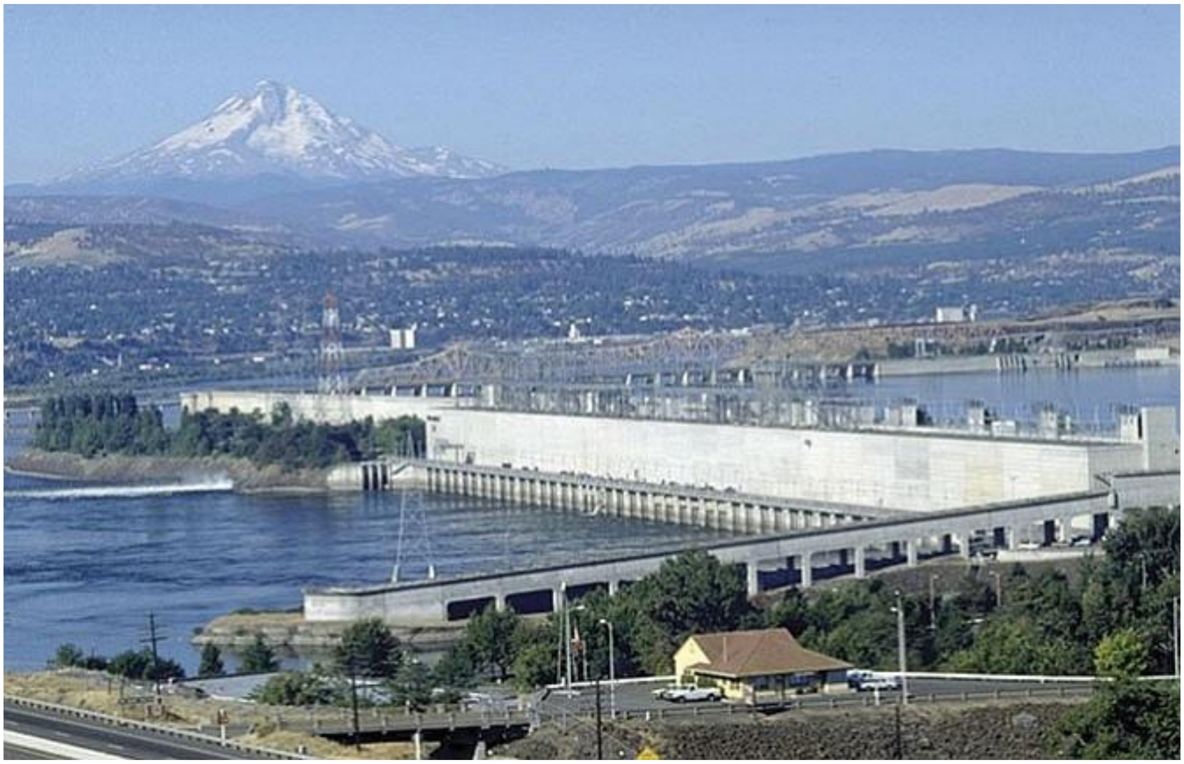
The Dalles Fish Water Units 1 and 2

US Army Corps of Engineers ®
Portland District

Refurbishing The Dalles Fish Water Turbine Generators – Phase 1A Report



Final Report – REVIEW DRAFT

prepared by:

US Army Corps of Engineers

Portland District

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REHABILITATION of the FISH UNIT TURBINE GENERATORS at THE DALLES DAM, PHASE 1A REPORT

SECTION 1 – EXECUTIVE SUMMARY

This section summarizes these five key areas of the Phase 1A report:

- Project purpose – background of the existing fish attraction system operation, state of the existing fish water units, and definition of the design problem for refurbishing the units.
- Review of the constraints and criteria that frame the design solutions, which are system reliability, compliance with fish attraction flow requirements, and operational flexibility.
- Description and comparison of the eight solutions evaluated by the PDT, Alternatives A through H.
- Discussion of the Recommended Alternative and the Next Best Alternative.
- Comparison of costs among the Alternatives.

BACKGROUND AND PURPOSE

The Dalles existing Fish Water turbine/generator units were installed in the 1957 timeframe and are 62 years old. The generators were rewound is 1997 and are rated at 16.3 MVA. The current rated condition for the Kaplan turbine runners is 18,800 horsepower at 74 feet net head, which is equivalent to a generator output of 13.74 MW, assuming a generator efficiency of 98%.

The purpose of this Phase 1A study is to identify and evaluate alternatives, and to recommended work that will improve reliability of the fish water units, Fish Units 1 and 2 (FUs), at The Dalles Dam. These units are located adjacent to Main Unit 1 at the powerhouse and supply attraction water to the Auxiliary Water Supply System (AWS) conduit which runs laterally along the full length of the tailwater section of the dam. The Auxiliary Water Supply Backup System (AWSBS – distinct from the conduit) is a recent addition to the attraction water system for The Dalles Dam. This backup system became operational in late 2018. The AWS Backup System is a 10-foot diameter hole in the dam from forebay to tailwater that initially was constructed as an emergency source of attraction water to operate only if both FUs were shut down. This Backup System is designated to deliver *at least 1,400 cfs* to The Dalles fish attraction system. Recently, the Portland District has decided to allow the AWS Backup System to be operated in conjunction with one FU in an emergency situation when one of the two FUs is taken out of service.

With both fish units operating the total fish attraction discharge is approximately 5,000 cfs to the fish ladder. Presently, both fish units must be in operation to maintain full entrance flow criteria conditions as specified in the Fish Passage Plan[1]. However, results of the recent operational testing of the fish units and the AWS Backup System at the end of 2018 demonstrated the capability to provide minimum acceptable fish flow attraction water with only one FU operating in conjunction with the AWS Backup System. This testing confirmed that the AWS could be operated continuously during any season, 24/7, to reliably augment attraction flow of the FUs.

The recommendation of the PDT is to take advantage of AWS contribution to augment FU flows as necessary, especially during maintenance or repair periods when either FU is out of service.

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[1] http://pweb.crohms.org/tmt/documents/fpp/2018/final/FPP18_02_BON_061418.pdf

With the ability to use the 1,400 cfs flow from the AWS Backup System the importance of recommending an uprated Kaplan turbine to have redundancy in the system is removed. The PDT therefore recommends that the best option is Alternative B, the replacement of the turbine with a propeller unit and no uprate required. This recommendation is also the least expensive alternative. The PDT strongly recommends that FU generators also be rewound to fully improve the reliability of the entire fish attraction water system.

CRITERIA AND CONSTRAINTS

Fish Passage-Hydraulic System

The PDT identified the following criteria and constraints that frame the Alternative solutions:

Criteria. The applicable criteria are derived from the adult fish passage requirements for water elevation, entrance head difference, channel flow velocities, ladder head, diffuser efflux velocities, and debris removal. Based on hydraulic modeling, the results of the target cases are as follows:

- The fishway system can FULLY meet all fisheries criteria at all times when both fish units are operating and producing a combined turbine discharge of 5,000 cfs or more.
- The AWSBS can supply 1,400 cfs, enough flow to supply one entrance.
- The fishway system can MINIMALLY meet entrance criteria with the operation of a single FU in conjunction with the operation of the AWSBS delivering a combined discharge of ~3,900 cfs. (1,400 cfs from the AWSBS plus 2,750 cfs from one FU). However, the flow criteria is comfortably met at the East entrance and only minimally at the other two entrance locations (with a limitation of one weir opening at the South entrance).
- The fishway system *cannot* meet entrance flow criteria with a single fish unit.

Constraints. Physical constraints include the dimensions of the AWS conduit, the mechanical and functional constraints of the weirs that control head and flow at the fishway, as well as the volume discharge limits in operation of Fish Units 1 and 2.

Fish Unit Turbines and Generators

The PDT identified these criteria and constraints:

Criteria. The criteria applied to the Alternatives, as reviewed in this Phase 1A report, are listed in order of decreasing importance, from most to least: reliability/dependability (in operation), unit flexibility, meeting water discharge requirements, environmental friendliness (or minimal negative environmental impacts), power production and generator/turbine efficiency, low-frequency of maintenance, minimum outage duration, ease of construction, and cost. With the exception of costs and water flow requirements, these criteria can be applied to various Alternatives mainly by qualitative comparison (see Table 15 in the main body of the Phase 1A report, *Selection Criteria Matrix for the Refurbishment of the Fish Water Turbines*.)

Constraints. Physical constraints include the dimensions of the generator stator/rotor, turbine intake, discharge ring, draft tube, wicket gates, and other stationary components in the turbine water passage. In addition, the net project head across The Dalles dam has a known range, which cannot change. Other constraints are the shaft maximum power capability and the rotational speed of the fish water turbines.

ALTERNATIVES EVALUATED

The PDT considered quite a number of options, but limited the final number to eight Alternative combinations of turbine runners and generators, as listed in this table.

Table 1. Turbine Runner and Generator Combinations for Alternatives

Alternative	Turbine Runner Type	Level of Generator Uprate
Alternative A	Oil-Filled Kaplan	No Uprate
Alternative B	Propeller	No Uprate
Alternative C	Oil-Filled Kaplan	Small Uprate
Alternative D	Oil-Free Kaplan	Small Uprate
Alternative E	Propeller	Small Uprate
Alternative F	Oil-Filled Kaplan	Medium Uprate
Alternative G	Oil-Free Kaplan	Medium Uprate
Alternative H	Propeller	Medium Uprate

These approaches are discussed in Section 9 of the report in more detail. Each Alternative is divided into replacement or refurbishing of the two complementary parts that comprise a turbine-generator system: the turbine runner (mechanical) and the generator (electrical), along with ancillary systems.

The differences among these Alternatives really come down to combinations of only three different types of turbines and ranges of turbine/generator uprates. In each case, the turbine runner is either a Kaplan or propeller type, and the extent of uprate for the generator is either small, medium or none at all.

RECOMMENDED ALTERNATIVE AND NEXT BEST ALTERNATIVE

Recommended Alternative. *Alternative B, Replace Turbines with Propeller Runners, with the Same Rated Output as Existing, 13.74 MW*. This Alternative provides the fishway attraction water system with the same flows as the current Kaplan units employing an alternate type of reliable turbine runner. Use of the propeller turbine runners, if coupled with AWSBS operation, assures attraction water flows will be more than sufficient to meet fishway criteria. It should be emphasized that the flexibility to provide sufficient flow to continuously meet the marginal flow criteria of the fish attraction system is a critical consideration. For Alternative B this flexibility is contingent on the capability of having an integrated single FU and AWSBS operation that would at least marginally meets entrance criteria. Additionally, the propeller turbine runners are very good environmentally since the runner hubs do not contain oil.

Next Best Alternative. *Alternative C, Replace Turbines with Oil-Filled Kaplan Runners, Uprated to Shaft Limit at 24,520 hp (17.92 MW)*. This Alternative addresses all three of the primary criteria as discussed in the main Phase 1A report and summarized above: system reliability, sufficient fish attraction water discharge, and operational flexibility. Alternative C provides an acceptable turbine runner for the fishway attraction water system, offering a broad range of flows that can operate within the normal range, but also having the capability of providing flow at the level of 3,400 cfs in the absence of integrated operation with AWSBS. This Alternative has the advantage of the flexibility to operate FUs at normal flow levels while also being capable of providing additional flow with a single unit so that minimum flow criteria can be met at most of the entrances. However, with this Alternative, deployment of the AWS would not be necessary, but the cost would be approximately $3.6 million more than the Recommended Alternative B.

COST ANALYSIS

The cost estimates for refurbishment of The Dalles Fish Water Turbine-Generators are documented in Appendices C and I of this Phase 1A report, with all major cost components broken out in detail. The construction cost of the Recommended Alternative B is estimated at $19.27 million, whereas the construction cost of the Next Best Alternative C is estimated at $22.86 million – a difference of about $3.6 million. The total rehab construction costs include a 21% contingency, and 7.8% escalation based on Class 3 cost estimates.

Table 2. Cost Estimates of Alternatives

Cost Component	Alternative B – Recommended Alternative	Alternative C – Next Best Alternative
	Replace turbine with propeller runner, same rated output as existing units (2,200 cfs - 2700 cfs)	**Replace turbine with oil-filled Kaplan runner, uprate unit to shaft limit (2,200 cfs to 3,300 cfs)**
Turbine	$1.013 million per unit	$1.792 million per unit
Miscellaneous Mechanical	$5.42 million per unit	$6.24 million per unit
Generator Rewind	$2.0 million per unit	$2.0 million per unit
New Stator Core	$600,000 per unit	$600,000 per unit
Rotor Pole Refurbishment	$300,000 per unit	$300,000 per unit
Exciter Replacement	$300,000 per unit	and uprate: $300,000 per unit
Generator Uprate Study	not applicable	$400,000
Total Rehab Construction Costs (both units) [a, b]	**$19.27 million**	**$22.86 million**

a. The total estimated Class 3 construction costs include 21% contingency and 7.8% escalation.

b. There would be a Net Present Value savings due to improved operation and maintenance with refurbished units in service. However, this O&M credit is an expense and not a capital (first) cost. The net reduction in labor and materials costs from operating and maintaining improved, refurbished fish units is of the order of about $150,000 per year for both units.

BPA analysts project a revenue loss with Fish Units out of service during two years, rehabbing each FU back to back, to run approximately $5.5 million. However, this opportunity cost is not accounted for as part of the rehab costs in Tables C-1 and C-2.

Net Benefit of Reduced O&M Costs

A significant advantage of fish unit refurbishment would be to lower overall operations and maintenance costs relative to O&M costs incurred with the current fish unit systems. O&M data from the operations staff at The Dalles estimate a net annual cost benefit of about $150,000 for both fish units, which is a nominal savings of $7.5 million over a 50-year life. Granted, this benefit is an operating cost reduction, and does not offset the capital cost of refurbishing the turbine runners and generators. An intangible benefit is the improvement in fish passage water supply reliability and meeting legal requirements to do so.

SIMILARITIES/DIFFERENCES BETWEEN ALTERNATIVES B AND C

The lower costs of Alternative B compared to Alternative C are attributable to the less expensive propeller turbine and its associated mechanical systems plus the fact that an uprate study will not need to be conducted. The key difference between the two Alternatives lies in the flexibility of the Kaplan turbine runner to provide a wider band of water flow for fish attraction, whereas the propeller type of Alternative B has a much more restricted flow range of operation. If integrated operation of the FUs with the AWS Backup System is employed, the need for this operational flow flexibility would be unnecessary. The AWS Backup System can compensate for any shortfall in attraction water flow from the FUs with propeller-type turbine runners. An additional difference is the environmental risk reduction provided by the oil-free hub of the propeller runner.

For the most part, the inspection, repair, refurbishing, and replacement requirements would be similar for both Alternatives B and C. It is expected that the life cycle costs for operations and maintenance will be somewhat less for Alternative B over Alternative C.

Uprate Study Required to Implement the Recommended Alternative

With the recommendation of Alternative B it will not be necessary to perform an uprate study because the units will not be uprated.

Rehabbing Both Turbine Runner and Generator – An All-Or-None Option?

Review of the Project Charter states the justification for this project is that the fish units are the primary source of attraction water for the three entrances of the Oregon shore ladder and that the reliability of the fish units is important in the upstream adult fish migration. Our objective for this Phase IA is to increase the reliability of the fish units and the overall fish unit system. Currently the HydoAMP ratings of the turbine runners are MARGINAL and there is generally no question that they should be replaced. The generator stator and rotor Hydro AMP scores are MARGINAL and FAIR, respectively, and currently have 22 years of service on the rewind that was performed in 1997. By the time the fish unit generators are actually refurbished they will have more than 25 years in-service after the rewind. For the sake of the reliability of the fish unit system the PDT recommends both generators and turbine runners be refurbished as the same time.

Recognizing the large investment for refurbishing both fish units, the PDT considered whether sequencing refurbishment or reducing refurbishment scope would provide any economic advantages. The PDT believes that sequencing refurbishment would add additional costs to the rehab of the fish unit system and curtailing the scope would be reducing the long term reliability of the fish unit system. Synchronizing mechanical and electrical rehabs eliminates additional design work and future contracting costs, minimizes out-of-service down time and lost generation as well as reducing overhead costs associated with each disassembly and re-assembly of a turbine generator. Therefore scheduling the rework of both mechanical and electrical systems onto the same rehab cycle would be the most efficient and economical way to proceed.

SECTION 2 – INTRODUCTION

This report covers the analysis and results developed by the Project Delivery Team (PDT): outlines the need for, applicable assumptions to, and the roles and importance of Units 1 and 2 within the fish guidance system; describes the existing conditions of the major equipment components; identifies the criteria and constraints for the Alternatives evaluated; includes cost estimates for each Alternative; and concludes with explanations of the Recommended Alternative as well as the Next Best Alternative.

PURPOSE

The purpose of The Dalles Fish Water Turbine Phase 1A Report is to present alternatives considered and identify recommended work to improve reliability of the Fish Water units and the overall fish unit system. These units are located adjacent to main Unit 1 at the powerhouse and are the primary source of attraction water for the Oregon shore fish ladder. This report provides documentation for the development of all practical alternatives for the rehabilitation of Fish Water Units 1 and 2, evaluation of those alternatives, and the rationale for the selection of the Recommended Alternative. This report has been made available to the Capital Work Group (CWG) along with a Decision Support Document (DSD) package for approval of the Recommended Plan and agreement to move this project forward for the completion of Plans and Specifications (Phase 1). Upon completion of the Plans and Specifications, a DSD package will be presented to the CWG for the completion of a construction contract that can implement the Recommended Plan (Phase 2).

This report provides pertinent information, evaluations, and discussions that support the recommendation for how to proceed with rehabbing Fish Water Units 1 and 2, following these steps:

1. A brief Project Description outlines the need for Units 1 and 2.
2. General Considerations are discussed to explain the role and importance of FU1 and FU2 within the fish guidance system and assumptions are identified.
3. Existing Conditions of the major equipment components are discussed.
4. Criteria and Constraints outlines the scope of the project and identifies the criteria by which the alternatives are compared and the constraints are applied to the project.
5. Design Alternatives are identified and explained in detail.
6. Cost estimates are presented for each alternative.
7. The Alternatives are evaluated by considering the existing conditions of the major equipment, comparing each Alternative to the criteria, and comparing each Alternative to the other Alternatives.
8. Finally, a recommendation is made regarding which Alternative the Product Delivery Team (PDT) believes to be the best Alternative.

The primary purpose of this report is to identify recommended work to improve reliability of the Fish Water Units (FUs) and the fish ladder system. The majority of fish that pass The Dalles Dam through the annual cycle utilize this ladder system. The water supply for the ladder system is linked with power generation benefits. However, no economic analysis has been conducted to quantify the power or fish passage benefits since the primary use for the FU turbines is water supply for the ladder and optimal operating criteria is already defined. It is imperative for the system to be reliable in meeting the attraction water requirements as stated in the US Army Corps of Engineers (USACE), Northwest Division, 2018 Fish Passage Plan and the National Marine Fisheries Service (July 2011), Anadromous Salmonid

Passage Facility Design in accordance with the NOAA Fisheries, Federal Columbia River Power System, 2008 Biological Opinion (BiOp) and the 2010 and 2014 Supplemental BiOps. Presently, both fish units must be in operation to maintain full criteria entrance conditions.

The construction of The Dalles Auxiliary Water Supply (AWSBS) Backup system has been completed and it was successfully commissioned under full flow in August 2018. Additional flow testing in November 2018 confirmed that AWSBS could be operated with either fish unit without any apparent issues. The backup system delivers at least 1,400 cfs to The Dalles East Fish Ladder system in the event both fish units fail. However, the AWS Backup system was not initially designed to work in conjunction with the current Fish Water units. Nevertheless, after the November 2018 tests, the discharge from the AWS backup system can be added to single fish unit flow to alleviate the loss of the other fish unit.

PRODUCT DEVELOPMENT TEAM

Table 3. Participants and Roles

Name	Title	Role
Bui, Tam (HDC-E)	Electrical Engineer	Generators & Exciters
Chase, Luke (BPA)		BPA Project Representative
Colesar, Michael (OD-D)	Chief of Tech	Project Point of Contact
Cordie, Bob (OD-D)	Fishery Biologist	Fish Passage & Biology
Andes, Carolina (EC-CC),	Electrical Engineers	Construction Constraints & Cost Engineering
Deatherage, Drew (BPA)	Economist	BPA Representative
Demeaux, Sharon (HDC-M)	Structural Engineer	Structural Design
Eppard, Mathew (PM-E)	Chief Fish Passage Section	Fish Passage
Gray, Amber (RM-F)	Accountant	Expense and Capital Asset Evaluation
Hanson, Matt (EC-DS)	Chief, Structural Design Section	Structural Reviewer
Jones, Jackie (EC-TB)	Budget Analyst	Labor Codes, PR&Cs
Rerecich, Jon (PM-E)	Fish Biologist	Fish Passage and Biology
Salber, Frank (OD-D)	Mechanical Engineer	Project Mechanical Design
Schaffer, Tessa (EC-DG)	Civil Engineer	Evaluation of lead, asbestos, hazardous waste.
Schlenker, Stephen (EC-HD)	Hydraulic Engineer	Hydraulic modeling of fish ladder, reservoir regulation, and water availability. Testing of the Auxiliary Water System.
Seacat, Damion (PM-PD)	Program Analyst	Labor Codes, PR&Cs
Sipe, Steve (EC-DM)	Mechanical Engineer	Mechanical Reviewer
Tran, Thong; Carolina Andes	Electrical Engineer	Cost Engineering
Schroeder, James (EC-DM), White, Tom (EC-DM)	Technical Lead	Day-to-day execution of product and coordination of technical disciplines.
Bluhm, Eric (PM-FP)	Project Manager	Overall responsible for product execution, budget, schedule, and quality
Wages, Ethan (HDC-M)	Mechanical Engineer	Bearing coolers, surface air coolers, Machine Condition Monitoring (MCM), e-closure system
Watson, Daniel (HDC-M)	Mechanical Engineer	Design Lead, Mechanical and Turbines
Weber, Jason (EC-T)	Value Engineering Officer	Value Engineering
Yazdani, Azedah (HDC-C)	Product Coordinator	Hydrologic Design Center (HDC) Point of Contact (POC) for scope, schedule, budget, and non-technical issues

DESIGN GUIDANCE

The following design guides and standards have been used in the preparation of this document:

- EM 385-1-1 (2014): Safety and Health Requirements Manual
- EM 1110-2-3006 (1994): Hydroelectric Power Plants – Electrical Design
- EM 1110-2-4205 (1995): Hydroelectric Power Plants – Mechanical Design
- ER 1110-2-1302: Engineering and Design – Civil Works Cost Engineering
- EM 1110-2-1304: Civil Works Construction Cost Index System

SCHEDULE

The project deliverables and the overall anticipated schedule are listed in these tables.

Table 4. Deliverables Schedule – Initial Plan

Description:	Date:
Existing Conditions and Scoping Report	April 2017
Criteria and Constraint Report	June 2017
Alternative Evaluation Report	October 2017
Draft Final Agency Technical Review	April 2018
Draft Final Report	May 2018

Table 5. Phase 1A Project Schedule

Deliverable:	Description:	Date:
1A Report	Phase 1A	FY17-FY18
Phase 1 Package	Plans and Specifications	FY18-FY20
Contract Acquisition	Advertise and Award	FY20
Phase 2 - Design	Turbine/Generator Design	FY21
Phase 2 – Manufacturing	Turbine/Generator Fabrication	FY22-FY24
Phase 2 - Construction	Onsite construction and installation	FY22-FY24
Closeout	Completion and Closeout	FY24

BACKGROUND

The two Fish Water turbines (FUs) at The Dalles are the primary source of fish attraction water for the South, West and East entrances to the fishway, which guides fish to the East fish ladder. The two fish water units at The Dalles power plant have vertical axis Kaplan type turbine runners and synchronous salient-pole generators. The runners are 120-inch, 6-bladed units operating at a rated net head of 74 feet and rotating at 200 rpm. The design head for the units ranges from 55 to 88 feet. The nameplate turbine output is 18,800 hp (equivalent to 13.74 MW). It should be noted though that although the turbines are rated at 18,800 hp they were designed to be capable of a maximum output of 22,600 hp (which is 115% of generator nameplate at unit power factor). These units were placed on line in the late

1950s and have been operating for the last 60 years. The average combined discharge for two units operating is 5,000 cfs.

The generators were manufactured and installed by Westinghouse Electric Corporation and brought on line also in in the late 1950s. Each generator was rated at 14,200 kVA, 13,800 volts, 3 phase, 0.95 power factor with 60°C temperature rise above 40°C ambient. The original generators were capable of continuously operating at 115% of their nameplate rating.

A first spare winding was purchased from National Electric Coil (NEC) for Unit 2 in 1993. It was installed by Tennessee Valley Authority (TVA) in 1997. The winding can operate at Class F temperature. The winding was uprated to 18,500 kVA, 13,800 volts, 3 phase, 60 hertz, 75 ºC temperature rise. A second spare winding was purchased from Westinghouse for Unit 1 in 1997. It was installed by Project personnel in the same year. The winding has the Westinghouse Thermalastic™ Insulation System which consisted of high density mica tape. The insulation is of Class F. The winding was uprated to 18,500 kVA, 13,800 volts, 3 phase, 60 hertz, 75°C temperature rise. See Figures 1 and 2.

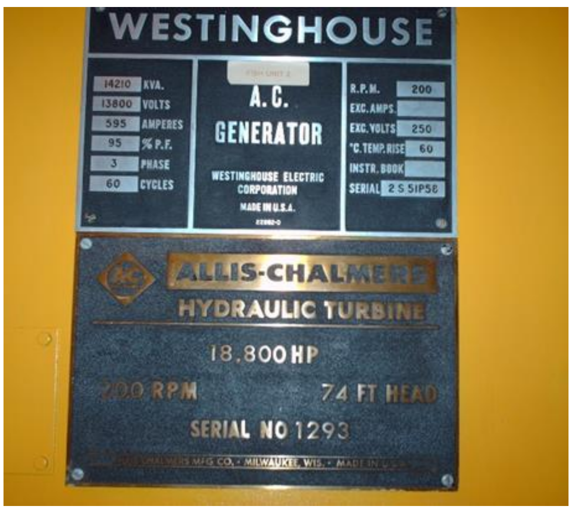


Figure 1. Generator Nameplate

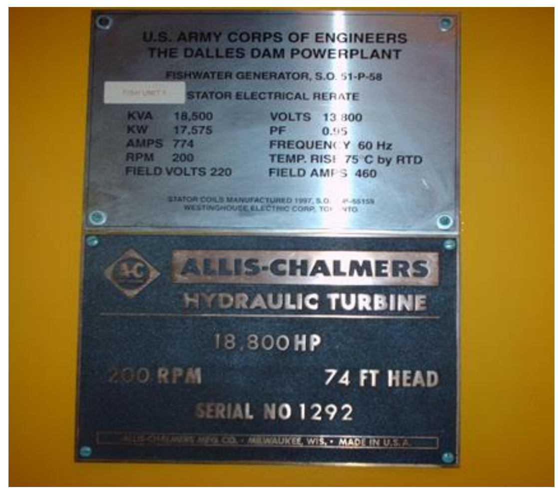


Figure 2. Rewound Nameplate

The draft tube for the fish water turbine runners empties into The Dalles AWS along the powerhouse tailrace and supplies attraction water for the East fish ladder. With both units operating the fish water can supply a total discharge as much as 5,500 cfs to the East fish ladder. Figure 3 shows the location of the fish units with respect to the overall project plan including powerhouse, spillway and fish ladder. Figure 4 shows a more detailed view of the how the fish units tie into the fish ladder.

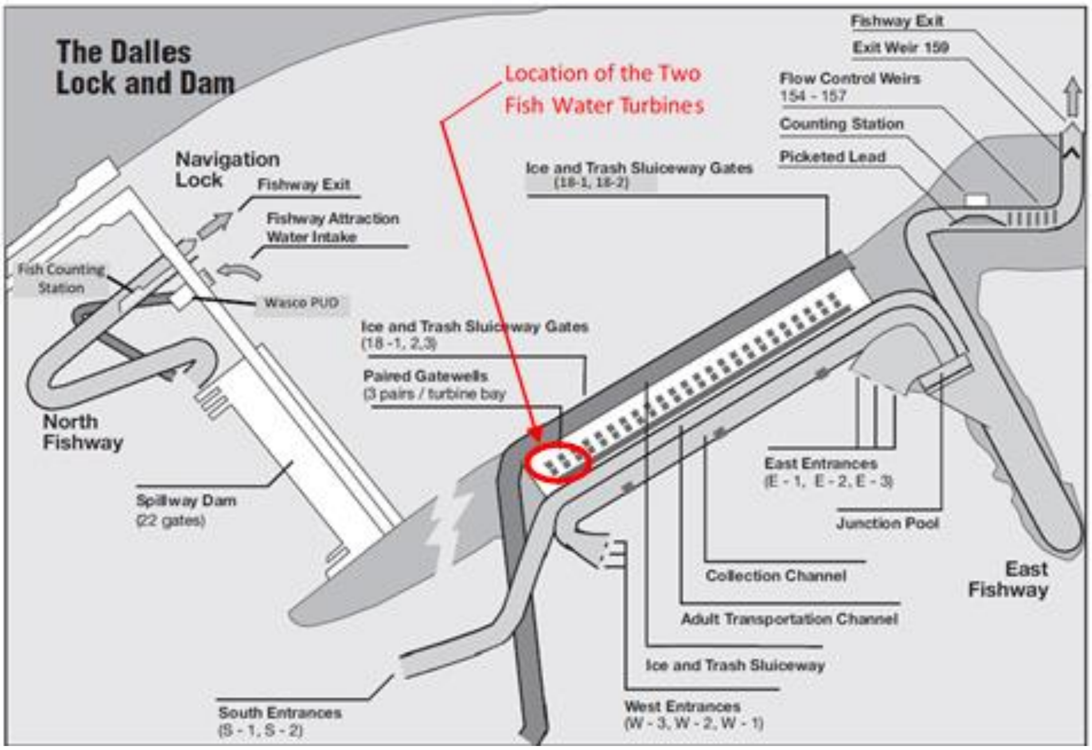


Figure 3. Spillway, Fishways, Powerhouse and Other Structures at The Dalles Dam

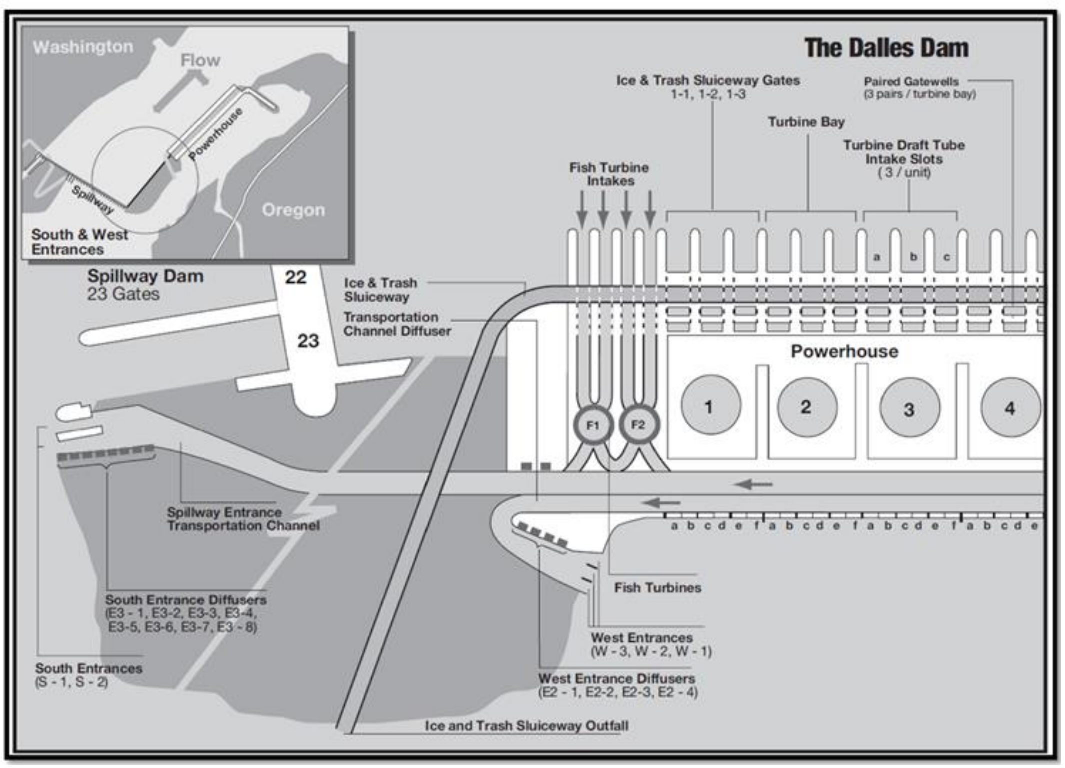


Figure 4. The Dalles Dam South and West Fish Entrances for the East Fish Ladder

OTHER CONSIDERATIONS

In addition to the capacity ratings and operational history, the fish water units are further characterized by uprating, and biological and construction considerations affecting scheduling.

Uprating Considerations

Generator and turbine uprating is being considered as a means to increase discharge through the units with the goal of providing enough discharge so that one unit by itself can meet the minimum fish ladder entrance criteria. Uprating would then provide overall system redundancy for fishway operation. Right now, under existing conditions, if one unit is not able to operate due to some system failure, the other unit is not able to provide enough discharge to continuously keep the fish water system in marginal compliance.

Biological and Construction Considerations

Only one fish unit will be available for fish ladder operation during the construction phase. It is anticipated that the rehabilitation schedule will exceed a typical winter maintenance period. The construction/rehabilitation schedule must be sequenced to minimize fish impacts.

SECTION 3 – EXISTING CONDITIONS

Section 3 describes the context for fish water attraction criteria and the state of operability and reliability of many of the key electrical and mechanical components of the Fish Unit turbine-generators.

FISH PASSAGE AND ENDANGERED SPECIES ACT SECTION 7(a)(2) CONSULTATION

Fish Unit rehab will meet fish passage objectives in accordance with the Endangered Species Act (ESA) section 7(a)(2) Consultation, National Oceanic and Atmospheric Administration's (NOAA), National Marine Fisheries Service, Endangered Species Act, analysis and determination for the Federal Columbia River Power System (FCRPS) issued in the NOAA Fisheries' FCRPS 2008 Biological Opinion and the 2010 and 2014 Supplemental Biological Opinions (BiOp). The BiOp recommended a Reasonable and Prudent Alternative (RPA) for the FCRPS, which was then adopted for implementation by the FCRPS Action Agencies that includes the U.S. Army Corps of Engineers and the Bonneville Power Administration (BPA).

Since the Action Agencies are operating under court order (see U.S. District Court for the District of Oregon's Order dated March 27th, 2017 and January 8th, 2018) and the Federal Defendants must comply with the Court's remand order by preparing a new biological opinion and following NEPA, the current configuration and operations are the baseline and represent the TDA (The Dalles Dam) project configuration and operations criteria for Phase 1A of this project. RPA 55, sub action 6, was intended for fish passage through main units and does not apply to this project.[2]

The Corps' Northwestern Division develops a strict operational plan, known as the Fish Passage Plan (FPP), which is used when operating TDA to maintain acceptable conditions for upstream and downstream migrating fish. The Fish Passage Plan (FPP) implements the NOAA Fisheries Biological Opinion and is a living document that is updated annually through the regional Fish Passage Operations and Maintenance (FPOM) technical work group. FPP requirements include seasonal operation, turbine unit operations, Bonneville Power Administration (BPA) power requirements, spillway operations, scheduled maintenance, unplanned outages, and others. All of these factors play a role in the operation of TDA in consideration of juvenile and adult fish migration. These factors are not variables within the context of this study and are assumed to be a part of the project operation. The current Fish Passage Plan is the approved method of operation of TDA.

Detailed descriptions of TDA operations criteria for adult and juvenile fish can be found at the following link: http://pweb.crohms.org/tmt/documents/fpp/

All work and operations associated with this project will comply with the current Fish Passage Plan requirements unless specifically coordinated through the Fish Passage Operations and Maintenance (FPOM) regional work group. All supporting field studies will be coordinated through the Fish Facility Design Review Work Group (FFDRWG) and the Northwestern Division Anadromous Fish Evaluation Program Studies Review Work Group (SRWG). Members include representatives from BPA, USACE, NOAA (National Oceanic and Atmospheric Administration), US Fish and Wildlife Service (USFWS), state

[2] G. Fredricks, NOAA Fisheries, personal communication, 2017.

fisheries managers from WA, OR, and ID, as well as the treaty tribes: Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, Nez Perce, and Warm Springs.

Fish Passage

Four species of Pacific salmon: Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*O. mykiss*), coho salmon (*O. kisutch*), sockeye salmon (O. nerka) and Pacific lamprey (*Entosphenus tridentatus*) annually migrate past TDA. Downstream migrants, including yearling and subyearling Chinook salmon, steelhead, sockeye salmon, and Coho salmon peak passage periods at TDA are from mid-April though early June. Subyearling fall Chinook salmon outmigrants typical peak passage period at the dam are from mid-June through August. Adult upstream migration occurs throughout the year, although passage during the winter months is relatively light. The adult and juvenile fish passage season is from March 1 through November 30, with a winter maintenance period from December 1 through February 28.

Fish Ladder Existing Conditions

There are two adult fish ladder systems at The Dalles: the East Fish ladder and the North Fish ladder (see Section 2, Figure 3). The East fish ladder abuts the south end of the spillway and both ends of the powerhouse; the North fish ladder abuts the north side of the spillway. The East fish ladder is the larger fish ladder and collects the majority of the upstream migrant fish. The East fish ladder operates three separate entrance locations supplied by a total AWS discharge up to 5,500 cfs; whereas the North fish ladder has one entrance supplied by 800 cfs AWS discharge.

Pertinent data for the three main East fish ladder entrance areas are provided in the USACE draft 2005, “Hydraulic Evaluation of Lower Columbia River Adult Bypass Systems (HELCRABS), John Day Dam South Fish ladder Hydraulic/Operational Evaluation” and the Fish Passage Plan. The average total discharge from each entrance area was computed from 2011, 2014 – 2016 data provided by The Dalles operations staff. The sum total entrance discharge comprises the flows (~ 5,000 cfs) from the AWS fish units and the upper ladder flow (109 – 138 cfs) from the forebay exit section.

Table 6. The Dalles East Fish Ladder Entrances

The Dalles East Fishladder Entrances		Number of entrance bays		Entrance Bay Width (ft)	Operating Entrance Head (ft)	Entrance weir submergence (feet)		Ave. Total Discharge (cfs) (2014-2016)
Entrance Name	Location	Total	Normal Usage			Minimum per Criteria	Typical Operation	
South	South of Spillway	2	2	15	1-2 ft	8	8.5 - 9.5 ft	1,990
West	West end of PH	3	2	8.5	1-2 ft	8	9.5 - 10.5 ft	1,190
East	East end of PH	3	2.5	8.5	1-2 ft	8	11 - 13 ft	1,950
Total		8	6.5					5,130

All three entrance areas are connected by separate conveyance channels that join at the junction pool near the East entrance. Once the fish arrive at the junction pool, they ascend the fish ladder, which consists of overflow weirs and orifices that rise in one-foot steps. As the fish move up the lower ladder section with floor diffusers, the flow becomes incrementally lower until the only remaining flow is supplied from the upper ladder. As the fish approach the forebay level, they pass through a counting station and an exit section, before entering into the forebay. The upper ladder flow varies as a function of the ladder head set at the top in the exit section: 1 foot ±0.1 feet for normal adult salmon passage (109 cfs) and 1.3 feet ±0.1 feet for shad passage (138 cfs).

The two fish units supply a total of up to 5,500 cfs discharge to the AWS conduit for The Dalles East Fish ladder. From the connection from the two turbine draft tubes to the AWS conduit, the AWS conduit extends both west and east to deliver flow to the three entrance locations, junction pool and lower fish ladder. Discharge is incrementally released from the AWS into the fish ladder channels through floor diffusers. Discharge passes from the AWS conduit through gated diffuser ports that lead to diffusion basin beneath the floor diffuser gratings. The diffuser gates are neither modulated or intentionally throttled, but are left either open or closed.

Presently both fish units must be in operation to maintain criteria entrance conditions as specified in the Fish Passage Plan. If a fish unit fails, steps are taken to provide best possible entrance condition by making adjustments to maintain entrance differential. This involves; increasing other unit operation to maximum output, close 1 of 2 south entrance weirs, raise east entrance weirs

In April 25 2017, the PDT observed a single Fish Unit operation at a relatively high tailwater level (82.0 feet at the West Entrance). (See TRIP REPORT: The Dalles Dam – Field Trip for East Fish Ladder (EFL) /Fish Unit (FU) Water Surface Levels and other Measurements on April 25 2017 prepared by CENWP-EC-HD in Appendix A2). The one FU was operating at 14.8 megawatts with fully open wicket gates and a discharge of 2720 cfs. In the fish ladder, two entrance weirs were open each at the West and East entrance locations, and only one was open at the south entrance. Entrance heads at the three locations varied between 1.0 - 1.6 feet (average 1.27 feet) and weir submergence varied between 8.0 – 8.6 feet (average 8.3 feet). The tailwater level was a relatively high 82.0 feet at the West Entrance. The estimated discharge to minimally meet entrance criteria is 2960 cfs, or 200 - 250 cfs higher than the discharge capacity of a single unit at the same tailwater elevation.

OD-D biologists have noted that a single Fish Unit operation may have become close to meeting entrance criteria at times depending on tailwater elevation and net head variance. However the EC-HD fish ladder model estimates that in order to minimally meet entrance criteria (assuming 1.1 entrance head and 8.1 at two entrance weirs at each location) a FU discharge of about 3200 cfs would be required at a low tailwater (75 feet at the West entrance) and about 2970 cfs at a high tailwater (83.5 at the west entrance).

An auxiliary water system (AWS) backup system has been installed to provide emergency supply of water in the event of a failure of both fish units. The AWS backup system consists of the 10-foot diameter penstock cored through the dam with multiple in-line orifices to dissipate the energy and multiple valves to activate or terminate discharge operations. This system will provide 1,400 - 1600 cfs of water only for the operation of the east entrance. The range in discharge is a function of the net head between the forebay and the water level in the AWS conduit where the final two 7-foot penstocks discharge. The AWS conduit head is a function of tailwater at the East Entrance, entrance gate operations, entrance head, and AWS penstock discharge.

The AWS backup system was designed to be operated only in the event of a dual fish unit outage. However, the November 2018 flow test confirmed that the AWSBS and a single fish unit can be operated simultaneously in the event of a single unit failure.

ADULT FISHERIES CRITERIA

The adult fish passage criteria for The Dalles fish ladders are the following:

1. Elevation entrance weir crest ≥ 8 feet below tailrace level (or entrance submergence ≥ 8 feet);
2. Maintain a minimum tailwater at 70 feet National Geodetic Vertical Datum of 1929 (NGVD 29) to remain in entrance weir criteria operating range (regulated by Reservoir Control Center).
3. Head difference across entrances should be between 1 – 2 feet, 1.5 feet optimum;
4. Channel velocities should be between 1.5 - 4 ft/s, 2 ft/s optimum;
5. Ladder head (water depth over ladder weirs) should be 1.0 ft (± 0.1 ft). During shad passage season (>5,000 shad/day per at Bonneville Dam count station), ladder head = 1.3 ft ± 0.1 ft.
6. Diffuser efflux velocities ≤ 0.5 ft/s.
7. Remove debris as required to maintain head below 0.5 ft on attraction water (i.e. fish unit) intakes and trash racks at all the ladder exits, with a 0.3 ft maximum head on all picket leads. Debris shall be removed when significant amounts accumulate.

Operationally, criteria bullets items 1, 2, 3 and 4 have the highest priority. Criteria items 1 and 2 pertain to entrance criteria, which depend on the quantity of the AWS discharge. Under normal operations, The Dalles East fish ladder meets entrance criteria at all entrances with a comfortable margin of safety. Due to a hydraulic imbalance built into the system, the East entrance must pass more flow to assure that the other two entrance areas meet criteria as well. This condition exists because the hydraulic grade line in the junction pool needs to have sufficient differential in elevation with respect to the tailwater levels at the south and west entrances to drive enough flow down the separate channels to the south and west entrances. The east entrance (being adjacent to the junction pool) is effectively a short circuit in comparison, and thus takes a larger volume of flow despite measures in the junction pool to restrict flow to the east entrance.

Channel velocity (item 3, above) is next in importance and also depends on AWS discharge and tailwater elevation, as well as design configuration and management of the diffusers. Most of channels in The Dalles East meet channel velocity criteria. However the powerhouse collection channel (connecting the junction pool to the West Entrance – see Section 2, Figure 3 in) sometimes does run below minimum velocity criteria. The low velocity in the powerhouse collection channel is appears to be primarily caused by an original design constraint, in which the hydraulic gradient is limited between the junction pool and west entrance. Previous fish passage studies do not indicate problems with passage through this section of the collection channel. However past experiences at other fishladders, such as those at John Day Dam, show that fish may either delay or leave the system entirely if average channel velocities are allowed to get below about one foot per second.

The minimum estimated AWS discharge to marginally meet entrance criteria is 3,200 cfs.

Combined 3,900 cfs discharge AWSBS (1,500 cfs) + Fish Unit (2,500 cfs) met the following in the field under conservative low tailwater conditions:

- East Entrance (2, 3 weirs open) optimally
- West Entrance (2 weirs) marginally
- South Entrance (2 weirs) out of criteria (1 weir would be in criteria)
- The minimum estimated AWS discharge to meet reliably entrance criteria is 4,320 cfs
- The minimum estimated AWS discharge to meet all criteria is 5,000 cfs

A simplified hydraulic model was developed to estimate the minimum AWS discharge required to meet entrance criteria (4,320 cfs). The model is documented in The Dalles East Fish Ladder Model Memorandum prepared by CENWP-EC-HD, located in Appendix A1 – Hydraulic Design and Modeling. The model was developed from OD-D fish ladder inspection data collected during 2011, 2014-2016, and April 2017. The second higher level was based on a review of the fish ladder operations over the same period and discussions with the Project Biologist.

