**Washington Group International**
Integrated Engineering, Construction, and Management Solutions

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**SUBJECT:** **THE DALLES LOCK AND DAM**
**CONTRACT NO. W9127N-06-D-0009, TASK ORDER NO.0004**
**NORTH AND EAST FISH LADDER RELIABILITY**
**ASSESSMENT REPORT, 100% SUBMITTAL**

Dear Randy:

Enclosed please find five (5) hard copies of the subject report as specified in the Statement of Work for Task Order No. 0004.

We appreciate the opportunity to have participated in this project. If you have any questions, please call me at (425) 451-4658.

Sincerely,

Doug Hartsock, P.E.
Project Manager

cc: File-29075.10.01.1

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# THE DALLES HYDROELECTRIC PROJECT

## Columbia River, Oregon

# NORTH AND EAST FISH LADDER RELIABILITY ASSESSMENT REPORT

## 100% SUBMITTAL

## PORTLAND DISTRICT
## US ARMY CORPS OF ENGINEERS

**Contract No. W9127N-06-D-0009**
**Task Order No. 0004**

**Washington Group International**
Integrated Engineering, Construction, and Management Solutions

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## EXECUTIVE SUMMARY

This report provides a reliability assessment of the North and East Fish Ladders at The Dalles Lock and Dam. It represents the second phase of a multi-phased project, the objectives of which are:

- Phase 1: Inspect the ladders and ladder systems to establish their function, importance, and condition
- Phase 2: Develop and apply a methodology to assess and quantify the reliability of the ladders and ladder systems
- Phase 3: Develop and evaluate alternatives to improve the reliability of the ladders and ladder systems

Using information gathered during the Phase 1 inspections, a matrix was developed listing the various ladder systems, their function, and the modes by which they could potentially fail. Using a one-to-five scoring criteria, the severity of the effect of the failure modes on ladder operating criteria, fish behavior, other ladder systems, or ladder-related processes was quantified. Also quantified was the failure modes' rates of occurrence and ability to be detected, and the downtime associated with repair or replacement of the failed system. The products of the various scores were computed and a Reliability Priority Number (RPN) assigned to each failure effect, with a high RPN denoting a failure effect that could most greatly compromise the reliability of the ladder.

Results of the assessment indicate that based on their RPN score, the following failure effects could most greatly compromise the reliability of the ladders:

**North Fish Ladder**

Approach to Ladder Impacted by Juvenile Spill (RPN = 96): High velocities adjacent to the ladder from spillway flow act to reduce the number of fish entering ladder. This reduction has already occurred based on verbal briefing by District fisheries biologists on 12/28/2006, as follows: *"North ladder used to attract about 30% of the adult salmon passing the project….Since installation of training walls and changes to spill procedures…the ladder attracts only about 10% of the adults. This is despite installation of a new wall between the ladder entrance pool and spillway bay 1 to keep the spillway flow from rolling across into the ladder flow."*

Diffuser grating mounting failure (RPN = 72): Displacement of the diffuser grating can allow migrating fish into the Auxiliary Water System (AWS) conduit, which provides attraction water to the lower pools and fish entrance by means of gratings in the floor of the pools. Due to the potential loss of fish into the system the condition is ranked as more severe than the case of the plugged grating. Mounting failure has been reported to occur in the TDA ladders due to aging studs and clips. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. Mounting failure can be best prevented by replacing corroded studs and clips during annual inspections..

Insufficient AWS Design Flow for Ladder Geometry (RPN = 60): This design flaw has not prevented the ladder from passing fish although it may have resulted in discouraging or delaying migration for some fish. It is considered a built-in impairment to ladder function rather than a failure of something that once worked properly. HELCRABS Executive Summary, Evaluation of Existing Operation, reads in part: *"The channel velocity criteria are not met most of the time at the upstream end of the lower fishway channel….The low velocities are caused by low rates of inflow from the ladder section and a general limitation of AWS inflow."* NMFS views this a little differently, having recently stated that the ladder is too large [for the available water].

**East Fish Ladder**

Imbalanced flow distribution, excess flow to East Entrance (RPN = 75): As a result of an imbalanced flow distribution at the junction pool, hydraulics at the entrances may be out of criteria, there may be impacts on fish passage, and/or a need for higher AWS flow than would be required if the junction pool flows were balanced. Detection of the imbalance is based on observations at the entrances, operations required at each entrance to maintain entrance criteria for excess or low entrance flows, and visual observation of flow patterns at the junction pool. The high RPN value is influenced by the duration value, since this imbalance is a typical occurrence.

Diffuser grating mounting failure, and inoperable diffuser gates (RPNs = 72): Displacement of the diffuser grating can allow migrating fish into the AWS conduit and therefore the condition is ranked as more severe than the case of the plugged grating. Mounting failure has been reported to occur in the TDA ladders due to aging studs and clips. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. Mounting failure can be best prevented by replacing corroded studs and clips during annual inspections. If the diffuser gates are inoperable, the AWS flow distribution to the three entrances can be affected. These gates are not operated regularly to throttle diffuser flow, but are used to control the amount of AWS flow to each entrance. The high RPN for the diffuser gates is associated with the history of corroded gate operators and observations during the inspections that showed gates in partially open positions at the NFL; leaking gates in the collection channel; and the expected inability to partition the ladder for partial dewatering when gates are leaking or inoperable.

Fish turbine failure modes (RPN = 10 to 40): Sixteen failure modes were identified by TDA operations staff as part of this reliability assessment. The range in RPN values depends on the history of previous failures and downtime associated with the repair/replacement. The failure modes include excitation failures, bearing failure, winding failure, generator cooling failure, and turbine component failure. The fish turbines are currently the sole AWS source for the EFL and therefore failure modes for the fish turbines have a significant impact on hydraulic conditions in the ladder.

It should be noted that the reliability assessment is a subjective evaluation of the relative reliability of ladder systems in the NFL and EFL and is intended as a tool for identifying systems and practices that are most effective in keeping each ladder operating reliably and those with the greatest potential for improvement. This study is not intended to provide an overall probability of failure and should not be interpreted to mean either ladder is in imminent danger of failing. It is also important to note that the ladder reliability assessments have been performed independently for the NFL and EFL and are not intended to provide a relative reliability of the ladders as compared to each other overall or for individual ladder systems.

# 1.0 INTRODUCTION

## 1.1 Purpose

The purpose of this study is to assess and quantify the reliability of the North and East fish ladders at The Dalles Lock and Dam to provide continuous passage for upstream migrating fish. The results of this study will be used in a future study to identify improvements to both ladders to increase their reliability.

## 1.2 Authorization

Washington Group International was authorized to conduct this study under Task Order No. 0004 of Contract No. W9127N-06-D-00009 between Washington Group and the Corps of Engineers' Portland District.

## 1.3 Background

### 1.3.1 Location

The Dalles Lock and Dam is a Corps of Engineers project located 47 miles upstream from Bonneville Dam on the Columbia River at River Mile 192.5, approximately three miles upstream from the City of The Dalles, Oregon.

### 1.3.2 Previous and Related Work

*Hydraulic Evaluation of Lower Columbia River Adult Bypass Systems (HELCRABS) North Fish Ladder draft August 2005*

*Powerhouse Fishway Dewatering Improvement, INCA/R W Beck, November 1997*

*Study of AFA Auxiliary Water Supply, The Dalles Project Improvements for Endangered Species, Ebasco, June 1994*

### 1.3.3 Need for Study

To facilitate the downstream passage of juvenile fish during seasonal migration periods at The Dalles Lock and Dam, current practice calls for approximately 40 percent of the Columbia River flow to be released from spillway bays one through six.

To reduce the potential for mechanical injury to juvenile fish as they pass over the spillway and into the stilling basin, a reinforced concrete wall was constructed in 2004 between spillway bays six and seven. Although the wall reduced the juvenile injury potential, total survival through the spillway remains less than desirable, with predation within the stilling basin shelf appearing to be a major contributing factor.

The spilling of water through spillway bays one through six also results in extremely high velocities near the entrance to the North Fish Ladder (NFL), which is adjacent to bay one. Historically the higher the spill the more spring Chinook were attracted to the ladder. However, the high velocities caused by the new spill regime reduced the utilization of the NFL by upstream migrating adult spring Chinook during the high spill year 2006 to 8% of the total passing The Dalles, as compared to an average of 50% during the most recent years of comparably high spill in 1998 and 1999 *(source: fish passage data received from D. Clugston Sept 17, 2007)*. The potential for this to occur was identified during the design of the wall that separates spillway bays six and seven, and was addressed by creating a spill pattern that reduces the spill from bays one and two, thereby reducing the velocity along the north shore. This spill pattern was employed in 2004 and 2005, but not in 2006.

To address the juvenile predation issue, an extension of the wall that separates spillway bays six and seven has been evaluated by the The Dalles Spillway Improvement Study (SIS) team (more recently, the SIS team is also evaluating the construction of a new wall separating spillways eight and nine). The wall would extend approximately to the river thalweg and is proposed to improve spillway egress by creating a physical barrier to separate the juveniles from the predators located within the stilling basin shelf and by directing spillway flow and juveniles to deeper the river thalweg and away from the bridge islands. Preliminary physical model studies have demonstrated that extending the wall between bays six and seven raises the level of the stilling basin near the NFL entrance by several feet (more recent model tests demonstrate that a wall between spillways eight and nine results in less raising of the stilling basin water level). The increased tailwater elevation has the desirable effect of reducing the spill-induced water velocities near the entrance of the NFL, but could also create operational difficulties for the ladder, including keeping it within its design criteria. In addition, although the velocity adjacent to the NFL entrance is reduced, the model studies showed an increase in velocity along the north shore downstream of the NFL entrance that could limit access to the NFL (the eight-nine wall creates similar shoreline velocities).

Out of concern for the potential impacts of an extended spillway 6/7 wall (or new spillway 8/9 wall) to the operation of the NFL, in December 2006 the District retained a consultant team led by Washington Group International to inspect and document the condition of the NFL and become familiar with the function and importance of its major systems (Appendix A). Since the East Fish Ladder (EFL) currently passes 70 to 90 percent of upstream migrating adult fish, a similar EFL inspection and condition assessment was conducted by the Washington Group team (Appendix B). The purpose of the inspections was to establish the structural, mechanical, electrical, hydraulic, and geological condition of the ladders and their supporting infrastructure so as to provide the information needed to conduct a reliability assessment of each ladder. This study comprises the reliability assessment.

## 1.4 Ladder Systems Description, Function, and Importance

### 1.4.1 North Fish Ladder

The Dalles NFL is located on the north end of the dam between the navigation lock and spillway bay one (Figure 1). The fish ladder is 1,761 feet long, 24 feet wide, and has a slope of 1:16. There are currently two downstream facing entrances to the fish ladder (a third side entrance has been permanently blocked with a reinforced concrete wall). The entrances are fitted with three-leaved, telescoping weirs that provide the ability to adjust flow and head leaving the ladder. Upstream of the entrances, a series of fixed overflow weirs span the ladder and allow upstream-migrating fish to ascend the ladder either over the weirs in one-foot increments, or through square orifices located near the bottom of each weir wall. The ladder transitions from concrete-lined to rock-lined and back to concrete lined over its 1,761-foot length. Upon reaching the upper end of the ladder, fish exit into the forebay.

Approximately 75 to 102 cubic feet per second (cfs) of the ladder's water is supplied by forebay water entering the fish ladder exit. Between 870 and 940 cfs of additional attraction water flow is supplied to the lower sections of the ladder via the discharge of a hydraulic turbine unit operated by the Northern Wasco County Public Utilities District. The North Wasco turbine and powerhouse was constructed and began operation in 1991 to capture the energy potential of the ladder's attraction water flow, which before the powerhouse was simply spilled by gravity into the ladder's attraction water system (AWS). The turbine's discharge enters the ladder through a conduit located beneath the ladder and a series of grated diffusers cast into the ladder floor. The former gravity fed AWS system is maintained as a backup to the hydraulic turbine.

A fish counting station was added to the upper section of the ladder in the late 1980s, at which time the ladder's exit section was modified to ensure that proper overflow weir submergence is maintained downstream of the counting station.

The various systems that comprise the NFL are described in more detail below, including their function and importance to the overall operation of the ladder. Photographs of the systems may be found in the NFL inspection report (Appendix C).

A. Ladder Entrance (System 1)

1. Description

Two (one plus one backup), telescoping, roller-guided steel weirs consisting of three leaves, 6’-9” high by 8’-6” wide, that are raised and lowered using an electric hoist and spreader beam arrangement.

2. Function

Provides access to the NFL from the stilling basin. Establishes ladder entrance velocity and water level.

3. Importance

Loss or failure of both weirs would eliminate the only opening for fish to enter the ladder. Backwater created by the entrance weirs affects entire ladder hydraulic performance.

B. Lower Ladder (System 2)

1. Description

24-foot wide rectangular concrete channel laid on a 1:16 rising slope with fixed concrete overflow weirs spanning the channel every 16 feet. Floor of channel fitted with steel grating to allow AWS flow to enter ladder from below.

2. Function

Provides transition from entrance to ladder. Floor grating provides AWS flow.

3. Importance

Floor grating provides inlet for majority of ladder’s AWS flow. Loss of AWS flow could hinder fishes’ ability to find ladder entrance.

C. AWS Conduit (System 3)

1. Description

Rectangular concrete conduit located directly beneath the lower ladder section. The AWS conduit is hydraulically connected to the draft tube of the North Wasco PUD powerhouse’s hydraulic turbine.

2. Function

Provides the path for water from the turbine discharge (auxiliary water supply, or AWS) to enter the lower ladder via the gratings in the floor of the ladder.

3. Importance

Provides AWS flow to the lower ladder. Failure of conduit would result in loss of AWS flow, hindering fishes’ ability to find ladder entrance.

D. North Wasco PUD Turbine (System 4)

1. Description

   Single, 5 MW Francis turbine, below ground powerhouse.

2. Function

   Discharge from turbine supplies primary AWS flow to the lower ladder.

3. Importance

   Loss of turbine discharge would require switching to the secondary AWS system, resulting in the temporary interruption of AWS flow.

E. Plunge Pool (System 5)

1. Description

   A system consisting of automatic slide gates fitted in the wall of the North Wasco powerhouse supply channel, a rock-lined plunge pool, and concrete overflow weir. When the gates are opened water from the supply channel is discharged into the Auxiliary Water System Conduit.

2. Function

   Provides gravity-fed, backup AWS flow when the North Wasco turbine discharge is not available.

3. Importance

   Provides backup to North Wasco turbine, which is subject to unplanned outages. Loss or failure of secondary AWS system would require uninterrupted operation of North Wasco turbine to provide AWS flow.

F. Rock-Lined Channel (System 6)

1. Description

   Middle section of ladder consisting of a channel excavated in native basalt rock on a 1:16 rising slope and fitted with fixed concrete overflow weirs spanning the channel every 16 feet.

2. Function

   Provides transition from lower ladder to upper ladder.

3. Importance

   Loss or failure of rock-lined channel would prevent passage of fish.

G. Counting Station (System 7)

1. Description

   A submerged room with viewing window that looks out into the channel. A motor-operated, moveable channel wall (crowder) operates to force fish to swim though a narrowed aperture in front of the window within view of a counting station operator. Equipped with lights and a window cleaner.

2. Function

   Provides the ability to observe fish movement as well as count the number passing through the ladder.

3. Importance

   Necessary to assess ladder efficiency and gather overall fish passage statistics. Failure would not necessarily affect the passage of fish, unless blockage of the channel occurred.

H. Exit Section AWS (System 8)

1. Description

   A water conduit cast into the wall of the upper ladder section used to divert as portion of the water entering the ladder from the forebay to a point just downstream of the counting station. Discharge from conduit controlled by a motor-operated slide gate.

2. Function

   Provides AWS flow downstream of counting station to ensure proper submergence of weirs.

3. Importance

   Loss or failure of the exit section AWS would result in less submergence of weirs downstream of counting station, possibly hindering fish passage over the weirs.

I. Ladder Exit Section (System 9)

1. Description

   Rectangular concrete channel fitted with vertical slot weirs.

2. Function

   Provides transition from middle, rock-lined section of ladder to forebay.

3. Importance

   Loss or failure of exit section would prevent passage of fish into the forebay.

### 1.4.2 East Fish Ladder

The Dalles EFL is located to the south of the spillway and extends along the length of the powerhouse to the east end of the dam (Figure 2). The fish ladder consists of three entrances, fish collection and transportation channels extending more than 2,000 feet along the powerhouse, a junction pool, and ladder section, count station, and flow regulating exit section to the forebay. There are three entrances to the EFL, the east, west, and south entrances, respectively located at the east and west ends of the powerhouse and at the south end of the spillway, with each entrance having two operable entrance gates. The entrances are fitted with three-leaved, telescoping weirs that provide the ability to adjust flow and head leaving the ladder.

Flow reaches the south entrance via the fish transportation channel, which is rock-lined in the exposed portion of the channel between the powerhouse and the south entrance, and concrete below the powerhouse. The west entrance flow is supplied through the fish collection channel. The east entrance is just downstream of the junction pool where flow is distributed from the ladder to each of the three entrances.

Approximately 160 cubic feet per second (cfs) of the ladder's water is supplied by forebay water entering the fish ladder exit. Approximately 4,500 to 5,000 cfs of attraction water flow is supplied to the lower sections of the ladder via the discharge of two 13.5 MW hydraulic fish turbine units. The turbines' discharge enters the ladder upstream of the junction pool and just upstream of each entrance through a conduit located beneath the ladder and a series of grated diffusers cast into the ladder floor. There is currently no backup auxiliary water supply system for the fish turbines. If one of the fish turbines is shut down for any reason, the ladder will not operate with all three entrances in criteria. A procedure is in place to allow continued ladder operation at reduced capacity, by adjusting the east entrance weirs and sequentially shutting down the south and west entrances by small steps until an east fishway entrance head of one foot is restored. A procedure also addresses the case of shutdown of both fish turbines.

Upstream of the junction pool, a series of fixed overflow weirs span the ladder and allow upstream-migrating fish to ascend the ladder either over the weirs in one-foot increments, or through square orifices located near the bottom of each weir wall. Upon reaching the upper end of the ladder, fish pass through the count station and exit into the forebay.

The various systems that comprise the EFL are described in more detail below, including their function and importance to the overall operation of the ladder. Photographs of the systems may be found in the EFL inspection report (Appendix D).

A. East Fish Entrance (System 1)

1. Description

The east fish entrance consists of three (one plus two backup) telescoping, roller-guided steel weirs consisting of three leaves, 6'-9" high by 8'-6" wide, that are raised and lowered using an electric hoist and spreader beam arrangement. Steel gratings installed in the floor of the entrance structure are hydraulically connected to the AWS conduit.

2. Function

Provides access to the fish ladder from the east end of the tailrace. Establishes east fish entrance velocity and water level.

3. Importance

Loss or failure of all three weirs would eliminate the only opening for fish to enter the east entrance of the ladder. Backwater created by the entrance weirs affects EFL hydraulic performance.

B. Junction Pool (System 2)

1. Description

The junction pool is a concrete-walled, open-topped chamber that hydraulically connects the east fish entrance, south fish entrance fish (via the transportation channel), and west fish entrance (via the collection channel). It is also hydraulically connected to the fish lock channel. Parallel rows of three telescoping, roller-guided steel weirs exist to hydraulically isolate the junction pool from the three fish entrances and also modulate the quantity of ladder and AWS flow distributed to each fish entrance. The floor of the junction pool is fitted with steel grating to allow AWS flow to enter the pool from below.

2. Function

The junction pool hydraulically connects the elevated ladder section of the EFL to the three fish entrances. It also provides a portion of the AWS flow to each entrance.

3. Importance

Loss or failure of the junction pool would prevent fish from entering the elevated ladder section of the EFL. Loss of AWS flow from the junction pool would hinder fishes' ability to find any of the three EFL fish entrances.

C. Collection Channel (System 3)

1. Description

The collection channel is a concrete-walled, open topped channel that extends from the west fish entrance to the junction pool along the length of the powerhouse. Steel gratings panels are installed at equal intervals along the floor of the channel and hydraulically connected to the AWS conduit located directly beneath it. Slide gates associated with the grating panels distribute AWS flow into the channel. Former fish entrance orifices in the channel wall adjoining the tailrace have been permanently sealed.

2. Function

The collection channel provides a conduit for fish entering the west fish entrance to swim to the junction pool and access the elevated section of the EFL.

3. Importance

Loss or failure of the collection channel would prevent the passage of fish via the west fish entrance.

D. AWS Conduit (System 4)

1. Description

The AWS conduit is a concrete-lined conduit located beneath the fish collection channel and extending from the west fish entrance partway up the elevated ladder section of the EFL. The conduit is hydraulically connected to the collection channel via gates and steel gratings in the floor of the collection channel.

2. Function

Provides AWS flow from the fish turbine discharge to the collection channel floor grating, junction pool floor grating, and floor grating in a portion of the elevated section of the EFL.

3. Importance

Loss or failure of AWS conduit would eliminate AWS flow, hindering fishes' ability to find any of the three EFL fish entrances and the entrances would not be operated within criteria.

E. West Fish Entrance (System 5)

1. Description

The west fish entrance consists of three (one plus two backup) telescoping, roller-guided steel weirs consisting of three leaves, 6'-9" high by 8'-6" wide, that are raised and lowered using an electric hoist and spreader beam arrangement. Steel gratings installed in the floor of the entrance structure are hydraulically connected to the AWS conduit.

2. Function

The west fish entrance provides access to the EFL from the west end of the tailrace. The entrance also establishes ladder entrance velocity and water level.

3. Importance

Loss or failure of all three weirs would eliminate the only opening for fish to enter the west entrance of the ladder. Backwater created by the entrance weirs affects EFL hydraulic performance.

F. Transportation Channel (System 6)

1. Description

The transportation channel is a concrete-walled, open-topped channel extending from the junction pool to the south fish entrance. A length of the channel walls near the south entrance is rock-lined.

2. Function

The transportation channel provides a conduit for fish entering the south fish entrance to swim to the junction pool and access the elevated ladder section of the EFL.

3. Importance

Loss or failure of the transportation channel would prevent the passage of fish via the south fish entrance.

G. South Fish Entrance (System 7)

1. Description

The south fish entrance consists of two (one plus one backup) telescoping, roller-guided steel weirs consisting of three leaves, 6'-9" high by 15'-0" wide, that are raised and lowered using an electric hoist and spreader beam arrangement. Steel gratings installed in the floor of the entrance structure are hydraulically connected to the AWS conduit. A third, side entrance weir has been permanently sealed.

2. Function

The south fish entrance provides access to the EFL from the south end of the spillway. The entrance establishes south fish entrance velocity and water level.

3. Importance

Loss or failure of all both weirs would eliminate the only opening for fish to enter the south entrance of the ladder. Backwater created by the entrance weirs affects EFL hydraulic performance.

H. East Fish Ladder (System 8)

1. Description

The ladder consists of the elevated section of the EFL beginning at the junction pool and ending at the forebay. Reinforced concrete channel with a 1:16 rising floor slope and fixed horizontal concrete overflow weirs spaced every 16 feet. The lower section of the ladder is fitted with steel floor gratings that are hydraulically connected to the AWS conduit.

2. Function

The ladder provides transition from the junction pool to the fish ladder exit.

3. Importance

Loss or failure of the elevated section of the EFL would prevent the passage of fish.

I. Fish Lock (System 9)

1. Description

The fish lock is a fish passage system that was designed to transport fish over the dam without using the elevated section of the ladder. It consists of a concrete-lined channel connecting the junction pool to a reinforced concrete silo. Fish would enter the silo via the channel. Once within the silo, gates would be closed and the silo gravity-filled with water taken from the forebay via a series of valves and piping. The fish would rise to the top of the silo where a gate would be opened, releasing the fish at the ladder exit.

2. Function

The function of the fish lock is to transport fish over the dam without using the elevated section of the ladder.

3. Importance

The fish lock has not been used to transport fish since the construction of the dam. It may hold promise as a backup AWS source for the EFL.

J. Fish Turbines (System 10)

1. Description

The fish turbines are two Kaplan units (13.5 MW/2,500 cfs nominal capacity each) located within the powerhouse whose discharge is hydraulically connected to the AWS conduit of the EFL.

2. Function

The fish turbines provide AWS flow to the EFL.

3. Importance

The fish turbines are the sole source of AWS flow to the EFL. Loss or failure of the units would hinder fishes' ability to find any of the three EFL fish entrances. In addition, the AWS provides flow needed to maintain entrance operations within hydraulic criteria. In the event that one or both fish turbines fail, procedures are in place to operate the ladder at reduced capacity until the turbines are restored.

K. Counting Station (System 11)

1. Description

The counting station is a submerged room with viewing window that looks out into the channel. A motor-operated, moveable channel wall (crowder) operates to force fish to swim through a narrowed aperture in front of the window within view of a counting station operator. The crowder is equipped with lights and a window cleaner.

2. Function

The counting station provides the ability to observe fish movement as well as count the number passing through the ladder.

3. Importance

The counting station is necessary to assess ladder efficiency and gather overall fish passage statistics. Failure would not necessarily affect the passage of fish, unless blockage of the channel occurred.

L. Fish Ladder Exit (System 12)

1. Description

The fish ladder exit section is the upper section of the EFL and consists of a concrete channel fitted with fabricated steel, adjustable horizontal overflow weirs.

2. Function

The exit section provides the transition from the ladder to the forebay. The adjustable weirs provide the ability to regulate flow through the ladder through a range of forebay elevations and maintain ladder weir head criteria.

