ENERGY NORTHWEST

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January 18, 2018
GO2-18-011
DIC 0015.65

Mr. Richie Graves
Columbia Hydropower Branch
National Marine Fisheries Service
1201 NE Lloyd Blvd, Suite 1100
Portland, Oregon 97232

VIA Email and US Mail

Dear Mr. Graves:

Subject: **INTAKE SCREEN MODELING AND STUDY DESIGN FOR COLUMBIA GENERATING STATION (NRC DOCKET 50-397)**

Reference: Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Renewing the Operating License for the Columbia Generating Station, Richland, Washington (NWR-2011-05286).

Per the above referenced Biological Opinion, Section 2.c of the Terms and Conditions, Energy Northwest is providing our Intake Screen Modeling and Study Design for your approval. The attached study design outlines the proposed approach for development of a numerical model of the expected flow field around the intake screens located within the Columbia River.

The study design approach outlines the methodology that we discussed with your staff in meetings on April 17, October 3, and a conference call on December 4, 2017. If you require any additional information to complete this approval, please contact me at (509) 377-8639. We look forward to completing this study and presenting the results to your agency.

Respectfully,

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Khounnala, Shannon E. , Environme... cosign

Shannon E. Khounnala
Environmental and Regulatory Programs Manager

SEK/nb

Attachment

Cc: Briana Grange, NRC, Briana.Grange@NRC.gov
NRC Document Control Desk: EndangeredSpecies.Resource@NRC.gov

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Solving flow problems since 1894

Intake Screen Modeling and Study Design for Columbia Generating Station

Alden Project No.: 1175ENWCGS

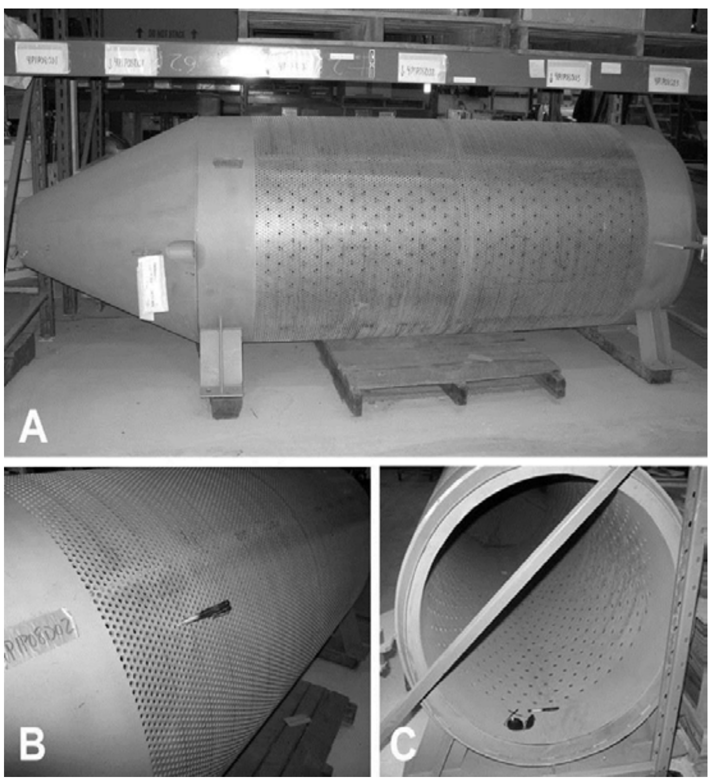
Prepared for:

Energy Northwest

Shannon Khounnala

Environmental and Regulatory Programs Manager

December 2017



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Name/Title	Signature/Date	Preparer (P) Reviewer (R)
Ben Mater, Ph.D. Engineer	12/11/2017	P
Dan Gessler Vice President	12/11/2017	R

Record of Revisions

Revision No.	Revision Date	Change Description	Reason for Change
0	12/11/2017	Initial Issue	

Table of Contents

1.0 Introduction

Energy Northwest operates Columbia Generating Station (CGS) approximately 10 miles north of Richland Washington. Columbia first produced power in May of 1984 and entered commercial operation in December 1984. Columbia produces 1,190 megawatts of electricity with a single GE boiling water reactor. Cooling of the CGS uses mechanically drafted cooling towers.

