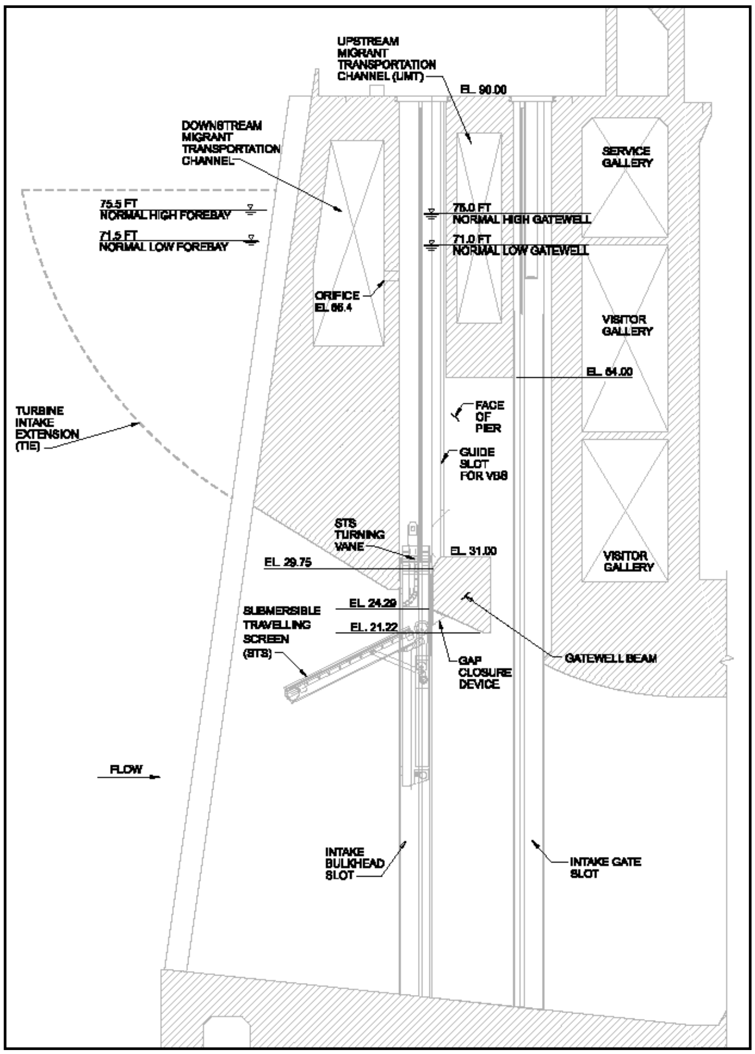
US Army Corps of Engineers®
Portland District

Alternatives Report

Bonneville Second Powerhouse Fish Guidance Efficiency (FGE) Program Post Construction



April 2009

30% Review

EXECUTIVE SUMMARY

This Alternatives Report presents the development of the Bonneville Second Powerhouse Fish Guidance Efficiency improvements.

Alternatives to investigate were chosen as a result of discussions with the regional Federal Agencies (see Appendix A, Memorandum For Record, October 3, 2008) as well as discussions within the in house Product Development Team.

Structural alternatives include:

- Construction of a device to control the flow up the gatewell. The device would be placed downstream of the VBS. Similar devices have been used at John Day and McNary Dams.
- Construction of a horizontal slot in place of the existing orifices or additional orifices to decrease fish retention time in the gatewell.
- Modify the existing VBS perforated plates resulting in a reduction of gatewell flow.

Operational alternatives include:

- Operating main turbine units at the lower to mid 1% peak operating range during the SCNFH juvenile fish release.
- Open the second Downstream Migrant System (DSM) gatewell orifice to decrease fish retention time in the gatewell.

A phased approach is recommended for the development and implementation of the FGE improvements. Phase I will represent development of a prototype design. A prototype will allow a check for errors, adjustments and modifications to a target velocity. Phase I may extend one to two seasons based on performance and cost. Phase II will follow and may extend from 1-3 seasons. The time duration will depend on complexity of design, cost and operations requirements.

