CFD Modeling Plan for B2FGE Alternatives Study
CENWP-EC-HD 1-19-2010

1. Introduction

Purpose

The CFD Modeling Plan describes the expected use of the Updated B2 CFD Model to support investigation of gate well flow alternatives for the B2FGE Alternatives Study.

Project Problem Statement:

In 1999, the region agreed to pursue a phased approach and focus on improving guidance and survival by maximizing the flow up the turbine intake gatewell (a guideline that has been used on similar programs to improve FGE). As a result, prototypes were designed and installed from 2001 to 2004 at units 15 and 17. These modifications included an increase in vertical barrier screen (VBS) flow area, installation of turning vanes to increase flow up the gatewell, addition of a gap closure device to eliminate fish loss at the submerged traveling screen, and installation of interchangeable VBS to allow for screen removal and cleaning without outages or intrusive gatewell dipping. Hydraulic modeling was conducted to design the turning vanes, VBS, and gap closure devices.

Prior to implementation of improvements across the powerhouse, gatewell testing was conducted on prototypes to make sure that improvements were beneficial to fish. Results from the biological studies showed an increase in FGE by 21% for yearling Chinook and 31% for subyearling Chinook. Test fish conditions showed no problem with descaling and gatewell retention time including fry in a newly modified unit. Based on these results the changes were implemented across the entire powerhouse. The changes cost approximately $20 million and were completed in 2008.

During the 2008 juvenile fish passage season, Spring Creek National Fish Hatchery (SCNFH) released hatchery sub-yearlings in early spring 2008, over a period of 3 months (March, April, May). Recent biological testing conducted by NOAA (Spring 2008) suggests that SCNFH subyearling are incurring high mortality and descaling when the newly modified units are being operated at the upper 1% range. Evidence suggests a relationship may exist between the operation of the powerhouse units (lower, mid and upper one percent) and survival of the SCNFH sub-yearlings. Poor hydraulic conditions within the gatewell may be the culprit.

The B2FGE Alternatives Study is being conducted to improve juvenile fish survival in the turbine gatewell. An Updated B2 CFD Model will be used to evaluate operational and structural alternatives.

2. B2FGE CFD Model Development

An existing CFD model of the B2 forebay was developed by PNNL (*Numerical simulations of the Bonneville Powerhouse 2 Forebay Supporting Fish Guidance Efficiency Improvement Studies)* and has been applied to investigate the impacts of forebay configuration on hydraulic conditions approaching and in the intake gate wells. The forebay configurations investigated included scenarios with the B2 Corner Collector on/off, Turbine Intake Extensions (TIEs) in/out, the Behavioral Guidance Structure (BGS) in/out and a range of spillway, B1, and B2 powerhouse flows. The Existing B2 CFD Model was used to identify the relative changes in gatewell flows rather than actual flow for different forebay configurations, as it does not include the current gatewell geometry details.

An Updated Sectional CFD Model will be developed for the B2 turbine units to include the following details:

1. TIEs
2. Trashrack, or adjustable porosity baffle to straighten flow in place of the trash rack
3. STS
4. Vertical barrier screens (VBS) and perforated plates
5. A turning vane below the gatewell
6. Gap closure device on top of the STS
7. Modified gatewell beam
8. Gate slots
9. Fish orifice openings
10. Emergency gates

The Updated Sectional CFD Model will be developed by creating a solid geometry of the turbine unit (Figures 1 and 2) and creating a computational grid using a grid generation program compatible with the STAR-CD CFD modeling software. The Updated Sectional CFD Model is expected to be of sufficient detail for analyzing relative impacts of flow control device alternatives and developing associated gate well/turbine flow rating curves.

The Updated Sectional CFD Model for a single turbine unit will be replicated and translated to update Units 11 through 18 as permitted by the number of computational cells in the Updated Sectional CFD Model.