Columbia generating station withdraws cooling water from the Columbia River through two 42 inch diameter inlets with 3/8th inch perforated screens, each approximately 20 feet long and placed parallel to the river flow. To satisfy a National Marine Fisheries Service (NMFS) requirement, Energy Northwest is required to develop and submit a proposed study scope to NMFS. If accepted, the proposed scope will be followed to develop a better understanding of the interaction of the screens with the river and how this influences entrainment and impingement of fish. Figure 1-1 shows the location of the plant. Figure 1-2 shows a schematic drawing of the intake taken from the Energy Northwest website. Figure 1-3 shows a photograph of the spare screen located at the plant. The intake withdraws an average of approximately 8,500 gpm (19 cfs) with a peak flow of 12,500 gpm (28 cfs).

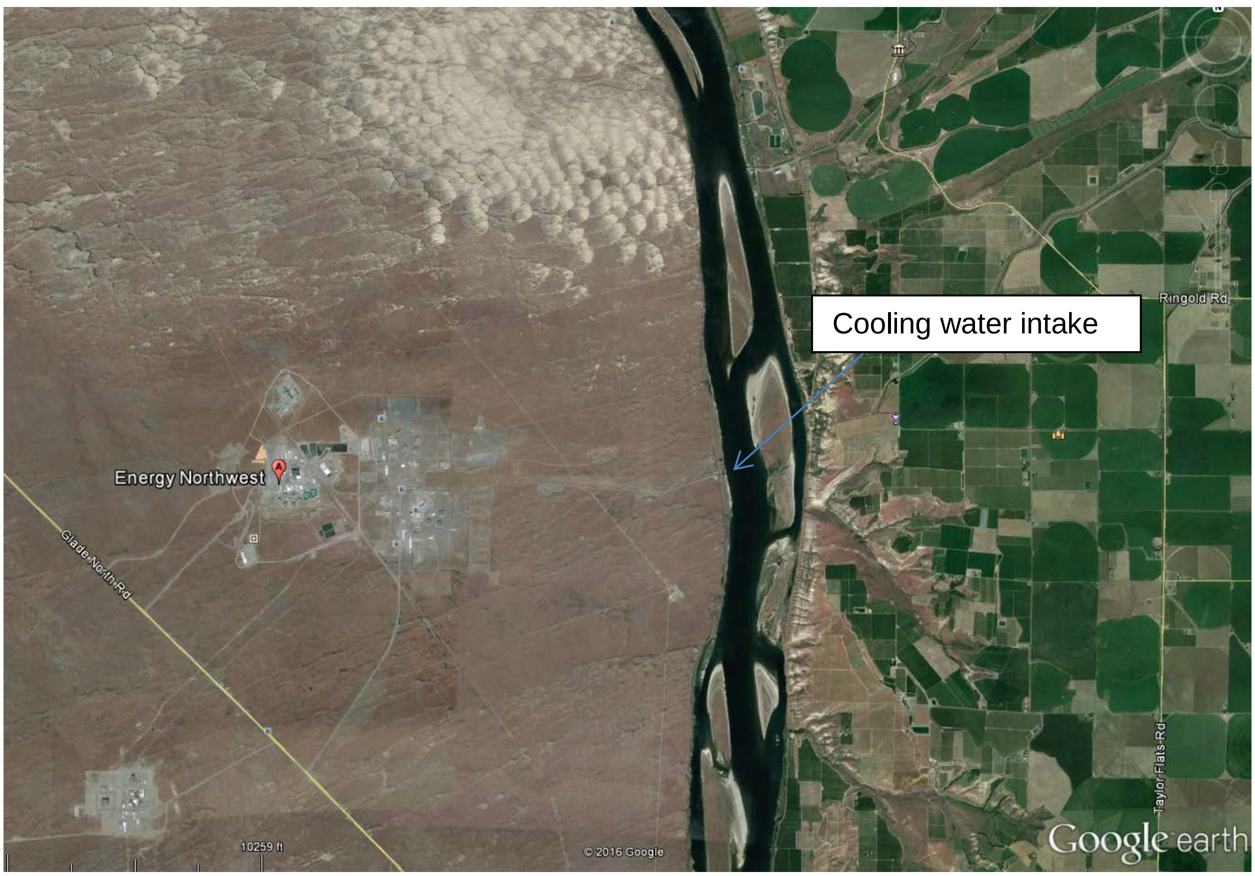

Figure 1-1: Columbia Generating Station

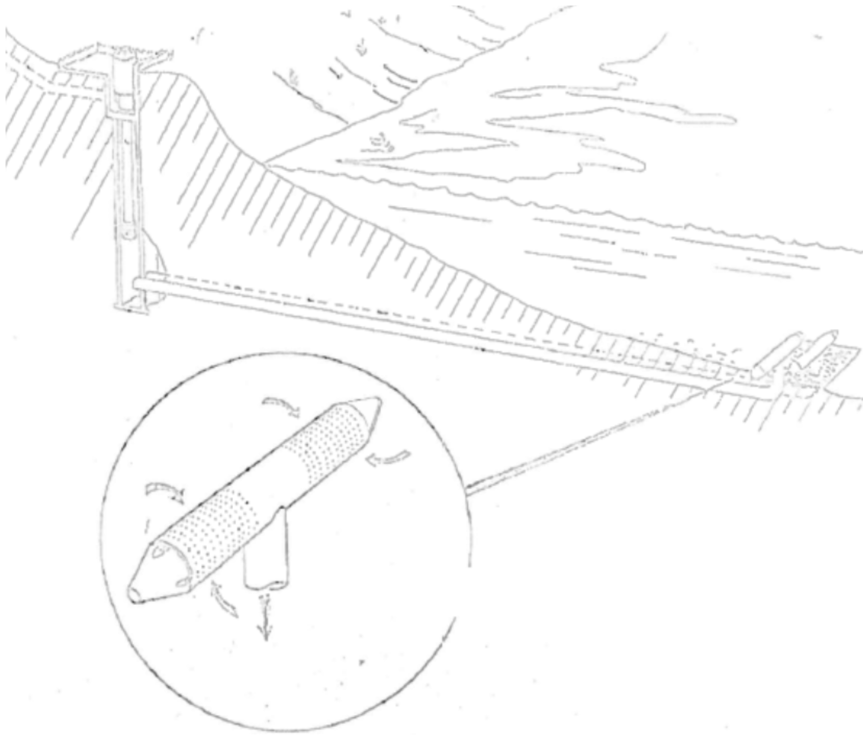

Figure 1-2: Schematic diagram of cooling water intake (from Energy Northwest)