River Flows (Summary Hydrograph)

The Columbia River at The Dalles Project, TDA, is a run of the river project and conditions are not controlled or set by specific operations or manipulations of the series of dams on the Columbia River. Due to power peaking and biological operational constraints there is significant fluctuation in project discharge and resulting tailwater in any 24 hours. Discharge will typically vary 50 to 60 kcfs in 24 hours but can vary as much as 100 kcfs. Flow statistics from USGS Gauge 14105700 – Columbia River at The Dalles are used to represent flow statistics at TDA.

Total Head on the Fish Units

The total head on the TDA fish turbines is the difference between forebay elevation and the energy grade line elevation (EGL) in the auxiliary water supply (AWS) conduit for the East fish ladder. The EGL in the AWS conduit is in turn a function of the tailwater elevations along the powerhouse channel and added AWS head required to drive the flow through the AWS conduits, diffusors and ultimately out of the fish ladder entrances. The added AWS head is a function of the total fish unit discharge and the number of open diffuser gates and operating entrance gates. The determination of the EGL is further complicated by that fact that there are three different entrance locations, each with different tailwater elevations. The tailwater increases in the upstream direction (east) along the powerhouse channel as a function of main unit discharges. Therefore the “tailwater” or AWS EGL for the fish units is dependent on Project and fish ladder operations.

Based on typical operations, the AWS EGL is on average about 9 - 12 feet above the Project tailwater elevation. The project tailwater is recorded at USGS Gauge 14105700 – Columbia River at The Dalles, which is typically lower than any of the three entrance tailwater elevations due to backwater effect of the powerhouse operations.

Figure 5 describes the head difference as a function of total fish unit discharge.

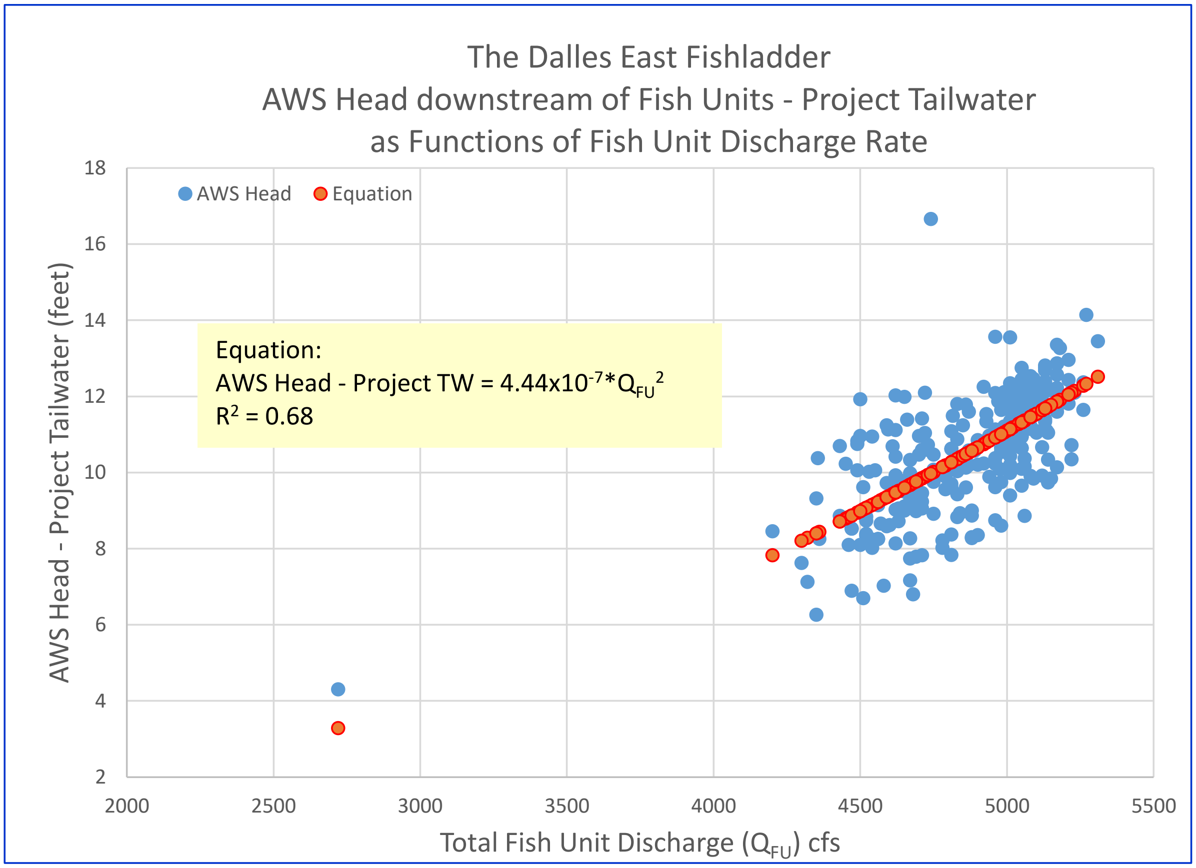


Figure 5. Comparison of Estimated and Recorded Differences between AWS Head and Project TW

GENERATOR

Stator End-Winding Inspection

The rotors of both units are still in place. Visual inspections of the stator end-windings were therefore limited. According the Project team at TDA, the windings have never been inspected or cleaned since they were rewound in 1997. Findings apply only to the areas visibly observed during the rotor inspection. Unit 1 end-windings have oil deposit and are covered with brake dust. Unit 2 end-windings were clean and dry. No signs of partial discharge activity or discoloration were evidence on both units. No cracking and bulging of the insulation was found. The blocking, lashing and ties appeared to be tight with no sights of movement. Wedges also appeared tight and there were no signs of migration. Overall the windings in both units appear in fair condition for their age. The rotor poles were inspected from above. There were no signs of movement. Inter-pole connections were examined. They appeared to be in good condition. The main and neutral leads were also inspected. No signs of insulation deterioration were observed.

Figure 6. Unit 1 Lower End-Windings

Figure 7. Unit 1 Upper End-Windings and Connection

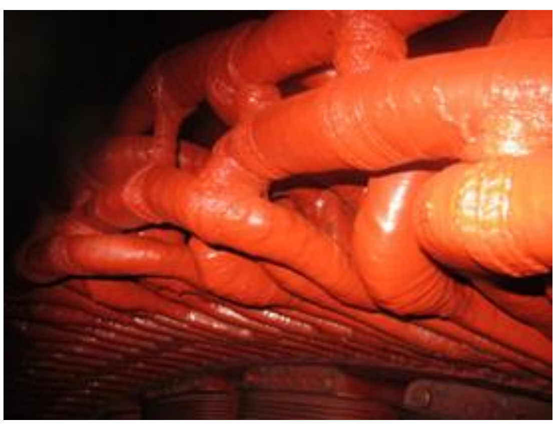


Figure 8. Unit 2 Upper End-Windings and Connection

Figure 9. Unit 2 Lower End-Windings

Figure 10. Unit 2 Rotor Poles

Figure 11. Main and Neutral Leads

Figure 12. Oil Found on the Bottom of Unit 2 Generator Frame

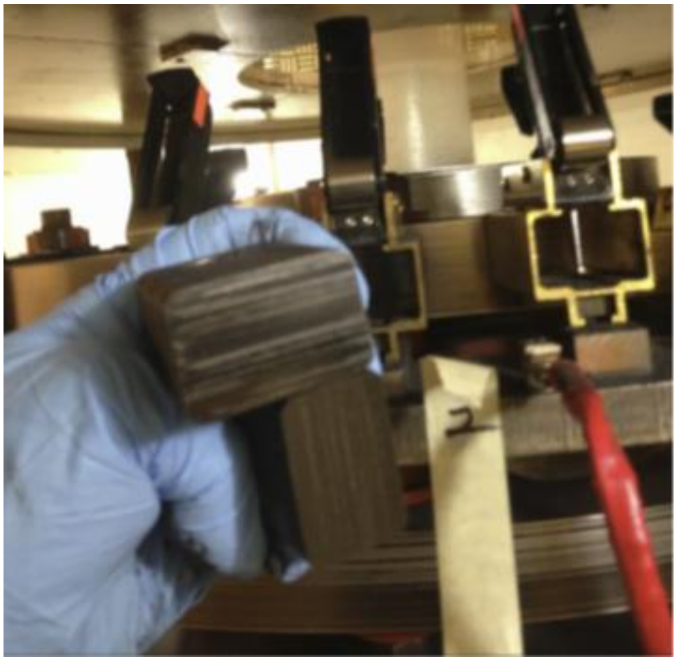


Figure 13. Brush Threading and Uneven Wear

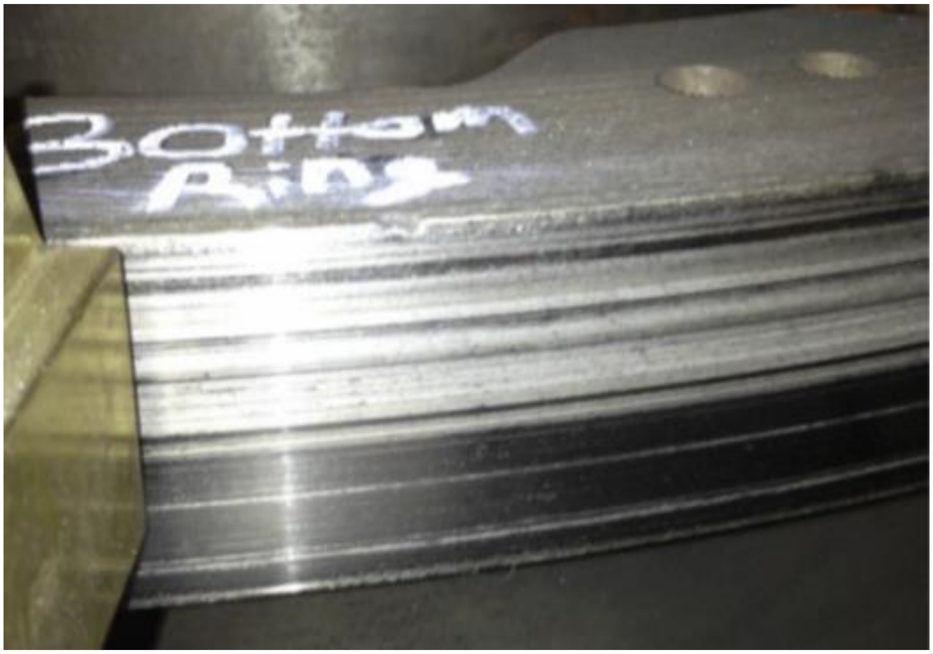


Figure 14. Typical Film and Streaking

Oil was seen on the bottom of the generator stator frame. It was not known where the oil came from or how it got deposited. However it did not appear that oil got on the winding or core. It is recommended that the oil be cleaned. Project has cleaned the oil since then.

Slip Ring Brush Assembly

The Dalles Maintenance staff noticed excessive brush wear for The Dalles Fish Units since at least 2011. Staff engaged The Dalles engineering, HDC, and Helwig, the brush manufacturer, in troubleshooting and developing a solution. Wear issues are still unresolved, as wear is considered excessive for less than two years of operation. The brushes as of the last check in 2015 is approximately one year old.

Electrical Testing and Visual Inspection

As with all equipment, generators have a finite service life. The service life of an electrical generator is directly related to the condition of the stator winding insulation materials of the generator. Therefore, it is advantageous to gain insight into the condition of the insulation system. There are several tools that can provide information about the existing condition of a generator. Although no diagnostic tools can pinpoint the exact date of failure, these tools can inform the owner/operator of the condition of the insulation by providing different bits of information. When these pieces of information are looked at together, a qualitative assessment can be made about the expected remaining useful life.

Tools that are commonly utilized to assess the condition of the electrical portion of the generator (stator winding and rotor/field winding) include:

1. Visual/Physical Inspection (rotor and stator windings)
2. Insulation Resistance/Polarization Index (IR/PI) Testing (rotor and stator)
3. DC Ramp Over Potential Testing (stator)
4. Partial Discharge Analyzer (PDA) Testing (stator)
5. Ozone Monitoring

Each test provides information and insight into the condition of the generator. The more information one gathers the more one can refine an estimate for remaining life. Due to funding limits, unit availability, access, and other circumstances, there is a limit to the testing that can be completed. Furthermore, in some cases, there is a diminishing return as more testing is performed.

Visual/Physical Inspection (Rotor and Stator)

The first step is to gather information on the condition of a generator is to complete a thorough visual/physical inspection by a knowledgeable generator specialist. There are limitations on what can be viewed without partial disassembly. Components that were not accessible were not inspected, so additional inspection may be considered in the scope of the Phase 1 effort.

Based on the visual inspection the windings in both units appear in fair condition for their age.

Insulation Resistance and Polarization Index (IR/PI) Test

IR/PI (Insulation Resistance/Polarization Index) testing is used to provide information on the condition of the insulation. IEEE Standard 43 recommends test voltages for the IR/PI tests to be performed at a voltage lower than the rated voltage of the winding, typically 10kV for a 13.8kV rated generator, so there is little risk of insulation rupture. The results of this test give some indication of the condition of the winding insulation, but mostly indicate whether the winding is dirty or wet. This test can be completed on the rotor in the same fashion as on the stator, with the notable exception that the applied test voltage is substantially lower.

The IEEE 43-2000 defines the Polarization Index (PI) is as the ratio of the 10 minutes insulation resistance (IR10) to the 1 minute insulation resistance (IR1), tested at a relatively constant temperature. The recommended minimum value of PI for AC and DC rotating machines are listed in this table:

Thermal Class Rating	**Minimum PI**
Class A	1.5
Class B	2
Class F	2
Class H	2

If the 1 minute insulation resistance is above 5,000 M-ohms, the calculated PI may not be meaningful. In such cases, the PI may be disregard as a measure of winding condition.

IEEE Standard 43, recommends, when feasible, that each phase be isolated and tested individually, with the other 2 phases grounded. Separate testing allows comparisons to be made between phases and tests the phase-to-phase insulation as well as the phase-to ground insulation. Testing all three phases together is also acceptable and less time consuming, but provides less useful information. When testing all phases concurrently, only the insulation to ground is tested and thus the phase-to-phase insulation is left out. Testing individual phase requires more effort than testing all three phase together.

The minimum insulation resistance after 1 minute, IR1min for overvoltage testing or operation of AC and DC machine stator windings and rotor windings can be determined from Table 7 below. The actual winding insulation resistance to be used for comparison with IR1min is the observed insulation resistance, corrected to 400°C, obtained by applying a constant direct voltage to the entire winding for one minute.

Table 7. Recommended Minimum Insulation Resistance Values at 40ºC (Values in M-Ohms)

Minimum insulation resistance	Test specimen
*IR*1 min = *kV* + 1	For most windings made before about 1970, all field windings, and others not described below
*IR*1 min = 100	For most DC armature and AC windings built after about 1970 (form-wound coils)
*IR*1 min = 5	For most machines with random-wound stator coils and form-wound coils rated below 1 kV

NOTES

1. IR 1 min is the recommended minimum insulation resistance, in M-Ohms, at 400°C of the entire machine winding
2. kV is the rated machine terminal to terminal voltage, in RMS kV

Correction to 400°C may be made by using Equation 1:

$$K_T = (0.5)\,(40 - 20)\,/10 = 0.25 \qquad \text{(EQ 1)}$$

The correction may be made by using Equation 2:

$$R_C = K_T R_T \qquad \text{(EQ 2)}$$

Where,

R_C is insulation resistance (in M-Ohms) corrected to 400°C

K_T is insulation resistance temperature coefficient at temperature T°C

R_T is measured insulation resistance (in M-Ohms) at temperature T°C

The tables below tabulate results of the Insulation Resistance and Polarization Index (IR/PI) tests (also known as Megger tests) for the stator and rotor of units 1 and 2. The Insulation Resistance (IR/PI) test is a useful indicator or the contamination and moisture on the exposed insulation surfaces of a winding, especially when there are cracks or major faults in the insulation. These values exceed the minimum acceptable values. This indicates that the winding insulation of the stator and rotor is clean and dry.

Table 8. Insulation Resistance and Polarization Index (IR/PI) Test Results for Fish Unit 1 Stator

TD FU01 Stator														
			Stator Wye-connected (Annual Only)			Stator Isolated_A-phase (Overhaul Only)			Stator Isolated_B-phase (Overhaul Only)			Stator Isolated_C-phase (Overhaul Only)		
Tested By	Date	Specimen Temperature (deg. C.)	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.
R. Ontiveros	27 Feb. 2007	20				7500	45000	6	7500	45000	6	8250	37500	4.54
S. Powell	30 Jan. 2014	20	2290	11800	5.15									
B. Sterrenberg	2 Mar. 2016	20	2590	14200	5.49									

Using Equation 1: $K_T = (0.5)\,(40 - 20)\,/10 = 0.25$

Using Equation 2: $R_C = K_T R_T = 0.25 \times 2{,}590\ M\Omega = 647.5\ M\Omega$

The minimum acceptable value for the stator is 100 MΩ.

The PI for Unit 1 stator winding insulation resistance test was 5.49, which exceeded the minimum requirement of 2.

Table 9. Insulation Resistance and Polarization Index (IR/PI) Test Results for Fish Unit 2 Stator

TD FU02 Stator															
			Stator Wye-connected (Annual Only)			Stator Isolated_A-phase (Overhaul Only)			Stator Isolated_B-phase (Overhaul Only)			Stator Isolated_C-phase (Overhaul Only)			
Tested By	Date	Specimen Temperature (deg. C.)	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.	1-min. IR @ 10kVDC (Megohms)	10-min. IR @ 10kVDC (Megohms)	P.I.	
T. Tillman	1 Feb. 2012	20			5.6										
S. Von Borstel	9 Mar. 2016	20	1660	9240	5.56										
S. Von Borstel	12 Jan. 2017	20	1920	11200	5.83										

Using Equation 1: $K_T = (0.5)\ (40 - 20) / 10 = 0.25$

Using Equation 2: $RC = K_T R_T = 0.25 \times 1{,}920\ M\Omega = 480\ M\Omega$

The minimum acceptable value for the stator is 100 MΩ.

The PI for Unit 2 stator winding insulation resistance test was 5.83, which exceeded the minimum requirement of 2.

Table 10. Insulation Resistance and Polarization Index (IR/PI) Test Results for Fish Unit 1 Rotor

TD FU01 Rotor								
			Rotor & Slip Ring (Annual Only)			Rotor & Slip Ring (Overhaul Only)		
Tested By	Date	Specimen Temperature (deg. C.)	1-min. IR @ 500VDC (Megohms)	10-min. IR @ 500VDC (Megohms)	P.I.	1-min. IR @ 500VDC (Megohms)	10-min. IR @ 500VDC (Megohms)	P.I.
S. Powell	12 Feb. 2013	20	175	569	3.25			
S. Powell	30 Jan. 2014	20	183					
S. Von Borstel	5 Feb. 2015	20	117					
B. Sterrenberg	2 Mar. 2016	20	232					

Using Equation 1: $K_T = (0.5)\ (40 - 20) / 10 = 0.25$

Using Equation 2: $RC = K_T R_T = 0.25 \times 232\ M\Omega = 58\ M\Omega$

The minimum acceptable value for the rotor is 14.3 MΩ.

Table 11. Insulation Resistance and Polarization Index (IR/PI) Test Results for Fish Unit 2 Rotor

TD FU02 Rotor								
			Rotor & Slip Ring (Annual Only)			Rotor & Slip Ring (Overhaul Only)		
Tested By	Date	Specimen Temperature (deg. C.)	1-min. IR @ 500VDC (Megohms)	10-min. IR @ 500VDC (Megohms)	P.I.	1-min. IR @ 500VDC (Megohms)	10-min. IR @ 500VDC (Megohms)	P.I.
D. Christensen	17 Feb. 2004	20	75					
T. Tillman	1 Feb. 2012	20	48					
R. Brumbaugh	12 Feb. 2013	20	251	565	2.25			
J. Borra	12 Feb. 2014	20	314					
S. Von Borstel	9 Mar. 2016	20	279					
S. Von Borstel	12 Jan. 2017	20	267					

Using Equation 1: $K_T = (0.5)\ (40 - 20) \,/\, 10 = 0.25$

Using Equation 2: $RC = K_T R_T = 0.25 \times 267\ M\Omega = 66.75\ M\Omega$

The minimum acceptable value for the rotor is 14.3 MΩ.

DC Ramp Over Potential Test (Stator Only)

The DC ramp over potential test is similar to the IR test in that a voltage is applied to the winding one phase at a time with the other two phases grounded. However, in this test an automatic tester raises the test voltage at 1kV/minute to render the capacitive current constant over the period of the test. By plotting the applied voltage against the measured current, a characteristic curve can be developed and compared to future (or past) test results, or results from sister units or other phases of the same winding. Also, this test provides real time feedback to the test technician or engineer of a sudden change in current, thus possibly allowing the test to be stopped before an insulation rupture occurs. This real time feedback allows the technician to apply a much higher voltage to the winding, above the nominal voltage rating, which will provide information that is not otherwise provided in a standard IR/PI test. Note that due to the over voltage nature of the test, there is a greater risk of damaging the insulation of the winding.

DC over potential testing is not recommended on the field winding (rotor) circuits.

Per IEEE Standard 95, tests are made on each phase of the winding. Separate testing allows comparisons to be made between phases.

It appears a DC ramp over potential test has never been performed on these units. According to the Project, it was very difficult to disconnect the phases.

Partial Discharge Analyzer (PDA) Test

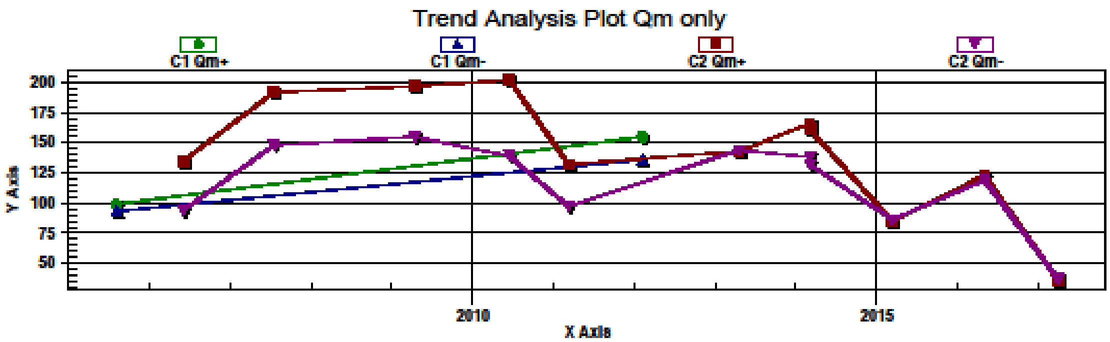
Partial discharge tests are sensitive to a wide variety of stator ground wall insulation deterioration mechanisms. The PDA test in an on-line test suitable for hydro-electric generators. In the PDA test, high voltage capacitors are permanently installed in the stator winding. An instrument called the Partial Discharge Analyzer is used to measure the partial discharge activity when the generator is in service.

Below are the trend reports of Partial Discharge for the Fish Units.

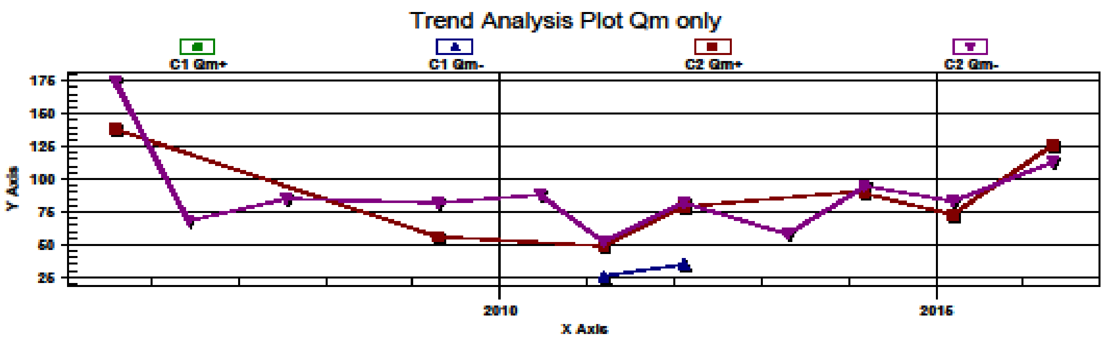
PD Trend Analysis
Asset Name: F.U.# 1

IRIS POWER
A QUALITROL Company

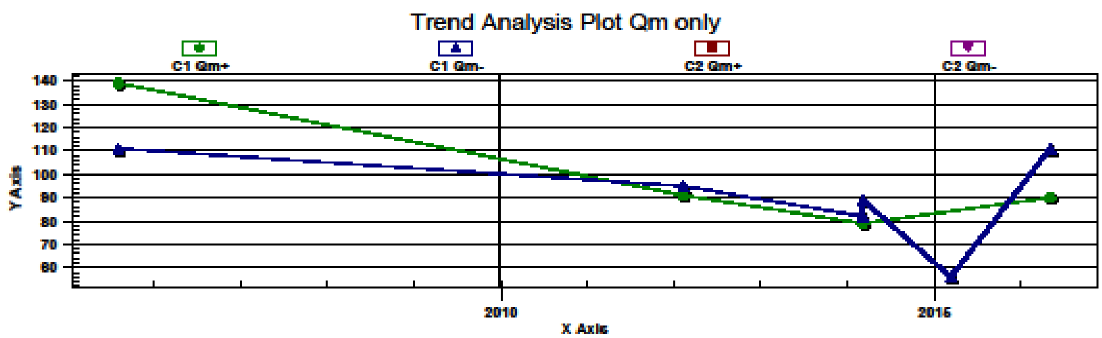
Folder: F.U. & M.U. Generators\, Asset Class: Hydro Generator



Phase: A, Sensor(s): A-C1A-C2



Phase: B , Sensor(s): B-C1B-C2



Phase: C, Sensor(s): C-C1C-C2

Manufacturer: WESTINGHOUSE, Year of Installation: 1957, Re-Wind Manufacturer: WESTINGHOUSE, Re-Wind Year: 1998
Stator Voltage Rating: 13800.000, Active Power Rating: 15.52 MW, Reactive Power: 16340000.153, Gas Pressure Rating: N/A
Cooling System: Air Only, Winding Type: Unknown, Insulation Type: Epoxy Mica
Insulation Class: F, Insulation Process: Unknown

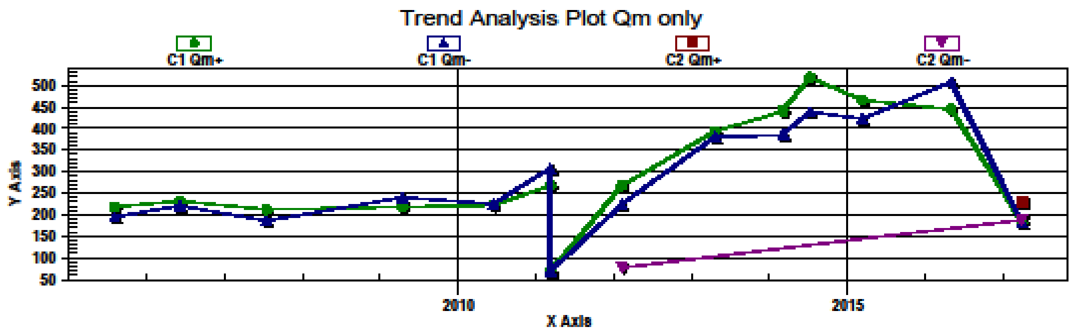
Iris Power LP, 3110 American Dr., Mississauga, On, Canada L4V 1T2, Phone: +1 (905)-677-4824, Fax: +1 (905) 677-8498

Figure 15. PD Trend Analysis, Fish Unit 1

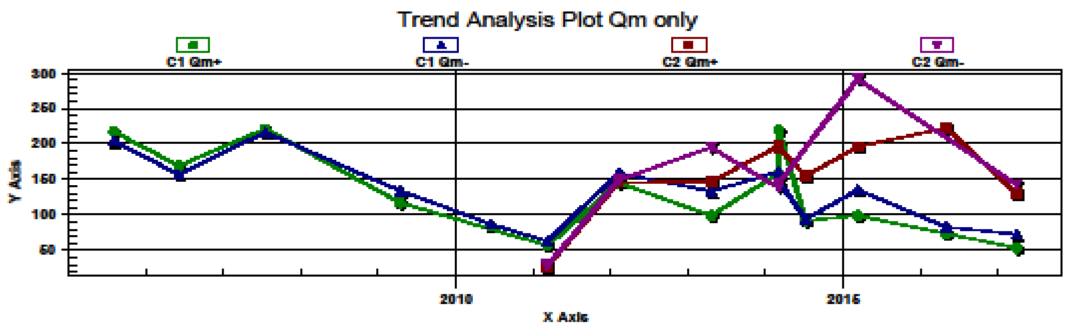
PD Trend Analysis
Asset Name: F.U.# 2

IRIS POWER
A QUALITROL Company

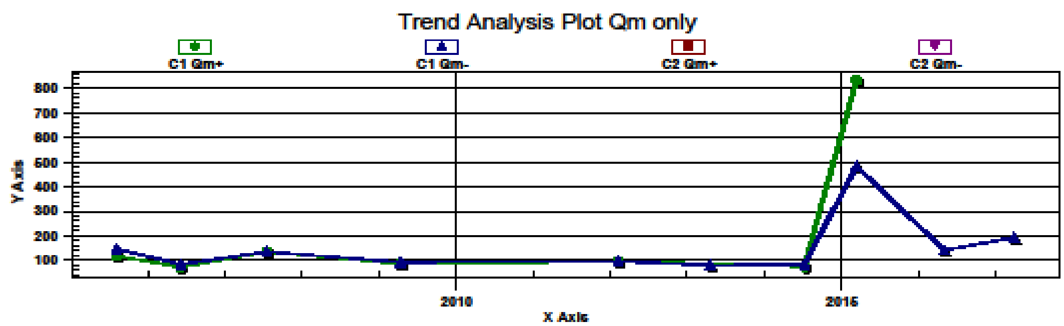
Folder: F.U. & M.U. Generators\, Asset Class: Hydro Generator



Phase: A, Sensor(s): A-C1A-C2



Phase: B , Sensor(s): B-C1B-C2



Phase: C, Sensor(s): C-C1C-C2

Manufacturer: WESTINGHOUSE, Year of Installation: 1957, Re-Wind Manufacturer: WESTINGHOUSE, Re-Wind Year: 1997
Stator Voltage Rating: 13800.000, Active Power Rating: 15.52 MW, Reactive Power: 16340000.153, Gas Pressure Rating: N/A
Cooling System: Air Only, Winding Type: N/A, Insulation Type: Epoxy Mica
Insulation Class: F, Insulation Process: N/A

Iris Power LP, 3110 American Dr., Mississauga, On, Canada L4V 1T2, Phone: +1 (905)-677-4824, Fax: +1 (905) 677-8498

Figure 16. PD Trend Analysis, Fish Unit 2

Table 12. Categorizes the Magnitude (mV) of Measured PD

PD Severity	+/-Qm for 13-15kV Hydro-generators
Negligible (25%)	< 34 mV
Low (50%)	< 88 mV
Average (75%)	< 190 mV
Moderate (90%)	< 364 mV
High (95%)	< 530 mV
Very High (99%)	> 530 mV

This information is based on Iris Engineering's 2016 Statistical Analysis

***The frequency of discharges in pulses per second (NQN) are no longer categorized by Iris Engineering as they discovered that NQN did not correlate well with regards to the insulation condition.

2016 and 2017 Summary of Operational Status for Units 1 and 2

2016 Summary for Unit 1–The overall long-term trend continues to be stable for all three phases. Historically there has been low to moderate PD detected at the C2 capacitor for A- and B- phase and at the C1 capacitor for C-phase. All of the PD appears to be "non-Classic" and possibly the result of the oil/brake dust contamination noted in the January 2015 inspection. Results still confirm that the C1 and C2 connections for A-phase had been inadvertently reversed in 2005 and 2012.

2016 Summary for Unit 2 – The C1 capacitor for A-phase continues to detect a significant amount of Classic PD that is considered high for 13.8kV hydro-generators (the severity has doubled since 2005 and is greater than 95% of similar machines). A "spike" in the PD pattern suggests that the discharges are occurring outside of the slot in the voltage stress coating. This condition exists on only A-phase and while the condition is stable, it will continue to be monitored more frequently. A visual inspection was performed during routine maintenance in January 2015 and the winding itself appeared to be very clean. While a band of white powdery residue at the coil slot exit is evidence of discharges in this area - no powder was noted. The severity of the PD for B-phase has historically been average to moderate and a cloud-like pattern suggests that gap-type discharges are also occurring in the end winding area. In March 2015, the C1 capacitor for C-phase detected high PD that is now average. Historically it also has produced a cloud-like pattern which supports gap-type discharges.

2017 Summary for Unit 1 – Recent discharges were much less severe on all three phases when compared to historical results. Neither B- or C-phase produced any PD at either capacitor. The overall long-term trend continues to be stable. Historically there has been low to moderate PD detected at the C2 capacitor for A- and B- phase and at the C1 capacitor for C-phase. All of the historical PD appears to be non-Classic and possibly Inter-phasal. There is also evidence that temperature may have a direct effect on the magnitude of the PD being measured. The higher the winding temperature has been, the greater the magnitude of the discharges. Results still confirm that the C1 and C2 connections for A-phase had been inadvertently reversed in 2005 and 2012.

2017 Summary for Unit 2 –This year, both the C1 and C2 capacitors for A-phase detected PD having average severity and it likely appears to represent Classic PD with no predominance. Additionally, there was no "spike" in the PD pattern this year and therefore these discharges may not have been occurring just outside of the slot in the voltage stress coating. For now, this condition appears to be stable. The severity of the PD for B-phase remains average to moderate and a cloud-like pattern still suggests that non-Classic gap-type discharges are still occurring in the end winding area. In March 2015, the C1 capacitor for C-phase detected high PD that is now moderate. Historically it also has produced a cloud-like pattern which supports gap-type discharges.

Ozone Monitoring

When winding discharges occur in air-cooled machines such as hydro-generators, ozone gas is created. Thus monitoring of the ozone concentration in a machine is an indirect (non-electrical) means of determining if certain types of partial discharge (PD) are occurring in the stator winding. The monitoring is performed during normal operation.

The ozone concentration is considered high if it exceeds 1 parts per million. Ozone monitoring is typically done annually.

Two main methods are available to measure the ozone concentration. The fairly easy and relatively inexpensive method uses gas analysis tubes which are sensitive to ozone. One brand is made by Draeger and is available from chemical supply companies. When the tubes are broken open, a chemical inside the tube changes color and the approximate ozone concentration can be read. It is recommended the test be repeated once every six months. A second method uses an electronic instrument which can measure the ozone concentration continuously. A sensor is placed within the machine enclosure or in the exhaust air stream. The sensor is expensive and requires calibration annually. An analyzer is required to collect the data.

With the exception of June 2016 measurement on unit 2 (0.12 ppm), the level in both units were found acceptable. The ozone level appears trending upward. This is an indication of more slot discharge activities.

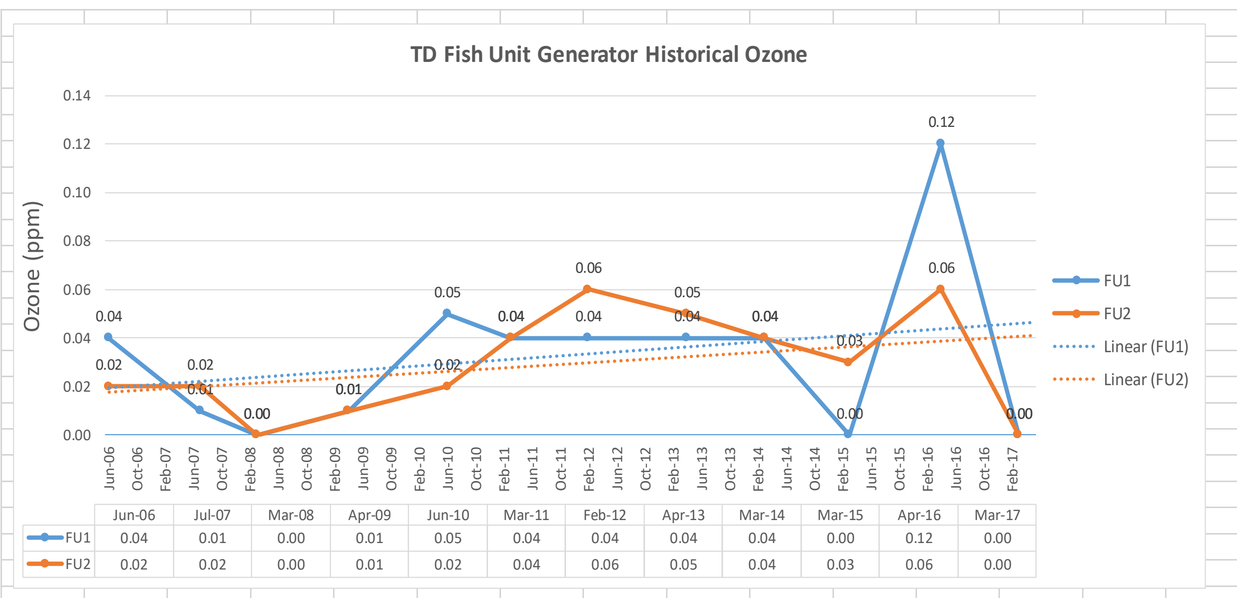


Figure 17. Ozone Data

Overall, the inspection and analysis of the operational status of the stators and rotors of the two Fish Units show a trending decline in reliability and maintainability, putting the units at risk of failure and in need of significant refurbishment of the generator major components and supporting systems.

Excitation System

The original rotating excitation systems were replaced with the UNITROL F Series solid state excitation systems by ABB in 2000. While the excitation systems are in satisfactory condition, replacement parts are difficult to locate or are no longer available.

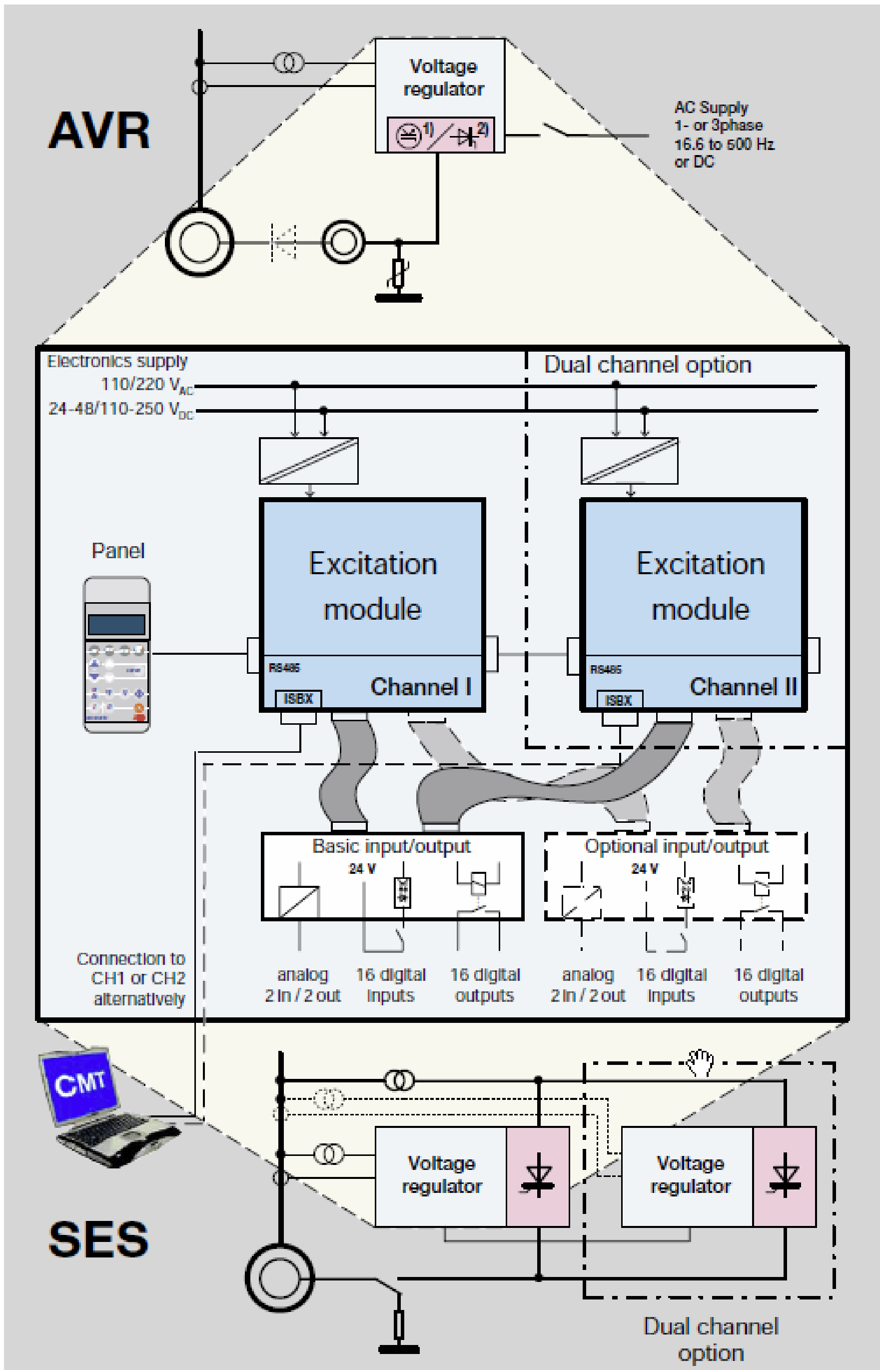


Figure 18. Unitrol F System Configuration

No failures occurred on the excitation system. However, there was a failure on the main Unit 13, which also has UNITROL F model.

TURBINE

All inspections on the mechanical features of The Dalles fish water units were done visually. No other non-destructive inspections were performed (such as penetrant dye, magnetic particle, or ultrasonic).

Discussions with Project staff revealed that overall the fish water units have historically been very dependable. There have been problems with blade cracks occurring in the leading and trailing edge blade radiuses to the blade trunnions. In recent years these cracks have been addressed in a more robust fashion which seems to have greatly mitigated the cracking problem. There has been no recent crack propagation on any of the fish water turbine runner blades in the last three or so years. It should be noted though that once crack propagation has been noted it is rarely repaired without there being recurrences in the future. In the case of these turbine blades it is expected that cracking will be an ongoing problem that will have to be constantly monitored and repaired. Each repair of the turbine blade cracks will further weaken the base metal in the cracking zone.

There is minimal cavitation damage on the runner surfaces, but cavitation has been addressed and looked in good repair at the time of the 2016 inspected. Cavitation is an ongoing issue that must be addressed during scheduled outages. At this point it looks like cavitation repair of the blades, hub and discharge ring liner is well in hand, although vigilant inspection will be a constant necessity in the future.

Figure 19. Stainless Steel Overlay on the Blades Suction Side (Underside, Leading Edge)

Figure 20. Paint Still Visible on the Runner Hub

Figure 21. Blade Cracks That Have Been Repaired and Are Not Re-Cracking

The components inside the runner and oil head cannot be inspected, without disassembly, so even though the exterior of the runner is in good shape there is no way to verify that the components inside the runner and oil head are in good functioning order. These Kaplans are 60 years old so all components inside the runner have six decades of wear. The risk of a failure will increase with age. It should be pointed out, though, that in the past when a Kaplan has failed there has always been a way to perform an in-place repair that will allow the runner to continue to function however in most cases without its full Kaplan functionality. In the case of a potential failure, the unit may be unavailable for several months while it is being repaired which may be a major concern since the failed unit will be unwatered and not able to provide attraction water for the fish way. Turbine pit components including the operating ring, two wicket servos, wicket gate linkages, turbine guide bearing and packing box appear to be in good operating order.

Water Passageway and Turbine Pit

All carbon steel hydraulic surfaces inspected had some buildup of corrosion on the surface intermixed with the original paint system. The corrosion buildup appeared to be superficial and should not affect unit operation. The wicket gates and stay vanes were free of any cavitation damage. There is some cavitation damage on the discharge ring, runner blades and runner hub that was seen during the 2016 inspection however these components were well maintained. These small fish units do not have a penstock but have a normal intake similar to the main units at this powerhouse. During the 2016 inspection the water passage was in very good condition especially considering the number of years the units have been in service.

The original paint system is still visible in many locations on the carbon steel surfaces. This is very good as the paint is continuing to protect the steel surfaces.

Turbine Runner

The turbine runner is original, as manufactured by Allis Chalmers Co. in the mid-1950s. The runner is a Kaplan type turbine runner with a 120 inch diameter at the blade centerline. The runner blades can change pitch which gives it a relatively broad range of operation at any single head. The runner converts hydraulic energy into rotational energy. There are no known operational issues with the runner at this time other than the blade cracks which appear to have been addressed. There is a small buildup of corrosion on the carbon steel portion of the blades. The stainless steel overlays looked to be in good repair the last time they were inspected in 2016. There is cavitation damage on the blades and hub, but it has been repaired and the carbon steel surfaces are in good condition.

Figure 22. Wicket Gates and Stay Vane in Good Condition

Figure 23. Discharge Ring SS Repair Shown Below a Blade with a Cavitation Fin

Figure 24. Additional Photo Showing Wicket Gates and Stay Vane with a Corrosion Patina

Head Cover

The turbine head covers are original as manufactured by Allis Chalmers in the mid-1950s. There are three components of the head cover: the outer head cover, the intermediate head cover and the inner head cover. The outer head cover mounts to the stay ring and supports the wicket gates. The intermediate head cover is mounted to the outer head cover inner flange and supports the turbine guide bearing housing and the turbine guide bearing. The inner head cover in turn mounts to the inner flange of the intermediate head cover and supports the packing box.

The combination of all three head covers acts primarily as structural components, providing a separation of river water from the powerhouse and acting as a hydraulic surface for water flow through the water passage. The outer head cover is a low to medium carbon steel casting while the inner and intermediate head covers are carbon steel fabrications. Based on operational history with no known issues and limited visual inspection, the head covers appear to be in good working condition. There is no visual evidence of cracking, excessive corrosion, or overloading. However, portions of the head cover, including critical surfaces, are not visible without disassembly.