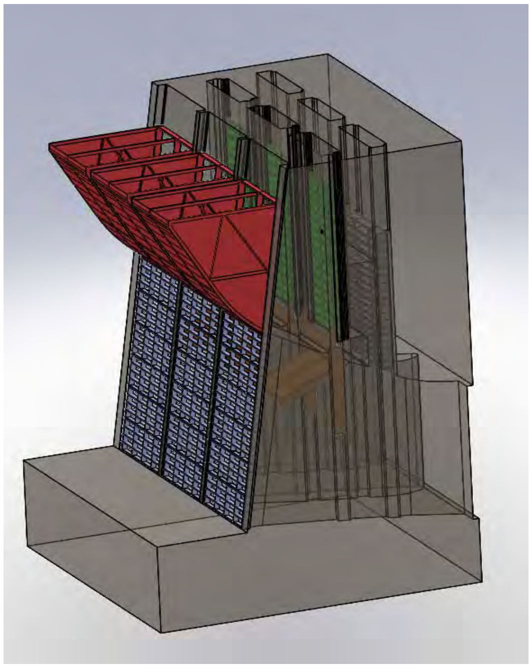

Figure 1: Isometric view of turbine unit

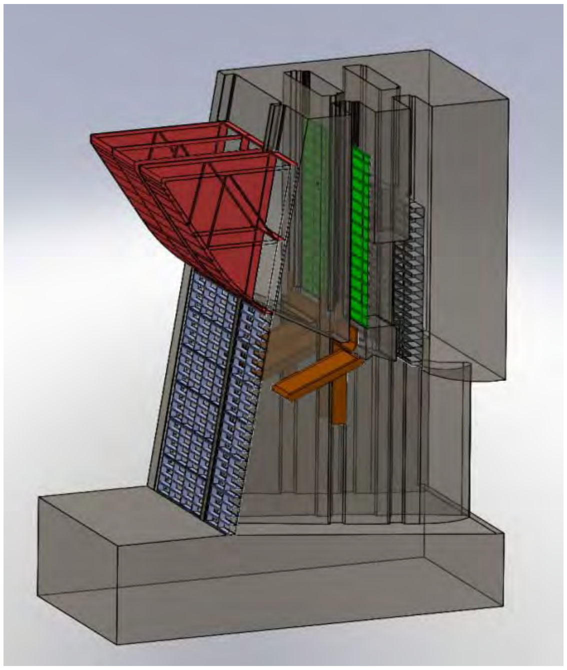

Figure 2: Section view of turbine unit

3. Updated CFD Model Runs

Preliminary forebay model runs have been conducted with the existing B2 Forebay CFD Model to investigate the impacts of forebay configuration on hydraulics approaching and in the intake gatewells.

Future runs will be conducted with the Updated CFD Model, including the current geometry for the gatewell. The Forebay CFD Model will be configured to include the B2CC, the BGS, TIEs, and flows (B1, spillway, and unit flows) as applicable for the conditions modeled. The following CFD Model runs will be conducted to calibrate and validate the Updated CFD Model and evaluate baseline hydraulic conditions in the gatewell:

Baseline Runs

Calibration and Validation Runs

The Sectional CFD Model will be calibrated for conditions matching those for data collected in the 1:12 sectional physical model (ENSR, August 2005). The model calibration will include adjustment to the model porosity coefficients for the trashrack, STS, and VBS screen porosities. The full forebay model will be run for conditions matching those from the 2010 PNNL prototype VBS velocity measurements as a validation condition.

Baseline – 2007/2008 Unfavorable Conditions

The Updated CFD Model will be run for conditions known in 2007/2008 to have resulted in high mortality and descaling for subyearlings. The purpose of this simulation will be to establish a baseline for poor gatewell hydraulic conditions for subyearlings. PSMFC sampling showed an increase in Spring Creek subyearling mortality rate in 2007, approximate doubling from 2000-2006 results.

Baseline Condition- Low Flow Favorable Conditions

The Updated CFD Model will be run for low turbine flow conditions from 2007/2008 shown to reduce mortality for run-of-river subyearlings. The purpose of this simulation is to identify hydraulic conditions in the gatewell that may be favorable. This simulation will include the B2 corner collector (B2CC) flow, the behavioral guidance structure (BGS) in, TIEs in, and low flow conditions.

Baseline Conditions - Future Forebay Configuration

Future conditions refer to both the updated configuration in the sectional turbine model and the future forebay conditions. Future operations in the forebay will not likely include the TIEs or the BGS. This will be reflected in this simulation run without the proposed alternatives. This simulation run is intended to understand the effects of future operating conditions on the current configuration without alternatives giving a “future conditions” baseline in order to better understand the effects that the alternatives will have and separate out the effects of removing the TIE’s and BGS.

Alternative Runs

Each design or combination of design alternative described below will be run in the Updated Sectional CFD Model for high, middle, and low flow operation to gain an understating of how the proposed design changes will affect flow and velocity distributions in the gatewell. The structural and operational alternatives identified to date as a result of discussions with regional Federal Agencies are described below.

Alternatives A through C are structural alternatives and Alternatives D and E are operational alternatives. The structural flow control alternatives will be included in the Updated CFD Model to a level of detail to capture hydraulic influence of structures (i.e., overall shape and dimensions as available, but not fasteners or minor structural details).

Alternative A1: Adjustable Louvers

This alternative involves installation of a series of adjustable plates (louvers) in opening downstream of the VBS (Figure 3) to control flow up the gatewell. The louvers would be adjusted accordingly to meet the target flow in the gatewell. This system can be constructed of stainless or carbon steel and can be designed to vary the opening width at top and bottom. For a permanent design, opening and closing adjustments may be made from a separate device lowered into the downstream VBS slot, through a conduit that is cored through the existing concrete or by remote control.