3. Importance

Loss or failure of the exit section channel or any of the adjustable weirs would prevent fish from entering the forebay. Failure of the exit weir in the closed position would dry up the upper sections of the ladder.

M. Fish Turbine Controls (System 13)

1. Description

The fish turbines have local control cabinets adjacent to the units, and can also be monitored from the powerhouse control room.

2. Function

The fish turbine operation is monitored and relayed by the control system.

3. Importance

Loss or failure of fish turbine controls could result in the loss of AWS flow to the EFL.

# 2.0 RELIABILITY ASSESSMENT

## 2.1 Methodology

One of the common tools used in reliability engineering is Failure Modes and Effects Analysis (FMEA). FMEA was developed by the U.S. military in 1949. It found application in planning the Apollo space missions in the 1960s and was adopted by the Ford Motor Company in the 1980s to prevent recurrence of problems of the type associated with the Pinto automobile, in which seemingly minor collisions caused the gas tank to explode. Today its use has spread to many industries. It is associated with the respected quality assurance systems QS-9000 and ISO/TS 16949. Washington Group International has used it for evaluation of potential problems of hydroelectric plants such as powerhouse flooding and generating unit control failures.

One definition of the tool reads as follows: "FMEA is a team-based systematic and proactive approach for identifying the ways that a process or design can fail, why it might fail, the effects of that failure and how it can be made safer." *(source: Institute for Safe Medication Practices Canada)*

Step one is to pick a team consisting of people knowledgeable in the process or design. Based on their knowledge, the team selects, in a brainstorming session, the failure modes to be considered (the "whats"). The team then identifies the causes (the "whys") and the effects of each failure. The failure modes and effects are then listed in a matrix format and evaluated against several criteria using a predetermined scoring system.

In its original form FMEA uses 3 criteria to evaluate each specific failure: Severity (S), frequency of occurrence (O), and likelihood of detection (D). Each criterion is assigned a numerical rank based on a predetermined scale. The scales selected will be unique to the application; for example, frequency of occurrence in the case of a mechanical device could relate to number of cycles of operation per failure. The rankings of the three criteria are multiplied to obtain a Risk Priority Number (RPN) for the specific failure being evaluated (thus, RPN = S x O x D). The RPNs for all failure modes considered are then compared to identify those having the highest risk. Priority for repairs or modifications is determined in order of highest to lowest RPN. In some applications, items with high severity rankings are also given priority regardless of RPN ranking.

A limitation of FMEA is that it is unable to discover complex failure modes involving multiple failures. Thus, it would not be used to evaluate the risk of an airliner crash, which is almost always the result of multiple failures in a complex system. Another limitation of FMEA is its difficulty addressing some powerhouse systems, such as fire protection, where there is a series of components all of which must operate properly to prevent system failure. The reliability of the series system is then the product of the reliabilities of all the components. Operation of the fish ladders at The Dalles does not involve such risks as complex failure modes or failure of one component in a series system. In general, single event failure probabilities are adequate to describe the reliability of the ladders. Therefore, application of FMEA to The Dalles Dam Ladder Reliability Assessment is appropriate.

In applying FMEA to the ladders, it was found useful to assess a failure mode's severity of effects on individual aspects of ladder function and operation, rather than trying to assess the severity of effects on the overall ladder function and operation (WGI has also done this before in applying FMEA to other projects). The "severity of effects" column was subdivided to display 7 areas that were of concern to the District. For calculation of the RPN, the highest ranking of the 7 was used as the multiplier.

Because of its importance to the District, a column was added to display a fourth multiplier, representing duration of "downtime," which is the period when the ladder system component, and in some cases the ladder, would be out of service following the failure. A column was also added to convey information about availability of redundant or backup parts or equipment. The redundancy column was not factored directly into the RPN, but the redundancy information was used to develop the downtime ranking.

Using information gathered during the Phase 1 inspections, a matrix was developed for each ladder listing the various ladder systems, their function, and the modes by which they could potentially fail (Appendices A and B). Using a one-to-five scoring criteria, the severity of the effect (severity factor) of the failure modes on ladder operating criteria, fish behavior, other ladder systems, or ladder-related processes was quantified. Also quantified were the failure modes' rates of occurrence (occurrence factor), ability to be detected (detection factor), and the downtime associated with repair or replacement of the failed system (downtime factor). The existence of redundant systems was not assigned a numerical factor, but rather simply noted in the matrix. The products of the various factors were computed and a Reliability Priority Number (RPN) assigned to each failure effect, with a high RPN denoting a failure effect that could most greatly compromise the reliability of the ladder, and a low RPN representing a relatively minimal effect.

The matrix was developed, populated, and scored during a two-day workshop held at Washington Group's offices. Following the workshop, District operation personnel were consulted to develop specific failure modes related to the fish turbines that were not obvious during the inspection of either ladder.

## 2.2 Matrix Definitions

Terms and criteria listed in each matrix are defined in Table 1:

**Table 1 – Matrix Definitions**

| Term | Definition |
|---|---|
| Potential Failure Mode | Any manner in which the system could fail to perform its intended function |
| Potential Effect of Failure | The impact a failure could have should it occur |
| Potential Cause of Failure | Possible events or actions that could lead to a failure |
| Ladder Criteria (listed below) | The key criteria, systems, or processes that could be effected by a failure |
| • Inspection and Maintenance | How severely the failure mode affects the ability to inspect and maintain the specified system, component, or process |
| • Velocity at Entrance Weir/Lower Ladder | How severely the failure mode affects the ability to maintain the proper velocity of water at the ladder entrance |
| • Submergence at Entrance Weir | How severely the failure mode affects the ability to maintain the proper submergence at the ladder entrance |
| • Head on Ladder Weirs | How severely the failure mode affects the ability to maintain proper head across the ladder weirs |
| • North Wasco Powerhouse | How severely the failure mode affects the operation of the North Wasco Powerhouse |
| • Fish Turbine Generation | How severely the failure mode affects the generation of power by the fish turbines |
| • Ability to Count Fish | How severely the failure mode affects the ability to count fish passing through the ladder |
| • Fish Behavior | How severely the failure mode affects the behavior of fish |
| Occurrence | Probability that the cause or mechanism of failure will occur |
| Current Detection Method | Existing procedures or systems that would detect the cause, mechanism of failure, or the failure mode itself |
| Detection | Likelihood that the current detection methods could prevent or detect the failure mode |
| Downtime | Length of time that a failed system is out of service and adversely affecting the ladder operation |
| Redundant System | A system that can replace the function of a failed system |
| RPN | Reliability priority number. The product of the greatest severity, occurrence, detection, and downtime factors |

### 2.3 Severity Factor Scale

The severity factor scale is defined in Table 2:

**Table 2 – Severity Factors**

| Factor (score) | Definition |
|---|---|
| **1** | No effect |
| **2** | Nominal effect |
| **3** | Affected system operable, but at reduced performance level |
| **4** | Affected system operable, but certain abilities lost |
| **5** | Affected system inoperable with loss of primary function |

### 2.4 Occurrence Factor Scale

The occurrence factor scale is defined in Table 3.

**Table 3 – Occurrence Factors**

| Factor (score) | Definition | Probability |
|---|---|---|
| **1** | Failure is unlikely | < 1 in 1,000,000 cycles |
| **2** | Failure is uncommon | 1 in 15,000 cycles |
| **3** | Occasional failures | 1 in 2,000 cycles |
| **4** | Failure is typical | 1 in 25 cycles |
| **5** | Failure is almost inevitable | 1 in 5 cycles |

### 2.5 Detection Factor Scale

The detection factor scale is defined in Table 4:

**Table 4 – Detection Factors**

| Factor (score) | Definition |
|---|---|
| 1 | Almost certain that the current detection methods will detect a potential cause or failure mechanism and subsequent failure mode |
| 2 | High chance that the current detection methods will detect a potential cause or failure mechanism and subsequent failure mode |
| 3 | Moderate chance that the current detection methods will detect a potential cause or failure mechanism and subsequent failure mode |
| 4 | Low chance that the current detection methods will detect a potential cause or failure mechanism and subsequent failure mode |
| 5 | Remote chance that the current detection methods will detect a potential cause or failure mechanism and subsequent failure mode |

## 2.6 Downtime Factor Scale

The downtime factor scale is defined in Table 5:

**Table 5 – Downtime Factors**

| Factor (score) | Definition |
|---|---|
| 1 | System or condition can be repaired or corrected on same day it is detected |
| 2 | System or condition can be repaired or corrected within one week of its detection |
| 3 | System or condition can be repaired or corrected within one month of its detection |
| 4 | System or condition can be repaired or corrected within three months of its detection |
| 5 | System or condition can be repaired or corrected within six months of its detection |

## 3.0 RELIABILITY ASSESSMENT RESULTS

The paragraphs below correspond to similarly numbered line items in each reliability matrix (Appendices A and B). The content of the matrix is not reproduced, rather the basis for the rankings in the matrix is provided. Special attention is given to those items that scored an RPN of 30 or above (shown in **bolded** text).

### 3.1 North Fish Ladder

3.1.1 System 1: Ladder Entrance

A. Telescoping Weir Leaves Separate (**RPN = 30**)

The entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Replacement time may vary if diver is required for the fix which will restore the normal redundant condition with two gates available. The severity of this condition, which has occurred in the recent past, is increased if it occurs at high tailwater levels when the upper gate leaves could become widely separated from the bottom leaves. This problem may be eliminated if the guide slots are repaired.

B. Hoist Failure (RPN = 10)

Inability to operate entrance weir. The entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

C. Entrance Weir Control System Malfunction (RPN = 10)

Inability to operate entrance weir. The entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

D. Hoist Rope Breaks (RPN = 15)

Inability to operate entrance weir. The entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair period may vary if diver is required for fix.

E. Approach to Ladder Impacted by Juvenile Spill (**RPN = 96**)

High velocity flow along the bank since implementation of the juvenile spill regime acts to reduce the number of fish entering ladder. This reduction has already occurred based on verbal briefing by District fisheries biologists on 12/28/2006, as follows: *"North ladder used to attract about 30% of the adult salmon passing the project….Since installation of training walls and changes to spill procedures…the ladder attracts only about 10% of the adults. This is despite installation of a new wall between the ladder entrance pool and spillway bay 1 to keep the spillway flow from rolling across into the ladder flow."* ~ Complete text in Trip Report dated January 16, 2007. Remedy of this condition would require major hydraulic structure modifications, so for the near future at least the "Downtime" is measured by the duration of the spill. The volume of water spilled, which is variable, affects the severity of the condition. Therefore a Downtime of up to three months was chosen although spill may continue longer at a reduced rate.

F. Approach to Ladder Impacted by Juvenile Spill (**RPN = 96**)

Based on model studies at ERDC, increased tailwater elevation, cross flow, aerated flow and inability to operate ladder within criteria are expected to reduce number of fish entering ladder following installation of the extended spill wall between bays 8 and 9. See HELCRABS, Executive Summary, Evaluation of Existing Operation: *"As the tailwater rises, the low velocity problems spread downstream to most of the lower fishway channel."* This item shares the same Downtime reasoning as the item above.

G. Sloughing of North Bank into Tailrace (RPN = 24)

Change of tailwater level may occur in excess of ability to operate ladder within criteria. Probability of occurrence of a failure that large is not considered high given the favorable geology of the bank although some cracking and sloughing has occurred. The recent changes to the spill patterns may be encouraging some rock plucking from the surface of the bank.

### 3.1.2 System 2: Lower Ladder

A. Diffuser Grating Plugged (RPN = 12)

This condition affects distribution of AWS flow, however, at average tailwater levels there is negligible effect because the lower ladder weirs are drowned out to the level of AWS head. At low tailwater (a rare occurrence) the effect could become significant.

B. Diffuser Grating Mounting Failure (**RPN = 72**)

Displacement of the diffuser grating can cause loss of migrating fish into the AWS and therefore the condition is ranked more severe than the case of the plugged grating. This has happened elsewhere in the TDA ladders. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. The best medicine is prevention, by replacing corroded studs and clips during annual inspections.

C. Failure of Weir Attachment to Wall (RPN = 24)

The resulting weir collapse can place the immediate upstream weir head out of criteria, unless the failure occurs to one of the drowned lower weirs. Although such failures have occurred in the East Ladder, they are not considered frequent events. In the lower ladder a weir failure may not impact fish passage at all because many weirs are drowned out.

### 3.1.3 System 3: AWS Conduit

A. Structural Cracking at Transition from N. Wasco Discharge (RPN = 20)

This is considered to have a severe effect on fish passage and on the North Wasco powerhouse during the repair period when the AWS cannot be operated. Fortunately, it is a low probability event and the downtime for repair is short.

B. Diffuser Gate Inoperable (Stuck Open/Closed) (RPN = 18)

Like the plugged diffuser grating above, this affects the distribution of flow from the AWS into the ladder. The effect is significant only at low tailwater—a rare occurrence.

C. Structural Failure of Stovepipe Weirs (**RPN = 30**)

The weirs prevent backflow of water from the ladder into the AWS conduit. A failure near the upper end of the AWS could result in loss of some or all of the ladder flow for nearby pools. This results in a larger ranking than the other postulated events affecting the AWS conduit. Unlike the main weir failures, we have no report of this type of failure occurring in the past; if it occurred it would probably be due to earthquake.

D. Failure of AWS Dewatering Pump (RPN = 20)

This failure would delay performance of annual inspection until it was repaired.

E. Insufficient AWS Design Flow for Ladder Geometry (**RPN = 60**)

This design flaw has not prevented the ladder from passing fish although it may have resulted in discouraging or delaying migration for some fish. It is considered a built-in impairment to ladder function rather than a failure of something that once worked properly. HELCRABS Executive Summary, Evaluation of Existing Operation, reads in part: *"The channel velocity criteria are not met most of the time at the upstream end of the lower fishway channel….The low velocities are caused by low rates of inflow from the ladder section and a general limitation of AWS inflow."* NMFS views this a little differently, having recently stated that the ladder is too large [for the available water]. One HELCRABS recommendation is to lower the crests of the stovepipe weirs to *"improve lower channel velocities by about 10 – 20% at the upstream end."* (Section 5.2

Option 2); another is to remove certain flooded-out weirs from the lower ladder (Option 1). The downtime ranking is based on implementing these recommendations. Other recommendations requiring longer downtime to implement might eventually be required, but were not considered in this assessment.

3.1.4 System 4: North Wasco PUD Turbine

A. Trip of North Wasco PUD Turbine Assuming Plunge Pool Operable (RPN = 15)

Detection is immediate, and the original (now backup) AWS supply can be routed through the plunge pool by opening the gate.

B. Trip of North Wasco PUD Turbine Assuming Plunge Pool Inoperable (RPN = 10)

Detection is immediate, although recovery is dependent upon the restart of the PUD turbine. Nevertheless, the RPN is lower than in the previous case because this failure is considered to be rare.

3.1.5 System 5: AWS Plunge Pool

A. Plunge Pool Gate Fails in Open Position (RPN = 20)

The primary impact is to the North Wasco PUD's turbine operation, rather than the fish ladder.

B. Plunge Pool Gate Fails in Closed Position (RPN = 10)

The RPN is lower than in the previous case because this failure in combination with a turbine trip is considered to be rare.

C Structural Failure of Tiebacks Leading to Collapse of Pool Walls (RPN = 24)

Since the PUD turbine acts as a backup this is not likely to impair fish ladder operation.

3.1.6 System 6: Rock-Lined Channel

A. Weir Collapse (RPN = 24)

Although this failure would affect the ability of fish to use the ladder, there has been no report of such a failure so it is considered uncommon.

B. Rock Falling in the Channel (RPN = 27)

Although there have been rockfalls, as far as could be determined, none had ever blocked the channel or an orifice (each weir has two orifices).

C. Vegetation Damaging or Blocking Ladder (RPN = 18)

Vegetation has grown in or fallen into the ladder but there were no reported disruptions to fish passage.

3.1.7 System 7: Counting Station

A. Crowder Failure (RPN = 20)

This leads to inability to count fish but does not in itself impair fish passage.

B. Picketed Lead Failure in Open Position (RPN = 20)

Counting ability is impaired as some fish pass through the leads. Debris may be passed down the ladder and interfere with fish passage.

C. Picketed Lead Failure in Closed Position (RPN = 24)

If the failure is caused by debris accumulation, the ladder flow and fish passage may be impaired. In the worst case all water may be forced through the gap between the crowder and the counting window, perhaps making passage impossible until a structural collapse of the picketed leads occurs.

D. Failure of Counting Window Lighting (RPN = 10)

This causes brief impairment or loss of ability to count fish but does not affect ladder performance or fish migration.

E. Failure of Count Window Cleaner (RPN = 20)

Similar to preceding item but repair time can be longer.

F. Failure of Count Window Electrical Systems (RPN = 10)

Similar to preceding items. It is assumed that power can be restored promptly.

3.1.8 System 8: Exit Section AWS

A. AWS Intake Grating Attachment Failure (**RPN = 30**)

Debris can enter the AWS and foul the floor gratings, reducing or stopping AWS flow. However, this is a low probability event.

B. AWS Intake Grating Plugged (RPN = 12)

The design makes this a low probability event and the fix, should the problem ever occur, is easy.

C. Failure of Sluice Gate (Open) (RPN = 12)

The ladder flow from counting station on down the central ladder cannot be regulated. A stuck open sluice gate is unlikely to prevent fish passage, however.

D. Failure of Sluice Gate (Closed) (RPN = 16)

Loss of AWS to the upper ladder with resulting impairment of fish passage. It is assumed that the gate may be manually opened if the automated power operator has failed.

E. Water Level Reader Failure (RPN = 16)

At worst the gate could fail closed, duplicating the previous item.

F. Floor Diffuser Grating Plugged (**RPN = 30**)

This condition is more serious than the previous ones because it is necessary to shut the ladder down and unwater it in order to clean out the diffuser.

G. Diffuser Grating Mounting Failure (**RPN = 72**)

If the grating is displaced loss of fish into the AWS may occur. This has happened elsewhere in the TDA ladders. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. The best medicine is prevention, by replacing corroded studs and clips during annual inspections.

3.1.9 System 9: Ladder Exit Section

A. Failure of Weir Attachment to Wall (RPN = 18)

Although there is precedent for this occurring elsewhere in the TDA ladders, it presents only a minor impediment to fish passage and is readily detected.

B. Trashrack Clogging, Trashrake Failure (RPN = 16)

It is assumed that ladder flow, though reduced, will still be sufficient to keep fish in the ladder alive until the rake is repaired. The worst-case scenario of total clogging was considered too improbable to affect the ranking.

## 3.2 East Fish Ladder

3.2.1 System 1: East Fish Entrance

A. Telescoping Weir Leaves Separate (**RPN = 30**)

As a result of separation of telescoping weir leaves, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Replacement time may vary if diver is required for the fix which will restore the normal redundant condition with two gates available. The severity of this condition, which has occurred in the recent past, is increased if it occurs at high tailwater levels when the upper gate leaves could become widely separated from the bottom leaves. This problem may be eliminated if the guide slots are repaired.

B. Hoist Failure (RPN = 10)

If the entrance weir hoist fails and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

C. Control System Failure (RPN = 10)

If the control system fails, and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

D. Hoist Rope Breaks (RPN = 15)

If the hoist rope breaks, and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair period may vary if diver is required for fix.

3.2.2 System 2: Junction Pool

A. Failure of the Telescoping Weirs (RPN = 20)

As a result of failure of the telescoping weirs at the junction pool, the flow distribution to the east, south, and west entrances would be affected. Depending on the weir failure, it is possible that the flow imbalance could be compensated for by adjustment of the entrance weirs at each entrance to keep each entrance within criteria despite the flow imbalance. Detection chance is high because water level in each of the entrances is monitored. Operator action is required after the detection to repair the weir.

B. Hoist Failure (RPN = 10)

If the hoist fails, and the junction pool weirs are subsequently inoperable, the flow distribution to the east, south, and west entrances would be affected. It is likely that the flow imbalance could be compensated for by adjustment of the entrance weirs at each entrance to keep the entrance within criteria.

C. Control System Failure (RPN = 10)

If the junction pool weir control system fails, and the junction pool weirs are subsequently inoperable, the flow distribution to the east, south, and west entrances would be affected. It is likely that the flow imbalance could be compensated for by adjustment of the entrance weirs at each entrance to keep the entrance within criteria.

D. Hoist Rope Breaks (RPN = 15)

If the hoist rope fails, and the junction pool weirs are subsequently inoperable, the flow distribution to the east, south, and west entrances would be affected. It is likely that the flow imbalance could be compensated for by adjustment of the entrance weirs at each entrance to keep the entrance within criteria.

E. Diffuser Grating Plugged (RPN = 12)

This condition can affect distribution of AWS flow to the entrances. It is necessary to unwater the ladder to clean debris from the diffuser grating.

F. Diffuser Grating Mounting Failure (**RPN = 72**)

Displacement of the diffuser grating can allow migrating fish into the AWS and therefore the condition is ranked as more severe than the case of the plugged grating. Mounting failure has been reported to occur in the TDA ladders due to aging studs and clips. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. Mounting failure can be best prevented by replacing corroded studs and clips during annual inspections.

G. Imbalanced Flow Distribution, Excess Flow to East Entrance **(RPN = 75)**

As a result of an imbalanced flow distribution at the junction pool, hydraulics at the entrances may be out of criteria, there may be impacts on fish passage, and/or a need for higher AWS flow than would be required if the junction pool flows were balanced. Detection of the imbalance is based on observations at the entrances, operations required at each entrance to maintain entrance criteria for excess or low entrance flows, and visual observation of flow patterns at the junction pool. Rebalancing the flow distribution at the junction pool could reduce the load on the fish turbines by reducing the total quantity of AWS flow required for operation of the three entrances within criteria. The flow could be rebalanced by introducing the equivalent of one or more additional weirs in the east entrance, either by repositioning existing gate leaves using existing guides or by new construction. The high RPN value is influenced by the duration value, since this imbalance is a typical occurrence.

3.2.3 System 3: Collection Channel

A. Diffuser Gate Failure or Leakage (RPN = 24)

If the diffuser gates do not close properly due to sedimentation in the gatewells or accumulation of clams and mussels, the AWS flow distribution can be affected. However, these gates are not operated on a regular basis to throttle diffuser flow and the leakage is likely minimal.

B. Diffuser Grating Mounting Failure **(RPN = 72)**

Displacement of the diffuser grating can allow migrating fish into the AWS and therefore the condition is ranked as more severe than the case of the plugged grating. Mounting failure has been reported to occur in the TDA ladders due to aging studs and clips. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. Mounting failure can be best prevented by replacing corroded studs and clips during annual inspections.

3.2.4 System 4: AWS Conduit

A. Diffuser Gate Inoperable (Stuck Open/Closed) **(RPN = 72)**

If the diffuser gates are inoperable, the AWS flow distribution to the three entrances can be affected. These gates are not operated regularly to throttle diffuser flow, but are used to control the amount of AWS flow to each entrance. At present the condition of the gates is not a concern for normal ladder operations. The high RPN for the diffuser gates is associated with the history of corroded gate operators and observations during the inspections that showed gates in partially open positions at the NFL, Leaking gates were observed in the collection channel and would likely result in the inability to partition the ladder for partial dewatering in the future.

B. Structural Failure of Stovepipe Weirs **(RPN = 36)**

The weirs prevent backflow of water from the ladder into the AWS conduit. A failure near the upper end of the AWS could result in loss of some or all of the ladder flow for nearby pools. This results in a larger ranking than the other postulated events affecting the AWS conduit. Unlike the main weir failures, we have no report of this type of failure occurring in the past; if it occurred it would probably be due to earthquake.

C. Failure of AWS Dewatering Pumps (RPN = 20)

Failure of the AWS dewatering pumps would prevent dewatering of the transportation and collection channels for routine annual maintenance. The RPN is influenced primarily by the severity of impacts to inspection and maintenance.

3.2.5 System 5: West Fish Entrance

A. Telescoping Weir Leaves Separate **(RPN = 30)**

As a result of separation of telescoping weir leaves, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Although there are spare gate leaves, replacement time may vary if diver is required for the fix, which will restore the normal redundant condition with two gates available. The severity of this condition, which has occurred in the recent past, is increased if it occurs at high tailwater levels when the upper gate leaves could become widely separated from the bottom leaves.

B. Hoist Failure (RPN = 10)

If the entrance weir hoist fails and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

C. Control System Failure (RPN = 10)

If the control system fails, and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

D. Hoist Rope Breaks (RPN = 15)

If the hoist rope breaks, and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair period may vary if diver is required for fix.

E. Diffuser Grating Plugged with Debris (Gravel) (RPN = 18).

Plugging of the diffuser grating with debris or gravel may affect the distribution of AWS flow. It is necessary to shut the ladder down and unwater it in order to clean out the diffuser grating.

### 3.2.6 System 6: Transportation Channel

A. Rock Falls into Channel (RPN = 18)

Rock fall into the channel affects channel roughness and channel shape, depending on the amount of rock. The rock may also provide holding areas for fish and affect the local velocity patterns along the channel bottom. Staff reported during the inspections that rock fall into the transportation is relatively common and that several truckloads of material were removed during the maintenance period.

### 3.2.7 System 7: South Fish Entrance

A. Telescoping Weir Leaves Separate **(RPN = 30)**

As a result of separation of telescoping weir leaves, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Although there are spare gate leaves, replacement time may vary if diver is required for the fix, which will restore the normal redundant condition with two gates available. The severity of this condition, which has occurred in the recent past, is increased if it occurs at high tailwater levels when the upper gate leaves could become widely separated from the bottom leaves.

B. Hoist Failure (RPN = 10)

If the entrance weir hoist fails and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

C. Control System Failure (RPN = 10)

If the control system fails, and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair can be prompt once condition is detected.