BONNEVILLE LOCK AND DAM
BONNEVILLE SECOND POWERHOUSE FISH GUIDANCE EFFICIENCY PROGRAM
IMPROVEMENTS ALTERNATIVES REPORT

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PERTINENT PROJECT DATA

1. Project Description

STREAM:	COLUMBIA RIVER (RIVER MILE 146.1)
LOCATION:	BONNEVILLE, OREGON
OWNER:	U.S. ARMY CORPS OF ENGINEERS, PORTLAND DISTRICT
PROJECT AUTHORIZATION:	1935 RIVERS AND HARBORS ACT 1935
AUTHORIZED PURPOSE:	POWER, NAVIGATION
Other Uses:	Fisheries, Recreation

2. Lake/River Elevations (elevation above sea level in feet)

MAXIMUM CONTROLLED FLOOD POOL	90.0
MAXIMUM SPILLWAY DESIGN OPERATING POOL	82.5
MAXIMUM REGULATED POOL	77.0
MINIMUM POOL	69.5
NORMAL OPERATING RANGE	71.5-76.5
MAXIMUM 24-HOUR FLUCTUATION AT STEVENSON GAGE	4.0
MAXIMUM FLOOD TAILWATER (SPILLWAY DESIGN FLOOD)	51.5
MAXIMUM OPERATING TAILWATER	33.1
STANDARD PROJECT FLOOD TAILWATER	48.9
MINIMUM TAILWATER	7.0
BASE (100-YR) FLOOD ELEV. (AT PROJECT SITE TAILWATER)	39.8

3. Powerhouses

FIRST POWERHOUSE (OREGON)	
LENGTH	1027 ft
NUMBER OF MAIN UNITS	10
NAMEPLATE CAPACITY (2 @ 43 MW, 8 @ 54 MW)	518 MW
OVERLOAD CAPACITY (2 @ 47 MW, 8 @ 60 MW)	574 MW
STATION SERVICE UNITS (1 @ 4 MW)	4 MW
HYDRAULIC CAPACITY	136,000 ft^3/s

SECOND POWERHOUSE (WASHINGTON)	
LENGTH INCLUDING SERVICE BAY & ERECTION BAY	985.5 ft
NUMBER OF MAIN UNITS	8
NAMEPLATE CAPACITY (8 @ 66.5 MW)	532 MW
OVERLOAD CAPACITY (8 @ 76.5 MW)	612 MW
FISH WATER UNITS (2 @ 13.1 MW)	26.2 MW
Hydraulic Capacity	152,000 ft^3/s

4. Spillway

Capacity at pool elevation (El. 87.5) 1,600,000 cfs

5. Fish Passage Facilities

FISH LADDERS
- WASHINGTON SHORE
- CASCADES ISLAND
- BRADFORD ISLAND

JUVENILE BYPASS SYSTEM - FIRST POWERHOUSE
DOWNSTREAM MIGRANT SYSTEM – SECOND POWERHOUSE
Upstream Migrant System

ABBREVIATIONS AND ACRONYMS

SECTION 1 – INTRODUCTION

1.1 Purpose

The purpose of this report is to document alternatives to improve juvenile fish survival in the turbine gatewell. Operational and structural alternatives are considered.

1.2 Background

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 gatewells (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.

1.3 Scope

The scope of this report includes structural and operational modifications. Alternatives to investigate were chosen as a result of discussions with the regional Federal Agencies (see Appendix A Memorandum For Record, October 3, 2008).

Structural alternatives include:

- Construction of a device to control the flow up the gatewell. The device would be placed downstream of the VBS. Similar devices have been used at John Day and McNary Dams.
- Construction of a horizontal slot in place of the existing orifices to decrease fish retention time in the gatewell.
- Modify the existing VBS perforated plates resulting in a reduction of gatewell flow.