Alternative A2: Sliding Plate

This alternative involves a system of two sliding plates attached to the top of the gatewell beam (Figure 4). Gatewell flow could be controlled by one plate sliding over the other adjusting the opening depending on the required velocity. Both plates can be made of carbon or stainless steel and Teflon coated to reduce friction. Similar to Alternative A1, a permanent design may be operated from a separate device lowered into the downstream VBS slot, through a conduit that is cored through the existing concrete or by remote control.

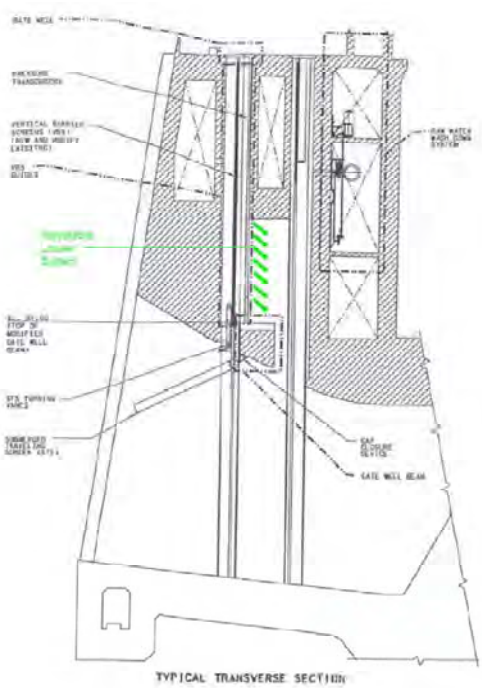

Figure 3 Flow Control Device - Louver Concept

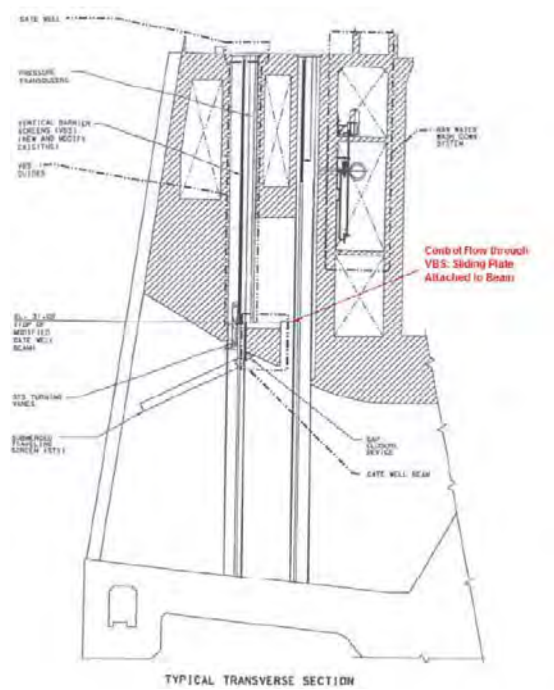

Figure 4 Flow Control Device - Sliding Plate Concept

Alternative B: Additional Orifice or Horizontal Slot

The DSM system has 2 fish passages orifices in the gatewell slots of units 11-14. Each is located toward the side walls and is about 20' apart. Under present operating conditions one orifice in each gatewell is used. This alternative involves constructing additional orifices or slots to help facilitate faster movement of fry through the orifices and decrease fish retention in the gatewell as explained in previous design memorandum, *Bonneville Second Powerhouse Downstream Migrant System Improvements Supplement No.6 to Design Memorandum No.9, August 1997*. In conjunction with running this alternative in the sectional CFD turbine model, an existing numerical model will be run to analyze the impacts to hydraulics in the downstream migrant system due to higher flows from the gatewell.

Alternative C: Modify Vertical Barrier Screen Perforated Plates

This alternative involves reducing the gatewell flow by modifying the existing perforated plates. A separate, modified perforated plate is attached to the existing perforated plate and allowed to slide to constrict flow to meet a target flow velocity. This perforated plate can be constructed of carbon steel with a Teflon coating to reduce friction during operation. A permanent design may be attached to the existing perforated plate and mechanically or remotely controlled. The 24 VBS panels in the sectional CFD model have individual porosity parameters that will be adjusted to test the results of constricted flow through the VBS. The CFD model would only be a preliminary investigation to gain an initial understanding of the screen perforated plates for viability. If the CFD model shows this alternative to be a viable option, further physical hydraulic modeling investigations would be needed for this alternative to finalize porosities and confirm velocity distribution. A typical model would be at a scale of 1:12 and would reproduce one turbine bay.