D. Hoist Rope Breaks (RPN = 15)

If the hoist rope breaks, and the entrance weirs are subsequently inoperable, the entrance velocity, head and/or submergence may be out of criteria. Detection chance is high because water level is monitored. Operator action is required after detection of the condition to close the entrance gate in service and open the out of service gate. Repair period may vary if diver is required for fix.

3.2.8 System 8: Ladder

A. Diffuser Grating Plugged (RPN = 12)

This condition can affect distribution of AWS flow to the entrances. It is necessary to unwater the ladder to clean debris from the diffuser grating.

B. Diffuser Grating Mounting Failure **(RPN = 72)**

Displacement of the diffuser grating can allow migrating fish into the AWS and therefore the condition is ranked as more severe than the case of the plugged grating. Mounting failure has been reported to occur in the TDA ladders due to aging studs and clips. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. Mounting failure can be best prevented by replacing corroded studs and clips during annual inspections.

C. Failure of Weir Attachment to Wall (RPN = 24)

If a weir attachment fails and a weir collapses, it can place the immediate upstream weir head out of criteria. Although such failures have occurred in the EFL, they are not considered frequent events. Downtime for such an event could be significant, requiring up to a month for repair/replacement of the weir attachment or components.

3.2.9 System 9: Fish Lock

A. Junction Pool Bulkhead Gate Failure (RPN = 24)

If the junction pool bulkhead gate fails, there is a minimal potential for fish holding or injury and a potentially significant downtime for repairs.

B. Silo Bulkhead Gate Failure (RPN = 24)

If the silo bulkhead gate fails, flow from the upper ladder could enter the fish lock and result in the ladder being out of criteria and a potential for fish injury. There is a potential for downtime associated with this failure of up to one month.

3.2.10 System 10: Fish Turbines

For the following failure modes, either one fish turbine or both turbines are assumed to fail as indicated. A single turbine failure will result in reduction in ladder capacity during the repair period. Failure of both turbines is much less likely but can occur due to certain events in common; such failures would take the AWS out of service and greatly reduce the effectiveness of the ladder. There is not currently a backup AWS system at TDA EFL. The major difference between the following failure modes is the turbine downtime required to replace or repair. Blade crack repairs are not listed below because they take place during scheduled outages.

A. Stator Winding Failure - One or Two Bad Coils **(RPN = 40)**

Single turbine failure. A stator winding failure would require one to two months to cut out the bad coils and re-rate the unit.

B. Stator Winding Failure - Forcing Unit Rewind (RPN = 25)

Single turbine failure. A stator winding failure forcing a unit rewind would require up to two years of downtime to repair or replace the unit.

C. Main Transformer Failure (RPN = 15)

Both turbines failure. A main transformer failure would require one day to repair/replace. A bus tie to main unit transformer can also be closed to restore service to the fish turbines.

D. Powerhouse Line Failure (RPN = 15)

Both turbines failure. A powerhouse line failure would require one month to repair/replace.

E. Generator Breaker Failure **(RPN = 40)**

Single turbine failure. A generator breaker failure would require up to three months to repair/replace.

F. Thrust Bearing Failure **(RPN = 40)**

Single turbine failure. A thrust bearing failure would require up to three months to repair/replace.

G. Guide Bearing Failure **(RPN = 40)**

Single turbine failure. A guide bearing failure would require up to three months to repair/replace.

H. Governor Failure (RPN = 15)

Single turbine failure. A governor failure would require up to one month to repair/replace.

I. Wicket Gate Failure (RPN = 25)

Single turbine failure. A wicket gate failure would require up to six months to repair/replace.

J. Turbine Failure – Loss of Blade (RPN = 25)

Single turbine failure. A loss of blade failure would require up to one year to repair/replace.

K. Turbine Failure - Blade Bushing Failure (RPN = 25)

Single turbine failure. A blade bushing failure would require up to one year to repair/replace.

L. Excitation Failure - Component Problem (RPN = 10)

Single turbine failure. An excitation failure due to component problem would require up to one week to repair/replace.

M Excitation Failure - System Meltdown (RPN = 25)

Single turbine failure. An excitation failure due to system melt down would require up to two years to repair/replace.

N. Generator Cooler Failure - Plugged with Clams (RPN = 10)

Single turbine failure. A generator cooler failure due to plugging with clams would require up to one week to repair/replace.

O. Generator Cooler Failure - Leak in Cooler (RPN = 20)

Single turbine failure. A generator cooler failure due to a leak in the cooler would require up to two months to repair/replace.

P. Turbine Packing Gland Failure (RPN = 15)

Single turbine failure. A turbine packing gland failure would require up to two weeks to repair/replace.

3.2.11 System 11: Counting Station

A. Crowder Failure (RPN = 20)

The most significant impact of a crowder failure is the inability to effectively count fish.

B. Picket Lead Failure (in Open Position) (RPN = 12)

A picket lead failure in the open position could result in debris passage through ladder and would limit the ability to count fish.

C. Picket Lead Failure (in Closed Position) (RPN = 12)

If the failure is caused by debris accumulation, the ladder flow and fish passage may be impaired. In the worst case all water may be forced through the gap between the crowder and the counting window, perhaps making passage impossible until a structural collapse of the picketed leads occurs.

D. Failure of Count Window Lighting (RPN = 10)

Failure of the count window lighting results in inability to effectively count fish but does not impair fish passage through the ladder.

E. Failure of Count Window Cleaner (RPN = 20)

Failure of the count window cleaner results in inability to effectively count fish but does not impair fish passage through the ladder. This system may require slightly more downtime to repair than the lighting system.

F. Failure of Count Station Electrical Systems (RPN = 10)

Failure of the count station electrical systems results in inability to effectively count fish. It is assumed that the electrical system failure is due to power outage and will be restored within one day.

3.2.12 System 12: Fish Ladder Exit

A. Weir Operation Failure **(RPN = 30)**

Failure to properly operate the exit section movable weirs through hoist failures, motor failures, cable failures would result in the inability to maintain velocity and weir head criteria in the ladder. Impacts are greatest to hydraulic criteria and fish behavior due to incorrect ladder flows and/or flow patterns in the exit section.

B. Trashrack Clogging (RPN = 16)

If intake trashrack clogging is significant, the ladder flow would be reduced. However, this is unlikely to occur to a significant level with routine cleaning.

3.2.13 System 13: Control Room

A. Entrance Weir Control Panel Electrical Failure (RPN = 20)

If the entrance weir control panel fails due to aged components, the result is loss of ability to control entrance gates and regulate ladder flow. The downtime associated with replacement/repair of components is assumed to be one week.

B. Fish Turbine Control Panel Electrical Failure (Assumes Both Units Affected) (RPN = 20)

If the fish turbine control panel fails due to aged components, the result is loss of ability to control the fish turbines and regulate AWS flow. The downtime associated with replacement/repair of components is assumed to be one week.

# 4.0 CONCLUSIONS

## 4.1 General

It should be noted that the reliability assessment is a subjective evaluation of the relative reliability of ladder systems in the NFL and EFL and is intended as a tool for identifying systems and practices that are most effective in keeping each ladder operating reliably and those with the greatest potential for improvement. This study is not intended to provide an overall probability of failure and should not be interpreted to mean either ladder is in imminent danger of failing. It is also important to note that the ladder reliability assessments have been performed independently for the NFL and EFL and are not intended to provide a relative reliability of the ladders as compared to each other overall or for individual ladder systems.

Several general conclusions were made as a result of the reliability assessment:

A. In general, the occurrence values for ladder system failures are typical for mechanical or structural failure of aging components. Some failure is unavoidable in systems that were built over 50 years ago. Several failure modes (separation of telescoping entrance weir leaves, diffuser grating mounting failure, and EFL junction pool imbalance) may require additional attention to reduce occurrence values and improve reliability.

B. Detection is generally very good for systems that are visible and able to be monitored. Prompt detection of failures by alarm systems and operators improves reliability. The annual inspection and maintenance period for both ladders kept the detection values low for many of the failure modes, meaning that potential failures were observed and corrected during annual maintenance.

C. Downtime required for repair/replacement of failed systems is generally within one week of failure. However, downtime could be further reduced for systems as practical by keeping spare components on hand. The redundant systems were noted on the matrix for reference.

## 4.2 North Fish Ladder

Conclusions specific to the NFL include:

A. The effectiveness of the ladder has been reduced by the impact of the new juvenile spill regime. Adverse conditions introduced or made worse by the changes to juvenile spill include increased tailwater velocity affecting the ladder entrance.

B. Internally the lower ladder operates much of the time out of criteria due to insufficient AWS flow, which may also be expressed as, “the ladder is too large for the available water supply.” Although this condition has not prevented the ladder from passing large numbers of fish in the past, future installation of the new extended spill wall between bays 8 and 9 is expected to raise the tailwater, exacerbating the problem.

C. It is possible for AWS diffuser gratings in both the lower and upper ladder to be displaced if the mountings fail due to corrosion, vibration, and/or water pressure. Such failures have occasionally been reported in the East Ladder. Displacement of the gratings can lead to loss of fish, especially lamprey, into the AWS conduits.

D. The consequences of several postulated component failures, such as large gates and weirs, can include removal of the ladder from service for significant periods. However, one failure that has actually occurred and may be recurrent is the separation of the telescoping weir leaves at the ladder entrance. This failure has the potential to reduce both the velocity and head at the ladder entrance, particularly at high tailwater, or vice versa. Once detected, the flow can be switched to the spare entrance.

### 4.3 East Fish Ladder

Results of the assessment indicate that based on their RPN score, the following failure effects could most greatly compromise the reliability of the EFL:

A. Imbalanced flow distribution, excess flow to East Entrance (RPN = 75): As a result of an imbalanced flow distribution at the junction pool, hydraulics at the entrances may be out of criteria, there may be impacts on fish passage, and/or a need for higher AWS flow than would be required if the junction pool flows were balanced. Detection of the imbalance is based on observations at the entrances, operations required at each entrance to maintain entrance criteria for excess or low entrance flows, and visual observation of flow patterns at the junction pool. The high RPN value is influenced by the duration value, since this imbalance is a typical occurrence.

B. Diffuser grating mounting failure, and inoperable diffuser gates (RPNs = 72): Displacement of the diffuser grating can allow migrating fish into the AWS and therefore the condition is ranked as more severe than the case of the plugged grating. Mounting failure has been reported to occur in the TDA ladders due to aging studs and clips. The condition is difficult to detect outside of annual inspections because it does not affect flow or water levels. Mounting failure can be best prevented by replacing corroded studs and clips during annual inspections. If the diffuser gates are inoperable, the AWS flow distribution to the three entrances can be affected. These gates are not operated regularly to throttle diffuser flow, but are used to control the amount of AWS flow to each entrance. The high RPN for the diffuser gates is associated with the history of corroded gate operators and observations during the inspections that showed gates in partially open positions at the NFL.

C. Fish turbine failure modes (RPN = 10 to 40): Sixteen failure modes were identified by TDA operations staff as part of this reliability assessment. The range in RPN values depends on the history of previous failures and downtime associated with the repair/replacement. The failure modes include excitation failures, bearing failure, winding failure, generator cooling failure, and turbine component failure. The fish turbines are currently the sole AWS source for the EFL and therefore failure modes for the fish turbines have a significant impact on hydraulic conditions in the ladder.

# 5.0 RECOMMENDATIONS

## 5.1 North Fish Ladder

Remedying the ladder entrance problems associated with the new juvenile spill regime is outside the scope of this report. The subject will be addressed in other tasks.

Improving criteria compliance within the lower ladder was addressed in the August 2005 draft HELCRABS report on The Dalles Dam North Fish Ladder. Recommended operational changes included closing the lowest fishway diffuser gates and opening the entrance weir further. Potential structural improvements included removing the four lowest ladder weirs; lowering the stovepipe diffuser weirs; and adding a second turbine to the AWS, or alternatively, opening the plunge pool gate to gain added AWS flow. To this list may be added a new suggestion based on the observation that the ladder is too large for the available water: partition the lower ladder lengthwise to reduce the water cross-section and thereby increase its velocity.

The issue of displacement of AWS diffuser gratings is best addressed by replacing loose or corroded attachments during annual inspection outages.

Based on the description of the separation of the telescoping weir leaves, it seems likely that replacement or rebuild of the leaves, and possibly the guides as well, will solve the problem, since it is a recent development following many years of service with no such occurrence.

## 5.2 East Fish Ladder

Based on the reliability assessment results, the following items provide the greatest potential for improving EFL reliability.

Improve the flow distribution in the EFL's junction pool. Additional study of the hydraulic conditions in the junction pool, the hydraulic grade line, velocities in the pool and nearby east entrance would provide information for developing a solution to the junction pool distribution imbalance. Improving the flow distribution to the three entrances would improve entrance conditions, could potentially decrease the amount of AWS flow required for the ladder, and in turn improve the reliability of the fish turbines due to decreased load requirements.

Improve reliability of the diffuser mounting and gate operations. During annual maintenance, proactive replacement of worn clips on diffuser grating will prevent failure. Repair or replacement, along with exercise, of the diffuser gates will improve reliability of the diffuser gates.

A. Improve reliability of the AWS by developing a redundant system for AWS to protect against fish turbine failure. This could include re-visiting a 1994 study of 16 alternatives to provide backup EFL AWS (Study of AFA Auxiliary Water Supply, The Dalles Project Improvements for Endangered Species, Ebasco, June 1994)

B. Review list of spares on hand for the fish turbines to determine if any additional items are required to cover likely failures.

# Appendix A

# NFL Reliability Matrix

## The Dalles Dam
## North Fish Ladder
## Reliability Matrix

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: | | | | | | | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | North Wasco Powerhouse | Ability to Count Fish | Fish Behavior | | | | | | | | |
| 1A | Ladder Entrance | Controls entrance velocity, depth, submergence, in order to maintain entrance criteria for fish attraction and migration. | Telescoping weir leaves separate | Velocity at entrance out of criteria | 1 | 5 | 5 | 2 | 1 | 1 | 3 | Worn gate rollers, structural failure of connection between leaves | 3 | Operator Observation | 2 | 1 | X | 30 | Backup Gate Available, Spare Leaves Available |
| 1B | | | Hoist failure | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 3 | Mech/elec failure of gearbox, sheave, etc. | 2 | Operator Observation | 1 | 1 | X | 10 | Backup Gate Available |
| 1C | | | Entrance weir control system malfunction | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 3 | Control system failure | 2 | Operator Observation | 1 | 1 | X | 10 | Backup Gate Available |
| 1D | | | Hoist rope breaks | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 3 | Structural failure due to cycling, corrosion | 3 | Operator Observation | 1 | 1 | X | 15 | Backup Gate Available |
| 1E | | | Approach to ladder impacted by juvenile spill | Cross-flow and aerated flow | 1 | 4 | 3 | 1 | 1 | 1 | 4 | Spill patterns | 3 | Decreased fish count | 2 | 4 | | 96 | Downtime same as Duration of Spill |
| 1F | | | Approach to ladder impacted by juvenile spill | Increased tailwater elevation, inability to operate ladder within criteria | 1 | 3 | 3 | 2 | 2 | 1 | 4 | Spill patterns | 3 | Decreased fish count | 2 | 4 | | 96 | Downtime same as Duration of Spill |
| 1G | | | Sloughing of north bank into tailrace | Change of tailwater level in ladder entrance approach | 1 | 4 | 3 | 2 | 2 | 1 | 3 | Weathering, Earthquake | 2 | Operator Observation | 1 | 3 | | 24 | |
| 2A | Lower Ladder | Maintain attraction velocity and head drop between pools for fish migration | Diffuser grating plugged | Affects distribution of AWS flow | 1 | 1 | 1 | 3 | 2 | 1 | 2 | Corrosion and debris accumulation | 2 | Annual inspection | 1 | 2 | | 12 | |
| 2B | | | Diffuser grating mounting failure | Diffuser grating may be displaced, loss of fish into AWS | 1 | 1 | 1 | 1 | 1 | 1 | 3 | Corrosion or failure of attachment clips | 3 | Annual Inspection | 4 | 2 | | 72 | Ladder shutdown required for repair |
| 2C | | | Failure of weir attachment to wall | Weir collapse | 1 | 1 | 1 | 4 | 1 | 1 | 3 | Structural failure of attachment to wall | 2 | Operator Observation | 1 | 3 | | 24 | This failure has occurred in past |
| 3A | AWS Conduit | Provides auxiliary water for ladder | Structural cracking at transition from N. Wasco discharge | Downtime associated with crack repair | 1 | 1 | 1 | 1 | 5 | 1 | 5 | Settlement | 2 | Annual inspection | 1 | 2 | | 20 | |
| 3B | | | Diffuser gate inoperable (stuck open/closed) | Affects distribution of AWS flow | 1 | 1 | 1 | 3 | 2 | 1 | 2 | Gate operator corroded | 3 | Annual inspection | 1 | 2 | | 18 | |
| 3C | | | Structural failure of stovepipe weirs | Backflow of water from ladder into AWS conduit | 1 | 1 | 1 | 4 | 1 | 1 | 5 | Structural failure of attachment to wall | 2 | Operator Observation | 1 | 3 | | 30 | This failure has not occurred in past |

**The Dalles Dam**
**North Fish Ladder**
**Reliability Matrix**

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | North Wasco Powerhouse | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3D | | | Failure of AWS dewatering pump | Prevents dewatering of AWS conduit | 5 | 1 | 1 | 1 | 1 | 1 | 1 | Mech/elec failure of pump | 2 | Annual inspection | 1 | 2 | | 20 | |
| 3E | | | Insufficient AWS design flow for ladder geometry | Inadequate AWS flow | 1 | 4 | 3 | 3 | 1 | 1 | 3 | Insufficient AWS flow from N. Wasco PUD turbine | 5 | Rating curves from N. Wasco and Hydraulic Modeling | 1 | 3 | | 60 | Downtime associated with 2 modifications to ladder |
| 4A | North Wasco PUD Turbine | Provides auxiliary water for ladder | Turbine trip | Interruption of primary AWS (assuming plunge pool operable) | 1 | 2 | 2 | 2 | 5 | 1 | 2 | Loss of Offsite Power | 3 | PUD Operator | 1 | 1 | X | 15 | |
| 4B | | | Turbine trip | Interruption of primary AWS (assuming plunge pool inoperable) | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Loss of Offsite Power | 1 | PUD Operator | 1 | 2 | | 10 | |
| 5A | AWS Plunge Pool | Provides backup auxiliary water supply for ladder | Mechanical failure of gate in open position | Must use plunge pool as AWS, impacts N. Wasco PUD | 2 | 1 | 1 | 1 | 5 | 1 | 1 | Mech/elec failure of actuator, debris in guides | 2 | Operator Observation | 1 | 2 | | 20 | |
| 5B | | | Mechanical failure of gate in closed position | No backup AWS available for ladder (assumes turbine offline) | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mech/elec failure of actuator, debris in guides | 1 | Operator Observation | 1 | 2 | | 10 | |
| 5C | | | Structural failure of tie-backs | Collapse of plunge pool walls may affect AWS backup flow | 1 | 2 | 2 | 2 | 1 | 1 | 2 | Corrosion, vibration | 3 | Operator Observation, Annual Inspection | 1 | 4 | X | 24 | |
| 6A | Rock-Lined Channel | Maintain attraction velocity and head drop between pools for fish migration | Failure of weir attachment to wall | Weir collapse | 1 | 1 | 1 | 4 | 1 | 1 | 3 | Structural failure due to EQ or weathering | 2 | Operator Observation, Annual Inspection | 1 | 3 | | 24 | |
| 6B | | | Rock falling in channel | Affects channel roughness or blocks orifice | 1 | 1 | 1 | 1 | 1 | 1 | 3 | Erosion, Earthquake | 3 | Annual inspection | 1 | 3 | X | 27 | |
| 6C | | | Vegetation damaging or blocking ladder | Affects weir or pool hydraulics | 1 | 1 | 1 | 1 | 1 | 1 | 2 | Severe weather | 3 | Annual inspection, post-storm inspection | 1 | 3 | X | 18 | |
| 7A | Counting Station | Provides a means of assessing ladder efficiency | Crowder failure | Inability to crowd fish for counting | 1 | 1 | 1 | 1 | 1 | 5 | 2 | Structural, mech/elec wear | 2 | Operator Observation | 1 | 2 | | 20 | |
| 7B | | | Picket lead failure (in open position) | Debris passage through ladder, inability to count fish | 1 | 1 | 1 | 2 | 1 | 5 | 3 | Structural failure, debris accumulation | 2 | Operator Observation | 1 | 2 | | 20 | |

**The Dalles Dam**
**North Fish Ladder**
**Reliability Matrix**

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | North Wasco Powerhouse | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7C | | | Picket lead failure (in closed position) | Debris accumulation on rack | 1 | 1 | 1 | 3 | 1 | 1 | 4 | Structural failure, debris accumulation | 2 | Operator Observation | 1 | 3 | | 24 | Worst-case could have much higher RPN |
| 7D | | | Failure of count window lighting | Inability to effectively count fish | 1 | 1 | 1 | 1 | 1 | 5 | 1 | Burned out lamps, loss of electrical power | 2 | Operator Observation | 1 | 1 | | 10 | |
| 7E | | | Failure of count window cleaner | Inability to effectively count fish | 1 | 1 | 1 | 1 | 1 | 5 | 1 | Mechanical failure of drive, brush, or linkages | 2 | Operator Observation | 1 | 2 | | 20 | |
| 7F | | | Failure of count station electrical systems | Inability to effectively count fish | 1 | 1 | 1 | 1 | 1 | 5 | 1 | Loss of electrical power | 2 | Operator Observation | 1 | 1 | | 10 | |
| 8A | Exit Section AWS | Provides auxiliary water for count station and weirs downstream of count station | AWS intake grating attachment failure | Intake grating displaced, debris enters AWS reducing flow | 1 | 1 | 1 | 1 | 1 | 1 | 5 | Corrosion | 2 | Operator Alarm/Monitor of Water Level | 1 | 3 | | 30 | Ladder shutdown required for repair |
| 8B | | | AWS intake grating plugged | AWS flow reduced | 1 | 1 | 1 | 2 | 1 | 1 | 3 | Debris accumulation, Corrosion | 2 | Operator Alarm/Monitor of Water Level | 1 | 2 | | 12 | |
| 8C | | | Failure of sluice gate (open) | Inability to regulate flow | 1 | 1 | 1 | 2 | 1 | 1 | 3 | Mech/elec failure of actuator, debris in guides | 2 | Operator Alarm/Monitor of Water Level | 1 | 2 | | 12 | |
| 8D | | | Failure of sluice gate (closed) | Inability to regulate flow (no AWS flow) | 1 | 1 | 1 | 3 | 1 | 1 | 4 | Mech/elec failure of actuator, debris in guides | 2 | Operator Alarm/Monitor of Water Level | 1 | 2 | | 16 | |
| 8E | | | Failure of the water level reader/AWS control system | Inability to automatically regulate AWS flow | 1 | 1 | 1 | 3 | 1 | 1 | 4 | Loss of power, control system failure | 2 | Operator Alarm/Monitor of Water Level | 1 | 2 | | 16 | |
| 8F | | | Floor diffuser grating plugged | Affects distribution of AWS flow | 1 | 1 | 1 | 3 | 1 | 1 | 5 | Corrosion and debris accumulation | 2 | Operator Alarm/Monitor of Water Level | 1 | 3 | | 30 | Ladder shutdown required for repair |
| 8G | | | Diffuser grating mounting failure | Diffuser grating may be displaced, loss of fish into AWS | 1 | 1 | 1 | 1 | 1 | 1 | 3 | Corrosion or failure of attachment clips | 3 | Annual Inspection | 4 | 2 | | 72 | Ladder shutdown required for repair |
| 9A | Ladder Exit Section | Regulate ladder flow for a range of forebay elevations | Failure of weir attachment to wall | Weir collapse | 1 | 1 | 1 | 3 | 1 | 1 | 3 | Structural failure of attachment to wall due to corrosion | 2 | Operator Observation, Annual Inspection | 1 | 3 | | 18 | |

**The Dalles Dam**
**North Fish Ladder**
**Reliability Matrix**

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | North Wasco Powerhouse | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9B | | | Trashrack clogging | Reduces ladder flow | 1 | 3 | 2 | 4 | 1 | 1 | 4 | Failure to clean trash rack | 2 | Operator Observation | 1 | 2 | | 16 | |

