a report of results from the ERDC modeling work prepared by ERDC staff. The schedule was to have this report available sometime in December 2015, however no draft was available at the time of this writing.

Proposed Change:

5.2. Turbine Unit Operating Range.

5.2.1. From April 1 through October 31, turbine units will be operated within ±1% of peak turbine efficiency (1% range), as specified in the *BPA Load Shaping Guidelines* (**Appendix C**). Lower and upper limits of the 1% range are defined in **Tables BON-14** (PH1), **BON-15** (PH2).

5.2.2. From April 10 through June 15, as a soft constraint, PH2 units should not be operated below the 1% mid-range (below 13 kcfs) to minimize turbulence that may impact fish that pass through the turbines.

Comments:

12/17/2015 FPOM Meeting: FPOM needs more time to review; add to Jan 28th agenda.

Record of Final Action: APPROVED at FPP meeting 1/28/2016.

October 8, 2015

FILE MEMORANDUM

FROM: Gary Fredricks and Ed Meyer, NOAA Fisheries

SUBJECT: ERDC Trip Report – Bonneville PH2 Runner Evaluation, September 21-23, 2015

Participants: Bob Davidson and Danea Polk – Corps ERDC, Dan Patla and Doug Komoroski - Corps HDC, Brad Trumbo – Corps Walla Walla, Jon Rerecich – Corps Portland, Scott Bettin and Julie Doumbia – BPA.

Purpose of the trip: To review ERDC's hydraulic analysis of the existing Bonneville Dam Powerhouse Two turbine environment as it relates to fish passage.

Methods: We used the Corps' 1:25 scale general PH2 turbine model to assess flow passage characteristics. Neutrally buoyant beads (= ~4" prototype size), dye and air were released at various points in the model to assess hydraulic passage characteristics. During model set up periods we viewed some previously recorded video that showed slow motion passage of beads through the wicket gates/stay vane and the runner. We also reviewed the quantitative analysis data previously collected by the ERDC staff using basic bead analysis and Laser Doppler Velocimetry based flow vector and velocity analysis methods.

Over the course of the two days, the model was observed under three primary conditions with one secondary observation at the end of the day on Wednesday. The primary conditions were lower one percent (16.5 degree blade angle (BA), ~11.3 kcfs), peak (20.3 degree BA, ~14.9 kcfs), generator limit (26.5 degree BA, ~19.8 kcfs) and the secondary condition was a point between lower 1% and peak (approx. 18 degree BA, ~13.2 kcfs).

Results:
We discussed the model vs. prototype cam curves first. Both ERDC and HDC state that the cam curves in the model are now correct for the prototype. We had lots of discussion on the inaccuracies of the measurement process in the prototype. Bob says it is best to use blade angle as a measurement, not flow. However, the FPP criteria are based on flow, which he says is inaccurate. There may be some need to make sure HDC has the correct blade angle/flow relationship in the FPP.

Model Observations:

Condition 1. Lower 1%.

- Hub bead release. A very pronounced long rope off the hub deflector extends well down into the draft tube elbow with violent turbulence extending to the pier nose. Some beads drop through the runner calmly with little spin or swirl but others get caught in the rope or flow adjacent to the rope and twist violently. These can either get caught right at the hub or later in the elbow. Some beads actually started passing the C barrel but then would suddenly whip around into the A barrel. A few of these would contact the pier nose.

• Tip bead release. Fewer beads were caught in the rope but there was still a lot of larger diameter swirl to the path of many of the beads.
• Video. Lower end of 1%. Beads. Rope wasn't apparent due to no air in the model but it was still there hydraulically. Significant gap passage of beads. We didn't see a lot of twisting but that is hard to tell in slow motion. Mid-blade release looked good with little contact with the runner.

Condition 2. Peak. (Note: the model may not have been set up properly for this operation, however the condition set up for the video was correct and showed significantly better flow conditions than those we observed.)
• Hub bead release. Lots of spinning and twisting beads. We estimated that at least 20% of the beads twisted violently.
• Tip bead release. Overall this looked better for the majority of the beads.
• Air released near the hub showed a long rope off the hub deflector (something Bob says is not present when the model is set correctly at peak).
• Draft tubes. A-barrel looked good except for some small amount of flow reversal in the upper right corner (ceiling and pier). C-barrel was much more turbulent overall than A-barrel.
• Tailrace near-field egress showed a good number of beads in the backroll, however most off the beads moved out directly downstream.
• Video. Hub bead release showed low gap passage. Mid-blade release indicated little contact with runner. Tip release showed more twisting and some contact with leading edge of the blade than for other releases. No rope off the deflector.

Condition 3. Generator limit.
• Hub bead release. Most of the beads looked good although a few still had some twist indicating a slight swirl off the deflector although air failed to show a rope.
• Tip bead release. Also mostly looked good although we noted that occasionally a bead would hit the pier nose as they passed into the draft tubes.
• Draft tubes. A-barrel looked good with dye. We did note a small area of slower flow area near the pier near the floor of the tube. C-barrel dye appeared to separate with the lower tube flow moving out well and the upper tube flow showing quite a bit of turbulence and some reversal near the ceiling from the pier all the way to the outer wall.
• Tailrace egress looked good, quick passage with only a few beads caught in the backroll area.
• We spent a bit of time looking at bead release just below the STSs to get an idea of how particles would distribute as they approached the stay vane/wicket gate area. Beads released just below the screen in the gatewell A slot mostly passed the mid to upper wicket gate area (the upper gate passage occurred less frequently and more in the last portion of the scroll case) indicating that most beads would likely pass the mid-blade region. As the release point was dropped several inches (model), the bead distribution through the wicket gate area become more random with likely passage all along the blade.