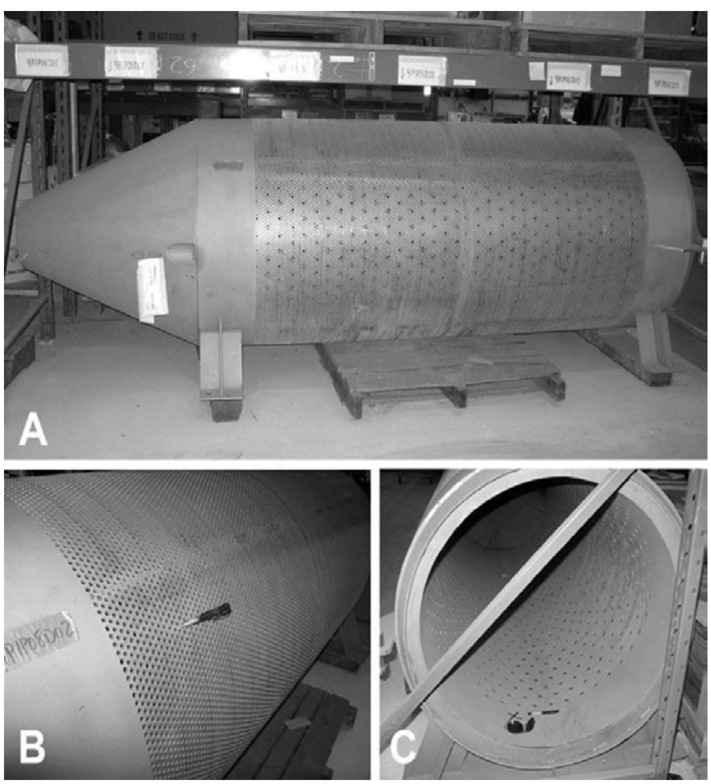

Figure 1-3: Spare intake screen at CGS.

2.0 Scope of Work

The proposed scope of work includes the following major tasks:

Task 1: Attend in person meeting in Portland. Dan Gessler from Alden will travel to Portland Oregon to attend a meeting with NMFS.

Task 2: Develop a final modeling plan based on meeting. Alden will develop a final modeling plan and scope based on the meeting results. The written document will be provided to Energy Northwest for review and comment.

Task 3: Develop a CFD model of the entire screen. As described in subsequent sections of this proposal, Alden will develop a CFD model to evaluate flow patterns approaching the entire screens from 5 different angles. The intake screen is parameterized.

Task 4: Complete 30 CFD simulations. Each CFD model developed in Task 3 will be run with three different water velocities while the screen is withdrawing water, and when the screen it is turned off. Model results will be post processed to provide flow visualization to fisheries biologists.

Task 5: Develop detailed CFD model of screen section (Sectional Model). A very detailed model of a section of screen will be created to determine near field differences in flow patterns with the screen in operation and when it is off. The detailed screen section will resolve individual screen holes and will be embedded within the geometry of a global model of a single T-screen unit.

Task 6: Complete 10 CFD simulations with Sectional Model. The sectional model from Task 5 will be run using boundary conditions from the full model for at least 5 scenarios with and without the intake in operation.

Task 7: Review of CFD results by fisheries biologist. Steve Amaral from Alden will review the CFD results and provide an assessment of the expected performance of the screens for preventing entrainment and impingement of fish. Under separate contract to CGS, Chuck Coutant is also providing a biological opinion.

Task 8: Final Report. Alden will prepare a final report about the modeling and the biological assessment of the screens.

Task 9: Attend two in person meetings in Portland to present results. Ben Mater from Alden will travel to Portland Oregon to attend two meetings with NMFS and NRC. The first meeting will be to present results of the global modeling and will be used to direct the subsequent near field effort. The second meeting will be to present results of the near field modeling.

Task 10: Support for study plan development. Alden will assist ENW in preparing technical portions of a project study plan for NMFS and NRC.

3.0 Modeling Approach

It is postulated by Northwest Energy that the shape of the screen creates a pressure gradient and shear layer (similar to a bow wave) at the front of the screen. The pressure gradient extends downstream and contributes to the overall efficacy of the system for minimizing entrainment and impingement. However, the flow patterns around the screens have not previously been studied. Therefore, Alden proposed a detailed computational fluid dynamics (CFD) modeling program of the intake.

The objective of the modeling is twofold: 1) Determine the detailed flow patterns around the screen while it is in operation. The modeling will provide the velocity and pressure field around the screen. 2) Determine how different the velocity field around the screens is when they are in operation and when they are not in operation. The biological team can evaluate the model results and provide an opinion on if the fish will respond to the operating screen the same as they would to a non-operating screen.

To achieve the objectives, two models are required, a global model and a sectional model. The global model extends 5 to 10 screen lengths upstream and downstream of the screens. The screens are approximately 20 feet long, resulting in a model that extends about 200 feet upstream and downstream of the screens. In the global model, the individual holes in the screen are too small, relative to the size of the model domain, to include. Therefore, the surface of the screen will be parameterized and a uniform withdrawal velocity applied to the screen. Parameterizing the screen will yield accurate flow patterns to within about 3 opening diameters of the screen surface. Within one hole diameter of the screen the velocity field becomes non uniform and includes flow patterns that reflect the detailed geometry of the screen.

