FISH PASSAGE CENTER

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MEMORANDUM

TO: FPAC

FROM: Michele DeHart

DATE: July 30, 2012

RE: Open Geometry Operations

In response to your request, we have reviewed the background data supporting the operation of turbines at the Bonneville Dam first powerhouse in an “open geometry” mode. In 2012 operations, the COE chose to operate the Bonneville Dam first powerhouse turbine units in “open geometry” (passing more water through each turbine) to maintain flow neutrality at the Bonneville project while flow through the turbine units at the second powerhouse was reduced to address the increased mortality and descaling of juvenile salmonids.

The current information regarding open geometry is very limited, consisting of ERDC model observations and a balloon tag study from 2000 (Skalski et al. 2000). These studies provide little information on fish survival through turbines at open geometry. Based on the one balloon tag study (Skalski et al. 2000) there has been no demonstrated statistical difference in fish survival through open geometry than other turbine operations. However, the study was not designed to specifically address the operation of units at open geometry. Furthermore, by increasing flows through turbines, open geometry increases the probability of injury and mortality in the gatewells. Additionally, the proportion of fish passed through the turbines is increased with additional flow, which may have negative effects when compared to passage through the spillway (Haeseker et al. 2012, Petroksy and Schaller 2010, Schaller and Petrosky 2007).

Although the current limited information indicates the potential for high turbine survival under open geometry, the information is insufficient for a management decision of this magnitude. We strongly recommend that rigorous and controlled studies on juvenile survival and survival to adulthood be conducted before open geometry becomes a standard operating procedure at Powerhouse 1. This is particularly important because all in-river migrating juvenile salmonids pass the Bonneville project and, since it is the last project in the hydrosystem, there is no way of validating the efficacy of the decision to operate the first powerhouse turbine units in open geometry during normal monitoring projects.

Our overall conclusions about the evidence supporting open geometry are listed below, followed by a more detailed discussion on each topic.

- The presently available data are not sufficient to make the management decision to operate Bonneville Powerhouse 1 in "open geometry".

- The observational studies using turbine models have indicated that there may be less turbulence around the blade runners and hub under open geometry than while operating within the 1% efficiency range.
    - Although personal notes of these observations have been provided by NOAA, the final reports on Bonneville models will not be available until at least September 2012.
    - These observations have not been corroborated by juvenile fish survival experiments with the current configurations at Bonneville.

- The balloon tag studies completed in 2000 contain serious experimental design flaws which limit their usefulness in accurately quantifying passage survival. These problems include:
    - Only large Chinook yearlings were used, so results cannot be applied to other groups of migrating salmonids.

    - Test fish are transported to turbines from the surface via hoses, while the run-at large passes through the gatewells and screens at high flows, both factors known to affect survival.

    - Fish that are balloon tagged have difficulty swimming and are unlikely to have similar behavior and orientation through the turbine as the run-at-large.

    - In this study, release locations within the turbine are compared. Open geometry provided the highest survival in two of three release locations, and the lowest in hub-released fish. However, no data on the passage routes used by untagged fish are available, so the applicability of data is minimal.

    - In this study, only immediate and 48-hour survival rates were estimated. Any delayed turbine passage effects not expressed until the estuarine or oceanic life stages will be missed by this study.

Description of Open Geometry

The operation "open geometry" at Bonneville Powerhouse 1 refers to the turbine operating condition in which stay vanes, wicket gates and runner blades are all close to wide open. This operation is expected to reduce turbulence and therefore shear and impingement injuries to juvenile fish migrating through the turbine.

When Bonneville Powerhouse 2 is operated above the mid-point of the 1% efficiency range, mortality and descaling rates for juvenile salmonids has exceeded normal background levels, particularly for subyearling Chinook and Sockeye smolts. During the juvenile outmigration in 2012, managers have requested that flows through Powerhouse 2 be limited to increase survival. Flow not passed through Powerhouse 2 due to this operation was diverted to Powerhouse 1 to maintain project flow neutrality, operating at open geometry, rather than through the spillway. The COE's justification for this operation was that turbine passage at open geometry is assumed to be a relatively safe fish passage route. However, as outlined below, this assumption is largely untested.

Bead Studies at ERDC

Scale models of Bonneville turbines have been built at ERDC (Engineer Research and Development Center) to facilitate understanding of the hydraulic conditions within turbines. These models have used observations of dye, neutrally buoyant beads, and the passage of air bubbles to draw conclusions about fish passage. Beads approximate to-scale smolts in the model turbines.

Notes from the use of ERDC models in January 2011 (Fredricks and Meyer, 2011) indicate that open geometry at Powerhouse 1, when compared to the lower limit of the 1% and peak efficiency, had less turbulence in draft tubes and uniform flow below the runner. Beads were observed to have fewer direct strikes than at other turbine flow levels.