# Appendix B

# EFL Reliability Matrix

## The Dalles Dam
## East Fish Ladder
## Reliability Matrix

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | Fish Turbine Generation | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | East Fish Entrance | Controls entrance velocity, depth, and submergence in order to maintain entrance criteria for fish attraction and migration. | Telescoping weir leaves separate | Velocity at entrance out of criteria | 1 | 5 | 5 | 2 | 1 | 1 | 4 | Worn gate rollers, structural failure of connection between leaves | 3 | Operator Observation of low entrance pool velocity | 2 | 1 | X | 30 | Backup gates available, Spare leaves available |
| 1B | | | Hoist failure | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Mech/elec failure of motor, gearbox, sheave, etc. | 2 | Operator Observation | 1 | 1 | X | 10 | Backup gates available |
| 1C | | | Control system failure | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Electronics failure due to age, lightning strike | 2 | Operator Observation | 1 | 1 | X | 10 | Backup gates available |
| 1D | | | Hoist rope breaks | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Structural failure due to cycling, corrosion | 3 | Operator Observation | 1 | 1 | X | 15 | Backup gates available |
| 2A | Junction Pool | Distributes flow between ladder entrances | Failure of the telescoping weirs | Affects flow distribution to entrances, more flow to east entrance | 1 | 5 | 3 | 1 | 1 | 1 | 4 | Worn gate rollers, structural failure of connection between leaves | 2 | Operator Observation | 2 | 1 | | 20 | |
| 2B | | | Hoist failure | Inability to operate weirs | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Mech/elec failure of motor, gearbox, sheave, etc. | 2 | Operator Observation | 1 | 1 | | 10 | |
| 2C | | | Control system failure | Inability to operate weirs | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Electronics failure due to age, lightning strike | 2 | Operator Observation | 1 | 1 | | 10 | |
| 2D | | | Hoist rope breaks | Inability to operate weirs | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Structural failure due to bending, corrosion | 3 | Operator Observation | 1 | 1 | | 15 | |
| 2E | | | Diffuser grating plugged | Affects distribution of AWS flow | 1 | 1 | 1 | 3 | 2 | 1 | 2 | Corrosion and debris accumulation | 2 | Annual Inspection | 1 | 2 | X | 12 | |
| 2F | | | Diffuser grating mounting failure | Diffuser grating displaced | 1 | 1 | 1 | 1 | 1 | 1 | 3 | Corrosion or failure of attachment clips | 3 | Annual Inspection | 4 | 2 | | 72 | |
| 2G | | | Imbalanced flow distribution, excess flow to East Entrance | Hydraulics may be out of criteria, impacts on fish passage, need for additional AWS flow | 1 | 5 | 3 | 1 | 1 | 1 | 4 | Insufficient head loss in East Entrance reach as compared to other entrances | 5 | Operator Observation | 1 | 3 | | 75 | Downtime associated with 2 modifications to ladder |

## The Dalles Dam
## East Fish Ladder
## Reliability Matrix

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | Fish Turbine Generation | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3A | Collection Channel | Transports fish from the West Entrance to the Junction Pool | Diffuser gate failure or leakage | Diffuser gates not closed properly, affects AWS flow distribution | 1 | 1 | 1 | 3 | 2 | 1 | 2 | Accumulation of sediment, mussels, debris in diffuser chamber | 4 | Annual Inspection | 1 | 2 | | 24 | |
| 3B | | | Diffuser grating mounting failure | Diffuser grating displaced | 1 | 1 | 1 | 1 | 1 | 1 | 3 | Corrosion or failure of attachment clips | 3 | Annual Inspection | 4 | 2 | | 72 | |
| 4A | AWS Conduit | Provides auxiliary water for ladder | Diffuser gate inoperable (stuck open/closed) | Affects distribution of AWS flow | 1 | 1 | 1 | 3 | 2 | 1 | 2 | Gate operator corroded | 4 | Annual inspection | 3 | 2 | | 72 | |
| 4B | | | Structural failure of stovepipe weirs | Backflow of water from ladder into AWS conduit | 1 | 1 | 1 | 4 | 1 | 1 | 3 | Structural failure of attachment to wall | 1 | Annual inspection | 3 | 3 | | 36 | |
| 4C | | | Failure of AWS dewatering pumps | Prevents dewatering of AWS conduit, transportation and collection channels | 5 | 1 | 1 | 1 | 1 | 1 | 1 | Mech/elec failure of pump | 2 | Annual inspection | 1 | 2 | | 20 | |
| 5A | West Fish Entrance | Controls entrance velocity, depth, and submergence in order to maintain entrance criteria for fish attraction and migration. | Telescoping weir leaves separate | Velocity at entrance out of criteria | 1 | 5 | 5 | 2 | 1 | 1 | 4 | Worn gate rollers, structural failure of connection between leaves | 3 | Operator Observation of low entrance pool velocity | 2 | 1 | X | 30 | Backup gates available, Spare leaves available |
| 5B | | | Hoist failure | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Mech/elec failure of motor, gearbox, sheave, etc. | 2 | Operator Observation | 1 | 1 | X | 10 | Backup gates available |
| 5C | | | Entrance weir control system malfunction | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Electronics failure due to age, lighning strike | 2 | Operator Observation | 1 | 1 | X | 10 | Backup gates available |
| 5D | | | Hoist rope breaks | Inability to operate entrance weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Structural failure due to bending, corrosion | 3 | Operator Observation | 1 | 1 | X | 15 | Backup gates available |
| 5E | | | Diffuser grating plugged with debris (gravel) | Affects distribution of AWS flow | 1 | 1 | 1 | 3 | 2 | 1 | 2 | Corrosion and debris accumulation | 3 | Operator Observation | 1 | 2 | X | 18 | |
| 6 | Transport-ation Channel | Transports fish from the South Entrance to the Junction Pool | Rock falls into channel | Affects channel roughness and channel shape | 1 | 1 | 1 | 1 | 1 | 1 | 3 | Erosion, earthquake | 3 | Annual Inspection | 1 | 2 | | 18 | |

**The Dalles Dam**
**East Fish Ladder**
**Reliability Matrix**

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | Fish Turbine Generation | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7A | South Fish Entrance | Controls entrance velocity, depth, and submergence in order to maintain entrance criteria for fish attraction and migration. | Telescoping weir leaves separate | Velocity at entrance out of criteria | 1 | 5 | 5 | 2 | 1 | 1 | 4 | Worn gate rollers, structural failure of connection between leaves | 3 | Operator Observation of low entrance pool velocity | 2 | 1 | X | 30 | Backup gates available, Spare leaves available |
| 7B | | | Hoist failure | Inability to operate weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Mech/elec failure of motor, gearbox, sheave, etc. | 2 | Operator Observation | 1 | 1 | X | 10 | Backup gates available |
| 7C | | | Entrance weir control system malfunction | Inability to operate weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Electronics failure due to age, lighning strike | 2 | Operator Observation | 1 | 1 | X | 10 | Backup gates available |
| 7D | | | Hoist rope breaks | Inability to operate weir | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Structural failure due to bending, corrosion | 3 | Operator Observation | 1 | 1 | X | 15 | Backup gates available |
| 8A | Ladder | Maintain attraction velocity and head drop between pools for fish migration | Diffuser grating plugged | Affects distribution of AWS flow | 1 | 1 | 1 | 3 | 2 | 1 | 2 | Corrosion and debris accumulation | 2 | Annual inspection | 1 | 2 | X | 12 | |
| 8B | | | Diffuser grating mounting failure | Diffuser grating displaced | 1 | 1 | 1 | 1 | 1 | 1 | 3 | Corrosion or failure of attachment clips | 3 | Annual inspection | 4 | 2 | | 72 | |
| 8C | | | Failure of weir attachment to wall | Weir collapse | 1 | 1 | 1 | 4 | 1 | 1 | 3 | Structural failure of attachment to wall | 2 | Operator Observation, Annual Inspection | 1 | 3 | | 24 | |
| 9A | Fish Lock | No current function | Junction pool bulkhead gate failure | Potential for fish holding or injury | 1 | 1 | 1 | 1 | 1 | 1 | 4 | Structural | 2 | Operator Observation | 1 | 3 | | 24 | |
| 9B | | | Silo bulkhead gate failure | Ladder out of criteria, potential for fish injury | 1 | 1 | 1 | 1 | 1 | 1 | 4 | Structural | 2 | Operator Observation | 1 | 3 | | 24 | |
| 10A | Fish Turbines | Provide AWS for ladder | Stator winding failure - one or two bad coils. | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 4 | | 20 | Cut out coils and de-rate unit |
| | | | Stator winding failure - Forcing unit rewind | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 5 | | 25 | Rewind unit requires two years |
| | | | Main transformer failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Electrical | 3 | Control Room Alarm | 1 | 1 | | 15 | Requires one day to replace/repair |

**The Dalles Dam**
**East Fish Ladder**
**Reliability Matrix**

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | Fish Turbine Generation | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Powerhouse line failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Electrical | 1 | Control Room Alarm | 1 | 3 | | 15 | Requires one month to replace/repair |
| | | | Generator breaker failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Electrical | 2 | Control Room Alarm | 1 | 4 | | 40 | Requires three months to replace/repair. |
| 10B | | | Thrust bearing failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 2 | Control Room Alarm | 1 | 4 | | 40 | Requires three months to replace/repair. |
| 10C | | | Guide bearing failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 2 | Control Room Alarm | 1 | 4 | | 40 | Requires three months to replace/repair. |
| 10D | | | Governor failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 3 | | 15 | Requires one month to replace/repair |
| 10E | | | Wicket gate failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 5 | | 25 | Requires six months to replace/repair |
| 10F | | | Turbine failure - loss of blade | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 5 | | 25 | Requires one year to repair/replace |
| 10G | | | Turbine failure - blade bushing failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 5 | | 25 | Requires one year to repair/replace |
| | | | Excitation failure - component problem | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 2 | | 10 | Requires one week to replace/repair |
| | | | Excitation failure - system melt down | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 5 | | 25 | Requires one to two years to replace/repair |
| | | | Generator cooler failure - plugged with clams | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 2 | | 10 | Requires one week to replace/repair |
| | | | Generator cooler failure - leak in cooler | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 4 | | 20 | Requires one to two months to repair/replace |
| | | | Turbine packing gland failure | Loss of sole AWS if two units, loss of partial AWS if one unit | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Mechanical | 1 | Control Room Alarm | 1 | 3 | | 15 | Requires two weeks to repair/replace |

## The Dalles Dam
## East Fish Ladder
## Reliability Matrix

| No. | System | Function | Potential Failure Mode | Potential Effect of Failure | Severity of Effect on: Inspection and Maintenance | Velocity at Entrance Weir/Lower Ladder | Submergence at Entrance Weir | Head on Ladder Weirs | Fish Turbine Generation | Ability to Count Fish | Fish Behavior | Potential Cause of Failure | Occurrence | Current Detection Method | Detection | Downtime | Redundant System X = yes | RPN | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11A | Counting Station | Provides a means of assessing ladder efficiency | Crowder failure | Inability to effectively count fish | 1 | 1 | 1 | 1 | 1 | 5 | 2 | Structural, mech/elec wear | 2 | Operator Observation | 1 | 2 | | 20 | |
| 11B | | | Picket lead failure (in open position) | Debris passage through ladder/inability to count fish | 1 | 1 | 1 | 2 | 1 | 1 | 3 | Structural failure, debris accumulation | 2 | Operator Observation | 1 | 2 | | 12 | |
| 11C | | | Picket lead failure (in closed position) | Debris accumulation on rack | 1 | 1 | 1 | 1 | 1 | 1 | 2 | Structural failure, debris accumulation | 2 | Operator Observation | 1 | 3 | | 12 | |
| 11D | | | Failure of count window lighting | Inability to effectively count fish | 1 | 1 | 1 | 1 | 1 | 5 | 1 | Burned out lamps, loss of electrical power | 2 | Operator Observation | 1 | 1 | | 10 | |
| 11E | | | Failure of count window cleaner | Inability to effectively count fish | 1 | 1 | 1 | 1 | 1 | 5 | 1 | Mechanical failure of drive, brush, or linkages | 2 | Operator Observation | 1 | 2 | | 20 | |
| 11F | | | Failure of count station electrical systems | Inability to effectively count fish | 1 | 1 | 1 | 1 | 1 | 5 | 1 | Loss of electrical power | 2 | Operator Observation | 1 | 1 | | 10 | |
| 12A | Fish Ladder Exit | Regulate ladder flow for a range of forebay elevations | Weir operation failure | Failure to maintain velocity and weir head criteria | 1 | 3 | 3 | 3 | 1 | 1 | 5 | Mech/elec failure of hoist, motor, cables, etc. | 2 | Operator Observation, Annual Inspection | 1 | 3 | | 30 | |
| 12B | | | Trashrack clogging | Ladder flow reduced | 1 | 3 | 2 | 4 | 1 | 1 | 4 | Failure to clean trash rack | 2 | Operator Observation | 1 | 2 | | 16 | |
| 13A | Control Room | Control operation of fish turbines and monitor entrance weir operations | Entrance weir control panel electrical failure | Loss of ability to control entrance gates | 1 | 5 | 5 | 2 | 2 | 1 | 4 | Failure of aged components | 2 | Operator Observation | 1 | 2 | | 20 | |
| 13B | | | Fish turbine control panel electrical failure (assumes both units affected) | Loss of ability to control AWS flow | 1 | 5 | 5 | 5 | 5 | 1 | 5 | Failure of aged components | 2 | Operator Observation | 1 | 2 | | 20 | |

# Appendix C

# NFL Inspection Report

Washington Group International
Integrated Engineering, Construction, and Management Solutions

January 31, 2007

U.S. Army Corps of Engineers
Hydroelectric Design Section
Attention: Randy Lee, USACE
P.O. Box 2946
Portland, OR 97208-29746

Subject: The Dalles North Fish Ladder Inspection
Contract No. W9127N-06-D-0009, Task Order No. 0004
Final Trip Report

Dear Randy:

The Dalles North Fish Ladder was inspected by the USACE, Washington Group International (WGI), and ENSR on December 28, 2006. The purpose of the inspection was to establish baseline conditions of the ladder to support future reliability studies. The attached trip report summarizes the observations of the inspection participants. Photos referenced within the body of the report are attached.

We appreciate the opportunity to have participated in this inspection. Please contact me if you have any questions.

Sincerely,

*No signature required*

Doug Hartsock, P.E.
Project Manager

Attachment: Report and Photos

cc: File

Washington Group International
Integrated Engineering, Construction, and Management Solutions

**THE DALLES DAM**

**COLUMBIA RIVER BASIN, WASHINGTON - OREGON**

# The Dalles Dam North Fish Ladder Inspection Report

**JANUARY 2007**

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## INTRODUCTION

The Dalles North Fish Ladder (NFL) was inspected by the USACE, Washington Group International (WGI), and ENSR on December 28, 2006. The purpose of the inspection was to establish baseline conditions of the ladder to support future reliability studies. This trip report summarizes the observations of the inspection participants. Photos referenced within the body of the report are attached.

## INSPECTION PARTICIPANTS

**The follow individuals participated in the inspection:**

| | | | |
|---|---|---|---|
| Randy Lee | PM/Hydraulic | USACE | (503) 808-4876 |
| Bob Cordie | Fishery Biologist | USACE | (541) 298-7406 |
| Bob Wertheimer | Fishery Biologist | USACE | (503) 808-4777 |
| Paul Keller | Biologist Technician | USACE | (541) 298-7406 |
| Dave Scofield | Civil | USACE | (503) 808-4867 |
| Rachel Calnon | PM Specialist | USACE | (503) 808-4706 |
| Joe Brackin | Electrical | USACE | (503) 808-4922 |
| Bob Guidinger | Hydro Dept. Mgr. | N. Wasco County PUD | (541) 298-3325 |
| Ken Graham | Operator | N. Wasco County PUD | (541) 715-2887 |
| Doug Hartsock | PM/Mechanical | Washington Group Int'l | (425) 451-4658 |
| Brian Grant | Civil/Geo | Washington Group Int'l | (360) 794-4580 |
| Satendra Jain | Structural | Washington Group Int'l | (425) 451-4693 |
| George Thomas | Electrical | Washington Group Int'l | (425) 451-4236 |
| Liza Roy | Hydraulic | ENSR | (503) 715-2887 |

## BACKGROUND AND PURPOSE

As part of The Dalles System Improvement Study (SIS), a spillwall was constructed in 2004 between spillway bays six and seven of The Dalles Dam. During the downstream migration of juvenile fish, approximately 40 percent of the river flow is released between the spillwall and spillway bay one.
The spillwall and concentrated spill pattern, however, create a new set of fish migration issues, including:

1. Downstream migrating juvenile survival rates, although improved, are not to the level desired due to predation from predator fish located in rock outcrops adjacent to the stilling basin.
2. Water velocities in the vicinity of the north fish ladder (NFL) entrance are relatively high, reducing the availability of the ladder to upstream migrating fish.

To address the predation issue, the SIS team is evaluating a 650-foot extension of the spillwall to the river thalweg. The extended spillwall would facilitate the egress of juveniles from the stilling basin and farther downstream, past the predators. As far as access to the NFL by upstream migrating fish is concerned, preliminary physical hydraulic model investigations on a 1:80 scale general model of The Dalles Dam at the Corps Engineer Research and Development Center show that the extended spillwall would reduce the velocities near the NFL entrance, and the resulting increase in water surface elevations could impact the operation of the fish ladder. The model studies also predict an increase in velocities along the north shore as a result of extending the spillwall, which could hamper access to the NFL by upstream migrating fish.

The purpose of the NFL inspection is to observe and document the current civil/structural, mechanical, hydraulic, electrical, and geotechnical conditions of the overall facility. The observations will be used to support future NFL reliability and spillwall extension studies.

## METHODOLOGY

The following methodology was adopted for this task:

1. Review NFL and N. Wasco PUD facility drawings
2. Conduct site inspection
3. Prepare draft trip report
4. Review draft trip report with USACE
5. Finalize trip report

## INSPECTION CHRONOLOGY

The following represents an approximate chronology of the inspection day:

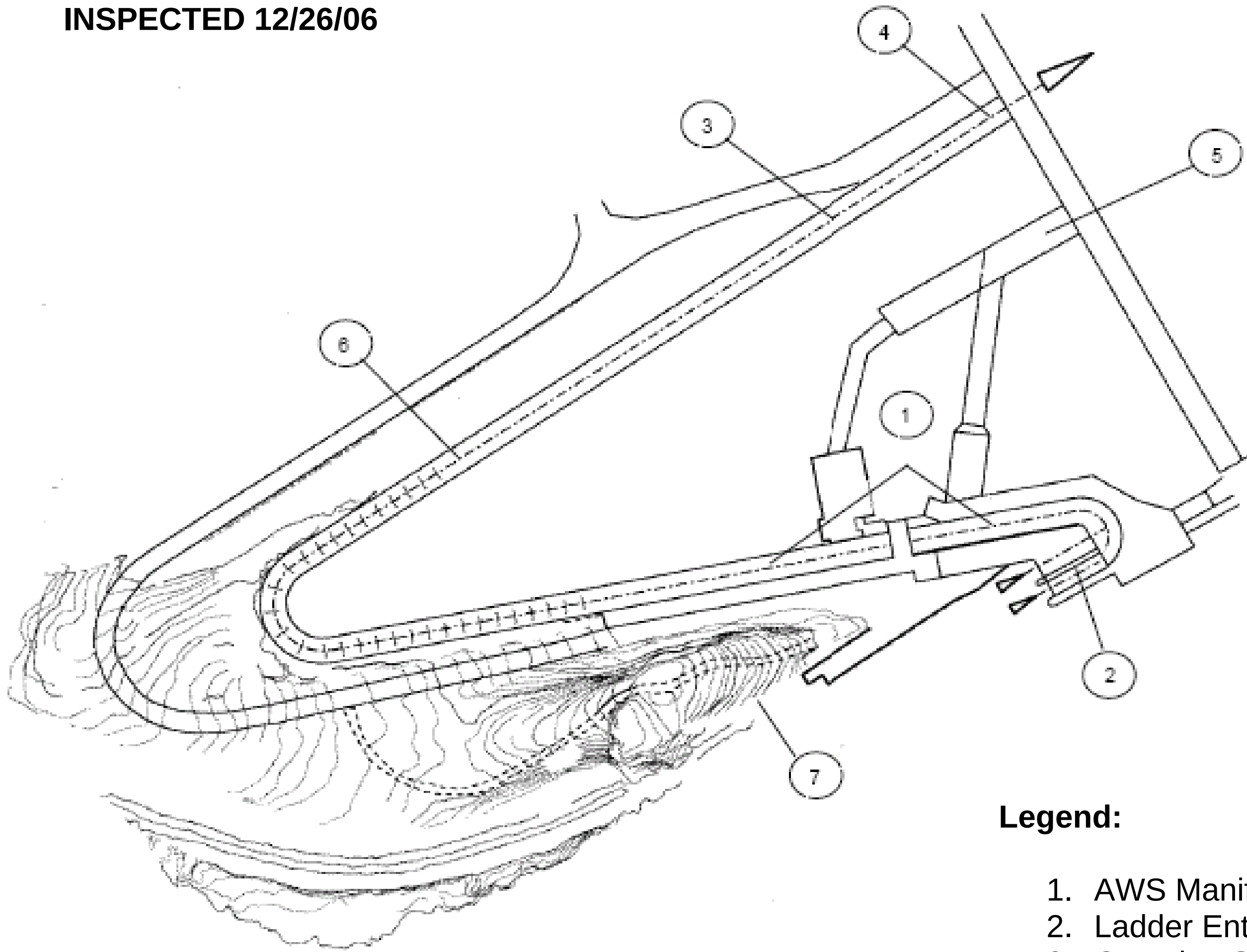
1. Met at The Dalles Fisheries Office at 8:30 a.m. Introduced participants, reviewed project history and objectives, safety, and agenda.
2. Drove to North Wasco PUD Powerhouse. Accessed Auxiliary Water System (AWS) water supply conduit via draft tube. Observed conduit structure, diffusers, original AWS plunge pool, and conduit dewatering pump.
3. Exited draft tube, observed miscellaneous elements of powerhouse.
4. Walked to fish ladder entrance facilities. Observed weir gates, north shoreline (from a distance) plunge pool (from above), gate hoists, and channel structure.

5. Drove to fish ladder exit section. Observed counting station, fish crowder, control channel structure. Walked upstream within channel to inspect weirs and exit facilities.
6. Walked to North Wasco PUD Powerhouse intake structure. Observed electrical panels, tainter gate and hoist, AWS gates and hoists, powerhouse shutoff gates, gantry crane and hoist, juvenile bypass gate, hoist and pipeline.
7. Drove to transition of concrete channel with rock lined channel. Observed weirs, channel structure.
8. Drove to fisheries office, dropped off gear.
9. Drove to east side of dam, met at conference room adjacent to powerhouse. Ate lunch and reviewed day. Interviewed operations and fisheries personnel. Made additional document requests. Discussed plan going forward.
10. Departed at 3:00 p.m.

## INSPECTION RESULTS

The following sections provide a description of the areas that were inspected (Figure 1), followed by discipline specific observations.

**FIGURE 1: THE DALLES NORTH FISH LADDER AREAS INSPECTED 12/26/06**




**Legend:**

1. AWS Manifold
2. Ladder Entrance
3. Counting Station
4. Ladder Exit
5. AWS Supply Channel
6. Channel Transition
7. North Shore

## ***Auxillary Water System (AWS)***

The water that flows through the NFL originates from two sources: the ladder's fish exit, which provides between 75 and 102 cubic feet per second (cfs) of flow, and the turbine discharge from the N. Wasco PUD powerhouse, which provides between 870 and 940 cfs. Under normal operating conditions, water exits the powerhouse draft tube and enters a rectangular, concrete-lined water supply conduit that extends beneath the floor of the ladder between units 10 and 18. From the conduit, water passes through a series of square orifices fitted with slide gates located in the wall of the conduit and into the channel via grated floor diffusers. If the powerhouse unit goes offline, flow to the powerhouse is diverted to a plunge pool and enters the water supply conduit through a separate entrance. The overall system is referred to as the auxiliary water system (AWS).

### Civil/Structural Observations

Structural concrete work within the water supply conduit appeared to be maintaining its integrity with mostly hairline cracking revealed by seeping water (Photo **CS-1**).

### Mechanical Observations

It was reported that the slide gates in the lower section of the water supply conduit (Photo **M-1**) are designed for unseating head and therefore need to be fully open or fully closed in order to operate correctly. A few of the gates downstream of Unit 15, however, were observed to be partially open. It was unclear whether this indicated that the gates were stuck, or if they were intentionally placed in a partially open position (Note: the project has since opened them).

Considerable corrosion was evident on the gates (Photo **M-2**). The PUD operator advised that the gates were exercised within the past year, and that normally they are left in a fully open position.

A submersible centrifugal pump is located in a pipe well at the downstream end of the water supply conduit (Photo **M-3**) and is used to dewater the conduit for inspection and maintenance purposes. The pump was operating during the inspection to remove water that was seeping from the river into the water supply conduit.

### Hydraulic Observations

During the inspection, we entered the AWS conduit via the N. Wasco PUD draft tube at AWS diffuser chamber unit 15. Walking toward the upstream units (10 through 12) in the diffuser chamber, fine sediment and mud was observed on the chamber floor, indicating that velocities in the chamber are likely quite low during operation and fine sediment settles out. The sediment was not observed in the lower units. The conduit connection to the N. Wasco PUD draft tube, conduit floor, walls, and ceiling are smooth concrete.

Staff reported that the diffuser outlet gates are designed to operate either fully open or closed. Several of the diffuser outlet gates were observed from units 10 through 15 and were fully open (Photo **H-1**). A few of the diffuser gates from diffuser units 15 through 19 were closed approximately 9 to 15 inches (Note: the project has since opened them). The upstream-most gate opening had been permanently sealed by a metal plate. The diffuser chambers beyond the gated openings are rough rock on the outside wall, much like that observed in the AWS pool and the rock portion of the fish ladder, with considerably higher roughness than the inner concrete walls.

The junction between the original AWS plunge pool and the diffuser conduit was observed from the downstream side. Several structural reinforcements were noticed as described in the geotechnical notes. A view of the plunge pool from the upstream side is shown in Photo **H-2**.

The conduit dewatering pump was operating at the downstream end of the dewatering conduit and 12 to 15 inches of water was present in the conduit (Photo **H-3**).

**Geotechnical Observations**

The rock anchors and strapping on the walls of the original AWS plunge pool (Photo **G-1**) were heavily corroded and appeared loosened from the rock face in places. It appeared that rock had fallen out from behind some of the strapping.