Turbine Shaft

The main shafts are original as manufactured by Allis Chalmers in the mid-1950s. The main shaft transfers the torque from the turbine runner to the generator shaft and is the mechanical work portion of producing electrical power. The main shaft contains the stainless steel packing sleeve which is the rotating surface on which the packing material (or water seal) runs preventing water from the water passage from entering the powerhouse. The shaft sleeve has many years of service and likely has wear grooving on the seal surface. The main shaft also contains the journal for the turbine guide bearing and the coupling where the runner attaches to the shaft.

Based on historical operation with no known issues and limited visual inspection, the main shaft appears to be in good working condition. There is no visual evidence of corrosion or overloading. However, portions of the shafts, including critical surfaces, are not visible without disassembly. An analysis assuming 22,600 hp (rating is 18,800 hp) shows the shaft stress to be below 6,000 psi, which is used by HDC as the allowable stress threshold for turbine and generator shafts. The shafting stresses were evaluated in Appendix F.

Turbine Guide Bearing

The fish water units have the main journal guide bearing or turbine guide bearing located directly above the turbine runner and packing box. These bearings are original as manufactured by Allis Chalmers in the mid-1950s. The guide bearings maintain the alignment of the unit during operation. The bearing consists of a journal (rotating portion on the turbine shaft) and babbitted or oil-lubricating surface (stationary portion). The turbine guide bearing is a typical cylindrical carbon steel shell bearing containing two halves that fasten together around the turbine shaft and are mounted to a bearing housing that in turn is mounted to the intermediate head cover which is a stationary component. The journal dimension for this bearing is 20.260/20.262 inches.

Based on historical operation with no known issues, the turbine guide bearings appear to be in good working condition. There is no historical or operational evidence of issues associated with the guide bearings. However, critical surfaces of the bearings are not visible without disassembly and the existing condition of the babbitted bearings and water-lubricating bearing can only be known after disassembly. Nevertheless, it is common for babbitted bearings of this age and vintage to have disbonding of the babbitt.

The Dalles has a spare turbine guide bearing for the fish water turbines. These bearing will have to be inspected and refurbished.

Figure 25. Unit 2 Disassembled Showing the Combination Generator Thrust Bearing/Upper Guide Bearing

The wicket gate bushings are original as manufactured by Allis Chalmers in the mid-1950s. The wicket gate bushings were manufactured from bronze and require grease for operation. The bushings are lubricated by an automatic grease system. The stainless steel sleeved wicket gate stems are the journal surface which rotates inside the bronze bushings and they are a guide and low friction surface for the wicket gates. There are two sets of wicket gate bushings: two upper bushings mounted in the outer headcover and one lower bushing mounted in the bottom ring. Both bushings are exposed to the water passageway. There are no known operational issues pertaining to the wicket gate bushings. During most rehabilitations the greased bronze system as installed here on the fish water turbines are replaced with a self-lubricated bushing and the grease system is removed from the unit.

Wicket Gates

The wicket gates are original as manufactured by Allis Chalmers in the mid-1950s. The wicket gates regulate the flow through the turbine. The wicket gate are fabricated from carbon steel with stainless steel stem sleeves.

Based on historical operation with no known major issues, the wicket gates appear to be in good working condition. There is no evidence of cracking. There is no cavitation damage to the wicket gates; however, the wicket gates have a moderate corrosive build up.

Wicket Gate Operating Ring and Mechanism

The operating ring transmits the force from the wicket gate servomotor to all the wicket gate operating mechanisms, which in turn operate the wicket gates. The operating ring is fabricated from a low to medium carbon steel and original as manufactured by Allis Chalmers in the mid-1950s. The wicket gate mechanism (linkage components) appear to be in good working condition with no known operational issues.

Based on historical operation with no known issues and limited visual inspection, the operating ring and mechanism appear to be in good working condition. There is no visual evidence of corrosion, cracking, or overloading. However, portions of the operating ring, including critical surfaces, are not visible without disassembly. There is a strong likelihood the operating ring bronze pads have significant wear.

Wicket Gate Servomotor

The fish water turbines have two servomotors that actuate the wicket gates. The servomotor operates the wicket gates through the operating ring and gate linkage. There are no known issues with the servomotors or wicket gate linkage, but many portions of the servomotor are not visible without disassembly. The servo motors are normally refurbished during a rehabilitation.

Wicket Gate Bushings

The wicket gate bushings are original as manufactured by Allis Chalmers in the mid-1950s. The wicket gate bushings were manufactured from bronze and require grease for operation. The bushings are lubricated by an automatic grease system. The stainless steel sleeved wicket gate stems are the journal surface which rotate inside the bronze bushings and they are a guide and low friction surface for the wicket gates. There are two sets of wicket gate bushings- two upper bushings mounted in the outer headcover and one lower bushing mounted in the bottom ring. Both bushings are exposed to the water passageway. There are no known operational issues pertaining to the wicket gate bushings. During most rehabilitations the greased bronze system as installed here on the fish water turbines are replaced with a self-lubricated bushing and the grease system is removed from the unit.

Generator Shaft

The generator shaft is original as manufactured by Westinghouse Co. in the mid-1950s. The generator shaft transfers the torque from the main shaft and runner to the generator. The generator shaft also contains the journal for the generator lower guide bearing and the mounting location for the thrust bearing collar, the OD of which also acts as the journal for the generator upper guide bearing. The rotor is mounted to the generator shaft below the thrust bearing so this unit has a suspended generator. The exciter was originally mounted to the top of the generator shaft with the Kaplan head mounted above the exciter.

Based on operational history, the generator shaft appears to be in good working condition and there is no evidence of damage to it. Although a large portion of the shaft is not visible for inspection there is no reason to believe there are any problem areas.

A preliminary stress analysis has been performed on the generator shaft and the calculation shows it to be capable of producing 17.92 MW (assuming generator efficiency of 98%). The generator shaft has the smallest cross section and is the limiting shaft of the turbine and generator shafts.

Generator Guide Bearings

There are two generator guide bearings. The upper generator guide bearing uses the OD of the thrust collar as the journal. There are fourteen guide shoes for this bearing with the journal OD being 52-3/8 inches. The lower generator guide bearing is mounted around the journal on the generator shaft. There are eight guide shoes for this bearing with the journal OD being 28½ inches. Neither of these bearings are accessible for easy inspection, however it is rare that generator guide shoes would fail in operation. During a rehabilitation these bearing shoes will be inspected and most likely it will be an opportunity to rebabbitt them. The Dalles Project team has a spare set for both of these bearings.

Thrust/Upper Guide Bearing Assembly

The combination thrust bearings/upper guide bearings are original as manufactured by Westinghouse Corp. in the mid-1950s. The combination bearing consists of a thrust collar, thrust runner, eight babbitted thrust shoes and guide shoes, base ring, jack screws, and support system. The thrust bearing is located above the generator rotor. The Dalles fish water units do not have a high pressure lift system and the unit requires jacking prior to start-up after it is down for a period of time. There are no known operational issues; however, the condition of the bearing cannot be determined until after disassembly and completion of non-destructive testing (NDT). It is common for bearing shoes of this age and vintage to have disbonding of the Babbitt which would be addressed during a rehabilitation by rebabbitting the bearing. The Dalles has a spare thrust bearing runner and shoes. The thrust bearing/upper guide bearing combination shown in the photo was disassembled in December 2015 due to an oil overheating problem in the bearing tub. The bearing shoes were hand scraped and the oil changed. When the unit was reassembled the overheating issue stopped.

Figure 26. Lower Generator Guide Bearing

Figure 27. The Turbine Pit Showing the Two Wicket Gate Servos and the Wicket Gate Linkage.

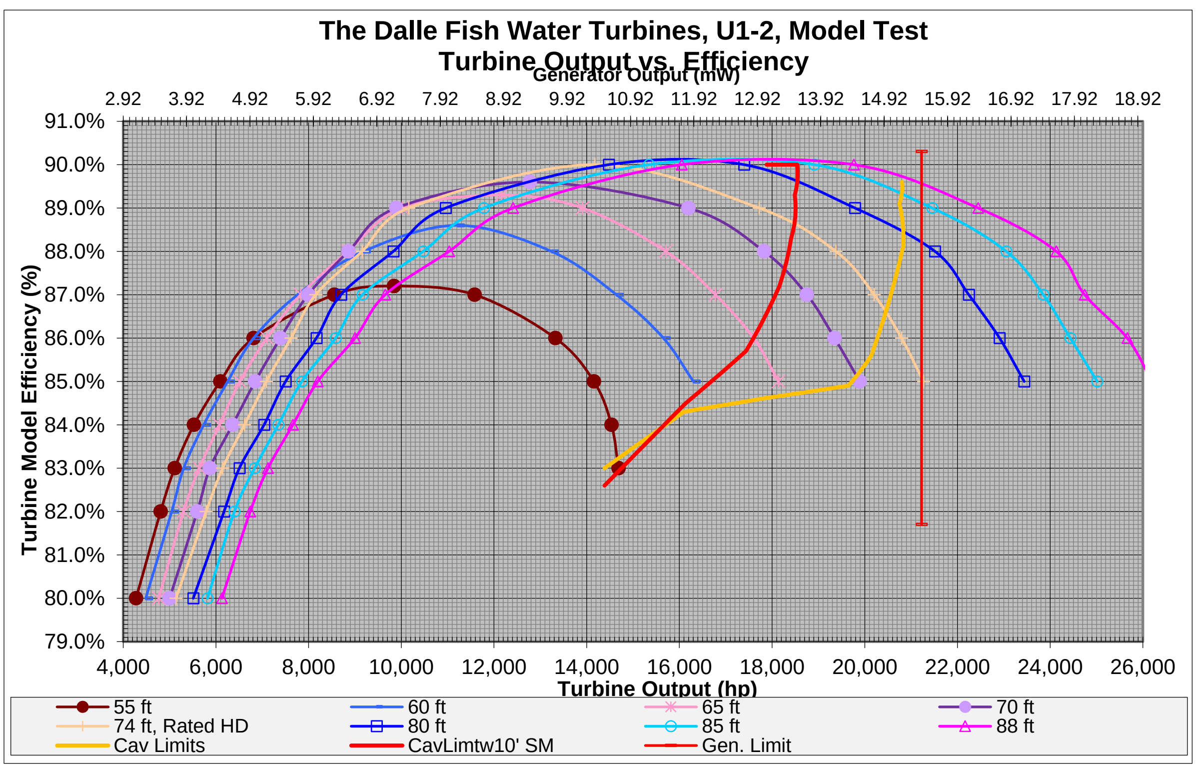


Figure 28. Existing Turbine Performance, Turbine Horsepower vs. Turbine Efficiency

Turbine Performance of Existing Units

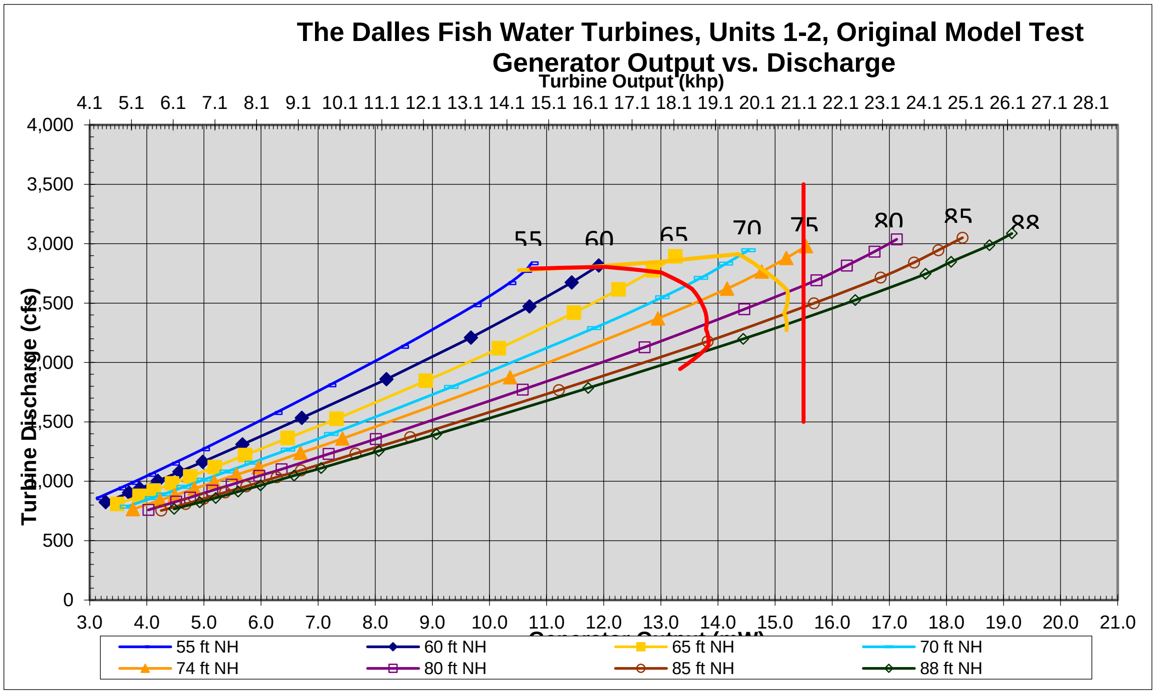


Figure 29. Existing Performance, Turbine Discharge vs. Generator Output in MW

ANCILLARY EQUIPMENT

Governor

The governors were originally supplied by Pelton and converted from mechanical to digital control by American Governor. This work was completed in 2012. These governors are currently in good operating condition.

Figure 30. American Governor Digital Governors Installed Circa 2012

Thrust/Upper Guide Bearing Oil Coolers

The Project staff has increased monitoring and maintenance of the internal thrust bearing oil coolers. The coolers provide the cooling capacity necessary to maintain thrust bearing oil temperatures that are required for proper lubrication of the thrust bearing.

The coolers are a fin and tube design and are submersed in an oil bath concentric to the thrust bearing.

The finned tubes are "coiled" to make six rows of finned tubes. They are built in a semi-circular design such that two halves are required per unit. Raw river water flows through the tubes and acts as the cooling medium. The tubes are soft copper, and are a major source of failure.

The coolers are in poor overall condition and require replacement parts and down time for repairs. Repeated failures have occurred, some causing unplanned outages. The end turns are subject to the most wear and are consequently the most prone to leakage. Failures have come primarily from this area which is a symptom of wear showing the components are at the end of their useful life. In a worst case scenario leakage of cooling water into the oil bath can cause a thrust bearing to wipe. Maintenance and repairs are particularly difficult because of the location of the coolers. Access to the thrust tub requires a partial unstack of the unit down to the thrust bearing. Additionally, repairs often require drainage of the 350 gallons of oil in the thrust tub. The rehabilitation of the units will involve replacement of the coolers. Appendix E contains an alternative analysis for bearing cooler replacement options.

Lower Guide Bearing Oil Cooler

The lower guide bearing oil is cooled by a tube heat exchanger that is immersed in the lower guide bearing tub. Raw river water is used as the cooling medium. The rotating shaft journal creates a mixing action that effectively distributes cool oil amongst the bearing pads. The coolers have many years of service and will be replaced or rehabilitated. This work would be completed under a normal rehabilitation. Appendix E contains an alternative analysis for bearing cooler replacement options.

Turbine Guide Bearing

The turbine guide bearing is lubricated by a pump that pressurizes lubricating oil and is piped to the bearing. After lubricating the bearing the oil drains into a sump under the bearing by gravity where it is cooled and then pumped back through the bearing again. For redundancy, the turbine guide bearing lubrication system utilizes both AC and DC pumps. The AC pump is typically used during start up. In the case that AC power is unavailable because of a blackout scenario, the DC pump would be utilized. It is assumed that the pumps are original to the installation of the turbine/generator and should be replaced to maintain unit reliability.

Surface Air Coolers

The four air coolers keep the stator at a temperature that protects the stator windings and insulation from thermal damage. Additionally, they provide the same cooling benefit to other equipment located within the air housing. Raw river water flows through the tubes in the cooler while air is forced around the tubes by baffles on the rotating rotor. The coolers are located within the air housing, around the outside of the stator. The stator air coolers are plate and fin design with integral tubes that circulate water to and from the river. The stator air coolers are not a significant source of failure for the fish units.

However, these coolers do have a history of fouling, and maintenance can only be expected to increase. It is assumed that the coolers have reached the end of their useful life and need to be replaced.

Water and Oil Piping

The turbine-generator has a piping system to deliver cooling water to the bearing coolers and air coolers. Additionally, there is oil piping to fill and drain the bearing tubs. This piping is original to the installation of the unit. The piping is not in good condition and must be replaced.

Brake and Jack System

The unit has brake cylinders that are used to slow and stop the unit. The cylinders are actuated using pressurized station air. HDC does not have detailed information on the brakes, but it is assumed that they are original to the installation of the equipment. While further inspection will be needed, it is reasonable to assume that the cylinders and pistons are in serviceable condition and can be refurbished. Refurbishment can include new seals and honing of the cylinders or pistons. The pads should be replaced and the air lines inspected and replaced if necessary.

E-Closure System

The emergency-gates (E-Gates) serve as the final line of defense in a unit runaway situation, wicket gate failure, or head cover failure. The E-Closure System involves deploying gates to the intake water passage to stop the water flowing into the unit. E-Gates differ from typical bulkheads in that they are designed to deploy under flow.

At The Dalles, the original E-Closure System consisted of dedicated gates and hydraulic cylinders that would deploy the gates at the Corps standard; under 10 minutes. Circa 2004, The Dalles removed the hydraulic cylinders in an effort to reduce the possibility of oil leakage entering the river. The water entering the unit is divided between two water passages and therefore there are two E-Gates per unit. These gates currently hang in the slots and are deployed by the Hammerhead Crane. This crane, however, was not designed for this function. A new E-Closure System is strongly recommended and will increase plant safety and reliability

Several years ago, a nitrogen pressure backup system was added to the units for emergency closure of the wicket gates.

Other Electrical Components

There are currently other projects underway to replace the transformers and the 15 kV breakers for the fish water turbines.

SECTION 4 – STRUCTURAL ENGINEERING AND HYDRAULIC DESIGN

Structural engineering and hydraulic design are two areas of primary consideration in the rehab of The Dalles Fish Units.

CRITERIA AND CONSTRAINTS – FISH UNIT OUTFALL INTO THE AUXILIARY WATER SYSTEM (AWS)

The report "The Dalles Dam Powerhouse Fishway Dewatering Improvements" dated September 1999 prepared by CH2M Hill - Montgomery Watson Joint Venture indicates concerns about the design of the downstream wall of the AWS channel which the Fish units discharge into. The report recommends that "a finite element analysis is recommended to clearly define the maximum tailwater elevation at which the Fish Collection Channel and the Auxiliary Water (AWS) Conduit can be dewatered. The analysis completed to date indicates that the AWS Conduit can be dewatered when the tailwater elevation is maintained below elevation 70-fmsl. A maximum tailwater elevation closer to 80-fmsl is more conducive to the project operations." Such an analysis was performed as an addendum to the 1999 report in March of 2000. The conclusion of this analysis was as follows: "...it is recommended that the maximum tailwater elevation not exceed 70.0-fmsl with the auxiliary water conduit and the fish collection channel completely dewatered. It is also recommended that the maximum tailwater not exceed 82.0-fmsl with water in the auxiliary water conduit at a minimum elevation of 55.5-fmsl."

The AWS channel is oriented at a right angle to the Fish Unit draft tubes. The Fish Unit stop logs are located immediately upstream of the AWS channel. The Fish Units can be unwatered without impact to this area and without unwatering this area of the AWS. However, the new unit may have increased velocities. The current condition of the area was unknown, however, in order to mitigate risks associated with not knowing the current physical condition, the PDT recommended that the AWS conduit which the fish units discharge into be visually inspected using an ROV during the development of the Phase 1A report. This inspection was completed and no damage was visible on the AWS wall in front of the two turbines discharge.

HYDRAULIC DESIGN AND THE LIMITED FISH LADDER MODEL

The primary purpose of the hydraulic design section is to provide potential targets for upgraded fish unit discharge capacity.

Limited Fish Ladder Model

A limited 1-D hydraulic model was developed to estimate fish unit discharge rates required to meet minimum entrance criteria conditions. Previously developed models for The Dalles East Fishladder are no longer available. The entrance discharge rates were estimated from known conditions (geometry, weir settings and entrance head at each entrance) and compared with the recorded fish unit discharge at the same time.

The Dalles Project staff provided fishladder inspection data for the years 2011, 2012 (limited), 2014, 2015, 2016, and some brief data in 2017. The fishladder inspection data has been historically handwritten on hardcopy forms, requiring transcription to an electronic file in order to perform analyses. The data from all years included the tailwater levels and entrance heads at each entrance location (3 total), weir levels in each entrance bay (8 total), fish unit megawatts generated and discharges for most days of the fish passage season. 2011 and 2012 data included the recorded AWS head in the turbine draft tube (referred to as "channel" in the operation room). Prior to the addition of the governor (2012), this information was required in order to determine the fish unit discharge from the combination of megawatts and net head. Since the addition of the governor, fish unit discharge is directly computed and provided, and the data for the AWS draft tube level is no longer being collected. The 2017 data included a period of days under a single fish unit operation.

The fish unit discharges were estimated from the hydraulic model and compared with the recorded fish unit discharges. The estimated fish unit discharges were determined by estimating the sum of the entrance discharge and deducting the flow from the upper ladder, 109 cfs.

Estimated QFU = ΣED - QL

in which:

QFU = sum of fish unit discharges

$\Sigma ED = \Sigma\{Q_i + Q_{i+1} \ldots Q_n\}$

QL = Flow form upper ladder = 109 cfs for normal operations

Q_i = Entrance discharge in bay i

n = 8 bays total

The equations and methodology applied in the model are detailed in The Dalles East Fishladder Ladder Model Memorandum in Appendix A1 – Hydraulic Design and Modeling.

The summary statistics show a comparison between the recorded and estimated fish unit discharge for 2011-12, 2014, 2015, and limited 2017 are shown here in Table 13. The overall correlation coefficient is 0.679 and the standard error of the estimate for the whole data sample is 254 cfs or 5.1 % of the average recorded fish unit discharge.

Table 13. Summary Statistics of the Recorded vs. Estimated Fish Unit Discharge, R^2 = 0.679

Years	2011-12	2014	2015	2017 single	Average
Avg. ED - QL	4,784	5,217	5,023	2,739	4,974
Avg. FU	4,881	5,177	4,980	2,623	4,977
Avg. Diff	-97	40	43	116	-3
% of Avg. FU	-2.0%	0.8%	0.9%	4.4%	-0.1%
SD Daily Diff	390	246	189	94	306
% of Avg. FU	8.0%	4.7%	3.8%	3.6%	6.2%
Stand Error	244	138	59	47	254
% of Avg. FU	5.0%	2.7%	1.2%	1.8%	5.1%

Figure 31 shows a graphical comparison between the recorded and estimated fish unit discharge for all of the data from 2011-12, 2014, 2015, and limited 2017.

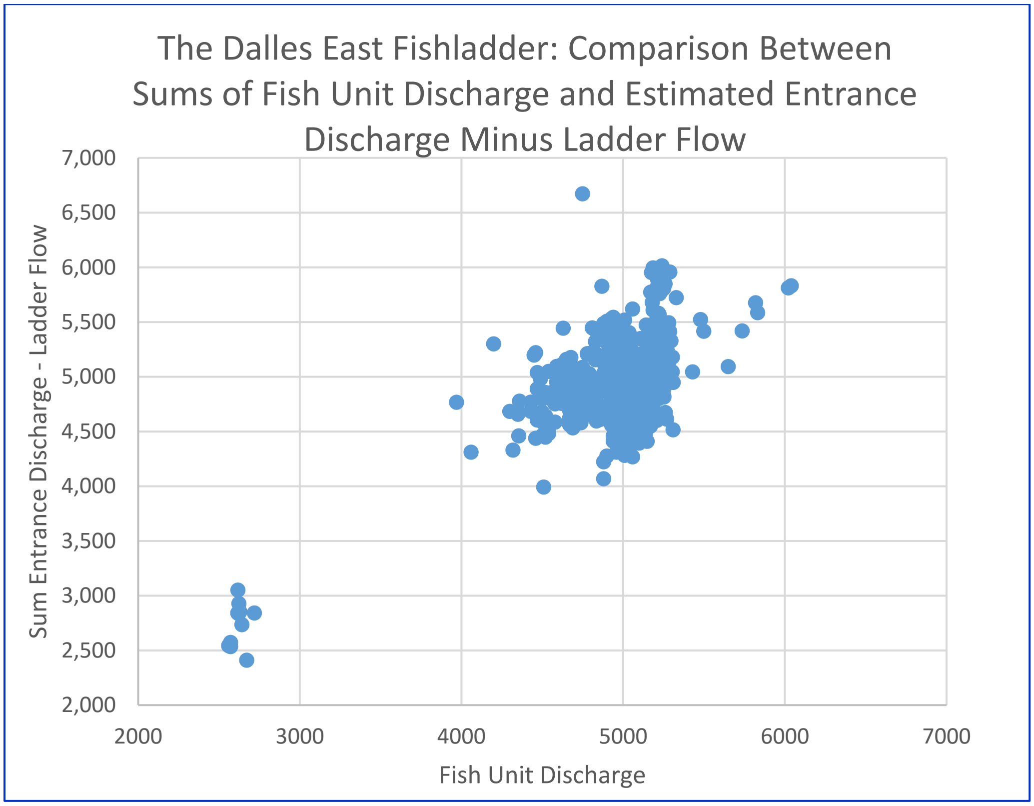


Figure 31. Comparison of Recorded and Estimated Fish Unit Discharges

CRITERIA AND CONSTRAINTS

The current total fish unit flow capacity is amply sufficient to meet fisheries criteria, so the remaining question is how much single unit capacity should be raised to provide one of the following potential targets:

1. Marginally meet entrance criteria with a single FU operation (3,200 cfs)
2. 6 entrance weirs open at 8.1 feet submergence, 2 weirs at each entrance location
3. Entrance head = 1.1 feet at each entrance
4. Fully meet all fisheries criteria (5,000 cfs) at all times.
5. Dual FU units (2,500 cfs per unit)
6. Fully meet all fisheries criteria (5,000 cfs) at all times.
7. Single FU (5,000 cfs per unit)

In the early PDT discussions, it was acknowledged that target number 3 is not feasible.

A review of the operations at relatively low tailwater elevations ranging between 74 – 76 feet from 2014 - 2016, and 2011 indicate a total fish unit discharge of 5,000 cfs is required to meet full fisheries criteria. At the same tailwater levels, this FU discharge should supply sufficient flow for entrance submergence levels of about 11.5 feet at the East, 9.5 feet at the West and 8.5 feet at the South entrances, all at 1.5 feet of entrance head. Given equivalent entrance parameters (submergence and head), the largest flow rates will be required at the lower tailwater elevations (This conclusion is explained in the description of the modelling development, Appendix A1). At higher tailwater elevations, the same flow will pass through entrances at deeper weir submergences, the only remaining possible concern is whether channel velocity is maintained. A review of 2017 data at relatively high tailwater elevations showed that channel velocities were well within criteria under fish unit operations of about 4,500-4,600 cfs.

Based on the model, the results of the target cases are the following:

1. Marginally meet entrance criteria with single FU unit (emergency operation):
2. 3,220 cfs at low tailwater
3. 2,930 cfs at high tailwater
4. Fully meet all fisheries criteria at all times
5. Dual FU units (normal operation)
6. Dual combined FU discharge = 5,000 cfs total
7. Meet Target #3 (full criteria, normal or emergency operation, redundant fish unit)
8. 5,000 cfs single fish unit

The flow criteria for Case 1 was based on results from the hydraulic model, which estimates the required fish unit flow as a function of the sum entrance discharge less upper ladder flow (see Hydraulic Design Memorandum in Appendix A1). For each case, the estimated and recorded fish unit discharges were compared from data taken from similar magnitudes (2,500 – 3,000 for Case 1). The estimated predicted Fish Unit discharges were adjusted upwards by a percentage based on the standard error of the estimates divided by the average recorded fish unit discharge form the data samples. The adjustments were made to account for the variability between the predicted versus recorded fish unit discharge and provide additional assurance that the criteria as specified would be met in the event that such operations will be required.

REQUIRED FISH UNIT DISCHARGE = Estimated Fish Unit Discharge x (1 + SE/Average QFU), in which:

- Estimated Fish unit discharge = estimated sum entrance discharge – upper ladder flow;
- Upper ladder flow = 109 cfs;
- SE = standard error of the estimate between the estimated and recorded fish unit discharges with data sample;
- Average QFU = average recorded fish unit discharge within data sample;
- Case 1 data samples include estimated or recorded between 2,500 - 3,000 cfs (single unit);

JOINT OPERATION of AWSBS and SINGLE FISH UNITS

In November 2018, The Dalles AWS backup system (AWSBS) was successfully operated simultaneously with a single fish unit. The fish turbines and fish ladder were monitored during the tests and showed no adverse conditions developed in either system. The tests included the startup and shut down of the AWSBS while a fish unit was operating—which would represent a typical scenario following an outage of one of the fish units.

The estimated combined discharge was 3,900-4,100 cfs. The East entrance met optimal entrance criteria, the West met entrance criteria marginally and the South entrance did not meet criteria.

A memo documenting the combined AWS-FU tests is located in Appendix J.

SECTION 5 – TURBINE ENGINEERING

In order to help develop the alternatives for the Dalles Fish Water turbines and to narrow the scope of alternatives to be considered, several criteria and constraints were identified. The criteria and constraints guide the alternative choices and the evaluation of those alternatives.

CRITERIA AND CONSTRAINTS

The following criteria will be used to develop and evaluate each alternative (in order of descending importance):

Reliability/Dependability: A very important criterion for fish water turbines is reliable/dependable operation. It is desired that these units operate without failure over their design life. Design life is defined as 30 years.

Increased Discharge: Another very important criterion is producing increased discharge through the unit since the discharge is used to feed the fish attraction system. The goal for increased discharge is that one unit be able to keep the fishway in marginal entrance criteria (about 3200 cfs) should one unit fail. However the units have to have the flexibility to also operate in the normal flow region between 2,100 cfs and 2,700 cfs.

Environmental Friendliness: A runner hub filled with oil increases the risk of oil entering the river. Though refurbishment and redundant oil seal modifications can mitigate this risk, it cannot be completely removed. One alternative will be to replace the existing oil filled hubs with an oil-free hub. Another possibility is to replace Kaplan turbine with a propeller type turbine containing fixed blades. The use of this turbine type will lessen the risk of oil leakage

Power Production/Turbine Efficiency: A replacement turbine runner should be able operate at a reasonable overall efficiency and if uprated shall be able to operate at a high power output.

Low Maintenance Frequency: Another important criterion for the fish water units is a low maintenance frequency. Because these units operate most of the time to provide required discharge to the fish system, low maintenance requirements are preferred.

Outage Duration: The amount of time the unit will be out of service.

Ease of Construction: Alternatives will be evaluated for ease of construction, this represents the uncertainty and risk involved in a particular construction activity. As an activity gets more complex, the uncertainty in price increases. Designs that require significant modifications to the dam structure should be minimized.

Cost: Cost will be considered separately from other criteria, but is an important criterion. The units are not required for power production but for fish passage. The value of fish passage cannot be measured quantitatively since it is not a measurable item so no economic study will be performed.

Physical Constraints

The fish water turbines were constructed similar to other hydro turbine in that the majority of the hydraulic passageways are embedded in concrete. This type of construction makes it impracticable to make substantial changes to these passageways; therefore, these passageways are a constraint (turbine intake, discharge ring, draft tube, wicket gate circle and pad height, and other physical components.).

Similarly, the generator has physical limitations as well. The physical configuration of the generator stator and rotor prevent large-scale alteration of the unit configuration. A change to the generator design would require significant changes to the structures within the powerhouse and is not practical.

The current gross head at The Dalles project will not change and is therefore also a constraint.

Existing Fish Water Rating

The current rated condition for The Dalles fish water turbine runners is 18,800 horsepower at 74 feet net head. This is equivalent to a generator output of 13.74 MW assuming a generator efficiency of 98%.

Shaft Limit

The mechanical stress on the existing turbine shaft and generator shaft was investigated to determine maximum allowable horsepower. The Corps has designed new runners for a maximum shaft shear stress of 6,000 psi. The existing generator shaft minimum diameter is 19 inches OD with a 7-3/8 inch interior hole diameter (for oil head piping). The existing turbine shaft minimum diameter is 20 inches OD with a 9¾ inch interior hole diameter (for oil head piping). Due to the cross section of the generator shaft it becomes the limiting factor in determining the maximum output of the turbine runner. The maximum output of the unit assuming that the unit is operated to the 6,000 psi maximum shaft shear stress is 17.95 MW. This is equivalent to 24,071 horsepower (with generator efficiency 98% and pf. 1.0). This works out to about a 28% increase over the existing unit’s rated output of 18,800 horsepower.

Additional Shaft Limit Information

There have been several instances where the maximum design shear stress was allowed to be higher than this 6,000 psi limit. However, this max is only allowed based on a field study in which the shafting system is tested by applying strain gauges to the shaft and operating units to determine the actual loading on the shafts under field conditions. A study like this one is also an opportunity to measure special shaft stresses such as unit starts and unit stops and unit load rejections so a more realistic understanding of the specific field conditions for the shafting system can be determined. Based on this field study the shear load limits may be raised to a higher value. In the past units have been allowed to be taken to a maximum shaft shear stress of 6,500 psi or 6,800 psi based on the field studies.

The power limit for the fish water turbines at The Dalles has been calculated for the normal 6,000 psi shear stress limit in the paragraph above. The generator shaft is the limiting component. The potential estimated unit output if the shear limit is raised to 6,500 psi is 18.48 MW (18.48 MVA x 1.0 pf, 24,782 horsepower, 32.0% increase). The potential estimated unit output if the shear limit can be raised to 6,800 psi is 19.33 MW (19.33 MVA x 1.0 pf., 25,922 horsepower, 37.8% increase).

It should be noted that with these substantial increases in output there may be other systems that would have to be upgraded, i.e. the governor system operating pressure may have to be increased.

Hydro Turbine Runner

The existing turbine runner is a Kaplan-type runner with a rated head of 74 feet. New runners, therefore, will be limited to either a fixed–blade propeller-type or an adjustable blade Kaplan-type.

TURBINE "SUB-ALTERNATIVES"

Alternatives Analysis

In order to provide the best evaluation of alternatives for the Phase 1A report, alternatives with little merit are eliminated from further consideration. This allows the PDT to focus effort on the alternatives that demonstrate the most promise.

Alternatives are evaluated on the following major criteria established in Section Turbine Criteria and Constraints: Reliability/Dependability, Increased Discharge, Power Production/Efficiency, and to a lesser extent, Lower Maintenance Frequency, Environmental Friendliness, outage duration, ease of construction and cost.

- Reliability/Dependability is judged on the expected length of service, i.e. a new runner installation will be judged as more reliable/dependable than a rehabilitation of an existing runner.
- Increased discharge is judged as to whether it increases unit discharge by a measurable amount greater than the existing units, i.e. 10%.
- Power production and efficiency are ranked on whether it increases, decreases, or makes no change in MW-hrs, as compared to the current baseline.
- Environmental friendliness are ranked on whether the alternative will increase, decrease, or make no change in the positive aspects of environmental impacts.
- Outage duration and ease of construction are judged as the length of time that a unit is out of service, i.e. the rehabilitation of an existing unit will take longer than the installation of a new runner.
- Difficult constructability will tend to increase actual costs during construction. Ratings include complex, moderate, and easy.
- Cost is presented as a dollar value, rounded to the nearest tenth of $1M. All costs are for both units at The Dalles.

Alternative Analysis Assumptions

The following assumptions have been included in the analysis below:

A minimum level of generator maintenance or cleaning is prudent with turbine runner rehabilitation or replacement. It is unlikely that it would be advantageous to unstack a generating unit and not perform some work on the generator. It is further assumed that maintenance functions detailed in Existing Conditions of Section 3, could be applied for any scenario; that is, a selected maintenance item would cost the same for one alternative as another.

Generator rewind or maintenance would not occur as a stand-alone construction item.

Turbine Sub-Alternatives that were considered:

- Do nothing/Operate to Failure
- Convert the existing units to fixed blade (by pinning/blocking blades)
- Rehabilitate existing units
- In-kind Kaplan runner replacement with same rated output as existing
- Replacement propeller runner with same output as existing

- Uprate units to 6000 psi shaft limit and replace runners with Oil-Filled Kaplan units
- Uprate units to 6000 psi shaft limit and replace runners with Oil-Free Kaplan units
- Uprate units to 6000 psi shaft limit and replace runners with fixed-blade propeller units
- Uprate units to Higher than 6000 psi shaft limit and replace runners with Oil-Filled Kaplan units
- Uprate units to Higher than 6000 psi shaft limit and replace runners with Oil-Free Kaplan units
- Uprate units to Higher than 6000 psi shaft limit and replace runners with fixed-blade propeller units

Sub-Alt 1, Base Case – Do Nothing and Operate to Failure

In this case the turbine components will be operated until failure. Normal maintenance will be performed on the units as has been done in the past but no extra effort will be made to replace any components. The fish unit turbines still have a spare bearing so any bearing failure could be readily addressed.

Sub-Alt 2, Convert the Existing Units to Fixed Blade

In this case the blades would be pinned or blocked in one position and oil would be removed from the runner hub converting the unit to oil-less operation as a propeller unit. This conversion would remove oil from the runner hub which eliminates a potential environmental issue from consideration and would make the Kaplan linkage inside the runner hub inoperable, removing a potential major failure scenario.

Sub-Alt 3, Rehabilitate Existing Units

This alternative would rehabilitate the existing runner and other stationary and rotating components and make the existing unit like new with new linkages inside the runner hub.

Sub-Alt 4, In-Kind Kaplan Runner Replacement

This alternative would replace the existing runners with a new unit with the same output and discharge.

Sub-Alt 5, Fixed Blade Propeller Replacement with Same Rated Output as Existing

This alternative would replace the existing runners with a new unit with the same output and discharge

Sub-Alt 6, Uprate Units to the 6,000 psi Shaft Limit and Replace with Oil-Filled Kaplan Units (adjustable blade runners)

This alternative would replace the existing units with an uprated Kaplan runner (adjustable bladed runners) potentially producing more power and discharge. The flow may be able to be increased to about 20% over flow from the existing units.

Sub-Alt 7, Uprate Units to the 6,000 psi shaft limit and Replace with Oil-Free Kaplan Units (adjustable blade runners)

This alternative would replace the existing Kaplan units with an oil-free hub design. This is an environmental upgrade but it may come with an associated risk of shorter life and less dependability.

Sub-Alt 8, Uprate to the 6,000 Psi Shaft Limit and Replace with Propeller Units (non-adjustable blades)

This alternative would replace the existing units with an uprated propeller runner (non-adjustable bladed runners) potentially producing more power and discharge. The flow may be able to be increased to about 20% over flow of the existing units. The propeller units would not have the flow flexibility of the Kaplan units.

Sub-Alt 9, Uprate Units to Higher than 6,000 Psi Shaft Shear Limit and Replace with Oil-Filled Kaplan

This alternative would uprate the units to higher than the 6,000 psi limit. More power and discharge will be produced than Sub-Alt 5, possibly as much at 30% more discharge. This alternative would require performing a shaft life study to determine whether the turbine and generator shafts could be operated at the higher output. Because of the higher output there may be other additional costs associated with this alternative.

Sub-Alt 10, Uprate Units to Higher than 6,000 psi Shaft Limit and Replace with Oil-Free Kaplan Units (adjustable blade runners)

This alternative would replace the existing Kaplan units with an oil-free hub design and uprate the units to higher than the 6,000 psi limit. More power and discharge will be produced than Sub-Alternative 6, possibly as much at 30% more discharge. This alternative would require performing a shaft life study to determine whether the turbine and generator shafts could be operated at the higher output. Because of the higher output there may be other additional costs associated with this alternative. This is an environmental upgrade but it may come with an associated risk of less operation life and less dependability. These details will be refined in the engineering analysis of Phase 1.

Sub-Alt 11, Uprate to Higher than 6,000 Psi Shaft Limit and Replace with Propeller Units (Non-Adjustable Blades)

This alternative would uprate the units to higher than the 6,000 psi limit and install a fixed blade propeller. More power and discharge will be produced than Sub-Alt 7, possibly as much at 30% more discharge. This alternative would require performing a shaft life study to determine whether the turbine and generator shafts could be operated at the higher output. Because of the higher output there may be other additional costs associated with this alternative.

SECTION 6 – GENERATOR ENGINEERING

CRITERIA AND CONSTRAINTS

Reliable operation of the generators as defined by:

1. **Reliability/Dependability**: A very important criterion for fish water generators is reliable/dependable operation. It is critical that these units operate reliably for many years into the future.
2. **Power Production/Generator Efficiency**: A replacement generator should be able operate at a reasonable overall efficiency and if uprated shall be able to operate at a high power output.
3. **Cost**: Cost is considered separately from other criteria, but is an important criterion. The units are not required for power production but for fish passage. The value of fish passage cannot be measured quantitatively since it is not a quantitative item so no economic study is performed.

The physical configuration of the generator stator and rotor prevent large-scale alteration of the unit configuration. A change to the generator design would require significant changes to the structures within the powerhouse and is impractical.

GENERATOR ALTERNATIVES

The following five generator alternatives were developed for consideration and were evaluated to determine how well each satisfies the criteria and stays within the constraints outlined above.

Alternative G1 – Do nothing. In this alternative, no corrective action except continued operation and maintenance is considered.

Alternative G2 – Overhaul. In this alternative, perform generator disassembly, inspect, clean and test the rotor and stator inspection, repair the stator and rotor as needed. This alternative would also include the option for reinsulating the field poles based upon the results of the testing.

Alternative G3 – Rewind of Fish Unit 2, overhaul Fish Unit 1. In this alternative, perform generator disassembly, rotor cleaning, inspection, testing, alignment and reassembly for Fish Unit 1. Perform stator winding replacement for Fish Unit 2. This alternative would also include the option for reinsulating field poles based upon the results of the testing.

Alternative G4 – Rewind both units. In this alternative, perform generator disassembly, rotor cleaning, inspection, testing, stator winding replacement, alignment and reassembly. This alternative would also include the option for reinsulating the field poles based upon the results of the testing.

Alternative G5 – Rewind and replace core for both units. In this alternative, replacing the core is added to the scope of Alternative C. This change allows the circularity, plumb, and concentricity of the core to be improved. This alternative would also include the option for reinsulating the field poles based upon the results of the testing.

Alternatives G3, G4, and G5 require the following efforts:

- **Mobilization and Demobilization**: This item is required to in order for the contractor on site to perform the work.
- **Lead Abatement, Asbestos, and Painting**: This item is required to ensure a safe working environment.

- **Disassembly, Reassembly, and Testing**: All alternatives will require disassembly, reassembly, and testing of the units. In particular, effort would be extended to capture vibration data for the generator prior to disassembly to baseline and ensure improvements.
- **Thrust Bearings**: Both of the thrust bearing coolers will be replaced with new internal coolers.
- **Base Mechanical Work**: There are many mechanical items that will be addressed. Examples include cleaning, inspection, consumable replacement, on-site machining, and miscellaneous testing and welding.
- **Base Electrical Work**: There are a number of electrical items that will be addressed. Examples include electrical testing, conduit, and cabling.

A cost for each of these items is included for each alternative.

Discussed below are the design alternatives for each major piece of equipment associated with the fish attraction water units under each alternative (above and beyond the efforts listed above). For each alternative, the advantages and disadvantages are discussed to assist in the evaluation process for selecting the preferred alternative. Unless specifically noted, the alternatives apply to both fish attraction water units. After a discussion of each piece of major equipment, the schedule is considered for each alternative. Table 14 shows the alternatives and majors pieces of equipment in tabular format.

Table 14. Summary of Actions in Each Alternative

Action	Alternative				
	G1	G2	G3	G4	G5
Inspect, clean and test rotor windings	-	X	X	X	X
Inspect, clean and test stator winding – F1	-	X	X	-	-
Inspect, clean and test stator winding – F2	-	X	-	-	-
Repair stator and rotor Unit 1	-	X	X	-	-
Repair stator and rotor Unit 2	-	X	-	-	-
Supply and install new stator winding Unit 1	-	-	-	X	X
Supply and install new stator winding Unit 2	-	-	X	X	X
Supply and install new cores	-	-	-	-	X
Refurbish rotor poles	-	O	O	O	O

NOTE: X – *Action to be included in the identified alternative*

O – *Action to be optionally included in the identified alternative, pending test results*

ALTERNATIVE G1 – DO NOTHING (NO ACTION)

Under this alternative, no corrective action is taken to improve the life expectancy of key components of the generators.

Performance of Alternative Relative to Criteria

As there are no corrective actions associated with this alternative, none of the project criteria are met by choosing it. No improvement in anticipated stator winding forced outage rates are likely nor could be attributed to this alternative

Cost Estimate for Alternative

There is no capital cost in choosing this alternative.

ALTERNATIVE G2 – OVERHAUL

While the unit is disassembled, the rotor and stator windings are cleaned and inspected. Focus during the cleaning and inspection will be on the end turns of the stator winding and the rotor poles and inter-pole connectors. Testing will be performed on the field winding and the stator winding to ensure that they are fit to return to service with a reasonable life expectancy. If the rotor winding testing indicates severely deteriorated conditions, rotor pole refurbishment may be undertaken to establish effective insulation with a long life expectancy.

Performance of Alternative Relative to Criteria

Stator winding failure risk and life expectancy should both improve as a result of thorough cleaning and repairs, and better understanding of life expectancy and condition may be gained through testing. Rotor winding condition may also be improved and better assessed as well as a result of this effort, although condition will not be improved greatly without full refurbishment of the rotor poles. Depending upon test results, it is possible that rotor pole refurbishment may be warranted. In this case, life expectancy for the rotor poles would be greatly improved.

Cost Estimate for Alternative

The cost estimate for Alternative G2 was derived from historical data from Hills Creek Turbine and Generator Replacement contract. It is assumed that one unit per year can be accomplished, which establishes a two year construction period.

Fish Unit Alternative G2, the total estimated Class 5 construction Cost without contingency or escalation for the work described above is $450,000 for both units.