Operational alternatives include:

- Operating main turbine units at the lower to mid 1% peak operating range during the SCNFH juvenile fish release.
- Open the second Downstream Migrant System (DSM) gatewell orifice to decrease fish retention time in the gatewell.

1.4 Project Authorization

The Bonneville Project began with the National Recovery Act, 30 September 1933 and was formally authorized by Congress in the River and Harbor Act of 30 August 1935. Authority for completion, maintenance, and operations of Bonneville Dam was provided by Public Law 329, 75th Congress, 20 August 1937. This act provided the authority for the construction of additional hydroelectric generation facilities (Bonneville Second Powerhouse) when requested by the Administrator of the Bonneville Power Administration. Letters dated 21 January 1965 and 2 February 1965 from the Administrator developed the need for construction of Bonneville Second Powerhouse. Construction started in 1974 and completed in 1982.

1.5 Project Location

The Bonneville Project is located on the Columbia River approximately 42 miles east of Portland, Oregon at River Mile 146. Bonneville Dam's second powerhouse is located between Cascades Island and the river's north shore in the State of Washington. **(add figure or plate)**

1.6 Project Features

Bonneville second powerhouse consists of eight 66 MW Kaplan turbine main units and two 13.1 MW turbine units that supply water to the adult fish passage facilities.

1.7 Project Coordination

This report will be coordinated with the fisheries agencies and tribes through the Fish Facility Design Review Work Group (FFDRWG).

SECTION 2 – DESIGN CRITERA

The purpose of this section is to set forth the criteria used in the development of the alternatives report.

2.1 Biological

Biological Opinion for Bonneville Dam juvenile survival goal is 93% subyearling Chinook and 96% yearling Chinook and steelhead. B2FGE improvements made to the turbine environment originally showed benefits, with a 0.1-0.3% overall FGE improvement for yearling Chinook, subyearling Chinook and steelhead during regular spill (April-August). A 0.7% FGE improvement was found after spill termination September 1.

With the recent discovery of poor survival of Spring Creek hatchery fish, the biological goal is to improve conditions for these fish, while maintaining (or improving) the FGE and survival improvements of the original B2FGE design.

Relevent information:

- PSMFC sampling showed increase in Spring Creek subyearling mortality rate in 2007, approximate doubling from 2000-2006 results.
- PSMFC sampling showed no substantial increase in descaling from 2000-2007.
- NMFS B2FGE research 2008 revealed high mortality rate of spring creek subyearling, increasing with Turbine operation increase.
- NMFS B2FGE research revealed little mortality for run-of-river subyearling, yet maintaining a notable mortality increase (0.4 to 2.6%) with a turbine operation increase.
- NMFS B2FGE 2008 research had 4 Spring Creek subyearling data sets, 1 run-of-river yearling data set and 1 run-of-river subyearling data set.

Decision considerations:

- Spring Creek hatchery fish required for mitigation of John Day Dam.
- Past concern from tribes for not performing ‘in place, in kind’ John Day Dam mitigation i.e. upriver brights release from John Day pool.
- Spring creek hatchery operation had some flexibility to alter dates of release and release locations in 2009.
- Run-of-river fish show minimal mortality rates, but nothing is known of delayed mortality.
- Since the impact is selected to Spring Creek subyearlings, it may warrant swim test research to determine results are size dependent or fitness dependent.

2.2 Hydraulic

Turbine Intake Screens and Vertical Barrier Screens

Turbine intake screen and vertical barrier screens at mainstem Columbia and Snake River hydroelectric dams are exception to design criteria for conventional screens. Turbine intake screens are considered partial screens, because they do not screen the entire turbine discharge. They are high-velocity screens, meaning approach velocities are much higher than allowed for conventional screens. Turbine intake screens were retrofitted at many mainstem Columbia and Snake River powerhouses (which cannot be feasibly screened using conventional screen criteria) to protect juvenile fish from turbine entrainment to the extent possible.

Vertical barrier screens (VBS) pass nearly all flow entering the gatewell from the intake screen and intake ceiling apex zone. Fish pass upward along the VBS, then accumulate in the upper gatewell, near an orifice that is designed to pass them safely into the Downstream Migrant System (DSM).