A three dimensional sectional model will be created in which the holes along a subsection of the outer screen of a single T-screen unit will be fully resolved. The hole-resolving subsection will be 0.3 ft wide (in the circumferential direction) and 6.5 ft in the axial direction (extending the entire length of an intake section). The remainder of the outer screen area will be modeled as a “porous jump” (i.e., a porous surface with a prescribed drag to approximate pressure drop across the screen without actually resolving the holes), as will the inner screen areas. The intake flow rate boundary condition will be prescribed within the vertical shaft of the T-screen, so the flow across the screen areas will be free to evolve in response to the river conditions (rather than being fixed at a uniform value as in the global model). The sectional model will resolve every hole in the outer screen along the embedded 0.3 ft by 6.5 ft subsection and will calculate the detailed flow patterns created by the screen very near the screen surface (i.e., in the near field). By embedding the highly resolved subsection region within the larger-scale domain of the T-screen, the global flow patterns (e.g., bow waves, boundary layers, leeward eddying, non-uniform through-screen velocity) will be allowed to directly influence near field dynamics at the hole-resolving subsection. Such a setup is preferable to a simpler setup in which the hole-resolving subsection is modeled on its own and boundary conditions must be manually prescribed. In the simpler setup, the global and near field flow dynamics are largely decoupled because prescribed boundary conditions cannot capture all aspects of the flow dynamics. For example, the simpler setup would not capture potential non-uniform through-screen velocity. The embedded approach will also show the outward extent of the near field influence of withdrawing water and will provide the biologists with an understanding of the very local effects of the screen on velocity and pressure.

In the global model it is necessary to know the approximate water depth at the screens. The river bed can be assumed flat because the purpose of the model is to compare flow patterns when the screen is in operation and when it is not in operation. It is also necessary to know the approaching water velocity, including magnitude and direction. Alden recommends that the water velocity be measured during a time where the river flow is similar to what is expected while the juvenile fish are in the water. CGS will measure water velocities near the intake during April 2017 to determine a representative velocity for use in the model.

4.0 Numeric Model Description

Alden primarily uses Fluent (by ANSYS), Star-CCM+ and FLOW-3D (by Flow Science) for three-dimensional CFD simulations. The fluid solvers of the three models are similar in that all solve the Reynolds Averaged Navier-Stokes (RANS) equations, but they use various models for the creation, transport and dissipation of turbulent kinetic energy. FLOW-3D uses a Cartesian mesh while Fluent and Star-CCM use a body-fitted computational grid. Further, implementation of the governing equations in FLOW-3D differs from that in Star-CCM and Fluent, making the models well suited to different types of flow problems.

Fluent uses a body-fitted computational mesh, which allows for very accurate and detailed prediction of the influence of modeled obstructions on resulting bulk flow patterns. While FLOW-3D is well suited for problems involving a deformed free surface (i.e. open channel or riverine flow with large free surface deflections) and is efficient at time dependent solutions, Fluent is more efficient at reproducing the detailed flow patterns in and around modeled structures as well as the effects of surface boundary layers (friction) and obstruction geometries (form drag).

Due to the complex geometric details of the wedge-wire screen and the importance of its effects on the flow patterns around the screen, Alden proposes to use Fluent to simulate the 3-dimensional nature of the flow patterns. Alden has successfully used Fluent to model the flow field around several intakes involving wedge wire screen arrays in lakes and rivers, including the design of the Elm Road intake (see included project experience summaries), where Alden provided detailed modeling of the screens to demonstrate for regulatory agencies how screen to screen interaction can influence through slot velocity on nearby screens. Alden also used Fluent for modeling the proposed 144 screen array at Indian Point Nuclear Power Plant.