The full study and analysis of turbine operations using ERDC scale models will not be available until September 2012. Although the available notes provide some indication of the expected results, it is impossible to evaluate the effectiveness of open geometry when compared to other operations.

Even if the final reports indicate that open geometry may provide better fish passage than other turbine operations, these models cannot replace biological studies. Although affected by the hydraulic conditions in the turbine, smolts actively migrate and their passage survival cannot be accurately modeled with passive particles. Before these operations are adopted as a standard procedure, testing with outmigrating salmonids must be completed.

Balloon Tag Studies

During the winter of 1999 – 2000, Normandeau Associates conducted survival tests through Powerhouse 1 turbines at Bonneville Dam (Skalski et al. 2000). This test was designed to compare survival through Minimum Gap Runner units with the previously existing Kaplan turbines. One of the operations tested is similar to what is now referred to as open geometry (stay vanes, wicket gates, and runner blades close to wide open), although the study was not specifically designed to test survival with an open geometry configuration. The conclusions of this study should be considered with strong reservations as to its applicability to the run at large. The State, Federal and Tribal Fishery Agencies Joint Technical Staff (18 May 2004, 23 March 2005) and the Fish Passage Center (30 January 2004) have previously provided critiques of balloon tagging studies.

Selection of study fish

In this study, only hatchery Chinook yearlings were used. The average fish size was 166 mm, and fish with descaling, fungal infections, or other maladies were not included. The percentage of the run-at-large that would be eliminated by this experimental design is unknown, so its applicability cannot be assessed. This study does not address survival of subyearling Chinook and other migrating species, and is representative only for the largest and healthiest Chinook yearlings.

Overestimates of Survival

Survival in this study is estimated at one and 48 hours from turbine to tailrace. Mortality in the gatewells and due to screens is not estimated, although it is likely that the additional flow required for open geometry will increase injury and mortality prior to turbine entry.

In addition to gatewell mortality, migrating fish in the run-at-large experience different ambient pressures than fish released from the surface to the turbines through hoses. Experimental fish are acclimated to surface pressure prior to release, while migrating fish passing through turbines experience much higher pressures while entering turbines. This longer-term acclimation to high pressure before turbine passage can lead to higher mortality (Cada et al. 1997) that will not be experienced by experimental fish.

Orientation of fish in turbine

Another source of mortality not accounted for in the 2000 study is tag effects on swimming behavior. Migrating fish generally orient parallel to flow, and if this orientation is maintained in turbines fish will be perpendicular to turbine blades with a high chance of a turbine strike. In contrast, due to the large tag size balloon tagged fish are unlikely to swim normally. Tagged fish from hoses also enter the turbine directly at high speed, further increasing the probability of random orientation in the turbine. Randomly orientated fish are less likely to suffer turbine strikes than fish swimming parallel to flow. This is likely to underestimate the injury and mortality rate of experimental fish when compared to the run-at-large.

Unknown distribution of fish through turbine locations

In the Skalski et al. study (2000), survival is compared through three turbine locations. However, there is no information available on the distribution of migrating fish through the turbine, so there is no way to apply these study results to the run-at-large. When survival estimates for the three release locations are combined, the point estimate of survival is highest at open geometry although there is no statistical difference between turbine flow levels. Survival at open geometry when compared to other efficiency levels was highest for fish released at the blade tip, but among the lowest for fish released at the mid-blade, and equal to the other power levels for fish released nearest the hub. It is only when combined that open geometry appears to have the highest survival, but if migrating fish are not distributed equally across the turbine blades this will not be true.

Long Term Effects of Turbine Passage

Survival estimates in this study were completed at one and 48 hours. Although this accounts for immediate mortality due to turbine passage, it does not provide any information on the effects of turbine passage that manifest during later life stages. There is an increasing body of evidence that turbine passage negatively affects survival during the estuarine and oceanic life stages (Haesker et al. 2012, Petrosky and Schaller 2010, Schaller and Petrosky 2007; also reviewed in FPC Memos 16 March 2012 and 6 October 2010). By increasing flows through the turbines, operating at open geometry increases the probability that lower adult returns may be observed due to turbine passage at Bonneville.

In summary, it is possible that open geometry provides turbine passage with higher survival than other turbine operations, however, there is currently too little data to base operations on this assumption. In addition, even if open geometry has equal survival to other operations within the 1%, the higher flows will direct a higher proportion of migrants through the turbines, rather than other passage routes, such as the spillway, with higher survival and minimal delayed effects. Before open geometry is utilized as a standard operation, rigorous testing of juvenile survival and its relation to subsequent adult survival is required under the open geometry operation.

References

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