***Ladder Entrance***

The NFL fish entrance is located adjacent to spillway one. It consists of two triple-leafed weirs designated N-1 and N-2. Two rollers on each side of each 6'-9" by 15'-0" fabricated steel leaf ride in vertical guides cast into concrete slots. The leaves are raised and lowered using a wire rope hoist and spreader beam arrangement. A third weir gate designated N-3 and situated 90° to N-1 and N-2 has been removed and the opening permanently sealed with concrete. During normal operation, only one weir is operated.

**Mechanical Observations**

The District and the PUD agreed that their current number one need is to obtain a new set of entrance weirs. They also shared that the guide rollers for the original weirs were thought to be damaged by pulsating water from the adjacent spillway, which made raising the leaves difficult, that the leaves often became disconnected from each other when being raised, and that the hoist's wire ropes had failed in the past, possibly due to vibration or being submerged for long periods. The method for lifting the leaves was improved by adding a lifting beam (Photo **M-4**).

Steel bulkheads were installed in weir gate bays N-1 and N-2 during the inspection (Photo **M-5**). The gate leaves were evident in N-1, but missing from N-2.

The electric hoist (Photo **M-6**) used to raise and lower the weir gates appeared to be in serviceable condition.

The hoist push button control enclosure (Photo **M-7**) was fairly corroded.

**Hydraulic Observations**

Based on discussions with staff, the N-1 weir is currently being repaired. Maintenance issues have included problems with the hoist cables, the rollers on the weir leaf sides, and the infrequent operation of the lower leaf due to high tailwater elevations. Some of the hoist cable problems have been remedied using a new spreader beam arrangement for operation and hydraulic operation of the entrance weirs has been effective. The weir leaves for N-1 and N-2 are interchangeable with those used for the EFL. The weirs are operated greater than 8 feet below tailwater to achieve a channel to tailwater differential of one foot to two feet under normal operating conditions. Optimum differential is 1.5 feet. Normally, the channel to tailwater differential is 1.3 feet. The closed entrance weirs at N-1 and N-2 are shown in Photo **H-4**.

Just upstream of the entrance weirs, the diffuser grating for the AWS system is visible in Photos **H-5**, **H-6**, and **H-7**. The diffuser grating has approximately 1-in by 4-in openings and appears to be in satisfactory condition with plating securing the grating to prevent lifting in the flow. We were only able to view this area from above, not in the ladder channel due to access constraints.

The Corps reported that the north ladder used to attract about 30% of the adult salmon passing the project, the percentage varying depending on the run. Since installation of training walls and changes to spill procedures to use only spill gates 1 through 6 for downstream migrant spill, the ladder attracts only about 10% of the adults. This is despite installation of a new wall between the ladder entrance pool and spillway bay 1 to keep the spillway flow from rolling across into the ladder flow. Photos provided by the Corps and the PUD show white water extending from the spillway across the ladder entrance to the north riverbank.

The Corps is studying the problem of predation on downstream migrating smolts using the spillway. The predation occurs in the shallow tailwater. One idea for protecting the smolts is to extend the training wall at spill gate 6 further downstream to the rim of the thalweg canyon. They expect that this may locally raise the tailwater in the vicinity of the approach to the NFL entrance.

**Electrical Observations**

The water supply conduit dewatering pump control enclosure was located on the deck adjacent to the intake (Photo **E-1**).

PUD powerhouse staff was interviewed with regards to the operation of weir gates N-1 and N-2. No problems were reported with either operation or control of the gates.

### Geotechnical Observations

The north shore of the fish ladder facility was visible from this vantage point (Photo **G-2**). From a distance, the bank appears to be rougher than other rock cut slopes in the vicinity. The blocky, near vertical fracture pattern appears to be susceptible to plucking, possible due to the spill turbulence. However, there does not appear to be major local recession of the bank or evidence of caving.

## ***Counting Station***

The fish counting station is located on the upper ladder leg between weirs 151 and 152. The original station was modified in the late 1980's and currently consists of a viewing room with window, upstream and downstream fish leads, a fish crowder with light box, and a rotary brush mechanism for cleaning the viewing window and light box. Fish climbing the ladder are directed to the crowder opening by the leads. As they pass in front of the viewing window, the light box illuminates the crowder opening, facilitating the counting process. When algae accumulates on the window and light box, the rotary brush mechanism is activated to clean both surfaces.

### Civil/Structural Observations

The condition of the various structural elements of the counting station appeared to be generally sound, although the floor diffuser grating appeared to be somewhat corroded (Photo **CS-2**). The District's fishery biologist stated that the diffuser grating just upstream of the counting station had 1-inch openings, which is too coarse to prevent Lampreys from falling or swimming through and getting lost in the exit section's AWS system. The District stated that future analyses will be conducted to detemine how reducing the grating opening to prevent the passage of Lampreys and other fish may impact the hydraulics of the fish ladder.

### Mechanical Observations

The fish crowder operates to crowd fish towards and past the viewing window for counting. A Rotork actuator (Photo **M-8**) drives two Acme screws (Photo **M-9**) that translate the moving half of the crowder towards or away from the viewing window. The range of movement is a reported 12 to 36 inches. The Rotork actuator appeared to be relatively new.

The viewing window (Photo **M-10**) and opposing light box are cleaned using an electric rotary brush mechanism (Photo **M-11**). District staff reported that the mechanism had been troublesome in the past, but that routine maintenance had corrected the situation.

### Hydraulic Observations

During the crowding operation, picket gates (Photo **H-8**) exclude fish and allow water to pass downstream past the counting station and appeared adequate hydraulically. The opening size on the pickets may be wide enough to allow lamprey to pass through the pickets rather than through the crowder and miss the counting window. Observations about the flow control section and the associated auxiliary water are provided in the Ladder Exit Section.

### Electrical Observations

Staff reported that changing the lamps in the lightbox was difficult due to inaccessibility. A District-designed PLC level control panel for controlling the water level between the upstream floor diffuser and the downstream picket of the counting station was installed recently to maintain the ladder water level downstream of the counting station at 80 feet. The interior of the counting station was inspected, and five electrical distribution panels noted. One panel was for lighting, two for control of the crowder, and two were undesignated.

## ***Ladder Exit Section***

The NFL fish exit section was modified in the late 1980's at the same time as the counting station. The section of ladder between the counting station and the dam opening was narrowed from 24 to 20 feet, and new vertical slot weirs constructed. Auxiliary water is diverted immediately downstream of the fish exit into a conduit that parallels the ladder and diffused through the ladder floor immediately upstream of the counting station. This auxiliary flow is controlled by a differential water surface level system that regulates a slide gate supplying the floor diffuser, thereby ensuring that the flow downstream of the counting station meets ladder operating criteria.

### Civil/Structural Observations

The ladder weirs appear to have been raised by the addition of concrete (Photo **C/S-3**). The walls of the ladder exhibit slight spalling of fines which is normal for concrete exposed to flowing water.

### Mechanical Observations

The electric gate actuator (Photo **M-12**) used to control flow to the floor diffuser appeared to be in serviceable condition.

### Hydraulic Observations

This section of the ladder is the flow control section and is used to regulate flow into the fish ladder. Based on discussions with staff on site, the flow control section and the associated upstream auxiliary water supply system between the dam and the counting station are operating sufficiently. A new water level sensor was installed recently to control the auxiliary water flow through the floor diffuser into the ladder upstream of the counting section.

Flow enters from the forebay into the modified flow control section and passes through a slotted weir and orifice section with PIT tag detectors on the slot and orifice (Photo H-9). Flow then passes through a series of slotted weirs with orifice openings. Each weir has a different slot height (Photo H-10). We walked through the entire flow control section and the slotted weirs and orifices appear to be in satisfactory hydraulic condition.

The auxiliary water supply system for the flow control system draws water through the grating shown in Photo **H-11** at the upstream end of the flow control section and diffuses flow through the floor grating just upstream of the counting section (Photo **H-12**). Both areas of grating are 1-in by 4-in grating and have reduced open area due to significant corrosion.

## ***AWS Supply Structure***

The AWS supply channel, or powerhouse intake structure, was constructed at the same time as the N. Wasco PUD Powerhouse. It consists of a reinforced concrete channel with grated roof. Under normal operation, water passes a normally open tainter gate and into the channel. The channel is fitted with a fish screen that prevents fish from entering the powerhouse penstock. The screened fish are passed along with 10 cfs of flow through an HDPE by-pass pipe and discharged at the mouth of the ladder entrance.

If the powerhouse trips, a pair of slide gates at the upstream end of the channel are opened and flow is diverted into a plunge pool as described previously.

### Civil/Structural Observations

The upper end of the fish bypass pipe (Photo **CS-4**) is separating from the intake structure wall. The PUD intends to repair it.

### Mechanical Observations

The hoists used to operate the tainter gate, AWS bypass gates, and turbine inlet gates appeared to be in serviceable condition. No problems were reported by PUD staff.

### Hydraulic Observations

The AWS tainter gate shown in Photo **H-13** and the fish channel structure were observed from above. The fish screen was not visible from above and was not accessed during the trip. The tainter gate has new side seals and staff reported that the gate operation is improved with the new seals.

The plunge pool was observed from above as shown in Photo **H-2** previously. The plunge pool structural issues are described in the geotechnical observations section and were noted during the hydraulic inspection.

### Electrical Observations

The switchgear located inside the dam was inspected.  The switchgear observed was reported to supply power to the gates.

## ***Channel Concrete/Rock Transition***

The NFL consists of a reinforced concrete channel transitioning to a rock-lined channel at Unit 9.

### Civil/Structural Observations

A step on the bridge crossing the transition was damaged (Photo **CS-5**).

### Hydraulic Observations

The NFL was observed from the transition from concrete channel to rock-lined channel at unit 9. We did not walk the entire length of the interior of the ladder due to time and access constraints, but the weirs and orifice openings appeared in satisfactory condition from our viewpoints. The orifice openings were modified to a smaller open area as shown in Photo **H-14** by the addition of a metal collar around each orifice. These modified orifice plates appear to have a relatively smooth transition from the concrete ladder weir to the orifice opening. The ladder weirs appear to be intact from visual inspection from above, with no large sections missing. Most of the weirs have moss growing on the downstream edge.

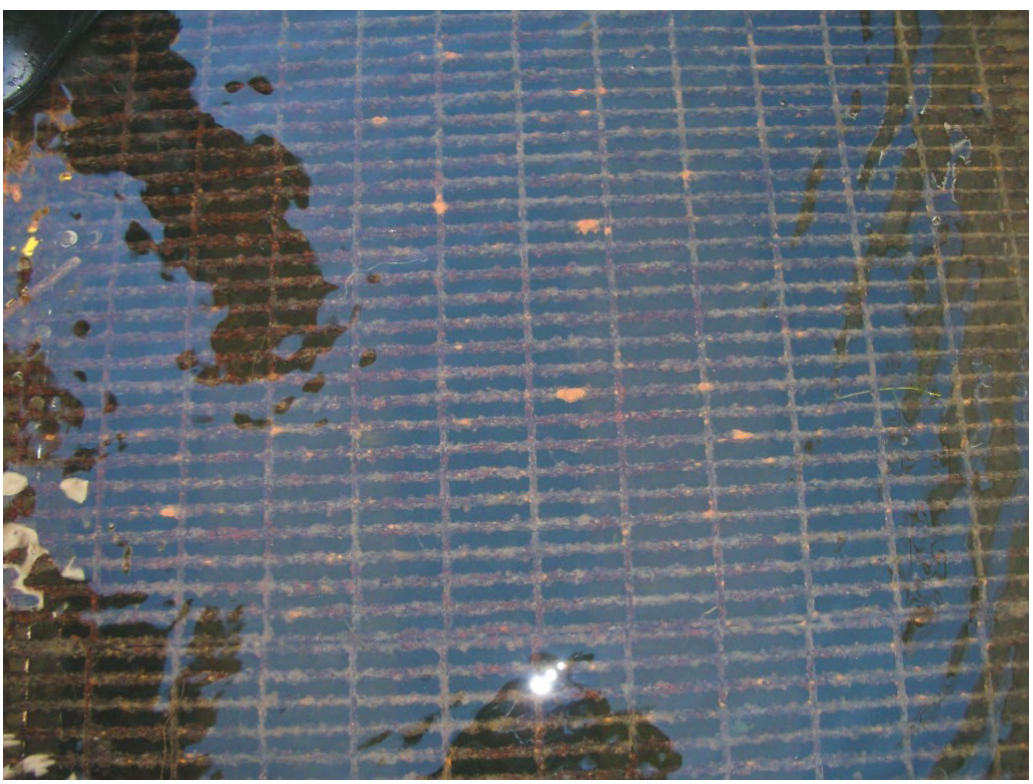
Just upstream of the transition to the rock-lined channel, a root wad was observed growing into the weir opening on one of the ladder weirs (Photo **H-15**). The operating water line is also visible in Photo **H-15** at the mossy line, with a gray line extending above the water line from splash and/or the higher operating levels for shad migration.

## Geotechnical Observations

The walls of the rock-lined reach of ladder are supported in some of the deeper sections by concrete struts. Although doubtless there has been occasional spalling from the rock faces, in general the rock appears to be sound. Only a few small rockfall fragments were observed lying about during the inspection.

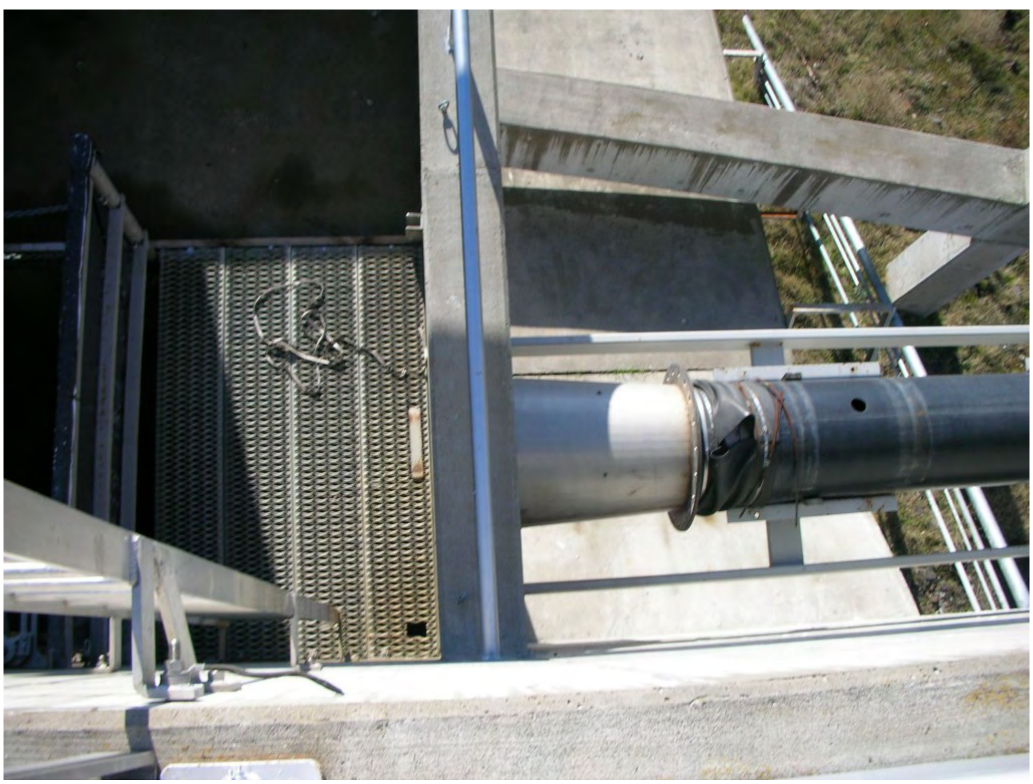
The Dalles Dam NFL Inspection Report
January 16, 2007
Photos

CS-1 Concrete Crack



CS-2 Diffuser Grating

CS-3 Weir Extensions



CS-4 Fish Bypass Pipe

CS-5 Crossover Bridge

E-1 Dewatering Pump Panel

G-1 Plunge Pool Tiebacks

G-2 North Shore View Looking Downstream

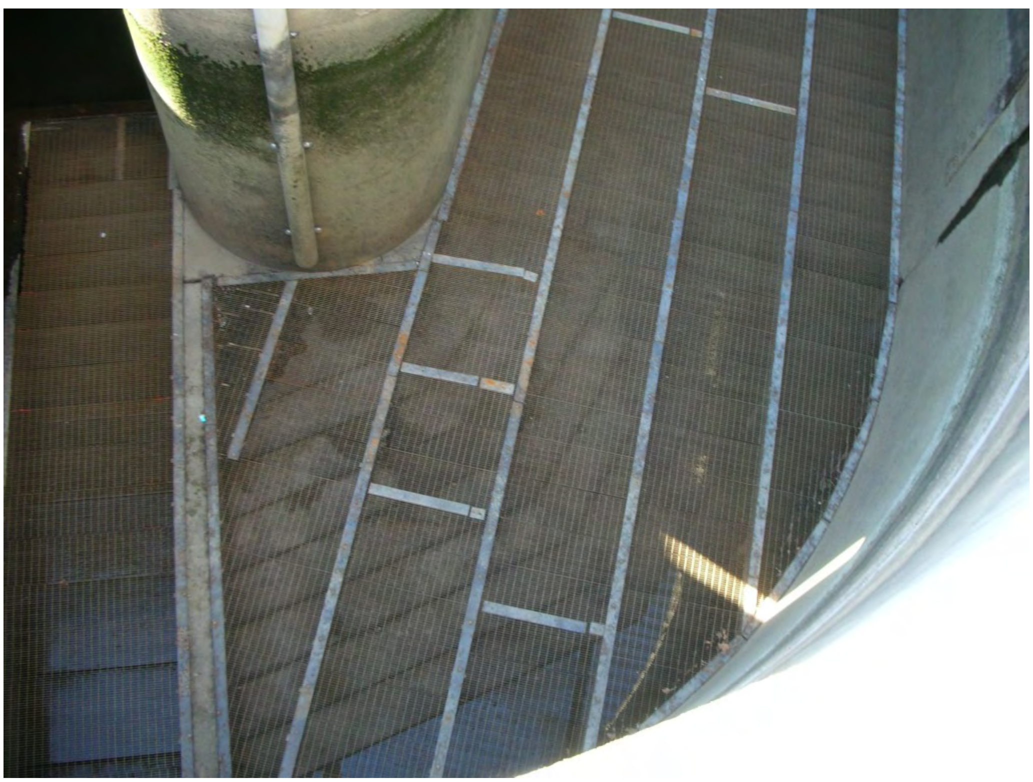
H-1 Diffuser Gate

H-2 Original AWS Plunge Pool

H-3 Conduit Dewatering Pump

H-4 Entrance Weirs

H-5 Entrance Pool Floor Diffuser Grating

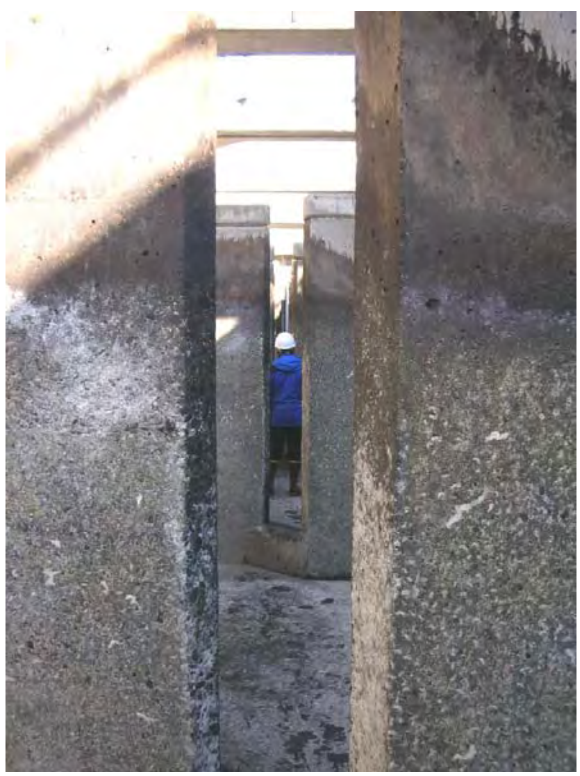


H-6 Entrance Pool Floor Diffuser Grating

H-7 Floor Diffusers and Weirs

H-8 Picket Leads at Counting Station

H-9 Exit Section Flow Control Weirs Looking Upstream



H-10 Vertical Weir Slot Looking Upstream

H-11 Fish Channel Exit

H-12 Counting Station Floor Diffuser Grate and Picket Leads

H-13 Tainter Gate

H-14 Modified Orifice

H-15 Root Ball in Channel

M-1 Diffuser Gate Opening In AWS Chamber

M-2 Diffuser Gate Corrosion

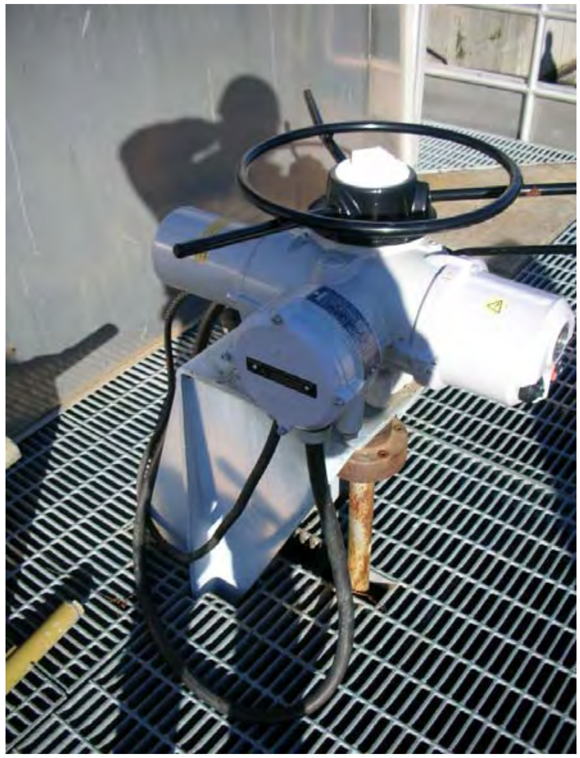
M-3 Conduit Dewatering Pump

M-4 Entrance Weir Lifting Beam

M-5 Entrance Weirs


M-6 Entrance Weir Hoist For Gate N-1


M-7 Entrance Weir Controls



M-8 Counting Window Crowder Actuator

M-9 Counting Window Crowder Drive Screw

M-10 Counting Window (View from above)

M-11 Counting Window Cleaner

M-12 Juvenile Fish Bypass Gate Actuator

# Appendix D

# EFL Inspection Report

**Washington Group International**
Integrated Engineering, Construction, and Management Solutions

March 23, 2007

U.S. Army Corps of Engineers
Hydroelectric Design Section
Attention: Randy Lee, USACE
P.O. Box 2946
Portland, OR 97208-29746

Subject: The Dalles East Fish Ladder Inspection
Contract No. W9127N-06-D-0009, Task Order No. 0004
FINAL Trip Report

Dear Randy:

The Dalles East Fish Ladder was inspected by the USACE, Washington Group International (WGI), and ENSR on February 7 and 8, 2007. The purpose of the inspection was to establish baseline conditions of the ladder to support future reliability studies. The attached trip report summarizes the observations of the inspection participants.

We appreciate the opportunity to have participated in this inspection. Please contact me if you have any questions.

Sincerely,

Doug Hartsock, P.E.
Project Manager

Attachment: Report

cc: File

Washington Group International
Integrated Engineering, Construction, and Management Solutions

**THE DALLES DAM**

**COLUMBIA RIVER BASIN, WASHINGTON - OREGON**

# The Dalles Dam East Fish Ladder Inspection Report

**MARCH 2007**

# TABLE OF CONTENTS

## INTRODUCTION

The Dalles East Fish Ladder (EFL) was inspected by the USACE, Washington Group International (WGI), and ENSR on February 7 and 8, 2007. The purpose of the inspection was to establish baseline conditions of the ladder to support future reliability studies. This trip report summarizes the observations of the inspection participants.

## INSPECTION PARTICIPANTS

The follow individuals participated in the inspection:

| | | | |
|---|---|---|---|
| Randy Lee | COE | 503.808.4876 | randall.t.lee@usace.army.mil |
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| Miro Zyndal | COE | 541.506.4823 | |
| Bob Cordie | COE | 541.298.7406 | |
| Dale Klindt | COE | 541.506.7823 | |
| Paul Keller | COE | 541.506.7823 | |
| Joe Brackin | COE | 503.808.4922 | joseph.p.brackin@usace.army.mil |
| Dave Kloewer | COE | 503.808.4959 | david.j.kloewer@usace.army.mil |
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| Liza Roy | ENSR | 503.715.2887 | lroy@ensr.aecom.com |
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| Doug Hartsock | WGI | 425.451.4658 | doug.hartsock@wgint.com |

## BACKGROUND AND PURPOSE

The Dalles EFL currently passes between 70 and 90 percent of upstream migrating adult fish (the North Fish Ladder on the opposite bank passes the remainder). The continuous availability of the EFL is therefore crucial to the overall adult fish passage success at The Dalles Dam.

The purpose of the EFL inspection was to observe and document the current civil/structural, mechanical, hydraulic, electrical, and geotechnical conditions of the overall facility. The observations will be used to support future EFL reliability studies.

## METHODOLOGY

The following methodology was adopted for this task:

1. Review EFL drawings and reports
2. Conduct site inspection
3. Prepare draft trip report
4. Review draft trip report with USACE
5. Finalize trip report

## INSPECTION CHRONOLOGY

The following represents an approximate chronology of the inspection. See Figure 1 for area descriptions.