Alternatives should be designed to operate within the design forebay level range (el. 71.5 – 76.5). Forebay levels remain within this range 97.3 percent of time (1974-81 forebay data)

Turbine Intake Screens – Specific Criteria

Maximum Approach Velocity: Maximum approach velocity (normal to the screen face) for turbine intake screens must be 2.75 ft/s.

Stagnation Point: The stagnation point (point where the component of velocity along the turbine intake screen face is 0 ft/s) must be at a location where the submerged screen intercepts between 40% to 43% of turbine intake flow, and must be within 5 feet of the leading edge of the screen.

Vertical Barrier Screens – Specific Criteria

Through-Screen Velocity: Average VBS through-screen velocity must be a maximum of 1.0 ft/s, unless field testing is conducted to prove sufficiently low fish descaling injury rates at a specific site.

VBS must be designed to achieve uniform velocity distribution and minimize turbulence in the upper gatewell.

If a flow vane is used at the gatewell entrance to increase flow up the gatewell, the VBS should be constructed of stainless steel bar screens with bars oriented horizontally, and a maximum clearance between bars of 1.75 mm.

Downstream Migrant System – Specific Criteria

a. General

The hydraulic design of the DSM is driven by hydraulic criteria for safe passage of downstream migrating juvenile salmon. The primary objective of this criteria is to minimize injury or delay to the fish. Criteria for the forebay range, orifices, collection channel, dewatering structure, and exit section, provided by NMFS, are listed below:

b. Design Forebay Operating Ranges

- Design forebay elevation for DSM constant flow operation: 71.5 - 76.5 ft. (normal operating range)

c. Orifices

- Plate velocity ≥ 10 ft/s
- Orifice discharge ≥ 11 cfs
- Centerline trajectory of the orifice jets should enter the collection channel water surface at least 4 feet from the opposite wall.

d. Collection Channel

- Channel velocity ≥ 2 ft/s (acceptable for unit 11 per NMFS discussion)
- Channel velocity between 3 - 5 ft/s at downstream end
- Channel water depth ≥ 4 ft.

e. Dewatering Facility

- Channel velocity between 3 - 5 ft/s
- Average gross velocity entering dewatering screens ≤ 0.4 ft/s
- Bypass outflow rate = 30 cfs
- Channel water depth ≥ 2 ft.

f. Exit Section

- Flow rate: 30 cfs
- Ratio of bend radius to pipe diameter (R/D) ≥ 5
- Velocities should not increase or decrease at rates greater than 0.1 ft/s per unit foot of conduit length

2.3 Structural

2.4 Mechanical/Electrical

2.5 Cost Engineering

Total Project Costs: Total project costs will be generated for the alternatives. These costs are applicable to structural alternatives which require design and construction to modify the VBS or installation of additional equipment. These costs include design, construction, escalation to the mid-point of construction, supervision and inspection, engineering during construction, and contingency costs. ETL 1110-2-573; Construction Cost Estimating Guide for Civil Works provides the criteria for developing these costs, which is to estimate a fair and reasonable cost for the alternative.

Life Cycle Costs: Life Cycle Costs, LCC, will also be generated for the alternatives. LCC is used to compare alternatives with high initial costs and low operational costs, with other alternatives with low initial costs and high maintenance costs, or in this case, lost power costs. LCC will included ALL costs involved in the alternative during its project life, such as design, construction, operation, and lost power costs as applicable. For comparison purposes, all these costs will be calculated as the present worth, using appropriate discount rates for future costs and assuming a nominal 50 year project service life. They will also be presented as an average annual cost. ER 1110-2-8159, Life Cycle Design and Performance defines the policies for long-term performance and life cycle costs.

2.6 Economic Analysis

SECTION 3 – ALTERNATIVES

This section describes the configuration and components of the alternatives. The technical analysis used in the design will also be described.

3.1 Description of Alternatives

Alternatives are categorized into structural and operational modifications.