4.1.1 Grid, Bathymetry and Domain, Global Model

The proposed domain for the 3-dimensional model is shown in Figure 4-1. The model domain is about 400 feet long and 200 feet wide with an estimated depth of about 20 to 30 feet (to be confirmed by CGS). A body-fitted gridding scheme, including the required resolution around the wedge wire screen array, yields a total estimated cell count of approximately 3,000,000 to 5,000,000 cells. The actual cell size will vary from the estimated size; however, the cell count demonstrates that a sufficiently high resolution can be achieved while maintaining a reasonable cell count. It is assumed that this information will be provided to Alden.

Figure 4-1 Proposed global model boundaries.

4.1.2 Grid, Bathymetry and Domain, Sectional Model

The proposed domain for the 3-dimensional sectional model will encompass a single T-screen unit and will have a width and length sufficiently large so as to avoid contamination of results by the numeric boundary conditions. The sufficient width and length will be determined from the global model results. The hole-resolving subsection with be 0.3 ft wide (in the circumferential direction) and will extend the entire length of an intake section in the axial direction (6.5 ft) as shown in Figure 4-2. The mesh resolution will be sufficient to resolve the flow through each hole within the subsection. Subsection size is limited by computational power since many cells are needed to resolve the individual holes; the proposed 0.3 ft x 6.5 ft subsection will provide accurate results for a practical computation cost.

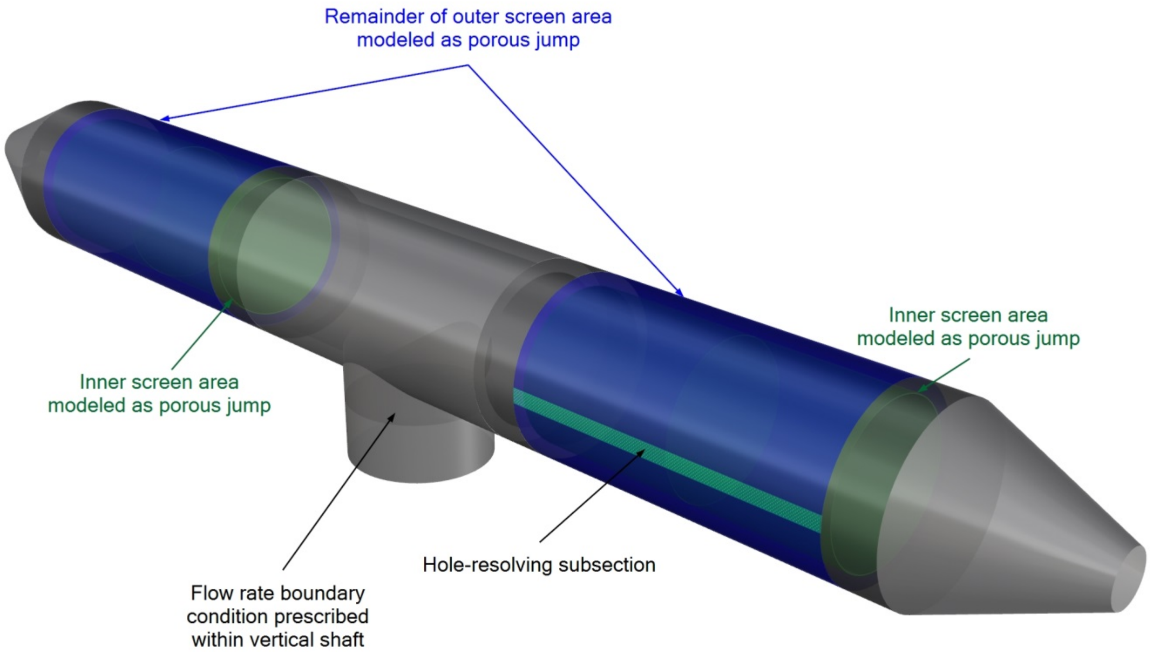

Figure 4-2: Proposed geometry of sectional model.