ALTERNATIVE G3 – REWIND FISH UNIT 2, OVERHAUL FISH UNIT 1

In this alternative, a rewind of Fish Water Unit 2 is performed. This will include full disassembly, removal of the existing stator winding, cleaning/inspection/testing of the stator core, furnishing and installing the stator winding, acceptance testing, miscellaneous electrical work, and assembly and alignment. Fish Water unit 1 is overhauled, to include cleaning, inspections, repair of corona damage, and testing. Rotor pole refurbishment may be necessary for one or both units, depending upon test and inspection results.

Performance of Alternative Relative to Criteria

By rewinding the stator for Fish Water Unit 2, there would be a decrease in risk of stator winding failure for this unit when compared to present conditions. By thoroughly cleaning and inspecting the unit, risk of future failure may be reduced compared to present conditions.

Cost Estimate for Alternative

The cost estimate for Alternative G3 was derived from historical data from Hills Creek Turbine and Generator Replacement contract. It is assumed that one unit per year can be accomplished, which establishes a two year construction period.

Fish Unit Alternative G3, the total estimated Class 5 construction Cost without contingency or escalation for the work described above is $2,400,000. This does not include the cost of rotor pole refurbishment.

ALTERNATIVE G4 – REWIND BOTH UNITS

In this alternative, a rewind of both stator windings is performed. This will include full disassembly, removal of the existing stator winding, cleaning/inspection/testing of the stator core, furnishing and installing the stator winding, acceptance testing, miscellaneous electrical work, and assembly and alignment.

Performance of Alternative Relative to Criteria

By rewinding both stators, there would be a decrease in risk of stator winding failure for both units when compared to present conditions. The incremental risk of failure being reduced for Fish Water Unit 1 versus a repair of the end winding is likely not substantial given the fact that it is a relatively new winding.

Cost Estimate for Alternative

The cost estimate for Alternative G4 was derived from historical data from Hills Creek Turbine and Generator Replacement contract. It is assumed that one unit per year can be accomplished, which establishes a two year construction period.

Fish Unit Alternative G4, the total estimated Class 5 construction Cost without contingency or escalation for the work described above is $4,300,000. This does not include the cost of rotor pole refurbishment.

ALTERNATIVE G5 – REWIND AND REPLACE CORE FOR BOTH UNITS

In this alternative, all of the steps taken in Alternative G3 are taken, with the addition of core replacement being included. The replacement of the stator core includes removal of the existing core, frame inspection, manufacturing and testing of new core laminations, assembly of the new core including clamping assemblies, and testing of the stator core before installation of the new stator winding.

Performance of Alternative Relative to Criteria

As all of the corrective actions taken under the alternative for stator rewind are taken here as well, the performance for this alternative are similar. The additional performance gained in this case is a potentially increased lifespan for the stator core. However, no issues with the current stator cores have been determined and therefore the amount of risk being reduced is minimal. Therefore, the incremental increase in performance of this alternative against the criteria is very small when compared to the stator rewind alternative.

Cost Estimate for Alternative

The cost estimate for Alternative G5 was derived from historical data from Hills Creek Turbine and Generator Replacement contract. It is assumed that one unit per year can be accomplished, which establishes a two year construction period.

Fish Unit Alternative G5, the total estimated Class 5 construction Cost without contingency or escalation for the work described above is $4,900,000. This amount does not include the cost of rotor pole refurbishment.

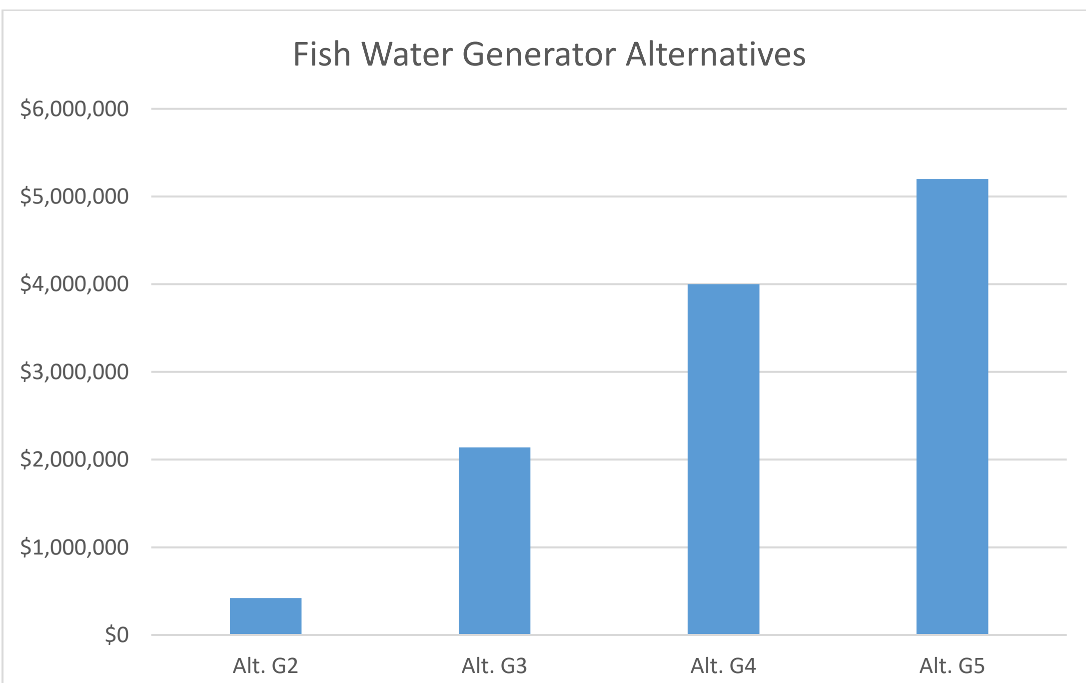


Figure 32. Summary of Alternative Performance, and Cost, Fish Attraction Water Unit Generator Alternatives

SECTION 7 – EXCITATION SYSTEM ENGINEERING

The original rotating excitation systems were replaced with the UNITROL F Series solid state excitation systems by ABB in 2000. While the excitation systems are in satisfactory condition, replacement parts are difficult to locate or no longer available.

From the beginning of 2017, UNITROL F system is in the limited phase of its life cycle. ABB cannot guarantee life cycle services and support due to scarcity of electronic components and limited technical know-how.

Based on the current status of a customer's installed based, ABB recommends to begin migration planning to replacement the UNITROL F model. Figure 33 shows the current state of product support.

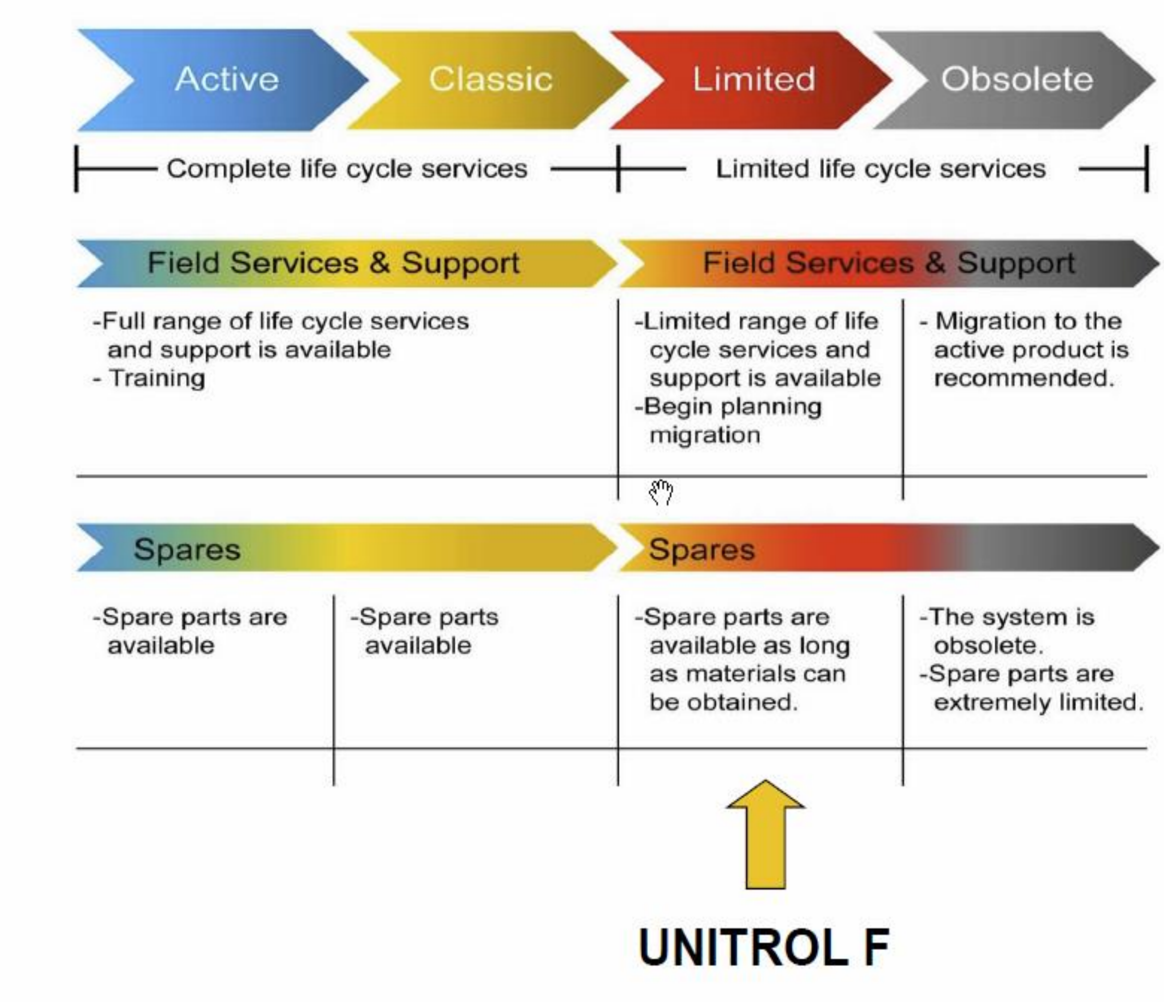


Figure 33. ABB Excitation System Life Cycle Cost Management. The figure was obtained from ABB web site.

RETROFIT EXISTING EXCITATION SYSTEM

In this rehab, there is a need to replace the existing automatic voltage regulators (AVRs) with new AVRs to improve voltage control and faster response time. The existing thyristor bridges (SCRs), power potential transformers (PPTs), and the power feeders (AC bus tap and DC leads) will be retained.

Digital Static Excitation System

This option replaces the existing excitation system with digital static excitation that will includes new automatic voltage regulators (AVRs), new thyristor bridges (SCRs), new power potential transformers (PPTs), and new power feeders (AC bus tap and DC leads).

Brushless Excitation System

This option replaces the existing excitation system with a brushless excitation system. A brushless exciter, a low 3-phase current is rectified and used to supply the field circuit of the exciter located on the stator. The output of the exciter's armature circuit on the rotor is rectified and used as the field current of the main machine.

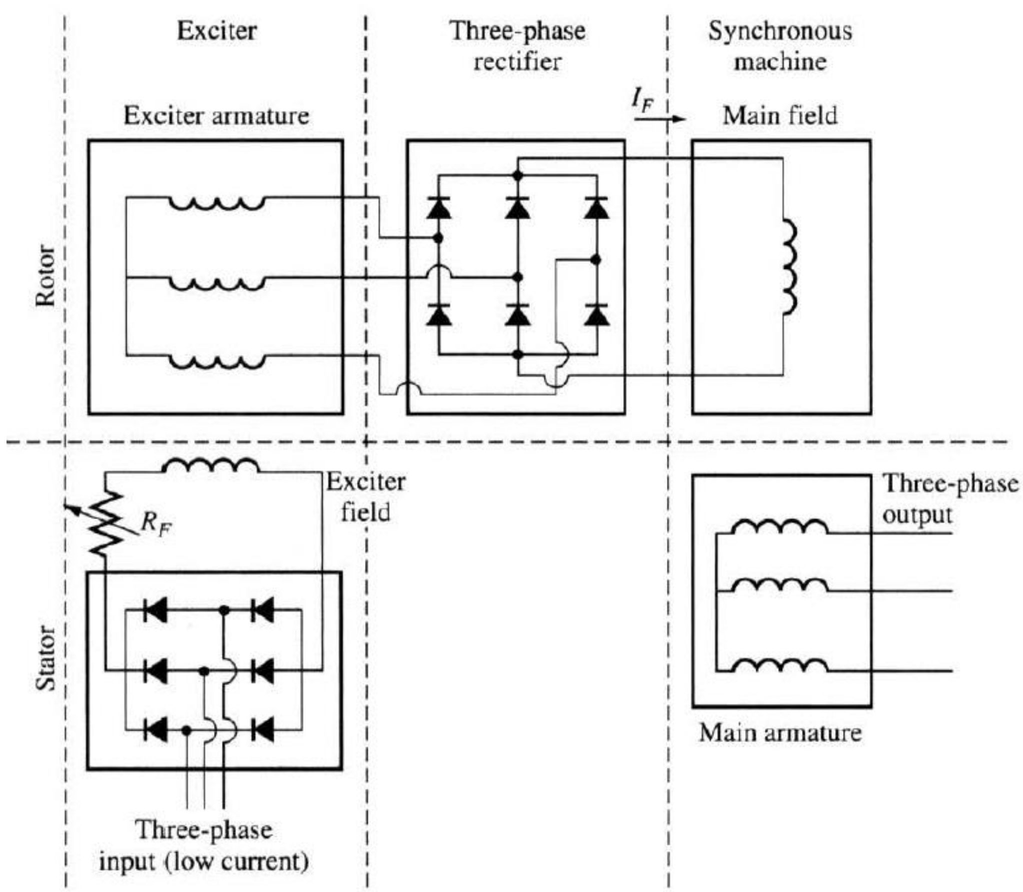
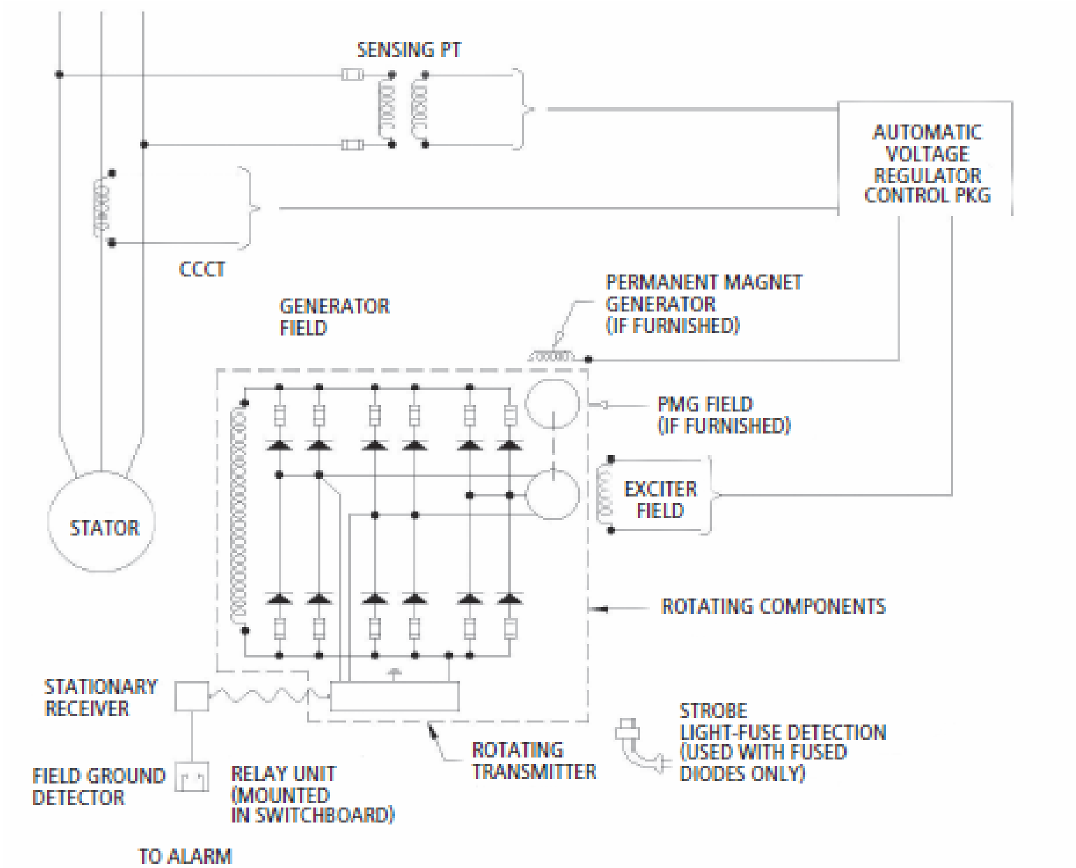


Figure 34. Brushless Exciter Schematic Diagrams



Functional diagram of exciter with Permanent Magnet Generator.

Brushless excitation provides increased reliability and reduced maintenance costs.

The Permanent Magnet Generator (PMG) supplies high frequency AC power to the voltage regulator. The voltage regulator receives voltage and reactive current feedback provided by potential and current transformers to provide voltage and reactive current feedback. Comparing these signals to a reference setpoint in the voltage regulator, the voltage regulator provides a controlled variable DC current to the stationary field of the rotating exciter. With its stationary field and rotating armature, the exciter generates three phase high frequency AC output. This output is rectified by the rotating rectifiers. This DC current is fed via conductors to the center of the rotor shaft and carried by a special lead bar in the hollow shaft area under the bearing journal which is then applied to the main generator field winding. The rotating rectifier is a three phase full wave diode bridge. 100% diode redundancy provides 100% of full rating with a diode out of service.

For parallel redundancy, 100% rated redundant diodes with indicating fuses in series connected in parallel paths permit full load operation even with one diode out of service caused by a failure to a shorted condition. Open fuses are detected during operation by using the strobe light furnished.

Field ground detection is provided without slip rings by means of a transmitter mounted on the diode wheel assembly. A light signal is sent across an airgap to a stationary receiver and relay to indicate presence of a ground.

EXCITATION SYSTEM CRITERIA AND CONSTRAINTS

Reliable operation of the excitation systems as defined by:

- **Reliability/Dependability.** A very important criterion for fish water units is reliable/dependable operation. It is critical that these units operate reliably for many years into the future.
- **Spare Parts Availability.** Replacement parts are difficult to locate or are no longer available.
- **Maintenance.** Collector rings, brushes, and brush holders require maintenance.

The physical space limitation at the powerhouse prevents larger footprint of the new exciters.

EXCITATION SYSTEM ALTERNATIVES

Alternative E1 – Base Case (Do Nothing)

Under this alternative, no corrective action is taken to improve the life expectancy of key components of the exciters. This alternative has the highest risk of unscheduled outages. In addition, because of the unavailability of parts for the existing exciter and voltage regulator, outages will be of a longer duration when they occur as parts are rebuilt or in some way replaced.

Performance of Alternative against Criteria

As there are no corrective actions associated with this alternative, none of the project criteria are met by choosing it. No improvement in anticipated exciter forced outage rates are likely nor could be attributed to this alternative

There is no capital cost in choosing this alternative.

Alternative E2 – Replace With New Exciter Control

This alternative replaces the existing excitation controls with new excitation controls.

Performance of Alternative against Criteria

This option retains the existing Power Potential Transformers (PPTs) and thyristor bridges. This retention could adversely impact future reliability of the excitation systems.

The total estimated Class 5 construction cost without contingency or escalation to replace a digital excitation control is estimated to be $250,000 for both units.

Alternative E3 – Replace with New Static Excitation System

This alternative replaces the existing excitation systems with new modern digital static excitation systems. This option would include replacing the excitation power potential transformers (PPTs) and the excitation automatic voltage regulators (AVRs) with a fully redundant system (redundant controls and redundant rectifier bridges). This approach would restore the excitation system reliability and eliminate the spare parts problem.

The total estimated Class 5 construction cost without contingency or escalation to replace a digital excitation controls including the PPTs and AVRs, is estimated to be $1,000,000 for both units.

Alternative E4 – Replace with Brushless Excitation System

This alternative replaces the existing excitation system with a brushless excitation system. Brushless excitation provides high reliability through elimination of brushes, collector rings and carbon dust. The brushless system is recommended because the carbon fiber dust from previous installations has caused electrical reliability issues. The main component would include brushless exciter stator, brushless exciter rotor, and brushless exciter diode wheel. This change would eliminate the dust problems.

The total estimated Class 5 construction Cost without contingency or escalation to replace entire excitation systems with brushless excitation systems is estimated to be about $600,000 for both units.

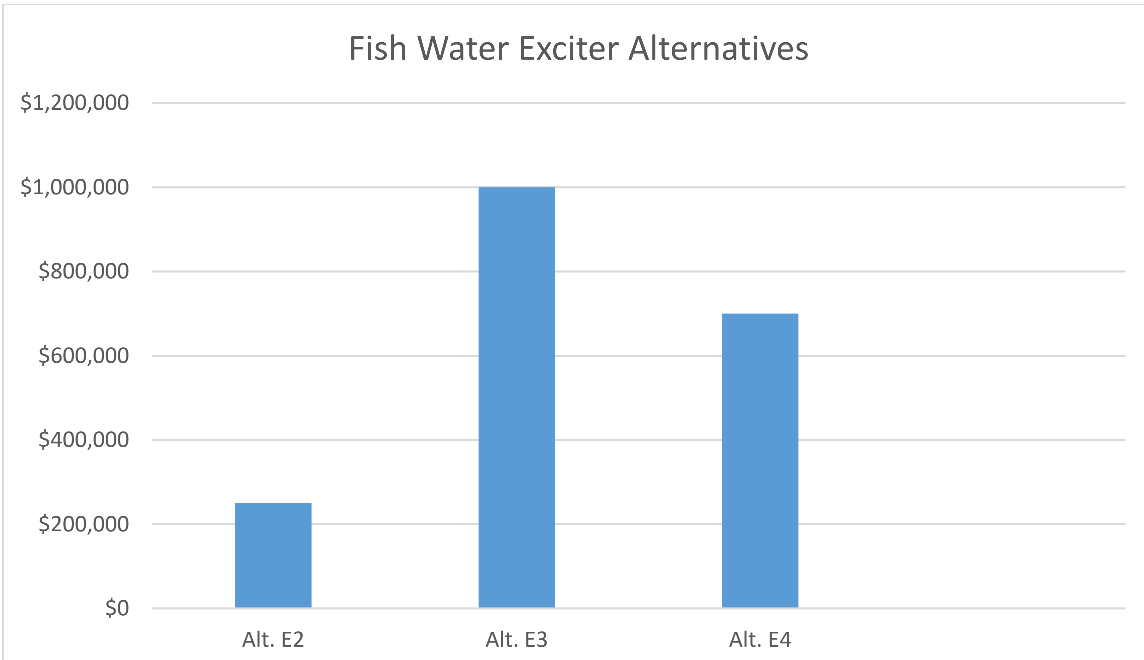


Figure 35. Summary of Fish Attraction Water Unit Exciter Alternatives, Cost for both FUs

SECTION 8 – EVALUATION OF TURBINE, GENERATOR AND EXCITER COMBINATIONS

This section combines the generator and turbine sub-alternatives into Alternatives for Fish Water Units rehabilitation.

REMOVAL OF SUB-ALTERNATIVES

In order to provide the best evaluation of alternatives for this Phase 1A report, alternatives with little merit have been eliminated from future consideration. The four "sub-alternatives" eliminated are:

- "OPERATE TO FAILURE"
- "GENERATOR LIMITED REHABILITATION"
- "CONVERSION TO FIXED BLADE OPERATION"
- "REHABILITATION OF EXISTING UNITS"

This simplification allowed the PDT to focus on the alternatives that demonstrate the most promise. For elimination purposes, sub-alternatives were evaluated on the criteria and constraints established in *Section 5, Turbine Engineering* and *Section 6, Generator Engineering.*

On this basis the generator and turbine sub-alternatives were removed from consideration due to failing to meet the primary criteria of the rehabilitation which is reliability/dependability.

Removal of the "Operate To Failure" Sub-Alternative

Generator sub-alternative 1 and turbine sub-alternative 1, described in Sections 6 and 7, "operating to failure" would operate the units until failure of some component. A generator failure scenario, for example, would most likely be the failure of a coil. In either case, a generator or a turbine failure would put the fish unit out of service for an extended period of time. Such failures would be repairable but the unit would still not be operable during repair.

If one fish unit failed and required several months to a year to repair the fish attraction system would be at high risk of failing to meet flow criteria since there would be no redundancy during the repair period. The discharge from one unit is not sufficient to meet the requirements of the system and there is also the possibility that the second unit could fail during this time.

These scenarios would fail the most important criteria which is the reliability/dependability of the turbine generator unit. Therefore, the turbine and generator sub-alternatives for doing nothing – operating to failure – was eliminated from any serious consideration.

The total discharge from the new AWS backup system is equivalent to about one half the discharge from one fish unit, so the AWS by itself would not be able to supply the required flow. A combination of AWS flow in conjunction with at least one operating fish unit would be required to meet attraction flow criteria.

Prototype flow tests have confirmed that The Dalles AWS Backup System (AWSBS, or just AWS) can be operated simultaneously with a single fish unit without issues. The fish turbines and fish ladder monitored during the November 2018 tests showed no adverse conditions developed in either flow system. Notably, the combined flow (3,900 – 4,100 cfs) from AWS and a fish unit with existing capacity exceeds the capacity of an upgraded fish unit. A memo documenting the flow tests may be found in Appendix J. The USACE test team has concluded that discharges from two very different sources are capable of comfortably merging and providing adequate attraction flow to the three fish entrances at The Dalles Dam.

Removal of the "Generator Limited Rehabilitation" Sub-Alternative

Generator sub-alternative 2 is a "Limited Rehabilitation" which includes inspecting, cleaning and testing the stator winding and rotor poles. This generator rehabilitation alternative is clearly a better sub-alternative than the "operate to failure" (do nothing) option. However the generator has 20 years of operating life used up. The possibility of a generator failure is higher than it would be with a newly rewound unit. The scenario of "operate to failure," as described above, would also apply here. The most important reliability/dependability criteria is still not addressed with this sub-alternative so it was be removed from consideration.

Removal of the "Conversion To Fixed Blade Operation" Sub-Alternative

Turbine Sub-alternative 2 is conversion of the Kaplan turbine units to fixed blade propeller operation. This turbine alternative would require the modification of the existing turbine to run as a fixed blade unit. Since this would be a conversion for long term use the suggested method to fix the blades would be by pinning them to the turbine hub. Additionally, oil would be removed from the hub. This approach is a permanent conversion with no option to revert back to Kaplan function at a later date. Most importantly, this rehabilitation would not address the continued blade cracks that these units have had and which show an inherent weakness in the design of these runner blades. This deficiency alone is enough to disqualify this sub-alternative.

Additionally though, since this is a conversion of the turbine runner only and since the unit is not normally disassembled to convert it to fixed blade, the conversion would not address other mechanical components of the unit. For instance the bearings, bearing coolers, shaft sleeve, packing box, generator air coolers would not be rehabilitated. For this reason the reliability/dependability issue would not be addressed appropriately. Also, fixed blade operation of the existing turbine runner may reduce the flexibility of the unit and therefore may cause a deficiency in the operation of the fish water attraction system. The current fish water turbines have a range of operation of about 700 cfs which would be difficult for a propeller runner to meet. For these reliability/dependability and performance range issues this sub-alternative was removed from consideration.

Removal of the "Rehabilitation Of Existing Units" Sub-Alternative

Turbine sub-alternative 3 is the rehabilitation of the existing units similar to what is being performed at John Day and some units on the Lower Snake. This proposal does positively affect the dependability/reliability of the units. However, although better than turbine sub-alternatives 1 and 2 it still does not address the blade cracks that these units have and does not match what could be done with a full rehabilitation with the installation of new turbine runners. Since this alternative does not really match what could be accomplished with a complete rehabilitation it has also been removed from consideration.

DESCRIPTION OF ALTERNATIVES

For the alternatives the generator sub-alternatives 3 and 4 are matched with the appropriate turbine alternatives 4 through 8.

Alternative A – Replace Turbine with Kaplan Runner, Same Output as Existing

Turbine: The turbine runner would be replaced with new runner that would have the same rated output as the current existing turbine runner. The turbine and generator shaft will be retained. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. New packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal cooler will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

Generator: The generator will be rewound to its existing capacity.

Exciter: The exciter system will be replaced with the brushless excitation system

- Reliability/Dependability – Reliable
- Unit Flexibility – Moderate
- Increased Discharge – No increase in discharge
- Environmental Risk – Moderate to low environmental risk due to oil-filled hub
- Power Production – No increase in power production
- Frequency of Maintenance – no increase in maintenance
- Outage Duration – medium outage duration
- Ease of Construction – medium ease of construction
- The total estimated Class 5 construction Cost without contingency or escalation is $21.63 million for both units. High level costs include:
    - Turbine: $1.546 million per unit
    - Misc. Mechanical: $6.07 million per unit
    - Generator: $2.0 million per unit
    - New Stator Core: $0.6 per unit
    - Rotor Pole Refurbishment: $0.3 per unit
    - Exciter: $0.3 million per unit

Alternative B – Replace Turbine with Propeller Runner, Same Rated Output as Existing

Turbine: The turbine runner would be replaced with new fixed blade propeller-type runner that would have the same rated output as the existing units. The turbine and generator shaft will be retained. The static oil pressure system and the blade servo would be removed and other conversions would be performed to convert the propeller operation. Basically, all oil (high pressure and static) is removed from the two units. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. New packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal cooler will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

Generator: The generator will be rewound to its existing capacity.

Exciter: The exciter system will be replaced with the brushless excitation system

- Reliability/Dependability, More reliable than either the oil-filled and oil-free hub sub-alternatives
- Unit Flexibility, Moderate.
- Increased Discharge, No Increase in discharge
- Environmental Risk, Low environmental risk due to no oil in hub or blade servo
- Power Production, No Increase in power production
- Frequency of Maintenance, Low Frequency of Maintenance
- Outage Duration, Medium
- Ease of Construction, Medium
- The total estimated Class 3 construction Cost with 21%contingency and 7.8% escalation is $19.27 million for both units. High level costs include:
    - Cost, Turbine: $1.013 million per unit
    - Misc. Mechanical: $5.42 million per unit
    - Generator: $2.0 million per unit
    - New Stator Core: $0.6 million per unit
    - Rotor Pole Refurbishment: $0.3 million per unit
    - Exciter: $0.3 million per unit

Alternative C – Replace Turbine with Oil-Filled Kaplan Runner, Uprate Unit to Shaft Limit

Turbine: The turbine runner would be replaced with new Kaplan-type runner that would be uprated to the shaft limit. The turbine and generator shaft will be retained. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. New packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal cooler will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

- Generator: The generator will be rewound to its uprated capacity.
- Exciter: The exciter system will be replaced with the brushless excitation system.
- Reliability/Dependability, Reliable
- Unit Flexibility, Best Flexibility
- Increased Discharge, Increase in discharge
- Environmental Risk, Moderate to Low environmental risk due to oil-filled hub

- Power Production, Increase in power production
- Frequency of Maintenance, No increase in maintenance
- Outage Duration, Medium outage duration
- Ease of Construction, Medium ease of construction
- The total estimated Class 3 construction Cost with 21% contingency and 7.8% escalation is $22.86 million for both units. High level costs include:
    - Cost, Turbine: $1.792 million per unit
    - Misc. Mechanical: $6.24 million per unit
    - Generator: $2.0 million per unit
    - New Stator Core: $0.6 million per unit
    - Rotor Pole Refurbishment: $0.3 million per unit
    - Exciter: $0.3 million per unit
    - Generator Uprate Study: $0.4 million

Alternative D – Replace Turbine with Oil-Free Kaplan Runner, Uprate Unit to Shaft Limit

Turbine: The turbine runner would be replaced with new Kaplan-type runner with an oil-free hub that would be uprated to the shaft limit. The turbine and generator shaft will be retained. The static oil pressure system would be removed from the shaft and other conversions would be performed to convert the hub to oil-free operation. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. New packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal cooler will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

Generator: The generator will be rewound to its uprated capacity; the existing stator core will be replaced with a new core; the existing rotor field poles may require refurbishment.

Exciter: The exciter system will be replaced with the brushless excitation system

- Reliability/Dependability, Lowest Reliability due to water in hub. Highest Risk due to minimal
- operating experience in industry.
- Unit Flexibility, Medium
- Increased Discharge, Increase in discharge
- Environmental Risk, Low environmental risk due to oil-free hub
- Power Production, Increase in power production
- Frequency of Maintenance, No increase in maintenance
- Outage Duration, Medium
- Ease of Construction, Medium
- The total estimated Class 5 construction Cost without contingency or escalation is $22.52 million for both units. High level costs include:
    - Cost, Turbine: $1.792 million per unit
    - Misc. Mechanical: $6.07 million per unit

  - Generator: $2.0 million per unit
  - New Stator Core: $0.6 per unit
  - Rotor Pole Refurbishment: $0.3 per unit
  - Exciter: $0.3 million per unit
  - Generator Uprate Study: $0.4 million

Alternative E – Replace Turbine with Propeller Runner, Uprate Unit to Shaft Limit

Turbine: The turbine runner would be replaced with new fixed blade propeller-type runner that would be uprated to the shaft limit. The turbine and generator shaft will be retained. The static oil pressure system and the blade servo would be removed and other conversions would be performed to convert the propeller operation. Basically, all oil (high pressure and static) is removed from the two units. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. New packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal cooler will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

Generator: The generator will be rewound to its uprated capacity, the existing stator core will be replaced with a new core; the existing rotor field poles may require refurbishment.

Exciter: The exciter system will be replaced with the brushless excitation system

- Reliability/Dependability, More reliable than either the oil-filled and oil-free hub sub-alternatives
- Unit Flexibility, Will lose flexibility because blades no longer are rotatable and operating range too high.
- Increased Discharge, Increase in discharge
- Environmental Risk, Very Low environmental risk due to no oil in hub or blade servo
- Power Production, Increase in power production.
- Frequency of Maintenance, Less maintenance is expected than the other options
- Outage Duration, Medium outage
- Ease of Construction, Medium ease of construction.
- The total estimated Class 5 construction Cost without contingency or escalation is $20.32 million for both units. High level costs include:
  - Cost, Turbine: $1.013 million per unit
  - Misc. Mechanical: $5.75 million per unit
  - Generator: $2.0 million per unit
  - New Stator Core: $0.6 per unit
  - Rotor Pole Refurbishment: $0.3 per unit
  - Exciter: $0.3 million per unit
  - Generator Uprate Study: $0.4 million

Alternative F – Replace Turbine with Oil-Filled Kaplan Runner, Uprate Unit Above Shaft Limit

Turbine: The turbine runner would be replaced with new Kaplan-type runner that would be uprated to a value higher than the shaft limit. The turbine and generator shaft will be retained. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. New packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal cooler will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

Generator: The generator will be rewound to its uprated capacity, the existing stator core will be replaced with a new core; the existing rotor field poles may require refurbishment.

Exciter: The exciter system will be replaced with the brushless excitation system

- Reliability/Dependability, Reliable
- Unit Flexibility, Loss of flexibility due to discharge being too high
- Increased Discharge, Discharge will increase
- Environmental Risk, Moderate to Low environmental risk due to oil-filled hub
- Power Production, Highest Increase in power production, but not possible due to cavitation limits exceeded.
- Frequency of Maintenance, No increase in maintenance
- Outage Duration, Medium outage duration
- Ease of Construction, Medium ease of construction
- The total estimated Class 5 construction Cost without contingency or escalation is $22.32 million for both units. High level costs include:
    - Cost, Turbine: $1.546 million per unit
    - Turbine Shaft Study: $0.3 million
    - Misc. Mechanical: $6.07 million per unit
    - Generator: $2.0 million per unit
    - New Stator Core: $0.6 million per unit
    - Rotor Pole Refurbishment: $0.3 million per unit
    - Exciter: $0.3 million per unit
    - Generator Uprate Study: $0.4 million

Alternative G – Replace Turbine with Oil-Free Kaplan Runner, Uprate Unit Above Shaft Limit

Turbine: The turbine runner would be replaced with new Kaplan-type runner with an oil-free hub that would be uprated to a value higher than the shaft limit. The turbine and generator shaft will be retained. The static oil pressure system would be removed from the shaft and other conversions would be performed to convert the hub to oil-free operation. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. New packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal cooler will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

Generator: The generator will be rewound to its uprated capacity, the existing stator core will be replaced with a new core; the existing rotor field poles may require refurbishment.

Exciter: The exciter system will be replaced with the brushless excitation system

- Reliability/Dependability, Lowest Reliability due to water in hub, Highest Risk due to minimal operating experience in industry time for this type of unit
- Unit Flexibility, Loss of flexibility due to discharge being too high
- Increase Discharge, Increase to highest discharge
- Environmental Risk, Low environmental risk due to oil-free hub
- Power Production, Increase to highest power production, but not possible due to cavitation limits exceeded.
- Frequency of Maintenance, No increase in maintenance
- Outage Duration, Medium outage duration
- Ease of Construction, Medium ease of construction
- The total estimated Class 5 construction Cost without contingency or escalation is $22.82 million for both units. High level costs include:
    - Cost, Turbine: $1.792 million per unit
    - Turbine shaft study: $ 0.3 million
    - Misc. Mechanical: $6.07 million per unit
    - Generator: $2.0 million per unit
    - New Stator Core: $0.6 million per unit
    - Rotor Pole Refurbishment: $0.3 million per unit
    - Exciter: $0.3 million per unit
    - Generator Uprate Study: $0.4 million

Alternative H – Replace Turbine with Propeller Runner, Uprate Unit Above Shaft Limit

Turbine: The turbine runner would be replaced with new fixed blade propeller-type runner that would be uprated to a value higher than the shaft limit. The turbine and generator shaft will be retained. The static oil pressure system and the blade servo would be removed and other conversions would be performed to convert the propeller operation. Basically, all oil (high pressure and static) is removed from the two units. The wicket gates may be either refurbished or new wicket gates provided. All turbine bushings will be replaced with self-lubricating bushings and the grease system will be removed. A new packing boxes and packing sleeves will be provided. Stationary components will be re-machined to level and plumb conditions. The discharge ring will be overlaid with stainless steel to be more resistant to cavitation damage. The upper and lower guide bearing pads, the turbine guide bearings and the thrust bearing shoes will be rebabbited. The thrust bearing runner and collar will be inspected. New generator air coolers will be installed and thrust bearing internal coolers will be removed and external coolers will be installed. The turbine/generator unit will be realigned.

Generator: The generator will be rewound to its uprated capacity, the existing stator core will be replaced with a new core; the existing rotor field poles may require refurbishment.

Exciter: The exciter system will be replaced with the brushless excitation system

- Reliability/Dependability, More reliable than either the oil-filled and oil-free hub sub-alternatives
- Unit Flexibility, Will lose flexibility because blades no longer are rotatable and operating range too high.
- Increased Discharge, Increase in discharge
- Environmental Risk, Low environmental risk due to no oil in hub or blade servo
- Power Production, Increase in power production, but not possible due to cavitation limits exceeded.
- Frequency of Maintenance, No increase in maintenance
- Outage Duration, Medium outage duration
- Ease of Construction, Medium ease of construction
- The total estimated Class 5 construction Cost without contingency or escalation is $20.62 million for both units. High level costs include:
    - Cost, Turbine: $1.013 million per unit
    - Turbine shaft study: $0.3 million
    - Misc. Mechanical: $5.75 million per unit
    - Generator: $2.0 million per unit
    - New Stator Core: $0.6 million per unit
    - Rotor Pole Refurbishment: $0.3 million per unit
    - Exciter: $0.3 million per unit
    - Generator Uprate Study: $0.4 million

MATRIX OF SELECTION CRITERIA FOR ALTERNATIVES

The following table is presented as a summary of the eight final alternatives with a qualitative assessment of their ability to meet the four main criteria shown on the right side of the table: reliability/dependability, unit operational flexibility, increased discharge, and environmental risk as well as the other five criteria to a lesser extent were used to refine the list down to the recommended alternative and the next best alternative.

Table 15. Selection Criteria Matrix for the Refurbishment of the Fish Water Turbines

The Dalles Fish Water Turbines — Criteria Matrix										
Alternative	**Ease of Construction**	**Outage Duration**	**Frequency of Maintenance**	**Class 5 and *Class 3 Cost**	**Power Production**	**Environmental Risk**	**Increased Discharge**	**Unit Operational Flexibility**	**Reliability/ Dependability**	**Rank**
A Same as Existing	Medium	Medium	No Increase	$21.63M	No Increase	Moderate to Low	No Increase	Moderate	Reliable	**3**
B Propeller, No Uprate	Medium	Medium	Low	$19.27M	No Increase	Low	No Increase	Moderate	More Reliable	**2**
C Oil-Filled Kaplan, Small Uprate	Medium	Medium	No Increase	$22.86M	Increase	Moderate to Low	Increase	Best Flexibility	Reliable	**1**
D Oil-Free Kaplan, Small Uprate	Medium	Medium	No Increase	$22.52M	Increase	Low	Increase	Moderate	Lowest Reliability/ Highest Risk	**7**
E Propeller, Small Uprate	Medium	Medium	Low	$20.32M	Increase	Low	Increase	Loss of Flexibility	More Reliable	**4**
F Oil-Filled Kaplan, Medium Uprate	Medium	Medium	No Increase	$22.32M	Too High	Moderate to Low	Highest Increase	Loss of Flexibility	Reliable	**5**
G Oil-Free Kaplan, Medium Uprate	Medium	Medium	No Increase	$22.82M	Too High	Low	Highest Increase	Loss of Flexibility	Lowest Reliability/ Highest Risk	**8**
H Propeller, Medium Uprate	Medium	Medium	Low	$20.62M	Too High	Low	Highest Increase	Loss of Flexibility	More Reliable	**6**
<<<<<<< Less Important -- More Important >>>>>>>										

SECTION 9 – EVALUATION OF ALTERNATIVES

This section evaluates the eight alternatives the PDT converged on, comparing the pros and cons of the different turbine-generator-exciter combinations.

EXISTING UNIT DISCHARGE AND PROSPECTIVE NEW UNIT DISCHARGE

The figure below shows a comparison of the discharges currently provided by the fish water units in red and the discharges expected with new Kaplan turbines in green and new propeller turbines in blue. The current range discharge available from the existing Kaplan units is about 700 cfs at any head. With propeller units some of this range may be lost with the possible range being lessened to about 500 cfs at any head. The expected range in new Kaplans however would be as much as 1,200 cfs. This turbine type push the maximum discharge expected in new Kaplans to about 3,200 to 3,300 cfs which is an increase of 500 to 600 cfs or about 20%.

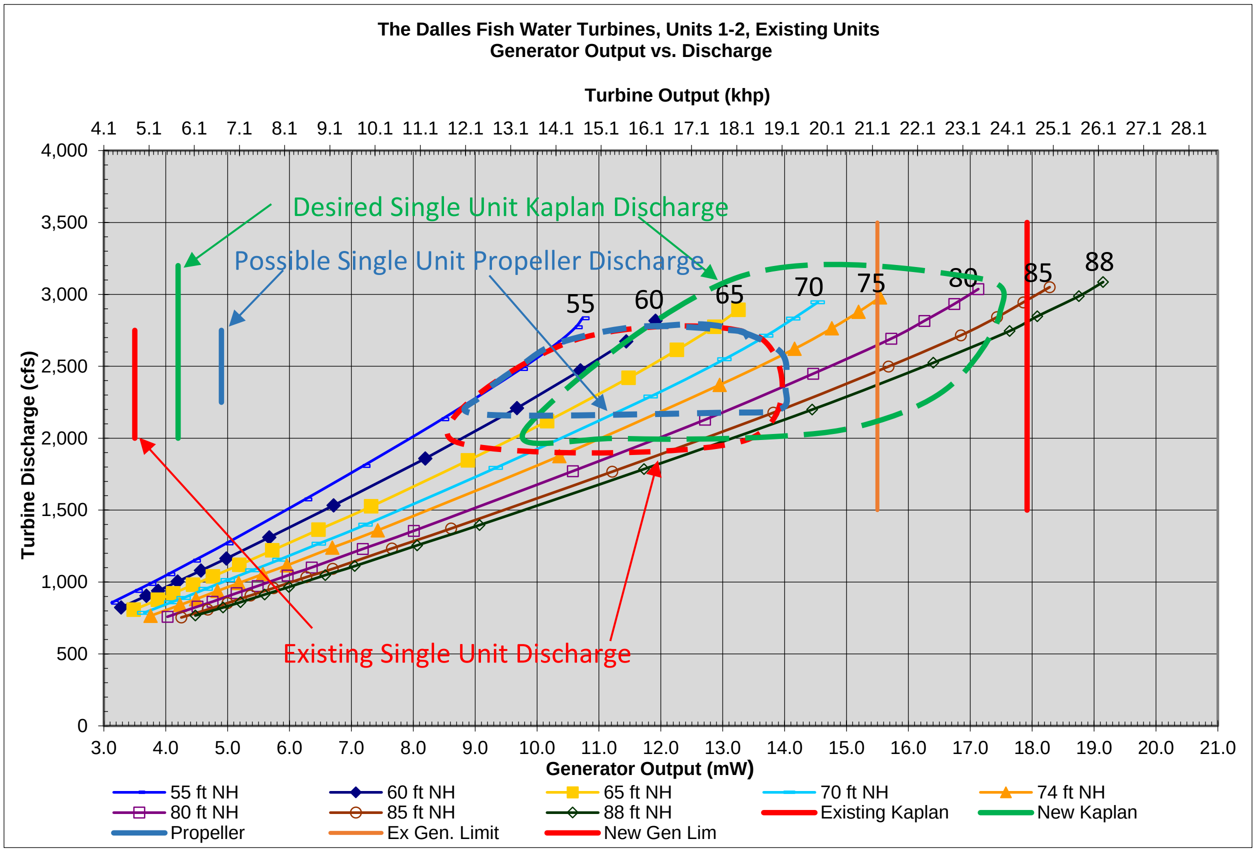


Figure 36. Existing and Desired Turbine Single Unit Discharge, in CFS Removal of Some Alternatives

Replace with an Oil-Free Kaplan Runner

Oil-free hydro-turbine runners were seriously considered for this rehabilitation. However, there were several shortcomings that could not be overcome:

1. **Oil-free hubs.** Using oil-free hubs considerably decreases the amount of oil that is exposed to the potential of leaking into the river water but it does not eliminate the possibility of oil escaping into the river. This is because oil is still necessary for the lubrication of the bearings

used to operate the turbine. There are two generator guide bearings and one turbine guide bearing as well as a thrust bearing for each unit that the rotating unit sets on top of. Additionally, there is a hydraulically operated servo that moves the turbine blades during operation to efficiently convert water hydraulic energy to electrical power. Oil use is decreased but not removed.