Structural alternatives include:

- Construction of a device to control the flow up the gatewell. The device would be placed downstream of the VBS. Similar devices have been used at John Day and McNary Dams.
- Construction of a horizontal slot in place of the existing orifices or add additional orifices to decrease fish retention time in the gatewell.
- Modify the existing VBS perforated plates resulting in a reduction of gatewell flow.

Operational alternatives include:

- Operating main turbine units at the lower to mid 1% peak operating range during the SCNFH juvenile fish release.
- Open the second Downstream Migrant System (DSM) gatewell orifice to decrease fish retention time in the gatewell.

Monitoring Requirements

Each of the alternatives outlined requires some degree of real time monitoring for flow velocity. This will be required to determine baseline flow conditions, compare prototype performance and fine tuning to meet the target requirements.

Considerations

Issues have been identified that have to be considered during design of modifications. They are as follows:

1. The vertical inlet opening that may require flow control is 25’-3” tall by 21’-3” wide. This represents an area of 539 sq. ft. that a flow control device will have to installed and operate.
2. The horizontal inlet opening that may require flow control is 21’-3” long by 7’-8” wide. This represents an area of 163 sq. ft. that a flow control device will have to be installed and operated. This does not include any adjustment for the configuration of the downstream bulkhead guides.
3. The horizontal or normal downstream flow varies from 0.2 ft/sec at the top intake elevation of 54.00’ to a maximum of 0.6 ft/sec at the bottom sill elevation 31.00’.

4. The vertical flow velocity varies from 1.5 ft/sec at the top intake elevation to a maximum of 6.3 ft/sec at the bottom sill elevation.
5. The VBS frames must be pulled and cleaned throughout the year of heavy drift wood debris. During the peak months of October thru December they are pulled and cleaned 2 times a week.
6. Flow circulates inside the slot. It starts at the bottom near the flow control device, moves up vertically to the water surface at elevation __’, then drops.

3.2 Alternative A – Flow Control Device – Adjustable Louvers

3.2.1 Description

This alternative involves installation of a series of adjustable plates (louvers) in the opening downstream of the VBS (Figure 1). 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.

3.2.2 Hydraulic Design

3.2.2.1 Hydraulic Modeling.

Computational Fluid Dynamics (CFD) modeling will be used to acquire the flow field in the gatewell for this alternative. Different scenarios of planned operation conditions and Turbine Intake Extensions (TIES) will be used in the model.