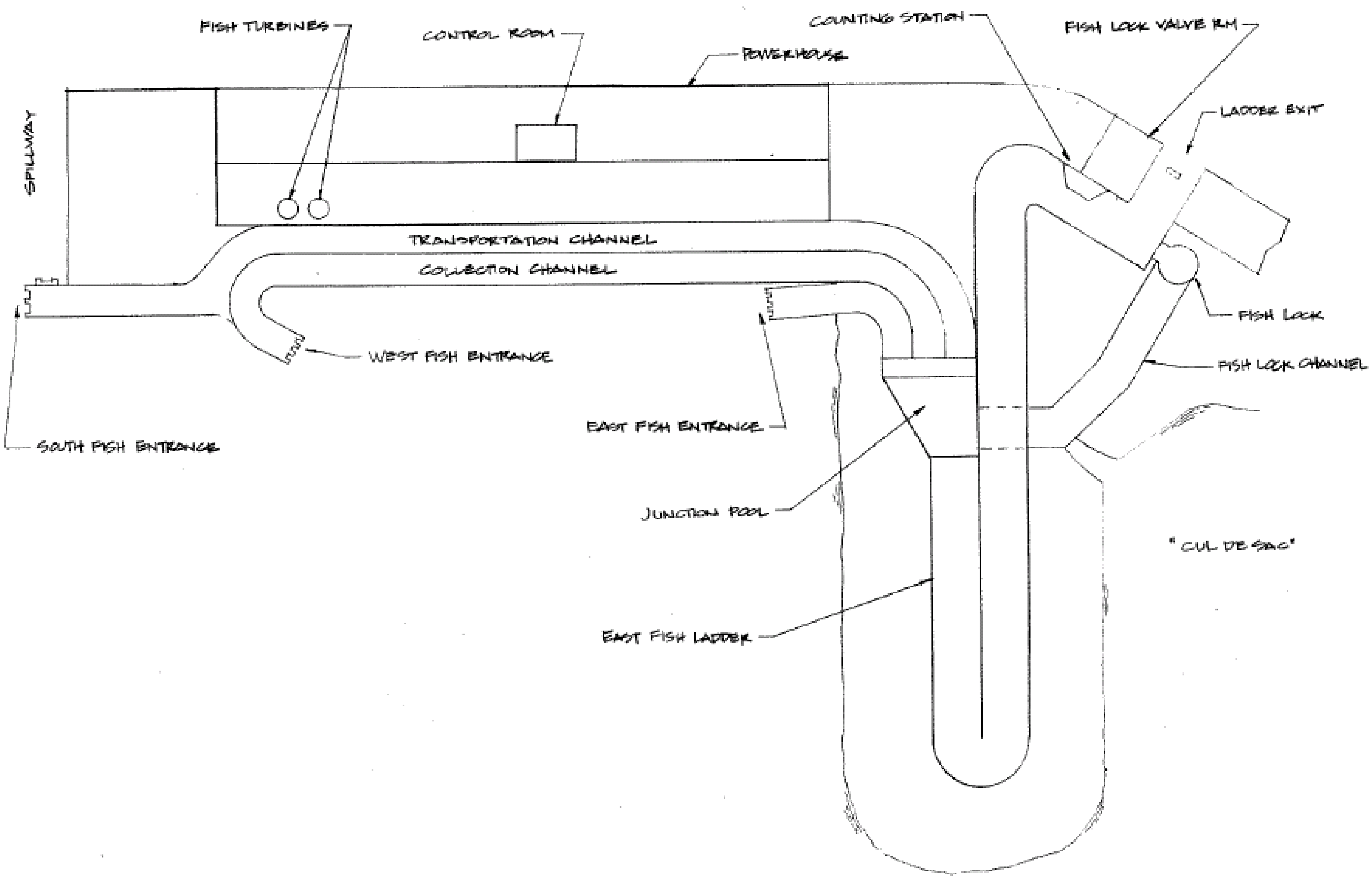
1. Met at The Dalles Fisheries Office at 9:00 a.m. Introduced participants, reviewed project history and objectives, safety, and agenda.
2. Drove to east end of The Dalles powerhouse. Lowered by manbasket into East Fish Entrance. Observed East Fish Entrance telescoping weirs, Junction Pool, and Fish Lock bulkhead.
3. Geotechnical participants proceeded south along Transportation Channel. The remaining participants proceeded south along the Collection Channel. Observed Collection Channel structure, gates, bulkheads, orifices, dewatering equipment, and diffuser grating.
4. Geotechnical participants continued south in Transportation Channel until reaching the concrete-to-rock transition point. Continued south, observing the rock portion of the channel until access blocked by deep ponded water.
5. Collection Channel participants reached the West Fish Entrance and observed the telescoping weirs, diffuser grating, and gates.
6. Both participant groups were lifted from their respective channels and broke for lunch.
7. Following lunch, the participants met at the South Fish Entrance. Select participants were lowered by manbasket into the entrance to observe the structure, telescoping weirs, diffuser grating, and gates.
8. Following removal from the South Entrance, participants observed the south weir hoists and rigging. The group then drove to the East Fish Ladder and observed the Junction Pool from above. Observations were also made of the lower half of the ladder structure and weirs.
9. The participants entered the Fish Lock Valve Room to observe the various large valves used to supply forebay water to the Fish Lock and other areas.
10. Leaving the valve room, participants entered and observed the Fish Counting Station. Exiting the Fish Counting Station, participants observed the Fish Lock silo, Ladder Exit weirs, and various hoists and electrical controls before quitting for the day.

11. Day Two began at the Fisheries Office at 8:30 a.m. Participants walked to the North Fish ladder to observe it in operation. The group then drove to the west end of The Dalles powerhouse and entered the powerhouse to observe the Fish Turbines and associated electrical controls.
12. Participants then proceeded to the Powerhouse Control Room to observe the fish turbine control panel.
13. The group then drove to the site conference center where a wrap up meeting was held and attended by operations personnel.
14. The meeting adjourned and all participants departed at 3:00 p.m.

**INSPECTION RESULTS**

The following sections provide a description of the areas that were inspected (Figure 1), followed by discipline specific observations.

**FIGURE 1: THE DALLES EAST FISH LADDER AREAS INSPECTED FEBRUARY 7-8, 2007**



## *East Fish Entrance*

### Civil/Structural Observations

The East Entrance is separated into two parts by a divider wall, and thus requires two bulkheads for dewatering. Only one telescoping weir was observed, installed in the south opening immediately behind the bulkhead. The bulkheads leaked slightly. We were told that the seals on the bulkheads were new and therefore there was much less leakage now than previously.

Concrete work appeared to be intact and unweathered with little joint leakage, only a few places showing dampness. Diffuser grillages are in good condition with light corrosion.

### Mechanical/Electrical Observations

Bulkheads were observed to be installed in the three east fish entrance gate openings. (Photo ME-1) A telescoping gate was suspended by wire rope in the center opening. Gate slots and seals appeared to be in good condition. Three pairs of telescoping weirs (called out as junction pool weirs on drawings) were observed between the east entrance and the junction pool. The two northernmost weirs were suspended in what appeared to be the full up position; the southernmost weir was dropped to the floor in what appeared to be a full down position. Leaf seals on the southernmost weir were observed to be in good condition. (Photo ME-2) Crustacean shell fragments were observed to be piled against the sill of the weirs at the bottom of the gate slots.

### Hydraulic Observations

The east entrance gates appear to be in satisfactory condition, except the center gate is under repair as shown in Photo H-1. The east entrance gates operate with the same lifting beam mechanism used for the North Fish Ladder. The diffuser grating in the east entrance appears to be in satisfactory condition and the diffuser panels in the entrance area operate as part of the auxiliary water supply.

## *Junction Pool*

### Civil/Structural Observations

There are low concrete sills, about 3 feet high, between the junction pool and the east entrance, collection channel, and transportation channel. The collection and transportation channels have telescoping weirs stored in a raised position out of water as shown in Photo CS-1.

Concrete work appeared to be intact and unweathered with no joint leakage except for one damp (but not leaking) joint in the right wall of the transportation channel entrance. Diffuser grillages are in good condition with light corrosion. The fishlock bulkhead has a small leak.

### Hydraulic Observations

The junction pool was observed as shown in Photo H-2. USACE staff noted that the junction pool 3-leaf weirs are open to the collection and transportation channels and operated at 7 feet below tailwater in the east entrance channel. The 1” by ~ 4 in” floor diffuser grating appeared to be in satisfactory condition. The diffuser panels in the junction pool are normally in operation for the auxiliary water supply.

The lower weirs for the East Fish Ladder are shown in Photo H-3. Some debris was caught in the gap between the grating and the orifice floor at each orifice opening as shown in Photo H-4. We also observed the bulkhead for the fish lock channel entrance to the junction pool. The fish lock is not operated at this time.

We were advised that there was a distribution problem in the junction pool, whereby an excessive amount of water was lost out the east entrance. Due to this loss, in order to furnish sufficient water to the collection and transportation channels a total of about 4,500 cfs of auxiliary water was needed. Both fish water turbines were therefore required to operate near rated capacity at all times. It was believed that the auxiliary water flow could be much reduced, perhaps by as much as 1,000 cfs, if the excessive east entrance outflow could be controlled. At present it cannot be controlled because the differential head criterion for the telescoping weirs would be violated if they were raised further.

## *Collection Channel*

### Civil/Structural Observations

The only major leak observed on the inspection tour was found at one of the floating orifices. All the floating orifices were closed, and only the one exhibited significant leakage (Photo CS-2). The concrete bulkheads exhibited very small leakage in varying amounts. We were advised that the seals were new. The dewatering pumps were also new. These items were part of the "Adult Fishway Dewatering Improvements" undertaken since the Inca condition inspection report recommended them ten years ago. Only a few of the joints in the concrete walls showed dampness. Structural condition of the concrete work appeared excellent.

The auxiliary water system (AWS) tunnel under the collection channel floor was at least partially dewatered, which revealed that several of the diffuser gates were leaking. The water level beneath the diffuser grills was drawn down by varying amounts despite the constant inflow from collection channel leakage. Where the drawdown was large enough we could observe that there were piles of bivalve shells, stones and muck on the floor of the diffuser chambers, which probably interfered with the closure of the diffuser gates and caused the leakage into the AWS from the collection channel.

The diffuser grills were considerably more corroded than were the similar grills in the junction pool. Nevertheless, they were all intact, well fastened down, and had no holes or missing bars.

### Hydraulic Observations

We walked the entire length of the collection channel as shown in Photo H-5. The gate housing for the diffuser gates are visible in the channel as shown in Photo H-6. The diffuser gates are closed during current operations. The floating orifices in the collection channel are closed during normal operation as well (Photo H-7). We were advised that the floating orifices in the collection channel were no longer used, since they had not been effective for fish attraction. With the orifices closed, the diffuser gates were also closed; thus no attraction water from the AWS entered the collection channel along its length, only at the junction pool and the west powerhouse entrance.

During the site visit some of the diffuser gate wells were drained below the floor level. This was likely due to some leakage through the diffuser gates in these wells. In the gate wells with lower water levels, sedimentation and growth of mussels or other bivalve populations were observed. It is possible that the sediment prevents full closure and sealing of the diffuser gates. Photo H-8 shows one of the diffuser wells that was partially drained. The diffuser grating appeared to be in satisfactory condition but showed signs of sedimentation.

**Mechanical/Electrical Observations**

A series of diffuser gates were observed at regular intervals along the upstream wall of the fish collection channel. (Photo ME-3) District staff advised that the gates were fully closed and were maintained in the fully closed position. A few gates appeared to be partially open, allowing water to enter the collection channel through the diffuser gratings. Six dewatering pump casings were observed at regular intervals along the upstream side of the channel. (Photo ME-4) The pumps were operating and removing water that was leaking into the channel past bulkheads or the partially open diffuser gates. Floating orifices were abandoned in place along the downstream wall of the channel. Water was observed to be leaking past the downstream bulkheads in a few locations. (Photo ME-5)

## *West Fish Entrance*

**Civil/Structural Observations**

There is a telescoping weir between the collection channel and the transportation channel which closes the west powerhouse bypass opening. According to the drawings it is always closed.

The west entrance has three openings. Three telescoping weirs were present, stored in a raised position behind the bulkheads. The concrete floor exhibited some laitance which was flaking off; this is of no structural significance, although it may indicate that part of the floor has been replaced or patched recently. Small amounts of seepage were present at several locations on the concrete walls, particularly at one horizontal lift joint near the normal water level. The diffuser grills appeared to be new. There were shells and stones lying atop the diffuser grills. It is not obvious how the stones were transported to this location, since they were too large to come up through the diffuser grills. In the entire inspection we never observed any missing diffuser grills, although we did observe grills being replaced in the fish ladder itself.

**Mechanical/Electrical Observations**

Bulkheads were installed in all three west fish entrance openings. (Photo ME-6) Telescoping weirs were suspended in each opening. Gates, slots, and seals appeared to be in good condition. A fourth telescoping “bypass” gate was observed between the collection channel and the transportation channel. (Photo ME-7) All four gates appeared to be in good condition.

**Hydraulic Observations**

The West Entrance gates were observed and appear to be in satisfactory condition as shown in Photo H-9. The diffusers in the west entrance operate during normal operations and the grating appeared to be in satisfactory condition.

## *Transportation Channel*

**Civil/Structural Observations**

As viewed from grade, the open-cut concrete walled portion of the transportation channel appeared to be in good condition. There was approximately one-inch of water in the Transportation Channel. Locally, there were pieces of spalled concrete on the floor of the channel. There was also some miscellaneous debris that had fallen from the grating above, i.e., keys, coins, bolts, etc. At one location near the entrance of the transportation channel near the junction pool, an area of sand approximately 1 to 2-feet in dimension was present at the floor of the channel near a construction joint as shown in Photo CS-3.

Nearer to the rock-lined channel, a piece of formed concrete was found on the floor of the channel. The inspection team could not find where the concrete had dislodged, as the walls appeared to be intact, but the piece of concrete had fresh sharp corners and appeared to be a recent addition to the transportation channel debris.

**Geotechnical/Geologic Observations**

From conversations with Corps of Engineers personnel, it is our understanding that the rock-lined portion of the EFL had been cleaned of loose rock debris approximately 2 years prior to our inspection. This was the only time it had been cleaned since the construction of the channel. COE site personnel who were there at the time of the cleaning mentioned that there was quite a bit of rock removed, which had accumulated over the 50-year time period. At the time of our inspection, only small pieces of rock were present on the floor of the channel.

The rock in the channel is part of the Columbia River Basalt Group. Two flows were noted during the inspection and are separated by a thin layer of material that supports growth of a moss layer with minor vegetation. The lower layer had a closer spaced joint pattern and the upper layer tended to be more massive. The rock required blasting to be constructed and the blast holes are still evident in the rock slopes (Photo G-1). The rock maintains vertical slopes. The basalt is fresh to slightly weathered. Although it is jointed, due to cooling, no pervasive joint pattern was noted that was deleterious to the stability of the slope. Most rock fall that has occurred is likely the result of loosening of individual basalt rocks (Photo G-2). A few areas of large blocks that have been loosened from the slope are also shown in this photograph.

In areas where fill has been placed, the area was stabilized with concrete wall and cross struts (Photo G-3).

### Hydraulic Observations

Significant rock-fall in the rock-lined portion of the transportation channel may change the effective roughness coefficient of this portion of the channel and impact head loss through the channel. This can be minimized by periodic channel maintenance.

## *South Fish Entrance*

### Civil/Structural Observations

The south entrance has two openings. The two bulkheads appeared to be leak free, although the sills could not be observed due to being submerged. The structural concrete appeared sound. The diffuser grills were somewhat corroded but were intact and well secured. The rocks and shells which were found lying on the grills at the west powerhouse entrance were not observed here.

### Mechanical/Electrical Observations

Bulkheads were installed in both south fish entrance openings. (Photo ME-8) A telescoping weir was suspended in the south opening; the north opening weir was missing and reported to be installed in the North Fish Ladder Entrance. A dual sheaved lifting beam used to raise and lower the telescoping weirs was observed. (Photo ME-9) The beam is a relatively recent addition designed to improve the reliability of the gate by removing the wire ropes from the flow stream. Hoists used to raise and lower the telescoping gates were observed to be in good condition. (Photo ME-10) Gate slots also appeared to be in good condition. Hoist electrical controls appeared to be somewhat weathered and old but no reports of malfunction were reported. (Photo ME-11)

### Hydraulic Observations

The South Entrance gates and diffusers were observed as shown in Photo H-10 and appeared to be in satisfactory condition. The diffusers in the South Entrance operate during normal operations as part of the auxiliary water supply.

## *East Fish Ladder*

### Civil/Structural Observations

The exterior of the concrete of the ladder shows considerable efflorescence, especially at the horizontal joint between floor and walls. This is probably a sign of historical leakage at the joint, likely long since stopped by autogenous healing. The diffuser grills were being replaced and the expansion joints in the concrete walls recaulked. It was noted that some of the concrete weirs in the lower part of the ladder, such as Weir 72 (second weir from end of ladder) were supported by steel angle clips; no one in the party was able to supply any information what had happened that resulted in the installation of the clips (Photo CS-4). Some concrete had been cut off from the base of the buttress walls of other weirs, and the pieces were lying in the fishway; it was unclear what motivated their removal.

The upper ladder weirs were modifications made to the original ladder. They were steel bulkheads, rather than concrete, and were adjustable. The fish exit weirs were also modifications, as was the fish counting station near the ladder exit. PIT tag detectors had been recently installed on the weirs and orifices at one location downstream of the counting station. All of the modifications appeared to be in good condition.

### Mechanical/Electrical Observations

A hoist control station appeared to be somewhat weathered and old, but no reports of malfunction were reported. (Photo ME-12) Hoists and rigging appeared to be in good condition. Evidence of regular changing of hoist gearbox oil was noted on several gearbox housings. (Photo ME-13) District staff pointed out that the gearboxes were located over water.

### Hydraulic Observations

The East Ladder appeared to be in good condition, with the weirs and orifices appearing in satisfactory condition. On the lower approach to the junction pool, several weir pools contained chunks of concrete as shown in Photo H-11. It appears that the concrete may have come from under the upstream weir approach wall. Several of the diffuser sections have new grating.

The upper section of ladder weirs upstream of the 180° bend was observed to have significantly greater algal growth as shown in Photo H-12.

We were advised that the AWS could only supply water to the ladder diffusers when the river water level was high.

## *Fish Lock*

### Mechanical/Electrical Observations

The original east fish ladder construction included a fish lock designed to lift fish from the junction pool to the ladder exit. (Photo ME-14)The fish lock had not been used in several years; District staff reported that 1) fish were not inclined to enter it, and 2) fish that did enter it experienced descaling during the lifting operation. A valve room used to supply forebay water to the fish lock and other areas was entered and observed. (Photo ME-15) The valves, actuators, and controls appeared to be in good condition. District staff shared that operation of the valves had been considered to supply additional attraction flow to the east fish ladder via the fish lock.

### Hydraulic Observations

We were told that the fish lock has not been used since early in the operation of the project because it descaled the fish. There are no plans to use it for fish passage. However, it is of interest as an alternative source of attraction water, possibly requiring modifications to obtain water delivery in the right quantity, head and location.

We found that on Drawing DDF-1-0-5/3, “East Fish Ladder and East Non-Overflow Dam General Plan,” a tunnel was shown from the fish lock under the ladder to the AWS conduit. No one present had ever seen the tunnel, so it could not be confirmed if it actually exists.

## *Fish Turbines*

### Mechanical/ Electrical Observations

The two fish turbine transformers (one per unit) were observed and appeared to be in good condition. (Photo ME-16) The fish turbine units and controls were observed and appeared to be well-maintained. (Photo ME-17, ME-18)

The condition of the fish turbines was discussed. Although they have been very reliable, they are showing signs of age. New windings have been installed. The original 50-year-old bearings are "sagging." The carbon packing would be the first item to fail and would take 3 weeks to replace. If replacing the packing only was not sufficient, it would then take 3 months to replace the bearings.

It was confirmed that a low side bus had been installed so that the fish turbines could feed the Turbine 1 transformer in event of failure of their own transformer. Both fish turbines are on that same bus, however.

## *Counting Station*

### Mechanical/Electrical Observations

The counting station was entered and observed. District staff reported no problems with the operation of the crowder or window cleaning mechanisms. The counting room ventilation and cooling system was reported to need improving.

### Hydraulic Observations

The picket gates, counting station, crowder and water level measurement station all appeared to be in satisfactory condition. The water level measurement station is located just downstream of the count station.

## *Fish Ladder Exit Section*

### Mechanical/Electrical Observations

Several adjustable weirs were observed in the ladder exit section. (Photo ME-19) The weirs were in various positions. District staff reported that the number of adjustable weirs added complexity and maintenance to the operation of the ladder, and questioned whether they were needed. The ladder exit consists of two smaller adjustable weirs that appear to have been fabricated from a former single weir. (Photo ME-20) Bulkheads were observed on the upstream side of the weirs. The various adjustable weirs are controlled by a motor control center and PLC located in a room adjacent to the gates. (Photo ME-21) No electrical or control problems were reported.

### Hydraulic Observations

Photo H-13 shows the four adjustable exit section weirs. Each of the adjustable weirs has a slightly different geometry. Typical operation is that the downstream-most weir is in place, the next two upstream alternate operating, and the upstream-most is almost always out of the ladder. Staff reported occasional automation problems with the system. The orifice openings on the adjustable weirs are not flush with the ladder floor as in the permanent ladder weirs. The removable weirs are a retrofit and are not part of the original design. Water levels are monitored in the ladder just downstream of the counting station.

The exit weirs are shown in Photo H-14. The pair of weirs are automatically operated based on forebay elevation. The downstream weir tracks at 1 foot below the upstream (weir 159) weir elevation. The weirs appear to be in satisfactory condition.

## *Control Room*

### Mechanical/Electrical Observations

The fish turbine control panels located in the powerhouse control room were observed. Operators reported no problems with their operation. (Photo ME-22, ME-23)

# APPENDIX

# SITE PHOTOS

The Dalles Dam EFL Inspection Report
March 23, 2007
Photos


Photo CS-1 Overall view of the East Entrance, Collection Channel and Transportation Channel

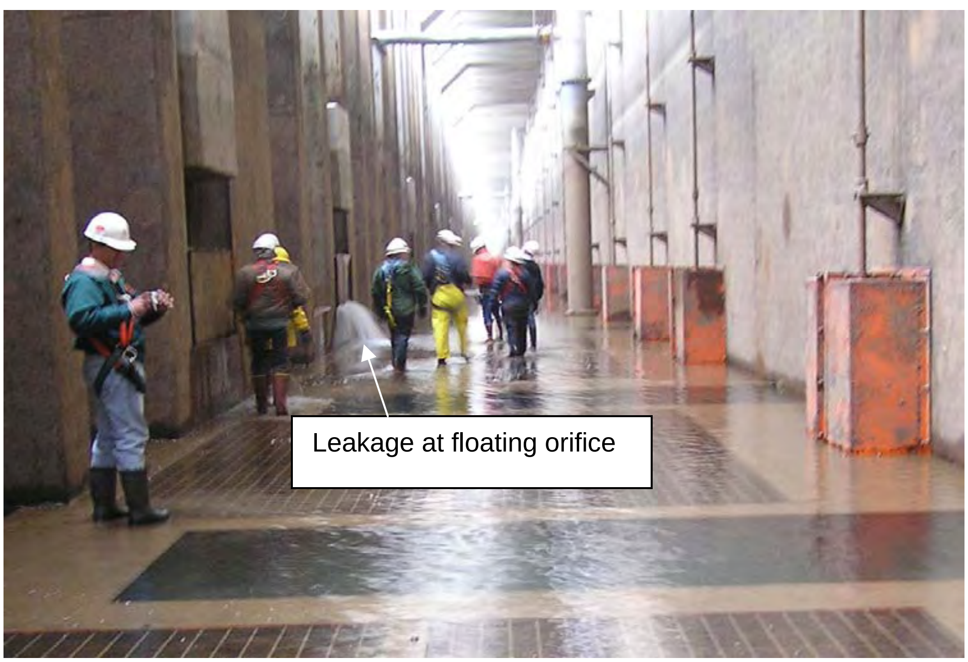



Photo CS- 2 Collection Channel. Note leakage at one floating orifice.