2. **Larger cross-sections.** Because the interior of the hub contains no lubricating oil, the components inside the hub especially the blade operating components must have larger cross sections to resist the possibility of fatigue failure.
3. **Increased bearing surface area.** Also, due to the lack of lubricating oil the bearing surface area must be larger to lower the blade trunnion loading.

The result of number 2 and number 3 above will cause the runner to have a larger diameter (on the order of 7% increase in diameter) which is a limiting factor in increasing flow through the unit. Additionally, the oil-free hubs will be more expensive on the order of about a 20% increase in cost of the runner. There will be a significant amount of work to redesign some of the existing rotating and stationary components to address the new oil-less turbine hub.

There is not a great deal of operating data to support the dependability or lack thereof of the oil-less turbine hubs. Oil-less hubs have only been in operation since about 1985. Because of this paucity of experience there is a risk that the reliability/dependability criteria is not met with this type of turbbine, but this objective is one of the most important of the nine criteria that must be addressed (see Table 15 above).

For these reasons oil-less Kaplan hubs are removed from consideration for rehabilitation of The Dalles Fish Water turbines. Therefore Alternative D, Replacement Turbine with Oil-Free Kaplan Type Runner, Uprate Unit to Shaft Limit and Alternative G, Replacement Turbine with Oil-Free Kaplan Type Runner, Uprate Unit to Higher than Shaft Limit are not given further consideration.

Replace with Fixed Blade Propeller Runner Uprated to Shaft – Limit/Uprated Above Shaft Limit

Fixed Blade Propeller Turbines were also considered for this rehabilitation. However as with the oil-free hubs there are some shortcomings requiring that two of the three alternatives be removed from consideration.

The fish water turbines are each currently operated from about 2,000 cfs to 2,700 cfs. The new turbines would need to be able to operate in this range also. Additionally, it would be an added benefit if the new turbines had the capability and flexibility to operate in a consistent manner *above this range*. Unfortunately, propeller units have a narrow range of operation. Although the two uprated propellers would have the capability to operate at higher kW outputs and flow discharges, they would not have the flexibility to also operate in the standard range at 2,000 to 2,700 cfs.

Since any turbine runner replacement option would have to be capable of providing the existing discharge, uprated propellers would not have the flexibility to replace the existing units. For this reason fixed blade propellers Alternative E, Replacement Turbine with Propeller Type Runner, Uprate Unit to Shaft Limit and Alternative H, Replacement Turbine with Propeller Type Runner, Uprate Unit to Higher than Shaft Limit were removed from consideration. There is no discharge capability with these units in the normal operating range, 2,000 cfs to 2,700 cfs. See next two figures below.

The next figure shows that the turbine discharges from uprated propeller units not to have the flexibility to operate in the 2,000 to 2,700 cfs range which is imperative for operation under normal conditions.

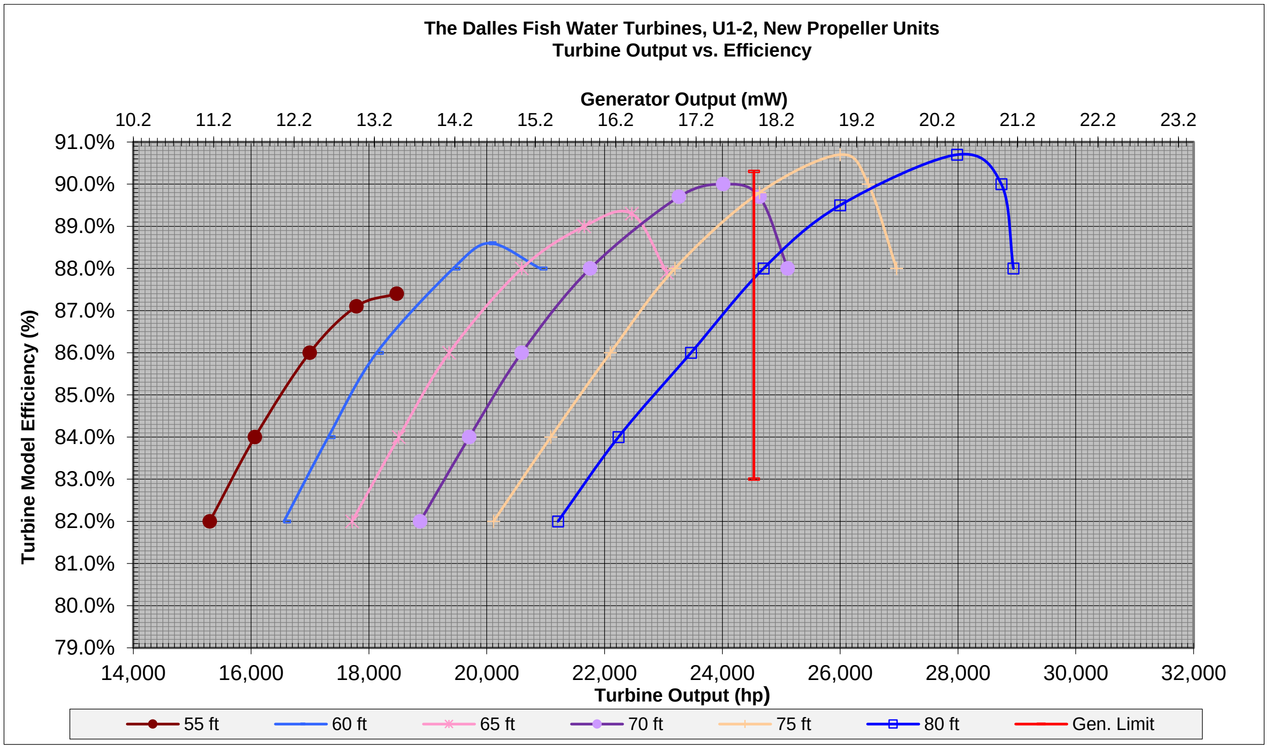


Figure 37. Power vs. Efficiency for the Turbine Propeller Unit Uprated to Shaft Limit

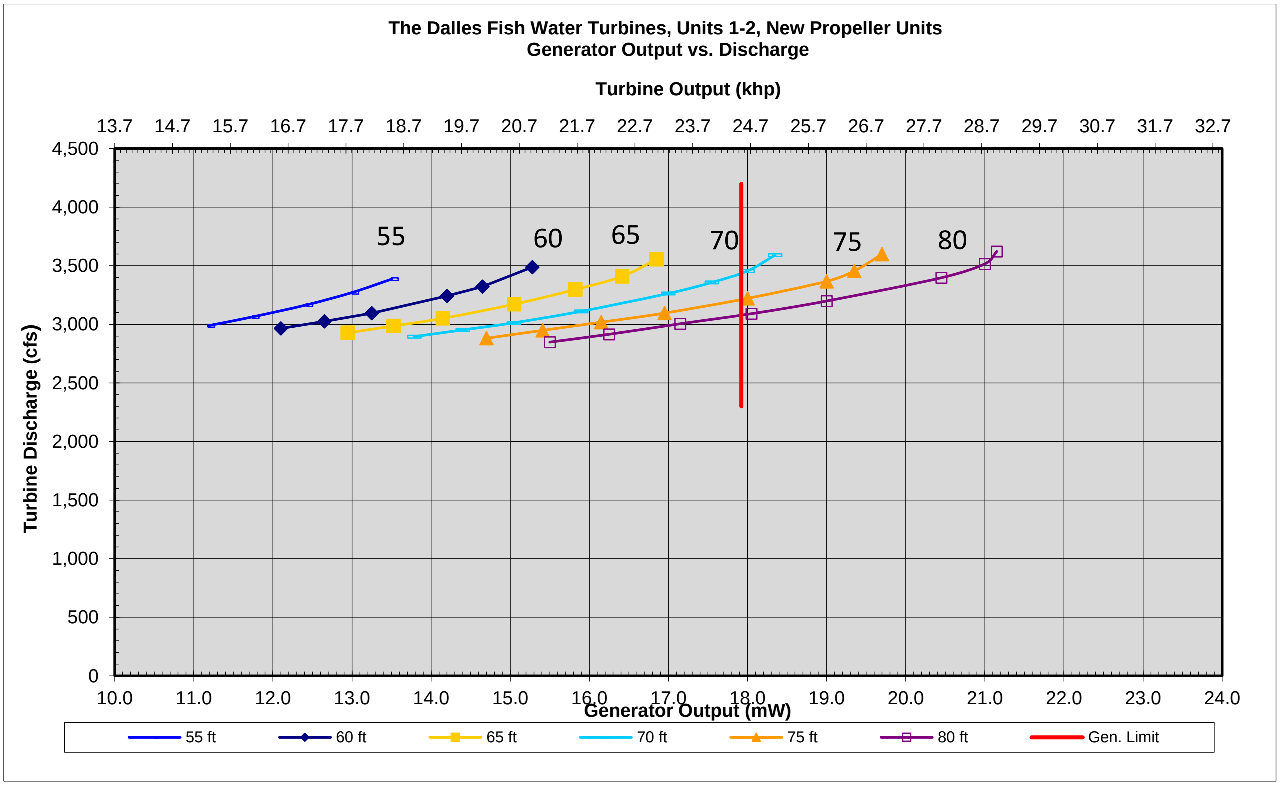


Figure 38. Power vs. Discharge for Turbine Propeller Unit Uprated to Shaft Limit

Replace with a Kaplan Runner Uprated Above Shaft Limit

This alternative requires the study of shaft performance before it can actually be seriously considered. It would have been necessary to visit the powerhouse and perform a physical shaft study and evaluate the results. Additionally an FEA would need to be performed to assess the shaft capabilities.

However, evaluation of the uprate potential by turbine manufacturers recommended that this uprate would be beyond the capability of the existing unit's physical constraints to be able to operate at the higher output. The major constraint was not being able to pass enough water through the unit to operate at the higher outputs.

Also, a new uprated Kaplan unit would have difficulty meeting the existing runaway speed. For these reasons Alternative F, Replacement Turbine with Oil-Filled Kaplan Type Runner, Uprate Unit to Higher than Shaft Limit was removed from further consideration.

CONVERGENCE ON FINAL ALTERNATIVES

Replace with Kaplan Runner Having the Same Rated Output as Existing Units

This alternative would replace the existing units with a new Kaplan that has the same performance as the existing units. This alternative addresses the requirement that the unit be reliable/dependable and have operational flexibility, but will not increase discharge through the unit. Regardless, this unit is still an acceptable alternative. This alternative would be a replacement in kind of the existing units. Therefore, Alternative A, Replacement Turbine with Kaplan Type, Same Rated Output as Existing was determined to be a third recommended alternative.

Replace with a Fixed Blade Propeller Runner Having the Same Rated Output as Existing Units

Fixed-blade propeller turbines have a narrow range of operation, so the only way it would be possible for a propeller unit to be recommended as a replacement option is if it were designed to provide the *same flow* that the existing Kaplans are currently providing. The strength of the propeller type option is that the runner hub has no moving parts, which makes this choice more reliable. They are not filled with oil as a Kaplan is so they are more environmentally friendly. The down side is that they have no flow flexibility. A propeller turbine, by itself, would rarely be able to meet the fishway marginal flow requirements with single unit operation. The existing Kaplan units can meet single unit marginal flow in some cases but propeller units would not have this capability. It should be emphasized that having the flexibility to provide sufficient flow to continuously keep the fish attraction system in marginal criteria is a very important consideration. Flow flexibility gives the project some “breathing room” should system failures occur. Propeller units will not have this operational advantage.

On the strength of their simplicity and dependability these units, Alternative B, Replacement Turbine with Propeller Type, Same Rated Output as Existing, is also recommended as an acceptable alternative.

Replace with a Kaplan Turbine with Uprate to Shaft Limit

This alternative would replace the existing units with new Kaplans that have performance uprated to the shaft limit. This alternative addresses the requirement that the unit be reliable/dependable, have operational flexibility and also meets the requirement for increase discharge through the unit. This alternative addresses the desire to have the replacement units be capable of meeting marginal discharge requirements with *single unit operation*. It is an important consideration to have units that have the flexibility to both operate at the normal flow levels under normal conditions and additionally to be capable of providing additional flow under all conditions to keep the fish attraction system in marginal criteria. This functionality gives the project some breathing room should system failures occur. The capability to quickly provide the additional flow is a tremendous asset.

Alternative C, Replacement Turbine with Kaplan Type, Uprated to Shaft Limit is a recommended alternative, but cost also becomes a consideration when Alternative C is compared with other recommended alternatives.

SECTION 10 –RECOMMENDED ALTERNATIVE AND NEXT BEST ALTERNATIVE

This report provides information that supports the best decision for refurbishing the Fish Water Units. An important implication is that the fish unit turbines as power production systems does not have the overriding importance that would be the emphasis in a typical unit rehabilitation. The three most important components of the fish water turbine rehabilitation are dependability, attraction discharge, and operational flexibility.

- **Dependability** is defined as operating without failure over the design life of 30 years, allowing only for routine scheduled maintenance and repairs or expected component replacements.
- **Attraction discharge.** Since turbine discharge is very important for the fish attraction system, it is mandatory that the rehabbed system can still produce the same approximate discharge as is now available. The current discharge per unit generally varies between 2,000 cfs and 2,700 cfs.
- **Operational Flexibility** means that the rehabilitated system has approximately the range of discharge available for attraction flow as the current system which is about 500 - 700 cfs under normal conditions. It would be desirable to extend the range to 1,000 - 1,200 cfs if possible.

It would be desirable to have the capability to provide more discharge than is currently available, but only if the additional discharge allows a single unit to provide enough flow to keep the fishway in marginal compliance. Having both units in this operating mode would yield redundancy in the system.

The alternative that best meets these requirements is Alternative C, Replacement Turbine with Kaplan Type, Uprated to Shaft Limit. However, as is explained in this Section, Alternative C is approximately $3.6 million *more expensive* that Alternative B. With the option to operate the Fish Units with augmented attraction flow from the AWS, the choice of recommended alternatives is viewed in a in a different light. With Alternative B operating in conjunction with AWS augmented flows it will be possible to provide as much as 3,200 to 3,400 cfs while still maintaining the current normal discharge through the units. See figures in Section 9.

Given the latitude to operate the Fish Units concurrently with the AWS, Alternative B becomes the Recommended Alternative and Alternative C becomes the Next Best Alternative.

RECOMMENDED ALTERNATIVE B – REPLACE TURBINE WITH PROPELLER RUNNER, SAME RATED OUTPUT AS EXISTING

The rehabbed units will be designed to operate to approximately the same output as existing units, output of 18,800 hp (~ 13.74 MVA). It would be conceivable to slightly increase the output to a point below the shaft limit for this alternative as long as the proper discharge for the fishway can be achieved. An output of 20,000 hp (14.62 MVA) is reasonable. This level of power capacity would slightly increase the output of the units but would not result in an appreciable increase of water discharge through the units. See Figures 39 and 40.

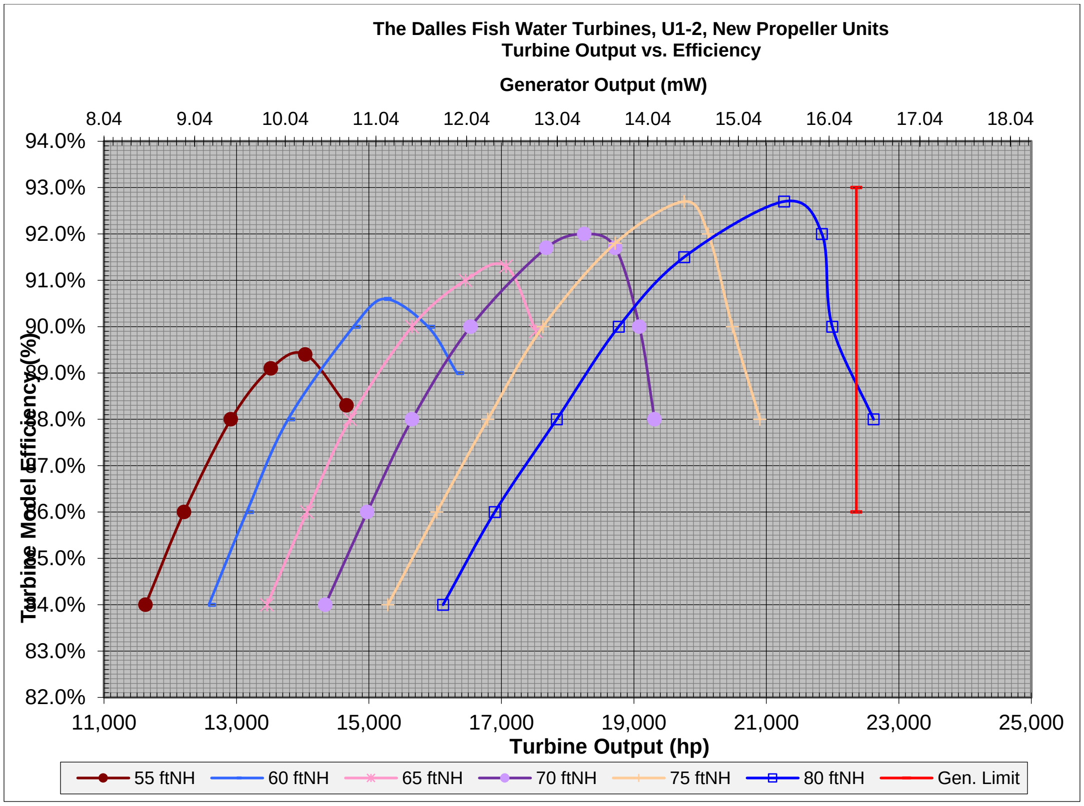


Figure 39. Expected Propeller Turbine Performance, Horsepower vs. Efficiency

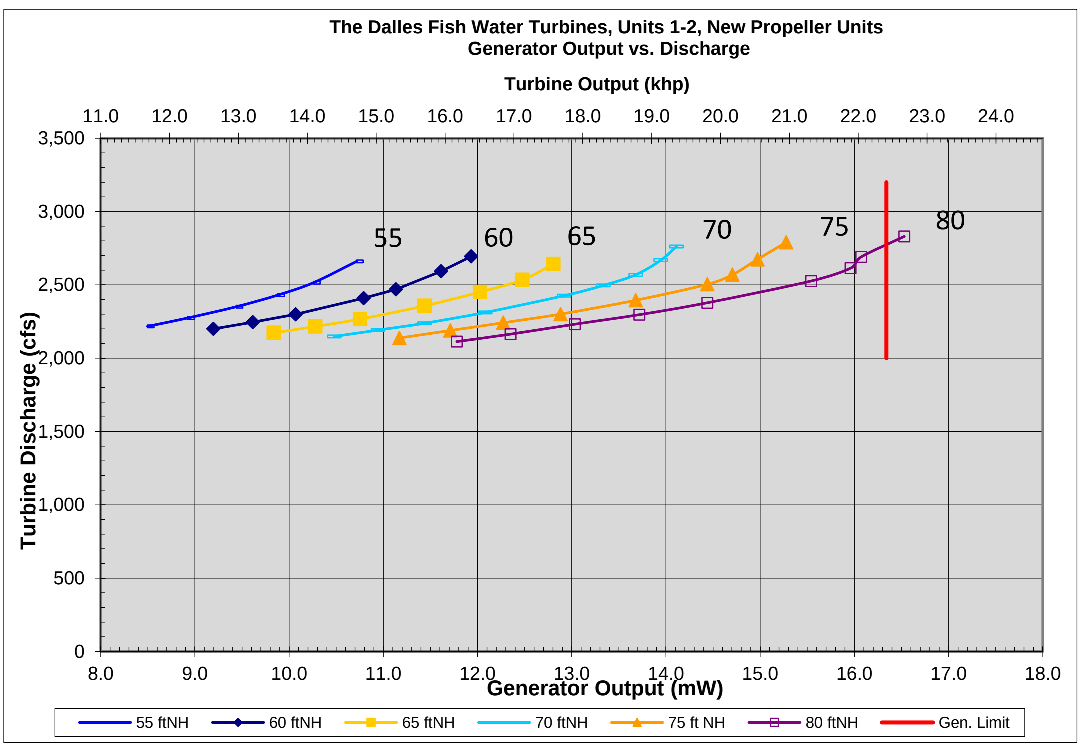


Figure 40. Expected Propeller Turbine Performance, Discharge vs. Generator Output

NEXT BEST ALTERNATIVE C – REPLACE TURBINE WITH KAPLAN RUNNER, UPRATED TO SHAFT LIMIT

For this alternative, the rehabbed units would be designed to operate up to the shaft limit at 24,520 hp (17.92 MVA). This alternative best addresses the three most important criteria described in the matrix in Section 8, Table 15. This alternative will be able to deliver the same discharge as the existing units and will be able to provide additional discharge as necessary up to at least 20% more so a single unit can be used to provide enough discharge to keep the fishway in marginal compliance.

Manufacturers have stated though that to get the higher flows several design aspects will have to be addressed.

More water through the unit will require the gates to open to a larger opening than existing which may require new wicket gate servos. Contract language will have to address this point.

The maximum runaway speed of the units may be affected but will not be completely known until a proposal is received from the manufacturers. There will have to be language in the contract to address this requirement so potential contractors will provide additionally information in their proposal. It's possible that the runner minimum angle will be limited due to this issue.

Higher flows may cause flow separation on the leading edge of the stay vanes and it may be necessary to add extensions to the stay vane to address this problem. This need also will have to be addressed in the contract language.

Additionally, the required generator uprate study may identify items to be replaced not mentioned in the cost analysis

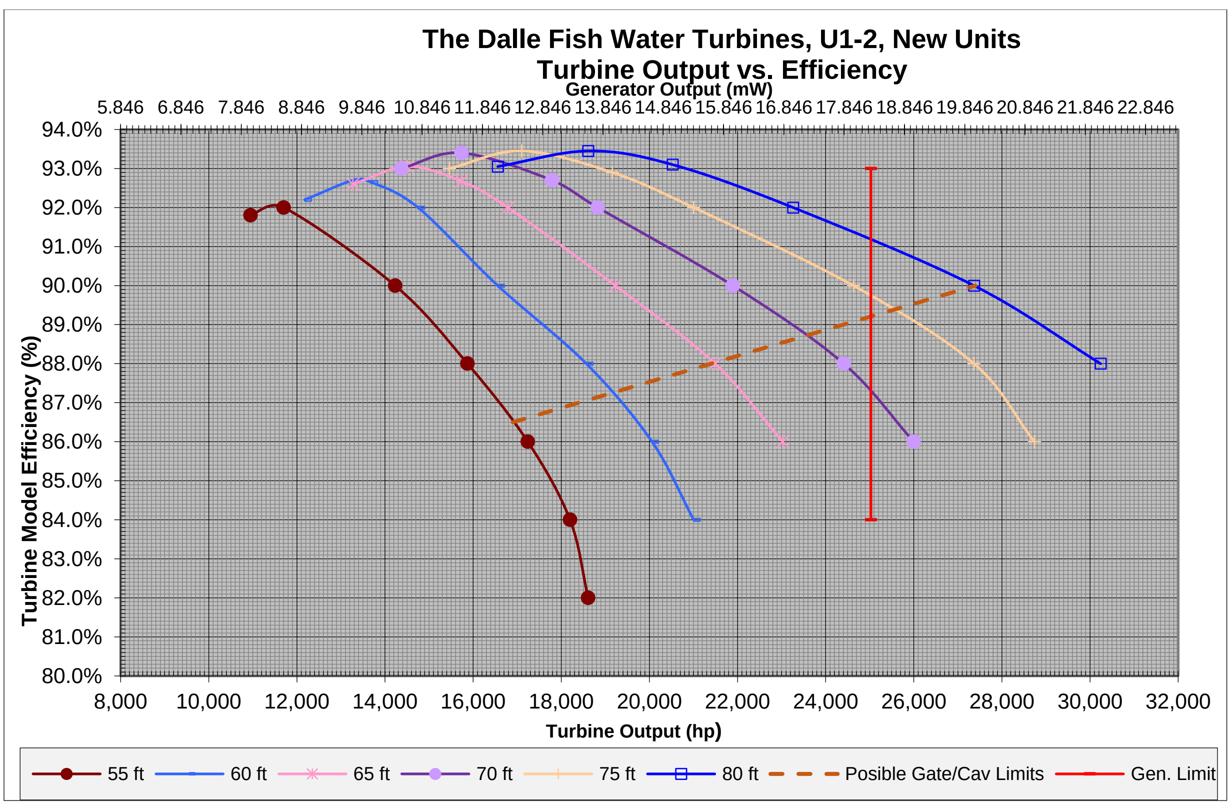


Figure 41. Performance, Horsepower and Efficiency of the New Units

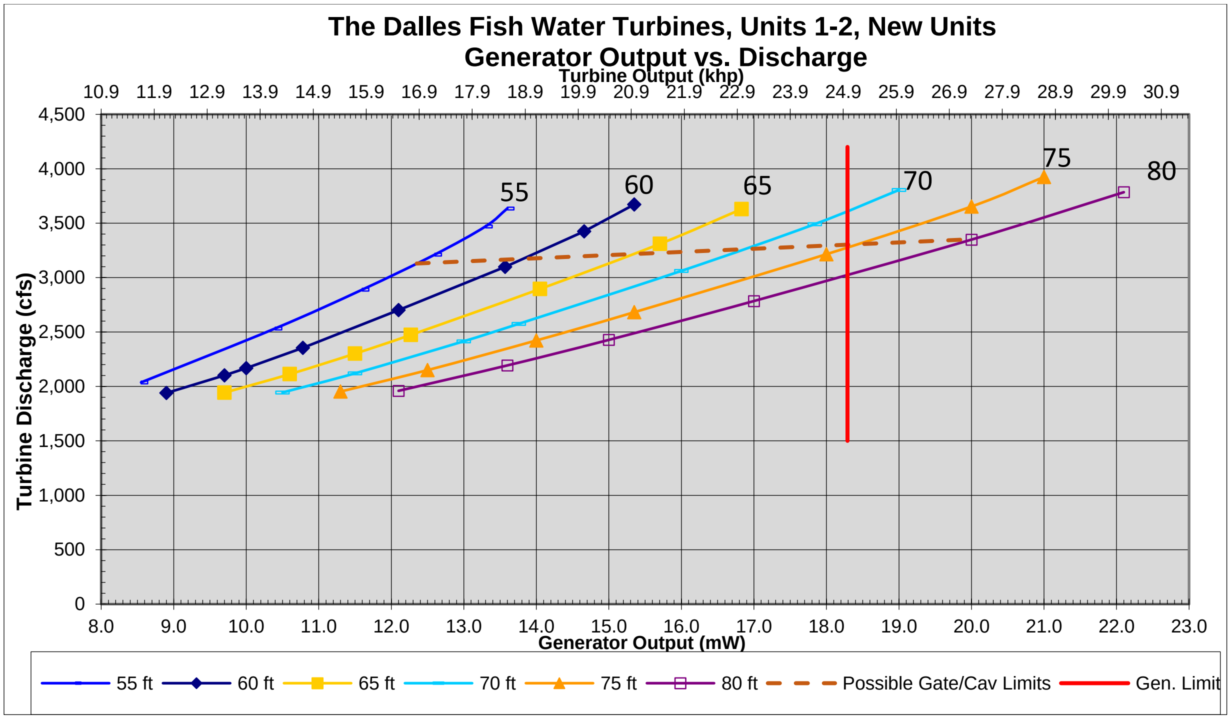


Figure 42. Performance, Generator Output (MW) and Discharge (cfs) of New Units

PHASE 1 SCOPES OF WORK FOR THE RECOMMENDED AND NEXT BEST ALTERNATIVES

Whether Recommended Alternative B or Next Best Alternative C becomes the funded rehab strategy, there are several considerations that would apply to either Alternative, affecting the design functions and physical limits of Phase 1 Plans and Specifications. These considerations are listed here.

Design Documentation Report

A design documentation report (DDR) will be developed as companion documentation for the plans and specs. As such, the DDR will chronicle the development of specific design aspects of Phase 1 documents. The DDR document will serve as a roadmap and justification for specific aspects of the design.

Fish Friendly

It is assumed that the units will not have to conform to any fish friendly constraints that will impact the dependability, flexibility and discharge capability of the new units. Since these units will be designed to provide the best and maximum discharge for the fish attraction system it is imperative that engineers are free to design for this purpose. It should be noted that these units currently have fish screens.

Plans

Plans will be developed primarily by HDC, with supporting information added as necessary by Portland District ENC Division.

Specifications

Specifications will be developed in parallel by HDC and ENC. HDC will provide technical specifications related directly to the turbine and generator work. ENC will provide technical specifications related to general site work, lead and asbestos abatement, and environmental protection. Contracting division will work with ENC staff to develop contract clauses and documents related to Contracting. ENC staff will assemble the specifications package for reviews and advertisement.

Generator Uprate Study – Applicable to Alternative C, Kaplan Turbine Runner with Generator Uprate

Before the Phase 1 work can be started a generator uprate study would have to be performed. This work is normally contracted to an A/E company capable of performing this work and will take about 10 to 12 months. Recommendations provided in this report will be reviewed the Corps of Engineers and may be added to the specification. HDC believes there is a low probability of any major work being necessary due to this uprate study.

Included Plant and Equipment

Table 16 for Alternative B and Table 17 for Alternative C capture the proposed rehabilitation and replacement of components for the Fish Water Turbines at The Dalles Dam.

Table 16. HDC Engineer's Estimated Cost for the Recommended Alternative B, Historical Data

	Propeller Runner, Same Rated Output as Existing	First Unit	Second Unit
1	New Propeller Runner	$1,013,000	$1,013,000
2	Turbine Model Test	$1,000,000	---
3	Site Mobilization/Demobilization	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly testing	$177,734	$177,734
7	Disassemble/Assembly Equipment	$10,000	$3,017
8	Painting & Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
11	Bearing Refurbishment	$313,588	$313,588
12	Furnish New Wicket Gates	$701,179	$701,179
13	Remove Wicket Gate Grease System	$20,000	$20,000
14	Furnish Greaseless Bushings	$47,078	$47,078
15	Refurbish Wicket Gate Operating System	$25,712	$25,712
16	Refurbish Outer Head cover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
17	Refurbish Wicket Gate Servos	$86,242	$86,242
18	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
19	Furnish New Packing Box	$24,792	$24,792
20	Furnish New Shaft Sleeve, Mandrel & Clamps	$27,500	$26,562
21	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
22	Replace TGB Oil System	$23,670	$23,670
23	Furnish New TB External Oil Cooler	$200,000	$200,000
24	Braking System Refurbishment	$33,017	$33,017
25	Braking Ring Inspection and Refurbishment	$15,000	$15,000
26	Generator Rewind	$2,000,000	$2,000,000
27	Exciter	$300,000	$300,000
28	Generator Surface Air Coolers	$80,000	$80,000
30	New Stator Core	$600,000	$600,000
31	Rotor Pole Refurbishment	$300,000	$300,000

Table 17. HDC Engineering Estimated Cost for the Next Best Alternative C, Historical Data

Alternative C, Replacement Turbine *Oil-Filled* Hub, Uprate to Shaft Limit		First Unit	Second Unit
1	New Kaplan Runner	$1,546,000	$1,546,000
2	Turbine Model Test	$1,500,000	---
3	Site Mobilization/Demobilization	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly testing	$177,734	$177,734
7	Disassemble/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating rod	$5,000	$5,000
11	Furnish New Piston and Rod Rigs	$50,720	$50,720
12	Furnish Super bolt Nuts for Piston Rod	$14,513	$14,513
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurbish Outer Head Cover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurbish Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel & Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Generator Rewind	$2,000,000	$2,000,000
30	Exciter	$300,000	$300,000
31	Generator Surface Air Coolers	$80,000	$80,000
32	New Stator Core	$600,000	$600,000
33	Rotor Pole Refurbishment	$300,000	$300,000
34	Generator Uprate Study	$400,000	---

Rehabilitation and Replacement of Components

The proposed rehabilitation and replacement of components for the Fish Water Turbines at The Dalles Dam are described here for both Alternatives B and C:

<table>
<tr><th>Alternative B - Replace Turbine with Propeller Runner, Same Rated Output as Existing</th><th>Alternative C - Replace Turbine with Kaplan Runner, Uprated to Shaft Limit</th></tr>
<tr><td colspan="2">CFD analysis – The contract will call for a computational fluid dynamic (CFD) analysis to maximize the discharge through the unit. Additionally the contract will call for a physical model test to be fabricated and tested to verify the design provided by the manufacturer.</td></tr>
<tr><td>Turbine Runner Hub and Blades – The runner hub will be designed and fabricated from carbon steel. The blades will be stainless steel, fabricated or cast from CA6NM which is a low chromium stainless steel with excellent physical properties.

The runner is a propeller unit so no oil is in the runner hub.</td><td>Turbine Runner Hub and Blades – The runner hub will be designed and fabricated from carbon steel. The blades will be stainless steel, fabricated or cast from CA6NM which is a low chromium stainless steel with excellent physical properties.

The blade seals will be required to be redundant in both directions and the best technically possible to lower the risk of oil leakage. Both the dynamic seal on the blade and the static seal on the runner hub will be either weld overlaid with stainless steel or sleeved with stainless steel weld metal to increase the seal capability.

The shaft seal will be double redundant, i.e. two O-ring seals between the runner hub and the shaft to lower the risk of oil leakage. The fastener bores in the runner hub for the shaft coupling will be blind hole to eliminate a potential leak path.</td></tr>
<tr><td>Kaplan Oil Head – The Kaplan oil head will be removed since there is no blade servo or static oil in the hub inspected and refurbished. New bronze bushings will be installed. The Kaplan pipes will be removed.</td><td>Kaplan Oil Head – The Kaplan oil head will be inspected and refurbished. New bronze bushings will be installed. The Kaplan pipes will be generally inspected, inspected for straightness and refurbished as necessary.</td></tr>
<tr><td colspan="2">Wicket Gates – New stainless steel wicket gates with stainless steel sleeves and self-lubricated bushings will be provided. Since new wicket gates are to be provided the manufacturer will be able to modify the wicket gate profile to increase efficiency and discharge through the unit. Wicket gate bushings will be replaced with self-lubricated composite material.</td></tr>
<tr><td colspan="2">Wicket Gate Packing – Wicket gate packing will be replaced.</td></tr>
<tr><td colspan="2">Stay Vanes – Stay vanes will be inspected. Defects, dents, or dings will be repaired. There is a possibility that stay vane extensions will be installed to address potential leading edge flow separation due to increased flow passing through the unit. Vanes will be repainted. The stay vane flange which is the mounting flange for the outer head cover will be inspected and re-machined to flat and plumb.</td></tr>
</table>

Wicket Gate Servomotors – New wicket gate servos will be installed with a longer stroke to allow the wicket gates to open to a larger angle. This is necessary to increase discharge through the unit.	**Wicket Gate Servomotors** – The existing servo motors will be used and modified for a longer stroke or new wicket gate servos will be installed with a longer stroke to allow the wicket gates to open to a larger angle. This is necessary to increase discharge through the unit.
Operating Ring and Wicket Gate Operating Links – Links between operating ring and wicket gates will be refurbished to improve operational capabilities and reduce wear. All bearing or bushing surfaces will be replaced with self-lubricated materials. All pins will be replaced. The Farval automatic greasing system will be removed.	
Turbine Packing Box and Shaft Sleeve – The packing box and shaft sleeve will be replaced.	
Turbine Guide Bearings, Generator Guide Bearings and Thrust Bearings – All generator and turbine guide bearings and the thrust bearings will be inspected, repaired as necessary and rebabbitted. The spare bearings will also be inspected, repaired as necessary and rebabbitted.	
Turbine Oil Supply Piping – Oil supply piping in the immediate vicinity of the turbine will be removed, inspected, and returned to service.	
Head Covers – The head covers will have be 100% visually inspected and repaired as necessary and repainted. The facing plated mounted on the outer head cover will be inspected and replaced as necessary and machined to flat and plumb.	
Bottom Ring – The bottom ring will be inspected for flatness and most likely be re-machined to flat and plumb. The facing plated will be inspected and replaced as necessary.	
Discharge Ring – The discharge ring will be inspected machined to overlay with a 48 inch stainless steel band. The band will be centered in the high cavitation area to provide protection to this area of the unit when operating.	
Generator Maintenance – General maintenance on the unit will be performed upon disassembly. This includes cleaning and inspection of all components as they are disassembled.	
Unit Alignment – Alignment of each unit will be checked for plumb, centering, offset, and dogleg. Allowable limits will be established in plans and specifications.	
Paint – The steel components in the water passage from the stay vane to the elevation of the runner and draft tube platform will be painted. Previous paint will be removed and lead abated as necessary.	
Generator Rewind – A generator rewind will be performed. This includes the supply of a stator winding and accessories, stator core, reinsulated rotor poles, neutral current transformers, stator Resistance Temperature Detectors (RTDs), Partial Discharge Analyzer (PDA) system, and spare parts; removal and installation of the stator core, rotor poles, and current transformers; installation of the stator winding, and the PDA system. Additional work also includes factory and field tests for the stator winding and accessories, the stator core, the rotor poles, and special field tests.	

Generator Uprate Study – An uprate study does not have to be performed for this alternative since the rated output of the new units will not change.	**Generator Uprate Study** – An uprate study will be conducted to determine other items that need to be refurbished or renewed to get the complete uprated output from the unit.
Not Applicable	**Excitation System Replacement** – The existing excitation systems will be replaced with brushless excitation systems. The work would include designing, manufacturing, factory testing, delivery, installing, field testing, and commissioning completed excitation systems.
Asbestos Removal – Asbestos pipe insulation on pipe that is disturbed will be abated and replaced with non-asbestos insulation. It is expected that unit wiring may also contain asbestos, which requires abatement.	
Expendables and Consumables – Non-durable goods and materials will be replaced in-kind when components are disassembled. Examples are bolts, nuts, washers, packing, seals, gaskets, cotter pins, and grease fittings.	
Update data acquisition and controls for the unit. Items include replacement of all: • bearing resistance temperature detectors (RTDs) • bearing over-temperature protection devices • analog pressure and temperature gauges with 4-20 mA devices • wiring and cabling from the generator to external control boards, valves, etc.	

RECOMMENDATION REVIEW – AWS IMPACTS ON THE ALTERNATIVES

The estimated lost generation revenue by using the backup AWS during construction for two years would be $5.5 million per year, due to redirected flow that isn't used for power generation. [This annual revenue loss during fish unit (FU) rehabs is not factored into cost tables C-1 (propeller type runner) and C-2 (Kaplan-type runner) in this report. As such, foregone generation revenue could be construed as part of the capital investment first costs]. Regardless, this lost revenue would be a one-time opportunity cost that would *apply equally* to either alternative – whether propeller or Kaplan turbine runner type, so the cost difference for power revenue between the two alternatives is a wash.

If the TDA Project team were to implement Alternative C, Kaplan turbine runners with a 20% uprate, and not use the AWS, this approach could of course would make AWS flow available for generation. In considering whether Alternative C (Kaplan type turbine) relative to Alternative B (propeller type turbine) has a large enough economic benefit to outweigh its additional $3.6 million cost, operational flexibility and net power revenue would have to be factored in for a more detailed economic analysis: (a) what is the value of the operation flexibility of using the Kaplan turbine runners to adjust fish attraction flows*, without resorting to using the AWS to supplement FU flows?* And (b) whether the net present value of additional power generation revenues from Kaplan turbines, Alternative C (relative to the propeller type, Alternative B) is significantly large enough to warrant the extra rehab costs? This economic benefit of power revenue would have to be compared to a more intangible benefit of fish migration support.

During a 9- to 12-month rehabbing of the existing Kaplan turbine generator fish units, there will inevitably be a need to supplement attraction flows using the AWS since a single, existing FU cannot be expected to always meet the fish flow criteria. The initial motivation for creating the AWS was to have this back-up in place during periods when either or both of the FUs would be out-of-service. One year operating with one existing FU and without AWS would show flows of 2,500 cfs rather than 4,000 cfs operating in conjunction with the AWS.

To minimize dependency on AWS backup operation and save water, the question arose whether the rehab duration can be shortened. Estimates for turbine-generator rehab range from 9 months to a year out-of-service. It is not realistic to assume that such an effort can be short-cut by attempting to arrange disassembly/rehab/reassembly tasks in parallel rather than sequentially.

Further, to manage dependency on the AWS as a regular contributor to fish water flows, the question was posed whether the TDA Project team could operate the AWS during daylight hours only during FU rehab, which requires active valve control every day. Rather than operate the AWS based on day/night scheduling, the more important question would be, "What would be the day-to-day, hour-by-hour operational requirements of the AWS to assure attraction water flows are met on a continuous basis?" This schedule would be dependent upon river flows and coordination with other operations at TDA.

Although AWS reliability is improving, some expressed concern with the expectation of reliable AWS performance during fish unit rehab construction is a workable assumption. Valuing or characterizing the dependability of the AWS contribution, which underscores the primary criterion of operational reliability, is really a question best deferred to the AWS PDT.

There were suggestions that a Kaplan turbine running with uprate, not using the AWS except in emergency, may be a preferred operation strategy. Having uprated, re-habbed Kaplan units in place, assumes that the $3.6 million additional cost over the propeller type runner alternative can be justified on the power revenue advantage alone. The general guidance that the PDT received was to value the fish water attraction criterion as a higher priority than power revenue, since the main purpose of the FUs is to provide attraction flows, and power generation is incidental to this objective – a synergistic side benefit.

Regardless of reliability concerns and AWS operational constraints, operating without the use of the AWS during rehab construction does not change the Recommended Alternate B, rehab with the propeller type turbine runner. A propeller fixed blade unit would remain as the preferred alternative, regardless of the use of the AWS during construction, based on our evaluation criteria including long term reliability and use of the AWS with one FU if in forced FU outage situation following construction. As noted in elsewhere in this report, the general guidance of "meeting Phase 1A objectives with the least costly alternative" is met with Alternative B, the propeller turbine runner option, *as long as* the AWS can be deployed at any given time to supplement potential flow shortfalls. Not only does this alternative avoid the uprate study cost, which would be required for rehabbing the FUs with the Kaplan type alternative, but hub lubrication – required for the Kaplan alternative – is eliminated, which is a

SECTION 11 –COST ENGINEERING

This section presents the cost estimates for The Dalles Fish Water Unit Refurbishment. The construction cost of the recommended alternative developed by ENC-CC was estimated at $19.27 million. All the construction cost for this project includes 21% contingency, and 7.8% escalation based on a Class 3 cost estimate. The Class 3 cost estimate doesn't account for unforeseen details addressed during the DQC review process.

Contingency/ Risk Analysis – The cost risk analysis have been produced and a contingency value of 21% is assumed for this preliminary estimate.

Overtime – Cost for this work component might be necessary for the rehab construction depending on the season, dependent on risk of flood events, and fish passage or/and the possibility of extending the duration of the contract.

Basis of Estimate – The estimate for this project was developed using information provided by the designers, including places and quantities. The estimate was prepared using MCACES MII version 4.3.4, and is based on historical data from Chief Joseph Station Service Rehab and HDC engineering estimate of costs. The electrical portions of the estimate were developed in detail for labor and equipment crews, quantities, production rates, and material price quotes.

RECOMMENDED ALTERNATIVE B AT PHASE 1A

The major base items are for the mechanical systems: the hydraulic design, a prototype propeller blade turbine runner (2,200 cfs to 2,700 cfs), new wicket gates and linkage components, refurbishing servomotors and associated items, bearings inspection and refurbishments. For the electrical systems, the goal is to maintain the existing generator specs (no uprate study). The work includes the generator winding replacement, stator core replacement, and exciter replacement. For environmental items, costs apply to asbestos and lead paint removal, and painting of the fish units.

The construction cost estimated for the Recommended Alternative developed by EC-CC is $19.27 million based on Class 3 cost estimate.

NEXT BEST ALTERNATIVE C AT PHASE 1A

The major base items are for the mechanical systems: the hydraulic design, a prototype oil-filled Kaplan blade turbine runner (2200 cfs to 3300 cfs), new wicket gates & linkage components, new servomotors and associated items, bearings inspection and refurbishments. For the electrical systems, the goal is to perform an uprate generator study by A&E contract prior to writing the plans and specifications for the new units. The electrical work includes, generator winding replacement, stator core replacement, and exciter replacement. For environmental items, asbestos & lead paint removal, and painting of the fish units.

The construction cost estimated for the Next Best Alternative developed by ENC-CC is $22.86 million based on Class 3 cost estimate.

LIFECYCLE COSTING

O&M costs among the several Alternatives evaluated would likely be "a wash" – no one Alternative shows a significant cost advantage relative to the other Alternatives.

Discussions with Operations and HDC indicated that the O&M costs for the Recommend Alternative and Next Best Alternative for Fish Units are not expected to be significantly different, therefore a life cycle cost analysis that includes O&M would not show any difference in overall cost.

However, operations and maintenance costs – as tabulated by the projects staff (See Appendix I, Table I-5) – suggests that rehab of the turbine-generator units will significantly decrease annual O&M costs, by about $150,000 per year, resulting in a nominal net present worth benefit (or credit) of about $7.5 million over the 50-year life of the refurbished fish units.

ACQUISITION STRATEGY

The acquisition strategy is yet to be determined at this early phase of planning. However, the project is likely to be complex, with an engineering design by the contractor and known long lead times for manufacturing/refurbishment. Based on these challenges, the recommendation for the acquisition strategy is unrestricted Best Value Trade Off source selection, where a work plan can be identified with realistic durations and timeframes for each required work task sequencing in a logical order; and identification of the challenges to be encountered during construction, emphasizing minimizing major power outages.