Alternative D: Operate main turbine units at the lower to mid 1% peak operating range to occur during the SCNFH juvenile fish release

Alternative D involves reducing the gatewell flow by operating B2 main units off the 1% peak operating range (lower, mid one percent) to improve fish survival. During the 2008 juvenile fish passage season, Spring Creek National Fish Hatchery (SCNFH) released sub-yearlings in early spring 2008, over a period of 3 months (March, April, and May). Biological testing conducted by NOAA (Spring 2008) suggests that SCNFH sub-yearling are incurring high mortality and descaling when turbine units are being operated at the upper 1% range.

Alternative E: Open Second Downstream Migrant Systems Orifices

The DSM system has 2 fish passages orifices in the gatewell slots of units 11-14. Under present operating conditions one orifice in each gatewell is used. This alternative involves opening the second gatewell orifice to decrease fish retention time in the gatewell. Previous design memorandum Bonneville Second Powerhouse Downstream Migrant System Improvements Supplement No.6 to Design Memorandum No. 9, August 1997 will be used. In conjunction with the CFD model, an existing numerical model to analyze the hydraulics in the system due to opening two orifices per gatewell will be used. Opening of the second orifices could mean possible modification of some weirs in order to meet required flows within the system.

The expected order of investigation in the CFD Model is shown in Table 1 and has been determined with PDT input to streamline the modeling and design process.

4. Alternative Analysis

An evaluation of alternatives in the Updated B2FGE Turbine model will be conducted using the hydraulic design criteria described in the 30% B2 FGE Alternatives Report (USACE, April 2009). Any alternatives not meeting the hydraulic design criteria will be eliminated. For each of the Updated Sectional CFD Model runs, the gate well flows will be quantified in the CFD model by post-processing the model results for mass-flux, vertical momentum, and turbulence intensity at the gate well entrances.

The PDT in discussion with the regional Federal Agencies will undergo an evaluation of remaining alternatives for feasibility with considerations to include biological, structural, mechanical/electrical, operations, cost, and hydraulic. The PDT will select 1 to 2 optimal alternatives to proceed with. The alternatives that have been selected will be run in the full Updated Forebay CFD model for a range of flows (high, middle, and low flow) to confirm that the alternatives are effective in all units with the future forebay configuration.

4. Reporting

Model development, runs, and results will be described along with figures of results for each phase of modeling:

- Existing B2 Forebay CFD Modeling;
- Updated B2 Forebay CFD Model Grid Development, Calibration, and Validation;
- Alternative Runs;
- Confirmation Runs.

A Draft CFD Modeling Report will be prepared. Comments from Peer Review and PDT Review will be incorporated into a Final CFD Modeling Report. Information from the report will be used to support the B2 FGE Alternatives Report.

Table 1. B2 CFD Modeling Plan for B2 FGE Alternatives Study

Model Run	Description
Baseline Runs	
Calibration	Run Sectional CFD Model and calibrate to B2FGE 1:12 Intake Model Gatewell Velocity Measurements (ENSR, Aug 2005)
Validation	Run Full Forebay CFD Model and validate to PNNL 2010 field data
Baseline – 2007/2008 Unfavorable Conditions	Run CFD Model for conditions known in 2007/2008 to have resulted in high mortality and descaling for subyearlings as a baseline to identify hydraulic conditions in the gatewell that may be unfavorable.
Baseline – Low Flow Favorable Conditions	Run CFD Model for conditions for low turbine flow conditions shown to reduce mortality for run-of-river subyearlings to identify hydraulic conditions in the gatewell that may be favorable.
Baseline – Future Forebay Conditions	Run CFD Model for future forebay conditions at high turbine flow to establish baseline conditions to which alternatives will be applied. Future forebay conditions will include B2CC operation, BGS out, TIEs out.
Alternative Runs	
D: Low Turbine Flow	Operate main turbine units at the lower to mid 1% peak operating range to occur during the SCNFH juvenile fish release.
E: Open Second Downstream Migrant System Orifice	Open second downstream migrant system orifice in units currently containing a second fish passage orifice (Units 11-14).
B: Additional Orifice or Horizontal Slot	Construct a second orifice or horizontal slot so that all units have additional outflow capability from the gatewell. Open both orifice openings in all units.
C: Modify Vertical Barrier Screen Perforated Plates	Reduce the gatewell flow by modifying the porosity coefficients of the existing perforated plates in the model. Implementation of this alternative would require physical modeling to finalize plate porosities.
A2: Sliding Plate	Control gatewell flow with a sliding plate attached to the top of the gatewell beam or similar device.
A1: Adjustable Louvers	Control gatewell flow with adjustable louvers in the opening downstream of the VBS.
Confirmation Runs	
Select Alternatives (up to 2)	Run select alternatives in the full Updated Forebay CFD Model to confirm performance over the entire powerhouse for low, medium, and high flows.