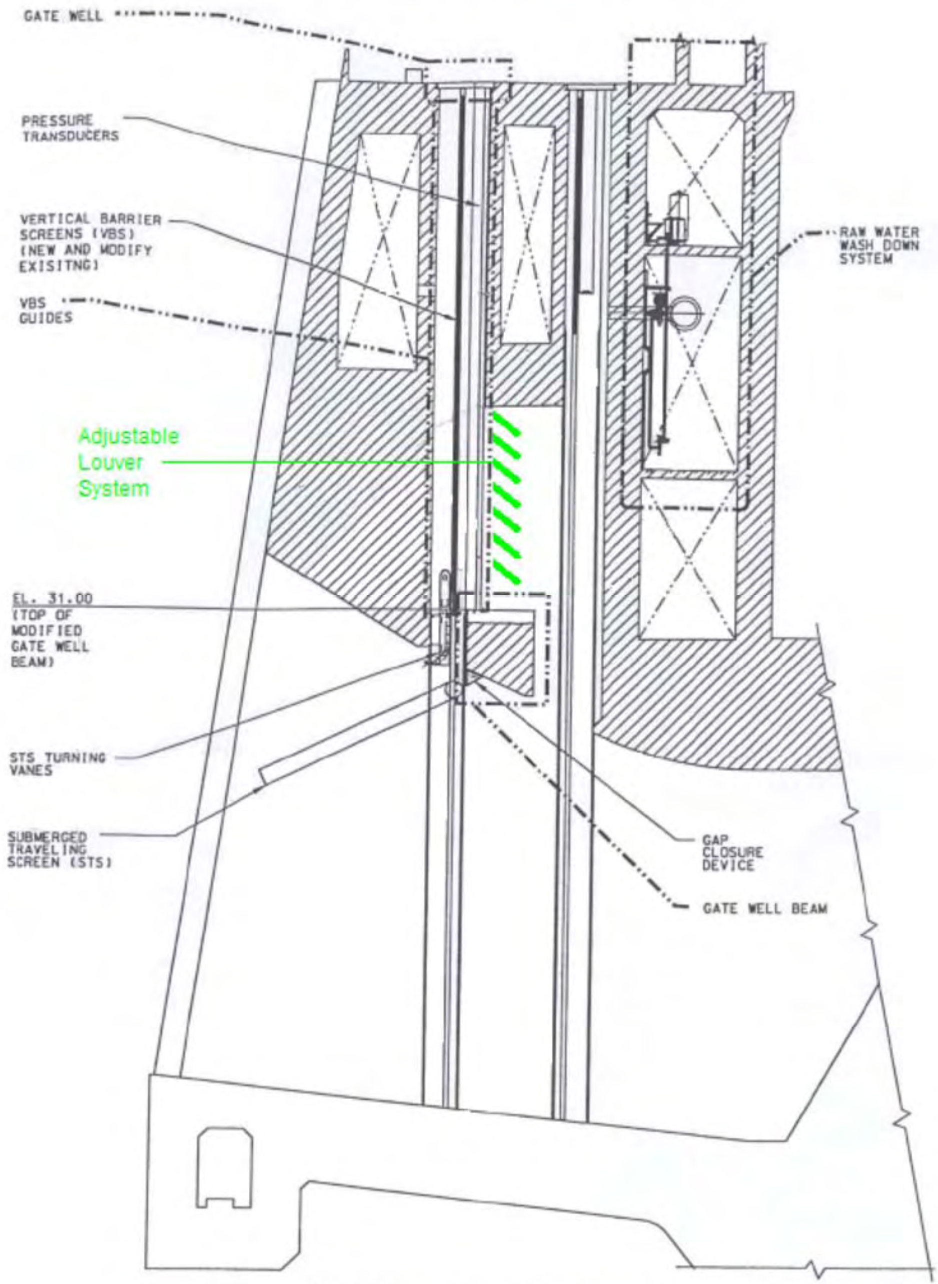
Previous model investigations used to develop the current FGE improvements will be used. These include physical hydraulic model report *Bonneville Second Powerhouse Fish Guidance Efficiency Program, Interchangeable VBS Investigation by ENSR, August 2004*, as well as existing CFD model and previous model report from Pacific Northwest National Laboratory *Numerical simulations of the Bonneville Powerhouse 2 Forebay Supporting Fish Guidance Efficiency Improvement Studies.*

Verification of CFD model was done from prototype study, B2FGE, 1:12 Intake Model Gatewell Velocity Measurements (ENSR, August 2005) and Engineer Research and Development Center (ERDC) 1:25 scale physical model.

The current CFD model takes the existing full forebay model and modifies Unit 15 to match existing conditions. The modifications include addition of the following items:

1. VBS and perforated plates
2. A turning vane below the gatewell
3. Gap closure device on top of the STS
4. A DSM orifice within the gatewell.
5. Lowering the gatewell block to 31.0 ft.

Figure 1: Flow Control Device - Adjustable Louver Concept



TYPICAL TRANSVERSE SECTION

Model flow and velocity distribution in the gatewell will be verified with the ENSR 1:12 prototype model report. Structural alternatives will be made to the calibrated model. Each design or combination of design alternatives will be run under various configurations and operating conditions simulating hi, mid, and low flow conditions to gain an understanding of how the design changes will affect flow and velocity distributions in the gatewell.