4.1.3 Boundary Conditions

Boundary conditions for the proposed 3D CFD model include:

- Upstream – Water velocity and direction.
- Downstream –Uniform hydrostatic pressure distribution.
- Free Surface – The water surface in the model will be fixed throughout the domain. Simulating different water levels in the river will require modifying the computational mesh. The sectional model will not include a free surface.
- Screen Intake – In the global model, a mass sink will be applied to the surface of each screen creating a uniform withdraw of water with a constant normal velocity vector across the screen surface. Alden has used this approach on other numeric modeling projects and has verified the validity of the simplification using flume tests. Detailed drawings of the intake screen installation will be required to ensure the approach is appropriate. In the sectional model, boundary conditions will be prescribed in a fashion

similar to the global model, with the exception that the intake flow rate will be prescribed within the vertical shaft of the T-screen, rather than at the outer screen faces. This will allow the flow to freely move into the screen unit more naturally. The magnitude and direction of river velocity to be imposed will be informed by results of the global model.

4.1.4 3D Model Validation

Model validation is an important consideration for any numeric simulation effort. Model validation involves comparing observed and predicted water velocity and directions. In this application no near screen measured water velocities are available to compare with predicted water velocities. Therefore, the model will be unvalidated. However, that does not mean the model is not valid. Alden will use a grid sensitivity study to determine if the results are grid independent.

5.0 Model Test Program

The global CFD model will be run with three different water velocities and five different approach angles for a total of 15 tests. The tests will be completed with and without the screen in operation, resulting in 30 tests total. Flow angle is expected to have a more pronounced effect on the results than velocity magnitude.

Post processing of the model results will include the following plots and analysis:

- Plan and profile plots with water velocity vectors for each test. Figure 5-1 shows an example plan view of computed velocity vectors at the centerline of an array of intake screens.
- Two plots showing stream lines (colored by water velocity) around the screen.
- Plan and profile plots with pressure contours for each test.
- Plan and profile plots to evaluate velocity gradients for each test. Figure 5-2 shows an example plan view of computed velocity at the centerline of a screen. The plot shows how the velocity changes around the screen. A similar plot can be made for pressure.
- Plan and profile plots to evaluate pressure gradients for each test.

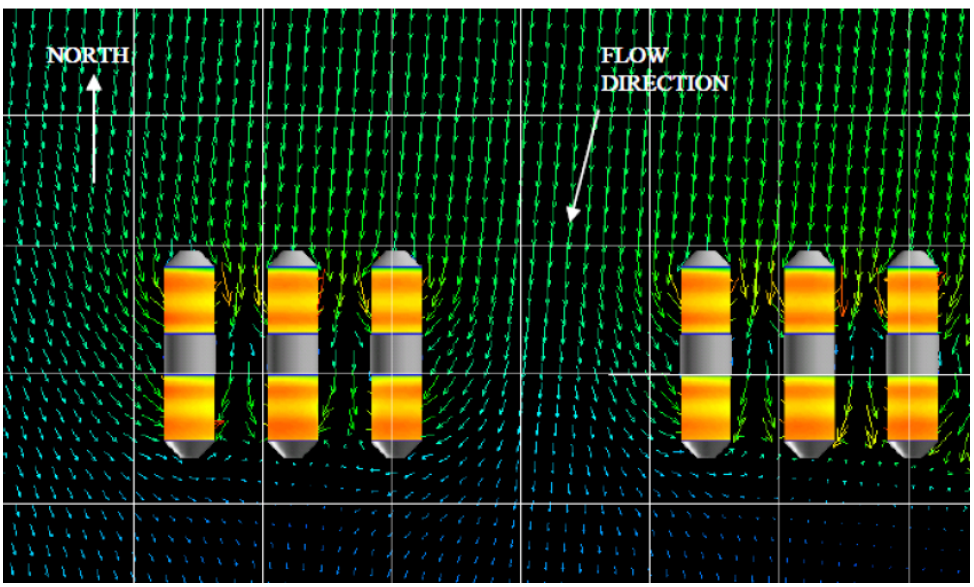

Figure 5-1: Example of computed velocity vectors at screen centerline.