Photo CS-3  Sand accumulated from seepage at joint between concrete sections in Transportation Channel

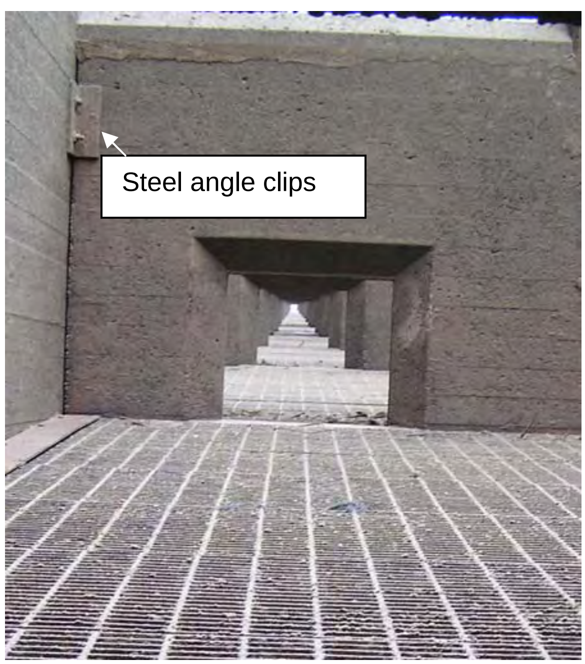



Photo CS-4 – East Fish Ladder Concrete Weir supported by steel angle clips

Photo ME-1 Bulkheads present in the three east fish entrance gate openings

Photo ME-2 Leaf seals on the southernmost weir at East Entrance

Photo ME-3  Diffuser gates along upstream wall of fish collection channel

Photo ME-4  Dewatering pump casings along upstream side of collection channel

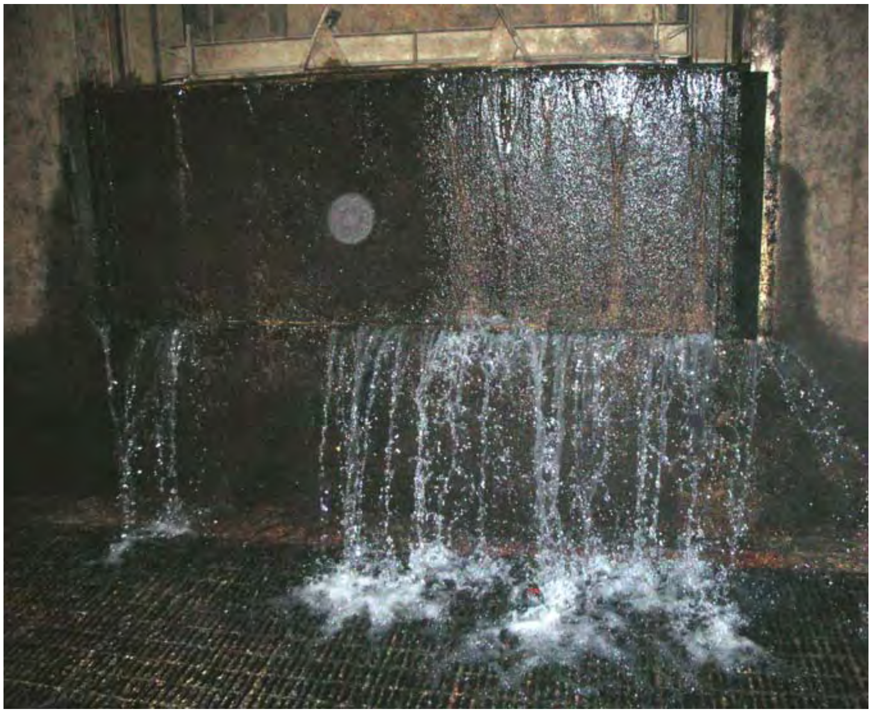


Photo ME-5  Water leaking past downstream bulkhead in collection channel

Photo ME-6  Bulkheads at west fish entrance openings

Photo ME-7 Telescoping “bypass” gate between collection and transportation channels

Photo ME-8 South fish entrance bulkheads

Photo ME-9  Dual sheaved lifting beam for raising and lowering telescoping weirs

Photo ME-10  Hoists for raising and lowering telescopic gate at south fish entrance


Photo ME-11  Hoist electrical controls at South Entrance showing older condition

Photo ME-12  Hoist Control Station at Junction Pool


Photo ME-13  Gearbox Housing

Photo ME-14  Fish Lock – View from top

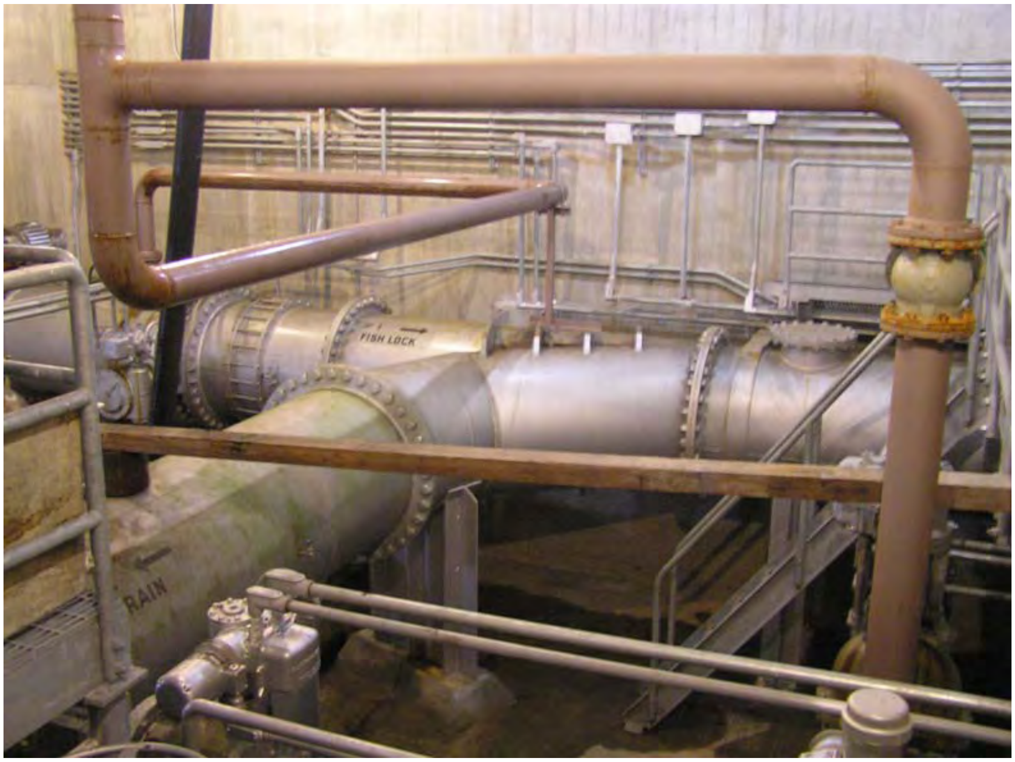



Photo ME-15  Fish Lock Valve Room


Photo ME-16  Fish Turbine Transformer

Photo ME-17  Fish Turbine Units

Photo ME-18  Fish Turbine Controls

Photo ME-19  Adjustable weirs in fish ladder exit section

Photo ME-20  Weirs fabricated from a former single weir


Photo ME-21  Motor Control Center and PLC


Photo ME-22  Fish Turbine Control Panels


Photo ME-23  Fish Turbine Control Panels

The Dalles Dam EFL Inspection Report
March 23, 2007
Photos


Photo H-1  EFL East Entrance


Photo H-2  EFL Junction Pool


Photo H-3 Junction Pool


Photo H-4 Debris between diffuser grating and orifice


Photo H-5  Collection Channel


Photo H-6  Diffuser Gate Housing


Photo H-7 Floating Orifice


Photo H-8 Sediment on diffuser grating


Photo H-9  West Entrance


Photo H-10  South Entrance


Photo H-11 Typical East Ladder Weir

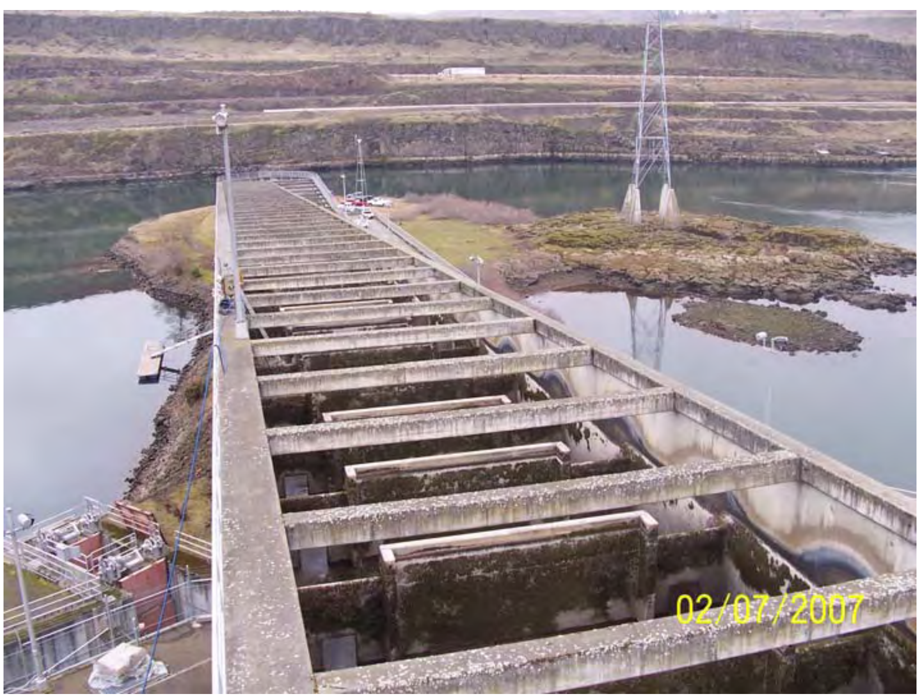



Photo H-12 Upper EFL


Photo H-13 Exit Section


Photo H-14 Exit Weirs

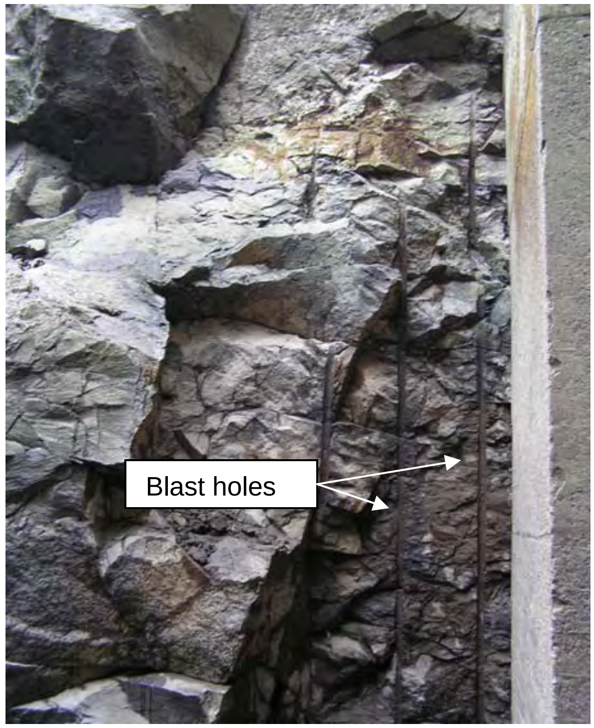



Photo G-1  Blast holes drilled for the construction of the channel


Photo G-2  Vertical slopes in the rock-lined channel. Notice zones where larger rocks have been displaced into channel. Only minor amount or rock debris on floor of the channel.

Photo G-3 – Area of rock-lined channel that is stabilized with concrete and cross struts.

# Appendix E

# Figures

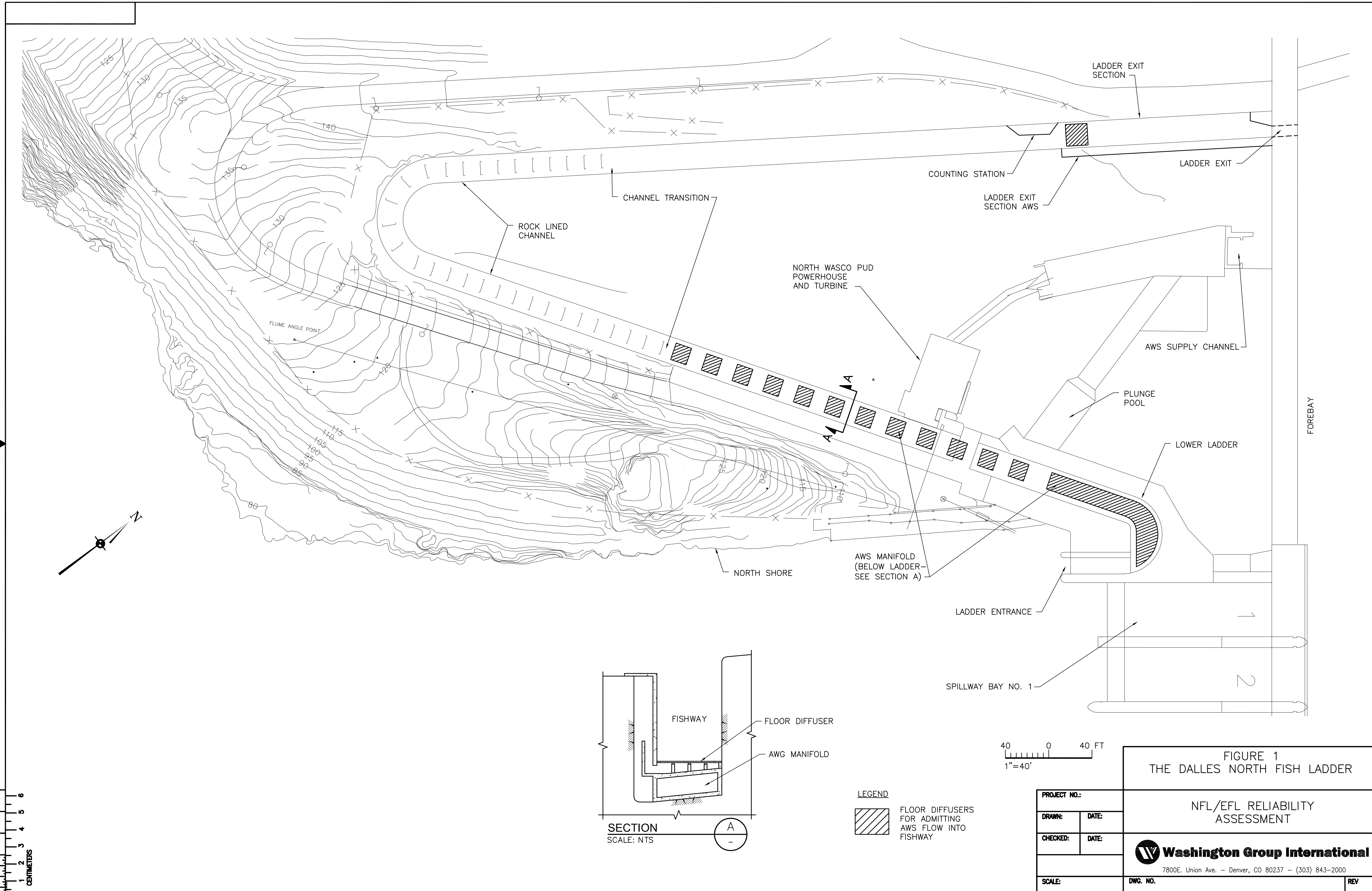



FIGURE 1
THE DALLES NORTH FISH LADDER

NFL/EFL RELIABILITY ASSESSMENT

PROJECT NO.:
DRAWN: DATE:
CHECKED: DATE:
SCALE:
DWG. NO.
REV

Washington Group International
7800E. Union Ave. – Denver, CO 80237 – (303) 843–2000

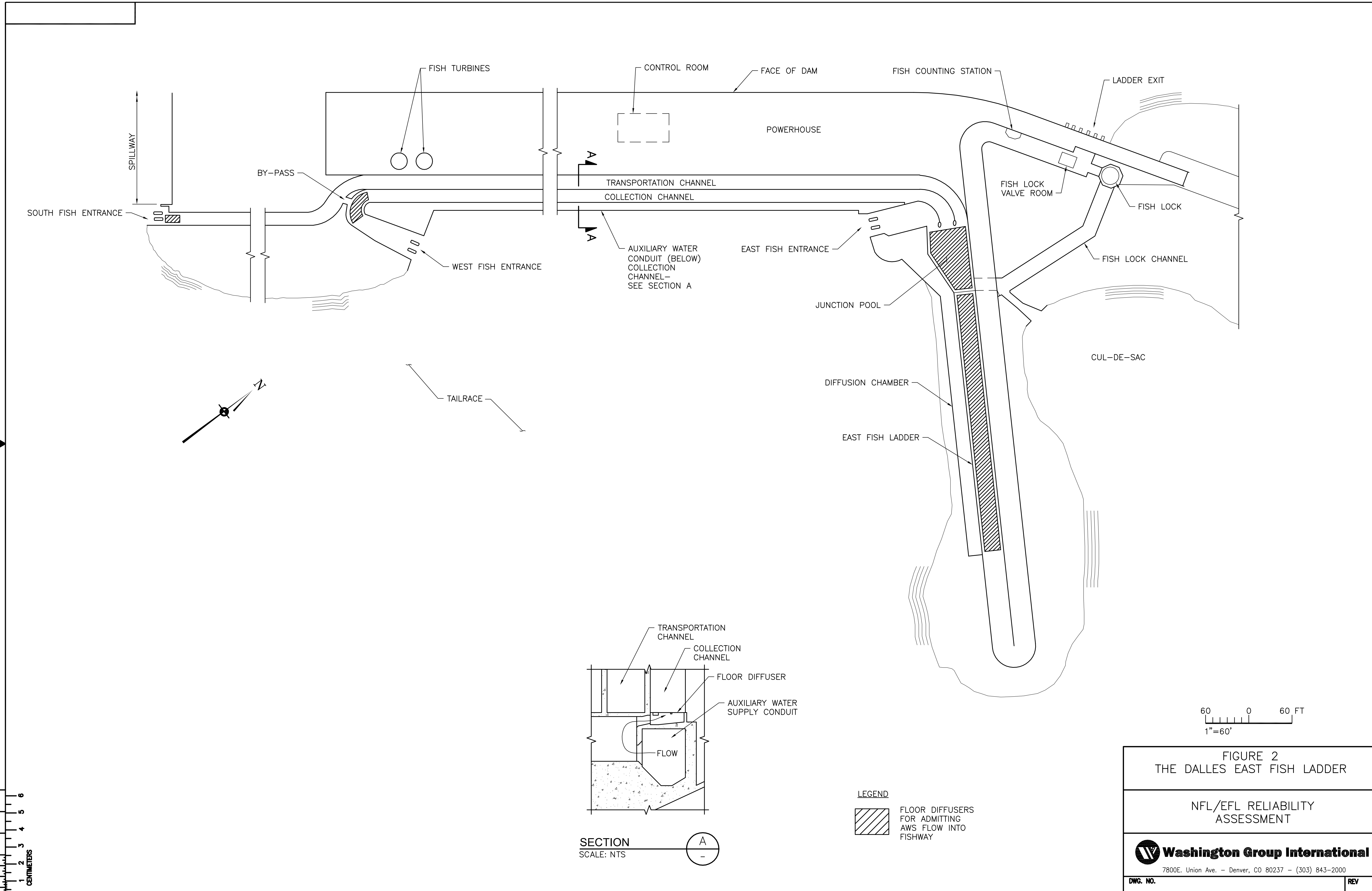



FIGURE 2
THE DALLES EAST FISH LADDER

NFL/EFL RELIABILITY ASSESSMENT

Washington Group International
7800E. Union Ave. – Denver, CO 80237 – (303) 843-2000

DWG. NO. | REV

# Appendix F

# Fish Turbine Spare Parts

The Dalles Lock and Dam
Fish Turbine Spare Parts

| EQNUM | ITEMNUM | DESCRIPTION |
|---|---|---|
| G2TDFU1GOVPR | G2D-20030 | ASSEMBLY, BASE, 3 POLE, W-H #1490400, TYPE N, SIZE 3 LINE STARTER CONTACT BASE TDD, JDD |
| G2TDFU2GOVPR | G2D-20030 | ASSEMBLY, BASE, 3 POLE, W-H #1490400, TYPE N, SIZE 3 LINE STARTER CONTACT BASE TDD, JDD |
| G2TDFU1GOVPR | G2D-20035 | ASSEMBLY, BASE, 3 POLE, #1490403, SIZE 3, 3 POLE, TDD, JDD |
| G2TDFU2GOVPR | G2D-20035 | ASSEMBLY, BASE, 3 POLE, #1490403, SIZE 3, 3 POLE, TDD, JDD |
| G2TDFU1BKR | G2D-20086 | STUDS, CONTACT, FOR 4,000 AMP GE BREAKER DISCONNECTS (PR 16684) |
| G2TDFU2BKR | G2D-20086 | STUDS, CONTACT, FOR 4,000 AMP GE BREAKER DISCONNECTS (PR 16684) |
| G2TDFU1BKR | G2D-20087 | CONTACT, STATIONARY, FOR 4,000 AMP GE BREAKER DISCONNECT |
| G2TDFU2BKR | G2D-20087 | CONTACT, STATIONARY, FOR 4,000 AMP GE BREAKER DISCONNECT |
| G2TDFU1BKR | G2D-20100 | SNUFFER ASSEMBLY (ARC CHUTE FOR DMB-50-T), TDD |
| G2TDFU2BKR | G2D-20100 | SNUFFER ASSEMBLY (ARC CHUTE FOR DMB-50-T), TDD |
| G2TDFU1BKR | G2D-20105 | UPPER STATIONARY ASSEMBLY, DMB-25-IT BREAKER (MAIN CONTACT), TDD |
| G2TDFU2BKR | G2D-20105 | UPPER STATIONARY ASSEMBLY, DMB-25-IT BREAKER (MAIN CONTACT), TDD |
| G2TDFU1BKR | G2D-20106 | TRIP ATTACHMENT, SHUNT, FED. PAC. #11550757, TDD |
| G2TDFU2BKR | G2D-20106 | TRIP ATTACHMENT, SHUNT, FED. PAC. #11550757, TDD |
| G2TDFU1BKR | G2D-20120 | BARRIER, BOX, COMPLETE, TDD, JDD, GE#61C41662 |
| G2TDFU2BKR | G2D-20120 | BARRIER, BOX, COMPLETE, TDD, JDD, GE#61C41662 |
| G2TDFU1GOV | G2D-20135 | BEARING, PMG FU, SKF BRAND #6209-2RS1/C3HT51, KOYO #62092RDC3, TDD |
| G2TDFU2GOV | G2D-20135 | BEARING, PMG FU, SKF BRAND #6209-2RS1/C3HT51, KOYO #62092RDC3, TDD |
| G2TDFU2GEN | G2D-20135 | BEARING, PMG FU, SKF BRAND #6209-2RS1/C3HT51, KOYO #62092RDC3, TDD |
| G2TDFU1GEN | G2D-20178 | BEARING, GENERATOR GUIDE, FU 1-2, TDD |
| G2TDFU2GEN | G2D-20178 | BEARING, GENERATOR GUIDE, FU 1-2, TDD |
| G2TDFU1GOV | G2D-20190 | BEARING, PMG FU, SKF #6208-2RS1/C3HT51 OR KOYO #6208-2RSC3 , METRIC SINGLE ROW, LIGHT |
| G2TDFU2GOV | G2D-20190 | BEARING, PMG FU, SKF #6208-2RS1/C3HT51 OR KOYO #6208-2RSC3 , METRIC SINGLE ROW, LIGHT |
| G2TDFU2GEN | G2D-20190 | BEARING, PMG FU, SKF #6208-2RS1/C3HT51 OR KOYO #6208-2RSC3 , METRIC SINGLE ROW, LIGHT |
| G2TDFU1GOV | G2D-20192 | BEARING, NSK 626ZZ & FAFNIR 36KDD, FOR FU AND SELSYN SYNCHRONIZE MOTORS, TDD |
| G2TDFU2GOV | G2D-20192 | BEARING, NSK 626ZZ & FAFNIR 36KDD, FOR FU AND SELSYN SYNCHRONIZE MOTORS, TDD |
| G2TDFU1GOV | G2D-20194 | BEARING, TORRINGTON B-812X, FOR SPEED ADJUST SHAFT IN GOVERNOR CABINETS, OLD UNITS |
| G2TDFU1GEN | G2D-20204 | BEARING, FAG OR SKF #6203-2ZJEM, METRIC SINGLE ROW, LIGHT 200 SERIES, |
| G2TDFU1 | G2D-20240 | BLOCK, INSULATING (F.U. F-1, F-2 RTDS),TDD |
| G2TDFU2 | G2D-20240 | BLOCK, INSULATING (F.U. F-1, F-2 RTDS),TDD |