Operations During Construction

All construction work associated with fish units will comply with the current Fish Passage Plan (FPP) requirements unless specifically coordinated through the Fish Passage Operations and Maintenance (FPOM) regional work group. Presently both fish units must be in operation to maintain criteria entrance conditions as specified in the Fish Passage Plan.

Construction Schedule

Taking into consideration the Recommended Alternative scope of work for the Fish Units; the construction on-site is anticipated to start in 2022 with the first fish unit rehab assuming a duration between 10-12 months, and second unit rehab with a duration of 8-10 months. Major lead time items are the model test and fabrication for turbine runner and the design/fabrication of the winding. It's anticipated that the first fish unit rehabilitation schedule will exceed a typical winter maintenance period and notice shall be submitted to the fish entities related to this issue. After the new first runner construction of the recommended alternative it will be possible to provide as much as 3,200 cfs to 3,400 cfs which will maintain marginal compliance with FPP.

Table 18.The Dalles Fish Units Generator and Turbine Runner Rehabs – Summary of Alternatives with Cost Break Outs [a b c d]

Cost Component	Alternative A	Alternative B – Recommended	Alternative C - Next Best	Alternative D	Alternative E	Alternative F	Alternative G	Alternative H
	Replace turbine with Kaplan runner, same output as existing	Replace turbine with propeller runner, same rated output as existing (2200 cfs - 2700 cfs)	Replace turbine with oil-filled Kaplan runner, uprate unit to shaft limit (2200 cfs to 3300 cfs)	Replace turbine with oil-free Kaplan runner, uprate unit to shaft limit	Replace turbine with propeller runner, uprate unit to shaft limit	Replace turbine with oil-filled Kaplan runner, uprate unit above shaft limit	Replace turbine with oil-free Kaplan runner, uprate unit above shaft limit	Replace turbine with propeller runner, uprate unit above shaft limit
Turbine	$1.546 million per unit	$1.013 million per unit	$1.792 million per unit	$1.792 million per unit	$1.013 million per unit	$1.546 million per unit plus $300,00 shaft study	$1.792 million per unit plus $300,00 shaft study	$1.013 million per unit plus $300,00 shaft study
Miscellaneous Mechanical	$6.07 million per unit	$5.42 million per unit	$6.24 million per unit	$6.07 million per unit	$5.75 million per unit	$6.07 million per unit	$6.07 million per unit	$5.75 million per unit
Generator Rewind	$2.0 million per unit	$2.0 million per unit	$2.0 million per unit	$2.0 million per unit	$2.0 million per unit	2.0 million per unit	$2.0 million per unit	$2.0 million per unit
New Stator Core	$600,000 per unit	$600,000 per unit	$600,000 per unit	$600,000 per unit	$600,000 per unit	$600,000 per unit	$600,000 per unit	$600,000 per unit
Rotor Pole Refurbishment	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit
Exciter Replacement	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit	$300,000 per unit
Generator Uprate Study	not applicable	not applicable	$400,000?	$400,000	$400,000	$400,000	$400,000	$400,000
Total Rehab Construction Costs (both units) [a, b]	$21.63 million*	$19.27 million **	$22.86 million **	$22.52 million *	$20.32 million *	$22.32 million *	$22.82 million *	$20.62 million *

* no contingency or escalation; ** calculated with 21% contingency and 7.8% escalation for both units

NOTES

a. The total estimated Class 3 construction costs include 21% contingency and 7.8% escalation, except where noted with single asterisk *.

b. There would be a Net Present Value savings due to improved operation and maintenance with refurbished units in service. However, this O&M credit is an expense and not a capital (first) cost. The net reduction in labor and materials costs from operating and maintaining improved, refurbished fish units is of the order of about $150,000 per year for both units.

c. Sums of the Total Rehab Construction Costs need to be verified; any discrepancies might be due to more than round-off errors.

d. All costs are on a per unit basis, applied to each of the two Fish Units, except for the Generator Uprate Study or otherwise as noted

APPENDIX A1 – HYDRAULIC DESIGN AND MODELING

ITEM 1 – THE DALLES EAST FISHLADDER LADDER MODEL MEMORANDUM

This memorandum describes the purpose, methodology and equations used for the development of a limited hydraulic 1-D model of The Dalles East Fishladder.

Date: June 22, 2017

Purpose: Develop Hydraulic Criteria and Constraints for The Dalles Fish Unit (FU) Rehabs.

Background: The two fish turbine units at The Dalles dam are nearing the end of their design life and a Phase 1-A report has been completed (including this Appendix) to assess their rehabilitation. The 30% Phase 1A report called for “constraints and criteria” to determine the revised capacity of the fish unit turbines. HDC tentatively anticipated that a 10% - 25% increase in flow capacity might be reasonably feasible.

As the fish unit rehab study is ongoing, a construction project for The Dalles Auxiliary Water Supply (AWS) backup system will be completed in March 2018. The design capacity of the gravity fed AWS backup system is 1400 – 1600 cfs depending on the difference in forebay and level in the AWS conduit near the East Entrance, which in turn is dependent on tailwater and entrance operations at the East Entrance and discharge from the AWS backup system. The use of the AWS backup system as supplemental water supply is being considered in the event of a single fish unit outage or during the construction phase of the fish unit upgrades. However until a prototype test can be performed with a simultaneous operation with the AWS backup system and a fish unit a fish unit, there is no certainty that the two systems will be hydraulically compatible. [This test was conducted in November, 2018, resulting in the conclusion that the AWS could be operated on a continuous basis, when necessary, to augment the attraction flows from the Fish Units – especially under circumstances when the Fish Units are not operable or are operating at reduced flow capacity].

ATTRACTION FLOW CRITERIA FOR FISH UNIT DISCHARGE

Criteria and constraints were described in the 30% Phase 1A Report. The PDT developed criteria based on potential flow targets that would apply to upgraded discharge capacities of fish units.

The current fish unit flow capacity is amply sufficient to meet fisheries criteria, so the remaining question was how much single unit capacity should be raised to provide one of the following potential targets:

1. Marginally meet entrance criteria with a single FU operation.
   - Six entrance weirs open at 8.1 feet submergence, two weirs at each entrance location
   - Entrance head = 1.1 feet at each entrance
2. Reliably meet entrance criteria in combination with the AWS backup operation.
   - Six entrance weirs open, two weirs at each entrance location
   - East entrance weirs open at 9.0 feet submergence
   - West and South entrance weirs open at 8.5 feet submergence
   - Entrance head = 1.5 feet at each entrance
   - 1400 cfs contribution from AWS backup system
   - Meet full fisheries criteria in combination with the AWS backup operation.

3. Meet full fisheries criteria in combination with the AWS backup operation.
   - Same as above except total AWS discharge = 5000 cfs.
4. Meet Target #2 (entrance criteria) without contribution from AWS backup system
5. Meet Target #3 (full criteria) without contribution from AWS backup system

In the early PDT discussions, it was acknowledged that targets items 4 and 5 were both unnecessary and unattainable without major structural modifications.

A review of the operations at low tailwater elevations ranging between 74 – 76 feet from 2014-2016, and 2011 indicate a total fish unit discharge of 5000 cfs is required to meet full fisheries criteria. At the same tailwater levels, this FU discharge should supply enough flow for entrance submergence levels of about 11.5 feet at the East, 9.5 feet at the West and 8.5 feet at the south entrances, all at 1.5 feet of entrance head. Given equivalent entrance parameters (submergence and head), the largest flow rates will be required at the lower tailwater elevations (This point is explained in the description of the modelling development). At higher tailwater elevations, the same flow will pass through entrances at deeper weir submergences, the only remaining possible concern is whether channel velocity is maintained. A review of 2017 data at relatively high tailwater elevations showed that channel velocities were well within criteria under fish unit operations of about 4500 - 4600 cfs.

HYDRAULIC MODELING

A hydraulic model was developed to estimate the FU discharge required for the entrance criteria described in target items 1 and 2.

Previous Hydraulic Models of The Dalles East Fishladder

Two hydraulic numerical 1-D models were previously developed for The Dalles East Fishladder:

1. *Hydraulic Evaluation of the East Fishway Adult Bypass System* prepared by Northwest Hydraulic Consultants (1995)
2. *The Dalles Fishladder Model* prepared by CENWP-EC-H (2008)

The first (1995) model was developed under the Hydraulic Evaluation of the Lower Columbia River Adult Bypass System (HELCRBS) program by Northwest Hydraulic Consultants (NHC). NHC developed the model in a proprietary software to compute the open channel flow and called upon used a pipe network program called Kentucky Pipes to compute the closed conduit flow. The model cannot be run on the current version of Windows and the 1995 version of Kentucky Pipes is no longer available. Also, EC-HD evaluations of the model output revealed that the model was not reliable as the output results could not be replicated by hand calculations from the equations that were reportedly applied in the model.

The second (2008) model was developed in Visual Basic and called up geometric data in Excel sheets and a library of sub functions (and possibly more data). Attempts to rerun the model have failed as the library has not been located.

Limited Hydraulic Model Used for Criteria Development

Since neither of the previous models was available, a limited model was developed for the purposes of this study. With short schedule available, there was only sufficient time to develop a simplified model based on the entrance operations.

The entrance discharge rates were estimated from known conditions (geometry, weir settings and entrance head at each entrance) and compared with the recorded fish unit discharge at the same time. The Dalles Project staff provided fishladder inspection data for the years 2011, 2014, 2015, 2016, and some brief data in 2017. All years included the tailwater levels and entrance heads at each entrance location (three total), weir levels in each entrance bay (eight total), and the fish unit discharges for most days of the fish passage season. 2011 data included the recorded AWS head in the turbine draft tube. 2017 data included a period of days under a single fish unit operation.

The fish unit discharges were estimated from the hydraulic model and compared with the recorded fish unit discharges. The estimated fish unit discharges were determined by estimating the sum of the entrance discharge and deducting the flow from the upper ladder, 109 cfs.

Estimated $Q_{FU} = \Sigma ED - Q_L$

In which:

Q_{FU} = sum of fish unit discharges

$\Sigma ED = \Sigma\{Qi + Qi{+}1 \ldots Qn\}$

Q_L = Flow form upper ladder = 109 cfs for normal operations

Qi = Entrance discharge in bay i

n = 8 bays total

Entrance Dimensions and Typical Operational Parameters

The entrance dimensions and typical operations averaged during 2011, 2014-2016 are shown in Table A-1. The targeted operation is to have at least two entrance bays operating in criteria (> 8 feet of weir submergence and 1-2 feet of entrance head) at each of the three entrance locations.

Table A1-1. Entrance Dimension and Typical Operational Parameters

The Dalles East Fishladder Entrances		Number of entrance bays		Entrance Bay Width (ft)	Operating Entrance Head (ft)	Entrance weir submergence (feet)		Ave. Total Discharge (cfs) (2011, 2014-2016)
Entrance Name	Location	Total	Normal Usage			Minimum per Criteria	Typical Operation	
South	South of Spillway	2	2	15	1-2 ft	8	8.5 - 9.5 ft	1,990
West	West end of PH	3	2	8.5	1-2 ft	8	9.5 - 10.5 ft	1,190
East	East end of PH	3	2.5	8.5	1-2 ft	8	11 - 13 ft	1,950
Total		8	6.5					5,130

Difference in Total Discharges between Fish Unit and Entrances

The entrance discharge is the sum of the total fish unit discharge and the flow from the upper ladder and exit section. The ladder is a function of the ladder head set at the exit section, 1 foot for normal salmon passage to 1.3 feet for shad. The estimated ladder discharges are 109 cfs for 1 foot ladder head and 138 cfs for ladder head at 1.3 feet. In comparing discharge from entrances and fish units for the calibrations, 109 cfs was deducted from the estimated total entrance discharges.

Entrance Weir Coefficients

The entrance weir coefficients (C_W) are based on the theoretical weir discharge coefficients (CD) as shown in Figure A-1. The discharge coefficients are a function of the ratio of head over the weir (H) to weir height above invert (P). The channel invert elevations are 60 feet NGVD 29. With the minimum weir heights being 2 feet and assuming up to 16 feet of upstream weir head, the maximum ratio of H/P at The Dalles East Fishladder is approximately 8.

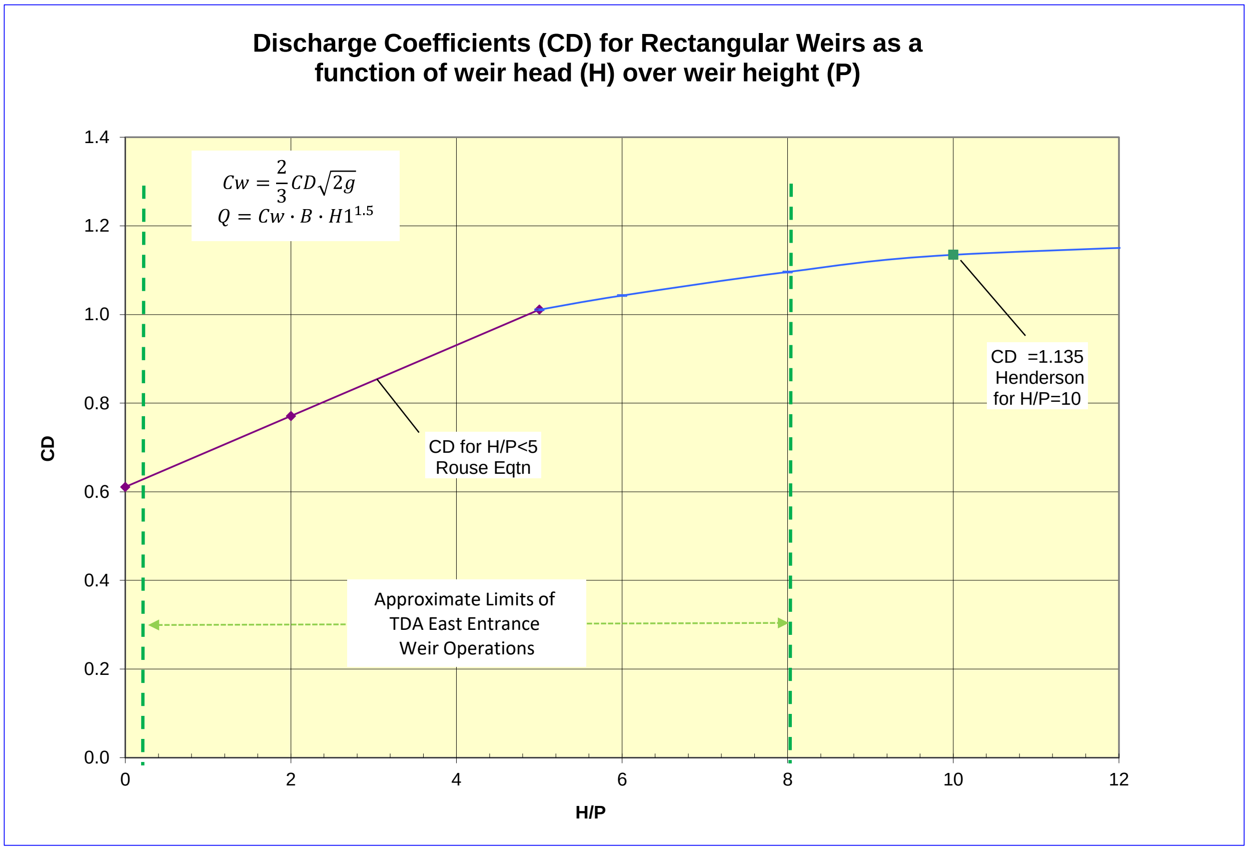


Figure A1-1. Weir Discharge Coefficients (CD) as Function of Weir Head (H) to Weir Height (P)

The weir coefficient (C_W) is determined directly from the discharge coefficient (C_D), and adjusted with submergence coefficient (C_V) and contraction coefficient (C_C). The equations for weir discharge and coefficients are listed below. The submergence coefficient (C_V) is a correction to the weir discharge computation as a function of the downstream submergence of the weir. All entrance weirs operate with a submergence of at least 8 feet per NMFS criteria. The contraction coefficient is an adjustment to address reductions in weir flow caused by weir edge contractions and reduced proportion of channel conveyance due to approach channel curvature.

Equations for Estimation of Entrance Discharge

$Q = B \cdot C_W \cdot C_V \cdot H_1^{1.5}$

$H = TW - Zwr + DH$ $P = Zwr\text{-}Cha\ Invert$

Zwr = Weir Crest Elevation DH=entrance head

B = entrance width TW=Tailwater Elevation

C_W =Weir Coefficient

Cv = Villemonte Coefficient for weir submergence

C_C = Contraction Coefficient

$$\text{IF:} \frac{H}{P} < 5, \quad \text{THEN: } Cw = \left(\frac{H}{P} \cdot 0.08 + 0.61\right) \cdot \frac{2}{3}\sqrt{2g} \cdot (1 - Cc)$$

$$\text{IF:} \frac{H}{P} > 10, \quad \text{THEN: } Cw = 1.135 \cdot \frac{2}{3}\sqrt{2g} \cdot (1 - Cc)$$

$$\text{IF: } 5 > \frac{H}{P} > 10, \quad \text{THEN: } Cw = \left(\frac{H}{P} - 5\right)\left[\frac{1.135 - 1.01}{10 - 5}\right] \cdot \frac{2}{3}\sqrt{2g} \cdot (1 - Cc)$$

$$Cv = \left(1 - \left(\frac{TW - Zwr}{H}\right)^{1.5}\right)^{0.385}$$

$$\sum_{i=1}^{n} ED = Q_i + Q_{i+1} + \cdots Q_n$$

ΣED = Sum total entrance discharge rates

Qi= entrance discharge in entrance bay i

n = total number of entrance bays = 8

Contraction Coefficients and Model Calibration

The contraction coefficient (C_C) is only parameter that is available for calibration of the model computation of entrance discharge. As stated above, the contraction coefficient addresses reductions in weir flow caused by weir edge contractions and reduced channel conveyance due to approach channel curvature. The largest contraction coefficient (Cc) is set at the West Entrance due the approximate 135 degree bend approaching the entrance. The East entrance has the next largest Cc with a 90 degree approach bend. The South entrance has the lowest Cc as there is no approach bend. The contraction loss coefficients Cc shown listed in Table A1-2.

Table A1-2. Contraction Coefficients

East	0.07
West	0.14
South	0.03

Comparison of Recorded Fish Unit Discharge versus Estimated Fish Unit Discharge from the Model

The model is used to estimate the required fish unit discharge by estimating the entrance discharge from given weir settings and entrance heads, minus the upper ladder flow 109 cfs.

The magnitude of average difference between recorded and estimated fish unit discharges is within 0.1% with a standard deviation of 306 cfs. A standard error of the estimate is 254 cfs, or 5.1% of the average recorded fish unit discharge. The summary statistics for each year of data collection is shown in Table A-3.

Table A1-3. Summary Statistics of the Recorded vs. Estimated Fish Unit Discharge

Years	2011-12	2014	2015	2017 single	Average
Ave. ED - QL	4,784	5,217	5,023	2,739	4,974
Ave. FU	4,881	5,177	4,980	2,623	4,977
Ave. Diff	-97	40	43	116	-3
% of Ave. FU	-2.0%	0.8%	0.9%	4.4%	-0.1%
SD Daily Diff.	390	246	189	94	306
% of Ave. FU	8.0%	4.7%	3.8%	3.6%	6.2%
Stand Error	244	138	59	47	254
% of Ave. FU	5.0%	2.7%	1.2%	1.8%	5.1%

R^2 = 0.679

A graph of the sum fish unit discharge versus sum entrance discharge minus fish ladder (109 cfs) flow is shown in Figure A1-2.

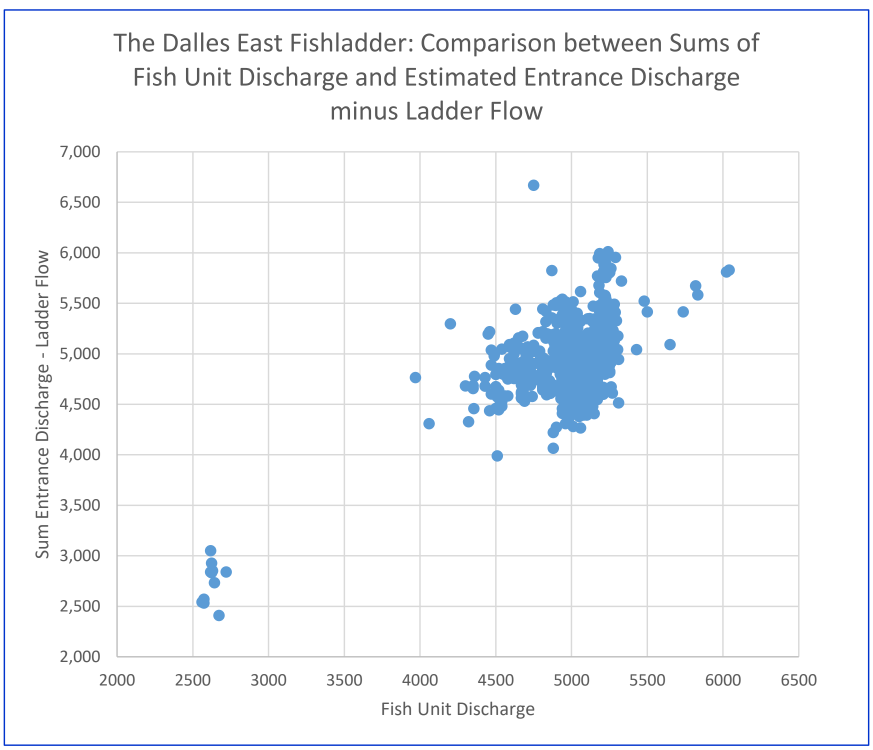


Figure A1-2. Comparison of Sums of Fish Unit Discharge and Estimated Sum of Entrance Discharges minus Ladder Flow

Factors contributing to the differences include calibration error, hydraulic transients moving through the system and possible data errors. For example, the project biologist reported that there have been occasions when the dials showing the positions of some entrance weirs did not correctly report their actual positions.

Estimated Difference Between the AWS Channel Gage and Tailwater Elevation

The net head of the fish turbines is the difference between the forebay and the head in the AWS conduit into which the FU discharges. The head at the AWS “Channel”’ gage is routinely 9 to 12 feet higher than the daily project tailwater (USGS gage) and is assumed to be a function of the square of the sum of the fish unit discharge. The equation and graph of the estimated difference versus measured difference is shown in Figure A1-3:

AWS Head – Project Tailwater = $C \cdot Q_{FU}^2$

Q_{FU} = Sum Fish Unit Discharge (cfs)

$C = 4.44 \cdot 10^{-7}$ ft / cfs^2

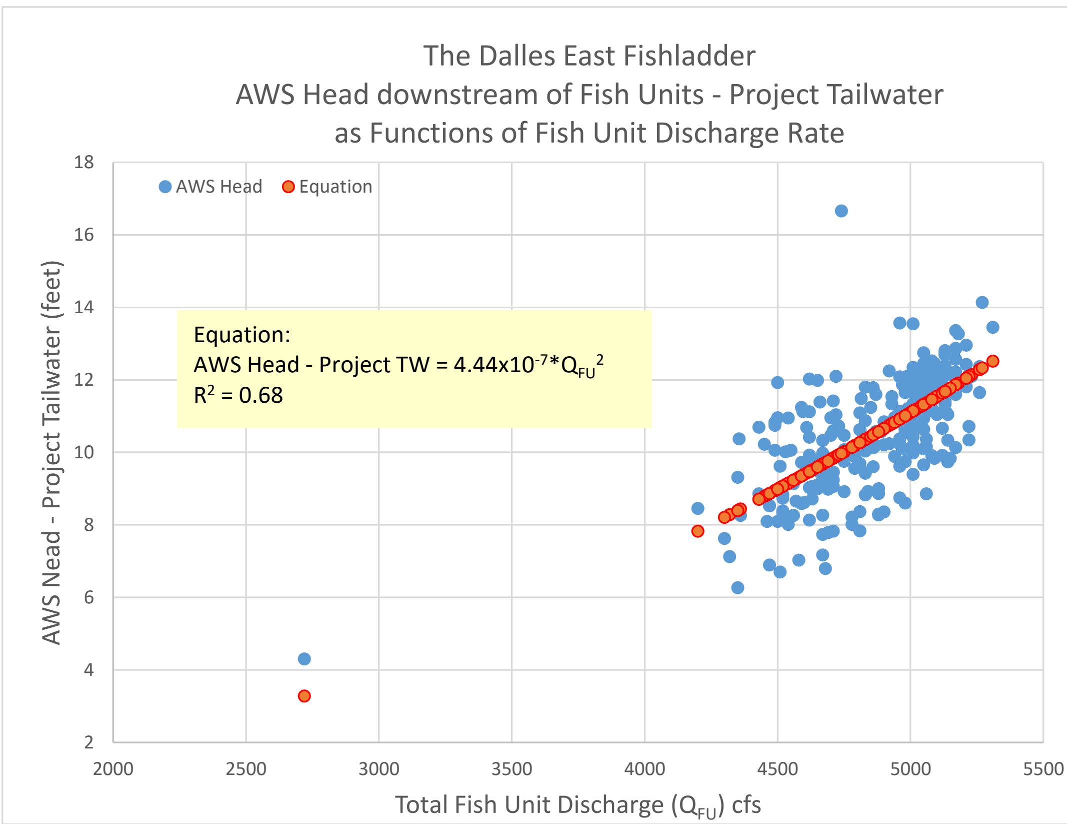


Figure A1-3. Comparison of Estimated and Recorded Differences Between AWS Head and Project Tailwater

As the tailwater becomes higher, the overall hydraulic efficiency of the AWS system becomes higher as additional lower ladder diffusers come on line. The trend showing the decreased head loss as a function of higher tailwater is shown in Figure A1-4.

Attempts to improve the relationship using multivariate regression did not lead to a significant improvement in the correlation.

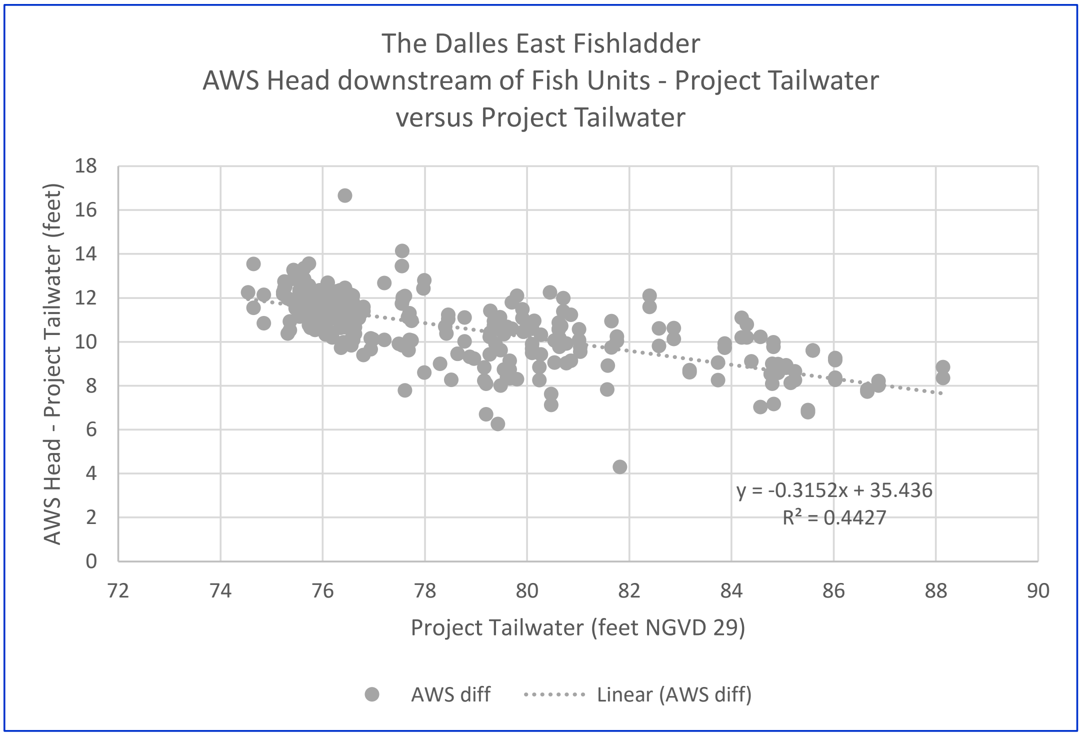


Figure A1-4. Comparison of Estimated and Recorded Differences Between AWS Head and Project Tailwater

Additional correlations were made with recorded data from the East, West and South entrance tailwater elevations. The best correlation was with the East entrance tailwater elevation.

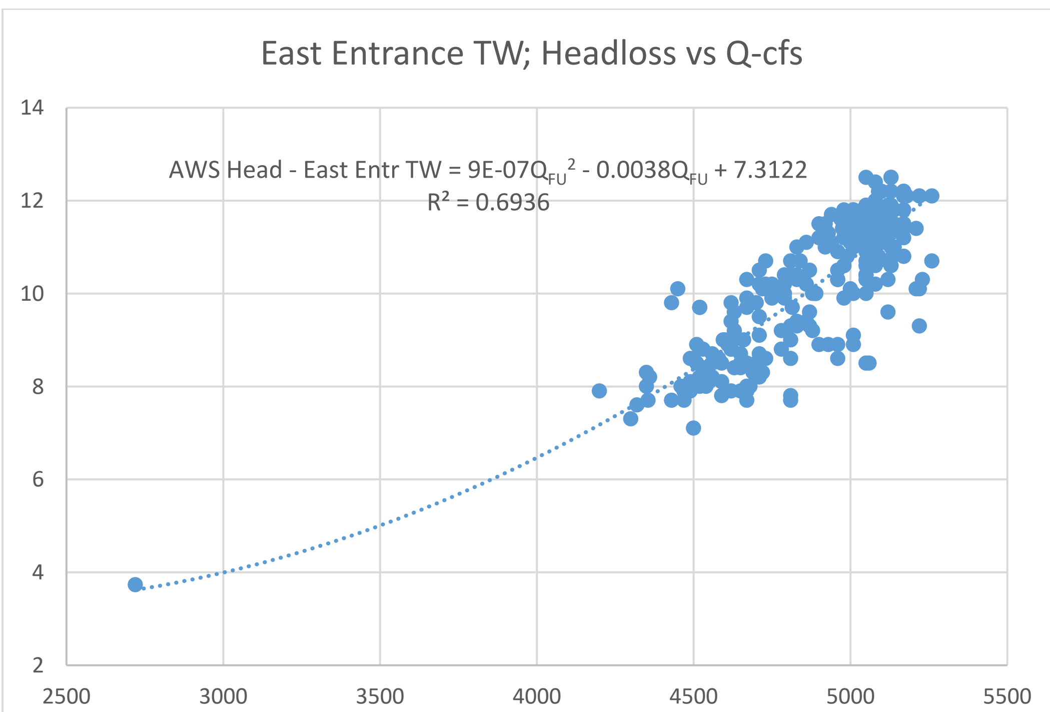


Figure A1-5. Comparison of Estimated and Recorded Differences Between AWS Head and East Entrance Tailwater

APPLICATION OF THE HYDRAULIC MODEL TO FISHERIES CRITERIA

Based on the model, the results of the target cases are the following:

1. Minimally meeting entrance criteria with a single Fish Unit:
    a. 3220 cfs at low tailwater
    b. 2930 cfs at high tailwater
2. Reliably meet entrance criteria in combination with the AWS backup operation.
    a. 4320 cfs total
    b. 2920 cfs with a single Fish Unit
3. Meet full fisheries criteria in combination with the AWS backup operation.
    a. 5000 cfs total
    b. 3600 cfs from a single Fish Unit
4. Meet Target #2 (entrance criteria) without contribution from AWS backup system.
    a. 4320 cfs from one single Fish Unit
5. Meet Target #3 (full criteria) without a contribution from the AWS backup system.
6. 5000 cfs from a single Fish Unit

The flow criteria for Cases 1 and 2 were based on results from the hydraulic model, which estimates the required fish unit flow as a function of the sum entrance discharge less upper ladder flow. For each case, the estimated and recorded fish unit discharges were compared from data taken from similar magnitudes (2500 - 3000 cfs for Case 1; and 4000-4500 cfs for Case 2). The estimated, predicted Fish Unit discharges were adjusted upwards by a percentage based on the standard error of the estimates divided by the average recorded Fish Unit discharge from the data samples. The adjustments were made to account for the variability between the predicted versus recorded Fish Unit discharge, and to provide additional assurance that the criteria as specified would be met in the event that such operations will be required.

- Required fish unit discharge = estimated fish unit discharge x (1 + SE/average Q_{FU})
- Estimated Fish unit discharge = estimated sum entrance discharge – upper ladder flow
- Upper ladder flow = 109 cfs
- SE = standard error of the estimate between the estimated and recorded fish unit discharges with data sample
- Average Q_{FU} = average recorded fish unit discharge within data sample
- Case 1 data samples include estimated or recorded between 2500 - 3000 cfs (single unit)
- Case 2 data samples include estimated or recorded between 4000 - 4500 cfs (dual unit, low flow)

REFERENCES

1. Brater, E. F., King, H. W., Handbook of Hydraulics, 1976.
2. Northwest Hydraulic Consultants (1995), Hydraulic Evaluation of the East Fishway Adult Bypass System.
3. USACE CENWP-EC-HD and Cook Consulting (2002), John Day North Fish Ladder Evaluation Study Report.
4. USACE, CENWP-EC-H (2008), The Dalles Fishladder Model.
5. CENWP-EC-HD
    - Stephen Schlenker, Hydraulic Engineer
    - Martin Hansen, Hydraulic Engineer
    - Gabe Asch, Engineer-in-Training

APPENDIX A2 – THE DALLES DAM: FIELD TRIP REPORT

EAST FISH LADDER (EFL) /FISH UNIT (FU) WATER SURFACE LEVELS AND OTHER MEASUREMENTS

Scope/Purpose: Trip Report on The Dalles East Fish Ladder and Fish units on April 25 2017 to record and verify the key water level and head gages during a single fish unit operation.

Date Prepared: 26 April 2017

Location: The Dalles Dam vicinity – from the South EFL Entrance to the Junction Pool and Forebay above the two 5 MW Fish Unit Units

Inspection Date: 25 April 2017, departed 8:00 AM, on-site between 1000 to 1400 hours

Submitted Martin P. Hansen, P.E., Hydraulic Design Section – USACE, Portland Oregon District

cc: S. Schlenker, M. Hansen, G. Asch, D. Watson, Andrew Braun

Participants and other information

- Dan Watson-ME, CENWP-EC-HDC
- Andrew Braun, EIT, HDC
- Martin P. Hansen, P.E., CENWP-EC-HD
- Gabriel Asch, EIT, HD
- James Schroeder-TL, ENC-DM
- Supporting The Dalles Project Personnel: Bob Cordie and others

Schedule – the breakdown of the itinerary follows:

- 10:00 to 10:30 Discussions in Bob Cordie's office
- 10:30 to 12:00 Field collection of measurements from TW to FB for FU, per HDC
- 12:00 to 1:30 Water-surface measurements for the S., W., E. Entrance to the EFL and spot measurements in the Junction Pool, located u/w of the East Entrance.
- 1:30 to 2:00 On-hold for Conference Call, then departed to Portland. Arrived 4:00 PM

Site Conditions During Inspection

The weather was mild, with overcast skies and some broken cloud cover, with no wind and some sunshine. Visibility was good. Temperature was about 60°F. Releases from the 13 operating main units in the Powerhouse were 121.8 kcfs. Spillway releases were 201.3 kcfs. Flows in the fish ladder and Ice Chute Bypass were about 100 cfs and 4904 cfs, respectively.

INTRODUCTION AND GENERAL DESCRIPTION

For the TW and FB measurements for the single, operating FU #1, all listed participants worked as a group. FU #2 was not generating due to apparent exciter problems. The HD staff (Hansen and Asch) then separately undertook the EFL entrance measurements and also for the Junction Pool. A list of requested readings follows at the end of the report. Also see these Appendices for further information, including the numeric water surface elevations, determined by measurements using the "Solinst" water level meters, Model 101. Bob Cordie was quizzed about the operation settings of the bypass Ice Chute. The seasonal pattern will now be incorporated into the database on flows. The electronic technician was also queried about the radar sensing units located by each of the Main Units and likewise in the afterbay. A print was provided which will be marked up showing the location.

Requested Measurements at TDA by HDC and HD

The follow requested measurements were made, consistent with safety and location of guard rails. Follow-up will be needed to determine the elevation of the concrete deck at the South Entrance to the EFL.

a. FB, Water Elevation, both units
b. FB, (inside gate slots) Water Elevation, (both sides, both units)
c. Turbine exit, Stop-Log slot water elevation (both sides, both units)
d. Fishway water elevation - (from the current collection point)
e. TW water elevation (immediately outside Units 1 and 2)
f. Unit Info on the HMI for both units during data collection, before, during and after.

1. Entrances

South entrance readings: per photographic record

TW: 81.5 ft, weir crest: 72.9 ft, 'Channel elevation: 83.10 ft
CH - TW: (elevation difference) 0.9 ft
S1: closed @ 82.6 ft, S2: open @ crest = 72.9

West entrance readings: per photographic record

TW: 82.0 ft, weir crest: 72.9 ft, 'Channel elevation: 83.20 ft
CH - TW: (elevation difference) 1.2 ft
W1: open @ crest = 73.6 ft, W2:open @ crest = 73.6, E3: closed @ w/bulkhead = 73.6 ft.

East entrance: per photographic record

TW: 82.4 ft, weir crest: 72.9 ft, 'Channel elevation: 83.30 ft
CH - TW: (elevation difference) 0.9 ft
E1: closed @ 83.4 ft, E2: open @ crest = 74.4, E3: open @ crest = 74.3 ft

2. AWS turbines: (requested data and tabulated data noted below):

FU1 Set point and instantaneous. (is the ‘instantaneous, moving around a lot ?, (staying on one side of the setpoint)

FU2 same as above

Total setpoint and instantaneous

Head at downstream AWS gauge (is it steady?)

Per photographic record:

FU1: forebay = 158.31’ fish channel level = 86.13’ flow setpoint=2628 cfs,
MW setpoint = 15.0 MW speed= 200.0 rpm frequency = 59.9 Hz @ 100% gate

FU2: not generating

Per manual reading which match, more or less:

FB (manual) = 158.55’ control room: FWfb = 158.52, Unit 22 fb=158.65 (ok)

Forebay @ roller-gates = 156.4 TW Fishway = 82.8, TW by stop-log slots = 86.7

Stilling Well to AWS conduit = 86.3’ per Stevens w.s. tape recorder

TW(manual) d/s = 80.85’ control room: FU1 tw=80.68’, unit 22 tw = 80.8’

3. Junction pool: Recorded in the Gabriel Asch “Rite-in-Rain” field book

- Weir elevation to east entrance channel
- Water level elevation upstream of the weir in JP
- Water level elevation in east entrance (i.e. “channel” required under no.1)

4. **Forebay elevation:** Recorded in the Gabriel Asch “Rite-in-Rain” field book

5. Estimated number of PH units operating, and total PH discharge if available.

13 units generating – discharging 121.8 kcfs.

Conclusions

The HDC staff (Watson and Braun) repeated the w.s. measurements in the forebay and tailrace slot that leads to the Auxiliary Water Supply conduit, which supplies the EFL entrances and the lower portion of the Fish Ladder via diffusor gratings. The initial readings and subsequent FB and TW readings proved consistent with the PH operators screens and other display screens.

Recommendations

No recommendations are provided at this time. HD will undertake further hydraulic analyses and then determine if more measurements are in order.

SELECTIVE PHOTOS

From 04-25-2017 site visit – below:

See other images @ \\nwd\nwp\ETDS\Engineering_Division\CENWP-EC-H\CENWP-EC HD\Internal_Files\Inspections\TDA visit_04-25-2017\Photos

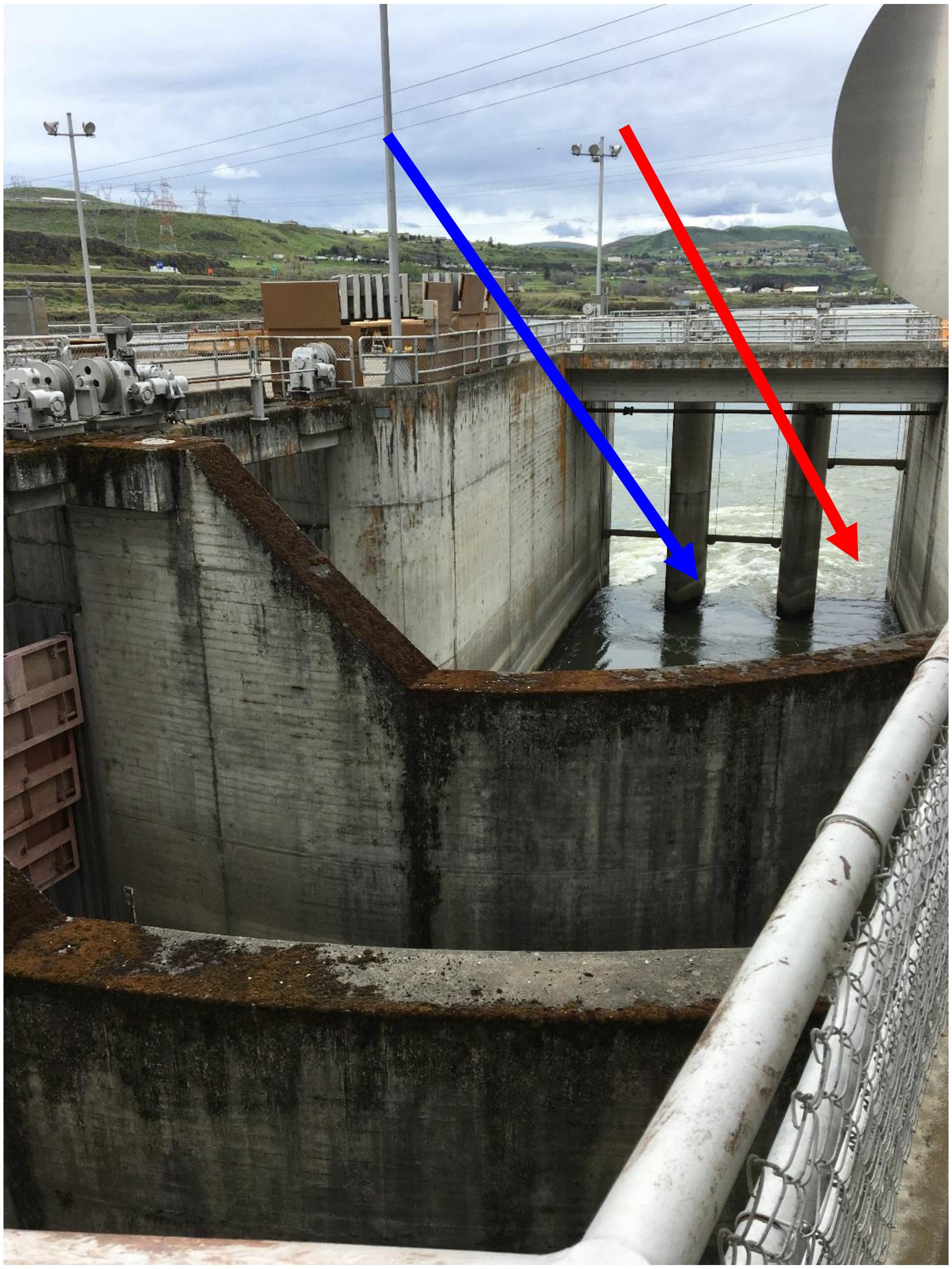


Figure A2-1. East EFL Entrance – Looking D/S w/ The Dalles, OR in the Distant Background.

Location on 111.5 ft deck of TW reading for E. Entrance.
Note two weirs are discharging, E3 and E2 (E1 on the right nearest to the Powerhouse is closed).

Figure A2-2. Looking u/s Toward Junction Pool, w/ Fish Ladder to the Left of the Photo. East EFL Entrance is just outside of the photo to the right.

Three readings taken u/s and d/s from bridge deck, at end of Junction Pool, bridge deck curbing elev. = 112.0 ft.

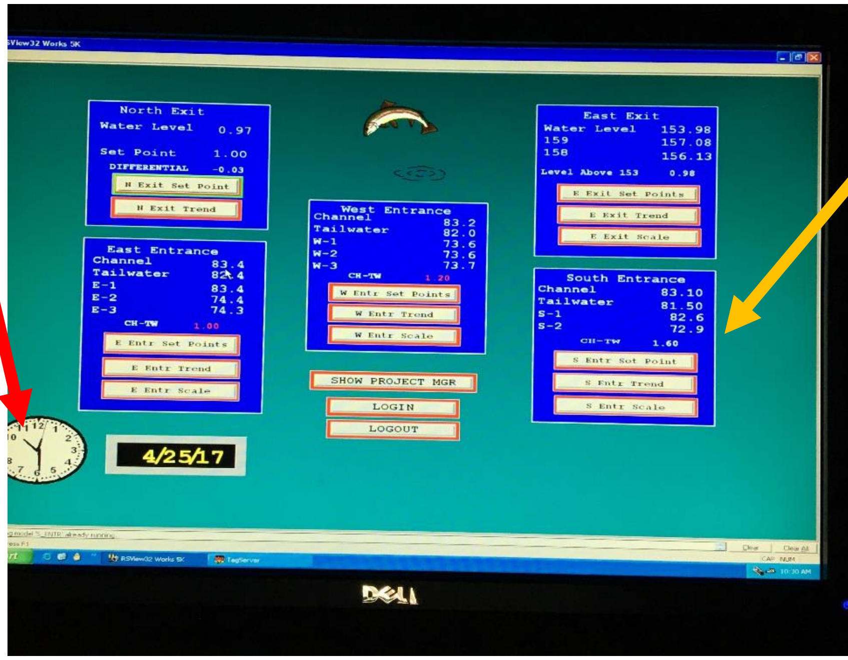


Figure A2-3. Operator's Status Screen within Powerhouse.

Note time on clock. Weir difference in ft is third entry, typ.

Figure A2-4. Panel Outside of PH Showing Gate Position in EFL Entrances.