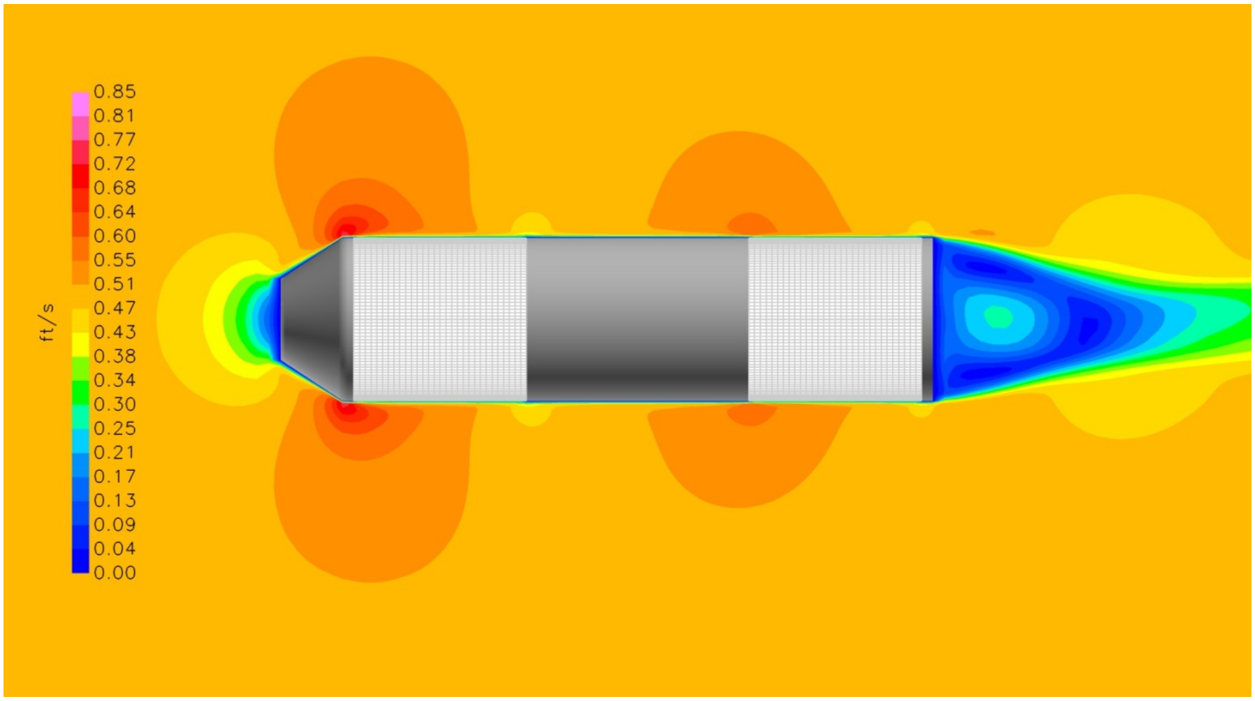

Figure 5-2: Example plot of velocity contours along screen centerline.

The magnitude and direction of river flow most problematic for fish impingement will be estimated (through consultation with NMFS) based on the results of the global model. These boundary conditions will then be applied to the sectional model.

In both global and sectional models, a rectangular domain will be used. The angle and magnitude of the river velocity will be prescribed at the upstream face(s). Therefore, for each modeling phase, a single mesh will be used for each flow angle and magnitude.

6.0 Project Schedule

The proposed numeric modeling program will include the development of two numeric models, one that includes the body geometry of both screens (holes not resolved) and a sectional model where holes are resolved along a portion one screen of one unit. Upon completion of the numerical modeling, the biological team will evaluate the model results and provide an opinion on if the fish will respond to the operating screen in a way that may preclude impacts.

Following completion of the tasks outlined in Section 2.0, Energy Northwest and Alden will provide NMFS and the NRC with a Draft Final Report and will present the material in-person to both agencies for their review and comment. It is expected that this in-person meeting will occur in late winter or early spring 2018.