3.2.3 Structural Design
3.2.4 Mechanical/Electrical Design
3.2.5 Fisheries Considerations
3.2.6 Operational and Maintenance
3.2.7 Cost

3.3 Alternative A1 – Flow Control Device – Sliding Plate

3.3.1 Description

This alternative involves a system of two sliding plates attached to the top of the gatewell beam (Figure 2). 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 A, 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.

3.3.2 Hydraulic Design

3.3.2.1 Hydraulic Modeling.

Computational Fluid Dynamics (CFD) modeling will be used to acquire the flow field in the gatewell for this alternative. Different scenarios of planned operation conditions and Turbine Intake Extensions (TIES) will be used in the model.

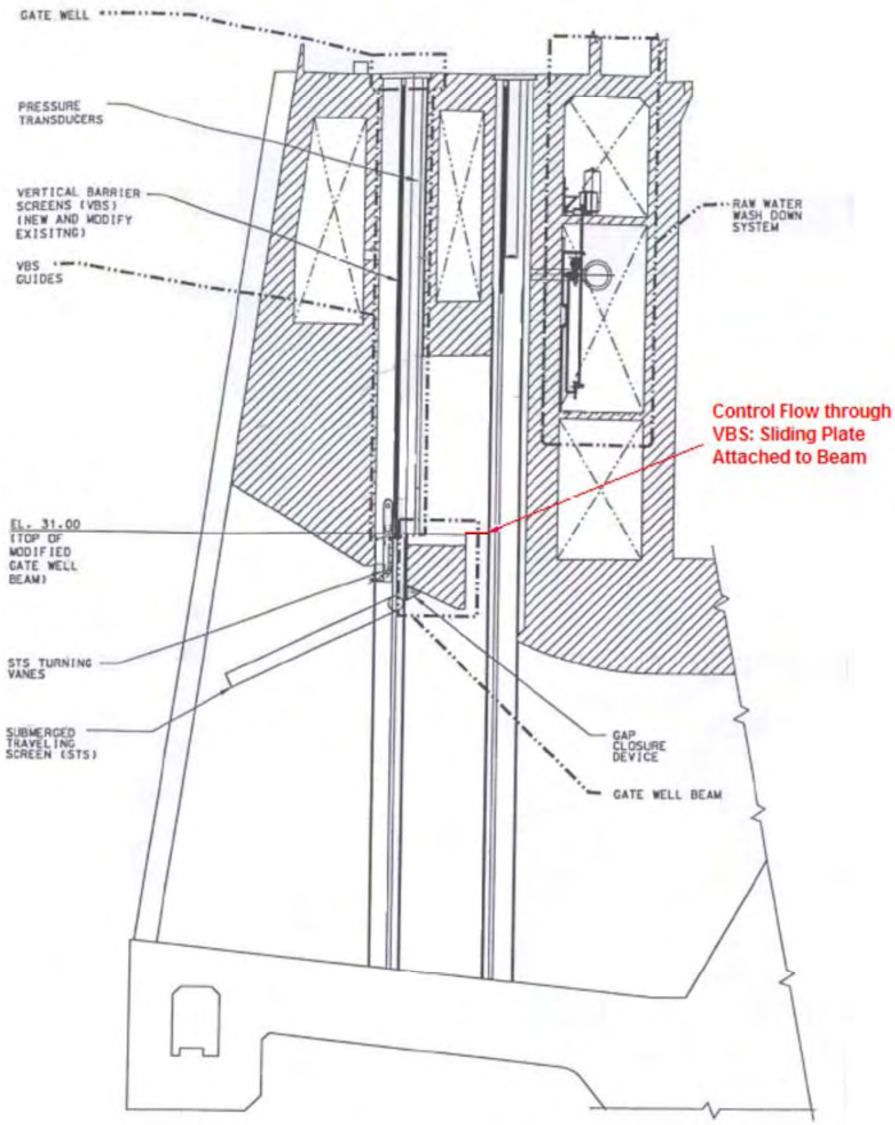
Previous model investigations used to develop the current FGE improvements will be used. These include physical hydraulic model report *Bonneville Second Powerhouse Fish Guidance Efficiency Program, Interchangeable VBS Investigation by ENSR, August 2004*, as well as existing CFD model and previous model report from Pacific Northwest National Laboratory (PNNL) *Numerical simulations of the Bonneville Powerhouse 2 Forebay Supporting Fish Guidance Efficiency Improvement Studies.*

Verification of CFD model was done from prototype study, B2FGE, 1:12 Intake Model Gatewell Velocity Measurements (ENSR, August 2005) and Engineer Research and Development Center (ERDC) 1:25 scale physical model.