APPENDICES: INCLUDED BY REFERENCE

- Dalles (TDA) Fishway / Fishwater Unit Measurement Summary April 25, 2017 by Gabriel Asch
- TDA Diffuser Location and Numbering
- Photo Collage references
- Water Control Manual – may need updating per ER-1110-2-240 and 1110-2-8156.
- Design Basis Memoranda
- Project drawings
- Survey datum sheet and location of survey control points – from Cliff Bondurant
- EM – Corps of Engineer's Engineering Manuals
  http://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/

REFERENCES

- Water Control Manual – may need updating per ER-1110-2-240 & 1110-2-8156.
- Design Basis Memoranda
- Project drawings
- Survey datum sheet and location of survey control points – from Cliff Bondurant
- EM – Corps of Engineer's Engineering Manuals
  http://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/

OTHER REMARKS AND NOTES

A Sea-Lion was noted swimming in the Tailwater area near the E. Entrance of the EFL. Elevations shown are referenced to NGVD29 Datum. To convert from NGVD29 to NAVD88, add 3.6 feet.

PERTINENT FACTS: THE DALLES DAM PROJECT

Location/Stream: Columbia River at river mile (RM) 192
Drainage Area, sq. miles 237,000
Dam Completion Date........ 1957
Normal Pool elevation .... 160 ft
Min. power pool elevation........ 155 ft
Approx. operating pool elevations: .... 162.5 ft. to 155 ft.
Approx. range of tailwater elevations, min. to max .... 69.5 to 97.2 ft
Spillway Type Concrete gravity, gate controlled
Dam Length (overall)........ 1,447 ft
Central (South) Non-overflow dam between spillway and powerhouse .... 1,527 ft
Gates (23) .... 50-ft tainter gates
Crest elevation .... 121.0 ft
Deck elevation........ 185.0 ft
Design Discharge (pool el. 182.3) .... 2,290,000 cfs
Maximum discharge to date – May 1948 .... 1,240,000 cfs

NAVIGATION LOCK TYPE: SINGLE LIFT

Normal lift .... 87.5 ft
Maximum lift........ 90.5 ft
Inside clearance – width and length .... 86 x 675 ft
Minimum depth over lower sill........ 15 ft
Depth over upper sill (pool el. 160) .... 20 ft
Valving in conduits: tainter gates........ 12 ft x 14 ft
Miter Gates: up-steam & down-stream........ 54 ft x 106 ft
Powerhouse length:........ 2,089 ft
Turbine type and number of units .... Kaplan automatic-adjustable blades, 22 main units
Turbine capacity........ 14 @ 123,000 hp at 81 ft head, eight @ 140,000 hp at 81 ft head
.... 1,806,800 kW total generating capacity
East non-overflow dam (powerhouse to closure dam) .... Length 452 ft
Rockfill closure dam .... Length 2,017 ft
Total length of dam........ 8,735 ft

APPENDIX A3 – JOINT OPERATION OF A SINGLE FISH UNIT AND AWS BACKUP SYSTEM AT THE DALLES

On November 28 2018, The Dalles AWS backup system was successfully operated simultaneously with a single fish unit. The AWS system was operated with each of the two fish units at separate times. In addition, the tests included the startup and shutdown of a fish unit while the AWS backup system was operating; and conversely, the startup and shut down of the AWS backup system while a fish unit was operating. The latter operation represents a typical scenario in during which one of the fish units goes down and the AWS backup system can be called into service to augment the auxiliary water flow for the fish ladder.

The fish turbines and fish ladder were monitored during the tests and showed no adverse conditions developed in either system. No seiching (standing waves caused by water inflows into an expanse of open water) was seen in the fish ladder and no abnormal pressure variations were observed with the turbines. The flow in the fish ladder appeared similar to a normal operation with two fish units. Recorded channel velocities were also similar to a normal dual unit operation.

The discharge in the single fish units were run at 2500 cfs and the estimated AWS backup discharge was about 1550 cfs, for a combined 4050 cfs. Tests were done at a relatively low tailwater, which creates a more conservative test in terms of meeting fish ladder entrance criteria. (The ladder entrance weirs become increasingly hydraulically efficient with lower tailwater since the lower settings of the ladder entrance weirs create a lower projection into the water column.) The project tailwater was 75.5 feet, which is exceeded 85% of the time during the year.

The fish ladder entrance data at all three entrances were physically recorded during the joint AWS and fish unit operation with the following summary results:

Entrance Location	Number of Weirs	Weir Submergence	Entrance head
East	2.3	10.5 ft	1.5 ft
West	2	8.3 ft	1.25 ft
South	2	8.5 ft	0.5 ft

During the joint fish unit and AWS backup system operation, the east and west entrances were reliably within criteria; however the south entrance was not. (This being in spite of the combined AWS entrance flow (~ 4000 cfs) being higher than the estimated marginal target rate, 3200 cfs). Noteworthy was that the fish ladder programmable logic control (PLC) screen indicated the south entrance was within criteria at the same time. The physical measurements are accurate, whereas the PLC data relies on calibrations which have been known frequently to stray.

The criteria problem at the south entrance can be easily corrected by raising one of the two weirs sufficiently to raise the entrance head back into criteria. The south entrance weirs are 15-feet wide each, which represents 86% of the combined width of two narrower entrance weirs at the east and west entrance locations. As noted above, this was a conservative test towards meeting entrance criteria due to the particularly low tailwater.

APPENDIX B – TURBINE AND GENERATOR SECTION DRAWINGS

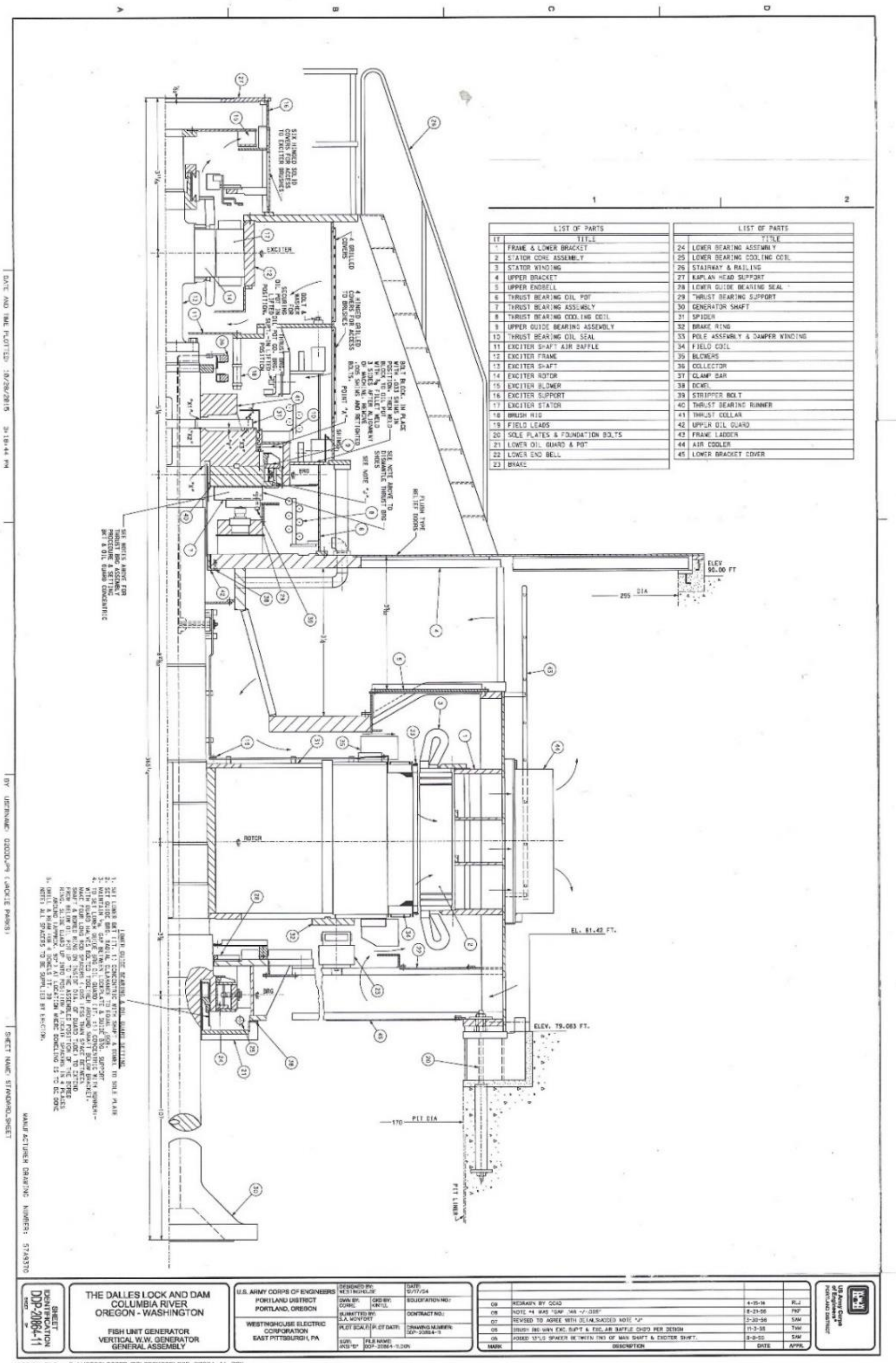


Figure B-1. Cross Section of The Dalles Fish Unit Generator

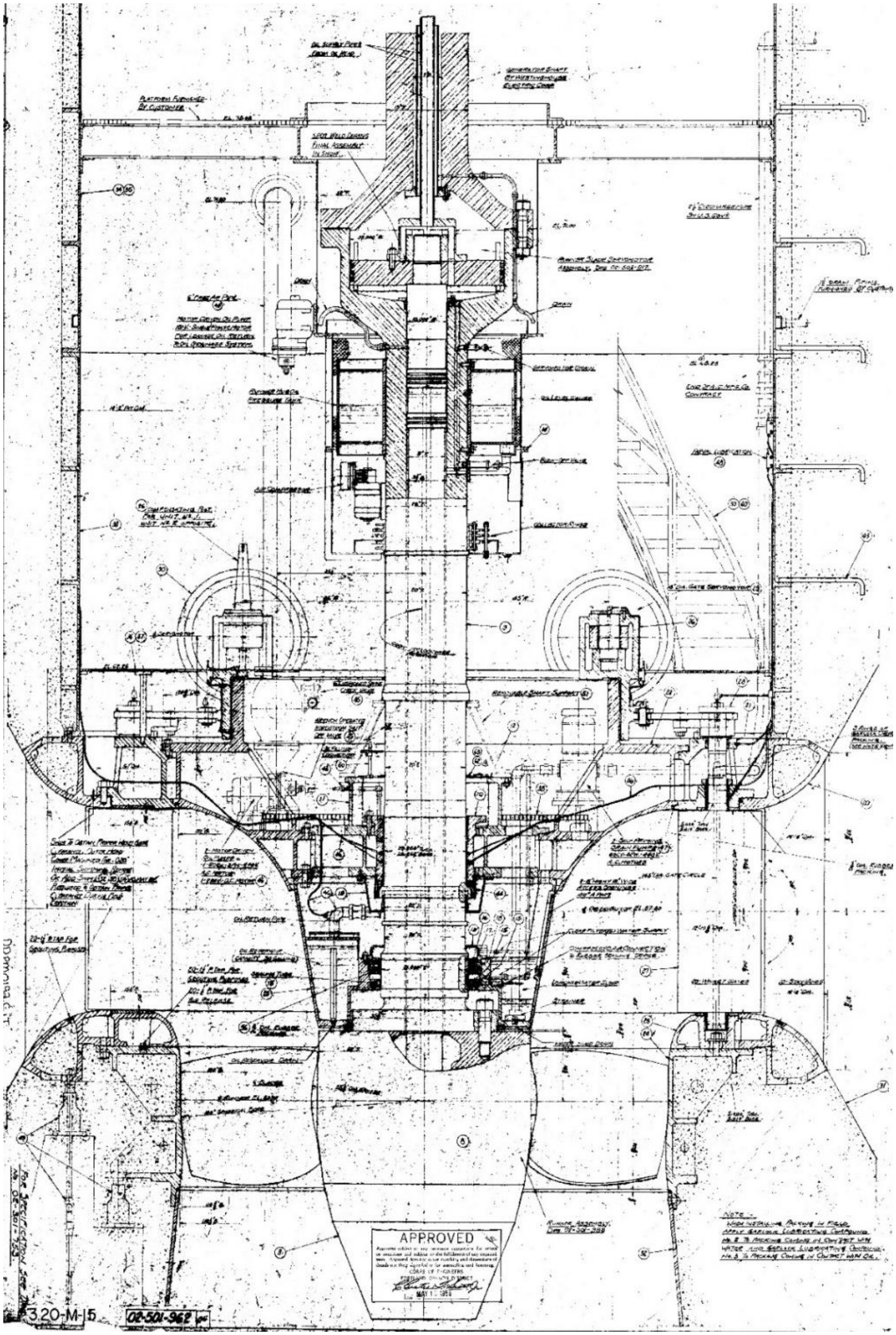


Figure B-2. Cross section of The Dalles Fish Unit Turbine

APPENDIX C – ALTERNATIVE COSTS

Table C-1. Alternative A, In Kind Runner Replacement, Same Rated Output

		First Unit	Second Unit
1	New Kaplan Runner	$1,546,000	$1,546,000
2	Turbine Model Test	$1,500,000	---
3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly testing	$177,734	$177,734
7	Disassembly/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating Rod	$5,000	$5,000
11	Furnish New Piston and Rod Rigs	$50,720	$50,720
12	Furnish Superbolt Nuts for Piston Rod	$14,513	$14,513
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurbish Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurbish Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	---	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000

33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study		---
	Subtotal	**$11,650,358**	**$10,142,437**
	Total	**$21,792,795**	

Table C-2. Alternative B, Propeller Runner, Same Rated Output as Existing

		First Unit	Second Unit
1	New Kaplan Runner	$1,013,000	$1,013,000
2	Turbine Model Test	$1,000,000	---
3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly testing	$177,734	$177,734
7	Disassem/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating Rod	---	---
11	Furnish New Piston and Rod Rigs	---	---
12	Furnish Superbolt Nuts for Piston Rod	---	---
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurb Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurb Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017

28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	---	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000
33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study	---	---
	Subtotal	**$10,547,125**	**$9,539,204**
	Total	**$20,086,329**	

Table C-3. Alternative C, Replacement Turbine *Oil-Filled* Hub, Uprate to Shaft Limit

		First Unit	Second Unit
1	New Kaplan Runner	$1,546,000	$1,546,000
2	Turbine Model Test	$1,500,000	---
3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic Turbine	$663,636	$663,636
6	Pre-Disassembly Testing	$177,734	$177,734
7	Disassem/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating Rod	$5,000	$5,000
11	Furnish New Piston and Rod Rigs	$50,720	$50,720
12	Furnish Superbolt Nuts for Piston Rod	$14,513	$14,513
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurb Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurb Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792

23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	---	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000
33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study	$400,000	---
	Subtotal	**$12,050,358**	**$10,142,437**
	Total	**$22,192,795**	

Table C-4. Alternative D, Replacement Turbine *Oil-Free* Hub, Uprate to Shaft Limit

		First Unit	Second Unit
1	New Kaplan Runner	$1,792,000	$1,792,000
2	Turbine Model Test	$1,500,000	---
3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly testing	$177,734	$177,734
7	Disassem/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating Rod	$5,000	$5,000
11	Furnish New Piston and Rod Rigs	$50,720	$50,720
12	Furnish Superbolt Nuts for Piston Rod	$14,513	$14,513
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078

18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurb Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurb Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	---	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000
33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study	$400,000	---
36	**Subtotal**	**$12,296,358**	**$10,388,437**
	Total	**$22,684,795**	

Table C-5. Alternative E, Replacement Turbine , *Propeller* Type Runner, Uprate to Shaft Limit			
		First Unit	**Second Unit**
1	New Kaplan Runner	$1,013,000	$1,013,000
2	Turbine Model Test	$1,000,000	---
3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly Testing	$177,734	$177,734
7	Disassembly/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating Rod	---	---
11	Furnish New Piston and Rod Rigs	---	---
12	Furnish Superbolt Nuts for Piston Rod	---	---

13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurb Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurb Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	---	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000
33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study	$400,000	---
36	**Subtotal**	**$10,947,125**	**$9,539,204**
	Total	**$20,486,329**	

Table C-6. Alternative F, Replacement Turbine *Oil-Filled* Hub, Uprate Above Shaft Limit			
		First Unit	**Second Unit**
1	New Kaplan Runner	$1,546,000	$1,546,000
2	Turbine Model Test	$1,500,000	---
3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly Testing	$177,734	$177,734
7	Disassembly/Assembly Equipment	$10,000	$3,017

8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating rod	$5,000	$5,000
11	Furnish New Piston and Rod Rigs	$50,720	$50,720
12	Furnish Superbolt Nuts for Piston Rod	$14,513	$14,513
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurb Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurb Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	$300,000	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000
33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study	$400,000	---
36	**Subtotal**	**$12,350,358**	**$10,142,437**
	Total	**$22,492,795**	

Table C-7. Alternative G, Replacement Turbine *Oil-Free* Hub, Uprate Above Shaft Limit			
		First Unit	**Second Unit**
1	New Kaplan Runner	$1,792,000	$1,792,000
2	Turbine Model Test	$1,500,000	---

3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic turbine	$663,636	$663,636
6	Pre-Disassembly Testing	$177,734	$177,734
7	Disassembly/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating rod	$5,000	$5,000
11	Furnish New Piston and Rod Rigs	$50,720	$50,720
12	Furnish Superbolt Nuts for Piston Rod	$14,513	$14,513
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurb Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurb Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	$300,000	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000
33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study	$400,000	---
	Subtotal	**$12,596,358**	**$10,388,437**
	Total	**$22,984,795**	

Table C-8. Alternative H, Replacement Turbine , *Propeller* Type Runner, Uprate Above Shaft Limit			
		First Unit	**Second Unit**
1	New Kaplan Runner	$1,013,000	$1,013,000
2	Turbine Model Test	$1,000,000	---
3	Site Mob/Demob	$132,727	$132,727
4	Disassembly of Hydraulic Turbine	$1,478,577	$1,478,577
5	Reassembly of Hydraulic Turbine	$663,636	$663,636
6	Pre-Disassembly Testing	$177,734	$177,734
7	Disassembly/Assembly Equipment	$10,000	$3,017
8	Painting and Lead Abatement	$100,264	$100,264
9	Furnish New Draft Tube Platform	$83,099	$83,099
10	Inspect Piston, Blade Servo, Operating rod	---	---
11	Furnish New Piston and Rod Rigs	---	---
12	Furnish Superbolt Nuts for Piston Rod	---	---
13	Inspect/Refurbish Gen/Turbine Shafts	$60,611	$60,611
14	Bearing Refurbishment	$313,588	$313,588
15	Furnish New Wicket Gates	$701,179	$701,179
16	Remove Wicket Gate Grease System	$20,000	$20,000
17	Furnish Greaseless Bushings	$47,078	$47,078
18	Refurbish Wicket Gate Operating System	$25,712	$25,712
19	Refurb Outer Headcover, Bottom Ring, Stay Ring, Operating Ring, Air Valve	$275,700	$275,700
20	Refurb Wicket Gate Servos	$86,242	$86,242
21	Line Bore Wicket Gate Stem Bushing Bores	$23,010	$23,010
22	Furnish New Packing Box	$24,792	$24,792
23	Furnish New Shaft Sleeve, Mandrel and Clamps	$27,500	$26,562
24	Discharge Ring Stainless Steel Overlay and Cav Repair	$730,989	$730,989
25	Replace TGB Oil System	$23,670	$23,670
26	Furnish New TB External Oil Cooler	$200,000	$200,000
27	Braking System Refurbishment	$33,017	$33,017
28	Braking Ring Inspection and Refurbishment	$15,000	$15,000
29	Shaft Study	$300,000	---
30	Generator Rewind	$2,000,000	$2,000,000
31	Exciter	$300,000	$300,000
32	Generator Surface Air Coolers	$80,000	$80,000

33	New Stator Core	$600,000	$600,000
34	Rotor Pole Refurbishment	$300,000	$300,000
35	Generator Uprate Study	$400,000	---
	Subtotal	**$11,247,125**	**$9,539,204**
	Total	**$20,786,329**	

APPENDIX D – HYDROAMP GENERATOR/TURBINE CONDITION ASSESSMENT

This Appendix describes the HydroAMP condition assessment for the major components of the Fish Unit turbine-generators, the turbines and governors in particular. The HydroAMP scoring follows the ranges and conditions index (CI) as defined in Table D-1.

Table D-1. HydroAMP Condition Index, Condition Equipment Ratings and Definitions

Condition Index (CI)	Condition Equipment Rating	Definition
8 ≤ Index ≤ 10	Good	There is a high level of confidence that the component will perform well under normal operating conditions. Continue current O&M practices. Repeat condition assessment on normal frequency. Consider performing Tier 2 tests when convenient to provide good base line data for comparison with future tests.
6 ≤ Index <8	Fair	There is a medium level of confidence that the component will perform well under normal operating conditions. The component may require additional investigations to confirm adequacy. Continue current O&M practices, minimal restrictions to operation and/or minor maintenance may be necessary. Repeat condition assessment on normal frequency. Consider performing Tier 2 tests to provide further insight into equipment condition and adjust Condition Index score as necessary.
3 ≤ Index <6	Marginal	There is a low level of confidence that the component will perform well under normal operating conditions. The component requires additional investigation to confirm adequacy. Restricted operation and/or non– routine maintenance are necessary. Perform applicable Tier 2 tests and adjust Condition Index score as necessary. Consult with technical specialists. Repeat condition assessment more frequently.
0 ≤ Index < 3	Poor	The component does not perform well under normal operating conditions. Physical signs of serious damage or deterioration are present. Significant restrictions to operation and/or extensive non– routine maintenance are necessary. Perform immediate Tier 2 testing and adjust Condition Index score as necessary. Consult with technical specialists. Repeat condition assessment more frequently.

SUMMARY HYDROAMP ASSESSMENT

The HydroAMP assessments for major components of the two Fish Water Unit (FU) turbine-generators were reported in 2014 and again in 2018.

In the four years between HydroAMP reports, the stator windings show significant deterioration, rated from FAIR in 2014, downgraded to MARGINAL in 2018. The rotor ratings remain very stable, in FAIR condition with a score of 7.6. The exciter components show some degradation, from GOOD to FAIR over the four-year period. Stator cores in 2018 were rated at the maximum of 10.

	Stator Winding	**Stator Core**	**Rotor**	**Exciter**
FW Unit 1	7.8	No data	7.6	8.1
FW Unit 2	6.1	No data	7.6	8.1

HydroAMP Condition Index Assessment performed in 2018

	Stator Winding	**Stator Core**	**Rotor**	**Exciter**
FW Unit 1	4.7	10	7.6	7.7
FW Unit 2	3.7	10	7.6	7

HYDROAMP GENERATOR CONDITION ASSESSMENTS

The next set of figures, Figures D-1 thru D-8 are copies of the Tier 1 assessments for HydroAMP scores applicable to the Fish Unit turbines, governors, and exciters. The current conditions of the stator windings are MARGINAL. As documented in the report the turbine runners are both 60 years old and in MARGINAL condition (see figures, below). The governors are fairly new and rated in GOOD condition.

Tier 1 Condition Assessment

Turbine

Plant:	**The Dalles**	Unit:	F1	Type:	Kaplan
Manufacturer:		Partial Rehab Year (non runner):		Rated Power:	(HP)
Rated Head:	(ft)	Discharge Diameter:	(ft)	Speed:	(RPM)

Tier 1 Turbine Condition Assessment

(For Instructions on indicator scoring, please refer to the condition assessment guide)

No.	Condition Indicator	Score	x Weighting Factor	= Total Score
1	In-Service Year Partial Rehab Year (runner) Age: 60 years	0	0.67	0
2	Physical Condition Cracks Cavitation and Surface Damage	3	1.25	3.75
3	Operation Limitations	3	0.5	1.5
4	Corrective Maintenance	1	0.5	0.5
	Turbine Condition Index			5.8 Marginal

Data Quality Indicator	10

Tier 2 Turbine Condition Assessment

(For instructions on how to adjust the Tier 1 Condition Index (CI) by conducting Tier 2 tests or inspections, please refer to the condition assessment guide)

Total Tier 2 Adjustment:	
In this comment box, please list which of the Tier 2 tests or inspections you conducted and note the incremental adjustment for each that was used in calculating the total adjustment reported above:	

Certification Information

Last Assessment Date: **1/25/2017**

Evaluated By: **Caracciolo, Lou on 1/25/2017**

Approved By: **N/A**

Comment on Update: 12/2014 turbine integrity testing completed, no issues noted. 2015 OH, blade packing ring oil leaks repaired. 2014 Assessment: Blade cracks seem to be stable and in a area of compression. 2011 Assessment: Blade cracks continue even w/ periodic repair every 2 years.

Figure D-1. 2017 HydroAMP Assessment for the FU #1 Tier 1 Turbine, Score = 5.8 (MARGINAL)

Tier 1 Condition Assessment

Turbine

Plant:	**The Dalles**	Unit:	F2	Type:	Kaplan
Manufacturer:		Partial Rehab Year (non runner):		Rated Power:	(HP)
Rated Head:	(ft)	Discharge Diameter:	(ft)	Speed:	(RPM)

Tier 1 Turbine Condition Assessment

(For Instructions on indicator scoring, please refer to the condition assessment guide)

No.	Condition Indicator		Score	x Weighting Factor	= Total Score
1	In-Service Year Partial Rehab Year (runner)	Age: 60 years	0	0.67	0
2	Physical Condition Cracks Cavitation and Surface Damage		3	1.25	3.75
3	Operation Limitations		3	0.5	1.5
4	Corrective Maintenance		1	0.5	0.5
	Turbine Condition Index				5.8 Marginal

Data Quality Indicator	10

Tier 2 Turbine Condition Assessment

(For instructions on how to adjust the Tier 1 Condition Index (CI) by conducting Tier 2 tests or inspections, please refer to the condition assessment guide)

Total Tier 2 Adjustment:	
In this comment box, please list which of the Tier 2 tests or inspections you conducted and note the incremental adjustment for each that was used in calculating the total adjustment reported above:	

Certification Information

Last Assessment Date: **1/25/2017**

Evaluated By: **Caracciolo, Lou on 1/25/2017**

Approved By: **N/A**

Comment on Update: Dec 2015 Turbine integrity testing completed, no issues noted. Normal maintenance frequency 2 years

Figure D-2. 2017 HydroAMP Assessment for the FU #2 Tier 1Turbine, Score = 5.8 (MARGINAL)

Tier 1 Condition Assessment

Governor

Plant:	**The Dalles**	Unit:	F1
Manufacturer:		Year Manufactured:	
Year Rehabilitated:			

Tier 1 Governor Condition Assessment

(For Instructions on indicator scoring, please refer to the condition assessment guide)

No.	Condition Indicator		Score	x Weighting Factor	= Total Score
1	Type of Governor Control System		**2**	0.25	0.5
	In-Service Year	Age: 4 years			
2	Operation & Maintenance History		**3**	1.17	3.51
3	Availability of Spare Parts		**1**	0.83	0.83
4	Performance		**2**	1.75	3.5
	Governor Condition Index				**8.3**
					Good

Data Quality Indicator	**10**

Tier 2 Governor Condition Assessment

(For instructions on how to adjust the Tier 1 Condition Index (CI) by conducting Tier 2 tests or inspections, please refer to the condition assessment guide)

Total Tier 2 Adjustment:	Choose numerical value:
In this comment box, please list which of the Tier 2 tests or inspections you conducted and note the incremental adjustment for each that was used in calculating the total adjustment reported above:	

Certification Information

Last Assessment Date: **1/25/2017**

Evaluated By: **Caracciolo, Lou on 1/25/2017**

Approved By: **N/A**

Comment on Update: FY16, HMI touchscreen computer is obsolete, we are precluded from buying replacements by HDC,ACCS. 2013 Assessment: Digital governor installation completed Jan. 2013. 2011 Assessment: New digital governors scheduled for installation starting in 2012.

Figure D-3. 2017 HydroAMP Assessment for the FU #1 Tier 1 Governor, Score = 8.3 (GOOD)

Tier 1 Generator - Winding Condition Assessment

Operation & Maintenance History

Operation and Maintenance normal

3.0

Physical Inspection

Inspection shows significant deterioration

1.0

Insulation Resistance and Polarization Index

Results are Normal and similar to Previous tests

3.0

Winding Age

Multi-turn (>=6.9kV) 20 to 29 years

1.0

Tier 1 Data Quality Indicator

Tier 1 Data Quality Indicator

All completed within the normal testing frequency.

10.0

Tier 2 Adjustment

Tier 2 Adjustment

-1.0

Adjusted Weighted Score

4.7

Figure D-4. Assessment of Generator Winding Condition

a. Partial Discharge (No Change)
b. Ozone (-1.0)

1 year ago

FY16-3Q: Average PD still thought to be result of oil/brake dust contamination; first detection of ozone. FY15 - 2nd Quarter Assessment: PD analysis in March 2014 again produced some discharges having average severity but stable; a visual inspection (cover plates hoisted) in Dec. 2014 found all of the winding insulation to be significantly oily and dirty. 2013 Assessment: In Feb. 2012, partial discharges of average quantity and severity being measured on all three phases. 2011 Assessment: Partial discharges of moderate quantity and moderate severity are being measured on the A-phase winding.

1 year ago

Adjusted Weighted Score	3.7
Tier 1 Generator - Winding Condition Assessment	
Winding Type: Multi-turn	1.0
Maintenance History: Some additional maintenance above normal occurring	2.0
Operational Performance: Operation normal	3.0
Physical Inspection: Inspection results are normal	3.0
Insulation Testing: Results indicate minor decrease in insulation resistance or polarization index	2.0
Data Quality Indicator	
Data Quality Indicator: All completed within the normal testing frequency.	10.0
Tier 2 Generator - Winding Condition Assessment	
Service Age Adjustment Scoring	0.0
Ramped Voltage Test Scoring	0.0
Partial Discharge Measurements Scoring: Widespread and abnormally high PD readings	-2.0
High-Potential Withstand Test Scoring	0.0
Corona Probe Test Scoring	0.0
Dissipation (or Power) Factor Measurements Scoring	0.0
Ozone Monitoring Scoring: Ozone levels < 0.1 ppm	0.0
Black Out Test Scoring	0.0
Wedge Tightness Evaluation Scoring	0.0
Other Specialized Diagnostic Tests	0.0
Tier 1 Condition Index	5.7
Tier 2 Adjustment	-2.0
Adjusted Weighted Score	3.7

Figure D-5. Assessment of Generator Winding Condition

Tier 1 Excitation Condition Assessment

Age

10 to 19 years

3.0

Operation & Maintenance History

Some additional Maintenance above normal occuring

2.0

Availability of Spare Parts

Spare Parts are Unavailable

0.0

Power Circuitry Tests

Power Circuit Elements are Normal

3.0

Control Circuitry Tests

Control Circuitry in Functioning Normally, Stability requirements met

3.0

Tier 1 Data Quality Indicator

Tier 1 Data Quality Indicator

All completed within the normal testing frequency.

10.0

Tier 2 Adjustment

Tier 2 Adjustment

Adjusted Weighted Score

7.0

Figure D-6. Assessment of Excitation Condition, FU #1

Tier 1 Excitation Condition Assessment

Age

10 to 19 years

3.0

Operation & Maintenance History

Operation and Maintenance Normal

3.0

Availability of Spare Parts

Spare Parts are Unavailable

0.0

Power Circuitry Tests

Power Circuit Elements are Normal

3.0

Control Circuitry Tests

Control Circuitry in Functioning Normally, Stability requirements met

3.0

Tier 1 Data Quality Indicator

Tier 1 Data Quality Indicator

All completed within the normal testing frequency.

10.0

Tier 2 Adjustment

Tier 2 Adjustment

Adjusted Weighted Score

7.7

Comments

FY17/2Q: ABB informs us that the DCS501 and DCS501B bridge has been discontinued. 2009 Assessment: Turning off 125VDC control power for extended periods during maintenance results in loss of stored parameters on circuit cards; requires reprogramming.

Figure D-7. Assessment of Excitation Condition, FU #2

Tier 1 Condition Assessment

Governor

Plant:	**The Dalles**	Unit:	F2
Manufacturer:		Year Manufactured:	
Year Rehabilitated:			

Tier 1 Governor Condition Assessment

(For Instructions on indicator scoring, please refer to the condition assessment guide)

No.	Condition Indicator		Score	x Weighting Factor	= Total Score
1	Type of Governor Control System In-Service Year	Age: 3 years	2	0.25	0.5
2	Operation & Maintenance History		3	1.17	3.51
3	Availability of Spare Parts		1	0.83	0.83
4	Performance		2	1.75	3.5
	Governor Condition Index				8.3 Good

Data Quality Indicator	10

Tier 2 Governor Condition Assessment

(For instructions on how to adjust the Tier 1 Condition Index (CI) by conducting Tier 2 tests or inspections, please refer to the condition assessment guide)

Total Tier 2 Adjustment:	Choose numerical value:
In this comment box, please list which of the Tier 2 tests or inspections you conducted and note the incremental adjustment for each that was used in calculating the total adjustment reported above:	

Certification Information

Last Assessment Date: **1/25/2017**

Evaluated By: **Caracciolo, Lou on 1/25/2017**

Approved By: **N/A**

Comment on Update: FY16, HMI touchscreen computer is obsolete, we are precluded from buying replacements by HDC,ACCS. FY14, 3rd Quarter Assessment: digital governor installed in Feb. 2014. 2013 Assessment: Scheduled for digital governor installation Jan. 2014. 2011 Assessment: New digital governors scheduled for installation starting in 2012. 2009 Assessment: Some tuning performed in '08.

Figure D-8. 2017 HydroAMP Assessment for the FU #2 Tier 1 Governor, Score = 8.3 (GOOD)

APPENDIX E – MISCELLANEOUS MECHANICAL SYSTEMS

THE DALLES FISH UNITS RUNNER REPLACEMENT – PERTINENT MECHANICAL SYSTEMS

The following sections are a general discussion and a pros versus cons assessment of select pertinent ancillary mechanical systems. "Machine Condition Monitoring," bearing oil coolers, generator surface air coolers, and emergency closure systems are discussed. These items do not affect a final Recommended Alternative for the new turbine-generator rehabs, but are worthy of discussion.

MACHINE CONDITION MONITORING

Machine Condition Monitoring (MCM) is a critical addition to any new or rehabilitated hydropower generating unit. The Corps has installed machine condition monitoring at multiple projects for various reasons, but all under the premise that plant safety and unit reliability are significantly increased by monitoring unit stability and vibration. Integrated as an interlock required for unit operation, machine condition monitoring provides a level of safety that cannot be achieved otherwise. The associated software allows for trending and improved preventive maintenance.

There are various levels of complexity – data processing, automation, and diagnostics that can be integrated in a machine condition monitoring system. The Corps has a recommended minimum for all hydropower generating units that monitors vibration in critical areas to prevent severe damage. Full scale machine condition monitoring can sense dramatic vibration in multiple areas and record and process corresponding data. These systems are more complex than the Corps' recommended minimum, but can justifiably be installed. Such a decision must be made on a per unit basis by considering overall need, historical operation, available funding, as well as future operational needs.

For The Dalles Fish Units, machine condition monitoring would be particularly insightful in providing operational data to ensure that the Fish Units do not experience an unplanned outage and can continuously perform their primary mission – deliver fish attraction water downstream.

Option 1: No Action ("Do nothing")

Pros

The "do nothing" option is exactly as it sounds. The pros are limited. The only foreseeable advantages to this option lies in foregoing costs due to procurement and construction, and less maintenance.

Cons

The cons associated with the "do nothing" option directly counter the brief detail of advantages outlined above. Personnel safety and unit reliability are jeopardized without proper vibration monitoring. Data analysis cannot be performed so there cannot be trending to support preventive maintenance and intervention prior to a potential failure. The primary purpose of the Fish Units, to deliver water downstream, is jeopardized.

Option 2: Full Scale MCM

Pros

Full scale machine condition monitoring has many benefits. As discussed above, monitoring of vibration levels allows for intervention prior to a potential catastrophic event. Personnel safety and unit reliability can be enhanced. Data is collected and stored for access. Historical data is useful in characterizing a generating unit's vibration levels and supporting proper maintenance. Additionally, in the event of a unit experiencing significant vibration, plant Operations can plan accordingly to minimize downtime and reduced downstream flow.

Full scale MCM in Corps hydropower generating units typically consists of proximity sensors located near bearings, air-gap measurement of stator and rotor, and all associated processing units, hardware, software, and controllers. The instrumentation is typically readily available. The system, as a whole, can be installed by plant personnel which increases their familiarity and overall sense of awareness of the operational characteristics of the generating units.

Cons

The cons of full scale MCM have marginal impacts compared to the pros, or the cons of a lesser MCM option. The costs associated with full scale MCM range from 100 – 600% higher than lesser options, depending on the complexity of instrumentation and automation. It is important to note that these costs will be significantly reduced because the installations occur while a unit is disassembled for rehabilitation. Construction is increased. Engineering and technical effort is increased as well. However, the Corps has historical guidance on MCM design and has established relationships with various MCM equipment suppliers. Additionally, maintenance will be increased for Operations personnel. The level of maintenance can be minimized, however, with the addition of more expensive addressable instrumentation. The overall level of effort is increased, concurrent with cost – so operational tasks and corresponding costs are the foremost disadvantages of a full-scale MCM.

Option 3: Critical Vibration Monitoring (CVM)

Pros

Critical Vibration Monitoring (CVM) has been coined as the term to describe the "recommended minimum" vibration monitoring system for Corps hydropower generating units. See the HDC report entitled *Hydro Turbine-Generator Machine Condition Monitoring Guidelines* from June 6, 2014 for a more in-depth study of why and how CVM should be implemented.

The essence of CVM is a scaled down version of full scale MCM that incorporates proximity probes at the turbine guide bearings to detect sizable vibration changes. An alarm high point triggers an annunciation and can force a unit trip automatically. CVM protects the generating unit from severe damage. Similar to a full scale MCM, CVM can prevent a catastrophic failure event. But rather than promoting preventive maintenance via data trending, CVM simply shuts the unit down before the potential failure occurs. Also, for this reason, CVM enhances the level of safety and protection for plant personnel. In comparison to full scale MCM, costs, construction, and maintenance are significantly reduced, as well is overall effort in part of the design engineers and plant personnel.

Cons

The cons of CVM are a reduced level of protection for the generating unit. The lack of data storage and processing makes data trending much more difficult, and sometimes not possible – depending on the complexity of the data acquisition device. Contrary to full scale MCM, CVM may allow for minor damage to occur to the unit. An example is thrust bearing or upper guide bearing damage due to some misalignment, or unbalance in the upper portions of the turbine-generator. However, vibration limits can be more stringent to force a trip over a larger range of vibration levels. CVM employs less monitoring, therefore it may be difficult to diagnose a potential issue.

A Developing Alternative (Hypothetical Option 4)

The USACE is currently investigating a “middle-of-the-road” alternative in which there could be more monitoring locations and a higher level of data acquisition and processing than what is typical for CVM. This option would not quite meet criteria that is typical for full scale MCM, however. As the Corps makes determinations about this option, the option might be pursued for The Dalles Fish Units.

Costs

The costs in Table E-1 were compiled from historical and manufacturer data. The ranges encompass various levels of complexity. For full-scale MCM and CVM, these can be described as the following:

- Full Scale MCM: amount of automation, limits of data storage, and levels of data processing – these factors significantly affect cost.
- CVM: options for supplementary sensors, levels of data processing – these factors significantly affect cost.

Table E-1. Estimated Itemized ROM Costs Per Unit

Machine Condition Monitoring Options	One-time costs				Annual costs
	Materials	Installation[1]	Engineering	Contracting	Software Updates
Option 1: Do nothing	$0	$0	$0	$0	$0 [4]
Option 2: Full Scale MCM	$58,000 - $102,000	$40,000 - $70,000	$8,000 - $20,000	–	$4,000 - $8,000
Option 3: CVM	$4,000 - $10,000	$10,000 - $15,000	$2,500 - $6,000	–	$2,000 – $4,000
Option 4: (Hypothetical) [2]	$30,000 - $40,000	$30,000 - $40,000	$3,000 - $8,000	–	$20,000 - $40,000 [3]

[1] Installation costs are for in-house installation, performed by Project personnel.

[2] Option 4 costs are hypothetical.

[3] Software updates for Option 4 include annual maintenance and data reports.

[4] No-action costs could be determined as the costs of catastrophic failures or costs of operational inefficiencies.

Table E-2. Estimated MCM Total ROM Costs, Per Unit [1]

Option 1: Do nothing	$0 [3]
Option 2: Full Scale MCM	$110,000 - $200,000
Option 3: CVM	$18,500 - $35,000
Option 4: (Hypothetical) [2]	$83,000 - $128,000

[1] Total ROM includes one-time costs and first year of annual recurring costs.

[2] Option 4 costs are hypothetical.

[3] No action costs could be determined as the costs of catastrophic failures or costs of operational inefficiencies.

Recommended Option

The recommended option is Option 3, Critical Vibration Monitoring. This option is the recommended minimum for all Fish Unit turbine-generator rehabilitation alternatives. The Fish Units possess a certain importance that has far-reaching effects on citizens of the Northwest and assures the livelihood of salmon as they migrate through Corps dams. The consequence of an unplanned outage or catastrophic failure cannot be easily accommodated and for this reason, Option 3 meets the requirements of this Turbine-Generator Rehabilitation study. Option 2 is not preferred due to unnecessary additions of a monitoring system that would be sufficient with the features that are included in Option 1.

THRUST BEARING and GENERATOR GUIDE BEARING OIL COOLERS

The thrust bearing and upper guide bearing share cooled lube oil. Both bearings are contained within an oil tub. Also, within the oil tub is a copper, finned, coiled tube oil cooler. The oil is circulated within the oil tub by the rotary motion of the generator shaft. Cool river water is pumped through the oil cooler and removes the heat absorbed by the lube oil.

As described in the *Existing Conditions*, section of this report, these oil coolers – termed Internal Bearing Oil Coolers – have reached the end of their useful service life. Maintenance and repairs are more frequent than acceptable. Accessing the coolers is difficult, requiring a partial unit unstack. Replacement coolers are completely justified for these reasons. Additionally, it is standard procedure to replace and modernize these coolers during a unit rehabilitation.

For the replacement, two options are considered: internal bearing coolers and external bearing coolers. The following sections review the pros and cons of each alternative, and provide a recommended option that the PDT could pursue as the job progresses into Phase 1. It is important to note that HDC performed an in-depth study of replacement thrust bearing oil coolers for all of The Dalles hydropower generating units. Many of the points discussed in this text are drawn from the *Phase 1A Report for The Dalles Powerhouse Thrust Bearing Oil Cooler Replacement*.

Lower Guide Bearing Oil Coolers

The lower guide bearing lube oil is cooled by a finned tube cooler that is immersed in oil in the in the lower guide bearing oil tub – also considered an Internal Bearing Oil Cooler. Cool river water flows through the tube and draws the heat out of the oil and is discharged back into the river. The rotating shaft journal creates a mixing action that assists is distributing cool oil amongst the bearing pads.

Similarly to the thrust and upper guide bearing cooler, the aging lower guide bearing cooler should be replaced. Maintenance is more frequent than what is acceptable. Repairs require significant down time and are unreasonably difficult. In a turbine-generator rehabilitation, the Corps' standard procedure is to replace these coolers. This ensures a renewed reliability for years of continuous use. For the replacement, the Corps is examining two options – internal bearing coolers and external bearing coolers. The following text will describe the pros and cons of each option as they apply to The Dalles Fish Units.

Option 1: Internal coolers (replace in-kind)

Pros

Replacement of the existing internal coolers with new internal coolers is a practical "replacement in-kind." The design of the coolers will not change. All of the efforts associated with engineering, procurement, and installation will be at a minimum. Internal coolers are proven to be simple, reliable, and functional. Maintenance is relatively infrequent when considering the years identified to be within the "useful service life" of the cooler, typically 15-20 years. Shop drawings of the existing coolers are available. Overall, replacement of the existing internal coolers with new internal coolers is the simplest and most cost effective option to provide the necessary cooling to the bearing lube oil.

Cons

A "replacement in-kind" introduces the potential for failure with consequences that are unacceptable under the current operational requirements of the Fish Units. The coolers can essentially fail in only one fashion, and that is a leak. The consequences of a leak can be significant. If oil enters the cooler, it could eventually wind up in the Columbia River. A more likely scenario is that the cooling water enters the oil tub and damages the bearings. Either scenario will necessitate a repair of the cooler. Maintenance and repair is a significant effort. The generator has to be partially unstacked. Outage times are too excessive to ensure that the required downstream flow conditions are met. If both Fish Units happen to have cooler failures, the downstream fish channels cannot adequately coerce migrating salmon through the fish ladders.

A replacement in-kind has the immediate benefit of ease and low cost. But the consequences of an eventual failure make this option undesirable.

Option 2: External coolers

Pros

External bearing oil coolers are becoming more common for Corps hydropower generating units. They nearly eliminate the potential for oil discharge into the river. Leaks are more easily detected and have practically zero impact on operation of the unit. Routine maintenance is not complex and the components of an external bearing cooler can be readily stocked as spares. Additionally, the coolers can be designed with redundancy so that maintenance and repairs do not cause an outage. External bearing coolers are installed on other Main Stem Columbia River Plants – Bonneville 1 and McNary. For The Dalles Fish Units, external bearing coolers provide a relief from the inevitable failure and outage that accompany an internal bearing cooler.

Cons

External bearing coolers present an initial higher investment in both dollars and effort. Engineering is significantly increased with the need for in-depth scoping and studying to discern the best locations and configurations of an external cooling system. The procurement of materials itself is not significant, but compared to an internal cooler, more involved. Construction and commissioning activities are considerable and it can be difficult to modify the system once commissioning starts. Construction efforts will involve modifications of the existing water and oil supply/return systems. Phase 1 work, Plans and Specifications, must be extremely thorough to ensure the contractor provides the system required by the unit. Routine maintenance is increased, as plant personnel will need to perform daily checks to ensure continued operation. Overall, the increased initial investment of time and money is the primary disadvantage.