The Dalles Lock and Dam
Fish Turbine Spare Parts

| EQNUM | ITEMNUM | DESCRIPTION |
|---|---|---|
| G2TDFU1 | G2D-20260 | BRIDGE ASSEMBLY, MOVABLE, #181474-K1, TDD |
| G2TDFU2 | G2D-20260 | BRIDGE ASSEMBLY, MOVABLE, #181474-K1, TDD |
| G2TDFU1TUR | G2D-20340 | BUSHING, GATE, BRONZE, 4" LONG, F.U. TURBINE, TDD |
| G2TDFU2TUR | G2D-20340 | BUSHING, GATE, BRONZE, 4" LONG, F.U. TURBINE, TDD |
| G2TDFU1 | G2D-20345 | BUSHING, BRONZE, BLADE SHANK F1 & F2, 4--3/4"L X 11-1/2" ID, TDD |
| G2TDFU2 | G2D-20345 | BUSHING, BRONZE, BLADE SHANK F1 & F2, 4--3/4"L X 11-1/2" ID, TDD |
| G2TDFU1GEN | G2D-20690 | CLOTH, GLASS, .007 X 36" (50 YD ROLLS), TDD |
| G2TDFU2GEN | G2D-20690 | CLOTH, GLASS, .007 X 36" (50 YD ROLLS), TDD |
| G2TDFU1GENEXC | G2D-21034 | FIELD COIL AND POLE FOR EXCITER, F1 & F2 |
| G2TDFU2GENEXC | G2D-21034 | FIELD COIL AND POLE FOR EXCITER, F1 & F2 |
| G2TDFU1GENEXC | G2D-21035 | ASSEMBLY, FIELD COIL, F.U., TDD |
| G2TDFU2GENEXC | G2D-21035 | ASSEMBLY, FIELD COIL, F.U., TDD |
| G2TDFU1GEN | G2D-21185 | COIL, G.E. #22D151G-41, 125VDC, F1 & F2 |
| G2TDFU2GEN | G2D-21185 | COIL, G.E. #22D151G-41, 125VDC, F1 & F2 |
| G2TDFU1GEN | G2D-21280 | COLLAR, INSULATING, STATOR COILS, (F.U. GENERATOR) TDD |
| G2TDFU2GEN | G2D-21280 | COLLAR, INSULATING, STATOR COILS, (F.U. GENERATOR) TDD |
| G2TDFU1TUR | G2D-21871 | SWIVEL, HIGH PRESSURE, ANTI-FRICTION, 1/4", #U997-6, FOR FARVAL GREASE SYSTEM,TURBINE PIT |
| G2TDFU2TUR | G2D-21871 | SWIVEL, HIGH PRESSURE, ANTI-FRICTION, 1/4", #U997-6, FOR FARVAL GREASE SYSTEM,TURBINE PIT |
| G2TDFU1GOV | G2D-21965 | COVER, DRIVE SHAFT, PUMP, (F.U. GOVERNOR) TDD |
| G2TDFU2GOV | G2D-21965 | COVER, DRIVE SHAFT, PUMP, (F.U. GOVERNOR) TDD |
| G2TDFU1GEN | G2D-22242 | GASKET, UPPER OIL GUIDE BEARING, M. U. 15-22, SET OF 4 SECTIONS, 79-1/2" OD X 74-3/4" ID |
| G2TDFU1TUR | G2D-22249 | GASKET, DRAFT TUBE DOOR, FU 1-2, TDD, 24" X 36" RECT ID X 31" X 43" RECT |
| G2TDFU2TUR | G2D-22249 | GASKET, DRAFT TUBE DOOR, FU 1-2, TDD, 24" X 36" RECT ID X 31" X 43" RECT |
| G2TDFU1TURKAP | G2D-22290 | GEAR, SPEED SWITCH, 1-1/2" DIA. FOR 12 POLE PERMANENT MAGNET GENERATOR, 1 EACH OF #1, #2, |
| G2TDFU2TURKAP | G2D-22290 | GEAR, SPEED SWITCH, 1-1/2" DIA. FOR 12 POLE PERMANENT MAGNET GENERATOR, 1 EACH OF #1, #2, |
| G2TDFU1TURKAP | G2D-22295 | GEAR, SPEED SW #35444-60, 3" DIA., TDD, |
| G2TDFU2TURKAP | G2D-22295 | GEAR, SPEED SW #35444-60, 3" DIA., TDD, |
| G2TDFU1GENEXC | G2D-22521 | TACH-PAK, AIRPAX, FOR F.U. EXCITERS, #T77430-11 |
| G2TDFU2GENEXC | G2D-22521 | TACH-PAK, AIRPAX, FOR F.U. EXCITERS, #T77430-11 |
| G2TDFU1GENEXC | G2D-22522 | SENSOR, #H1512-009, FOR F.U. EXCITERS |
| G2TDFU2GENEXC | G2D-22522 | SENSOR, #H1512-009, FOR F.U. EXCITERS |
| G2TDFU1GENEXC | G2D-22523 | SENSOR, #H1522-009, FOR FU EXCITERS |

The Dalles Lock and Dam
Fish Turbine Spare Parts

| EQNUM | ITEMNUM | DESCRIPTION |
|---|---|---|
| G2TDFU2GENEXC | G2D-22523 | SENSOR, #H1522-009, FOR FU EXCITERS |
| G2TDFU1TUR | G2D-22756 | BEARING, TURBINE,GUIDE ASSEMBLY, FU 1-2 TURBINE, 8TH FLOOR B-2, TDD |
| G2TDFU2TUR | G2D-22756 | BEARING, TURBINE,GUIDE ASSEMBLY, FU 1-2 TURBINE, 8TH FLOOR B-2, TDD |
| G2TDFU1TUR | G2D-22901 | MOTOR, BALDOR #VM3538, USED FOR FU AC TURBINE BEARING OIL PUMP, 1/2 HP, 208/230/460 VAC, |
| G2TDFU2TUR | G2D-22901 | MOTOR, BALDOR #VM3538, USED FOR FU AC TURBINE BEARING OIL PUMP, 1/2 HP, 208/230/460 VAC, |
| G2TDFU1 | G2D-22935 | MOTOR, INDUCTION, W-H 220/440 V, 3 PHASE, #77, F1 & F2, TDD |
| G2TDFU2 | G2D-22935 | MOTOR, INDUCTION, W-H 220/440 V, 3 PHASE, #77, F1 & F2, TDD |
| G2TDFU2TUR | G2D-23018 | METER, FLOW, 6,000 PSI, 1/2" PORT, NPTF, 0.5 - 5.0 GPM, #H613B-005. FOR WATER BASED FLUIDS |
| G2TDFU1GOV | G2D-23019 | METER, FLOW, 6,000 PSI, 1/2" NPTF, 1-15 GPM, #H613B-015, FOR WATER-BASED FLUIDS, BRASS |
| G2TDFU1GEN | G2D-23030 | PIN, MK #6503 15 KVA SYSTEM FOR F.U. & M.U. GENERATORS, TDD |
| G2TDFU2GEN | G2D-23030 | PIN, MK #6503 15 KVA SYSTEM FOR F.U. & M.U. GENERATORS, TDD |
| G2TDFU1TUR | G2D-23035 | PIN, SHEAR (F.U. TURBINE), TDD |
| G2TDFU2TUR | G2D-23035 | PIN, SHEAR (F.U. TURBINE), TDD |
| G2TDFU1TUR | G2D-23050 | PIN ASSEMBLY, SPEC., 1-3/4" DIA., X 3-11/16" LONG (F.U. TURBINES) TDD |
| G2TDFU2TUR | G2D-23050 | PIN ASSEMBLY, SPEC., 1-3/4" DIA., X 3-11/16" LONG (F.U. TURBINES) TDD |
| G2TDFU1GEN | G2D-23070 | PLATE, LOCK, METAL, #27D72911 (F.U. GEN., F-1, F-2) TDD |
| G2TDFU2GEN | G2D-23070 | PLATE, LOCK, METAL, #27D72911 (F.U. GEN., F-1, F-2) TDD |
| G2TDFU1TUR | G2D-23095 | PLUG, HEAD COVER JACKING BOLT, F.U. TURBINE (GATE CHAIN ASSEMBLY), TDD (DO NOT REORDER) |
| G2TDFU2TUR | G2D-23095 | PLUG, HEAD COVER JACKING BOLT, F.U. TURBINE (GATE CHAIN ASSEMBLY), TDD (DO NOT REORDER) |
| G2TDFU1 | G2D-23127 | PUMP, (F.U.) B&S PUMP, 2SA, WRV, CCW ROTATION. MOTOR: 1/2 HP, 1725 RPM, 250V DC, TEFC. |
| G2TDFU2 | G2D-23127 | PUMP, (F.U.) B&S PUMP, 2SA, WRV, CCW ROTATION. MOTOR: 1/2 HP, 1725 RPM, 250V DC, TEFC. |
| G2TDFU1 | G2D-23128 | PUMP, (F.U.) B&S #2SA, WRV, CW ROTATION. MOTOR: 1/2 HP, 115/230 VAC, 1 PH, 60 CYCLE TEFC. |
| G2TDFU2 | G2D-23128 | PUMP, (F.U.) B&S #2SA, WRV, CW ROTATION. MOTOR: 1/2 HP, 115/230 VAC, 1 PH, 60 CYCLE TEFC. |
| G2TDFU1 | G2D-23129 | PUMP, COMPLETE, FU, B&S PUMP #2SA, WRV, CW ROTATION, MOTOR: 1/2 HP, 1725 RPM, |
| G2TDFU2 | G2D-23129 | PUMP, COMPLETE, FU, B&S PUMP #2SA, WRV, CW ROTATION, MOTOR: 1/2 HP, 1725 RPM, |
| G2TDFU1TUR | G2D-23132 | PUMP REPAIR KIT, FOR B&S #2S, FU TURBINE BEARING OIL PUMP |
| G2TDFU2TUR | G2D-23132 | PUMP REPAIR KIT, FOR B&S #2S, FU TURBINE BEARING OIL PUMP |
| G2TDFU1TUR | G2D-23400 | RINGS, PISTON, 6-58" X 3/8" (F.U. TURBINE CYLINDERS, TDD |
| G2TDFU2TUR | G2D-23400 | RINGS, PISTON, 6-58" X 3/8" (F.U. TURBINE CYLINDERS, TDD |

The Dalles Lock and Dam
Fish Turbine Spare Parts

| EQNUM | ITEMNUM | DESCRIPTION |
|---|---|---|
| G2TDFU2TUR | G2D-23440 | ROLLER, BRASS, FOR PRESSURE RELEASE COVER, F.U. TURBINE, TDD(DO NOT REORDER) |
| G2TDFU1TUR | G2D-23440 | ROLLER, BRASS, FOR PRESSURE RELEASE COVER, F.U. TURBINE, TDD(DO NOT REORDER) |
| G2TDFU1GENROT | G2D-23445 | ROTOR, GOVENOR HEAD, F.U. GEN., MAIN UNIT PELTON, TDD |
| G2TDFU2GENROT | G2D-23445 | ROTOR, GOVENOR HEAD, F.U. GEN., MAIN UNIT PELTON, TDD |
| G2TDFU1TUR | G2D-23478 | SEAL, BLADE FISH UNIT, 17.00 X 18.50 X 1.440, SEAL CONSISTS OF ONE SET (2) SEALS, OPPOSED |
| G2TDFU2TUR | G2D-23478 | SEAL, BLADE FISH UNIT, 17.00 X 18.50 X 1.440, SEAL CONSISTS OF ONE SET (2) SEALS, OPPOSED |
| G2TDFU1TUR | G2D-23485 | SEAL, CARBON RING, F.U. (ALLIS-CHALMERS, *NOTE* SET CONSISTS OF TWO RINGS, EACH RING IS |
| G2TDFU2TUR | G2D-23485 | SEAL, CARBON RING, F.U. (ALLIS-CHALMERS, *NOTE* SET CONSISTS OF TWO RINGS, EACH RING IS |
| G2TDFU1TUR | G2D-23497 | SEAL, MECHANICAL FOR BROWN & SHARP (B&S) #2S PUMP., FU TURBINE BEARING OIL PUMP |
| G2TDFU2TUR | G2D-23497 | SEAL, MECHANICAL FOR BROWN & SHARP (B&S) #2S PUMP., FU TURBINE BEARING OIL PUMP |
| G2TDFU1TUR | G2D-23498 | SEAL, OIL #48520 RELIANCE MASTER TYPE SL (FOR BROWN & SHARPE MOTOR DRIVEN ROTARY GEAR PUMP |
| G2TDFU2TUR | G2D-23498 | SEAL, OIL #48520 RELIANCE MASTER TYPE SL (FOR BROWN & SHARPE MOTOR DRIVEN ROTARY GEAR PUMP |
| G2TDFU1TUR | G2D-23608 | SLEEVE, TURBINE SHAFT, FU, SEE HARD CARD FOR SPECS AND DRAWINGS, 23609 IS THE MANDREL. |
| G2TDFU2TUR | G2D-23608 | SLEEVE, TURBINE SHAFT, FU, SEE HARD CARD FOR SPECS AND DRAWINGS, 23609 IS THE MANDREL. |
| G2TDFU1TUR | G2D-23609 | MANDREL FOR F.U. TURBINE SHAFT SLEEVE, #23608 (SEE 23608 FOR DRAWINGS AND SPECS) |
| G2TDFU2TUR | G2D-23609 | MANDREL FOR F.U. TURBINE SHAFT SLEEVE, #23608 (SEE 23608 FOR DRAWINGS AND SPECS) |
| G2TDFU1GEN | G2D-23640 | SPACER, METAL, 1/4" X 1" X 3" (F.U. GEN. F-1, F-2) TDD |
| G2TDFU2GEN | G2D-23640 | SPACER, METAL, 1/4" X 1" X 3" (F.U. GEN. F-1, F-2) TDD |
| G2TDFU1GEN | G2D-23805 | STATOR, GOVENOR HEAD, F.U. GEN., TDD |
| G2TDFU2GEN | G2D-23805 | STATOR, GOVENOR HEAD, F.U. GEN., TDD |
| G2TDFU1GEN | G2D-23900 | SWITCH, SEE HARD CARD.AMMETER, TYPE W, STAYPUT, HEAVY DUTY ROUND HANDLE, ITEM 4-07 (N) |
| G2TDFU2GEN | G2D-23900 | SWITCH, SEE HARD CARD.AMMETER, TYPE W, STAYPUT, HEAVY DUTY ROUND HANDLE, ITEM 4-07 (N) |
| G2TDFU1GEN | G2D-24261 | THRUST RUNNER HALF F1 & F2 |
| G2TDFU2GEN | G2D-24261 | THRUST RUNNER HALF F1 & F2 |

| EQNUM | ITEMNUM | DESCRIPTION |
|---|---|---|
| G2TDFU1GEN | G2D-24262 | BEARING, THRUST, SHOES, F.U. (8 BX = 1 SET) |
| G2TDFU2GEN | G2D-24262 | BEARING, THRUST, SHOES, F.U. (8 BX = 1 SET) |
| G2TDFU1TUR | G2D-24263 | WICKET GATE ASSEMBLY, F.U. |
| G2TDFU2TUR | G2D-24263 | WICKET GATE ASSEMBLY, F.U. |
| G2TDFU1GOV | G2D-24515 | VALVE, PILOT, PC. #41468-A, DWG. C-35443-61-36, (F.U. & M.U. GOVENORS) TDD |
| G2TDFU2GOV | G2D-24515 | VALVE, PILOT, PC. #41468-A, DWG. C-35443-61-36, (F.U. & M.U. GOVENORS) TDD |
| G2TDFU1GOV | G2D-24520 | VALVE, RELAY, GATE. 8" (F.U. & M.U. GOVENORS) TDD |
| G2TDFU2GOV | G2D-24520 | VALVE, RELAY, GATE. 8" (F.U. & M.U. GOVENORS) TDD |
| G2TDFU1GEN | G2D-24550 | WASHER, IRON, ITEM #3, DWG. 21C4267-1, T |
| G2TDFU2GEN | G2D-24550 | WASHER, IRON, ITEM #3, DWG. 21C4267-1, T |
| G2TDFU1GEN | G2D-24555 | WASHER, LOCK, S#1240367, (F.U. GEN., F-1, F-2) TDD |
| G2TDFU2GEN | G2D-24555 | WASHER, LOCK, S#1240367, (F.U. GEN., F-1, F-2) TDD |
| G2TDFU1TUR | G2D-26015 | BOLT, SOCKET ALLEN HEAD, 1/2-13 X 1", S.S., FOR FU BLADE SEAL SEGMENT |
| G2TDFU2TUR | G2D-26015 | BOLT, SOCKET ALLEN HEAD, 1/2-13 X 1", S.S., FOR FU BLADE SEAL SEGMENT |
| G2TDFU1BKR | G2D-27540 | BOOSTER CYLINDER, (F.U. BKR, FXJ1), REF: P064-1417, TDD |
| G2TDFU2BKR | G2D-27540 | BOOSTER CYLINDER, (F.U. BKR, FXJ1), REF: P064-1417, TDD |
| G2TDFU1BKR | G2D-27545 | BUFFER, (F.U. BKR FXJ1) (REF: PO 64-1517) TDD |
| G2TDFU2BKR | G2D-27545 | BUFFER, (F.U. BKR FXJ1) (REF: PO 64-1517) TDD |
| G2TDFU1BKR | G2D-27550 | CLAMP, FOR BUFFER, (F.U. BKR, FXJ1) (REF: PO. 64-1517) TDD |
| G2TDFU2BKR | G2D-27550 | CLAMP, FOR BUFFER, (F.U. BKR, FXJ1) (REF: PO. 64-1517) TDD |
| G2TDFU1BKR | G2D-27555 | CONTACT, FINGER, PRIMARY, (F.U. BKR) (REF: PO. 64-1517) TDD |
| G2TDFU2BKR | G2D-27555 | CONTACT, FINGER, PRIMARY, (F.U. BKR) (REF: PO. 64-1517) TDD |
| G2TDFU1BKR | G2D-27565 | CONTACT, PRIMARY, (F.U. BKR. FXJ1) (REF: PO. 64-1517) TDD |
| G2TDFU2BKR | G2D-27565 | CONTACT, PRIMARY, (F.U. BKR. FXJ1) (REF: PO. 64-1517) TDD |
| G2TDFU1BKR | G2D-27575 | COVER, (F.U. BKR. FXJ1) (REF: PO. 64-1517) TDD |
| G2TDFU2BKR | G2D-27575 | COVER, (F.U. BKR. FXJ1) (REF: PO. 64-1517) TDD |
| G2TDFU1BKR | G2D-27580 | FILLER PLATE, ARC RUNNER (UPPER), (F.U. BKR FXJ1) (REF: 64-1517) TDD |
| G2TDFU2BKR | G2D-27580 | FILLER PLATE, ARC RUNNER (UPPER), (F.U. BKR FXJ1) (REF: 64-1517) TDD |
| G2TDFU1BKR | G2D-27585 | SPACER FOR ARC RUNNER |
| G2TDFU2BKR | G2D-27585 | SPACER FOR ARC RUNNER |
| G2TDFU1BKR | G2D-27590 | SPACER, (F.U. BKR. FXJ1) (REF: 64-1517), TDD |
| G2TDFU2BKR | G2D-27590 | SPACER, (F.U. BKR. FXJ1) (REF: 64-1517), TDD |
| G2TDFU1BKR | G2D-27595 | SPRING, RETAINER, TDD |
| G2TDFU2BKR | G2D-27595 | SPRING, RETAINER, TDD |
| G2TDFU1BKR | G2D-27600 | SUPPORT, ARC CHUTE, (F.U. BKR, FXJ1) (REF: PO 64-1517) TDD |
| G2TDFU2BKR | G2D-27600 | SUPPORT, ARC CHUTE, (F.U. BKR, FXJ1) (REF: PO 64-1517) TDD |

The Dalles Lock and Dam
Fish Turbine Spare Parts

| EQNUM | ITEMNUM | DESCRIPTION |
|---|---|---|
| G2TDFU1BKR | G2D-27605 | COIL, SUPPORT, (F.U. BKR, FXJ1) (REF: PO 64-1517) TDD |
| G2TDFU2BKR | G2D-27605 | COIL, SUPPORT, (F.U. BKR, FXJ1) (REF: PO 64-1517) TDD |
| G2TDFU1BKR | G2D-27610 | TUBE ASSEMBLY, (F.U. BKR, FXJ1) (REF: PO 64-1517) TDD |
| G2TDFU2BKR | G2D-27610 | TUBE ASSEMBLY, (F.U. BKR, FXJ1) (REF: PO 64-1517) TDD |
| G2TDFU1BKR | G2D-27645 | BLOCK, INSULATOR, #MK110, TDD |
| G2TDFU2BKR | G2D-27645 | BLOCK, INSULATOR, #MK110, TDD |
| G2TDFU1GENEXC | G2D-27691 | BREAKER, AIR CIRCUIT, TYPE FIS1250, PART # 3ACD5340A019, FOR MAIN UNIT EXCITERS, THIS IS |
| G2TDFU2GENEXC | G2D-27691 | BREAKER, AIR CIRCUIT, TYPE FIS1250, PART # 3ACD5340A019, FOR MAIN UNIT EXCITERS, THIS IS |
| G2TDFU1GENEXC | G2D-27933 | CONVERTER, SIGNAL, ENTRELEC #1SVR040001R0400 |
| G2TDFU2GENEXC | G2D-27933 | CONVERTER, SIGNAL, ENTRELEC #1SVR040001R0400 |
| G2TDFU1GENEXC | G2D-27934 | CONVERTER, SIGNAL, ENTRELEC #1SVR040000R1700 |
| G2TDFU2GENEXC | G2D-27934 | CONVERTER, SIGNAL, ENTRELEC #1SVR040000R1700 |
| G2TDFU1 | G2D-28000 | FLOAT, STAINLESS, FOR TOP PLATE FLOAT SWITCHES, 5" DIA. 1/4" NPT, 550 PSI, MU 15-22 |
| G2TDFU2 | G2D-28000 | FLOAT, STAINLESS, FOR TOP PLATE FLOAT SWITCHES, 5" DIA. 1/4" NPT, 550 PSI, MU 15-22 |
| G2TDFU1TUR | G2D-28120 | LINK, F.T.U. GATE, TDD |
| G2TDFU2TUR | G2D-28120 | LINK, F.T.U. GATE, TDD |
| G2TDFU1GEN | G2D-28245 | BEARING, LOWER GUIDE, W.H, #30D6748 F.U. GENERATORS, TDD |
| G2TDFU2GEN | G2D-28245 | BEARING, LOWER GUIDE, W.H, #30D6748 F.U. GENERATORS, TDD |
| G2TDFU1GEN | G2D-28250 | GUIDE BEARING SHOE, #51P60. S.S. GENERATOR, TDD |
| G2TDFU2GEN | G2D-28250 | GUIDE BEARING SHOE, #51P60. S.S. GENERATOR, TDD |
| G2TDFU1TUR | G2D-28816 | IMPELLER, PART #05-3219-06-R, TO FIT JACUZZI MODEL 1JM FOR FISH UNIT TOP PLATE PUMPS |
| G2TDFU2TUR | G2D-28816 | IMPELLER, PART #05-3219-06-R, TO FIT JACUZZI MODEL 1JM FOR FISH UNIT TOP PLATE PUMPS |
| G2TDFU1GENEXC | G2D-36305 | THYRISTORS, EXCITER, 5SPT16F2400 |
| G2TDFU2GENEXC | G2D-36305 | THYRISTORS, EXCITER, 5SPT16F2400 |
| G2TDFU1GENEXC | G2D-36329 | CONTACTOR, AC-3:37KW-400V, AE75-30-11-8711, FIELD FLASHING, FISH WATER EXCITERS |
| G2TDFU2GENEXC | G2D-36329 | CONTACTOR, AC-3:37KW-400V, AE75-30-11-8711, FIELD FLASHING, FISH WATER EXCITERS |

# Appendix G

## Independent Technical Review (ITR) Form

**Comment Report: Comments By ITR**
**Project: The Dalles Lock and Dam North and East Fish Ladders Reliability Assessment**
**Review: 90% Report**

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 01 | Civil | 1.0 East Fish Ladder/Figure 2 | 2 | 3 |

**Comment:**
The AWS could be better defined as it is first introduced into the report in text form and on a figure.

Submitted By:___M Pavone____________________ Submitted On: 9/14

**Response:**
The text has been changed at first mention of AWS, which is for north ladder. Appendix E figures have been revised to show AWS in Section A.

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 02 | Civil | 2.4.1 A - I | 5 - 8 | |

**Comment:**
Next to each system heading it would be helpful to put in parenthetically the System Number (e.g. Ladder Entrance (System 1) and so on. This will provide better linkage to the analysis and evaluation part of the report.

Submitted By: M Pavone Submitted On: 9/14

**Response:**
System numbers have been added.

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 03 | Civil | 2.4.1 D | 6 | |

**Comment:**

Is the System the North Wasco Powerhouse as it is stated here, or is it the PUD Turbine as it is described in the analysis portion of the report? The analysis focuses on the turbine and therefore 2.4.1D should be so headed.

Submitted By: . M Pavone Submitted On: 9/14

**Response:**
"Powerhouse" has been changed to "Turbine" in the text.

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 04 | Civil | 2.4.1E | 7 | |

**Comment:**
Is the "system" the Secondary AWS System or is it the Plunge Pool as it has been defined in the evaluation portion of the report? The terminology should be consistent.

Submitted By: M P Submitted On: 9/14

**Response:**
"System" has been changed to "Plunge Pool."

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 05 | Civil | 2.4.1H and Figure 1 | 8 | |

**Comment:**
The Exit Section AWS described here should be shown on Figure 1.

Submitted By: MP . Submitted On: 9/14

**Response:**
Appendix E, Figure 1 has been revised to show the Exit Section AWS.

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 06 | Civil | 2.4.2A 1 | 9 | |

**Comment:**

The description of the 3-segment East Fish Entrance does not agree with East Fish Entrance description provided in Appendix D, where it is described as a two part system, although the photos in D clearly show is as having 3 segments.

Submitted By: MP . Submitted On: 9/14

**Response:**
The Appendix D text is incorrect. Since it was submitted to client months ago, it is part of the record.

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 07 | Civil | 3.2 Table 1 | 9 | |

**Comment:**

The logic for including North Wasco Powerhouse as Ladder Criteria in the same category as I&M, Entrance Vel., Submergence, Head, Fish Count and Fish Behavior is unclear to me. I would have thought that the criteria are relative to the successful performance of the facility with regard to adult fish transport. The PH is part of the system. Otherwise, why not include ladder exit section, counting section, etc. as criteria?

Submitted By: MP . Submitted On: 9/14

**Response:**
The backup AWS, the Plunge Pool, is not presently capable of long term operation. Therefore the continued reliable functioning of the ladder depends on the PUD turbine from which comes the AWS water. Anything that impairs the turbine impairs the ladder.

| Id | Discipline | Section/Figure | Page Number | Line Number |
|---|---|---|---|---|
| 08 | Civil | Figure 2 | | |

**Comment:**
The North arrow should be included.
The AWS should be more clearly depicted on the figure. At least as related to the discharge points near the entrances.

Submitted By: MP . Submitted On: 9/14

**Response:**
Appendix E, Figure 2 has been revised to show a north arrow and the AWS.

I, Michael Pavone, P.E. hereby certify that I have performed an Independent Technical Review of The Dalles Lock and Dam North and East Fish Ladders Reliability Assessment report. My review comments have been resolved to my satisfaction and the required changes incorporated into the final report.

Signature: ______________________ Date: 9/19/07