The same CFD analysis under section 3.2 will apply to the sliding plate as well.

3.3.3 Structural Design
3.3.4 Mechanical/Electrical Design
3.3.5 Fisheries Considerations

Figure 2: Flow Control Device - Sliding Plate Concept



TYPICAL TRANSVERSE SECTION

3.3.6 Operational and Maintenance
3.3.7 Cost

3.4 Alternative B – Operating Main Unit Off 1% Peak Operating Range

3.4.1 Description

Alternative B 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 hatchery released sub-yearlings in early spring 2008, over a period of 3 months (March, April, 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.

3.4.2 Hydraulic Design

Gatewell flows under these conditions can be simulated in the updated CFD model to indicate the areas within the gatewell that may be causing adverse hydraulic conditions for fish passage.

3.4.3 Economic Considerations
3.4.4 Fisheries Considerations

3.5 Alternative C – Open Second Downstream Migrant System Orifices

3.5.1 Description

The DSM system has 2 fish passage 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.

3.5.2 Hydraulic Design

Previous design memorandum *Bonneville Second Powerhouse Downstream Migrant System Improvements Supplement No.6 to Design Memorandum No. 9, August 1997* will be used. 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.

3.5.3 Fisheries Considerations

3.6 Alternative C1 – Horizontal Slot or Additional Orifices for Downstream Migrant System

3.6.1 Description

The DSM system has 2 fish passage orifices in the gatewell slots of units 11-14. Each are located toward the side walls and are about 20' apart. Under present operating conditions one orifice in each gatewell is used. This alternative involves constructing additional orifices, or a slot to help facilitate faster movement of fry through the orifices and decrease fish retention time in the gatewell.

3.6.2 Hydraulic Design

Previous design memorandum *Bonneville Second Powerhouse Downstream Migrant System Improvements Supplement No.6 to Design Memorandum No. 9, August 1997* will be used. An existing numerical model to analyze the hydraulics in the system due to opening two orifices per gatewell will be used.

3.6.3 Structural Design

3.6.4 Mechanical/Electrical Design

3.6.5 Fisheries Considerations

3.6.6 Operations and Maintenance

3.6.7 Cost

3.7 Alternative D – Modify Vertical Barrier Screen Perforated Plates

3.7.1 Description

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 prototype could be built that would be adjustable and locked in place by hand. A permanent design may be attached to the existing perf plate and mechanically or remotely controlled.

3.7.2 Hydraulic Design

Physical hydraulic modeling investigations will be needed for this alternative. Preliminary investigation can be conducted using the working CFD model to gain an initial understanding of the screen perforated plates. A physical hydraulic model would need to be constructed. A typical model would be at a scale of 1:12 and would reproduce one turbine bay. The porosities of the perforation plates need to be studied with a prototype model to make sure vertical velocity distribution are within criteria.

3.7.3 Structural Design

3.7.4 Fisheries Considerations

3.7.5 Operations and Maintenance

3.7.6 Cost

SECTION 4 – EVALUATION OF ALTERNATIVES

This section will present a summary of results for the evaluation of each alternative. In general, the alternatives evaluation will consider estimated cost, perceived benefits and operational and maintenance impacts.

4.1 Introduction

Each alternative will be evaluated using a point based matrix approach. The matrix may include the following criteria: biological benefits, constructability costs, operating and maintenance cost, operational effectiveness. More discussion is needed to determine the details for evaluation.

4.2 Summary of Evaluation