Estimated Total ROM Costs Per Unit

The *Phase 1A Report for The Dalles Powerhouse Thrust bearing Oil Cooler Replacement* contains detailed cost information. For the purpose of the ROM cost evaluation, the numbers presented in that report are used. The report was finalized in September, 2015. The numbers in Table E-3 are representative of material procurement, installation, engineering, and contracting. Inflation of 3% has been added to account for 2016 and 2017.

Table E-3. Estimated Total ROM Costs Per Unit

	Thrust/Upper Guide Bearing	Lower Guide Bearing	TOTAL
Option 1: Internal Bearing Coolers w/ sump modifications	$114,059	$114,059	$228,119
Option 2: External Bearing Coolers	$209,084	$209,084	$418,168

Recommended Option

The recommended option is Option 1, Internal Bearing Cooler. But, this comes with the caveat that the access constraints are remedied – i.e. sumps shall be modified so that access to the thrust and upper guide bearing is possible without necessitating a partial unit unstack. After a visual inspection of the thrust/upper guide bearing, it seems feasible to add an access hatch on the perimeter of the sump that would allow install and removal of the cooler. The lower guide bearing sump will remain the same – access to this sump does not require a partial unit unstack. If a structural assessment reveals that the thrust and upper guide bearing cannot be modified, the recommended alternative then is Option 2.

SURFACE AIR COOLERS

The surface air coolers perform heat removal within the generator shroud and are a critical piece of equipment for ensuring continued operation of the Fish Units. It is standard Corps practice to replace and modernize these air coolers during a unit rehabilitation. Additionally, the *Existing Conditions* section of this report reveals that the existing coolers have a history of maintenance issues. There are no alternatives that address evaluating the surface air coolers. The air coolers will be sized to accommodate the required cooling capacity within the generator shroud.

Costs

The costs associated with replacement air coolers include all of the material procurement, installation, engineering, and contracting. In addition to replacing the coolers, there will likely be pipe replacement and minor modifications to retrofit new coolers. The expected Rough Order of Magnitude (ROM) costs per unit for new surface air coolers is $80,000.

EMERGENCY CLOSURE – GENERAL

Emergency closure is not be pursued in this Phase 1A study. The magnitude of engineering and construction justifies that this approach would be a stand-alone contract for the future. However, it is important to discuss during this turbine-generator rehabilitation since rehabilitation with new systems can influence emergency closure. The Fish Units do not have a final line of defense to stop the flow of water into the scroll case. The wicket gate servomotor cylinders are outfitted with a nitrogen booster system to quickly close the wickets gates to stop the flow of water past the turbine. But a catastrophic head cover failure might not be avoided.

Alternatives for emergency closure are developing every day. New, environmentally “acceptable” oils can be used in place of typical petroleum based hydraulic fluid such that dedicated cylinders and affixed emergency head gates can achieve the emergency closing. Other Corps plants have dedicated gantry cranes with hoisting capable of lowering the emergency gates (e-gates) in under 10 minutes – the Corps standard. Fixed hoisting machinery for both Fish Units could also be pursued, but these components introduce a footprint that might not be available at the plant and they might not meet the performance requirements for an emergency closure system.

The likely alternative will be new, dedicated cylinders that are mounted above the gate slots and lower the e-gates immediately and automatically. These gates will utilize a fluid that the Corps has vetted and deemed acceptable. This alternative [and others] will be investigated in the future.

APPENDIX F – SHAFT STRESS ANALYSIS

This Appendix presents that shaft stress analysis for uprating the existing Kaplan turbine runners to higher kW outputs of the generators.

GIVEN: 1. Shaft dimensions for turbines and generators.

2. Weights of shafts and rotating Components.

3. Hydraulic thrust of the turbine.

4. Material is ASTM 235-52T, class E which has yield = 37.5 ksi and tensile = 75 ksi.

Calculations were performed using the pertinent dimensions of the shaft and component weights to determine the maximum torsional load and therefore the generator output that the shaft can deliver. The turbine shaft would be able to deliver 20.4 MVA at a generator efficiency of 98% and a maximum shear stress of 6,000 psi. The generator shaft would be able to deliver 17.92 MVA at a generator efficiency of 98% and a maximum shear stress of 6,000 psi. The generator shaft is one inch smaller than the turbine shaft and is therefore the limiting factor on the shaft loading capability.

The maximum output the rotating components can deliver therefore is 17.92 MVA.

THE DALLES FISH WATER TURBINES, GENERATOR SHAFT – CALCULATION

$$\tau_{\text{allowable}} = \left[(\tau_{max})^2 - \left(\frac{\sigma_{axial}}{2}\right)2\right]^{½}$$

$$\tau = \frac{\tau_{\text{allowable}} J}{c}$$

$$J = \frac{\Pi}{32}\left(\text{OD}^4 - \text{ID}^4\right)$$

$$c = \frac{\text{OD}}{2}$$

$$\text{hp} = \frac{n\tau_{max}}{63{,}025}$$

Table F-1. Stress calculations for the turbine and generator shafts

Component	Generator	Turbine	Units
Generator Shaft:	19	20	inch, Outside Diameter (OD)
	7.375	9.75	inch, Inside Diameter (ID)
Generator Shaft Area:	240.81	239.50	in^2
Turbine Rotating Elements	51,600	51,600	lb. Turbine Drawings and calcs
Rotor and Generator Shaft	171,750	171,750	lb. Turbine Drawings and calcs
Total rotating weight below thrust bearing	223,350	223,350	lb.
Hydraulic thrust	376,000	376,000	estimate
Total Suspended Weight:	599,350	599,350	lb.
Stress in Turbine Shaft, σ_T:	2,488.89	2502.53	psi
τ_{max}:	6,000	6,000	psi
$\tau_{allowable}$:	5,870	5,868	psi
J:	12,504	14,821	in^4
c:	9.5	10.0	in
T_{max}:	7,725,411	8,696,942	lb-in
Shaft Speed	200	200	rpm
Turbine Output:	24,515	27,598	hp
Generator Output @ 98.0% efficiency	17.92	20.17	MW

APPENDIX G – FISH WATER TURBINE PROJECT DATA

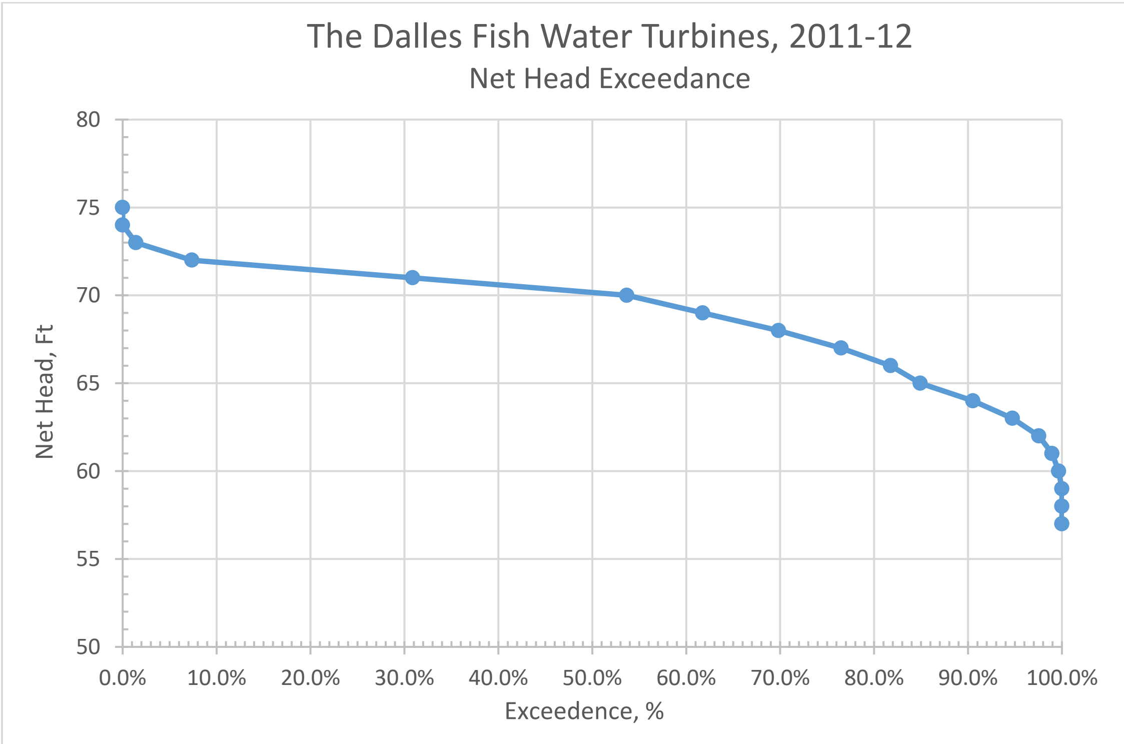


Figure G-1. The Dalles Fish Water Turbines, 2011 – 2012, Net Head Exceedance

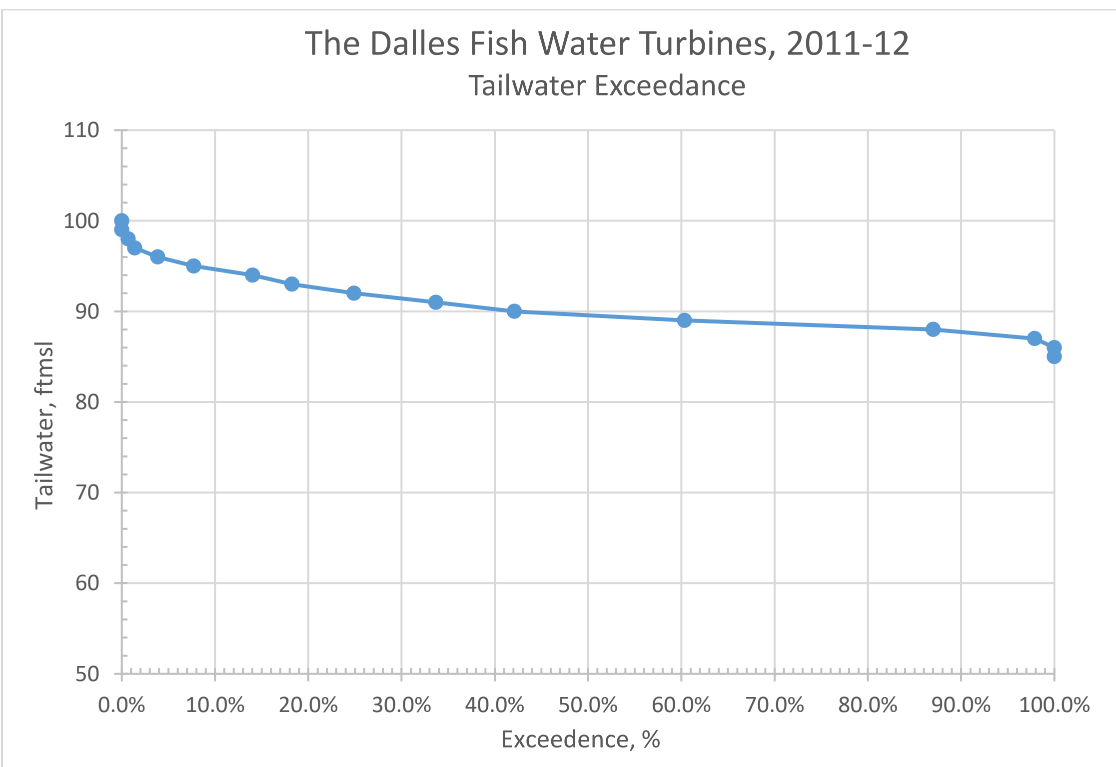


Figure G-2. The Dalles Fish Water Turbines, 2011 – 2012, Tailwater Exceedance

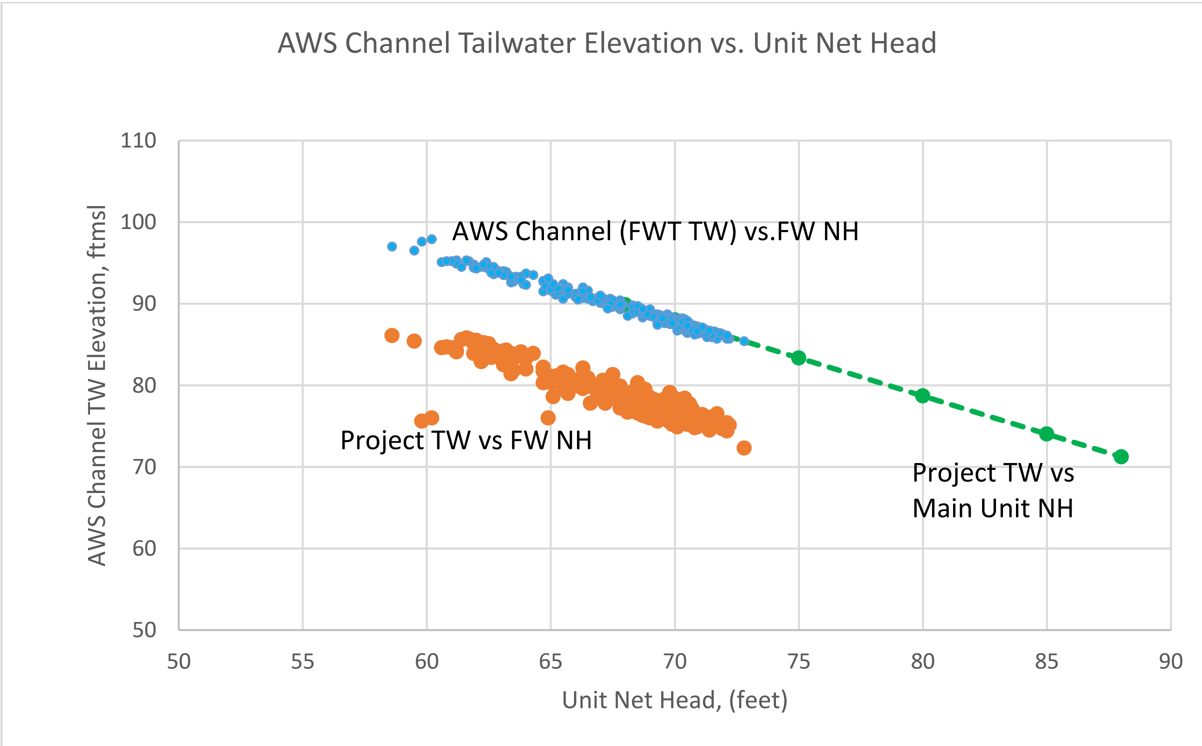


Figure G-3. The Dalles AWS Channel Tailater Elevation vs. Unit Het Head

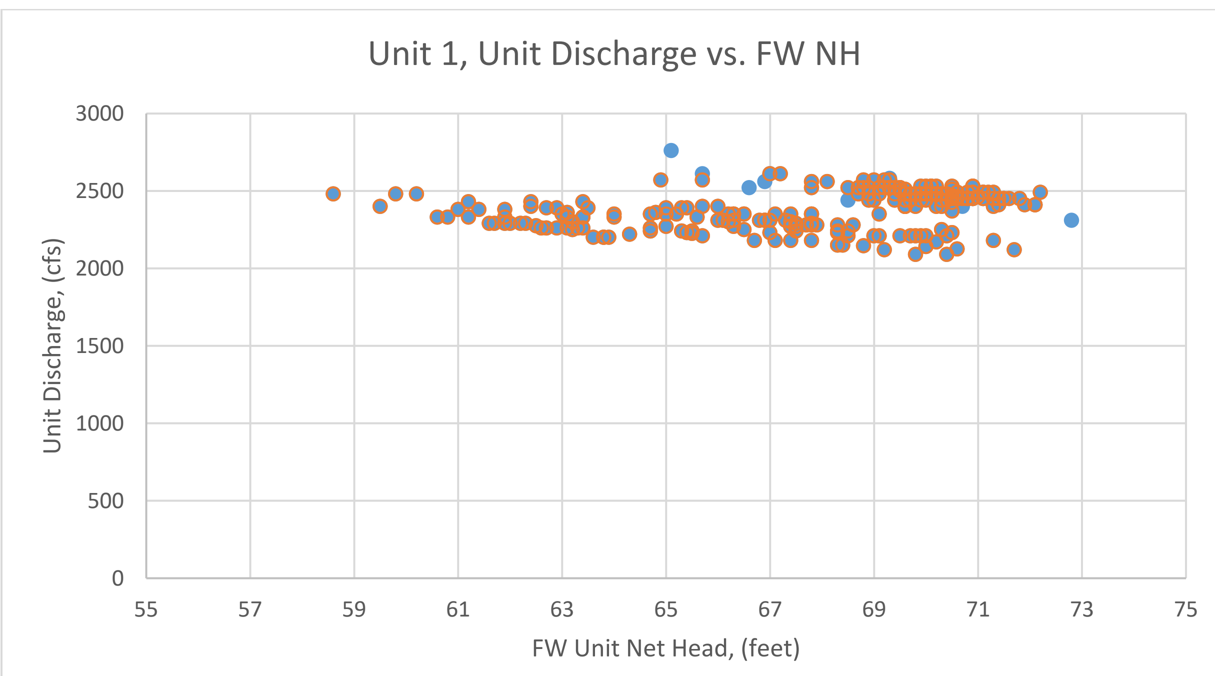


Figure G-4. The Dalles Fish Unit #1, Discharge (cfs) vs. Net Head (ft)

APPENDIX H – EXCITER BRUSHES AND BRUSH HOLDERS

The Fish Water Units (FUs) are operated to deliver continuous flow to the fish ladders. These generators see near continuous operation throughout a year at a loading of 70-75% of full nameplate capacity. The rated field current is 460 Amperes. At the nameplate capacity, the unit requires approximately 310 Amperes of field current.

FISH UNIT BRUSH WEAR ISSUES

The Dalles maintenance staff noticed excessive brush wear for The Dalles Fish Units since at least 2011. These problems are heavy threading, medium-to-heavy film, circulating current in brush holders. Staff engaged The Dalles engineering, HDC, and Helwig, the brush manufacturer, in troubleshooting and developing a solution. Wear issues are still unresolved, as excessive wear is considered less than two years of operation. The Project team has reported that some years, they've had to replace the brushes annually.

Brushes require a sufficient current density to cause gasification of the carbon brush material. The thin layer of off-gassing is actually the conductive medium between the brush and the surface of the slip ring. If the brush rides directly on the ring without the gaseous interface, it experiences mechanical wear. Mechanical wear is evident with threading in the brush face, streaking and filming on the ring, and excessive dusting in the housing. The dusting often coats the surface of the holder and insulating standoffs in the brush housing area, reducing the dielectric strength.

The gasification layer is very thin – only a few atoms of total thickness. In addition to the need to select the right current density for the operational case, the brushes must be aligned, faced, and seated with an appropriate pressure to maintain pressure against the slip ring as the unit "skates" within its guide bearing clearances.

It is also possible to increase the current density too far. In this case, the brushes will begin to exhibit pitting and possibly arcing damage, overheating, and other wear indicators. The case of The Dalles Fish Units is unique in that the generators run continuously at a partial load. Generally, brushes are selected for the maximum current passage under the assumption that they will spend minimal time at lower output values. With partial loading, it appeared that the brushes were wearing mechanically due to insufficient current density. This problem was further exacerbated by the continuous operation throughout the year. Without a protective gaseous layer, the mechanical wear was acting on the brushes continuously throughout the year causing them to wear significantly faster.

The recommended current density for ideal wear with the original brushes is 35-40 Amperes per square inch. The recommended current density for ideal wear with the new brushes is 40-60 Amperes per square inch.

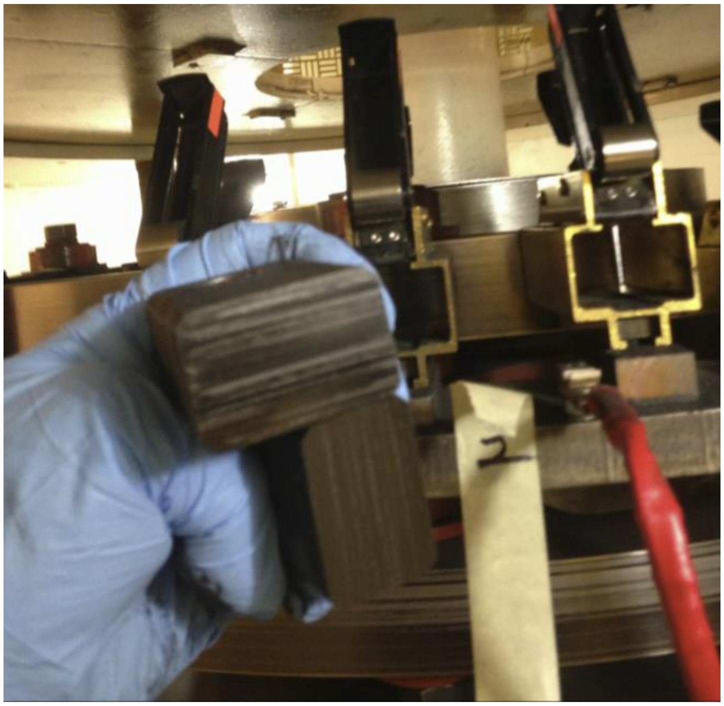


Figure H-1. Brush threading and uneven wear

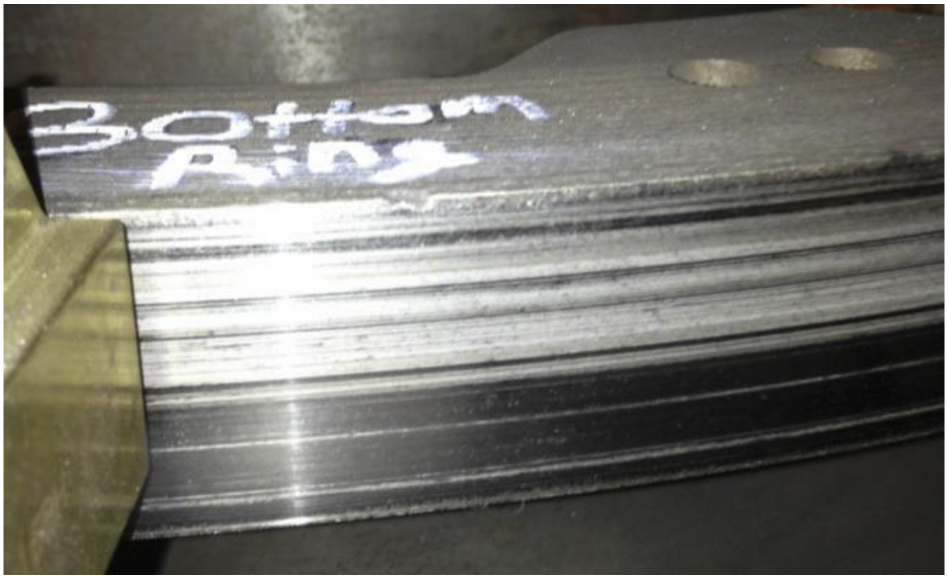


Figure H-2. Film and streaking

MITIGATION OF WORK

The Dalles Project staff initially worked with Helwig representatives to correct the issues noted in paragraph 0. The following mitigating work was performed:

- Brush type changed to a harder brush (Type H552 – the same as the main units)
- Corrected distance between brush holder box and slip ring to 1/8” – 3/16”, plus runout
- Corrected spring pressure to 5 - 6 lbs, change maintenance schedule to replace every 5 years regardless of pressure
- Change maintenance schedule to change polarity every two years

One final recommendation that was not initiated at this time was dropping a brush to increase the current density. At the average loading level, which is held consistent throughout the year, the calculations for current density are shown in Table H-1. Dropping a brush would achieve the current density shown in Table H-2.

Table H-1. Brush calculations with all brushes installed

6	Number of brushes
1.5	Square Inches / brush
9	Total Square Inches
460	Rated Field Current, Amps
310	Average Field Current, Amps
51.11	Current Density at Rated Field Current Amps / Sq. In.
34.44	Current Density at Average Field Current Amps / Sq. In.

Table H-2. Brush calculations with one brush removed

5	Number of brushes
1.5	Square Inches / Brush
7.5	Total Square Inches
460	Rated Field Current, Amps
310	Average Field Current, Amps
61.33	Current Density at Rated Field Current Amps / Sq. In.
41.33	Current Density at Average Field Current Amps / Sq. In.

In January of 2014, both a Helwig representative and HDC engineers traveled to The Dalles to discuss the brush wear issues. Existing actions were reviewed in conjunction with the exhibited wear.

The following actions were recommended and completed by The Dalles Maintenance and engineering:

- Clean rings
- Remove one brush – position six was selected
- Perform inspections during the year
- Each slip ring was stoned and polished/sealed with oak
- The bottom bevel on each brush was brought as close to 0 degrees as possible

Removing a second brush was also considered. As shown in Table H-3, removing a second brush puts the average operational current density toward the upper end of the acceptable values before wear begins to increase from excessive current. The consensus at the time was to remove one, inspect and determine if the additional brush needed to be removed.

Table H-3. Brush calculations with two brushes removed

4	Number of brushes
1.5	Square Inches / Brush
6	Total Square Inches
460	Rated Field Current, Amps
310	Average Field Current, Amps
76.67	Current Density at Rated Field Current Amps / Sq. In.
51.67	Current Density at Average Field Current Amps / Sq. In.

Additional testing also showed evidence of selective action – where resistance between brush and ring changes causing current to “skip” around the brush set – or current imbalance. The provided values were tabulated in Table H-4.

Table H-4. 2014 Fish Unit 1 brush current measurements at 14 MW load

Brush Type	**H552**						
Current, Amperes at 14 MW load	Position	1	2	3	4	5	6
	Top Ring	57	57	60	62	80	Removed
	Bottom Ring	57	59	66	56	84	Removed

Initial discussion focused on removing the second brush as originally proposed. Also considered was switching to a composite grade electrographite brush. During these discussions it was also proposed that the differential brush height with the removed brush position 6 could lead to a poor conductive film deposition for the corresponding height brush – brush 3 – relative to the remaining brushes as shown in photo 3.

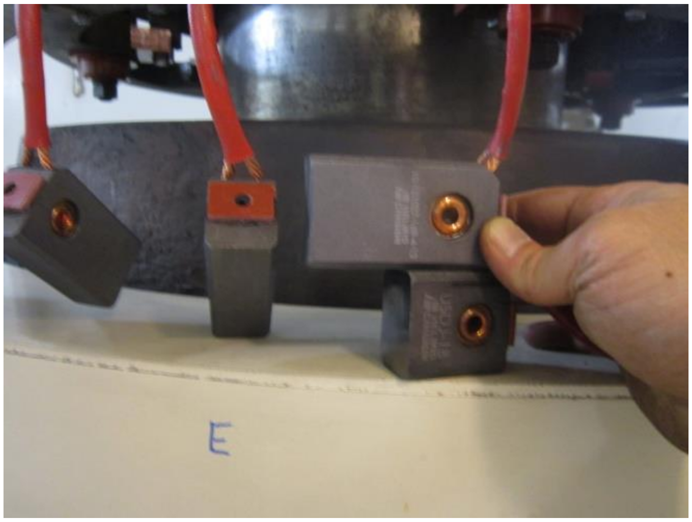


Figure H-3. Generator Brushes

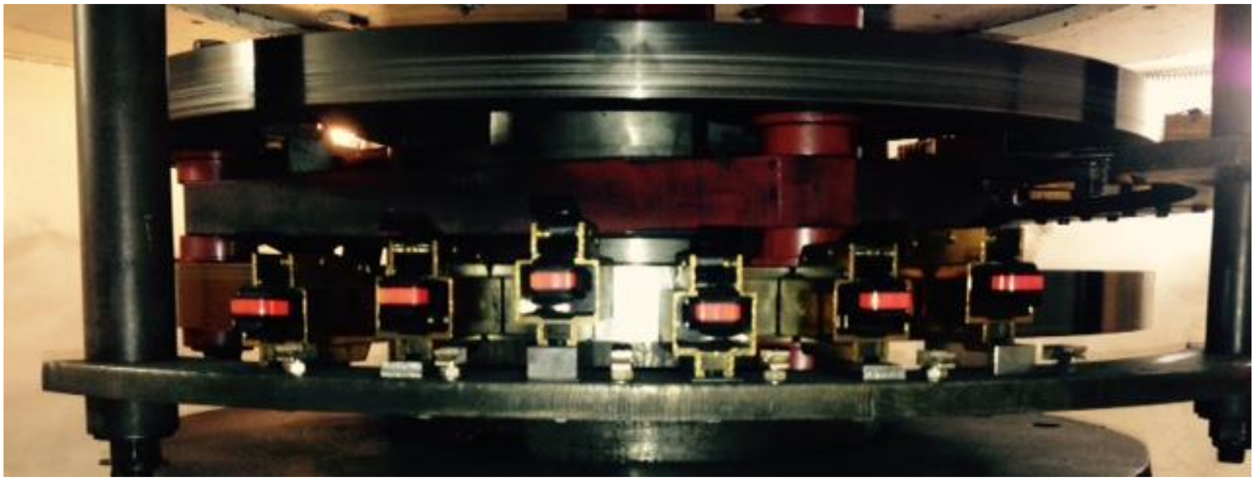


Figure H-4. Brush height distribution

Project Maintenance History

2012/2013

- Changed to a brush of greater density, type HS502.
- Installed “quick clips” on the brush rigging to except main unit brushes, and increasing surface area of the connector.
- Machined and polished slip rings to zero run out, these brush boxes and springs don’t require any.
- Changed out damaged brush boxes for new and set between 1/8” - 3/16” plus run out away from slip ring.
- Made one piece shims to obtain same elevation of brush box on ring as 2-3 shims which are installed now.
- Checked spring tension it should be between 5-6 Lbs.
- Changed polarity on our slip rings every other year, odd unit odd year even unit even year.

2013/2014:

- The slip rings was polished – the project stoned each ring.
- One brush was removed from each ring.
- All brushes exhibiting wear was replaced.
- In August one brush was found to have excessive wear – 1 ¾ in. past replacement point. Emergency outage taken to replace and clean rings. Slip ring condition improved, but brush selectivity is still present.

2014/2015:

- Dropped one more brush per ring for a total of 4 brushes per ring and monitored brush current.
- Rings were polished with untreated canvas.
- Cleaned units.
- FU2 had a brush with high current so it was changed back to 5 brushes per ring.

March 2015:

- To increase the operational range of the fish units the type HH brush was installed on both units. This brush would allow us to operate at 75 A/in^2 providing the extra range needed if one of the fish units had an emergency shutdown.
- After 28 days of operation, there was excessive wear on one brush 3/8" and ¼" on a couple other brushes. There was also a significant amount of carbon dust buildup for the 28 day period. The units were brought back down, cleaned and the type HS502 brushes were re-installed on both Fish Units with five brushes per ring.
- Since this outage there has been some selectivity with the brushes, but less overall. In June the units were brought back down and the rings were stoned on 6/4/15. Since this date there doesn't appear to be any selectivity issues and the amount of wear appear to be normal, ~1/8th inch.

February 2016:

- Changed out brushes on FU1 to Mersen type ED34G. Trying alternate manufacturer due to higher range of operation, 35-77 A/sq. in., as opposed to the Helwig type HS502, 35-60 A/sq. in. Brush boxes and connection to bus bar replaced. Installed 5 brushes per ring.

March/April 2016:

- Significant wear noted on one brush on the top ring of FU1 as well as low current on a couple brushes. FU1 had significant dusting in compared with FU2.

June 6, 2016:

- Shutdown on FU1 to replace brushes and clean the unit. One brush on top ring had 5/8" wear since February install. Unit cleaned, all brushes replaced on top ring and reduced to 4 brushes per ring. Once returned to service, brush currents look good, within 20% of each other range of 42-64 A/sq.in.

August 3, 2016:

- Unit shutdown for ROV inspection. Brushed inspected, ½" wear on brushes that were installed in June on top ring. Unit cleaned and no brushes replaced. Note, brush wear on bottom ring was ½" since February. This is around the expected normal wear rate projected by Mersen, 1/8" per 1000 operating hours. (161 days since FU1 went into service in February until Aug 1. Not accounting for the outage times, this is 3864 hours)

September 30, 2016:

- Significant wear noted on FU1 top ring brush. Brush not expected to last until December outage. Outage being planned for replacement and clean up.

October 11, 2016:

- Forced outage of FU1 due to wear on brushes. Cleaned carbon dust and replaced brush.

December 2016 - February 2017:

- Removed Mersen brushes on FU1 due to excessive dusting and reduced brush life. Reinstalled Helwig type HS502 brushes, 5 per ring, brush boxes and quick clip connection to bus bar.

APPENDIX I – COST ANALYSIS

Table I-1. The Dalles Turbine Runner and Generator Refurbishment, Total Project Cost Summary for Alternative B

**** TOTAL PROJECT COST SUMMARY ****

Printed:1/8/2019
Page 1 of 11

PROJECT: TDA Fish Unit Rehab_Recommended Alternative B
PROJECT NO: 0
LOCATION: The Dalles Dam

DISTRICT: Portland District CENWP
POC: CHIEF, COST ENGINEERING, Eileen Rodriguez
PREPARED: 1/8/2019

This Estimate reflects the scope and schedule in report; Phase 1A Report

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2018 Effective Price Level Date: 1 OCT 17									
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	TOTAL ($K) J	Spent Thru: 1-Oct-17 ($K)	TOTAL FIRST COST ($K) K	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
07	POWER PLANT	$15,200	$3,192	21.0%	$18,392	0.0%	$15,200	$3,192	$18,392	$0	$18,392	6.7%	$16,219	$3,406	$19,625
	CONSTRUCTION ESTIMATE TOTALS:	$15,200	$3,192		$18,392	0.0%	$15,200	$3,192	$18,392	$0	$18,392	6.7%	$16,219	$3,406	$19,625
30	PLANNING, ENGINEERING & DESIGN	$4,180	$878	21.0%	$5,058	0.0%	$4,180	$878	$5,058	$0	$5,058	7.4%	$4,490	$943	$5,432
31	CONSTRUCTION MANAGEMENT	$2,204	$463	21.0%	$2,667	0.0%	$2,204	$463	$2,667	$0	$2,667	13.8%	$2,508	$527	$3,034
	PROJECT COST TOTALS:	$21,584	$4,533	21.0%	$26,117		$21,584	$4,533	$26,117	$0	$26,117	7.6%	$23,216	$4,875	$28,091

Table I-2. The Dalles Turbine Runner and Generator Refurbishment, Contract Cost Summary for Alternative B

**** TOTAL PROJECT COST SUMMARY ****

Printed:1/8/2019
Page 2 of 11

**** CONTRACT COST SUMMARY ****

PROJECT: TDA Fish Unit Rehab_Recommended Alternative B
LOCATION: The Dalles Dam
This Estimate reflects the scope and schedule in report; Phase 1A Report

DISTRICT: Portland District CENWP
POC: CHIEF, COST ENGINEERING, Eileen Rodriguez
PREPARED: 1/8/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)					
		Estimate Prepared: Effective Price Level:			8-May-18 1-Oct-17	Program Year (Budget EC): Effective Price Level Date:			2018 1 OCT 17						
				RISK BASED											
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	TOTAL ($K) J	Mid-Point Date P	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
	PHASE 1 or CONTRACT 1													
07	POWER PLANT	$15,200	$3,192	21.0%	$18,392	0.0%	$15,200	$3,192	$18,392	2021Q2	6.7%	$16,219	$3,406	$19,625
	CONSTRUCTION ESTIMATE TOTALS:	$15,200	$3,192	21.0%	$18,392		$15,200	$3,192	$18,392			$16,219	$3,406	$19,625
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$380	$80	21.0%	$460	0.0%	$380	$80	$460	2019Q3	6.0%	$403	$85	$487
1.0%	Planning & Environmental Compliance	$152	$32	21.0%	$184	0.0%	$152	$32	$184	2019Q3	6.0%	$161	$34	$195
15.0%	Engineering & Design	$2,280	$479	21.0%	$2,759	0.0%	$2,280	$479	$2,759	2019Q3	6.0%	$2,417	$507	$2,924
1.0%	Reviews, ATRs, IEPRs, VE	$152	$32	21.0%	$184	0.0%	$152	$32	$184	2019Q3	6.0%	$161	$34	$195
1.0%	Life Cycle Updates (cost, schedule, risks)	$152	$32	21.0%	$184	0.0%	$152	$32	$184	2019Q3	6.0%	$161	$34	$195
1.0%	Contracting & Reprographics	$152	$32	21.0%	$184	0.0%	$152	$32	$184	2019Q3	6.0%	$161	$34	$195
3.0%	Engineering During Construction	$456	$96	21.0%	$552	0.0%	$456	$96	$552	2021Q2	13.8%	$519	$109	$628
2.0%	Planning During Construction	$304	$64	21.0%	$368	0.0%	$304	$64	$368	2021Q2	13.8%	$346	$73	$419
1.0%	Project Operations	$152	$32	21.0%	$184	0.0%	$152	$32	$184	2019Q3	6.0%	$161	$34	$195
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$1,520	$319	21.0%	$1,839	0.0%	$1,520	$319	$1,839	2021Q2	13.8%	$1,729	$363	$2,093
2.0%	Project Operation:	$304	$64	21.0%	$368	0.0%	$304	$64	$368	2021Q2	13.8%	$346	$73	$419
2.5%	Project Management	$380	$80	21.0%	$460	0.0%	$380	$80	$460	2021Q2	13.8%	$432	$91	$523
	CONTRACT COST TOTALS:	$21,584	$4,533		$26,117		$21,584	$4,533	$26,117			$23,216	$4,875	$28,091

Table I-3. The Dalles Turbine Runner and Generator Refurbishment, Total Project Cost Summary for Alternative C

**** TOTAL PROJECT COST SUMMARY ****

Printed:1/8/2019
Page 1 of 11

PROJECT: TDA Fish Unit Rehab_Next Best Alternative C
PROJECT NO: 0
LOCATION: The Dalles Dam

DISTRICT: Portland District CENWP
POC: CHIEF, COST ENGINEERING, Eileen Rodriguez
PREPARED: 1/8/2019

This Estimate reflects the scope and schedule in report; Phase 1A Report

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2018; Effective Price Level Date: 1 OCT 17									
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	TOTAL ($K) J	Spent Thru: 1-Oct-17 ($K)	TOTAL FIRST COST ($K) K	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
07	POWER PLANT	$17	$4	21.0%	$20	0.0%	$17	$4	$20	$0	$20	7.8%	$18	$4	$22
	CONSTRUCTION ESTIMATE TOTALS:	$17	$4		$20	0.0%	$17	$4	$20	$0	$20	7.8%	$18	$4	$22
30	PLANNING, ENGINEERING & DESIGN	$4	$1	21.0%	$5	0.0%	$4	$1	$5	$0	$5	8.5%	$4	$1	$5
31	CONSTRUCTION MANAGEMENT	$2	$0	21.0%	$2	0.0%	$2	$0	$2	$0	$2	16.1%	$2	$0	$3
	PROJECT COST TOTALS:	$23	$5	21.0%	$28		$23	$5	$28	$0	$28	8.6%	$25	$5	$30

Table I-4. The Dalles Turbine Runner and Generator Refurbishment, Contract Cost Summary for Alternative C

**** TOTAL PROJECT COST SUMMARY ****

Printed:1/8/2019
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**** CONTRACT COST SUMMARY ****

PROJECT: TDA Fish Unit Rehab_Next Best Alternative C
LOCATION: The Dalles Dam
This Estimate reflects the scope and schedule in report; Phase 1A Report

DISTRICT: Portland District CENWP
POC: CHIEF, COST ENGINEERING, Eileen Rodriguez
PREPARED: 1/8/2019

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 8-May-18 Effective Price Level: 1-Oct-17				Program Year (Budget EC): 2018 Effective Price Level Date: 1 OCT 17								
WBS NUMBER A	Civil Works Feature & Sub-Feature Description B	COST ($K) C	CNTG ($K) D	RISK BASED CNTG (%) E	TOTAL ($K) F	ESC (%) G	COST ($K) H	CNTG ($K) I	TOTAL ($K) J	Mid-Point Date P	INFLATED (%) L	COST ($K) M	CNTG ($K) N	FULL ($K) O
	PHASE 1 or CONTRACT 1													
07	POWER PLANT	$17	$4	21.0%	$20	0.0%	$17	$4	$20	2021Q4	7.8%	$18	$4	$22
	CONSTRUCTION ESTIMATE TOTALS:	$17	$4	21.0%	$20		$17	$4	$20			$18	$4	$22
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
1.0%	Planning & Environmental Compliance	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15.0%	Engineering & Design	$3	$1	21.0%	$4	0.0%	$3	$1	$4	2019Q3	6.0%	$3	$1	$4
1.0%	Reviews, ATRs, IEPRs, VE	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
1.0%	Life Cycle Updates (cost, schedule, risks)	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
1.0%	Contracting & Reprographics	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
3.0%	Engineering During Construction	$1	$0	21.0%	$1	0.0%	$1	$0	$1	2021Q4	16.1%	$1	$0	$1
2.0%	Planning During Construction	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
1.0%	Project Operations	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$2	$0	21.0%	$2	0.0%	$2	$0	$2	2021Q4	16.1%	$2	$0	$3
2.0%	Project Operation:	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
2.5%	Project Management	$0	$0	21.0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	CONTRACT COST TOTALS:	$23	$5		$28		$23	$5	$28			$25	$5	$30

Table I-5. O&M Cost Reductions Due to Improved Operation with Rehabbed Units

THE DALLES FISH UNITS 1 & 2

Labor								FY12-FY17
	FY18	FY17	FY16	FY15	FY14	FY13	FY12	6 Year Average
Reduction Costs	$ 57,380.63	$ 84,311.23	$ 292,915.57	$ 137,144.63	$ 67,102.31	$ 105,875.15	$ 157,166.55	$ 140,752.57
Routine	$ 47,458.77	$ 20,665.11	$ 37,409.59	$ 22,197.63	$ 34,368.31	$ 53,828.42	$ 289.93	$ 28,126.50
Non Routine	$ 201.24	$ 364.44	$ 4,871.80	$ 983.69	$ 13,066.43	$ -	$ 4,005.37	$ 4,658.35
Overhauls	$ 52,763.45	$ 84,895.18	$ 84,408.81	$ 59,118.93	$ 34,938.23	$ 40,130.35	$ -	$ 60,698.30
TOTAL	$ 157,804.09	$ 190,235.96	$ 419,605.77	$ 219,444.88	$ 149,475.28	$ 199,833.92	$ 161,461.85	$ 223,342.94

Materials								FY12-FY17
	FY18	FY17	FY16	FY15	FY14	FY13	FY12	6 Year Average
Reduction Costs	$ 1,782.23	$ 1,323.64	$ 22,333.58	$ 13,077.78	$ 3,796.00	$ 48,979.74	$ 1,734.25	$ 15,207.50
Routine	$ 7,576.84	$ 1,250.28	$ 3,052.25	$ 4,903.83	$ 2,799.65	$ 2,728.18	$ 36.61	$ 2,461.80
Non Routine	$ -	$ -	$ -	$ 422.54	$ 399.40	$ -	$ 2,533.38	$ 1,666.40
Overhauls	$ 912.46	$ 4,197.93	$ 3,661.85	$ 5,134.72	$ 1,235.02	$ 3,245.98	$ -	$ 3,495.10
TOTAL	$ 10,271.53	$ 6,771.85	$ 29,047.68	$ 23,538.87	$ 8,230.07	$ 54,953.90	$ 4,304.24	$ 21,141.10

APPENDIX J – MEMO ON JOINT OPERATION FLOW TEST OF AWSSB AND SINGLE FISH UNITS

Prepared by: Stephen Schlenker, CENWP-ENC-H 12/14/2018

Joint Operation of a Single Fish Unit and AWS Backup System at The Dalles East Fishladder.

On November 28, 2018, The Dalles AWS backup system (AWSBS) was successfully operated simultaneously with a single fish unit. The AWSBS was operated with each of the two fish units at separate times. In addition, the tests included the startup and shutdown of a fish unit while the AWSBS was operating; and conversely, the startup and shut down of the AWSBS while a fish unit was operating. The latter operation represents a typical scenario in during which one of the fish units goes down and the AWSBS can be called into service to augment the auxiliary water flow for the fish ladder.

The fish turbines and fish ladder were monitored during the tests and showed no adverse conditions developed in either system. No *seiching* (standing waves caused by water inflows into an expanse of open water) was seen in the fish ladder and no abnormal pressure variations were observed with the turbines. The flow in the fish ladder appeared similar to a normal operation with two fish units. Recorded channel velocities were also similar to a normal dual unit operation.

The discharge in the single fish units were run at 2,500 cfs and the estimated AWS backup discharge was about 1,550 cfs, for a combined 4,050 cfs. Tests were done at a relatively low tailwater, which creates a more conservative test in terms of meeting fish ladder entrance criteria. (The ladder entrance weirs become increasingly hydraulically efficient with lower tailwater since the lower settings of the ladder entrance weirs create a lower projection into the water column). The project tailwater was 75.5 feet, which is exceeded 85% of the time during the year.

The fish ladder entrance data at all three entrances were physically recorded during the joint AWS and fish unit operation with the following summary results:

Table J-1. Fish ladder entrance data at all three entrances of The Dalles Dam

Entrance Location	Number of Weirs	Weir Submergence	Entrance Head
East	2, 3	10.5 ft	1.5 ft
West	2	8.3 ft	1.25 ft
South	2	8.5 ft	0.5 ft

During the joint fish unit and AWSBS operation, the east and west entrances were reliably within criteria; however the south entrance was not. (This being in spite of the combined AWS entrance flow (~ 4000 cfs) being higher than the estimated marginal target rate, 3200 cfs). Noteworthy was that the fish ladder programmable logic control (PLC) screen indicated the south entrance was within criteria at the same time. The physical measurements are accurate, whereas the PLC data relies on calibrations which have been known frequently to stray.

The criteria problem at the south entrance can be easily corrected by raising one of the two weirs sufficiently to raise the entrance head back into criteria. The south entrance weirs are 15-feet wide each, which represents 86% of the combined width of two narrower entrance weirs at the east and west entrance locations. As noted above, this was a conservative test towards meeting entrance criteria due to the particularly low tailwater.