Condition 4. Between lower 1% and peak.
• Air showed a small rope off the hub, however this was much smaller than we observed in the 1% operating condition.
• Hub bead release. Lots of spinning beads, particularly those passing close to the deflector tip.
• Tip bead release. Overall good, but some beads still spin.

- Draft tubes. Some beads start to pass the C-barrel then twist around the pier nose into the A-barrel. Lots of bead recirculation in C-barrel. Overall, A-barrel flow looked good. C-barrel dye showed separation and reversal near the ceiling from mid-barrel on downstream. Overall, lots of turbulence and vertical movement of dye and beads. Despite the turbulence and short reversals, overall dye passage through this barrel was quick.
- Tailrace. More entrainment into the backroll than at the higher discharges, much like the lower 1% condition.
- Beads released below the STS passed all areas of the stay vane/wicket gate area.

Bead Data Analysis Review. During a portion of both days we worked through the bead analysis data summaries. These data were provided in hard copy form. The trend that showed up over and over again throughout this analysis was that bead blade contact and direction change scores were worse for the lower 1% condition than for the peak and generator limit conditions. The difference between the lower 1% and peak scores was always somewhat higher than the difference between the peak and generator limit scores, which were generally quite close together. It was a bit of a surprise to see that the blade tip scores for direction change were lower (worse) than the hub scores even though our model observations would suggest a more tortuous route for the hub passed beads. This demonstrates how difficult it is to truly assess blade passage characteristics visually real-time in the model. In all conditions, the mid-blade region was the most benign for bead passage.

The stay vane/wicket gate gap was also an area of bead passage and contact. There is an inverse relationship with wicket gate opening and gap size. As the wicket gates are opened for higher unit flows, this gap is reduced. Bead contact and direction change followed the gap opening fairly directly with a lower percentage of contact and direction change as the gap was reduced at the higher operating flows. One point that was made by the ERDC staff was that the shape of the stay vanes at this powerhouse were a bit unusual with more beveling of the leading and trailing edges. This may lead to better flow and fish passage conditions.

The draft tube data indicated that the flows through the A and C barrels were unbalanced for all unit flows and varied from a A vs C split of about 60/40% at the peak and generator limit flows to 80/20% at the lower end of 1% flow. C-barrel flow was less uniform and had higher turbulence intensity than A-barrel, as we noted in the model. As unit flow increased, flow characteristics in both barrels tended to improve with the greatest improvement between the lower 1% and peak efficiency unit flows.

The tailrace egress conditions were evaluated by releasing beads in the downstream tail log slot assessing the time and depth of bead passage to a point 200 feet (prototype) downstream of the powerhouse. Also, the percentage of beads entrained in the backroll was assessed. Two conditions, lower 1% and generator limit were evaluated. The higher flow condition was somewhat better in all measurements including time to egress (60 vs 120 prototype seconds), percentage of beads pass near the surface (19% vs 34%) and percentage of beads in the backroll (4% vs 19%).

General Observations and Recommendations:

- The lower end of the 1% operating range should be avoided, at least as a soft constraint. The 18 degree blade angle (13.2 kcfs) operating condition could serve as the lower operating limit.
- HDC and FPOM should work out the proper unit flow (per blade angle) as an update for the Fish Passage Plan. This should be done for all units in the system.
- The observations of bead and dye passage through the model fit, at least to a rough degree, the trend of the biological data (Weiland et al. 2015 draft) in that the lower end of the 1% range looked worse in the model and this was reflected to a small degree by a lower steelhead survival point estimate for the lowest operational treatment flow.
- However, the severity of the conditions seen in the model, particularly at the lower 1% level, are not reflected in the biological data which showed fairly high and consistent survival levels for all the operating ranges.
- One reason for the seeming discrepancy between model and biological observations may be due to the relatively good tailrace egress noted for this powerhouse.
- Another reason for this could be due to higher pressure nadirs within these units which are set deeper than is typical for other FCRPS projects (greater plant sigma). We recommend that TSP look into pressure mapping similar to what was done by Voith Hydropower for the Ice Harbor new runner design.
- Another reason survivals don't seem to follow the observed conditions could be that fish distribution in the runner is skewed towards the better conditions seen in the mid-blade region of the runner. We noted that bead passage through the wicket gate for beads released near the end of the STS tended to miss the hub region where the passage conditions are poor. Fish obviously can alter their distribution from that predicted by beads, however, it is likely that the beads do provide some indication of potential distribution.
- Further work should include a comparison exercise with the bead analysis data from other existing FCRPS turbines (e.g., Bonneville PH1, Ice Harbor, McNary dams). We suggest this be included in the final ERDC report for this project.